Interstate BRIDGE Replacement Program

River Crossing Bridge Clearance Assessment Report – Movable Span Options

November 2022

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TABLE OF CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

BNSF	BNSF Railway
CFR	Code of Federal Regulations
CRC	Columbia River Crossing
FAA	Federal Aviation Administration
I-5	Interstate 5
IBR	Interstate Bridge Replacement
LRT	light-rail transit
O&M	operation and maintenance
OCS	overhead catenary system
ODOT	Oregon Department of Transportation
PNCD	Preliminary Navigation Clearance Determination
SUP	shared use path
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
WSDOT	Washington State Department of Transportation

1. INTRODUCTION

The Interstate Bridge Replacement (IBR) program will replace the existing Interstate 5 (I-5) bridges crossing the Columbia River between Vancouver, Washington, and Portland, Oregon. Multiple design options are being considered for the bridge replacement.

In June 2022, the U.S. Coast Guard (USCG) responded to the IBR's program's Navigation Impact Report and issued a Preliminary Navigation Clearance Determination (PNCD) for the IBR program that prescribed the vertical and horizontal navigation clearance that would have a high likelihood of obtaining a favorable permit decision. The PNCD indicated that vertical navigation clearance over the Columbia River is currently, and needs to continue to be, equal to or greater than the existing I-5 bridges' clearance of 178 feet. The USCG also requires that the horizontal navigation clearance meet the U.S. Army Corps of Engineers' (USACE) requirement. The IBR program's Navigation Impact Report assumed a mid-level fixed span bridge providing 116 feet of vertical clearance (herein referred to as the Fixed Span Bridge) and a horizontal navigational clearance of 300 feet with an additional 50 foot buffer on either side of the navigation channel.[1] A movable span bridge is an option that could achieve 178 feet of vertical clearance. The purpose of this report is to clarify the implications of using a movable span bridge that would use a dynamic mechanical design to provide 178 feet of or unlimited vertical clearance as needed for vessel passage.

The IBR program assembled a group of professional engineers, including those with international experience in movable bridge design and construction, to provide a comprehensive conceptual review of the suitability of a movable bridge span that would provide a navigational opening with a vertical clearance that meets or exceeds that provided by the existing movable bridge span.

The following three movable span options were investigated from interdisciplinary perspectives, including design, construction, operations, environmental considerations, and cost considerations:

1) **Vertical lift span** (178 feet of vertical clearance)

2) **Bascule span** (unlimited vertical clearance)

3) **Swing span** (unlimited vertical clearance)

[1] The USCG made a preliminary determination of a 400-foot-wide navigation channel based on an authorized 300-foot channel plus 50-foot additional clearance on each side requested by the USACE for channel maintenance. In the event the federal agencies reconsider and allow a 300-foot-wide navigation channel, the design, construction, operation, and environmental considerations for a movable bridge span as described herein would be similar to those reported for the 400-foot-wide channel. The USACE decision to allow modification to the navigation channel buffer requirements is pending. The conceptual costs shown in this report are based on historical costs per square foot, so for comparison purposes, the cost for 300-foot-wide navigation channel options can be estimated at 75% of the cost for the 400-foot-wide navigation channel options.

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 by program leadership.

2. FIXED SPAN BRIDGE

The IBR program will replace the existing I-5 bridges crossing the Columbia River between Vancouver, Washington, and Portland, Oregon. For comparison purposes, this assessment assumes a Fixed Span Bridge comprising two side-by-side fixed-span bridges as the basis for the river crossing (Figure 1). The upstream bridge would accommodate northbound I-5 lanes on the upper deck and a shared-use path (SUP) on the lower deck. The downstream bridge would accommodate southbound I-5 lanes on the upper deck and two-way light rail transit (LRT) (two tracks) on the lower deck. The roadway would consist of three through-lanes and one auxiliary lane in each direction, along with full inside and outside shoulders.

The Fixed Span Bridge's alignment provides a horizontal tangent across the river and allows for the ability to construct a new bridge and maintain traffic on I-5 during construction. The two bridges have a horizontal curvature introduced in the north two spans (between Piers 6 and 8) as the bridge approaches Vancouver. Based on past work, the Fixed Span Bridge is assumed to have a grade of just under 4% as it transitions from each land side of the river with a long crest vertical curve providing the high point for navigation at the proposed primary navigation channel.

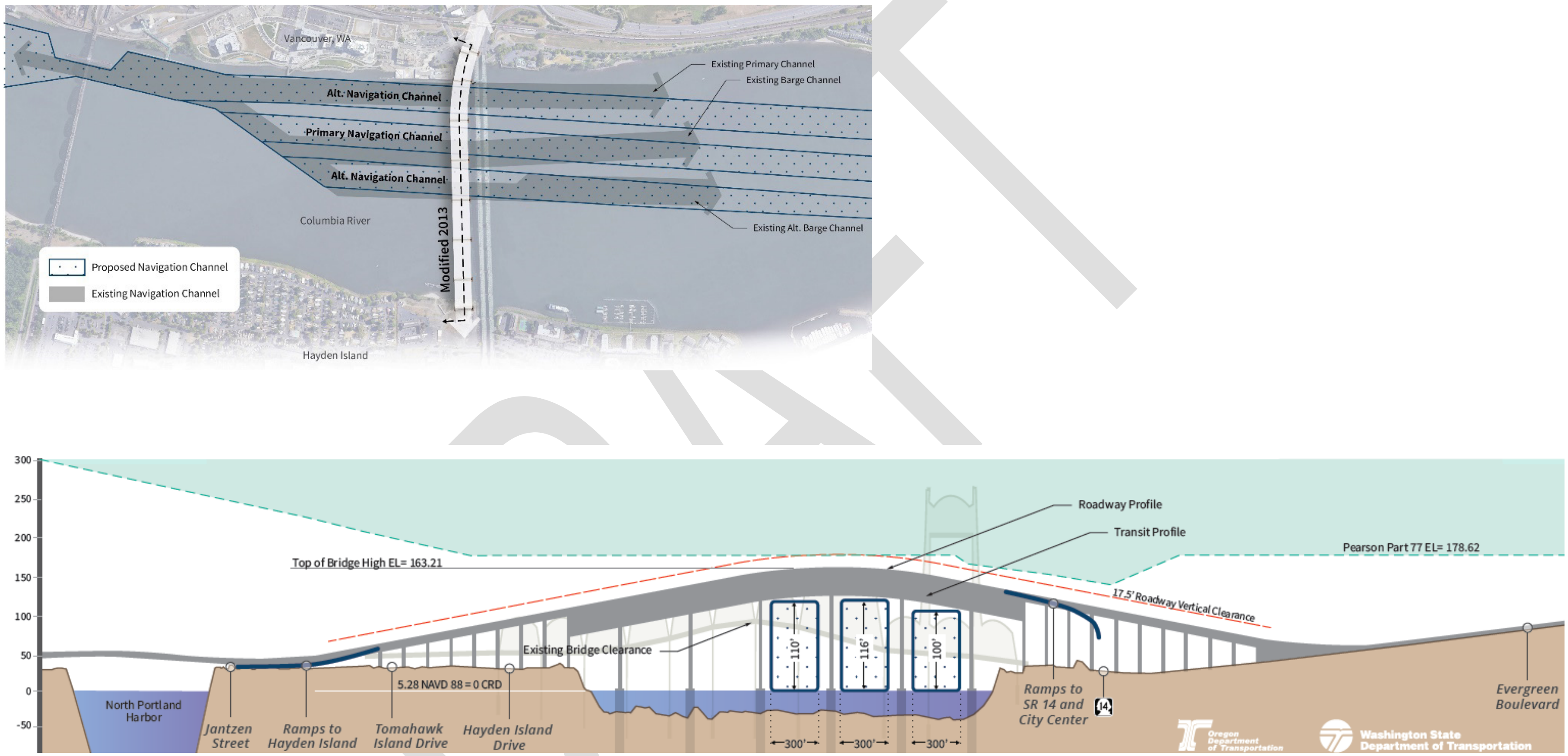
3. MOVABLE SPAN OPTIONS

This assessment assumes that the upstream and downstream fixed spans between Piers 5 and 6 of the Fixed Span Bridge, which flank the proposed primary navigation channel, would be replaced with movable spans. The movable spans would accommodate vehicular traffic, LRT, and a SUP and would be among the largest of their kind in the world.

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 Railway (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.

Figure 1. Mid-Level Fixed Span Bridge Plan and Profile



3.1 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[2] 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 LRT 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 2 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.

Figure 2. Double-deck Vertical Lift Bridge Example – Portage Lake Bridge, Houghton, MI

3.2 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

[2] 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.

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[3] similar to the Fixed Span Bridge. Figure 3 shows an example of a double-deck double-leaf bascule bridge in Chicago, Illinois.

Figure 3. Double-deck Double-leaf Bascule Bridge Example – Wells Street Bridge, Chicago, IL

3.3 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 LRT 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

[3] 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 LRT and the SUP.

navigation channel (400 feet to accommodate the authorized width of 300 feet plus a buffer of 50 feet on either side for advanced dredging as specified by the USACE).

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 LRT would be on the lower deck.

