



Office of the
Inspector General
Commonwealth of Massachusetts

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Inspector General

A Recommendation for
Cost Recovery Against the
Big Dig's Management
Consultant:

Grout Heave-Related Contractor Claims on the
C11A1 Contract

February 2003

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Executive Summary

This report identifies \$65 million in Central Artery/Tunnel Project (Project) construction cost increases relating to ground movement, or "grout heave," that may be attributable to deficient work on the part of the Project's management consultant, Bechtel/Parsons Brinckerhoff (B/PB). The findings in this report indicate that these grout heave-related costs may be attributable to B/PB's failure to:

- anticipate construction difficulty;
- prepare adequate contract specifications;
- conduct an adequate ground monitoring operation;
- investigate and gather sufficient information regarding contractor claims; and
- document evidence and decisions.

As discussed in this report, B/PB failed to anticipate and prepare for the possibility of "grout heave" during soil stabilization operations at the Red Line tunnel construction site. The ground movement, or grout heave, occurred on the C11A1 (I-93 Central Artery – Kneeland to Congress Street) construction contract. The contract began in February 1995 and is nearly complete. Between 1995 and 2002, change orders increased contract costs by 23 percent, from \$378 million to approximately \$490 million. Grout heave took place from mid-1997 to June 1998 and reportedly caused movement of the Red Line subway tracks and station platform at South Station. The construction contractor, following B/PB's instructions, eventually controlled the heave but continued to seek compensation through the dispute resolution process and litigation for these efforts. This Office did not examine the merits of the contractor's claims or of B/PB's negotiating position. Rather, this Office's review focused on B/PB's decision-making and management process concerning the grout heave and the contractor claims. - This Office's review found that Project staff did not initiate any investigation into the causes of the grout heave, nor did Project staff attempt to determine the extent to which design errors by B/PB were to blame.

The Commonwealth's estimated financial exposure from grout heave-related claims could be tens of millions of dollars higher than \$65 million. This added exposure relates to the impact of grout heave on other construction contract schedules and scopes of work, the overall Project schedule, and B/PB management costs. B/PB's failure to anticipate and plan for grout heave in the project design has also caused the Project to become embroiled in mediation and litigation efforts that have consumed the time and attention of Massachusetts Turnpike Authority and B/PB staff.

This report contains the following specific findings:

- 1. B/PB failed to anticipate and plan for grout heave.**
- 2. B/PB's construction contract specifications failed to take into account the likelihood of grout heave.**
- 3. After encountering grout heave, the Resident Engineer declared a differing site condition without adequate evidence.**
- 4. B/PB failed to adequately investigate the differing site condition claim as required by state law.**
- 5. The grout heave issue is inadequately documented in Project records.**

Although B/PB stated that its actions saved money by maintaining the Project schedule, this Office concludes that B/PB may have been the cause of these multi-million dollar claims. However, B/PB shifted the financial responsibility for the claims onto the Commonwealth, in effect nullifying the need for Turnpike Authority officials to determine why the grout heave was not anticipated.

The basis for the decisions made by consultants being paid billions of dollars by the Commonwealth and a potential \$65 million contract increase should be readily explainable. The taxpayers and tollpayers of the Commonwealth have a right to expect that the Project will hold consultants accountable for their work. The Turnpike Authority should require B/PB to explain cost overruns and any design, management, or other

possible errors that occurred under B/PB's watch. If responsible for these cost overruns, B/PB should pay for its mistakes.

In an October 3, 2001 letter to the Chairman of the Massachusetts Turnpike Authority, this Office and the Office of the Auditor of the Commonwealth jointly expressed concern about B/PB's refusal to acknowledge any responsibility for or to share in the burden for increasing Project cost overruns. The letter also reiterated an issue first raised in this Office's December 2000 report entitled *A Review of the Central Artery/Tunnel Project Cost Recovery Program*, which found that the Turnpike Authority had not successfully pursued any significant cost recovery cases against B/PB. This Office is not aware of any case where the Turnpike Authority pursued a cost recovery action or contractual remedy against B/PB for errors, mismanagement, or contract violations. As the findings of this report make clear, the grout heave issue should be the subject of a cost recovery investigation. This Office will continue to work with the Turnpike Authority and other officials to identify and pursue other cost recovery cases.

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Project Description

The \$14.625 billion¹ Central Artery/Tunnel Project (Project) involves constructing a new tunnel across Boston Harbor, placing the Central Artery underground, and constructing a new Charles River crossing.² According to Project officials, the Project is the most complex and costly urban highway project in U.S. history. The Project is scheduled for completion in 2005. As of December 2002, approximately 85 percent of construction and virtually all design work had been completed.

In the early 1980s, the Massachusetts Highway Department (MassHighway) had the responsibility for planning and overseeing the Project for the Commonwealth. In 1985, MassHighway hired the joint venture of Bechtel/Parsons Brinckerhoff (B/PB) to manage the design, construction, and day-to-day administration of the Project. B/PB's contract requires it to prepare preliminary design documents, manage – and, in some cases, perform – final design work, manage construction, provide administrative and technical support, and prepare cost estimates and budget forecasts. B/PB also assists in preparing Finance Plans³ and many other reports; negotiates construction contract changes; maintains management information systems; and is the Project archivist.

Since 1985, the Commonwealth has paid B/PB nearly \$2 billion through a series of 16 contracts, also known as “Work Programs.” By Project completion, B/PB will have been paid nearly \$2.2 billion – 15 percent of the total Project cost.⁴ Although B/PB's current

¹ Source: The Turnpike Authority's December 2002 "Project Management Monthly Report."

² This Project also includes utility relocations, the incorporation of project control and operations systems, ventilation buildings, utility structures, maintenance and emergency response facilities, parks, and surface restoration. The Project is composed of hundreds of design, construction, service, and consulting contracts.

³ Finance Plans are required by 23 USC 106(h) and by M.G.L. c.81A, §17.

⁴ This does not include the \$48 million Work Program 13 for operations and system start-up services. The Project also plans to implement Work Program 16 for operations and maintenance transfer activities.

contract is with both the Massachusetts Turnpike Authority⁵ and MassHighway, B/PB now serves under the direction of the Turnpike Authority under the terms of a 1997 agreement between the two agencies to implement the Metropolitan Highway System.⁶

From 1997 until February 2000, Project officials had maintained that Project costs would not exceed \$10.8 billion, despite the concern of federal and state oversight agencies that Project officials had based the estimate on overly optimistic and possibly faulty assumptions. On February 1, 2000, Project officials announced an estimated cost increase of \$1.4 billion. Oversight agencies estimated the cost overrun at closer to \$2.4 billion and predicted that total costs would exceed \$14 billion. By October 2002, the cost estimate had increased to \$14.625 billion.⁷

Project officials had expected the Federal Highway Administration (FHWA) to fund at least 80 percent⁸ of the Project cost, but the furor in early 2000 over cost overruns had caused the federal government to impose an \$8.549 billion funding cap. As currently projected, the FHWA will now only fund about 58 percent of total costs. This includes \$1.5 billion in funding for the redemption of Grant Anticipation Notes (GANs) that are Commonwealth bonds issued in anticipation of future FHWA allocations through 2015.⁹

⁵ To avoid confusion, this report refers to the Turnpike Authority as the Project owner and responsible agency.

⁶ Chapter 3 of the Acts of 1997 (M.G.L. c. 81A) established a plan for operating and financing a roadway network that includes a completed CA/T Project, called the Metropolitan Highway System (MHS). The law empowers the Turnpike to “own, construct, maintain, repair, reconstruct, improve, rehabilitate, finance, refinance, use, police, administer, control and operate” the MHS.

⁷ This number may increase further. Leaks in the Fort Point Channel area caused schedule delays and ongoing discussions between the Project and the U.S. Department of Transportation about what should be included in the Project costs may be factors that drive the total cost estimate higher. One member of the Turnpike Authority Board estimates that costs could increase by \$1 billion.

⁸ Earlier in Project history officials had anticipated that the FHWA would fund 90 percent or more of Project costs.

⁹ Without the inclusion of GANS funding, the federal contribution would be 48 percent.

The estimated \$900 million in interest expense for the GANs is not considered a Project cost.

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Background

The C11A1 (I-93 Central Artery – Kneeland to Congress Street) construction contract is one of the largest of more than 125 Project construction contracts. The scope of work for the C11A1 contract includes the construction of a four lane highway tunnel with appropriate utility structures, new surface streets, underpinning for the Red Line subway, and the partial construction of a new transitway¹⁰ tunnel and station for the Massachusetts Bay Transportation Authority (MBTA). The construction contractor is a joint venture of Perini Construction Corp., Kiewit Construction Co. and Jay Cashman Construction Inc. (PKC). The joint venture began work in February 1995. The most recent completion date had been December 31, 2002.¹¹ At this time, the contract is nearly complete. The contract has a current value of \$490 million¹² (from the original \$378 million) not including millions in unresolved contractor claims.¹³

The construction contractor is allowed to make claims against the Project for additional money and/or a schedule extension. Contract modifications either result from resolved claims or are issued by management and act to amend the construction contract. According to the most recent Project Cost and Schedule Update (Revision 9), the cost of the C11A1 contract has increased by nearly \$112 million or 23 percent since 1995. Much of the cost growth is attributable to approximately 1,000 contract modifications.

¹⁰ The new transitway is the Silver Line that will run from South Station to D Street in South Boston near the new Convention Center, which is also currently under construction.

¹¹ The contract originally called for a completion date of September 15, 2000.

¹² This amount includes the construction of a new subway station for the MBTA, originally estimated to be \$65 million. Current estimates exceed \$100 million.

¹³ While many claims remain outstanding, the Project has set aside only minimal funds for future allowances. A budget review (September 2001) by Deloitte and Touche (D&T) concluded that the construction allowances might be too low.

This report deals with approximately \$35 million in known cost increases tied to contract modifications – nearly 20 percent¹⁴ of the total contract cost increase since 1995 (excluding MBTA related scope and cost increases). These contract modifications pertain to contractor requests for additional time and money resulting from extended soil grouting activity.

