July 21
2021

CAP Report
Appendix I //

Cost and Constructability

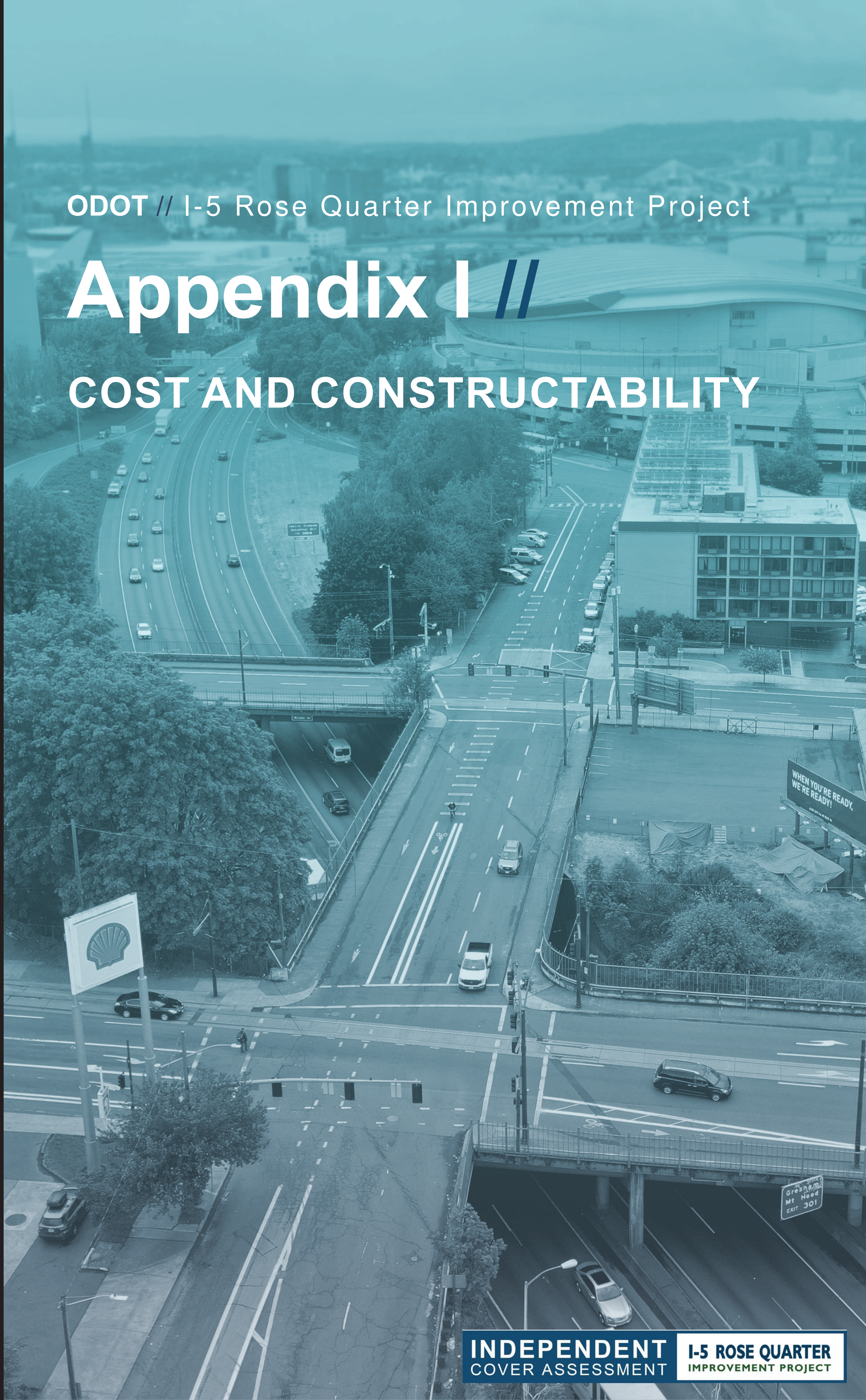
Task 2.3

ODOT EA:
PE002591000J71

ODOT // I-5 Rose Quarter Improvement Project

Appendix I //

COST AND CONSTRUCTABILITY



INDEPENDENT
COVER ASSESSMENT

I-5 ROSE QUARTER
IMPROVEMENT PROJECT

ZGF

Rose Quarter Independent Cover Assessment

Constructability and Cost Analysis Report

|

Job number 276613

Arup North America Ltd
560 Mission Street, Suite 700
San Francisco, CA 94105

ARUP

Contents

1 Report Findings

- Based on the Independent Cover Assessment's (ICA) evaluation and professional experience, all three ICA Scenarios 1, 4, and 5 studied can meet the Rose Quarter Improvement Project's (RQIP) purpose and need. ICA technical team found no fatal design flaws. A fatal flaw is defined as when an aspect of the design is infeasible or unworkable from an engineering perspective, and therefore should not be further studied.

- The highway cover can be designed to support between 2-5 stories while maintaining the I-5 mainline width reflected in the amended 20% Design. Taller than 5 stories can potentially be designed for areas with spans less than 80 feet, or would require mainline width reduction.

- The cost of all three ICA Scenarios are estimated to be within a 10% budget range of $819M to $998M total construction-related costs for the highway cover, mainline improvements related to the cover area, and city street improvements described in this report. These estimates include the cost to support 2 to 3 story buildings. To support up to 5 stories over the full developable area of the covers would require an additional $172M to $201M in cost. The cost of supporting buildings over 5 stories in specific portions of the covers would need to be evaluated in a future phase of work.

- Scenarios 4 and 5 provide more high-quality developable land for the restoration of the neighborhood on top of the freeway.

- Certain design elements in Scenarios 4 and 5 (primarily the movement of the ramps to the south of the cover) will require additional technical studies and could add to the schedule. Further details are provided in Appendix H (*Environmental Assessment Pathways Task 2.2.2*). If commenced without delay, the schedule for needed studies could take advantage of ODOT's current schedule, which already allows time for NEPA re-evaluation and engineering. Additional schedule would add approximately 3% to 3.5% per year of inflation cost to total estimated construction costs.

- Width of the highway cover was designed with full-width travel lanes and shoulders, as well over 24 feet for egress pathways, which are not customary for a cover structure or tunnel, especially in an urban area. We recommend that the project team consider appropriate reductions of the width and design speed of the highway within the cover structure to:

  - Reduce construction cost,
  - Minimize impact to adjacent properties,
  - Further enhance the ramp geometry, and
  - Improve development potential on and adjacent to the cover.

2 Executive Summary

The ICA team's scope required the exploration of at least one highway cover scenario that falls within the already approved Environmental Assessment (EA) Area of Potential Impact (API), and allows development of up to two other scenarios that may require additional environmental review. This Constructability and Cost Report supports the ICA team's analysis by providing a technical narrative analyzing the 15% design for the EA, the RQIP's current amended 20% Design, and three scenarios developed by the ICA team.

The comparison of cost is limited to the three scenarios developed by the ICA team:

- Flint and Broadway Boulevards (ICA Scenario 1)
- Center on the Cover (ICA Scenario 4)
- Restore the Grid (ICA Scenario 5)

Based on the evaluation and on professional experience, all three ICA scenarios presented in this report can meet the RQIP's purpose and need. We found no fatal flaws and all three scenarios could be further advanced to detailed design.

Based on our preliminary analysis, the freeway cover structure can be designed to support up to 5-story commercial or residential buildings while maintaining the mainline widths in the amended 20% Design. The cost estimates provided in this Report include the costs of supporting 2 to 3-story buildings, and provide an estimate of the additional cost of supporting 5-story buildings. Building the structural capacity to go taller than 5 stories is technically feasible for areas with spans less than 80 feet or would require mainline width reduction. See Figures 9, 12 and 14 in Section 5 summarizing buildings on cover height limitations.

Based on the preliminary cost analysis, all three scenarios are in a similar budget range, per the summary below. Arup has provided a cost estimate according to industry standards and commensurate with the concept level of design of the ICA scenarios for the project scope of work as further described in this report. The project scope of work included in the cost estimate is focused on the highway cover, mainline improvements related to the cover area, and city street improvements. Our estimates include direct cost, additional cost for contractors including contingency, as well as Owner's soft costs and contingency.

Table 1 Scenario Cost Summary

Scenario	Cost Range (2025 USD)
Flint and Broadway (ICA Scenario 1)	$819M - $916M
Center on the Cover (ICA Scenario 4)	$822M - $919M
Restore the Grid (ICA Scenario 5)	$894M - $998M

Added cost for 5 story buildings on the cover	$172M - $201M

Among these three scenarios, Scenarios 4 and 5 restore city blocks and create the most high-quality developable land with good urban qualities by redirecting highway ramp traffic to the south end of the proposed freeway cover.

We understand that some of the proposed ramps in Scenarios 4 and 5 may have different traffic impacts compared to the EA. With the additional project focus on restorative justice and the means to improve community cohesion to address the harm to the Black Historic Albina community, the ICA estimates that the duration of NEPA re-evaluation could be minimized. Certain design elements in Scenarios 4 and 5 (primarily the movement of the ramps to the south of the cover) will require additional technical studies and could add to the schedule. Further details are provided in Appendix H (*Environmental Assessment Pathways Task 2.2.2*). If commenced without delay, the schedule for needed studies could take advantage of ODOT's current schedule, which already allows time for NEPA re-evaluation and engineering. Additional time to the project-wide schedule would incur increased cost of due to expected escalation at a rate of 3% per year.

However, these are reasonable trade-offs to restore a well-connected street grid, provide more land with regular shaped and sized parcels for future development, and high-quality open space – all these elements essential for a thriving community.

Regardless of which project design is advanced, we also found that the width of the highway cover was designed with features that are not customary for a cover structure or tunnel, especially in an urban area. These features include full-width travel lanes and shoulders, as well more than 24 feet for egress pathways. We recommend that the project team consider appropriate reductions of the width and design speed of the highway within the cover structure to:

- Reduce construction cost,
- Minimize impact to adjacent properties,
- Further enhance the ramp geometry, and
- Improve development potential on and adjacent to the cover.

Finally, the analysis regarding the surface street network and corresponding circulation and traffic is included in the Appendix J (*Surface Street Network and Circulation Task 2.3.1)*.

3 Introduction

3.1 Independent Cover Assessment

In early 2020, the Oregon Transportation Commission (OTC) directed the Oregon Department of Transportation (ODOT) to retain a consultant team to conduct an independent assessment of the highway covers included in the I-5 Rose Quarter Improvement Project (RQIP). Led by ZGF Architects, the Independent Cover Assessment (ICA) consultant team is charged with understanding the goals and objectives of stakeholders in the project area, generating potential highway cover scenarios, and assessing the impacts and benefits of these scenarios. An Executive Steering Committee (ESC) was appointed by the OTC to oversee the assessment.

The ICA team based its highway cover scenario options on the stated Values and Outcomes of the ESC as well as input from stakeholder workshops attended primarily by Black Historic Albina community members. Overarching highway cover outcomes include: community wealth, community health, community cohesion, and mobility.

The ICA team has sought design solutions that maximize the developable and usable land on and around the covers, to maximize restoration of the neighborhood to create the greatest potential for restorative justice outcomes for the Black Historic Albina community. Based on the evaluation and on professional experience, all ICA scenarios meet the RQIP original purpose and need of improving safety and addressing congestion within the I-5 corridor.

The ICA team's scope requires the exploration of at least one highway cover scenario that falls within the already approved Environmental Assessment (EA) Area of Potential Impact (API), and allows development of up to two other scenarios that may require additional environmental review.

3.2 Constructability & Cost Analysis Report

This Constructability and Cost Report supports the ICA team's analysis by providing a technical narrative and cost estimates utilizing ODOT's 15% Baseline Scenario design utilized in the EA, the RQIP's current amended 20% Design, and three ICA-explored scenarios:

- Flint and Broadway Boulevards (ICA Scenario 1)
- Center on the Cover (ICA Scenario 4)
- Restore the Grid (ICA Scenario 5)

3.2.1 Flint and Broadway Boulevards Scenario (ICA Scenario 1)

The Flint and Broadway Scenario (ICA Scenario 1) proposes modifications to the 15% Baseline EA design that create a moderate amount of land available for community use and prioritizes creating active local streets along Broadway and Flint. This scenario also proposes to reconnect N Flint from NE Tillamook, and extend it south to Weidler ,. Hancock is reconnected straight across the cover to reestablish a part of the street grid. The cover is extended further north to support Flint, and there are structures proposed over the ramp terminals to reduce air and noise pollution. The Clackamas Overcrossing connection is proposed to be removed, and the Green Loop is aligned as a two-way facility on the south side of Weidler.

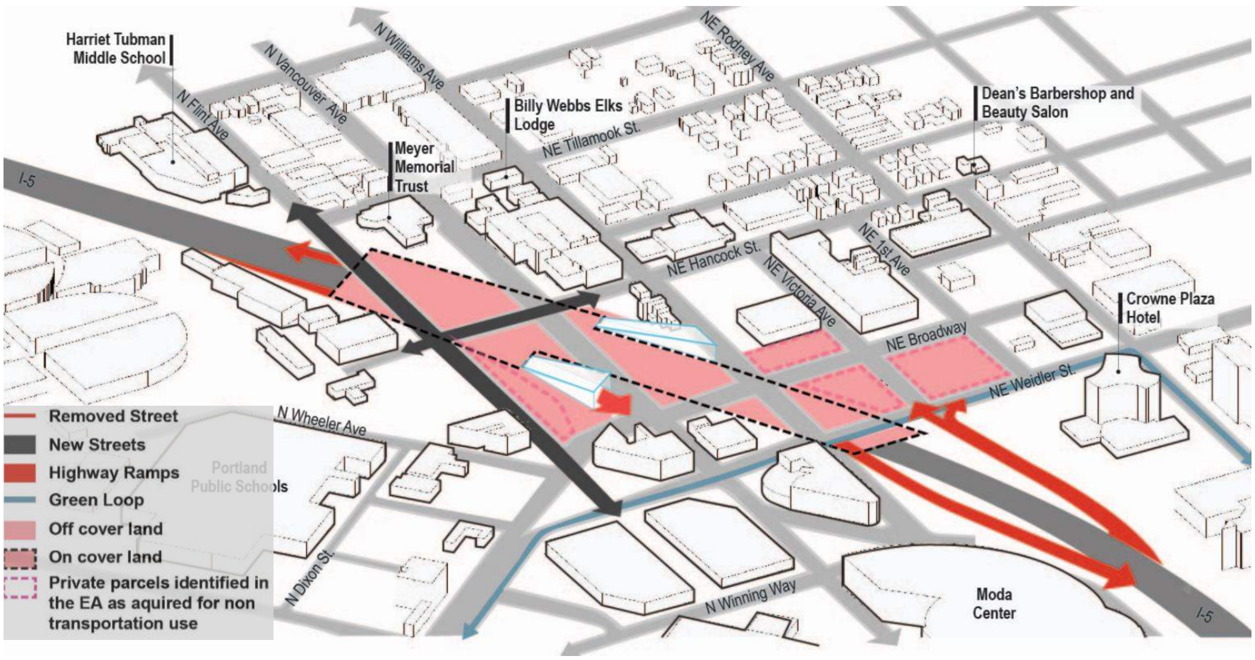


Figure 1 Flint and Broadway (ICA Scenario 1)

3.2.2 Center on the Cover (ICA Scenario 4)

The Center on the Cover Scenario (ICA Scenario 4) proposes to relocate the southbound and northbound interchange ramps south of Weidler. The scenario also proposes to merge Flint with Vancouver, and remove N Vancouver Avenue to the south of Hancock. The Clackamas Overcrossing connection is proposed to be removed, and the Green Loop is routed as a pair of facilities, one aligned on the north side of Broadway and one on the south side of Weidler.