Figure 4 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 4. Single-deck Double-swing Bridge Example – Coleman Bridge, York County, VA

4. DESIGN CONSIDERATIONS

4.1 Columbia River Navigation

Operational requirements for vessel navigation and channel maintenance on the Columbia River would define the length of the movable span.

The USACE maintains the authorized federal navigation channels on the Columbia River. River navigation features are authorized for specific locations, widths, and depths. Navigation features differ upstream and downstream of the existing I-5 bridges, as shown in Figure 5, Figure 6, and Figure 7. As shown, and described further below, there are three navigation channels and a turning basin designated at the location of the existing bridges.

Figure 5. Columbia River Navigation Channels

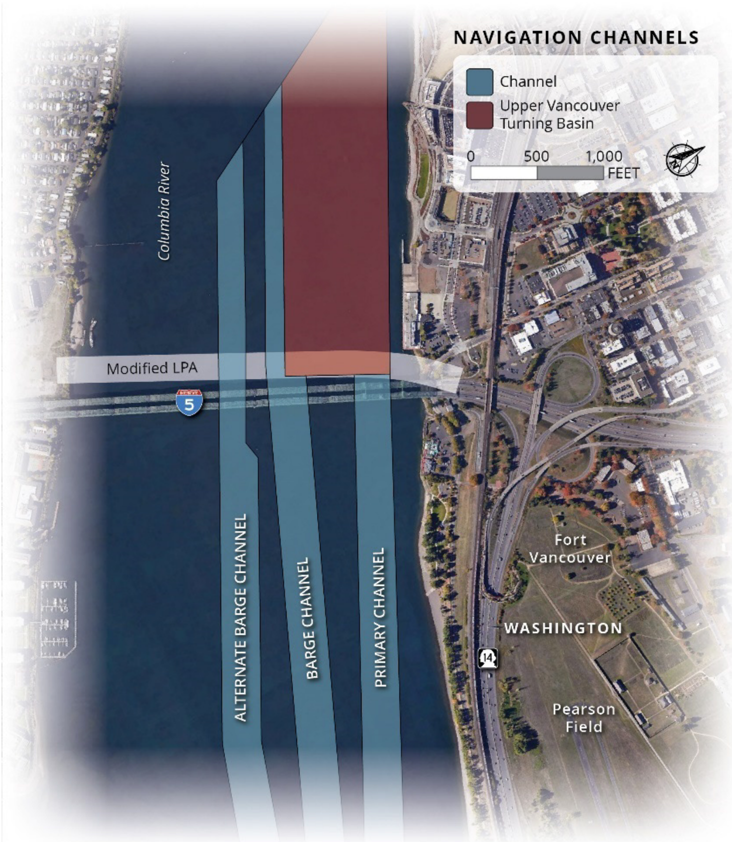


Figure 6. Navigation Channel Downstream of the Exisiting Bridge

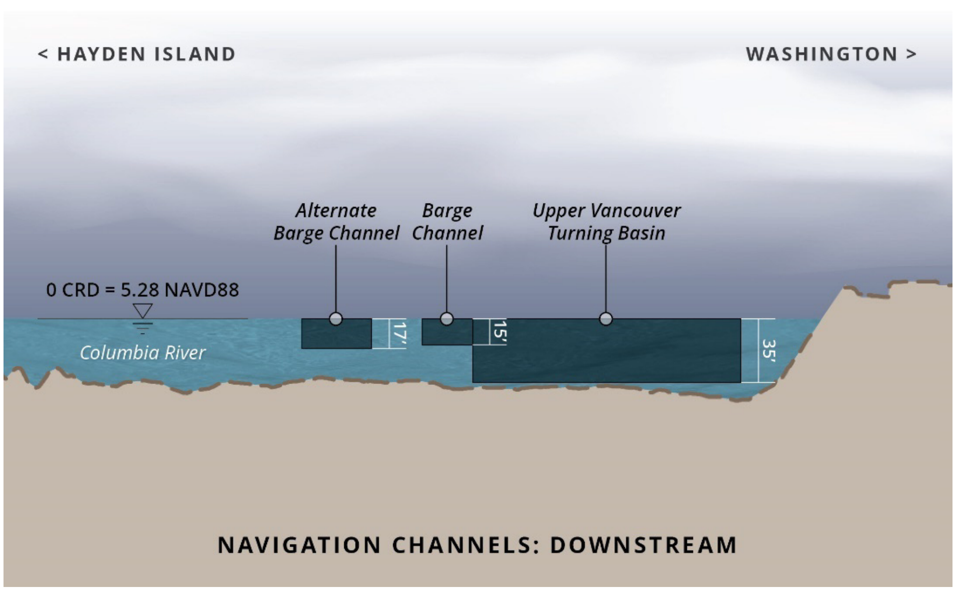
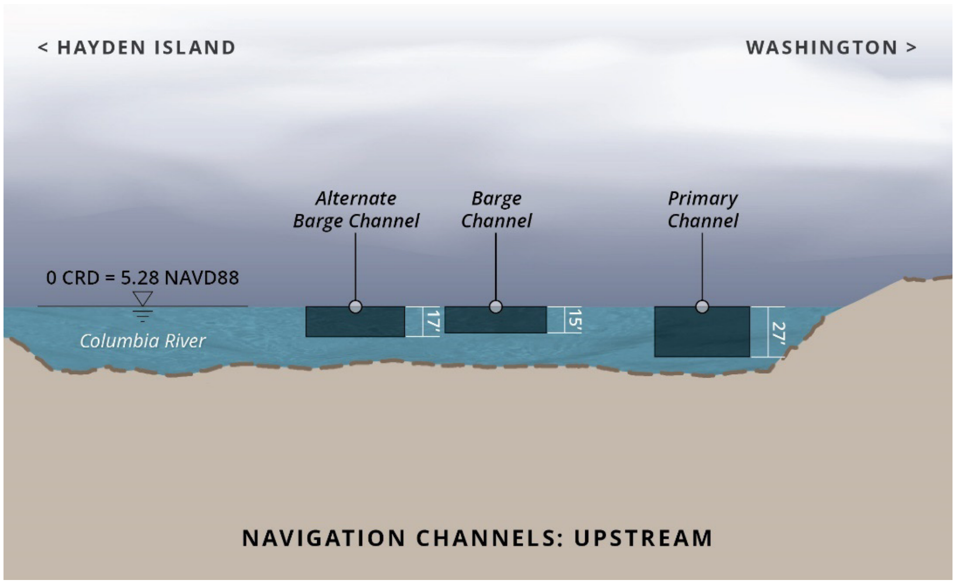


Figure 7. Navigation Channel Upstream of the Existing Bridge



The Vancouver to The Dalles project[4] begins just downstream of the existing I-5 bridges and was originally authorized by the Rivers and Harbors Act of 1937. The authorization specifies a channel 300 feet wide and 27 feet[5] deep. The USACE maintains the channel to 17 feet deep based on current uses. However, the dredging analysis completed in 2014 for the Columbia River Crossing (CRC) project shows that the USACE has not dredged at this location for at least 25 years and that the river naturally maintains a depth greater than 17 feet. None of the movable span options would constrain dredging operations in any way.

Two alternate channels were authorized subsequent to the Vancouver to The Dalles project to accommodate vessel traffic that does not need the vertical clearance provided by the existing lift span. The Alternate Barge channel has an authorized width of 200 feet under the bridge and 300 feet upstream of the bridge, with a depth of 17 feet, and the Barge Channel has an authorized width of 300 feet and a depth of 15 feet. The Upper Vancouver Turning Basin, downstream of the existing I-5 bridges, has an authorized depth of 35 feet (see Figure 6).

The USACE has indicated that an additional 50 feet on each side of the channel is needed for advanced maintenance dredging to accommodate potential side slopes for unstable sloughing of material. Vessels navigating upstream of the BNSF railroad bridge are restricted by the 150 feet of horizontal clearance provided by that bridge. In addition, vessels with origins or destinations above Bonneville Dam are restricted by the 86 feet of horizontal clearance provided by the locks.

The USCG publishes bridge guide clearances for certain navigable waters of the U.S. Compliance with these guide clearances will ordinarily receive favorable consideration under the bridge permitting

[4] https://www.nwp.usace.army.mil/Missions/Navigation/Channels/Vancouver-to-The-Dalles/

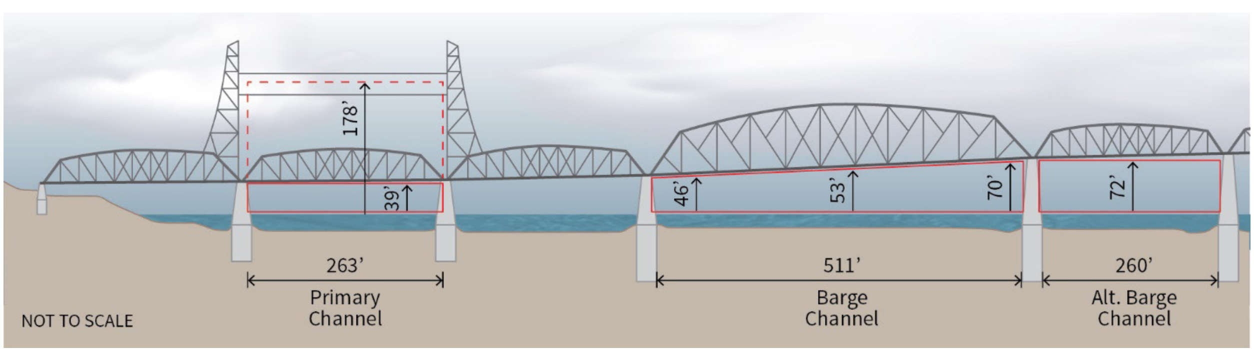
[5] All channel depths are relative to 0 feet Columbia River Datum.

process as providing for the reasonable needs of navigation. According to the clearance guide for the Columbia River, the horizontal navigational clearance is indicated as 450 feet.[6] The USCG notes that guide clearances are not intended to be regulatory, and greater or lesser clearances may be required or approved as necessary to meet navigation needs at a particular location.

