Willamette River, Hwy 1 (Boone Bridge)

I-5 BOONE BRIDGE AND SEISMIC IMPROVEMENT PROJECT
TECHNICAL REPORT

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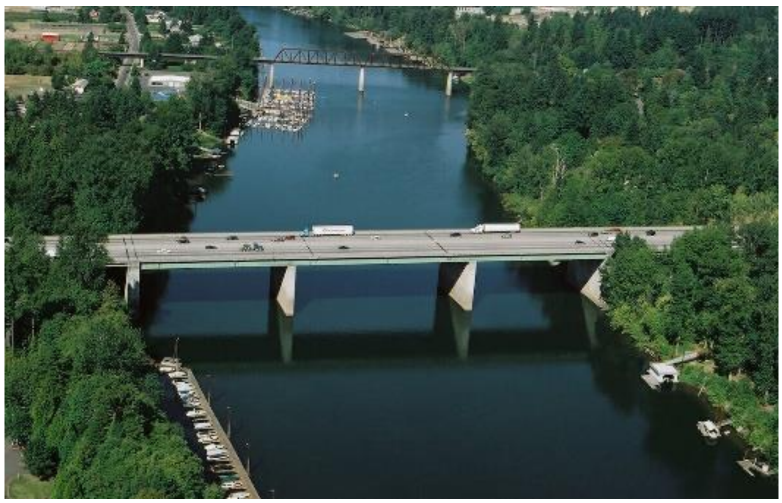

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EXECUTIVE SUMMARY

Study Purpose

This study has been prepared to provide the feasibility and order of magnitude cost estimates for upgrading the Boone Bridge, a 1137-foot long bridge on Interstate 5 (I-5) over the Willamette River in Wilsonville. Two options have been studied:

- Seismic Retrofit of the existing structure to better withstand the Cascadia Subduction Zone Earthquake and Widening to add a southbound auxiliary lane
- Full Bridge Replacement with a bridge designed to current design standards, including a southbound auxiliary lane

In both cases, the project would also extend the existing northbound auxiliary lane, which currently starts at the Miley Road northbound entrance ramp, further south to connect to the Canby / Hubbard entrance ramp.

Seismic Retrofit and Widening

This option would retrofit the southbound bridge and widen it by approximately 30 feet toward the west to provide a southbound auxiliary lane connecting the Wilsonville Road Interchange (Exit 283) to the Charbonneau / Hubbard Interchange (Exit 282A).

It is feasible to retrofit the existing bridge, however, significant work is required. The retrofit generally includes:

- New pier supports and foundations (the existing foundations cannot be retrofitted)
- Ground improvements on the riverbanks under the land spans
- Abutment upgrades to prevent the structure from falling off its support

There are also a number of documented long-term maintenance issues with the bridge, some of which are assumed to be addressed as part of the retrofit, others that will not. Fracture critical features of the bridge include the original 1952 superstructure, and the pin and hanger hinges. These issues will need to be addressed within the next 20 years and will involve replacement of the 1952 superstructure if this option is pursued. The cost of this work has been included in the retrofit and widening estimate.

Traffic can be maintained by constructing the retrofit in five stages. Much of the work can be performed below the bridge via work platforms in the river accessed from the riverbanks north and south. The abutment retrofit must be constructed from the top and staged to keep three lanes of traffic open in each direction.

The cost of retrofit and widening, including engineering, right of way, and inflation, ranges from $425 to $490 million.

Full Bridge Replacement

This option would replace the existing bridge with a new approximately 150-foot wide bridge that provides three through traffic lanes with an auxiliary lane in each direction connecting the Wilsonville Road Interchange (Exit 283) to the Charbonneau / Hubbard Interchange (Exit 282A).

Several bridge types are feasible. However, the most cost advantageous is a steel girder bridge. The soils below the bridge are poor and lighter steel girders minimize bridge foundation sizes and, therefore, cost.

Traffic can be maintained by constructing the new bridge in five stages. The concept developed with this study results in a minor shift of the I-5 centerline of 3 feet toward the east.

The cost of full replacement, including engineering, right of way, and inflation, ranges from $450 - $550 million.

Recommendation / Next Steps

During this feasibility study, the seismic assessment of the existing bridge revealed that the entire substructure of the bridge must be replaced. In addition, once widened, there will be ongoing costs to continue monitoring fracture critical details as well as the future expense of replacing the original bridge superstructure. The cost of the widening and retrofit, combined with the necessary future capital expenses, is nearly the cost of replacing the bridge. Under normal circumstances, it is advisable to consider a replacement structure if the cost of the retrofit is greater than one half the cost of the new structure. In this extreme case where the retrofit is very nearly the same as the cost of a new bridge over the next 20-year lifecycle, no further analysis is needed to recommend that the Widening and Seismic Retrofit option be discarded and future efforts be focused on evaluating the replacement options.

Additional analyses are needed to complete a more thorough evaluation of replacement alternatives. These additional studies include data collection (topographic, geotechnical, and environmental field studies), analysis, concept bridge and roadway design, and advance stakeholder outreach (City of Wilsonville, Clackamas County, and Metro). This additional work, described in this report, will lead to a better understanding of options and issues at the site, that will in turn result in selecting the structure type and span configuration to address site conditions. It is expected that five years of planning and design are needed to develop construction documents. Construction would take approximately four years to complete.

PROJECT BACKGROUND

Location

The project is located on Interstate 5 (I-5) in Clackamas County. A portion of the project is located within the Wilsonville City limits. A Vicinity Map is provided in Appendix A. I-5 in the project area is a six-lane separated freeway with median cable barrier north of the Boone Bridge and a concrete barrier-separated freeway with a narrow median on the bridge and to the south. The posted speed is 65 mph.

Project Purpose and Need

The project will improve safety on I-5 by upgrading the Boone Bridge to be able to withstand the Cascadia Subduction Zone Earthquake. ODOT has designated I-5, with the exception of a short segment in Portland, a Seismic Lifeline Route, which means it must be operational quickly after an earthquake if other roadways are rendered unusable or impassable. Lifeline routes will play a critical role in getting supplies and services to the region in the event of a significant seismic event or other catastrophe.

The project will also improve safety and operations by adding a southbound auxiliary lane between the Wilsonville Road (Exit 283) and Charbonneau / Hubbard Interchanges (Exit 282A). This section of I-5 experiences significant congestion during the afternoon commute hours especially. Southbound traffic queues at the Wilsonville Road Interchange extend for many miles on a daily basis.

Existing Site Conditions

This section of I-5 is a freeway with six general purpose lanes and a northbound auxiliary lane. The bridge has standard lane widths, but non-standard outside shoulder widths and non-standard median width. Concrete median barrier separates traffic on the bridge as well as to the south. Immediately north of the bridge, the median widens to 76 feet,with cable barrier separating the two directions of traffic..

Willamette River below Boone Bridge is a navigable waterway with recreational boating. Many residents immediately upstream and downstream of the Boone Bridge have docks in the river for pleasure boating.

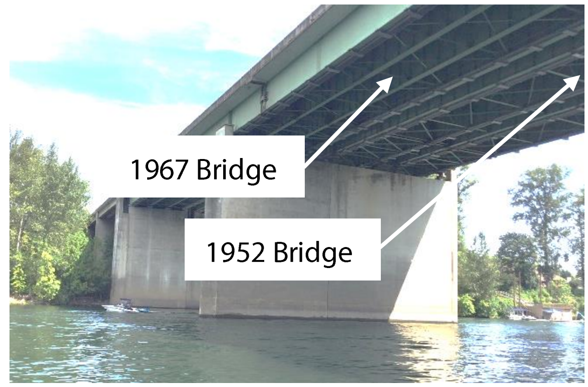
Bridge Description

The Boone Bridge is a 7-span 1136’-9” long bridge that was originally constructed in 1952 and then substantially widened and modified in 1967. The bridge has a common substructure, with two separate and parallel superstructures, each carrying one direction of traffic.

The bridge was seismically retrofitted in the late 1990's with a Phase 1 Retrofit designed primarily to prevent the superstructure from falling from its supports. ODOT had not yet started Phase 2 seismic retrofits to strengthen the substructure of any of its bridges at that time.

1952 Bridge

The original bridge was 67-foot wide and carried 2 lanes of traffic in each direction. This bridge was a 9-span structure, with 3 reinforced concrete deck girder (RCDG) approach spans on either side of the river and 3 steel girder spans over the river. The northbound and southbound traffic lanes were carried by two separate parallel bridges, each with a 27-foot wide travelled way.



1967 Bridge

In 1967, the bridge was widened, to the west, doubling the width of the bridge from 59 feet to 119 feet. At that time, the structure was modified as follows:

Approach Spans

1. The existing spans on each end of the bridge were removed and replaced with new 2-span approach structures over the full width of the widened bridge.
2. A new abutment and bent were also constructed the full width of the bridge.

Main Spans

1. The deck of the main spans (two separate bridges) was removed and replaced with a new deck that connected these two structures into one bridge to carry NB traffic.
2. A completely new steel girder structure was constructed next to the newly connected existing bridge to carry SB traffic.
3. The existing piers (Piers 1-4) continued to support the existing bridge, now carrying NB traffic
4. The piers were widened to support the new SB spans

A median barrier was constructed on the NB bridge to separate the two bridges. A longitudinal deck joint separates the NB and SB bridges at the toe of SB side of the barrier.

Bridge Superstructure

Approach Spans

With the completion of the1967 bridge widening, the approach spans on either end of the bridge consist of AASHTO Type V precast prestressed concrete girders spaced at approximately 6'-9". The NB bridge, which is ~65'-foot wide, has 8 girders, while the SB bridge, ~53.5-foot wide, has 7 girders. Each bridge has a 7 ½ inch thick reinforced concrete deck. In 2000, a microsilica overlay has been added on top of the deck for each bridge.

Main Spans

The main spans consist of 3-span steel girder spans composite with a reinforced concrete deck. These spans are continuous from the outer piers (Piers 1, 4) and then cantilever over the inner piers (Piers 2, 3) to support a suspended span in the center span of the bridge.

Recall that the NB bridge comprises the original two bridges that were linked together during the 1967 widening. Those two bridges consisted of two main girders linked together with a truss floor beam that in turn supports 2 rows of stringers between the two main girders.

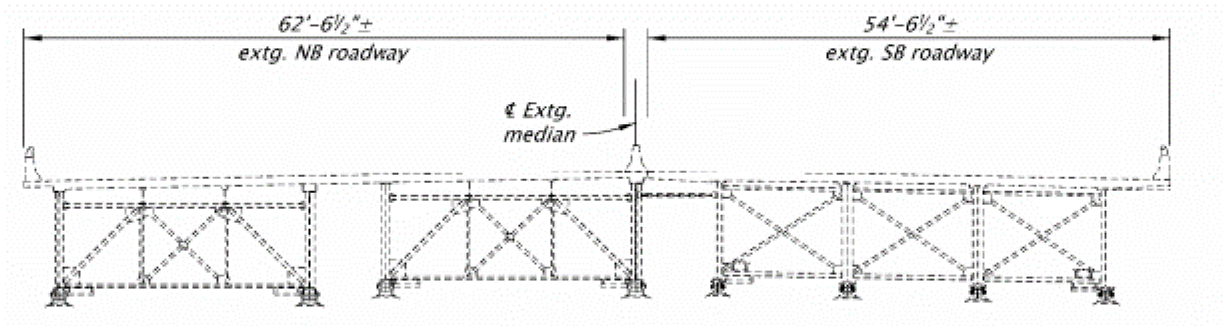


Figure 1 – Existing Bridge Steel Girder Spans

This is significant when considering how to remove the bridge for the replacement option because this side of the bridge can only be removed in whole, or in one-half due to this configuration.

The SB bridge consists of four composite steel girders with a suspended span in the middle span to match the 1952 bridge.

All steel girder spans are supported by lead rubber isolation bearings that were installed as part of the Phase 1 Seismic Retrofit project.

