INTERSTATE 5 COLUMBIA RIVER CROSSING

Electromagnetic Fields (EMF) Technical Report

May 2008

TO: Readers of the CRC Technical Reports

FROM: CRC Project Team

SUBJECT: Differences between CRC DEIS and Technical Reports

The I-5 Columbia River Crossing (CRC) Draft Environmental Impact Statement (DEIS) presents information summarized from numerous technical documents. Most of these documents are discipline-specific technical reports (e.g., archeology, noise and vibration, navigation, etc.). These reports include a detailed explanation of the data gathering and analytical methods used by each discipline team. The methodologies were reviewed by federal, state and local agencies before analysis began. The technical reports are longer and more detailed than the DEIS and should be referred to for information beyond that which is presented in the DEIS. For example, findings summarized in the DEIS are supported by analysis in the technical reports and their appendices.

The DEIS organizes the range of alternatives differently than the technical reports. Although the information contained in the DEIS was derived from the analyses documented in the technical reports, this information is organized differently in the DEIS than in the reports. The following explains these differences. The following details the significant differences between how alternatives are described, terminology, and how impacts are organized in the DEIS and in most technical reports so that readers of the DEIS can understand where to look for information in the technical reports. Some technical reports do not exhibit all these differences from the DEIS.

Difference #1: Description of Alternatives

The first difference readers of the technical reports are likely to discover is that the full alternatives are packaged differently than in the DEIS. The primary difference is that the DEIS includes all four transit terminus options (Kiggins Bowl, Lincoln, Clark College Minimum Operable Segment (MOS), and Mill Plain MOS) with each build alternative. In contrast, the alternatives in the technical reports assume a single transit terminus:

- Alternatives 2 and 3 both include the Kiggins Bowl terminus
- Alternatives 4 and 5 both include the Lincoln terminus

In the technical reports, the Clark College MOS and Mill Plain MOS are evaluated and discussed from the standpoint of how they would differ from the full-length Kiggins Bowl and Lincoln terminus options.

Difference #2: Terminology

Several elements of the project alternatives are described using different terms in the DEIS than in the technical reports. The following table shows the major differences in terminology.

DEIS terms	Technical report terms
Kiggins Bowl terminus	I-5 alignment
Lincoln terminus	Vancouver alignment
Efficient transit operations	Standard transit operations
Increased transit operations	Enhanced transit operations

360/737-2726 503/256-2726 WWW.COLUMBIARIVERCROSSING.ORG 700 WASHINGTON STREET, SUITE 300, VANCOUVER, WA 98660

Difference #3: Analysis of Alternatives

The most significant difference between most of the technical reports and the DEIS is how each structures its discussion of impacts of the alternatives. Both the reports and the DEIS introduce long-term effects of the full alternatives first. However, the technical reports then discuss “segment-level options,” “other project elements,” and “system-level choices.” The technical reports used segment-level analyses to focus on specific and consistent geographic regions. This enabled a robust analysis of the choices on Hayden Island, in downtown Vancouver, etc. The system-level analysis allowed for a comparative evaluation of major project components (replacement versus supplemental bridge, light rail versus bus rapid transit, etc). The key findings of these analyses are summarized in the DEIS; they are simply organized in only two general areas: impacts by each full alternative, and impacts of the individual “components” that comprise the alternatives (e.g. transit mode).

Difference #4: Updates

The draft technical reports were largely completed in late 2007. Some data in these reports have been updated since then and are reflected in the DEIS. However, not all changes have been incorporated into the technical reports. The DEIS reflects more recent public and agency input than is included in the technical reports. Some of the options and potential mitigation measures developed after the technical reports were drafted are included in the DEIS, but not in the technical reports. For example, Chapter 5 of the DEIS (Section 4(f) evaluation) includes a range of potential “minimization measures” that are being considered to reduce impacts to historic and public park and recreation resources. These are generally not included in the technical reports. Also, impacts related to the stacked transit/highway bridge (STHB) design for the replacement river crossing are not discussed in the individual technical reports, but are consolidated into a single technical memorandum.

360/737-2726 503/256-2726 WWW.COLUMBIARIVERCROSSING.ORG 700 WASHINGTON STREET, SUITE 300, VANCOUVER, WA 98660

Title VI

The Columbia River Crossing project team ensures full compliance with Title VI of the Civil Rights Act of 1964 by prohibiting discrimination against any person on the basis of race, color, national origin or sex in the provision of benefits and services resulting from its federally assisted programs and activities.

Americans with Disabilities Act (ADA) Information

If you would like copies of this document in an alternative format, please call the Columbia River Crossing project office at (360) 737-2726 or (503) 256-2726. Persons who are deaf or hard of hearing may contact CRC using Telecommunications Relay Service by dialing 7-1-1.

¿Habla usted español? La informacion en esta publicación se puede traducir para usted. Para solicitar los servicios de traducción favor de llamar al (503) 731-3490.

This page intentionally left blank.

Cover Sheet

Interstate 5 Columbia River Crossing

Electromagnetic Fields (EMF) Technical Report:

Submitted By:

Gary Maynard

This page intentionally left blank.

TABLE OF CONTENTS

List of Exhibits

This page intentionally left blank.

