



Kenilworth Shallow LRT Tunnel

Basis of Design – *DRAFT*

REV 2

November 2014

Southwest LRT Project Technical Report

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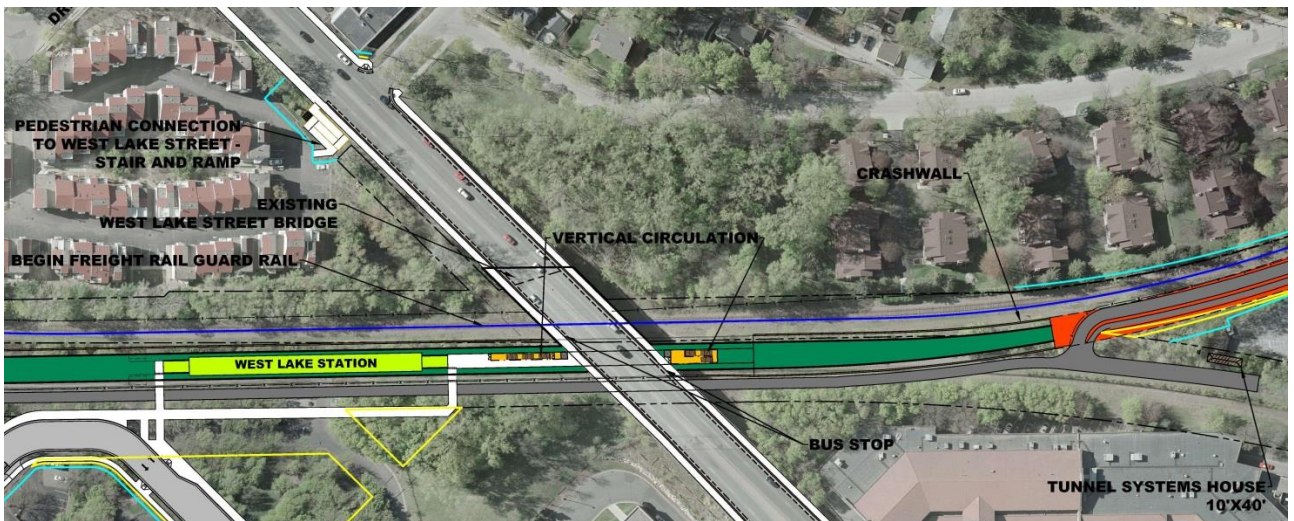
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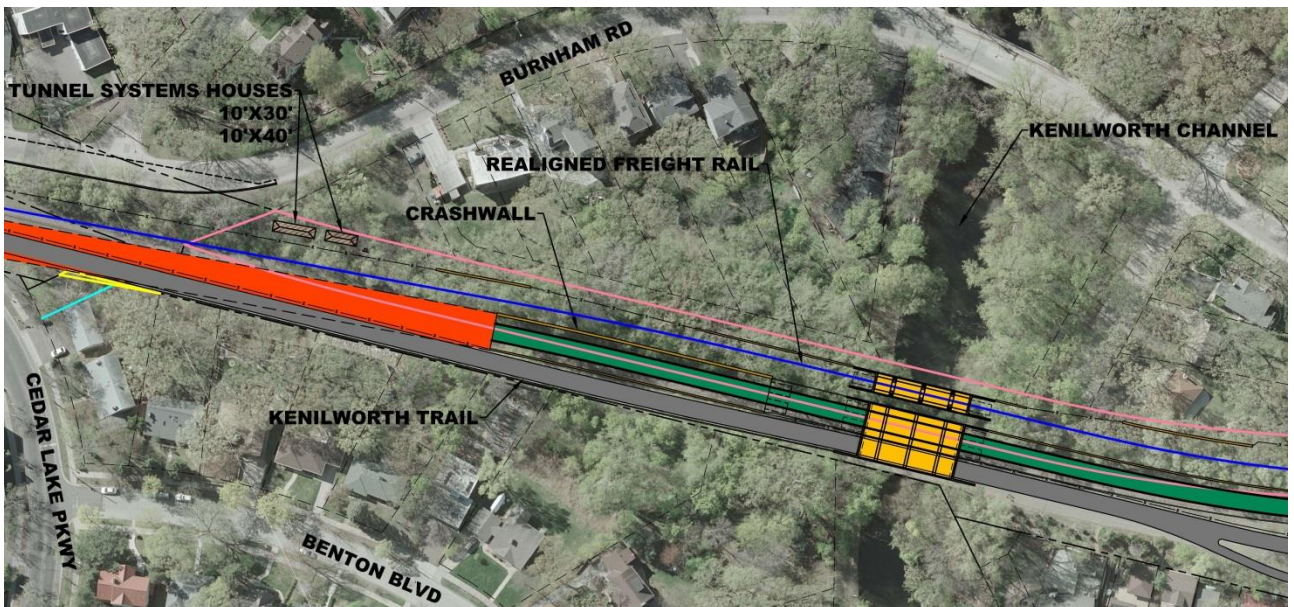
1 Shallow LRT Tunnel Characteristics

The Kenilworth shallow LRT tunnel, as shown in the Preliminary Engineering Plans (September 2014) is 2,236' long and begins about 500' north of the West Lake Street bridge, passes underneath Cedar Lake Parkway and ends about 400' south of the Lake of the Isles-Cedar Lake channel (Kenilworth Channel).

A tunnel portal is located at each end of the tunnel. The portals for the tunnel are 350' long at the south end and 264' long at the north end. At each portal, the LRT guide way is visible but lowers below the surrounding ground to enter the tunnel. The portals are supported by retaining walls on each side of the tracks. The south portal begins just north of the West Lake Street bridge, avoiding the existing bridge foundations.



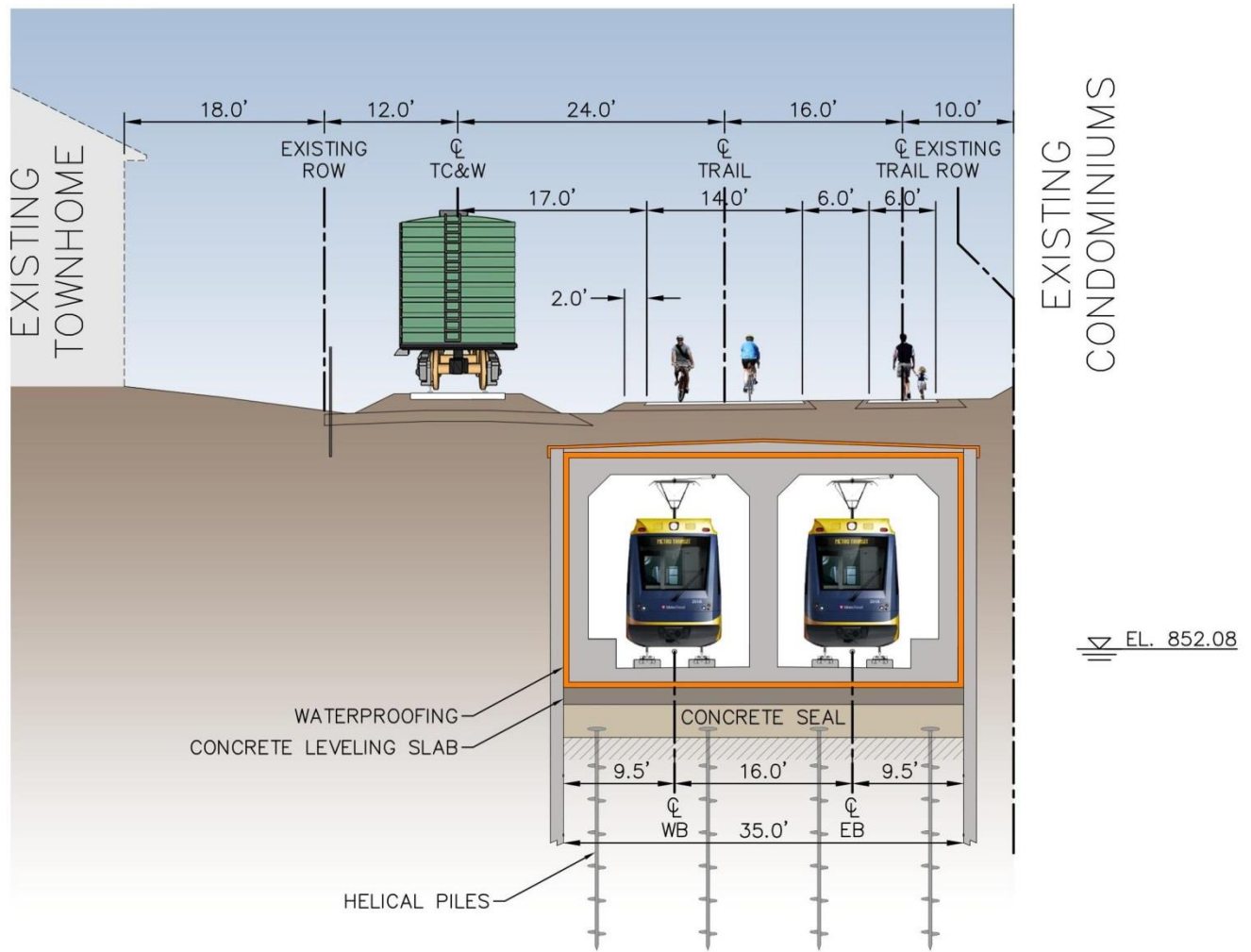
Kenilworth Shallow LRT Tunnel – South Portal



Kenilworth Shallow LRT Tunnel – North Portal

At the north and south portals of the LRT tunnel, the freight track is located west of the tunnel, within 25' of the portal retaining walls. A 6' high (above top of freight rail) by 2'6" wide crash wall is located on top of the portal retaining walls adjacent to the freight track in these areas only. The crash walls are as long as the retaining walls at each portal – 350' long at the south portal and 264' long at the north portal.

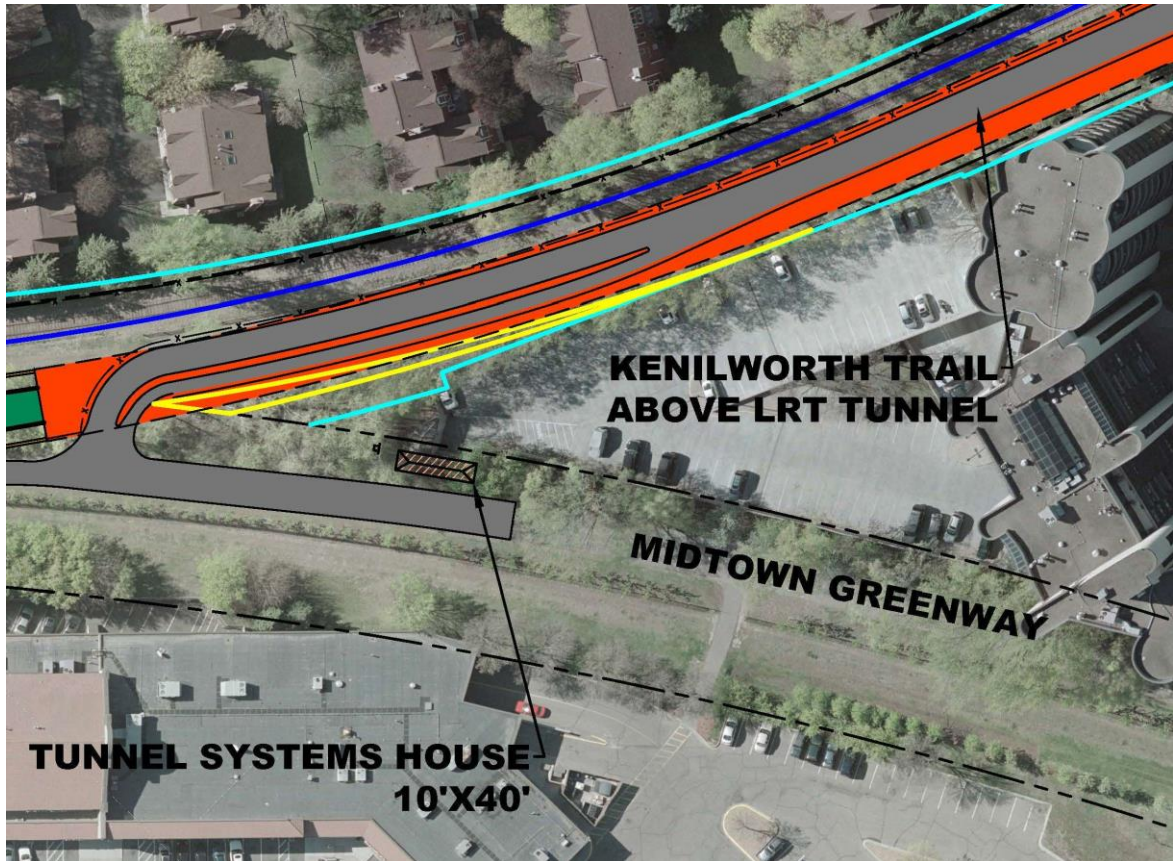
The shallow LRT tunnel is a two-cell, cast-in-place box structure. Above the tunnel, the freight track and the Kenilworth Trail remain within the existing corridor right-of-way. The trail is generally located on top of the tunnel, except at the tunnel portal areas where the trail is located to the side, and there is a varying thickness of soil between the bottom of the trail surface and the top of the tunnel that ranges between 6' and 8'.



