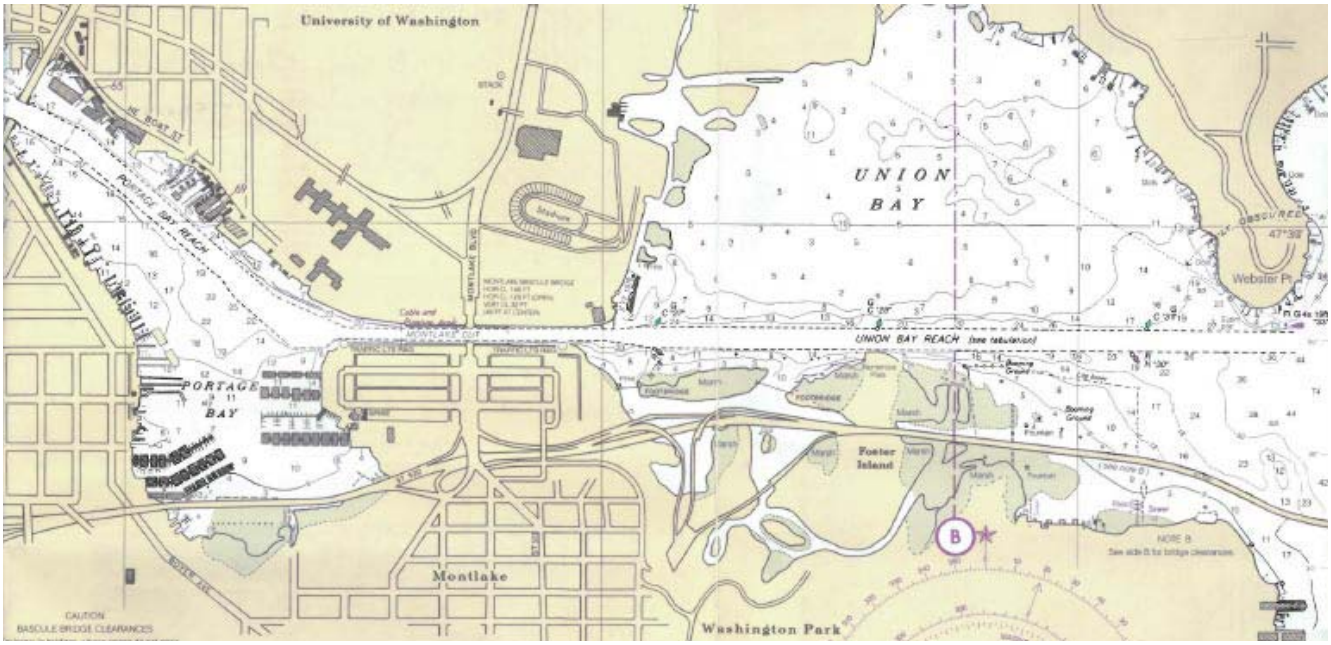
SR 520 Project
Montlake Cut Tunnel
Expert Review Panel Report
Executive Summary



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1. EXECUTIVE SUMMARY

1.1. INTRODUCTION

As part of the SR 520 Mediation process required by the Washington State Legislature, an alternative was developed called “The Parkway Plan,” also known as “Alternative K.” This alternative envisions an interchange connection from the SR 520 mainline just east of Montlake, to the University of Washington area via a tunnel under the Montlake Cut.

The tunnel was described in a report by COWI, the Mediator’s engineering and construction consultant, released March 17th, 2008 and titled “Tunnels at East Montlake and the Arboretum, Conceptual Design and Cost Estimate, Part 1.” COWI had previously examined several tunnel methods, including Cut-and-Cover, Immersed Tunnel, Bored Tunnel and Sequential Excavation. The March 17th report focused on an immersed tunnel type of construction for a tunnel passing under Union Bay approximately 200 feet east of the Montlake Cut. The tunnel included two 12 foot wide travel lanes in each direction, four foot shoulders on each side and provision for wider shoulders to permit the required sight distance on the inside of the curve. A plan view of this alignment is shown in Figure 5 – “General arrangement of the COWI Immersed Tunnel Proposal” in the body of the report.