ACRONYMS

Acronym	Description
AC	Alternating Current
ACGIH	American Conference of Government Industrial Hygienists
ADA	Americans with Disabilities Act
CRC	Columbia River Crossing
DC	Direct Current
ELF	Extremely Low Frequency Fields
EMF	Electric and Magnetic Fields
EPA	U.S. Environmental Protection Agency
FCC	Federal Communications Commission
G	Gauss
HCT	High Capacity Transit
Hz	Hertz
ICNIRP	International Commission on Non-Ionizing Radiation Protection
kHz	Kilohertz
kV	Kilovolt
kV/m	Kilovolts per Meter
LRT	Light Rail Transit
mG	milligauss
MHz	Megahertz
V	Volt
VLF	Very Low Frequency

This page intentionally left blank.

1. Summary

1.1 Introduction

This report assesses the potential for human health impacts from exposure to electromagnetic fields (EMF) during operation of the new high-capacity transit facilities proposed as part of the I-5 Columbia River Crossing (CRC) project. Alternatives 3 and 5 include the potential extension of the TriMet MAX light rail transit (LRT) system from its existing terminus at Delta Park into Vancouver, Washington. Alternatives that include extending the light rail line would result in the generation of EMF and thus could have potential impacts. Alternatives that do not involve extending LRT would not produce any appreciable amounts of EMF above existing levels.

This report relies on measurements of EMF from existing sections of the MAX LRT and available data on similar light rail systems in California. Based on EMF measurements and available data, operation of future segments of the MAX LRT are unlikely to generate sufficiently intense levels of EMF to cause significant exposure risks to human health. The anticipated intensities of electromagnetic fields at locations where humans would be exposed (within and adjacent to the LRT right-of-way, near power substations, or in the light rail vehicles) are considerably below exposure guidelines set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the American Conference of Governmental Industrial Hygienists (ACGIH).

1.2 Description of the Alternatives

The alternatives being considered for the CRC project consist of a diverse range of highway, transit and other transportation choices. Some of these choices – such as the number of traffic lanes across the river – could affect transportation performance and impacts throughout the bridge influence area or beyond. These are referred to as “system-level choices.” Other choices – such as whether to run high-capacity transit (HCT) on Washington Street or Washington and Broadway Streets – have little impact beyond the area immediately surrounding that proposed change and no measurable effect on regional impacts or performance. These are called “segment-level choices.” This report discusses the impacts from both system- and segment-level choices, as well as “full alternatives.” The full alternatives combine system-level and segment-level choices for highway, transit, pedestrian, and bicycle transportation. They are representative examples of how project elements may be combined. Other combinations of specific elements are possible. Analyzing the full alternatives allows us to understand the combined performance and impacts that would result from multimodal improvements spanning the bridge influence area.

Following are brief descriptions of the alternatives being evaluated in this report, which include:

- System-level choices,
- Segment-level choices, and
- Full alternatives.

1.2.1 System-Level Choices

System-level choices have potentially broad influence on the magnitude and type of benefits and impacts produced by this project. These options may influence physical or operational characteristics throughout the project area and can affect transportation and other elements outside the project corridor as well. The system-level choices include:

- River crossing type (replacement or supplemental)
- High-capacity transit mode (bus rapid transit or light rail transit)
- Tolling (no toll, I-5 only, I-5 and I-205, standard toll, higher toll)

This report compares replacement and supplemental river crossing options. A replacement river crossing would remove the existing highway bridge structures across the Columbia River and replace them with three new parallel structures – one for I-5 northbound traffic, another for I-5 southbound traffic, and a third for HCT, bicycles, and pedestrians. A supplemental river crossing would build a new bridge span downstream of the existing I-5 bridge. The new supplemental bridge would carry southbound I-5 traffic and HCT, while the existing I-5 bridge would carry northbound I-5 traffic, bicycles, and pedestrians. The replacement crossing would include three through-lanes and two auxiliary lanes for I-5 traffic in each direction. The supplemental crossing would include three through-lanes and one auxiliary lane in each direction.

Two types of HCT are being considered – bus rapid transit and light rail transit. Both would operate in an exclusive right-of-way through the project area, and are being evaluated for the same alignments and station locations. The HCT mode – LRT or BRT – is evaluated as a system-level choice. Alignment options and station locations are discussed as segment-level choices. BRT would use 60-foot or 80-foot long articulated buses in lanes separated from other traffic. LRT would use one- and two-car trains in an extension of the MAX line that currently ends at the Expo Center in Portland.

Under the efficient operating scenario, LRT trains would run at approximately 7.5 minute headways during the peak periods. BRT would run at headways between 2.5 and 10 minutes depending on the location in the corridor. BRT would need to run at more frequent headways to match the passenger-carrying capacity of the LRT trains. This report also evaluates performance and impacts for an increased operations scenario that would double the number of BRT vehicles or the number of LRT trains during the peak periods.

1.2.2 Segment-Level Choices

See Exhibit 1-1 for a map of the project area and segment boundaries.