This scenario would achieve the following:

- Create the most amount of land available for community control anduse, and provide a large civic space to support community events and recreation.
- Create a large flexible development parcel..
- Reduce the footprint of each of the intersections comprising "the box," making more space around the new development area available for pedestrian and bicycle facilities.

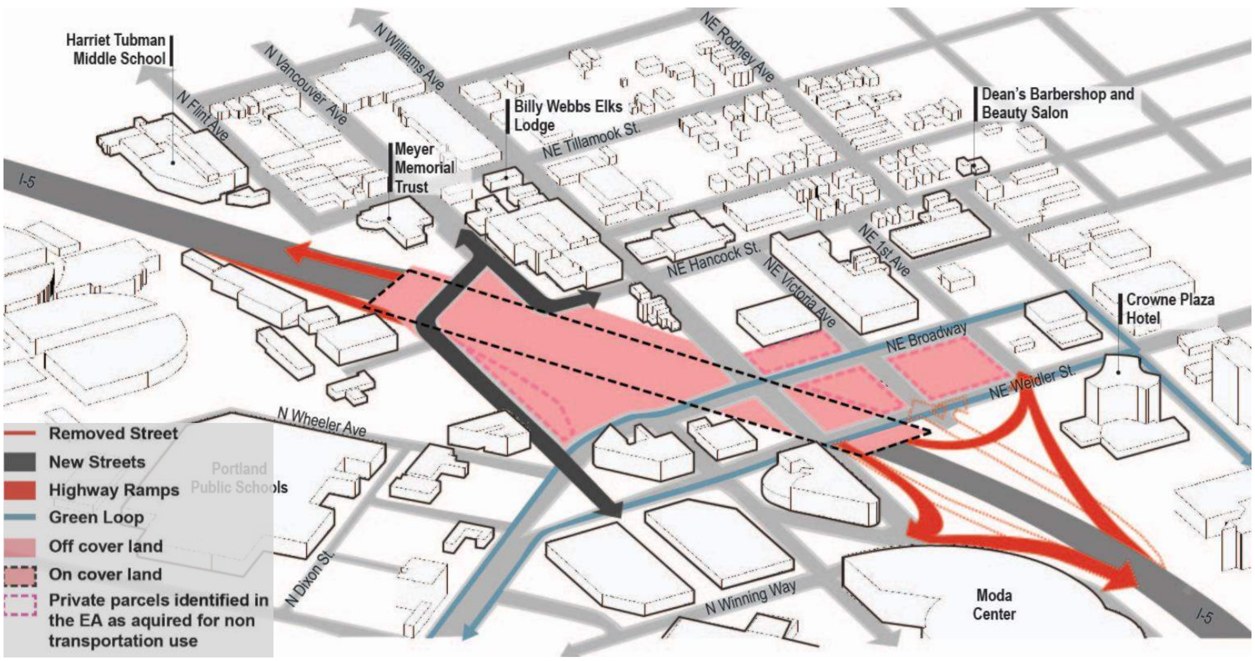


Figure 2 Center on the Cover (ICA Scenario 4)

3.2.3 Restore the Grid (ICA Scenario 5)

The Restore the Grid Scenario (ICA Scenario 5) proposes to relocate the south bound and north bound interchange ramps south of Weidler. The scenario also proposes to reconnect N Flint from NE Tillamook, and extend it south to Weidler Hancock is reconnected straight across the cover to reestablish a part of the street grid. The cover is extended further north to support Flint. The Clackamas Overcrossing connection is proposed to be removed, and the Green Loop is routed as a pair of facilities, one aligned on the north side of Broadway and one on the south side of Weidler.

This scenario would achieve the following:

- Create the second most amount of land and more active streets for development.
- Reduce the footprint of each of the intersections comprising “the box,” making more space around the new development area available for pedestrian and bicycle facilities.

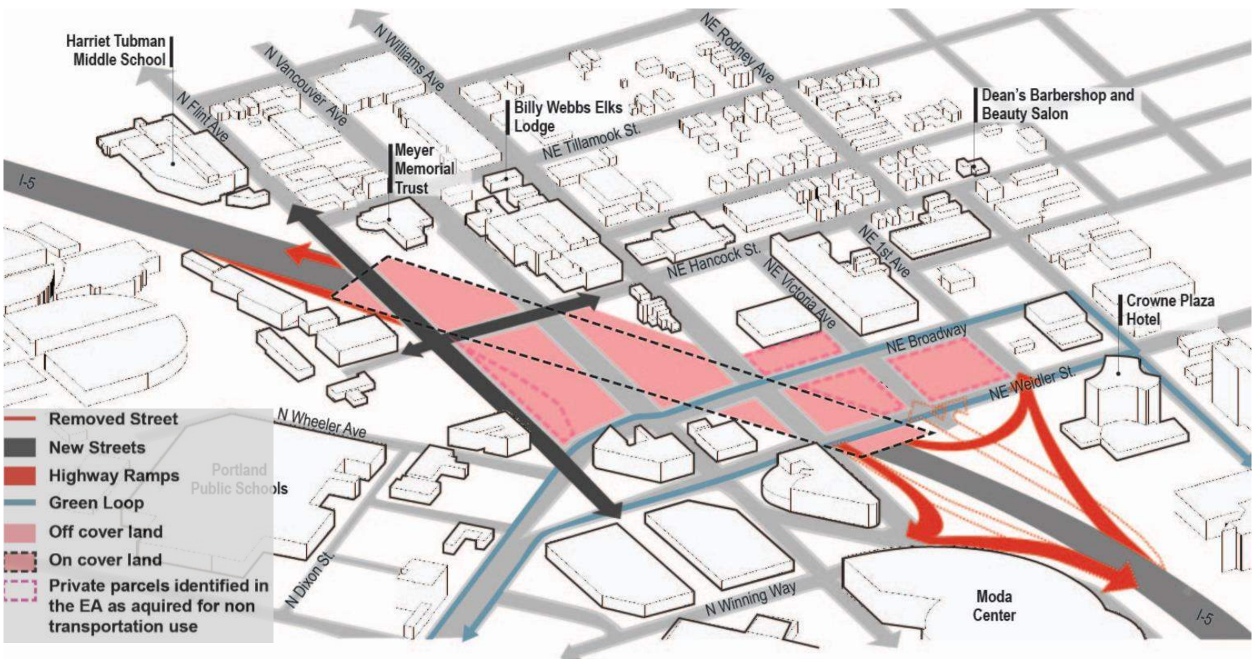


Figure 3 Restore the Grid (ICA Scenario 5)

3.3 Basis of Design for Selected Scenarios

The following codes, standards and guidelines are used for the conceptual design and feasibility evaluation of the selected scenarios.

- *AASHTO A Policy on Geometric Design of Highways and Streets -2011*
- *AASHTO LRFD Bridge Design Specifications 8th Edition, 2017)*
- *FHWA Technical Manual for Design and Construction of Road Tunnels – Civil Elements – 2009*
- *ASCE 7-2016*
- *2018 International building code*
- *National Fire Protection Association (NFPA) 502 – Standard for Road Tunnels, Bridges and Other Limited Access Highways – 2020*
- *ODOT 2012 Highway Design Manual*
- *ODOT Bridge Design Manual (BDM) - 2019*
- *ODOT Blueprint for Urban Design, 2020*
- *ODOT Bicycle and Pedestrian Design Guide, 3rd Edition, 2011*
- *2019 Oregon Structural Specialty Code*

Specific requirements and assumptions for the development of scenarios are adopted from ODOT's 15% and amended 20% Designs and are as follows:

- Roadway design criteria:
  - Design speed (mainline and ramps):
    - Mainline: 70 mph.
    - Ramps: 35 – 60 mph.
    - For Center on the Cover Scenario & Restore the Grid Scenario, the design speed for the ramps: 25mph to 50 mph.
  - Lane and shoulder width:
    - Mainline: 12-foot lane and 12-foot shoulder.
    - Ramps: 12-foot lane with 4-foot left and 8-foot right shoulders.
  - Radius:
    - Mainline: 2817.82'.
  - Longitudinal Slope:

        - Mainline: 5% Maximum.
        - Ramps: 7% Maximum.
    - Vertical clearance: 17'-4" for mainline, 16'-6" for ramps.
- Design Exceptions:
    - Flint and Broadway Boulevards (Scenario 1):
        - Ramp Shoulder width: 4-6' Lt & 6-10' Rt
        - Stopping sight distance – Mainline (near highway cover): 620'
        - Vertical Clearance: 16.5' over on / off ramps
        - Intersection Offset: 2.3' +
        - Ramp Interchange Spacing: Entrance to Exit less than 2000' & Exit to Exit: less than 1000'
        - Superelevation: NB mainline 5.5%
        - Spiral length – ramps: less than 360'
        - Ramp Entrance Angle: NB Broadway
        - Ramp Exit Angle: NB Weidler St
        - Sag Curve – K value: at SB Exit to Broadway & NB Exit to Weidler.
    - Center on the Cover (Scenario 4) & Restore the Grid (Scenario 5): Preliminary list of additional design exceptions for the ramps at the south entrance of the cover structure includes:
        - Spiral transition between curves.
        - Shoulder widths: 2 feet inside at the NB on-ramp
- Structural design:
    - The depths of the cover structures are determined based on the assumption that the mainline profile should not be lowered any further than the deepest location of the amended 20% Design.
    - The capacities of the cover structures are evaluated based on the allowable structural depths and the Basis of Design as described above.
    - Residential or office buildings with regular structural systems are assumed for evaluating the capacities of the cover structures.
- Fire life safety and ventilation design criteria (from EA design): Fire and Life Safety (FLS) systems are required for the highway cover structures to satisfy code requirements for safe egress of people (tenability) for facility occupants and structural protection during events. Design fires include the following:

- Tenability: 300 megawatt fire with an "ultrafast" growth rate for a Heavy Goods Vehicle (HGV).
- Structural Fire Protection: 300 megawatt fire with a "hydrocarbon" growth rate based on a flammable liquid fire spill.
- Additional details for FLS analyses, as discussed in Study Zones 4n and 4s (Chapter 4.4.3.3) of the 15% BOD Memo.

4 Baseline Scenario – 15% Design

The RQIP 15% design is the baseline generating the assumptions used in constructability and cost estimating as described in the Cost to Complete Report. From a costing perspective, the 15% design is not comparable to the ICA scenarios because it does not have a continuous cover, nor does it account for vertical realignment of the mainline freeway and other improvements in the RQIP amended 20% Design.

The ICA team also reviewed the information that was available for the RQIP amended 20% Design and added elements to the ICA scenarios to improve its potential to support restorative justice for the Historic Albina community.

4.1 Roadway Design

As part of the RQIP project, the following elements are included in the Baseline Scenario.

- Constructing 12-foot auxiliary lanes and 12-foot shoulders in the study area, in both the northbound (NB) and southbound (SB) directions.
- Relocating the I-5 SB entrance ramp from N Wheeler Avenue to N Williams Avenue.
- Widening the I-5 NB to NE Weidler Street exit ramp.
- Removal of the existing overcrossing structures at NE Weidler Street, N/NE Broadway, and N Williams Avenue and replacement with a single highway cover structure over I-5. The I-5 mainline profile will be lowered in this area to meet the minimum vertical clearance.
- Removal and replacement of the existing N Flint Avenue, N Vancouver Avenue overcrossing structure with highway cover over the I-5, including a new roadway crossing at NE Hancock Street and N Dixon Street. The I-5 mainline profile will be lowered from the existing ground in this area to meet the minimum vertical clearance.
- Removal of the existing overcrossing structure at N Flint Avenue.

4.2 Structural Design

The project consists of the following new I-5 structures:

- North and south highway covers.

- Clackamas Pedestrian and Bicycle Bridge over I-5.

The North Cover (N Vancouver & NE Hancock over I-5) is composed by four primary regions:

- Region 1: North area of highway cover consisting of two-span, cast-in-place post-tensioned box girders with a depth of 5 feet spanning over I-5 SB and exit ramp, as well as I-5 NB and entrance ramp.
- Region 2: Area of highway cover consisting of 30-inch deep voided slab girders with a 5-inch topping slab spanning over the I-5 SB exit ramp.
- Region 3: Area of highway cover consisting of three-span continuous, cast-in-place post-tensioned box girders with a minimum depth of 4 feet spanning over I-5 SB, as well as I-5 NB and entrance ramp.
- Region 4: Area of the highway cover south of N Hancock Street consisting of two-span, cast-in-place post-tensioned box girders with a minimum depth of 5 feet spanning over I-5 SB and I-5 NB.