The immersed tunnel construction proposed by COWI would have environmental effects to the Montlake area, Montlake Cut and Union Bay. Tribal fishing rights would also need to be considered with the COWI proposed method. The mediation panel asked for consideration of other tunneling options that would reduce these effects and consider tribal fishing rights. The report responds to that request.

1.2. ENVIRONMENTAL CONSIDERATIONS

The Expert Review Panel considered environmental and community impacts identified during their assessment of potential construction methods and alignments. The panel met with mediation participants to hear the specific concerns of the neighborhoods and individuals.

Environmental topics include:

- Fisheries and fish habitat
- Wetlands and riparian vegetation
- Historic and cultural resources
- Tribal rights
- Parks and recreation

The list of concerns and their relationships to the tunneling methods and alignments, with potential avoidance, mitigation and minimization strategies, are listed in Table C in the body of the report. These concerns, with the associated avoidance, mitigation and minimization strategies and issues, will be a strong determinant of acceptability of tunneling methods and possible alignments.

Fish and fish habitat protection are strong considerations and severely restrict available work windows in the water and on the near shore. Table D lists salmonid migration timing in order to establish possible work-windows in the Montlake Cut and Union Bay.

1.3. TUNNELING METHODS CONSIDERED

Three tunneling methods were identified as feasible construction methods for a tunnel that connects the SR 520 mainline and Pacific Street. These methods are:

1. Immersed tunneling method: A concrete or steel tube or tunnel would be constructed in an adjacent "dry dock." The dry dock would then be flooded and the immersed tunnel unit floated into position and lowered into an excavated trench across the Montlake Cut or Union Bay shipping channel depending on the alignment. The width of the concrete or steel tunnel would be approximately 80 feet.
2. Bored tunneling method: A tunnel boring machine (TBM) would be directed under the Montlake Cut or just east in Union Bay, to create two parallel tunnels. Typical cross-sections of each tunnel are shown in the body of the report. The out-to-out width of the tunnels plus a center earth support pillar would be approximately 150 feet.
3. Sequential excavation method (SEM), including ground stabilization measures such as ground freezing: Sequential excavation would be directed under the Montlake Cut or nearby in Union Bay to create two parallel tunnels. Typical cross-sections are shown in the body of the report. The out-to-out width of the tunnels plus a center earth support pillar would be approximately 150 feet.

Cut-and-cover construction will be necessary in combination with the three tunnel options listed above. Cut-and-cover construction will be required for the approach ramps to the tunnel on both the south and north sides of the Montlake cut. Cut-and-cover construction for the approach areas will allow the tunneling to begin at a suitable elevation and in appropriate geotechnical material.

Details of the tunneling methods considered are given in the body of the report. Typical examples and cross-sections of the three tunneling methods are shown in Figures 1-3.

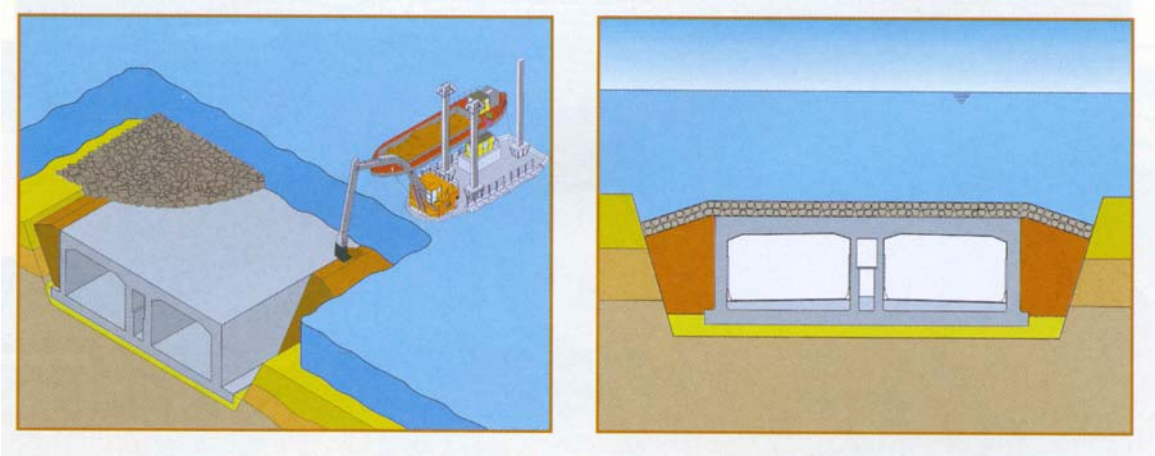


Figure 1 - Immersed Tunnel Construction (General)