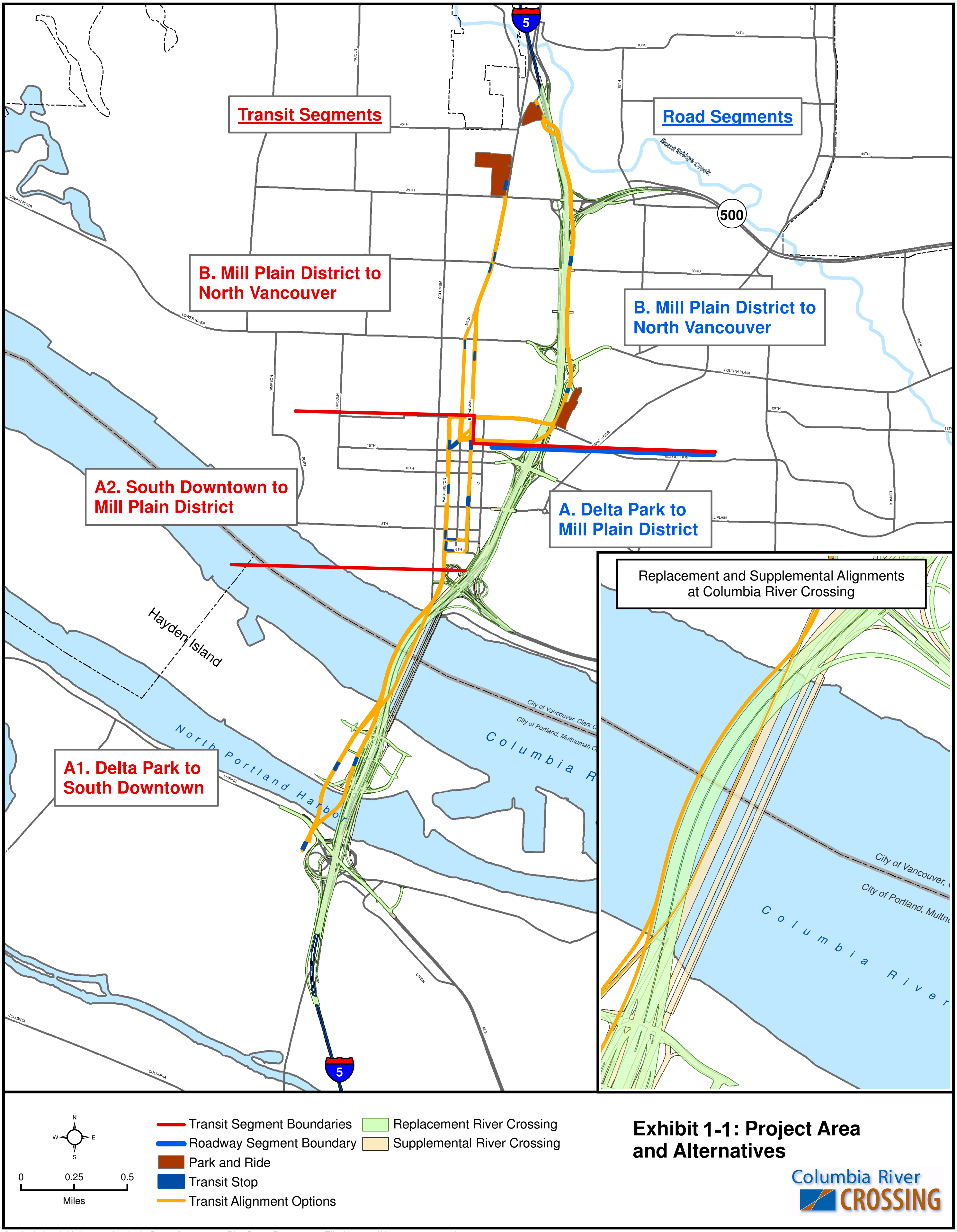

Exhibit 1-1: Project Area and Alternatives

Analysis by J. Koloszar; Analysis Date: Aug.-2007; Plot Date: Dec.-2007; File Name: JH_014_8x11.mxd

The transit alignment choices are organized into three corridor segments. Within each segment the alignment choices can be selected relatively independently of the choices in the other segments. These alignment variations generally do not affect overall system performance but could have important differences in the impacts and benefits that occur in each segment. The three segments are:

- Segment A1 – Delta Park to South Vancouver
- Segment A2 – South Vancouver to Mill Plain District
- Segment B – Mill Plain District to North Vancouver

In Segment A1 there are two general transit alignment options - offset from, or adjacent to, I-5. An offset HCT guideway would place HCT approximately 450 to 650 feet west of I-5 on Hayden Island. An adjacent HCT guideway across Hayden Island would locate HCT immediately west of I-5. The alignment of I-5, and thus the alignment of an adjacent HCT guideway, on Hayden Island would vary slightly depending upon the river crossing and highway alignment, whereas an offset HCT guideway would retain the same station location regardless of the I-5 bridge alignment.

HCT would touch down in downtown Vancouver at Sixth Street and Washington Street with a replacement river crossing. A supplemental crossing would push the touch down location north to Seventh Street. Once in downtown Vancouver, there are two alignment options for HCT – a two-way guideway on Washington Street or a couplet design that would place southbound HCT on Washington Street and northbound HCT on Broadway. Both options would have stations at Seventh Street, 12th Street, and at the Mill Plain Transit Center between 15th and 16th Streets.