PKC's scope of work included the construction of underpinning for the Red Line subway station. The underpinning would support the Red Line station while the contractor built the new underground roadway beneath the station. Before the tunneling work for the underpinning and subsequently the underground roadway could begin, the soil had to be stabilized with grout.

Grouting assists with underground construction by making soil impermeable to groundwater. The designers considered groundwater control a major concern in the C11A1 contract area. According to Project documents, tunneling is nearly impossible and dangerous for workers in ground permeated with water.

PKC used two types of grout. The first type, a mixture of cement, bentonite,¹⁵ and water, is used to fill large spaces in soil or rock. The second type, a sodium-silicate¹⁶ mixture, is used to fill small spaces and displace groundwater. PKC used pressure to inject grout material into the soil. For this work, PKC built temporary grouting galleries (small tunnels) 20 feet beneath the subway tunnel from which the grouting operation could proceed. To do this, PKC dug two elevator-like shafts to a depth of about 50 feet. PKC then constructed a 60-foot horizontal tunnel from the bottom of each shaft to form the grouting galleries. From the grouting galleries, PKC drilled hundreds of small shafts a few inches in diameter in a fan-like pattern from the gallery down to bedrock 50 to 70 feet below. PKC inserted porous pipes into the small shafts and began injecting the

¹⁴ According to PKC's estimate, the grouting operation accounted for about five percent of the total contract price of \$378 million. With the contract modifications, the cost of the grouting work has doubled.

¹⁵ Bentonite is a clay-like material that absorbs water and hardens to form a soil mass.

¹⁶ Sodium silicate is a chemical that creates a solidified soil mass.

grout into the soil. After the completion of the grouting operation, construction of the underpinning structure could begin. (See Appendix One.)

Because ground movement caused by construction activity or groundwater changes could damage nearby structures such as the Red Line tunnel, South Station, One Financial Center, and the Federal Reserve Bank,¹⁷ the C11A1 contract required the contractor to monitor ground movement, groundwater pressure, and the response of nearby structures to construction activity. The contract specifies that the contractor must provide, install, and maintain geotechnical instrumentation before beginning underground construction. The contractor must then collect, process, interpret, and report the recorded geotechnical data. B/PB's independent geotechnical subconsultant also installed and monitored geotechnical instrumentation for this contract.

PKC hired a grouting sub-contractor, Hayward Baker (HB) to perform the grouting operation. On November 12, 1997 (shortly after grouting began) during routine monitoring, the PKC's geotechnical consultant, GZA Inc. (GZA) detected heave of the Red Line subway platform at South Station. (See Table 1 for a listing of contractors.) "Heave" is the upward movement of soil or other ground material. Heave can occur under certain conditions during any grouting operation. The volume of grout injected into the soil or the grout injection process itself may create zones of high pressure in the soil that cause heave.

¹⁷ Groundwater movement affected surrounding structures including South Station, the Federal Reserve Building, and One Financial Center which settled about one-quarter of an inch between 1996 and 1998 because of a lowering of the area's water table.

Table 1.
Firms Involved with the Grout Heave Issue

<i>Contract Type</i>	<i>Bechtel/ Parsons Brinckerhoff (B/PB)</i>	<i>Section Design Consultant (SDC)</i>	<i>Construction Contractor</i>
Prime Contract	B/PB	Seelye, Stevenson, Value, Knecht/DeLeuw Cather SSDC (joint-venture)	Perini Corp., Kiewit Construction Inc., Jay Cashman, Inc. PKC (joint-venture)
Geotechnical Consultant	GEI Inc.	Haley & Aldrich Inc.	GZA GeoEnvironmental Inc.
Grouting Subcontractor	NONE	NONE	Hayward Baker Inc.
Survey/Geotechnical Instrumentation	BSC Group, Cullinan (joint- venture)	NONE	A-Plus Construction Services Corp. & GZA GeoEnvironmental Inc.
Other Consultants	Mueser – Rutledge Consulting Engineers	NONE	UNKNOWN
Legal	Donovan & Hattem LLP	Donovan & Hattem LLP	Hinckley, Allen & Snyder LLP

Source: Prepared by Office of the Inspector General staff based on Project documents.

Heave occurred after HB began the grouting operation. The reasons for the occurrence of heave remain unknown and Project documents contain no evidence that the Project conducted an investigation into the matter. After encountering heave, PKC and HB attempted remedial measures. According to interviews with B/PB staff, B/PB, acting through its Resident Engineer¹⁸ (RE) became unsatisfied with these measures. The RE assumed direction of the grouting operation in December 1997. Shortly thereafter, the RE declared a differing site condition. Declaring a differing site condition in this case allowed the RE to direct a change in PKC's methods. In effect, the RE assumed a direct role in the grouting operations, which constituted a contract change. This

¹⁸ The Resident Engineer manages the construction contract for B/PB and acts as the Project Director's authorized representative in negotiations with the contractor.

required the Project to make an “equitable adjustment” to the contractor’s schedule and price.

According to the Project’s construction contract with PKC, a differing site condition exists when actual latent subsurface or physical conditions at the contract site:

[D]iffer substantially or materially from those shown in the contract documents, or from those conditions ordinarily encountered in work of the nature undertaken. The contractor may be entitled to an equitable adjustment in the contract price if the awarding authority determines that such conditions caused an increase or decrease in the cost of performance.

Declaring a differing site condition enabled PKC to file claims requesting compensation for additional work and schedule delays. The heave eventually stopped but the differing site condition allowed PKC to file \$65 million worth of claims. [Table 2.] The Project is still reviewing parts of these and other claims dealing with schedule delays.¹⁹ The heave issues have been part of the dispute resolution process between the Project and contractor, and have led to litigation as well.²⁰

¹⁹ According to PKC, the schedule delays made the completion of the Red Line underpinning critical to schedule maintenance.

²⁰ In August 2001, the independent C11A1 Dispute Resolution Board (DRB) awarded \$17.5 million to PKC for schedule delays. A portion of this award is for delays that ensued because of grout heave and would therefore be in addition to the \$35 million already agreed to between the Project and the contractor. The DRB decision, however, is unclear about how much of the award deals with grout heave related claims. The Project appealed this and other DRB decisions. In March 2002, a Superior Court judge upheld the \$17.5 million DRB award to the contractor and signaled that the courts will not overturn DRB decisions.

Table 2.
C11A1 Contract Modifications (Mods) Related to Grout Heave
(as of December 2002)

Contractor Claim Proposal #	Contract Mod #	B/PB \$ Value	Contractor Claim \$ Value
375A	188	\$ 0	\$ 0
389	533	300,000	926,063
391	60/533	200,000	550,000
398	533	150,000	4,700,000
403	533	100,000	See Claim 398
403A	88	1,570,276	1,884,000
404/679	394/533	1,600,000	See Claim 596A
419	632	136,376	N/A
421	112	0	1,500,000
432A	N/A	0	0
459	N/A	0	See Claim 404
481	430/584	1,527,143	N/A
527	102/584	0	0
532	533	2,425,000	0
532A,532B,533	710IA/B/II	519,021	0
568	277/630II	506,723	506,723
569	N/A	0	See Claim 532
578C	201	500,000	3,019,181
596	273	4,250,000	5,000,000
596A	273	0	3,958,778
619	273	0	See Claim 596
628	N/A	0	41,125
633	N/A	0	0
639	N/A	0	2,148,951
647	N/A	0	204,000
660	127	0	3,869
661	378	N/A	7,521
667/692	507/58/87	15,125,000	31,409,471
710	620	0	212,095
716,735/740	620	6,250,000	6,000,000
716A	669	0	2,600,000
733,735,749	620	0	See Claim 716
734	193	0	0
	TOTALS	\$35,159,540	\$64,671,780

Source: Prepared by Office of the Inspector General staff based on Project documents.

Note: The use of "N/A" in the above chart identifies unavailable information.

Could these claims have been avoided? This Office conducted this review with that question in mind. Even though B/PB and the contractor told this Office that grouting can be difficult, problematic, and can cause heave and even though B/PB considered the control of groundwater to be a major concern, B/PB did not anticipate heave and so did not require the contractor to have a Plan of Action to employ if heave occurred. B/PB staff stated that they did not recall a discussion about the likelihood of grout heave before it occurred. B/PB staff reviewed and in some cases drafted the grouting-related specifications. It may be that soil conditions in the South Station area made contract modifications and added costs inevitable. However, B/PB's use of deficient specifications, deficient oversight, and use of contract modifications to remedy these failings indicate that soil condition alone cannot be blamed for the grout heave-related contract cost increases.

Methodology

During this investigation, staff from this Office conducted fifteen interviews with B/PB engineering, design, geotechnical and construction staff, Section Design Consultant and Area Geotechnical Consultant staff, construction contractor staff, and other design, geotechnical, and construction subcontractors including the grouting subcontractor. Office staff also reviewed hundreds of documents, including contract modification files, contracts, correspondence, engineering reports, geotechnical reports, design reports. B/PB's C11A1 construction contract field office files, industry literature, academic studies, Federal Highway Administration documents pertaining to chemical grouting and construction control procedures, and studies of other construction projects in the United States that used grouting for soil stabilization. This Office also reviewed dozens of contractor claim and Project change order files relating to the grout heave issue.

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Findings

Finding 1. B/PB failed to anticipate and plan for grout heave.

B/PB and the Section Design Consultant²¹ (SDC) should have foreseen the possibility of grout heave during the planning and design phases of the C11A1 contract. Heave can occur during any grouting operation according to Project consultants, including B/PB staff interviewed by this Office. Other factors increased the risk of heave. For example, the C11A1 grouting operation had to be performed in a complex urban environment. Additionally, according to the grouting subcontractor, the design called for the use of “unprecedented” amounts of grout.²² According to an FHWA report²³ about chemical grouting, case studies revealed that increased grout volume increases heave risk. In fact, contractor documents claim that the use of large amounts of grouting, as directed by the RE, actually caused grouting problems. B/PB and SDC staff should have anticipated that the grouting operation could cause heave and that using large volumes of grout increased the heave risk.