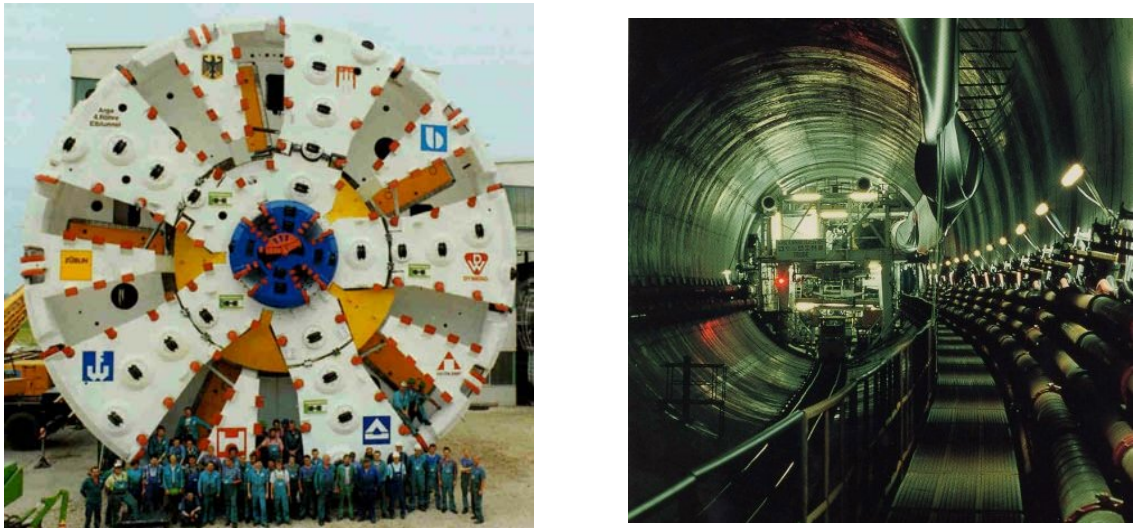


Figure 2 - Tunnel Boring Machine (Elbe River, Hamburg)

Figure 3 – Sequential Excavation Method (Beacon Hill Tunnel, Seattle)

All tunneling methods require adjacent cut-and-cover sections of variable lengths. Several cut-and-cover construction scenarios are feasible as described in the report. Only the immersed tunnel method will require cut-and-cover activities immediately adjacent to the shoreline and through designated wetlands on the south side of the Montlake Cut. The bored tunneling or sequential excavation methods can avoid these sensitive areas.

The three tunneling alternatives were evaluated in consideration of potential environmental impacts, expressed community issues and concerns, site constraints, highway requirements and standards, construction means and methods, safety issues and, geotechnical conditions.

1.4. GEOTECHNICAL CONSIDERATIONS

Suitable geotechnical conditions are necessary for the tunneling and sub-surface structures. Data from nearby projects indicate that the soils at the east end of the Montlake Cut are likely to be favorable to tunneling, as they consist of a mix of hard to very dense clay, till, sand, and gravel with water levels somewhat higher than the lake levels. The tunnel boring or sequential excavation methods must be located in these good soils with approximately one tunnel diameter of competent material over the crown of the tunnels. In addition, the tunnel boring and SEM require a width of one tunnel diameter horizontally between the tunnels. The immersed tunnel does not require this top cover or horizontal allowance.

In Union Bay, the depth to the top of the competent soils increases moving east from the Montlake Cut. In Union Bay these competent soils are covered with an increasing thickness of very soft peat and very soft clay reaching over 100 feet thick. These soil conditions extend to the north in Union Bay and are not suitable for tunnel boring or sequential excavation. The conditions would also not be suitable for use as a foundation beneath the sunken tube or cut or cover structures. These concerns have been taken into consideration for the alignments and specific tunneling methods discussed in the report.

It should be noted that the available subsurface data on which the report is based is derived from several borings within 500 feet of the various alignments. These borings are of varying quality and reliability and span over 50 years. Due to the wide variety of sampling methods, the brevity of many of the classifications, and the lack of information on reference elevation datums, an accurate portrayal of the various glacial and interglacial soils is not possible at this time. While the conclusions of this report are believed appropriate, the specifics of the soil data – depths, soil types, strengths etc. need to be verified for further work to be done.

