NOVEMBER 2019
CITY OF SEATTLE

WA12 N NORTHLAKE WAY WALL REPLACEMENT ALTERNATIVE EVALUATION

TASK 4 – WALL ALTERNATIVES EVALUATION

FINAL REPORT

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CONTENTS

APPENDICES

1 Executive Summary

This report summarizes the findings of the Task 4 - Wall Alternatives Evaluation for the N Northlake Way Wall Replacement Alternative Evaluation Project.

An alternatives analysis has been completed to define and evaluate several concepts for wall replacement. Three basic wall configurations were considered, including:

- Alternative 1: Cantilever walls with soil liquefaction mitigation (3 variants)
- Alternative 2: Anchored walls (2 variants)
- Alternative 3: Ground Improvement with Fascia Wall

Table 1 provides a summary of the alternatives analysis, including system descriptions, an evaluation summary, and preliminary rough order-of-magnitude (ROM) cost estimates of the alternatives considered.

For Alternative 1, cantilever wall alternatives that do not include soil liquefaction mitigation due to the presence of liquefiable soils at the site are not technically feasible or cost-effective due to the size of the structural elements that would be required. Consequently, all cantilever wall options include soil liquefaction mitigation measures (assumed to consist of stone columns and wick drains).

For Alternative 2, the anchored wall alternative includes use of anchor piles since deadman anchors or drill-in permanent ground anchors are also not feasible in liquefiable soils.

Alternative 3 – Ground Improvement with Fascia Wall is recommended for advancement to the Task 6 – Wall Replacement Concept Design phase of the Project. Deep soil mixing or jet grouting have been considered for ground improvement. This alternative was selected primarily because it is more readily constructible, addresses liquefaction issues, and has the lowest estimated overall cost as compared to the other alternatives considered.

The site contains numerous utilities: overhead power and communication, and buried sanitary sewer, water, gas, and drainage features. Impacts to utilities both during and after construction are addressed in Appendix D. Regardless of selected alternative, it is proposed to temporarily relocate utilities around the site during construction. Utilities would then be restored to their existing condition after completion of substantial work items (pile installation, ground improvement, backfilling, etc.). It is also proposed to upgrade the storm drainage at the site with a new cartridge-type catch basin system.

Table 1 N Northlake Way Retaining Wall - Alternatives Analysis Executive Summary

	WALL TYPE	WALL DESIGN SUMMARY	WALL TYPE EVALUATION			WALL LOCATION FEASIBILITY	ROUGH-ORDER-OF-MAGNITUDE (ROM) COMPARATIVE CONSTRUCTION COST ESTIMATE[1]
			Advantages	Disadvantages	Critical Design/Construction Issues		
ALT 1. CANTILEVERED WALL	1A. Soldier Pile	› Up to W40 soldier pile steel sections in ~5ft dia. shafts @ 8 ft on-center › Timber lagging between soldier piles, with concrete facing in front › Liquefaction mitigation behind wall to reduce wall loading	› Drilled pile installation – reduced vibration › Soldier piles can be installed between existing wall tie rods	› Large and heavy pile steel sections required › Large drilling equipment required for soldier pile shaft construction › Unloading existing wall prior to start of new wall construction would be required › Lagging installation requires special construction sequence to accommodate existing tie rods › Relatively expensive alternative › Cantilever concept is not feasible unless liquefaction mitigation soil improvement is included	› Construction loads from large driving equipment may overload existing wall › Cantilever wall is flexible • protection measures for utilities and pavements would likely be required • seismic loading deflection (at top of wall) exceeds 24" • post-seismic permanent deflection would be significant › Large and heavy pile steel sections may not be readily available	<u>In Front of Ex. Wall:</u> › Not feasible. Soldier pile shafts are too large to safely fit between the existing wall and the existing buildings. <u>Behind Ex. Wall:</u> › Appears feasible, if critical issues can be addressed during design.	$22M
	1B. Secant Pile	› 48" dia. secant pile conc. shafts with embedded steel sections › Liquefaction mitigation behind wall to reduce wall loading	› Drilled pile installation – reduced vibration › Continuous wall with reduced wall thickness relative to Alternative 1A Cantilevered Soldier Pile Wall › Improved system redundancy	› Large drilling equipment required for secant pile shaft construction › Unloading existing wall prior to start of new wall construction would be required › Construction sequence to accommodate existing tie rods would be challenging › One of the most expensive alternatives › Cantilever concept is not feasible unless liquefaction mitigation soil improvement is included	› Construction loads from large driving equipment may overload existing wall › Cantilever wall is flexible • protection measures for utilities and pavements would likely be required • seismic loading deflection (at top of wall) exceeds 24" • post-seismic permanent deflection would be significant › Accommodating existing utilities crossing wall may be difficult	<u>In Front of Ex. Wall:</u> › Not feasible – secant pile wall systems are not intended for above ground applications (soil is needed for wall "formwork") <u>Behind Ex. Wall:</u> › Appears feasible, if critical issues can be addressed during design	$29M
	1C. King Pile	› 42" dia. steel pipe piles with pairs of intermediate sheet piles (~8'-4" pipe spacing) › Liquefaction mitigation behind wall to reduce wall loading	› Closed pipe pile sections are less susceptible to marine corrosion › Driven sheet piles in between pipe piles provide a simpler "lagging" solution to that of the soldier pile wall option › Improved system redundancy	› Driving large diameter steel pipe sections would cause significant vibration at the site › Unloading existing wall prior to start of new wall construction would be required › If wall is located behind existing wall, construction sequence to accommodate existing tie rods would be challenging › Due to non-matching pipe pile spacing between new and existing wall systems, this alternative will likely require unique design and construction sequencing at locations of geometric conflict with the existing structure › Relatively expensive alternative › Cantilever concept is not feasible unless liquefaction mitigation soil improvement is included	› Construction loads from large driving equipment may overload existing wall › Pipe pile driving may lead to unacceptable levels of vibration for existing structures › Cantilever wall is flexible • protection measures for utilities and pavements would likely be required • seismic loading deflection (at top of wall) exceeds 24" • post-seismic deflection would be significant › Accommodating existing utilities crossing wall may be difficult	<u>In Front of Ex. Wall:</u> › Not feasible – driving equipment for pipe piles would be too large to safely drive piles within the limited space between the existing wall and existing buildings. <u>Behind Ex. Wall:</u> › Appears feasible, if critical issues can be addressed during design.	$27M

	WALL TYPE	WALL DESIGN SUMMARY	WALL TYPE EVALUATION: Advantages	WALL TYPE EVALUATION: Disadvantages	WALL TYPE EVALUATION: Critical Design/Construction Issues	WALL LOCATION FEASIBILITY	ROUGH-ORDER-OF-MAGNITUDE (ROM) COMPARATIVE CONSTRUCTION COST ESTIMATE[1]
ALT 2. ANCHORED WALL	2A. Soldier Pile with Tie Rod & Anchor Piles	› Up to W36 soldier pile sections in ~4ft dia. conc shafts @ 8 ft on-center › Anchor pile and tie rod anchor system › Timber lagging between soldier piles, with concrete facing in front	› Drilled pile installation – reduced vibration › Better wall deflection control relative to cantilever wall alternatives › No soil improvement required	› New tie rods and anchor piles would require coordination with existing utilities – it is proposed to temporarily relocate or remove these items prior to new wall installation › New tie rods and anchor piles would constrain future utility and roadway work behind wall › Relatively expensive alternative	› Deadman concrete anchors not feasible without liquefaction mitigation and high load demands › Anchor piles and tie rods may conflict with future land use behind the wall	In Front of Ex. Wall: › It may be feasible, however very challenging and risky. Limited space between existing wall and existing buildings would require tight construction tolerances to avoid the risk of damaging existing buildings. Behind Ex. Wall: › Appears feasible, if critical issues can be addressed during design.	$24M
	2B. King Pile with Tie Rod & Anchor Piles	› 30" dia. steel pipe piles with pairs of intermediate sheet piles (~7'-4" pipe spacing) › Anchor pile and tie rod anchor system	› Better wall deflection control relative to cantilever wall alternatives › Closed pipe sections are less susceptible to marine corrosion › Driven sheet piles in between pipe piles provide a simpler "lagging" solution to that of the soldier pile wall option › No soil improvement required	› New tie rods require coordination with existing utilities › New tie rods and anchor piles would constrain future utility and roadway work behind wall › Due to non-matching pile spacing between new and existing wall systems, this alternative will likely require unique design and construction sequencing at locations of geometric conflict with the existing structure. › One of the most expensive alternatives.	› Deadman concrete anchors not feasible without liquefaction mitigation and high load demands › Pipe pile driving may lead to unacceptable level of vibration for existing structures › Large pile installation equipment may put too much demand on existing wall › Anchor piles and tie rods may conflict with future land use behind the wall	In Front of Ex. Wall: › Not feasible – driving equipment for pipe piles would be too large to safely drive piles within the limited space between the existing wall and existing buildings. Behind Ex. Wall: › Appears feasible, if critical issues can be addressed during design.	$30M
ALT 3. GROUND IMPROVEMENT	Non-Structural Fascia	› Deep soil mixing (DSM) or jet grouting (JG) improved soil mass columns behind the existing wall, of approx. 35 ft-max in height › Steel sheet pile required for containment during construction › Self-supporting soil mass (MSE or geogrid wrapped fill) behind wall near grade › Precast concrete fascia panels	› Soil mass behind existing wall is improved › Lower vibration relative to alternatives that require pile driving › Mitigates settlement behind wall › Minimal conflict with future utilities • installed ground improvement can be trenched with conventional construction equipment › May be able to save existing timber lagging or install similar wall fascia › Least expensive alternative	› Installation of containment wall in front of existing wall would be challenging – it is proposed to install this sheet pile wall behind the existing wall › Working around utilities and existing tie rods will present a challenge – it is proposed to temporarily relocate or remove these items prior to ground improvement › A large volume of spoils will be generated which will need to be contained, hauled off site, and disposed of off site › JG / DSM columns installation will need to be sequenced to avoid pressurizing existing wall	› Ground improvement typically requires use of specialty contractor to complete installation › Ground improvement cost and ease of installation can vary widely depending on unknown site conditions	In Front of Ex. Wall: › Not applicable. Behind Ex. Wall: › Appears feasible, if critical issues can be addressed during design.	$16M

TABLE NOTES:

1 The following notes apply to the Rough Order of Magnitude (ROM) Cost Estimates:

1.1 Cost estimates are based on 2019 dollars and a 1 to 10% level of design definition.

1.2 The costs presented were prepared for the purpose of comparing the evaluated alternatives. Actual long-term and construction costs will differ from the costs shown. Final project costs are dependent on upon many variable factors including, but not limited to, labor and material costs, site conditions, productivity, competitive market conditions, final project scope, and contractor's implementation schedule.

1.3 The costs shown do not include: financing, operation and maintenance (O&M) costs, sales taxes, environmental mitigation (if needed), contaminated soil characterization/handling/disposal, engineering costs, construction contingency, construction engineering, right-of-way costs (all alternatives should fit within existing right-of-way), or escalation.

1.4 See Appendix A Wall Alternatives Evaluation Rough-Order-of-Magnitude Cost Estimate Breakdown for cost summary breakdown tables.

2 Introduction

2.1 Project Background and Description

2.1.1 Background

The N Northlake Way Wall is a 1950's era, 432-foot long, 7 to 15-foot tall (with respect to existing mudline), timber wall that acts as a bulkhead between Lake Union and N Northlake Way in Seattle, WA. The existing wall is comprised of timber soldier piles spaced at 8 feet centers, timber lagging spanning between soldier piles, and steel tie rods with concrete deadman anchors located in the soil behind the wall. The timber wall is in a severely deteriorated condition and has been identified by the Seattle Department of Transportation (SDOT) as at risk of failure and in need of replacement.

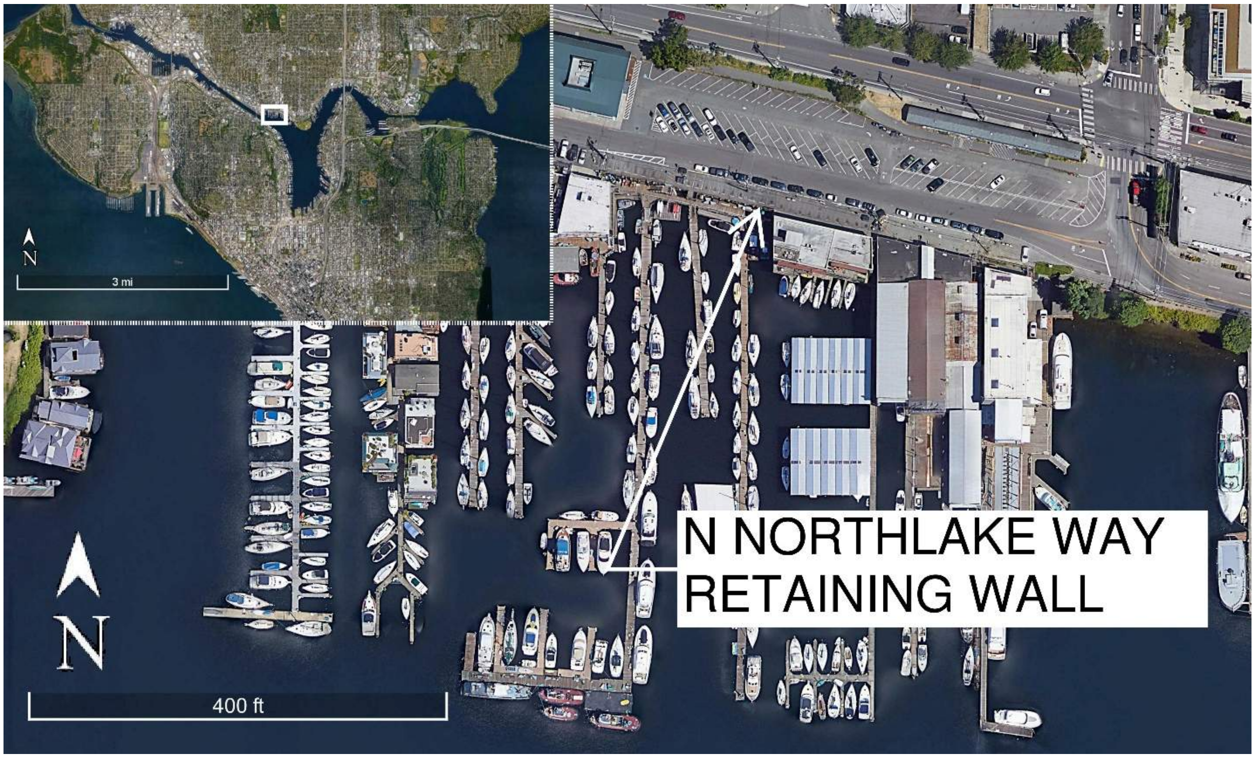
This wall has been identified by the Seattle Department of Transportation (SDOT) as at risk of failure and in need of replacement, as indicated in the following SDOT Technical Memorandums:

- Technical Memorandum - Northlake Way Retaining Wall Evaluation, prepared by SDOT, dated May 23, 2018
- Technical Memorandum - Northlake Way Retaining Wall – Parking Evaluation, prepared by SDOT, dated June 20, 2018

As noted by the above references, SDOT has:

- restricted access/loading behind the wall – parking, vehicle access, and pedestrian gathering space are restricted
- instrumented several timber piles of the existing wall with inclinometers to measure wall rotations
- proposed temporary repairs to the existing wall
- recommended replacement of the wall

Figure 1 shows the location of the existing wall and a representative photograph.



a) Vicinity Map

b) Wall Elevation
(looking northwest)

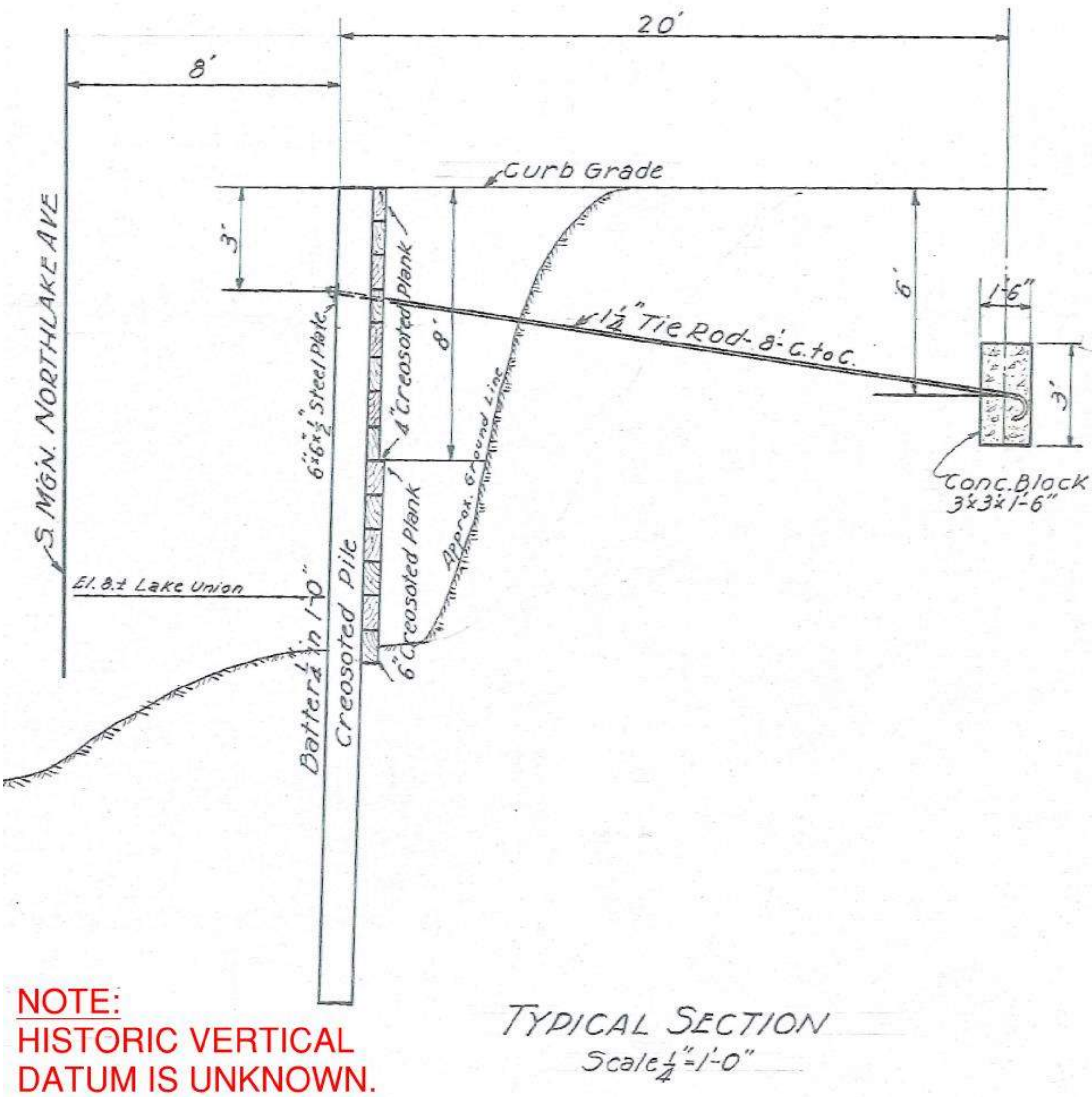
Figure 1 North Northlake Way Retaining Wall

Existing Wall Details

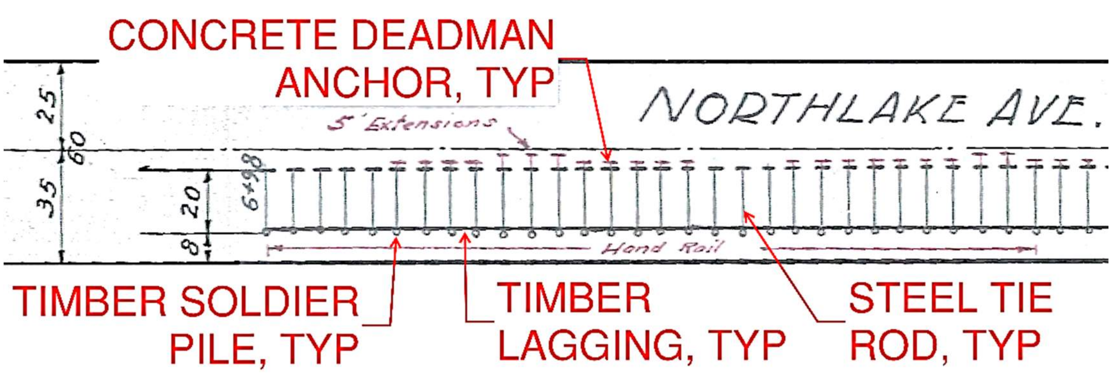
The existing wall has the following key geometry:

- 432± foot plan length
- Exposed Wall Height
  - Maximum – ~17 ft
  - Minimum – ~7 ft
  - Typical - ~12 to ~15 ft
- Typical Wall-Section
  - ~12” diameter timber soldier piles @ 8 ft spacing
  - Timber lagging spanning between soldier piles
  - Steel tie rods to concrete deadmen anchors
  - Deadman Anchor Setback
    - 20 ft typical
    - Extended to 23 or 25 ft at some anchor locations

Figure 2 shows a representative wall section and plan taken from available historic as-built drawings.



a) Wall Typical Section



b) Wall Plan

Figure 2 Existing Wall Drawings

2.1.2 Project Description

The N Northlake Way Wall Replacement Alternative Evaluation Project has been undertaken to develop a preliminary design concept for the replacement of the existing timber wall.

This report summarizes the Task 4 Wall Alternatives Evaluation phase of the Project. In this phase several design alternatives have been evaluated, and a preferred alternative is recommended for advancement to the next phase of the Project.

A subsequent phase of the Project, Task 6 Wall Replacement Concept Design, will advance analysis and design efforts for the selected alternative to a 30%± level of design completion.

2.2 Objectives

2.2.1 Overall Project Objective

The ultimate objective of the Project is to:

- Identify and develop a preferred design concept to be advanced to preliminary and final design for the replacement of the existing, deteriorated North Northlake Way Retaining Wall.

The replacement concept (and evaluated alternatives) must meet current design standards, including seismic design requirements, in addition to satisfying project constraints.

2.2.2 Wall Replacement Alternatives Evaluation

This report summarizes the alternatives analysis that has been completed for the Project. The objectives of this Project phase were to:

- Review the Project site conditions
- Identify key design challenges and constraints
- Evaluate several alternatives, including:
  - Basic preliminary design information and design sketches for the alternatives
  - Advantages, disadvantages, and critical design/constructability issues for each alternative
  - Perform feasibility analysis for constructing each alternative in front of or behind the existing timber wall
  - Develop rough order of magnitude (ROM) cost estimates for construction
- Recommend a preferred alternative for design advancement in future phases of Project development
- Study existing utilities at the site and propose actions for temporary relocation and restoration after wall construction (see for Appendix D Utilities Report)

3 Design Criteria

3.1 Constraints and Critical Considerations

The following constraints and critical considerations have been identified for the alternatives analysis:

- Constructability
  - The stability of the deteriorated existing wall must be maintained during demolition and during construction of the wall replacement.
  - The recommended alternative must fit within geometric constraints at the site location, including:
    - Right of Way limits
    - Locations of existing utilities unless they can be temporarily removed or relocated
    - Locations of existing wall structure components
    - Available clearances for the equipment required to install the wall replacement concept
  - Disruption to existing adjacent buildings should be minimized.
    - Vibration monitoring of adjacent buildings and piers ~~during~~ should be included.
    - A monitoring plan for adjacent structures should be included.
  - Temporary easements will likely be required for temporary services or construction access/staging area
  - The existing timber soldier pile wall will be removed (existing timber piles will be pulled or cut at mudline, and removed with the lagging and anchor system)
    - Construction scheduling will be impacted by available in-water-work period due to fish window. It is noted that the applicable fish window is from October to April.
    - The work will need to be contained from Lake Union; temporary sheet piles or debris barrier may be required.
    - The existing timber is creosote treated (shown on historic as-built drawings) and will need to be isolated from Lake Union during construction removals, and then need to be disposed of at an approved upland facility.

- Utilities

See the Utilities Report (included as Appendix D) for additional detailed discussion.

- It is proposed to maintain utility services during construction by temporarily relocating utilities around the project work area.
  - The existing overhead power that runs through the site would be temporarily re-routed and stopped at the ends of the site. The overhead power would then have its voltage reduced, be brought down to grade, and directed to adjacent property owners.
  - All other existing utilities would be temporarily relocated to an alignment along the existing wall face.
  - Utilities would then be restored (to approximate existing configurations) after primary structural and ground improvement work has been completed.
- Further design phases should include additional coordination with existing utility owners in order to temporarily relocate, provide temporary service, and reestablish services. The following utilities and owners have been identified and coordinated with as part of this study:
  - Seattle City Light (SCL) – overhead power
  - Seattle Public Utilities (SPU) – sanitary sewer and water
  - Puget Sound Energy (PSE) – natural gas
  - Comcast and Century Link – overhead communication
- There does not appear to be an existing, formal drainage system along the site. The site appears to have inlets, catch basins, and outfalls which discharge stormwater directly into Lake Union. A new storm drainage system has been proposed for the site (see Appendix D Utilities Report for details). The proposed system is a cartridge catch-basin type system that will connect to an existing storm main at the adjacent intersection with Stone Way N.
- It is preferred that the recommended replacement alternative does not restrict future utility and road work within the Project vicinity.

- Permitting
  - The replacement wall concept must be able to obtain required environmental permits for construction.
  - Anticipated permits required include:
    - US Army Corps Section 404/10 (Nationwide Permit)
    - Washington Department of Fish and Wildlife Hydraulic Project Approval
    - City of Seattle Shoreline Permit
    - City of Seattle Construction Permit
  - Other reviews likely necessary to obtain required permits include:
    - SEPA environmental review
    - Endangered Species Act consultation
    - National Historic Preservation Act Section 106 review
    - Likely consultation with the Muckleshoot Indian Tribe as they have fishing rights in Lake Union.

- Contaminated Soils
  - According to the "Draft Geotechnical Report – N Northlake Way Bulkhead Seattle, Washington", prepared by Seattle Public Utilities (SPU) Geotechnical Engineering, dated May 2015, borings taken behind the existing wall indicated that contaminated soils may be present at the site.
  - However, soil contamination would be expected to equally affect all alternatives considered for this study, and therefore have not been further considered for this Project phase.
  - It is recommended that subsequent Project phases include characterization of the site in order to identify the limits and extent of contaminated soils.
- Temporary Access
  - Temporary access to adjacent private properties will need to be maintained during construction.
  - It is noted that this issue is expected to impact all evaluated alternatives and should not affect alternative selection.
- Drainage
  - Temporary drainage system will be required during construction in order to provide drainage of groundwater and surface stormwater.
  - Permanent drainage system will be required after construction is complete for drainage of groundwater and surface stormwater.
  - It is noted that this issue is expected to impact all evaluated alternatives and should not affect alternative selection.

Constraints and critical considerations related to existing conditions are conceptually shown on Figure 3.

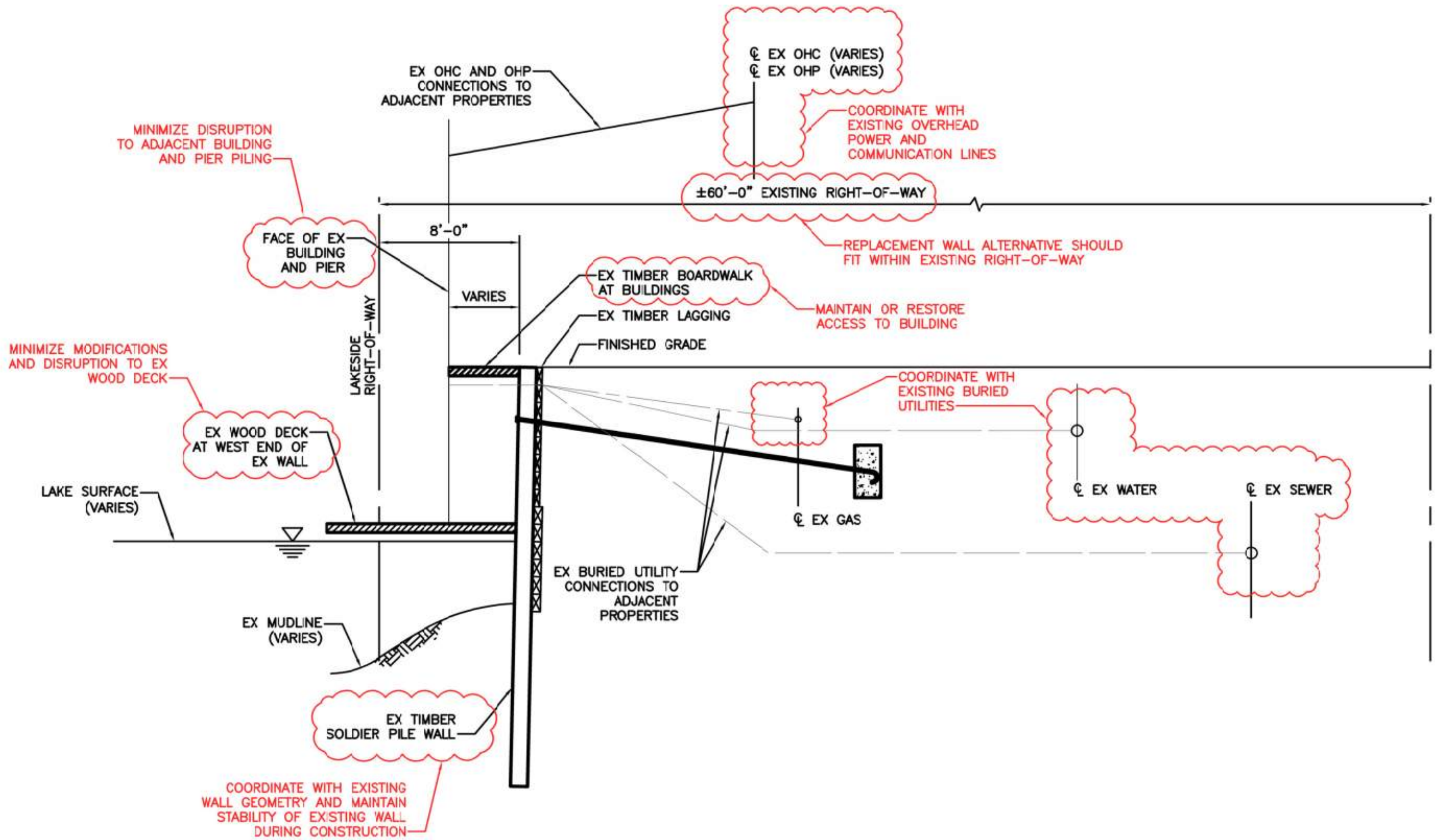


Figure 3 Existing Constraints and Critical Considerations at Project Location

3.2 Design Standards and Project References

3.2.1 Design Standards

The following standards will be used for this phase of the Project as applicable:

- AASHTO LRFD Design Specifications – 8th Edition
- WSDOT Bridge Design Manual (BDM)

Final detailed design for the wall replacement project should also consider:

- City of Seattle Standard Plans
- City of Seattle Standard Specifications
- WSDOT Standard Plans
- City of Seattle Right-of-Way Improvements Manual

3.2.2 Project References

The following references have been identified and provide background for the Project and site location:

- Technical Memorandum - Northlake Way Retaining Wall Evaluation, prepared by SDOT, dated May 23, 2018
- Technical Memorandum - Northlake Way Retaining Wall – Parking Evaluation, prepared by SDOT, dated June 20, 2018
- Draft Geotechnical Report – N Northlake Way Bulkhead Seattle, Washington, prepared by Seattle Public Utilities (SPU) Geotechnical Engineering, dated May 2015
- Improvement of Northlake Avenue Retaining Wall, Inspectors Book No. 106, dated 1954 (historic as-built drawing of the existing timber wall)
- TRC0314_X-BASE.dwg (SDOT AutoCAD model of site base map)

4 Geotechnical Recommendations

Subsurface conditions and engineering parameters are based on the "Draft Geotechnical Report – N Northlake Way Bulkhead Seattle, WA", prepared by Seattle Public Utilities (SPU) Geotechnical Engineering dated May 2015. The geotechnical report presented a summary of historic boring logs and 4 new boring logs taken behind the wall.

