Design of the University Link Tunnels and Stations

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ABSTRACT: The University Link project extends Seattle's light rail from downtown to University of Washington (UW). It includes 5.0 kilometers (3.15 miles) of twin-bored, 6.4 meters (21 feet) excavated diameter tunnels, and two cut-and-cover stations. The Capitol Hill Station (CHS) requires an excavation 170.7 meters (560 feet) long, 22.6 meters (74 feet) wide, and 22.9 meters (75 feet) deep. The University of Washington Station (UWS) requires an excavation of about 238.4 meters (782 feet) long, 21.3 meters (70 feet) wide, and 33.5 meters (110 feet) deep. The project is within the glacially diverse soils of the Puget Sound region, below groundwater. This paper highlights major station and tunnel design elements, including the approach to support of excavation at both station boxes, and the site staging requirements.

INTRODUCTION

The Central Puget Sound Regional Transit Authority (Sound Transit) broke ground on the initial Link segment back in 2003. This 22.5-kilometer (14-mile) stretch, which opens in 2009, will connect Downtown Seattle to Sea-Tac Airport. Sound Transit hopes to capitalize on Link's success south of Seattle and extend the line north to the UW campus by 2016. The next section to the North, referred to as University Link (U-Link), will extend from the Central Business district through Capitol Hill and the Montlake area, and into the UW, connecting the three largest urban centers in Washington. When it opens, the U-Link section of Seattle's Light Rail Transit (LRT) program will increase Iinital Segment/Airport ridership by an estimated 70,000 travelers a day.

U-Link is perhaps the most ambitious part of Sound Transit's overall program, as it is entirely underground. The project includes 5.0 kilometer (3.15 miles) of twin-bore tunnels; two below-grade, cut-and-cover stations—one at the UW adjacent to Husky Stadium, and one in the heart of Capitol Hill; and transition structures where the new tunnels connect into the existing system. The project also involves 20 cross passages and four relatively shallow but complex underpinning pits within Interstate 5 (I-5) off ramps, which is a key artery through the Seattle metro area connecting Canada to Mexico, which the tunnels must traverse. The project's overall alignment is indicated in Figure 1.

Figure 1. University Link alignment plan

SUBSURFACE EXPLORATION PROGRAM

The subsurface exploration program for the U-Link has been developed over several phases. Prior to December 2006, more than 80 borings were drilled during initial studies either along or in the vicinity of the alignment. Since the start of final design, an additional 57 borings have been completed, as well as 53 pressuremeter tests. The purpose of the exploration program was to obtain subsurface data to interpret the geologic and geotechnical conditions along the tunnel alignment, at the cross passages, at each Station, and the Pine Street Connector. Drilling was performed using three different drilling methods: mud rotary, rotary sonic and wireline coring. Most borings were completed with truck-mounted drill rigs; although some difficult-access borings were completed with track-mounted drill rigs. Two interesting areas where geotechnical investigations were performed include drilling for the Montlake Cut and the drilling of one of the cylinder pile wall adjacent to I-5.

The Montlake Cut, located south of the UWS, is a canal connecting Lake Washington to Lake Union that provides a very important Salmon migration route for the region. Accordingly, the U-Link tunnels, which run under the Cut at relatively shallow depths, are subject to rigorous regulatory review. In addition to this review, technical issues such as buoyancy, slope stability, and settlement of the structures, lead to a detailed investigation of its existing condition. The Cut, was excavated around 1910, and has side slopes slightly flatter than 1H:1V (about 40°). The steepest portion of the Cut is about 18.3 meters (60 feet) high. After the excavation, about 1.5 meters (5 feet) of concrete was poured at the toe of the cut and over lower portions of some side walls. Since excavation, about 1.5 meters (5 feet) of muck has settled on the bottom of the Cut floor. Two borings were drilled from a barge in the Cut using wireline drilling methods. Tube samples were obtained from the soil below the base of the Cut for strength and index testing to gain more information on the conditions of the soil above the crown of the bored tunnels.