See Plan of Alignment B (Modified). Contours representing top of competent material will be discussed in the Mediation meeting presentation.

1.5. ALIGNMENTS CONSIDERED

The Expert Review Panel discussed several alignment options within the designated study area, as shown in Figure 4 below. The east alignment limit is constrained by the rapid drop off of the lake bottom and the associated increasing depth of the hard, competent material required for the bored and sequential excavation tunneling.

To the west, the alignment is limited by the short lengths of the ramps, which requires steep ramp grades in order to pass over the top of the Sound Transit Light Rail station cross-over box (shown in yellow in Figure 4). Three of the alternative alignments evaluated (A, B and D) must pass above the cross-over box which is a serious vertical constraint (the cross-over box has a six foot notch included in the design to better allow the road ramps to pass over). We note that the cross-over box has 3 levels – track level plus two mechanical levels. If it were possible to utilize the top mechanical level for the road ramps, Alignments A, B and D could be designed with better ramp grades.

One alternative, Alignment C, was evaluated with the alignment passing just to the south of the Sound Transit vent shaft. This alignment allows the ramps to descend more quickly from Pacific Street by eliminating the cross-over box's vertical restraint and would also keep construction further away from the stadium and car parking area. However, this alignment currently results in ramp grades of 13 to 16 percent.

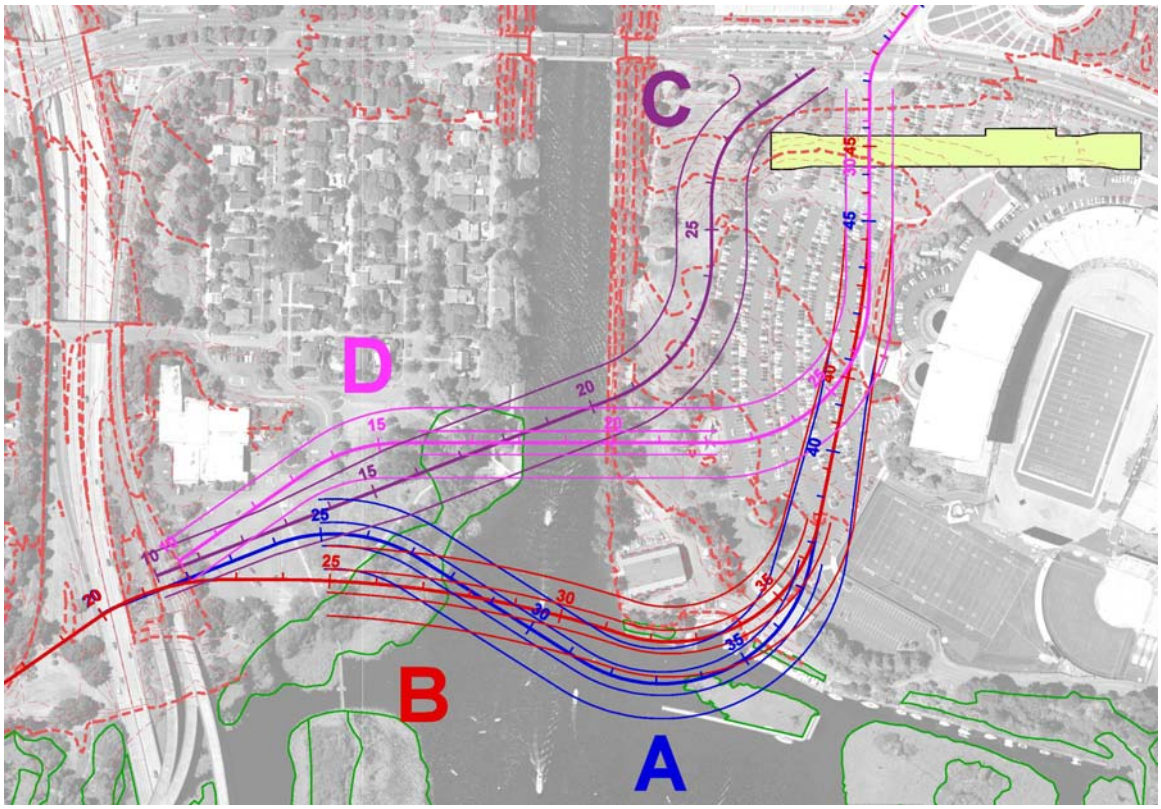


Figure 4 - Plan of tunnel alignments A, B, C and D

The total length and the underwater length of the tunnel increases as the alignment extends east into Union Bay. Because the environmental concerns increase as the alignment moves further east, with a longer alignment in Union Bay and more impacts to shoreline and wetlands, a shorter water crossing is preferable if it can be achieved with acceptable ramp grades.