4.1 Site Stratigraphy

The following presents a general description of the soil units encountered in SPU borings B-101 through B-104.

Fill (Hf): Approximately 17 to 37 feet of fill was encountered below the existing pavement behind the existing wall. The fill consists of a medium stiff, light brown clay with trace fine sand. The Standard Penetration Test (SPT) blow count (SPT N-values) for the fill ranged between 4 and 11 blows per foot.

Glacial Till (Qva): A dense to very dense layer of glacial till was encountered beneath the fill. The till consists of sand and gravel with trace cobble and boulders. The SPT N-values for the clay ranged between 47 and 100 blows per foot.

Groundwater: The water level of is assumed to be the same as Lake Union, which is conservatively taken at elevation +16 ft-NAVD88 (12 feet below ground level), for the wall analysis. As noted by the "Draft Geotechnical Report – N Northlake Way Bulkhead Seattle, WA" (prepared by SPU and dated May 2015), the water level of Lake Union is not tidally influenced, but rather controlled by the Hiram Chittenden lock and spillway complex in Ballard. The water level typically varies from +16.8 to +18.8 ft-NAVD88 in the winter and summer, respectively.

4.2 Earth Pressures

For cantilevered and single anchored walls, design earth pressures are depicted on Figures B-1 through B-3 of Appendix B Design Earth Pressures. These recommended earth pressure diagrams were adapted from SPU (2015). Figure B-1 presents earth pressures for static and seismic conditions prior to the initiation of liquefaction. Figure B-2 presents earth pressures for post-seismic conditions after the initiation of liquefaction. Figure B-3 presents static earth pressures for a deadman anchor.

It is noted that ground improvement proposed for Alternative 3 would be self-supporting in the final condition, and therefore will not exert an earth pressure on the forward wall under both static and seismic conditions.

4.3 Seismic Design Considerations

The following provides seismic design parameters for the site that are in conformance with the 2015 AASHTO LRFD Bridge Design Specifications, which specifies a design earthquake having a 7% probability of occurrence in 75 years (return interval of 975 years). Based on review of subsurface conditions at the wall location, which includes liquefiable soils, Site Class F is deemed appropriate for the site. However, because site specific analysis is required for Site Class F sites which is beyond the scope of this alternatives analysis, Site Class D was assumed for developing alternatives which will include ground improvement options where Site Class D does apply.

Retaining walls are typically considered short period structures designed to some percentage of the peak ground acceleration (PGA). The following design parameters are recommended for seismic design of retaining walls:

Table 2 Seismic Design Parameters

Site Class	Peak Ground Acceleration of Rock PGA_{rock} [g]	Site Coefficient F_{PGA}	Design PGA [g]	Seismic Coefficient k_H [g]
D	0.43	1.07	0.46	0.23

4.3.1 Liquefaction Potential

In general, the loose fill soils behind the wall and in front of the wall are considered to be liquefiable under seismic shaking. The thickness of the liquefiable soils behind the wall range from 17 feet to 37 feet (to elevation -9 ft-NAVD88). Liquefiable soils in front of the wall are likely to flow away from the wall face and should be neglected for seismic design (i.e., liquefied soils in front of the wall do not provide passive resistance).

The following mitigation measures have been considered to reduce or eliminate the effects of soil liquefaction behind the wall:

- Stone Columns with Wick Drains
- Deep Soil Mixing Columns
- Jet Grouting Columns

4.3.2 Hydrodynamic Forces

The presence of water out-board of a retaining wall can exert dynamic pressures on the face of the wall during seismic events, which is referred to as hydrodynamic water pressure. The approach to develop this load effect is taken from "The Seismic Design of Waterfront Retaining Structures", US

Navy – Naval Civil Engineering Laboratory 1993. Hydrodynamic pressures are estimated from Westergaard's solution:

$p_w = \frac{7}{8} k_h \gamma_w \sqrt{z_w H}$ amplitude of hydrodynamic pressure

where:

$\gamma_w =$ unit weight of water
$k_h =$ seismic coefficient
$z_w =$ depth below water table
$H =$ distance from water table to top of soil (existing mudline for non-liquefied conditions, or glacial till for liquefied conditions)

The resultant hydrodynamic force is given by:

$$P_w = \frac{7}{12} k_h \gamma_w H^2$$

where the resultant is located at a depth of 0.6H from the water table elevation.

Hydrodynamic forces were applied to the Seismic Earth Pressure Diagrams shown in Appendix B Design Earth Pressures.

5 Wall Replacement Alternatives

5.1 Basis for Preliminary Design

Preliminary analysis and design development for the alternatives considered the input listed herein:

Wall Geometry

- Elevations
  - Finished Grade: +28 ft-NAVD88
  - Water Level: +16.8 ft-NAVD88
  - Existing Mudline: +10 ft-NAVD88
  - Local Scour: 2 feet
  - Top of Glacial Till: -11 ft-NAVD88 (minimum)
- Exposed Wall Height
  - Existing Conditions = 20 feet max (after including 2 feet local scour)
  - Seismic Liquified Condition = 39 feet max (finished grade to top of glacial till)

Wall Loading

- Earth Pressures

See Section 4 for explanation of geotechnical recommendations, and see Appendix B Design Earth Pressures for wall pressure diagrams.

- Live Load
  - Surcharge, Qs = 250 psf

    (note that future design phases should consider a firetruck with 50 kip outrigger load on matting)

- Seismic

Seismic loading is checked for two general cases:

  - Non-Liquefied Soil Conditions
  - Fully Liquefied Soil Conditions

The non-liquefied case refers to the duration of a seismic event in which inertial effects (due to ground accelerations) are experienced at a site, but liquefaction and lateral spreading of soils has not yet developed. For this case, a dynamic inertial loading component is applied to the back of the wall, the retained native fill exhibits its static properties, and the mudline elevation in front of the wall is the same as the existing "pre-seismic" condition. However, it is noted that if the native fill behind the wall were improved with liquefaction mitigation, then the wall analysis should consider the dynamic inertial loading component acting simultaneously with loss of mudline in front of wall. The rationale being that peak inertial effects could act simultaneously with the onset of liquefaction and lateral spreading of the native fill.

The fully liquefied case refers to the duration of a seismic event in which soils at the site have liquefied and lateral spreading / slope movement has developed, but peak inertial forces have passed. For this case, dynamic inertial loading component was not applied to the back of the wall, but the native fill exhibits its fully liquefied soil properties (resulting in much greater retained earth pressures). Further, a significant depth of the mudline in front of the wall is lost for lateral support, as the top layer of native fill slides away from the wall and the effective "mudline" becomes the top of the underlying glacial till.

Finally, the hydrodynamic force component acting on the wall was applied to all seismic loading cases.

It is noted that preliminary analyses and designs completed for this alternatives analysis were largely governed by the seismic liquefied load case.

Further, it is recommended that final design employ numerical modeling of the wall such that the appropriate combination of inertial and kinematic (i.e., liquefaction) effects can be determined during seismic events.

Analysis Method

For the alternative analyses performed for this report, linear, pseudo-static, equivalent force methods were used.

Wall Design

The replacement wall concept must be able to meet the requirements of current design standards, including seismic design requirements.

See the design standards listed in Section 3.2.1, which establish the required design performance for the wall. Preliminary structural designs were completed to meet the capacity requirements of AASHTO LRFD -8th Edition and the WSDOT Bridge Design Manual (BDM).

Final structural design and detailing of the wall should also consider design and detailing requirements of City of Seattle Standard Plans and Specifications and WSDOT Standard Plans.

Maintenance and Serviceability

Lake Union is understood to be a brackish body of water, but primarily freshwater. The marine environment is understood to be relatively mild with respect to corrosion.

Based on the analyses performed for this report, the alternatives evaluated are considered to provide the design service life required by final design for the project. Annual maintenance and service efforts would generally not be required for the alternatives that have been considered and presented herein.

The following corrosion-mitigation design strategies can be considered for final design of the project:

- Structural Steel
  - Marine coatings (i.e., paint systems)
  - Zinc coatings (hot-dip-galvanizing or thermal spray metalizing)
  - Additional sacrificial steel thickness
  - Passive cathodic protection (i.e., sacrificial zinc anodes)
  - Corrosion resistant steels
  - Or a combination thereof
- Reinforced Concrete
  - Marine concrete with low permeability
  - Reinforcing with protective coating (epoxy or galvanizing) and adequate concrete cover
  - Corrosion resistant metal used for reinforcing
  - Closely spaced reinforcing to mitigate concrete cracking

5.2 Alternative 1 - Cantilevered Wall

Cantilever wall systems are a common type of wall used in infrastructure applications (e.g., roads, bridges, grade separations, bulkheads, etc.). For this wall type, a frontal vertical structural element is embedded into the ground, which then retains soil (typically backfill) on the back side of the wall in cantilever action, thereby creating a grade separation between the front and back sides of the wall. The reaction due to the earth pressures acting on the back of the wall is transmitted to the underlying soil entirely through the frontal wall structural elements.

A cantilever wall type is typically suitable for applications of up to a maximum of around 15 feet of exposed wall height. For this Project, approximately 40 feet of exposed wall height would occur after soil liquefaction in front of the wall, indicating that this wall type would be atypical and generally not expected to be cost-effective.

For this alternatives analysis, a cantilever wall solution would comprise of:

- A pile installed behind the existing timber wall
- Liquefaction mitigation of the native soils behind the new wall (assumed to consist of stone columns and wick drains installed through the liquefiable soils in a 6 ft x 6 ft gridwork pattern).

Figure 4 provides a conceptual-level design sketch (typical section) for a cantilever wall alternative.

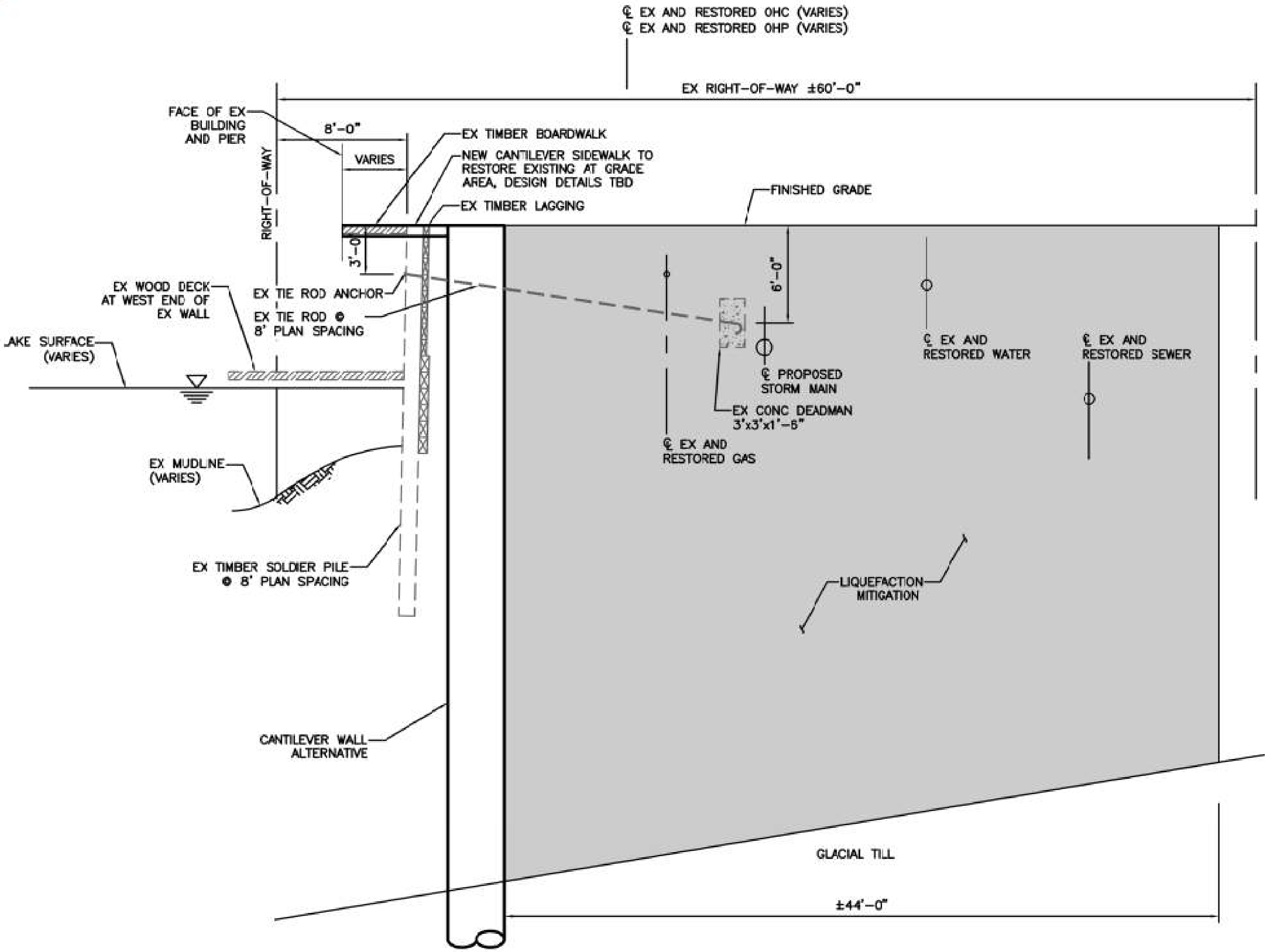


Figure 4 Alt 1 – Cantilevered Wall Typical Section

Three variants have been considered for the cantilevered wall alternative:

- 1A. Soldier Pile Wall
- 1B. Secant Pile Wall
- 1C. King Pile Wall

Each of these options is discussed more fully in the subsections below.

5.2.1 Alt 1A. Soldier Pile Wall

Description

A soldier pile wall is a standard structural system that is commonly found in highway and waterfront applications. The system is comprised of vertical soldier piles typically spaced at approximately 8' centers along the wall. The soldier piles are typically steel W-beam or HP sections. The soldier piles would be installed in pre-drilled shafts of appropriate diameter. After installing the solider pile sections in the drilled shaft holes, the shaft would be filled with structural concrete below the existing mudline elevation and lean concrete above. Then, timber lagging that spans between steel soldier piles would be installed above the top of the structural drilled shaft. A concrete facing could then be installed to the exposed face of the wall if desired.

Finally, the native soil behind the new cantilever soldier pile wall would need to treated with liquefaction mitigation measures since the cantilever wall option is unfeasible if required to retain liquefied earth pressures during seismic loading.

Alternative Evaluation

A cantilever soldier pile wall system has several advantages. Firstly, the soldier piles are installed by a drilling method (as opposed to pile driving). Therefore, the pile installation method results in less vibration and risk to adjacent structures than a solution that requires pile driving. The soldier pile spacing can be tuned to the geometry of the existing wall, such that new soldier piles readily fit between existing tie rod and timber pile locations, and field adjustments can be made relatively easily if required.

However, a cantilever soldier pile wall option also has several disadvantages. Relatively large and heavy pile steel sections are required for the design. Large drilling equipment would be required for the soldier pile shaft construction. The existing wall would need to be unloaded prior to the start of new wall construction. Because a cantilever wall system is inherently flexible, wall deflections would be severe following seismic events in which the ground liquefies in front of the wall. The timber lagging installation between steel soldier piles would require special construction sequencing in order to accommodate the existing tie rods. The alternative is relatively expensive (see Section 6.2).

Finally, a cantilever soldier pile wall solution does have some critical design/construction issues. Soldier piles construction may require use of drill casing or slurry to keep the drilled holes open for steel pile and concrete placement. Also, construction would require large land-based equipment (as opposed to marine equipment) due to limited access imposed by the existing buildings and structures along the lakeside of the wall. Construction loads from the required large driving equipment may overload the existing wall, and special measures may be required at some locations. A cantilever wall design is inherently very flexible, and protection measures for adjacent utilities and pavements would likely be required.

Wall Location Evaluation

Installation of a cantilever soldier pile wall in front of the existing wall is not feasible. This is because the required soldier pile shafts are too large to safely fit between the existing timber wall and adjacent existing buildings.

5.2.2 Alt 1B. Secant Pile Wall

Description

A secant pile wall solution is a continuous wall type. For this wall, overlapping secant pile shafts using lean concrete alternating with structural concrete make up the system. The lean concrete shafts are installed first drilled. Then, the structural shafts are drilled overlapping the lean concrete shafts. A heavy steel pile section is inserted into the structural shafts. Finally, the remaining shafts are infilled with structural concrete. It is noted that in order to satisfy strength requirements, the shafts must have an embedded internal steel section as opposed to more typical concrete reinforcing cages.

Finally, the native soil behind the new cantilever secant pile wall would need to treated with liquefaction mitigation measures since the cantilever wall option is unfeasible if required to retain liquefied earth pressures during seismic loading. Stone columns and wick drains installed in a 6 ft x 6 ft grid pattern has been assumed for the liquefaction mitigation of this alternative.

Alternative Evaluation

A secant pile wall system has some advantages. Firstly, the secant piles are installed by a drilled shaft method (as opposed to pile driving). Therefore, the pile installation method results in relatively less vibration and disruption to adjacent buildings than a solution that requires pile driving. Next, because of the tighter steel pile section spacing, a secant wall could have a reduced overall wall thickness relative to a soldier pile wall. In addition, the continuous nature of a secant pile wall design has improved system redundancy over wall types with discrete pile locations.

However, a secant pile wall option also has several disadvantages. Large drilling equipment would be required for the secant pile shaft construction. The existing wall would need to be unloaded prior to the start of new wall construction. Construction sequencing required to install the continuous system across existing tie rod locations would be challenging. Finally, the secant wall alternative is one of the most expensive of the options considered in this alternatives analysis (see Section 6.2).

Finally, a secant pile wall solution does have some critical design/construction issues. Shaft construction may require use of drill casing or slurry to keep the drilled holes open for steel and concrete placement. Construction loads from the required large driving equipment may overload the existing wall, and special measures may be required at some locations. A cantilever wall design is inherently very flexible, and protection measures for adjacent utilities and pavements would likely be required. Accommodating existing utilities that cross the wall may not be possible.

Wall Location Evaluation

The secant wall type is not feasible for installation in front of the existing timber wall. For this wall design, drilled shafts are required for the complete wall height in order to provide soil "formwork".

5.2.3 Alt 1C. King Pile Wall

Description

A cantilever king pile wall option has been considered. This wall type is also known as a "Pipe/Z-Combination Wall" or "Combi-Wall". The wall system is comprised of steel pipe piles driven with pairs of intermediate steel sheet piles between the pipes. The driven sheet piles are connected to the adjacent pipe piles by a special steel interlock component that is pre-welded to the side of the steel pipe. Finally, the native soil behind the new cantilever king pile wall would need to treated with liquefaction mitigation measures since the cantilever wall option is unfeasible if required to retain liquefied earth pressures during seismic loading. Stone columns and wick drains installed in a 6 ft x 6 ft grid pattern has been assumed for the liquefaction mitigation of this alternative.

Alternative Evaluation

A cantilever king pile wall system has several advantages. Firstly, closed pipe sections are less susceptible to marine corrosion, and are therefore often preferred for marine construction. Pipe pile sizes can be varied to meet design conditions, typically ranging from 18” diameter up to 60-inch diameter. The pairs of intermediate sheet piles between pipe piles also effectively function as lagging between the pipes. While sheet pile installation equipment would be required, it is a somewhat more straightforward construction operation to install the sheets rather than the timber lagging of a soldier pile option. Due to the continuous nature of a king pile wall system, this option has improved structural redundancy over a soldier pile wall that relies on individual piles.

However, a cantilever king pile wall option also has several disadvantages. Driving the large diameter steel pipe sections would cause significant vibration at the site and would require large driving equipment. The existing wall would need to be unloaded prior to the start of new wall construction. The pipe pile spacing of this system type is a function of the sections used in the wall. It is unlikely that the pipes can be perfectly spaced at the same 8' to match the existing pile and tie rod spacing. Therefore, geometric conflicts with the existing soldier piles and tie rods will likely arise along the wall. This may require unique detailing and construction sequencing at some locations. The cantilever king pile alternative is one of the most expensive (see Section 6.2).

Finally, a king pile wall solution does have some critical design/construction issues. Construction loads from the required large driving equipment may overload the existing wall, and special measures may be required at some locations. The large pipe pile driving may lead to unacceptable levels of vibration at adjacent existing structures. A cantilever wall design is inherently very flexible, and protection measures for adjacent utilities and pavements would likely be required. Accommodating existing utilities that need to cross the wall may not be possible.

Wall Location Evaluation

A cantilever king pile wall is not feasible for installation in front of the existing timber wall. The required driving equipment would be too large to safely drive piles within the limited space between the existing timber wall and adjacent buildings.

5.2.4 Alt 1 – Cantilever Wall Proposed Construction Sequence

Firstly, it is noted that the secant pile shaft alternative appears unlikely to be recommended and advanced to detailed design for the Project. Therefore, construction sequencing conceptualization has been focused on the cantilever soldier and king pile wall variants.

The anticipated general construction sequencing for a cantilever wall alternative (soldier pile or king pile) is as follows:

Stage 1

- Existing utilities would be disconnected and transferred to temporary service. Existing timber boardwalks adjacent to buildings would be removed to facilitate temporary utility installation along the face of the existing wall.
- The site is then prepared by removing pavements behind the existing timber wall as required.
- Next, existing utilities behind the wall would be removed or protected in-place as required.

Stage 2

- The piles of the front wall system (i.e., soldier piles or king pipe piles) would then be installed in between existing tie rod locations. It is noted that the pipe spacing of a king pile system would not perfectly align with the 8 foot spacing of the existing timber soldier piles and tie rod anchors, and special sequencing may be required at locations of conflict with the new king piles.
- A temporary anchor rod and waler system would then be installed to connect the new piles to the existing timber piles. This would transfer reaction load from the existing tie rods and deadmen to the new cantilever piles, so that the existing wall anchoring system could then be removed.

Stage 3

- With the existing timber piles supported by the temporary waler and anchor rod system, trenches could be excavated behind the wall in order to remove the existing tie rods and concrete deadman anchors. Alternatively, it could be considered to simply cut the existing tie rods just behind the new cantilever piles and leave the remaining tie rods and concrete deadmen in place.
- After the existing tie rods are removed, install the new timber lagging or intermediate sheet piles between existing soldier or king piles.
- Liquefaction mitigation measures (stone columns and wick drains) would then be installed.
- Buried utilities would then be restored, and the site backfilled.
- New pavements would then be installed along with restoring the overhead utilities along the site.

Stage 4

- Services would then be transferred to the restored utilities, and the temporary utilities along the existing wall face would be removed.

- The existing timber soldier piles and lagging can then be removed along with the temporary anchor rod and waler system.
- With the new wall system components fully installed, new replacement boardwalk can be installed next to the adjacent buildings.
- Surface features would then be installed as required.

5.3 Alternative 2 - Anchored Wall

Anchored walls are also commonly found in infrastructure applications (e.g., roads, bridges, grade separations, bulkheads, etc.) installed in "cut" situations. For this wall type, vertical, structural pile elements are embedded into the ground, and anchors extending into support behind the wall are installed, which then retains earth behind the wall.

However, unlike a cantilever wall, some type of horizontal anchor element (e.g., a large diameter thread bar) is used to connect the frontal structure to a rear anchor structure that is located behind the front wall. The anchoring elements are typically located below finished grade and connected near the top of the frontal wall element.

The rear anchor structure is often a large concrete block (deadman anchor), drilled-in permanent ground anchors, or an independent reaction pile. The retained earth pressure acting on the back side of the frontal wall are then resisted by both a reaction from the anchor system at the top of the frontal wall, and reaction from the soil in front of the wall (along the embedded vertical length of the front wall element). For permanent ground anchors the anchor capacity is achieved by bond stresses between the anchor element and embedded soil behind the wall.

Anchored walls are more suitable for configurations which have greater than 15 feet of exposed wall height. Some design advantages of anchored walls over cantilever walls are:

- Small deflections
- Smaller frontal structural elements – the top reaction of the anchor system reduces load demands in the front structural elements,
- Higher retained earth heights.

For this alternatives analysis, an anchored wall solution would be comprised of:

- A pile installed behind the existing wall
- A reaction pile A-frame structure behind the new wall
- Tie rod anchors connecting the front pile and reaction pile A-frame

It is noted that, due to the poor soil conditions of the native fills behind the wall and large load demands that develop during seismic loading, relatively simple concrete deadman anchors are not suitable for this wall, and the reaction pile system is required for an anchored wall.

Figure 5 provides a conceptual-level design sketch (typical section) for an anchored wall alternative.

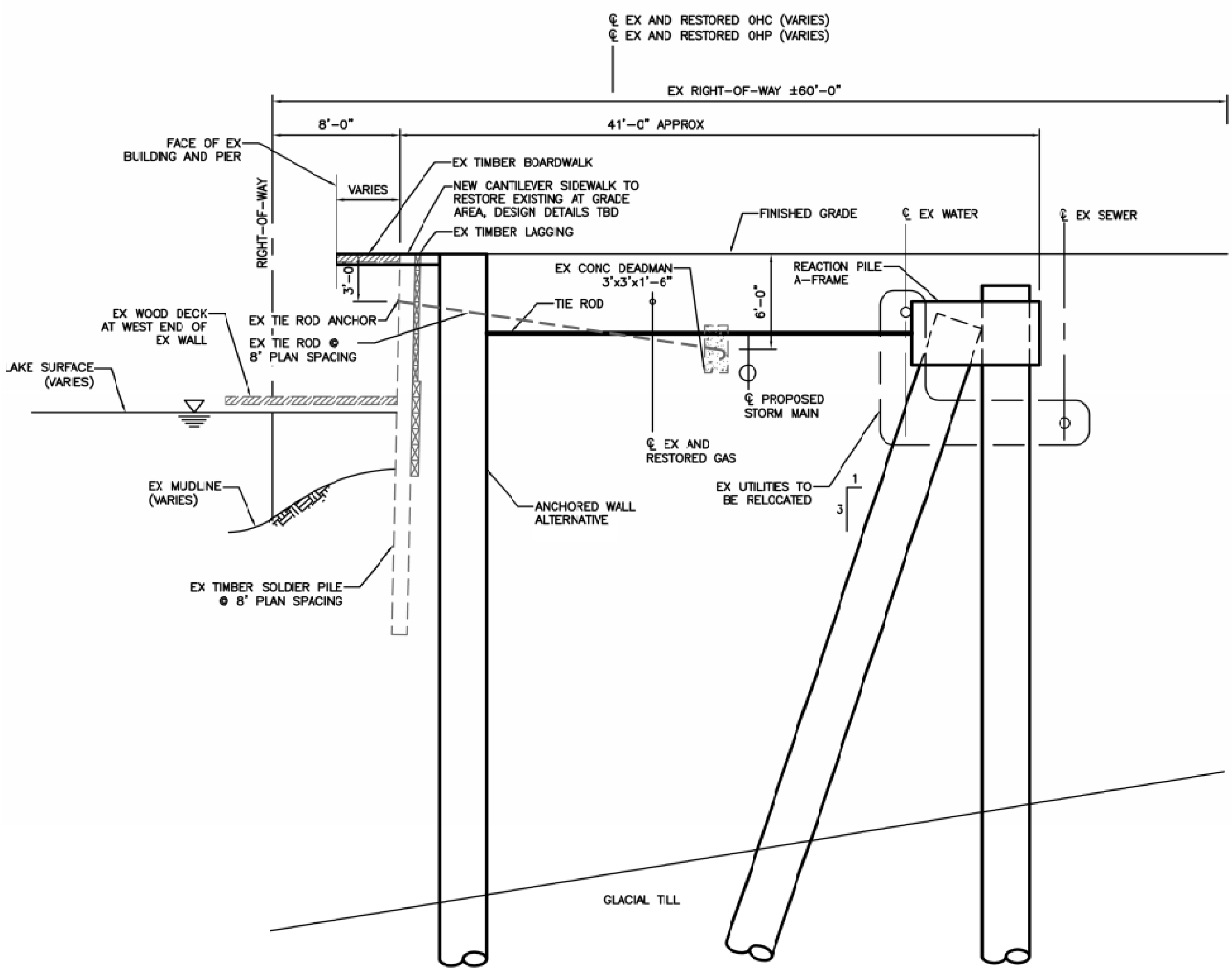


Figure 5 Alt 2 – Anchored Wall Typical Section

Two variants have been considered for the anchored wall alternative:

- 2A. Soldier Pile with Tie Rod & Reaction Pile A-Frame
- 2B. King Pile with Tie Rod & Reaction Pile A-Frame

5.3.1 Alt 2A. Soldier Pile with Tie Rod & Anchor Piles

Description

An anchored soldier pile system is comprised of soldier piles spaced at 8' on center along the wall. The soldier piles would be of a fairly heavy steel beam section (up to W36 steel section) – somewhat lighter than that required for a cantilever option. The soldier piles would be installed in pre-drilled shafts of approximately 4 feet in diameter. After installing the solider pile sections in the drilled shafts, the shafts would be filled with concrete below the existing mudline elevation. Then, timber lagging that spans between steel soldier piles would be installed above the top of the drilled shaft. A concrete facing would then be applied to the exposed face of the wall.

Next, a rear reaction pile frame consisting of a front batter pile, and a rear plumb tension pile would be installed behind the wall. Steel framework would be installed at the top of this frame in order to connect the two piles. A tie rod anchor would then be installed to connect the soldier piles of the front wall with the reaction pile frames behind the wall.

It is noted that for the eastern quarter of the wall limits, where the top of glacial till is deepest, some special design details may be required to mitigate undermining during a liquefaction event. Measures could be closer-spaced soldier piles, pressed-in lagging or vibrated intermediate sheet piles, or local liquefaction mitigation treatment of the native soil.

It is further noted that the anchored soldier pile wall is feasible without applying liquefaction mitigation measures behind the wall. However, a relatively simple concrete deadman anchor is not feasible for the required wall reaction, and the reaction pile system is required.

Alternative Evaluation

An anchored soldier pile wall system has several advantages. Firstly, the front soldier piles are installed by a drilled shaft method (as opposed to pile driving). Therefore, the pile installation method results in relatively less vibration and disruption to adjacent buildings than a solution that requires pile driving. Next, the anchored wall design gives much better deflection control relative to cantilever wall alternatives. A smaller sized section is required for the front soldier piles relative to a cantilever option. Further, the soldier pile 8 foot spacing is tuned to the geometry of the existing wall, such that new soldier piles readily fit between existing tie rod and timber pile locations. Finally, an anchored wall type does not require soil improvement behind the wall.

The anchored soldier pile wall type also has several disadvantages. The new tie rods and anchor piles would require coordination with existing utilities and may even constrain future utility and roadway work behind the new wall. Secondly, while the front soldier piles would be installed with a drilled shaft installation, the piles of the rear reaction frame would likely be driven into place. Therefore, the reaction frame installation may result in vibration and disruption to adjacent existing buildings. Further, the anchored soldier pile alternative is relatively expensive (see Section 6.2).

Finally, an anchored soldier pile option has several critical design/construction issues. Soldier pile shaft installation may require use of drill casing or slurry to keep the drilled holes open for steel pile and concrete placement. Relatively simple concrete deadman anchors are not feasible due to the high wall reaction load demands and the poor soil properties behind the wall. Further, the rear anchor piles and tie rods may conflict with future land use behind the new wall.

Wall Location Evaluation

Because the front soldier piles are relatively thinner, it may be feasible to install an anchored soldier pile wall in front of the existing wall. However, such a layout would be challenging and risky. There is limited space between the existing wall and existing buildings, and tight construction tolerances would be required to avoid the risk of damaging existing buildings.

