River Crossing Option Comparison

November 2022

TABLE OF CONTENTS

FIGURES

TABLES

ATTACHMENTS

ACRONYMS AND ABBREVIATIONS

API	area of potential impact
BNSF	BNSF Railway
CRC	Columbia River Crossing
C-TRAN	Clark County Public Transportation Benefit Area Authority
CFR	Code of Federal Regulations
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
I-5	Interstate 5
I-205	Interstate 205
IBR	Interstate Bridge Replacement
ITT	immersed tube tunnel
Metro	Oregon Metro
NEPA	National Environmental Policy Act
NIR	Navigation Impact Report
ODOT	Oregon Department of Transportation
OHWM	ordinary high-water water mark
PDX	Portland International Airport
ROD	Record of Decision
ROW	right-of-way
RTC	Southwest Washington Regional Transportation Council
SR	State Route
SUP	shared use path
TBM	tunnel boring machine
TriMet	Tri-County Metropolitan Transportation District of Oregon
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard

1. INTRODUCTION

The Interstate Bridge Replacement (IBR) program is a continuation of the Interstate 5 (I-5) Columbia River Crossing (CRC) Project and will replace the aging I-5 bridges across the Columbia River with a modern, seismically resilient, multimodal structure. The Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) are the lead federal agencies responsible for ensuring that the program complies with the National Environmental Policy Act (NEPA) and associated regulations and policies.[1]

The IBR program must define the type of river crossing that will replace the existing bridges over the Columbia River. In June 2022, the U.S. Coast Guard (USCG) responded to the IBR's program's Navigation Impact Report (NIR) and issued a Preliminary Navigation Clearance Determination for the IBR program that prescribed a vertical and horizontal navigation clearance for the river crossing that would have a high likelihood of obtaining a favorable permit decision. The USCG also requires that the horizontal navigation clearance meet the U.S. Army Corps of Engineers (USACE) requirement, which is currently set to equal to or greater than 400 feet. The IBR program continues to coordinate with the USACE regarding their requirement for a 400 feet horizontal clearance and proposed shift in the primary navigation channel toward the center of the Columbia River. The IBR program anticipates a final decision from the USACE in 2023. Based on technical evaluations, agency coordination, public outreach, and discussions with partner agencies, the IBR program recommends a fixed span bridge with a vertical clearance of 116 feet.

This report provides context for the replacement crossing, identifies the various river crossing options, including their advantages and disadvantages, and provides the IBR program's reasoning for the recommended bridge configuration and height.

[1] In addition to FHWA and FTA, there are six joint lead agencies: Oregon Department of Transportation, Washington State Department of Transportation, Oregon Metro (Metro), and Southwest Washington Regional Transportation Council, Tri County Metropolitan Transportation District (TriMet), and Clark County Public Transportation Benefit Area (C-TRAN).

2. PURPOSE AND NEED

A “Purpose and Need” statement is a foundational document under NEPA that identifies and defines the transportation problem(s) that a project must address. The adopted statement for the IBR program is paramount to considering various river crossing options because the selected option must address the identified transportation problems.

As part of the NEPA process, the IBR program worked with regional and local partner agencies and the public to confirm the program’s Purpose and Need statement. Through work completed in 2021, the IBR program determined that the needs identified in the CRC Project’s Purpose and Need statement are still pertinent. Thus, the Purpose and Need statement for the IBR program, provided below, remains the same as in the 2011 Record of Decision (ROD) for the CRC Project. The Purpose and Need statement was developed by the lead agencies, project sponsors, and the CRC Task Force.[2]

Note: The text of the Purpose and Need statement has not been edited or updated, with the exception of references to the program name. More recent data and supplemental information are provided in sidebars.

2.1 Project Purpose

The purpose of the proposed action is to improve I-5 corridor mobility by addressing present and future travel demand and mobility needs in the IBR program area. The program area extends from approximately Columbia Boulevard in the south to State Route (SR) 500 in the north. Relative to the No-Build Alternative, the proposed action is intended to achieve the following objectives: a) improve travel safety and traffic operations on the I-5 bridges and associated interchanges; b) improve connectivity, reliability, travel times, and operations of public transportation modal alternatives in the program area; c) improve highway freight mobility and address interstate travel and commerce needs in the program area; and d) improve the I-5 river crossing’s structural integrity (seismic stability).

[2] The CRC Task Force was a 39-member group formed in 2005 comprising leaders representing a broad cross section of Washington and Oregon communities. Public agencies, businesses, civic organizations, neighborhoods, and freight, commuter, and environmental groups were represented on the task force. The group met 23 times over the course of the project development phase to advise the CRC Project team and provide guidance and recommendations at key decision points. The task force concluded its work in summer 2008 after making its recommendation on the locally preferred alternative.

2.2 Project Need

The specific needs to be addressed by the proposed action are:

- **Growing travel demand and congestion**: Existing travel demand exceeds capacity of the I-5 bridges and associated interchanges. This corridor experiences heavy congestion and delays lasting 4 to 6 hours daily during the morning and afternoon peak travel periods and when traffic accidents, vehicle breakdowns, or bridge lifts occur. Due to excess travel demand and congestion in the I-5 bridge corridor, many motorists take the longer, alternative Interstate 205 (I-205) route across the river. Spillover traffic from I-5 onto parallel arterials such as Martin Luther King Jr. Boulevard and Interstate Avenue increases local congestion. In 2005, the two crossings carried 280,000 vehicle trips across the Columbia River daily. Daily traffic demand over the I-5 crossing is projected to increase by more than 35% during the next 20 years, with stop-and-go conditions increasing to approximately 15 hours daily if no improvements are made.
- **Impaired freight movement**: I-5 is part of the National Truck Network and the most important freight highway on the West Coast, linking international, national, and regional markets in Canada, Mexico, and the Pacific Rim with destinations throughout the western United States. In the center of the program area, I-5 intersects with the Columbia River's deep-water shipping and barging, as well as two river-level transcontinental rail lines. The I-5 crossing provides direct and important highway connections to the Port of Vancouver and Port of Portland facilities located on the Columbia River, as well as the majority of the area's freight consolidation facilities and distribution terminals. Freight volumes moved by truck to and from the area are projected to more than double over the next 25 years. Vehicle-hours of delay on truck routes in the Portland-Vancouver area are projected to increase by more than 90% over the next 20 years. Growing demand and congestion will result in increased delay, costs and uncertainty for all businesses that rely on this corridor for freight movement.
- **Limited public transportation operation, connectivity, and reliability**: Due to limited public transportation options, a number of transportation markets are not well served. The

The duration of **congestion** on the I-5 bridges has roughly doubled over the past 14 years. In 2019 there were approximately 10 hours of congestion per day (3 hours in the morning and 7 hours in the afternoon/ evening).

Travel demand in 2019 exceeded capacity during peak periods on the Interstate Bridge on weekdays and weekends. The total number of vehicles using the bridge was 139,000 (average weekday daily traffic).

Over 13,500 **medium and heavy trucks** crossed the Interstate Bridge daily in 2019, accounting for just under 10% of daily traffic across the bridge. Freight tonnage in the Portland region is expected to double by 2040, with 75% of total freight tonnage moved by truck.

Bus travel times in 2019 were up to four times longer during parts of the morning and evening peak period compared to off-peak periods.

key transit markets include trips between the Portland Central City and the city of Vancouver and Clark County; trips between north/northeast Portland and the city of Vancouver and Clark County; and trips connecting the city of Vancouver and Clark County with the regional transit system in Oregon. Current congestion in the corridor adversely impacts public transportation service reliability and travel speed. Southbound bus travel times across the bridge are currently up to three times longer during parts of the a.m. peak compared to off peak. Travel times for public transit using general purpose lanes on I-5 in the program area are expected to increase substantially by 2030.

- **Safety and vulnerability to incidents**: The I-5 river crossing and its approach sections experience crash rates more than twice the statewide averages for comparable facilities. Incident evaluations generally attribute these crashes to traffic congestion and weaving movements associated with closely spaced interchanges and short merge distances. Without breakdown lanes or shoulders, even minor traffic accidents or stalls cause severe delay or more serious accidents.
- **Substandard bicycle and pedestrian facilities**: The bike/pedestrian facilities on the I-5 bridges are about 3.5 to 4 feet wide, narrower than the 10-foot standard, and are located extremely close to traffic lanes, thus impacting safety for pedestrians and bicyclists. Direct pedestrian and bicycle connectivity are poor in the program area.
- **Seismic vulnerability**: The existing I-5 bridges are in a seismically active zone. They do not meet current seismic standards and are vulnerable to failure in an earthquake.

The program area experiences **crash rates** nearly three times higher than statewide averages for comparable facilities. There were six fatal crashes in the program area between 2015 and 2019. In 2019, crashes were more than twice as likely to occur during peak travel periods compared to off-peak periods.

The existing **shared use paths** are narrower than current standards and are not compliant with the Americans with Disabilities Act. The paths are in close proximity to traffic lanes, which for bicyclists and pedestrians increases the exposure to vehicular traffic, noise, and emissions.

Seismic issues include that the structures lack the ductility of similar modern bridges and that both bridge spans are supported by hundreds of timber piles that sit within loose sand that will liquefy during a strong earthquake. The combined effect—settlement and lateral movement—would prove devastating to the bridge spans, likely triggering their collapse even if the bridge managed to somehow survive the shaking.

3. CRC PROJECT ALTERNATIVES ANALYSISh SCREENINGhAND SELECTED ALTERNATIVE

For the CRC Project, an alternatives development, screening, evaluation, and refinement process was conducted under NEPA, which led to the selection of a reasonable range of alternatives that were studied in the CRC Draft Environmental Impact Statement (EIS). A wide range of transportation alternatives and improvements were considered during screening and subsequent evaluation, including bored tunnels as well as supplemental and replacement bridges of different heights and types, such as movable span bridges and fixed span bridges.

Two rounds of evaluation and screening (known as Step A and Step B) were conducted for the CRC Project to narrow these components. In April 2006, the Step A screening evaluated 37 transit and crossing components. Step A focused on whether a component could meet the Purpose and Need statement; any components that failed to meet the Purpose and Need were dismissed from further study. The screening eliminated 22 river crossing types and transit modes, including a replacement bored tunnel and high-level bridges (such as cable stay or suspension bridges) that would encroach on protected airspace for Pearson Airfield and not improve safety or decrease vulnerability to incidents compared to a mid-level bridge.

During the Step B screening in June 2006, the remaining 15 crossing and transit components were scored on the adopted project values,[3] which were developed and formalized by the CRC Task Force. The intent of the Step B screening was to evaluate the remaining components against a more detailed set of criteria, so that only the most promising and potentially effective components would be advanced into alternatives packaging and modeling. All of the components that entered the Step B round were advanced for further evaluation.

While all components passed Step B, additional analysis was being completed at the same time to further screen several components. Further evaluations and additional information revealed substantial issues with several river crossing components, including low-level bridges and a supplemental bored tunnel, and these were dismissed from further study. At the June 14, 2006, CRC Task Force committee meeting, members passed two motions without opposition to eliminate further consideration of all supplemental and replacement movable span and tunnel alternatives. Representatives of partner agencies, including City of Portland, City of Vancouver, Oregon Metro (Metro), Southwest Washington Regional Transportation Council, Tri-County Metropolitan Transportation District of Oregon (TriMet), Clark County Public Transportation Benefit Area Authority (C-TRAN), Port of Vancouver, and Port of Portland, were in attendance.

[3] The adopted project values were community livability and human resources; mobility, reliability, accessibility, congestion reduction, and efficiency; safety; regional economy, freight mobility; stewardship of natural resources; and distribution of benefits and impacts.

As summarized above and detailed in the CRC Final EIS, a thorough and detailed alternatives analysis was conducted for the CRC Project that considered numerous types of river crossings. The outcome of this process identified the reasonable range of alternatives that were evaluated in the Draft EIS, which consisted of four build alternatives (two supplemental crossings and two replacement crossings) and one no-build alternative.

The approved Selected Alternative for the CRC Project was described in the 2011 ROD and included a replacement fixed span bridge with 95 feet of vertical clearance over the primary navigation channel. Following the issuance of the ROD, the project entered the final design and permitting phase. In response to the concerns raised by the USCG, impacts on the ability of the USACE dredge Yaquina to transit the bridge, and concerns raised by other river users over the bridge height in the ROD, the project team evaluated options for a mid-level bridge with greater vertical clearance for navigation. Based on the analysis in the CRC NIR, the project team decided to refine the bridge design and increase the vertical clearance to 116 feet. In 2012, the CRC Project team conducted a NEPA reevaluation to determine whether refining the bridge's proposed vertical clearance to 116 feet and the new information on river users and vessels would result in any new significant adverse environmental impacts that were not evaluated in the previous NEPA process. The reevaluation concluded that there were no new significant impacts under NEPA for the 116-foot bridge. A permit application and supporting materials were provided to the USCG and a permit was issued for a bridge with this vertical clearance in 2013; however, that permit was contingent on securing other required permits and authorizations as well as implementing mitigation to affected marine users. The mitigation effort was halted when the CRC project was suspended, therefore making the permit issued by the USCG inexecutable.

A bridge height of 116 feet was selected based on the vessel analysis contained within the 2012 NIR and because that height balances the needs of navigation and surface transportation while minimizing additional landside and environmental impacts. A bridge height of 116 feet would allow the project to avoid or minimize impacts to nearly all river users and vessels and to mitigate the remaining impacts.

As detailed in Section 2 and Section 3, the Purpose and Need statement and the proposed main river crossing component of the program have not changed since 2013. The proposed replacement of the existing two lift span bridges with two fixed span bridges that provide a vertical navigational clearance of 116 feet over the primary navigation channel is the result of several decades of work, which included a thorough review of various river crossing options to select a crossing that best meets the needs of all users while addressing the Purpose and Need statement. The IBR program conducted a NEPA reevaluation in 2021 that evaluated physical and contextual changes in the program area since 2013. Based on the reevaluation, FHWA and FTA determined that a supplemental EIS is required to update and supplement the design, evaluation of impacts and benefits, and mitigation commitments that led to the CRC ROD in 2011 and subsequent updates in 2012–2013.

4. SITE CONDITIONS

This section describes the site conditions at the river crossing location, including navigation considerations, existing conditions in the built and natural environment, and anticipated future conditions.

4.1 Navigation Considerations

The Columbia River, including both the main channel and the North Portland Harbor,[4] is considered a navigable waterbody. Vertical constraints on vessels are determined largely by vessel height, bridge height, and river water levels. As part of requirements for the Rivers and Harbors Act Section 9 Bridge Permit, the IBR program completed a NIR that included a survey of vessels that typically pass through the location of the bridges, including their vertical clearance needs. The following sections summarize existing navigation conditions on the Columbia River, anticipated future navigational needs, and the potential impacts to vessels from different vertical clearances at the Interstate Bridge.