From downtown Vancouver, HCT could either continue north on local streets or turn east and then north adjacent to I-5. Continuing north on local streets, HCT could either use a two-way guideway on Broadway or a couplet on Main Street and Broadway. At 29th Street, both of these options would merge to a two-way guideway on Main Street and end at the Lincoln Park and Ride located at the current WSDOT maintenance facility. Once out of downtown Vancouver, transit has two options if connecting to an I-5 alignment: head east on 16th Street and then through a new tunnel under I-5, or head east on McLoughlin Street and then through the existing underpass beneath I-5. With either option HCT would connect with the Clark College Park and Ride on the east side of I-5, then head north along I-5 to about SR 500 where it would cross back over I-5 to end at the Kiggins Bowl Park and Ride.

There is also an option, referred to as the minimum operable segments (MOS), which would end the HCT line at either the Mill Plain station or Clark College. The MOS options provide a lower cost, lower performance alternative in the event that the full-length HCT lines could not be funded in a single phase of construction and financing.

1.2.2.1 Highway and Bridge Alignments

This analysis divides the highway and bridge options into two corridor segments, including:

- Segment A – Delta Park to Mill Plain District
- Segment B – Mill Plain District to North Vancouver

Segment A has several independent highway and bridge alignment options. Differences in highway alignment in Segment B are caused by transit alignment, and are not treated as independent options.

The replacement crossing would be located slightly downstream of the existing I-5 bridge. At the SR 14 interchange there are two basic configurations being considered. A traditional configuration would use ramps looping around both sides of the mainline to provide direct connection between I-5 and SR 14. A less traditional design could reduce right-of-way requirements by using a "left loop" that would stack both ramps on the west side of the I-5 mainline.

1.2.3 Full Alternatives

Full alternatives represent combinations of system-level and segment-level options. These alternatives have been assembled to represent the range of possibilities and total impacts at the project and regional level. Packaging different configurations of highway, transit, river crossing, tolling and other improvements into full alternatives allows project staff to evaluate comprehensive traffic and transit performance, environmental impacts and costs.

Exhibit 1-2 summarizes how the options discussed above have been packaged into representative full alternatives.

Exhibit 1-2. Full Alternatives

	Packaged Options				
Full Alternative	River Crossing Type	HCT Mode	Northern Transit Alignment	TDM/TSM Type	Tolling Method[a]
1	Existing	None	N/A	Existing	None
2	Replacement	BRT	I-5	Aggressive	Standard Rate
3	Replacement	LRT	I-5	Aggressive	Two options[b]
4	Supplemental	BRT	Vancouver	Very Aggressive	Higher rate
5	Supplemental	LRT	Vancouver	Very Aggressive	Higher rate

[a] In addition to different tolling rates, this report evaluates options that would toll only the I-5 river crossing and options that would toll both the I-5 and the I-205 crossings.

[b] Alternative 3 is evaluated with two different tolling scenarios, tolling and non-tolling.

Modeling software used to assess alternatives' performance does not distinguish between smaller details, such as most segment-level transit alignments. However, the geographic difference between the Vancouver and I-5 transit alignments is significant enough to warrant including this variable in the model. All alternatives include Transportation Demand Management (TDM) and Transportation System Management (TSM) measures designed to improve efficient use of the transportation network and encourage alternative transportation options to commuters such as carpools, flexible work hours, and telecommuting. Alternatives 4 and 5 assume higher funding levels for some of these measures.

Alternative 1: The National Environmental Policy Act (NEPA) requires the evaluation of a No-Build or "No Action" alternative for comparison with the build alternatives. The No-Build analysis includes the same 2030 population and employment projections and the same reasonably foreseeable projects assumed in the build alternatives. It does not include any of the I-5 CRC related improvements. It provides a baseline for comparing the build alternatives, and for understanding what will happen without construction of the I-5 CRC project.

Alternative 2: This alternative would replace the existing I-5 bridge with three new bridge structures downstream of the existing bridge. These new bridge structures would carry Interstate traffic, BRT, bicycles, and pedestrians. There would be three through-lanes and two auxiliary lanes for I-5 traffic in each direction. Transit would include a BRT system that would operate in an exclusive guideway from Kiggins Bowl in Vancouver to the Expo Center station in Portland. Express bus service and local and feeder bus service would increase to serve the added transit capacity. BRT buses would turn around at the existing Expo Station in Portland, where riders could transfer to the MAX Yellow Line.

Alternative 3: This is similar to Alternative 2 except that LRT would be used instead of BRT. This alternative is analyzed both with a toll collected from vehicles crossing the Columbia River on the new I-5 bridge, and with no toll. LRT would use the same transit alignment and station locations. Transit operations, such as headways, would differ, and LRT would connect with the existing MAX Yellow Line without requiring riders to transfer.

Alternative 4: This alternative would retain the existing I-5 bridge structures for northbound Interstate traffic, bicycles, and pedestrians. A new crossing would carry southbound Interstate traffic and BRT. The existing I-5 bridges would be re-striped to provide two lanes on each structure and allow for an outside safety shoulder for disabled vehicles. A new, wider bicycle and pedestrian facility would be cantilevered from the eastern side of the existing northbound (eastern) bridge. A new downstream supplemental bridge would carry four southbound I-5 lanes (three through-lanes and one auxiliary lane) and BRT. BRT buses would turn around at the existing Expo Station in Portland, where riders could transfer to the MAX Yellow Line. Compared to Alternative 2, increased transit service would provide more frequent service. Express bus service and local and feeder bus service would increase to serve the added transit capacity.