It appears feasible to install this wall type behind the existing timber wall, if the critical issues can be addressed during design.

For the purpose of this alternatives evaluation, it is assumed that an anchored wall type would be installed behind in the existing wall.

5.3.2 Alt 2B. King Pile with Tie Rod & Anchor Piles

Description

An anchored king pile wall option has been considered. This wall type is also known as a "Pipe/Z-Combination Wall" or "Combi-Wall". The front wall of the system is comprised of large diameter (approximately 30 inches) driven steel pipe piles with pairs of intermediate steel sheet piles between the pipes. The driven sheet piles are connected to the adjacent pipe piles by a special steel interlock component that is pre-welded to the side of the steel pipe. The resulting pipe pile spacing for this system is approximately 7'-4".

Next, a rear reaction pile frame consisting of a front batter pile, and a rear plumb tension pile would be installed behind the wall. Steel framework would be installed at the top of this pile frame to connect the two reaction piles. A tie rod anchor would then be installed to connect the king piles of the front wall with the reaction pile frames behind the wall.

It is noted that the anchored soldier pile wall is feasible without applying liquefaction mitigation measures behind the wall. However, relatively simple concrete deadman anchor is not feasible for the required wall reaction, and the reaction pile system is required.

Alternative Evaluation

An anchored king pile wall system has several advantages. Firstly, closed pipe sections are less susceptible to marine corrosion, and are therefore often preferred for marine construction. Next, the pairs of intermediate sheet piles between pipe piles also effectively function as lagging between the pipes. While sheet pile installation equipment would be required, it is a somewhat more straightforward construction operation to install the sheets rather than the timber lagging of a soldier pile option. Next, the anchored wall design gives much better deflection control relative to cantilever wall alternatives. Finally, an anchored wall type does not require soil improvement behind the wall.

An anchored king pile wall type also has disadvantages. The new tie rods and anchor piles would require coordination with existing utilities, and may even constrain future utility and roadway work behind the new wall. While the front piles of the wall are smaller than that required for a cantilever system, the pile installation may result in vibration and disruption to adjacent existing buildings. The pipe pile spacing of this system type is a function of the sections used in the wall. It is unlikely that the pipes can be perfectly spaced at the same 8' to match the existing pile and rod spacing. Therefore, geometric conflicts with the existing soldier piles and tie rods will likely arise along the wall. This may require unique detailing and construction sequencing at some locations. Finally, the anchored king pile alternative is one of the most expensive (see Section 6.2).

Finally, an anchored king pile option has several critical design/construction issues. Firstly, relatively simple concrete deadman anchors are not feasible due to the high wall reaction load demands and the poor soil properties behind the wall. The pipe pile driving may result in unacceptable levels of vibration for existing structures, and the required pile installation equipment may put too much demand on the existing wall. Further, the rear anchor piles and tie rods may conflict with future land use behind the new wall.

Wall Location Evaluation

It is not feasible to install an anchored king pile wall in front of the existing timber wall. There is limited space between the existing wall and adjacent buildings, and the required construction equipment would be too large to safely install the piles.

However, it appears feasible to install an anchored king pile wall behind the existing timber wall, if the potential critical issues can be addressed during design.

5.3.3 Alt 2 – Anchored Wall Proposed Construction Sequence

For detailed construction sequencing figures, see Appendix C Alternatives Analysis Figures.

The anticipated general construction sequencing for an anchored wall alternative (regardless of variant type) is as follows:

Stage 1

- At wall locations with existing buildings on adjacent piers, the existing timber boardwalk that spans between the wall and pier would be removed.
- Temporary utilities would then be installed along the existing wall face, and service transferred from existing utilities to temporary.
- The existing, de-energized overhead utilities would then be removed.
- The site is then prepared by removing pavements behind the existing timber wall.
- Next, excavation trenches would be dug at locations of new piles (typically spaced between existing timber piles and anchor rods).
- Next, existing buried utilities behind the wall would be removed or protected in-place as required.

Stage 2

- The front wall system (soldier or king pile), rear reaction pile A-frame, and connecting tie rods would then be installed behind the existing wall.

- A temporary anchor rod and waler system would then be installed to connect the new anchored piles to the existing timber piles. This would transfer reaction load from the existing tie rods and deadmen to the new anchor system.
- With the existing timber piles supported by the temporary waler and anchor rod system, complete additional excavation as required behind the wall in order to remove the existing tie rods and concrete deadman anchors.

Stage 3

- After the existing tie rods are removed, install the lagging or intermediate sheet piles between existing soldier or king piles.
- Buried utilities would then be restored, as all trenches and excavations are backfilled.
- New pavements would then be installed behind the replacement wall.
- The overhead utilities would then be restored.

Stage 4

- Services would then be transferred from the temporary to the restored utilities. The temporary utilities along the face of the existing wall would then be removed.
- The existing timber soldier piles and lagging can then be removed along with the temporary anchor rod and waler system.
- With the new wall system components fully installed, new replacement boardwalk can be installed next to the adjacent buildings.
- New surface features would then be installed as required.

5.4 Alternative 3 - Ground Improvement

Description

The ground improvement option or improved soil mass (ISM) consists of constructing a cellular grid of soil-cement panels surrounding unimproved soil by jet-grouting (JG) or deep soil mixing methods (DSM). The jet-grouting method of soil improvement uses a modified rotary drill to inject water, cement, and air into the soil under pressure, simultaneously removing soil and mixing the suspended soils with cement grout to create a stronger "soilcrete" soil-cement columns. The JG method uses a small diameter drill to penetrate the soil to the desired depth. The injection of water, cement, and air begins at the bottom of the hole and continues upward to the desired elevation. The DSM method uses a large diameter auger or cutter head system to mechanically mix cement into the soil/water matrix during excavation to create "soilcrete" soil-cement panels or walls. Because the DSM equipment must penetrate the soil from the surface, this method is only appropriate for areas in which there are no subsurface conflicts like existing tie rods or existing utilities. These features must typically be removed from the work area prior to DSM installation. DSM is a mechanical process that does not require high pressures during mixing which may reduce the risk of cement being injected into Lake Union, utilities, and other unintended locations.

JG and DSM methods can be used to construct soil-cement columns that typically range from 2 to 8 feet in diameter. A series of adjacent or overlapping columns would be used to construct the ISM soil-cement panels in a cellular configuration. The interior cells of the ISM would consist of unimproved soil. In our opinion, DSM approach would reduce construction costs and limit pressurization of the existing retaining wall and is therefore the preferred methodology.

The ISM would be constructed as two continuous panels at the front and back of the ISM zone, with transverse ISM center panels joining the front and back panels at approximately regular intervals as shown conceptually in Figure 6. The ISM would typically extend from a few feet above the ground water table (approximate elevation +20 ft-NAVD88) to the top of the hard or very dense, glacially overridden soils that exist throughout the project site (approx. 35 feet maximum height), as shown on Figure 7. In order to provide a working platform behind the existing wall, up to 8 ft to 10 ft of soil behind the existing timber wall will be removed, which will reduce the lateral load on the wall and allow the removal of the existing tie rods. A sheet pile cut-off wall will be installed behind the existing timber soldier piles which will serve as a containment wall separating the DSM work from Lake Union.

The ISM would be self-supporting under seismic loading, the structural elements at the wall face would not provide significant lateral resistance to seismic loading, and the ISM would apply no lateral earth pressure to the seawall face structure. The ISM would provide the foundation for the wall facing, sidewalk, street, and other project elements. The ISM would also serve to reduce the liquefaction potential of the unimproved soils within the ISM cells. A replacement ratio (improved soil volume as a percentage of total ground volume) of approximately 50% is considered sufficient to mitigate liquefaction and provide a self-supporting ISM. Typical Unconfined Compressive Strength (UCS) requirements for the improved soil for this application typically range from 300 psi to 500 psi.

It is expected that the ground improvement limits and relocated utilities can fit within the approximately 60 ft wide existing right-of-way. But it is noted that an excavation required for the ground improvement would likely encroach 8 to 10 ft into the parking lot along the north side of the wall at its east end. A temporary shoring wall at the back of the excavation is proposed here. Alternatively, a temporary easement (with removal and replacement of paving) can also be considered.

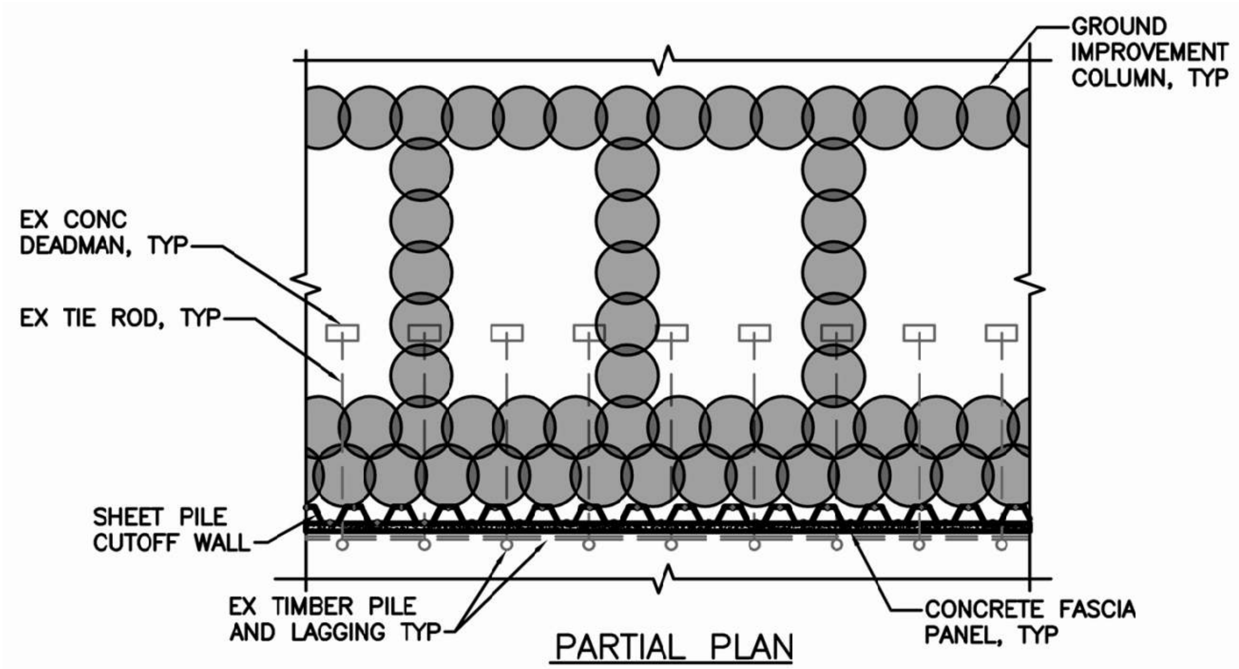


Figure 6 Alt 3 - Ground Improvement Plan

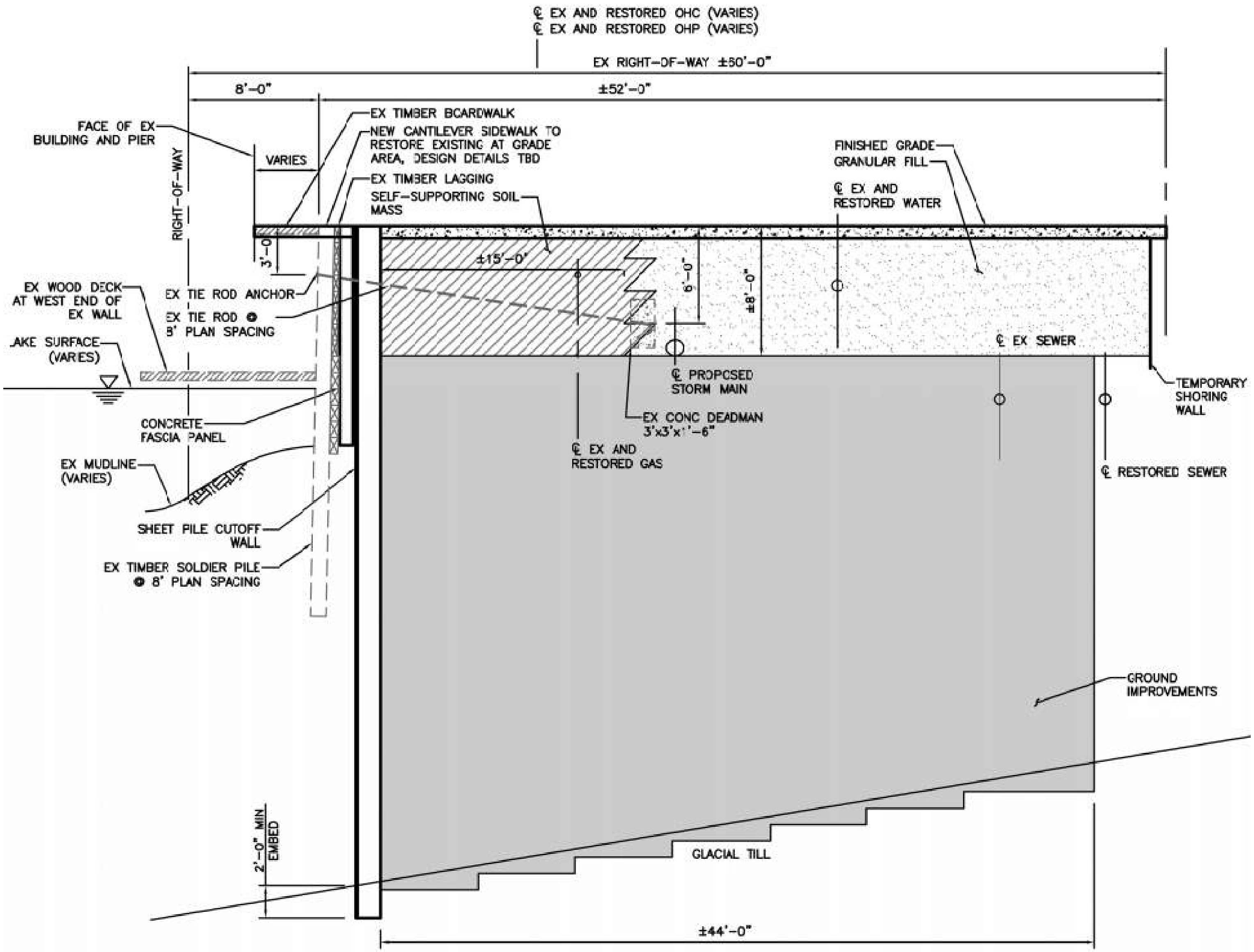


Figure 7 Alt 3 – Ground Improvement Typical Section
Note: sheet pile cutoff wall to be vibrated to 2' embed into till.

Alternative Evaluation

A soil improvement concept consisting of deep soil mixing or jet grouting would have several benefits including:

- Soil mass behind existing wall is improved and liquefaction mitigated.
- Low vibration relative to alternatives that require pile driving of large pile sections.
- Mitigates settlement behind wall.
- No conflict with future utilities – trenching can occur in the DSM.
- Relatively inexpensive.

Disadvantages of the soil improvement option could consist of:

- Installation of containment wall in front of existing wall would be challenging given this requires removing the tie rods from the existing timber wall and would require low vibration specialty methods for installing the cut off wall.
  - Typically, the cut off wall would be vibrated to the top of the till.
  - However, for ~80 ft of wall length near west end, the existing mudline is low and the till elevation is relatively high. Therefore, temporary shoring piles with approximately 8 to 10 ft of embedment into the till will be required in this area, and a drilled-in solution may be needed. Alternatively, an anchored temporary shoring system can be considered here. It is noted that there are no adjacent buildings/piers on the outboard side of the wall at this location, and vibration is less of a concern here than elsewhere along the wall.
- A large volume of spoils will be generated which will need to be contained and disposed of.
- JG / DSM columns installation will need to be sequenced to avoid pressurizing the cut off and existing wall.

Wall Location Evaluation

The ISM concept would be installed behind the existing wall and require the removal of tie rods for both jet grout and deep soil mixing methods. Utility lines will need to be relocated for both jet grout and deep soil mixing improvement methods.

5.4.1 Alt 3 – Ground Improvement Proposed Construction Sequence

For detailed construction sequencing figures, see Appendix C Alternatives Analysis Figures.

The anticipated general construction sequence for a ground improvement alternative is as follows:

Stage 1

- Firstly, remove existing timber boardwalks at wall locations adjacent to buildings/piers.
- Install temporary pile repairs or shoring piles at broken existing timber piles.
  - For ~80 ft of wall length at west end of wall, temporary shoring pile embedment of 8 to 10 ft into till, or a local temporary anchored shoring system, will likely be required due to low mudline and high till elevation.
- Next, install temporary utilities along the face of the existing wall, and transfer services.
- Remove existing overhead power and communication lines that run through the site.

- Then remove pavement behind the existing timber wall.
- Excavate site to the work pad elevation in order to remove the existing tie rods and relieve lateral soil pressure along the existing wall. Install temporary shoring wall along the landward right-of-way as required.
- Remove existing buried tie rods and concrete deadman anchors.
- Remove existing buried utilities. At this point, the site would be free of obstructions for the installation of ground improvement.

Stage 2

- Install sheet pile cut off wall behind the existing (now cantilever) timber retaining wall using the low vibration press in method or variable eccentric moment vibratory methods. For containment of the soil-cement slurry (for both DSM and JG), the cut off wall will only need to installed to 2 ft embed into the till layer.
- Install jet grout / deep soil mixing panels.

Stage 3

- After the ground improvement is installed, install restored buried utilities (gas, water, sanitary sewer, proposed storm main, etc.).
- Place and compact granular fill to grade in lifts from the back of the excavation to approximately 15 feet behind the cut off wall. Place self-supporting soil mass in the space between the cut off wall and granular fill in matching lifts. The self-supporting soil could consist of:
  - flowable fill/CDF
  - geogrid wrapped fill
  - mechanically stabilized earth (MSE)
- Remove any temporary shoring walls during backfilling operation.
- Install new pavements behind the new wall.
- Install restored overhead power and communication lines.

Stage 4

- Transfer services from temporary to restored utilities. Remove temporary utilities and support system along face of existing wall.
- Remove the existing timber wall (piles and lagging), along with any shoring piles or pile repairs at broken piles.
- Install decorative concrete fascia panels along exposed limits of the wall.
- Install new boardwalk adjacent to buildings.
- Install new surface features as required.

5.5 Environmental Issues and Permitting

Based on the preliminary understanding of the Project at the time of this report, the following general discussion is offered on environmental issues and permitting:

- no one alternative is thought to be advantageous with respect to environmental permitting

- no alternative is thought to have fatal flaws with respect to environmental permitting

General environmental permitting issues for the Project are anticipated to include:

- Water quality concerns
  - turbidity
  - material falling into water
- Grout blowout during ground improvement (if applicable to final design)
  - mitigated by the containment wall (included in the Alternative 3 concept)
  - mitigated by directional application of grout
- Aquatic habitat loss or construction impacts

6 Alternatives Cost Estimates

6.1 Cost Estimates Development

6.1.1 Construction Costs

The development of comparative construction cost elements are provided in Table 3.

Table 3 Explanation of Estimated Construction Costs

NO.	CONST. ITEM	EXPLANATION
1	Traffic Control	› $50,000 lump sum assumed for all alternatives
2	Existing Wall Removal	› $30 / square foot has been assumed for removal of the existing wall (including mitigation measures near existing structures) › The applicable quantity is based on exposed area of wall face for existing conditions

3	New Retaining Wall	› Preliminary designs have been completed for each alternative and variant
		› Material takeoff and exposed face wall area were determined for those preliminary designs
		› WSDOT BDM unit costs were then taken in order to develop the structure cost of the new wall:
		  › Structural Steel Unit Cost: $2.60 / LB
		  › Cantilever Soldier Pile Wall: $130 / SF base cost with increase due to required heavy pile sections
		  › Anchored Soldier Pile Wall: $200 / SF (not including additional cost of anchor pile structures)
		  › CIP Concrete: $750 / CYD
		  › Reinforcing: $1.70 / LB
		  › Concrete Fascia Panel: $50 / SF

NO.	CONST. ITEM	EXPLANATION
4	**Ground Improvement**	› Special Mobilization and Demobilization of a specialty sub-contractor assumed to be $175,000 › DSM/JG Installation and Spoil Clean Up: $300/cy › Soil Haul Off Via Landfill in Eastern Washington: $60/ton › Soil Replacement assumed to be 50% by volume. › Additional Earth Items: › Excavation – $50/CY (SDOT project experience for work in Seattle) › Granular Backfill - $95/CY (SDOT project experience for work in Seattle) › Reinforced Fill – $140/CY (granular fill plus assumed geotextile fabric cost)
5	**Roadway Restoration**	› Installing the new wall will require pavement removal behind the existing wall › $20 / square foot has been assumed for removal and restoration of the roadway after new wall installation › Restored area quantity has been estimated based on the length of wall and removal of pavement across complete width of existing Right-of-Way
6	**Boardwalk Removal and Replacement**	› Represents the removal of boardwalks that span between the existing timber pile wall and adjacent buildings, and replacement with cantilever sidewalks › Unit Costs: › Removal - $10 / SF (assumed) › Replacement - $330/SF (WSDOT BDM App 12.3-A1 for "Reinforced Concrete Flat Slab" bridge type, high cost
7	**Utilities**	› See detailed utility cost estimate backup provided in the Utilities Report (included as Appendix D to this report) › Cost estimates for utilities have been broken down by type and respective owner/agency: › Private utilities – gas and communication › Seattle City Light (SCL) – power › Seattle Public Utilities (SPU) – water and sanitary sewer › Seattle Department of Transportation (SDOT) – storm drainage › Utility cost estimates have all been broken down by phase › Temporary relocation › Restoration
8	**Mobilization**	› 10% applied to the sum of Items 1-7
9	**Allowance for Undefined Items**	› This line item is meant to capture minor items that are unforeseen or unknown at this conceptual design level, in addition to miscellaneous items not directly considered › Cost taken as 40% applied to the sum of Items 1-8
10	**Total Comparative Construction Cost**	› Sum of Items 1-9

6.1.2 Items Not Included in Cost Estimates

The costs that are shown in this report do not include:

- financing
- operation and maintenance (O&M) costs
- sales taxes
- environmental mitigation costs (if needed)
- contaminated soils characterization, handling, or disposal
- engineering costs
- construction contingency
- construction engineering
- right-of-way cost (all alternatives should fit within existing right-of-way)
- escalation
- decommissioning and removal of existing underground storage tanks
- temporary ground-/stormwater drainage system during construction, and groundwater drainage system for permanent conditions

6.2 Cost Estimates Summary

A summary of the cost estimates is given in Table 4; see Appendix A Wall Alternatives Evaluation Rough-Order-of-Magnitude Cost Estimate Breakdown for additional details and breakdown of cost estimates.

Table 4 N Northlake Wall Alternatives Analysis – Cost Estimate Summary

	WALL TYPE VARIANT	ROUGH-ORDER-OF-MAGNITUDE (ROM) COMPARATIVE COST ESTIMATE
ALTERNATIVE 1 CANTILEVERED WALL	**1A. Soldier Pile**	$22M
	1B. Secant Pile	$29M
	1C. King Pile	$27M
ALTERNATIVE 2 ANCHORED WALL	**2A. Soldier Pile with Tie Rod & Anchor Piles**	$24M
	2B. King Pile with Tie Rod & Anchor Piles	$30M
ALTERNATIVE 3 GROUND IMPROVEMENT	**Non-Structural Fascia**	$16M

7 Conclusion and Recommended Alternative

Alternative 3 – Ground Improvement is recommended for advancement to Task 6 – Wall Replacement Concept Design phase of this Project.

This conclusion and recommendation were reached in coordination with SDOT for the following reasons:

- The ground improvement alternative is less costly than the cantilever and anchor wall alternatives.
- Due to the poor soil conditions at the site, the preliminary sizing of the cantilever and anchored wall alternatives were largely controlled by liquefied soil conditions during seismic loading. Improvement of the native soils at the site more directly addresses this controlling load effect for the structure.
- The cantilever and anchored wall alternatives require heavy pile sections, which would require large construction equipment for their installations. It is expected that installing a ground improvement solution would be less disruptive to adjacent buildings. However, it is noted that a steel sheet pile cutoff wall is still required for ground improvement.

Appendix A Wall Alternatives Evaluation Rough-Order-of-Magnitude Cost Estimate Breakdown

Appendix A - Wall Alternatives Evaluation Rough-Order-of-Magnitude (ROM) Cost Estimate Breakdown

Cantilevered Wall Concepts

ROM Cost Estimate: Alternative 1A - Cantilever Soldier Pile Wall

No.	Item	Unit of Measure	Unit Cost	Total Qty	Line Cost	Basis / Notes / Calculation Formula
(1)	Traffic Control	LS	50,000	1	$ 50,000	*assume $50,000 for traffic control*
(2)	Existing Wall Removal	SF	30	6,200	$ 186,000	*quantity based on exposed SF in current condition; cost includes removal and disposal of existing timber wall*
(3)	New Retaining Wall	SF	580	16,900	$ 9,802,000	*install new cantilever soldier pile wall (steel pile sections in drilled shafts, with intermediate lagging between piles)*
(4)	Ground Improvement	LS	800,000	1	$ 800,000	*install liquefaction mitigation measures (stone aggregate columns with wick drains)*
(5)	Roadway Restoration	SF	20	26,000	$ 520,000	*remove and reinstall existing pavements directly behind wall*
(6)	Boardwalk Removal and Replacement	SF	340	2,300	$ 782,000	*remove and reinstall existing boardwalks adjacent to piers/buildings; qty is based on (larger) reinstalled area*
(7a)	PSE Utility - Gas Relo. and Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7b)	Century Link Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7c)	Comcast Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7d)	SCL Utility - Power Temp Relocation	LS	211,000	1	$ 211,000	*See Utilities Report*
(7e)	SCL Utility - Power Restoration	LS	299,500	1	$ 299,500	*See Utilities Report*
(7f)	SPU Utility - Water Temp Relocation	LS	266,000	1	$ 266,000	*See Utilities Report*
(7g)	SPU Utility - Water Restoration	LS	230,000	1	$ 230,000	*See Utilities Report*
(7h)	SPU Utility - Sewer Temp Relocation	LS	158,000	1	$ 158,000	*See Utilities Report*
(7i)	SPU Utility - Sewer Restoration	LS	269,000	1	$ 269,000	*See Utilities Report*
(7j)	SDOT - Storm Drainage Relocation	LS	-	1	$ -	*Temporary addressed by TESC plan; see Utilities Report.*
(7k)	SDOT - Storm Drainage	LS	183,750	1	$ 183,750	*See Utilities Report*
(8)	Mobilization				$ 1,400,000	*10% applied to sum of above items*
(9)	Allowance for Undefined Items				$ 6,100,000	*40% applied to sum of above items*
(10)	**Total Comparative Construction Cost**				**$ 22,000,000**	*=(1)+(2)+(3)+(4)+(5)+(6)+(7)+(8)+(9)*

NOTES:

1. Cost estimates are based on 2019 dollars and a 1 to 10% level of design definition.

2. The costs presented herein are Rough-Order-of-Magnitude (ROM), and were prepared for the purpose of comparing the evaluated alternatives. Actual long-term and construction costs will differ from the costs shown. Final project costs are dependent upon many variable factors including, but not limited to, labor and material costs, site conditions, productivity, competitive market conditions, final project scope, and the contractor's implementation schedule.

3. The costs shown do not include:
   > financing
   > operation and maintenance (O&M) costs
   > sales taxes
   > environmental mitigation costs (if needed)
   > contaminated soil characterization, handling, or disposal
   > engineering costs
   > construction contingency
   > construction engineering
   > right-of-way cost (all work should fit within existing right-of-way, assume zero cost)
   > escalation
   > decomissioning and removal of existing underground storage tanks
   > temporary ground-/stormwater drainage system during construction, and groundwater drainage system for permanent conditions

4. For detailed utility cost backup and explanation, see Utilities Report (dated Nov 2019 and prepared by SG3 Strategies, LLC) - included as Appendix D to N Northlake Way Retaining Wall - Alternatives Analysis Report. The costs shown above are the associated line item subtotals stated in that report, for a given utility owner and phase of construction.

5. For narrative explanation of individual cost items, see Table 3 of the Alternatives Analysis Report main body.

Appendix A - Wall Alternatives Evaluation Rough-Order-of-Magnitude (ROM) Cost Estimate Breakdown

Cantilevered Wall Concepts

ROM Cost Estimate: Alternative 1B - Cantilever Secant Pile Wall

No.	Item	Unit of Measure	Unit Cost	Total Qty	Line Cost	Basis / Notes / Calculation Formula
(1)	Traffic Control	LS	50,000	1	$ 50,000	*assume $50,000 for traffic control*
(2)	Existing Wall Removal	SF	30	6,200	$ 186,000	*quantity based on exposed SF in current condition; cost includes removal and disposal of existing timber wall*
(3)	New Retaining Wall	SF	850	16,900	$ 14,365,000	*install new cantilever secant pile wall (closely spaced drilled shaft piles with embedded steel pile sections)*
(4)	Ground Improvement	LS	800,000	1	$ 800,000	*install liquefaction mitigation measures (stone aggregate columns with wick drains)*
(5)	Roadway Restoration	SF	20	26,000	$ 520,000	*remove and reinstall existing pavements directly behind wall*
(6)	Boardwalk Removal and Replacement	SF	340	2,300	$ 782,000	*remove and reinstall existing boardwalks adjacent to piers/buildings; qty is based on (larger) reinstalled area*
(7a)	PSE Utility - Gas Relo. and Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7b)	Century Link Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7c)	Comcast Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7d)	SCL Utility - Power Temp Relocation	LS	211,000	1	$ 211,000	*See Utilities Report*
(7e)	SCL Utility - Power Restoration	LS	299,500	1	$ 299,500	*See Utilities Report*
(7f)	SPU Utility - Water Temp Relocation	LS	266,000	1	$ 266,000	*See Utilities Report*
(7g)	SPU Utility - Water Restoration	LS	230,000	1	$ 230,000	*See Utilities Report*
(7h)	SPU Utility - Sewer Temp Relocation	LS	158,000	1	$ 158,000	*See Utilities Report*
(7i)	SPU Utility - Sewer Restoration	LS	269,000	1	$ 269,000	*See Utilities Report*
(7j)	SDOT - Storm Drainage Relocation	LS	-	1	$ -	*Temporary addressed by TESC plan; see Utilities Report.*
(7k)	SDOT - Storm Drainage	LS	183,750	1	$ 183,750	*See Utilities Report*
(8)	Mobilization				$ 1,900,000	*10% applied to sum of above items*
(9)	Allowance for Undefined Items				$ 8,100,000	*40% applied to sum of above items*
(10)	**Total Comparative Construction Cost**				**$ 29,000,000**	*=(1)+(2)+(3)+(4)+(5)+(6)+(7)+(8)+(9)*

NOTES:

1. Cost estimates are based on 2019 dollars and a 1 to 10% level of design definition.

2. The costs presented herein are Rough-Order-of-Magnitude (ROM), and were prepared for the purpose of comparing the evaluated alternatives. Actual long-term and construction costs will differ from the costs shown. Final project costs are dependent upon many variable factors including, but not limited to, labor and material costs, site conditions, productivity, competitive market conditions, final project scope, and the contractor's implementation schedule.

3. The costs shown do not include:
   > financing
   > operation and maintenance (O&M) costs
   > sales taxes
   > environmental mitigation costs (if needed)
   > contaminated soil characterization, handling, or disposal
   > engineering costs
   > construction contingency
   > construction engineering
   > right-of-way cost (all work should fit within existing right-of-way, assume zero cost)
   > escalation
   > decomissioning and removal of existing underground storage tanks
   > temporary ground-/stormwater drainage system during construction, and groundwater drainage system for permanent conditions

4. For detailed utility cost backup and explanation, see Utilities Report (dated Nov 2019 and prepared by SG3 Strategies, LLC) - included as Appendix D to N Northlake Way Retaining Wall - Alternatives Analysis Report. The costs shown above are the associated line item subtotals stated in that report, for a given utility owner and phase of construction.