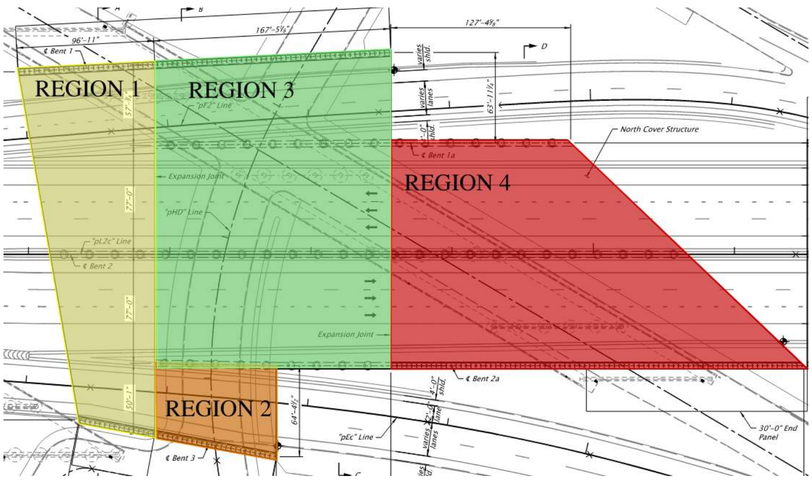


Figure 4 Plan View of the Baseline Scenario North Cover.

Interior bents consist of 4-foot diameter columns on 6-foot drilled shafts. Wall elements are constructed using precast or cast-in-place elements to enclose the space between the structural columns in order to produce continuous smooth walls between NB and SB directions of traffic, and also to provide separation to the I-5 entrance and exit ramps. Abutments consist of 4-foot diameter secant walls with cap beams and drilled shafts.

The South Cover (N Williams, NE Broadway, and NE Weidler over I-5) consists of BT48 prestressed concrete girders with an 8-inch deck spanning over the I-5 mainline. The girders are spaced radially from the I-5 alignment at the center bent until girder flaring is required to accommodate the southern geometry of the highway cover.

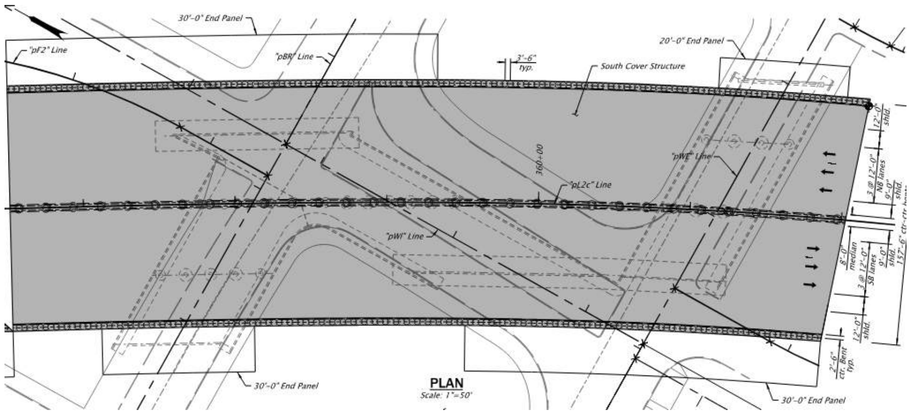


Figure 5 Plan View of the Baseline Scenario South Cover.

The interior bent consists of 4-foot diameter columns on 6-f00t drilled shafts. Wall elements are constructed using precast or cast-in-place elements to enclose the space between the structural columns in order to produce continuous smooth walls between NB and SB directions of traffic. Abutments consist of 4-foot diameter secant walls with cap beams and drilled shafts.

The Clackamas Pedestrian and Bicycle Bridge is a two-span cast-in-place post-tensioned box girder bridge crossing the I-5. It provides approximately 24-foot of clear distance for a path between barriers. Utilizing this bridge type allows for an aesthetic and affordable bridge that can accommodate the non-tangent bridge alignment. The center support for the structure consists of a bent column supported by 5-foot diameter drilled shafts. The abutments consist of a bent cap supported by 4-foot diameter columns on 5-foot diameter drilled shafts. Retaining walls surround and support the west and east approaches of the structure.

4.3 Fire and Life Safety

FLS systems for each highway cover consist of the following components:

- Early detection.
- Early notification.
- Median wall cross passages.
- Fire-resistant cover board.
- Water-based fixed fire-fighting system.
- Standpipes.
- Drainage for hydrocarbons.
- Polypropylene fibers in bottoms of concrete girders.

5 ICA Design Scenarios

The following sections describe the engineering parameters and findings for the design of the three ICA Scenarios 1, 4, and 5. For construction cost considerations please refer to Section 7 of this report, below.

5.1 Flint and Broadway Boulevards (ICA Scenario 1)

5.1.1 Roadway Design

The following elements are included in the Flint and Broadway Scenario.

- Adding 12-foot auxiliary lanes and 12-foot shoulders in the study area, in both the northbound (NB) and SB directions.
- Relocating the I-5 SB entrance ramp from N Wheeler Avenue to NE Weidler Street.
- Widening the I-5 SB to NE Weidler Street exit ramp.
- Removal of the existing overcrossing structures at N Vancouver, NE Weidler Street, N/NE Broadway, and N Williams Avenue and replacement with a single highway cover structure over I-5, including a new roadway crossing at N Hancock Street. The I-5 mainline profile will be lowered from the existing ground in this area to meet the minimum vertical clearance, consistent with the RQIP amended 20% Design.
- Adding cover over the I-5 SB to N/NE Broadway exit ramp and the I-5 NB entrance ramp from N Williams Avenue.

5.1.2 Structural Design

Four primary regions compose the highway cover with the following girder types:

- Region 1: The north area of the highway cover consists of a two-span cover structure over the I-5 SB and exit ramp as well as the I-5 NB and entrance ramp. The maximum span length of this structure is about 135’, and the superstructure depth is 5’. A cast-in-place post-tensioned box girder structure is proposed for this relatively slender structure to meet the vertical clearance requirement on the NB entrance ramp. This structure is also sufficient to support an office or residential building that is up to 5-story high.
- Region 2: This area of highway cover adjacent to Region 1 spans over the I-5 SB and exit ramp as well as the I-5 NB and entrance ramp. The cover structures over the I-5 NB and the I-5 SB mainlines consist of an 8” topping slab on 5’ deep precast prestressed girders spaced at 8 ft, with a maximum span length of 80 ft. This structure is sufficient to support up to 5-story office or residential buildings. Girders in areas over the exit and entrance ramps consist of 30”-deep voided slab girders with a 5” topping slab. The shallower structure is required here to meet a minimum vertical clearance of 16’-6” at the ramps, see figure below. The voided slab structure over the ramps is not sufficient to support any building but can be used to support a maximum of 2’ of landscaping soil. If a building is

proposed in this area, a different structure type with raised deck slab can be considered to maintain the required vertical clearance below.

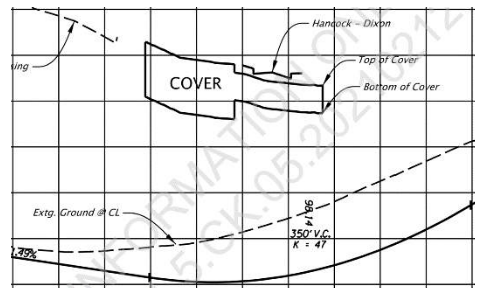


Figure 6 I-5 SB Exit Ramp To Broadway

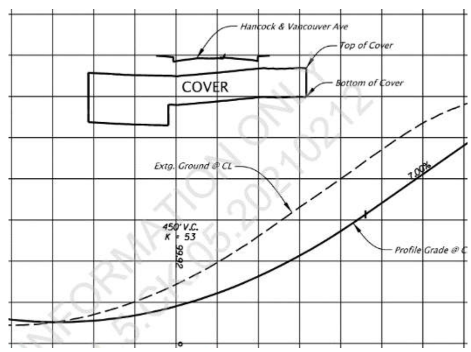


Figure 7 I-5 NB Entrance Ramp From Broadway

- Region 3: Area of highway cover adjacent to Region 2 spanning over the I-5 SB and the I-5 NB. The maximum span length in this region is 80 ft. Girders in this region consist of an 8” topping slab on 5’ deep precast prestressed girders spaced at 8 ft. This cover structure can support up to 5-story office or residential buildings.
- Region 4: Area of highway cover south of Region 3 consisting of a two-span structure over the I-5 NB and the I-5 SB. The structure will be a 5’ deep cast-in-place prestressed box girder with girder webs spaced at 6’-0”. This cover structure can support up to 5-story office or residential buildings. And it will also be used to support the triangle cover area that is part of the I-5 SB entrance ramp. The triangle cover structure can be either a cast-in-place box girder or precast I girder structure.

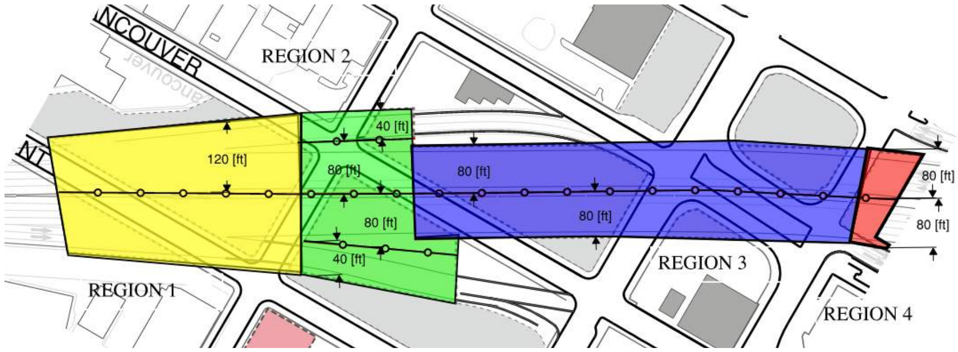


Figure 8 Plan View of the ICA Scenario 1 Cover

Girders in regions 1 and 4 are supported by the following bents and abutments throughout the highway cover:

- Semi-integral abutments: Cast-in-place abutment walls will be supported on pile caps and 30” diameter driven pipe piles. Design is used in locations where retaining fill is required.
- Median bent wall: Cast-in-place bent wall will be supported on a shaft cap and 6' diameter drilled shafts. Wall has intermittent FLS egress doors. Design is used throughout the length of the highway cover between I-5 NB and I-5 SB.
- Column bent between ramps and freeway mainline: Cast-in-place column bent will be supported on shaft cap and drilled shafts.

To avoid high seismic load on the bridge substructures and foundation, seismic isolation bearings can be installed on the bridge deck to support the proposed building. Based on preliminary evaluation, the bridge structure as described can be designed to meet the seismic performance as specified in ODOT Bridge Design Manual.

Finally, we note that from a structural feasibility perspective, buildings taller than 5 stories can potentially be designed for areas with spans less than 80 feet. These areas are marked in blue in Figure 9. A case study of highway covers with 60-foot spans supporting 12-story buildings is provided in Section 8 of this report, below.

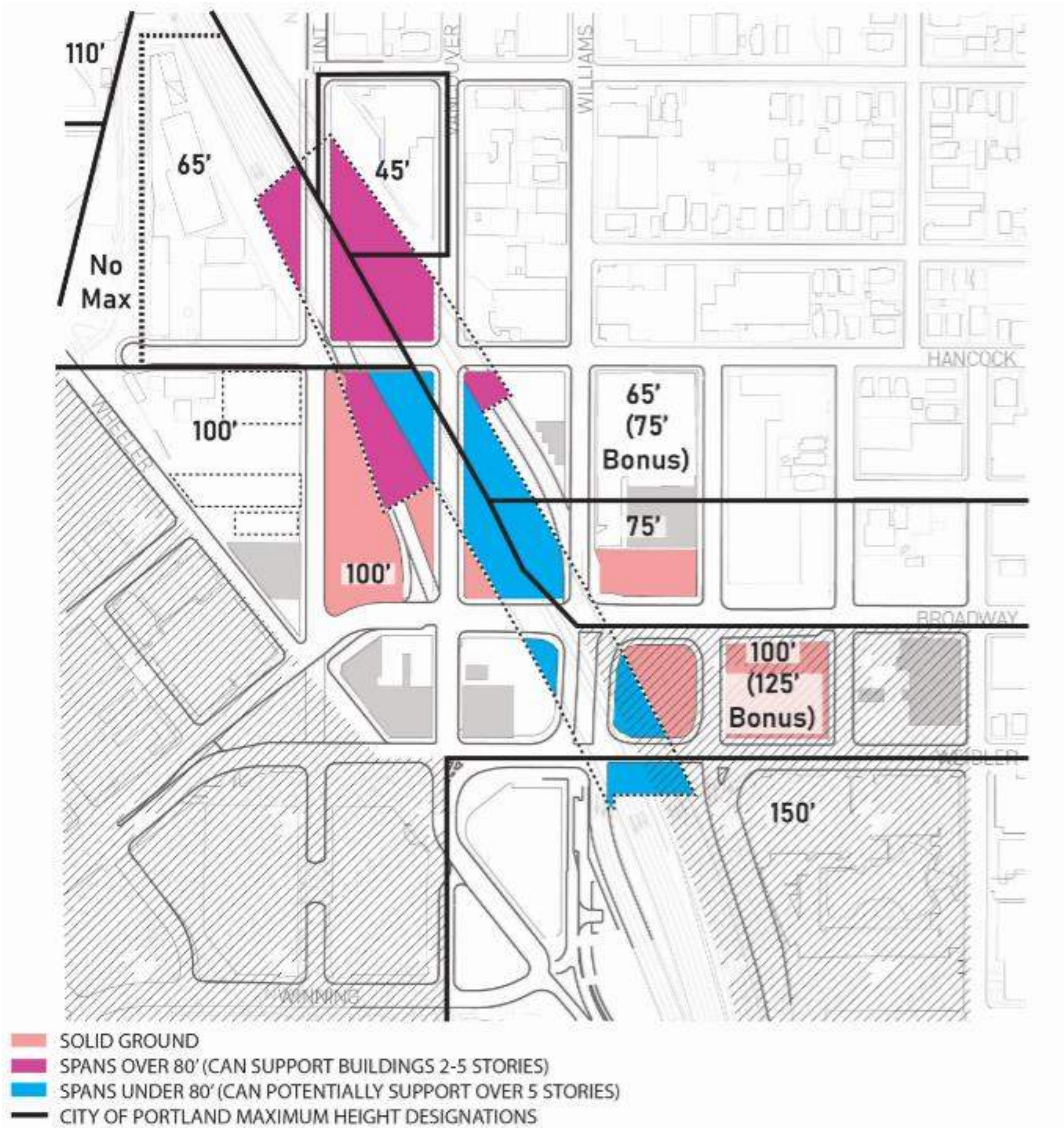


Figure 9 ICA Scenario 1 Buildings on Cover Height Limitations

An alternative approach to support buildings taller than 5 stories would be to consider mainline width reduction. Possible approaches to achieve reasonable width reductions are provided in Section 9 of this report, below. These approaches are consistent with current highway design practice in the United States, especially for urban highways and for highways in cover structures or tunnels.