The USCG's PNCD specified that the minimum required horizontal clearance must be greater than or equal to that of the current or future permitted USACE federal navigation channel projects. This results in a minimum horizontal width between bridge elements of 400 feet to accommodate the authorized width of 300 feet plus a buffer of 50 feet on either side for advanced dredging as specified by the USACE. The USACE may accept a reduction in the required buffer based on conditions at the site. The existing river depths are greater than the current depth to which the channel is maintained, and there are no side slopes present. This request would be considered as part of the Section 408 Authorization process that is required by the USACE to modify the navigation channel locations and the bridges spanning the navigation channels. If approved this could reduce the horizontal width between bridge elements.

In addition to horizontal clearance, vessels' vertical clearance requirements are relevant to the height of the movable span when open or closed and to adjacent fixed spans. As noted earlier, a movable span would provide either a vertical clearance equivalent to the existing lift span (178 feet) or unlimited vertical clearance (bascule span or swing span). The existing I-5 bridges are only opened for approximately 5% to 7% of river traffic. Because the height of the existing bridge accommodates the majority of vessel traffic, the existing clearances provided by the bridge can be used as a starting point to determine a preferred height of fixed and closed spans to be able to reduce the bridge height as much as possible for costs and other reasons while minimizing the need for an opening and resulting delays to vehicles on I-5, transit, and active transportation. Figure 8 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.

Figure 8. Vertical Clearances Provided by the Existing Bridges



*Vertical clearance shown relative to 0 feet Columbia River Datum

[6] The published guide clearance also specifies a vertical clearance of 135 feet as measured from a river stage of 600,000 cubic feet per second. This is superseded by the PNCD issued by the USCG and described in Section 1.

As part of USCG requirements for the Section 9 Bridge Permit, the IBR program completed a Navigation Impact Report that included a survey of vessels that typically pass through the location of the bridge, including their vertical clearance needs. This information can be used to inform the appropriate vertical clearance of the movable span in the closed position or alternate fixed spans so that a height can be selected that is as low as possible but still accommodates the majority of vessel traffic without the opening of a movable span. 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	# 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. Compared to a fixed bridge, a movable bridge may not require mitigation to compensate for impacts to river users.

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 as some openings are not due to height constraints.

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.

The movable span would need to span the Vancouver to The Dalles channel as this is the primary channel to accommodate river navigation. To accommodate grades, roadway connections, and the need for the movable span to be located in a tangent (straight and flat) section, the Vancouver to The Dalles channel would be moved south to the approximate location of the existing barge channel.

4.2 Aviation

A movable span could result in a crossing that continues to impact the Pearson Field Part 77 Airspace.[7] The IBR program would be required to submit a Form 7460 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 Federal Aviation Administration (FAA) would use that information to determine if the proposed facility *poses a hazard to air navigation or causes inefficient use of airspace.* If a hazard or inefficient use of airspace determination results, adjustments to the bridge or construction means and methods may have to be incorporated. 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 termination of the development.

With a vertical lift, the lift towers would encroach permanently into FAA airspace. Two of the movable span options—bascule and swing—would improve aviation operations into and out of Pearson Field over the existing condition. The degree of improvement depends on the associated profile, signing, and lighting on the bridge, and the hours of operation of the bascule span. When open, the bascule span leaves would encroach into FAA airspace. When closed, a bascule span would not encroach into FAA airspace. A swing span would not cause an obstruction when open or closed.

4.3 Alignment and Profile

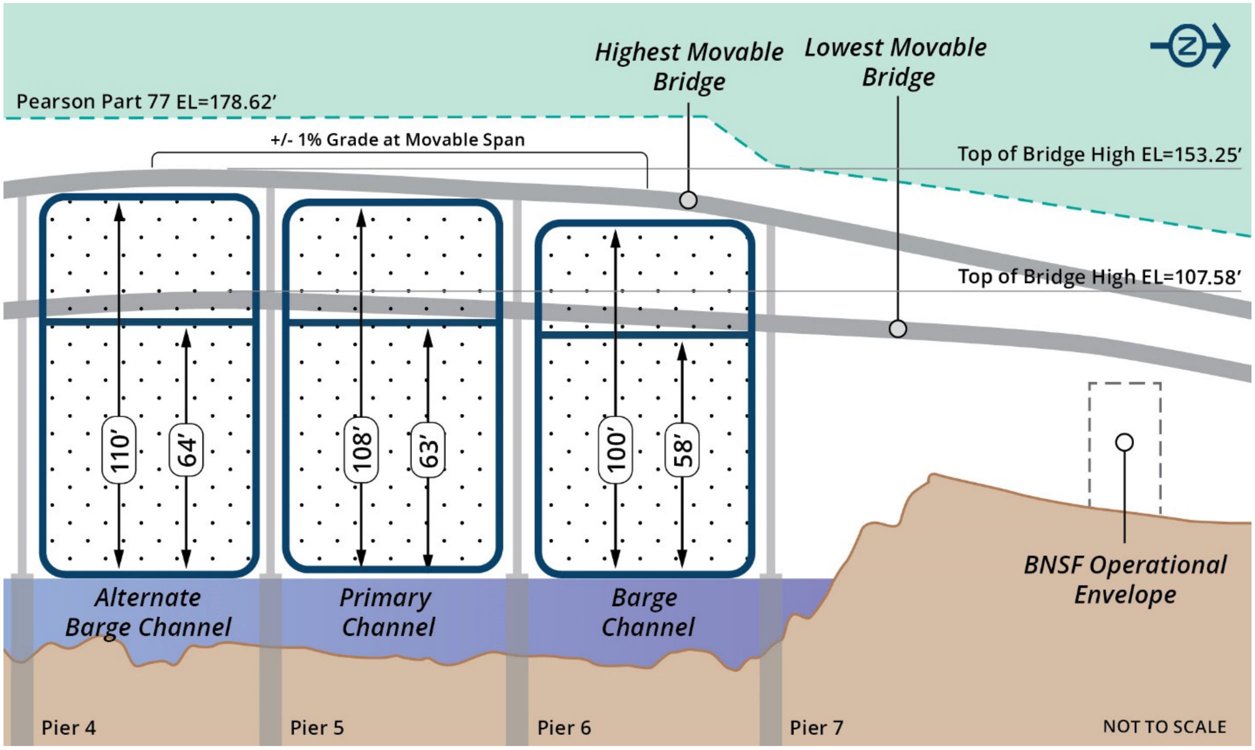
With a movable span, the I-5 alignment would be the same as that proposed for the Fixed Span Bridge (see Section 2 and Figure 1). Regardless of option, the movable span would need to be located in the straight section of the bridge (i.e., south of the current vertical lift span and current primary channel location). The Fixed Span Bridge's profile grade would also need to be altered to provide a level (or near level) profile at the movable span (between Piers 5 and 6). The Fixed Span Bridge's profile does not provide the nearly level profile necessary for a movable span. However, a lowered profile would allow a nearly level section to be located over the proposed primary navigation channel between Piers 5 and 6. A range of profiles is feasible. The profile would be determined based on the desired navigation clearance without a bridge opening. Figure 9 illustrates the bounds of moveable span

[7] Federal Aviation Administration (FAA) Title 14 CFR Part 77, Objects Affecting Navigable Airspace.

bridge heights with the highest and lowest profiles shown and the corresponding vertical navigation clearances.

Lowering the profile would improve operational grades for the highway. The length of the approximately 4% grade portion on both sides of the river would be shorter and could result in improved speed for freight vehicles as they climb the grade between land and the high point at the navigation channel. Lowering the grades would also lower the profile of I-5 over Hayden Island. However, the need to clear the BNSF rail line on the north side of the river would control the profile requirements on the Vancouver end of the bridge.

Figure 9. Movable Bridge Profiles



Note: The USCG's PNCD requires a vertical clearance of at least 72 feet from the barge channels to match the existing high fixed span clearance. Therefore, the lowest possible movable bridge elevation would increase by approximately 14 feet.[8]

4.4 Structural Considerations

The Fixed Span Bridge would have a variety of structural considerations (e.g., load, seismic, etc.). However, the Fixed Span Bridge would not include any mechanical systems to move spans of the

[8] The lowest possible movable span bridge profile shows 58 feet of vertical clearance over the Barge Channel. To provide 72 feet of vertical clearance, the bridge elevation would need to increase by 14 feet.

bridge, as would be required for the movable span options. The following sections identify some of the additional structural considerations that would need to be accounted for with the movable span options.