5. For narrative explanation of individual cost items, see Table 3 of the Alternatives Analysis Report main body.

Appendix A - Wall Alternatives Evaluation Rough-Order-of-Magnitude (ROM) Cost Estimate Breakdown

Cantilevered Wall Concepts

ROM Cost Estimate: Alternative 1C - Cantilever King Pile Wall

No.	Item	Unit of Measure	Unit Cost	Total Qty	Line Cost	Basis / Notes / Calculation Formula
(1)	Traffic Control	LS	50,000	1	$ 50,000	*assume $50,000 for traffic control*
(2)	Existing Wall Removal	SF	30	6,200	$ 186,000	*quantity based on exposed SF in current condition; cost includes removal and disposal of existing timber wall*
(3)	New Retaining Wall	SF	770	16,900	$ 13,013,000	*install new cantilever king pile wall (steel pipe pile sections with intermediate sheet piles between)*
(4)	Ground Improvement	LS	800,000	1	$ 800,000	*install liquefaction mitigation measures (stone aggregate columns with wick drains)*
(5)	Roadway Restoration	SF	20	26,000	$ 520,000	*remove and reinstall existing pavements directly behind wall*
(6)	Boardwalk Removal and Replacement	SF	340	2,300	$ 782,000	*remove and reinstall existing boardwalks adjacent to piers/buildings; qty is based on (larger) reinstalled area*
(7a)	PSE Utility - Gas Relo. and Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7b)	Century Link Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7c)	Comcast Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7d)	SCL Utility - Power Temp Relocation	LS	211,000	1	$ 211,000	*See Utilities Report*
(7e)	SCL Utility - Power Restoration	LS	299,500	1	$ 299,500	*See Utilities Report*
(7f)	SPU Utility - Water Temp Relocation	LS	266,000	1	$ 266,000	*See Utilities Report*
(7g)	SPU Utility - Water Restoration	LS	230,000	1	$ 230,000	*See Utilities Report*
(7h)	SPU Utility - Sewer Temp Relocation	LS	158,000	1	$ 158,000	*See Utilities Report*
(7i)	SPU Utility - Sewer Restoration	LS	269,000	1	$ 269,000	*See Utilities Report*
(7j)	SDOT - Storm Drainage Relocation	LS	-	1	$ -	*Temporary addressed by TESC plan; see Utilities Report.*
(7k)	SDOT - Storm Drainage	LS	183,750	1	$ 183,750	*See Utilities Report*
(8)	Mobilization				$ 1,700,000	*10% applied to sum of above items*
(9)	Allowance for Undefined Items				$ 7,500,000	*40% applied to sum of above items*
(10)	**Total Comparative Construction Cost**				**$ 27,000,000**	*=(1)+(2)+(3)+(4)+(5)+(6)+(7)+(8)+(9)*

NOTES:

1. Cost estimates are based on 2019 dollars and a 1 to 10% level of design definition.

2. The costs presented herein are Rough-Order-of-Magnitude (ROM), and were prepared for the purpose of comparing the evaluated alternatives. Actual long-term and construction costs will differ from the costs shown. Final project costs are dependent upon many variable factors including, but not limited to, labor and material costs, site conditions, productivity, competitive market conditions, final project scope, and the contractor's implementation schedule.

3. The costs shown do not include:
   > financing
   > operation and maintenance (O&M) costs
   > sales taxes
   > environmental mitigation costs (if needed)
   > contaminated soil characterization, handling, or disposal
   > engineering costs
   > construction contingency
   > construction engineering
   > right-of-way cost (all work should fit within existing right-of-way, assume zero cost)
   > escalation
   > decomissioning and removal of existing underground storage tanks
   > temporary ground-/stormwater drainage system during construction, and groundwater drainage system for permanent conditions

4. For detailed utility cost backup and explanation, see Utilities Report (dated Nov 2019 and prepared by SG3 Strategies, LLC) - included as Appendix D to N Northlake Way Retaining Wall - Alternatives Analysis Report. The costs shown above are the associated line item subtotals stated in that report, for a given utility owner and phase of construction.

5. For narrative explanation of individual cost items, see Table 3 of the Alternatives Analysis Report main body.

Appendix A - Wall Alternatives Evaluation Rough-Order-of-Magnitude (ROM) Cost Estimate Breakdown

Anchored Wall Concepts

ROM Cost Estimate: Alternative 2A - Anchored Soldier Pile Wall

No.	Item	Unit of Measure	Unit Cost	Total Qty	Line Cost	Basis / Notes / Calculation Formula
(1)	Traffic Control	LS	50,000	1	$ 50,000	*assume $50,000 for traffic control*
(2)	Existing Wall Removal	SF	30	6,200	$ 186,000	*quantity based on exposed SF in current condition; cost includes removal and disposal of existing timber wall*
(3)	New Retaining Wall	SF	700	16,900	$ 11,830,000	*install new anchored soldier pile wall (steel piles in drilled shafts, intermediate lagging between piles, tie rod to rear reaction structure)*
(4)	Ground Improvement	LS	-	-	$ -	*not applicable to anchored wall concept*
(5)	Roadway Restoration	SF	20	26,000	$ 520,000	*remove and reinstall existing pavements directly behind wall*
(6)	Boardwalk Removal and Replacement	SF	340	2,300	$ 782,000	*remove and reinstall existing boardwalks adjacent to piers/buildings; qty is based on (larger) reinstalled area*
(7a)	PSE Utility - Gas Relo. and Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7b)	Century Link Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7c)	Comcast Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7d)	SCL Utility - Power Temp Relocation	LS	211,000	1	$ 211,000	*See Utilities Report*
(7e)	SCL Utility - Power Restoration	LS	299,500	1	$ 299,500	*See Utilities Report*
(7f)	SPU Utility - Water Temp Relocation	LS	266,000	1	$ 266,000	*See Utilities Report*
(7g)	SPU Utility - Water Restoration	LS	230,000	1	$ 230,000	*See Utilities Report*
(7h)	SPU Utility - Sewer Temp Relocation	LS	158,000	1	$ 158,000	*See Utilities Report*
(7i)	SPU Utility - Sewer Restoration	LS	269,000	1	$ 269,000	*See Utilities Report*
(7j)	SDOT - Storm Drainage Relocation	LS	-	1	$ -	*Temporary addressed by TESC plan; see Utilities Report.*
(7k)	SDOT - Storm Drainage	LS	183,750	1	$ 183,750	*See Utilities Report*
(8)	Mobilization				$ 1,500,000	*10% applied to sum of above items*
(9)	Allowance for Undefined Items				$ 6,600,000	*40% applied to sum of above items*
(10)	**Total Comparative Construction Cost**				**$ 24,000,000**	*=(1)+(2)+(3)+(4)+(5)+(6)+(7)+(8)+(9)*

NOTES:

1. Cost estimates are based on 2019 dollars and a 1 to 10% level of design definition.

2. The costs presented herein are Rough-Order-of-Magnitude (ROM), and were prepared for the purpose of comparing the evaluated alternatives. Actual long-term and construction costs will differ from the costs shown. Final project costs are dependent upon many variable factors including, but not limited to, labor and material costs, site conditions, productivity, competitive market conditions, final project scope, and the contractor's implementation schedule.

3. The costs shown do not include:
   > financing
   > operation and maintenance (O&M) costs
   > sales taxes
   > environmental mitigation costs (if needed)
   > contaminated soil characterization, handling, or disposal
   > engineering costs
   > construction contingency
   > construction engineering
   > right-of-way cost (all work should fit within existing right-of-way, assume zero cost)
   > escalation
   > decomissioning and removal of existing underground storage tanks
   > temporary ground-/stormwater drainage system during construction, and groundwater drainage system for permanent conditions

4. For detailed utility cost backup and explanation, see Utilities Report (dated Nov 2019 and prepared by SG3 Strategies, LLC) - included as Appendix D to N Northlake Way Retaining Wall - Alternatives Analysis Report. The costs shown above are the associated line item subtotals stated in that report, for a given utility owner and phase of construction.

5. For narrative explanation of individual cost items, see Table 3 of the Alternatives Analysis Report main body.

Appendix A - Wall Alternatives Evaluation Rough-Order-of-Magnitude (ROM) Cost Estimate Breakdown

Anchored Wall Concepts

ROM Cost Estimate: Alternative 2B - Anchored King Pile Wall

No.	Item	Unit of Measure	Unit Cost	Total Qty	Line Cost	Basis / Notes / Calculation Formula
(1)	Traffic Control	LS	50,000	1	$ 50,000	*assume $50,000 for traffic control*
(2)	Existing Wall Removal	SF	30	6,200	$ 186,000	*quantity based on exposed SF in current condition; cost includes removal and disposal of existing timber wall*
(3)	New Retaining Wall	SF	940	16,900	$ 15,886,000	*install new anchored king pile wall (steel pipe piles, intermediate sheets between pipes, tie rod to rear reaction structure)*
(4)	Ground Improvement	LS	-	-	$ -	*not applicable to anchored wall concept*
(5)	Roadway Restoration	SF	20	26,000	$ 520,000	*remove and reinstall existing pavements directly behind wall*
(6)	Boardwalk Removal and Replacement	SF	340	2,300	$ 782,000	*remove and reinstall existing boardwalks adjacent to piers/buildings; qty is based on (larger) reinstalled area*
(7a)	PSE Utility - Gas Relo. and Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7b)	Century Link Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7c)	Comcast Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7d)	SCL Utility - Power Temp Relocation	LS	211,000	1	$ 211,000	*See Utilities Report*
(7e)	SCL Utility - Power Restoration	LS	299,500	1	$ 299,500	*See Utilities Report*
(7f)	SPU Utility - Water Temp Relocation	LS	266,000	1	$ 266,000	*See Utilities Report*
(7g)	SPU Utility - Water Restoration	LS	230,000	1	$ 230,000	*See Utilities Report*
(7h)	SPU Utility - Sewer Temp Relocation	LS	158,000	1	$ 158,000	*See Utilities Report*
(7i)	SPU Utility - Sewer Restoration	LS	269,000	1	$ 269,000	*See Utilities Report*
(7j)	SDOT - Storm Drainage Relocation	LS	-	1	$ -	*Temporary addressed by TESC plan; see Utilities Report.*
(7k)	SDOT - Storm Drainage	LS	183,750	1	$ 183,750	*See Utilities Report*
(8)	Mobilization				$ 2,000,000	*10% applied to sum of above items*
(9)	Allowance for Undefined Items				$ 8,500,000	*40% applied to sum of above items*
(10)	**Total Comparative Construction Cost**				**$ 30,000,000**	*=(1)+(2)+(3)+(4)+(5)+(6)+(7)+(8)+(9)*

NOTES:

1. Cost estimates are based on 2019 dollars and a 1 to 10% level of design definition.

2. The costs presented herein are Rough-Order-of-Magnitude (ROM), and were prepared for the purpose of comparing the evaluated alternatives. Actual long-term and construction costs will differ from the costs shown. Final project costs are dependent upon many variable factors including, but not limited to, labor and material costs, site conditions, productivity, competitive market conditions, final project scope, and the contractor's implementation schedule.

3. The costs shown do not include:
   > financing
   > operation and maintenance (O&M) costs
   > sales taxes
   > environmental mitigation costs (if needed)
   > contaminated soil characterization, handling, or disposal
   > engineering costs
   > construction contingency
   > construction engineering
   > right-of-way cost (all work should fit within existing right-of-way, assume zero cost)
   > escalation
   > decomissioning and removal of existing underground storage tanks
   > temporary ground-/stormwater drainage system during construction, and groundwater drainage system for permanent conditions

4. For detailed utility cost backup and explanation, see Utilities Report (dated Nov 2019 and prepared by SG3 Strategies, LLC) - included as Appendix D to N Northlake Way Retaining Wall - Alternatives Analysis Report. The costs shown above are the associated line item subtotals stated in that report, for a given utility owner and phase of construction.

5. For narrative explanation of individual cost items, see Table 3 of the Alternatives Analysis Report main body.

Appendix A - Wall Alternatives Evaluation Rough-Order-of-Magnitude (ROM) Cost Estimate Breakdown

Ground Improvement Concept

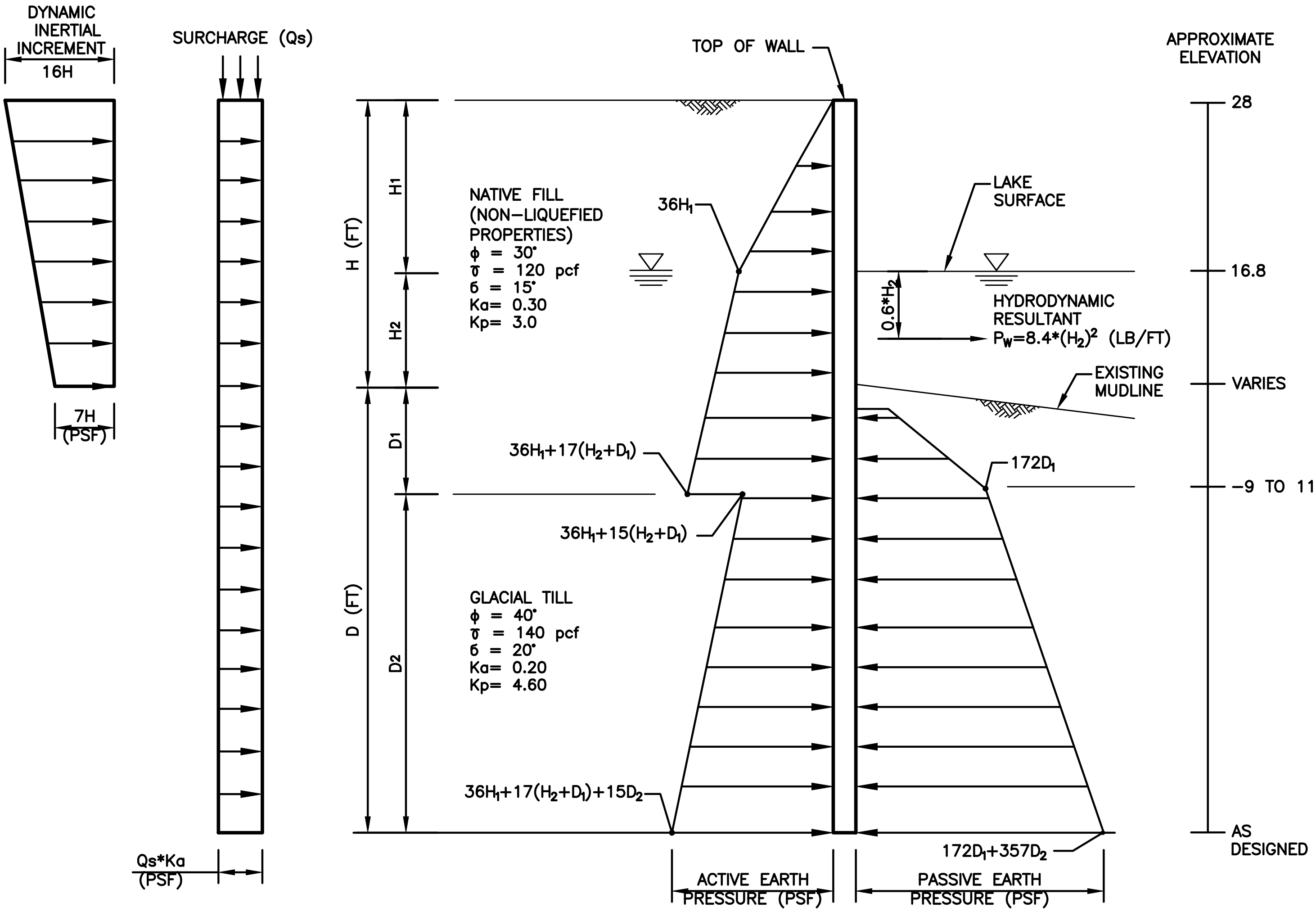
ROM Cost Estimate: Alternative 3 - Deep Soil Mixing Ground Improvement

No.	Item	Unit of Measure	Unit Cost	Total Qty	Line Cost	Basis / Notes / Calculation Formula
(1)	Traffic Control	LS	50,000	1	$ 50,000	*assume $50,000 for traffic control*
(2)	Existing Wall Removal	SF	30	6,200	$ 186,000	*quantity based on exposed SF in current condition; cost includes removal and disposal of existing timber wall*
(3)	New Retaining Wall	SF	220	8,700	$ 1,914,000	*install new sheet pile cut-off wall with non-structural (decorative) concrete fascia*
(4)	Ground Improvement	LS	4,700,000	1	$ 4,700,000	*install self-supporting DSM ground improvement (cost includes spoils disposal and haul, and earth items above top of DSM)*
(5)	Roadway Restoration	SF	20	26,000	$ 520,000	*remove and reinstall existing pavements directly behind wall*
(6)	Boardwalk Removal and Replacement	SF	340	2,300	$ 782,000	*remove and reinstall existing boardwalks adjacent to piers/buildings; qty is based on (larger) reinstalled area*
(7a)	PSE Utility - Gas Relo. and Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7b)	Century Link Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7c)	Comcast Utility - Comm. Relo & Rest.	LS	-	1	$ -	*All costs belong to the provider; see Utilities Report.*
(7d)	SCL Utility - Power Temp Relocation	LS	211,000	1	$ 211,000	*See Utilities Report*
(7e)	SCL Utility - Power Restoration	LS	299,500	1	$ 299,500	*See Utilities Report*
(7f)	SPU Utility - Water Temp Relocation	LS	266,000	1	$ 266,000	*See Utilities Report*
(7g)	SPU Utility - Water Restoration	LS	230,000	1	$ 230,000	*See Utilities Report*
(7h)	SPU Utility - Sewer Temp Relocation	LS	158,000	1	$ 158,000	*See Utilities Report*
(7i)	SPU Utility - Sewer Restoration	LS	269,000	1	$ 269,000	*See Utilities Report*
(7j)	SDOT - Storm Drainage Relocation	LS	-	1	$ -	*Temporary addressed by TESC plan; see Utilities Report.*
(7k)	SDOT - Storm Drainage	LS	183,750	1	$ 183,750	*See Utilities Report*
(8)	Mobilization				$ 1,000,000	*10% applied to sum of above items*
(9)	Allowance for Undefined Items				$ 4,400,000	*40% applied to sum of above items*
(10)	**Total Comparative Construction Cost**				**$ 16,000,000**	*=(1)+(2)+(3)+(4)+(5)+(6)+(7)+(8)+(9)*

NOTES:

1. Cost estimates are based on 2019 dollars and a 1 to 10% level of design definition.
2. The costs presented herein are Rough-Order-of-Magnitude (ROM), and were prepared for the purpose of comparing the evaluated alternatives. Actual long-term and construction costs will differ from the costs shown. Final project costs are dependent upon many variable factors including, but not limited to, labor and material costs, site conditions, productivity, competitive market conditions, final project scope, and the contractor's implementation schedule.
3. The costs shown do not include:
   - > financing
   - > operation and maintenance (O&M) costs
   - > sales taxes
   - > environmental mitigation costs (if needed)
   - > contaminated soil characterization, handling, or disposal
   - > engineering costs
   - > construction contingency
   - > construction engineering
   - > right-of-way cost (all work should fit within existing right-of-way, assume zero cost)
   - > escalation
   - > decomissioning and removal of existing underground storage tanks
   - > temporary ground-/stormwater drainage system during construction, and groundwater drainage system for permanent conditions
4. For detailed utility cost backup and explanation, see Utilities Report (dated Nov 2019 and prepared by SG3 Strategies, LLC) - included as Appendix D to N Northlake Way Retaining Wall - Alternatives Analysis Report. The costs shown above are the associated line item subtotals stated in that report, for a given utility owner and phase of construction.
5. For narrative explanation of individual cost items, see Table 3 of the Alternatives Analysis Report main body.

Appendix B Design Earth Pressures



GENERAL SOIL PRESSURES

NOTES

1. ALL DIMENSIONS ARE IN FEET UNLESS NOTED OTHERWISE.
2. WATER LEVELS ARE ASSUMED AT APPROXIMATELY THE SAME ELEVATION ON BOTH SIDES OF THE WALL, AS A RESULT UNBALANCED HYDROSTATIC PRESSURES DO NOT ACT ON THE WALL.
3. THESE DESIGN CRITERIA ARE APPLICABLE FOR WALL THAT ARE ALLOWED TO YIELD AT LEAST 0.002 * HEIGHT OF THE WALL. DO NOT USE THESE CRITERIA FOR DESIGN OF ANY OTHER TYPE OF WALL.
4. ACTIVE AND PASSIVE EARTH PRESSURES ARE ASSUMED TO ACT OVER THE PLAN LENGTH OF THE WALL.
5. ACTIVE AND PASSIVE EARTH PRESSURES ARE SHOWN AT ULTIMATE VALUES. AN ACTIVE LOAD FACTOR OF 1.00 SHOULD BE APPLIED FOR THE SERVICE AND EXTREME LIMIT STATES AND 1.50 FOR THE STRENGTH LIMIT STATE. A PASSIVE RESISTANCE FACTOR OF 0.75 SHOULD BE APPLIED FOR THE STRENGTH LIMIT STATE AND 1.00 FOR THE SERVICE AND EXTREME LIMIT STATE.
6. FOR THE SEISMIC CASE Kh = 0.23g.
7. TREAT THE SURCHARGE (Qs) AS A VEHICULAR LIVE LOAD (LL) WHEN APPLYING LOAD FACTORS AS PER AASHTO LRFD TABLE 3.4.1-1.
8. SURCHARGE (Qs) IS THE VEHICULAR AND CONSTRUCTION SURCHARGE AND SHOULD NOT BE LESS THAN 250 PSF.
9. IGNORE PASSIVE RESISTANCE IN THE UPPER TWO FEET TO ALLOW FOR EROSION/SCOUR AT THE FACE OF WALL.
10. VERTICAL DATUM: NAV88.
11. RESULTANT FORCE OF HYDRODYNAMIC EFFECT IS SHOWN. SEE ALTERNATIVES ANALYSIS REPORT FOR ADDITIONAL DETAILS.

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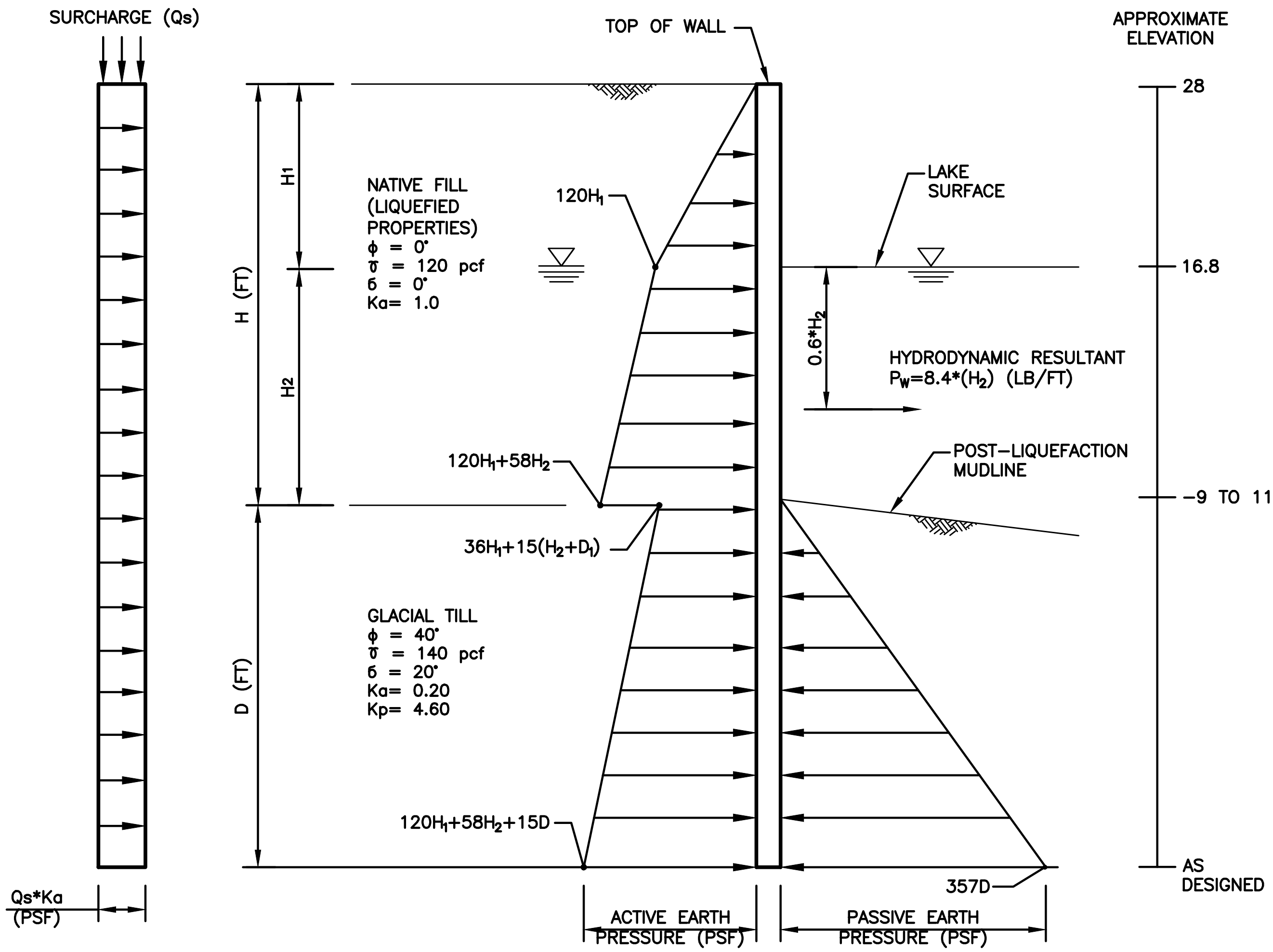
N NORTHLAKE WAY BULKHEAD
SEATTLE, WA

LATERAL EARTH PRESSURES: STATIC AND SEISMIC NON-LIQUEFIED CASES

FIGURE
B-1

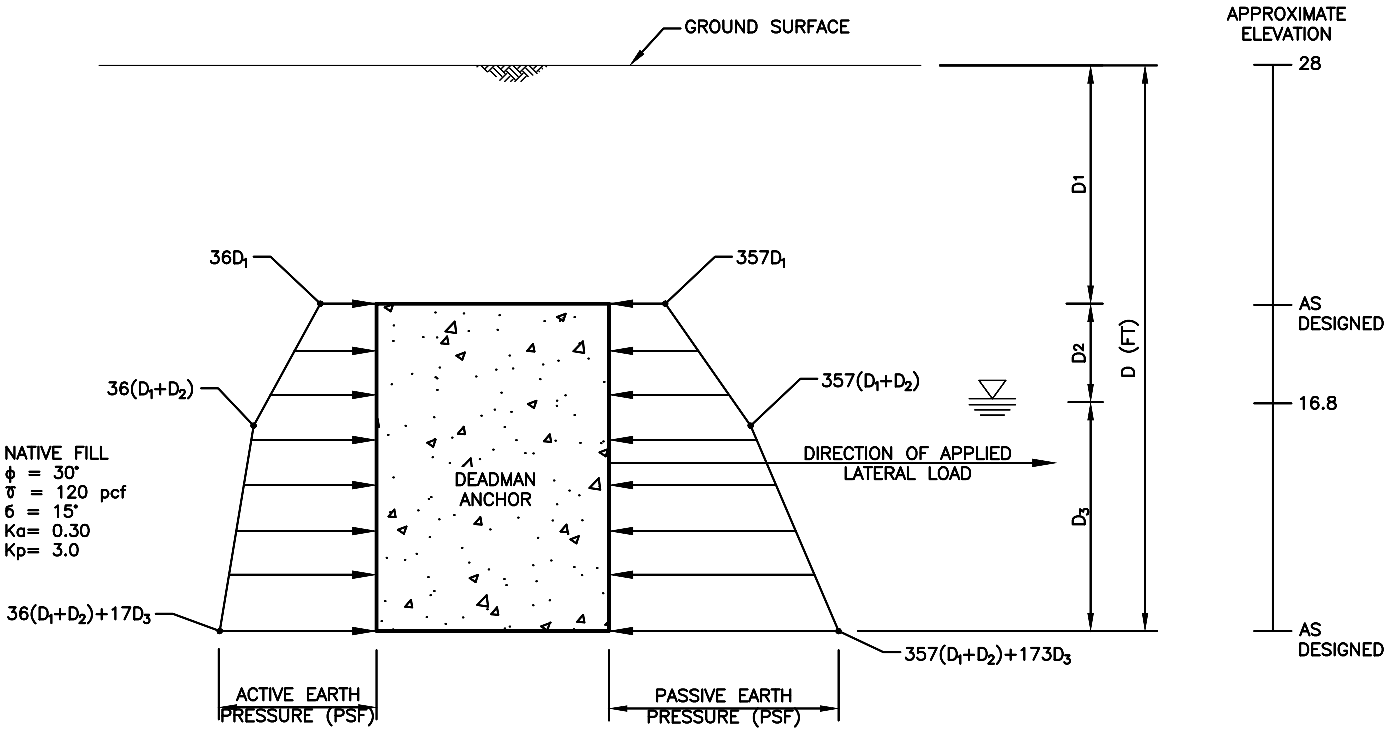


GENERAL SOIL PRESSURES

NOTES

1. ALL DIMENSIONS ARE IN FEET UNLESS NOTED OTHERWISE.
2. WATER LEVELS ARE ASSUMED AT APPROXIMATELY THE SAME ELEVATION ON BOTH SIDES OF THE WALL, AS A RESULT UNBALANCED HYDROSTATIC PRESSURES DO NOT ACT ON THE WALL.
3. THESE DESIGN CRITERIA ARE APPLICABLE FOR WALL THAT ARE ALLOWED TO YIELD AT LEAST 0.002 * HEIGHT OF THE WALL. DO NOT USE THESE CRITERIA FOR DESIGN OF ANY OTHER TYPE OF WALL.
4. ACTIVE AND PASSIVE EARTH PRESSURES ARE ASSUMED TO ACT OVER THE PLAN LENGTH OF THE WALL.
5. ACTIVE AND PASSIVE EARTH PRESSURES ARE SHOWN AT ULTIMATE VALUES. ACTIVE LOAD FACTOR AND PASSIVE RESISTANCE FACTOR OF 1.00 SHOULD BE APPLIED FOR THIS EXTREME LIMIT STATE LOAD CASE.
6. TREAT THE SURCHARGE (Qs) AS A VEHICULAR LIVE LOAD (LL) WHEN APPLYING LOAD FACTORS AS PER AASHTO LRFD TABLE 3.4.1-1.
7. SURCHARGE (Qs) IS THE VEHICULAR AND CONSTRUCTION SURCHARGE AND SHOULD NOT BE LESS THAN 250 PSF.
8. VERTICAL DATUM: NAVD88.
9. IF SOIL BEHIND WALL IS TREATED WITH LIQUEFACTION MITIGATION, THEN APPLY NATIVE FILL NON-LIQUEFIED PROPERTIES AND DYNAMIC INERTIAL INCREMENT SHOWN ON FIGURE B-1 (BUT WITH THE POST-LIQUEFIED MUDLINE SHOWN ABOVE)
10. RESULTANT FORCE OF HYDRODYNAMIC EFFECT IS SHOWN. SEE ALTERNATIVES ANALYSIS REPORT FOR ADDITIONAL DETAILS.