Bridge Substructure

Intermediate Supports

Bents 2, 3 (land supports)

These supports were constructed the full width of the bridge with the 1967 widening and consist of 6-foot wide hollow reinforced concrete pier walls supported on reinforced concrete footings and 4 rows of driven steel piles. Bent 2 is supported by 116 piles, while Bent 3 is supported by 108 piles. In both bents only 24 of the over 100 piles are connected to the footing that can provide uplift resistance to seismic loads. Therefore, these foundations have very little uplift resistance to prevent overturning in the longitudinal direction.

Piers 1, 4

These supports consist of 15-foot wide hollow reinforced concrete pier walls supported on reinforced concrete footings. The pier extends all the way to the deck level. The roof of these piers is a 10'-10 1/2" wide transverse t-beam span that comprises the actual deck of the bridge between the concrete girder approach spans and the steel girder main spans, resulting in deck joints only 11 feet apart.

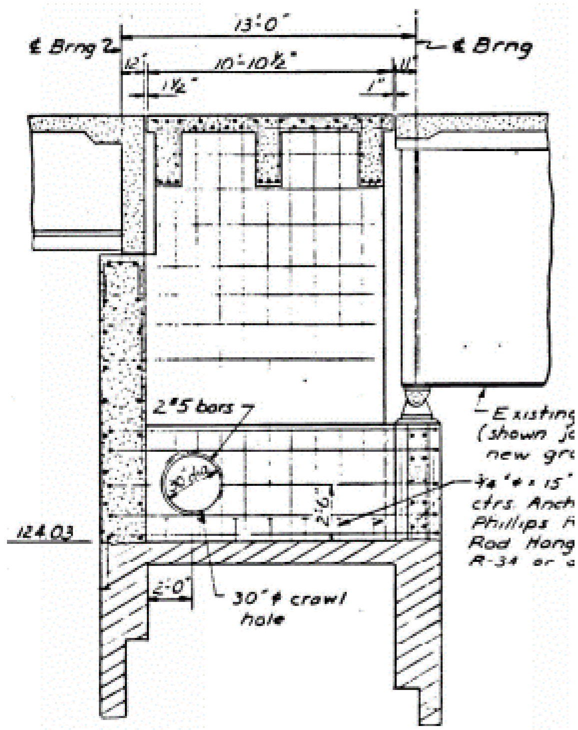


Figure 2 – Existing Pier 1 Cross Section

The approximately 70-foot wide original pier is supported on six rows of driven untreated timber piling. The 53-foot wide widening portion of the pier is supported on six rows of driven steel piles, with only 12 of 90 piles connected to the footing for uplift.

Piers 2, 3

These supports consist of 10-foot wide hollow reinforced concrete pier walls supported on reinforced concrete footings. The 81'-foot wide original is supported on eight rows of driven untreated timber piling. The 45-foot wide widening portion of the pier is supported on eight rows of driven steel piles, with only 12 of 106 piles connected to the footing for uplift

All piles supporting intermediate supports are vertical, i.e., no piles are battered.

End Bents

In the 1967 widening, these supports were replaced completely. The end bents consist of reinforced concrete footings (pile cap) supported on two rows of driven steel piles, with the front row battered at 4:1. The abutment itself is a semi-integral diaphragm encasing the ends of the girders, which in turn sits directly on elastomeric bearing pads beneath each girder. There is no connection between the diaphragm and the pile cap.

Material Properties

The following is a summary of materials used to construct the bridge.

Component	Strength
Prestressed Girders	6,000 psi

Prestressing Strand	250,000 psi
Concrete	3,300 psi
Reinforcing Steel	40,000 psi
Steel Girders	36,000 psi

Geotechnical

Limited geotechnical investigations were developed to inform the study. Two cone penetrometer tests were completed in June 2020, one near Bent 2, and the other in the roadway embankment south of the bridge. This information has been combined with previous investigations that were completed in the 1990's as part of the Phase 1 seismic retrofit bridge design effort. Based on this combined information, the geotechnical site conditions beneath the bridge consist of the following soil layers, shown in Figure 3 below:

- Fill material at each end of the bridge
- Sand alluvium riverbanks
- Troutdale formation in which the bridge foundation is located
- Mudstone ~200' below the bridge
- Basalt over 300' beneath the riverbed.

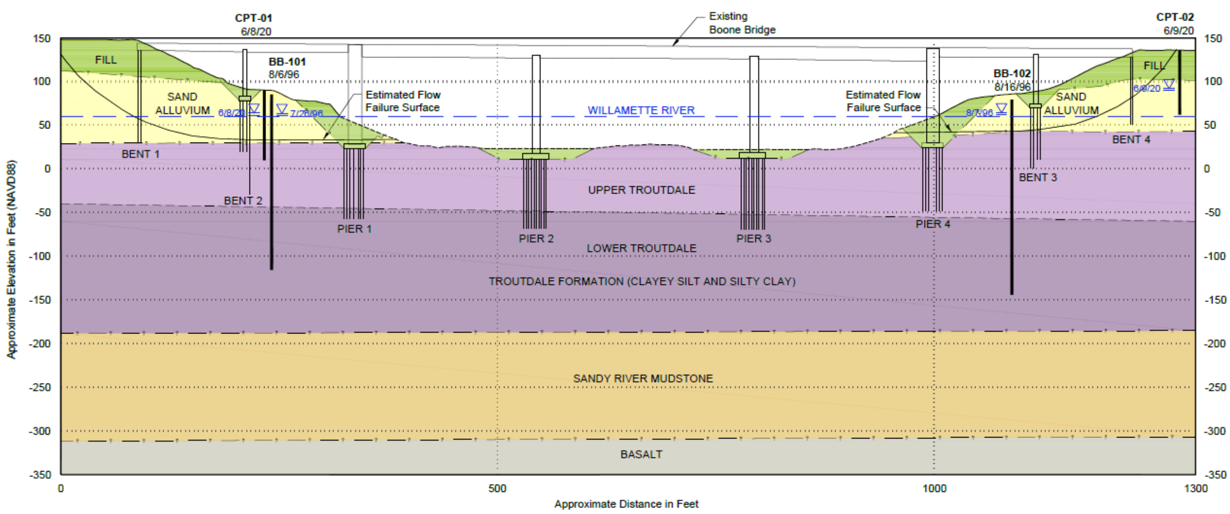


Figure 3 – Foundation Soil Cross Section

The composition of the soils results in two main features:

1. The sand alluvium riverbanks are subject to liquefaction in an earthquake that will result in loss to pile friction for the land supports, as well as lateral spread and slope instability, both of which will result in the embankments sloughing into the river and endangering the land support foundations.
2. The footings for the in-water supports are located at the top of the Troutdale formation. These footings are in turn supported on timber or steel piles driven into the Troutdale formation.

These piers are located below the sand alluvium layer so are generally not affected by the embankment issues.

Due to the presence of the sand alluvium, retrofit foundations will need to be supported in the Troutdale formation, which will provide reasonable foundation capacities. However, the retrofit measures will have large demands and be better suited to being supported by the basalt layer. The basalt layer is more than 300 feet below the ground surface, and it is not practical to economically construct foundations to that depth. Capacities for foundations supported in the Troutdale will be less than half of the capacity of foundations supported in basalt.

BRIDGE WIDENING AND SEISMIC RETROFIT CONCEPT

(NOT RECOMMENDED)

Bridge Widening

At the outset of the project, only the Southbound roadway and bridge was to be widened to provide an auxiliary lane and standard outside shoulder and median. Because the NB and SB bridges are not connected, it was decided that the NB bridge would remain as is, with non-standard shoulders. However, due to the desire to be able to shift traffic temporarily over the longitudinal deck joint, it was later decided to link the two existing bridge together at the deck level, which will enable the NB structure to be widened to provide standard outside shoulder and median widths in that direction as well.

The bridge will be widened approximately 30 feet on the west side, on the southbound structure. In addition, the bridge deck between the 1952 bridge and the 1967 bridge will be connected by removing the interior overhangs of each bridge and reconstructing the concrete deck.

The approach spans will be widened with five additional girder lines of AASHTO Type V prestressed concrete girders to match the existing girders. The main spans will be widened with 3 girder lines of steel plate girders to match the existing steel girders. The widening will include a reinforced concrete deck in all spans

The existing supports are seismically deficient. The substructure widening and retrofit are discussed below.

Seismic Retrofit

Design Criteria

The bridge was evaluated for ODOT's two-tiered Seismic Performance Criteria. The Boone Bridge is a Standard Bridge (in importance) with an anticipated service life of 16-50 years (ASL2). It is therefore expected to perform to the following standards:

- Lower Level (LL) – Operational, Performance Level 2 (PL2)
- Upper Level – Life Safety, Performance Level 1 (PL1)

A project specific Seismic Retrofit Design Criteria has not been developed, but several seismic retrofit projects have been completed now and a reasonably comprehensive criteria is beginning to take shape. Additionally, ODOT has developed policies for certain structural elements and their allowable, or disallowed, behavior. In general, the I-205 Corridor Widening Project (K19786) Seismic Retrofit Design Criteria has been used for guidance. That project includes the Abernethy Bridge Widening and Seismic Retrofit, with very similar issues and requirements. This criterion should be used for this project in future phases and updated as needed.

The most significant ODOT policy for seismic performance that applies to this project is the determination to consider all timber piling inadequate to resist seismic loads. Since the main spans of this bridge are supported by timber pile foundations, this means the substructure for this portion of the bridge is not functional in an earthquake unless these piles can be replaced or an alternate support system is provided.

Geotechnical

A Preliminary Geotechnical Engineering Letter Report prepared by Shannon & Wilson as part of this project has determined that the bridge lies within a Site Class E location. The following acceleration response spectrum has been used in this evaluation.

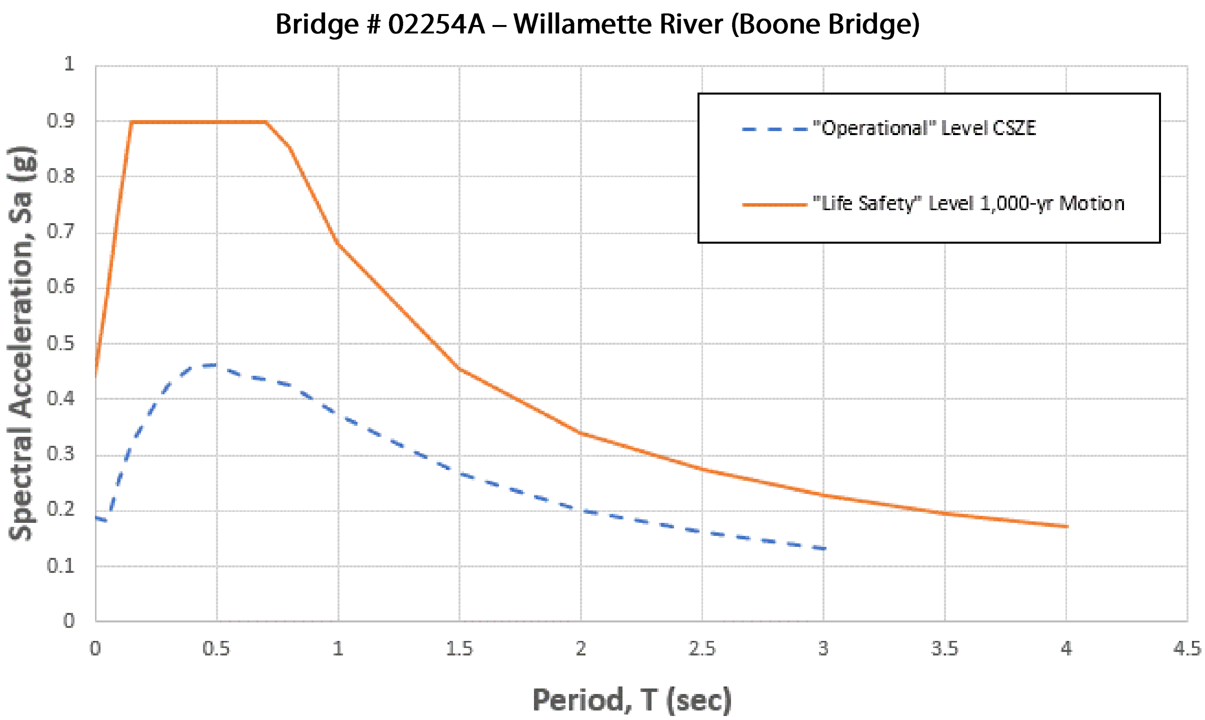


Figure 4 – ARS Curves

The subsurface conditions at the site are significant factors in the behavior of the bridge. The foundation soils on both riverbanks consist of soils above the river bottom that will liquefy in an earthquake and then flow into the river. This affects the supports located within this flowable mass, Bents 1 through 4. The in-water supports are generally not affected by these soil conditions because the weak soils reside above the Pier 1-4 foundations. These soils can be strengthened to greatly reduce the movement of this soil toward the river, but they cannot reduce the loss in soil strength below the supports of the bridge, which will result in a reduced load carrying capacity of piles located within this area, which can lead to unacceptable settlement in these areas of the bridge.