5.1.3 Fire Life Safety and Ventilation

FLS systems for the highway cover consists of the following components:

- Early detection.
- Early notification.
- Median wall cross passages.
- Mainline section: egress pathways protected by physical barriers outside shoulders for ramps inside the covered area, with discontinuous barriers to allow access to the egress pathways[1].
- Fire-resistant cover board.
- Jet fans are likely required for an approximate 1100’ long cover structure. To minimize width of cover structure, jet fans near exterior walls can be placed on niches. Alternatively, either structural options such as haunched girders can be used to place appropriately-sized jet fans in the ceiling over the traveled lanes or the jet fans can be designed to be located only near the portals[2]. All of these practices have been used in this type of structure to address FLS requirements while minimizing cover structure width and height.

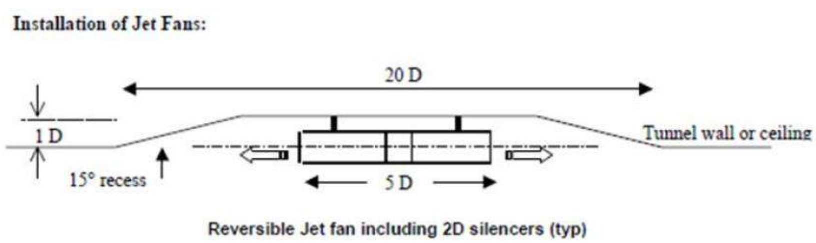


Figure 10 Installation of Jet Fans

- Water-based fixed fire-fighting system (FFFS).
- Standpipes can be placed in niches to avoid encroaching to highway shoulders.

5.2 Center on the Cover (ICA Scenario 4)

5.2.1 Roadway Design

The following elements are included in the Center on the Cover Scenario.

- Adding 12’ auxiliary lanes and 12’ shoulders in the study area, in both the northbound (NB) and SB directions.

[1] We note, however, that NFPA 502 allows use of the roadway as part of the egress pathway, provided that there is the appropriate support of the traffic management system. The proposed approach for the RQIP Amended 20% Design would require support of the traffic management system as well, so that in an emergency people exiting vehicles can use the roadway to access the egress pathways behind the barriers.
[2] For example, the recently-constructed I-70 covers in Denver, CO, as part of the Central 70 project, have a bank of 9 jet fans all located only near the portals in a relatively narrow band with the structure designed to accommodate the jet fans at those locations only. The covers for the Central 70 project are similar in size as those proposed for the RQIP project: over 1000’ in length and over 200’ in total width.

- Relocating the I-5 SB exit ramp from N Broadway to NE Weidler Street with design speed of 25 mph (36-degree curve) at the termini.
- Relocating the I-5 NB entrance ramp from N Williams Avenue to NE Weidler Street with design speed of 25 mph (36-degree curve) at the termini.
- Relocating the I-5 NB exit ramp termini from NE Victoria Avenue to NE 1st Avenue with design speed of 25 mph (36-degree curve) at the termini.
- Removal of the existing overcrossing structures at N Flint Avenue, N Vancouver Avenue, NE Weidler Street, N/NE Broadway, and N Williams Avenue and replacement with a single highway cover structure over I-5, including a new roadway that connecting N Vancouver Avenue to N Flint Avenue. The I-5 mainline profile will be lowered from the existing ground in this area to meet the minimum vertical clearance, consistent with the RQIP amended 20% Design.

5.2.2 Structural Design

Three primary regions compose the highway cover with the following girder types:

- Region 1: The north area of highway cover consists of a two-span structure over the I-5 SB and exit ramp as well as the I-5 NB and entrance ramp. The spans vary in length and reach a maximum span of about 120’. With an 8” concrete deck on 5’ deep precast, prestressed girders spaced at 4’-2”, the cover structure is sufficient to support up to 5-story office or residential buildings where the span length is up to 120 ft. The maximum number of stories can be increased to 5 where the span length is lower than 80 ft.
- Region 2: This area of the highway cover south of Region 1 and approximately north of Weidler St consists of a three- or four-span structure over the I-5 SB and exit ramp as well as the I-5 NB and entrance ramp. The cover structure over the mainline is supported by 5’ deep precast, prestressed girders with a maximum span length of 120 ft. The cover structure on the side spans over the ramps is supported by the same size of precast, prestressed I-girders. With an 8” concrete deck on girders spaced at 4’-2”, the cover structure over the mainline is sufficient to support up to 5-story office or residential buildings where the span length is 120 ft. The maximum number of stories can be increased to 5 where the span length is lower than 80 ft.
- Region 3: This area of the highway cover south of Region 2 and approximately south of Weidler St consists of a four-span structure over the I-5 SB and exit ramp as well as the I-5 NB and entrance ramp. A 5 ft deep cast-in-place post-tensioned box girder is proposed over the mainline, and a 1.5 ft thick cast-in-place slab is proposed over the ramps. The maximum span of the structure over the mainline is about 85’. At its longest span, the cover structure is sufficient to support up to 5-story office or residential buildings.

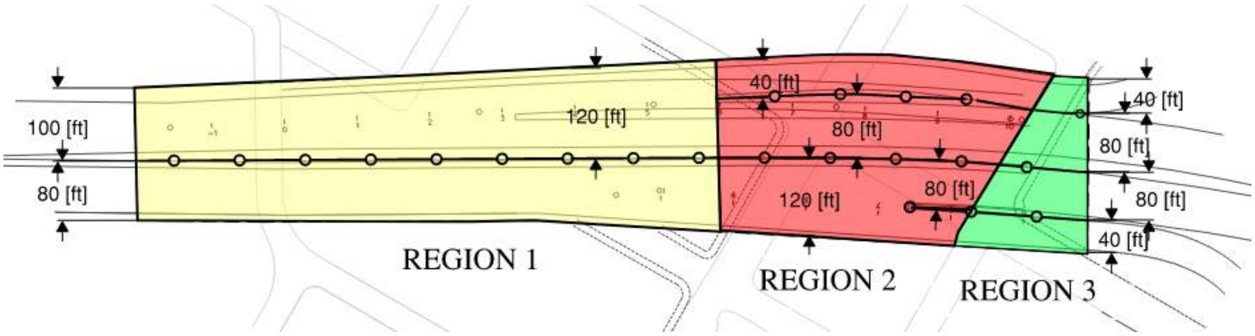


Figure 11 Plan View of the ICA Scenario 4 Cover

Girders in regions 1, 2, and 3 are supported by the following bents and abutments throughout the highway cover:

- Semi-integral abutments: Cast-in-place abutment walls will be supported on pile caps and 30" diameter driven pipe piles. Design is used in locations where retaining fill is required.
- Median bent wall: Columns with cast-in-place in-fill wall will be supported on a shaft cap and 6' diameter drilled shafts. Wall has intermittent FLS egress doors. Design is used throughout the length of the highway cover between I-5 NB and I-5 SB.
- Column bents between ramps and the mainline: Cast-in-place column bents will be supported on shaft cap and drilled shafts. These column bents extend up to the gore area only and do not extend the full length of the cover.

To avoid high seismic load on the bridge substructures and foundation, seismic isolation bearings can be installed on the bridge deck to support the proposed building. Based on preliminary evaluation, the bridge structure as described can be designed to meet the seismic performance as specified in ODOT Bridge Design Manual.

Finally, with regards to the potential for buildings over 5 stories in height, see comments provided above at the end of Section 5.1.2 of this report and summary diagram below.

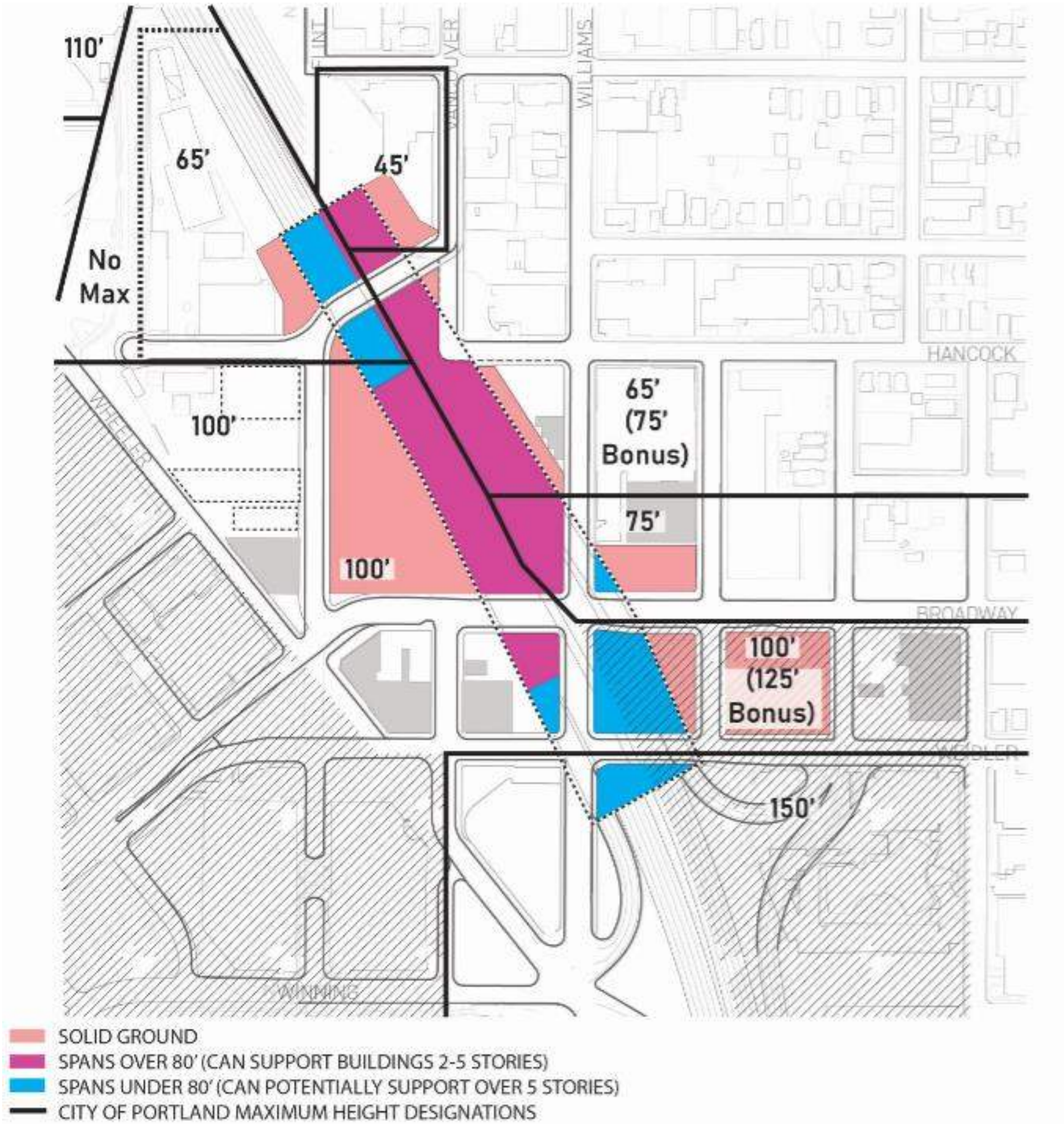


Figure 12 ICA Scenario 4 Buildings on Cover Height Limitations

5.2.3 Fire Life Safety and Ventilation

The approach to fire life safety and ventilation design is similar to the Flint and Broadway Boulevards Scenario.

5.3 Restore the Grid (ICA Scenario 5)

5.3.1 Roadway Design

As part of the project, the following elements are included in the Restore the Grid Scenario.

- Adding 12’ auxiliary lanes and 12’ shoulders in the study area, in both the northbound (NB) and SB directions.
- Relocating the I-5 SB exit ramp from N Broadway to NE Weidler with design speed of 25 mph (36-degree curve) at the termini.
- Relocating the I-5 NB entrance ramp from N Williams Avenue to NE Weidler Street with design speed of 25 mph (36-degree curve) at the termini.
- Relocating the I-5 NB exit ramp termini from NE Victoria Avenue to NE 1st Avenue with design speed of 25 mph (36-degree curve) at the termini.
- Removal of the existing overcrossing structures at N Flint Avenue, N Vancouver Avenue, NE Weidler Street, N/NE Broadway, and N Williams Avenue and replacement with a single highway cover structure over I-5, including extending NE Hancock Street to N Flint Avenue. The I-5 mainline profile will be lowered from the existing ground in this area to meet the minimum vertical clearance, consistent with the RQIP amended 20% Design.

5.3.2 Structural Design

Three primary regions compose the highway cover with the following girder types:

- Region 1: The north area of highway cover consists of a two-span structure over the I-5 SB and exit ramp as well as the I-5 NB and entrance ramp. The maximum span of the structure is about 120’. With an 8” concrete deck on 5’ deep precast, prestressed girders spaced at 4’-2”, the cover structure is sufficient to support up to 5-story office or residential buildings where the span length is 120 ft. The maximum number of stories can be increased to 5 where the span length is lower than 80 ft.
- Region 2: This area of the highway cover south of Region 1 and approximately north of Weidler St consists of a three- or four-span structure over the I-5 SB and exit ramp as well as the I-5 NB and entrance ramp. The cover structure over the mainline is supported by 5’ deep precast, prestressed girders with a maximum span length of 120 ft. The cover structure on the side spans over the ramps is supported by the same size of precast, prestressed I-girders. With an 8” concrete deck on girders spaced at 4’-2”, the cover structure over the mainline is sufficient to support up to 45-story office or residential buildings where the span length is 120 ft. The maximum number of stories can be increased to 5 where the span length is lower than 80 ft.
- Region 3: This area of the highway cover south of Region 2 and approximately south of Weidler St consists of a four-span structure over the I-5 SB and exit ramp as well as the I-5 NB and entrance ramp. A 5 ft deep cast-in-place post-tensioned box girder is proposed

over the mainline, and a 1.5 ft thick cast-in-place prestressed slab is proposed over the ramps. The maximum span of the structure over the mainline is about 85'. At its longest span, the cover structure is sufficient to support up to 5-story office or residential buildings.