COWI	City of Seattle Seattle Department of Transportation ORDINANCE NO. . . N/A . APPROVED. . . . N/A. FUND: . . . . N/A . SCALE: NTS INSPECTOR'S BOOK . . N/A.	N NORTHLAKE WAY BULKHEAD SEATTLE, WA LATERAL EARTH PRESSURES: SEISMIC LIQUEFIED CASE	FIGURE B-2



LATERAL EARTH PRESSURES
STATIC AND PSEUDOSTATIC CASES

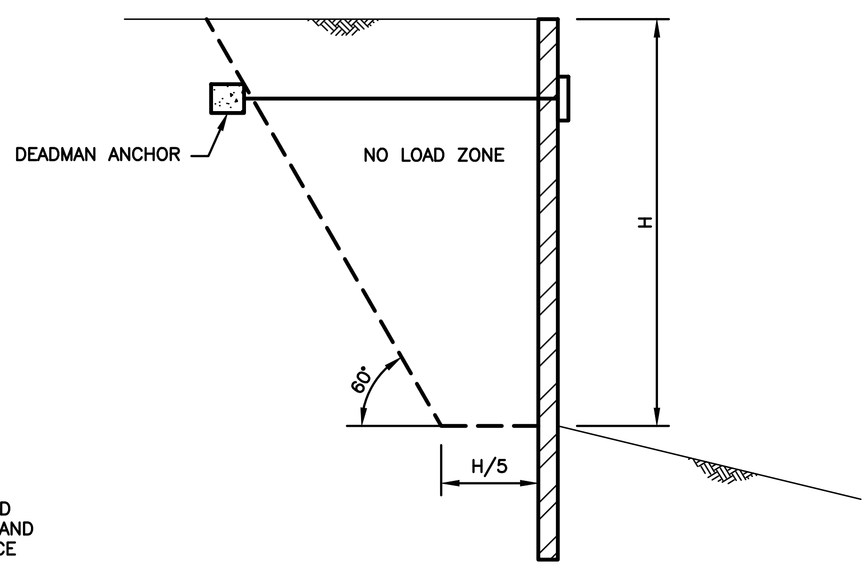


DIAGRAM A
ANCHOR NO LOAD ZONE

NOTES

1. ALL DIMENSIONS ARE IN FEET UNLESS NOTED OTHERWISE.
2. ACTIVE AND PASSIVE EARTH PRESSURES ARE SHOWN AT ULTIMATE VALUES. AN ACTIVE LOAD FACTOR OF 1.00 SHOULD BE APPLIED FOR THE SERVICE AND EXTREME LIMIT STATES AND 1.50 FOR THE STRENGTH LIMIT STATE. A PASSIVE RESISTANCE FACTOR OF 0.75 SHOULD BE APPLIED FOR THE STRENGTH LIMIT STATE AND 1.00 FOR THE SERVICE AND EXTREME LIMIT STATE.
3. THE ANCHOR SHOULD BE PLACED OUTSIDE OF THE NO LOAD ZONE INDICATED IN DIAGRAM A.
4. VERTICAL DATUM: NAVD88.
5. DEADMAN ANCHOR NOT TO BE USED IN LIQUEFIABLE SOIL.

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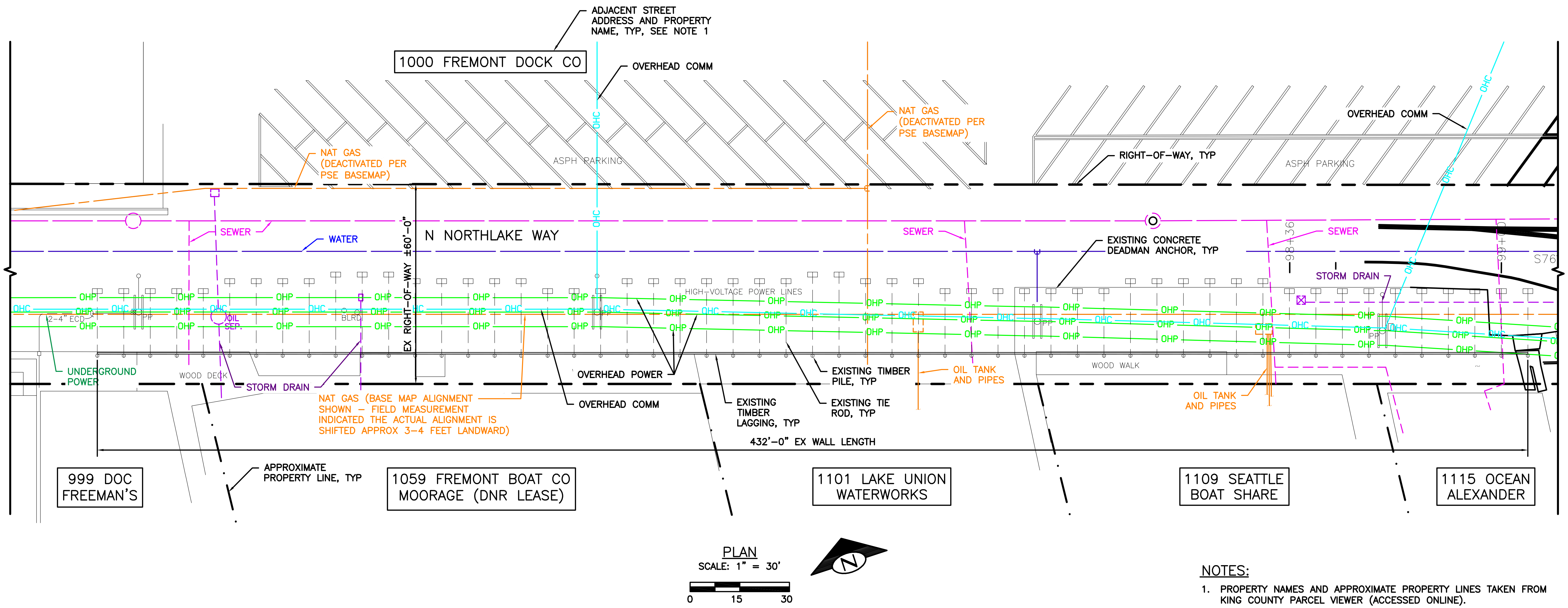
N NORTHLAKE WAY BULKHEAD
SEATTLE, WA

DEADMAN ANCHOR DESIGN

FIGURE
B-3

Appendix C Alternatives Analysis Figures



NOTES:

1. PROPERTY NAMES AND APPROXIMATE PROPERTY LINES TAKEN FROM KING COUNTY PARCEL VIEWER (ACCESSED ONLINE).
2. EXISTING RIGHT-OF-WAY TAKEN FROM OWNER-PROVIDED BASE MAP (TRC0314_X-BASE.DWG)
3. UTILITY POTHOLING HAS NOT OCCURRED - EXISTING UTILITY LOCATIONS TAKEN FROM OWNER-PROVIDED BASE MAP (TRC0314_X-BASE.DWG) AND ARE ESTIMATES.
4. SEE UTILITIES REPORT (INCLUDED AS APPENDIX D TO THIS REPORT) FOR ADDITIONAL DETAILS AND INFORMATION ON UTILITIES.

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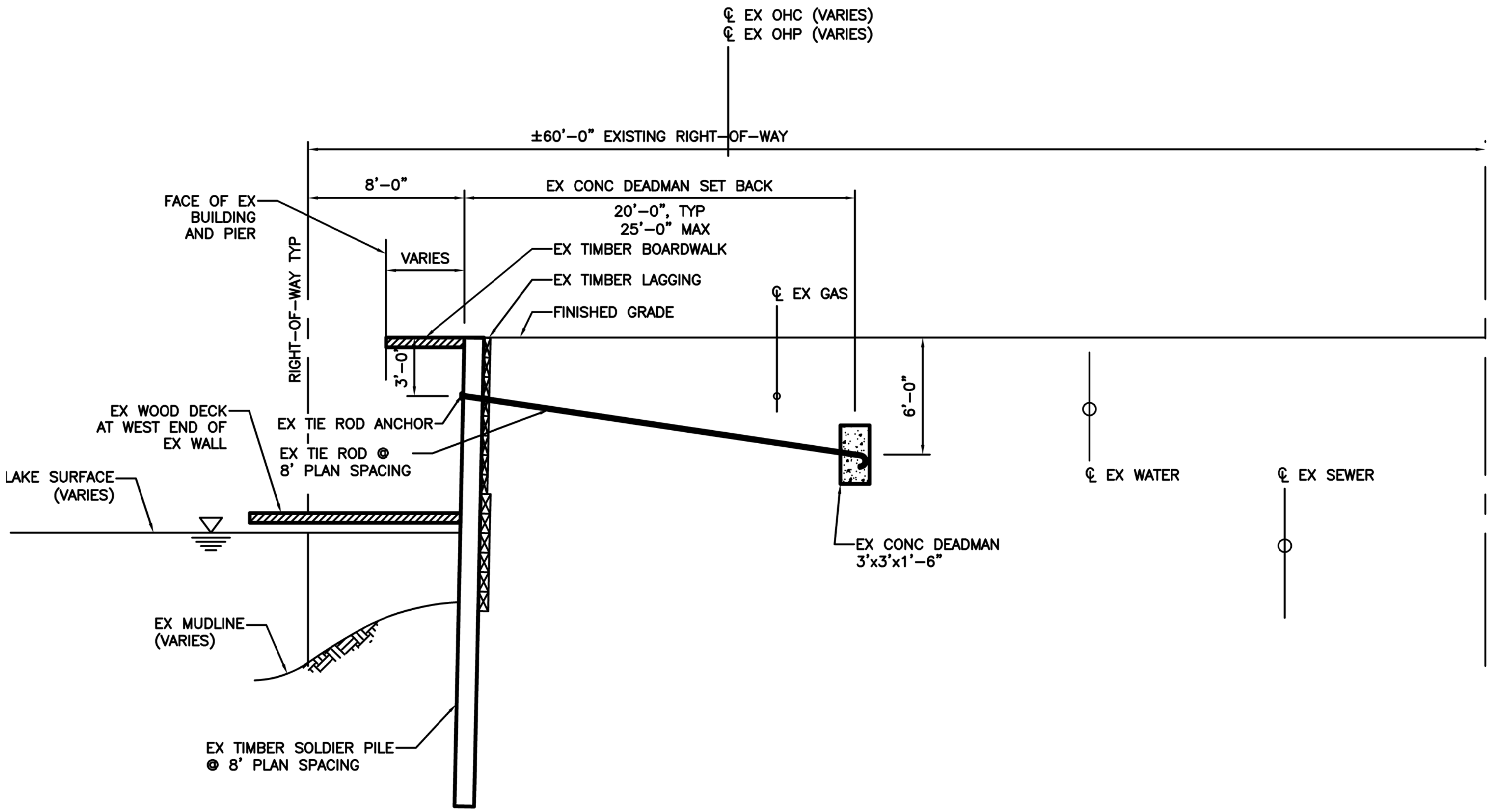

NOTE:

1. UTILITY POTHOLING HAS NOT OCCURRED – UTILITY LOCATIONS AND ELEVATIONS ARE ESTIMATES. GAS POSITION SHOWN BASED ON APPROXIMATE FIELD MEASUREMENTS – ALL OTHER UTILITY POSITIONS TAKEN FROM OWNER–PROVIDED BASE MAP (TRC0314_X–BASE.DWG).
2. EXISTING WALL GEOMETRY AND DETAILS TAKEN FROM AS–BUILT DRAWINGS.
3. RIGHT–OF–WAY TAKEN FROM OWNER–PROVIDED BASE MAP (TRC0314_X–BASE.DWG).

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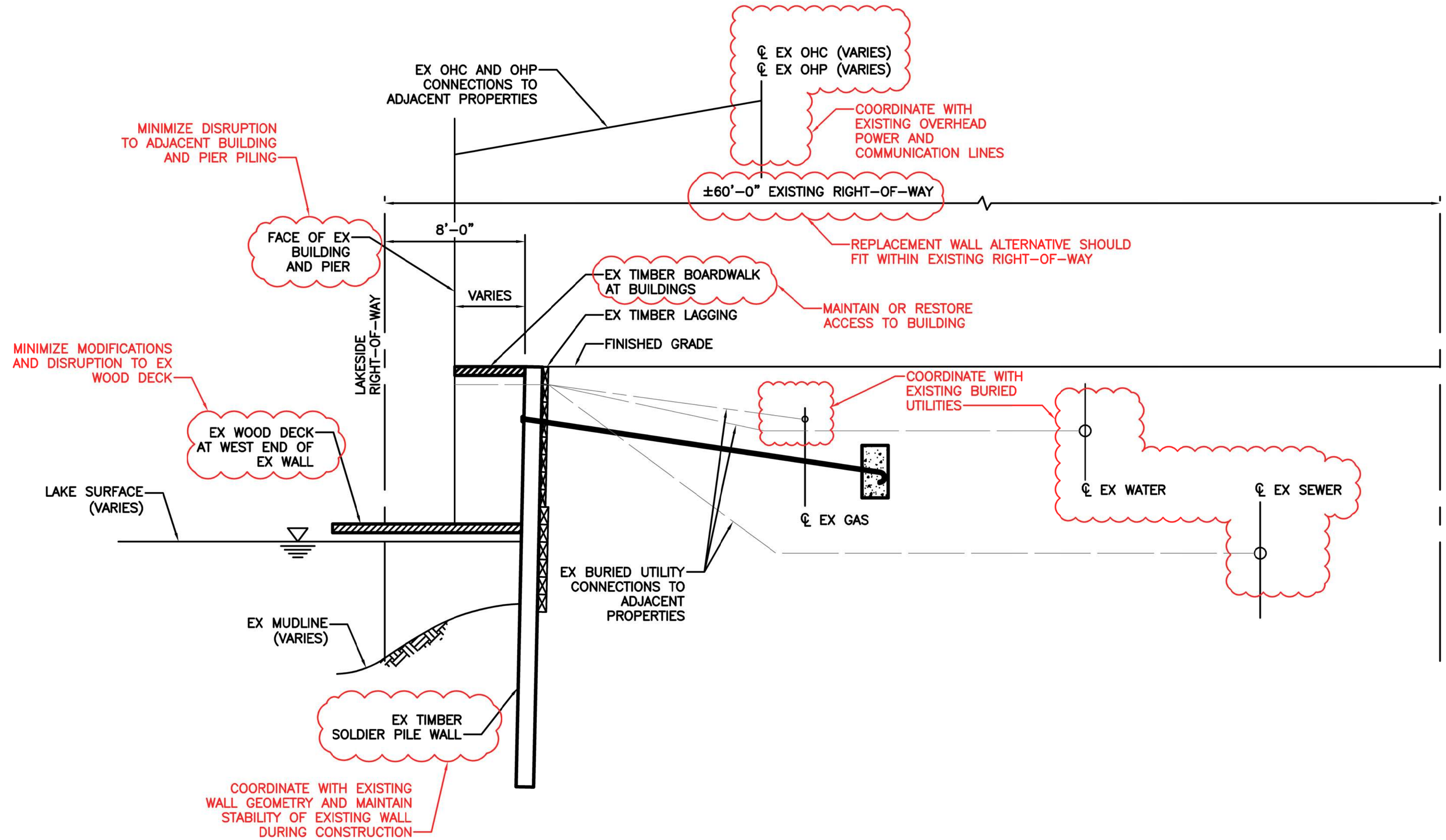
N NORTHLAKE WAY WALL REPLACEMENT
ALTERNATIVE EVALUATION
SEATTLE, WA

EXISTING WALL TYPICAL SECTION

FIGURE
C–2A



NOTE:

1. UTILITY POTHOLING HAS NOT OCCURRED – UTILITY LOCATIONS AND ELEVATIONS ARE ESTIMATES. GAS POSITION SHOWN BASED ON APPROXIMATE FIELD MEASUREMENTS – ALL OTHER UTILITY POSITIONS TAKEN FROM OWNER-PROVIDED BASE MAP (TRC0314_X-BASE.DWG).
2. THE CONSTRAINTS IDENTIFIED ABOVE REFLECT PRELIMINARY UNDERSTANDING OF PROJECT AND SITE LOCATION.
3. RIGHT-OF-WAY TAKEN FROM OWNER-PROVIDED BASE MAP (TRC0314_X-BASE.DWG).
4. EXISTING UTILITIES TAKEN FROM OWNER-PROVIDED BASE MAP (TRC0314_X-BASE.DWG).
5. UTILITY SERVICE WILL NEED TO BE MAINTAINED DURING CONSTRUCTION. SEE UTILITIES REPORT (INCLUDED AS APPENDIX D TO THIS REPORT) FOR ADDITIONAL DETAILS AND INFORMATION ON UTILITIES.

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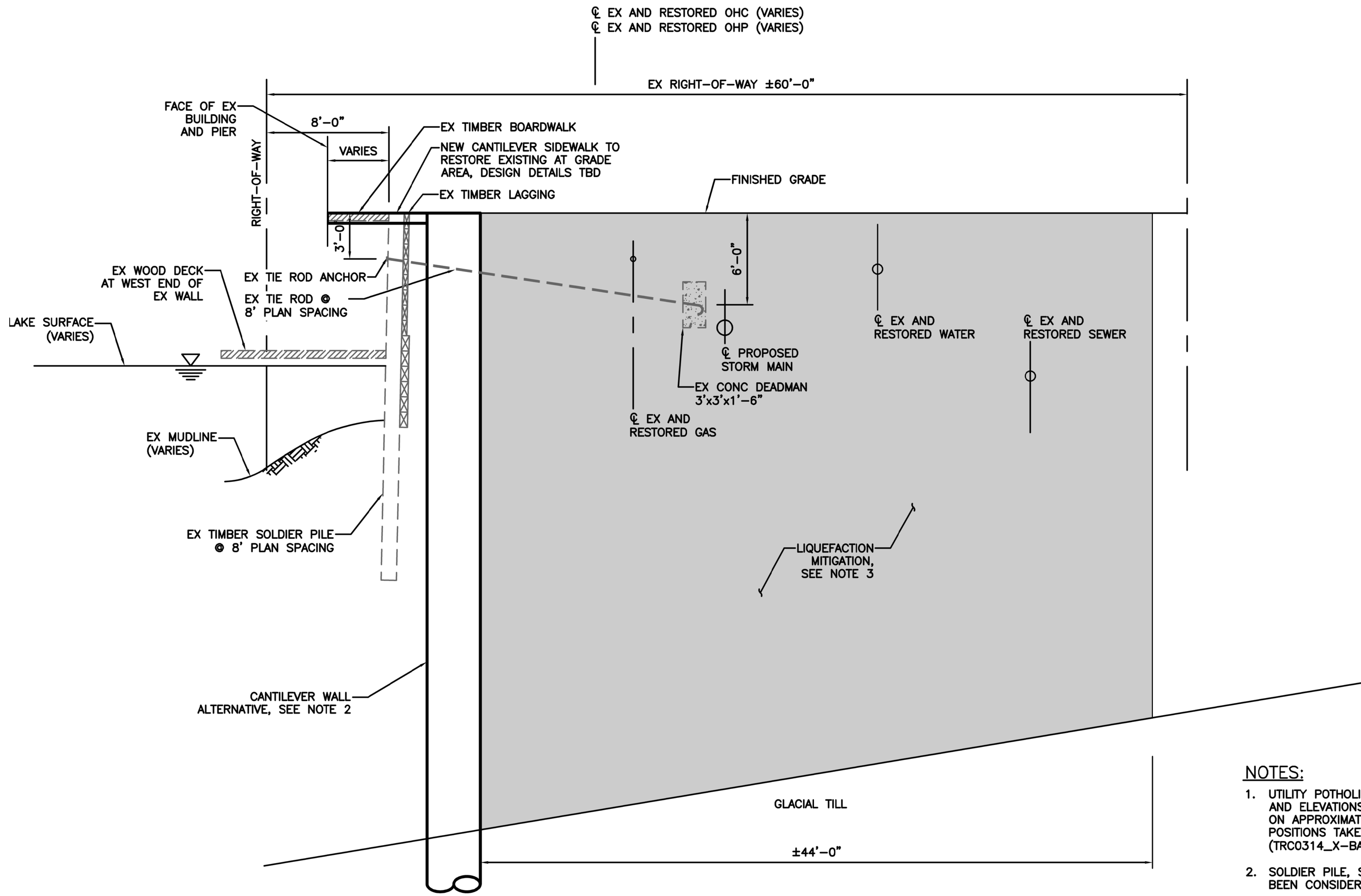
N NORTHLAKE WAY WALL REPLACEMENT
ALTERNATIVE EVALUATION
SEATTLE, WA

EXISTING PROJECT CONSTRAINTS

FIGURE
C-2B



NOTES:

1. UTILITY POTHOLING HAS NOT OCCURRED – UTILITY LOCATIONS AND ELEVATIONS ARE ESTIMATES. GAS POSITION SHOWN BASED ON APPROXIMATE FIELD MEASUREMENTS – ALL OTHER UTILITY POSITIONS TAKEN FROM OWNER-PROVIDED BASE MAP (TRC0314_X-BASE.DWG).
2. SOLDIER PILE, SECANT PILE, AND KING PILE VARIANTS HAVE BEEN CONSIDERED FOR CANTILEVER WALL ALTERNATIVE.
3. LIQUEFACTION MITIGATION SOIL IMPROVEMENT CONSISTING OF STONE COLUMNS AND WICK DRAINS INSTALLED IN 6 FT x 6 FT GRIDWORK PATTERN IS REQUIRED BEHIND THE NEW WALL.
4. TEMPORARILY RELOCATE POWER AROUND PROJECT SITE. TEMPORARILY RELOCATE ALL OTHER UTILITIES TO TEMPORARY SUPPORT STRUCTURE ALONG EXISTING WALL FACE. RESTORE ALL UTILITIES TO EXISTING LOCATIONS AFTER NEW WALL CONSTRUCTION.

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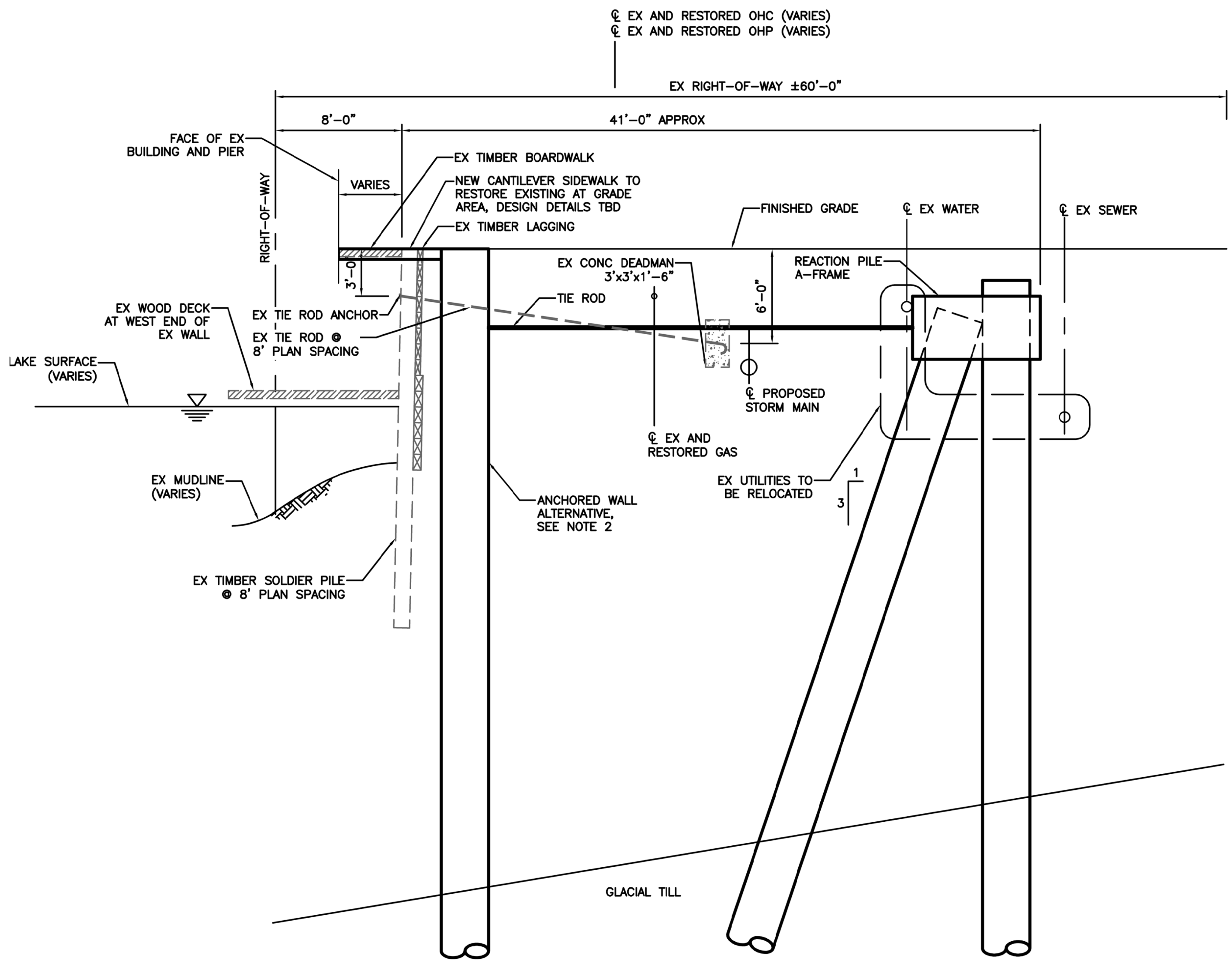
N NORTHLAKE WAY WALL REPLACEMENT
ALTERNATIVE EVALUATION
SEATTLE, WA

ALTERNATIVE 1 – CANTILEVER WALL

FIGURE C-3



NOTES:

1. UTILITY POTHOLING HAS NOT OCCURRED – UTILITY LOCATIONS AND ELEVATIONS ARE ESTIMATES. GAS POSITION SHOWN BASED ON APPROXIMATE FIELD MEASUREMENTS – ALL OTHER UTILITY POSITIONS TAKEN FROM OWNER–PROVIDED BASE MAP (TRC0314_X–BASE.DWG).
2. SOLDIER PILE AND KING PILE VARIANTS HAVE BEEN CONSIDERED FOR ANCHORED WALL ALTERNATIVE.
3. TEMPORARILY RELOCATE POWER AROUND PROJECT SITE. TEMPORARILY RELOCATE ALL OTHER UTILITIES TO TEMPORARY SUPPORT STRUCTURE ALONG EXISTING WALL FACE. RESTORE ALL UTILITIES TO EXISTING LOCATIONS AFTER NEW WALL CONSTRUCTION, UNLESS NOTED OTHERWISE.

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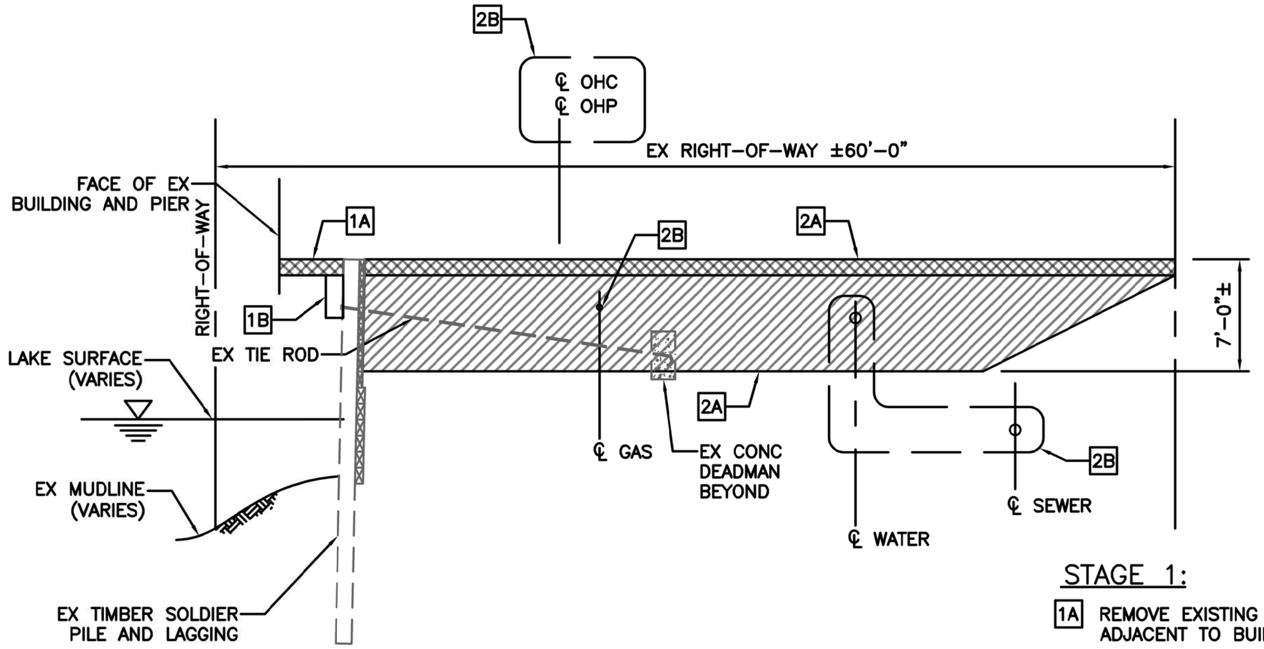
N NORTHLAKE WAY WALL REPLACEMENT
ALTERNATIVE EVALUATION
SEATTLE, WA

ALTERNATIVE 2 – ANCHORED WALL – CONCEPT DESIGN

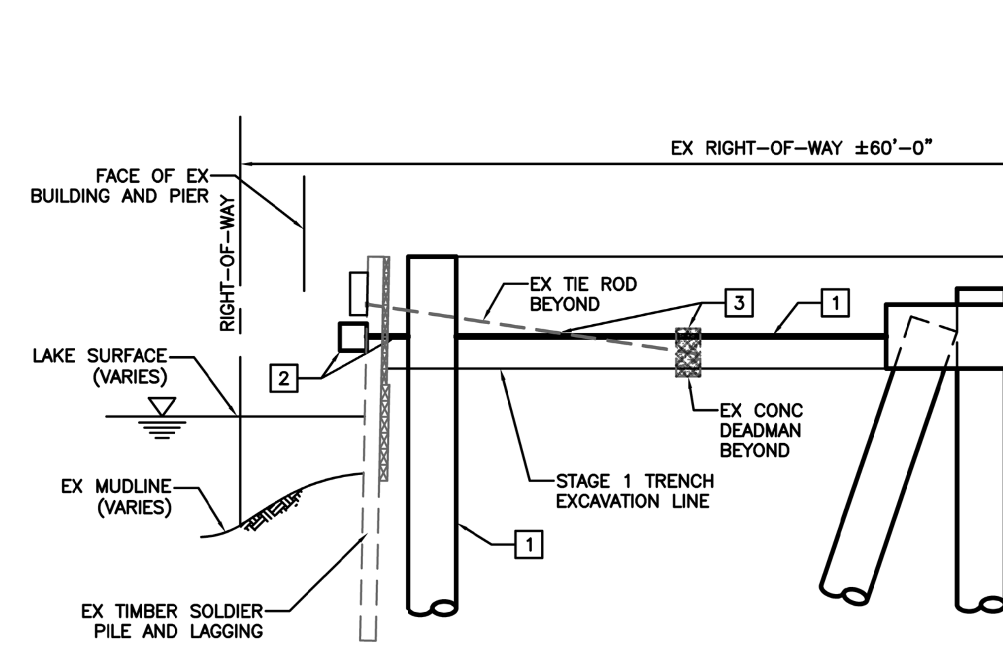
FIGURE
C–4A



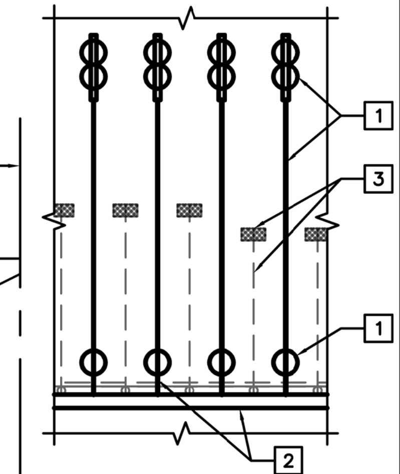
STAGE 1

STAGE 1:

- [1A] REMOVE EXISTING TIMBER BOARDWALKS ADJACENT TO BUILDINGS.
- [1B] ESTABLISH TEMPORARY UTILITIES ALONG FACE OF EXISTING WALL AND TRANSFER ALL SERVICES.
- [2A] REMOVE EXISTING PAVEMENTS AND EXCAVATE AND TRENCH AS REQUIRED BETWEEN EXISTING TIE RODS AND DEADMAN ANCHORS.
- [2B] REMOVE EXISTING UTILITIES AS REQUIRED.



