

ADAPTATION: Block 75 Redevelopment Shoring and Dewatering

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ABSTRACT

The City Creek Block 75 Project encompasses a large city block in Salt Lake City, involving excavations to 90 feet below street grade and over 40 feet below groundwater. Earth retention, in combination with dewatering systems, was installed to support five adjacent high rise structures and three major streets abutting the site. Ground conditions are comprised of dense cobbles and gravels overlying interlayered lakebed deposits with incised stream deposits which provide conduits for groundwater recharge from the ancestral City Creek. The design and construction scheme provided the flexibility required and often emphasized by Terzaghi to adjust in response to actual underground conditions using the available means and methods. This case history traces the innovative modifications to dewatering and shoring systems implemented in response to subsurface conditions identified during Block 75 shoring and dewatering construction.

Initial subsurface projections allowed for a dewatered approach using a complex multi-stage wellpoint system combined with soil nail and shotcrete shoring, supplemented by soldier or secant piles and post-tensioned elements for added stiffness at critical sections. In general, the wellpoint systems reduced pore pressures within the upper aquifer, but groundwater remained perched in an intermittent zone of interlayered silts and clays along the east wall. Modified shoring design, dewatering systems and changes to construction procedures were required to complete this wall. Consequently, the north perimeter of the project was redesigned as a composite shoring and groundwater cut-off system combining secant piling, jet grouting and soil nailing. The revised shoring and dewatering configurations from the east and north walls are presented with performance data for these unique earth retention systems.

SITE AND PROJECT DESCRIPTION

City Creek comprises a 20 acre redevelopment for mixed residential, retail and commercial use with five levels of underground parking and facilities. Block 75 is the central segment of the project, located adjacent to Temple Square in downtown Salt Lake City. The site extends 650 feet south from South Temple to 1st Street, and

450 feet east from Main Street to the Key Bank Tower. The existing retail structures on the site were demolished, leaving driven piles abandoned in place. Existing high rise commercial structures were located at each corner of the site, and remained in operation throughout construction. A site layout plan is presented as Figure 1.