Girders in regions 1, 2, and 3 are supported by the following bents and abutments throughout the highway cover:

- Semi-integral abutments: Cast-in-place abutment walls will be supported on pile caps and 30" diameter driven pipe piles. Design is used in locations where retaining fill is required.
- Median bent wall: Columns with cast-in-place in-fill wall will be supported on a shaft cap and 6' diameter drilled shafts. Wall has intermittent FLS egress doors. Design is used throughout the length of the highway cover between I-5 NB and I-5 SB.
- Column bents between ramps and the mainline: Cast-in-place column bents will be supported on shaft cap and drilled shafts. These column bents extend up to the gore area only and do not extend the full length of the cover.

To avoid excessive seismic load on the bridge substructures and foundation, seismic isolation bearings can be installed on the bridge deck to support the proposed building. Based on preliminary evaluation, the bridge structure as described can be designed to meet the seismic performance as specified in ODOT Bridge Design Manual.

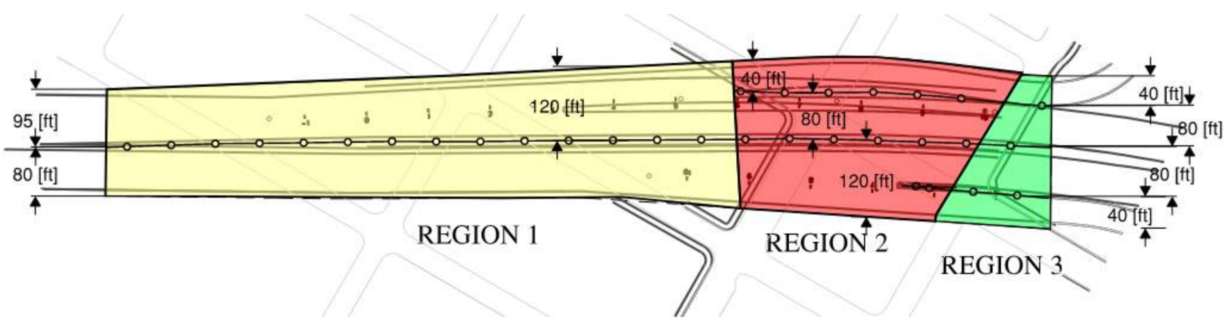


Figure 13 Plan View of the ICA Scenario 5 Cover

Finally, with regards to the potential for buildings over 5 stories in height, see comments provided above at the end of Section 5.1.2 of this report and summary diagram below.

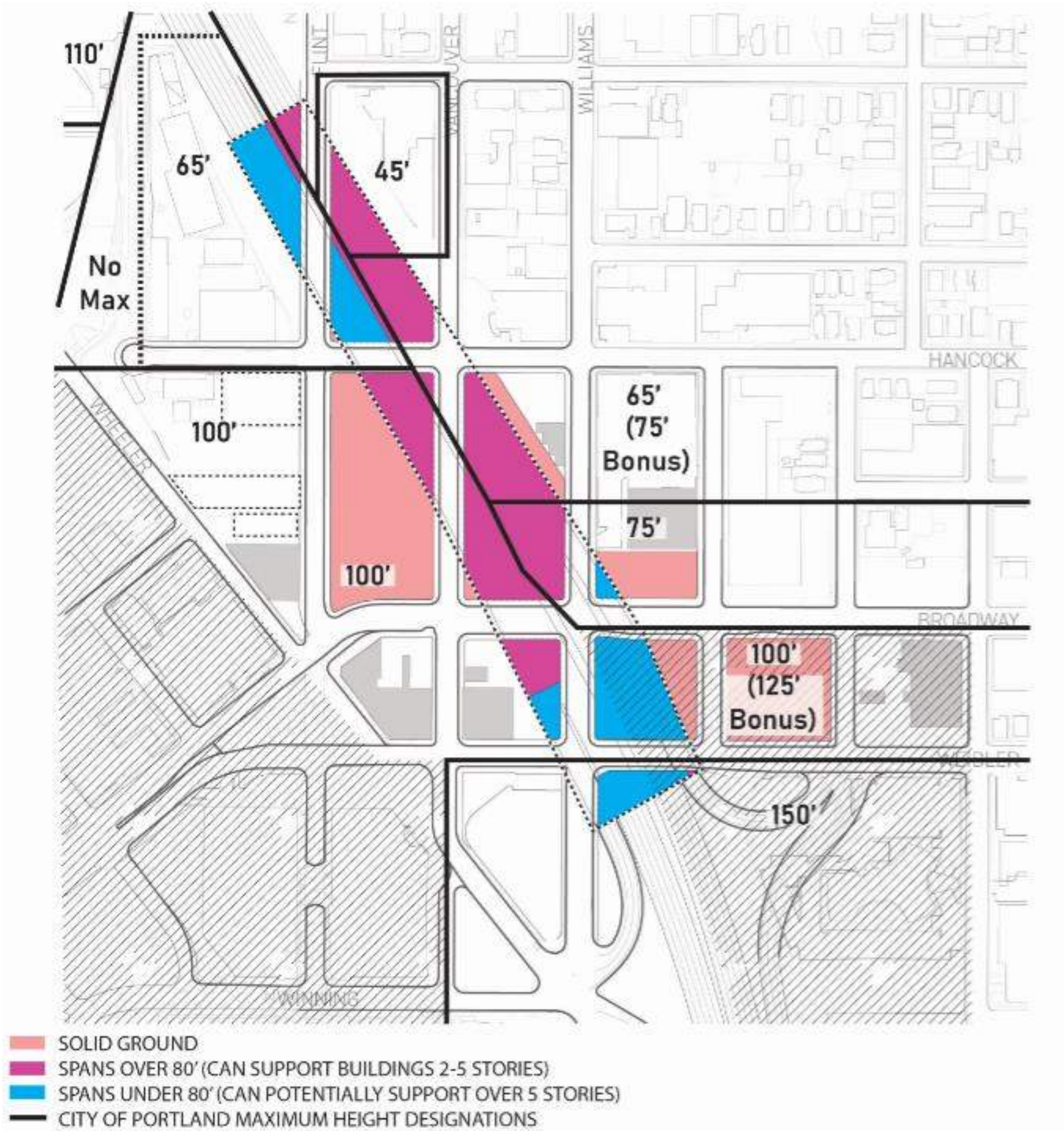


Figure 14 ICA Scenario 5 Buildings on Cover Height Limitations

5.3.3 Fire Life Safety and Ventilation

The approach to fire life safety and ventilation design is similar to Flint and Broadway Boulevards.

6 Constructability Assessment

Constructability and construction phasing for each Scenario should, as much as possible:

- Minimize the impacts to freeway traffic.
- Minimize the impacts to the surrounding streets, business and public transportation.
- Reduce construction risks and impacts to the public and environment.

Arup has not developed a detailed construction schedule, but it is assumed that construction will require approximately 4 to 5 years. Maintenance of traffic requirements and staging will be a major determinant of the duration of construction.

6.1 Constructability of Flint and Broadway Boulevards (ICA Scenario 1)

6.1.1 Overall Construction Sequence

- Construct detour structure north of Broadway to accommodate through traffic during construction.
- Widen I-5 in SB and NB directions, moving through traffic to the inside lanes.
- Remove existing structures on N/NE Broadway and N/NE Weidler Streets and Williams Avenue.
- Construct cover abutment walls.
- Excavate and lower outside I-5 lanes in SB and NB directions.
- Reroute traffic to the new outside I-5 lanes.
- Lower inside I-5 lanes in SB and NB directions.
- Construct median cover piers.
- Set cover girders.
- Construct cover deck.
- Remove temporary Broadway bridge.
- Construct remaining portion of the cover.
- Remove existing structure on Flint Avenue.
- Construct new SB on-ramp.
- Remove existing I-5 SB on-ramp.

- Construct Clackamas Pedestrian and Bicycle crossing.

6.1.2 Construction of Cover Structure

- Region 1: Cast-in-place post-tension box girder structures will be constructed on falsework. During construction, 2-lane traffic will be maintained in each direction of I-5 mainline. Based on the mainline profile in the amended 20% Design, a minimum vertical clearance of 17’-4” can be achieved.

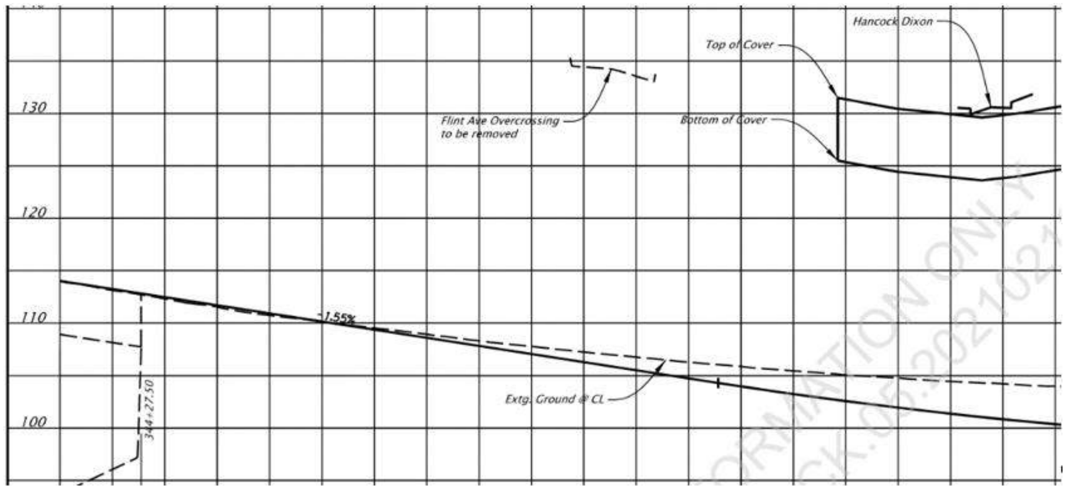


Figure 15 Vertical Clearance - ICA Scenario 4 Region 1

- Region 2 & 3: Falsework will not be required for the construction of precast structures. The precast girders and voided slabs can be transported to site and erected to positions during night closures. The topping slab can be cast after the slabs/girders are in position. Traffic closure is not required during cast of topping slab.

6.1.3 Management of Traffic Considerations (I-5 Mainline only)

- Stage 1: Shift mainline traffic toward the median and maintain all ramps open. Temporary ramp closure might be required to connecting existing ramp to the widened freeway.

- Stage 2: Shift N/NE Broadway onto the temporary shoofly over I-5 mainline and shift I-5 mainline.

- Stage 3: Restore local traffic on N/NE Broadway and shift NE Weidler traffic onto temporary shoofly over new cover.

- Stage 4: Shift I-5 SB entrance ramp to NE Weidler Street.

- Local traffic (N Vancouver Avenue, N Flint Avenue, N Williams Avenue and N Wheeler Avenue) might require additional local detours during construction.

6.2 Constructability of Center the Cover (ICA Scenario 4)

6.2.1 Overall Construction Sequence

- Construct detour structure north of Broadway to accommodate through traffic during construction.
- Widen I-5 in SB and NB directions, moving through traffic to the inside lanes.
- Remove existing structures on N/NE Broadway and N/NE Weidler Streets and Williams Avenue.
- Construct cover abutment walls.
- Excavate and lower outside I-5 lanes in SB and NB directions.
- Reroute traffic to the new outside I-5 lanes.
- Lower inside I-5 lanes in SB and NB directions.
- Construct median cover piers.
- Construct cover deck.
- Remove temporary Broadway bridge.
- Construct remaining portion of the cover.
- Construct new NB on-and off ramps.
- Remove existing I-5 NB off-ramp.

6.2.2 Construction of Cover Structure

- Regions 1 & 2: Falsework will not be required for the construction of precast girder structures. The precast girders can be transported to site and erected to positions during multiple night closures. The topping slab will be cast after the girders are in position. Traffic closure is not required during cast of topping slab.
- Region 3: Cast-in-place post-tension box girder structures will be constructed on falsework. During construction, 2-lane traffic will be maintained in each direction of I-5 mainline. Based on the mainline profile in the amended 20% Design, a minimum vertical clearance of 17’-4” can be achieved.

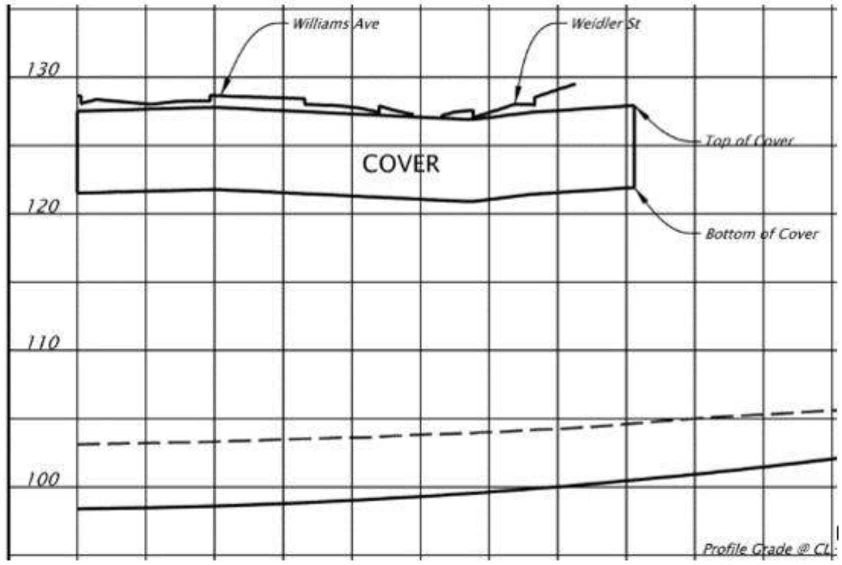


Figure 16 Vertical Clearance - ICA Scenario 4 Region 2

6.2.3 Management of Traffic Considerations

Similar to Flint and Broadway Boulevards except the following:

- Stage 1: construct 1-5 NB exit ramp to N 1st Street & 1-5 SB exit ramp to N Williams Avenue.
- Stage 3: construct I-5 NB entrance ramp from NE Weidler Street.