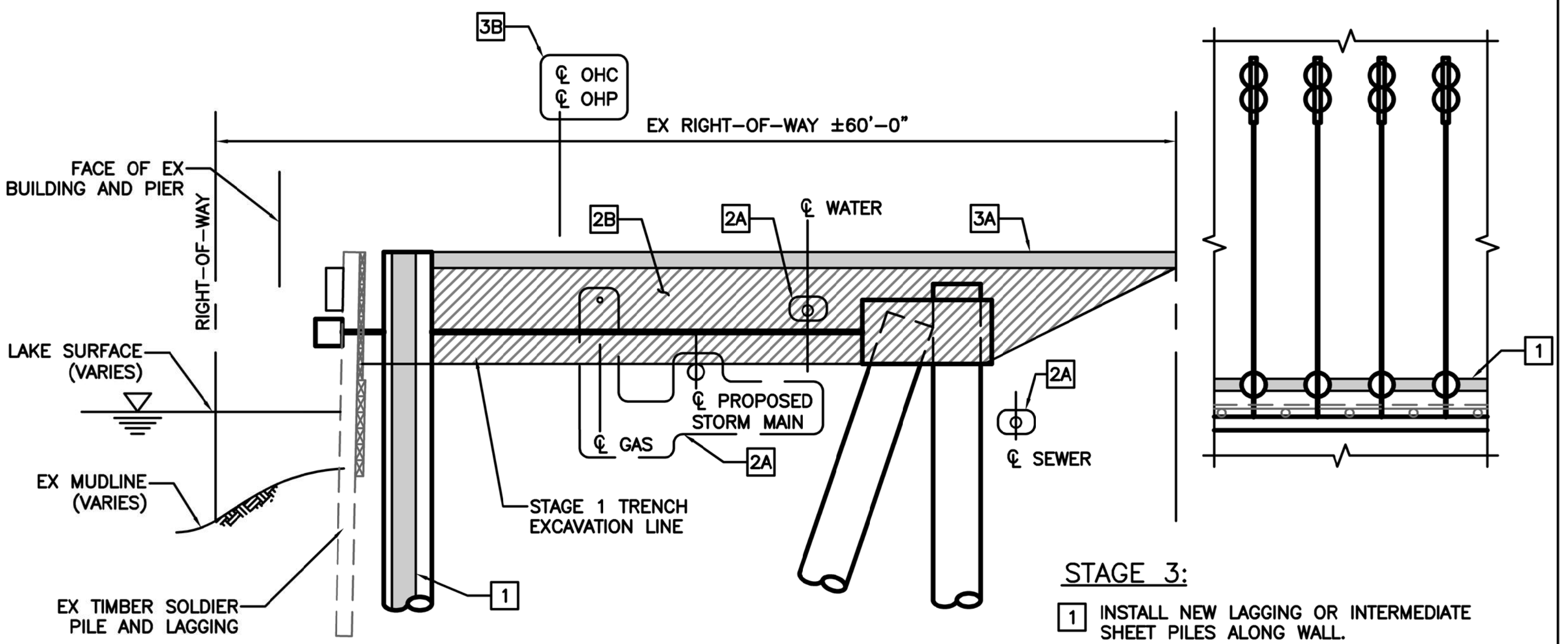
STAGE 2



PARTIAL PLAN

STAGE 2:

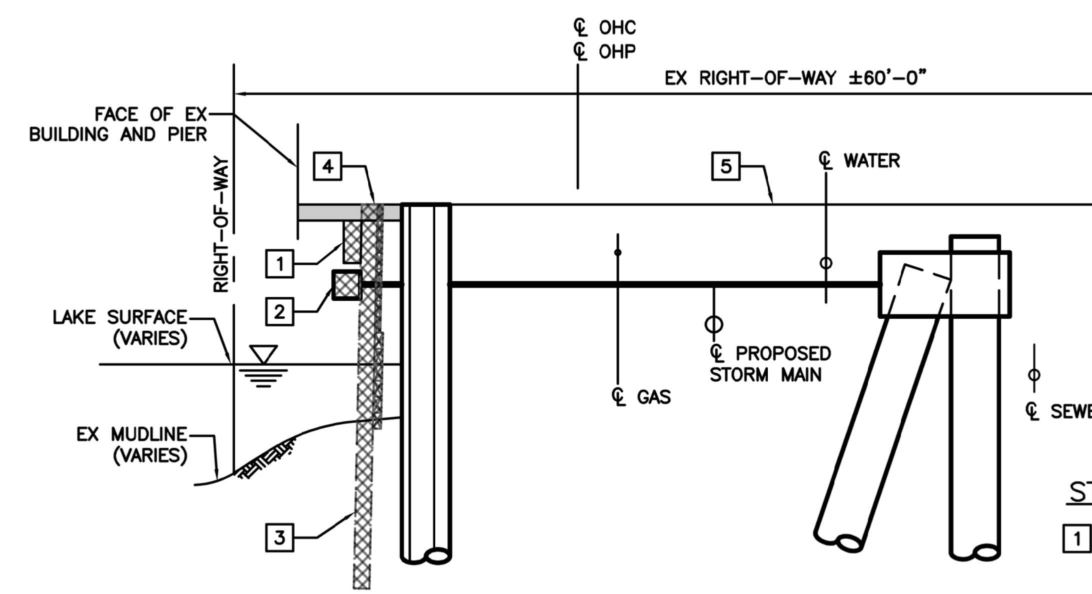
- [1] INSTALL SOLDIER/KING PILES, REACTION PILE A-FRAMES, AND TIE RODS.
- [2] INSTALL TEMPORARY TIE RODS AND WALER BEYOND EXISTING TIMBER PILES.
- [3] EXCAVATE AS REQUIRED AND REMOVE EXISTING TIE RODS AND CONCRETE DEADMAN ANCHORS. MAINTAIN EXISTING WALL STABILITY DURING REMOVALS.



STAGE 3

STAGE 3:

- [1] INSTALL NEW LAGGING OR INTERMEDIATE SHEET PILES ALONG WALL.
- [2A] INSTALL RESTORED BURIED UTILITIES (GAS, WATER, SEWER, AND PROPOSED STORM MAIN).
- [2B] BACKFILL TRENCHES AND EXCAVATIONS.
- [3A] INSTALL NEW PAVEMENTS.
- [3B] INSTALL RESTORED AERIAL UTILITIES (OVERHEAD POWER AND COMMUNICATION).



STAGE 4

STAGE 4:

- [1] TRANSFER SERVICES FROM TEMPORARY TO RESTORED UTILITIES. REMOVE TEMPORARY UTILITIES AND SUPPORT SYSTEM.
- [2] REMOVE TEMPORARY SUPPORT WALER AND ANCHOR RODS.
- [3] REMOVE EXISTING WALL.
- [4] INSTALL NEW BOARDWALKS AND CANTILEVER SIDEWALK TO RESTORE EX AT GRADE AREA..
- [5] INSTALL NEW PAVEMENTS AND SURFACE FEATURES AS REQUIRED.

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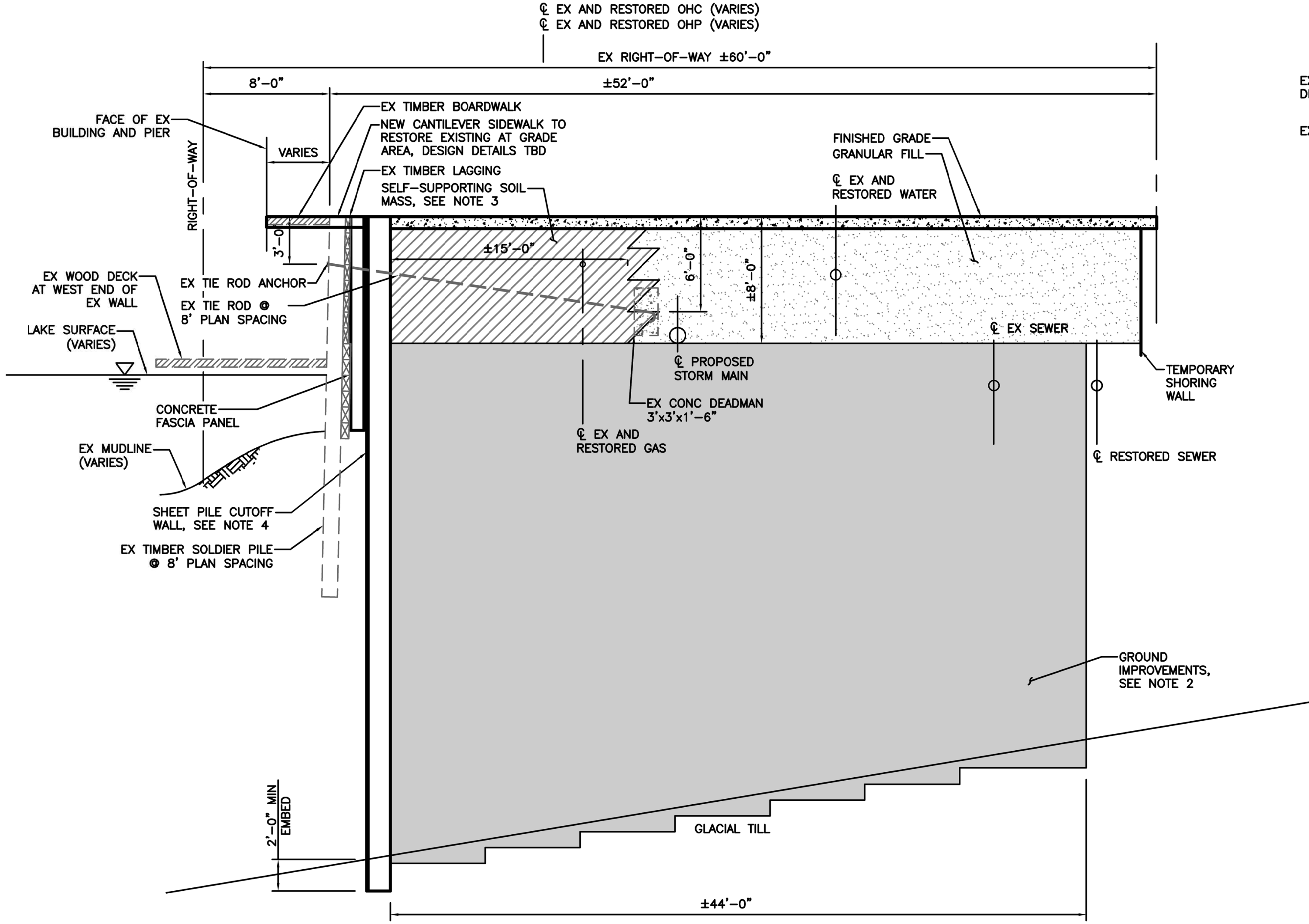

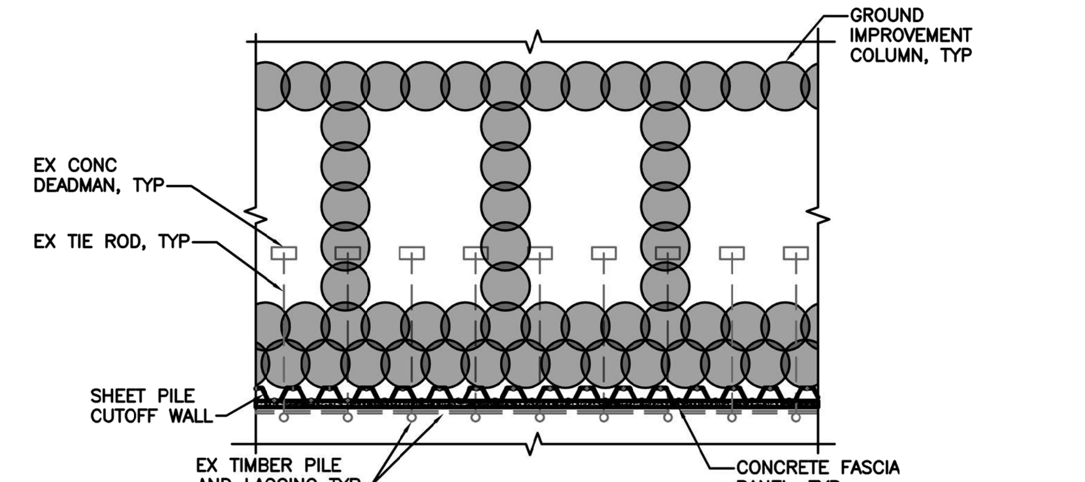

PARTIAL PLAN

NOTES:

1. UTILITY POTHOLING HAS NOT OCCURRED – UTILITY LOCATIONS AND ELEVATIONS ARE ESTIMATES. GAS POSITION SHOWN BASED ON APPROXIMATE FIELD MEASUREMENTS – ALL OTHER UTILITY POSITIONS TAKEN FROM OWNER-PROVIDED BASE MAP (TRC0314_X-BASE.DWG).
2. DEEP SOIL MIXING AND JET GROUTING HAVE BEEN CONSIDERED FOR GROUND IMPROVEMENT ALTERNATIVE.
3. FLOWABLE FILL, MECHANICALLY STABILIZED EARTH, OR GEOGRID WRAPPED FILL CAN BE CONSIDERED FOR SELF-SUPPORTING SOIL MASS.
4. SHEET PILE CUTOFF WALL TO BE VIBRATED 2' MIN EMBED INTO GLACIAL TILL FOR TYPICAL WALL SECTION AS SHOWN.
5. TEMPORARILY RELOCATE POWER AROUND PROJECT SITE. TEMPORARILY RELOCATE ALL OTHER UTILITIES TO TEMPORARY SUPPORT STRUCTURE ALONG EXISTING WALL FACE. RESTORE ALL UTILITIES TO EXISTING LOCATIONS AFTER NEW WALL CONSTRUCTION, UNLESS NOTED OTHERWISE.

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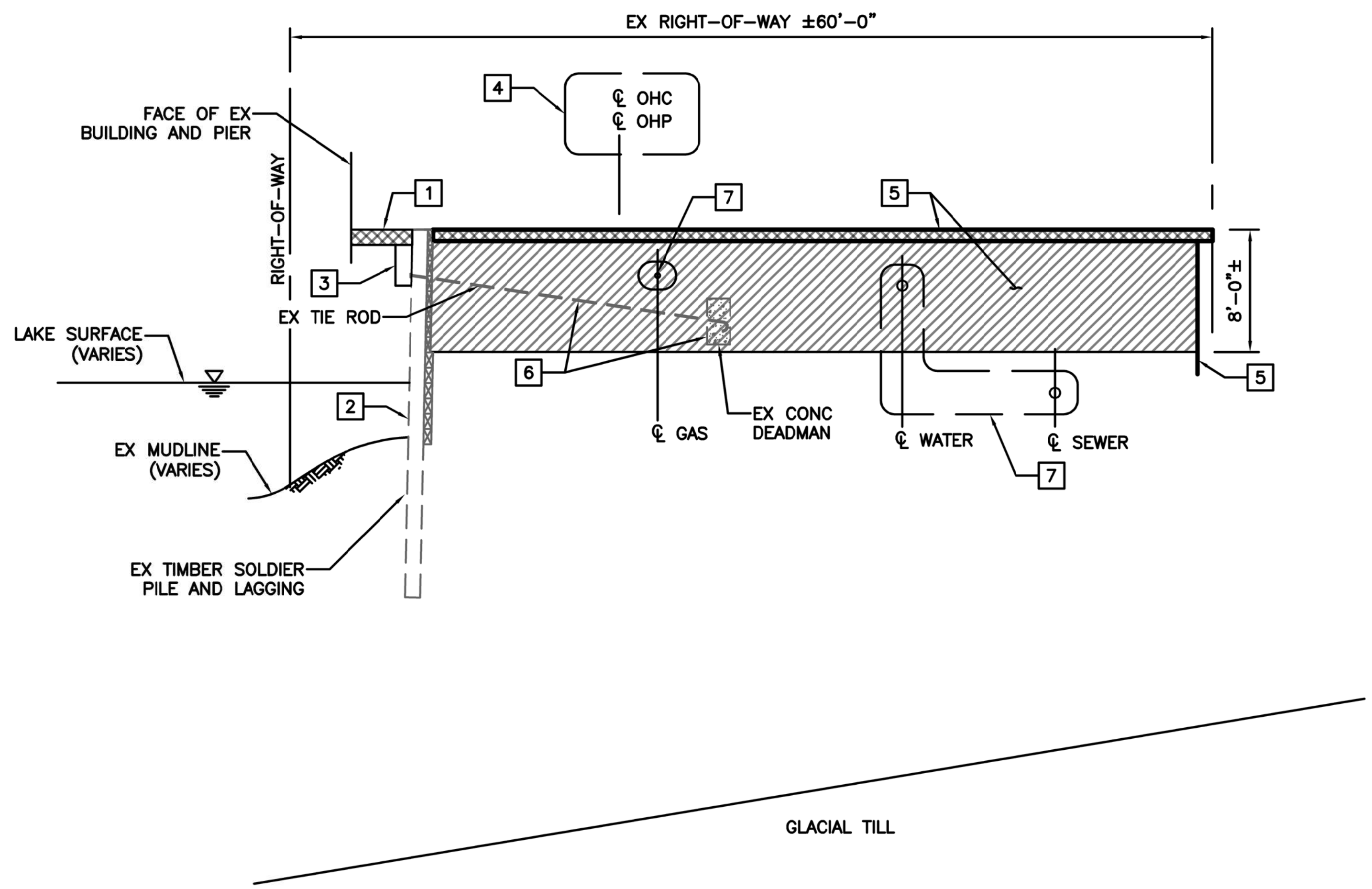
N NORTHLAKE WAY WALL REPLACEMENT
ALTERNATIVE EVALUATION
SEATTLE, WA

ALTERNATIVE 3 – GROUND IMPROVEMENT

FIGURE C-5A

STAGE 1:

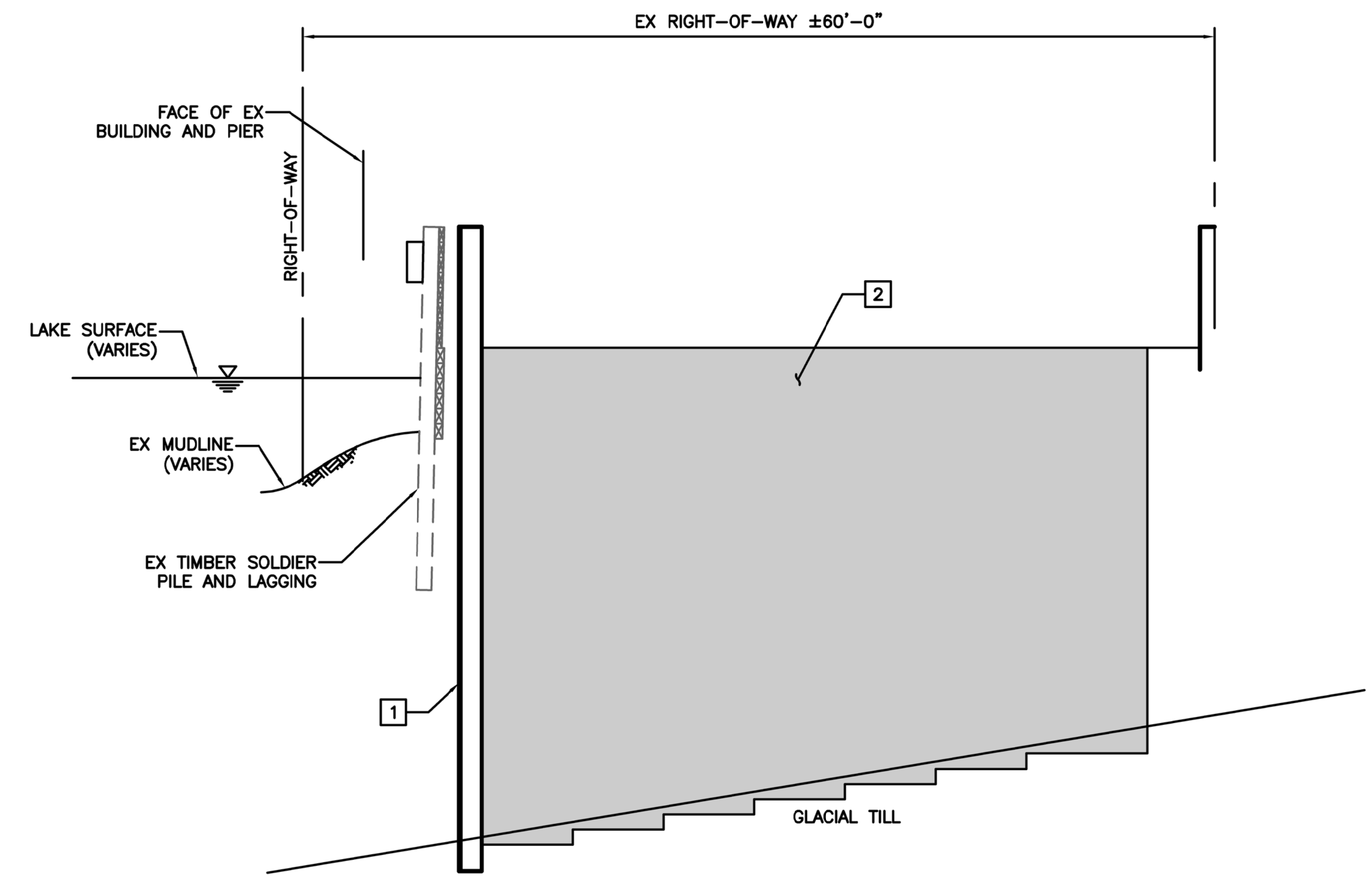
1. REMOVE EXISTING TIMBER BOARDWALKS ADJACENT TO BUILDINGS.
2. INSTALL TEMPORARY PILE REPAIRS OR SHORING PILES AT BROKEN EXISTING TIMBER PILES. 8' – 10' OF TEMP PILE EMBED INTO GLACIAL TILL, OR ANCHOR SYSTEM, REQUIRED FOR APPROX 80' AT WALL WEST END.
3. ESTABLISH TEMPORARY UTILITIES ALONG FACE OF EXISTING WALL AND TRANSFER ALL SERVICES.
4. REMOVE EXISTING OVERHEAD POWER AND COMMUNICATION.
5. REMOVE EXISTING PAVEMENTS AND EXCAVATE. INSTALL TEMPORARY SHORING WALLS AT BACK OF EXCAVATION AS REQUIRED. INSTALL DRAINAGE SYSTEM (DESIGN TBD) TO ALLOW STORMWATER TO DRAIN DURING CONSTRUCTION.
6. REMOVE EXISTING CONCRETE DEADMAN ANCHORS AND TIE RODS. MAINTAIN EXISTING WALL STABILITY DURING REMOVALS.
7. REMOVE EXISTING BURIED UTILITIES.



STAGE 1

STAGE 2:

1. INSTALL SHEET PILE CUTOFF WALL.
2. INSTALL JET GROUTING/DEEP SOIL MIXING GROUND IMPROVEMENT TO TOP OF WORK PAD.



STAGE 2

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N NORTHLAKE WAY WALL REPLACEMENT
ALTERNATIVE EVALUATION
SEATTLE, WA

ALTERNATIVE 3 – GROUND IMPROVEMENT CONSTRUCTION STAGING
SHEET 1 OF 2

FIGURE
C–5B

STAGE 3:

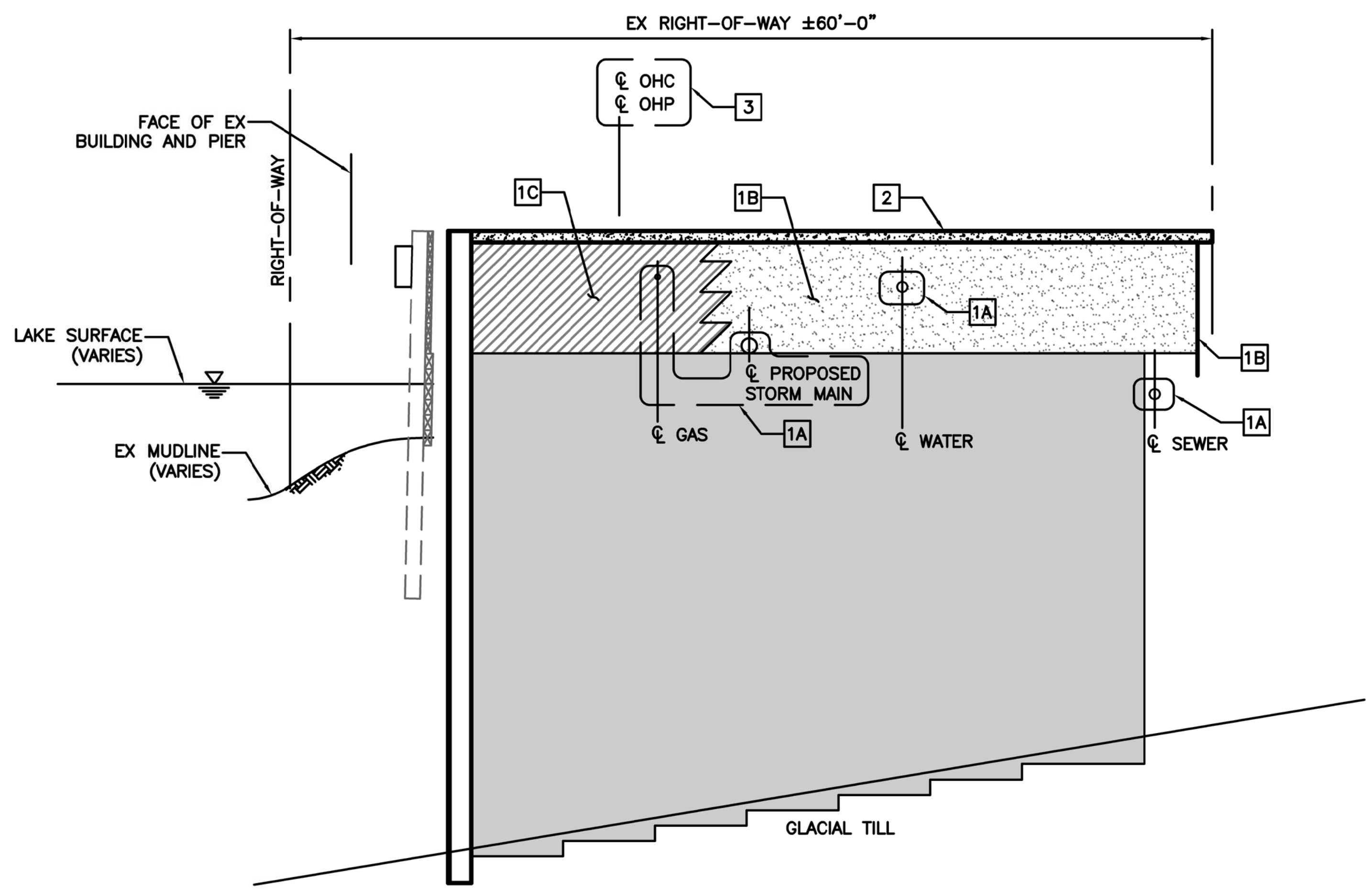
1A INSTALL RESTORED BURIED UTILITIES (GAS, WATER, SEWER, AND PROPOSED STORM MAIN). INSTALL PERMANENT DRAINAGE SYSTEM (DESIGN TBD) TO ALLOW GROUNDWATER BEHIND WALL TO DRAIN IN PERMANENT CONDITION.

1B BACKFILL WITH GRANULAR FILL TO FINISHED GRADE (IN 2' LIFTS) AND REMOVE TEMPORARY SHORING WALL.

1C INSTALL SELF-SUPPORTING SOIL MASS (MSE OR GEOGRID WRAPPED FILL) BEHIND WALL TO FINISHED GRADE (IN 2' LIFTS).

2 INSTALL NEW PAVEMENTS.

3 INSTALL RESTORED OVERHEAD POWER AND COMMUNICATION.



STAGE 3

STAGE 4:

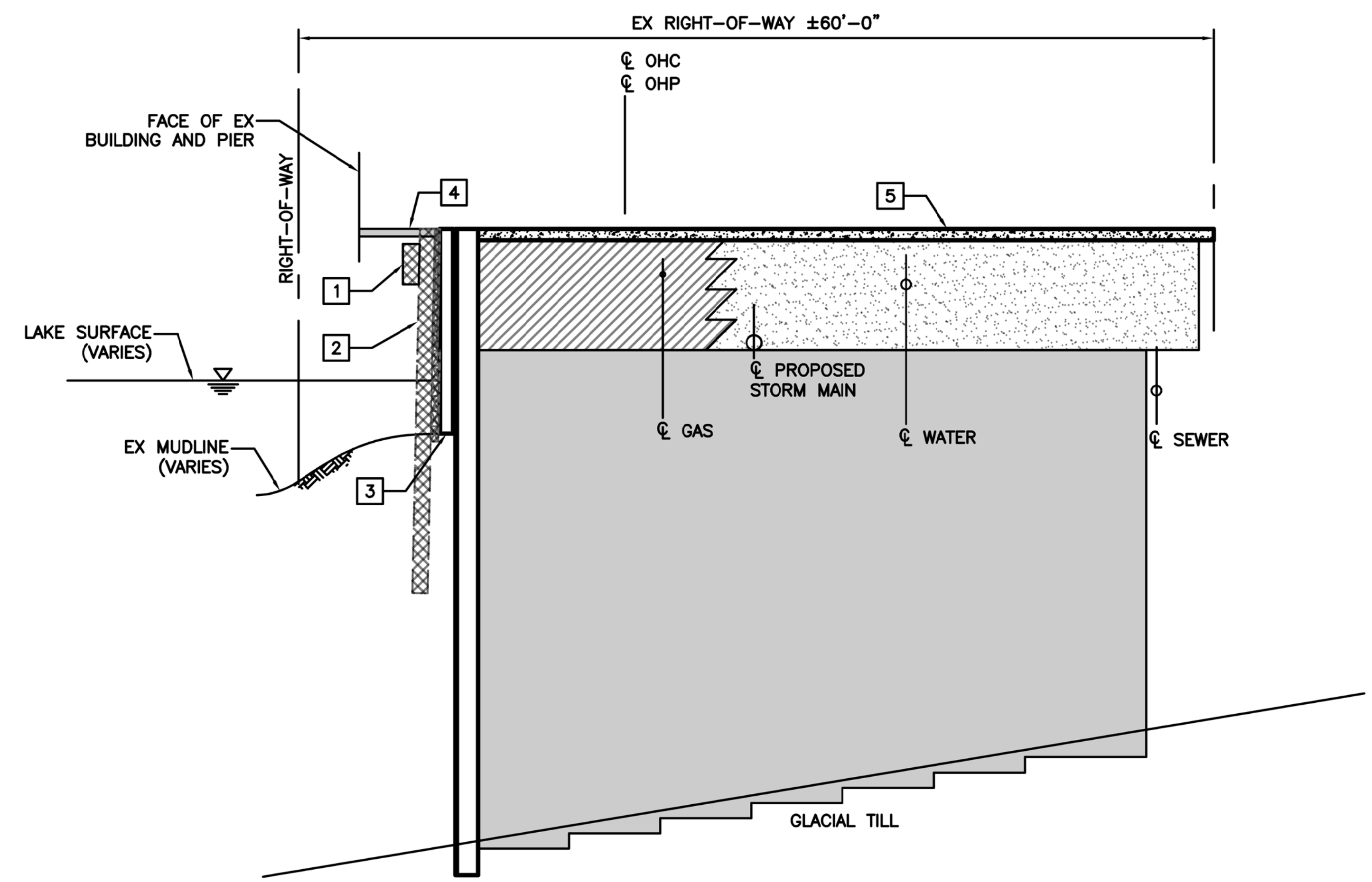
1 TRANSFER SERVICES FROM TEMPORARY TO RESTORED UTILITIES. REMOVE TEMPORARY UTILITIES AND SUPPORT SYSTEM.