B/PB geotechnical staff interviewed by this Office could not recollect any discussion during the planning and design phase of the likelihood of heave occurring. The geotechnical staff reviewed all specifications and in some cases wrote the specifications for the grouting operations. B/PB’s geotechnical group manager stated that he had not encountered heave on previous projects and so did not believe heave would be an issue on this contract. B/PB staff also argued that a contract cannot reasonably

²¹ The SDC is hired by MassHighway to be the final designer for a specific final design package. The SDC bases the final design on B/PB’s preliminary design package.

²² According to Project documents, the grouting efforts required twice as much grout as specified in the C11A1 contract.

²³ Federal Highway Administration (FHWA) staff indicated to this Office that *Design and Control of Chemical Grouting*: Vol. 1, Construction Control, Vol. 2, Materials Description Concepts, Vol. 3, Engineering Practice, and Vol. 4, Executive Summary, FHWA/RD - 82 - 036 through 039 (April 1983) are considered the definitive resource on chemical grouting methodology.

anticipate every contingency. However, staff also acknowledged that a contract should anticipate realistically probable occurrences.

The contract did anticipate the potential for ground movement resulting from changes in the water table. The contract required the C11A1 contractor to submit for B/PB's approval a Plan of Action to provide a mechanism for the contractor to deal with this ground movement. With the Plan of Action, the contractor had a clear contractual obligation to assume a reasonable amount of responsibility for mitigating ground movement caused by changes to the water table. With this understanding, the contractor could bid on the contract work accordingly.

The contract failed, however, to address the potential for grout heave. According to Project documents, B/PB staff believed that even without a Plan of Action requirement, the contractor had a responsibility to mitigate heave conditions – regardless of the source of the heave – in order to protect structures in the construction area. This may be true, but without an approved Plan of Action, the contractor's means and methods is subject to debate, which can lead to contractor claims.

Certain construction problems should have triggered B/PB's concerns about grout heave after PKC began work. For example, before the start of the grouting activity and the grout heave events discussed in this report, PKC performed other grouting work. As mentioned earlier, PKC used a series of tunnels²⁴ to complete the grouting work. To protect these tunnels from groundwater intrusion, PKC injected grout into the soil to form what is called a "grout plug."²⁵ During the formation of this grout plug in July 1997, three months before the first reported heave of the Red Line, Project claims documents state that the grouting galleries experienced heave that caused "substantial cracking of the concrete working slab" and movement of the "structural steel cross struts." In response, the RE wrote to the contractor:

²⁴ PKC prepared underground passages on the East and West sides of the future underpinning to assist with construction of the roadway tunnel.

²⁵ PKC used grout to create an impermeable barrier or plug to resist the upward movement of groundwater below the access tunnels.

We are concerned that these movements have induced additional stresses in the Tunnel ribs and framing and we are further concerned about the procedures, the active grouting pressures and remedial plan of action to correct any deficiencies that may have occurred. [Emphasis added in bold.]

Project documents also show that as early as May 1997 - six months before the “first” reported grout heave - grout heave impacted the Red Line station. According to these documents, the Red Line moved up to one-half inch due to grouting operations that predated the soil pre-stabilization grouting. Therefore, B/PB knew about unacceptable Red Line movement from a heave condition between May and October 1997, months before the “first” reported heave of the Red Line. Project documents also refer to this earlier grout heave as being “typical with this type of operation” and states that the heave “was not unexpected.”

B/PB staff should have taken the earlier heave occurrences as warnings that grouting around the galleries might be difficult and that the soil might not respond as anticipated. The RE could have prepared for future grout heave by negotiating with PKC for an acceptable Plan of Action in the event that heave reoccurred. The RE should have investigated the heave events that had occurred to that date. [See Table 3.]

A comparative review of reports about two other large U.S. tunnel projects that used soil stabilization grouting reveals that the designers and construction managers anticipated grout heave. The two projects are the Washington (D.C.) Metropolitan Area Transit Authority (WMATA) system constructed in the 1970s, and the Pittsburgh Light Rail Transit System (LRTS) constructed in 1983. The WMATA designers stabilized the soil between two subway tunnels and a major sewer line with a chemical grouting operation. When the construction contractor observed heave during the grouting operation it followed a pre-arranged remediation plan that stopped the heave with a change in grouting material. Bechtel Corp. had an active role in the design and construction of the WMATA system. Bechtel also played a role in the C11A1 construction contract.

Table 3.
Brief Chronology for the Grout Heave Issue

February 14, 1995	Notice to Proceed issued to the Contractor (PKC).
May - October 1997	Grout heave appears to impact Red Line and access tunnels during installation of "grout plug."
November 3, 1997	Ground pre-stabilization grouting operation begins.
November 12, 1997	First reported heave event during the ground pre-stabilization grouting process.
November 26, 1997	Second reported heave event. PKC notifies RE of first grout heave-related claim.
December 3, 1997	Third heave event; Red Line impacted. RE halts operation. PKC prepares Plan of Action for review. (12 day delay.)
December 10, 1997	SDC recommends an investigation into why heave is occurring. B/PB rejects recommendation.
December 17, 1997	Heave reported. Work halted then limited grouting until March 10, 1998. (82 day delay.)
January 14, 1998	RE orders grouting to continue under the direction of the RE until completed.
February 12, 1998	RE signs Contract Modification 273.
March 10, 1998	Grouting resumes.
March 25, 1998	Heave reported; Red Line impacted; work halted.
April 7, 1998	Heave reported; Red Line impacted; work halted.
April 28, 1998	RE submits a remedial Plan of Action three months after assuming direction of grouting operation.
June 17, 1998	PKC reports grouting plan completed.
September 15, 2000	Original Contract completion date.
August 31, 2001	Dispute Resolution Board awards PKC \$17.5 million for claims that may be grout-heave related.
March 20, 2002	Superior Court upholds \$17.5 million award.

Source: Prepared by Office of the Inspector General staff based on Project documents.

The construction of the Pittsburgh LRTS required that the buildings on the street above be properly supported during excavation. The designers determined that chemical grouting would be the only practical way to support the buildings. In anticipation of possible grout heave from this type of operation, the specifications required the contractor to set up a system to monitor heave. A joint venture of Parsons Brinckerhoff/Gibbs & Hill completed the design for the project and Hayward Baker performed the grouting work. Parsons Brinckerhoff and Hayward Baker both played a role in the C11A1 construction contract.

The project managers for the WMATA and Pittsburgh LRTS projects had anticipated the possibility of grout heave and made preparations for heave monitoring and control. These two projects could have provided guidance for B/PB during their design and management of the C11A1 contract.

In addition to these two projects, grout heave is discussed in *Design and Control of Chemical Grouting*, the previously cited FHWA grouting report that, according to FHWA staff, is well known in the geotechnical engineering and chemical grouting communities. This report emphasizes, as did earlier FHWA reports, that grout heave must be anticipated during the planning and design of any major grouting project, especially for grouting projects in the vicinity of (and especially beneath) structures.

Interestingly, a “lessons learned”²⁶ document issued by B/PB just days before the first reported grout heave event refers to “complicated construction techniques” specified in construction contracts that include “extensive deep excavations and subsurface work. . . performed immediately adjacent to existing . . . structures, which can be adversely affected by ground movements. . . .” B/PB’s recommended action for this lesson included establishing a program where geotechnical issues are discussed during Pre-Bid Conferences for construction contracts. The recommendation stated:

²⁶ B/PB has a program through which staff report “lessons learned” for communication to other Project staff. These lessons or knowledge gained through Project experience and/or analyses are intended to assist staff in avoiding problems or to improve efficiency based on the prior experiences of Project staff.

The goal of this approach is to mitigate post-bid claims, disputes and change orders by alerting bidders to these critical areas of the contracts so that they will give them due consideration when pricing their bids, and by stimulating bidders [sic] questions about areas of uncertainty.

The RE on the C11A1 contract stated in an unpublished article that he co-wrote about the grout heave²⁷ that staff learned the following:

Do not underestimate the phenomenon of soil heave caused by grouting, particularly when under a sensitive structure. [Emphasis added in bold.]

MassHighway hired B/PB in 1985 specifically for its vast experience and expertise in the types of construction that were to be part of the Project. The fact that Bechtel and Parsons Brinckerhoff did not apply the lessons learned from their independent experiences in Washington and Pittsburgh to the management of the Central Artery/Tunnel Project should not result in added costs to the taxpayers and tollpayers.

Finding 2. B/PB's construction contract specifications failed to take into account the likelihood of grout heave.

B/PB's failure to anticipate grout heave meant that contract specifications did not address this contingency. After heave occurred, PKC filed a series of claims against the Project. Some or all of these claims could have been avoided if B/PB and Project consultants supervised by B/PB had anticipated heave and added a Plan of Action requirement to the construction contract specifications.

The geotechnical instrumentation specification²⁸ and the grouting specification²⁹ did not cross-reference each other. The geotechnical instrumentation specification references 17 types of subsurface work³⁰ but failed to reference the ground pre-stabilization grouting in the grouting specification. The geotechnical instrumentation specification

²⁷ The Project Engineer (PE) managed the C11A1 SDC contract for B/PB co-authored the article with the RE.

²⁸ C11A1 contract - Division II – Special Provisions - Section 160.010.

²⁹ C11A1 contract - Division II – Special Provisions - Section 130.314.

³⁰ The specification references 17 construction activities, including blasting, excavation, tunneling, and grouting for other than ground pre-stabilization.

required the construction contractor to submit a Plan of Action that outlined what remedial actions the contractor would take if unacceptable ground motion readings were recorded. However, because the contract did not reference the grouting specifications and the geotechnical instrumentation specifications an incidence of grout heave would not be covered by the Plan of Action requirement. Without a Plan of Action to implement, the contractor only had to report heave and attempt mitigation as a matter of prudent construction management. The SDC's Final Design Summary Report explains the importance of a Plan of Action:

Should data indicate that Response Values³¹ are being exceeded, the Contractor is responsible [for] taking action which may include installation of additional instrumentation, increased instrument monitoring frequency, modification of construction procedures and/or implementation of a remedial plan of action to further limit detrimental effects related to construction.