Seismic Retrofit Analysis

Seismic retrofit involves two types of analysis, the first to determine demands on the bridge by a given seismic event (for both upper and lower level events), and the second to determine the capacity of the bridge to resist those demands. The upper level event is the earthquake with a 1,000-year return period, and for this project, the lower level event is the M9.0 Cascadia Subduction Zone Earthquake.

SEISMIC DEMANDS

A linear elastic multimodal response spectrum analysis is used to capture the various modes of behavior that the bridge will experience. There are a number of different deformed shapes (modes) to which a bridge can be driven in an earthquake. This analysis method evaluates each shape and determines the percentage of the total structure mass contributing to each mode. These modes are then assembled to provide their combined total effect on the bridge and each of its components. As the name implies, this is a linear elastic analysis, which is a simplified method that is applied to a non-linear, inelastic structure. In general, in order for this method to be effective, the non-linearities and inelastic behaviors must be understood and accounted for in the modeling to ensure reasonable results from the analysis. An example of a non-linearity is the behavior of bridge joints, which close up and transmit compression when portions of the bridge move toward each other. However, since there is no physical connection across a joint, there is no force transfer (tension) when the same portions move apart. Inelastic behavior typically occurs in the substructure of a bridge when seismic forces exceed the nominal strength of a member. When pushed beyond this range, the member can provide a sustained resistance level as the deflection exceeds the elastic limit of the various materials, up to an ultimate capacity of the inelastic system.

For bridges with multiple expansion joints, two separate models are used to bracket the behavior of the bridge. In a "compression" model, all bridge joints are locked, effectively making the bridge continuous in the analysis. This typically results in somewhat conservative demands on the substructure since forces are transferred through a joint immediately, rather than waiting for the joint itself to close up before transferring forces to the adjacent member or frame. In a "tension" model, the members on either side of an open joint are allowed to overlap each other, thereby maximizing displacements at these joints. While this overlapping behavior cannot physically occur when the members move toward each other, this is a rational method to estimate displacements of members when they are moving away from each other. This information is then typically used to evaluate whether or not a superstructure member could fall from its support and is the currently accepted industry practice.

SYSTEM CAPACITIES

There are a number of bridge elements that combine to resist seismic forces. As a general statement, the accepted practice is for the superstructure of a bridge to remain elastic, and for the columns to experience ductile (inelastic) behavior to resist and dissipate seismic demands. The substructure consists of multiple elements, some of which must remain elastic to provide stability. Bent caps (crossbeams), pile caps, and sometimes even deep foundation elements (piles, shafts, etc.) are expected to remain essentially elastic, while the columns supporting the bent cap and supported by the pile cap are expected to behave in an inelastic, ductile manner. A Pushover Analysis is performed to determine the ductile displacement capacity of the columns. For this bridge, bents and piers are all pier walls in the transverse direction. They are so wide they act as shear walls and do not exhibit inelastic behavior. In the longitudinal direction, these supports exhibit ductile behavior if their foundations are strong enough. In this direction, the pier and foundation system is subject to a lateral displacement that imparts force into the system to determine the displacement capacity of the pier and the associated demands in the other elements of the bent. This displacement capacity is then compared against the demand displacement to determine if portions of the structure require retrofit.

ERS Selection Process

Before any analysis of the bridge was completed, two very significant issues were identified.

1. Timber piles supporting the majority of the main spans are not reliable and are therefore ignored for the evaluation of the bridge.

2. Geotechnical site conditions consist of soil liquefaction and lateral spreading on both banks of the river. The geotechnical evaluation of these conditions show that ground improvements will only affect Bents 2 and 3, and ground improvements designed to limit lateral spreading will not prevent soil liquefaction. The liquefaction occurs to near the tips of the piles supporting these bents so the pile foundations are grossly overloaded, and these supports will sink under the weight of the bridge.

Given these two factors, the Earthquake Retrofit System selection was directed to replacement of the existing substructure in its entirety. For this structure, there are two potential retrofit alternatives.

- Type 1 – this system consists of a ductile substructure with an elastic superstructure and is the most common ERS in use. Columns and/or piers are designed and detailed to provide inelastic behavior within tolerable limits, with foundations and connections to the superstructure being capacity protected. Analysis of this type of structure is typically done with a response spectrum analysis to bound the behavior of the bridge in an earthquake.
- Type 3 – This system uses seismic isolation devices to greatly reduce the amount of force in the bridge. This can reduce the amount of retrofitting including size of retrofit members needed to resist an earthquake. The use of these devices requires a much more complex form of dynamic analysis that this study can provide at this time and should be evaluated for effectiveness in future phases.

Due to the limited nature of this study, a Type 1 system has been assumed. With further evaluation, a Type 3 system could lead to smaller retrofit elements. However, due to the need to replace the entire substructure, savings will be limited, so further investigation is not warranted.

Demand Model – Response Spectrum Analyses

A Response Spectrum Analysis was completed using the computer program SAP 2000 that includes the following model features:

- The superstructure was modeled with a single spline of beam elements, located at the center of gravity. (Because the bridge is supported on pier wall supports, there are no crossbeams or multiple columns at each bent so modelling each girder line was unnecessary.)
- Intermediate bents and piers were modeled as frame elements.
- Gross section properties were used for piers.
- Superstructure members used uncracked (100% of gross) section properties since the connections to the substructure are pinned and do not cause cracking in the superstructure.
- Demands included the self-weight of the bridge (dead load) and seismic effects. An additional 25 psf (pounds per square foot) was added to the deck to represent the weight/mass of the microsilica overlay. Since the bridge already has a PPC overlay, no additional weight/mass was added for a future deck overlay.
- The superstructure is pinned to the substructure – isolation bearings supporting spans 3-5 were not evaluated in the interest of time.
- Abutment longitudinal stiffness was based on the passive ultimate stiffness (assumed to be 5 ksf) of the soil behind the abutment.
- Transversely, because the abutment piles are located in liquefiable soil and will lose much of their strength, the abutments were modeled as both pinned and released to bound the overall behavior of the bridge
- 5% damping was included in all models.
- No live load effects were included.

A single compression model was analyzed for only the upper level events because the piers are so stiff they will behave elastically in all events. Thus, maximum demands on the elastic piers occur in the upper level event. As described earlier, compression models simulated closed deck joints that effectively result in the superstructure being pinned at these joints.

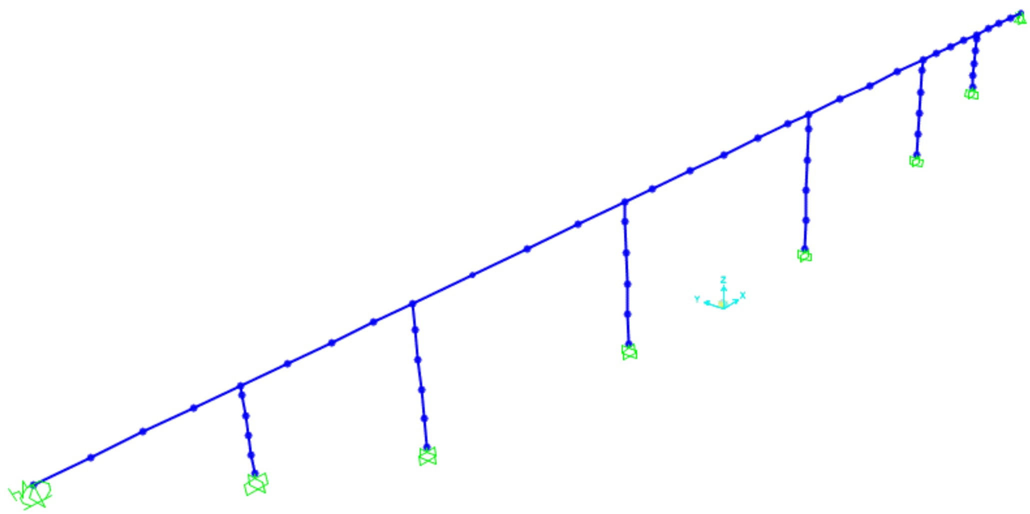


Figure 5 – Isometric View of SAP 2000 Global Model

Local Models

Once column demands were determined, seismic loads were applied to superstructure connections and cross frames and diaphragms to determine demands using local static and free body models for the upper level event.

Capacity Models

Pushover Analyses

Due to the deficiencies identified for existing foundations, capacity determinations for the existing piers and bents were not completed. With the failure of the foundations and the impracticality of retrofitting them, the existing supports will be replaced.

Local Analysis

Capacity analyses were completed for the connections between the superstructure and substructure, as well as the lateral bracing system of the superstructure itself. These components must be strong enough to resist seismic demands so that the superstructure remains connected to its supports and that the girders do not sustain unacceptable damage.

Capacity / Demand Ratio Summary Tables

Upper Level Event (1,000-year Return Period) — C/D Ratios

BRIDGE COMPONENT	C/D RATIO	DESCRIPTION
End Bents 1 & 4		
Abutment Seat Width	N/A	Girders pinned to seats so cannot move. If dowels fail, seat width C/D will be determined during retrofit assessment.
Girder End Diaphragm Flexure	0.7	Girders roll over transversely due to diaphragm failure
Transverse Shear Keys	7.1	From Phase 1 Retrofit
Pile Axial	N/A	Soils below abutment liquefy causing loss of friction along most of pile length
Steel Pile Combined Stress	0.0	Soils below abutment liquefy, reducing lateral bracing of piles over most of their length causing piles to buckle.
Bents 2 & 3		
Transverse Shear Keys	2.1	From Phase 1 Retrofit
Concrete Girder End Diaphragm Flexure	0.66	Girders roll over transversely due to diaphragm failure
Concrete Girder Dowel Shear	0.22	Dowels through end of girder
Bent Longitudinal Flexure	0.06	Extremely lightly reinforced for longitudinal flexure
Bent Transverse Shear	2.68	Bent is a shear wall
Pile Uplift	0.12	Only three piles at each corner connected to footing
Pile Axial	<1	Soils below bent liquefy causing loss of friction along most of pile length. Downdrag load exceeds end bearing capacity of pile and will lead to 6-12" of settlement
Steel Pile Combined Stress	0.0	Soils below abutment liquefy, reducing lateral bracing of piles over most of their length causing piles to buckle.
Pile Caps	N/A	Since piles fail, pile caps were not evaluated
Piers 1 & 4		
Timber Piles	0.0	Timber piles are unreliable in an earthquake so are assumed to provide no support.