6.3 Constructability of Restore the Grid (ICA Scenario 5)

Construction considerations for the cover structure and Management of Traffic considerations of Scenario 5 are similar to those described above for Scenario 4.

7 Cost Assessment

7.1 Cost Estimating Methodology

Cost estimates are used primarily as inputs for budgeting cost, value analysis, decision-making, asset/project planning, and schedule control processes.

Each project is defined by scope, cost, and time. Change in any of these factors can cause variations in the other two. If the scope of the project changes, that could have implications on both project duration and project cost. In the case that duration is increased, it would have impact on the project cost. During the time between planning and project development to the construction of the project, significant changes may occur.

The main objective of the cost estimation process is to provide an estimate based on recommended practices, independent from potential stakeholder bias and uninfluenced by overly optimistic tendencies or other external factors that can influence the estimations.

Arup's Cost Classification Matrix, shown in Table 2, which is consistent with Association for the Advancement of Cost Engineering (AACE) International recommended practices, delineates the methodology used and the resulting estimate accuracy based on the project's design phase.

The cost estimation level appropriate for this stage is classified as AACE level 5, which is a rough order of magnitude estimate commensurate with the early-stage, concept level of design. This is reflected by the accuracy range of the estimates indicated in Table 2. As the Project moves to more advanced phases of designs, the level of definition of the design and therefore the accuracy of the cost estimates will increase.

It is important to note that the above considerations are applicable to all project alternatives under consideration, including the Baseline Scenario and the ICA Scenarios, each with their different respective levels of design.

At the time of writing of this draft report, the ICA estimates and the Baseline Scenario estimates have not been reviewed and harmonized with respect to each other to ensure that they have a common basis of assumptions, scopes of work, inclusions, and exclusions. As such, the estimates for the ICA Scenarios presented in this report are separate from and not comparable to ODOT's 15% cost to complete analysis.

ODOT has reviewed assumptions Arup has made during the cost estimating process and confirmed that they are in line with what they would expect at this stage of project development. In order to gain a better comparison of the estimated costs of different project alternatives, the ICA team recommends further detailed analysis of the approach, scopes of work, and requirements.

Table 2 Cost Classification Matrix

Estimate Level	Description	Design phase	Level of completion	Methodology	Accuracy range
5	Rough order of magnitude	• Planning • Schematic design	0% to 5%	• Parametric models • Capacity factored • Historical costs	L: -20% to -50% H: +30% to +100%
4	Concept feasibility	• Planning • Schematic design	1% to 15%	• Equipment factored • Parametric models	L: -15% to -30% H: +20% to +50%
3	Budget authorization	• Planning • Schematic design • Design documents	10% to 40%	• Unit costs • Assembles	L: -10% to -20% H: +10% to +40%
2	Budget control estimate	• Preliminary design • Engineering • Design documents • Construction	30% to 70%	• Detailed unit cost • Detailed take-off	L: -5% to -15% H: +5% to +30%
1	Bid	• Detailed design • Engineering • Construction	50% to 100%	• Detailed unit cost • Detailed take-off • Production based estimate	L: -2% to -5% H: +3% to +15%

7.2 Cost Breakdown

Arup has developed an independent cost estimate for the Project's ICA Scenarios presented in this report. The project scope of work included in the cost estimate is focused on the highway cover, mainline improvements related to the cover area, and city street improvements – each as further described in this report.

We have developed a Work Breakdown Structure (WBS) to capture all elements of the construction and project costs. The WBS uses the outline from the ODOT Cost Estimating Manual.

The major categories for WBS include:

- Direct cost.
- Indirect cost and contractors' markups.
- Right-of-way, land, and existing improvements.
- Professional costs.
- Project Contingencies/reserves.

7.2.1 Direct Cost

Direct cost includes labor, material and equipment needed for the construction. Direct cost was estimated based on the ODOT cost database and Arup experience from previous projects with similar scope and conditions.

7.2.2 Indirect Cost and Markups

Indirect cost captures all costs for the contractor which cannot be directly appropriated to a single construction item. It includes all site related costs, temporary utilities, parking, laydown areas, quality control, and surveying. It also includes equipment mobilization and demobilization, as well as all construction related management of traffic. Arup has used the ODOT Cost Estimating Manual recommendations and our experience to estimate these costs.

At the planning phase all indirect cost is estimated as a percentage of direct cost:

- Indirect fixed cost – includes cost for mobilization, construction set up and demobilization
- Indirect variable cost – includes all cost that is time dependent such as: Site supervision and management, general site expenses, temporary utilities, monitoring and testing, Site services, traffic control and management and travel and subsistence.
- Overhead cost and Profit
- Bond and insurance
- Design Contingency

- Construction Contingency

The above assumptions are based on common industry practice and are based on previous projects of similar in size and scope, as well as the estimator's experience.

7.2.3 Right-of-Way (ROW), Land and Existing Improvements

ROW cost includes land for permanent use by ODOT or City of Portland, as well as areas needed for temporary use such as easements to accommodate safe and efficient construction access and staging, laydown areas and other construction requirements.

Based on the current design and analysis done by ODOT there are several parcels adjacent to I-5 which will be impacted; however, no homes will be displaced. Additional coordination will be necessary during design phase and acquisition.

Arup assumed there are certain changes to the ROW needed for each ICA Scenario compared to the Baseline Scenario, which are relatively limited in scope. We assumed the same ROW budget as proposed in the Cost to Complete Report for the Baseline Scenario: $58M in 2025 USD. For Scenarios 4 and 5, due to added ROW near the south end of the cover, at the location of new NB on and off ramps, an additional $10M was included as an estimated allowance.

7.2.4 Professional Services

Professional services include all cost related to the project development. At this stage all professional cost is shown as a percentage of construction cost and include the following:

- Project Development / Preliminary Engineering
- Engineering
- Project Management for Design and Construction
- Construction Administration and Management
- Professional Liability and other non-construction Insurance
- Legal; Permits, review fees by other agencies, cities, etc.

7.2.5 Project contingency – Owner's Reserve

The Owners Reserve is an overall project contingency added to the total project cost estimate as 15% of total cost, which is appropriate at an early stage of design.

7.2.6 Added Cost for 5-Story Buildings on the Cover

The base estimate shown in the Sections 7.5, 7.6 and 7.7 of this report includes cost for the structure to support up to 2 to 3-story buildings on the cover. Arup has also estimated the added cost for enhanced foundation structures to support 5-story office or residential buildings over the full developable area of the covers (i.e., all areas that are not designated for uses such as local streets, etc).

7.3 Quantities

Arup cost estimators used preliminary plans provided by the ICA team to quantify major construction elements. Given the early stage level of design, all quantities are estimated using Google Earth to measure lengths, surface areas, etc. Volumes were estimated based on the available profiles for earthworks, while concrete structures used typical cross sections. We made assumptions based on available design information and engineering good practice.

The majority of the work can be divided into the categories shown in Table 3, as follows.

Table 3 ODOT Cost Categories

Item No.	Item
0100	Demolitions
0200	Temporary features and appurtenances
0300	Roadwork
0400	Drainage and Sewers
0500	Bridges / Structures
0600	Bases
0700	Wearing Surfaces
0800	Permanent Traffic Safety and Guidance Devices
0900	Permanent Traffic Control and Illumination Systems
1000	Right-of-Way Development and Control

7.4 Assumptions and Exclusions

During the cost estimating process Arup has made the following assumptions and exclusions.

7.4.1 Assumptions

This cost estimate includes the following assumptions:

- All costs are provided in 2025 US Dollars. Material and labor cost escalation was not included in the unit cost. Escalation has been included in the cost as a range of 3% to 3.5% annually.
- Pricing shown reflects probable construction costs obtainable for the infrastructure works on the date of this estimate and subject to the assumptions and exclusions listed in this report. This estimate is a determination of fair market value for the construction of this project. It is not a prediction of low bid.
- Pricing assumes competitive bidding for every portion of the construction work for all subcontractors, that is to mean at least 4 to 5 bids. If fewer bids are received, bid results can be expected to be higher.
- Most of the work is done within the existing ODOT and City of Portland right-of-way (ROW). Additional ROW has been estimated for each Scenario and cost was provided based on the prorated cost from the 15% BOD Memo and the Cost to Complete Report.
- I-5 lane and City streets closures and traffic interruptions are expected and proposed to be minimized whenever possible. Arup has proposed possible options for traffic management during construction in Section 6 of this Report.
- Most unit costs used in this estimate originate from the most recent publicly-available ODOT Cost Database, using relevant bid items and adjusted to 2021 US Dollars. Where unit costs were not available, Arup used experience from previous similar projects from our database, adjusted for time and location.
- Overall project escalation was added at 3%- 3.5% per year to the mid-point of construction and consistent with current project-wide assumptions.
- Existing utilities will require protection during construction or replacement. This includes the following: subsurface utilities, overhead power transmission lines, gas lines, sewer lines and street utility poles. It is estimated as an allowance at this stage and will require further study as design develops. Arup did not identify utilities which would be possible to be reimbursed. Arup understands ODOT is currently discussing project implications with utility providers.
- The existing streetcar will be temporarily displaced on a temporary structure over I-5 during construction of the cover. Once the new structure is in place, the light rail line will be relocated and the temporary structure demolished.

7.4.2 Exclusions

This cost estimate does not include the following items:

- Cost for any buildings or public/private open space improvements on the cover (this includes any utility connections to them). Potential buildings or public/private open space improvements on the cover are described in the Design section but excluded from the cost estimate.

- Cost of additional schedule is not included in the cost estimate. It is expected that any time additions to the current project-wide schedule assumptions would incur increase due to expected inflation escalation at a rate of 3% to 3.5% per year, consistent with escalation assumptions stated above.
- Hazardous or contaminated material mitigation.
- Ground water mitigation during construction.
- Full freeway closures.
- Discovery of archeological artifacts and their consequent effect on the project.
- Risk-based contingency was not included in the estimate; however, contingency line items for design and construction are included, as well as an owner's reserve, all based on good industry practice.
- Financial cost was not included in the estimate. In the future budget development, we recommend that this cost be evaluated and added if applicable.

7.5 Estimated Cost for the Flint and Broadway Boulevards Scenario (ICA Scenario 1)

The total estimated project cost presented in Table 4 is based on the Flint and Broadway Boulevards Scenario. The project scope of work included in the cost estimate is limited to the highway cover, mainline improvements related to the cover area, and city street improvements. This cost has been escalated to the estimated mid-point of construction, consistent with current project-wide assumptions.

Table 4 Flint and Broadway Boulevards Scenario Cost Range

PROJECT FEATURES	**Cost Range (2025 USD)**
Mainline	$147M - $165M
Highway Cover	$509M - $569M
Local Streets Improvement	$71M - $79M
Utilities	$92M - $103M
Total Project Cost	$819M - $916M

Added cost for 5 story buildings on the cover	$179M - $201M

7.6 Estimated Cost for the Center of the Cover Scenario (ICA Scenario 4)

The total estimated project cost presented in Table 5 is based on the Center of the Cover Scenario. The project scope of work included in the cost estimate is limited to the highway cover, mainline improvements related to the cover area, and city street improvements. This cost has been escalated to the estimated mid-point of construction, consistent with current project-wide assumptions.

Table 5 Center of the Cover Scenario Cost Range

PROJECT FEATURES	Cost Range (2025 USD)
Mainline	$144M - $161M
Highway Cover	$500M - $559M
Local Streets Improvement	$88M - $98M
Utilities	$90M - $101M
Total Project Cost	$822M - $919M

Added cost for 5 story buildings on the cover	$172M - $192M

7.7 Estimated Cost for the Restore the Grid Scenario (ICA Scenario 5)

The total estimated project cost presented in Table 6 is based on the Restore the Grid Scenario. The project scope of work included in the cost estimate is limited to the highway cover, mainline improvements related to the cover area, and city street improvements. This cost has been escalated to the estimated mid-point of construction, consistent with current project-wide assumptions.

Table 6 Restore the Grid Scenario Cost Range

PROJECT FEATURES	Cost Range (2025 USD)
Mainline	$143M - $160M
Highway Cover	$563M - $629M
Local Streets Improvement	$89M - $99M
Utilities	$99M - $110M
Total Project Cost	$894M - $998M

Added cost for 5 story buildings on the cover	$172M - $192M

7.8 Statement of the Cost Estimate

Arup has no control over the cost of labor and materials, general contractor's or any subcontractor's method of determining prices, or competitive bidding and market conditions. This opinion of cost estimate of construction is made based on the experience, qualifications, and best judgment of the professional consultant familiar with the construction industry. Arup cannot and does not guarantee that proposals, bids, or actual construction costs will not vary from this or subsequent cost estimates.

8 Reference Projects

Eight completed urban highway tunnels reference projects were identified by the team for comparison with the proposed Project. Most of these reference projects were constructed over the last decade. A summary of design widths of each is presented in Figure 17.

For comparison, the Rose Quarter Improvement Project has the following widths:

- Traveled lane width: 12 feet.
- Inside shoulder width: 12 feet.
- Outside shoulder width: 12 feet.