Typical Kenilworth Shallow LRT Tunnel Section

No acquisition of homes is proposed for tunnel segment or any other LRT or freight infrastructure. Minimal permanent and temporary right-of-way impacts to property along the corridor have been identified. A permanent and temporary right-of-way impact example is shown below at the Calhoun Isles Condominiums (yellow outlined area = permanent; light blue outlined area = temporary).

The Preliminary Engineering Plans (September 2014) depict the layout of the LRT tunnel, trail, freight tracks, right-of-way impacts and other configuration features of the tunnel within the corridor.



Typical Permanent and Temporary Right-of-Way Impact

2 Construction Sequencing and Schedule

2.1 Tunnel Sequencing


A sequencing methodology has been developed for the shallow LRT tunnel construction. This methodology has been prepared to establish a basis for evaluating the impacts of the tunnel construction within the constraints of the Kenilworth Corridor. The Southwest LRT Project Office (SPO) will develop performance-based construction specifications and require that the contractor develop a work plan identifying its means and methods to construct the shallow tunnel that will be subject to SPO review. The SPO will coordinate this review with the City of Minneapolis technical staff.

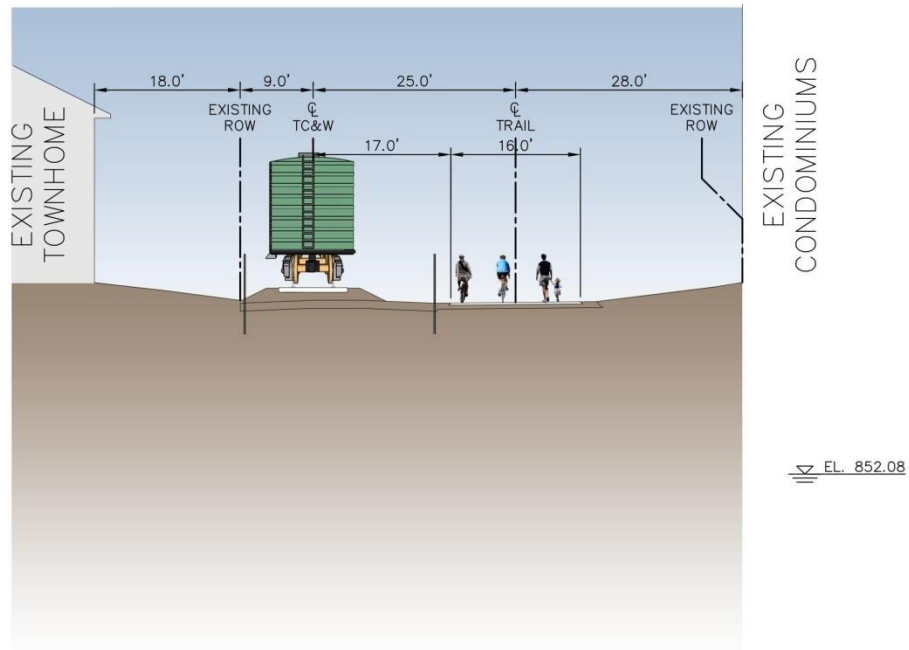
The construction of the shallow LRT tunnel is anticipated to be a linear process that includes various phases of bulk excavation, temporary groundwater pumping, and tunnel concrete construction by progressing through a “cell-by-cell” construction approach. Sheet pile installation is anticipated to be performed by a method that avoids hydraulic drop hammers. Methods such as a high frequency vibratory hammer or a hydraulic “press-in” device would minimize vibration and noise created by the sheet pile installation. Actual construction means and methods will be determined prior to construction in coordination between the contractor and the SPO.

It is assumed that freight rail traffic will continue through the Kenilworth Corridor during construction of the shallow tunnel. It is also assumed that trail use will continue during construction, but will require temporary detours out of the Kenilworth Corridor likely between the Midtown Greenway and 21st Street. Minimizing the length of time a temporary trail detour is in place will be a priority of the performance-based construction specifications.

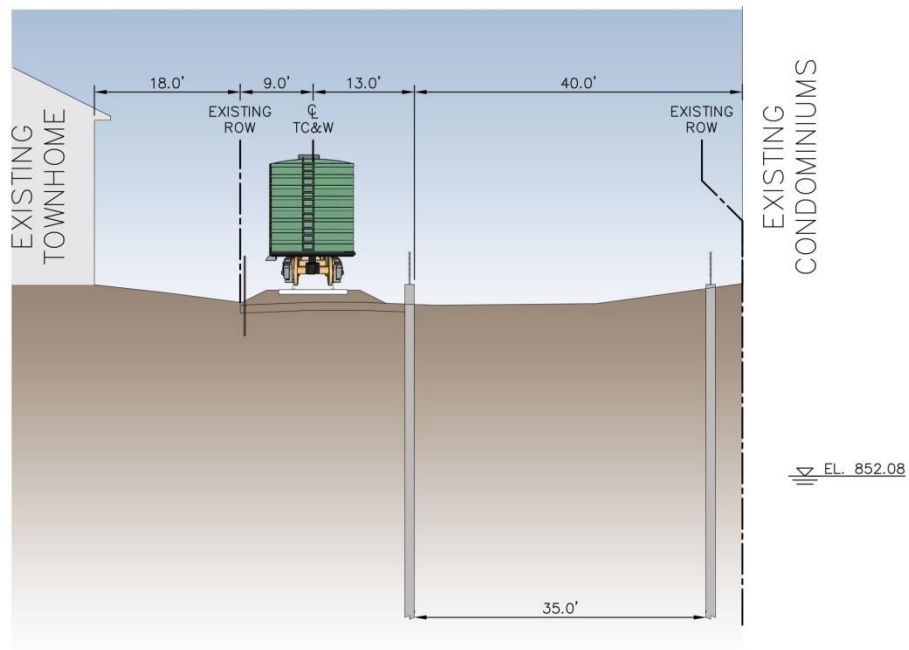
The SPO will require the contractor to coordinate construction activities with the Hennepin County Railroad Authority (HCRRA) and the operator of the railroad, Twin Cities and Western Railroad (TC&W), as well as the City of Minneapolis and the Minneapolis Park and Recreation Board (MPRB) with respect to the trail and bridge construction at the Lake of the Isles-Cedar Lake channel crossing.

An overview of the anticipated shallow LRT tunnel construction sequencing (where the existing right-of-way width is limited) is as follows with additional detail provided in Appendix A.:

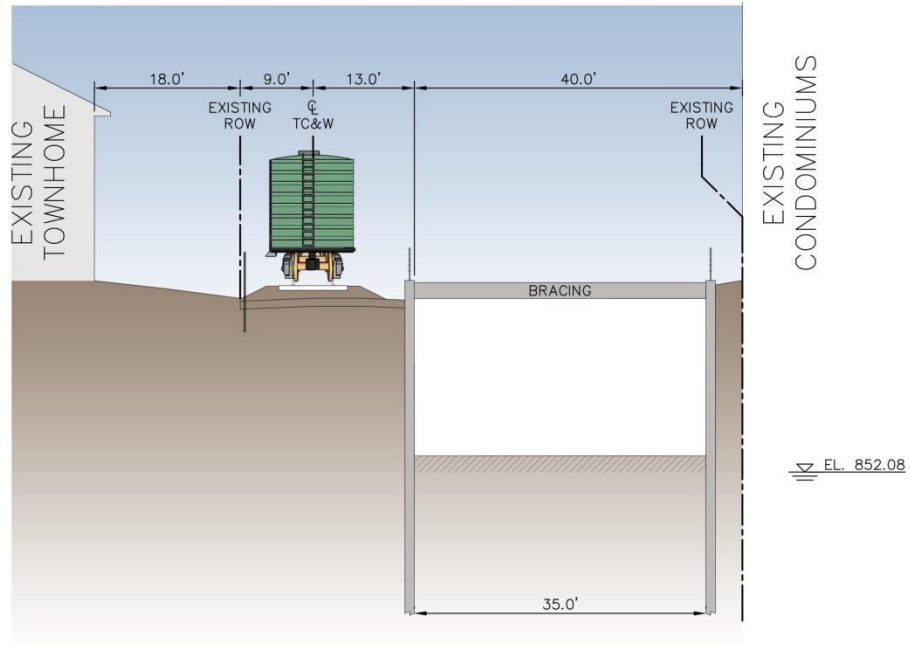
- The freight track is temporarily shifted approximately 3' (south of Cedar Lake Parkway only) to the west to provide space for construction of the tunnel.  = Location of Water Table (Normal Lake Water Elevation - Typ.)



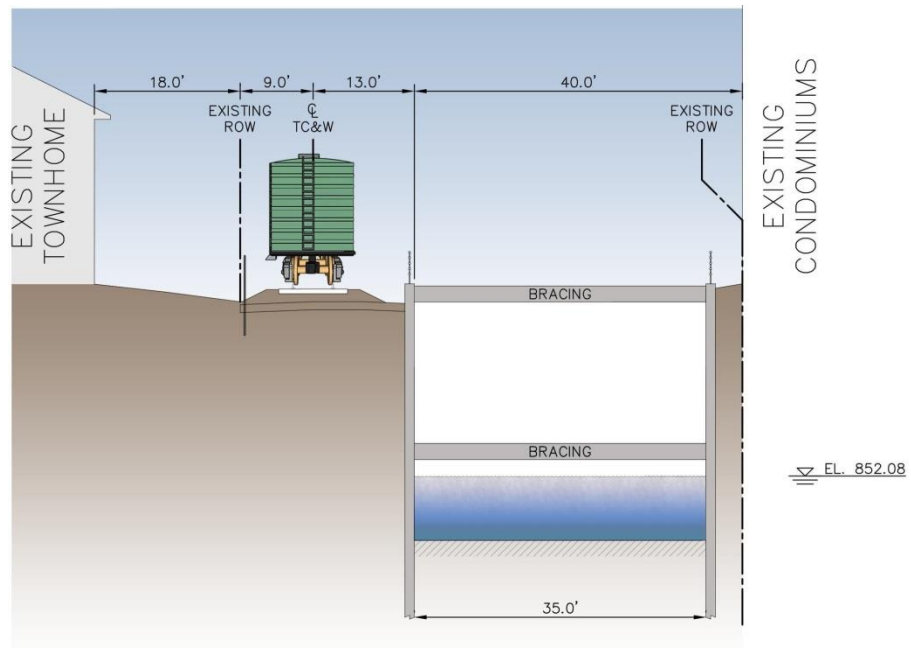
- Sheet piles are installed on each side of the tunnel area. Sheet piles are also installed transverse to the main sheet piles creating cells so as to contain the amount of groundwater removed during excavation.