2 REMOVE EXISTING WALL AND TEMPORARY REPAIRS OR SHORING PILES.

3 INSTALL CONCRETE FASCIA PANELS.

4 INSTALL NEW BOARDWALK AND CANTILEVER SIDEWALK TO RESTORE EX AT GRADE AREA.

5 INSTALL NEW PAVEMENTS AND SURFACE FEATURES AS REQUIRED.



STAGE 4

COWI

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FUND: N/A
SCALE: NTS INSPECTOR'S BOOK N/A

N NORTHLAKE WAY WALL REPLACEMENT
ALTERNATIVE EVALUATION
SEATTLE, WA

ALTERNATIVE 3 – GROUND IMPROVEMENT CONSTRUCTION STAGING
SHEET 2 OF 2

FIGURE
C-5C

Appendix D Utilities Report

NOVEMBER 2019
SEATTLE DEPARTMENT OF TRANSPORTATION

N NORTHLAKE WAY RETAINING WALL – ALTERNATIVES ANALYSIS FINAL REPORT

UTILITIES REPORT

SG3

SG3 Strategies, LLC
8201 164th Avenue NE
Suite 200
Redmond, WA 98052

425.285.4488

Contents

Executive Summary

Please note that the conclusions and recommendations of this report are focused on Alternative 3 – Ground Improvement. The concept for maintaining utility services to customers located on the water side of the existing wall during construction is to temporarily relocate the utility infrastructure to the exposed south face of the existing wall, providing a free and clear work space for soil improvement operations, structure installation and roadway restoration work. The challenge in some locations will be the presence of private facilities such as water heaters, electrical panels, plumbing and other items under the sidewalk, so within the public right-of-way. Customers should experience only brief interruptions in service during actual cut over from permanent to temporary service and back again to restored permanent service. This analysis did not investigate options for restoration or protection of any utilities affected by emergency situations such as premature wall failures, as the extent and nature of such a failure is undefined and the types of utilities potentially affected cannot reasonably be predicted.

After ground and structural improvements are completed, most utilities will be restored in essentially their current locations. The sewer main may be reinstalled at the north edge of the right of way to avoid the ground improvement zone. One notable difference may be that the current storm water drainage system which outfalls at multiple points directly to Lake Union may be replaced with a new drainage collection and filtered discharge system.

Water, **communications** and **natural gas** utilities are similar in flexibility and adaptability for a temporary configuration. The temporary service approach is to provisionally align each of these utilities along the south side of the existing wall in a vertically stacked configuration. Water and natural gas services will be connected near their current service points. Communications lines will require temporary risers affixed to customer structures to connect the temporary lines to the existing aerial service entry points. Restored water, communications and natural gas utilities will be placed in approximately the existing locations. An additional fire hydrant may be placed near Stone Way.

Electrical distribution and electrical services are more complex, with aerial service entries and a variety of service voltages. There is potential for the temporary aerial distribution to stop near the east and west ends of the site. This temporary electrical distribution configuration would require various circuit feeds from beyond the project limits, including a temporary aerial alignment west of the project limits connecting to existing aerial power along N 34th Street. This may include installation of a temporary surface-mounted transformer in the right-of-way just west of Stone Way, north of North Northlake Way. Customer service lines would run in conduits racked with the other utilities at the south face of the wall, then in temporary risers affixed to customer structures to connect the temporary lines to the existing aerial service entry points.

Sanitary sewer is relatively complex, with a potential mix of gravity and pumped side sewers for which detailed information on side sewer locations and types is not yet available. There are no visible surface markers for these locations. Sewer flows from the west to the east in a gravity sewer 11' south of the north right-of-way margin of Northlake Way. This is within the soil improvement area, so the sewer must be temporarily routed around the work area in parallel with other utilities. This may require a temporary lift station and electrical service with a force main to pump around the area, with a connection to a maintenance hole (MH) placed west of Stone Way, just east of the work area. It may be necessary to collect side sewer flows to small grinder pump stations that each pump into the temporary force main. It appears feasible to reconstruct the sewer main just north of the improved soil area, to avoid disturbing the soil improvement structure. This would likely place the sewer three to four feet inside the right of way, providing adequate access for future maintenance. Side sewers must be designed to penetrate the new wall at defined elevations, and it may be necessary, if structurally acceptable, to trench new lateral runs through the improved soil block. The typical side sewer trench depth and width can only be determined after the number, type and depth of the existing side sewers is determined during design, including whether these side sewers are pumped or gravity services.

Storm drainage currently consists of an informal collection of local discharge points. Detention will not be required in the restored condition, but treatment must be provided in the form of a cartridge-type catch basin system, as preliminarily defined by Seattle Public Utilities. Drainage will connect to the existing 54” storm main at Stone Way.

Temporary utility costs are estimated at $635,000 and restored utilities at $983,000 for a total of $1,618,000. This is estimated construction cost of items only and does not include any additional mark ups. Private utility costs for natural gas and telecommunications are not included as these are the responsibility of the associated private utility provider. Review and input on cost has yet to be provided by Seattle City Light and Seattle Public Utilities.

Scope of Utility Coordination Conducted

City of Seattle records vault research was conducted for Seattle Public Utilities (SPU) and other facilities existing within the project area of influence. Seattle City Light (SCL) does not offer public access to facility records but most existing facilities are above ground and readily visible. Underground electrical conduit locations are paint-marked on the ground surface. Records indicate the presence of buried underground fuel tanks but whether they are currently in use must be determined during design, as well as a temporary and restored plan for these facilities if they are in service. SDOT provided a base map compiled of records research from previous projects but no field survey has been conducted. Additional detailed information on the location of individual utility services will be required during the design phase.

SDOT staff met with the Seattle Fire Department (SFD), which provided guidance on truck access, fire flows and fire fighting access. SFD requires 24-hour access from the land side to fight fires on piers and docks. They need a minimum 24’-wide access road and two fire hydrants. One of these hydrants is existing to the west of the project area. The other should be placed east of the project area to replace the hydrant to be temporarily removed from the work area. Fire boats may access the ends of the piers and docks but land-side access is required for other emergencies.

Record information requests were made to and fulfilled by Comcast, Century Link and Puget Sound Energy (PSE). The utility records are reflected in the revised base map. Four utility coordination meetings were conducted:

1) SPU regarding sewer, water and drainage,
2) SCL regarding electrical power,
3) PSE regarding natural gas
4) SPU specifically on drainage requirements.

Instead of meetings, concurrence letters were delivered via email to Century Link and Comcast on September 30th requesting they provide comments on a draft summary of their current locations and the proposed temporary and restored service approaches. Century Link responded with supplemental information and concurrence on October 16th. No response was received from Comcast and a follow-up request was made.

Utility Coordination included review and feedback of the following documents:

1) Alternatives Analysis – Draft Report
2) Alternatives Analysis – SDOT Review Comments (on Draft Report)
3) Emergency Response Plan – Pre-Final.

This analysis did not investigate options for restoration or protection of any utilities affected by emergency situations such as premature wall failures, as the extent and nature of such a failure is undefined and the types of utilities potentially affected cannot reasonably be predicted. Localized failures may not affect all utilities. For example, 100 lineal feet of wall failure may not have any effect on aerial utilities, while adjacent gas and water systems could be damaged.

Utility Summary Table

The following table summarizes the applicable utility elements and likely restored conditions. Materials for temporary utilities may vary as a function of support and physical protection requirements and may or may not match existing or restored utilities. Exposed gas pipe is likely to be steel with plastic underground. Temporary water and sewer pipes are likely to be HDPE while the existing system uses no HDPE. Temporary electrical and telecommunication lines will run in PVC conduits, but the restored condition should follow the existing aerial configuration.

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Table 1. Utility Summary

Utility Type	Existing Size and Materials	Temporary Construction Easement Required?	Temporary Materials	Temporary Cost Estimate	Restored Size and Materials	Restored Condition Alignment	Restored Cost Estimate
Water Main	8" cast iron	No	HDPE	$240,000	8" ductile iron	Match existing	$180,000
Water services	Various sizes of plastic, iron, copper domestic and fire services	No	Copper and ductile iron	$26,000	Same sizes in copper and ductile iron	Match existing	$50,000
Sewer Main and Services	8" concrete	No	HDPE and grinder pumps, temporary lift station	$158,000	8" vitrified clay	Realign to 3-4 ft. south of N. ROW N. Northlake	$269,000
Electrical	26 kV, 480V, 240V, 120V aerial & buried copper	Yes, for risers on buildings and aerial line	Wood poles & copper electrical cables, PVC & steel conduit	$211,000	Same as existing	Match existing	$299,500
Storm Drainage	Various sizes concrete and PVC with no treatment	No	Not included – part of construction stormwater plan	n/a	12" concrete with stormfilters	to be defined during design – must meet utility setback needs	$183,750
Natural Gas	2" Steel (STW) intermediate pressure	No	Steel and polyethylene	n/a	2" steel or polyethylene intermediate pressure	Match existing	n/a
Telecom	Various sizes copper, fiber optic and coaxial cable	Yes, for risers on buildings	PVC conduit and telecom cables	n/a	Same as existing	Match existing	n/a

Notes:
1. See detailed estimate later in report with notes on items not included in estimate.
2. The cost for optional sewer protection is included in the sewer cost.

Utility Construction Sequence

Existing utilities must be moved out of the way before ground improvement and structural work can occur. The sequence listed below suggests a potential order of relocation and restoration to maintain utility services. The actual, specific order of work will be defined during the full design phase.

1. Establish temporary erosion and sediment control measures, including rerouting existing storm drains into a temporary system
2. Construct a temporary utility support system where needed south of the existing wall
3. Install temporary water main and services – this frees up roadway space for installing the temporary sewer lift station
4. Install temporary sewer lift station, force main and side sewer connections
5. Install temporary electrical poles, risers and guying systems and install temporary electrical services and realigned distribution power
6. Install temporary telecommunications services
7. Remove wood poles by cutting to ground level
8. Install temporary gas main, purge gas from abandoned gas main, remove abandoned main
9. Establish 24'-wide corridor for Fire Department access and maintain access throughout construction.
10. Establish containment walls and other items necessary to complete ground improvement and construct new wall structure
11. Perform ground improvement
12. Construct new wall fascia
13. Construct new sanitary sewer and remove temporary sewer, transferring sewer services to new system
14. Construct new water main and remove temporary water, transferring sewer services to new system
15. Construct new utility poles and electrical system and remove temporary electrical systems and poles, transferring electrical services to new system
16. Construct new gas system and remove temporary gas, transferring gas services to new system
17. Construct new storm system
18. Remove temporary utility support structure
19. Remove existing timber wall, factoring in live overhead utilities during design
20. Construct sidewalk south of new wall face

Temporary Utility Support Systems

The project site appears to be suitable for installation of a temporary utility support system or several types of support systems to provide physical support and protection of the various utility services. The utility relocation figures later in this report indicate the general locations and types of utilities to be supported in each area. SDOT has had success with similar temporary utility support structures on the Elliott Bay Seawall Project and examples from that project are included below.

With agreement from the various utilities during design, underground utilities can typically be configured in a common trench. Where utilities exit the ground and run in parallel, a physical support structure may be required. Portions of the existing wood wall structure may be structurally deficient to provide adequate support for the temporary utility configuration. Design and construction sequencing must consider the stability and details for constructing, maintaining and removing this temporary utility support system while maintaining utility service continuity and

The project will likely require removal of the existing sidewalks and boardwalks adjacent to the buildings, so the support structures for those sidewalks may be suitable for the base of a support system. No investigation of such suitability has been conducted. If not suitable, a different system must be designed. The system must support the operating weight of the utilities attached to it and be inherently stable and resistant to potential construction mishaps. Estimated temporary utility sizes and weights per lineal foot include:

1. 8” HDPE water main with water: 30.25 lbs
2. 8” HDPE sewer force main: 30.25 lbs (may be smaller)
3. 2” gas main: 3.65 lbs
4. Up to 6 electrical services in separate conduits: 19.1 lbs
5. Up to 6 telecomm services in separate conduits: 15.0 lbs

These estimated weights do not include the weight of the support system itself or assemblies to connect the utilities to the support system. Detailed design must be completed to design this system, including definition and analysis of any horizontal loads and how the system might react during a seismic event or as a result of forces imparted, for example, by a cycling pump system or pumped side sewers entering the sewer force main.

The configuration of the utilities on the support structure is a factor in design, as telecommunications, natural gas and electrical conduits are generally smaller and lighter than water and sewer lines. Separation requirements for buried, underground utilities typically differ from requirements for above ground temporary systems as long as maintenance access is provided and logical configuration achieved. For example, a leaking sewer line cannot be allowed to drip onto a potable water main. Utilities can be arranged horizontally, vertically or in a triangular arrangement, depending on space availability, support structure stability and maintenance access requirements.

An example of a temporary utility support structure supporting natural gas, water, sewer, telecommunications, electrical and construction storm outfall piping is provided in Figure 1 below. The beam structure spans the excavation and utilities with a unistrut racking system for the utility lines. This project may not require a utility support system to span the excavation, but it is feasible.

Figure 1. Example temporary utility support

Figure 2 below shows a jet grout and seawall construction work zone with a temporary 13,800-volt electrical service crossing the work area and a movable temporary pedestrian bridge. Equipment can easily work under such a structure if the excavation is deep enough. In this view, the utility is approximately ten feet above the work surface with the excavator and pile grinder.

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Figure 2. Electrical duct bank spanning jet grout work zone, pedestrian bridge beyond

The Northlake Way Retaining Wall project may not require temporary structures with spanning capability but there are different requirements in each work zone. The zone adjacent to the buildings on the east end of the project appears to have soil below the sidewalk. The temporary utility configuration may require installation of pin piles or a similar element to provide temporary utility support independent of the existing piles and sidewalk supports. That may require in-water work.

The zone along the wall at the marina appears to be entirely over open water, with the water below the wood walkway. Support for water, sewer, gas and telecom services will be required, although no electrical service crossing should be necessary. The support structure must provide for physical support, protection, separation and isolation of the utilities from marina patrons and residents. The walkway is relatively narrow, so this configuration will require a detailed design. The marina has dock boxes and several other items stored in this area, most of which must be relocated during construction, as seen in Figure 3 below.

Figure 3. Temporary utility requirements across the marina zone

Temporary Construction Easements

Although most of the temporary utility work can occur within the road right-of-way, the proposed temporary electrical alignment at the west end of the project requires an aerial easement across the Fremont Dock parcel.

The temporary service concepts for electrical and telecommunication propose to attach PVC riser conduits to buildings, requiring temporary attachment agreements that may fit the description of temporary easements and which should address attachment locations, utility types, attachment methods and removal and restoration requirements.

If SDOT defines a need for construction staging space within the parking lot area north of the project site, that temporary construction easement area should include language for a temporary SCL pole guy wire to address the guy wire crossing the site. See the electrical description and figure later in this report.

Water

Seattle Public Utilities (SPU) maintains an 8” diameter cast iron water main through the site. This main provides water to domestic services, fire services and a fire hydrant within the project area, all of which must be maintained during construction, although the hydrant may be relocated/resituated in consultation with the Seattle Fire Department.

The temporary water concept depicted in Figure 4 (see appendix) includes installing a temporary HDPE water main from Stone Way to a short distance beyond the west end of the wall reconstruction, in front of Doc Freeman's. The temporary main would run underground from the Stone Avenue connection to the south, cross the Ocean Alexander driveway then exit the ground and run along the ivy-covered slope, continue west on a support structure along the wall face, under the wood and concrete sidewalk structures, then back into open air across the marina. Continuing past the marina, the pipe would run under the concrete sidewalk at Doc Freeman's, past the work limits, where it would turn north and connect to the existing water main. Domestic and fire services would be reconnected, and a new fire hydrant will be necessary for both temporary and restored condition to meet fire department requirements. So, hydrants will be set at each end of the project instead of one in the middle. Provisions will be included for routine inspection and maintenance.

The water system, including fire valves, meters and hydrant(s) will be restored to approximately the same locations as existing. Like the side sewers, provisions will be included in the wall design for service penetrations and potentially also hangers for the pipes bridging across to the customers, as well as for trenching restored services through the improved soil mass. Services through the soil behind the fascia wall may require casings to limit future potential disturbance to the engineered fill. This project provides an opportunity to upgrade from the old cast iron pipe with lead joints to a new ductile iron pipe. Customer services, some of which are plastic, can be replaced with ductile iron for the larger fire services and copper for the smaller domestic services.

Sanitary Sewer

SPU maintains an 8” diameter concrete sanitary sewer through the site, flowing from west to east. Because sewer is grade-sensitive, both the temporary system and restored sewer must reflect proper grades to match the upstream and downstream connection points.

The temporary sewer concept depicted in Figure 5 includes a temporary lift station constructed by placing a properly configured MH into the flow line of the sewer at the west edge of the work area. Station sizing will be based on flows determined during design. This lift station would be powered from the adjacent SCL pole. The force main out of the lift station would run south toward Doc Freeman’s and then turn east to run south of the existing wall face in an HDPE pipe, with side sewers connected through backflow-valve-protected tees on the temporary main. The force main would be racked with the other temporary utilities, with proper care given to its separation from the water supply pipe. The force main would outfall to an existing sewer MH to the east of the work zone, likely a MH added to the sewer line west of Stone Way, to avoid construction disruptions to Stone Way This force main alignment and subsurface connection will require surface restoration for the temporary installation and then for a permanent restoration after the temporary facilities are removed.

It may be feasible to construct the restored sewer in the new northerly alignment and then complete the ground improvement while protecting this new sewer in place. While that would maintain sewer main flow except during short cut-over periods, lift stations and associated piping would be necessary for the customers south of the work area.

The restored sewer configuration will likely change the sewer alignment by adding a MH as an angle point near the west end of the work area, paralleling the north right of way at an offset of three or four feet, angling at another MH near the east end of the work area, and reconnecting to the existing sewer near Stone Way.

Side sewers within the work area all appear to connect to the south side of the main. Investigation during design will reveal elevations for reconnections and whether these are pumped or gravity side sewers. The new wall will include penetrations and possibly support accommodations to hang the pipes under the sidewalk for the crossing from the buildings. Services through the soil behind the fascia wall may require casings to limit future potential disturbance to the engineered fill.

Protecting the Sewer in Place

The alternative to maintain the sanitary sewer main in place during soil improvement operations, as opposed to its temporary relocation, must address these primary considerations:

1. Risk of sewer main structural damage from the ground improvement operation
2. Displacement from the existing line and grade, and
3. Grout intrusion with potential for grout to enter into SPU's sewer system

The sanitary sewer is approximately fourteen feet below the road surface. Each ground improvement alternative proposes to remove approximately the top eight feet of soil to reduce the soil pressures on the existing retaining wall. Ground improvement equipment would be moved into this lowered area, which would provide effective containment for a relatively messy operation involving grout and, in the case of jet grouting, grout return volumes.

Jet grouting uses relatively high pressures to inject a cement mixture into the ground. Experience has shown that jet grout is likely to find available weaknesses or gaps in underground utilities. The pipe was installed in approximately 1952, so has been subject to the influences of resting in liquefiable soil for nearly 70 years. Side sewers extend to the south from the main, serving customers on the south side of the retaining wall. Because these side sewers almost certainly extend up through the top eight feet of soil to be removed, they would be exposed and impossible to protect during ground improvement. The plan described for temporary relocation would leave the tees or connection points at the main as weak points with potential for grout entry. Every pipe joint also poses a potential entry point for jet grout.

One method to protect the pipe in place while preventing grout intrusion might be to line the sewer pipe with a UV-cured or thermally-cured sewer pipe liner. These are common technologies with which SPU has extensive experience. Employing this method, the side sewers would be removed and the liner would extend through the work zone with no openings. There are two sewer MHs within the work zone which present additional physical obstacles to be addressed. Methods to protect or rebuild these structures and to work around them during soil improvement would require significant constructability review. After the ground improvement was completed, reinstallation of side sewers would have to be closely coordinated with the backfill sequence.

Jet grouting has significant potential to lift or “heave” the gravity sewer vertically and/or horizontally. Horizontal movement is mostly a concern if it opens a pipe joint or if the displacement creates pipe joint offsets that can affect the pipe maintainability or flow characteristics. Vertical heave can create a high point in the pipe that would have severe negative effects on the pipe flow and could require sewer replacement. A previous SDOT project (Elliott Bay Seawall Project) resulted in heave of major sewer elements exceeding four inches.

Deep soil mixing uses a spinning head to create a column of improved soil. Jet grouting can be reliably designed to create columns under and encasing utilities, while deep soil mixing is more like a large drill bit that precludes maintaining any utilities in the column alignment. Deep soil mixing has a similar potential for grout to enter and heave pipes but pressures are likely lower than jet grouting.

Both methods of ground improvement pose significant risks to successful protection in place of the existing sewer. If either grout entry or heaving occurred during construction, any potential savings for maintaining the sewer would be lost and the schedule would be delayed while the project team investigated the issue, designed the replacement, removed the existing sewer and then installed the replacement sewer. The temporary relocation approach described above eliminates both the risk of grout entering the sewer system and the potential for heaving the pipe. Based on this range of considerations, it is recommended to avoid a protect-in-place strategy for the sewer main.

Storm Drainage

SPU does not appear to have records of any formal drainage systems within the project area, although inlets, catch basins and outfalls are visible. Current drainage systems, including one private outfall, appear to outfall directly to Lake Union at multiple points.

Temporary drainage during construction must address groundwater and rainwater falling within the soil improvement area and surface water drainage around the construction zone. Treatment and discharge systems must address this construction-phase water treatment and disposal.

Restored drainage must address immediate roadway drainage as well as the structure design addressing groundwater influence from uphill. SDOT must work with SPU to determine appropriate collection, treatment and an outfall location for the storm water. The structural design may need to incorporate weep holes or wall drains to address groundwater.

SPU has stated that stormwater detention will not be required but treatment by means of a solution such as PerkFilter catch basins with internal cartridges must be included.

The drainage can be connected to the 54” storm outfall pipe at Stone Way. Figure 9 depicts a schematic storm drainage concept. Actual inlet and storm main locations will depend upon the road surface and the overall utility design.

Electrical Power

Seattle City Light (SCL) maintains four wooden poles within the project area. These poles support 26 kV aerial distribution power entering the site from the east and terminating aerially at the pole in front of Doc Freeman’s, within the soil improvement area. The distribution lines end at transformers that supply lower voltage customer power through pole risers connected to an underground supply to Doc Freeman’s and an aerial feed to a service at the corner of Doc Freeman’s.

SCL supplies three different customer voltages (120V, 240VA and 480V) within the project area, all from transformers on the poles. Three of the four poles have transformers. Except for the Doc Freeman’s underground service, all of the services are aerial strikes at customer weatherheads on or near the north faces of the buildings.

Pole anchors are connected either to the existing wooden wall or to ground anchors just inside the wall. One pole anchor supports a guy wire to the north for a pole on the south side of N 34th Street, resisting the force of a wire heading north on Woodland Park Avenue N.

The temporary service concept depicted in Figure 6, 6A and 6B includes a reconfiguration of the aerial distribution system that eliminates 26 kV distribution throughout both the soil improvement zone and the rack-mounted temporary utility pathway. Only customer services would run through the temporary utility configuration, entering from each end and running only as far as the connection point for each service.

To feed distribution power to the west end and to west of the work area, SDOT would obtain an aerial easement across private property west of the Millworks Building. SCL would set a temporary pole in an alignment to be determined during design and run aerial power from N 34th Street to this temporary pole and then east to another temporary pole to be installed in the current aerial alignment set west of the work zone. Transformers and pole risers would move to this pole to serve Doc Freeman’s aerial and underground services.

Only individual customer services would enter the work zone from the east. SCL would set another temporary pole near Stone Way to support transformers for services to run to the three easterly customers (Ocean Alexander, Seattle Boat Share and Lake Union Waterworks). The services would drop down this temporary pole in risers and run underground with the telecom services to the west, cross the Ocean Alexander driveway in a joint trench with water, sewer and gas, and then run to a point below each existing aerial strike point, then up a riser affixed to the building face to a weatherhead-to-weatherhead connection. Alternatively, SCL may consider setting a temporary surface-mounted transformer just west of Stone Way and running services to the customers east of the marina. Design of the temporary distribution and services will require close coordination and involvement with SCL engineers and SCL will perform the construction and electrical work.

Once the temporary power and telecom services are in place, the four existing poles can be cut near the ground. Pole removal prior to installation of a containment wall is not a good idea, as the disturbance may damage the existing wall before the containment wall is in place or the soil burden removed. The wall contractor can remove the pole bases.

Once the wall is completed and backfilled, new poles can be placed and the electrical services reestablished. Provisions for pole anchors can be included in the wall design or as independent elements, if the locations are coordinated with the wall design.

Telecommunications

Century Link and Comcast have telecommunication facilities in the project area. Each maintains aerial distribution and customer services, attached to SCL poles. Century Link is a co-owner of the poles with SCL.

The temporary service concept depicted in Figure 7 is similar to the water and sewer approach. Existing distribution lines and service connections are to be realigned around the active construction area. To facilitate this, temporary conduit with telecom lines will be rerouted at the east and west ends of the wall structure and run along the water side of the existing retaining wall in a rack configuration with other utilities, maintaining proper clearance and separation. On the west end it may be necessary to shift the connection point on the aerial line to the west with a bridle to change the wire entry angle to gain horizontal separation from construction equipment to minimize potential for damage. Temporary service connections would be routed up the buildings to each overhead connection as necessary. Supply and services are to be restored to essentially their current locations upon completion of construction.

Natural Gas

PSE maintains a system of distribution and service lines through the project area, with their 2" steel intermediate pressure main approximately 16 feet north of the retaining wall. PSE has customer services to 999 North Northlake Way (Doc Freeman's) and 1115 North Northlake Way (Ocean Alexander). PSE's service to 1101 North Northlake Way (Lake Union Waterworks) has been retired. The gas base map, together with field observation of paint marks and fresh asphalt support this information.

The temporary service concept depicted in Figure 8 proposes to relocate existing natural gas distribution lines and service connections outside of the active construction area. To facilitate this, temporary supply will be rerouted at the east and west ends of the wall structure and run along the water side of the existing retaining wall with other utilities in a rack configuration, maintaining required clearance and separation. Services will be cut over to the temporary supply, allowing all existing lines to be removed from the excavation zone. Note that PSE records show no occurrence of a line running east-west to 1100 North Northlake Way and beyond along the north margin of the North Northlake right of way, although these are shown in the base map provided by SDOT. Gas distribution and services are to be restored to essentially their current locations – at a depth above the top of the ground improvement - upon completion of construction.

The new wall will include penetrations and, possibly, support accommodations to hang the pipes under the sidewalk for the crossing from the buildings. Services through the soil behind the fascia wall may require casings to limit future potential disturbance to the engineered fill.

Differentiations in Utility Work Depending on Wall Replacement Method

COWI analyzed three primary wall type alternatives. Alternative 1, Cantilevered Wall, included soldier pile, secant pile and king pile options. Alternative 2, Anchored Wall, included soldier pile and king pile options with tie rods to deadman anchors or anchor piles. Alternative 3, Ground Improvement, includes non-structural fascia panels. Each wall replacement alternative presents nearly identical challenges for utilities during construction but the structural analysis recommends proceeding with Alternative 3, consequently it is the focus of this Utility Report. The existing retaining wall must have the soil pressure reduced, requiring removal of approximately eight feet of soil. Except for the sanitary sewer main, this removes the soil encasing buried utilities and the soil supporting the utility poles supporting aerial utilities. In all proposed alternatives the best approach is to provide temporary utility relocations outside the ground improvement zone.

The structural attachment method for the non-structural fascia panels must be considered in all utility designs. MSE wall straps or other support methods similar to tiebacks pose potential spatial challenges for installing and maintaining utilities. The fascia panel design must similarly recognize the utility requirements for installation and future maintenance access.

Work Required in Subsequent Phases

Several utility-specific work elements are necessary to support the detailed design and finish the plans.

1. Survey to locate existing surface utilities including hydrants, water valves, water meters, poles, pole anchors, guy wires, bollards, maintenance holes, gas valves and other visible features.

2. Measurements must be made under the sidewalks and along the fronts of the buildings and in the marina to identify the type, size, location, elevation and alignment of utilities including water, sewer, gas, storm drainage, telecommunications and other items found.

3. Survey must collect the locations of aerial utility connection points for electrical power and telecommunications.

4. Building entrances and access points must be surveyed, including doors both large and small, as well as windows, gates, ramps, stairs, mailboxes and other items related to resident or building occupant access, in order to avoid blocking these access points with temporary or restored utilities.

5. Items protruding beyond the building faces must be surveyed, including signs, awnings, crane rails, lighting and weatherheads.

6. Topographic survey must extend north to at least the south curb of N 34th St from the east margin of Stone Way N to approximately Troll Avenue N, to include poles, sidewalks, roadway and roadway markings, parking striping, parking pay boxes and all visible utilities.

7. Coordination with SCL must include incorporation of poles and pole guy anchors.

8. Coordination with SPU and PSE must include incorporation of wall penetrations and potentially utility hanger provisions for services crossing under the sidewalk.

9. Define, prepare and acquire Temporary Construction Easements.

Construction Cost Estimate

The utility cost estimate is based on installation of temporary utilities as described in the report, with an alternative for protecting the sewer in place. How a bidder would price the complexity of working around the sewer is unclear, but it would certainly present a spatial and scheduling challenge. A lump sum bid item has been added for working around the sewer and the cost of a small sewer relining project has been included.

Cost estimates are based on recent bid items from SDOT projects, including the S Lander St Grade Separation and the Waterfront Seattle Main Corridor, which both include major utility relocations as part of SDOT roadway projects. Both projects include major structural elements that affect and are affected by utilities. Not all bid items have direct parallels to the N Northlake way project, so judgment has been applied to address the unique nature of the project. The Elliott Bay Seawall Project from 2014-2017 included complex temporary utility systems which, by the time the work was complete, incurred nearly three times the cost of the permanent utilities. That project had many work zones, which are not expected on this project. However, a contractor may propose a work approach that could increase utility costs, so each bid item is estimated higher than normal. Cost estimates are in 2019 dollars and must be revised during design.

In the cost estimate on the following page, the line items for protecting the existing sewer in place and for relining that sewer are shown as separate line items and then also shown as totaling with the services and lift station. Maintenance of sewer service during construction would select one option or the other. For the sake of simplicity, all potential temporary sewer work is shown as a total cost, although it may be less than this total.