Steel Piles	N/A	Since Timber Piles fail, Steel Piles not analyzed
Pile Cap Shear	N/A	Since Timber Piles fail, Pile Cap, not analyzed
Pile Cap Flexure	N/A	Since Timber Piles fail, Pile Cap, not analyzed
Concrete Girder End Diaphragm Flexure	0.66	Girders roll over transversely due to diaphragm failure
Concrete Girder Dowel Shear	0.22	Dowels through end of girder
Steel Cross Frames	0.06	Cross frames cannot even resist reduced forced from base isolation bearings.
Girder Connection to Pier	N/A	Girders are supported on base isolation bearings
Piers 2 & 3		
Timber Piles	0.0	Timber piles are unreliable in an earthquake so are assumed to provide no support.
Steel Piles	N/A	Since Timber Piles fail, Steel Piles not analyzed
Pile Cap Shear	N/A	Since Timber Piles fail, Pile Cap, not analyzed
Pile Cap Flexure	N/A	Since Timber Piles fail, Pile Cap, not analyzed
Concrete Girder End Diaphragm Flexure	0.66	Girders roll over transversely due to diaphragm failure
Concrete Girder Dowel Shear	0.22	Dowels through end of girder
Steel Cross Frames	0.05	Cross frames cannot even resist reduced forced from base isolation bearings.
Girder Connection to Pier	N/A	Girders are supported on base isolation bearings

Red text indicates deficient: Green text indicates adequate

Design Assumptions

Due to the high-level nature of this evaluation, and the simplified behavior assumptions of the foundations, the following modelling assumptions were used:

- Fixed base foundations
- Compression model
- Fixed bearings
- Locked expansion joint near Pier 2 from prior phase 1 seismic retrofit

Analysis Conclusions

The following is a summary of the deficiencies and the conclusions of the analysis:

Seismic Deficiencies

The bridge is a simple structure since it is only supported by pier wall type intermediate supports and pile cap abutments. The failure mechanisms for bents and piers are very limited:

- In the transverse direction the walls are so wide that they behave as shear members, with no bending. The shear forces they attract are so large that the existing foundations are overwhelmed by seismic demands.
- In the longitudinal direction, the walls are so thick that their flexural strength is many times greater than their foundations. They can never behave inelastically without simply overturning.
- Deficiencies for the bents and piers are therefore limited to either their foundations or the superstructure connections at the top of the pier.

Globally there are two major deficiencies that affect the entire bridge:

- Timber piles supporting Piers 1 through 4 are unreliable in a seismic event. Thus Piers 1 through 4 cannot be retrofitted because it is not feasible to replace or retrofit these piles.
- Liquefaction occurs in the approach embankments, resulting in lateral spreading toward the river. Ground improvements can be implemented to reduce the lateral spreading effects, but this will not reduce liquefaction which will lead to loss of vertical capacity for the steel piles supporting the land Bents.

Finally, the previous retrofit to prevent the superstructure from coming off its supports provided adequate connections to keep the superstructure on top of its supports. However, the strength of the bracing system in the superstructure to resist lateral forces is insufficient and as a result these components are deficient.

- Precast Concrete Girder Spans – the end diaphragms between the girders were not strengthened and have insufficient capacity to prevent the girders from rolling over transversely.
- Steel Girder Spans – similar to the approach spans, the end bracing between the girders is also understrength. The diagonal bracing will buckle and collapse, also allowing the girders to roll over transversely.

Retrofit Recommendations

Timber piles, foundation soil liquefaction and lateral spreading result in complete failure of the existing bridge's foundations. As a result, the only earthquake retrofit system available is to completely replace the substructure. The following table is a summary of the earthquake resisting elements.

DEFICIENCY	ERE ELEMENT
Timber pile foundations at Piers 1-4	Outrigger bent consisting of: • Drilled shaft foundations outside existing piers and bents (multiple shafts for each side of each bent) • Shaft cap (crossbeam) on top of shafts • Columns on top of shaft caps • Prestressed Crossbeam encasing the existing pier (remove pier below new crossbeam)
Steel pile foundations at Bents 2 & 3	Outrigger bent similar to Piers

Steel pile foundations at End Bents 1 & 4	New pile foundations consisting of piles on either side of the pile cap (driven through the bridge deck and end panel connected to existing pile cap
Concrete girder pin connections	Shear keys on top of outrigger crossbeams
Concrete girder diaphragms	Strengthen diaphragm between girders
Steel girder cross frames	Replace with solid plate diaphragms
Foundation soil liquefaction and lateral spreading	Ground improvements between Bents and 3 and the river

As a side note, the outrigger bent strategy has been used on the I-205 Abernethy Bridge, which is also being widened and seismically retrofitted. However, the foundation conditions for the Boone Bridge, while not problematic, are not as favorable, resulting in the need for twice the foundation costs as the Abernethy Bridge.

Refer to Appendix E for Widening and Seismic Retrofit concept plans.

Construction Staging – Methodology and Impacts

The bridge widening and seismic retrofit and requires five stages to complete the work.

Stage 1

With the decision to increase the shoulder and median width to standard, the median of the deck is reconstructed to link the bridges together.

The seismic retrofit consists of work below the bridge deck including the substructure for the widening. (This could also be completed at the beginning of Stage 2)

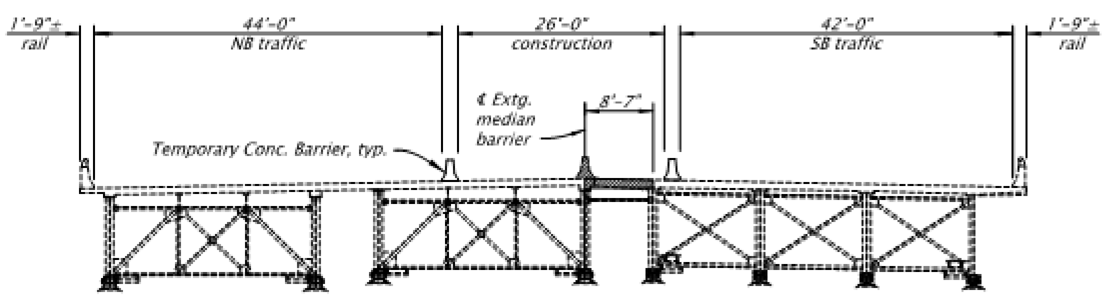


Figure 6 – Retrofit and Widening Stage 1

Stage 2

Upon completion of the seismic retrofit and widening of the substructure in Stage 1, traffic is shifted to the east to provide sufficient construction area to widen the bridge.

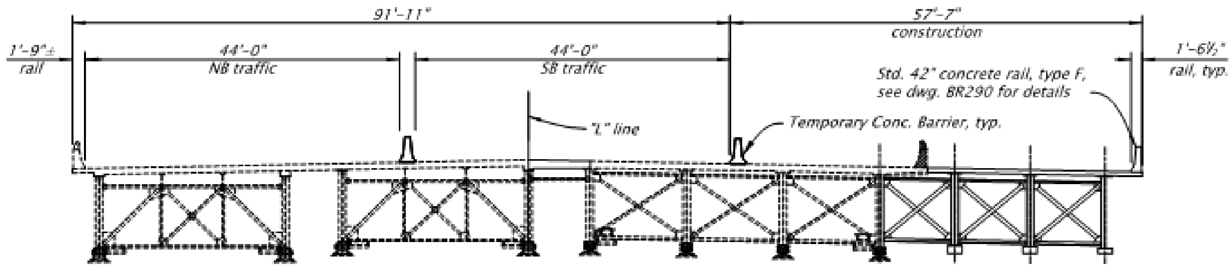


Figure 7 – Retrofit and Widening Stage 2

Stage 3

Seismic retrofit of the end bents requires work in the roadway at each abutment. This work will require 3 steps, the first of which is done during bridge widening construction in Stages 1 and 2. Once the widening is completed, SB traffic is shifted onto the widening so that the abutment work can be completed in the middle section of the bridge.

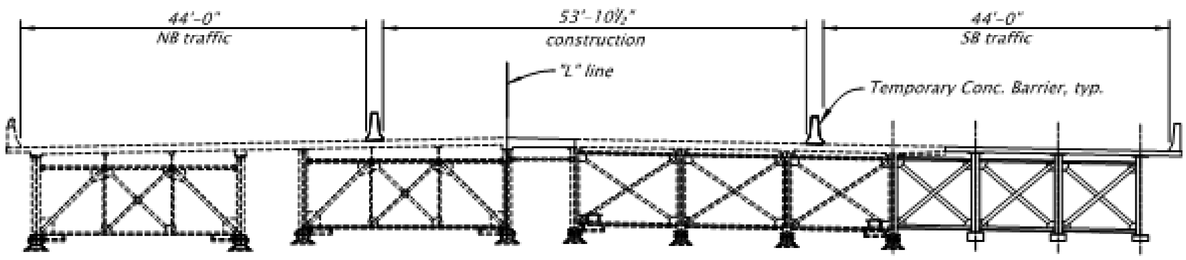


Figure 8 – Retrofit and Widening Stage 3

Stage 4

NB traffic is shifted into the middle of the bridge and abutment retrofit work is complete on the east third of the bridge.

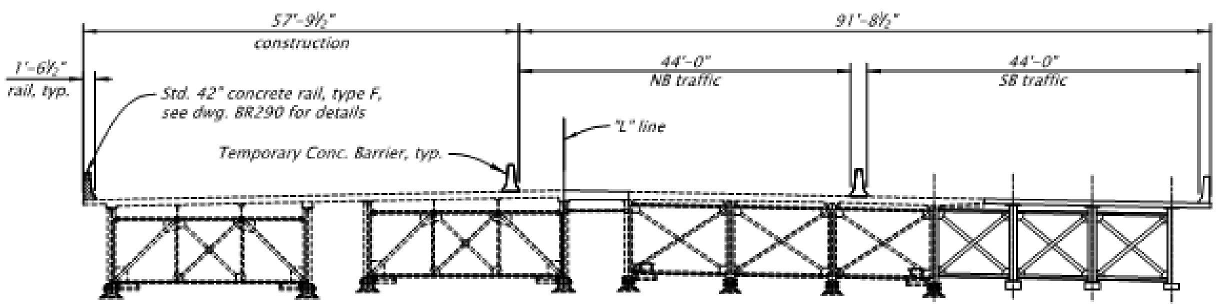


Figure 9 – Retrofit and Widening Stage 4

Stage 5

Upon completion of Stage 4, NB traffic is shifted back to the east side of the bridge and the median barrier is constructed. Traffic is then shifted into its final lane configurations on both sides of the road.

Ground improvements are required in the river banks on the river side of Bents 2 and 3. This work can be completed at any time, including after the rest of construction is finished and the bridge is fully opened to traffic in the final configuration.

A Stage Construction plan in included with the bridge plans in Appendix E.

Construction Access

Below the Bridge

Most of the work for the seismic retrofit will be beneath the bridge. Large equipment will be used to construct the drilled shafts and outrigger bents. Access will be provided to the site with the following considerations.

- Access to the site will be needed from both sides of the river in order to maintain river traffic.
- Residences on the east side of the freeway will all but preclude access from this side.
- From the north, access should be provided through the ODOT Maintenance Yard and the Boones Ferry Trail that passes south of the maintenance yard and beneath Span 2 of the bridge.
    - The trail between residences on the east side and Boones Ferry Park on the west will be temporarily impacted and will need to undergo various detours during construction to remain open
- From the south, access will need to be provided along the west side of the freeway through the ODOT right of way. This will require extensive clearing to get to the river
- Work bridges will be needed for work in the river and will be required on both sides of the bridge.
    - There is ample vertical and horizontal clearance for access to the east side by crossing below the bridge in spans 2 and 6 from the west.

A Construction Access plan is included in Appendix I.

From the Bridge Deck

The superstructure will likely be constructed mostly from the bridge deck. Girder erection and deck placement will require intermittent lane closures on the highway for material delivery and placement. The retrofit of the abutment will also involve work on the highway as discussed in Staging above.

Bridge Maintenance – Future Costs

In addition to the seismic deficiencies of the bridge, ODOT Bridge Section has identified three issues of concern for the existing bridge:

Modular Deck Joints – the deck joint adjacent to Pier 2 has been a maintenance issue for a number of years. Accordingly, this joint was assumed to be replaced as part of this project.