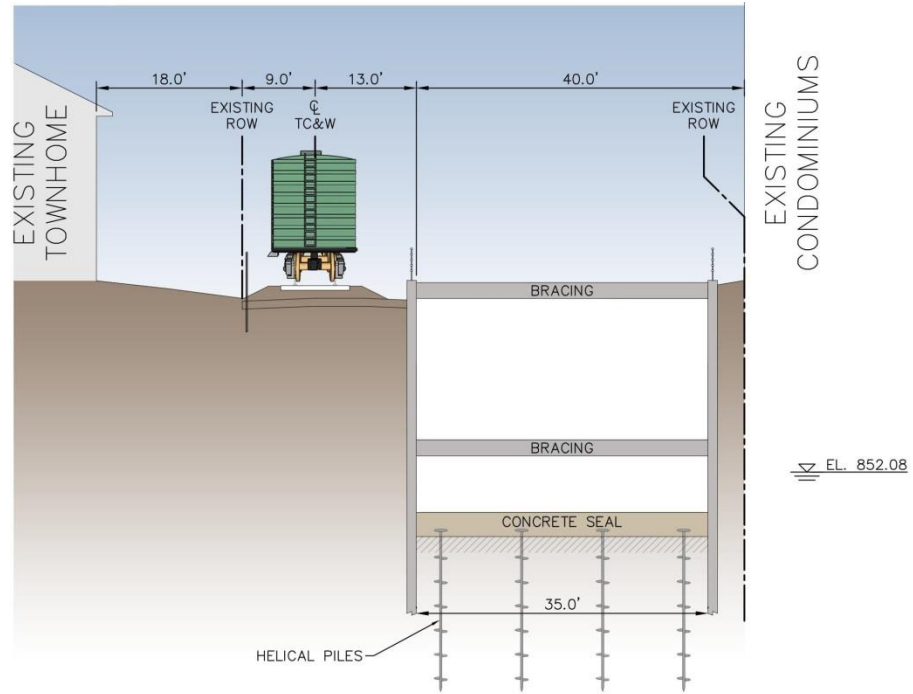
3. Excavation begins above the water line (represented as the Normal Lake Water Elevation) and initial temporary bracing is installed between the sheet piling.



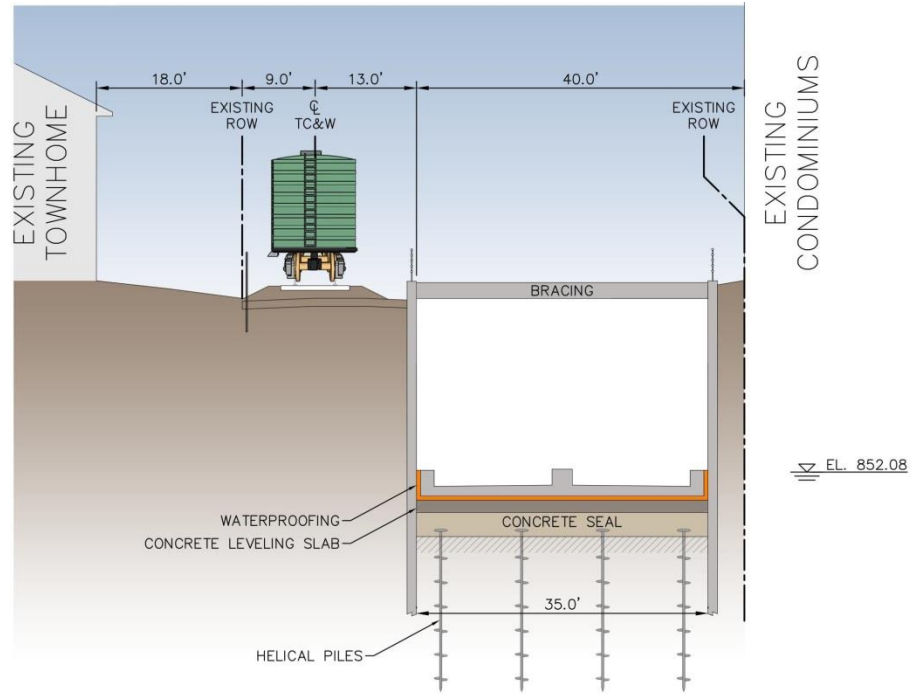
4. Further excavation occurs below the water line and additional temporary bracing is installed.



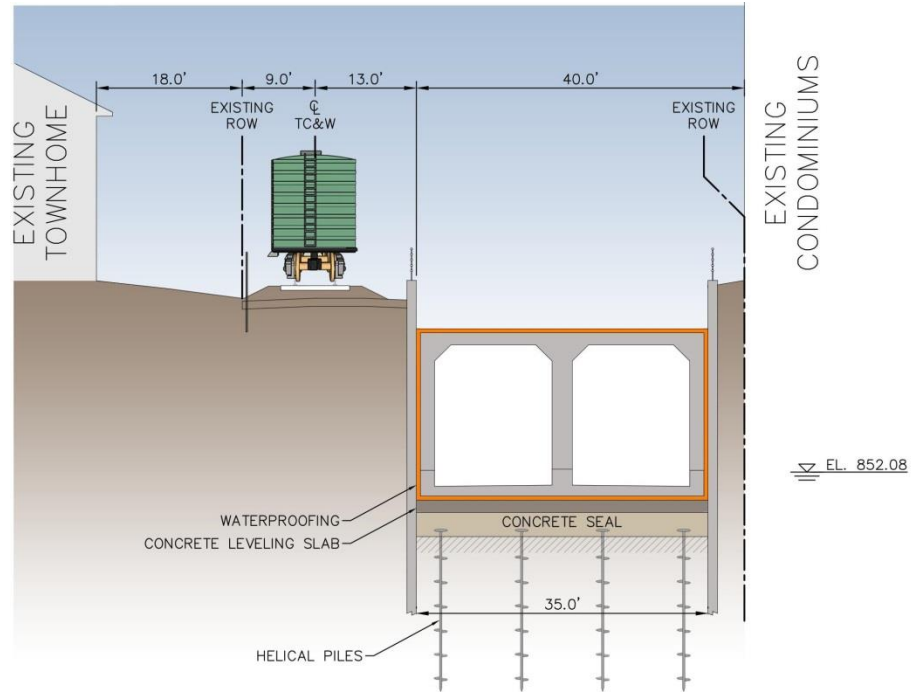
- Helical piles are installed and a concrete seal is cast at the base of the excavation, and once hardened, the groundwater within the sheet pile cell is removed.



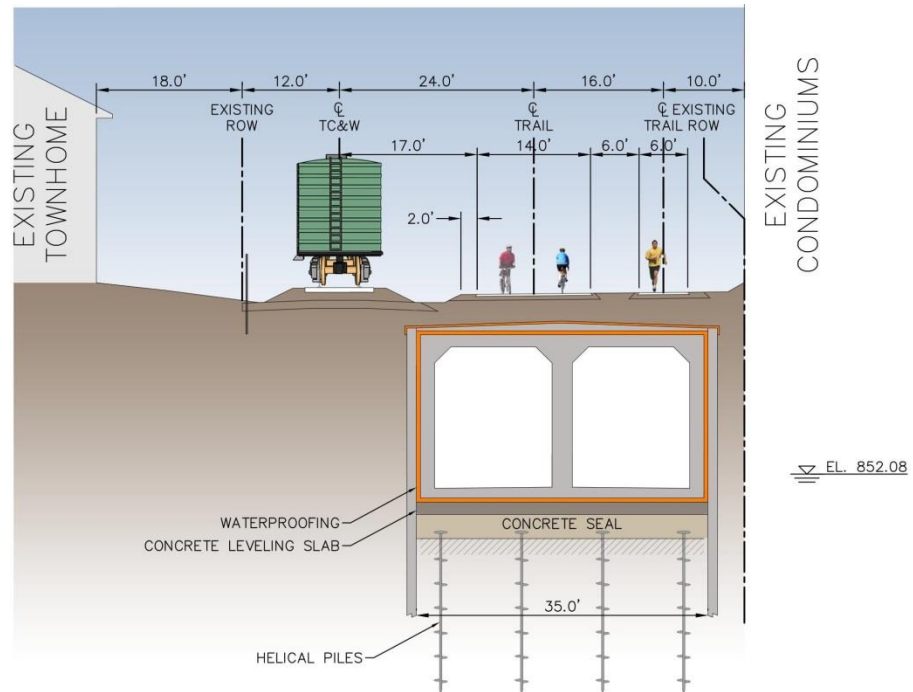
- A concrete leveling slab is poured, waterproofing installed, formwork is erected within the cell and concrete is placed to build the tunnel bottom slab.



- Formwork is erected and concrete is poured to build the tunnel walls and top slab. The waterproofing system is installed along the tunnel sides extending above the tunnel top slab.



- Finally temporary bracing is removed, the freight track is shifted back to its existing location and the trail is reconstructed. Trees and other landscaping features are then planted.



For the purposes of identifying potential construction durations it was assumed that construction activities would take place during five day work weeks and daily work hours of 7 AM to 7 PM. Construction activity duration estimates will be finalized during advanced design. Actual durations and schedules will be subject to review and coordination between the contractor and the SPO and in coordination with the City of Minneapolis. For example, some weekend or extended weekday construction activities may be required to complete certain construction tasks. Further, construction activities performed during the winter months or during other inclement periods may require adjustments to the durations.

Construction of the overall shallow LRT tunnel is estimated to take approximately two years. This includes 11 to 14 months to construct the tunnel structure and 5 to 6 months to construct the portals. Construction within each tunnel cell is anticipated to take approximately 2½ to 3 months from start to finish with cell construction work in any given cell sequenced as described above. The anticipated schedule assumes that a total of 19 cells will be used. Following the shallow LRT tunnel construction, systems work, LRT track installation, freight track completion, final trail reconstruction, and landscape restoration will be completed.

2.2 Tunnel Construction Adjacent to Freight Rail and Existing Structures

The tunnel sequencing plan has been developed so that the tunnel can be constructed within the limited right-of-way in the Kenilworth Corridor. On either side of the corridor, there are existing buildings and freight rail tracks immediately adjacent to the location of the tunnel. As described above, the existing freight track alignment will be temporarily adjusted in the vicinity of the tunnel construction to provide sufficient space to install sheet piling for the tunnel. Tunnel construction operations such as sheet pile installation, soil excavation, soil hauling and concrete placement will need to be closely evaluated and coordinated with freight rail operations to achieve the tunnel construction schedule.

With respect to existing buildings adjacent to the Kenilworth Corridor, the Calhoun Isles Condominium building and parking structure each have foundations that encroach into the corridor right-of-way. The Calhoun Isles Condominium is located near the south end of the LRT tunnel, north of the Midtown Greenway and along the east side of the Kenilworth Corridor. Since construction of the LRT tunnel will require the placement of sheet piles near the existing building foundations, potholing activities were carried out by vacuum excavation to verify the edge of foundation locations and depth to top of the foundations at select locations. The SPO performed these investigations between December 2013 and March 2014 and between August 2014 and October 2014.

Preliminary findings generally confirm information found in record drawings provided to the SPO by the Calhoun Isles Condominium Association for parking structure foundation locations that encroach into the corridor right-of-way. At the locations investigated, the existing parking structure foundations appear to be outside and clear of the limit of the planned tunnel construction.