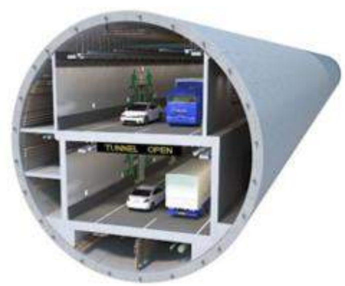
Presidio Parkway, CA
11 and 12' Lanes
4' Inside Shoulder
10' Outside Shoulder

TexPress I-635 E, TX
12' Lanes
2' Inside Shoulder
8' Outside Shoulder

I-93 Central Artery, MA
12' Lanes
0' Inside Shoulder
0' Outside Shoulder

I-5 Freeway Park Seattle, WA
11' Lanes
6' Inside Shoulder
8' Outside Shoulder

Caldecott Tunnel 4^{th} bore, CA
12' Lanes
2' Inside Shoulder
10' Outside Shoulder



Alaskan Way Tunnel, WA
12' Lanes
2' Inside Shoulder
8' Outside Shoulder

Midtown Tunnel, VA
12' Lanes
2' Inside Shoulder
2' Outside Shoulder

Port of Miami Tunnel, FL
12' Lanes
2' Inside Shoulder
2' Outside Shoulder

Figure 17 Case Study Comparison of Key Design Metrics

The following three case studies were selected for further analysis based on information available. A summary of relevant case study parameters are provided below. This is followed by a comparison of corresponding design, cost, and constructability features in Table 7.

Presidio Parkway

Photo: Caltrans

Project Overview

Location: San Francisco, CA
Construction start: 2009
Construction completed: 2015
Procurement type: Phase 1**:** Design-Bid-Build; Phase 2: Design-Build-Finance-Operate-Maintain
Cover type: Landscaping + local streets
Owner: Caltrans
Total Construction Cost: $928M
Project design:
Preliminary engineering: Arup / Parsons Brinckerhoff
Detailed engineering: Phase 1 – Arup / Parsons Brinckerhoff, Phase 2 -– HNTB
Phase 1 - Design-Bid-Build Construction Contractor: R&L Brosamer
Phase 2 - Design-build contractor: Flatiron-Kiewit JV
Existing Traffic volume: 120,000 auto trips per day

I-70 Mile High Shift Covers

Photo: Colorado DOT

__Project Overview__
Location: Denver, CO
Construction start: 2017
Construction completed: substantial completion 2021, final completion 2022/23
Procurement type: Design-Build-Finance-Operate-Maintain
Cover type: Landscaping, hardscaping, and playing fields
Owner: Colorado DOT
Total Construction Cost: $1.2B (includes full reconstruction of 10-mile stretch of I-70)
Project design: Jacobs/WSP
Design-build contractor: Kiewit
Existing Traffic volume: 200,000 auto trips per day

Capitol Crossing Project Covers

Photo: Balfour Beatty

Project Overview

Location: Washington, DC
Construction start: 2015
Construction completed: 2018
Procurement type: Private development (covers integrated with vertical development)
Cover type: 12-story office and residential buildings, local streets, public open space
Owner: Washington DC DOT (highway) / Property Group Partners (private development)
Total Construction Cost: $264 million (includes parking structure, utilities, repairs to adjacent structures, mainline and local street resurfacing, and relocation of historic building)
Project design: STV/LERA/RWDI/Arup
Design-build contractor: Balfour Beatty
Existing Traffic volume: 90,000 auto trips per day

Table 7 Reference Case Comparison

Project	**Design**	**Cost**	**Constructability**
Presidio Parkway: Battery Tunnel and Main Post Tunnel	**Type**: Cut-and-cover tunnels (twin tubes) **Length of Cover**: Battery Tunnel: 960' long / 116' wide Main Post Tunnel: 1000' long / 116' wide **Number of lanes**: 3 northbound / 4 southbound **Lane width**: 11' inside lanes, 12' outside lane **Inside Shoulder**: 4'; **Outside Shoulder**: 10'	**Total Project cost**: $928 million **Battery Tunnel construction cost**: approx. $60 million (southbound tube) **Unit cost**: $950 / sqft **Duration**: 67 months (total project duration)	**Structural construction type**: Shallow cast-in-place concrete cut-and-cover tunnel **Temporary shoring:** Soldier piles **Ventilation:** Jet fans installed in tunnel ceiling
I-70 Mile High Shift: Covers by Swansea Elementary School	**Type**: Cut-and-cover tunnels (twin tubes) **Size of cover**: Total width: varies 200' to 235' Mainline Length: 1007' **Number of lanes**: 6 each direction (4 general purpose lanes + 2 managed lanes) + ramps **Lane width**: 12' **Inside Shoulder**: 12' (for managed lanes); **Buffer**: 4'; **Outside Shoulder**: 8'	**Total Project cost:** $1.2 billion **Total Cover construction cost**: approx. $95 million (covers segment of the 10-mile project) **Unit cost**: $460 / sqft **Duration**: approx. 60 months (total project duration)	**Structural construction type**: Variable-depth prestressed/precast concrete box girders **Ventilation:** Jet fans installed in tunnel ceiling
Capitol Crossing: Covers for ~2 million square foot, 12-story real estate development	**Type**: Cut-and-cover tunnels (twin tubes) **Size of cover**: Total width: varies 120' to 150' Mainline Length: approx. 1100' **Number of lanes**: 3 each direction + ramps **Lane width**: 12' **Inside Shoulder**: 4'; **Outside Shoulder**: 8'	**Total Project cost:** $264 million (covers, parking structure, utilities, streets, mainline improvements, etc) **Total Cover construction cost**: approx. $100 million (covers only, excluding other scope items) **Unit cost**: $690 / sqft **Duration**: approx. 40 months	**Structural construction type**: steel Steel box girders with precast concrete planks **Ventilation:** Exhaust fans installed in FLS rooms (no jet fans)

9 Other Considerations

9.1 Project Cross Section Width

For the development of design scenarios for the RQIP the ICA team assumed the same widths for the I-5 mainline and ramps as the Baseline Scenario. The Baseline Scenario's widths include:

- Traveled lane width: 12 feet.
- Inside shoulder width: 12 feet.
- Outside shoulder width: 12 feet.

Based on these widths, plus allowances that the Baseline Scenario makes for additional items such as the median support structure and reserved zones for placement of jet fans and accommodating egress pathways, the Baseline Scenario's total proposed cross section for the new highway is in the order of 160 feet. This represents an approximately 70% increase in width over the current existing I-5 cross-section at this location, which is approximately 94 feet. The project is proposing an increase of total traveled lanes from four to six, for a net increase in traveled lane width of 24 feet.

In the northern section of the cover of the Baseline Scenario, where the SB off-ramp and NB on-ramp are within the cover, the proposed new width for the Baseline Scenario's cover structure is over 250 feet.

Because the ICA team scenarios assume the same lane and ramp width standards, the width of the proposed cross sections for the ICA scenarios range from 170 feet to 250 feet. These widths are similar in range as for the Baseline Scenario, notwithstanding that the total plan area of the covers is larger. The increase in cover area for the ICA scenarios is because a single contiguous cover is provided (as opposed to two separate and shorter covers for the 15% design), the cover extends farther north, and a longer portion of the SB off-ramp and NB on-ramp are within the cover. These design features of the covers for the ICA Scenarios are needed to deliver community benefits – for example, in terms of the extent, size, and quality of development potential on the covers.

The most significant driver of project cost (initial construction cost as well as ongoing maintenance and lifecycle costs), right of way impacts, and development potential on and adjacent to the covers is the cross-section width. As the project advances to its next stages of development, stakeholders should give careful consideration to these issues. We offer the following summary of current best practices for design of highway projects with cover structures to help guide those considerations with the goal to optimize the project.

9.1.1 Best Practices for Highway Cover Structures

DOTs around the country faced with similar highways through urban corridors with significant right of way constraints and cost considerations routinely utilize well-reasoned design exceptions to achieve their road safety objectives and to balance cost, right of way takings, impacts, and stakeholder concerns. Chief among these are issues related to lane, ramp, and shoulder widths.

For example, guidance in FHWA document FHWA-HOP-16-060[3] states: "*Implementing narrow lanes and shoulders to add a lane within an existing roadway footprint can be a viable and cost effective approach to reduce congestion. In addition to improving mobility, narrow lanes and shoulders may also be implemented with minimal negative impacts on safety and reliability. Potential scenarios for implementing narrow lanes include the following: … Adding a lane in and/or within the vicinity of an interchange, to provide additional capacity on a ramp,* ***an auxiliary lane between closely-spaced interchanges****, or additional capacity beyond the interchange to prevent traffic from backing up into the interchange area*" (emphasis added).

Setting aside project-specific considerations, state DOTs such as Florida and California, for example, provide general guidance in their design manuals that highways with 3 or more lanes should have 10-foot inside and outside shoulders, whereas others such as Georgia indicate 10 feet for inside shoulders and 12 feet for outside shoulders. Nevada indicates 4 feet to 8 feet for inside shoulders and 8 feet to 12 feet for outside shoulders. New York's approach is similar to Nevada's but adds consideration of the percentage of heavy goods vehicle traffic.

We also note that in Oregon ODOT's Highway Design Manual section 5.2.3 recommends the following:

- For 2 or less travel lanes (in each direction), the inside shoulder shall be a minimum of 6 feet wide and the outside shoulder be 10 feet.
- For 3 or more travel lanes (in each direction), the inside shoulder shall be a minimum of 10 feet wide and outside shoulder shall be 10 feet.

In addition to the proposed lane and shoulder widths, the Baseline Scenario proposes over 24 feet in total width for egress pathways and to place jet fans. As discussed in section 5.1.3 of this report, alternative approaches for the design of the fire and life safety systems (e.g., placement of jet fans) and for egress pathways could also help to reduce the cross section width regardless of considerations related to the lane and shoulder widths.

The above considerations of highway cross section width become paramount in projects that include covers or tunnel structures because their construction, ongoing maintenance and lifecycle costs are significantly higher than for a conventional, open-air surface highway construction.

Figure 15 above illustrates relevant reference cases of recently constructed urban cover or tunnel projects that have been designed with narrower lane and shoulder widths than the standard 12 feet, as well as optimized design of jet fans and egress pathways, while meeting their respective purpose and need.

For these reasons, in cover structures and tunnels, as well as on major bridge crossings, it is highly unusual to see full shoulders on both sides, full width lanes, and significant additional widths to accommodate jet fans and egress pathways. Arup is not aware of comparable highway cover or tunnel projects in the United States nor internationally that have been built with full width lanes and shoulders.

[3] "Use of Narrow Lanes and Narrow Shoulders on Freeways: A Primer on Experiences, Current Practice, and Implementation Considerations", July 2016.

According to FHWA Technical Manual for Design and Construction of Road Tunnels – Civil Elements, it is suggested for unidirectional road tunnels that the right shoulder be at 4 feet and left shoulder at least 2 feet. As mentioned in the same document, emergency alcoves are sometimes provided to accommodate disabled vehicles where there is no shoulder provided.

In our experience the above options should be considered to reduce the cover's width, and its cost.

In Figure 15 below we provide a comparative and indicative diagram showing the existing highway (top diagram) and proposed cross section widths for the Baseline Scenario (middle diagram). As explained in this report, ICA Scenarios 1, 4, and 5 have been developed with a cross section width that is consistent with the Baseline Scenario.

Also shown in Figure 18, in the lower diagram, is an alternative cross section that could achieve over 40 feet in total cover width potential reduction for the RQIP. This conceptual cross section is consistent with the FHWA guidance referenced above, as well as consistent with current practice for highways with cover structures or tunnels.

Evaluation of such a design scenario would require thorough evaluation and analysis of how it would meet the project's purpose and need. A recommended approach would be as provided by a Performance-Based Practical Design (PBPD) method.

Quoting from the above-referenced FHWA document, Performance-Based Practical Design "*modifies the traditional "top down, standards first" approach to a "design up" approach*". It is complementary to a Context-Sensitive Solutions (CSS) as a "*collaborative, interdisciplinary approach that includes the viewpoints of all stakeholders in the development of a shared vision of project goals, and uses a defined decision-making process*".

Projects such as the Presidio Parkway, which is referenced above in Section 6 of this report, are examples of the successful application of a CSS and PBPD approach to meet purpose and need. Those projects have successfully advanced through approvals, securing funding, and completing construction because they were able to generate broad stakeholder and community support through the use of that approach.

The RQIP should give consideration to adopting an approach to project development as described above and consistent with recent highway projects with cover structures and tunnels.

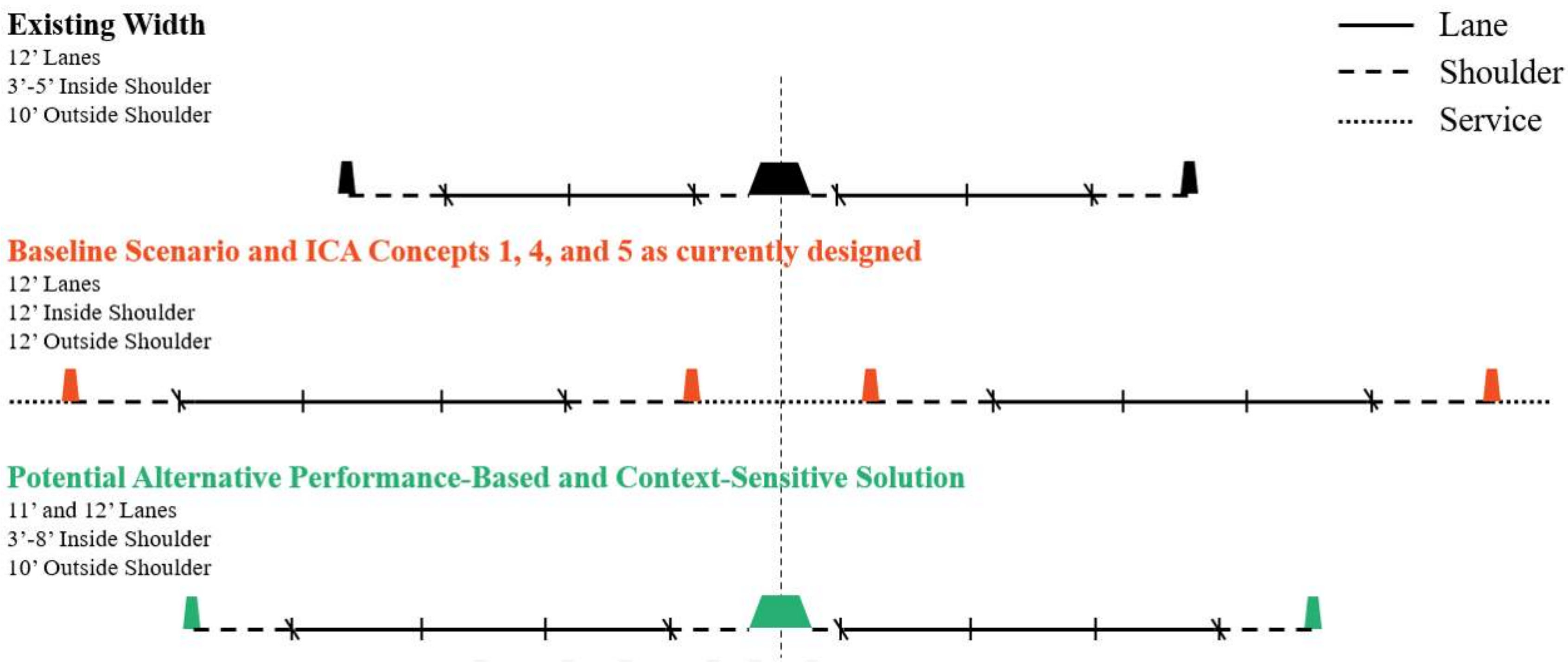


Figure 18 Lane Width Comparison

9.1.2 Construction Cost of the Covers

As indicated by the three reference project case studies above in Section 8 of this report (see Table 7), the unit cost of construction of highway covers recently built in the United States is in the range of approximately $500 to $1,200 per square foot of gross cover plan area (inflated to current dollars for comparison with the RQIP's cost estimates provided in this report). These are construction costs for the complete cover structures including foundations, mechanical, electrical, and drainage systems. As noted above, these case study highway covers are comparable to the RQIP's highway covers.