At I-5 the tunnels will be passing under the roadway with 4.6 meters (15 feet) of cover. In order to cross at this grade, portions of the existing cylinder pile walls adjacent to I-5 will need to be removed. These existing walls will be incorporated into four pits that will be excavated prior to the tunnels passing under I-5 and will act as lateral supports (see description below). Since no specific records of concrete strength exist on the walls, the Geotechnical Exploration Program was established to quantify their strengths. The testing was accomplished by core drilling a BX-sized core hole through cylinder pile number 20. Unconfined compression tests were performed on the core samples from the cylinder pile wall to determine the strength of the concrete. These strengths were then used in the analyses performed for the stability of the existing walls.

GEOLOGY

The project area lies near the southern end of the Seattle basin, a depression in the volcanic bedrock that is filled with middle to late Tertiary (36 to 2 million years before present) sedimentary and volcanic rock, and Quaternary (last 2 million years) sediments. Bedrock outcrops are present about 4.8 kilometers (3 miles) south of the project area where they have been uplifted and exposed by movement associated with the Seattle Uplift and Seattle Fault. Depth to bedrock increases abruptly north of the Seattle Fault. Beneath the project, depth to bedrock is estimated to range from 1,130 meters (3,700 feet) near the south end of the project area to 550 meters (1,800 feet) near the UWS. No bedrock was encountered during drilling.

The present-day land surface in the project area, which is part of the Puget Lowland, reflects glacial and non-glacial sediments deposited during the Quaternary Period over Tertiary volcanic and sedimentary bedrock. Only the late Quaternary and Holocene (within the last 10,000 years) deposits are exposed in the project area at land surface or present at the depths of the tunnels, stations and other project structures. The soils within the project consist of north to south trending modern stream valleys. In general, the ground conditions along the alignment consist of glacially consolidated pre-Vashon deposits consisting of hard cohesive clay and silt, very dense cohesionless silt and fine sand, very dense glacial till and till-like deposits, and very dense cohesionless sand and gravel. The glacial till and till-like deposits consist of a heterogeneous mixture of clay, silt, sand, gravel, cobble and boulders. The predominant soil type within the tunnel is expected to consist of hard cohesive silt and clay and very dense cohesionless silt and silty sand. Boulders may be present in all of these glacial deposits.

PROJECT CONTRACTS

The U-Link project will be constructed through eight contracts. Five of the contracts, U215, U220, U250, U230, and U240 include significant earthwork or tunneling. Contract U215, I-5 Undercrossing Construction Pits, consists of excavating four pits down to the tunnel elevations in the I-5 area, which is just north of the Pine Street stub tunnel (PSST), prior to the bored tunnel excavations. Contract U220, Bored Tunnels University of Washington to Capitol Hill, consists of 3.2 kilometers (2 miles) of twin bored tunnels, 15 cross passages, and the excavation of the southern half of the UWS box. U250, University of Washington Station Platform Structure, includes the UWS Station excavation (north half of box), station structures, finishes, and a concrete pedestrian bridge linking the station to the main campus. Contract U230, Bored Tunnels Capitol Hill to Pine Street, includes 1.85 kilometers (1.15 miles) of twin bored tunnels, 5 cross passages, and the excavation and temporary support of the CHS box. U240 includes station finishes, pedestrian tunnel excavation and structure linking the station to the west entrance, and the west entrance excavation and structure.