At the condominium building, preliminary findings indicate that the foundation edge of the building is outside the limit of the planned LRT tunnel construction. Potholes were able to positively identify the existing condominium foundation towards the south portion of the building along the corridor right-of-way. An investigation inside of the condominium tunnel located underneath the condominium foundation was performed in September 2014 to confirm the depth and size of the tunnel and approximate extent

beyond the edge of the building. Potholes conducted in October 2014 confirm the tunnel is outside the limit of the planned LRT tunnel construction.

For both the Calhoun Isles condominium building and the parking garage, the advanced design of the shallow LRT tunnel will need to incorporate structural loadings from the adjacent building foundations and address settlement potential of the existing building foundations during LRT tunnel construction. Details of the LRT tunnel sheet piling may need to be adjusted to address the limited space between the sheet pile alignment and the building foundation locations. Monitoring and recording of pre-construction and post-construction conditions of the condominium building and the parking garage will be necessary as well.

The Calhoun Isles Condominium Building and Parking Structure Foundations Technical Memorandum (November 2014) provides additional details.

3 Geology, Groundwater and Surface Water

3.1 Geology, Ground Water and Surface Water Existing Conditions

Descriptions of the existing soils and analysis related to existing groundwater found within the corridor are described in detail within the Shallow LRT Tunnel – Kenilworth Corridor geotechnical report. SPO has performed 37 soil borings and 8 cone penetrometer test (CPT) soundings between the proposed West Lake Station and Penn Station, and of this total, 17 soil borings and 4 CPTs were performed within the area where a LRT tunnel would be constructed. Generally the existing soils along the tunnel alignment include deep alluvial sands with pockets of silt and clay soils and organic (peat) deposits. Areas of soft soils (organics or silt and clays) occur near West Lake Street and just south of the Kenilworth Channel. The soft soils are approximately 4 feet in thickness in both locations. Silt and clays near West Lake Street extend to depths of approximately 20 feet or greater. Bedrock is located about 240 feet below the ground surface along most of the tunnel and is approximately 150 feet below the ground surface near West Lake Street (source - Minnesota Geologic Survey). No geologic hazards (such as sinkholes, shallow limestone formations, or near-surface karst) are expected.

The SPO installed a series of twelve piezometers within the Kenilworth Corridor and started collecting data in October 2013 to permit regular monitoring of the groundwater elevations along the tunnel alignment. One additional piezometer that was installed as part of the Metropolitan Council Environmental Services (MCES) sewer project near West 28th Street is included in the piezometers being monitored. The piezometer readings since their installation closely match lake levels and have shown a declining groundwater elevation through the fall until the spring of 2014, which is indicative of the relatively dry fall in 2013. Groundwater elevations measured in the spring and summer of 2014 rose to higher elevations indicative of the wet spring and summer of 2014. Piezometer readings taken on October 14, 2013 and monitored weekly through September 2014 indicate groundwater elevations varying by, on average, 5" at any given piezometer and groundwater elevations varying between approximately 850 to 855 feet along the corridor. Because of soil conditions near the West Lake Street bridge, higher groundwater elevations were observed in this area. See Shallow LRT Tunnel – Kenilworth Corridor geotechnical report for complete piezometer results.

The independent water resources evaluation performed by Burns and MacDonnell in the spring of 2014 made recommendations for additional investigations that the SPO should consider to better understand the subsurface hydro-geologic conditions along the corridor. The evaluation recommended that additional piezometers be installed lateral to the proposed corridor to better characterize the groundwater flow both along and transverse to the corridor. It was also recommended that nested piezometers be installed in the corridor area at a greater depth to help evaluate potential downward groundwater flow. SPO will install the additional piezometers and include them in the ongoing groundwater level monitoring program. This information will be available to support advanced design of the Southwest LRT (SWLRT) Project.

Cedar Lake and Lake of the Isles are hydraulically connected by the Kenilworth Channel. Prior to construction of the channel in the early 1900s, the water level in Cedar Lake was several feet higher than in Lake of the Isles, causing an eastward surface water flow from Cedar Lake toward Lake of the Isles. Construction of the lagoon allowed stabilization of water levels in the two lakes to a common level. The SPO began monitoring the surface water elevation of the Kenilworth Channel in concert with the

piezometers starting in October 2013. Historic surface water elevations were also obtained by the Minnehaha Creek Watershed District (MCWD), Minneapolis Park and Recreation Board (MPRB) and from course USGS 24K Topographic Maps. See Table 1 for a summary and comparison of surface water elevations.

Table 1 – Surface Water Elevation Summary

Description	Elevation Source	Datums	
		NAVD 1988 (ft)	NGVD 1929 (ft)
Normal Lake Elevation	MCWD	852.08	851.90
Ordinary High Water	MnDNR	853.18	853.00
100-Year Lake Elevation	MCWD	853.58	853.40
50-Year Historic Average High Water Elevation	MPRB	852.45	852.27
Historic High Water Elevation	MPRB	855.43	855.25
10/2013 – 8/2014 High Water Elevation	SPO	855.79	-
10/2013 – 8/2014 Low Water Elevation	SPO	852.13	-

Notes:

- NAVD 1988 minus 0.18 foot = NGVD 1929. Conversion per NOAA Vertcon online tool.
- Surface water measurements from Cedar Lake, Lake of the Isles or Kenilworth Channel.

3.2 Ground Water and Surface Water Impacts

When comparing a set of observed ground and surface water elevations, the observed groundwater elevations have been measured consistently lower than the surface water. Over time, as the groundwater and surface water elevations fluctuate, the surface water in the Kenilworth Channel is consistently higher than the adjacent groundwater elevations. In the summer of 2014, during weeks of particularly heavy rainfall and when the highest surface water elevations were measured, the groundwater elevations rose to nearly match the surface water elevations. The elevations of the groundwater and surface water to date suggest that groundwater in the corridor does not discharge to the channel and lakes and that the lakes may be recharging the aquifer.

Based on these observations, the surface water and groundwater appear to be generally equalized along the corridor. Due to the thickness of the alluvial sand aquifer that generally extends to bedrock along the length of the tunnel as compared to the depth of LRT tunnel including the sheet piling along each side of the tunnel (approximately 50' below grade for the sheet pile tips), it has been expected that the groundwater in the corridor will be able to easily transmit under the sheet piling without a measureable increase in water levels or blockage of groundwater on one side of the tunnel. As noted in the independent water resources evaluation performed by Burns and MacDonnell, the only foreseeable situation where a rise in water levels could occur in the vicinity of the tunnel would be near West Lake Street and just south of the Kenilworth Channel where pockets of silt and clay soils and organic (peat) deposits are located. However, these are isolated areas within the predominantly alluvial sandy soils so groundwater is expected to flow easily within these areas as well. Additional characterization of the groundwater elevation and potential groundwater flow is planned in the vicinity of the LRT tunnel during advanced design to further confirm these anticipated conditions. SPO will also address ways to use drainage materials to handle and manage groundwater around the tunnel and will develop a groundwater and surface water monitoring plan to evaluate groundwater and surface water during construction and during in-service operations.

3.3 Tunnel Waterproofing and Water Control Systems

The LRT tunnel will be designed to minimize the infiltration of groundwater into the tunnel through use of a waterproofing system and the permanent use of the steel sheet pile retaining wall system connected to the concrete seal that will be used for the cut-and-cover tunnel construction. The tunnel design and construction is comprised of (1) a relatively impermeable steel sheet pile system on the outside, (2) waterproofing installed between the inside faces of the sheet pile walls, along the surface of the concrete seal and around all sides of the outside of the concrete tunnel and (3) waterproofing applied to the outside of a sloped concrete cap on top of the tunnel.

3.3.1 Sheet Pile Sealing

Steel sheet piling is typically installed as a retaining wall or as cofferdams for bridge pier construction in bodies of water where work must be constructed in dry conditions. For the shallow LRT tunnel, the sheet piling system will be used in a similar way, and will be designed as a permanent system to function as a nearly impervious layer to groundwater infiltration, serving as a secondary defense to control groundwater seepage into the tunnel system.

The sheet pile sealing products applicable for this type of project include bituminous or liquid rubber products. The following are example products that may be considered for the shallow LRT tunnel sheet pile sealing:

http://sheetpiling.arcelormittal.com/uploads/files/AMCRPS_Impervious%20SSP_GB_.pdf

(Pages 23 to 30 in the PDF “The impervious steel sheet pile wall” describe the process of vertical sealing of sheet pile joints using hot installed bituminous products)

http://www.lbfoster-pilingproducts.com/pdf/Joint_Sealant.pdf

<http://www.adeka.com/roxan%20system.pdf>

<http://assets.pilepro.com/resources/PPGCatalogWADIT.pdf>

The sheet pile sealing products considered are applied to the interlocking joints between each sheet pile prior to installing the piling and are designed to prevent groundwater seepage from entering the construction cell or through the sheeting long-term. Depending on the specific product, the pre-installed joint sealing products generally use a plug at the bottom of the sheet pile joint to retain the sealant and to prevent the joints from filling with sand during installation. The sealing products each include repair procedures for supplementary surface applications in the event that seepage occurs after installation of the sheet piling during construction of the tunnel or in the future.

Sheet pile seal manufacturers have published numerous case studies and testing results for their products. The following links contain descriptions of successful installations of sheet pile sealing products:

http://www.wadit.com/case_studies/1

http://assets.pilepro.com/resources/GIKEN_Holly_Hills.pdf

http://assets.pilepro.com/resources/PTI_Wadit.pdf

<http://sheetpiling.arcelormittal.com/uploads/files/3c9b7051d2263fb3475699c4470ca02d.pdf>

The following project in Vienna, Austria successfully used similar overall construction techniques including sheet pile sealing products that are proposed for the shallow LRT Tunnel:

http://sheetpiling.arcelormittal.com/uploads/files/AMCRPS_U-Bahn%20Wien.pdf

One difference between the Vienna and SWLRT projects is that SWLRT will maintain the sheet piling in place permanently to provide an additional measure of seepage control, whereas the Vienna project removed the sheet piling once the tunnel was constructed.

In the unlikely event that the sealing products are not as effective as intended during construction, grout injection into the ground behind the leaking joint may be used or hydrophilic string or rope (<http://www.adeka.com/sheetpilerepair.html>) could be applied into the leaking joint from the inside of the construction cell during construction.

Over time after tunnel construction is complete and the LRT is in operation, the sheet piling joints are expected to “silt-in” thus filling any gaps in the joints with finer grained soil, further contributing to minimizing the amount of seepage through the sheet piling over the long term.

3.3.2 Concrete Seal

The concrete seal that is proposed at the base of the construction cell excavation is intended to establish a level surface to build the cast-in-place reinforced concrete tunnel, prevent upward seepage of groundwater into the construction cells and in combination with helical piles and the sheet piling system, resist uplift or buoyancy forces within each construction cell primarily during construction before the additional permanent weight of the completed tunnel structure and backfill is in place.

One factor that is typical of common “cofferdam” construction activities that needs to be considered is the potential for the development of preferential seepage pathways at the interface between the concrete seal pour and the sheet piling. It is acknowledged that this interface requires attention by the contractor during construction; however, such seepage and related soil piping is expected to be minimal as after the concrete seal is poured and water is initially removed from the construction cell, the outside pressures on the cell will force the sheet pile against the seal concrete. Another contributing factor that will minimize seepage is the adhesion between the steel sheet pile surface and the concrete seal. Additionally, the pressures that are anticipated to be developed at the base of the construction cells are significantly less than what is experienced with similarly constructed cofferdams that are used successfully in rivers or other waterways with 20 to 30 feet of retained water. Pages 57 to 59 in the PDF “The impervious steel sheet pile wall” referenced below describe potential methods that may be considered during advanced design of the LRT tunnel to reinforce and connect the sheet pile and concrete seal interface should they be needed.

http://sheetpiling.arcelormittal.com/uploads/files/AMCRPS_Impervious%20SSP_GB_.pdf

Another factor that needs to be considered that is typical of common cofferdam construction activities is the quality of the concrete seal with respect to susceptibility to cracking and/or seepage, both short-term and long-term. The concrete seal is intended to provide a “construction dry” work area for building the

tunnel structure. It is expected that some cracking and seepage of the concrete seal will occur during construction and the tunnel construction specifications will call for using grout sealants in the event they are needed to address cracks. Calculations for anticipated temporary water control rates and volumes of water in the construction cells will consider seepage through the sheet pile joints (four sides of one construction cell), seepage through the concrete seal and a direct rainfall volume over the construction cell.