4.1.1 Existing Navigation Conditions

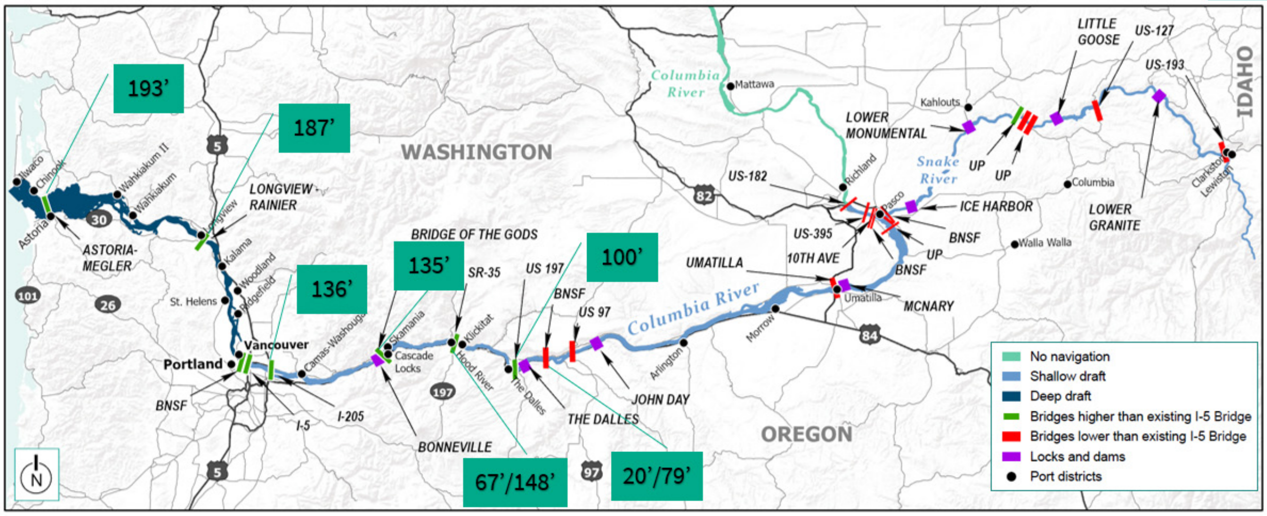
Through the Portland-Vancouver metropolitan area, the Columbia River is crossed by bridges at four locations: the I-5 crossing, known as the Interstate Bridge; the I-205 crossing, known as the Glenn L. Jackson Memorial Bridge; the BNSF Railway (BNSF) Vancouver railroad bridge; and the North Portland Harbor bridge. Figure 1 identifies the existing bridges over the Columbia River and their vertical clearances. The I-205 bridge is the closest crossing upriver (east) of the existing bridges and any vessels traveling upriver are restricted by that bridge's vertical clearance of 136 feet. An analysis of river users showed that most cargo comes from or is dropped at locations upriver of the I-5 bridges. There are numerous bridges between Vancouver and the cargo origins/destinations that have much lower vertical clearances, and the vessels are designed to accommodate those lower clearances.

Existing land uses are described in Appendix A of the NIR (Attachment A to this report). There are four existing water-dependent industrial sites within the jurisdiction of the City of Vancouver: CBC, Vigor, Marine Park marina, and the Western Forest Products property. It is likely that these areas will continue in industrial use. Only the uses at the CBC are currently height constrained, as detailed in the NIR. In addition, there are two marinas (McCuddy's Steamboat Landing Marina and Tidewater Cover Marina) and several private docks associated with private residences.

On the south side of the river, between the I-5 bridges and the I-205 bridge, there are many recreational marinas that are used by both powerboats and sailboats. See Attachment A for additional information on existing land uses and navigation needs.

[4] The North Portland Harbor is a side channel of the Columbia River that separates Hayden Island and the Oregon shore. This waterway is also known as the Oregon Slough.

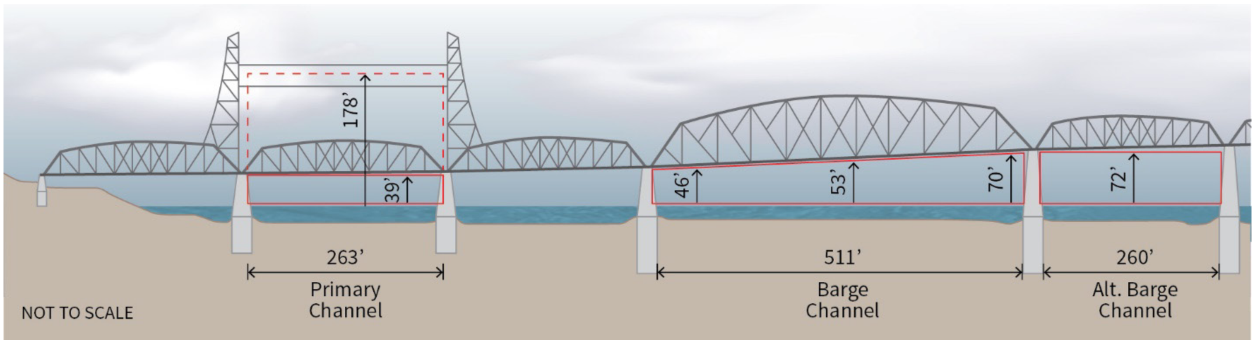
Figure 1. Existing Bridges Over the Columbia River



Under the I-5 bridges, vessels[5] pass through one of three channels: the primary channel, the barge channel, or the alternate barge channel. Figure 2 shows the vertical clearances provided by the existing I-5 bridges at both the lift span and fixed spans that align with the federal navigation channels. As shown, the primary channel lies under the existing lift spans and has a horizontal clearance of 263 feet and a vertical clearance of 39 feet in the closed position and 178 feet in the fully raised position. The highest clearance of the barge and alternate barge channels provides a vertical clearance of 72 feet.

[5] Vessels currently using the river in the vicinity of the IBR program area include tugs and barges, recreational sailboats and powerboats, marine contractor barges with construction cranes and materials, cruise and passenger boats, dredges, government vessels, vessels transporting shipments of marine industrial businesses and fabricators, and others.

Figure 2. Vertical Clearances Provided by the Existing I-5 Bridges



*Vertical clearance shown relative to 0 feet Columbia River Datum

Note: This figure is looking east (upriver), with the City of Vancouver to the left and the City of Portland to the right.

Most vessels do not require an opening of the lift span because they are low enough to transit the bridge using the vertical clearance provided by one of the three channels. Between 2012 and 2020, the lift span was used for vessels an average of 157 times per year (i.e., excluding lifts for maintenance and training). The existing I-5 bridges are opened for approximately 5% to 7% of river traffic. Figure 3 shows the number of bridge lifts per vessel type. Tugs and barges are responsible for the largest share of bridge openings (58%), followed by sailboats (33%).

Figure 3. Annual Bridge Openings: 2012–2020

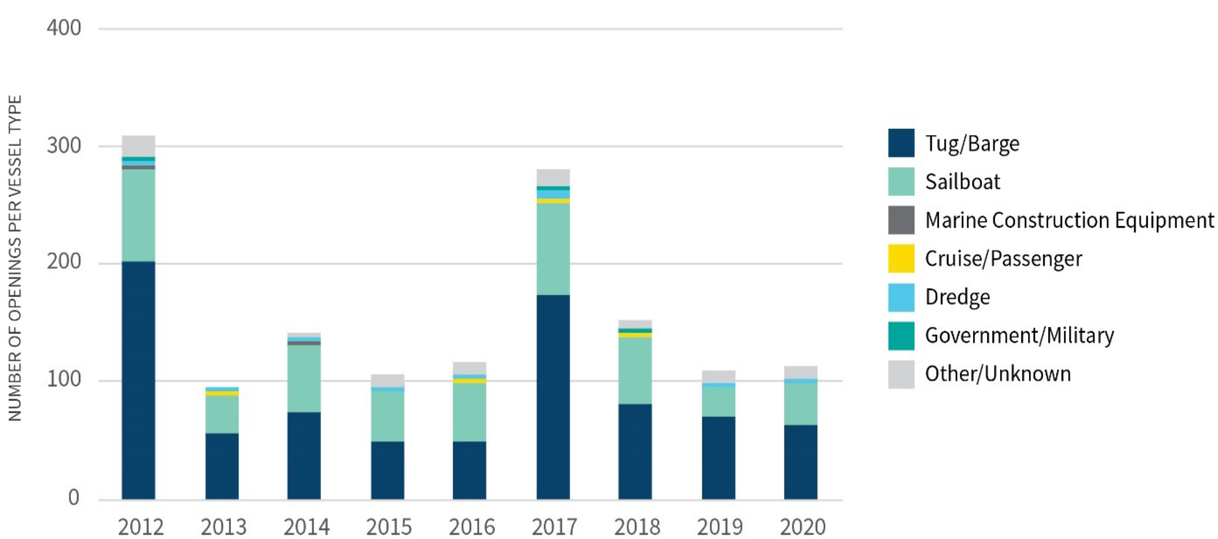


Table 1 lists the number of estimated openings per year and the number of vessels that would require an opening and could be restricted from passing at specific times when the bridge is restricted from opening per federal regulations. This does not include separate openings that may be needed for maintenance and training. The Code of Federal Regulations (CFR) stipulates that the current bridge shall not be opened for vessels Monday through Friday from 6:30 a.m. to 9 a.m. or from 2:30 p.m. to 6 p.m. (CFR Title 33 Chapter I Subchapter J, Part 117 § 117.869), corresponding to peak commute times. A replacement bridge with an opening would likely include similar restrictions and, depending on the vertical clearance provided in the closed position, may seek to further restrict openings to the period of lowest vehicular traffic (i.e., midnight to 4 a.m.).

Table 1. Number of Bridge Lifts per Year by Vertical Clearance

Bridge Height[a] (closed or highest fixed span)	Estimated Openings/Year	Number of Vessels/Users Requesting a Bridge Opening
116 feet[b]	85[c]	9[d]
95 feet	154[e]	53[e]
72 feet	157[f]	270[g]

a. Bridge heights as measured from 0 feet Columbia River Datum. For purposes of calculating potential bridge openings, water is assumed to be 16 feet Columbia River Datum.

b. During the CRC Project, mitigation agreements were negotiated with the four impacted users that were unable to modify operations (such as accepting an air gap of less than 10 feet) in order to transit a bridge height of 116 feet. Three upstream fabricators entered into mitigation agreements with the CRC Project. The anticipated mitigation agreements would have resulted in payments to the companies that would be used by the companies at their business discretion and control. Payments were never made as the project was stopped. The remaining vessel owner decided to terminate negotiations that involved a payment to compensate the owner for vessel modifications and an agreement was never finalized.

c. Based on vessels identified in the 2021 Navigation Impact Report and reported frequency of transit provided by user.

d. Represents worst case scenario. Five of the nine vessels would not require an opening based on mitigation such as accepting a lesser air gap, thereby also reducing the estimating openings per year.

e. Based on the CRC Navigation Impact Report and updated with 2012 to 2020 lift data and updated user information from the 2021 Navigation Impact Report.

f. Based on the average number of lifts for vessels for the existing bridge from 2012 to 2020, as 72 feet is the height of the highest fixed span on the existing bridge. This likely overestimates the number of openings by a small number because some openings are not due to height constraints. Additional lift data analysis is underway to narrow the potential overestimates regarding the number of openings.

g. Represents the number of distinct vessels noted in bridge logs from 2012 to 2020. Not every vessel requires a lift every year, and some vessels occur only once in the data.

Table 2 identifies the various categories of vessels and notes whether they would or would not be affected by a span with vertical clearances of 100 feet, 116 feet, and 125 feet. The majority of vessels and river traffic would not be impacted by any of the fixed span bridges shown. However, a bridge height of 100 feet would result in certain key vessels not being able to transit the bridge, such as the dredge Yaquina, that are critical for river operations as well as certain marine construction equipment and the tallest sailboats that are locally based. Certain marine contractors and industrial fabricators would be impacted at any of the heights shown.

Table 2. Bridge Height Impacts Comparison, 2012–2020

Vessel Type	Air Draft (typical)	100 feet	116 feet	125 feet	Vessel Frequency	Annual Lift Frequency
Tugs and Tows	<60 feet	Not impacted	Not impacted	Not impacted	High	64.2
Sailboats	<90 feet[a]	Impacted	Not impacted	Not impacted	High	18.8
Marine Contractor Equipment	40 to 90 feet[b]	*Sometimes impacted*	*Sometimes impacted*	*Sometimes impacted*	Unknown	Unknown
Cruise Ships	48 to 63 feet	Not impacted	Not impacted	Not impacted	High	0.1
Tall Ships	90 feet[c]	*Sometimes impacted*	Not impacted	Not impacted	Very Low	0.4
USCG Juniper Class Buoy Tenders	83 feet	Impacted	Not impacted	Not impacted	Not impacted	0.2
USACE Dredge Yaquina	92 feet	Impacted	Not impacted	Not impacted	Not impacted	2.4
U.S. Navy Vessels	43 to 59 feet	Not impacted	Not impacted	Not impacted	Not impacted	0
Fabricators/ Industrial Freight	Up to 178 feet	Impacted	Impacted	Impacted	Very Low	Unknown[d]

a. One sailboat with a reported vessel height of 120 feet was responsible for two bridge lifts during the 8-year period. This vessel is no longer based in the area.

b. Two contractors reported vessel heights of 120 feet or greater.

c. Step down mast to 65 feet.

d. Only Thompson Metal Fab Inc. reported trip details. Lift data from the Oregon Department of Transportation does not have detail to determine other trips. From 2012 to 2020, Thompson Metal reported 14 trips. Of these, 12 would be able to transit a bridge height of 100 feet, one trip would have not been able to transit a bridge height of 125 feet or less and one trip would not have been able to transit a bridge height of 100 feet or less.

4.1.2 Future Navigation Needs

The lifespan of the proposed replacement bridge, future industrial development upstream of the I-5 bridges, and future vessel sizes were considerations taken into account when identifying future navigation needs on this section of the Columbia River. The replacement river crossing will likely be designed for a service life of 100 years or more, and the NIR considered potential impacts from prospective upstream commercial development that could result in different navigation on the waterway. The analysis concluded that both political and geographic constraints were the primary factors affecting commercial/industrial development along the upstream waterway.

Land use restrictions imposed by the Columbia River Gorge National Scenic Area, topography, transportation access parallel to shorelines (SR 14, Interstate 84, and BNSF and Union Pacific Railroad), and existing open spaces limited the areas for future water-dependent land uses. All of the industrial uses between the BNSF bridge and BNSF Celilo Falls rail bridge are in urban areas and primarily within established industrial parks (e.g., Columbia Business Center, Port of Cascade Locks Industrial Park). According to the Future Use Analysis conducted for the NIR, there are no planned developments within the subject area[6] that would be served by marine transport that could be limited by a proposed replacement bridge with a vertical navigation clearance of 116 feet.

Efforts are underway in upriver counties to reuse vacant or underutilized industrial waterfront parcels in forest products manufacturing (which is not height constrained) or in non-water-dependent uses, including commercial business parks, mixed-use residential/commercial developments, and tourist centers.

There has been an overall trend in the shipping industry to larger vessel sizes.[7] This is particularly evident for container ships and other ocean-going vessels to take advantage of efficiencies and the increased ability of major navigation routes such as the Panama Canal.[8] Some vessels of this type operate in the Lower Columbia River, but there are no suitable origins or destinations located upstream of the I-5 bridges. The majority of the vessel traffic on the Columbia River are tugs and barges. These are limited by the size of the Columbia River lock system and other upstream vertical and horizontal constraints and have not seen a change in sizes or dimensions during the same period as ocean-going vessels. Because there are no destinations for ocean-going vessels upstream of the I-5 bridges, this increase in vessel size is not expected to impact future navigation needs.

