APPENDIX "A"

I-5 Columbia River Crossing
Bridge Influence Area (BIA) Conceptual Engineering
Qualitative Concept Assessment

This document summarizes the Conceptual Engineering Qualitative Assessment for the four BIA representative concepts on both the Washington and Oregon sides of the Columbia River.

OVERVIEW AND SUMMARY

There is a clear distinction between WSDOT and ODOT concepts related to the range of concepts considered and the level of engineering performed at this design level. The ODOT concepts reflect a range of concepts between the south bridgehead and the Columbia Boulevard interchange. The WSDOT concepts generally reflect a single collector-distributor (C-D) concept north of the bridgehead with minor variations to the configuration. The ODOT concepts have been developed to varying levels of detail but it appears ODOT generally considered three-dimensional design relationships. The WSDOT concepts appear to have been developed primarily addressing the horizontal plan and may not have considered three dimensional design relationships.

The ODOT concepts appear to have been generated to avoid impacts in the Delta Park area. In some cases, provisions for all local movements have not provided. Additionally, one concept introduces a weaving section on the mainline. As the concepts are developed, it would be reasonable to consider configurations that meet a comprehensive transportation objective at the expense of environmental impacts. With an understanding of total footprint needs, appropriate modifications could be made to balance design, avoidance, and mitigations.

Because the WSDOT concepts may not have been considered in three dimensions, the plans do not presently address contemporary design, operations, safety, and FHWA policy requirements. When the WSDOT concepts are developed to address these specific points, the impact areas in and around the corridor will likely exceed the footprint currently conveyed on the various concept plans.

QUALITATIVE CONCEPT ASSESSMENT

Our approach was to highlight potential design concerns quickly without the potential benefit of all the available background information. A narrative on design questions is challenging to comprehend. As a result, figures have been provided to accompany the narrative and to illustrate the various points and design related questions. The following general comments apply to ODOT and WSDOT developed concepts on the south and north sides of the Columbia River, respectively.

Horizontal Alignment

There are several key elements to consider when establishing a horizontal alignment. Current concepts have locations that would need to be addressed during the alternatives design development. The design features listed below are a few of the critical elements:

Broken-Back Curves

AASHTO recommends that "broken-back" arrangement of curves (with a short tangent between two curves in the same direction) be avoided. Successive curves in opposite directions meet driver expectation. Broken back curves can violate driver expectations and may degrade traffic operations and safety.

Compound Curves

Where topography or right-of-way restrictions may make compound curves necessary, AASHTO recommends exercising caution when using the design approach. The curve radii of the larger radius should not exceed the smaller radius by more than 50 percent. Compound curves with large differences in radius introduce potential speed reductions that can degrade traffic operations and safety.

Reverse Curves

Reverse curves require sufficient tangent lengths to provide appropriate super-elevation transitions. Back-to-back reverse curves do not allow sufficient transition and create potential operational issues.

Off-Ramp, On-Ramp and Loop Ramp Design

The following factors are critical in the determination of the length of an off-ramp:

- Deceleration length necessary from freeway design speed to ramp speed (especially in the presence of a sharp curve),
- Stopping sight distance to the back of queue, and
- The anticipated 95th percentile queue at the controlled terminal intersection.

For on-ramps, it is critical to know the speed differential between the ramp and the freeway to determine the required acceleration length, as well as the location of the on-ramp to meet the necessary sight distances. In addition, unconventional left-hand ramps should be avoided to maintain design consistency and driver expectation. Further, the number of successive off- and/or on-ramps and the spacing between these ramps are critical in order to provide adequate signing to assist the driver decision process. Combining two or more ramps and reducing access points to the freeway can minimize "friction" along the mainline. However, combining exits can create driver comprehension issues as signs require excessive message units for multiple destinations.

Lane Balance

Lane balance is a critical component of a successful highway design. A lack of lane balance can be the single-most contributor to poor traffic operations, excessive lane changing, and high crash experience. The questions listed below need to be revisited with the traffic volumes anticipated for the specific road sections to determine the required number and arrangement of lanes.

- Is it possible to serve multiple interchanges by one off-ramp from the freeway to the C-D road system and/or on-ramp from the C-D road system to the freeway? What are implications associated with developing the appropriate numbers and arrangement of lanes to accommodate the forecasted demand volumes? Can the facility be appropriately signed?
- Are adequate lane numbers (basic lanes plus auxiliary lanes) at all mainline ramp locations? Have traffic operations been adequately considered in locations of multiple off ramps and especially at two lane exits?
- Are there lane drops on the mainline? If so, what are the appropriate ways to reduce lane numbers while maintaining lane balance?