Having a Plan of Action requirement does not mean that the contractor must accept full responsibility for all remedial work. The Plan of Action is meant to reiterate contractual responsibility and establishes a basis for negotiating price adjustments to the contract at a later date. For 17 work items other than grouting, B/PB addressed the risk of ground movement inherent in some construction operations. By not including the Plan of Action requirement in the grouting specification, B/PB enabled the risk and responsibility for the costs to remediate grout heave and the effects of the heave to be shifted from the contractor to the Commonwealth.

Many of those associated with the C11A1 contract concur with the need for a Plan of Action. B/PB's geotechnical consultant (GEI Inc.) told this Office that construction contract specifications should include a Plan of Action requirement so contractors can react quickly to a problem when it occurs. B/PB's Project Engineer for the C11A1 design contract informed this Office that "in hindsight" a Plan of Action should have been required. A B/PB construction engineer with extensive knowledge of the planning for the C11A1 contract told this Office that the contract specifications should have referred

³¹ Response values are instrument readings indicating that ground movement has reached unacceptable limits.

to a Plan of Action. He stated that grouting would not have been specified in the contract if the designer did not have significant concerns about soil quality and ground movement. Even B/PB's RE expressed surprise that the contract did not require a Plan of Action stating that it probably should have been included since grouting is a unique science that "generally requires a Plan of Action."

The SDC informed this Office that it had included standard B/PB specifications in the construction contract document. During the early design and planning phase of the contract (before the Project hired the SDC), B/PB prepared the standard specification later used by the SDC. During this early design phase, B/PB had not considered the use of grouting for ground pre-stabilization. The SDC introduced the grouting concept. B/PB should have ensured that the standard specifications reflected changes made during the final design phase. B/PB should also have ensured that both §160.010 and §130.314 required a Plan of Action to remediate grout heave, but B/PB staff reported to this Office that they did not believe grout heave would likely occur and so did not want to engage in "overkill" by planning for every conceivable contingency. However, the evidence suggests that a prudent set of specifications would anticipate heave in grouting operations, particularly when working under sensitive structures.

Finding 3. After encountering grout heave, the Resident Engineer declared a differing site condition without adequate evidence.

Shortly after grout heave impacted the Red Line³² the RE assumed direction of the remedial work and declared a differing site condition. A differing site condition exists when subsurface or latent physical conditions encountered by a contractor differ substantially or materially from those shown in contract documents or differ from those conditions ordinarily encountered in work of the nature undertaken. If the awarding authority determines that such conditions caused an increase or decrease in the cost of performance, the contractor may be entitled to an adjustment in the contract price.

³² According to B/PB staff, the heave caused little if any damage to the Red Line or any other adjacent structure.

Declaring a differing site condition permitted the RE to modify the contract and compensate PKC for remedial work on a time and materials³³ basis, usually considered the most costly type of contractor work. This declaration opened the door for PKC to file a number of multi-million dollar claims for the necessary remedial work and schedule delays, many of which have yet to be settled almost four years later.³⁴ When questioned about the decision to declare a differing site condition, the RE told this Office that the grout heave created an urgent situation that called for the declaration. The RE continued by stating that in an urgent situation, “costs are secondary.”

Did the RE have adequate evidence to declare a differing site condition? Many individuals interviewed by this Office did not think so, and Project documents lack sufficient evidence to support the claim that a differing site condition existed.

By statute in Massachusetts, declaring a differing site condition requires that the site’s condition be investigated.³⁵ This Office requested that the Project provide all documents related to the RE’s determination of the differing site condition. The Project responded that other than the Contract Modification, no other documentation existed. The RE signed Contract Modification 273 on February 12, 1998 – two months after the first reported heave event. (See Appendix Two.) The modification states the RE’s reason for the contract change as follows:

³³ Time and materials is one method of calculating contractor payments. The T&M method reimburses the contractor for actual costs such as labor and equipment, the cost of materials, and overhead and profit (usually at a fixed percentage). Under this method, costs are usually not predetermined as with competitively bid work.

³⁴ According to PKC documents submitted for Dispute Resolution Board proceedings, the Section Design Consultant (SDC) and the SDC’s geotechnical consultant “expressed concern [to B/PB] about the potential liability” that B/PB asked them “to assume by directing PKC’s [the contractor] underpinning construction means and methods.”

³⁵ M.G.L. c. 30, §39N.

This change constitutes a Differing Site Condition, as determined by the Engineer³⁶, in accordance with Division I, GRC section 4.04. as the **apparent lack of permeability** in the in situ³⁷ soils, precludes the injection of grout without causing unacceptable harm to adjacent structures. Therefore, an equitable adjustment is warranted. [Emphasis added in bold.]

The sparse description in the contract modification does not recount what evidence the RE used to support this decision. Doubts about the justification for the RE's decision are exacerbated by the lack of information and evidence.

Questionable ground monitoring

Both B/PB's consultant contract and PKC's construction contract require that geotechnical instrumentation monitoring be used during construction. For the C11A1 contract, B/PB's geotechnical subcontractor (GEI) used an optical survey method for monitoring movement while PKC's geotechnical subcontractor (GZA Inc.) used a liquid level system. Project documents state that, "monitoring of the Red Line Station was complicated by a multitude of issues."

According to Project documents, GZA did not "initialize" the liquid level monitoring system until December 5, 1997, weeks after the first reported heave and months after the first evidence of apparent heave during the completion of the grout plug for the grouting galleries. Before December 5, 1997, only B/PB had instrumentation in place. According to the SDC's geotechnical consultant, Haley & Aldrich (H&A) B/PB informed H&A that B/PB's instrumentation had experienced problems in November 1997, around the time that the contractor first reported heave. According to Project documents, GEI had used the floor of the Red Line subway station platform as a benchmark measurement. As a result, if heave or settlement moved the platform, the benchmark

³⁶ The C11A1 contract refers to the Project Director (a public employee) when referring to an "engineer." For the C11A1 contract the RE is the Project Director's authorized representative. With the authority of an authorized representative, the RE functions as the contract executive making, among other things, engineering, contract, policy, and negotiating decisions.

³⁷ *In situ* refers to soil in its original undisturbed position.

measurement moved as well. Heave could not be measured reliably without a baseline or benchmark measurement having been taken before the grouting operation began.

Based on this information, it appears that the Project used an unreliable benchmark before the initial grout heave event in November 1997. Because B/PB used a flawed benchmark measurement from the start, all subsequent measurements could have been unreliable. As a result, the true amount of heave might never be known.

The SDC's geotechnical consultant (H&A) staff informed this Office that they questioned the reliability of the data from that period onward. According to PKC's grouting subcontractor, Hayward Baker (HB), "no one had a good handle on the heave." The grouting subcontractor also stated that it "never got a straight answer from anyone" about the monitoring problems. The SDC's geotechnical consultant also commented that, despite the questionable instrumentation readings, other information indicated that the heave did not damage the Red Line or nearby structures.

Contradictory statements by the RE

From the scant Project record, the only rationale for the RE's declaration of a differing site condition is found in the contract modification. The modification states that the differing condition declaration is due to ". . . the apparent lack of permeability" in the soils. However, two months earlier, in November 1997, the RE opposed an attempt by the contractor to have a differing site condition declared after the contractor detected grout heave for the first time at the onset of ground pre-stabilization grouting operations. The RE stated the exact opposite of the rationale given in the modification that declared a differing condition:

Since numerous factors may have contributed to these heave responses at this time, I believe PKC [the contractor] is premature to notify or conjecture a "changed condition". There is no geotechnical evidence to substantiate such a claim, particularly when this zone of grouting was so heavily permeated during the Access Tunnel "Invert Plug" grouting operation. [Emphasis included in original text.]

This response directly contradicts the justification for declaring a differing site condition. Was the soil impermeable to the grout or did the grout heavily permeate the soil? The

RE's November 1997 comment, cited above, refers to a lack of geotechnical evidence. Project files contain no evidence that the RE had any additional geotechnical data available to him when he declared a differing site condition. As mentioned previously, the contractor's geotechnical monitoring instruments were not operational in November 1997 and evidence suggests that B/PB's monitoring efforts were unreliable.

B/PB rejected a request to pursue the cause of the heave.

The RE claimed in November 1997, as cited above, that there existed a lack of geotechnical evidence. In late January 1998, the SDC requested that B/PB approve a work order for an evaluation of the heave situation that would include recommendations for reducing future heave. The SDC recommended a review and evaluation of grouting records, testing, and instrumentation data. B/PB did not approve the work order. B/PB staff stated in a letter of response to the SDC that they believed that they had enough information about the heave condition. B/PB staff also said that this type of evaluation would impose an unacceptable and unnecessary delay on the grouting work and would simply be an added expense.³⁸ In April 1998, the SDC claimed in a letter to B/PB that the evaluation would have been "extremely useful" in evaluating the heave issues facing the Project at that time. The SDC wrote:

You may recall that a work order assignment was previously contemplated by B/PB and submitted for your approval in January 1998 to conduct a detailed review of the heave problem. The results of that review could have been extremely useful in evaluating the current issues, however, the work order was never authorized . . . We are not convinced that the horizontal grouting/mining method will preclude the recurrence of the heave problem. We recommend that the review by H&A [geotechnical subconsultant] include an evaluation of "why" the heave is occurring and what alternative actions are indicated.

The SDC again recommended that B/PB approve a work order to examine the heave and to review the grouting operations for compliance with contract plans and specifications. Again, B/PB rejected the SDC's recommendation.

³⁸ Based on Project documents, this Office estimated that this work order would have cost approximately \$50,000 - \$100,000.