Vessels engaged in national defense activities or emergency response are also not expected to change. Current activity would not be limited by a proposed replacement bridge with a vertical navigation clearance of 116 feet. Larger vessels operated by the Military Sealift Command, such as the USNS Mercy hospital ship, infrequently visit the Lower Columbia River primarily for maintenance activities at the Vigor Swan Island facility or at other berths in the Columbia River. No needs to travel past the I-5 bridges have been identified in comments from agencies on the replacement bridge.

[6] The subject area for the Future Use Analysis was defined as extending from the I-5 bridges to the BNSF Railway rail bridge at Celilo Falls and landward from the river approximately 0.5 miles.
[7] International Transport Forum. 2015. The Impact of Mega-Ships.
[8] U.S. Department of Agriculture. No date. Bulk Vessel Types and Capacity.
https://agtransport.usda.gov/stories/s/Bulk-Vessel-Fleet-Size-and-Rates/bwaz-8sgs/

4.2 Existing Conditions

4.2.1 Airspace

There are two airports in proximity to the program area: Portland International Airport (PDX) in Portland, Oregon, and Pearson Field in Vancouver, Washington. PDX is located approximately 3 miles southeast on the Oregon side of the Columbia River and is the major regional airport. Pearson is located directly east of the existing I-5 bridges and is an active airfield managed by the City of Vancouver, serving general aviation users.

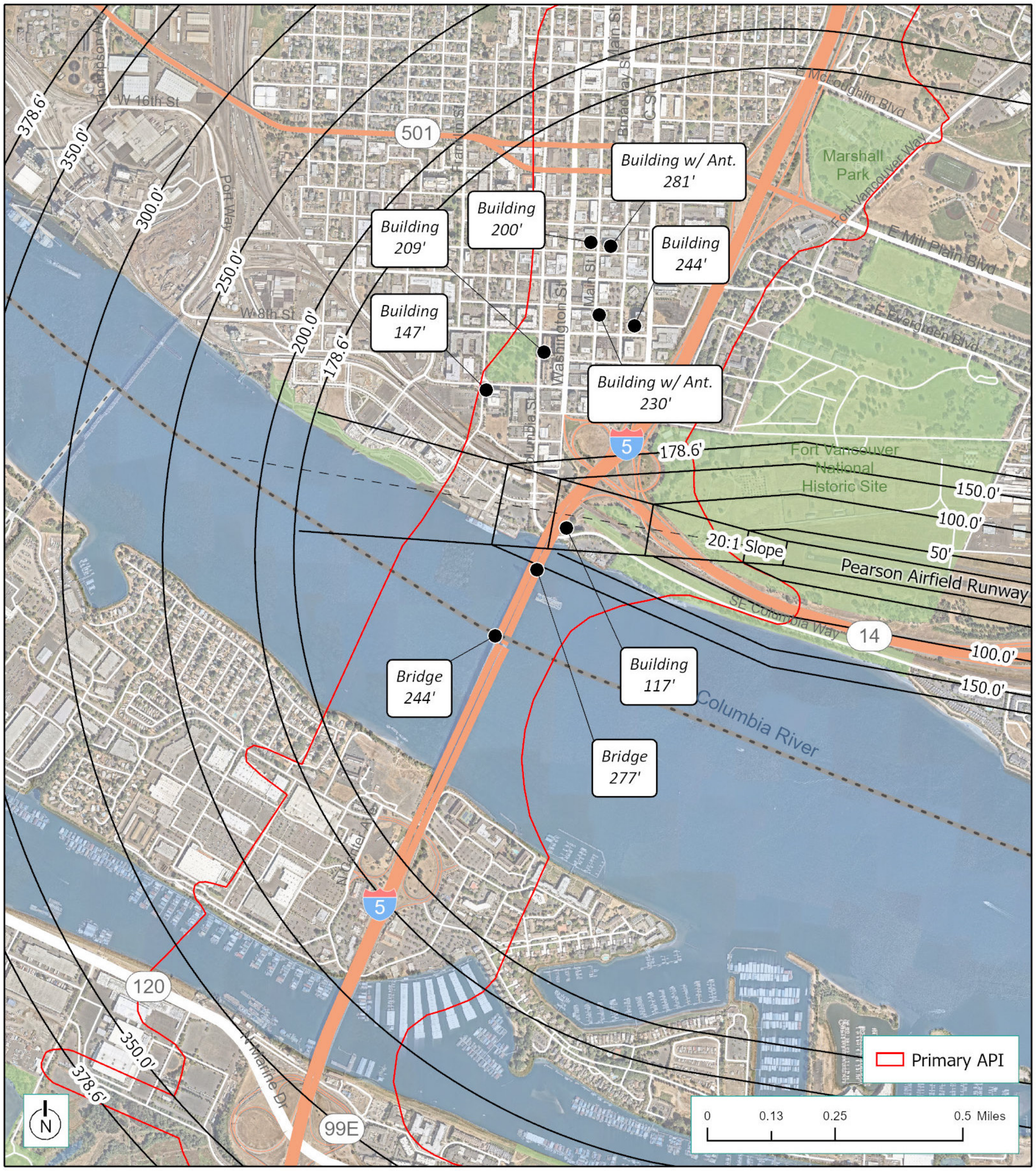
The departure and approach zones of both Pearson and PDX extend above the existing bridges and would therefore extend over the area of potential impact of a replacement river crossing. The previous analysis conducted for the CRC Project identified different types of airspace impacts that could occur with the CRC Project. The CRC analysis indicated that none the alternatives under consideration in the Draft EIS would have long-term effects on aviation activities at PDX, but they did have the potential to affect the aviation activities at Pearson. These included departure impacts associated with the proposed SR 14 interchange ramps and lighting and the proposed I-5 sign structures.

Any proposed changes to the Pearson Field Part 77 Airspace[9] will require review and approval by the Federal Aviation Administration (FAA). The IBR program would be required to submit a Form 7460 to the FAA for the program's design (by the designer) and one for construction (by the contractor). Each form would delineate any penetrations of the Part 77 Surface that would occur (permanent works relative to design and temporary works pertaining to construction). The FAA will use that information to determine if the proposed facility poses a hazard to air navigation or causes inefficient use of airspace.

Figure 4 shows the existing Part 77 airspace penetration for Pearson Field. As shown, the towers of the existing I-5 bridges currently penetrate this airspace as well as that of several buildings in downtown Vancouver. Pearson has special departure and take-off procedures that help the aircrafts avoid obstacles; aircrafts typically avoid flying directly over the existing bridges.

[9] FAA Title 14 CFR Part 77, Objects Affecting Navigable Airspace.

Figure 4. Existing Pearson Field Part 77 Airspace Penetration



If the FAA's review results in a hazard or inefficient use of airspace determination, the bridge or the means and methods of construction may have to be adjusted. Alternatively, it may be possible to restrict construction and/or airfield operations to accommodate any temporary intrusions. Permanent intrusions could require permanent airfield operational adjustments and the bridge owner would likely have to assume liability for any mishaps associated with the penetration(s). In the event the bridge is determined to be a hazard and/or results in efficient use of airspace, the Authority Having Jurisdiction would have the option to take legal action to force a revision to or terminate the development.

4.2.2 Cultural Resources, Section 106, and Section 4(f)

There are numerous cultural and recreational resources in and near the IBR program area, including resources protected by Section 106 of the National Historic Preservation Act and/or Section 4(f) of the U.S. Transportation Act. Section 106 resources are properties that are listed or eligible for listing in the National Register of Historic Places, defined in the Section 106 regulations as “historic properties.” Section 4(f) resources are publicly owned parks and recreation areas, waterfowl and wildlife refuges, and historic sites considered to have national, state, or local significance. A historic property is identified during the Section 106 evaluation and carried through to the Section 4(f) evaluation.

The historic built environment within the program area includes approximately 250 above-ground resources. These resources include residential, commercial, maritime, aviation, transportation, military, and other structures.

There is also a rich history of intertribal presence within the program area since time immemorial. As a result, the program area includes numerous high-significance resources. For the CRC Project, it was determined that all alternatives would be likely to impact these resources. Similarly, because potential impacts would be challenging to minimize or avoid under any alternative, it is anticipated that the IBR program would result in adverse effects on some archaeological resources as well.

There are approximately 200 Section 4(f) resources within the program area, including eligible historic resources, cultural resources, and public parks and recreation areas. As a result, Section 4(f) use and *de minimis* impact determinations are expected throughout the program area. Fort Vancouver, which is a National Historic Site managed by the National Park Service includes a plethora of sensitive resources (above and below ground) located throughout the property. These resources are protected under various regulations, including Section 106 and Section 4(f). Because of its proximity to the program area, adverse indirect and visual impacts to Fort Vancouver are possible. Figure 5 identifies the Section 4(f) parks and recreation resources near the program area, including National Historic Sites that are open to the public.

Figure 5. Section 4(f) Recreation Resources

4.2.3 Tribal Considerations

Native Americans have occupied this area since time immemorial. Pre-contact peoples established a strong relationship with the natural environment in addition to an expansive trade hub with other communities, fostering a cultural stronghold in the region across millennia. In the early 19th century, the Hudson's Bay Company established their regional headquarters at Fort Vancouver, building upon and integrating with the existing indigenous trading empire to establish a commercial epicenter and one of the largest settlements in the American West and connecting a wide range of diverse cultures with the resources in the region.

The IBR program recognizes and respects this expansive natural and cultural history, consulting with 11 Tribes and various natural resource organizations to ensure the program considers resources appropriately. Government-to-government consultation with 10 federally recognized Tribes is conducted regularly in addition to formal consultation under Section 106 of the National Historic Preservation Act.

Tribal considerations include culturally sensitive sites, impacts to aquatic species (including salmonid species and lamprey), aquatic and upland habitat, and water quality. Culturally sensitive sites include cultural resource locations on land and in the water, associated with the expansive cultural history of the area. Potential impacts on aquatic species and habitat and water quality include effects on fisheries upriver, downriver, and within the program area; treaty fishing sites above Bonneville; and culturally important species such as salmon, steelhead, lamprey, and eulachon. Potential sources of impacts include construction (e.g., pile driving and in-water work), direct habitat impacts, and stormwater runoff.

4.2.4 Habitat

The program area contains several different habitat types, including the Columbia River as well as North Portland Harbor and the Columbia Slough.[10] The Columbia River and North Portland Harbor provide habitat for a variety of native fish species (including Endangered Species Act [ESA]-listed species), such as several salmon and trout species, Pacific eulachon, and Pacific lamprey. Marine mammals are also present in the program area. The Columbia Slough is located in North Portland and provides habitat for many of the fish and wildlife species that use the Columbia River. The Columbia Slough provides some of the only remaining off-channel and refugia habitat[11] in the lower Willamette River area.

Terrestrial habitat within the program area includes fragmented forested riparian and wetland habitat, which supports species that are tolerant of human disturbance. The most highly functioning

[10] The Columbia Slough is a waterway just south of the program area.
[11] A location that supports an isolated and/or relict population of a once more widespread species. Relict populations are species that were more diverse and/or widespread in the past.

terrestrial habitats are those that still have connectivity to other areas with intact habitat. Figure 6 shows potential habitat areas in Vancouver, and Figure 7 shows potential habitat areas in Portland.

Key concerns for habitat related to the river crossing options include in-water work disturbing fish habitat and migration patterns, benthic habitat disturbance, and shading. Benthic habitats refer to the lowest ecological zone of a water body, including the sediment and substrate, and are generally areas of high biological activity, providing processes such as primary production, consumption, nutrient cycling and decomposition.[12] Benthic habitats provide a source of primary productivity for native fish, including several populations of ESA-listed salmon and steelhead, Pacific eulachon, white sturgeon, Pacific lamprey, and river lamprey.[13]

The river crossing options would have different impacts on habitats due to differences in the size of in-water structures (e.g., piers), length of time needed for in-water work, and construction methods (e.g., drilled shafts and pile driving for bridges or cut/cover and dredging for tunnels).

The program's effects on the different habitat types during construction would range from temporary to permanent impacts. Avoidance and minimization measures and best management practices would be implemented during construction to reduce habitat impacts. Impacts that are unavoidable would be mitigated through agency compensatory mitigation requirements, such as mitigation for waters of the U.S. Additional conservation efforts would be implemented for any impacts to habitats that are not currently covered under existing regulations, such as species of importance to Tribes.

[12] Benthic habitats within the Columbia River have been substantially altered from their historic condition by a variety of factors, including dredging activities; however, they continue to provide substantial habitat function to the aquatic species that rely on them.

[13] Shallow water benthic habitats in particular are important for outmigrating juvenile salmonids. Benthic habitats may provide substrate conditions that are suitable for adherence and incubation of Pacific eulachon eggs. Larval Pacific and river lamprey ammocetes burrow into benthic substrates and filter feed on algae, diatoms, and detritus for multiple years before metamorphizing into juveniles and outmigrating.