Alternative 5: This is similar to Alternative 4 except that LRT would be used instead of BRT. LRT would have the same alignment options, and similar station locations and requirements. LRT service would be more frequent (approximately 3.5 minute headways during the peak period) compared to 7.5 minutes with Alternative 3. LRT would connect with the existing MAX Yellow Line without requiring riders to transfer.

1.3 Summary of Impacts

Under the No-Build Alternative there would be no construction of a high-capacity transit line into Washington. Thus, there would be no potential for an increased risk of EMF exposures to the general public.

There would be no EMF-related impacts related to the highway alignment options. The CRC light rail options (Alternatives 3 and 5) would extend the existing MAX system, and would bring similar EMF levels to the new parts of the line. Where people could be exposed (within and near the light rail right-of-way, near power substations, or in the light rail vehicles) EMF emissions would be considerably below exposure guidelines set by the International Commission on Non-Ionizing Radiation Protection and the American Conference of Governmental Industrial Hygienists. While the light rail option would generate higher EMF intensities than bus rapid transit, none of the options or alternatives would pose significant EMF exposure risks to human health.

This page intentionally left blank.

2. Methods

2.1 Introduction

Potential cumulative effects from this project are evaluated in the Cumulative Effects Technical Report. Please refer to this report for an evaluation of possible cumulative effects.

The methods used in this report relied primarily on existing literature sources and field measurements of EMF. The following supplied information for this report:

- Literature on the TriMet light rail system, which included EMF measurements conducted for use in the Central Link EIS for Sound Transit in Seattle.
- Literature on electromagnetic field measurements of light rail systems similar to the TriMet system, such as the Santa Clara Valley Transit System in San Francisco and the Regional Rail Transit system in Sacramento.
- Literature on potential health effects from exposure to electromagnetic fields.

Data and measurements from the TriMet rail system and similar rail systems were used in comparison to exposure standards for electromagnetic fields as the basis for the assessment of probably human health impacts.

2.2 Effects Guidelines

There are no federal laws that limit exposure to EMF. Several agencies had been considering developing standards such as the U.S. Food and Drug Administration, U.S. Department of Defense, and the EPA. The Federal Communications Commission (FCC) has recently adopted and enforces limits for exposure in the workplace and out in public areas for radiofrequency radiation from AM, FM television and wireless sources (47 CFR 1.1307(b)).

Two organizations have developed voluntary occupational guidelines for EMF exposure. The guidelines are intended to prevent EMF effects such as nerve stimulation or inducing currents in cells (these effects have been shown to occur in higher frequency EMF than typically occurs in residences or occupations). These organizations include the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in association with the World Health Organization and the American Conference of Governmental Industrial Hygienists (ACGIH). Exhibit 2-1 shows the exposure guidelines for the typical power frequency (60 Hz) that have been developed by ICNIRP and ACGIH. The values shown in the table may be exceeded for several minutes.

Exhibit 2-1. Exposure Guidelines for Power Frequency (60 Hz) EMF

Exposure at 60 Hz	Electric Field (kV/m)	Magnetic Field (mG)
International Commission on Non-Ionizing Radiation Protection		
Occupational	8.3	4,200
General Public	4.2	833
American Conference of Governmental Industrial Hygienists		
Occupational Exposure Should not Exceed	25	10,000
Prudence Dictates Use of Protective Clothing Above this Level	15	---
Exposure of Workers with Cardiac Pacemakers Should not Exceed this Level	1	1,000

Source: ICNIRP and ACGIH.

Washington State has no standards relating to EMF exposure. Oregon does have a standard for electric field exposure. The electrical field exposure standard for Oregon is 9 kV/m within the right-of-way of an electrical transmission line.

The Oregon Energy Facilities Siting Council (Oregon Department of Energy) has a “prudent avoidance policy” safety standard. Many utility companies have adopted this policy. A prudent avoidance policy is the exercising of sound judgments and caution in dealing with EMF. For example, limiting or avoiding exposure to EMF particularly in the workplace. This type of policy arose based on the absence of absolute scientific proof that EMF affects human health (e.g., causes cancer).

3. Coordination

Coordination is not applicable to this technical report.

This page intentionally blank.

4. Affected Environment

4.1 Introduction to EMF

Electric and magnetic fields are an invisible force of radiated energy that is produced by many natural and man-made sources. Natural sources include the earth itself, which generates a weak magnetic field from currents flowing deep within the magma of the earth's core (the intensity of this DC magnetic field is approximately 500 milligauss [mG]). Air turbulence and other atmospheric activity such as lightning can also create electric fields (WHO 2005). Human sources of EMF are generally produced by electrical systems such as wireless telecommunications (including cell phones), electric motors, electronics, power transmission and distribution lines, and other electrically powered equipment.