The contractor's grouting subcontractor disagreed with the RE

The RE's claim that a differing site condition existed rested on the fact that grout could not permeate the soil, an assertion that has never been substantiated. HB informed this Office that he did not believe that a permeability problem existed. HB stated that it found the soils very permeable and that the soils readily accepted all grout *as it had expected*. B/PB's former Geotechnical Services Manager would not comment to this Office regarding the merits of the differing site condition claim stating that it remained a complicated issue.

Others disagreed with the RE.

In addition to HB, other consultants and B/PB staff questioned the RE's declaration of a differing site condition, and also questioned elements of the grouting operation. Despite these concerns the RE proceeded with the declaration of a differing site condition and the management of the grouting operation. The RE informed this Office that B/PB staff (including geotechnical staff and the Project Engineer) made consensus decisions regarding the remedial grouting work and the declaration of a differing site condition and that he simply had the role of spokesperson for these joint decisions. However, B/PB geotechnical staff informed this Office that the RE made all decisions and that he had ultimate responsibility for all decisions. The RE made his decisions despite the following:

- A construction engineer in B/PB's technical services department who claimed to have consulted with the RE informed this Office that he did not believe that a differing site condition existed. The construction engineer also stated that he did not involve himself in the grouting issue.
- In December 1997, the SDC informed the RE in writing that deficiencies existed in the contractor's grout monitoring program and that insufficient field data had been collected to analyze the nature of the heave condition.
- During the RE-directed grouting operation, the grouting subcontractor wrote to PKC suggesting that too much grout was being injected into the soil at the RE's direction. The subcontractor believed that the soil was accepting the grout as planned and that injecting too much grout could cause problems. This concern seemed justified later when, according to the subcontractor, the construction contractor complained that tunnel roadway excavation had

become difficult because of the presence of large amounts of hardened grout in the soil.

- In June 1998 the SDC questioned the contractor's quality assurance/quality control (QA) program for, and the likelihood of the success of, the grouting operation. Also in June 1998, the grouting subcontractor complained that the RE's continued direction of grouting operations did not allow the subcontractor to make an on-going evaluation of the grouting work through an analysis of the "tell-tale trends" (information that helps to identify grouting success). In July 1998, B/PB declared the grouting operation complete.

In 1998, the RE claimed that the soil lacked permeability. The RE later informed this Office that he had declared a differing site condition because the soil seemed to contain voids that accepted more grout than planned, thereby causing the heave. This seems to contradict the justification for declaring a differing site condition and supports the grouting subcontractor's assertion that the soil accepted more grout than planned.

All this information suggests that the RE declared a differing site condition without adequate and corroborating evidence. B/PB should have investigated the issue and worked to satisfy both the need for information and the need to maintain the schedule.

Finding 4. B/PB failed to adequately investigate its differing site condition claim as required by state law.

M.G.L. c. 30, §39N describes the rules for change orders on a public construction contract. This law requires that an owner investigate the claim of a differing site condition. B/PB's contract with MassHighway, which the Turnpike Authority has the responsibility to manage, requires that this be done in a timely manner. The investigation should be done before modifying a contract or making, as the law permits, an "equitable adjustment in contract price." Under its contract with the Commonwealth for contract management services as well as in its capacity as manager of the claims process,³⁹ B/PB is obligated to follow all of the Commonwealth's laws and regulations.

³⁹ The Turnpike Authority has modified its contract with B/PB in late 2001, placing the management of the claims process under the direction and control of Turnpike Authority's General Counsel staff.

This Office interviewed the RE, B/PB staff, and PKC staff regarding the grout heave investigation. Based on this Office's review, B/PB did not sufficiently investigate the grout heave matter before declaring the existence of a differing site condition and modifying the construction contract.

When questioned by staff from this Office, B/PB staff offered contradictory views on the issue of whether B/PB performed an investigation. The RE informed this Office that he conducted an investigation with B/PB's Geotechnical Services Manager and the geotechnical staff. The RE could not recall if the investigation produced a report or other work product but he believed that staff notes existed.

This Office requested that the Project provide all documents relating to the determination of a differing site condition. In response, the Project informed this Office that no "responsive documents" existed. B/PB's former Geotechnical Services Manager, who the RE claims was included in the grout heave review and remediation process, stated in an interview with this Office that he had no knowledge of an investigation into a differing site condition relating to grout heave.

The conflicting testimony, and the lack of any material proof that B/PB staff performed an investigation as required under M.G.L. c.30, §39N and B/PB's contract, leads this Office to conclude that B/PB, under the direction of the Turnpike Authority, failed to adequately perform its contractual responsibility. It appears that little if any effort has gone into explaining the heave and to attributing responsibility, if any, for the heave occurrence. Under its contract with the Commonwealth, B/PB should have completed and documented an investigation. This lack of documentation could weaken the Commonwealth's current negotiating position with the contractor for millions of dollars in claims relating to the heave issue.

Finding 5. The grout heave issue is inadequately documented in Project records.

As mentioned previously, this Office requested that the Project provide all documents pertaining to the declaration of a differing site condition. This Office learned that the

decision to pay for nearly \$20 million (of the \$65 million claimed by PKC) in public money is virtually undocumented. In addition, this report illustrates how the information that does exist regarding the identification, investigation, and remediation of the reported grout heave is incomplete and contradictory. The paucity of Project records documenting the required investigation points to B/PB's failure to perform the obligations of its contract, follow Project procedures, and follow basic professional care in its management of the heave issue. The sparse documentation that does exist is deficient. For example:

- B/PB staff failed to date or denote authorship on certain documents prepared to support B/PB's position on the contractor claims making it difficult to trace B/PB's efforts chronologically.
- This Office found no document that contained a value estimate of outstanding claims and a record of claims settled to date.
- An audit trail is lacking between the RE and upper management concerning the RE's declaration of a differing site condition.
- Little documentation exists relative to the RE's overall direction of the grouting program including the RE's attempts to resolve the outstanding contractor claims.
- This Office's review found no records evidencing that the RE investigated the cause of the heave.
- This Office found no evidence of correspondence between B/PB and state officials regarding the negotiation of claims and settlements.
- This Office found no evidence of correspondence between the Project and FHWA officials regarding the negotiation of claims and settlements.

Troubling as well, is the Project's assertion that certain documents had been removed from Project files for review by the Project's outside counsel in preparation for litigation dealing with contractor claims. Project staff could not produce an inventory of, or identify the specific documents being held by the Project's outside counsel.

The lack of documentation and investigation of the condition of the site, and the contradictory information and testimony by B/PB's own staff makes an understanding of the reasons for declaring a differing site condition nearly impossible to attain.

Conclusion

This report identifies \$65 million in Central Artery/Tunnel Project (Project) construction cost increases relating to ground movement, or "grout heave," that may be attributable to deficient work on the part of the Project's management consultant, Bechtel/Parsons Brinckerhoff (B/PB). The findings in this report indicate that these grout heave-related costs may be attributable to B/PB's failure to:

- anticipate construction difficulty;
- prepare adequate contract specifications;
- conduct an adequate ground monitoring operation;
- investigate and gather sufficient information regarding contractor claims; and
- document evidence and decisions.

As discussed in this report, B/PB failed to anticipate and prepare for the possibility of "grout heave" during soil stabilization operations at the Red Line tunnel construction site. The ground movement, or grout heave, occurred on the C11A1 (I-93 Central Artery – Kneeland to Congress Street) construction contract. The contract began in February 1995 and is nearly complete. Between 1995 and 2002, change orders increased contract costs by 23 percent, from \$378 million to approximately \$490 million. Grout heave took place from mid-1997 to June 1998 and reportedly caused movement of the Red Line subway tracks and station platform at South Station. The construction contractor, following B/PB's instructions, eventually controlled the heave but continued to seek compensation through the dispute resolution process and litigation for these efforts. This Office did not examine the merits of the contractor's claims or of B/PB's negotiating position. Rather, this Office's review focused on B/PB's decision-making and management process concerning the grout heave and the contractor claims. - This Office's review found that Project staff did not initiate any investigation into the causes of the grout heave, nor did Project staff attempt to determine the extent to which design errors by B/PB were to blame.

The Commonwealth's estimated financial exposure from grout heave-related claims could be tens of millions of dollars higher than \$65 million. This added exposure relates to the impact of grout heave on other construction contract schedules and scopes of work, the overall Project schedule, and B/PB management costs. B/PB's failure to anticipate and plan for grout heave in the project design has also caused the Project to become embroiled in mediation and litigation efforts that have consumed the time and attention of Massachusetts Turnpike Authority and B/PB staff.