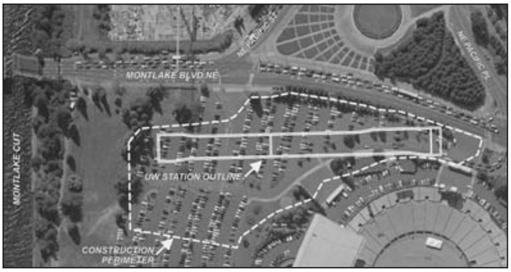

Figure 2. Plan view of University of Washington Station

U215 Contract: I-5 Undercrossing

The I-5 undercrossing consists of four excavation pits that are used to gain access to portions of existing cylinder pile retaining walls, installed around 1962 to create I-5. The four pits are located where the travel path of the twin bored tunnels intersects with the cylinder pile wall. The purpose of this contract is to remove these portions of walls to make-way for the TBM. The existing cylinder pile retaining walls are incorporated into the pit design and will be laterally supported with temporary tiebacks and wales to maintain stability during the excavation of the access pits. One of the major challenges of this contract is maintenance of traffic, as the work is entirely within the I-5 on and off-ramps at the Olive Street interchange. At this time, the intention is to close the ramps, sequentially, to minimize the overall impact of the work on traffic. Another challenge for the work is to complete the excavation (adjacent) and removal of portions of the wall without causing movement of the wall system. To help facilitate this, a strict excavation and removal sequence is required along with monitoring of the walls and adjacent pavements. The criteria for monitoring (e.g., trigger and action levels) will be set by the Washington Station Department of Transportation (WSDOT).

U220 and U250 Contract: Bored Tunnels University of Washington to Capitol Hill and Station Structures

UWS Station Box

Perhaps the most complex of the open cut structures, the UWS serves as the starting point for the first of the two major underground construction contracts. As shown in Figure 2 the station is located in the parking lot of Husky Stadium, just north of the Montlake Cut, and east of Montlake Blvd NE. The 238.4 meters (782-foot) long, 21.3 meters (70 feet) wide structure is comprised of a double cross-over structure and platform structure. The depth of the main excavation will vary from about 32 to 33.5 meters (105 to 110 feet). The double cross-over

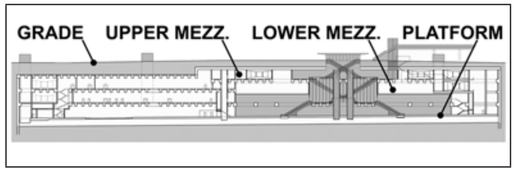

Figure 3. Profile through University of Washington Station

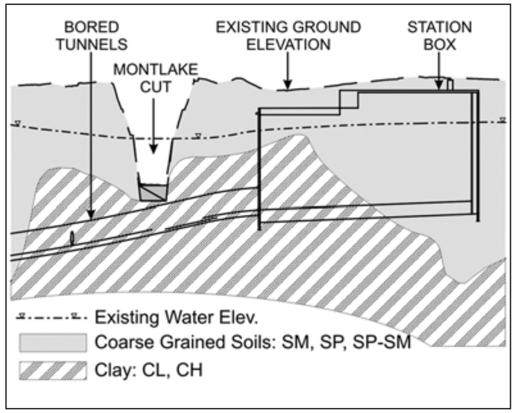

Figure 4. Subsurface conditions at University of Washington Station

is required to allow the station to serve as an interim terminus for the Link system. A 30% preliminary profile view through the station, showing the central mezzanine is shown in Figure 3.

Ground Conditions

Ground surface elevations vary from about elevation +17.6 meters (+58 feet) at the cross-over structure to + 20.4 meters (+67 feet) at the platform area. The bottom of the invert slab will vary from about elevation –14.3 meters (–47 feet) at the south end of the cross-over to about elevation –12.5 meters (–41 feet) at the north end of the platform. The site will be graded to an elevation of about +16.1 meters (+53 feet) prior to the station excavation.

The subsurface conditions include two distinctly different soil types as shown in Figure 4. The subsurface change, which occurs approximately at the midpoint of the station box, appears to reflect glacial outwash sand deposition in an erosional swale that lies predominantly to the north of the cross-over area. In general, the southern portion of the site is underlain by a thin veneer of fill followed by glacial till, followed by hard cohesive clays and silts. The northern portion of the site consists of a similar veneer of fill and glacial till; however, the till is underlain by glacial outwash. The outwash deposits are composed of dense to very dense, clean to silty sand, gravelly sand, and sandy gravel with lenses and layers of silt and sandy silt. The sand swale is more than 50.3 meters (165 feet) thick at its deepest point.