Figure 6. Potential Habitat in Vancouver, Washington

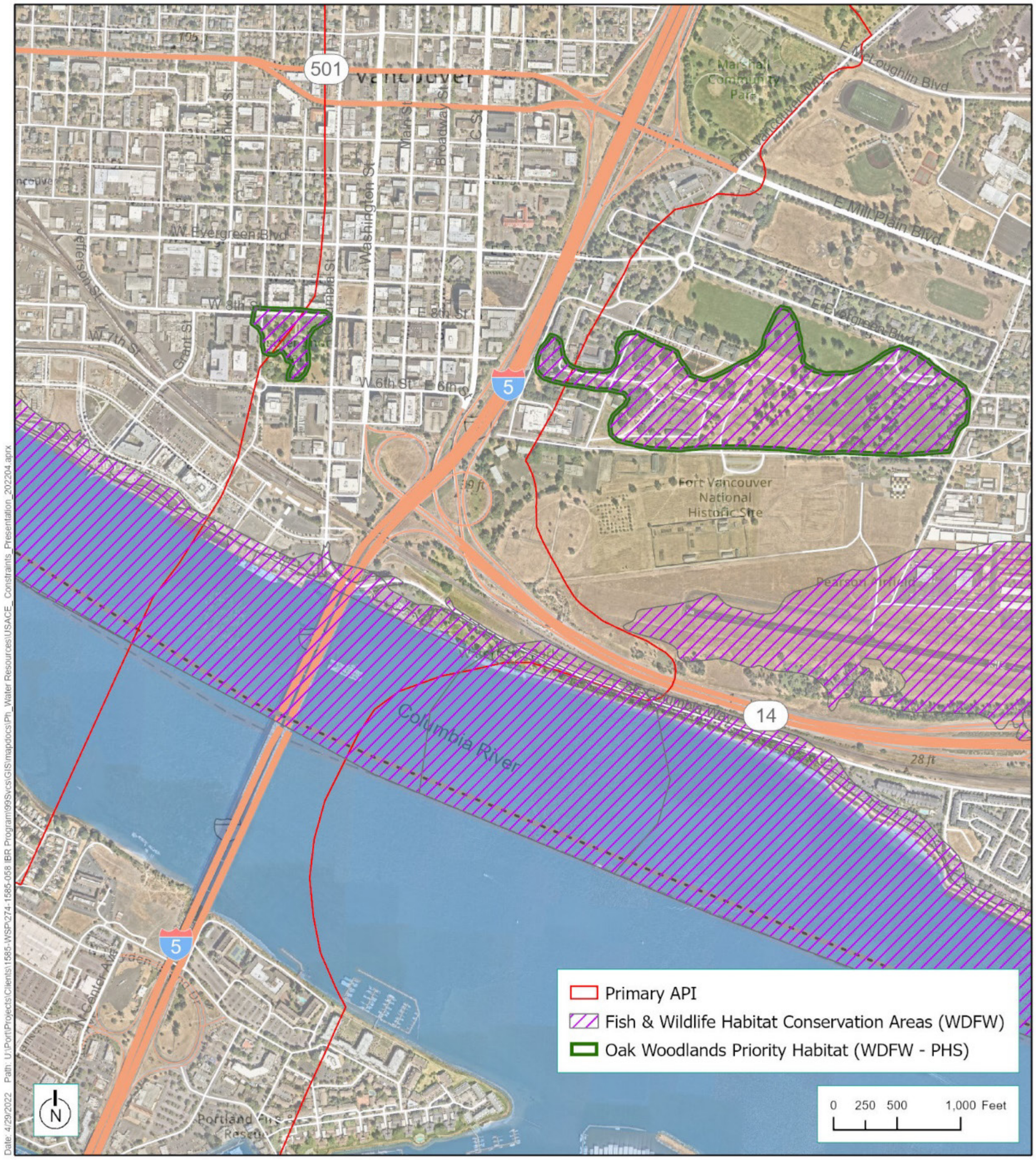
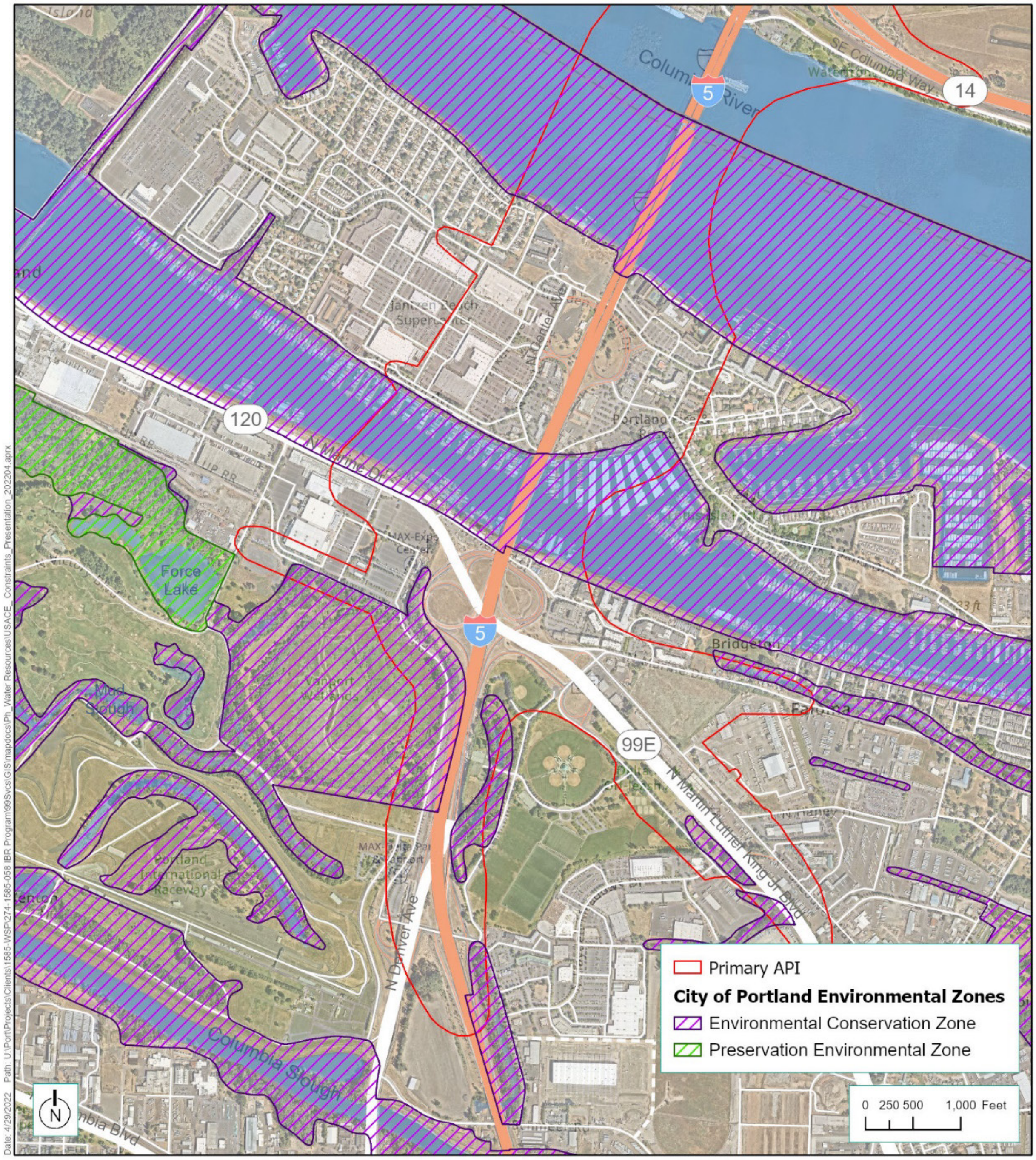


Figure 7. Potential Habitat in Portland, Oregon



4.2.5 Highway and Local Road Connections

Traffic data from 2019 shows that the various highway and local road connections experience different levels of daily vehicle volumes. Table 3 and Table 4 show the northbound and southbound daily vehicle volumes at the SR 14, Downtown Vancouver (Washington Street and C Street), and Hayden Island on and off ramps. The largest volumes are at the on ramp and off ramp to SR 14. The various river crossing options, which are described in Section 5, have different effects on how vehicles access these ramps and local streets.

Table 3. 2019 Daily Vehicle Volumes at Highway and Local Road Connections on I-5 Southbound

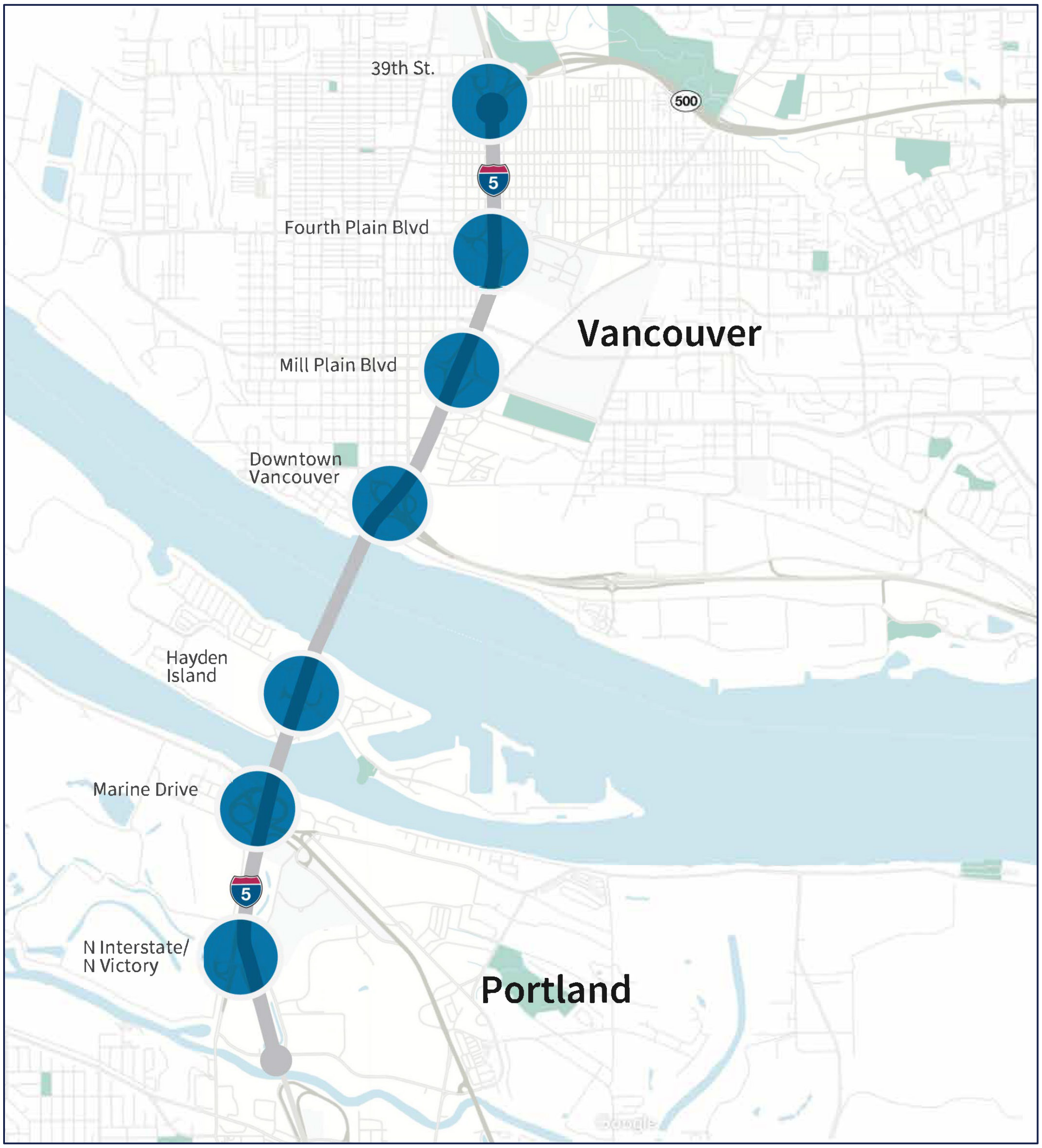
I-5 Southbound	2019 Daily Vehicle Volume
Off Ramp to SR 14 Eastbound	14,545
On Ramp from Washington Street (Downtown Vancouver)	3,680
On Ramp from SR 14 Westbound	11,220
Off Ramp to Hayden Island	8,730
On Ramp from Hayden Island	10,040

Table 4. 2019 Daily Vehicle Volumes at Highway and Local Road Connections on I-5 Northbound

I-5 Northbound	2019 Daily Vehicle Volume
On Ramp from SR 14 Westbound	16,505
Off Ramp to C Street (Downtown Vancouver)	3,110
Off Ramp to SR 14 Eastbound	13,110
On Ramp from Hayden Island	7,990
Off Ramp to Hayden Island	10,040

Figure 8 identifies the seven existing interchanges on I-5 within the program area. Depending on the type of river crossing selected, some of these interchanges may be eliminated if an option cannot connect to the existing routes in these locations. Eliminated interchanges would, in turn, affect the daily vehicle volumes experienced at other interchanges.

Figure 8. Interchanges in the Program Area



4.3 Future Considerations

Future considerations that may affect the river crossing include sea-level rise and the planned transportation networks in Portland and Vancouver, including active transportation, high-capacity transit, and highway design. The future transportation improvements described below include improvements proposed by the IBR program and local/regional partners.

4.3.1 Sea-level Rise

The IBR program is considering the potential effects of sea-level rise on the program, including how future conditions such as river levels and extreme weather events might impact the river crossing. Information on anticipated future conditions from the Climate Change Impacts Group[14] and the U.S. Geological Survey[15] was reviewed. Because of the distance from the ocean and the height above sea level, the anticipated effects of sea-level rise are reduced at the program site. A 0.5-foot increase in Columbia River levels is expected at Vancouver, based on a 3.3-foot (1-meter) sea-level rise.

Because the best available science provides no quantitative predictions of how daily or monthly average flows could change, it is difficult to translate the general climate change predictions into precise conclusions regarding future vessel clearances. However, a 0.5-foot increase would not be expected to change any vessel impacts due to the use of the ordinary high-water mark (OHWM) for determining available vertical clearance. Water levels are below the OHWM over 98% of the time and the river already has daily fluctuations greater than the predicted 0.5 foot increase due to tidal influence; therefore, the effect of sea level rise on water levels near the bridge area would be negligible.

In addition to river level changes caused by global sea-level rise, two planning efforts are underway and would have the potential to influence water levels at the I-5 bridges: the modernization of the international Columbia River Treaty between the U.S. and Canada and the proposed removal of the four lower Snake River dams. The IBR program is aware of these ongoing plans and all river crossing options will be designed in consideration of potential impacts in the program vicinity.

For these reasons, sea-level rise can be planned for/accommodated under any of the river crossing options (but may require specific design details).

[14] Miller, I.M., Morgan, H., Mauger, G., Newton, T., Weldon, R., Schmidt, D., Welch, M., Grossman, E. 2018. Projected Sea Level Rise for Washington State – A 2018 Assessment. A collaboration of Washington Sea Grant, University of Washington Climate Impacts Group, University of Oregon, University of Washington, and U.S. Geological Survey. Prepared for the Washington Coastal Resilience Project. Updated July 2019.
[15] Assessment of Columbia and Willamette River Flood Stage on the Columbia Corridor Levee System at Portland, Oregon, in a Future Climate. Scientific Investigations Report 2018–5161.

4.3.2 Active Transportation

Active transportation refers to human-powered modes of transportation, such as walking, biking, or rolling (e.g., using a wheelchair or scooter). Feedback from the community reinforced that improved connectivity between high-capacity transit and active transportation facilities is an important priority of the program. As part of the IBR program, there would be active transportation improvements, including a separated shared use path (SUP) on the river crossing. The SUP would have transit connections and connections to existing/planned trails and destinations, such as the Renaissance Trail, Columbia Way, and Hayden Island. Additionally, the highway design proposed by the IBR program will have a grade less than or equal to 5%, meeting Americans with Disabilities Act standards for the SUP.

4.3.3 High-capacity Transit

C-TRAN and TriMet both operate transit service in the program area. There is a benefit gained by integrating the established transit modes from both C-TRAN and TriMet with the transit component of the IBR program. C-TRAN designed their overall operations as a feeder-system to TriMet's expanded light rail service, which allows for the integration of a light rail terminus to provide effective reach into the transit services operated by C-TRAN.

The IBR program, with the support of local partners, is proposing a light rail transit extension of the TriMet's Yellow line from the Expo Center across the Columbia River and into Vancouver, terminating at Evergreen Boulevard, which best integrates existing transit investments in the region. To merge the two metro area transit systems together, the Evergreen bus terminus offers the best opportunity for faster, safer, and more reliable service while minimizing disruptions to downtown Vancouver.

4.3.4 Highway Design

The IBR program includes highway improvements on I-5 between SR 500 and Victory Boulevard, including modifications to seven interchanges. The general configuration of five interchanges would not change, but two interchanges would be modified: a full interchange would be located on Marine Drive and a partial interchange would be on Hayden Island. The IBR program is proposing a partial interchange on Hayden Island and a full interchange on Marine Drive and adding one auxiliary lane northbound and one auxiliary lane southbound between Marine Drive in Portland and Mill Plain Boulevard in Vancouver.

The IBR program also proposed adding one auxiliary lane northbound and one auxiliary lane southbound between Marine Drive in Portland and Mill Plain Boulevard in Vancouver, including on the replacement river crossing.