Several tables and descriptions are provided in the report which describe comparisons between, and characteristics of, the alignment alternatives. Included are considerations of the construction methods, the characteristic dimensions and potential environmental impacts. A summary of the methods, alignments and corresponding roadway grades is listed in Table A following.

1.6. METHODS, LENGTHS, GRADES AND MINIMUM SOIL COVER

The following table summarizes the alignments considered and key characteristics for the different alignments and tunneling methods. The grades shown are computed at the centerline of the alignment, that is mid-way between the inbound and outbound ramps. This means the down-grade will be slightly higher and the up-grade slightly lower than the value shown.

Alignment	A - in Lake	B -in Lake	C - across Cut	D -across Cut
Length considered	2000	1800	1400	1500
Sequential Excavation Method (SEM)				
Length of SEM	700 -1000*	700 - 950*	300 - 500*	250 - 400*
Length of Cut and Cover	1300 - 1000*	1100-850*	1100-900*	1250-1100
Road grade north %	11	9.5	16	13.5
Road grade south %	9	7	8	8.5
Cover over tunnel **	25	25	20	20
Immersed Tube Method				
Length of Immersed Tube	300 - 900	260 - 850	250	200 - 250
Length of Cut and Cover	1700-1100	1540-950	1150	1300 - 1250
Road grade north %	8	7	13.5	10.5
Road grade south %	7	5.5	5.5	6
Cover over tunnel ***	6	6	6	6
Bored Tunnel Method				
Length of Bored Tunnel	1550	1450	1050	1150
Length of Cut and Cover	450	350	350	350
Road grade north %	11	9.5	15	12.5
Road grade south %	9	7	7.5	8
Cover over tunnel **	20	20	20	20

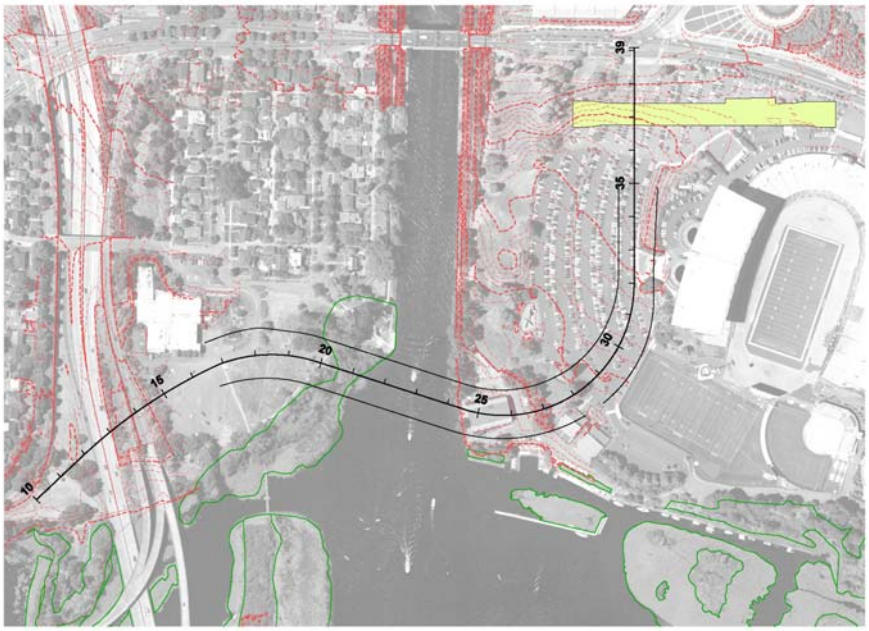
Alignments & Notes:
A - swings east furthest into Lake Washington to cross the channel
B - swings east to cross the channel just east of the UW Boat House
C - crosses the Montlake Cut at an angle, alignment is south of Sound Transit Vent Shaft
D - crosses the cut at 90 degrees west of the UW Boat House
* SEM - the longer length doesn't impact the wet lands, the shorter length does
** Cover (ft) = minimum depth over the tunnel crown of stable firm glacially overridden soils
*** Cover (ft) for the immersed tunnel is for protection, not a structural requirement