Once the tunnel is built and the full loading of the completed tunnel is applied to the concrete seal, external pressures on the sheet pile and concrete seal system will keep the concrete seal under compression reducing crack openings and seepage. The waterproofing materials placed around the perimeter of the tunnel will provide the intended tunnel waterproofing protection. The permanent waterproofing and drainage systems will be further evaluated in more detail during advanced design.

3.3.3 Waterproofing Systems

Between the inside faces of the sheet pile walls, the top surface of the concrete seal and around the outside of the concrete tunnel, a closed waterproofing system will be installed. A closed waterproofing system will extend around the perimeter of a concrete tunnel and prevent groundwater from entering the tunnel. The waterproofing system will be designed for the full hydrostatic water pressure head. See “Technical Manual for Design and Construction of Road Tunnels – Civil Elements”, FHWA-NHI_10_034, for additional explanation of tunnel closed waterproofing systems.

A blind-side membrane waterproofing will adhere to the outside of the cast-in-place concrete tunnel and wrap around the entire four sides of the tunnel. During advanced design, the potential for additional waterproofing systems will be investigated that may include applying a spray waterproofing system to the surfaces of the concrete seal and the sheet pile walls before tunnel concrete construction.

After the tunnel is complete, a sloped concrete cap will be placed across the top of the tunnel to facilitate drainage off the tunnel roof. A membrane waterproofing would be extended across the top of the sloped concrete cap that will be joined to the sheet pile walls on each side of the tunnel. This will protect the tunnel from surface drainage groundwater that will infiltrate into the ground above the tunnel. See the Preliminary Engineering Plans (September 2014) for details of the LRT tunnel waterproofing.

3.4 Permanent Water Control Systems

Permanent water control is handled with two distinct water control systems: 1) the tunnel portal water control system; and 2) the internal tunnel water control system. See the “Preliminary Water Resources Design, East Segment” for additional information.

3.4.1 Tunnel Portal Water Control System

The tunnel portal areas (total of two) are external to the enclosed LRT tunnel and have no cover or roof and are exposed to the environment. Rainfall, snowmelt, and groundwater infiltration will be collected at the portal areas in a drainage system. The portal structural elements (walls and base) will have external waterproofing, matching the tunnel, to reduce any groundwater seepage. Water entering the tunnel portals will be collected and prevented from entering inside the LRT tunnel with drains located in the base of the tunnel portals near the tunnel openings. The water collected in the drains will be routed by pumps to underground infiltration chambers, equipped with a pretreatment system to capture debris and

sediments. The infiltration chambers will be located below the seasonal frost line to allow for infiltration during the winter months.

The system will be designed for the Atlas-14 100-year design storm, which is the current state of practice. Drains in the tunnel portals will be sized for volumes in excess of design storm level. Excess stormwater that passes through the infiltration chambers will overflow into the existing storm sewer system and/or surface water bodies in the vicinity of the tunnel. For the south portal, the overflow stormwater will be routed to the existing storm sewer system near West Lake Street that outlets to Lake Calhoun. For the north portal, overflow stormwater will be routed to the Kenilworth Channel.

The amount of stormwater from the 100-year design storm is anticipated to be on the order of 85,000 gallons and the infiltration system will be designed to handle a flow rate on the order of 4 gpm.

3.4.2 Internal Tunnel Water Control System

The internal tunnel water control system is designed to be part of the closed system that prevents groundwater from entering the tunnel. If any water were to enter the LRT tunnel and be collected by the internal tunnel water control system, it would likely be either groundwater entering via small cracks or joints in the concrete walls, floors, and ceilings or water brought into the tunnel by light rail trains (e.g., dripping, melting ice), either of which are expected to be very small quantities. In order to provide a basis for the design of the internal tunnel water control system, an allowable seepage rate of 0.002 gal/sq ft/day (as recommended by FHWA-NHI_10_034) is used. By applying the allowable seepage rate to the tunnel design, as much as approximately 190,000 gallons of water per year could be collected by the internal tunnel water control system. Water collected in the tunnel will be collected and pumped to the adjacent sanitary sewer systems owned by either the City of Minneapolis or the Met Council Environmental Services, which will be determined during advanced design.

The internal tunnel water control system will also be designed to handle the fire suppression flow discharge rate during either an active event or system testing. The fire suppression system design flow rate is 1,250 gpm for 90 minutes, yielding a total volume of 112,500 gallons in the tunnel. The internal tunnel water control system will be designed to discharge at a rate of 500 gpm, which would empty the tunnel in approximately 4 hours and would discharge to the sanitary sewer system.

3.4.3 Water Exceeding Water Control System Design Rates

Water collected by both the portal and tunnel water control systems will be monitored via metering on the various lift stations, via regular inspection monitoring of water levels at the internal low points, and during other regular operation and maintenance safety inspections. This monitoring will be used to assess excessive water entering the systems and to prioritize any potential tunnel or portal repairs, if required.

The SPO will continue to work with the storm and sanitary sewer system owners to identify proper factors on design volumes and rates to determine sewer system capacities and limitations. All storm and sanitary sewer connections and all capacity analyses will be subject to review and approval by the City of Minneapolis and/or Met Council Environmental Services.

3.5 Temporary Construction Groundwater Control

Since traditional groundwater dewatering methods will not be used to build the LRT tunnel (e.g., well point dewatering), there will be little impact on groundwater levels within the corridor associated with the LRT tunnel construction.

This section describes regulatory requirements and anticipated activities during construction to control groundwater within the tunnel excavation.

3.5.1 Regulatory Requirements

The following regulatory requirements apply to water quality and discharge of stormwater. Except for the Minnesota Department of Natural Resources, the regulatory requirements do not specifically identify quantifiable thresholds for each requirement.

Minnesota Administrative Rules, 7050.0210, General Standards for Waters of the State, Subpart 2, Nuisance conditions prohibited.

“No sewage, industrial waste, or other wastes shall be discharged from either point or nonpoint sources into any waters of the state so as to cause any nuisance conditions, such as the presence of significant amounts of floating solids, scum, visible oil film, excessive suspended solids, material discoloration, obnoxious odors, gas ebullition, deleterious sludge deposits, undesirable slimes or fungus growths, aquatic habitat degradation, excessive growths of aquatic plants, or other offensive or harmful effects.”

Minnesota Department of Natural Resources, Permit Application for Appropriation of Waters of the State, Non-Irrigation.

“Any individual, agency, corporation, or entity appropriating in excess of 10,000 gallons/day and/or 1 million gallons/years must obtain a Water Appropriation Permit...”
“Flow meters are required by Minnesota Statutes 103G.281, Subdivision 2, for measuring the quantity of water appropriated within the degree of accuracy required by rule (10%).”

Minnesota Pollution Control Agency, General Permit Authorization to Discharge Stormwater Associated with Construction Activity under the National Pollutant Discharge Elimination System / State Disposal System Program, Permit No. MNR100001, Part IV.D., Dewatering and Basin Drainage.

“The Permittee(s) must discharge turbid or sediment-laden waters related to dewatering or basin draining (e.g., pumped discharges, trench/ditch cuts for drainage) to a temporary or permanent sedimentation basin on the project site unless infeasible. The Permittee(s) may discharge from the temporary or permanent sedimentation basins to surface waters if the basin water has been visually checked to ensure adequate treatment has been obtained in the basin and that nuisance conditions (see Minn. R. 7050.0210, subp. 2) will not result from the discharge. If the water cannot be discharged to a sedimentation basin prior to entering the surface water, it must be treated with the appropriate BMPs, such that the discharge does not adversely affect the receiving water or downstream properties.”

Minnehaha Creek Watershed District, Erosion Control Rule, Section 9.l., Maintenance.

“Dewatering or basin draining (e.g. pumped discharges, trench/ditch cuts for drainage) related to the construction activity that may have turbid or sediment laden discharge water must be discharged to a temporary or permanent sedimentation basin on the site whenever possible. If water cannot be discharged to a sedimentation basin prior to entering the surface water, it must be treated with the

appropriate BMPs, such that the discharge does not adversely affect the receiving water or downstream landowners.”

3.5.2 Process and Treatment

The construction of the tunnel is anticipated to occur within individual construction cells having an average dimension of 150 feet in length by 37 feet in width and will require temporary pumping of groundwater from within the limits of the construction cells. It is anticipated that there will be two distinct construction cells, with work activities as follows:

- Cell 1 (Excavation): excavation of soil within the cell, placement of temporary bracing, placement of helical piles, placement of the concrete seal, pumping of groundwater and precipitation, and sealing of sheet piling joints for any excessive infiltration.
- Cell 2 (Construction): forming and pouring of the structural concrete for the tunnel walls and pumping of any groundwater infiltration or precipitation.

The discharge from temporary pumping is proposed to be routed to temporary on-site treatment facilities prior to discharging onto the existing grade within the permitted project limits of disturbance, into existing storm sewer systems or existing sanitary sewer systems. The temporary on-site treatment could be in the form of an excavated basin with filter baffles or portable baffle tanks to treat the discharge to meet permit requirements. Pumping rates and volumes will be monitored by either installing a flow meter on the discharge hose or by simply monitoring the pump run time and the pump performance curve to equate the discharge volume. On-going monitoring of the sheet piling during construction will help ensure that seepage rates are maintained to within acceptable levels or whether additional measures to control seepage are required (e.g., grout injection). During the winter months, to address discharge temperature, several options are available including discharging to temporary infiltration chambers that are located under the seasonal frost line, discharging to the sanitary sewer, or discharging to tanks that are hauled off site. See the “Preliminary Water Resources Design, East Segment” for additional information.

4 Tunnel Systems and Operations and Maintenance Considerations

Required tunnel systems for the LRT tunnel include infrastructure for ventilation, operations and signaling, fire/life safety, security, power and electrical systems. See Volume 3 (Systems) of the Preliminary Engineering Plans (September 2014) for more details.

On-going operations and maintenance activities anticipated as a result of the tunnel include providing electrical services and maintaining installed systems related to water control and long term water monitoring, ventilation, fire/life safety, lighting, security and communications equipment.

4.1 Emergency Ventilation

Each tunnel segment will require emergency ventilation systems to address National Fire Protection Association standards (NFPA 130 - Standard for Fixed Guideway Transit and Passenger Rail Systems). NFPA 130 specifies fire protection and life safety requirements for underground, surface, and elevated fixed guideway transit and passenger rail systems including stations, trainways, emergency ventilation systems, vehicles, emergency procedures, and communications and control systems.

The design anticipates bi-directional jet fans mounted to the inside of the tunnel roof and located close to each portal area that will provide the required air velocity to effectively move smoke away to the closest portal or away from the passengers. Based on preliminary analysis, two sets of three jet fans will be required within each tunnel at each portal the tunnel (24 total fans).

Emergency ventilation is engaged only by heat detection or a human interface control. Normal tunnel ventilation will be accomplished by the normal LRT movements within the tunnel, which act like pistons (pushing and pulling air into and out of the tunnels during normal operations).

4.2 Operations and Signaling

During tunnel maintenance operations, when one half-tunnel is out of service, it is anticipated that LRT signal interlockings currently proposed near Beltline and Penn Stations will regulate single track operations in the tunnel.