Profile

Vertical curves must meet the appropriate design speed and have grades that are consistent with the roadway functional classification. The freeway grades are relatively flat and require relatively longer distances between exit gores and subsequent grade separations. Complex ramp systems require extensive evaluations to attain appropriate grades and vertical alignments. These evaluations are critical to ensuring an attainable profile and providing reasonable grades, alignments, and adequate decision and stopping sight distances.

Lane Changing

A C-D road system reduces weaving along the mainline freeway by shifting it to a lower order ramp system. However C-D systems require carefully considering the number (how many roadways are being served) and arrangement (left and right hand ramps) of accesses. Concepts requiring numerous lane changes over short distances can create poor operations caused by excessive signing (affecting driver decision making), weaving, and forced lane changes.

Gore Overlap

Ramps between the freeway and C-D road require a physical overlap of the gore areas. "Gore overlap" is needed to prohibit motorists from making unauthorized movements (across gore point) between the freeway and C-D system.

ASSESSMENT COMMENTS

The attached figures summarize design questions for Concepts 1, 4, 6 and 7. In addition, we thought it would be helpful to provide more specific feedback regarding the WSDOT concepts especially just north of the Columbia River, because the concepts do not conform to contemporary design, operations, safety, and FHWA policy requirements.

OREGON STATE (ODOT) CONCEPTS

We have generalized the topics into two primary categories: Bridgehead and Delta Park related issues. We understand configurations presented in Concepts 1, 4, 6, and 7 have superceded recent design alternatives developed for the I-5/Columbia Boulevard interchange. We will not address the prior interchange concepts at this location.

Bridgehead

Extensive development on Hayden Island creates constraints to physically locate the concept mainline and ramp system while tmodifying the existing local street network. Ramp lengths to and from I-5 should be investigated to ensure that there is sufficient storage and adequate deceleration distance for off ramps and sufficient acceleration distance for on ramps. Local connections on Hayden Island are critical for access and circulation for the various land uses. Ramp terminal intersection signals will need to be coordinated with local signals to provide an integrated system. LRT in this area can affect signal timing and alignment needs.

Delta Park

The Delta Park section is bound to the west by wetlands and to the east by park land. These constraints have clearly dictated the configuration of the various concepts. Depending on the concept, connections between Marine Drive and Interstate Avenue and the mainline have been accommodated in various ways; or not at all. Local street connections provide route choices and connectivity that can take local trips off the interstate system. We recommend investigating the impacts of providing those alternative connections in each concept while being sensitive to environmental impact needs. Given the size of the project, there may be alternatives to mitigate wetland or park impacts within the project corridor. While avoiding impacts is always a priority, at this concept stage, the concept alternatives should not be unduly compromised.

Summary

The ODOT concepts reflect a range of potential configurations with a spectrum of impacts. As the concepts are advanced, there are potential combinations or components between the schemes that may be intermixed. These variations could help optimize transportation system objectives in balance with known corridor constraints. Similarly, the concepts appear to have been developed to avoid corridor impacts. This is admirable and is consistent with objectives to eliminate or minimize impacts. However, it appears that in absolute avoidance of potential impacts, the transportation benefits of a comprehensive roadway network may have been compromised. Future alternatives within the EIS process should investigate the importance of local access and circulation connections to determine the long-term value of creating a well-connected network that meets system planning needs.

The following discussion highlights specific issues at various locations within each concept.

Concept 1

This concept uses the existing bridges for the northbound movements. The current southbound bridge will carry three mainline lanes and the current northbound bridge will be for the

northbound 3-lane C-D roadway. The future southbound traffic will have a new 5-lane bridge over light rail transit (LRT).

Design issues/ locations requiring review

- There appear to be profile issues between the LRT and the southbound ramp from Marine Drive.
- There may be constructability issues or profile conflicts between the I-5 southbound connection to eastbound Marine Drive and the LRT connection.
- At the northbound I-5 onramp from Marine Drive, the ramp gore and divider on the mainline should overlap.
- The southbound exit ramp from I-5 to Hayden Island should be analyzed to verify adequate ramp length can be provided and to be sure there are no profile conflicts with the LRT.

Concept 4

This concept has a new double deck structure over the existing northbound structure. The new mainline bridge will be 6 lanes northbound and 5 lanes southbound. A new bridge would be constructed west of the existing bridges to serve LRT.

Design issues/ locations requiring review

- There could be lane changing and weaving on the ramp connection northbound between the Columbia Boulevard connection and the Victory Boulelvard ramp terminal intersection. Current configurations for the Columbia Boulevard interchange may address this potential issue.
- The "local" movement between Marine Drive and Interstate Avenue occurs via the I-5 mainline. Serving this local movement violates system hierarchy and could degrade mainline operations within this short weaving section.
- The southbound exit ramp from I-5 to Marine Drive should be analyzed to verify that there are no profile conflicts with the LRT alignment.
- It will be challenging to construct the new double deck bridge and maintain mainline and interchanging traffic. The ability to maintain traffic during construction for the freeway, ramps, and local streets should be verified.