5. RIVER CROSSING OPTIONS

There are several types of river crossings that could be used to cross the Columbia River, either going under the river (tunnels) or over the river (bridges). These options provide different horizontal and vertical clearances for maritime navigation. Each option has both advantages and disadvantages in terms of meeting the Purpose and Need statement (Section 2), potential impacts to site conditions (Section 4), and other considerations, such as constructability and cost. The following sections provide an overview of each crossing option and identify the advantages, disadvantages, and other considerations that must be taken into account when identifying the preferred river crossing option for the IBR program.

The concepts assessed in this report are preliminary. They are not under design and remain at the planning conceptual level. They will not be advanced to the design stage until or unless deemed appropriate and necessary by program leadership in coordination with agency partners.

5.1 Tunnels

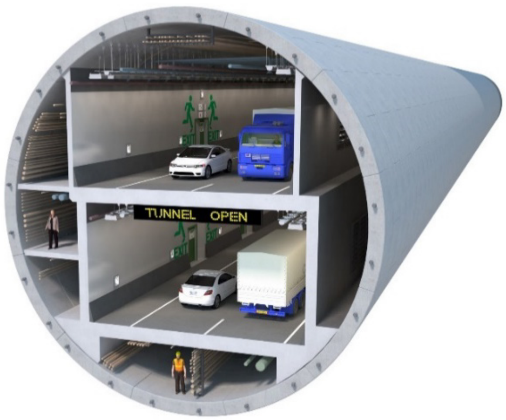
The IBR program investigated two types of tunnels that could potentially be used as a crossing for the Columbia River: a bored tunnel and an immersed tube tunnel (ITT). As described below, these tunnels differ in construction methods, possible alignments, general design, and some impacts (e.g., they have different upland connections) but are similar in other impacts (e.g., they both provide unlimited vertical clearance and eliminate over-water shading, etc.).

5.1.1 Bored Tunnel

A bored tunnel is constructed using a tunnel boring machine (TBM), which digs a bore (or tube) under the ground surface. For the IBR program's anticipated traffic and transit needs, a bored tunnel option would likely include four discrete bores, including two adjacent bores for vehicles (each up to 60 feet in diameter and spaced 60 feet apart) and two adjacent bores for transit (each 21 feet in diameter and spaced 20 feet apart); however, consideration would be given to a single, large-diameter transit bore during design development. Given this preliminary side-by-side layout, a bored tunnel option under the Columbia River would result in a footprint approximately 260 feet wide.

Figure 9 shows a cross-section of the SR 99 tunnel in Seattle, which consists of a single 56-foot bored tunnel with two lanes of traffic each way. A similar cross-section would initially be considered for the large-diameter vehicular bores for the IBR program.

Figure 9. Bored Tunnel Example – SR 99 Tunnel in Seattle

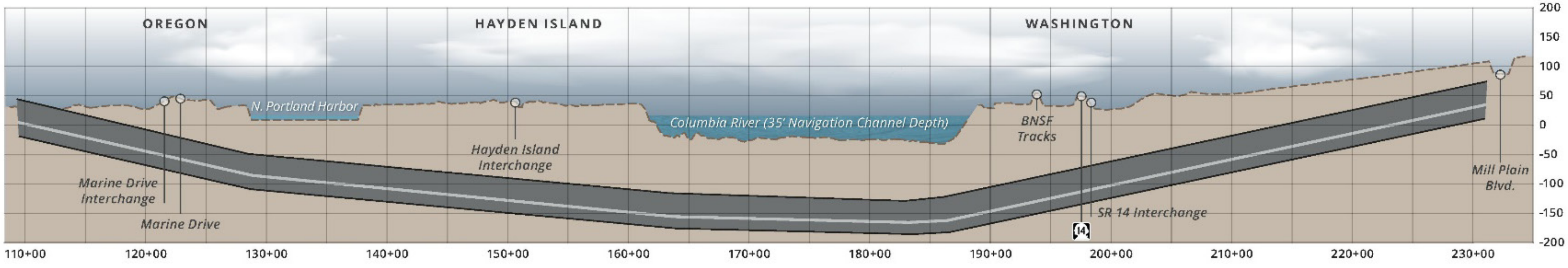


A profile concept for the larger, vehicular tunnel bores is provided in Figure 10. As shown, the bored tunnels would daylight south of Victory Boulevard and north of Mill Plain Boulevard, eliminating the existing interchanges (and their local connections) at Victory Boulevard, Marine Drive, Hayden Island, SR 14, and Mill Plain Boulevard. The top of the bores would initially be set at approximately 60 feet below river bottom, extending to approximately 175 feet below river bottom (at the lowest point of the tunnels). The steepest road grade in each tunnel would be between 4% and 4.5%. Transit stations between the tunnel portals would need to be located at significant depth below street level; however, it should be noted that a twin bore solution for the transit tunnel would allow for shallower tunnel and station depths than a four-bore tunnel, and refinement of layout of the respective bores would occur during design development. Additionally, design development for the bored tunnel would entail assessing ground improvements below the river to shallow up the profile of the respective bores, thereby reducing length and cost. This approach would require environmental clearances and would be evaluated on the basis of its benefits and/or impacts to the project cost and schedule.

In addition to the IBR program's evaluation, it should also be noted that bored tunnel options, including replacement and supplemental tunnels, were evaluated as part of the alternatives screening process during the CRC Project's alternatives analysis (described in Section 3). A replacement tunnel would be the only structure for the crossing as the I-5 bridges would be demolished. A supplemental tunnel would accommodate approximately half of the vehicular traffic on I-5, and the existing bridges would be retrofitted to handle the remainder.

In recent discussions with partner agencies, the IBR program revisited prior evaluations, reconfirmed the findings of the CRC screening process, and concluded that a bored tunnel would still not meet the Purpose and Need. Specifically, a replacement bored tunnel would fail to fulfill four needs because the tunnel would surface south and north of much of the program area, thereby not serving most of the access needs for this section of I-5, including the needs of active transportation, transit, private vehicles, and freight. In addition, a bored tunnel option presents significant, though not insurmountable, construction challenges and impacts, such as potential impacts to Fort Vancouver and temporary loss of local connections.

Figure 10. Bored Tunnel – Potential Highway Alignment Under the Columbia River

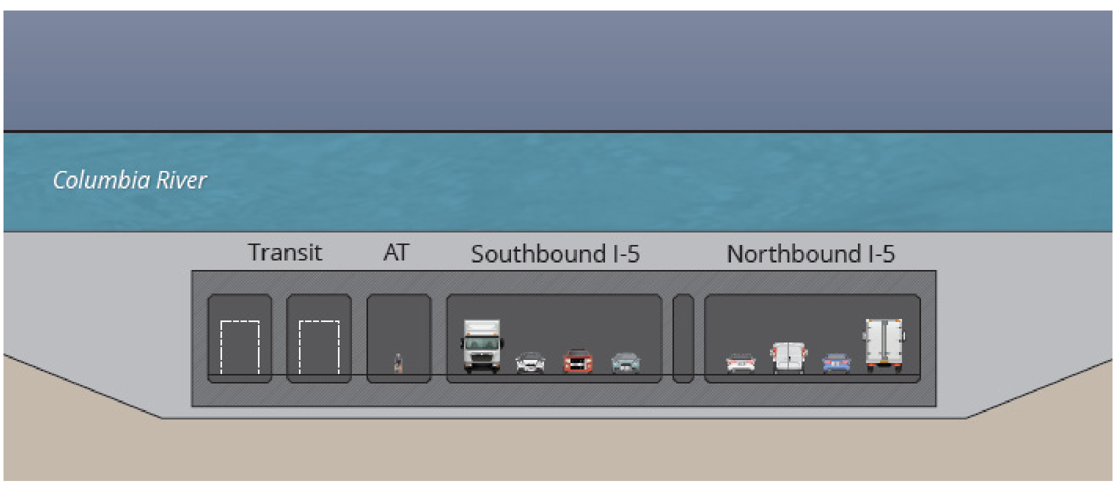


5.1.2 Immersed Tube Tunnel

An ITT consists of a series of prefabricated tunnel segments that are constructed on land and then sunk into a dredged trench (approximately 360 to 540 feet wide and 2,600 feet [0.5 miles] long) under the river bottom. In-water excavation would require approximately 4 million cubic yards of material. Total excavation for the tunnel facility would be approximately 8 to 9 million cubic yards of material. Tunnel segments would then be connected under water, and the tunnel would be dewatered. Recognizing that the previous planning effort assumed a bored tunnel, the IBR program assembled a group of professionals with international experience in tunnel design and construction to provide a comprehensive conceptual review of the suitability of an ITT.

The Tunnel Concept Assessment (Attachment B) details the technical considerations of designing, constructing, and operating an ITT, including the dredging process and soil removal. The ITT concept developed by the IBR program for the Concept Assessment would accommodate all three transportation modes: roadway, high-capacity transit, and an SUP for active transportation (Figure11). The tunnel section would consist of six adjacent cells, separated by concrete walls, located within a rectangular tube approximately 180 to 184 feet wide. One cell would accommodate four lanes of traffic for northbound I-5 and another cell would accommodate four lanes of traffic for southbound I-5. Two cells, one for each direction, would accommodate northbound and southbound high-capacity transit. One cell would accommodate the SUP. One cell would accommodate the operations and maintenance/egress route. It is assumed that all of these modes would be housed within a single immersed tube cross-section.

Figure 11. ITT – Conceptual Cross-Section Below the Columbia River



AT = Active Transportation

A profile of a potential ITT replacement crossing is provided in Figure 12. The land side approaches of the ITT would transition from an immersed tube to a cut and cover tunnel, and then to an open-air section as the tunnel returns to grade. Temporary easements would be required for construction, while permanent right-of-way would be the same (or similar) to what is currently needed for I-5.

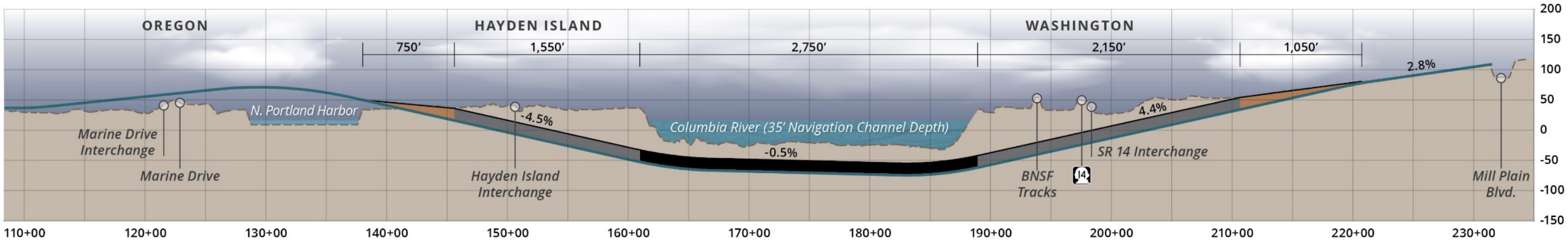
As shown, an ITT would likely daylight on the southern end of Hayden Island in Portland and near Evergreen Boulevard in Vancouver. This would eliminate connections to I-5 at SR 14 and Hayden Island. An ITT would require in-water work and trenching in the Columbia River. Transit stations between the two tunnel portals would be located approximately 50 to 100 feet below street level.

The top of the ITT would be approximately 10 feet below the river bottom, extending to approximately 70 feet below the river bottom (at the lowest point of tunnel). Like a bored tunnel, the steepest roadway grades would be between 4% and 4.5%.

The Tunnel Concept Assessment concluded that an ITT is technically feasible; however, there are numerous challenges, as identified in Table 5. These challenges include significant out-of-direction travel for drivers, freight, transit users, bicyclists and pedestrians; the inability to tie into existing connections, such as SR 14, Vancouver City Center, and Hayden Island; safety concerns for bicyclists and pedestrians; and significant archaeological, cultural, and environmental impacts. In-water work and trenching in the Columbia River would require substantial mitigation for impacts to habitat and species, including benthic habitat, salmonid species, and lamprey. Additionally, cost estimates for the ITT would be substantially higher than cost estimates for a replacement bridge and approaches (a comparison of tunnel options to bridge options is provided in Section 5.4). Notably, the cost estimate does not include other highway, interchange, and high-capacity transit improvements that would be necessary.

Figure 12. ITT – Potential Highway Alignment Under the Columbia River

Black = ITT; Gray = Cut and cover tunnel; Brown = Open-air section



PROFILE: DOWNSTREAM ALIGNMENT

5.1.3 Tunnel Crossing Evaluation and Considerations

Table 5 lists key details for the tunnel options that should be considered when selecting a river crossing for the IBR program. While there are some key differences in the impacts and considerations between a bored tunnel and an ITT, the tunnel options have many similarities (as identified by merged cells in the table below).

Table 5. Evaluation and Considerations for Tunnel Options

Topic	Bored Tunnel	ITT
Active Transportation/ SUP	• **Safety concerns** due to enclosed SUP for over 1 mile (e.g., no "eyes on the path," emergency egress, fire and life safety) • **Missed** direct connectivity from the SUP on the river crossing to local trails on both sides of the river (e.g., Renaissance Trail, Marine Drive Trail) • Opportunities to **improve connectivity** between existing trails on the Washington shore and potential for more park space along the river due to removal of existing I-5 connections	
Aviation	• **No penetration** into Pearson airspace	
Columbia River Navigation	• **Unlimited** horizontal and vertical navigation clearances • **Compatible** with to existing navigation channels • **Eliminates navigation hazards** at the bridge location (e.g., bridge piers, bridge deck) in/over the river	

Topic	Bored Tunnel	ITT
Construction Considerations	• Requires **significant, challenging** launching pits for the TBM(s) • Requires a **record or near-record diameter** TBM for vehicular tunnel bores	• Requires **unconventional and complex** below-grade construction to accommodate interchange connections consisting of cut and cover tunnels with large temporary excavations. This would make **construction impractical** • Construction would require **negotiation and approval of a permit from BNSF** to construct over/under/through their right-of-way (ROW); it is unlikely that BNSF would accept interruptions of their operations, and therefore construction would likely require the program construct a temporary alternative route; **there is no readily available route**
Cost Considerations	• Due to the significant disadvantages of a bored tunnel (e.g., would eliminate five interchanges), a conceptual cost estimate was not developed. However, it is certain that a bored tunnel would be **more expensive than an ITT** (due to such factors as increased construction method costs, significantly increased tunnel length, and increased construction risk mitigation)	• A conceptual construction cost estimate[a] of $**3.08 billion** for an ITT (from grade to grade) was developed based on previously completed projects and the collective expertise of the team