Vertical Lift Span

The vertical lift span option would require substantially tall towers to support the bridge in the open position. Due to machinery constraints and the counterweight rope connections, these towers would be up to 60 feet taller than the navigation clearance required, similar to existing conditions. As the height of the towers rises, their resultant cost increase at a non-linear rate. This is due to the steep increase in wind and seismic loading considerations at greater heights.

Bascule Span

Bascule bridges can experience operational problems due to span imbalance, keeping counterweight pits dry, and issues with center locks for a double-leaf bridge. The substructure of the bascule span requires larger concrete piers and massive foundations for each leaf, two machinery systems, and more moving parts (e.g., gearworks, etc.) and joints to maintain than other movable span options.

Bascule bridges must resist wind and seismic loading to a greater extent than other common movable bridge types. These load considerations require bascule bridge machinery to be more robust than it otherwise would have to be and are a bigger part of the machinery design than for vertical lift or swing bridges.

Swing Span

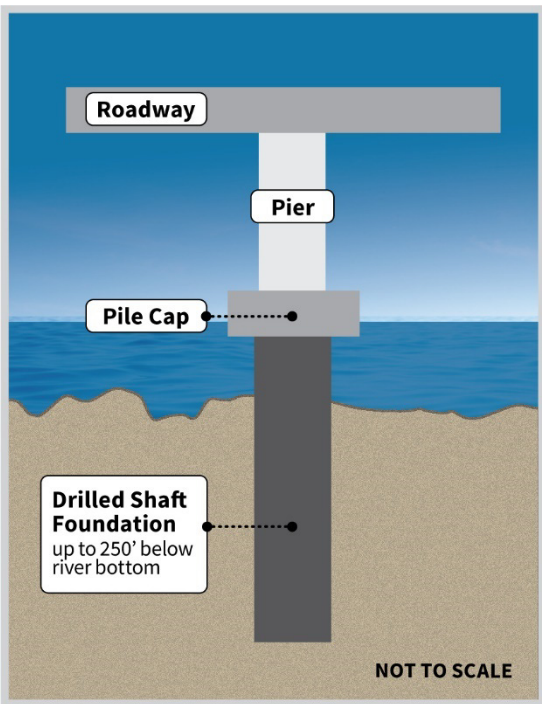
Swing bridges provide a low profile and do not require expensive counterweights. A swing bridge can thus be built with smaller piers than a bascule or vertical lift bridge. The swing spans can be through girders, truss, steel, or concrete, and a double-swing bridge can span up to 600 feet in length. Wider swing bridges require a wide center pier and are normally protected by an extensive fender system, which would increase the bridge length to meet the navigation channel width requirement, thus increasing the cost and time to operate the swing bridges.

A swing bridge requires more machinery than a bascule or vertical lift bridge. The swing bridge does not automatically align itself when closing and requires an active centering device to quickly align it in the closed position, something not required for bascule bridges or vertical lift bridges. The typical swing bridge also requires end-lifting devices to hold up the ends of the bridge when carrying traffic. The end lifts must develop a positive dead load reaction, as required by the American Association of State Highway and Transportation Officials, so that deflection of the opposite arm of the swing span, due to live load, will not cause the end of the span to lift off its supports.

4.5 Geotechnical Considerations

Deep foundations would be required to support either a fixed or movable span over the Columbia River (see Figure 10). Conceptually, multiple drilled shafts approximately 10 feet in diameter and extending up to about 250 feet below the river bottom would form the foundation for each pier for either bridge type (fixed or movable). What distinguishes a movable span is the size of the foundation needed for support. Because it is essentially a machine, a movable span would require more substantial river piers and pier foundations to support the span as compared to a fixed span because the movable parts are more sensitive to foundation settlement. This ensures smooth operation during repeated opening cycles over its lifetime. The design would favor consistent diameters of drilled shafts for the in-water work (constructability, economy of scale). The primary difference between piers that support fixed and movable spans is that the latter would require more drilled shafts to ensure adequate stiffness. More shafts translates to a larger foundation cap, which increases the footprint in the river.

Figure 10. Bridge Foundation Concept



4.6 Highway Traffic

4.6.1 Daily Traffic Profiles

Figure 11 and Figure 12 show the existing overall weekday traffic volumes (service volumes) on the I-5 northbound and southbound bridges, respectively. “Service volume” refers to the volume that is actually served during each hour, as opposed to the “demand volume,” which indicates the volume that would ideally be served.

As shown in Figure 11, between 6 a.m. and 11 p.m., there are over 2,000 vehicles per hour driving over the northbound I-5 bridge. The highest volume of northbound traffic occurs between 4 p.m. and 5 p.m. when approximately 4,800 vehicles cross the I-5 bridge from Portland to Vancouver.

Figure 12 shows there are over 2,000 vehicles per hour traveling over the I-5 southbound bridge between 4 a.m. and 9 p.m. The highest volume of southbound traffic occurs between 6 a.m. and 7 a.m., when approximately 5,500 vehicles cross the I-5 bridge from Vancouver to Portland.

The hour with the most vehicles crossing the I-5 bridges in both directions is 5 p.m. to 6 p.m., when approximately 9,000 vehicles are crossing the river.

Figure 11. Interstate Bridge Hourly Profile – Overall Northbound Weekday Service Volumes

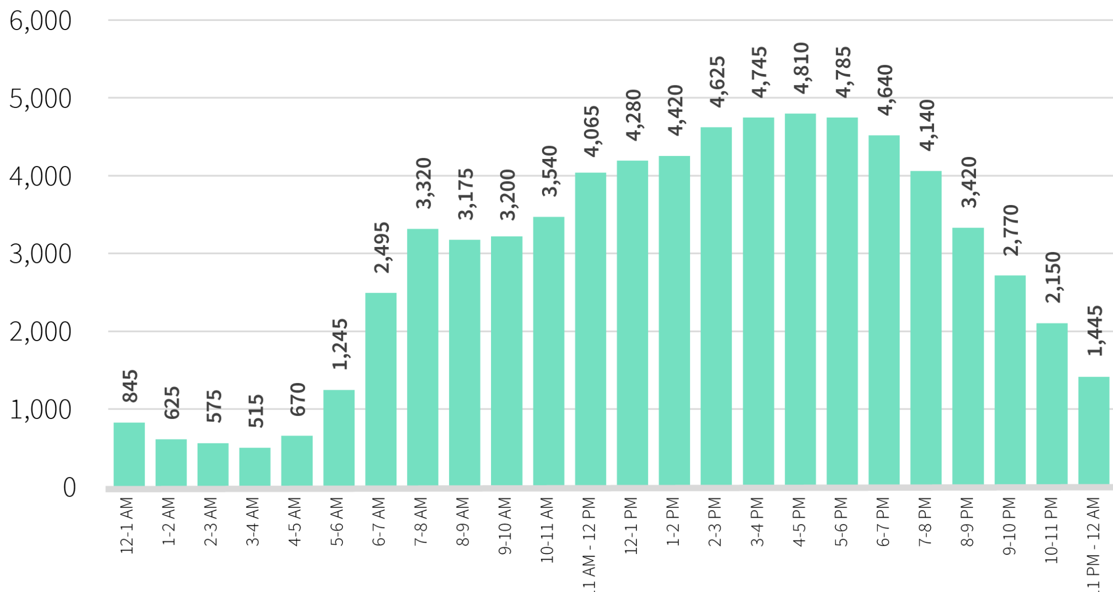


Figure 12. Interstate Bridge Hourly Profile – Overall Southbound Weekday Service Volumes

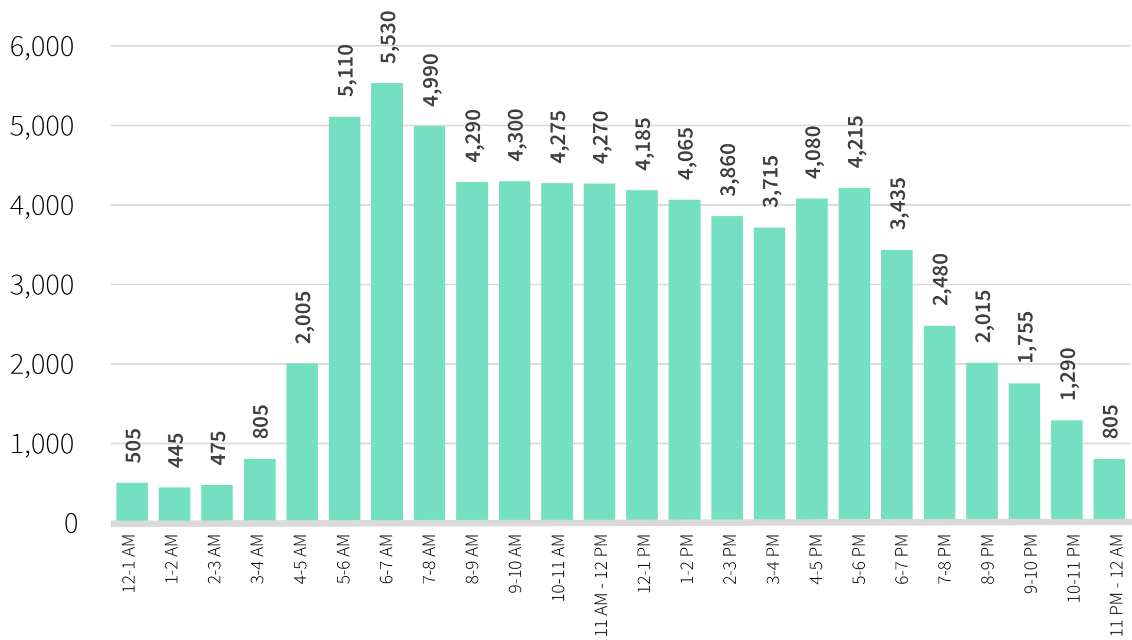


Figure 13 and Figure 14 show hourly bridge profiles across both northbound and southbound I-5 bridges for freight traffic only. As shown in Figure 13, there are more than 200 freight vehicles per hour driving northbound over the I-5 bridge between 4 a.m. and 11 p.m. The highest volume of northbound freight traffic occurs between 10 a.m. and 11 a.m. when approximately 565 freight vehicles cross the I-5 bridge from Portland to Vancouver.