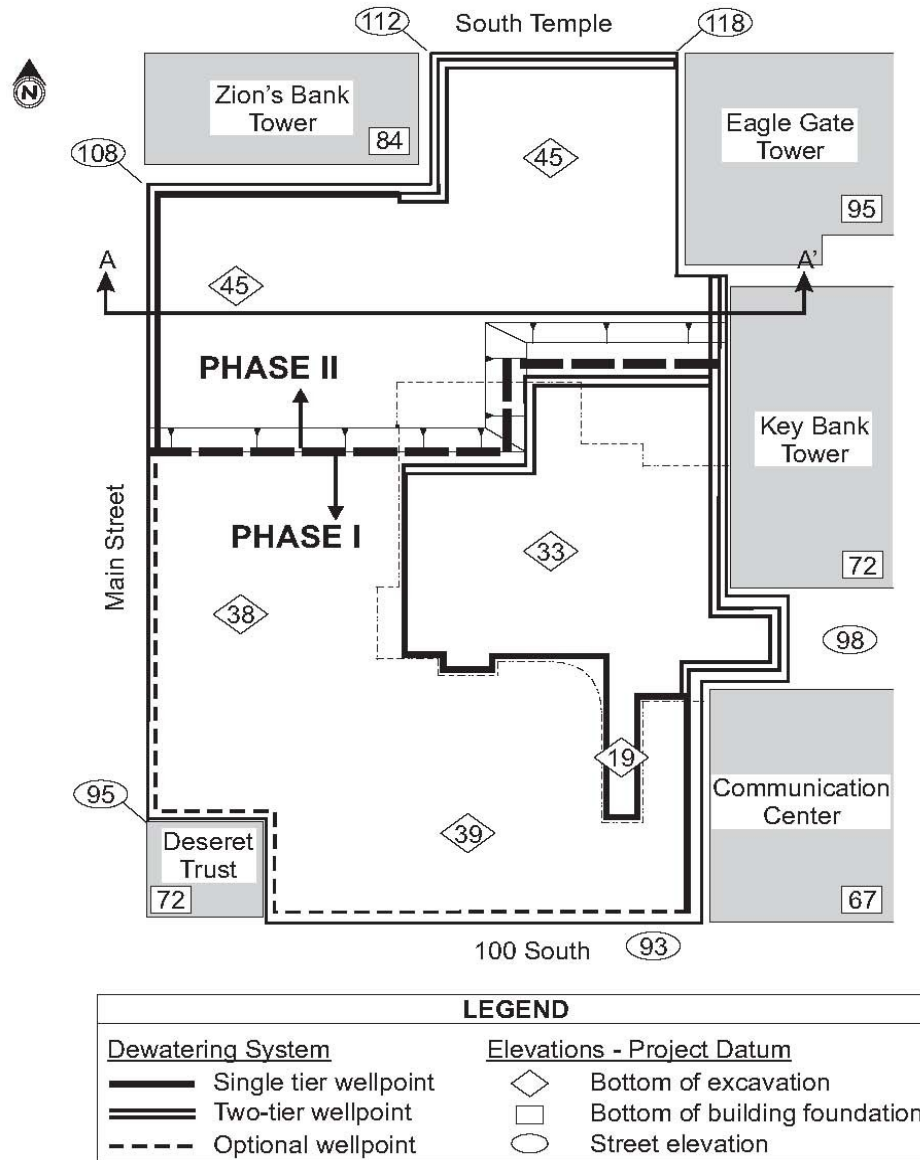


Figure 1. Site Plan

The topography of the project site and surrounding area generally slopes from project El. 118 in the northeast corner down to El. 92 at the southwest. Project El. 100 correlates to 4320 feet above Mean Sea Level. The base of excavation was at approximately El. 45, with a deepened zone along the east wall extending down to El. 33. The truck elevator in the southeast corner reached down to El. 19. The resultant shoring depths were approximately 75 feet from street level at the north wall and 55 feet along the south, with 99 feet overall vertical grade change between the high and

low points. The excavation and shoring were performed in two phases. Phase I, extending over the southern two thirds of the site, was completed in 2008. Phase II, the remaining northern segment, was performed in 2009.

SOIL AND GROUNDWATER ENVIRONMENT

Initial evaluation of the subsurface data indicated a stratified soil profile sloping from northeast to southwest across the site, consistent with the surface topography (See Figure 2). Variable fill materials extend down to existing foundation level 25 feet below street grade. The natural soils are gravel with some clay and silt which in-turn overlay silty sand and clay lenses. This unit of predominantly non-cohesive soils served as an unconfined aquifer which required dewatering. The underlying aquitard (lean interlayered clay and silty sand) has a typical thickness ranging from 30 to 50 feet, thinning to 15 to 20 feet in the northwest corner, and separates the upper aquifer from a lower, confined aquifer. Historical records and the soils data show that ancient streams meandered through the site from northeast to southwest, creating intermittent incised zones in the aquitard. The deeper confined aquifer consists of highly permeable gravel and sand with occasional lenses of clay.