4.3 Ice Control

It is anticipated that ice buildup inside the tunnels will be prevented using rail heaters designed to operate in series and attached to the direct fixation track at each of the tunnel portal areas. Electrical power will be provided for the rail heaters. Additional temperature gradient modeling and ice control system evaluations will be addressed in advanced design.

4.4 Fire/Life Safety

Passenger evacuation within the tunnel will be addressed with provisions for one cross passage door located mid-tunnel with fire rated doors. Each half-tunnel will have one emergency walkway and egress to each half-tunnel will be at the tunnel portals. Emergency cart evacuation requirements will be evaluated during advanced design.

Each half-tunnel will have a dry standpipe system for horizontal water distribution. The dry standpipe will be cross connected between the half-tunnels.

CCTV cameras will be installed at each portal. Firefighter phones/blue lights will be located within each half tunnel accessible from the emergency walkways. Radio systems and communications connections to tunnel systems houses will be made to the LRT tunnel and to the Rail Control Center.

4.5 Security

An intrusion detection system will be installed at each portal utilizing CCTV cameras. It is also anticipated that security fencing will be used to deter entry into the tunnel portals.

4.6 Lighting

Normal operating condition lighting is anticipated for the length of the tunnel. The normal operating lighting will include controls to adjust levels at portal areas and to potentially turn off lights during non-revenue service times. The tunnels will be equipped with emergency lighting as well. On-going maintenance of lighting includes replacing lamps and cleaning lenses.

4.7 Water Control

Permanent water control for the shallow LRT tunnel will require lift stations for water routed to infiltration chambers and water routed to sanitary sewer. It is anticipated that the tunnel will have one lift station at each portal associated with the Portal Water Control System and one sanitary lift station associated with the Internal Water Control System. Each lift station will have mechanical pumps that require both electrical feeds and communications links for monitoring.

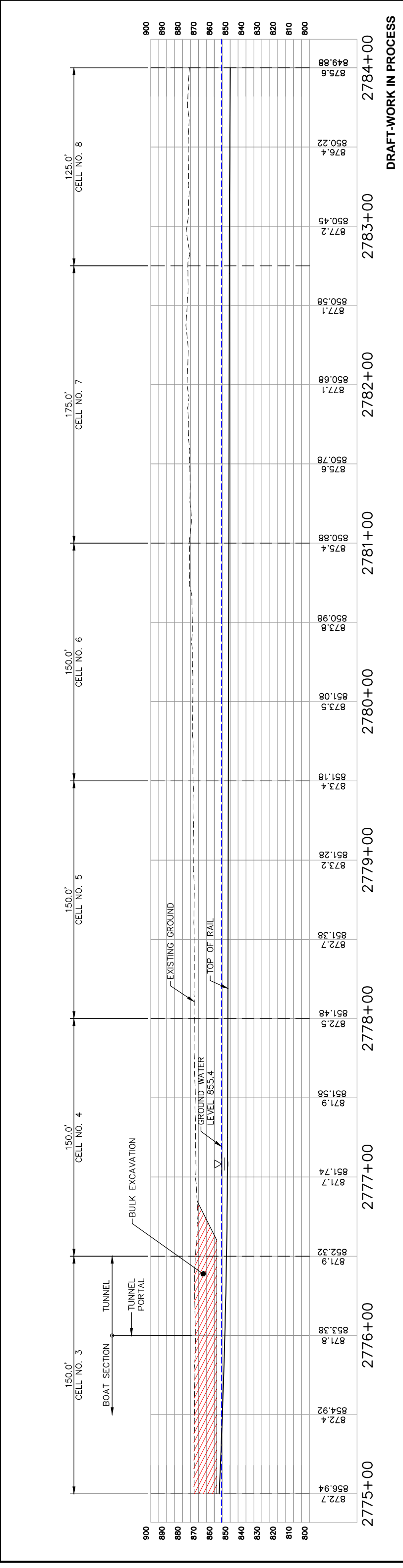
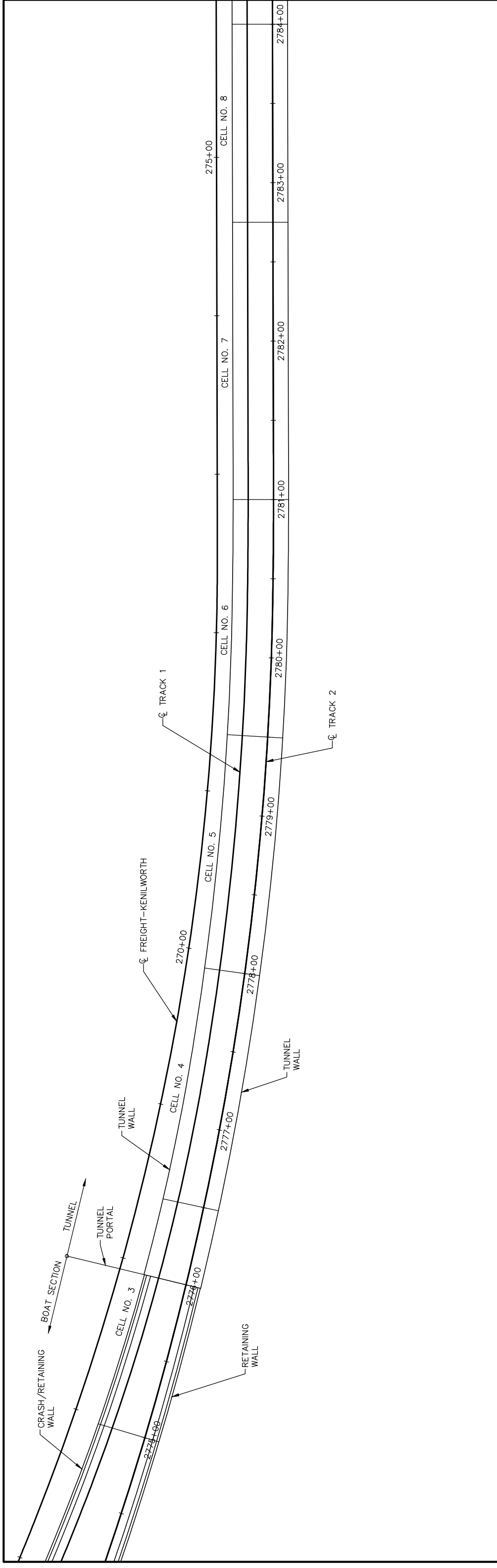
Appendix A – Shallow LRT Tunnel Typical Cell Sequencing

The construction of Kenilworth shallow LRT tunnel is anticipated to be a linear process with excavation and temporary groundwater pumping and construction of the concrete tunnel achieved by use of a cell-by-cell approach. Actual sequencing will be based on the contractor's means and methods as identified in a work plan that will be subject to SPO review.


To demonstrate this anticipated approach, a typical cell sequencing is outlined below. The typical sequencing describes construction of the south end of the LRT tunnel.

1. The existing freight tracks are temporarily shifted 3' to the west to provide space for construction of the tunnel.
2. Commence installing steel sheet piles (SSP) along each side of the tunnel area. This longitudinal process will start at the south end and work northward. About 450 feet of SSP will be installed to encompass the south portal area. The tunnel excavation depths in this area will become deeper and will encounter groundwater at some point along the initial 450 feet of SSP. Once SSP installation crosses the 600 foot mark, transverse sheeting can be installed at both the 450 foot and 600 foot marks creating a "cell".
3. As the longitudinal SSP installation continues northward beyond the 600 foot mark, work within the initial 450' and within the first cell will start. This work in the first cell will begin with excavation to the water line by conventional methods, installing temporary bracing between the longitudinal SSP walls, and then excavation using a clam bucket will be required. This excavation will extend below the bottom of the proposed tunnel to accommodate a concrete seal (or mud slab) and installation of helical piles that will support the concrete seal. Excavated soils are saturated and will require transport to a stockpile location for storage and drying. This location will likely require settling basins to accumulate water, settle solids, remove the separated water to approved locations which may be off site and eventually dispose of dried soils.
4. Once the clam shell excavation is completed and helical piles are installed, the seal concrete will be placed under the water using a tremie concrete placement method. This is accomplished by pumping the concrete through a tube or pipe, with the lower end of the pipe kept immersed in the fresh concrete. In this manner the rising concrete from the bottom displaces the water without washing out the cement content. After sufficient cure time, the seal concrete will act as a plug in the bottom of the SSP cell.
5. With the seal concrete cured in cell #1, initial groundwater pumping will occur and the transverse sheet pile at the 750 foot mark will be installed creating cell #2. Clam shell excavation then occurs in cell #2.

6. Cell #1 is now dry with only minor water accumulation within the SSP and concrete seal area. A concrete leveling slab is placed to establish the precise grades needed for the tunnel bottom slab. After waterproofing is installed, the tunnel bottom slab is formed and poured. Seal concrete in cell #2 is placed by tremie method.
7. After the slab is poured in cell #1, the waterproofing system and the wall and roof systems will be formed and poured. While this is occurring, the initial groundwater pumping of cell #2 takes place. Cell #3 is created by placing the transverse SSP at the 900 foot mark.
8. Cell #1 tunnel is completed up to the cell #2 transverse SSP, cell #2 is now dry, and cell #3 is being excavated by the clam shell method. The transverse SSP wall between cell #1 and cell #2 is cut off at the top of the seal concrete. With this blockage removed, the waterproofing system and forming and pouring concrete for the extension of the tunnel into cell #2 occurs.
9. The steps above are repeated until the entire length of tunnel is constructed.



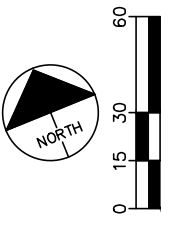
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Green Line LRT Extension