In the southbound direction over the I-5 bridge, there are over 200 freight vehicles per hour between 4 a.m. and 7 p.m. and again from 8 p.m. to 9 p.m. The highest volume of southbound freight traffic occurs between 12 p.m. and 1 p.m., when approximately 520 freight vehicles cross the I-5 bridge from Vancouver to Portland.

The hour with the most freight vehicles crossing the I-5 bridges in both directions is 10 a.m. to 11 a.m., when approximately 995 freight vehicles are crossing the river.

Figure 13. Interstate Bridge Hourly Profile –Northbound Weekday Freight Service Volumes

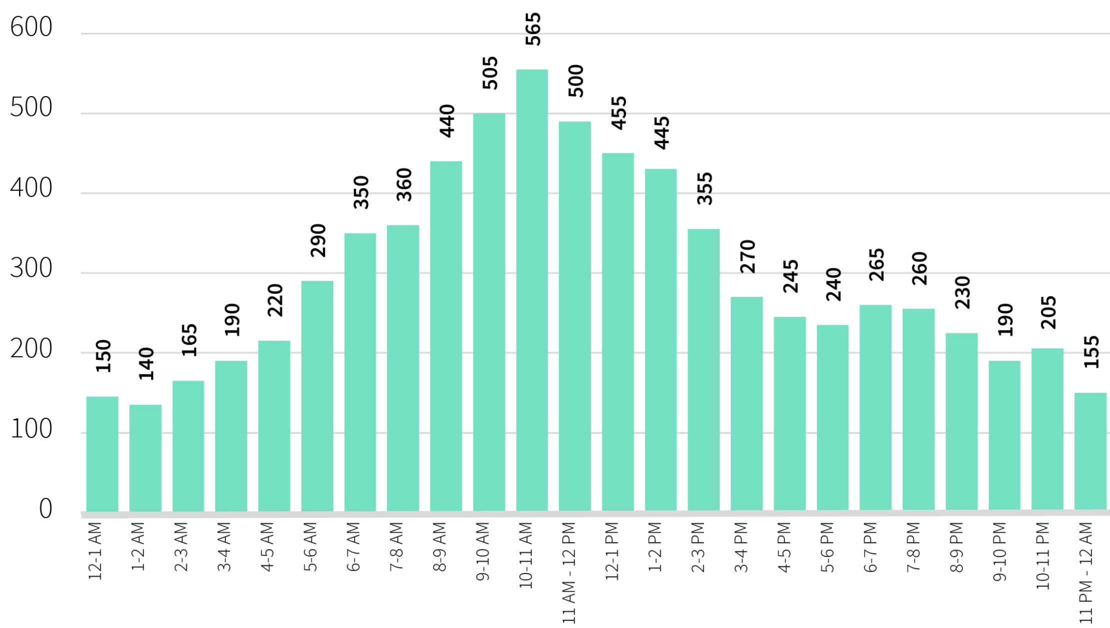
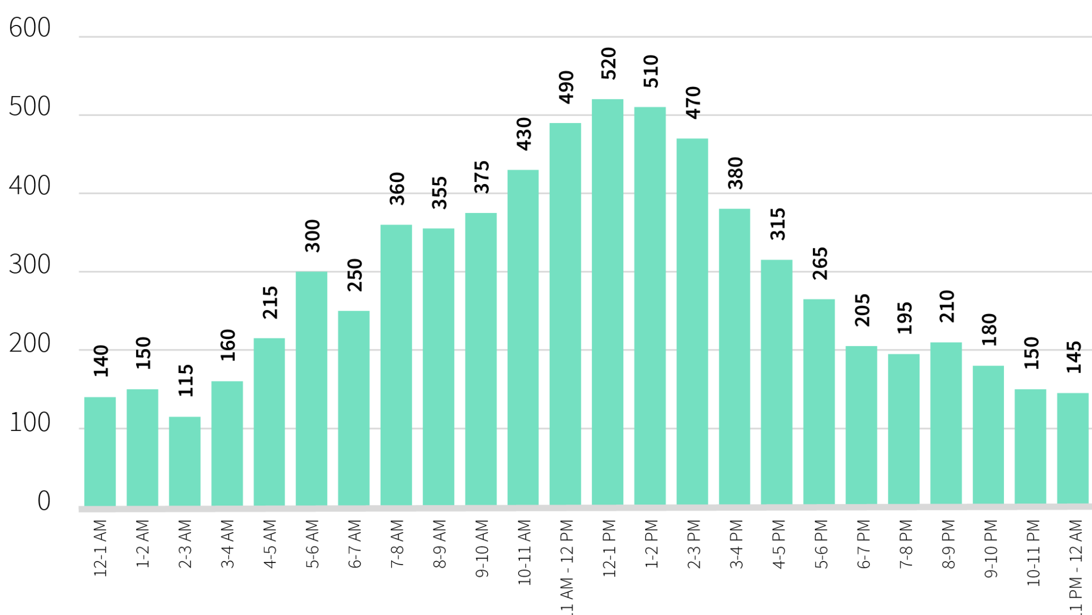


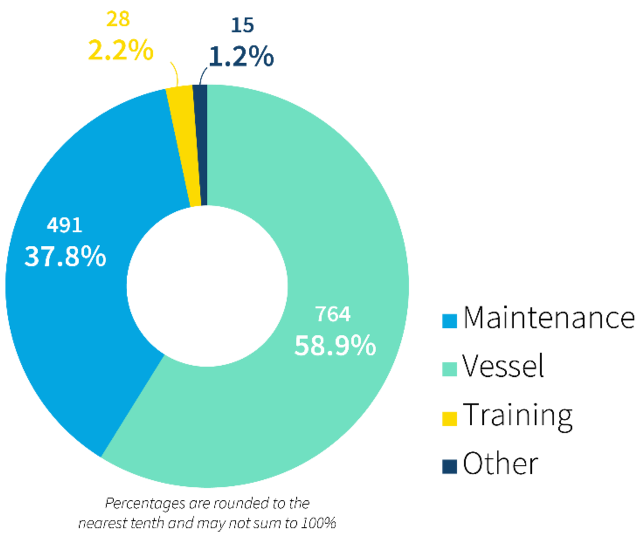
Figure 14. Interstate Bridge Hourly Profile –Southbound Weekday Freight Service Volumes



4.6.2 Bridge Lifts/Traffic Stoppages

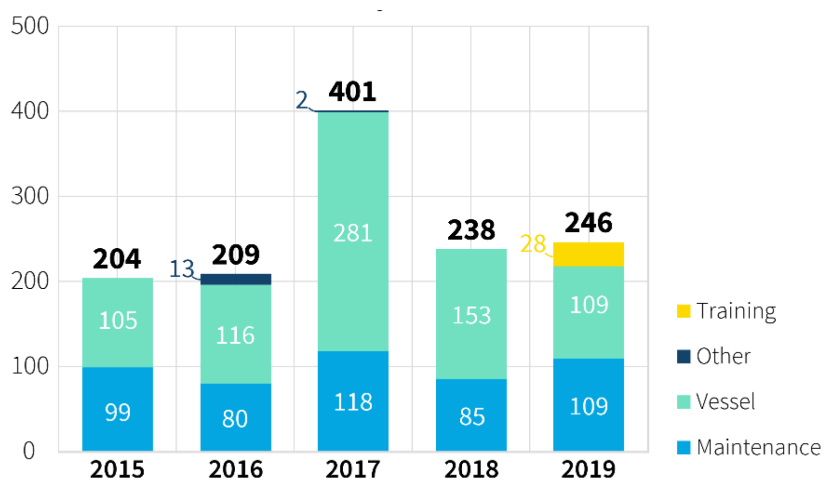
Over the five-year period from 2015 through 2019, there were almost 1,300 bridge lifts/traffic stoppages on the I-5 bridge. Bridge lift/traffic stoppages have been categorized for vessels, maintenance, training, and other purposes. Bridge lift events are those in which the bridge was physically raised, while other traffic stoppage events are those where traffic was stopped to allow for bridge-related activity without the bridge being raised. Training events are related times when the Oregon Department of Transportation (ODOT) conducts training with new employees. See Figure 15 for percentage of events by category.