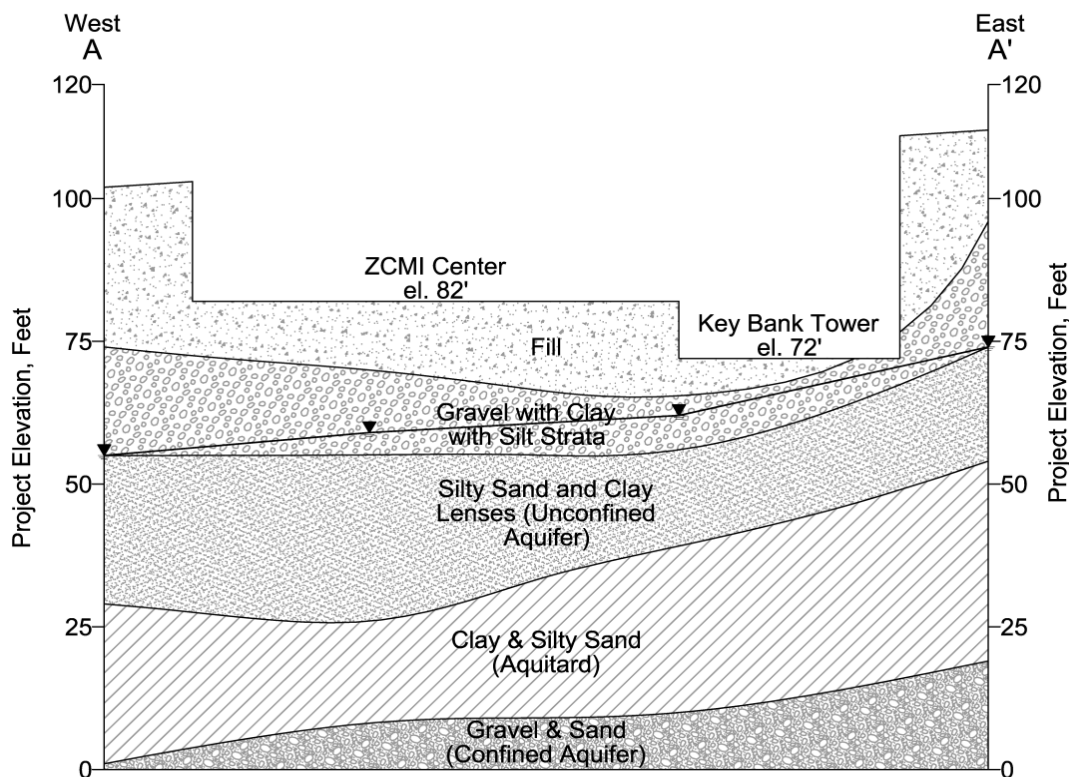


Figure 2. Block 75 subsurface cross-section A-A'

At the time of geotechnical studies, groundwater was encountered in the unconfined aquifer around El. 60 at the northeast corner and El. 42 at the southwest corner. Based on historical water level data, the geotechnical investigation concluded that design water levels could be about 10 feet higher. Groundwater levels in the confined aquifer were measured at around El. 33 feet during site pumping tests.

Borehole and water level data showed a strong correlation between direction of groundwater flow and inclination of fine-grained soil layers. The hydraulic conductivity of the finer grained soils is several orders of magnitude lower than the gravels and indicated these units may not readily yield groundwater to wells.

EXCAVATION SUPPORT PLAN

Soil nails and shotcrete was selected as the primary shoring system based on consideration of ground conditions and construction cost. This system requires dewatering to relieve hydrostatic pressure on the wall and maintain face stability. Soil nail and shotcrete shoring allows for flexible geometry to accommodate the existing structures and utilities which could not be exposed and dimensioned until demolition was nearly complete. Soil nails were relocated to mitigate any direct conflicts with obstructions, but maintained a minimum density across the excavation face, and in some cases were threaded through existing pile clusters behind the shoring walls. Vertical elements, comprising lengths of reinforcing steel encased on grout, were installed from grade before the start of excavation to improve face stability in the dense gravels. The specified deflection allowance was 1-inch for all shoring walls. The estimated soil nail wall deformations were consistent with the specified criteria for work adjacent to existing streets. Excavation support adjacent to the existing structures was evaluated on a case specific basis, with focus on enhanced deformation control using vertical and inclined micropiles and soldier pile elements in combination with post-tensioned nails and anchors to maintain confinement of retained soil and furnish shoring systems with significantly lower estimated deflections. Low yield systems were chosen to provide structural support while limiting deformation. Elements were sized with lateral pressure theory, recognizing the need to maintain low unit stresses and maximize use of composite soil-structure interaction. A variety of local and global stability analyses were employed to complete the design process.

DEWATERING APPROACH

Initial analyses suggested the majority of groundwater inflow could be controlled by measures implemented along the north and east sides of the excavation. Deep pumped wells and pressurized eductor or ejector wells were considered in project planning; however, the presence of existing buildings and access restrictions outside of the excavation footprint, prevented their use. The selected design employed vacuum wellpoints drilled through shoring walls at six to seven foot centers. Additional wellpoint systems were installed at the base of excavation to accommodate construction sequencing and deepened areas (see Figure 1). The dewatering scope was divided into required systems on north and east perimeters of both Phase I and II areas, and optional systems to be implemented as dictated by site conditions in other areas.

A two-tiered vacuum wellpoint system was used to manage groundwater up to 30 feet above the base of shoring along the Phase I north and east perimeter, with supplemental wells around the deepened east wall excavation and truck elevator pit.

Sumping was evaluated along the south and west walls; however since the soils did not readily yield groundwater, the optional wellpoint systems were installed. The Phase II work area was located north of Phase I and required new wellpoint systems along this up-gradient perimeter. A two-tier vacuum wellpoint system was designed along South Temple Street; however, the Eagle Gate Tower perimeter was designed as a combined shoring and cut-off wall due to risk of dewatering induced settlement.