Concept 6

This concept maintains the I-5 mainline on the existing lift bridges over the Columbia River. A new 4-lane bridge would be built west of the existing bridges as part of the northbound and southbound C-D system for distribution of local traffic and LRT.

Design issues/ locations requiring review

- Similar to Concept 4, the southbound exit ramp from I-5 to Marine Drive should be analyzed to verify that there are no profile conflicts with the LRT alignment.

- The ramp lengths to the split diamond interchange on Hayden Island appear to be minimal. These ramps should be evaluated to ensure that southbound traffic does not back on to the freeway and that adequate acceleration distance is provided to northbound I-5. The entrance appears to be a parallel type but the speed differential between the ramp and freeway traffic could be significant.

Concept 7

This concept splits the I-5 mainline over three bridges by using the two existing lift spans and adding a new three lane bridge on the east side. A combination LRT and local street bridge would be constructed west of the existing bridges. I-5 northbound would have three lanes on the new bridge. Southbound I-5 will have three lanes on the existing southbound bridge. Two bi-directional lanes (HOV, express, or reversible lanes) would use the existing northbound bridge.

Design issues/ locations requiring review

- The concept of splitting the mainline is unconventional and may not meet driver expectations. At a minimum, this concept creates extensive signing and striping challenges. The traffic operational adequacy of this plan should be verified including investigating if the system can be adequately signed.
- There should be a physical overlap of the gore between the northbound on-ramp from Interstate Avenue and the rightmost northbound freeway travel lane. As proposed, traffic from Interstate Avenue could cross the painted gore area to the left northbound freeway travel lane.
- The profiles between the northbound I-5 on-ramp from Marine Drive and the northbound I-5 off-ramp to Hayden Island should investigated to be sure that the desired grades are attainable.
- The Hayden Island circulation system contains relatively close signal spacing. These signals would need to be coordinated to ensure acceptable operations.

WASHINGTON STATE (WSDOT) CONCEPTS

We have organized the topics into three general categories related to the concepts: Bridgehead, Northbound C-D system, and Southbound C-D system. The following discussion summarizes issues in each category. This section is followed by more detailed observations for each concept in the bridgehead area.

Bridgehead

This area is complex given the close proximity of SR 14, service access to and from downtown Vancouver, and the beginning of the northbound and southbound C-D system. Each of the concepts requires modifications (some rather extensive) to conform to contemporary geometric design practice. These modifications would be needed to ensure that the roadway could physically be constructed and signed to meet operational and safety needs. We believe the required changes will expand the impact area into the Columbia River. Specific changes are likely needed for:

- Providing appropriate I-5 mainline alignments and ensuring adequate numbers and arrangements of lanes;
- Improving the vertical and horizontal geometric design of ramps for the SR 14 interchange;
- Increasing ramp spacing between successive ramps serving SR 14 and the Northbound C-D road system;
- Achieving attainable ramp profiles within the Bridgehead area; and
- Validating the constructability and identifying the potential impacts of temporary roadways.

Northbound C-D System

The proposed C-D system concept is a valid potential solution. Changes appear to be required to provide appropriate horizontal and vertical alignments between the Bridgehead and Mill Plain Boulevard. Minor improvements are needed along its length to assure adequate and safe traffic operations. These changes could result in increased right of way and impacts not currently anticipated based on the current plans.

Southbound C-D System

In concept, the proposed southbound C-D system is also valid; however, the current concept requires extensive revisions to conform to contemporary design practice and achieve desired operational objectives. As presently configured, the schemes are over ambitious in their plan of serving all local access via a C-D system. The conceptual layout requires extensive redesign to meet driver expectations, to provide adequate signing, and to achieve desired traffic operations. The required changes for the Southbound C-D, which are more extensive than the Northbound C-D, would likely result in more extensive impacts than are anticipated based on the current plans.

Summary

The complexity of these concepts can be attributed to the effort to maintain access to both State Routes (14 and 500) and both City arterials (4th Plain and Mill Plain) immediately north of the Columbia River. Retaining all access is a reasonable consideration, however, the appropriate design required to provide this access would be more impacting than the current concepts depict. While the FHWA supports "flexibility in design," there are minimum design requirements that must be met to provide a safe and effective plan.

The close proximity of SR 14 to the Columbia River as well as the constraints of the downtown, Pearson Airpark, and Fort Vancouver create a challenging design task. The current concepts attempt to reduce these impacts, while keeping the interchange influence area off the Columbia River. Unfortunately, the concepts developed within these constraints deviate significantly from contemporary design practice. In some cases the plans may not be constructible nor will they achieve acceptable operational and safety performance.