SOUTHWEST LRT
TYPICAL CELL SEQUENCING
STEP 1

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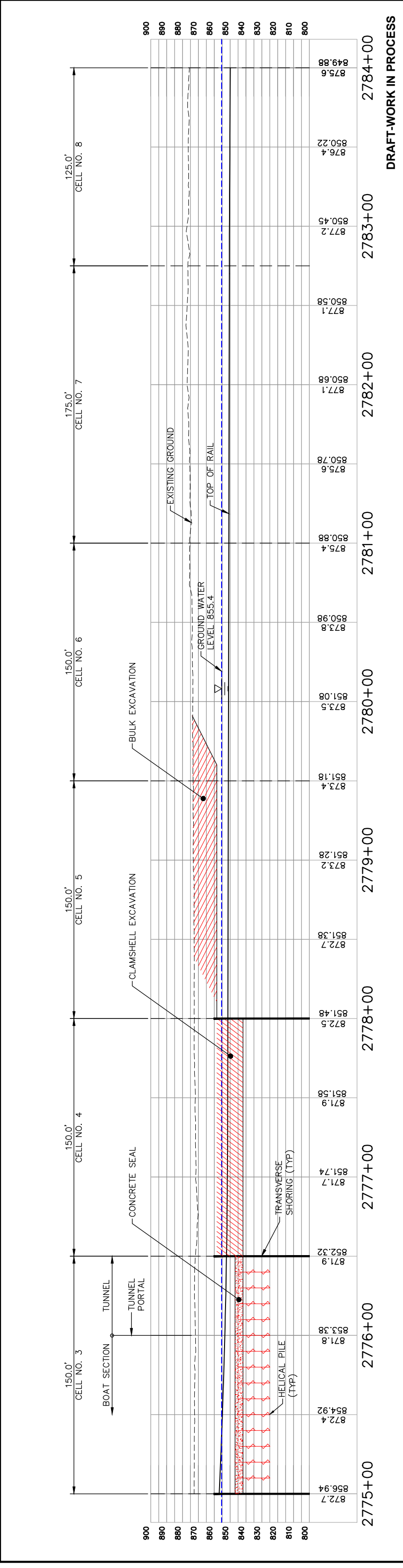
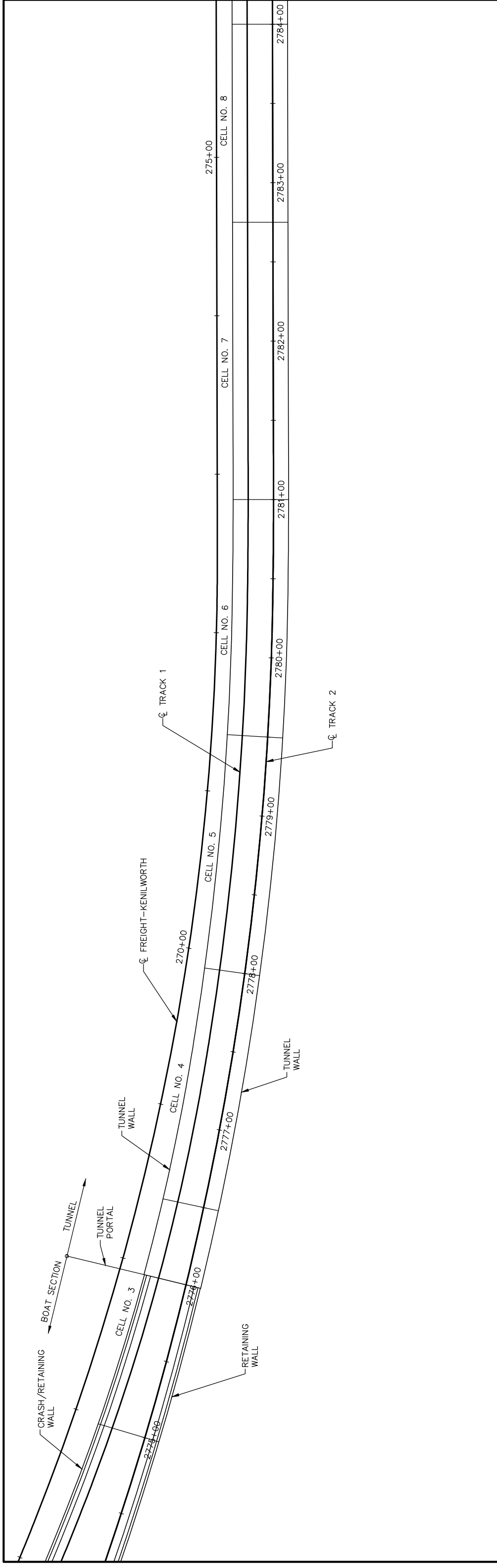





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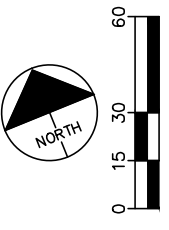
SOUTHWEST LRT
Green Line LRT Extension

SOUTHWEST LRT
TYPICAL CELL SEQUENCING
STEP 3


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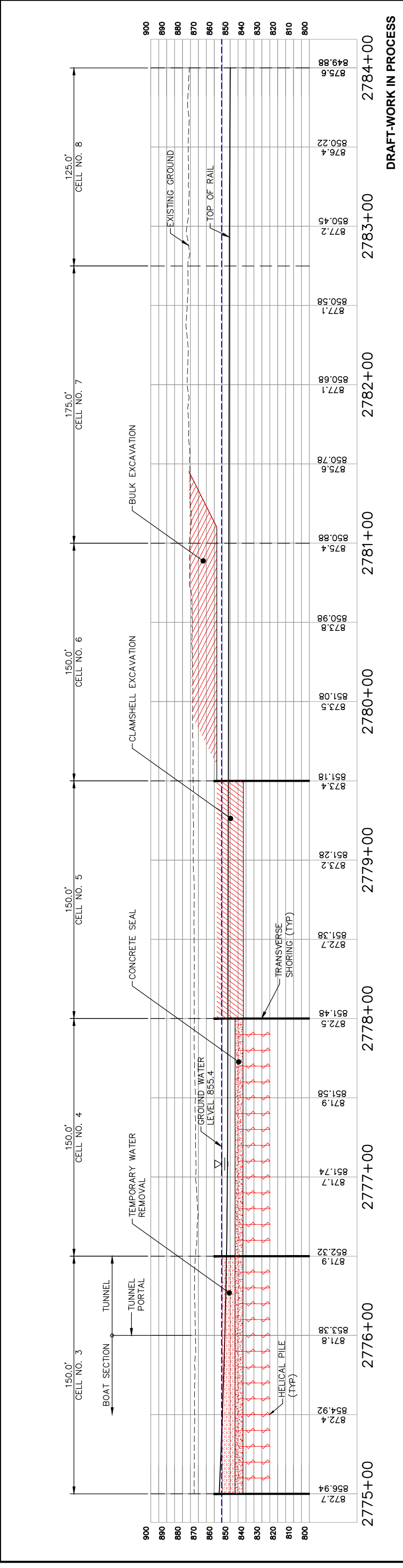
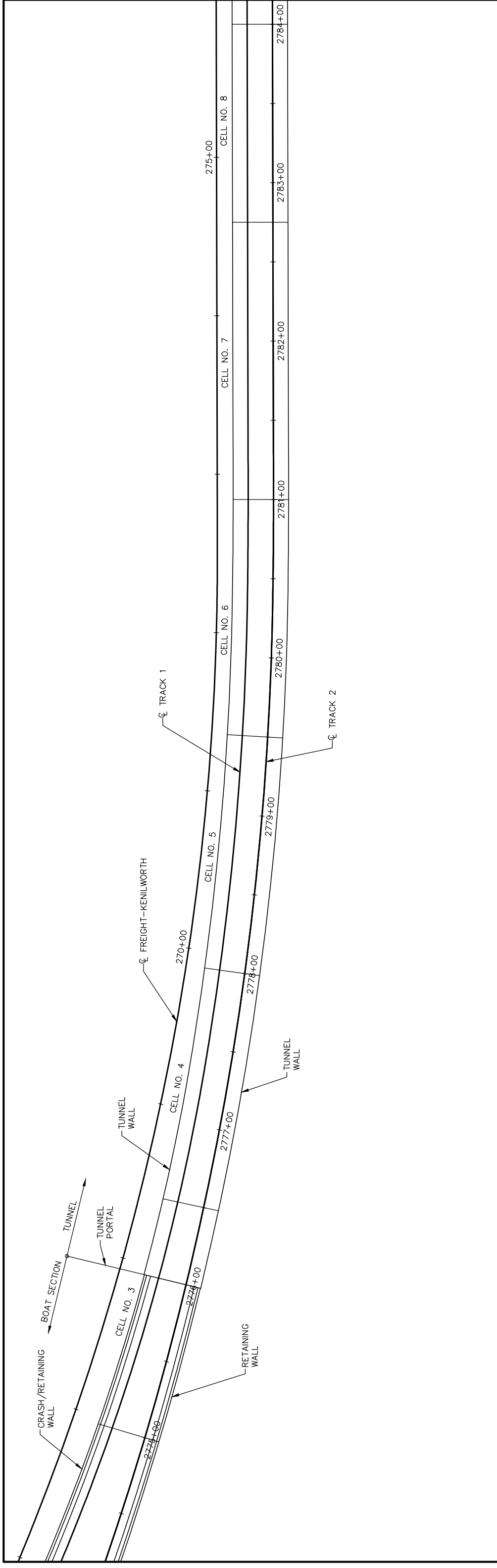
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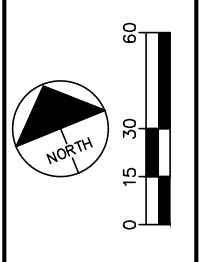
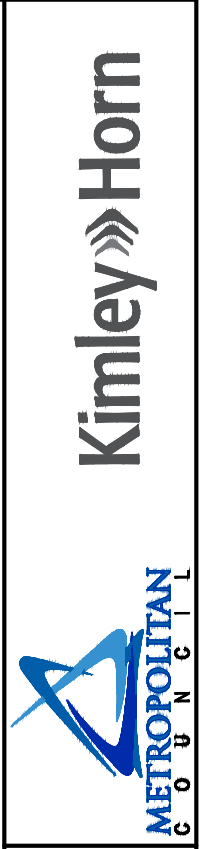
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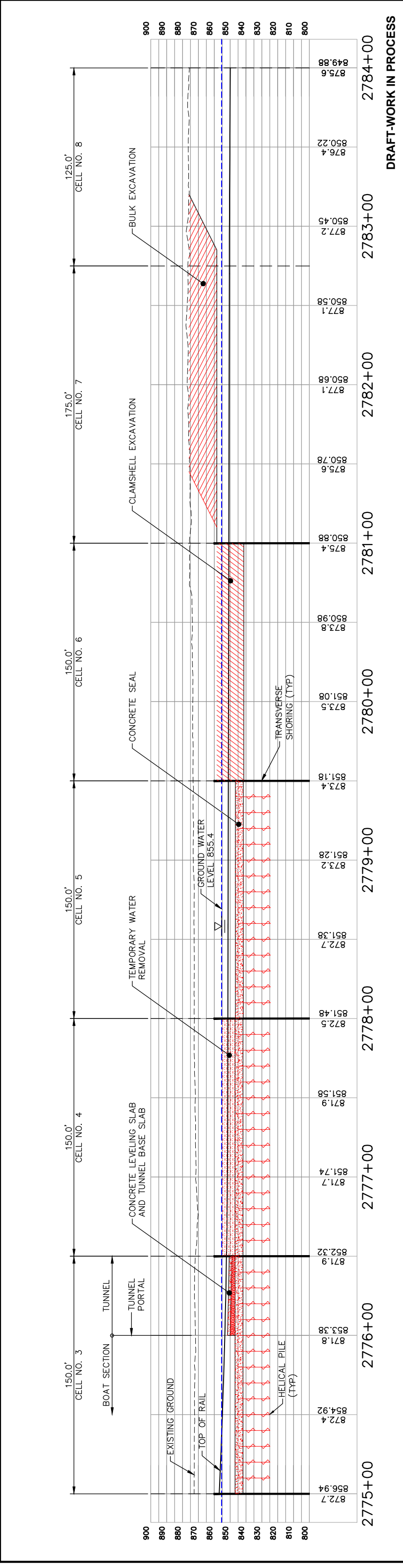
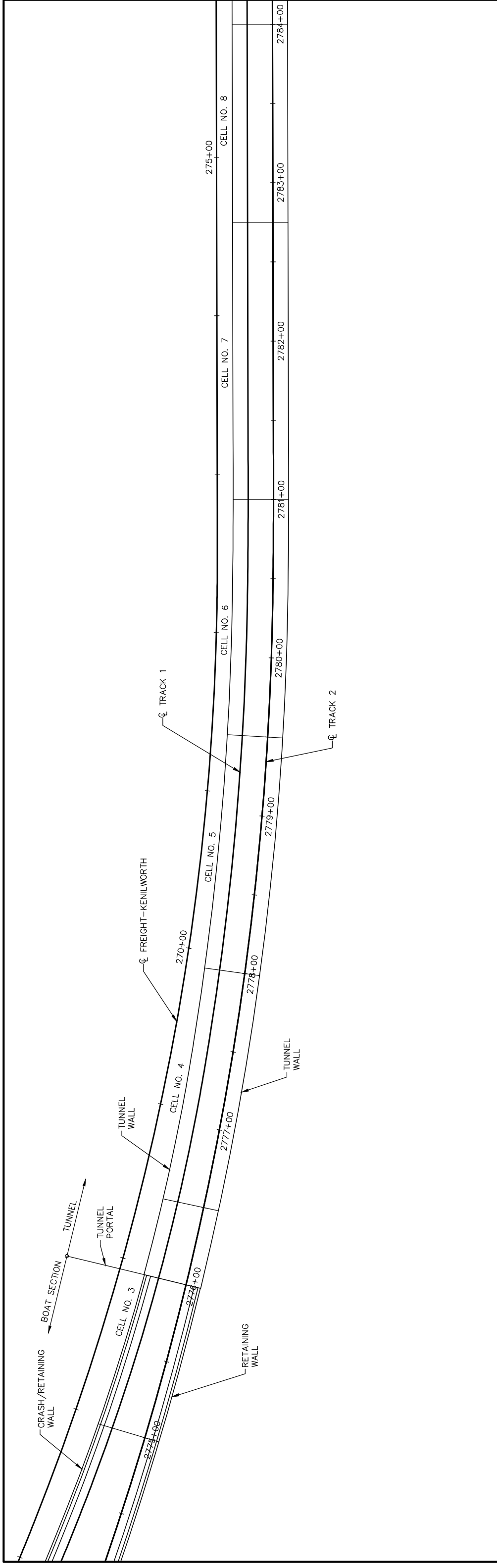
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TYPICAL CELL SEQUENCING
STEP 4