<table>
<tr><th>Topic</th><th>Bored Tunnel</th><th>ITT</th></tr>
<tr><td rowspan="2">Environmental Considerations</td><td colspan="2">• Eliminates over-water shading impacts to fish and marine habitat. While a bored tunnel would go under the river, thus reducing/avoiding impacts to the river, an ITT would require dredging the river bottom – see below for impacts specific to an ITT
• Potential to reuse riverfront properties/land above the tunnel; construction noise, vibration, and congestion impacts to businesses, impacts to neighborhoods and parks/recreation due to tunnel portals and local connections; utilities would require substantial relocations
• Impacts on local communities and neighborhoods from construction of the cut and cover sections, tunnel portals, and local connections, including displacement of businesses and residences and neighborhood isolation
• Removes the bridge from the viewshed, which benefits historic properties, parks and trails, and other resources</td></tr>
<tr><td>• Construction could avoid impacts to aquatic plants, fish, and other marine animals/plants by boring below the river bottom</td><td>• In-water trenching and dredging would disturb the river bottom across the entire width of the Columbia River, including the riverbanks (in-water excavation would require approximately 4 million cubic yards of material)
• Dredged material would need to be placed in an in-water or upland site and may require special handling if contaminated materials are found; disturbance of the river bottom and nearshore habitat would require mitigation
• In-water construction would impact aquatic plants, fish and other amphibians, marine mammals, and birds (including ESA-listed species)
• Concerns with cultural resources along the shoreline and underwater; could impact</td></tr>
</table>

<table>
<tr><th>Topic</th><th>Bored Tunnel</th><th>ITT</th></tr>
<tr><td></td><td></td><td>Fort Vancouver and Old Apple Tree Park; size and volume of excavation and vibration could disturb or permanently impact resources
Disturbance and suspension of potentially contaminated materials in the river; large excavation of contaminated soil on land may exceed capacity of existing disposal locations</td></tr>
<tr><td>Geotechnical Considerations</td><td>Control of ground loss during tunneling, particularly under the river
Groundwater control and water tightness in temporary excavations (e.g., launch pits) and permanent underground structures (e.g., stations)
Balancing incorporation of ground improvements for ground strengthening and liquefaction mitigation with tunnel profile depth to mitigate against tunnel buoyancy</td><td>Ground improvement may be required to improve the soils of the river bottom above, below, and around the ITT, which contributes to high construction schedule and cost risks</td></tr>
<tr><td>High-Capacity Transit</td><td colspan="2">An underground station could result in high costs and construction risks due to ground conditions near the river</td></tr>
<tr><td>Highway Traffic</td><td>Due to missed connections (loss of five interchanges), large volumes of traffic would be rerouted through local streets to access I-5</td><td>Due to missed connections (loss of two interchanges), large volumes of traffic would be rerouted through local streets to access I-5</td></tr>
<tr><td>Highway/Local Connections</td><td>Eliminates five[b] I-5 interchanges, resulting in a loss of access to local streets and requiring modifications to the adjoining corridors</td><td>Eliminates two[c] I-5 interchanges, resulting in a loss of access to local streets and require modifications to the adjoining corridors</td></tr>
</table>

Topic	Bored Tunnel	ITT
Operational Considerations	• Requires a **full-time staffed operations center** for monitoring the mechanical, electrical, and traffic control systems and security • Requires **additional and different systems requirements** (fixed firefighting systems; mechanical ventilation systems [jet fans]; standpipe system; tunnel thermal protection systems; drainage systems; traffic monitoring systems; security systems)	
Safety	• Requires **extensive fire and life safety systems** • Requires **additional and different safety requirements**[16] (fixed firefighting systems; mechanical ventilation systems [jet fans]; standpipe system; tunnel thermal protection systems; drainage systems; traffic monitoring systems; security systems) • Fire prevention and ventilation **difficult** at abrupt changes in geometry • Hazardous materials are **not typically permitted in tunnels** (would require approval at the state level) • **Safety concerns due to enclosed tunnel** with two points of access (e.g., potential delays in emergency response, road blockage due to a collision)	
Structural Considerations	• Requires **more rigorous design efforts** and specialty contractors	

[a] The conceptual construction costs do not include an allowance for soft costs such as design, construction management, contingency, or life-cycle considerations. These costs are for a facility that would accommodate I-5, high-capacity transit, and the SUP. This estimate does not include other highway, interchange, or high-capacity transit improvements that would be necessary. See Attachment B.

[b] Victory Boulevard, Marine Drive, Hayden Island, SR 14, and Mill Plain Boulevard

[c] Hayden Island and SR 14

[16] Note: These requirements are also listed under "Operational Considerations." The listed requirements also pertain to safety considerations.

5.2 Movable Span Options

This assessment assumes that the upstream and downstream spans between Piers 5 and 6 (which flank the proposed primary navigation channel) would be movable. All other spans of the river crossing would be fixed. The movable spans would accommodate vehicular traffic, light rail transit, and a SUP. Refer to Attachment C for a comprehensive assessment of the movable span options.

The three types of movable spans considered are described as follows:

1. A **vertical lift span** is similar to the type of movable span that exists on the crossing today, in which the span would rise vertically while remaining parallel with the deck.
2. A double-leaf **bascule span** would open in the middle, with each leaf rotating from a normal horizontal position to a nearly vertical position; to reach this position, each leaf would pivot around a horizontal axis on trunnion shafts attached to each side of the span.
3. A **swing span** is similar to the downstream BNSF bridge; in this design, the span opens by pivoting on a central pier and then rotating in a horizontal plane around a center support (vertical axis). For the IBR program, two swing spans would be required in order to provide the necessary horizontal clearance.

5.2.1 Vertical Lift Span

Vertical lift span bridges have been constructed with navigation channel (horizontal) clearances in the range of up to 500 feet and vertical clearance of approximately 200 feet. This type of span would provide a predetermined vertical clearance for river navigation, which, in this case, has been prescribed by the USCG to meet or exceed that of the current lift span (178 feet).

The cross-section of a vertical lift span would be consistent with that proposed for the fixed span Bridge with two[17] double-deck side-by-side bridges. The upstream bridge would have northbound I-5 lanes on the upper deck and a SUP on the lower deck, and the downstream bridge would have southbound I-5 lanes on the upper deck and two-way light rail transit on the lower deck.

The lift spans would be located between Piers 5 and 6 to provide up to 178 feet of vertical clearance over the proposed primary channel. Vertical lift spans are required to be on a straight section of bridge that has a level (or nearly level) deck.

Figure 13 shows an example of a single double-deck vertical lift bridge in Houghton, Michigan. The IBR program would require two side-by-side double-deck vertical lift bridges to accommodate multimodal traffic.

[17] The combination of the length, width, and depth of the lift spans required for the IBR program would result in one of the biggest, if not the biggest, lift span in the world. A single, wider lift span was not considered as it would significantly exceed the widest movable bridge span in the world.

Figure 13. Double-deck Vertical Lift Bridge Example – Portage Lake Bridge, Houghton, MI

5.2.2 Bascule Span

The practical limit for a double-leaf bascule span is approximately 350 feet long. If the IBR program were to use this type, the bascule spans would hinge from Piers 5 and 6 to provide unlimited vertical clearance over the proposed primary channel. Bascule spans are required to be on a straight section of bridge that has a level (or nearly level) deck.

A double-leaf bascule arrangement would be needed to accommodate the required width of the navigation channel. This option could be accommodated by a two-bridge double-deck arrangement[18] similar to the fixed span bridge options. Figure 14 shows an example of a double-deck double-leaf bascule bridge in Chicago, Illinois.

[18] Due to the machinery required to operate movable spans of this size, the bascule span option could also comprise three single-deck bridges by adding a third bridge, such that the upstream bridge would accommodate northbound I-5, the adjacent downstream bridge would accommodate southbound I-5, and a third bridge would be adjacent to the southbound I-5 bridge and accommodate light rail transit and the SUP.

Figure 14. Double-deck Double-leaf Bascule Bridge Example – Wells Street Bridge, Chicago, IL

5.2.3 Swing Span

The swing span option would require one double-deck swing span on Pier 5 and one on Pier 6. The spans would be approximately 150 feet wide to accommodate the width of both directions of I-5 on the upper deck and light rail transit and the SUP on the lower deck. The swing spans would pivot on Piers 5 and 6 to provide unlimited vertical clearance for river navigation on the primary navigation channel. The span would need to be approximately 550 feet long to provide the 400-foot-wide horizontal river navigation channel.

The cross-section of a swing span would be similar to that proposed for the Fixed Span Bridge, except there would be one bridge instead of two. Northbound and southbound I-5 would be on the upper deck, and a SUP and two-way light rail transit would be on the lower deck.

Figure 15 shows an example of a single-deck double-swing bridge in York County, Virginia. For this assessment, the swing span would be double-deck.

Figure 15. Single-deck Double-swing Bridge Example – Coleman Bridge, York County, VA

5.2.4 Movable Span Evaluation and Considerations

Table 6 identifies key details for each of the movable span options. As shown, all options have advantages and disadvantages that should be taken into consideration when selecting a river crossing replacement.

Table 6. Evaluation and Considerations for Movable Span Options

<table>
<tr><th>Topic</th><th>Vertical Lift Span</th><th>Bascule Span</th><th>Swing Span</th></tr>
<tr><td>Active Transportation/ SUP</td><td colspan="3">• Delay to SUP users during a bridge opening; no suitable detour route is available
• Lower bridge elevation would be a benefit for path users (reduced grades would increase ease of access and operability of the SUP)</td></tr>
<tr><td>Aviation</td><td>• Lift span towers would permanently penetrate Pearson airspace</td><td>• Leaves would temporarily penetrate Pearson airspace when open</td><td>• No penetration into to Pearson airspace</td></tr>
</table>

<table>
<tr><th>Topic</th><th>Vertical Lift Span</th><th>Bascule Span</th><th>Swing Span</th></tr>
<tr><td>Columbia River Navigation</td><td colspan="3">

Provides 178 feet or unlimited vertical clearance for navigation
Openings required to accommodate tall vessels/cargo
Lower vertical clearance (in the closed position) than that provided by a fixed span bridge (see Section 5.3)
Requires 400 feet of horizontal clearance per the USACE
Movable span operations, and thus river navigation operations, would likely need to be restricted to nighttime openings to minimize impacts to vehicle traffic and transit operations
Primary navigation channel would be moved south

</td></tr>
<tr><td rowspan="2">Construction Considerations</td><td colspan="3">

Extended construction schedule (approximately 1 to 2 years) due to in-water work, equipment, and specialized workforce required

</td></tr>
<tr><td>--</td><td>

Additional schedule extension with third bridge configuration

</td><td>--</td></tr>
<tr><td>Cost Considerations</td><td>

Construction cost of two 450-foot lift spans: $500 million
Total bridge cost (Pier 1-8): $930 million

</td><td>

Three bridge option: Construction cost of three 400-foot single-level bascule spans: $600 million
Total bridge cost: $1.03 billion
Two bridge option: Construction cost of two 400-foot double-deck bascule spans: $550 million.
Total bridge cost (Pier 1-8): $980 million

</td><td>

Construction cost of two 550-foot swing spans: $800 million.
Total bridge cost (Pier 1-8): $1.23 billion

</td></tr>
</table>

<table>
<tr><th>Topic</th><th>Vertical Lift Span</th><th>Bascule Span</th><th>Swing Span</th></tr>
<tr><td rowspan="2">Environmental Considerations</td><td colspan="3">• Increased air quality pollutant and greenhouse gas emissions due to vehicular idling during a bridge opening
• Increased in-water work due to size of foundations would increase impacts to biological resources, hazardous materials, and historic structures and archaeological resources
• Challenging stormwater containment due to the bridge joints that allow the movable span to function</td></tr>
<tr><td>• Permanent visual impacts due to lift towers</td><td>• Additional displacement of benthic habitat with third bridge configuration
• Additional over-water shading with third bridge configuration
• Visual impact during bridge opening</td><td>• Increased land use and development impacts due to downstream location of bridge (required for construction)</td></tr>
<tr><td>Geotechnical Considerations</td><td colspan="3">• Requires more substantial river piers and pier foundations to support the span as compared to a fixed span (movable parts are more sensitive to foundation settlement) to ensure smooth operation over its lifetime.</td></tr>
<tr><td>High-Capacity Transit</td><td colspan="3">• Reduced train speed over bridge
• Interruptions to operations during a bridge opening throughout 18-mile service network unless openings are restricted to nighttime only. Nighttime openings could also impact the start of service.
• Extensive maintenance to keep communications, power and track operable
• Opportunity to decrease the profile elevation and grade could improve connections to the Vancouver Waterfront station for transit vehicles and transit patrons</td></tr>
</table>

<table>
<tr><th>Topic</th><th>Vertical Lift Span</th><th>Bascule Span</th><th>Swing Span</th></tr>
<tr><td rowspan="2">Highway Traffic</td><td colspan="3">The cycle time for a bridge opening would be 20 to 30 minutes.
Daytime bridge lifts could impact traffic volumes for up to an hour or more; nighttime bridge lifts would not impact traffic volumes for multiple hours a day
To reduce congestion and improve mobility, movable span operations would likely need to be restricted to specific days and/or times</td></tr>
<tr><td>--</td><td>Fastest cycle time to open and close the bridge resulting in less congestion</td><td>--</td></tr>
<tr><td>Highway/Local Connections</td><td colspan="3">Maintains local highway and street connections
Retains existing interchange locations
Reduced grades would increase the ease of ramp connections, primarily on the Hayden Island end of the bridge</td></tr>
<tr><td>Operational Considerations</td><td colspan="3">More likely to result in misalignment or damage from a seismic event
Requires a bridge operator on site
Requires additional maintenance associated with mechanical and electrical systems</td></tr>
<tr><td>Safety</td><td colspan="3">Crash rate is expected to be 3 to 4 times higher during a bridge lift than during normal operating conditions</td></tr>
</table>

<table>
<tr><th>Topic</th><th>Vertical Lift Span</th><th>Bascule Span</th><th>Swing Span</th></tr>
<tr><td rowspan="2">Structural Considerations</td><td colspan="3">Requires more rigorous design efforts and specialty contractors</td></tr>
<tr><td>Towers up to 60 feet taller than vertical clearance required
Counterweights in the towers would require additional seismic design considerations to mitigate earthquake impacts</td><td>Would be one of the largest double-leaf bascule spans in the world
Potential for operational problems due to span imbalance, keeping counterweight pit dry, and center locks issues
Must resist seismic and wind loading to a greater extent than other movable bridge types</td><td>Would be one of the largest movable spans of its type in the world
Low profile and does not require expensive counterweights.
Less massive piers than a bascule or vertical lift bridge
More machinery than a bascule or vertical lift bridge: an end-centering device and end-lifting devices</td></tr>
</table>

5.3 Fixed Span Bridges

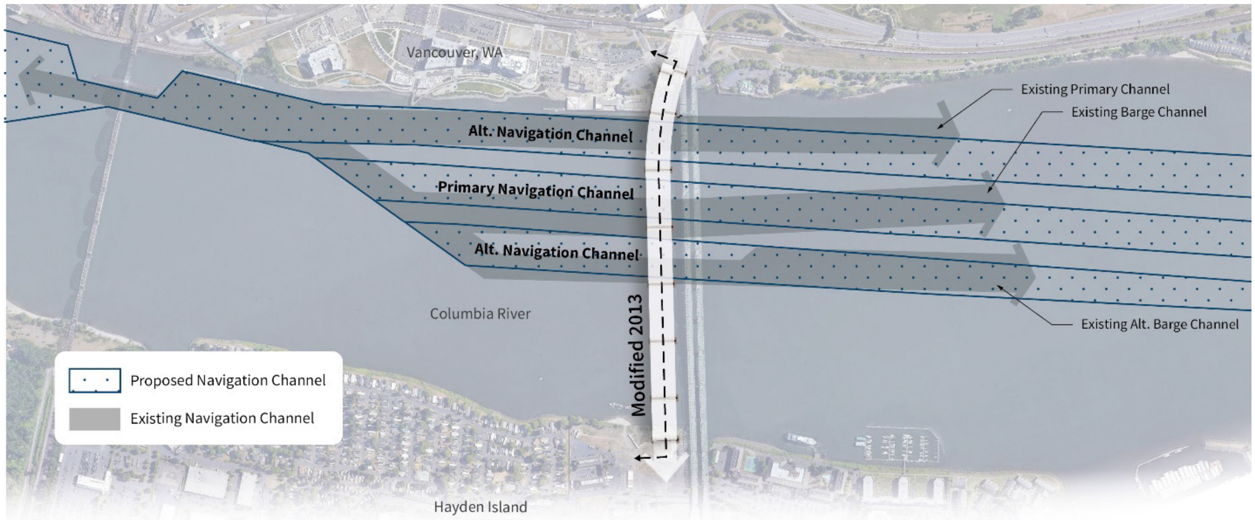
A fixed span bridge is a bridge with no moving parts (as opposed to a bridge with a movable span). A local example of a high-level fixed span bridge is the Astoria-Megler Bridge, which provides nearly 205 feet of vertical clearance for navigation (Figure 16). An example of a mid-level fixed span bridge is the Vicksburg Bridge between Louisiana and Mississippi, which provides 116 feet of vertical clearance (Figure 17).