First, we note that the case studies indicate a wide range of unit costs because of normal project-specific factors. These can include: geotechnical conditions, maintenance of traffic requirements, loading conditions on top of the covers, scope item differences, and geographic location factors. One of the three case study projects, the Capitol Corridor project in Washington DC, supports buildings up to 12 stories in height. It is notable that finished project supports buildings of that scale over three lanes of interstate highway traffic with a 60-foot span cover structure, which is significantly less than those currently contemplated for the RQIP.

Second, we also note that the cost estimates provided in Section 7 of this report indicate a unit cost for the covers of approximately $900 to $1,100 per square foot of gross cover plan area. Due to project specific factors noted above, it is difficult to make direct and precise comparisons of unit costs. However, general observations are possible and valuable.

We observe that the RQIP's unit costs are at the upper end of the range indicated by the recently-constructed comparable projects, regardless of which alternative is considered.

Our assessment is that this is because of the significant width of the RQIP's cover as it is currently proposed. The case study projects all have shoulders of varying widths that are significantly less than 12-foot standard shoulders, they use fire and life safety design approaches that do not add additional width to the cross section, and in one case they use 11-foot wide mainline lanes. As a result, each of those projects accommodates as many or more lanes of traffic inside their cover structures as the RQIP, but with significantly smaller cross-section widths.

It is important to note that the plan to support buildings on the RQIP's covers is a material factor in terms of the structural design, the planning for and accommodation of utility connections for future development, and construction cost. However, it is noteworthy that the Capitol Crossing project's cover, which supports up to 12 story buildings, has a unit cost that lies within the middle of the range indicated above for the three case study projects.

As further explained above in Section 9.1.1 of this report, by taking a performance-based and context-sensitive design approach, we believe that the RQIP has the opportunity to:

- Optimize the width and cost of the highway cover so that it is at the middle to lower end of the range indicated by the comparable projects.
- Potentially reduce its unit cost to be similar to the Capitol Corridor project over I-395 in Washington DC, which supports 12-story buildings over three lanes of traffic.

- Reduce the project's funding gap and improve its funding eligibility for discretionary funding sources, by demonstrating a cost-effective and optimized solution resulting in a positive benefit-cost analysis.
- Result in additional benefits, as noted above, such as increased land for development *not* located on the covers.

To give a sense of the rough order of magnitude of the potential cost reduction associated with an optimized cross-section width, we provide the following:

- For every 10-foot of reduction in the total width of the cover, we estimate an approximate total project cost reduction in the range of:
  - $23M to $30M for the case supporting 2-story buildings
  - $30M to $39M for the case supporting 5-story buildings
- Based on the conceptual cross-section width comparison shown in Figure 15 below, which indicates the potential of up to 40'+ in total cross-section width reduction, we estimate that the RQIP could potentially achieve cost reductions in excess of $100 million.

9.1.3 Addressing Congestion Through Traffic Operations

Operations and Maintenance planning can be integrated into the planning and design of the mainline and ramp cross sections and the horizontal geometry to deliver a flexible and resilient operating paradigm while minimizing the land take and structural volume of the underpass sections.

Consideration of physical and technological features to aid the day-to-day operations, peak flows and management of breakdowns and emergencies, such as displayed in Figure 19.

Figure 19 I-87/287 Mario Cuomo Bridge de-mountable barrier, NY

- Combine the asymmetric shoulders with emergency breakdown areas which are set back from the shoulder such that incident response teams could move a vehicle out of the roadway, or the space can provide safe refuge for a breakdown rolling into the area with a flat or loss of power.

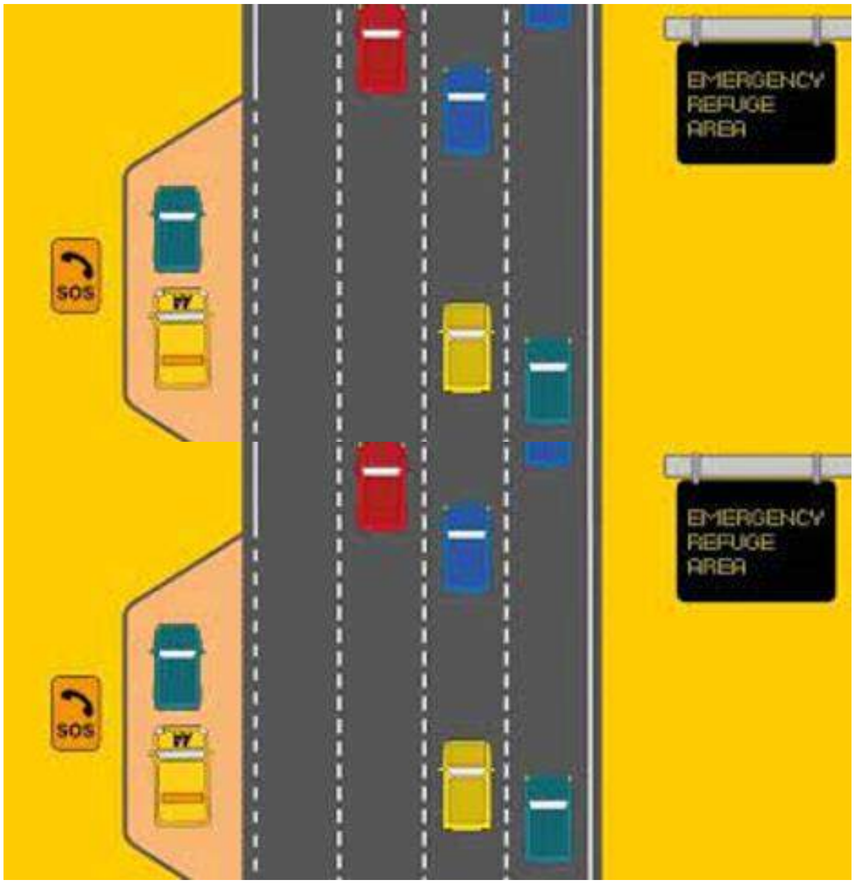


Figure 20 Emergency Refuge Area

- Matrix signals with speed advisory signs in heavy congestion periods to modulate traffic flows and manage congestion.

Figure 21 Matrix Signal, example from I-66 in Fairfax, VA

- On-shoulder running in peak times – I-66 in VA.

- Managed contraflow lanes, example Rte 495 North Bergen, NJ.

Figure 22 Managed contraflow lanes, example Route 495 North Bergen, NJ

- Ramp metering in peak times to modulate the entry flows.
- Integration of Vehicle-to-Infrastructure (V2I) Technologies: Smart Signs and Advanced Road Markings.

9.2 Design Speed

Currently, the I-5 main line is posted at a 50 miles per hour speed limit. Design speed is typically about 10 miles over posted speed. The Baseline Scenario's 15% design proposes a design speed of 70 miles per hour.

In urban areas, design speed is usually lower than rural areas due to site constraints and to reflect this the Oregon Highway Design Manual recommends a design speed of 50 miles per hour in "congested urban" areas. Taking these design speeds into consideration, Arup recommends a design speed of 60 mph (posted 50 mph) to:

- Improve safety outcomes;
- Simplify cover design to reduce project cost; and
- Improve community outcomes.

We note that a design speed of 60 mph would not require a design exception.

9.3 Ramp Removal

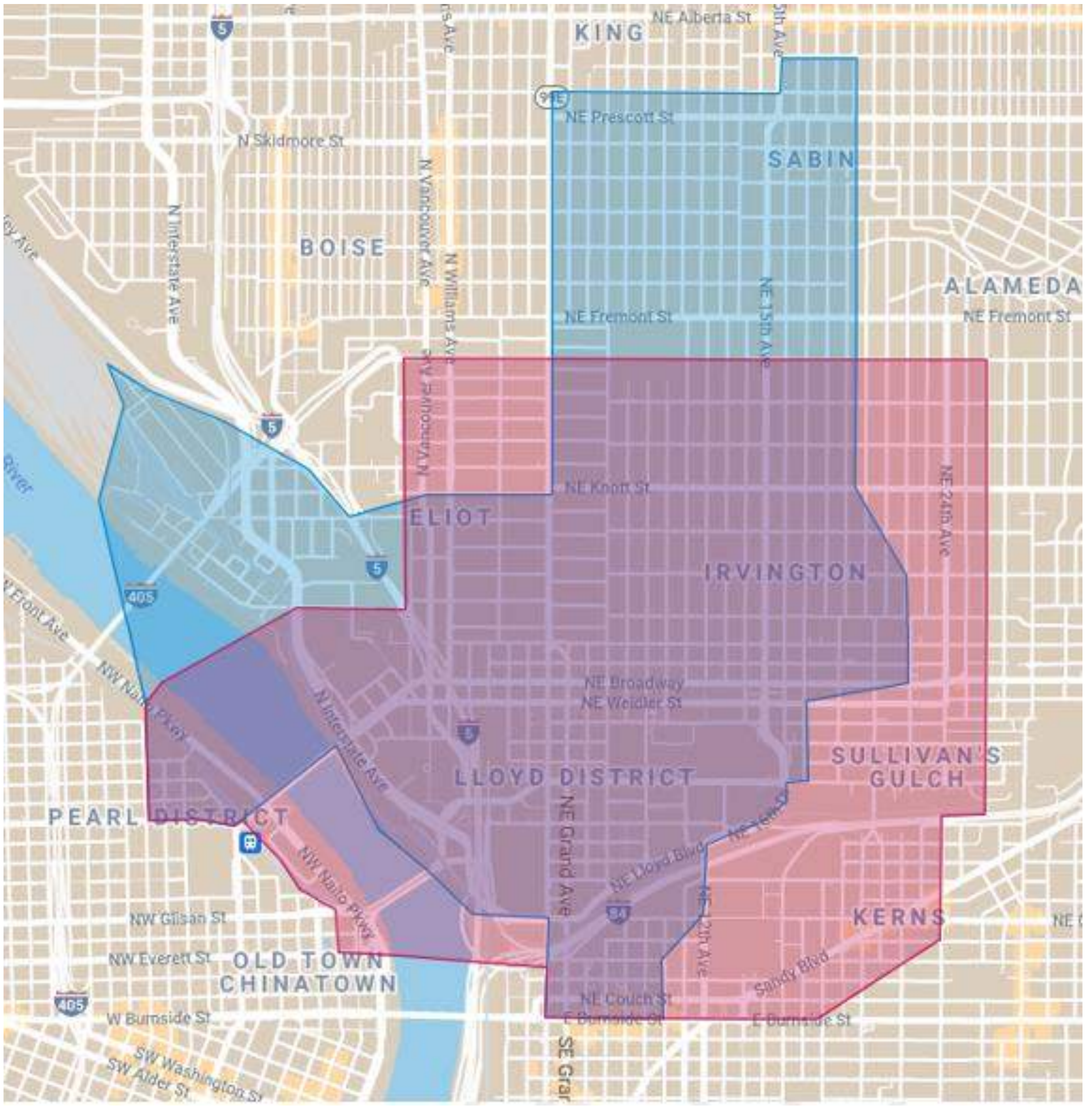
Removing the Broadway / Weidler interchange from the I-5 outright would eliminate the existing safety and traffic operations issues associated with weaving on four segments on the I-5 mainline:

- Northbound I-5, between I-84 / US-30 and Broadway / Weidler Street.

- Northbound I-5, between Broadway / Weidler Street and I-405 / US-30.
- Southbound I-5, between I-405 / US-30 and Broadway / Weidler Street.
- Southbound I-5, between Broadway / Weidler Street and I-84 / US-30.

However, the Broadway / Weidler Street interchange plays a key role in the local and regional roadway transportation system, connecting regional traffic on the I-5 with Broadway and Weidler Street. Broadway and Weidler Street are designated by the City of Portland as “major city traffic streets” and carry traffic between I-5 and Downtown (to the west, via the Broadway Bridge) and the Broadway / Weidler Corridor (to the east).

Figure 23 shows approximate car/truck access sheds for the Broadway / Weidler Street interchange (i.e., regions to/from which the Broadway / Weidler Street interchange provides the most convenient car/truck access to/from I-5).



■	Car/Truck Access Shed to/from South along I-5
■	Car/Truck Access Shed to/from North along I-5

Figure 23 I-5 Broadway / Weidler Street Interchange Car/Truck Access Sheds[4]

In 2019, ODOT reported an average annual daily traffic (AADT) of 48,070 vehicles using the interchange to either enter or exit the I-5[5].

Given the strategic importance of the interchange to the regional and local roadway transportation system, removal of the interchange was not further evaluated.

[4] Basemap credit: Google Maps.
[5] Oregon Department of Transportation, "Ramp Interchange Diagrams Average Daily Traffic Volumes." https://www.oregon.gov/odot/Data/Pages/Traffic-Counting.aspx