Fracture Critical Steel Girders – the water spans (Spans 3-5) of original bridge consist of two separate two-girder steel structures that were linked with a common deck at the time of the original widening in 1967. A two-girder system is by definition fracture critical, meaning the loss of a girder would lead to the collapse of that portion of the bridge. Widening the bridge would not address this issue, leaving this element for replacement in the future. Since the concrete girder approach spans were replaced when the bridge was widened, only Spans 3-5 would need to be replaced.

Fracture Critical Hanger Hinges – A 2018 Fracture Critical Inspection noted cracks in some welds at these hinges. The widening project will not address these issues.

While the first issue will be addressed by this project, the fracture critical issues will result in future capital costs to replace Spans 3-5 of the original 1952 portion of the superstructure.

Cost Estimate

The estimated construction cost for the retrofit and widening ranges from $170 to $205 million using 30% contingencies. This includes the cost of replacing spans 3 through 5 on the original bridge (fracture critical elements).

Applying Preliminary Engineering, Construction Engineering, Right of Way process costs, the Charbonneau Interchange improvements (see "Charbonneau Interchange" below), and inflation, the cost range is $425 - $490 million.

BRIDGE REPLACEMENT ALTERNATIVES

The following assumptions were identified as criteria a replacement bridge must meet to limit the impact to the travelling public and the adjacent properties:

1. 3 lanes of traffic must be maintained in each direction throughout construction.
2. The main span must be at least as long as the existing 250' span to secure a US Coast Guard permit for the project without complications during the permitting process.
3. The bridge should be of similar structure depth to limit the amount of roadway profile adjustment to maintain the existing vertical clearance. It was assumed this should not be reduced, again to ensure USCG approval
4. The roadway alignment goal is to minimize the project limits and thereby minimize impacts to the interchanges immediately north and south of the bridge.
5. With the new bridge being wider than the existing, widening to the east should be largely avoided to avoid impacts to the Charbonneau District at the southeast corner of the bridge, and to SW Parkway Avenue at the northeast corner
6. The foundations of the new bridge should be not be located at the same place as existing foundations to avoid conflicts with timber and steel pile foundations of the existing bridge to allow for constructability.

In order to maintain the existing horizontal clearance of the navigation channel and avoid the existing foundations, the main span of the new bridge has been set at 310'. The same structure type is also recommended over the length of the bridge, unlike the existing bridge, which has concrete girder and steel girder spans. This is done to maximize the span lengths and minimize the number of supports and deck joints. As stated earlier, in the interest of an economical replacement structure, only girder-type structures have been considered.

Steel Girders

This is the primary structure type because the girders have a lower overall weight than concrete structures, and they can be shipped to the site in transportable pieces and spliced on site to the span configuration of the bridge.

Key Advantages

- Lower weight will result in smaller, less expensive foundations
- Long span capabilities to meet desired clearances
- Local fabricators
- Conventional construction
- Lower cost
- Shorter construction
- Low maintenance costs if using weathering steel
- Fewer expansion joints – only needed at the abutments

Disadvantage

- On-site girder splicing could require temporary support towers at splices. Alternatively, they may be spliced on the deck and lifted into place, or in the air, eliminating the temporary supports.
- Higher maintenance costs IF weathering steel not used

Precast Concrete Girders

This span length is stretching the capacity of this structure type due to the weight limit of the girder that can be transported to the site. To achieve the span lengths of the 5-span bridge, the girder segments would need to be spliced together on temporary support towers and then post tensioned with continuous prestressing tendons. Alternatively, cast-in-place box girder sections could be constructed on supports that cantilever out to meet the precast segments. This option would also require post tensioning the girders together over the length of the bridge.

Key Advantages

- Generally lower cost but may not be for longer spans
- Local fabricators
- Mostly conventional construction

Disadvantages

- Higher weight of the girders would require much larger foundations
- Long Spans require more complex construction
- On-site splicing will require temporary support towers
- Likely will require additional deck joints to accommodate prestress shorting of the girders

Cast-in-Place Concrete Box Girder

This structure type can easily span this distance, with an upper span length of nearly 600'. The main disadvantage to this structure type is that it must be constructed on temporary falsework. For this span length, the main channel width would need to be greatly reduced temporarily.

Key Advantages

- Higher weight than a steel girder but lower weight than precast girders
- Long span capability
- High seismic resiliency
- Conventional construction
- Can be cost competitive

Disadvantages

- Higher weight would require larger foundations
- Built on falsework that will require many temporary supports in the river
- Longer construction duration
- Local contractors not as familiar with bridge type
- Deck is a structural element so cannot be replaced. (Deck rehabilitation is normally accomplished through a structural overlay)

Precast Segmental Concrete Box Girder

Similar to the CIP Box Girder, this structure can span longer lengths, reducing impacts in the river. Unlike the CIP box girder, this structure is constructed either of precast segments that are lifted into place, or of segments that are cast on formwork supported by the bridge piers, greatly reducing in-water work.

Key Advantages

- Long span capability could reduce the number of spans to just 3, with all supports out of the water
- No temporary supports

Disadvantages

- Higher weight will require larger foundations
- Higher Cost
- Complex Construction
- Local Contractors not familiar with bridge type

The scope of this study allows for the evaluation of a single structure type. While each of these are feasible at this site and could be evaluated in more depth once additional investigations are performed in the future, the recommended option at this point is based on a couple of factors as follows:

- Foundations will be supported in a Troutdale formation, which is capable of moderate foundation capacities at reasonable depths. Thus, heavy structures will generally require more considerably costly foundations at this site.
- Temporary supports in the river are less desirable.

In consideration of the advantages and disadvantages of each bridge type, with emphasis on these conditions, **the steel girder bridge is recommended**. The following is a detailed discussion of this bridge.

Bridge Layout

Due to span length capabilities of current bridge types and materials, some of which were not available when the original bridge was constructed, the replacement bridge is a 5-span structure, with only two supports in the river. In addition, through the use of higher strength steel, including hybrid girders using HPS Grade 70 steel, the structure depth is actually shallower. The composite steel girder cross section is only 9'6" deep.

The cross section of the superstructure comprises 11 girders on 14' spacing. A preliminary design study was completed by the National Steel Bridge Alliance, the technical support branch for the steel industry. The report is included in Appendix L. The girder layout is generally compatible with the stage construction but could require an additional girder line if the staging tolerances are not sufficient.

The substructure consists of 5 column bents, with columns located for staging. Pier walls like those supporting the existing bridge attract enormous seismic demands, which in turn require very large foundations. The use of multi column intermediate supports should result in smaller foundations. Because of stage construction and foundation spacing requirements, the bents will be wider than the bridge deck. This will provide for additional efficiency during one of the construction stages.

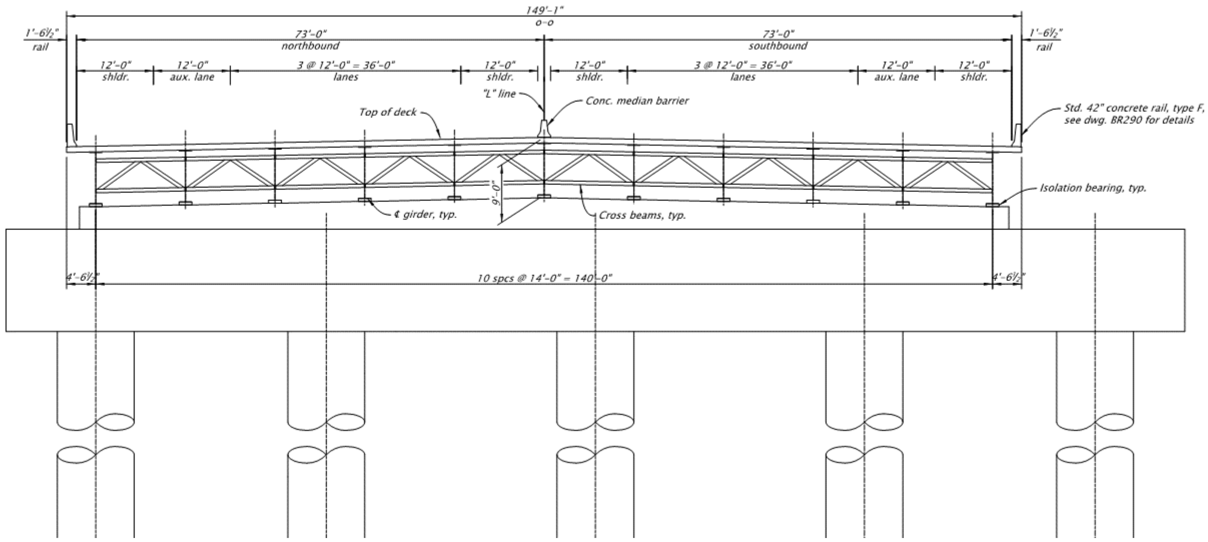


Figure 10 – Steel Replacement Bridge Layout

Foundations

The bridge is supported on large drilled shaft foundations that can be constructed with much smaller cofferdams than a convention pile footing foundation. As stated above, only two supports are located in the river, which will minimize in-water construction costs.

For preliminary design, a pile load test has been assumed to enable the use of ~50% higher capacities for the shafts.

Abutments are supported on steel pipe piles.

Refer to Appendix F for Replacement Bridge concept plans

Construction Staging

Constructing the new bridge while maintaining 3 lanes of traffic in each direction is directly affected by the composition of the existing bridge. Specifically, the original bridge was two separate bridges that were linked together when the bridge was widened in 1967. The superstructure of the original bridge can therefore only be removed one half at a time or all at once as shown below.

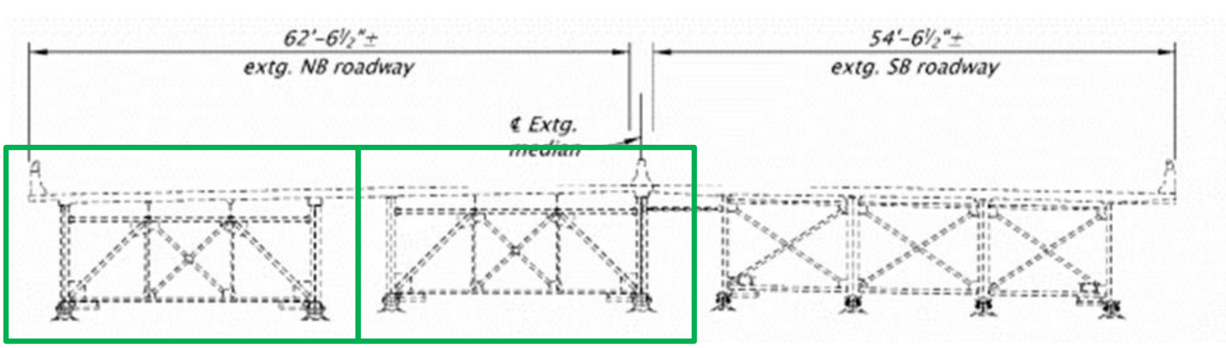


Figure 11 – Replacement Staging – Bridge Removal

Each of the original bridges, denoted in the green boxes above, are composed of two girder structure systems with cross frames and stringers between them. As a result, removing one of the two girders would result in the instability and collapse of that portion of the bridge because it could not be supported by the remaining girder.

Due to this unique girder configuration, five stages are required to replace the bridge as follows:

Stage 1

Reconstruct the median of the deck to link the bridges together to allow traffic to be shifted across the existing joint between bridges for subsequent stages of construction.