Anticipated groundwater flows to attain drawdown behind the shoring wall were 240 GPM in gravels and 50 GPM in sand/silt for a 400 foot long wellpoint system. Actual flow rates typically ranged from 100 to 200 GPM at the initiation of a new wellpoint system to less than 50 GPM at stabilization. Total flow from the entire dewatering system never exceeded 300 GPM.

EXCAVATION SUPPORT CHANGES DURING CONSTRUCTION

The dewatering systems performed as anticipated throughout Phase I with the exception of the eastern wall. The Communications Center and the Key Bank Tower were located adjacent to this segment of the site perimeter (see Figure 1). Perching layers within the aquifer, the presence of utility backfills and leaking water pipes all contributed to increased hydrostatic pressure behind the soil nail walls. The evidence of these conditions included water emanating from discrete perforations in the shoring, discharge of soil and non-native materials as well as discovery of steady mid-summer flows into a storm-drain.

The east wall groundwater conditions compromised excavation face stability and applied excess hydrostatic loads against the shoring system. The project team considered multiple solutions in order to progress shoring along this wall. Some supplemental weep holes were installed, but due to difficulty in targeting the zones of free groundwater a full additional level of wellpoints was added, effectively halving the spacing to 3 feet. This reduced some of the hydrostatic pressure measured behind the wall, but did not effectively stabilize zones of non-cohesive soils, and hence excavation could not advance without risk of ground loss undermining previously constructed shoring elements. The soil face exposed during construction was minimized by reducing shotcrete lift height and working in only limited lengths of wall. This combination of slot cutting, supplemental weeps and additional wellpoints allowed completion of the east wall, but required thickened shotcrete and additional soil nails to resist the increased hydrostatic loading. The Phase II shoring systems were re-evaluated based on the conditions encountered during construction on the east wall. This resulted in modified excavation support schemes using secant piles and grouting to provide full-face pre-excavation stabilization, combined with supplemental anchorage to accommodate lateral loading from retained groundwater.

EXCAVATION SUPPORT SYSTEM CROSS-SECTIONS:

Communications Center. Excavation depths of 45 ft were required along the north and west sides of the Communications Center, located at the southeast site corner. Face of shoring was limited to be only 2 ft offset from the edge of this concrete framed structure, however an easement allowed for temporary anchorage

elements to extend below. This layout constraint did not allow sufficient clearance for soldier pile drilling and placement so the design used deep hollow-bar soil nails as the primary retention element. Micropile A-frames, spaced at 3 ft centers, added flexural stiffness and overall deflection control to the wall face. The shoring configuration is illustrated in Figure 3. Settlement control was enhanced by post-tensioning of all the soil nails against the reinforced shotcrete facing. The micropiles were terminated slightly below the main shoring face in order to avoid a “hard spot” beneath the footing. This allowed structure loads to transfer within the support system and dissipate through the soil mass. A shallow grade beam was added all along the top of the wall to enhance fixity of the drilled elements before start of excavation. The two-tier wellpoint system was designed to capture groundwater behind the excavation face and lower hydrostatic pressures. Wellpoint tips were located within five to ten feet of the shoring face to minimize dewatering induced consolidation.