Scientists have classified EMF into an electromagnetic spectrum based on the wavelength and frequency of the various forms of radiation (expressed in hertz—Hz—or the number of wave cycles per second). The spectrum ranges from direct current (zero Hz) and extremely low frequency (ELF) radiation (3 to 3,000 Hz) to radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, x-rays and gamma rays (10^{20} to 10^{22} Hz). Some types of operations can generate electromagnetic energy in many frequencies simultaneously such as welding which produces energy in the ultraviolet, visible, infrared, radiowave, and ELF range. The typical power frequency used in the United States (such as in electrical transmission and distribution lines and residential wiring) is in the ELF range and is 60 Hz. EMF from electrical systems in the ELF range will be the focus of analysis for the purposes of this report.

In a typical situation that involves electrical wiring, an electrical field is generated. For example, a lamp or microwave oven that is plugged into a wall socket but turned off will generate an electrical field from the voltage in the line. The voltage can be thought of as "electrical pressure" in the line or the potential to do work, which is measured in volts (V) or kilovolts (kV). The electrical field produced by the voltage is measured in volts per meter (V/m). Once the lamp or oven is turned on it creates an electrical current through the line. This electrical current produces a magnetic field in addition to the electrical field. Magnetic fields are measured in units of gauss (G) (or tesla). Since most magnetic field exposure involves a fraction of a gauss, EMF exposure is typically measured in milligauss (1/1,000th of a gauss).

Electrical systems can be either direct current (DC) or alternating current (AC). Direct current is defined as the unidirectional flow or movement of the electric charge through a line. The intensity of the current can vary with time, but the general direction of movement stays the same at all times.

The electricity in residences and power lines is alternating current (AC). Alternating current does not move in one direction, but instead moves back and forth. The power frequency used in the United States alternates back and forth 60 times per second. This frequency is measured in Hertz (Hz), thus the typical frequency for electricity within a line (such as in household wiring or high voltage power transmission lines) is 60 Hz. Power line AC can be converted to DC by means of a power supply consisting of a transformer, a rectifier (which prevents the flow of current from reversing), and a filter (DC is used to power the MAX light rail system in Portland).

Electric and magnetic fields are stronger closer to the source and decrease with distance. For example, the electrical field directly beneath a 115 kV (kilovolt) power line is approximately 1.0 kV/m and the magnetic field is approximately 35 mG. At 50 feet, the electrical field is approximately 0.4 kV/m and the magnetic field is approximately 7 mG. Similarly, at 100 and 200 feet, the electrical field is approximately 0.07 kV/m and 0.01 kV/m, and the magnetic field is approximately 2 mG and 0.5 mG, respectively.

Research indicates electrical fields can be greatly reduced by the walls of homes (electric fields in homes are generated almost entirely by household wiring and appliances). However, magnetic fields are not blocked by most materials and can enter homes from nearby power lines. Magnetic fields in homes are also commonly caused by the electrical appliances and wiring within a home. These internal sources of magnetic fields can extend into rooms other than where the source is located. For example, if an electrical appliance is located near a wall, its magnetic field will extend into the room on the other side of the wall.

Electrical and magnetic fields that occur in the same place can add to or subtract from the strength of the field. For example, if there are two separate 60 Hz sources located at the same place and each has a field strength of 4 volts per meter (V/m); and if they are alternating in strength and direction together at 60 Hz (i.e., they are exactly in phase), then the electrical field will be 8 V/m. If the two fields are exactly out of phase then the field will measure 0 V/m. Because of this property, power companies frequently situate their high voltage lines in close proximity and operate them at different phases to help cancel out their electric and magnetic fields.

Exhibit 4-1 shows some typical ranges of electric and magnetic fields at the surface of the human body from power lines (directly beneath the power line) and next to an appliance (at a distance of 6 inches).

Exhibit 4-1. Approximate Strength of Average Electric and Magnetic Fields at the Surface of the Body Produced by Common Sources of 60 Hertz Fields

Power Source	Electrical Field (kV)	Magnetic Field (mG)
500 kV Electricity Transmission Line	0.9–7.5	20–800
Electrical Distribution Line	0.009–0.12	0.6–30
Electric Blanket	0.1–3.0	5–100
Shaver	0.05–1.0	100–1,500
Toaster	0.005–0.09	5–20
Microwave		100–300
Average Household Background Level	0.002–0.02	0.2–9
Copy Machine		4–200
Fax Machine		4–9
PC Video Display Terminal		7–20

Source: Department of Engineering and Public Policy, Carnegie Mellon University & Bonneville Power Administration.

4.2 Regional Conditions

The existing EMF environment in the API varies depending on location, as EMF levels are site and time-specific. The main sources of EMF considered in this report are the electrical lines associated with the TriMet MAX light rail system. The following discussion describes the MAX system.

MAX is served by two local utilities with three-phase AC electricity at 12.5 to 13.8 kV (Porter and Helig 2003). There is a system in place to regulate the electrical load so that loads throughout the system are balanced. The substations convert AC power into DC power for the overhead lines. The traction power substations for the Interstate MAX substations are rated at 1 MW. The other MAX line substations are rated at 750 kW. Substations along the alignments convert high voltage AC power from the public supply system to the 750-volt DC system used to power the trains. Substations are located approximately one mile apart.