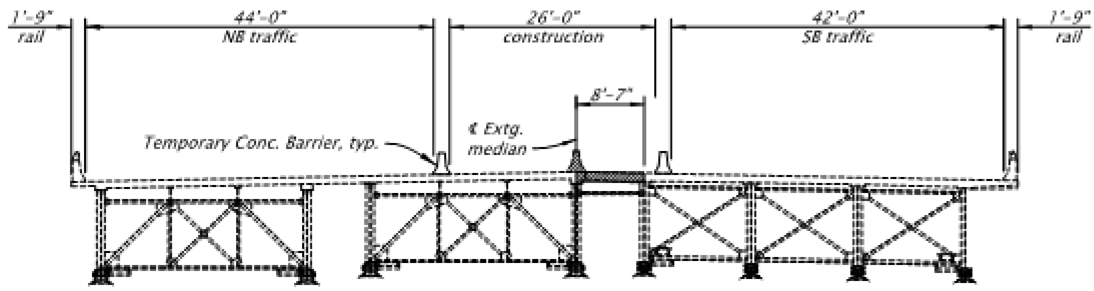


Figure 12 – Replacement Stage 1

Stage 2

Upon completion of the median reconstruction, NB and SB traffic is shifted to the east to allow partial removal of the SB bridge and construction on the west. The section of bridge constructed will be wide enough to convey 3 lanes of SB traffic in future stages as shown below. Two columns of each bent are constructed as well as a four-girder section of the superstructure.

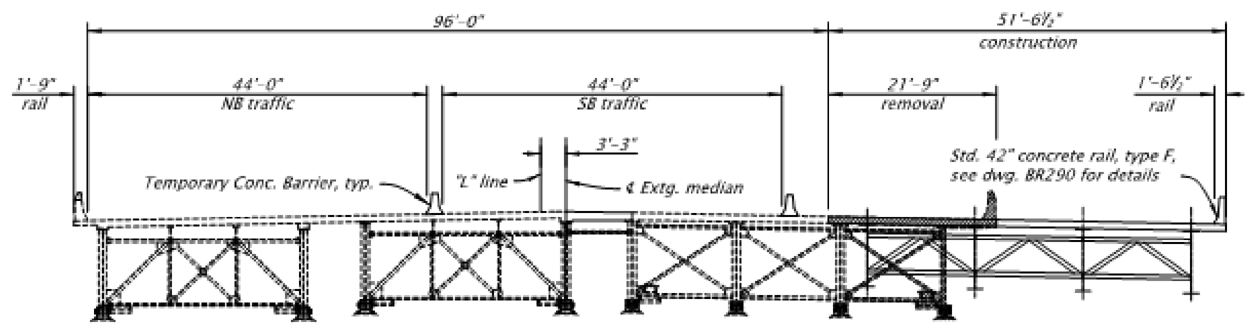


Figure 13 – Replacement Stage 2

Stage 3

SB traffic is shifted onto the new bridge and NB traffic is shifted to the middle of the existing bridge. The eastern half of the original bridge is removed to construct the eastern portion of the new bridge. During this stage there is ample room between the new SB bridge and the existing bridge to keep traffic on each structure without connecting the new bridge to the existing. Similar to Stage 2, two columns of each bent are constructed as well as a four-girder section of the superstructure.

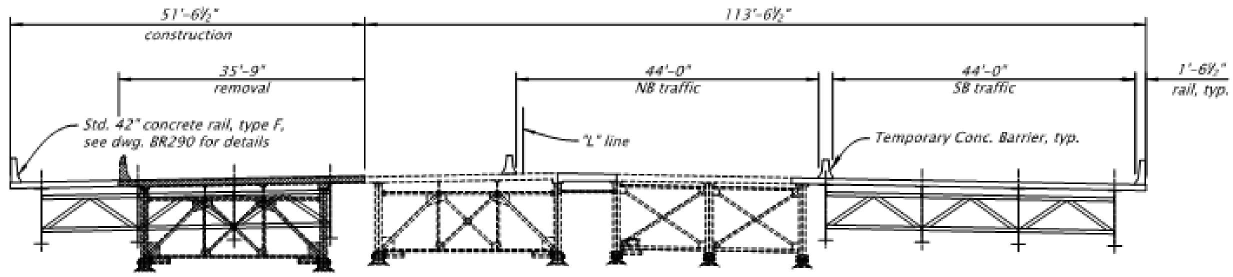


Figure 14 – Replacement Stage 3

Stage 4

NB traffic is shifted onto the new east section of the new bridge, while SB traffic remains on the west section of the new bridge. The remaining existing bridge is removed and the substructure of the new bridge is completed. One column is constructed, and the crossbeam is connected to the crossbeam from the prior two stages to complete the substructure. Then the remaining deck is constructed. This stage must accommodate large cranes and other equipment to construct the substructure. To provide the maximum practical room for this work, the Stage 2 superstructure was constructed farther to the west than its final location.

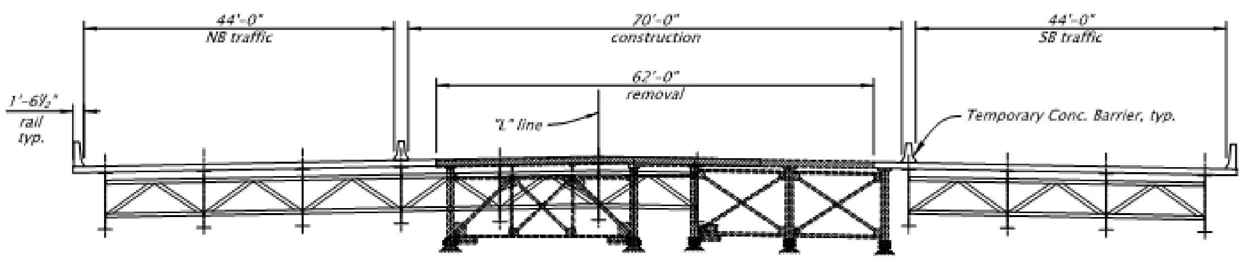


Figure 15 – Replacement Stage 4

Stage 5

Because the Stage 2 bridge was constructed farther to the west, the last stage consists of sliding this section of the bridge to the east about 15' and connecting it to the rest of the bridge. This will entail connecting cross frames between girders and a deck closure pour.

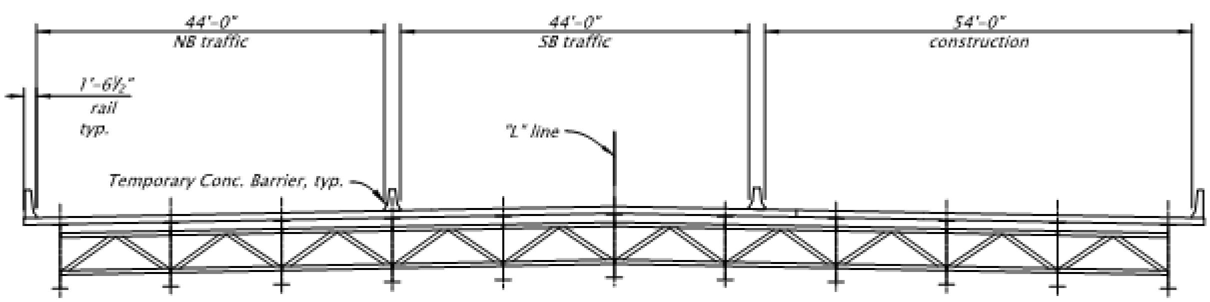


Figure 16 – Replacement Stage 5

A Stage Construction plan is included with the bridge plans in Appendix F

Construction Access

Below the Bridge

Large equipment will be used to remove the existing bridge and construct the drilled shaft foundations and substructure. Similar to the Widen and Seismic Retrofit alternative, access will be provided to the site with the following considerations.

- Access to the site will be needed from both sides of the river in order to maintain river traffic.
- Residences on the east side of the freeway will all but preclude access from this side.
- From the north, access should be provided through the ODOT Maintenance Yard and the Boones Ferry Trail that passes south of the maintenance yard and beneath Span 2 of the bridge.
    - The trail between residences on the east side and Boones Ferry Park on the west will be impacted and will need to be moved around during construction to remain open
- From the south access will need to be provided along the west side of the freeway through the ODOT right of way. This will require extensive clearing to get to the river
- Work bridges will be needed for work in the river and will be required on both sides of the bridge.
    - There is ample vertical and horizontal clearance for access to the east side by crossing below the bridge in spans 2 and 6 from the west.

From the Bridge Deck

The superstructure will likely be constructed mostly from the bridge deck. Girder erection and deck placement will require intermittent lane closures on the highway for material delivery and placement. Cranes located on work bridges and land below the bridge will lift girders from trucks on the deck. Because of their length, girders will be spliced on-site, either on temporary supports from the river, on the deck of the bridge, or in the air.

A Construction Access plan is included in Appendix I.

Cost Estimate

The estimated construction cost for the replacement ranges from $150 to $185 million using 30% contingencies and assuming the new bridge is not a signature bridge.

Applying a premium for a signature bridge option and adding Preliminary Engineering, Construction Engineering, Right of Way process costs, the Charbonneau Interchange improvements (see "Charbonneau Interchange" below), and inflation, the cost range is $450 - $550 million.

Additional Considerations

Signature Bridge

This site is a high visibility location, with residences on both sides of the river. The river also has a high boating usage, with a launch ramp just west of the bridge, and docks on either side of the river. There is a pedestrian path below the bridge. With this amount of public visibility, a signature bridge could be considered. The number of traffic stages needed to construct the bridge on-line would generally dismiss structure types with structural features above the roadway like cable supported structures. However, a deck arch, with the arches below the deck, could be constructed. These types of structures are generally considerably more costly than a girder structure, typically 50% or more higher. This type of structure is outside the purview of this study. Additional studies are needed to further assess a signature bridge, but this is one option that is feasible at this site.

Pedestrian Bridge Opportunity

In either the retrofit and widening option with proposed new outrigger supports or the replacement option with a resulting wider bridge deck, it is conceivable that the bridge could support a shared use path. Despite this opportunity, the French Prairie Bridge is the preferred option for bike/pedestrian traffic since it is a separate facility away from the freeway and provides more regional resiliency. A bike/ pedestrian option on the Boone Bridge would also need to consider connections at the interchanges, making it a more complicated alternative.

Alternative Delivery Methods

In addition to the traditional design-bid-build contracting typically used for public works projects, the following alternative project delivery methods may be considered. The following is a description of each method and the general circumstances when they should be considered.

Design-Build

In this approach, the owner/agency hires the construction contractor, who in turn has the ability to provide the design of the project, typically by teaming with a design consultant. This type of project typically results in faster delivery and construction for the project. The project cost is usually the same. The main cost to the owner is the administration of the contract for the work, including quality assurance to ensure the project adheres to the designed standards and achieves the desired outcome.

Once the owner and contractor have negotiated and agreed upon the terms the design-builder's involvement creates ownership and leads to understood expectations up front before executing the work of design and construction, thus significantly reducing scope, cost and schedule misunderstandings and creep. Public sector owners oftentimes require that a final project price be established at the time the design-builder is selected, demonstrating how they will meet the owner's requirements within the established budget.

The primary challenge for this delivery method is providing a well-defined project scope that leads to the desired outcome. This project would lend itself well to this approach because the project limits, constraints, and requirements (clearances, maintenance of traffic, etc.) can be well defined.

Progressive Design-Build (PDB)

A variation of design-build delivery is a stepped, or progressive process (commonly referred to as Progressive Design-Build or PDB). PDB uses a qualifications-based or best value selection, followed by a process whereby the owner then "progresses" towards a design and contract price with the team (thus the term "Progressive"). PDB core features include the following:

- The design-builder is retained by the owner early in the life of the project and, in some cases, before the design has been developed at all.
- The design-builder is generally selected primarily, if not exclusively, on qualifications and the design-builder's final project cost/price and schedule commitment is not established as part of the selection process.
- The design-builder delivers the project in two distinct phases:
    - Phase 1 including budget level design development, preconstruction services and the negotiation of a firm contract price for Phase 2
    - Phase Two including final design, construction and commissioning.

Typical benefits of PDB:

- Streamlines and simplifies the procurement process, which encourages competition and has a schedule benefit to the project
- Enables the owner to provide substantial input on the design and buyout decisions, as it collaborates with design-builder during design development
- Reduces pressure on the owner to review and act upon design submittals, since this is done during Phase One, before the contract price and schedule have been set.
- A Guaranteed Maximum Price (GMP) offers the owner transparency into the design-builder's proposal cost (and the ultimate cost for final design and construction.
- Offers the owner an "off-ramp" should the owner fail to accept the design-builder's price or other terms.