Figure 16. High-level Fixed Bridge Example – Astoria-Megler Bridge, Astoria, OR and Point Ellice, WA

Figure 17. Mid-level Fixed Bridge Example – Vicksburg Bridge, Delta, LA and Vicksburg, MS

Figure 18 shows a conceptual bridge plan (aerial view) of a fixed span replacement bridge over the Columbia River, which could apply to a high-level fixed span bridge (178 feet of vertical clearance) or a mid-level fixed bridge (116 feet of vertical clearance). As shown, a fixed span bridge would require changes to the existing federal navigation channels in order to align the channels with the bridge piers and to align the primary channel with highest point of the bridge profile.

Figure 18. Conceptual Bridge Plan: Fixed Span Bridge



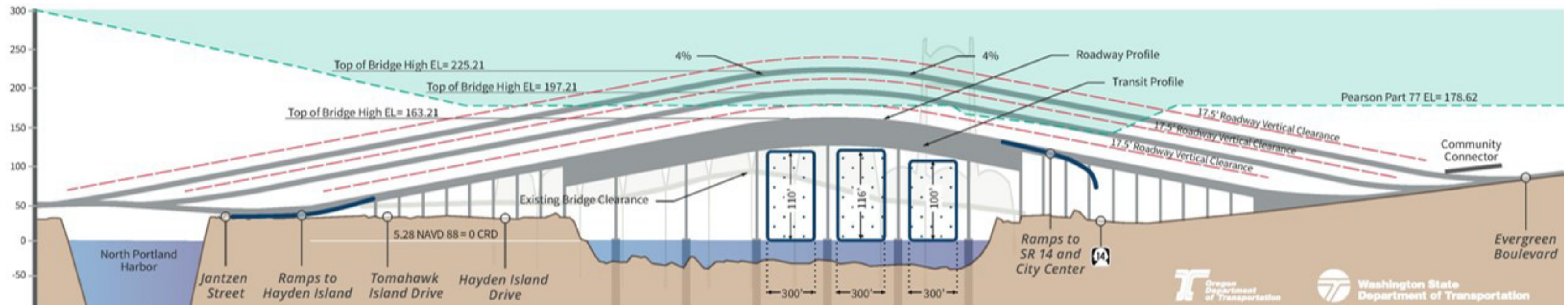
An evaluation of a high-level and mid-level fixed span bridges is provided below, along with a summary of the advantages and disadvantages of these river crossing options.

5.3.1 High-level Fixed Span

A high-level fixed span bridge would provide up to 178 feet of vertical clearance over the Columbia River, which is the current vertical clearance under the existing lift spans (when open). This height would require long transitions from the peak elevation down to match the existing grades of I-5. Due to grade limitations of highways, light rail, and SUPs, the 4% grade is the maximum profile recommended, but with the higher clearance, the length of grade is longer to match to existing I-5 grades north and south of the river crossing. The higher profile would make connections to SR 14 and Hayden Island extremely challenging and unrealistic to accomplish.

Figure 19 illustrates the anticipated bridge profile (side view, looking west) for a high-level fixed span bridge. The figure shows two navigational clearances, 178 feet and 150 feet, and a comparison to the 116-foot mid-level clearance. As shown, interchanges at SR 14 and Hayden Island would be removed, transit stations on Hayden Island and Vancouver waterfront would be extremely high, path users would climb to higher elevations, path connections to Hayden Island and the Vancouver Waterfront would be more challenging, and the bridge would encroach in the FAA Pearson Field restricted airspace (area highlighted in green in the figure).

Figure 19. Bridge Profile: High-level Fixed Span Bridge



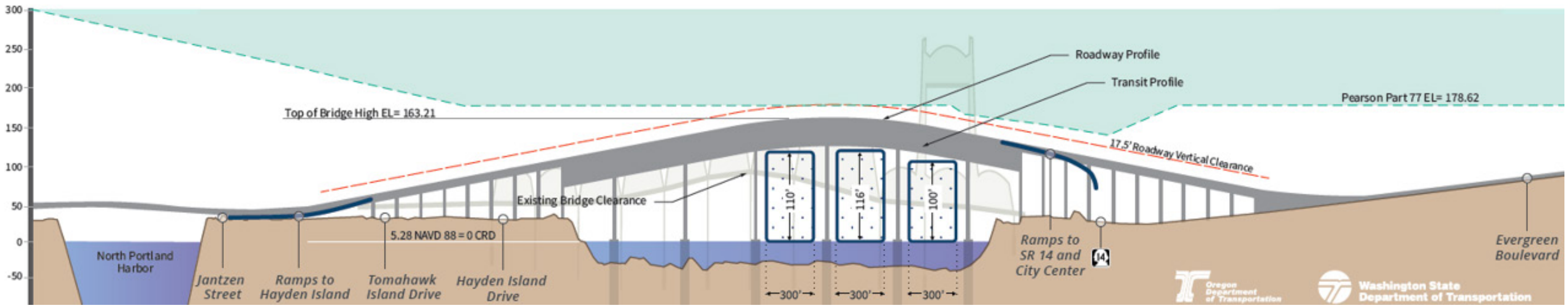
5.3.2 Mid-level Fixed Span

A mid-level fixed span bridge would provide 116 feet of vertical clearance over the Columbia River.[19] A mid-level fixed span bridge would connect to the existing I-5 grades on Hayden Island and south of Evergreen Boulevard in Vancouver with a recommended maximum grade of 4%.

Figure 20 illustrates the anticipated bridge profile (side view, looking north) for a mid-level fixed span. As shown, this option would touch down on Hayden Island in Portland and south of Evergreen Boulevard in Vancouver. The bridge height would fall below the Part 77 FAA Pearson Field airspace (i.e., it would not penetrate the airspace). The bridge would provide 116 feet of vertical clearance in the primary channel and 100 to 110 feet in the barge and alternative barge navigation channels.

[19] As noted in Section 3, the vertical clearance over the primary channel was raised to 116 feet as part of a NEPA reevaluation. The USCG issued a Section 9 bridge permit for this clearance in 2013; however, that permit was contingent on securing other required permits and authorizations as well as implementing mitigation to affected marine users.

Figure 20. Bridge Profile: Mid-level Fixed Span Bridge



5.3.3 Fixed Span Bridge Evaluation and Considerations

Table 7 identifies key details for both a high-level and mid-level fixed span bridge. As shown, both options have advantages and disadvantages that should be taken into consideration when selecting a river crossing replacement.

Table 7. Evaluation and Considerations for Fixed Span Bridge Options

Topic	High-level Fixed	Mid-level Fixed
Active Transportation/ SUP	• Connections to Hayden Island and Vancouver waterfront **would be challenging** due to height above ground	• Connections to existing grade at Hayden Island and Vancouver waterfront **can be achieved** with ramps
Aviation	• **Permanent protrusion** into Part 77 FAA Pearson airspace	• **Likely penetration** into Part 77 FAA Pearson airspace (lights and signs only – the bridge would not protrude)
Columbia River Navigation	• Primary navigation channel would be **moved south** to the bridge profile high point	
	• Would accommodate a vertical clearance **up to 178 feet** for river navigation	• Would accommodate a vertical clearance **up to 116 feet** for river navigation • Would **reduce** navigation clearances as they exist today • **Mitigation** proposed for 4 vessels/users (reported approximately 70 trips/year)[a]
Construction Considerations	• **Conventional** construction methods and risks	

<table>
<tr><th>Topic</th><th>High-level Fixed</th><th>Mid-level Fixed</th></tr>
<tr><td>Cost Considerations</td><td>The work completed for CRC, and supported by the IBR program, suggested higher costs for a higher fixed span bridge. This is in part due to the changes that would occur at each land side connection, accounting for differences in interchanges, transit stations, and active transportation connections</td><td>Construction cost of two 450-foot fixed spans: $70 million
Total bridge cost (Pier 1-8): $500 million</td></tr>
<tr><td rowspan="2">Environmental Considerations</td><td colspan="2">Smaller aquatic footprint compared to tunnels and movable span bridges; less in-water work/structures than tunnel options, and smaller pier foundations compared to movable span bridges</td></tr>
<tr><td>Sustained 4% grade would result in increased greenhouse gas emissions
Sustained 4% grade would create noise impacts due to the use of Jake brakes for freight vehicles on the descent
New visual impacts to/from Fort Vancouver and to/from Hayden Island</td><td>Shorter sustained 4% grade would result in less greenhouse gas emissions than high-level fixed
Shorter sustained 4% grade would result in less noise impacts than high-level fixed
Would have less viewshed impacts than a high-level bridge</td></tr>
<tr><td>Geotechnical Considerations</td><td>Smaller piers and foundations than a movable span</td><td>Smaller piers and foundations than movable span or a high-level fixed</td></tr>
<tr><td rowspan="2">High-Capacity Transit</td><td colspan="2">Avoids impacts to transit operations related to a movable span</td></tr>
<tr><td>Station locations (Hayden Island, downtown Vancouver) would be very elevated, which would make fire and life safety more challenging</td><td>Station location on Hayden Island would be a typical elevated station, one level up
Station in downtown Vancouver would be elevated but more reasonably able to accommodate fire and life safety</td></tr>
</table>

Topic	High-level Fixed	Mid-level Fixed
Highway Traffic	• **Avoids** traffic safety impacts related to a movable span	
	• Sustained 4% grade would **slow down freight** • Due to missed connections at **two interchanges**, large volumes of traffic would be **rerouted through local streets** to access I-5	• Shorter sustained 4% grade would have a **lesser impacts on freight speed**
Highway/Local Connections	• **Missed** local connections (would touch down at Marine Drive and at Mill Plain) • Would **eliminate two** I-5 interchanges (Hayden Island, SR 14/Downtown Vancouver)	• **Maintains** local highway and street connections • **Retains** existing interchange locations
Operational Considerations	• **Does not require** on-site or specialized operation staff	
Safety	• **Avoids traffic safety impacts** related to a movable span	
Structural Considerations	• No significant differentiators identified	

a. During the CRC Project, mitigation agreements were negotiated with the four impacted users that were unable to modify operations (such as accepting an air gap of less than 10 feet) in order to transit a bridge height of 116 feet. Three upstream fabricators entered into mitigation agreements with the CRC Project. The anticipated mitigation agreements would have resulted in payments to the companies that would be used by the companies at their business discretion and control. Payments were never made because the project was stopped. The remaining vessel owner decided to terminate negotiations that involved a payment to compensate the owner for vessel modifications, and an agreement was never finalized.

5.4 Comparison of River Crossing Options

Table 8 provides a detailed side-by-side comparison of each of the river crossing options in terms of effects on active transportation, aviation, Columbia River navigation, construction considerations, cost considerations, environmental considerations, geotechnical considerations, high-capacity transit, highway traffic, highway and local connections, operational considerations, safety, and structural considerations. The table is color coded and provides a symbol to indicate if a consideration is an advantage (green, with a "+" symbol), disadvantage (red, with a "-" symbol), or neutral (yellow, with a "•" symbol).

More detailed analyses of the tunnel options and the movable span options can be found in Attachments B and C, respectively.

Table 8. River Crossing Option Comparison

	Bored Tunnel	Immersed Tube Tunnel	Lift Span	Bascule Span	Swing Span	High-level Fixed	Mid-level Fixed
Active Transportation/SUP	– **Safety concerns** due to enclosed SUP for over 1 mile (e.g., no "eyes on the path, emergency egress, fire and life safety) – **Missed direct connectivity** from the SUP on the river crossing to local trails on both sides of the river (e.g., Renaissance Trail, Marine Drive Trail) + Opportunities to **improve connectivity** between existing trails on the Washington shore and potential for more park space along the river due to removal of existing I-5 connections		– **Delay to SUP users** during a bridge opening; **no suitable detour route** is available + Lower bridge elevation would be a **benefit for path users** (reduced grades would **increase ease of access and operability** of the SUP)			– Active transportation connections to Hayden Island and Vancouver waterfront **would be challenging** due to height above ground	+ Connections to existing grade at Hayden Island and Vancouver waterfront **can be achieved with ramps**
Aviation	+ **No penetration** in Pearson airspace		– Lift span towers would **permanently penetrate** Pearson airspace	• Leaves would **temporarily penetrate** Pearson airspace when open	+ **No penetration** in Pearson airspace	– **Permanent penetration** into Pearson airspace	• **Likely penetration** of lights and signs into Pearson airspace
Columbia River Navigation	+ **Unlimited** horizontal and vertical navigation clearances + **Compatible** with existing navigation channels + **Eliminates navigation hazards** (e.g., bridge piers, bridge deck) in/over the river		+ Provides **178 feet or unlimited vertical clearance** for navigation – **Openings required** to accommodate tall vessels/cargo – **Lower vertical clearance** (in the closed position) than that provided by the fixed span bridge – Movable span operations and thus river navigation operations would likely need to be **restricted to nighttime openings** to minimize impacts to vehicle traffic and transit operations • Primary navigation channel would be **moved south** • Requires **400 feet** of horizontal clearance per the USACE			+ **No change in vertical clearance** • Primary navigation channel would be **moved south** to the bridge profile high point	• Would accommodate a vertical clearance **up to 116 feet** for navigation • Would **reduce** navigation clearances as they exist today • Primary navigation channel would be **moved south** to the bridge profile high point – **Mitigation** for 4 vessels/users is proposed (reported approximately 70 trips/year)[a]