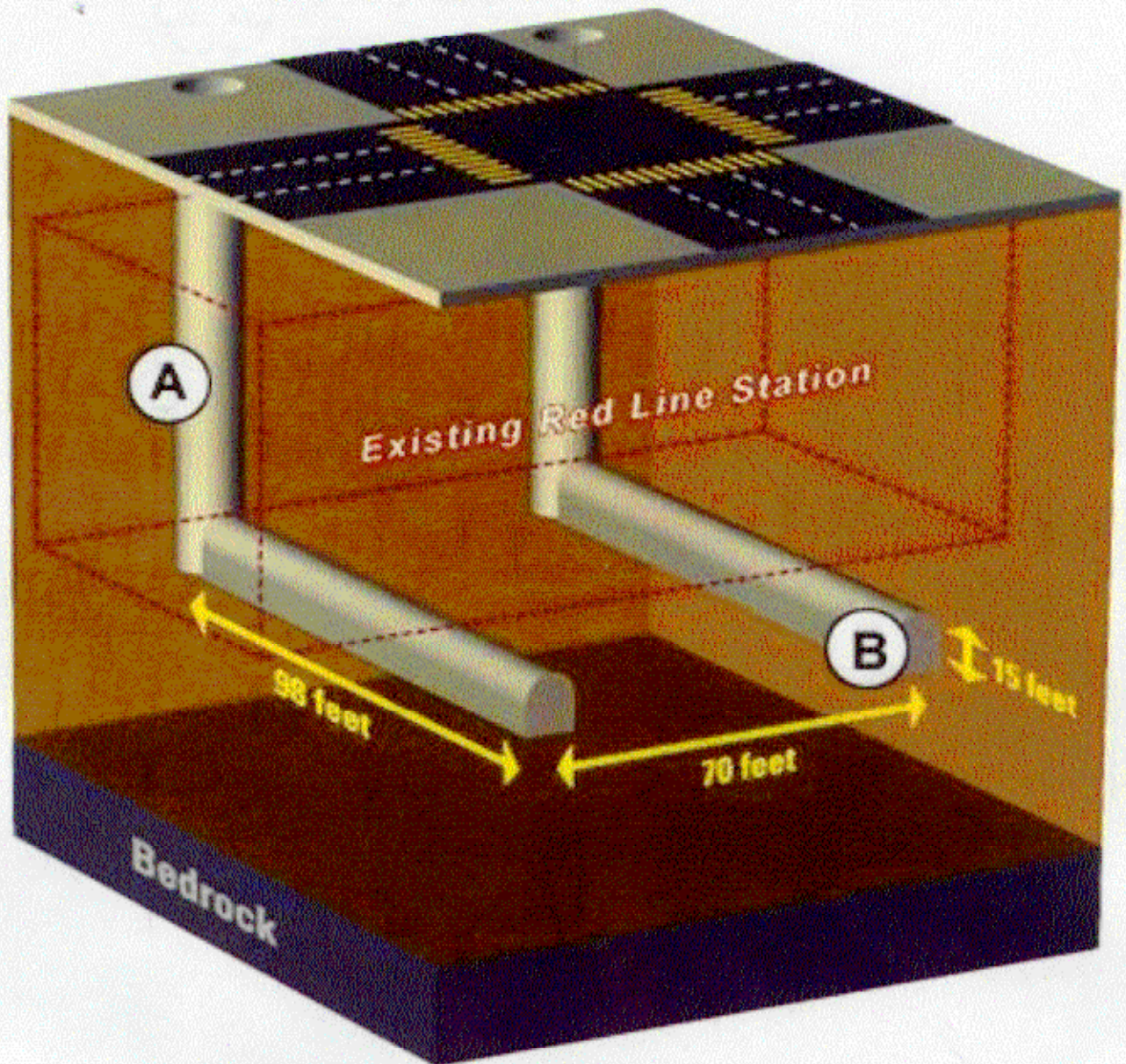
Although B/PB stated that its actions saved money by maintaining the Project schedule, this Office concludes that B/PB may have been the cause of these multi-million dollar claims. However, B/PB shifted the financial responsibility for the claims onto the Commonwealth, in effect nullifying the need for Turnpike Authority officials to determine why the grout heave was not anticipated.

The basis for the decisions made by consultants being paid billions of dollars by the Commonwealth and a potential \$65 million contract increase should be readily explainable. The Turnpike Authority should require B/PB to explain cost overruns and any design, management, or other possible errors that occurred under B/PB's watch. If responsible for these cost overruns, B/PB should pay for its mistakes.

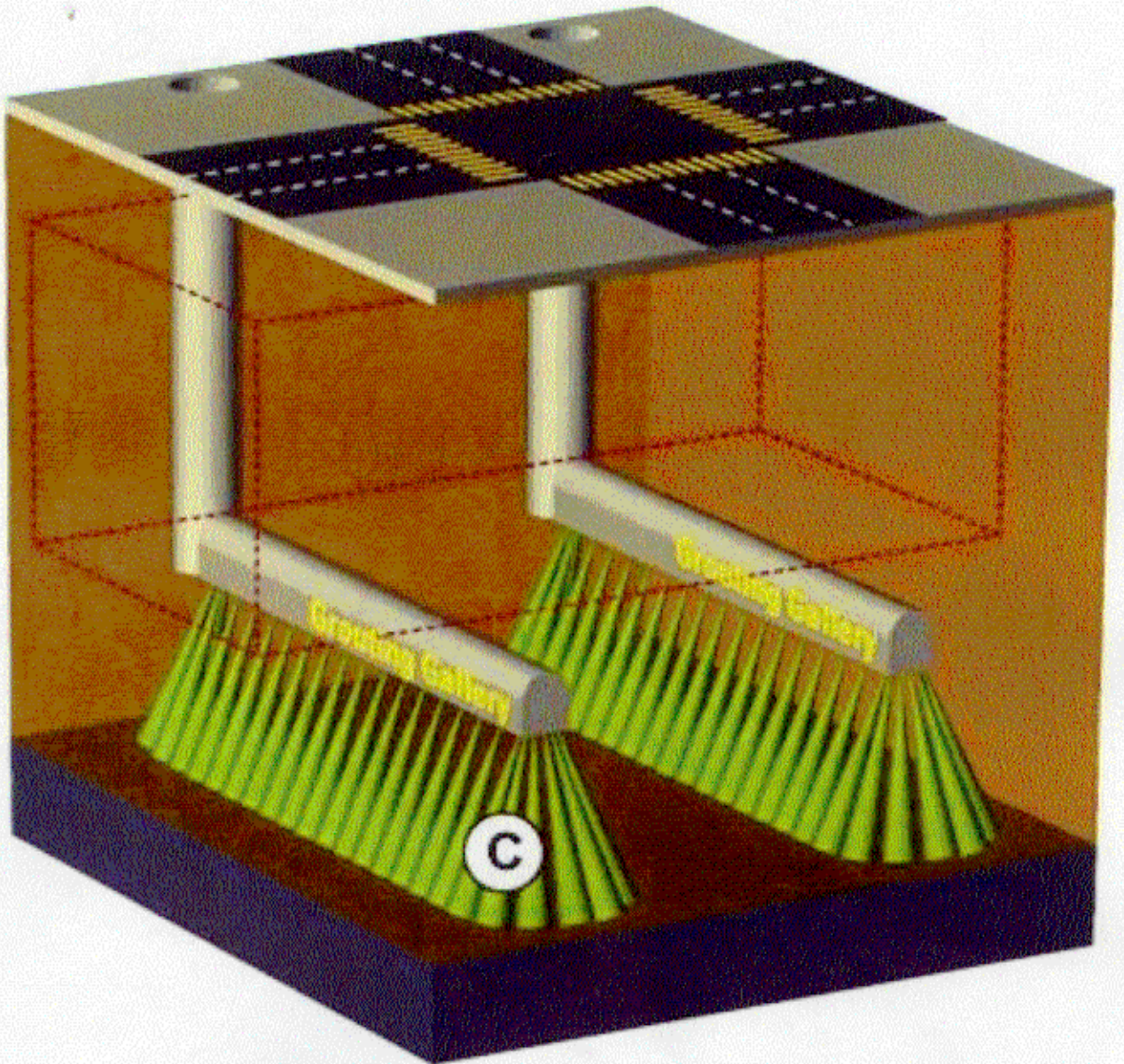
In an October 3, 2001 letter to the Chairman of the Massachusetts Turnpike Authority, this Office and the Office of the Auditor of the Commonwealth jointly expressed concern about B/PB's refusal to acknowledge any responsibility for or to share in the burden for increasing Project cost overruns. The letter also reiterated an issue first raised in this Office's December 2000 report entitled *A Review of the Central Artery/Tunnel Project Cost Recovery Program*, which found that the Turnpike Authority had not successfully pursued any significant cost recovery cases against B/PB. This Office is not aware of any case where the Turnpike Authority pursued a cost recovery action or contractual remedy against B/PB for errors, mismanagement, or contract violations. As the findings of this report make clear, the grout heave issue should be the subject of a cost recovery investigation. This Office will continue to work with the Turnpike Authority and other officials to identify and pursue other cost recovery cases.