While all the above attributes can be important, the primary benefits of PDB is that the owner wants to remain actively involved in the design decisions, and it allows the owner out of the relationship before going to construction if the project is not proceeding as desired toward the desired outcome.

For this project, the design decisions to be made appear to be reasonable clear, so the use of this method does not appear to be overly beneficial.

Construction Manager/General Contractor (CM/GC) (also known as Construction Manager at Risk)

In the CM/GC process the project owner hires a contractor to provide feedback during the design phase before the start of construction. The process is broken down into two contract phases.

- Phase 1- The first contract phase, design, the contractor works with the designer and the project owner to identify risks, provide costs projections and refine the project schedule. Once the design phase is complete, the contractor and project owner negotiate on the price for the construction contract.
- Phase 2 - If all parties are in agreement with costs then construction begins.

In CM/GC contractor acts as the consultant in the design process and can offer new innovations, best practices and reduced costs and schedule risks as a result of the contractor's years of proven experience doing the actual work. This process also allows the project owner to employ new innovations, assist in the design process, and make informed decisions regarding cost and schedule.

Additional benefits for using the CM/GC process include:

- Fostering innovation: The process encourages both contractor and project owner to look at all options including using innovative techniques or approaches that reduce time and cost.
- Mitigating risk: The project owner is able to understand the risk and explore mitigation options with feedback provided by the contractor.
- Improving design quality: The contractor is able to review the designs and provide feedback, answer designer questions, and provide changes. By including the contractor review, the designer can produce better designs that reduce issues in construction and prevent change orders that can lead to project overruns.
- Improving cost control: Value engineering is part of the CM/GC process where budget shapes the design approaches. With the contractor as part of the design team, the contractor is able to provide cost estimates for all designs and alternatives within the design phase. The project owner can use the estimates to make informed decisions around projects costs.
- Optimizing construction schedules: The CM/GC process allows the contractor to begin planning the construction schedule during the design phase. By planning during the design phase the

team can view how construction will impact traffic and adjust the construction schedule accordingly to minimize traffic impacts.

Projects that are best suited for the CM/GC process include when the owner needs contractor feedback during the design phase. These projects include complex components that require innovation, or "thinking out of the box”. The Boone Bridge Project should be able to be reasonable well defined so the benefits of innovation that his method provides do not necessarily seem applicable.

Of the three methods of alternative delivery, this project seems most suited to Design-Build.

NON-BRIDGE CONSIDERATIONS

Design Standards

The study is being developed using standards identified in the *2012 ODOT Highway Design Manual (HDM)*. Interstate 5 is classified as an interstate freeway. The current ADT is 131,700.

Design Standards

Item	ODOT Highway Design Manual	Proposed Design	Comment
Design Speed	70 MPH	70 MPH	Posted speed is 65 MPH
Traffic Lane	12′	12′	
Median	26′	26′	Provide for Tall Median Barrier
Right Shoulder	12′	12′	
Maximum Grade	4% (rolling)	1.5% - 4%	Match existing vertical profile
Vertical Clearance	17′-4″	>17′-4″	No existing height restrictions within project limits

The standard replacement bridge clear width is 146 feet and is comprised of 12-foot outside shoulders, four 12-foot lanes in each direction and a 26-foot wide median.

As a result of the staging of the retrofit and widening option, which included connecting the deck of the two bridges, the existing non-standard inside and outside shoulders on the northbound bridge can we widened to meet the current 12-foot standard. The I-5 centerline will be shifted by 3 feet to the east. This is easily accommodated and a positive outcome for what would otherwise have created standard widths southbound and perpetuated the non-standard widths northbound. This avoids non-standard shoulder design exceptions for the retrofit and widening option.

For both options, the existing 32-inch tall barrier on the bridge can be replaced with the taller 42-inch median barrier.

This study did not include detailed geometric design. However, it was noted that the horizontal geometry for north of the bridge that transitions northbound traffic lanes from the narrow median to the full unpaved median is non-standard. This study did not consider options for improving that geometry to meet current standards.

Freeway Improvements

Mainline I-5

For the mainline, a new southbound auxiliary lane will be added for both the Retrofit and Widening option and the Replacement option. In addition, both northbound and southbound I-5 will be widened to provide standard shoulders and median widths.

For either the Retrofit and Widening option or the Replacement option, the I-5 centerline will move. The direction and distance of the centerline shift is dependent upon three factors; specifically the removal of the northbound bridge (as discussed above in Bridge Replacement Alternatives, Construction Staging, and as shown in Figure 11), the opportunity to connect the existing bridges to allow traffic to be shifted against the existing northbound bridge rail, and an early assumption that any widening east of the existing edge of deck would result in unacceptable right of way impacts (i.e. the easterly edge of deck must not shift east). If the planned staging presented in this report is acceptable, then the freeway centerline will be moved approximately 3' to the east.

However, if decking the existing bridges was found to be unacceptable or the widening to the east cannot be tolerated, then the I-5 centerline would shift 25 feet to the west as a result of the width of bridge being constructed in the early stages to accommodate all six lanes of traffic. A centerline shift of more than two full traffic lanes would result in complete reconstruction of the ramps at both adjacent interchanges. Because there is no apparent reason to accept this extreme shift in the centerline, and it has been determined that a modest shift to the east does not have right of way impacts, this condition wasn't explored any further.

Despite the early concerns that allowing the east edge of deck to move easterly, it was found that the 10 feet of widening that occurs beyond the existing east edge of deck allows that existing outside shoulders on the freeway to nearly line up with the roadway approaches. The actual shift in the lane stripes is less than one foot.

Wilsonville Road Interchange

No improvements are planned for this interchange. Minor southbound entrance ramp work is needed to connect to the new southbound auxiliary lane. Beyond that work, no other ramp or mainline work is needed for either the Retrofit and Widening option or the Full Replacement option.

Boone Bridge

The bridge will be widened or replaced to meet standard lane and shoulder widths. The new bridge will accommodate three 12-foot lanes in each direction with a 12-foot auxiliary lane in each direction, 26-foot median and 12-foot outside shoulders; 146 feet between bridge rails.

Charbonneau Interchange

To the immediate south of the Boone Bridge, at the intersection of I-5 and OR 551, high volumes of free-flow traffic, including a large number of trucks, are forced to merge immediately onto I-5 without enough space to zipper merge safely. This segment of I-5, from the Charbonneau entrance ramp to the southern end of the Boone Bridge, is a top 10% Safety Priority Index System (SPIS) location due to short merging distances, closely spaced interchanges and frequently congested conditions both on and just south of the Boone Bridge. This issue is exacerbated by I-5 traffic positioning in the outside lane to take the next northbound exit at Wilsonville Road.

To improve safety in this section of I-5, ODOT recommends extending an auxiliary lane from the northbound OR 551 Canby-Hubbard entrance ramp to the existing northbound auxiliary lane across the bridge. The safety improvement must be incorporated into the design of the Boone Bridge replacement, either as a consideration for implementation at the same time as the Boone Bridge (to realize efficiencies of scale) or as an improvement to be accommodated by the bridge replacement design in the event this safety improvement is built prior to the bridge.

Traffic Staging

Traffic control concepts were prepared using the January 2020 *ODOT Traffic Control Plans Design Manual*.

For either option, construction of a new bridge would be completed in five stages. Several key assumptions were made. These must be confirmed during future studies.

Staging Assumptions / Key Criteria:

1. **Clear Width for Traffic** – The planned clear width for traffic between hard barriers is 44 feet each direction (three 12-foot lanes with 4-foot shoulders on each side).
2. **Bridge Removal Limitations** – The existing bridge girder geometry defines the available bridge removal widths. Removal is driven by the girder configuration and framing of the original bridge rather than by the most economical method to meet traffic staging widths.
3. **Close the Northbound Auxiliary Lane** – Based on discussions with region staff, this study assumes that the existing northbound auxiliary lane between the Charbonneau Interchange and the Wilsonville Road Interchange can be closed during construction. This limits the width of traffic during staging, reduces the ultimate bridge width, and minimizes the I-5 centerline shift. Note that a traffic analysis is needed in a future phase to confirm this assumption.
4. **Connecting the Existing Bridges** – The existing southbound and northbound bridges can be connected during construction. This allows all six lanes of traffic to be pushed against the outer bridge rail. Without this accommodation, significant additional bridge width would be needed and the I-5 centerline would be shifted more than 25 feet to the west.

Following is a discussion of how traffic is accommodated during the five stages needed to replace the bridge. The traffic staging for the retrofit option is very similar.

Stage 1 – Connect the existing bridges

This stage consists of closing the northbound auxiliary lane and shifting traffic to the outside edges and reconstructing the bridge deck between the two bridges to connect the two decks. This connection is needed to facilitate traffic shifts in subsequent stages. This is the only stage where the full 44 feet of clear width cannot be provided. This is due to the amount of bridge removal needed to reconstruct the closure. During this stage, only 42 feet is available on the existing southbound bridge, allowing for 3 lanes (one 12-foot wide and two 11-foot wide) and 4-foot shoulders on each side. (Alternatively, shoulder widths could be reduced to provide three 12-foot wide lanes) The full 44 feet is available northbound.

During this stage, a temporary southbound Charbonneau exit ramp must be constructed for use during subsequent stages. There is insufficient distance between the south end of the bridge and the existing exit ramp nose to transition southbound traffic lane quickly enough to use the existing ramp when southbound traffic is shifted to the east in Stages 2 and 5.

Similarly, the northbound entrance ramp from Charbonneau must be realigned slightly for use during subsequent stages.

An existing sign bridge at MP 282.82 (shown here) must be removed since its support located in the median will be in conflict with lane transitions during all subsequent stages.

Stage 2 – Shift Traffic to the East and Construct Westerly Bridge Portion

During this stage, traffic will be shifted to the east against the existing bridge rail. The full 44 feet of clear width for traffic will be provided. Northbound and southbound traffic lanes will be separated by a tall pinned median barrier.

During this stage, approximately 22 feet of the existing southbound bridge will be removed. Approximately 51 feet of the new bridge will be constructed on the west side. This bridge portion will be supported by new substructure placed in the final location, but the superstructure will be constructed approximately 15 feet further to the west. This approach will ensure that adequate temporary width is available for 3 lanes of traffic without building 14 feet of extra bridge width.

It is likely that the contractor would construct the embankment widening along southbound I-5 that is needed for the new southbound auxiliary lane during this stage.

Stage 3 – Shift Traffic to the West and Construct Easterly Bridge Portion

During this stage, traffic will be shifted to the west against the edge of the new westerly bridge piece constructed in Stage 2. The northbound auxiliary lane will remain closed. There will be three through lanes in both directions on I-5 with four-foot left and right shoulders. Northbound and southbound traffic lanes will be separated by tall pinned median barriers. Because traffic will be on two different structures, pinned barrier is needed on both. The needed clear width between outer rails remains 90 feet.

During this stage, approximately 36 feet of the existing northbound bridge would be removed. Approximately 51 feet of new bridge would be constructed; enough width to carry three lanes of northbound traffic during Stage 4.

Stage 4 – Shift Traffic to the Outsides and Construct Middle Bridge Portion

During this stage, southbound traffic will remain in the Stage 3 configuration, occupying the new bridge piece constructed in Stage 2. Northbound traffic will be shifted back to the east against the rail on the new easterly bridge portion constructed in Stage 3.

During this stage, the remaining 62 feet of existing bridge will be removed between the previously construction new bridge pieces. Only 50 feet of new bridge will be constructed in this center area; enough to accommodate the southbound lanes during Stage 5 and enough to achieve the ultimate 146 feet of clear width.

Stage 5 – Shift Southbound Traffic to the Center and Complete the Bridge

During this stage, northbound traffic remains in the Stage 4 configuration while the southbound traffic is shifted into the center of the bridge. During this stage, the bridge piece previously constructed in Stage 2 and used by southbound traffic during Stages 3 and 4 will be slid toward the east and connected to the other bridge portion. The resulting bridge width is 146 feet.