The groundwater levels increase from elevation +8.2 meters (+27 feet) at the south end to +10.4 meters (+34 feet) at the north end of the UWS site. Groundwater levels are expected to vary seasonally due to precipitation levels and regulated changes in the level of Lake Washington and Montlake Cut. Annual fluctuations at Montlake Cut are on the order of 0.6 meters (2 feet) with a low elevation of 5.1 meters (+16.7 feet) in January and a high elevation of +5.7 meters (+18.7 feet) in June. The season of low water levels in Lake Washington and the Montlake Cut generally corresponds with the high groundwater season, which would tend to moderate groundwater table fluctuations.

Excavation Support

The station excavation will be performed under two different contracts as previously mentioned, U220 and U250. The U220 Contractor is responsible for the installation of the slurry walls and the excavation and temporary support for the cross-over area (southern half), while the U250 Contractor is responsible for the excavation and temporary support of the platform area (northern half).The station box, which includes the cross-over and platform, will be excavated using concrete diaphragm walls as temporary support that will be incorporated into the final structure. The walls will be internally braced at vertical intervals of about 6.1meters (20 feet) as the station is excavated. The cross-over structure will be constructed using bottom-up methods while the platform structure will be constructed using either a bottom-up or a top-down approach. The excavation of the cross-over structure is on the project critical path and must be completed for the launch of the tunnel boring machines (TBMs). The excavation of the northern, platform end of the station does not have the same time considerations to commence, but is still constrained by area/time occupation limitations agreed to between the UW and Sound Transit.

One of the challenges of the UWS design is the hydrostatic uplift force acting on the invert slab due to the high water level. Typically, where hydrostatic forces exceed dead loads, stability can be created by adding dead load, reducing hydrostatic forces, or anchoring down the structure. Adding dead load would be a very costly solution because of the massive oversizing of the invert slab required to create enough weight. Reducing hydrostatic forces could be accomplished during construction at a significant cost premium using a dewatering program, but is not feasible for the permanent condition. Another viable option to counteract the hydrostatic uplift is to account for the frictional resistance between the ground and the slurry walls. However, the design criteria for the project does not allow for frictional resistance forces to be included in the design loads. A request for a deviation to the design criteria for the friction resistance was submitted by the design team and approved. The submittal provided analyses and case histories demonstrating that development of skin friction between the ground and slurry walls will occur. The final outcome was the removal of the tie-downs from the station design.

Construction Staging

Husky football and the University Medical Center are two very important entities for the UW. So much so that the University's agreement with Sound Transit requires that throughout the 60-month construction duration, Medical Center access to the portions of the parking lots not impacted by construction must be maintained and Husky Stadium must remain accessible on football Game Days and four other events during the year. To meet this goal, the design includes a two-contract and three-staged site plan, which includes 2.4 hectare (6 acres) of work area for the initial 36 months, 1.6 hectares (4 acres) of work area for the months 37–57 and 0.8 hectare (2 acres) of work area for the balance of the contract. Figure 5 presents the site layout for each of these stages. This shifting staging area enables the work to proceed with limited impact on the surrounding site uses and limited impact on the football season and other critical events. The work completed each phase is as follows:

- Phase 1: The U220 contractor establishes new roads, grades the site, constructs the slurry wall for the entire station, excavates the crossover box and constructs the tunnels. This is carried out during the first 36 months after occupation of the UW site. The U220 contractor will demobilize at the end of this 36 month period. The U250 contractor will mobilize approximately halfway through this phase and will excavate and place interior concrete for the station box using either bottom-up or top-down construction methods. The land available during this phase is 6 acres. The U250 contractor restores the 0.8-hectare (2-acre) site between Phase 1 and Phase 2 discussed below.
- Phase 2: The U250 contractor will complete station finishes, mechanical and electrical work and will begin start-up and testing operations. Construction of the pedestrian bridge will be started during this phase. This is a 21 month period, during which 4 acres of the site is available for construction staging. U250 restores the