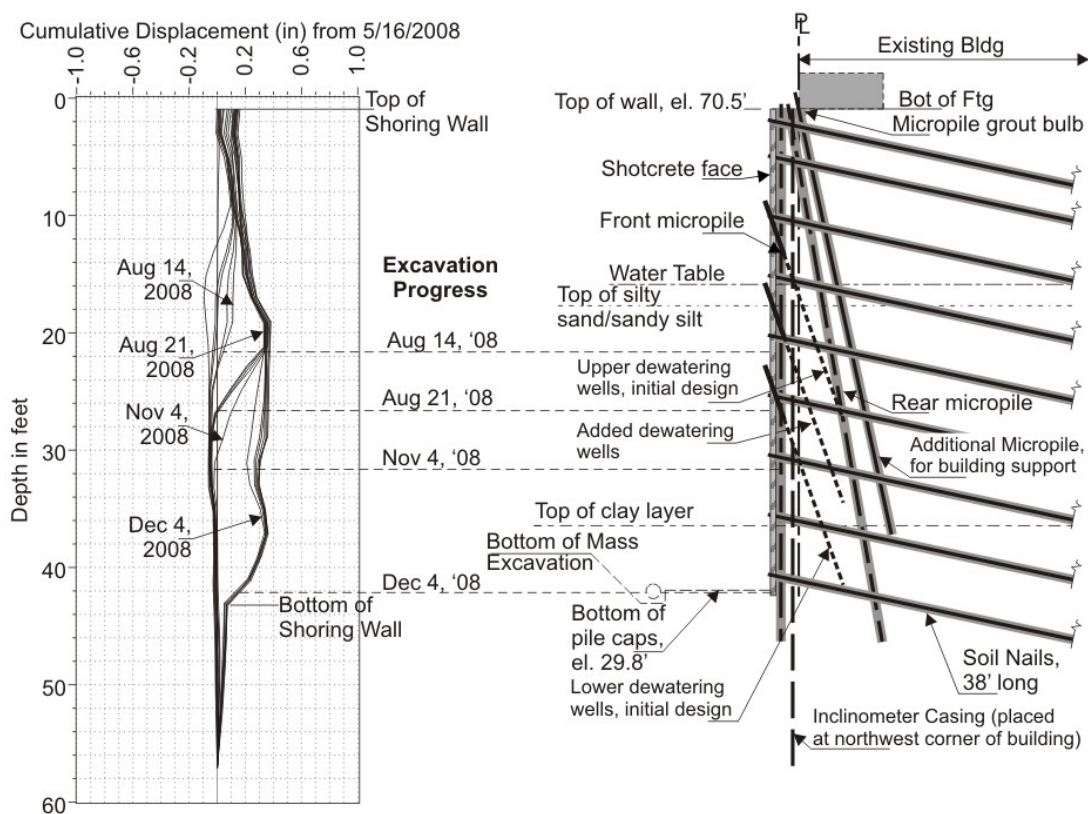


Figure 3. Communications Center inclinometer data and shoring cross-section

During construction an unanticipated layer of soft saturated silt was identified within the face of the excavation. It became apparent that wellpoints were not effectively dewatering this material. Consequently, the design was modified to include additional rows of nails and a ten-inch thick, reinforced shotcrete face. The inclinometer records show that the soil nails, which were tensioned after initial grout and shotcrete cure, effectively pulled the shoring face back into the soil near to the top of wall, countering some settlement induced by the dewatering and excavation. After a temporary hold in excavation for design and installation of the supplemental support, the cut was completed with total outward movement measured by the

inclinometer casing of approximately 0.5-inch. Settlement surveys by the owner show a total settlement of the building at 0.52-inches. The use of closely spaced, small diameter vertical and horizontal shoring elements accommodated the geometric constraints of this wall. This provided sufficient stability to allow excavation to final grade through extremely difficult soil conditions. Settlement matched the 0.5 inch maximum estimated during initial shoring design.

Eagle Gate Tower. This high-rise commercial building is supported on a mat foundation at El. 95, approximately 50 feet above the planned adjacent excavation. To avoid dewatering induced settlement, the project team proposed a secant wall with four rows of strand tieback anchors, designed to support hydrostatic head up to 20 feet above excavation grade. The secant wall was to be placed in a four-foot wide strip of ground along the west edge of the exposed building foundation.

After demolition was completed to El. 100, the abandoned foundations were exposed along the shoring alignment. Groups of driven pipe piles were identified within the shoring zone on 14 foot centers, and consequently a continuous secant wall could not be completed. The shoring and groundwater cut-off scheme was revised to combine segments of secant wall between the existing pile groups, with jet grouting, vertical spiling and shotcrete providing enclosure and sealing around the pipe piles, as shown in Figure 4. Some of the abandoned driven piles were out-of-plumb, requiring substantial real-time adjustments to secant pile and grouting configurations.