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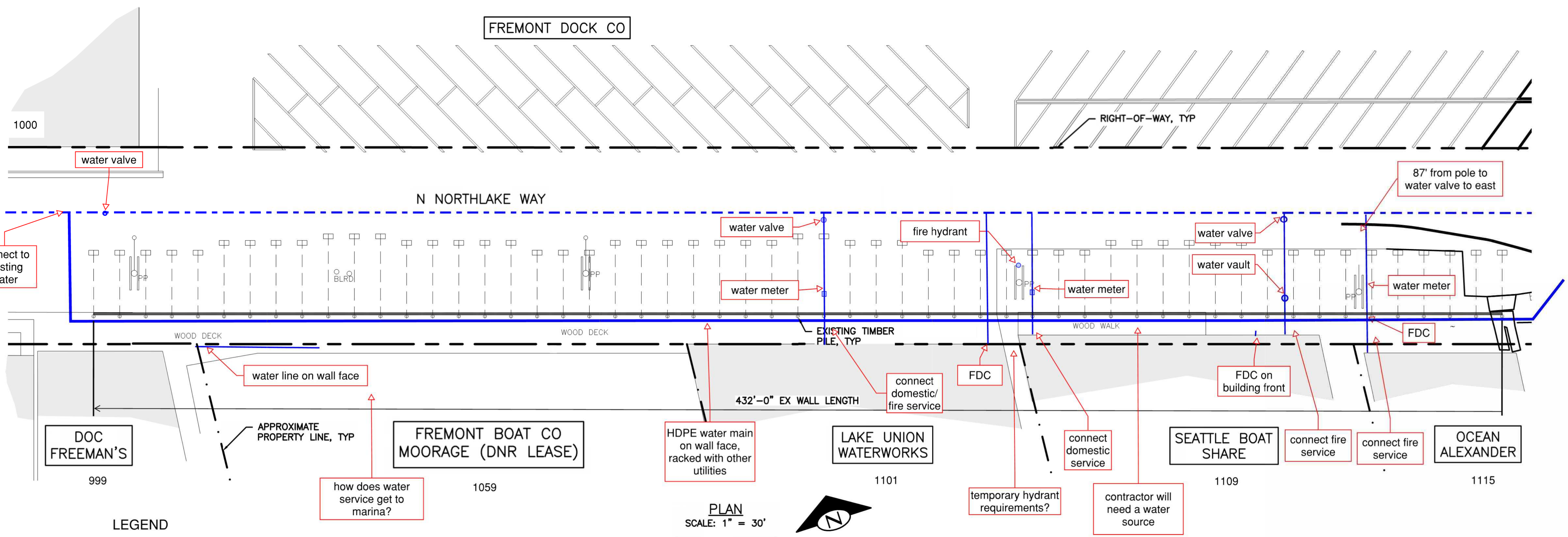
Cost Estimate by Utility Type

Temporary Relocations	Owner	quantity	units	price	total	Notes
temporary gas relocation	PSE	n/a			all costs belong to the provider	
temporary comm relocation	Century Link	n/a			all costs belong to the provider	
	Comcast	n/a			all costs belong to the provider	
temporary power relocation	SCL					
poles		3	ea	$ 5,000	$ 15,000	
underground/temp conduits		1000	LF	$ 100	$ 100,000	
services		9	ea	$ 3,000	$ 27,000	
6 each transformers or 1 pad-mount		6	ea	$ 7,000	$ 42,000	
34th guy anchor		1	ea	$ 2,000	$ 2,000	**subtotal**
remove temporary system		1	LS	$ 25,000	$ 25,000	**$ 211,000**
temporary water relocation	SPU					
8" HDPE water main		600	LF	$ 400	$ 240,000	
hydrant		2	ea	$ 2,000	$ 4,000	
services		6	ea	$ 2,000	$ 12,000	**subtotal**
remove temporary system		1	LS	$ 10,000	$ 10,000	**$ 266,000**
temporary sewer relocation	SPU					
services/temp lift stations		1	LS	$ 100,000	$ 100,000	
3 small grinder pump stations and 1 larger station in road at west end						
similar to typical bypass pumping bid item						
alt. cost to work around lined sewer protected in place		1	LS	40000	$ 40,000	**subtotal**
sewer relining to protect sewer in place		450	LF	40	$ 18,000	**$ 158,000**
storm drainage		n/a			temporary addressed by TESC plan	
					total temporary utility cost	**$ 635,000**
Restored Services	**Owner**	quantity	units	price	total	Notes
gas restoration		n/a			all costs belong to the provider	
comm restoration		n/a			all costs belong to the providers	
power restoration						
wood poles with anchors as needed		4	ea	$ 5,000	$ 20,000	
replace aerial 26 kV		600	LF	$ 250	$ 150,000	
reconnect underground lines and remove temp lines		1	LS	$ 25,000	$ 25,000	
reconnect services		7	ea	$ 4,000	$ 28,000	
transformers		9	ea	$ 7,000	$ 63,000	
reconnect guy anchor to 34th pole		1	LS	$ 3,000	$ 3,000	**subtotal**
street light luminaires		3	ea	$ 3,500	$ 10,500	**$ 299,500**
water restoration						
8" DIP water main		450	LF	$ 400	$ 180,000	
hydrant		1	ea	$ 10,000	$ 10,000	
services		6	ea	$ 6,000	$ 36,000	**subtotal**
gate valves		2	ea	$ 2,000	$ 4,000	**$ 230,000**
sewer restoration						
8" sewer main		450	LF	$ 500	$ 225,000	
sewer MH		2	ea	$ 10,000	$ 20,000	**subtotal**
side sewers		3	ea	$ 8,000	$ 24,000	**$ 269,000**
storm drainage						
12" storm drain main		450	LF	$ 225	$ 101,250	
Perk Filter Catch Basin w/ 4 - 18" cartridges		3	ea	$ 25,000	$ 75,000	**subtotal**
storm CB		3	ea	$ 2,500	$ 7,500	**$ 183,750**

Estimate does not include:	**total temporary utility cost**	**$ 635,000**
1. design costs	**total restored utility cost**	**$ 982,250**
2. easement and TCE costs	**combined temporary and restored utility cost**	**$ 1,617,250**
3. escalation		
4. contingency		
5. detailed breakdown of shoring, bedding, backfill, and similar utility bid items		
6. sales tax if applicable		

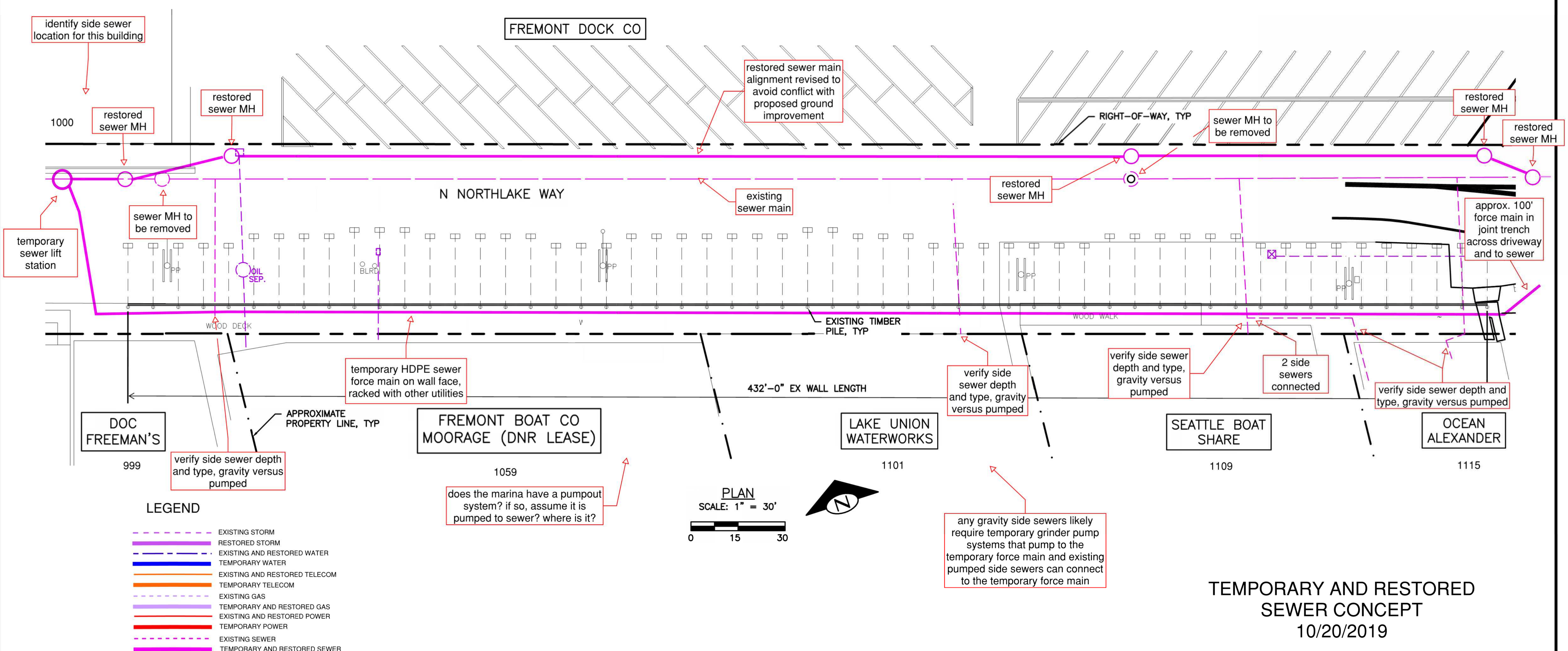


LEGEND

- EXISTING STORM
- RESTORED STORM
- EXISTING AND RESTORED WATER
- TEMPORARY WATER
- EXISTING AND RESTORED TELECOM
- TEMPORARY TELECOM
- EXISTING GAS
- TEMPORARY AND RESTORED GAS
- EXISTING AND RESTORED POWER
- TEMPORARY POWER
- EXISTING SEWER
- TEMPORARY AND RESTORED SEWER

TEMPORARY AND RESTORED WATER CONCEPT
10/20/2019

COWI SG3	City of Seattle **Seattle Department of Transportation** ORDINANCE NO. N/A APPROVED. N/A FUND: N/A SCALE: NTS INSPECTOR'S BOOK. N/A	N NORTHLAKE WAY RETAINING WALL – ALTERNATIVES ANALYSIS SEATTLE, WA EXISTING CONDITIONS	FIGURE 4



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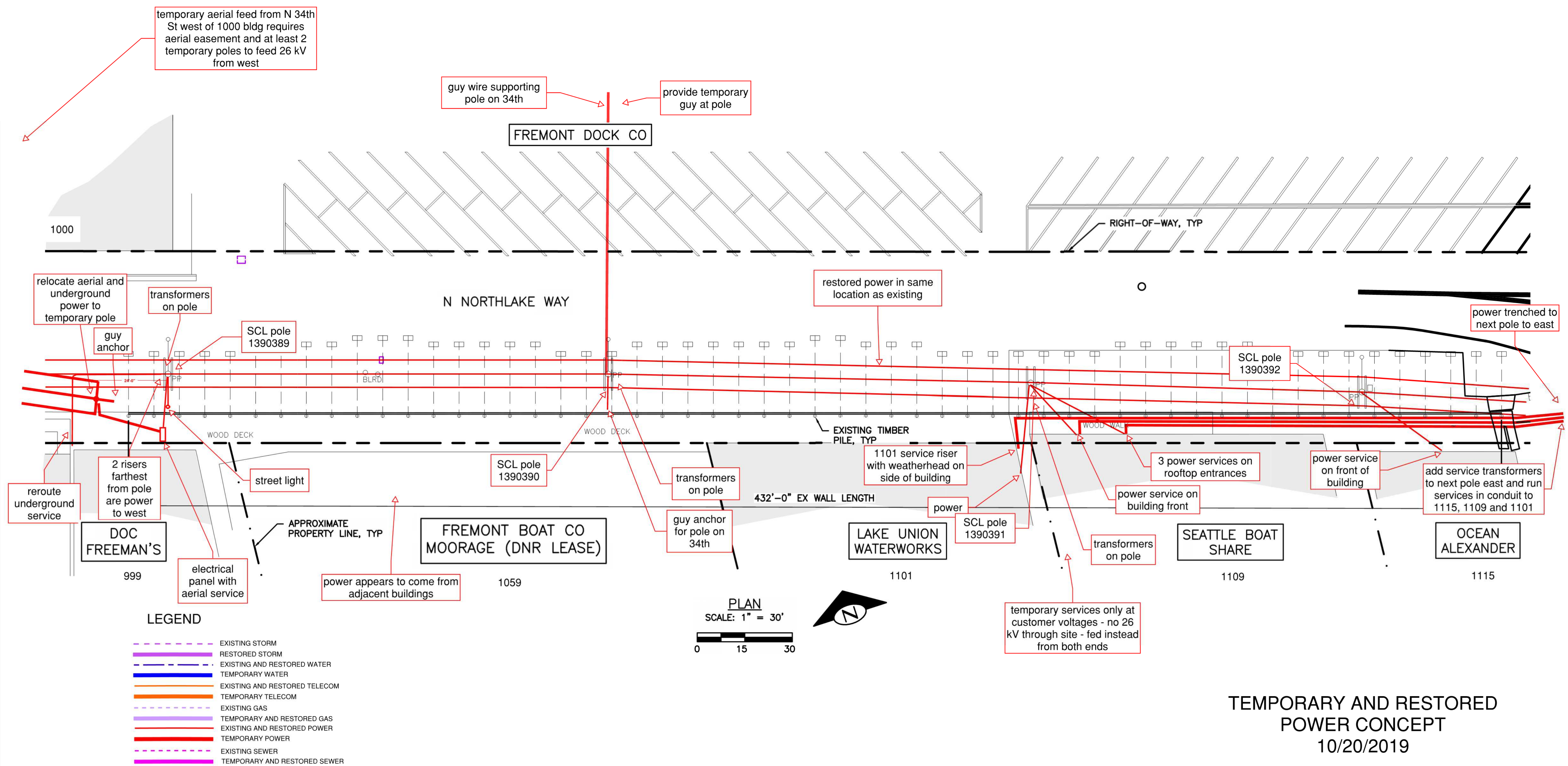
N NORTHLAKE WAY RETAINING WALL – ALTERNATIVES ANALYSIS
SEATTLE, WA

EXISTING CONDITIONS

FIGURE 5



TEMPORARY AND RESTORED POWER CONCEPT
10/20/2019

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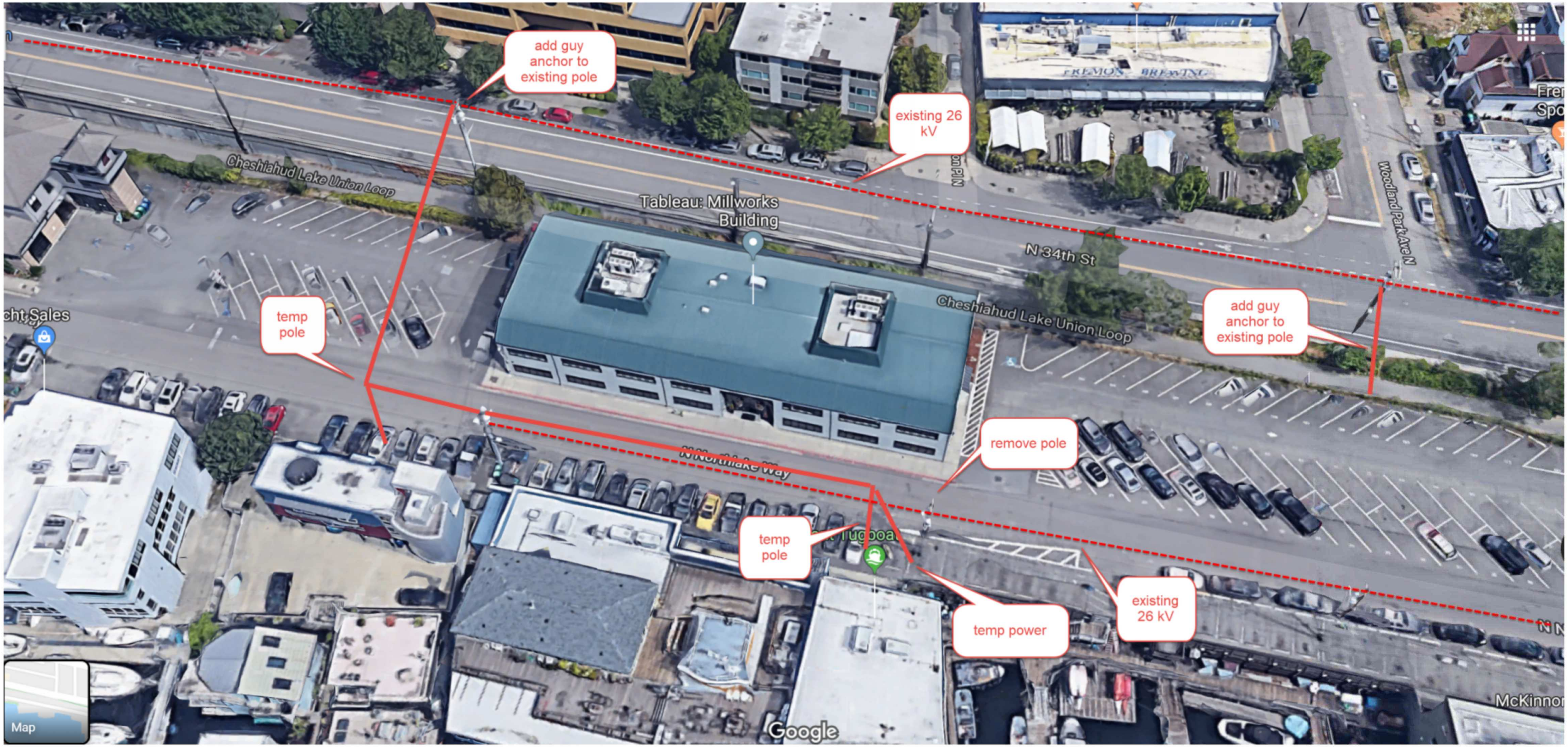
N NORTHLAKE WAY RETAINING WALL – ALTERNATIVES ANALYSIS
SEATTLE, WA

EXISTING CONDITIONS

FIGURE
6



TEMPORARY POWER CONCEPT
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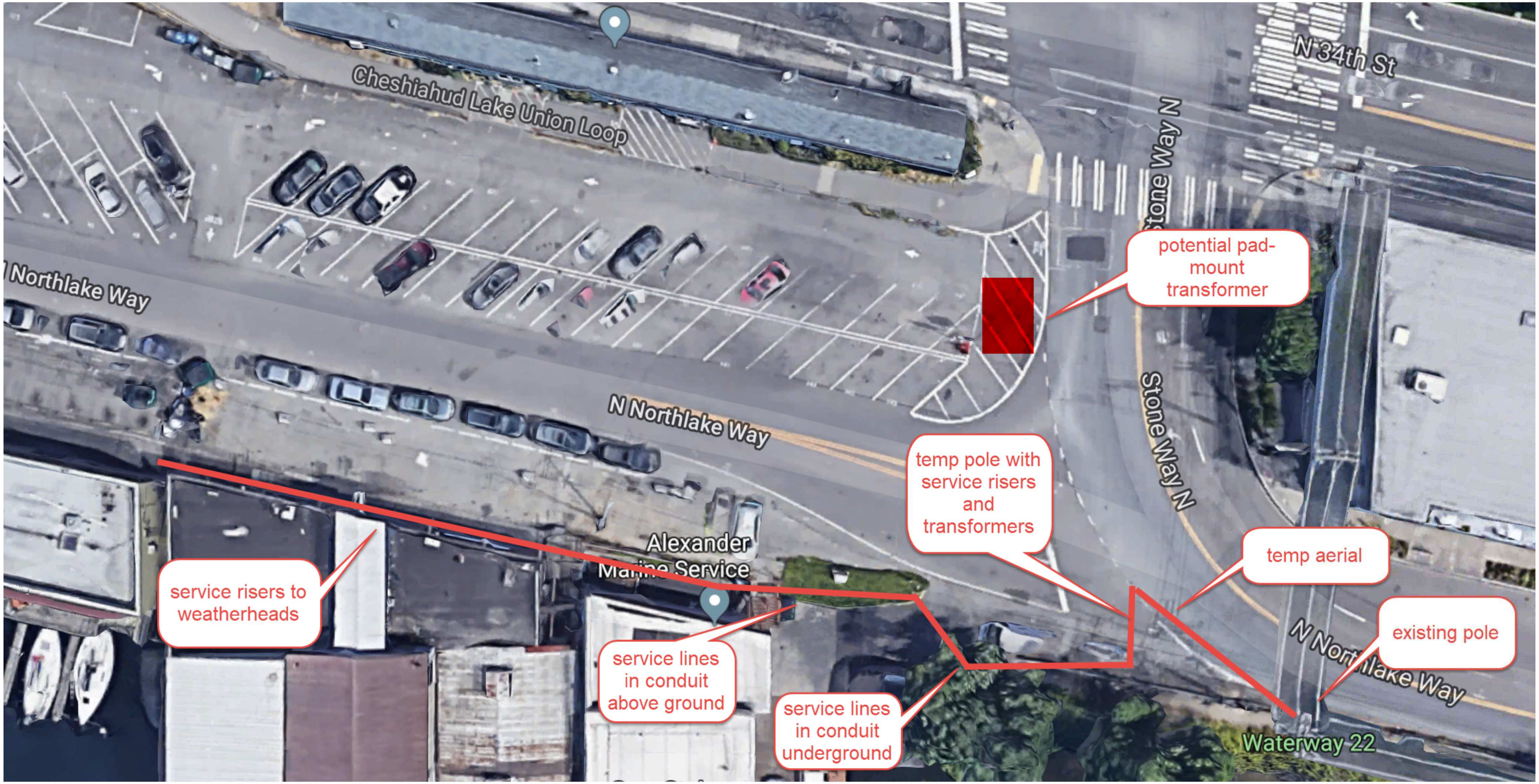
N NORTHLAKE WAY RETAINING WALL – ALTERNATIVES ANALYSIS
SEATTLE, WA

EXISTING CONDITIONS

FIGURE
6A



TEMPORARY POWER CONCEPT
10/20/2019

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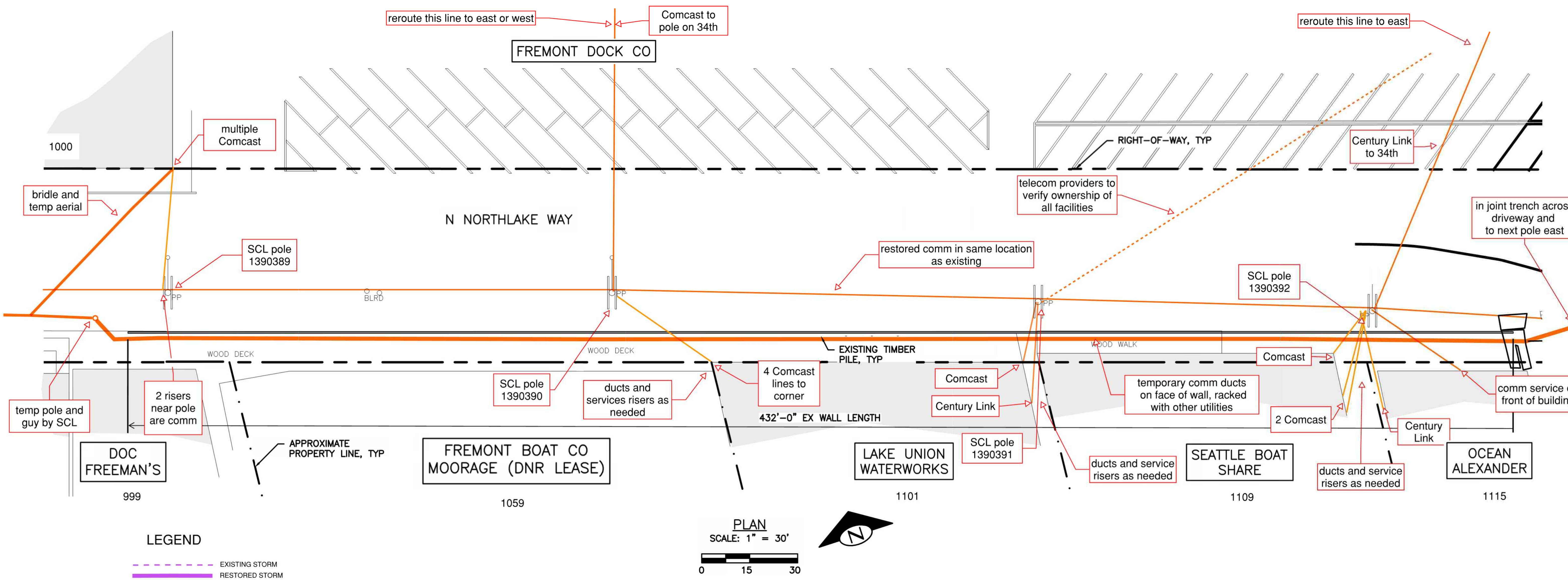
N NORTHLAKE WAY RETAINING WALL – ALTERNATIVES ANALYSIS
SEATTLE, WA

EXISTING CONDITIONS

FIGURE
6B



LEGEND

- EXISTING STORM
- RESTORED STORM
- EXISTING AND RESTORED WATER
- TEMPORARY WATER
- EXISTING AND RESTORED TELECOM
- TEMPORARY TELECOM
- EXISTING GAS
- TEMPORARY AND RESTORED GAS
- EXISTING AND RESTORED POWER
- TEMPORARY POWER
- EXISTING SEWER
- TEMPORARY AND RESTORED SEWER

TEMPORARY AND RESTORED
COMM CONCEPT
10/20/2019

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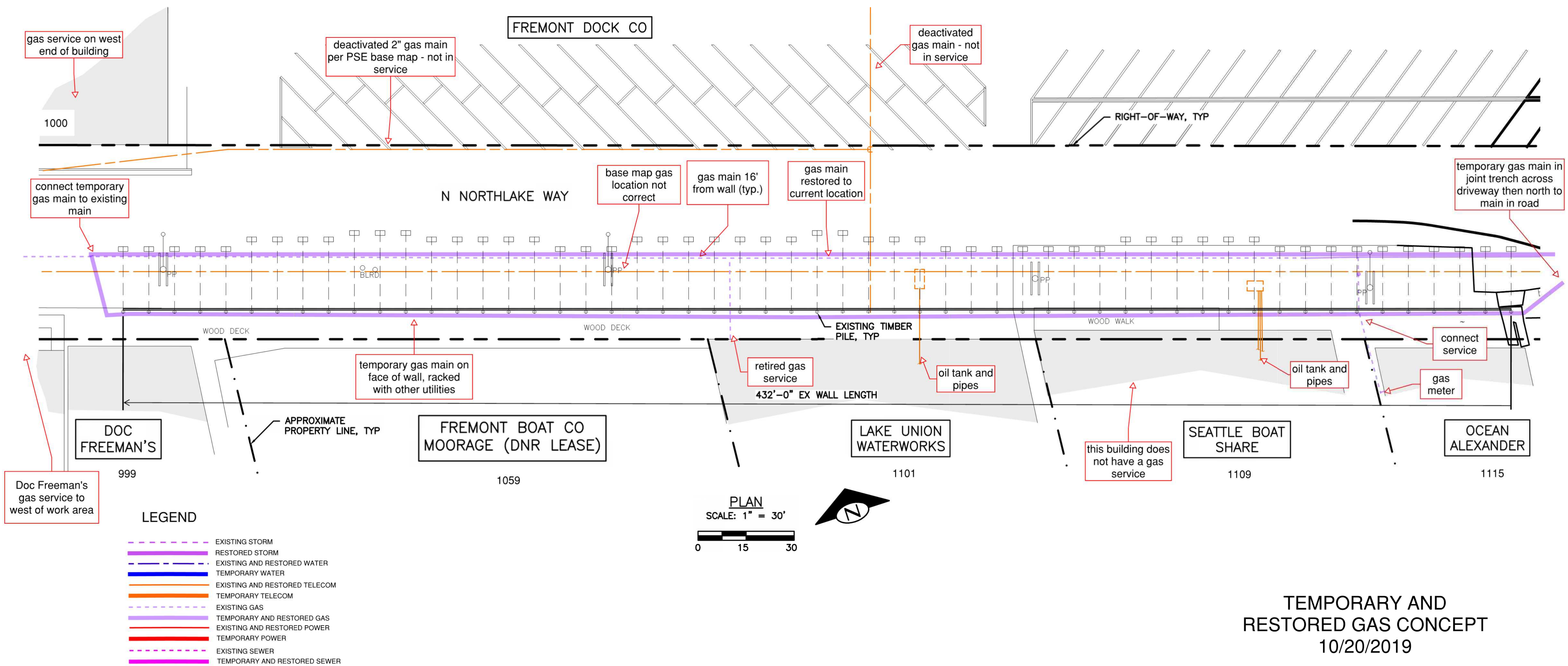
N NORTHLAKE WAY RETAINING WALL – ALTERNATIVES ANALYSIS
SEATTLE, WA

EXISTING CONDITIONS

FIGURE
7



TEMPORARY AND RESTORED GAS CONCEPT 10/20/2019

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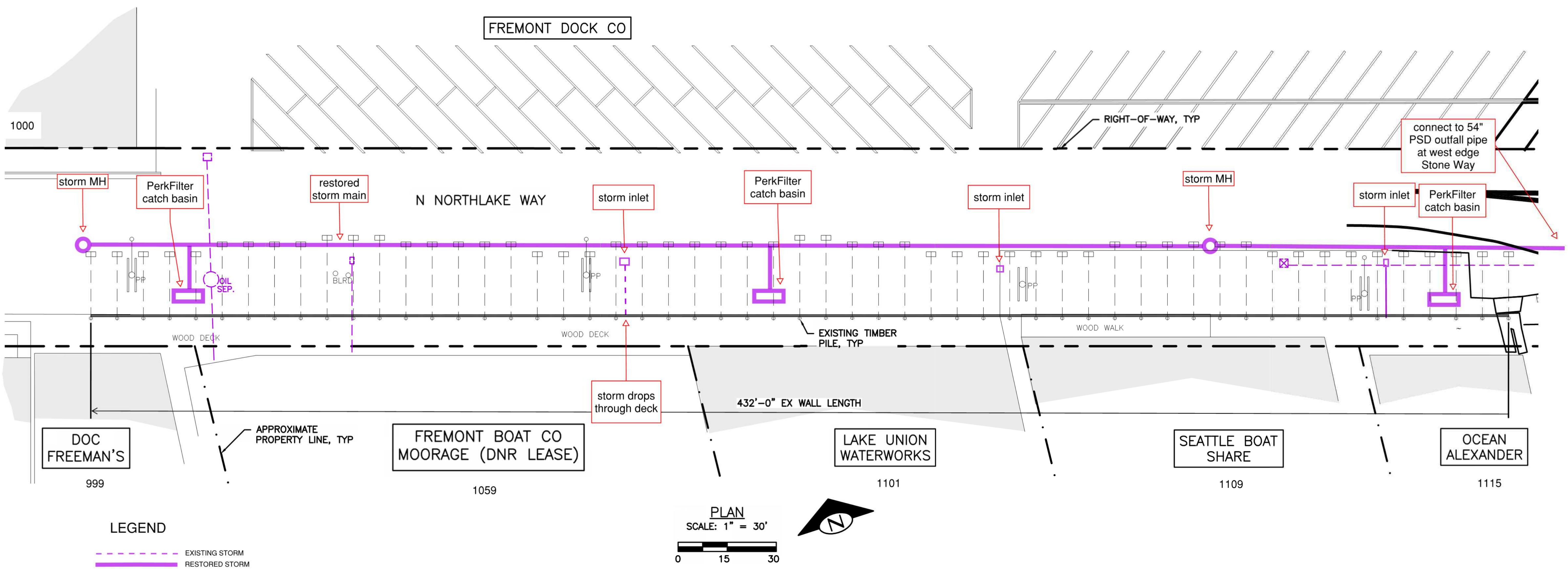
N NORTHLAKE WAY RETAINING WALL – ALTERNATIVES ANALYSIS
SEATTLE, WA

EXISTING CONDITIONS

FIGURE 8



LEGEND

- EXISTING STORM
- RESTORED STORM
- EXISTING AND RESTORED WATER
- TEMPORARY WATER
- EXISTING AND RESTORED TELECOM
- TEMPORARY TELECOM
- EXISTING GAS
- TEMPORARY AND RESTORED GAS
- EXISTING AND RESTORED POWER
- TEMPORARY POWER
- EXISTING SEWER
- TEMPORARY AND RESTORED SEWER

EXISTING AND RESTORED STORM CONCEPT
10/20/2019

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N NORTHLAKE WAY RETAINING WALL – ALTERNATIVES ANALYSIS
SEATTLE, WA

EXISTING CONDITIONS

FIGURE
9