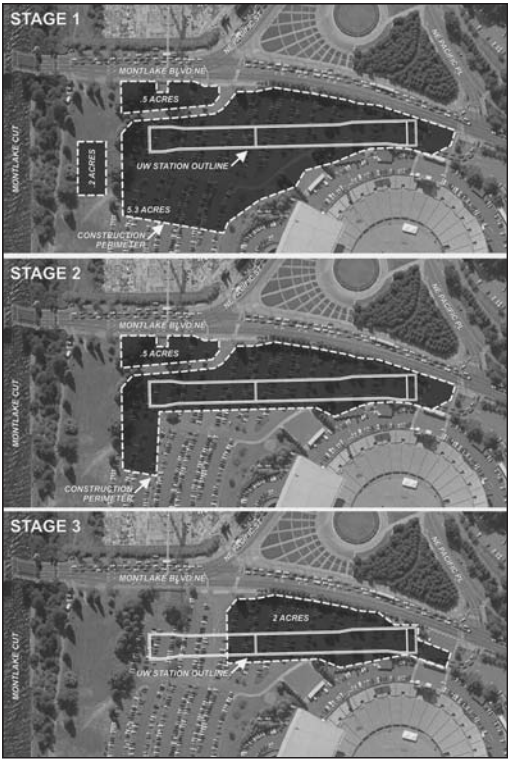

Figure 5. 6–4–2 site plan

next 0.8 hectares (2 acres) between Phase 2 and Phase 3.

- Phase 3: Completion of the UW Station. This is a 9 month period during which 0.8 hectare (2 acres) of the site can be used for construction staging. Final startup and testing will be done during this time and the pedestrian bridge will be completed and the remainder of the site restored.

Bored Tunnels

The twin tunnels running from the UWS to the south will consist of 6.4-meter (21-foot) excavated diameter bored tunnels, of the general cross section shown in Figure 6. Based on the site constraints at UWS, the project is currently being planned assuming that two tunnel boring machines, working concurrently, will be required for U220. These twin drives will face the challenges along the way such as moderately steep grades and passing under sensitive areas.

The vertical alignment of the tunnels begins with a 4.5% downhill gradient out of the UWS, such that the tunnels will cross safely beneath the Montlake Cut. After crossing beneath the Cut by about one tunnel diameter, the drive turns upgradient, and continues for nearly 1.9 kilometers (1.2 miles) in a long 4.1% uphill grade. Once near the top of the hill, the grade flattens out, and enters the CHS at a 0.5% grade.

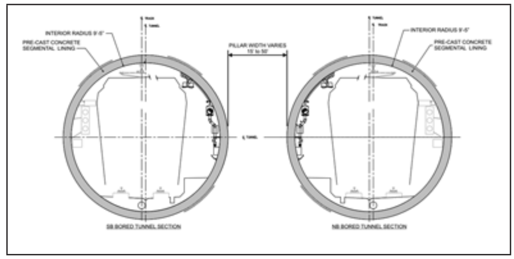

Figure 6. Bored tunnels section view

The tunnel alignment traverses beneath about 250 homes, and several municipal structures, including a historic Water Tower. Ground cover along the alignment ranges 4.6 to 91.5 meters (15 to 300 feet). The shallowest depth of ground cover is where the alignment passes beneath the base of the Montlake Cut with approximately 4.6-meters (15-feet) cover from the mudline to the crown of the tunnel. Stability analyses (based on the above description and results of the geotechnical investigations) have indicated the side slopes of the cut will remain stable and that tunnel buoyancy will not be an issue.

Cross Passages

Fifteen cross passages will be constructed along the U220 segment of the U-Link alignment using the sequential excavation method (SEM). The cross passages will be ovoid-shaped with a height of about 3.6 meters (12 feet) and a length of about 6.1 meters (20 feet), which depends on the distance between the northbound and southbound bored tunnels (pillar width at springline). The theoretical excavation limits for the cross passage involve an invert located at about 0.6 meters (2 feet) below the top of rail and the crown located about 3.8 meters (12.5 feet) above the top of rail of the adjacent tunnel. One of the cross passage will have a pump station located in the invert requiring an additional 1.8 meters (6 feet) excavation below top of rail.