The MAX light rail line uses a 750-volt DC overhead system to deliver power to the cars. The overhead system (catenary) is made up of either a single or dual wire. In the API, the catenary system is a dual wire (messenger and contact wire). Other elements of the light rail system use either AC or DC electricity for power. These include electricity for lights, signals, and switches along the alignment.

Generally, strong magnetic fields are not associated with the operation of light rail trains. The major LRT sources that generate magnetic fields are associated with the traction power and the control equipment under the vehicle's floor (Federal Railroad Administration 1993).

For the purposes of a study of EMF for the Sound Transit Link LRT project in Seattle, measurements were taken of the TriMet MAX system to help evaluate possible EMF effects from the new light rail line (Edelson and Holmstrom 1998). DC magnetic fields were measured at distances of 10, 20, and 30 meters (approximately 32, 65, and 98 feet, respectively) from the MAX light rail track. The results are shown in the Exhibit 4-2 and reflect measurements taken at an open field location with a DC magnetometer.

Exhibit 4-2. Magnetic Field Strength at Distance from MAX Light Rail Tracks (mG)

	10 Meters	20 Meters	30 Meters
Horizontal	167	44.6	13.3
Vertical	17.8	8.22	3.43

Source: Edelson and Holmstrom 1998.

As shown in the table, the DC magnetic field diminishes with distance from the track. The highest value was 167 mG at 32 feet from the track. These values are well below the ICNIRP standard of 833 mG for general public exposure to magnetic fields.

DC magnetic fields were measured at stations and substations during a recent site visit and found to range from 107 to 601 mG at substations (measured at the perimeter of the buildings that enclosed the Delta Park and Killingsworth substations). DC field intensities ranged from 47 to 551 mG at stations (Delta Park and Killingsworth). Similar to the DC magnetic field measurements conducted in 1998, the field intensities at the stations and substations were below the general public exposure standards.

AC magnetic field measurements were also made at rail stops and substations during the field visit. The AC magnetic field levels at light rail station stops (Delta Park and Killingsworth) fluctuated depending on the movement of the light rail cars (higher values were associated with the cars accelerating) and ranged from 0.76 to 12.77 mG at a distance of 3 feet from the track. The levels of the AC magnetic fields at the substations ranged from almost zero to 2.86 mG (measured at the perimeter of the buildings that enclosed the Delta Park and Killingsworth substations).

Measurements of AC and DC magnetic fields conducted at 20 feet from the Killingsworth station showed the predicted decrease in field strengths as AC fields ranged from 0.76 to 1.47 mG and DC fields ranged from 86 to 199 mG.

Measurements of EMF at other light rail systems have produced similar results. For example the Vascona Corridor for the Santa Clara Valley, California light rail system measured magnetic field strength at four light rail stations and one substation in 1999 (Santa Clara Valley Transportation Authority 2005) with the following results:

- At a distance of 20-30 feet from the closest track, DC magnetic fields were typically within a few hundred mG of the Earth’s ambient DC field (approximately 500 mG).
- Measured AC magnetic fields were typically 5 mG or less within 10 feet of the tracks and 2 mG or less at 20 feet from the track
- At the perimeter of substations, DC magnetic field levels ranged from 194-921 mG. AC magnetic fields ranged from 0.3 mG to 31.3 mG. (The higher levels at the substation were thought to be caused by the location of underground electrical feeder cables.)

The existing levels of AC and DC magnetic fields from MAX are largely isolated in the TriMet owned right-of-way because field intensities are relatively low and decrease quickly with distance from the track (and overhead catenary lines). This is also true of the substations. Thus, it is unlikely that there have been any exposures at adjacent residences located along the light rail line or near substations that would be a cause for concern since they do not exceed the ICNIRP exposure standards.

The general public and train operators are also currently exposed to EMF at station stops and in the light rail cars themselves. AC magnetic field measurements were taken in the light rail cars during a recent site visit (between the Delta Park and Killingsworth stations) and found to fluctuate from approximately 0.38 to 8.13 mG at a height of approximately 20 inches from the floor (approximate seat height). Thus, EMF emissions were also very low within the light rail vehicles.

To provide some perspective to the potential exposures of EMF from light rail, this section presents the results of a survey conducted for the EMF Rapid Program (a program conducted under the National Institutes of Health). The purpose of the 1997 survey was to characterize personal magnetic field exposure in the general population (Enertech Consultants 1998). Slightly over 1,000 people participated in the survey of exposure over a 24-hour period. The results indicated approximately 14 percent of the general population is exposed to a 24-hour average magnetic field strength exceeding 2 mG. About 25 percent of the people spent more than one hour at fields greater than 4 mG, and 9 percent spend more than one hour at fields greater than 8 mG. Approximately 1.6 percent of people experience at least one gauss (1,000 mG) during a 24-hour period.

Compared to the study above, the typical time that people would be riding the MAX system and would be exposed to its magnetic fields is very low, and when averaged over a 24-hour period would amount to an insignificant exposure from this source of EMF.

This page intentionally left blank.