Figure 15. Bridge Lift/Traffic Stoppage Event Reason, I-5 Bridge, 2015 through 2019



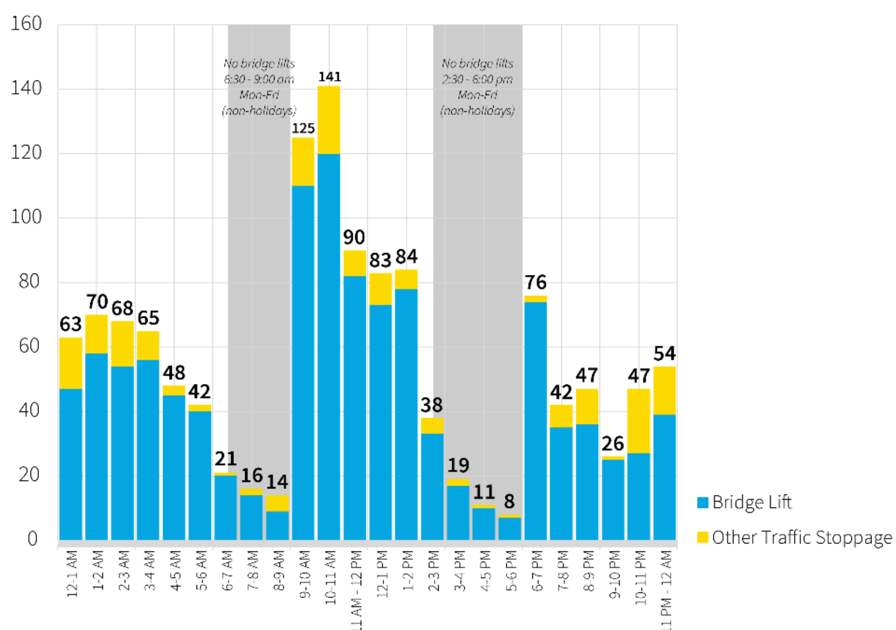
Bridge lifts/traffic stoppages vary by year depending on users, river flows, and river water levels. On average, there were about 260 events per year. Figure 16 shows the number of bridge lifts/traffic stoppages by year for the five-year period from 2015 through 2019.

Figure 16. Bridge Lift/Traffic Stoppage Events by Year



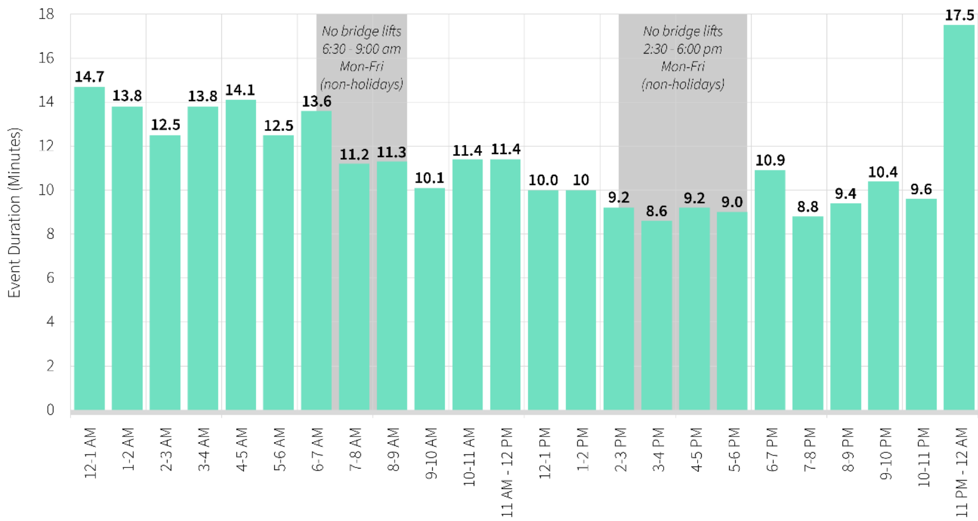
Bridge lifts/traffic stoppages were also summarized by hour to show when the bridge lifts occur. See Figure 17 for the hourly distribution of bridge lifts/traffic stoppages over the five-year period. The bridge lifts shown during the morning and afternoon peak periods (6:30 a.m. to 9:00 a.m. and 2:30 p.m. to 6:00 p.m.) occurred on weekends and federal holidays, when the restrictions on lifts imposed by federal regulations do not apply.

Figure 17. Bridge Lift/Traffic Stoppage Events by Hour



The average bridge lift/traffic stoppage for the five-year period from 2015 through 2019 lasts almost 12 minutes but ranges from 5 to 30 minutes in duration. See Figure 18 for the average event duration by hour.

Figure 18. Bridge Lift/Traffic Stoppage Events by Duration



To determine how long it takes traffic to recover to normal operating conditions from bridge lifts/traffic stoppages, the IBR team analyzed the bridge lift/traffic stoppage data and correlated that with INRIX[9] traffic speed data for days with bridge lifts. This was done for the year 2019 as it represents enough of a sample size to determine the recovery rate. The IBR team reviewed weekday volume, speed, and bridge lift data for two 1-hour periods to see if there was a difference in recovery time. The team analyzed this information for 10 a.m. to 11 a.m., and 10 p.m. to 11 p.m., on non-holiday weekdays. The analysis concluded that during the 10 a.m. to 11 a.m. time period, traffic can take 20 to 60 minutes to recover, if it can recover at all, as sometimes the bridge lift just never recovered for northbound traffic and combined with the northbound afternoon/p.m. peak-period congestion. Northbound congestion in 2019 at the I-5 bridge lasts approximately 7 hours from noon until 7 p.m. If the bridge lift occurs late in the 10 a.m. to 11 a.m. hour, it could not recover before noon. As for the 10 p.m. to 11 p.m. hour, the traffic returns to normal operating conditions in less than 15 minutes. This is based on the hourly volumes shown in Figure 11 and Figure 12, typical uncongested conditions, as well as some traffic diverting to Interstate 205 if needed during uncongested conditions.

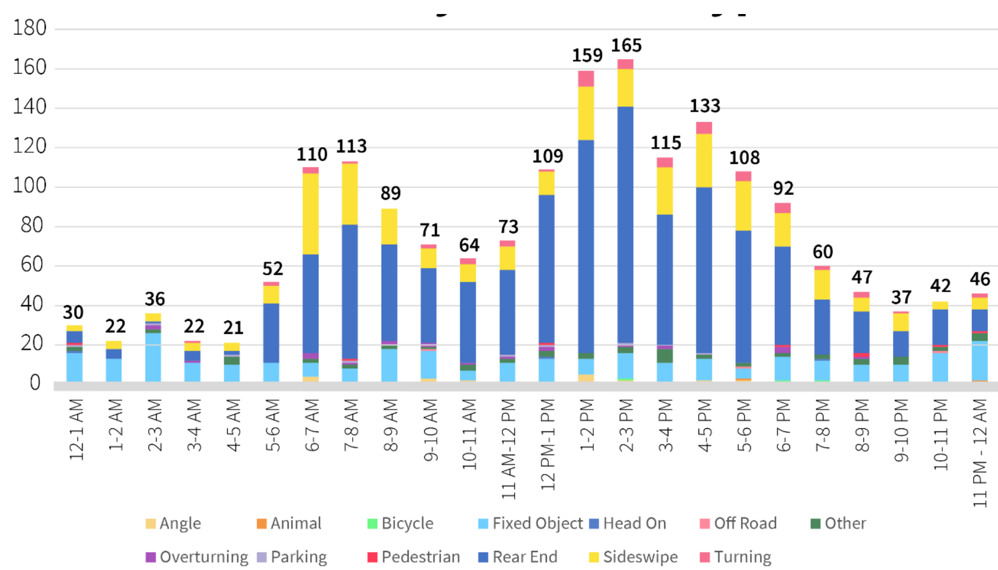
It is anticipated that the cycle time for a bridge opening for the different movable span options would be approximately 20 to 30 minutes (the bascule span would have fastest bridge opening). During the time the bridge is opened, traffic would be stopped in both directions and would be affected differently depending on the hour of the opening. Based on the 2019 traffic volumes, bridge lifts in the overnight hours would have minimal delay on traffic and transit volumes. If the bridge lift occurred during the middle of the day, it could take traffic 30 to greater than 60 minutes to recover, if it recovers at all.

[9] INRIX analyzes real time traffic data from road sensors and vehicles and summarizes this information on a daily basis.

4.6.3 Bridge Lift/Traffic Stoppages Crash Analysis

Figure 19 shows the existing number of crashes on I-5 and the ramps in the five-mile IBR program study area by hour and by type. As shown, more crashes occur during peak periods during congestion.

Figure 19. Crashes by Hour, by Type



Historical crash data gathered during the CRC Project suggests that the vehicular crash rates during bridge lifts/traffic stoppages are three to four times higher than during normal operating conditions. To determine if there was a different crash rate during days with a bridge lift/traffic stoppages and days under normal operations conditions (no bridge lifts/traffic stoppages), the CRC Project team summarized crash data for all hours between 9 a.m. and 2:30 p.m. for the five-year period from 2000 through 2004. This focused time period was chosen because bridge lifts/traffic stoppages are not allowed on weekdays (non-holidays) between 6:30 a.m. and 9:00 a.m., or 2:30 p.m. to 6:00 p.m. ODOT records exactly when bridge lifts/traffic stoppages occur, and both ODOT and the Washington State Department of Transportation (WSDOT) record crash information, including the time, type, and severity of crashes.