The majority of the cross passages will be constructed in very stiff to hard glacial and non-glacial lacustrine silts and clays. However, three of the passages will be constructed fully or partially in sandy and gravelly glacial diamictons (till-like deposits) and glacial and non-glacial fluvial sands and silty sands. Some of the cross passages along the U220 alignment are expected to have disturbed soil conditions, which can include scattered to abundant slickensides, shear zones, blocky fractured zones, brecciated (angular fragments or blocks of cohesive soil in a disturbed soil matrix) textures, and slightly

Figure 7. Plan view of Capitol Hill Station

to highly disrupted strata. Soil stabilization measures such as spiling and modified excavation techniques may be necessary. The stand-up time depending on the amount or continuity of the fracturing could range from short (less than 30 minutes) to none (less than a few minutes). All 15 cross passages will be below the regional water table, with groundwater heads ranging from 2.1 bars (21.3 meters; 70 feet) up to 5.9 bars (59.5 meters; 195 feet) at the cross passage invert.

U230 and U240 Contract: Bored Tunnels Capitol Hill to Pine Street, and Station Structures

Capitol Hill Station

The CHS is located in the Capitol Hill neighborhood adjacent to the Cal Anderson Park as shown in Figure 7. The station will take up approximately one and a half city blocks, as follows: the full block bounded by East John Street to the north, 10th Ave East to the east, East Denny Way to the south, and Broadway Ave East to the west; and the half block bounded by East Denny Way to the north, Nagle Place to the east, the Bonney Watson Funeral Home parking lots to the south, and Broadway Ave East to the west. The CHS box is about 166 meters long (545 feet), between 18.9 meters and 25.9 meters wide (62 feet and 85 feet) and about 21.3 meters deep (70 feet). The station box consists of a platform located in the middle portion of the box, with wider north and south belled ends. The CHS crosses beneath East Denny Way (which is to be closed during construction) and has three entrances, one at the north end and two at the south end. A profile view through the station, showing the central mezzanine, and the invert depth of 18.3 meters (60 feet) is shown in Figure 8.

The U240 Contract consists of the station finishes and the excavation and construction of the pedestrian tunnel as well as the west entrance structure shown in Figure 7. Both the tunnel and entrance structure will be excavated using cut-and-cover

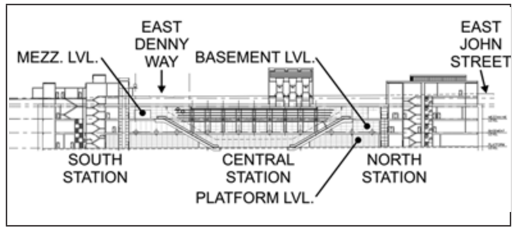

Figure 8. Profile through Capitol Hill Station

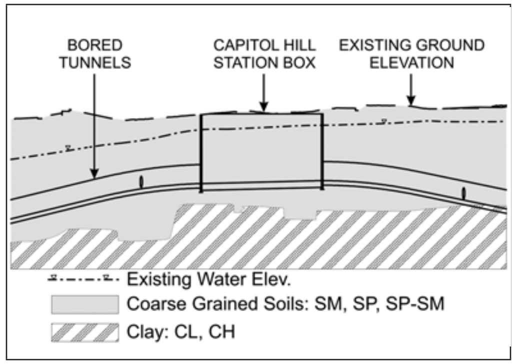

Figure 9. Subsurface conditions at Capitol Hill Station

methods, temporarily supported using solider pile and lagging systems.

Ground Conditions

The CHS site has about 3.05 meters (10 feet) of relief and slopes from about elevation +102.1 meters (+335 feet) on the west side to +99.1 meters (+325 feet) on the east side. The site will be graded to an elevation of about +99.1 meter (+325 feet) prior to the station excavation. The invert of the excavation is anticipated to be about +78.7 meters (+258 feet).