Table A – Alignments, Lengths, Road Grades and Minimum Cover

Because the grades for these alignments are, in most cases greater than the WSDOT Design Manual maximums (see following), a modification to Alignment B has been examined. This alignment reduces the north road grade from 9.5% to 8.5%.

Alignment B modified	
Length of Tunnel	500-700
Length of Cut and Cover	1300-1100
Road grade north %	8.50%
Road grade south %	7.50%
Cover over tunnel **	20

Table A-1 – Alignment B Modified



Plan of Alignment B Modified

1.7. ACCEPTABLE RAMP GRADES

WSDOT Design Manual M22-01 Dated January 2005 gives the following maximum ramp grades for various design speeds. For the SR 520 ramps, with 25 to 30 mph speeds, the maximum grades would be 7% up-grade and 9% down-grade.

WSDOT has indicated that they would evaluate a higher up-grade for these particular ramps. If the B modified alignment with an up-grade of 8.5% were possible, the tunneling options, *on this basis only*, would be:

(3) Grade

The maximum grade for ramps for various design speeds is given in Figure 940-2.

Ramp Design Speed (mph)	25-30	35-40	45 and above
Desirable Grade (%)	5	4	3
Maximum Grade (%)	7	6	5
On one-way ramps down grades may be 2% greater.			

Maximum Ramp Grade
Figure 940-2

Table B – WSDOT Design Manual, Maximum Grades for Ramps

Sequential Excavation Method (SEM)	Alignment B modified
Bored Tunnel (TBM)	Alignment B modified
Immersed Tunnel	Alignments A and B, B modified, D modified

1.8. FINDINGS REGARDING THE TUNNELING METHODS CONSIDERED

General:

1. It is considered feasible to tunnel the SR 520 ramps under the Montlake Cut or close-by in Union Bay, subject to further specific evaluation of geotechnical conditions
2. Because of maximum ramp grade requirements, even considering variances to these requirements, only some tunneling methods are possible for certain alignments. These combinations are:
    a. Sequential Excavation Method (SEM) with Alignment B modified.
    b. Bored Tunnel (TBM) with Alignment B modified.
    c. Immersed Tunnel with Alignments A and B, B modified and D modified.
3. The bored tunnel is not considered feasible for several reasons, as noted below and in the report.
4. The sequential excavation and immersed tunnel methods are considered capable of being successfully constructed in this location.
5. The sequential excavation method can avoid in-water work and impacts to the near shore environment and wetlands.
6. The immersed tunnel method will require in-water dredging and operations and will have impacts to the near shore environment and wetlands.

Specifics regarding the methods

1. Sequential excavation method (SEM)
    a. The SEM provides flexibility to change the cross-section and vary the pillar width along the alignment. These changes are made to accommodate sight lines and other safety requirements.
    b. The SEM requires the deepest cover under the channel and will have steep grades on the shortest alignment but has acceptable grades for Alignment B.
    c. The SEM requires significant time to condition the ground over the tunnel by freezing the soil. On the longer alignments, under Union Bay (Alignments A and B) the SEM could require sequential freezing operations during the tunnel excavation to ensure that the ground is completely frozen ahead of the tunneling. This will add time to the schedule.
    d. The SEM method does not require any in-water work.
2. Bored tunneling method
    a. The bored tunnel requires a very large tunnel boring machine. This size of machine would require a long lead time for procurement and set up for a relatively short length of tunnel.
    b. The bored tunnel involves steep grades and tight radius curves, requiring complex machine control and trained operators.
    c. It is possible that no manufacturer would be able to supply a TBM that could negotiate the tight radius (325 feet) in this location.
    d. This method does not require in-water work.
    e. This method is not recommended for this location or alignment.
3. Immersed tunnel
    a. The immersed tunnel can be constructed with the shortest length of tunnel across the cut.
    b. The ramps, constructed in the cut-and-cover sections, would have the lowest grades because the immersed tunnel does not require the additional cover of competent soil.
    c. The immersed tunnel plus cut-and-cover will have the shortest construction duration.
    d. Unforeseen soil conditions have little or no effect on the alignment, profile and constructability of the immersed tunnel.
    e. Variations in the cross-section of the roadway can be easily accommodated.
    f. This method requires in-water work and significant environmental mitigation.