Table 2 shows weekday crash data from 2000 through 2004 between 9 a.m. and 2:30 p.m. that was analyzed for the CRC Project. Crash data was analyzed on weekdays when bridge lifts/traffic stoppages did not occur (columns 4 and 5 in Table 2). Using this dataset, the crash rate when bridge lifts/traffic stoppages did not occur was calculated to be approximately 0.019 to 0.021 crashes per hour. Similarly, crash data was analyzed during weekdays that had bridge lifts/traffic stoppages (columns 2 and 3 in Table 2). Using this data, the crash rate when the bridge is open is approximately 0.060 to 0.067 crashes per hour. As such, the crash rate during bridge lifts/traffic stoppages is three to four times higher than during normal operating conditions (days without a bridge lift/traffic stoppage). Crash data is similar for the most recent five-year period collected for the IBR program

(2015 through 2019), so the conclusions about crash rates during bridge lifts/traffic stoppages are assumed to be similar to what was calculated for the CRC Project.

Table 2. Bridge Lift and Traffic Stop Crash Rate Summary (9:00 a.m. to 2:30 p.m., Monday through Friday, 2000 through 2004)

Year	Number of Crashes on Days with Bridge Lifts/Traffic Stoppages	Number of Hours on Days with Bridge Lifts/Traffic Stoppages	Number of Crashes on Days without Bridge Lifts/Traffic Stoppages	Number of Hours on Days without Bridge Lifts/Traffic Stoppages
Northbound				
2000	6	110	27	1,320
2001	10	151	21	1,279
2002	7	114	36	1,316
2003	7	100	28	1,330
2004	4	95	26	1,335
Total	*34*	*570*	*138*	*6,580*
Crashes/hour	*0.060*		*0.021*	
Southbound				
2000	4	110	23	1,320
2001	12	151	26	1,279
2002	8	114	22	1,316
2003	7	100	20	1,330
2004	7	95	33	1,335
Total	*38*	*570*	*124*	*6,580*
Crashes/hour	*0.067*		*0.019*	
Source: Columbia River Crossing I-5 Collision Analysis Technical Memorandum				

4.7 High-Capacity Transit

With a movable span, modifications to the bridge's profile would have a nominal effect on transit operations. A decrease in the bridge's profile elevation could result in a decrease in the height of the Vancouver waterfront station, but the decrease would be minimized by clearance requirements over the nearby BNSF railroad on the north side of the river. However, the opportunity to decrease the profile elevation and grade could improve connections to the Vancouver Waterfront station for transit vehicles and transit patrons. However, introducing a movable span would affect train operations and scheduling, as well as require additional maintenance. Maintenance needs would increase over time.

Modifications to accommodate the movable span would affect train speeds. Electric light rail vehicles can sustain speeds at the approximately 4% grades proposed, so lowering the profile over the river is not anticipated to cause any change to train speed. However, introducing movable joints on the rails is likely to slow the train. Typical light rail tracks are continuous welded tracks with no joints, or joints with retainers to maintain the alignment integrity over a joint. Inserting a movable span would create two to three joints in the track that would be specially designed to be able to open. As a result, for safety reasons, the train speed would likely be slower over the movable span. Significant reductions in travel time could reduce ridership and impact the LRT project's competitiveness for federal funding. Given that there are stations proposed in proximity to each end of the bridge, it is likely that trains would travel at a reduced speed between the Hayden Island station and the Vancouver Waterfront station.

Train operations would be interrupted if a movable span opened during operating hours. Currently, TriMet operates the light rail system between 5 a.m. and 1 a.m. The hours between 1 a.m. and 5 a.m. are used for maintenance and to allow trains to travel between their respective routes and the maintenance base. Any bridge openings between 1 a.m. and 5 a.m. could impact the start of service. For example, the first train would need to arrive in Vancouver prior to 5 a.m. If a 30-minute lift occurred between 4:30 a.m. and 5 a.m., trains could be impacted at the start of service.

TriMet's Yellow line would be extended north to Vancouver as part of the IBR program. Current operating frequency on the Yellow line is as follows:

- 5 a.m. to 7 a.m.: 30-minute frequency
- 7 a.m. to 11 p.m.: 15-minute frequency
- 11 p.m. to 1 a.m.: 30-minute frequency

The IBR program proposes to increase train frequency to 12 to 15 minutes during off-peak hours and 5 to 7.5 minutes during peak hours.

The program's Yellow line extended route would begin at Evergreen Boulevard in Vancouver and connect to the Expo Station in Portland. The Yellow line continues to downtown Portland. It then changes to the Orange line, which continues to Milwaukie and Oak Grove. The total route length, with the proposed Yellow line extension, would be approximately 18 miles. A movable span could disrupt operations for the entire 18-mile segment when trains would stop for a bridge opening. Any trains on either side of the river would be held at the stations until the movable span is closed. This disruption would affect up to five trains in each direction during peak operating hours over the river and up to two trains in each direction during off-peak hours. Riders in, and destined for, Vancouver would be delayed during the opening. If bridge openings occurred between 1 a.m. and 5 a.m., then no interruptions to riders would occur and maintenance could be scheduled around the bridge openings.

Complex designs would be required for the vehicle power and communications systems. The light rail vehicles use an overhead catenary system (OCS) for powering the trains, with the grounding system going through the rails. The OCS system is carefully designed and constructed to allow for high operating speeds. Inserting joints would affect the operation of the electrical system and would likely require extensive maintenance to keep it operational. Communications systems are required for vehicle operations and train safety. This system would require continuous communications, so the communications system would either have to be installed (directionally bored) under the river bottom (applicable for a bascule bridge or a swing span) or be suspended above the bridge (for a vertical lift span).

4.8 Shared-Use Path

To comply with accessibility standards, an SUP can have a maximum sustained grade of 5%, which would be accommodated by the highway profile grades of 4% or less. If a lower profile is used for the movable span bridge, the elevation changes required by path users would be reduced, thereby improving the walkability and rideability of the bridge. A lower bridge would also reduce the length of ramps connecting to the ground on either end of the bridge.

Bridge openings during daytime hours would delay path users as no suitable detour route is available. Current lift span operations have experienced significant safety challenges with active transportation users often attempting to go around safety mechanisms in place on the sidewalks. Additional work would be needed to determine a safe way to prevent active transportation users from entering the movable span in advance of a lift. Due to very low use during nighttime hours, late night bridge openings are not expected to adversely affect users of the path.

5. CONSTRUCTION CONSIDERATIONS

A program requirement stipulated by ODOT and WSDOT is that three lanes of I-5 traffic need to be maintained in each direction throughout construction during peak hours. It is infeasible to reduce the number of lanes of traffic on I-5 during construction because of the long-term impact this would have on regional and statewide traffic operations. During construction, reduced lane and shoulder widths are operationally permittable as needed. To maintain traffic during construction, it is assumed that the typical section will have to provide 76 feet of deck between the faces of the outside barriers on either side. This is derived from the assumption of 2-foot shoulders and three 11-foot lanes in each direction, separated by a 2-foot-wide median barrier. The permanent typical section would be restriped for three 12-foot lanes and one 12-foot auxiliary lane, consistent with the proposed Modified Locally Preferred Alternative. It is also assumed that the northbound bridge would be constructed to the same width to be able to accommodate an in-service incident or circumstance requiring the southbound bridge to be shut down for maintenance, incidence management, emergency response, or inspection.

Incorporating a movable span would likely increase the duration of the construction schedule, regardless of the type of movable span used, due to the need for more massive foundations and the procurement, installation, and testing of the mechanical, electrical, and support systems required to operate the movable span, as well as the specialized workforce needs. The construction cost and schedule and in-water work would significantly increase—a minimum of one to two construction seasons—with a three-bridge single-level bascule bridge configuration.

Because the swing bridge would have all modes on one structure, it would need to be constructed entirely offline while using the existing I-5 bridges for maintenance of traffic. This would eliminate the need for any staging but would push the new alignment farther downstream, causing additional property impacts and challenging connections to I-5.

6. OPERATIONAL CONSIDERATIONS

Operational considerations would be similar to those required and provided for the present movable spans on the I-5 bridges. The movable span would be designed for the same seismic event(s) as a fixed span would be. However, a movable span with moving parts and machinery is more likely to suffer misalignment and/or damage from a seismic event that would be detrimental to resuming operations without significant cost and down time.

Movable bridges would also require an operator to open and close the span for marine traffic. The current lift span requires enough operators to be staffed 24 hours a day.

The annual maintenance costs of a movable bridge are greater than a fixed bridge and require expertise with mechanical and electrical systems (see Section 8). The additional annual maintenance costs associated with a movable span include performing routine lubrication of the machinery bearings, rotating elements, testing the operation of the electrical and mechanical systems, and replacing worn or broken parts.