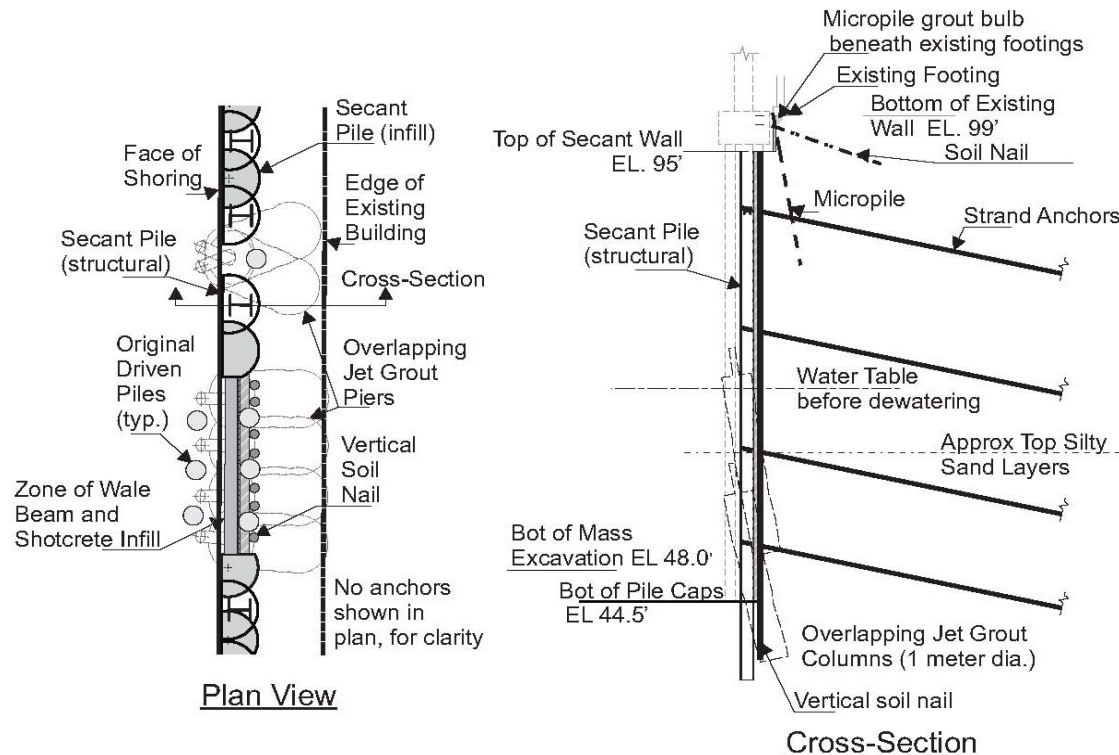


Figure 4. Eagle Gate Tower shoring details

During excavation, the deep tieback anchors were installed and stressed against either the secant pile reinforcing beams or wale beams bearing onto the

existing pipe piles. Some supplemental hollow-bar anchors were placed in zones which required reconfiguration due to obstructions. The jet grouting was installed using a steeply inclined drilling pattern at three different vertical intervals in order to work around the existing pipe piles. The resultant wall consisted of alternating vertical panels of secant piles and composite shoring elements, all intended to mobilize uniformly for support of the highly loaded mat foundation.

Two inclinometers were installed in this wall, but both were damaged during excavation and limited data was obtained. Optical surveys showed the maximum lateral movement of the wall was 0.54-inches and settlement was 0.26-inches during the 50 foot excavation extending below groundwater level. No collateral distress was identified in the building or on the actual shoring wall face.

South Temple Street. This 75 foot high shoring wall was the tallest vertical cut on the project and was scheduled under Phase II construction. The original design employed soil nails and shotcrete wall with a two-tier wellpoint system. However, based on experience gained during Phase I, the owner elected to redesign the wall as a composite shoring and groundwater cut-off system. The lower 40 feet utilized a tied-back secant pile wall while the upper 35 feet (above groundwater) remained a soil nail structure to minimize overall cost. The upper soil nail wall was set-back 3 feet in order to accommodate the lower tier secant pile installation, but existing utilities limited nail length to only 12 foot in the upper half of this wall section. Existing driven piles were exposed at 14 foot centers directly in front of the shoring zone and therefore jet grouting was used in combination with segments of secant piling to complete the wall. Tieback anchors were stressed against the secant piles during excavation.

The upper soil nailed section of South Temple shoring behaved erratically during construction. The west-end of this system terminated at a deep utility vault excavation. This outside corner, which was supported by short nails from the main shoring wall construction and by a simple corner brace in the vault area, indicated a trend of outward movement in both directions. A tie-rod bracing system was added to give adequate face support. The total settlement was consistent with the pre-construction estimate of 0.6 to 1.0 inch. The shoring cross-section is presented in Figure 5 with corresponding lateral deformation as measured by inclinometer.