Appendices

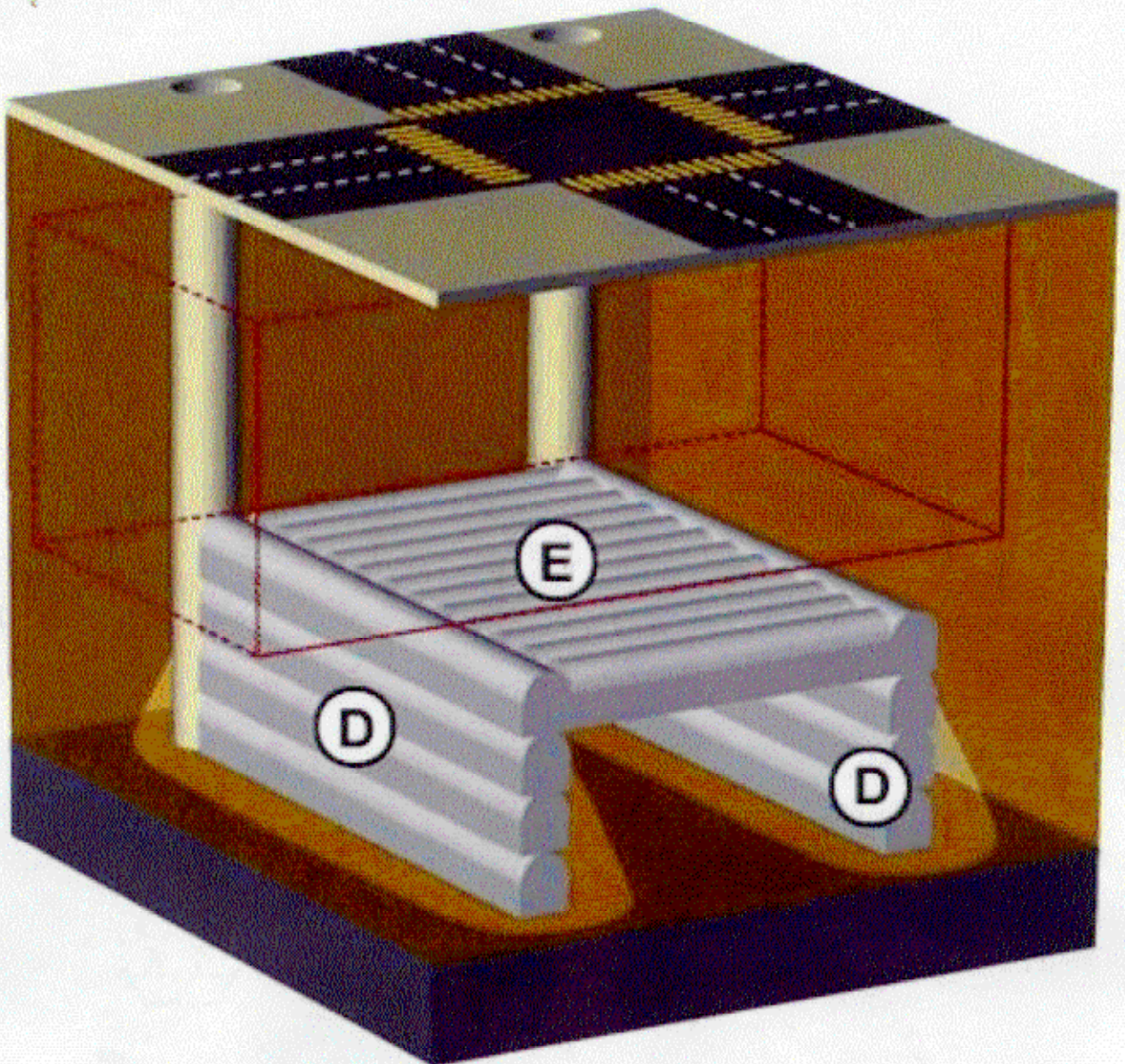
APPENDIX ONE



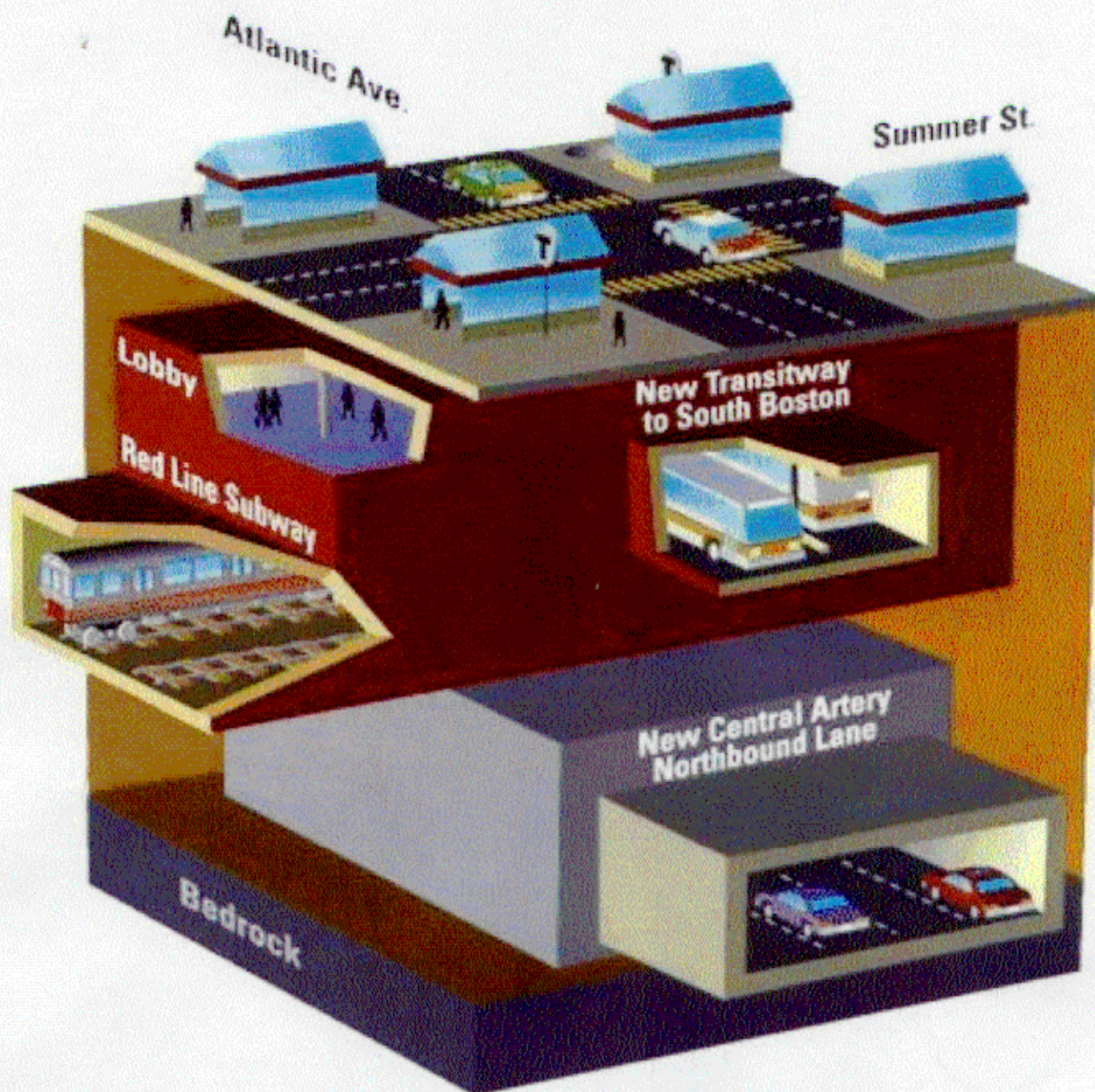
Step one was digging two shafts (A.), like elevator shafts, down to about 20 feet below the bottom of the subway tunnel. One shaft is on the Federal Reserve Bank corner across from South Station, the other on the old Peter Pan Bus Terminal corner across from One Financial Center. Next, horizontal tunnels (B.), called "grouting galleries," each about 15 feet high, were dug under the subway across Summer Street. The subway is only a few feet above the top of the tunnels; workers can hear the trains rumbling overhead.



Then hundreds of small shafts just a few inches in diameter were drilled in a fan pattern (C.) from the horizontal grouting galleries down to bedrock about 50 feet below. Porous pipes were inserted into the shafts and a liquid material called "grout" - like the liquid component of concrete - pumped through the pipes. The grout flowed out the tiny holes in the pipes and permeated the soil. When dry the grout makes the soil impermeable to water; tunneling is impossible in water-soaked ground. In fact, to make the first grouting gallery tunnel possible, the entire water table in Dewey Square had to be temporarily lowered by sinking wells to pump out the groundwater.



With the grout dry, the the vertical shafts could be sunk farther down to bedrock, so that a series of three more pairs of tunnels could be dug, one on top of the next, and filled with concrete (D), forming two massive concrete walls 100 feet long and 45 feet high underneath the grouting galleries and perpendicular to the subway. A series of small tunnels (E) between the grouting galleries atop the walls (all filled with reinforced concrete) will form the top of the table. Finally, the grouting galleries will be filled with concrete (leaving a duct for utilities) and the supporting structure will be finished.



With the soil above the underpinning structure grouted and the structure itself resting on bedrock, the subway tunnel will be fully supported and the highway will be mined between the sides of the "covered bridge" beneath the Red Line.

APPENDIX TWO

SECTION II



Central Artery/Tunnel

CONTRACT MODIFICATION

☒ EXTRA WORK ORDER☐ TIME EXTENSION☐ EXTRA WORK ORDER-SHORT FORM☐ TIME REDUCTION☐ MISCELLANEOUS ITEM☒ UNILATERAL - (Contractor's signature not required.
This Modification is a Change Order which is binding on the Contractor.)

CHECK ALL APPROPRIATE BOXES AS REQUIRED

CONTRACT NO: 95237 - C11A1

MODIFICATION NO: 273LA

CONTRACTOR: PERINI/KIEWIT/CASHMAN (JV)

EXTRA WORK ORDER NO: 273

CONTRACT DESCRIPTION: I-93 NORTHBOUND TUNNEL - ATLANTIC AVENUE

SUMMARY DESCRIPTION OF THIS MODIFICATION (for reference only):

CP 596, UNDERPINNING GROUT HEAVE

ISSUE NOS. RELATING TO THIS MODIFICATION:

A0273

ISSUE NUMBERS ARE FOR REFERENCE ONLY. THESE ISSUES ARE NOT INCORPORATED HEREIN UNLESS EXPRESSLY INCORPORATED BELOW.

This Modification is made to the above referenced Contract, subject to the conditions set forth herein. Except to the extent otherwise expressly stated herein: The Contractor shall perform all work and furnish all labor, materials, tools, equipment and incidentals necessary to accomplish this Modification and to incorporate it into the Contract work, in strict compliance with Division I, General Requirements and Covenants, Article 4.01, entitled "Intent of the Contract Documents" and all existing requirements of the Contract, including but not limited to all specifications, drawings and incorporated standards.

See attached Continuation Pages...



Central Artery/Tunnel

CONTRACT MODIFICATION (CONTINUATION SHEET)

CONTRACT NO: 95287—CH1A1

MODIFICATION NO: 273.1A

This is Part 1A of a Two Part Modification

1.0 The Work Includes that the Contractor shall take such efforts as directed by the Engineer, including:

1.1 Perform Water Pressure Testing and Packer Test of Grout plugs to determine plug integrity;

1.2 Perform Water Pressure Testing to attempt to determine required injection flows and pressures and confirm that grout curtain is not complete;

1.3 Lower water table including opening of grouted well points, installation of an additional well point; replacement of pumps if necessary, and all other ancillary work;

1.4 Maintain Grouting Subcontractor on Stand by during testing period;

1.5 Maintain Tunnel work force and equipment on standby during testing period;

1.6 Maintain grouting subcontractor on standby during lowering of the water table and evaluation period, until such time as the Engineer directs the Contractor to resume the grouting operation or terminate the subcontractor;

1.7 Provide the services of Geotechnical Consultant to attend meetings and recommend test procedures and participate in alternate grouting method discussions;

2.0 The Contract Schedule of Quantities and Prices shall be Modified to reflect the changes by adding the following Pay Item:

Item No	Quantity	Description	Max Interim Amount Contractor May Invoice
001.267	BLS	Underpinning Mitigation Efforts	\$2,000,000

3. This Contract Modification is Not intended to represent final settlement for Issue A0273 but does establish a budget to enable Contractor to receive interim payments. The Contractor shall maintain Time and Material records as a basis for requesting such interim payments. MHD reserves the right to adjust such payments. Prior to final settlement, the interim not to exceed budgeted amount may be adjusted, upwards or downwards, by a subsequent additional, Part 1 modification.