7. ENVIRONMENTAL CONSIDERATIONS

Most environmental considerations associated with a movable span would be consistent with the Fixed Span Bridge. However, due to the larger pier foundation required for the movable span options, the intensity of some impacts would be greater. There would be six in-water piers and two land piers per bridge. Therefore, for the lift span bridge and the two-bridge bascule span bridge, there would be a total of 12 in-water piers and four land piers. For the three-bridge bascule span bridge, there would be a total of 18 in-water piers and six land piers. For the swing span bridge, there would be six in-water piers and two land piers. The total width of the three-bridge bascule span bridge would also be approximately 25% greater than the other movable span options due to the addition of a third bridge. Specific impacts that would result from the moveable span options to the environment include:

- **Air Quality and Greenhouse Gas Emissions**. Bridge openings would increase vehicular idling and associated pollutant and greenhouse gas emissions.

- **Biological Resources:**
    - For all three movable span options, the footprint of the pier foundations is expected to be larger than would be required for the Fixed Span Bridge. The increase in footprint would be greatest for the bascule span, and the three-bridge bascule span option would result in a substantially larger footprint and number of piers because of the third bridge. Larger footprints would result in greater in-water disturbance to fisheries, benthic habitat, and other marine species.
    - Overwater coverage associated with a movable bridge would likely be comparable to the Fixed Span Bridge, with the exception of the three-bridge bascule span, which would result in additional new overwater coverage (approximately 25% increase) associated with the third bridge. Larger areas of overwater coverage would create more shading of the river, which could result in greater predation of protected or culturally significant fish and other marine species.
    - The need for larger pier foundations for a movable span bridge would likely increase in-water construction durations, which would increase the extent and duration of disturbance (e.g., degradation of water quality, vibration) on aquatic species and habitat.
    - Impacts from increased foundation footprints, new overwater coverage, and longer construction duration associated with the movable span options would require additional compensatory mitigation and/or conservation measures to offset the unavoidable impacts.
- **Hazardous Materials.** For all three movable span options, the larger footprint of the bridge foundations would increase the potential to encounter hazardous material sites in river bottom sediment. There would also be an increased potential for disturbance of contaminated soil and pollution from suspended sediment, resulting in a greater potential for additional negative impacts on aquatic resources. With the three-bridge bascule span option, potential impacts would be greater due to the additional piers needed to support the third bridge.
- **Historic Structures and Archaeological Resources.** For all three movable span options, submerged historic structures and archaeological resources could have a greater level of disturbance and permanently impact due to the size and volume of excavation required for the larger bridge foundations. With the three-bridge bascule option, there could be additional disturbance by virtue of its larger footprint and additional piers (both over water and landside).
- **Land Use.** The swing span option would be located farther downstream than the other movable span options, thereby increasing impacts to development on Hayden Island and downtown Vancouver.
- **Stormwater Management.** Stormwater treatment systems for each movable span option would be more maintenance-intensive than those associated with fixed bridge designs. These systems may also not perform as well, due to the joints between the movable span and the

fixed section of the bridge; and, therefore be less effective in capturing and treating stormwater.

- **Visual Resources.** The lift span bridge would have permanent visual impacts similar to those of the existing I-5 bridges, but more impacts than the Fixed Span Bridge because the lift towers would protrude into viewsheds toward and from Vancouver, including Fort Vancouver, and toward and from Hayden Island. The bascule span would have similar visual impacts; however, they would be temporary and would only occur during a bridge opening. The swing span bridge would have no new visual impacts, and would have fewer impacts to views than the Fixed Span Bridge.

8. CONCEPTUAL COSTS

Conceptual construction costs for a movable span were developed based on previously completed projects and the collective expertise of the team. These costs are for a movable span that would accommodate I-5, LRT, and the SUP (note that the costs are for the movable span only; there would be additional costs for the other fixed spans of the bridge). The relative conceptual construction costs in Table 3 identify overall construction cost difference measured in 2022 dollars.

The construction cost implications associated with each movable span option are described below.

- A **vertical lift** is the most economical of the three movable span options studied. Planning-level estimates and review of historical unit costs indicate an approximate construction cost of $7,000 per square foot for a vertical lift span.
- A **double-leaf bascule** is more complex and costly when compared to the vertical lift due to several factors. One of the most significant cost drivers of the double-leaf bascule option is the substructure, which requires larger concrete pier foundations for each leaf. Planning-level estimates and review of historical unit costs indicate an approximate construction cost of $6,250 per square foot for a single-deck, double-leaf bascule span and $8,500 per square foot for a double-deck, double-leaf bascule span.
- A **double swing span** is the most costly of the three movable span options studied due to the length of the swing spans (two swing spans that are each 550 feet long). Planning-level estimates and review of historical unit costs indicated an approximate construction cost of $4,500 per square foot for a double swing span. Note, however, the length of the overall swing span option is longer than the vertical lift span option, resulting in a higher overall construction cost.
- For comparison purposes, planning-level estimates and review of historical unit costs indicated an approximate construction cost of $1,000 per square foot for a fixed span.

The conceptual construction costs do not include an allowance for soft costs such as design, construction management, contingency, or life-cycle considerations. However, based on previous experience, O&M costs of the movable span would increase the cost by $0.5 million to $1 million a year[10] over a 75-year design life, adding $37 to $75 million to the overall cost of the IBR program (in 2022 dollars). Yearly O&M costs for a Fixed Span Bridge would be approximately $100,000 (in 2022 dollars).[11]

Table 3. Reasonable Order-of-Magnitude Construction Costs

Description	Construction Cost	Fixed Span Cost Equivalent to Movable Option (Baseline)*	Change in Cost
Fixed Span (Baseline): two at 450 feet	$70,000,000	--	--
Vertical Lift Span: two at 450 feet	$500,000,000	$70,000,000	+$430,000,000
Bascule Span: two at 400 feet	$550,000,000	$60,000,000	+$490,000,000
Bascule Span: three at 400 feet	$600,000,000	$60,000,000	+$540,000,000
Swing Span: two at 550 feet	$800,000,000	$170,000,000	+$630,000,000

*The Fixed Span Cost Equivalent to Movable Option is calculated by multiplying the cost per square foot of the fixed span ($1,000/square foot) by the length and width of the spans for each movable span option.

It is assumed that none of the movable bridge options would require mitigation of impacts on river users. It is estimated that mitigation for river users could be in the range of approximately $100-120 million and would take approximately six to twelve months to complete mitigation.

[10] The existing lift span bridge costs approximately $1.3 million per year (in 2022 dollars) to operate and maintain. Source: WSDOT. 2017. Columbia River I-5 Bridge Planning Inventory. (Dollars escalated from 2010 to 2022)

[11] WSDOT. 2017. Columbia River I-5 Bridge Planning Inventory. (Dollars escalated from 2010 to 2022)

9. SUMMARY

Table 4 includes a summary of the considerations associated with each movable span option.

Table 4. Summary of Movable Span Considerations

<table>
<tr><th></th><th>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.
• Lower vertical clearance (in the closed position) than that provided by the Fixed Span Bridge.
• Requires 400 feet of horizontal clearance per the USACE (400 feet to accommodate the authorized width of 300 feet plus a buffer of 50 feet on either side for advanced dredging as specified by the USACE).
• Movable span operations, and thus river navigation operations, would likely have to be restricted to nighttime openings to minimize impacts to vehicle traffic and transit operations.</td></tr>
<tr><td>Aviation</td><td>• Lift span towers would permanently penetrate Pearson Field airspace.</td><td>• Leaves would temporarily penetrate Pearson Field airspace when open.</td><td>• No impact to Pearson Field airspace.</td></tr>
<tr><td>Alignment and Profile</td><td colspan="3">• Movable span would need to be on a straight portion of the bridge (and level or near level grade), located south of the existing lift span over the relocated primary navigation channel between Piers 5 and 6.
• Reduced grades would increase the ease of ramp connections, primarily on the Hayden Island end of the bridge.
• 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.
• Reduced grades would increase ease of access and operability of the SUP.</td></tr>
</table>

<table>
<tr><th></th><th>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>
<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 because the movable parts are more sensitive to foundation settlement. This ensures smooth operation during repeated opening cycles over its lifetime.
• Requires a stiffer foundation provided by increasing both the size of the pier’s footprint and number of drilled shafts contained therein.</td></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.
• Crash rate is expected to be 3 to 4 times higher during a bridge lift than during normal operating conditions.
• 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>
</table>

<table>
<tr><th></th><th>Lift Span</th><th>Bascule Span</th><th>Swing Span</th></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.
• Extensive maintenance to keep communications systems 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>
<tr><td>Shared-Use Path</td><td colspan="3">• Delay to SUP users during a bridge opening; no suitable detour route is available.
• Lower elevation would be a benefit for path users.</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 with third bridge configuration.</td><td></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 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, similar to the existing I-5 bridges.</td><td>• Additional displacement of benthic habitat with third bridge configuration.
• Additional over-water shading with three bridge configuration.
• Visual impact during bridge opening.</td><td>• Increased land use and development impacts due to downstream location of bridge.</td></tr>
</table>

	Lift Span	Bascule Span	Swing Span
Conceptual Construction Costs Change Compared to the Fixed Span Equivalent	• +$430,000,000	• +$540,000,000 (three bridge) • +$490,000,000 (two bridge)	• +$630,000,000