Ground conditions at the CHS site consist of glacially consolidated units of sands, silts, and clays as shown in Figure 9. A portion of the site is covered by a layer of fill, about 3.0 to 6.1 meters thick (10 to 20 feet). Beneath the fill, there is a complex sequence of Vashon era glacial till and pre-Vashon sediments. The groundwater level at the site is about elevation +95.7 to 96.7meters (elevation +314 to +317 feet; or about 3.7 to 4.6 meters [12 to 15 feet] below ground surface).

Excavation Support

The station will be constructed using either a rigid wall system such as slurry or secant pile walls or a flexible wall system such as solider pile and lagging, which is the typical construction method used in the Seattle area. A rigid wall system would be used as the temporary excavation support and incorporated into the final structure. The walls would extend into the hard clay and silt layers, which have very low permeability, to prevent water from flowing into the excavation. An active dewatering system would not be required; however, passive measures such as sump pumps would be needed inside the excavation.

The flexible wall system would require a temporary excavation support system and a final cast-in-place structure to be built inside the excavation by the follow-on U240 Contract. The temporary excavation support would most likely be a solider pile and lagging system, with tiebacks and dewatering. Dewatering is expected in the form of multi-stage wellpoints or deep pumping or eductor wells. The walls would be internally braced with tie backs as the station is excavated. The final station box constructed by the follow-on U240 Contractor would be constructed with cast-in-place concrete, with a membrane waterproofing. Uplift forces on the final station box will be resisted by station weight and if necessary, uplift resistance provided by the soldier piles.

The TBM for the northbound tunnel will be launched first from the CHS box after the bottom slab has been placed. This will allow for construction of the station box while the northbound running tunnel is mined. Once the TBM reaches the PSST, the TBM will be moved back to CHS and then re-launched to mine the southbound running tunnel.

East Denny Way, which is perpendicular to the CHS box, is a minor arterial route and has numerous existing utilities. While most of these will be relocated or abandoned prior to the station excavation; two major utilities need to remain in service during construction; a 250 kilovolt oil-insulated distribution line and a 100-millimeter (4-inch) diameter high-pressure natural gas main. Other various shallow utilities that exist in East Denny Way will be interrupted during the excavation but reconnected prior to finishing the station and will be hung above the excavation using bridges. Two deep gravity utilities in East Denny Way, a storm drain and sanitary sewer, will also be interrupted during the excavation; however, they will be reconnected and incorporated into the final structure. The construction plans will call for East Denny Way to be closed during construction; however, the signalized intersection will remain, as the road will be used for the main site access during construction. Work done from the excavated box will need to be coordinated with both the utilities above, and the roadway access to the west.

Bored Tunnels

The twin tunnels running from the CHS to the PSST will consist of twin 6.4-meter (21-foot) excavated diameter bored tunnels, the same as shown in Figure 6. The twin drives will face similar challenges as the U220 Contract, such as steep grades and passing under sensitive areas. An additional challenge to the U230 Contract is the PSSTl area and the I-5 undercrossing.

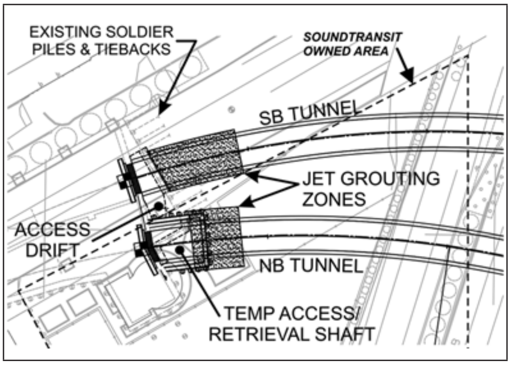

Figure 10. PSST shaft alternative plan view

The vertical alignment begins with a fairly level grade for about 61 meters (200 feet) south of the station and continues at a 4.88% downhill gradient to intersect the existing PSST area. The amount of ground cover will range from about 12.2 to 36.6 meters (40 to 120 feet), with an average cover of about 21.3 meters (70 feet). The shallowest areas of ground cover are most sensitive to surface settlements. The main settlement sensitive areas are just south of the CHS and the I-5 undercrossing. The buildings in the area to the south of the CHS are generally larger older type buildings of brick construction and are considered susceptible to settlements.