	Bored Tunnel	Immersed Tube Tunnel	Lift Span	Bascule Span	Swing Span	High-level Fixed	Mid-level Fixed
Construction Considerations	– Requires **significant, challenging** launching pits for the TBM(s) – Requires a **record or near-record** diameter TBM for vehicular tunnel bores	– Requires **unconventional and complex** below-grade construction to accommodate interchange connections consisting of cut and cover tunnels with large temporary excavations. This would make **construction impractical** – Construction would require **negotiation and approval of a permit from BNSF** to construct over/under/through their ROW; it is unlikely that BNSF would accept interruptions of their operations, and therefore construction would likely require the program construct a temporary alternative route; **there is no readily available route**	• **Extended construction schedule** (approximately 1 to 2 years) due to in-water work, equipment, and specialized workforce required			+ **Conventional** construction methods and risks	
			--	• Additional **schedule extension** with third bridge configuration	--		

	Bored Tunnel	Immersed Tube Tunnel	Lift Span	Bascule Span	Swing Span	High-level Fixed	Mid-level Fixed
Cost Considerations	– Due to the significant disadvantages of a bored tunnel (e.g., would eliminate five interchanges), a conceptual cost estimate was not developed. However, it is certain that a bored tunnel would be **more expensive than an ITT** (due to such factors as increased construction method costs, significantly increased tunnel length, and increased construction risk mitigation)	– Total tunnel cost (from grade to grade): **$3 billion**	– Construction cost of two 450-foot lift spans: $500 million – Total bridge cost (Pier 1-8): **$930 million**	Three bridge option: – Construction cost of three 400-foot single-level bascule spans: $600 million – Total bridge cost (Pier 1-8): **$1.03 billion** Two bridge option: – Construction cost of two 400-foot double-deck bascule spans: $550 million – Total bridge cost: **$980 million**	– Construction cost of two 550-foot swing spans: $800 million – Total bridge cost (Pier 1-8): **$1.23 billion**	• The work completed for CRC and supported by the IBR program suggested **higher costs** for a higher fixed span bridge. This is, in part, due to the changes that would occur at each land side connection, accounting for differences in interchanges, transit stations, and active transportation connections.	+ Construction cost of two 450-foot fixed spans: $70 million + Total bridge cost: **$500 million**
Environmental Considerations	+ **Eliminates over-water shading** impacts to fish and marine habitat. While a bored tunnel would go under the river, thus reducing/avoiding impacts to the river, an ITT would require dredging the river bottom – **see below for impacts specific to an ITT** + **Potential to reuse riverfront properties**/land above the tunnel + **Removes the bridge from the viewshed**, which benefits historic properties, parks and trails, and other resources – Construction **noise, vibration, and congestion** impacts to businesses – **Impacts to neighborhoods and parks/recreation** due to tunnel portals and local connections – Utilities would require **substantial relocations** – **Impacts on local communities and neighborhoods** from construction of the cut and cover sections, tunnel portals and local connections, including displacement of businesses and residences and neighborhood isolation		– **Increased air quality pollutant and greenhouse gas emissions** due to vehicular idling during a bridge opening – **Increased in-water work** due to size of foundations would increase impacts to biological resources, hazardous materials, and historic structures and archaeological resources – **Challenging stormwater containment** due to the bridge joints that allow the movable span to function			+ **Smaller aquatic footprint** compared to tunnels and movable span bridges + **Less in-water work/structures** than tunnel options + **Smaller pier foundations** compared to movable span bridges	

	Bored Tunnel	Immersed Tube Tunnel	Lift Span	Bascule Span	Swing Span	High-level Fixed	Mid-level Fixed
	+ Construction could **avoid impacts to aquatic** plants, fish, and other marine animals/plants by boring below the river bottom	– **In-water trenching and dredging would disturb the river bottom** across the entire width of the Columbia River, including the riverbanks (in-water excavation would require approximately 4 million cubic yards of material) – Disturbance of the river bottom and nearshore habitat **would require mitigation** – Dredged material would need to be placed in an in-water or upland site and **may require special handling** if contaminated materials are found – **In-water construction** would impact aquatic plants, fish, amphibians, marine mammals, and birds (including ESA-listed species) – **Concerns for cultural resources** along the shoreline and underwater; could impact Fort Vancouver and Old Apple Tree Park; size and volume of excavation and vibration could disturb or permanently impact resources – Disturbance and suspension of **potentially**	– **Permanent visual impacts** due to lift towers	– **Additional displacement of benthic habitat** with third bridge configuration; additional over-water shading with third bridge configuration – **Visual impact** during bridge opening	– **Increased land use and development impacts** due to downstream location of bridge (due to construction considerations)	– Sustained 4% grade would result in **increased greenhouse gas emissions** – Sustained 4% grade would create **noise impacts** due to the use of Jake brakes for freight vehicles on the descent – **New visual impacts** to/from Fort Vancouver and to/from Hayden Island	+ Shorter sustained 4% grade would result in **less greenhouse gas emissions** than high-level fixed + Shorter sustained 4% grade would result in **less noise** impacts than high-level fixed. + Would have **less viewshed impacts** than a high-level bridge

	Bored Tunnel	Immersed Tube Tunnel	Lift Span	Bascule Span	Swing Span	High-level Fixed	Mid-level Fixed
		contaminated materials in the river; large excavation of contaminated soil on land may exceed capacity of existing disposal locations					
Geotechnical Considerations	– **Control of ground loss** during tunneling, particularly under the river – **Groundwater control and water tightness** in temporary excavations (e.g., launch pits) and permanent underground structures (e.g., stations) – **Balancing incorporation of ground improvements** for ground strengthening and liquefaction mitigation with tunnel profile depth to mitigate against tunnel buoyancy	– **Ground improvement may be required** to improve the soils of the river bottom above, below and around the ITT, which contributes to **high construction schedule and cost risks**	• **Requires more substantial river piers and pier foundations** to support the span as compared to a fixed span (movable parts are more sensitive to foundation settlement) to ensure smooth operation over its lifetime			+ **Smaller** piers and foundations than a movable span	+ **Smaller** piers and foundations than movable span or a high-level fixed
High-Capacity Transit	– An underground station could result in **high costs and construction risks** due to ground conditions near the river		– **Reduced** train speed over bridge – **Interruptions to operations** during a bridge opening throughout 18-mile service network, unless openings are restricted to nighttime only – **Extensive maintenance** to keep communications, power and track operable + Opportunity to decrease the profile elevation and grade could **improve connections** to the Vancouver Waterfront station for transit vehicles and transit patrons			+ **Avoids impacts** to transit operations related to a movable span	
						– Station locations (Hayden Island, downtown Vancouver) would be **very elevated**, which would make **fire and**	• Station location on Hayden Island would be a **typical** elevated station, one level up • Station in downtown Vancouver would be elevated **but more reasonably able**

	Bored Tunnel	Immersed Tube Tunnel	Lift Span	Bascule Span	Swing Span	High-level Fixed	Mid-level Fixed
						life safety more challenging	**to accommodate fire and life safety**
Highway Traffic	– Due to missed connections (**loss of five interchanges**), large volumes of traffic would be **rerouted through local streets** to access I-5	– Due to missed connections (**loss of two interchanges**), large volumes of traffic would be **rerouted through local streets** to access I-5	– The cycle time for a bridge opening would be **20 to 30 minutes** – Daytime bridge lifts **could impact traffic volumes** for an hour or more; nighttime bridge lifts would not impact traffic volumes for multiple hours a day – To reduce congestion and improve mobility, movable span operations would **likely need to be restricted** to specific days and/or times + Reduced length of grade of the lower profile **would benefit freight and other vehicles** that might be affected by the lower speeds caused by steeper grades			+ **Avoids traffic safety impacts** related to a movable span	
			--	+ **Fastest cycle time** to open and close the bridge resulting in less congestion	--	– Sustained 4% grade would **slow down freight** – Due to missed connections at **two interchanges**, large volumes of traffic would be **rerouted through local streets** to access I-5	+ Shorter sustained 4% grade would have a **lesser impact on freight speed**
Highway/Local Connections	– **Eliminates five I-5 interchanges**. This would result in a loss of access to local streets and require modification to the SR 14 corridor	– **Eliminates two I-5 interchanges.** This would result in a loss of access to local streets and require modification to the SR 14 corridor	+ **Maintains** local highway and street connections + Reduced grades would **increase the ease of ramp connections**, primarily on the Hayden Island end of the bridge – **Retains** existing interchange locations			– **Missed** local connections (would touch down at Marine Drive and at Mill Plain) – Would **eliminate two I-5 interchanges** (Hayden Island, SR 14/Downton Vancouver)	+ **Maintains** local highway and street connections – **Retains** existing interchange locations
Operational Considerations	– Requires a **full-time staffed operations center** for monitoring the mechanical, electrical, traffic control systems, and security – Requires **additional and different systems requirements** (fixed firefighting systems; mechanical ventilation systems [jet fans]; standpipe system; tunnel		– More likely to result in **misalignment or damage** from a seismic event – **Requires a bridge operator** on site – Requires **additional maintenance** associated with mechanical and electrical systems			+ **Does not require** on-site or specialized operation staff	

	Bored Tunnel	Immersed Tube Tunnel	Lift Span	Bascule Span	Swing Span	High-level Fixed	Mid-level Fixed
	thermal protection systems; drainage systems; traffic monitoring systems; security systems)						
Safety	– Requires **extensive fire and life safety systems** would be required – Requires **additional and different** safety requirements (fixed firefighting systems; mechanical ventilation systems [jet fans]; standpipe system; tunnel thermal protection systems; drainage systems; traffic monitoring systems; security systems) – Fire prevention and ventilation **difficult at abrupt changes** in geometry – **Hazardous materials are not typically permitted** in tunnels (would require approval at the state level) – Safety concerns due to **enclosed tunnel with two points of access** (e.g., potential delays in emergency response, road blockage due to a collision)		– Crash rate is expected to be **3 to 4 times higher during a bridge lift** than during normal operating conditions			+ **Avoids traffic safety impacts** related to a movable span	
Structural Considerations	– Requires **more rigorous design efforts** and specialty contractors		– Requires **more rigorous design efforts** and specialty contractors			+ **Traditional** major complex bridge design delivery	
			– Towers up to **60 feet taller** than vertical clearance required – Counterweights in the towers would **require additional seismic design** considerations to mitigate earthquake impacts	– Would be **one of the largest** double-leaf bascule spans in the world – Potential for **operational problems** due to span imbalance, keeping counterweight pit dry, and center locks issues – Must **resist seismic and wind loading** to a greater extent than other movable span options	– Would be **one of the largest** movable spans of its type in the world – **More machinery** than a bascule or vertical lift bridge: an end-centering device and end-lifting devices • Low profile and **does not require** expensive counterweights • **Less massive piers** than a bascule or vertical lift bridge		

	Bored Tunnel	Immersed Tube Tunnel	Lift Span	Bascule Span	Swing Span	High-level Fixed	Mid-level Fixed

[a] During the CRC Project, mitigation agreements were negotiated with the four impacted users that were unable to modify operations (such as accepting an air gap of less than 10 feet) in order to transit a bridge height of 116 feet. Three upstream fabricators entered into mitigation agreements with the program. The anticipated mitigation agreements would have resulted in payments to the companies that would be used by the companies at their business direction and control. Payments were never made because the project was stopped. The remaining vessel owner made a decision to terminate negotiations that involved a payment to compensate the owner for vessel modifications, and an agreement was never finalized.

6. CONCLUSION

As part of the NEPA process, the IBR program will identify the type of river crossing that will be advanced for further study in the Supplemental Draft EIS. This report provides a summary of the different river crossing options that could be used to replace the I-5 bridges over the Columbia River.

Table 9 identifies how the river crossing options would (or would not) meet the six needs identified in the Purpose and Need statement.

Table 9. River Crossing Options and Purpose and Need

F = Fail; P = Pass

Purpose and Need	Tunnel (Bored and ITT)	Movable (Bascule, Swing, and Lift)	Fixed (High-level, Mid-level)
Growing travel demand and congestion	**F:** Missed connections would cause diversion onto local streets	**P:** Improved over existing conditions, although delays associated with openings	**F (High-level):** Missed connections would cause diversion onto local streets **P (Mid-level):** improved over existing conditions
Impaired freight movement	**F:** Missed connections at Hayden Island and SR 14/downtown. Vancouver would have negative impacts on freight movement	**P:** Lower grade would be more conducive to freight movement; Freight moving at night would be subject to delays	**F (High-level):** Missed connections at Hayden Island and SR 14/downtown Vancouver would have negative impacts on freight movement **P (Mid-level):** Would improve freight movement
Limited public transportation operation, connectivity, and reliability	**F:** Would not improve service due to missed connections	**P:** Feasible, although complicated due to disruptions and operations and maintenance	**F (High-level):** Cannot accommodate preferred grade **P (Mid-level):** Can accommodate preferred grade

Purpose and Need	Tunnel (Bored and ITT)	Movable (Bascule, Swing, and Lift)	Fixed (High-level, Mid-level)
Safety and vulnerability to incidents	**P:** May reduce potential for collisions compared to existing conditions	**P:** Similar potential for collisions compared to existing conditions	**P:** Would reduce potential for collisions compared to existing conditions
Substandard bicycle and pedestrian facilities	**F:** Problematic due to enclosed route for over 1 mile (safety, missed connections)	**P:** Lower grade would be better than fixed span bridge, although there would be delays during openings	**F (High-level):** Cannot accommodate preferred grade **P (Mid-level):** Can accommodate preferred grade
Seismic vulnerability	**P:** Can be constructed to current seismic standards	**P:** Can be constructed to current seismic standards (although more likely to suffer misalignment or damage in a seismic event)	**P:** Can be constructed to current seismic standards

As shown in the table, the tunnel options and high-level fixed span bridge fail to meet the Purpose and Need. The movable span options could be designed and operated (i.e., bridge openings restricted to a limited nighttime window) to meet the Purpose and Need; however, they are suboptimal options due to increased cost associated with a movable span, and complex constructability, operations, and maintenance.

The replacement fixed span bridge option with 116 feet of vertical clearance is the result of extensive technical and environmental work, as well as many years of public and agency coordination. In 2011, the CRC Project's Selected Alternative, which consisted of a replacement fixed span bridge with 95 feet of vertical clearance, was adopted in the ROD. In 2011/2012, the CRC Project raised the vertical clearance to 116 feet in response to feedback from the USCG and river users. A 2012 NEPA re-evaluation on the height increase concluded there were no new significant impacts, and in 2013 the USCG issued a bridge permit for 116 feet (contingent on receipt of the USACE Section 408 authorization and agreements with affected river users). As noted previously, the IBR program's update to the NIR in 2021 concluded that there have been no significant changes related to river users since the CRC Project.

Based on technical evaluations, agency coordination, public outreach, and discussions with partner agencies, all of which are reflected in this report and its attachments, the IBR program recommends a fixed span bridge with a vertical clearance of 116 feet. The rationale and analysis summarized in this report demonstrates that the identified option provides the best replacement river crossing for the community and region. A fixed bridge with 116 feet of vertical clearance is a solution that balances the needs of all users and modes of transportation, including freight and personal vehicles, transit, active transportation, aviation, and river users. This river crossing option has the best ability to meet the Purpose and Need statement, meet the community's values and priorities,[20] minimize environmental impacts, contributes to achievement of climate and equity goals and other program desired outcomes, and will use conventional design and construction methods, contributing to a lower cost.

[20] Community values and priorities for the IBR program were developed and adopted by the Community Advisory Committee and are available at: https://www.interstatebridge.org/media/t0kh3ey4/revised-community-values-priorities-5-20-21_remediated-1.pdf