SUMMARY & CONCLUSIONS

Block 75 was a large and complex excavation which required a variety of shoring and dewatering systems. Soil nail shoring and wellpoints provided the necessary flexibility to accommodate the range of site conditions and geometry. The initial excavation support scheme performed well for Phase I, with the exception of the east wall, where modified design details and construction methods were necessary for completion. Drawing on this experience, the north site perimeter was redesigned as a composite shoring and groundwater cut-off system combining secant piles, jet grouting, anchors, soil nails and shotcrete. The excavation and shoring was successfully completed with wall deformations consistent with pre-construction

predictions. Geo-structure performance on this project underscores the flexibility of composite design.

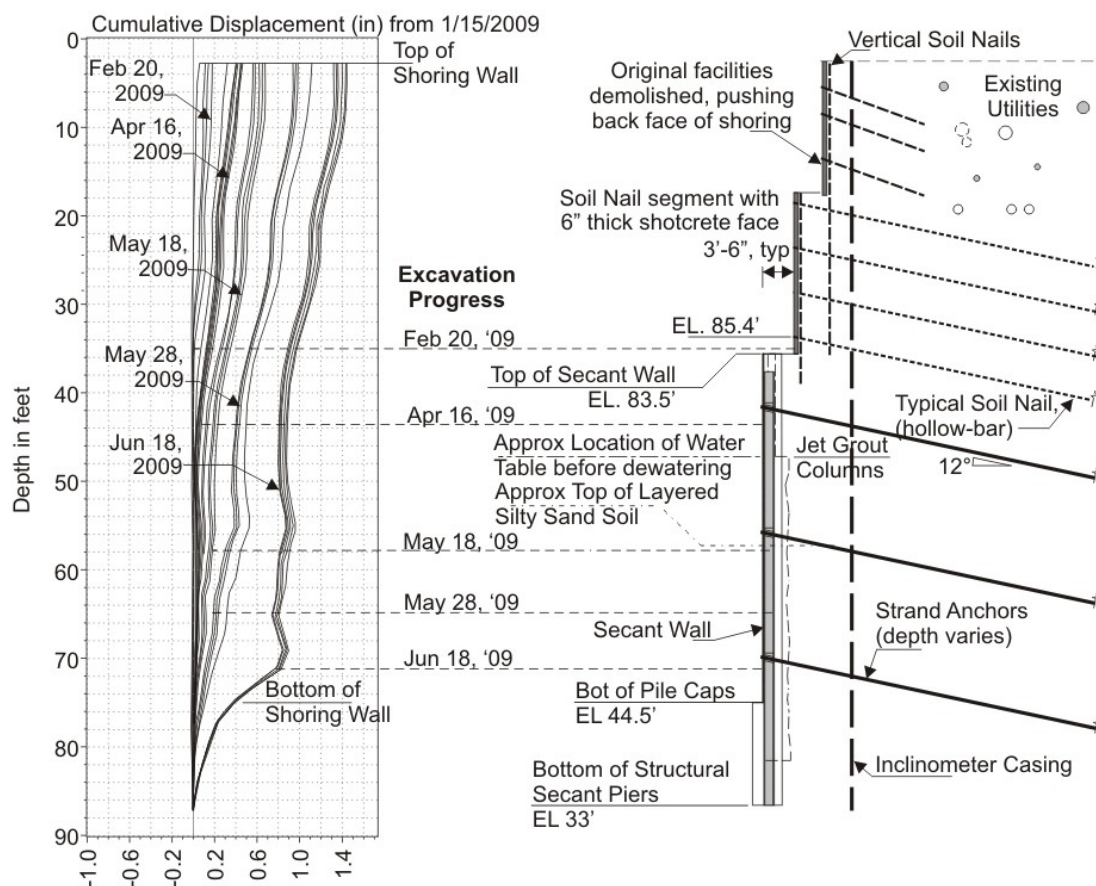


Figure 5. South Temple Street inclinometer data and shoring cross-section

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REFERENCES

Applied Geotechnical Engineering Consultants, Inc. (2006). "Geotechnical Investigation Block 75 and 76." *Prepared for Property Reserve, Inc.*