2. EXTRACTS FROM THE FULL REPORT

The full report is in final review and sign-off by the ERP members. Some of the exhibits are referenced in the above Executive Summary text – these are presented following.

As part of the SR520 Mediation process, required by the Washington State Legislature, an alternative was developed called "Tunnels at East Montlake and the Arboretum", also known as "Alternative K". This alternative envisioned an interchange connection from the main SR520 alignment, just east of Montlake, to the University area routed in tunnel under the navigation channel east of Montlake Cut to the University area. The alternative was described in a report by COWI, the Mediator's engineering and construction consultant, titled "Tunnels at East Montlake and the Arboretum, Conceptual Design and Cost Estimate, part 1" March 17th, 2008.

That report considered using an Immersed Tunnel type of construction, passing under Lake Washington approximately 200 feet to the east of the end of the Montlake Cut as shown below. The tunnel would accommodate 2 – 12 foot ramp-class lanes in each direction with 4 foot shoulders on each side with provision for wider shoulders to permit the required sight distance on the inside of the curve in plan.

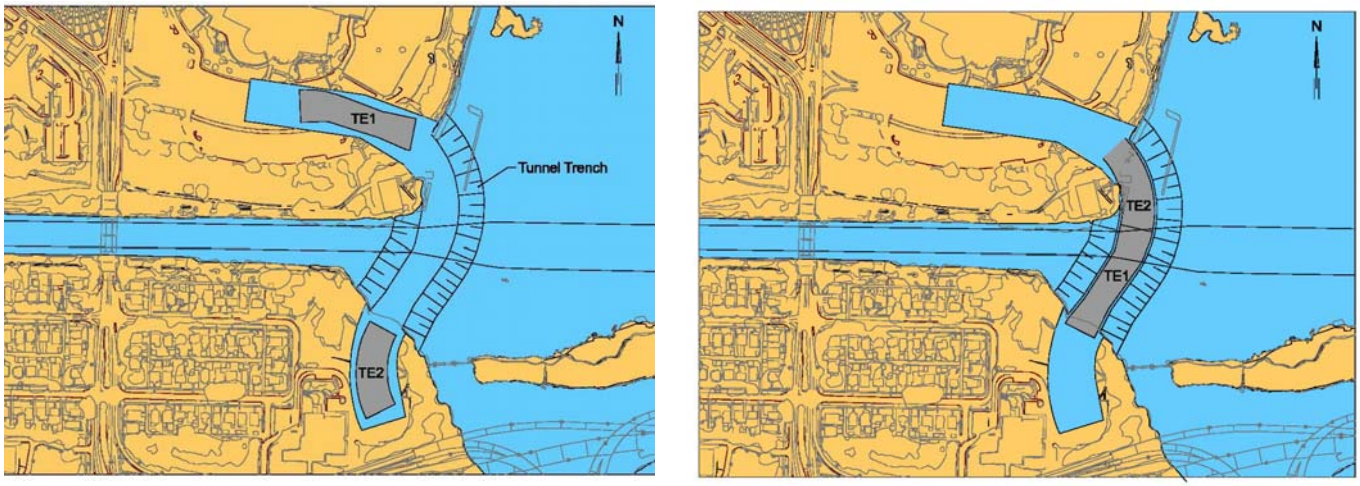


Figure 5 – General arrangement of the COWI Immersed Tunnel Proposal

Table of Salmonoids Migration Timing for ESA Listed Species in the Montlake Cut

Species/Life History Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult chinook migration												
Juvenile chinook migration												
Adult steelhead migration												
Juvenile steelhead migration												
Bull trout migration[a]												

Notes:
Red areas restrict in-water construction operations
Yellow areas represent times when limited migration may occur
Tribal fishing seasons are not shown in this table, but need to be recognized and may restrict in-water work work beyond time frames shown here.
Bull trout migration may occur outside the time period shown.

Table D – Salmonoids Migration Timing for ESA Listed Species in Montlake Cut