STAGE 6 – Final Paving and Striping

Lastly, I-5 would be overlayed and re-striped. Signage will be placed to reflect the new southbound auxiliary lane.

Refer to Appendix H for staging plans.

Temporary Pedestrian Access Route (TPAR)

During construction, bicycles and pedestrians would be accommodated in the 4' outside shoulders on the freeway. Signage to alert drivers to watch for bicyclists in the roadway would be included.

An existing pedestrian trail, the Kalyca Chia Wilsonville Boones Ferry Trail connects Boones Ferry Park west of the bridge to a trailhead at the end of Kalyca Drive east of the bridge. This trail passes under Boone Bridge on the north side of the river. This 4(f) resource can remain open during construction by constructing a temporary trail to detour away from the work zone.

Environmental

To identify the anticipated constraints and impacts related to the two options, a Project Prospectus was prepared for each option based on available information in inventories and databases along with a site visit. In both cases, we have concluded that a NEPA Documented Categorical Exclusion is the most likely environmental document. The Prospectus for each option is provided in Appendix J.

The anticipated disturbance area would extend approximately 100 feet to the east and 100 feet to the west of the existing edges of the bridge.

Wetlands and Waterways

There are no wetlands in the project limits. The Willamette River, however, is a navigable waterway and the project will involve fill and removal. There will be project elements within a FEMA 100-year floodplain and within a FEMA regulated floodway

Endangered Species Act (ESA) Compliance

A search of the OBIC data confirmed that Upper Willamette River Chinook salmon and Upper Willamette River steelhead (winter-run) are potentially present in the area. Both are federally- and state-listed as threatened. There is also Essential Fish Habitat within the project area for Upper Willamette River Chinook salmon and Lower Columbia River coho salmon. Western painted turtle, a state-listed sensitive species may be present near the project area.

All in-water work will need to occur during a designated in-water work window.

Stormwater treatment will be needed to avoid impacts to endangered species.

The FAHP (Federal Aid Highway Program) process would be used to document ESA compliance.

Migratory Bird Treaty Act (MBTA) Compliance

Tree removal will likely be needed for construction access and staging. This could impact migratory birds. The Boone Bridge is considered an active nesting site for peregrine falcons. Swallows are also present in large numbers. No bats were observed on the bridge during the site visit, but additional studies would be needed to confirm that bats are not present.

Historic / Archeological Resources

There are no recorded cultural or historic resources in the project area. However, the project area has a high probability for underground historic and pre-contact material. Section 106 clearance would be obtained by performing historic and archeological surveys and documenting the findings in baseline reports.

The City of Wilsonville Comprehensive Plan lists the area west of the bridge and north of the river as an Area of Special Concern due to its location with the "Old Town" Overlay Zone. The City uses this Overlay Zone to reinforce the appearance of the City's history and to create a unique commercial main street. Neither of these issues is likely to impact the project. The Comprehensive Plan also notes that the Calapooia Tribe occupied the north bank of the Willamette River.

Boone Bridge is more than 50 years old and would need to be evaluated for historic significance. It could be considered to be of historic interest.

Noise

Due to the freeway widening, a Noise Study will be needed to identify noise impacts and whether mitigation (possibly soundwalls) is warranted and feasible. The cost estimate provided includes costs for new soundwalls within the project limits, except across the bridge.

Park and Recreation Resources

The City of Wilsonville's Boones Ferry Park is located approximately 800 feet west of the bridge on the north side of the river. This is a Section 4(f) resource as well as a Section 6(f) resource. The Kalyca Chia Wilsonville Boones Ferry Trail is located underneath the bridge and is also a Section 4(f) resource. It is reasonable to assume that the project can be constructed without significant impacts to either of these resources. The project impact area can avoid the Park. The trail underneath the bridge may need to be temporarily closed for bridge construction activities directly overhead, such as girder erection. However, the trail can be detoured during construction staging to help minimize closures.

The City of Wilsonville Comprehensive Plan lists the Willamette River from the Boone Bridge as a scenic view, which may trigger a visual impact analysis.

Permits

Following is a list of anticipated permits, approvals, and clearances

- Local Land Use (City of Wilsonville)
- Local Agency Floodplain Permit
- U.S. Corps of Engineers Section 404
- DEQ (Oregon Department of Environmental Quality) 401 Certification
- U.S. Corps of Engineers Section 10
- DSL (Oregon Department of State Lands) Removal / Fill
- NPDES (National Pollutant Discharge Elimination System) 1200-CA
- U.S. Coast Guard Bridge (either New Bridge Permit or Permit Modification)
- FAHP Programmatic Biological Opinion (BO) and No Effect Memorandum
- Marine Mammal Protection Act – Incidental Harassment Authorization (IHA)
- ODFW (Oregon Department of Fish & Wildlife) Fish Passage Plan Approval
- State of Oregon Endangered Species Act (possible, not certain)
- Archeological Excavation Permit
- SHPO (State Historic Preservation Officer) Section 106
- FHWA Noise
- Hazardous Materials Study
- Section 4(f)

Stormwater & Drainage

In either option, the project will trigger the need for stormwater treatment.

Hazardous Materials

This report includes contaminated soil removal in the freeway shoulders and median to a depth of 18 inches for both options. This soil removal results from excavations needed for temporary and permanent pavement widening associated with construction staging and the addition of the southbound auxiliary lane.

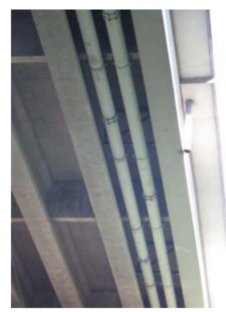
Right of Way

The State of Oregon owns significant right of way in the project area. Right of way extends to 450 feet and 550 feet on the west side of the bridge. On the east side, the right of way is at least 200 feet wide. No permanent right of way is needed to accommodate the bridge widening and the new auxiliary lane.

Construction access for the bridge work will be from the river via work platforms located within the state right of way. No temporary rights of entry or construction easements are anticipated. The planned Kalyca Chia Wilsonville Boones Ferry Trail temporary realignment can be fully contained within state right of way.

The ODOT Maintenance Yard in the northwest quadrant will be impacted by the I-5 widening. The I-5 widening in the quadrant can be contained by a retaining wall to minimize the impacts. Retaining walls have been included in the cost estimate.

Utilities



An Oregon Utility Notification Center (OUNC) ticket submitted to identify any utilities in conflict with the project. The only utilities on the bridge are a water line and a sewer line, both City of Wilsonville utilities.

Utilities on the bridge can be maintained during construction.

No utility relocation is anticipated.

Illumination

Interchange safety lighting will need to be replaced to match the new interchange ramp geometry.

Signing

A large overhead sign bridge over the southbound lanes at MP 282.8 will be impacted by construction staging. The sign message will need to be temporarily replaced and then a new sign bridge constructed as part of the project.

Signing will be added and/or upgraded to reflect the new auxiliary lane.

Construction Cost Estimate

RETROFIT AND WIDENING

	Cost ($1,000's)	Comment
Bridge	$105,000 - $125,000	Includes cost to address fracture critical elements of original bridge
Support Work	$68,000 - $80,000	Includes Charbonneau Interchange improvements work
Contingencies (30%)	$51,000 - $60,000	
Construction Engineering (30%)	$51,000 - $60,000	
Construction Subtotal	**$275,000 - $325,000**	
Preliminary Engineering, Right of Way, & Utilities	$90,000	Includes Design, Oversight, and Right of Way Acquisition
Inflation	$60,000 - $75,000	
Project Total	**$425,000 - $490,000**	Year 2026

BRIDGE REPLACEMENT

	Cost ($1,000's)	Comment
Bridge	$100,000 - $113,000	Non- signature bridge
Support Work	$70,000	Includes Charbonneau Interchange improvements work
Contingencies (30%)	$65,000 - $71,000	
Construction Engineering (30%)	$65,000 - $71,000	
Construction Subtotal	**$300,000 - $325,000**	
Signature Bridge	$0 - $55,000	
Preliminary Engineering, Right of Way, & Utilities	$90,000	Includes Design, Oversight, and Right of Way Acquisition
Inflation	$60,000 - $80,000	
Project Total	**$450,000 - $550,000**	Year 2026

RECOMMENDATION

The object of this feasibility study is to assess the existing bridge for widening for a SB auxiliary lane and to determine the feasibility of seismic retrofitting the bridge. The seismic assessment revealed that the entire substructure of the bridge must be replaced. In addition, once widened, there will be ongoing costs for the existing bridge to monitor fracture critical details as well as the future expense of replacing the original bridge superstructure. The cost of the widening and retrofit, combined with the future replacement expense for the original bridge superstructure exceeds the cost of replacing the bridge. Under normal circumstances, it is advisable to consider a replacement structure if the cost of the retrofit is greater than one half the cost of the new structure. In this extreme case, no further analysis is needed to recommend that the widening and retrofitting option be discarded and future efforts be focused on evaluating the replacement options. A life-cycle cost analysis would verify this conclusion, but again, is not necessary. This bridge should be replaced.

At this point, only a steel girder bridge alternative has been evaluated. That evaluation was sufficient to demonstrate that a new bridge is the best long-term solution and use of public funds.

ASSUMPTIONS

Following is a summary of the major assumptions that were made and included in this study. All have been presented and discussed above. This table is for the purposes of gathering those assumptions into a single location and to offer a risk statement for each. They are presented in no particular order.

ASSUMPTION	DISCUSSION	RISK / OPPORTUNITY
1. Maintain three lanes of traffic in each direction on I-5 throughout construction	This assumption should be confirmed through a Traffic Analysis Study.	If a traffic analysis shows that one lane can be closed for a period of 3-6 months, construction staging could be simplified.
2. Northbound Auxiliary Lane can be closed during construction	This assumption should be confirmed through a Traffic Analysis Study.	If traffic analysis shows that the auxiliary lane must remain open during construction, construction staging would be much more difficult and would likely involve additional temporary and/or permanent bridge construction, especially during the early stages.
3. Must maintain or enlarge the navigation channel width and vertical clearance	This assumption should be confirmed through consultation with US Coast Guard	If US Coast Guard requires channel enlargement, then the superstructure could require additional structure depth, which could result in a need to raise the roadway approaches.
4. Drilled shaft capacities	A pile load test should be performed during design to confirm the assumed shaft capacities	If capacities are significantly less than assumed, then substructures will be larger and more expensive.

5. Existing bridges can be connected	ODOT should confirm internally that the existing bridge decks can be connected both for construction staging (replacement option) and permanently (retrofit and widening option)	If bridge deck connection cannot be constructed, construction staging will be much more difficult and would likely involve additional temporary and/or permanent bridge construction, especially during the early stages.
6. Geotechnical Hazards consisting of liquefaction and lateral spreading can be mitigated	The need for and the extents of ground improvements should be evaluated through a detailed analysis of the existing foundation conditions (FLAC analysis)	Costs to address the hazards can grow significantly if ground improvement limits grow beyond assumptions and if foundation elements must increase in size.

NEXT STEPS

Additional data collection, analysis, design and advance stakeholder outreach are recommended to further define the Boone Bridge Replacement project's scope, schedule, and budget to deliver the 15% design milestone.

Task	DATA COLLECTION	ANALYSIS	DESIGN	STAKEHOLDER OUTREACH
Public Involvement				●
Survey	●			
Environmental Services	●	●		●
Utility Coordination		●		●
Geotechnical / Foundation Engineering	●	●	●	
Hydraulics and Stormwater		●		
Highway Design	●	●	●	
Bridge and Structures Design		●	●	
Traffic Analysis and Design	●	●	●	
Pedestrian + Bicycle Study		●		
Roadside Development			●	
Right of Way		●	●	
Constructability		●		●
Value Engineering		●		
Cost Risk Analysis		●		

These next steps would take approximately 5 years to complete.