This is Part 1A of a Two Part Mod. It is being issued unilaterally, as the Contractor has refused to accept a bi lateral, multi part Modification. The Contractor's refusal is due to a reservation of rights issue relative to consequential costs, if any, including time delay and associated costs and such other related direct costs as loss of productivity. The Contractor asserts these costs are difficult or impossible to quantify at this time. Therefore, the modification is being issued unilaterally to facilitate payment to the Contractor for incurred direct costs.

The Contractor is apprised of its obligations under the Contract, which remain in full force and effect, with respect to any claim it may have relative to such consequential costs, including but not limited to Division I Specification, General Requirements and Covenants, sections 4.03, 4.04, 4.04, 3.05, 3.10 and 9.03.

The Contractor is specifically apprised of the time period requirements for the filing of such claim pursuant to GRC Section 4.03, paragraph H.



Central Artery/Tunnel

SECTION II

CONTRACT MODIFICATION (CONTINUATION SHEET)

CONTRACT NO: 95287 - C11A1

MODIFICATION NO: 2731A

Except as expressly specified otherwise in this Contract Modification, this Contract Modification constitutes an all inclusive settlement, an accord and satisfaction, and complete and final compensation for any and all claims, whether consequential, direct, or indirect, resulting from or relating to this Contract Modification including, but not limited to, cost and time impacts associated with the provision of labor, materials, equipment, and field and home office overhead, necessary or incidental to the work specified in this Contract Modification; provided, further, Contractor agrees to release and discharge the Department and Bechtel/Parsons Brinckerhoff, and their respective officers, agents and employees, from any and all such claims or liabilities.

Except as expressly specified otherwise in this Contract Modification, Section 7.25 of the General Requirements and Covenants shall apply to this Contract Modification; provided, further, that the Contractor shall defend, indemnify, and hold harmless the Department and Bechtel/Parsons Brinckerhoff, and their respective officers, agents and employees, from any claims by Subcontractors, Suppliers, or Vendors of any tier arising from or relating to the claims settled or work required by this Contract Modification.

If this is a unilateral Contract Modification it shall become final and binding on the Contractor, without consideration of any prior reservation of rights, unless the Contractor delivers to the Engineer written Notice of Claim and Equitable Adjustment Proposal in accordance with sections 4.03 (E) and (G), Division I - General Requirements and Covenants, within the ten (10) day period when Notice of Claim on account of a Change Order becomes due.

This Contract Modification and any payment hereunder does not constitute an admission of liability by the Department, or a waiver of insurance coverage by the Department or the Contractor.

Except as expressly specified in this Contract Modification (or any prior part of this Contract Modification), this Contract Modification constitutes the entire agreement, and any other documents, correspondence or statements shall not constitute a part of this Contract Modification.

Except for any change made through this Contract Modification, all terms and conditions of the Contract remain unchanged.

ORIGINAL CONTRACT \$ 5577,933,000.00

THIS CHANGE - INCREASE 52,000,000.00

DAYS INCREASE/DECREASE: none

NEW DATE OF COMPLETION: no change

ACCEPTED:

MASSACHUSETTS HIGHWAY DEPARTMENT

 Unilateral Modification
NAME OF CONTRACTOR

BY:

BY:

SIGNATURE

DATE

MHD APPROVAL AUTHORITY:

DATE

 Not Required-Unilateral
PRINT NAME

 Peter Zuk
PRINT NAME

 Project Manager
TITLE

 Project Director
TITLE

*NOT REQUIRED FOR UNILATERAL MODIFICATIONS



Central Artery/Tunnel

SECTION I

CONTRACT MODIFICATION (CONSTRUCTION)

CONTRACT NO.: 95287-C11A1		MOD NO: A0273	
CONTRACTOR: PERINI/KIEWIT/CASHMAN (JV)			
MOD TITLE: CP 596, UNDERPINNING GROUT HEAVE			
PRELIMINARY ESTIMATE OF COST AND TIME:		SCHEDULE IMPACT:	
\$ 4,000,000.00		NO IMPACT	
CONSTRUCTION COST/TIME IMPACT TO OTHER CONTRACTS:		DOES APPROVAL OF THIS CONSTRUCTION MODIFICATION ALSO AUTHORIZE DESIGN PCN/WORK ORDER APPROVAL?	
<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO		<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO	
IF YES, CONTRACT NO: _____		IF YES, CONTRACT NO: _____ DESIGN PCN NO: _____	
ESTIMATED RANGE \$		PRELIMINARY ESTIMATE OF COST: \$	

GENERAL DESCRIPTION AND JUSTIFICATION FOR CHANGE:

What is this Change:

The C11A1 portion of the Northbound I-93 roadway alignment passes below the MBTA's Red Line South Station. As part of the planned Construction sequence for this roadway section, the design calls for underpinning this station. The underpinning consists of a series of stacked drifts, bearing on bed rock. These drifts in turn support a cross beam structure which will provide direct support of the Red Line Station, through out the construction period of that portion of the cut and cover tunnel section which passes under the Red Line Station.

In preparation for mining the stacked drifts, vertical access shafts and horizontal access tunnels were constructed on the east and west side of the Red Line Station. During construction, the area was maintained in a dewatered condition by drawing down the water table using well points. Per the Contractor's alternate construction methods procedure, stacked drift excavation proceeds from these access shafts. However, prior to commencing stacked drift excavation, the Contractor's submitted procedure and the specifications, Division II sections 140.150 and 158, require grouting of the in situ soils, for maintenance of the Red Line Passive Well dewatering system.

Radial grout injection bores were drilled from the horizontal access shafts. The bores were capped and the water table was allowed to restore itself to the natural level by ceasing operation of the well point dewatering pumps.

Once the water table stabilized, pressure injection grouting (sodium silicate) commenced under direction of the contractor's subcontractor, Haywood Baker. Per specification, the Red Line Station was monitored for movement as the grouting proceeded. The monitoring was performed by the Contractor's geotechnical consultant, GZA. On or about November 14, 1997, unacceptable vertical movement (heave) of the Red Line Station was detected and heave of the horizontal access tunnel floor was noticed. Alternative grouting methodologies, including injecting at lowered flow rates, were employed in an attempt to control the heave. These proved unsuccessful.

On or about December 11, 1997, a test program was conducted by GZA including pressure testing to determine the minimum injection pressure required to obtain the specified grout flow rate and packer tests to determine the integrity of the installed grout plugs.

As a result of this testing program, grouting resumed at reduced flow rates (4 GPM) at a pressure not to exceed 1.25 (psig) per foot of overburden. The viscosity of the chemical grout was also reduced. These measures proved unsuccessful.

On December 18, a decision was made to stop grouting, lower the water table and grout in a dewatered condition. To reduce schedule impact, the Contractor commenced mining of the cross adit tunnels which receive the station support beams.

This change is to recover the Contractor's costs including standby time for the grouting subcontractor, Haywood Baker, the tunnel workers performing the injection grouting, consultant costs for the test program, the cost of dewatering including reinstallation of grouted wells and the installation of a new well as well as other related costs. It does not include any commitment to compensate the Contractor for claimed inefficiencies of working out of alleged sequence.

Why is this Change Required:

This change constitutes a Differing Site Condition, as determined by the Engineer, in accordance with Division I, SDC section 4.04, as the apparent lack of permeability of the in situ soils, precludes the injection of grout with out causing unacceptable harm to adjacent structures. Therefore, an equitable adjustment is warranted.

SECTION I



Central Artery/Tunnel

CONTRACT MODIFICATION (CONSTRUCTION)

CONTRACT NO.: 95237-C11A1		MOD NO: A0273	
CONTRACTOR: PERINI/KIEWIT/CASHMAN (JV)			
MOD TITLE: CP 596, UNDERPINNING GROUT HEAVE			
PROPOSED FUNDING SOURCE:		<input checked="" type="checkbox"/> EXISTING CONTINGENCY? <input type="checkbox"/> OTHER (e.g. MBTA, MDC, MPA, MTA, etc.) If checked, obtain third party approval	
<input type="checkbox"/> INCREASE IN FUNDS			
COST RECOVERY INQUIRY FORM TO BE COMPLETED?		<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO COST RECOVERY ISSUE IDENTIFIED BY:	
POTENTIAL INSURANCE RECOVERY?		<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO <input type="checkbox"/> B/PB <input type="checkbox"/> MHD <input type="checkbox"/> FHWA	
IF VECT, PROVIDE #: _____			
COMMODITY CODE: N/A		CAUSE CODES: 0 OTHER (SEE REMARKS)	
RESIDENT ENGINEER SIGNATURE		MHD DIRECTOR OF CONSTRUCTION	
 Burton P. Kassap DATE 2/12/98		Joe Allegro DATE	
THIRD PARTY REQUIRED <input type="checkbox"/> YES <input type="checkbox"/> NO		B/PB CCAM SIGNATURE	
ORGANIZATION: _____		_____	
DATE _____		DATE _____	
<input type="checkbox"/> APPROVED <input type="checkbox"/> NOT APPROVED			
B/PB ACM SIGNATURE		FHWA REMARKS:	
 Jim Doebler DATE 4/2/98			
MHD ACM SIGNATURE		FHWA CONCURRENCE:	
John J. Wright DATE		John McVann DATE	
B/PB CONSTRUCTION MANAGER SIGNATURE		<input type="checkbox"/> APPROVED <input type="checkbox"/> NOT APPROVED <input type="checkbox"/> APPROVED, SUBJECT TO REMARKS	
 Don Hesson DATE 4-9-98			