The I-5 area has only about 4.6 meters (15 feet) ground cover below the I-5 interstate. To control ground loss during tunneling beneath the I-5 will require positive face pressures at the face of excavation and tail void grouting through the tail shield, as a minimum.

Two alternatives for the construction of the connection of the two bored tunnels from CHS to the PSST are currently being considered. The first, a "Shaft Alternative," requires construction of an approximately 9.1-meter by 9.1-meter (30-foot by 30-foot) temporary TBM retrieval shaft adjacent to the existing PSST vent structure. The shaft would be built directly above the Northbound tunnel as shown in Figure 10. This shaft will be used for removal of soldier piles within the profile of the Northbound tunnel bore (both existing piles left in place from the PSST construction, as well as piles required to excavate the temporary retrieval shaft). A small access drift will be constructed to the adjacent Southbound tunnel for the construction of a pile removal chamber for the removal of existing soldier piles within the profile of the Southbound tunnel bore and as a retrieval shaft for the TBM from the first Northbound tunnel excavation. The shaft, access drift, and pile removal chamber will be backfilled with CDF material prior to TBM excavation. Jet grouting will also be required for portions of the two tunnels to stabilize soils prior to pile removal activities.

The second alternative is an "SEM Alternative," comprising short SEM tunnels to be excavated from within the existing PSST structure (see Figure 11). For the Northbound tunnel, existing soldier piles will be removed from within the tunnel profile, out to a distance of approximately 6.1 meters (20 feet) from the existing structure. For the Southbound Tunnel, existing soldier piles and tie-back anchors will be removed from within the tunnel profile, out to a distance of approximately 23 meters to 24.5 meters (75 to 80 feet) from the existing structure.

Cross Passages

There are five cross passages in the U230 Contract that will be constructed using SEM. The dimensions of the passages are the same as discussed in the U220 Contract section. Four of the cross passages will be constructed in very stiff to hard glacial and non-glacial lacustrine silts and clays. However, one of the passages will be constructed fully or partially in clayey, silty sand. Soil stabilization measures such as spiles and modified excavation techniques may be necessary, as well as more stringent measures such as jet grouting or ground freezing have been considered. All 5 cross passages will be below the regional water table, with groundwater heads ranging from 0.6 bars (6.1 meters; 20 feet) up to 1.5 bars (15.2 meters; 50 feet) at the cross passage invert. The cross passages will have cover (crown to ground surface) ranging from about 15.2 to 36.6 meters (50 to 120 feet).

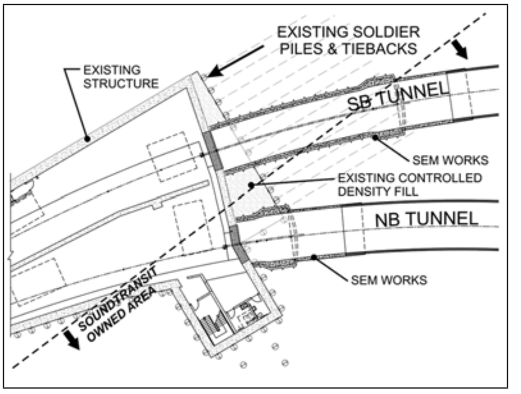

Figure 11.

PROJECT SCHEDULE

The detailed design for the Ulink project is currently between 60% and 90% complete, with some contracts (e.g., U215) being well ahead of others (e.g., U250). The proposed schedule for advertising the contracts discussed in this paper are as follows:

- U215: Fall of 2008
- U220: Spring 2009
- U230: Fall 2009
- U250: Winter/Spring 2011
- U240: Summer 2012

The project construction completion is expected in December 2014 with train operation commencing in 2016.