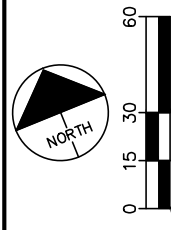
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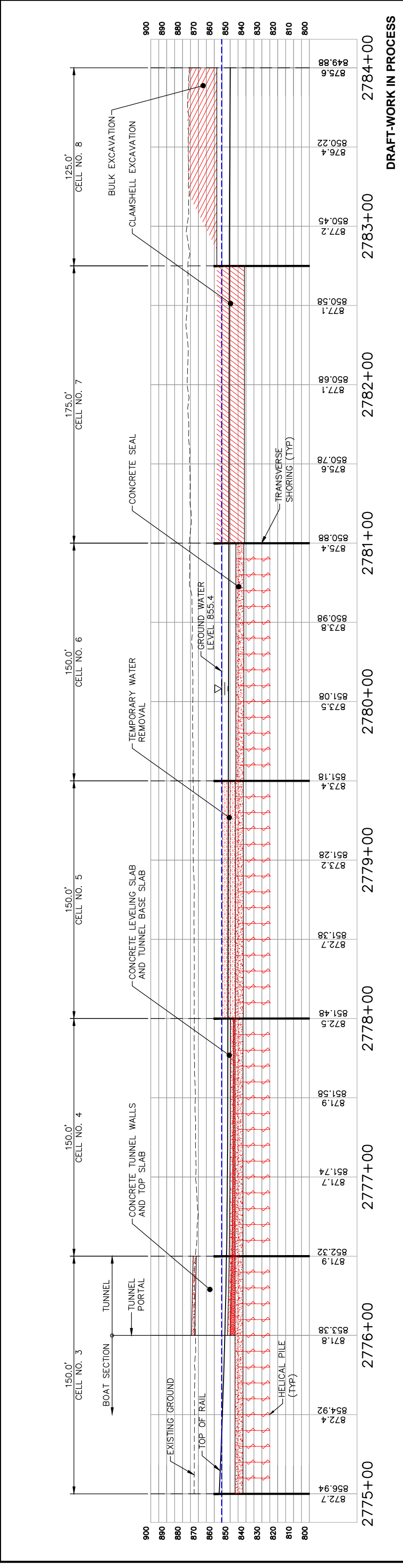
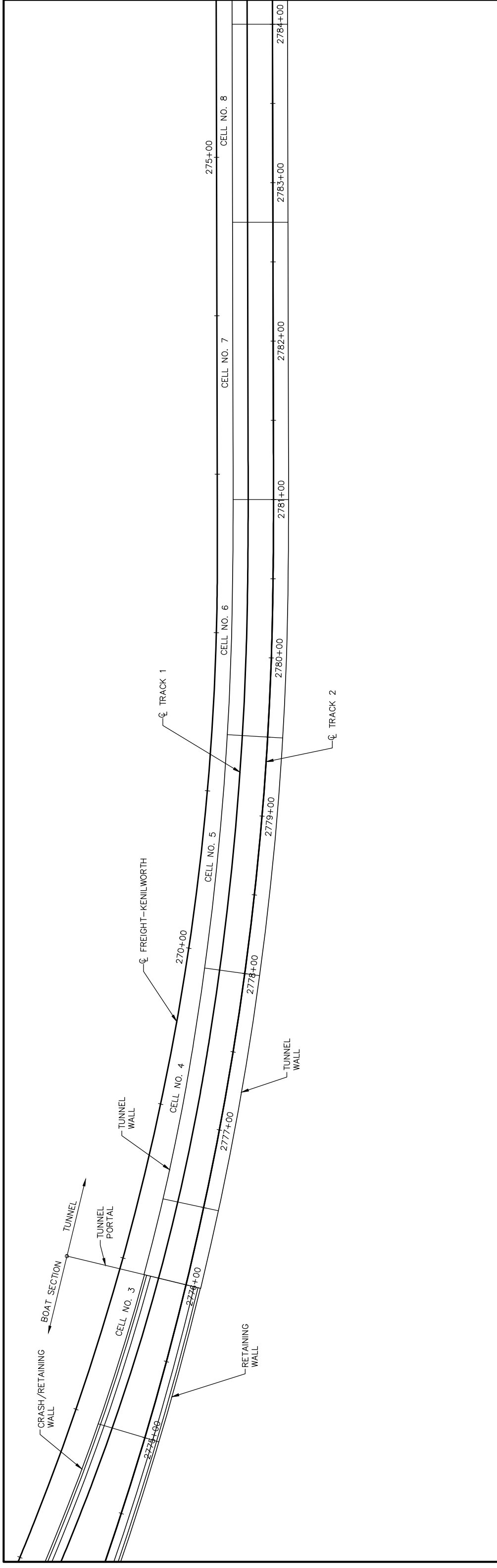
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TYPICAL CELL SEQUENCING
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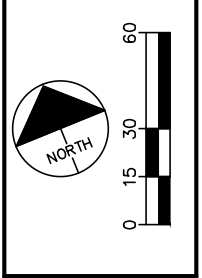
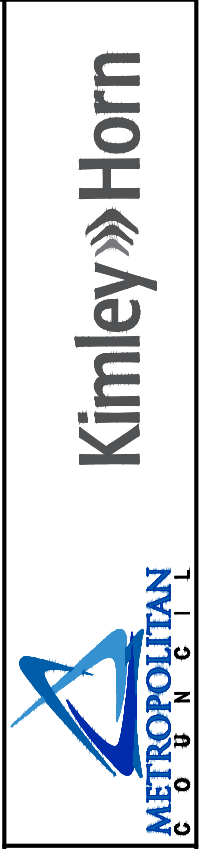








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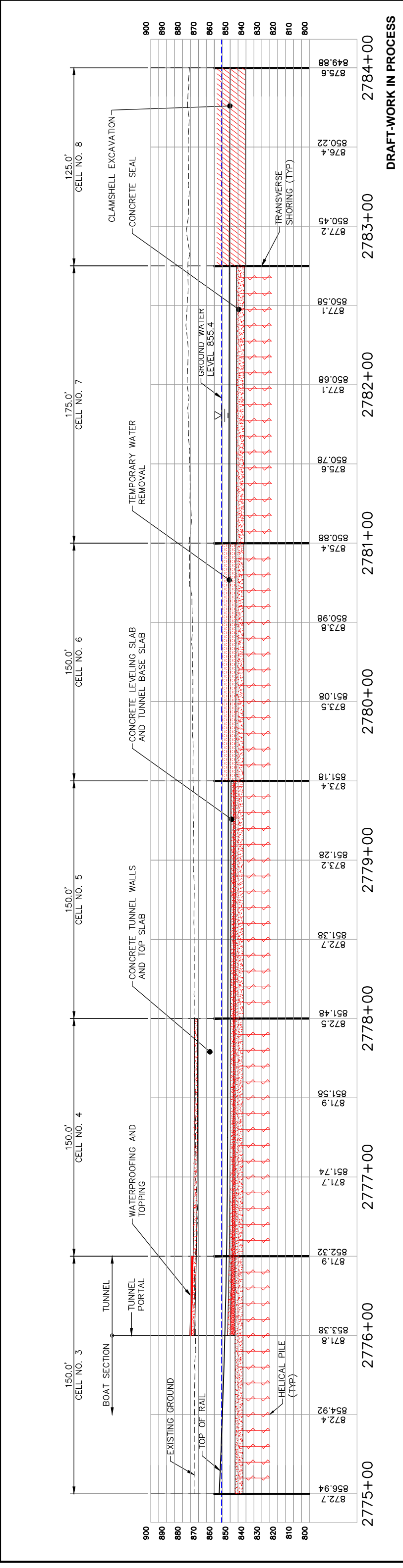
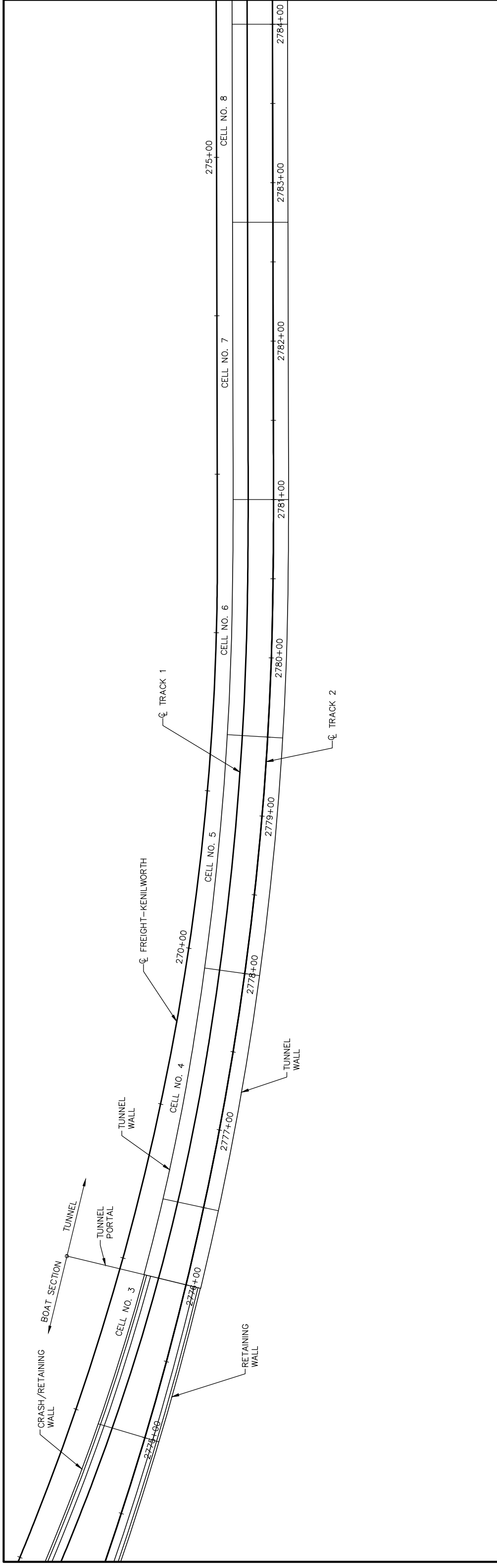


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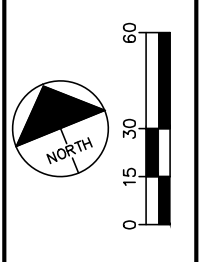
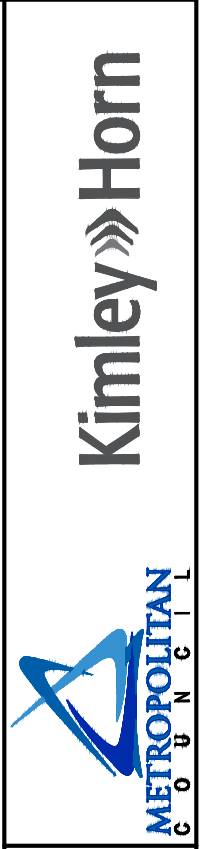
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STEP 6





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STEP 7