We appreciate the efforts and challenges undertaken by previous designers. It is understood that the completed design concepts will likely require deviations from "full standard" designs; however, we believe the concepts may dramatically underestimate the likely impacts when applying contemporary design principles. The northbound and southbound C-D concepts will require modifications; particularly southbound, which has more locations needing attention than the northbound system. The "fixes" for the C-D system are relatively straight forward compared to the bridgehead concepts. Adjustments to the C-D system will likely increase the footprint of the schemes. The following discussion focuses on the bridgehead area since changes to the current concepts to attain minimum AASHTO policy objectives could significantly affect the bridge concepts.

BRIDGEHEAD CONCEPTS

Concept 1

This concept uses the existing bridges for the northbound movements. The current southbound bridge will carry three mainline lanes and the current northbound bridge will be for the northbound 3-lane C-D roadway. The future southbound traffic will have a new 5-lane bridge over LRT.

Design issues/ locations requiring review

- The southbound I-5 mainline has horizontal alignment deficiencies including compound curves leading to back-to-back (little to no tangent between) reverse curves.
- The northbound C-D road and I-5 mainline should be physically separated.
- The SR 14 ramp to northbound I-5 profile and connection to the northbound C-D road appears unattainable. SR 14 loop ramp to southbound I-5 horizontal alignment and lane drop in combination with profile that appears unattainable given the shortened ramp and I-5 profile that must be climbing to clear LRT.

Concept 4

This concept has a new double deck structure over the existing northbound structure. The new mainline bridge will be 6 lanes northbound and 5 lanes southbound. A new bridge would be constructed west of the existing bridges to serve LRT.

Design issues/ locations requiring review

- The concept appears nearly impossible to construct (building in the location of the existing northbound bridge) while maintaining current I-5 crossing volumes. Potential use of the future LRT for temporary southbound I-5 traffic would require an extensive temporary roadway that would impact City land and close much of the SR 14 interchange.
- The southbound I-5 mainline has horizontal alignment deficiencies including a "broken back curve," short curve lengths, and insufficient radii to meet design speeds.
- The northbound I-5 mainline has short curve lengths and a broken back alignment.
- The northbound exit to SR 14 does not comply with contemporary design practice for a two-lane exit. The distance to the split to downtown is half of the 800 feet described by

AASHTO. In addition, this connection has back-to-back reverse curves that will not allow for the appropriate amount of super-elevation.

- The northbound I-5 exit to the northbound C-D does not comply with contemporary two-lane exit design. In addition to violating AASHTO policy by dropping two mainline lanes, the plan depicts a ramp with a profile that appears unattainable.

Concept 6

This concept maintains the I-5 mainline on the existing lift bridges over the Columbia River. A new 4-lane bridge would be built west of the existing bridges as part of the north and southbound C-D system for distribution of local traffic and LRT.

Design issues/ locations requiring review

- Northbound I-5 has three successive off ramps with spacing of about 750 feet and 300 feet between the Vancouver ramp and the C-D road. AASHTO states 1,000 feet is the minimum spacing to meet operational and signing needs.
- The SR 14 ramp to the southbound C-D road has a horizontal alignment inconsistent with a State Route ramp and a profile that appears unattainable.
- The profiles for ramps connecting to the northbound C-D road appear to be unattainable.

Concept 7

This concept splits the I-5 mainline over three bridges by using the two existing lift spans and adding a new three lane bridge on the east side. A combination LRT and local street bridge would be constructed west of the existing bridges. I-5 northbound would have three lanes on the new bridge. Southbound I-5 will have three lanes on the existing southbound bridge. Two bi-directional lanes (HOV, express, or reversible lanes) would use the existing northbound bridge.

Design issues/ locations requiring review

- Northbound and southbound I-5 mainline is reduced to <u>two basic lanes</u>. Northbound this occurs just beyond the SR 14 exit: the right lane drops as an auxiliary lane to the northbound C-D as the express lane is added. Southbound this occurs as the left lane is trapped as an express lane and the right lane is added as an auxiliary lane from the southbound C-D road.
- Northbound I-5 has an 800-foot, two-sided weave between the express lane and the exit to the northbound C-D road.
- The northbound exit to SR 14 does not comply with contemporary design practice and would need to be lengthened to provide adequate deceleration
- The northbound exit to the C-D road does not comply with contemporary design practices for length and reverse curves.
- The northbound I-5 entrance ramp from SR 14 has a profile that appears unattainable.
- The SR 14 ramp from the express lane has a profile under the railroad and over the northbound mainline that appears unattainable.

CLOSING

We appreciate the extensive amount of analysis completed over the years; and recognize our review was performed quickly without the benefit of all the potential available background information. However, we trust that our technically objective comments are viewed as opportunities to reduce project risks as the project development process proceeds. We look forward to working with all the previous design staff members to clarify how our observations may not be valid. Similarly, we offer our assistance in working with design staff to mitigate the potential design issues.