5. Long-Term and Temporary Effects

5.1 Potential Human Health Effects of EMF

No excessive EMF emissions would occur during construction

It is uncertain whether 60 Hz fields pose health risks. Scientists have found that electric and magnetic fields produce biological effects on humans and animals such as changes in the cell growth rates and intercellular communication (American Medical Association 1994). However, scientists do not agree on EMF's potential health effects because the available evidence is fragmentary, complex, and often inconclusive. The problem has been exacerbated by less careful studies, which have produced results that are contradictory to other studies (NIEHS 1991 and 2002).

Three kinds of studies have been done on EMF. These include: 1) laboratory studies that expose single or groups of cells and organs to EMF under a variety of conditions and look for effects; 2) laboratory studies that expose animals or humans to EMF and look for effects; and 3) epidemiological studies of varying human population groups which look for an association between EMF and diseases.

Researchers in the laboratory have studied the effects of EMF on isolated tissue and cells. These studies have indicated changes in cell growth rates, intercellular communication, movement of calcium ions and levels of various enzymes. The scientific community however, does not agree on the biological significance of these results. While changes from EMF have been shown to occur, it is uncertain what effect these changes have on human health or the incidence of diseases.

Laboratory studies have also found several effects from EMF on animals. Effects attributed to these fields include changes in behavior and activity, biological rhythms, some hormone levels, bone fracture healing, response to drugs and learning abilities. These effects have been small and required special conditions in the laboratory to achieve. For example, in some cases for changes to take place, very strong fields were needed, while in other studies, changes only occurred under certain field frequencies.

Epidemiological studies involve research on the statistical occurrence and possible causes of disease in human populations. These studies have resulted in conflicting conclusions. Some studies have found an association with cancer and certain types of power lines. Associations have been found for both increased occurrences of cancer and decreased occurrences of cancer for those living in proximity to power lines. Other studies have concluded that there is no association whatsoever.

Overall, the biological and epidemiological results suggest that there may be a link between EMF and certain diseases, however at this time no cause and effect relationship has been established. The most widely accepted consensus concerning the effects of EMF on human health is that more research is needed.

5.2 Impacts from Full Alternatives

This section describes the impacts from five full alternatives including the No-Build Alternative. These are combinations of highway, river crossing, transit and pedestrian/bicycle alternatives and options covering all of the CRC segments. They represent the range of system-level choices that most affect overall performance, impacts and costs. The full alternatives are most useful for understanding the regional impacts, performance and total costs associated with the CRC project.

5.2.1 No-Build Alternative (Alternative 1)

Under the No-Build Alternative there would be no construction of a high-capacity transit line into Washington. Thus, there would be no potential for an increased risk of EMF exposures to the general public.

5.2.2 Replacement Crossing with BRT and I-5 Standard Toll (Alternative 2)

There would be no appreciable amounts of EMF generated by this alternative and thus there would be no increased risk of EMF exposures to the general public.

5.2.3 Replacement Crossing with LRT and I-5 Standard Toll (Alternative 3 Toll)

The LRT system would be extended under this alternative, which would result in the operation of electrical power sources of AC and DC magnetic fields, particularly the overhead catenary lines and power substations. EMF would be generated from these sources during operation and the public (internal receptors) would be exposed to EMF along the light rail tracks, near substations, at station stops, and in the light rail cars.

It is anticipated that future levels of EMF along the extended LRT line will be identical to those produced in the current light rail system, since the elements of the system such as power levels, substation ratings, and facility and system design would not change. Because the current levels of EMF are not considered excessive and fall below the ICNIRP exposure standards there would be no expected adverse risk to human health.

External receptors located at greater distances from the MAX electrical system than passengers or MAX workers would also receive some exposure to EMF from the MAX line. However, because field strengths decrease rapidly with distance and generated field intensities are below the ICNIRP exposure standards, there would be no expected effect on the health of external receptors.

5.2.4 Replacement Crossing with LRT and No Toll (Alternative 3 No-Toll)

The potential impacts from EMF would be the identical to those described under Alternative 3.

5.2.5 Supplemental Crossing with BRT and I-5 Higher Toll (Alternative 4)

There would be no appreciable amounts of EMF generated by this alternative and thus there would be no increased risk of EMF exposures to the general public.

5.2.6 Supplemental Crossing with LRT and I-5 Higher Toll (Alternative 5)

The potential impacts from EMF would be identical to those described under Alternative 3.

5.3 Impacts from Segment-level Options

There would be no EMF-related impacts related to the highway alignment options.

The only difference between the transit alignment options for LRT is that EMF emissions would occur in one place or the other. There would be no difference in the field intensities generated by the LRT. However, because the EMF levels are low and decrease rapidly with distance there would be no expected adverse health effects from EMF exposure (see Section 5.2.2).

This page intentionally left blank.

6. Mitigation for Long-Term Effects

The levels of anticipated EMF would be low and under the exposure standards for either the workplace or general public. Thus, mitigation would not be necessary.

The design and location of facilities can help to reduce the intensity of magnetic fields and exposure of the public to EMF. Some examples include ensuring that all electrical equipment is operated with a good ground system and that proper shielding is provided for all electrical lines. Where electrical lines are located in close proximity, the frequency of electrical lines can be phased to cancel out the magnetic or electrical fields.

This page intentionally left blank.

7. Permits and Approvals

No permits or approvals associated with EMF-related impacts are required for any of the alternatives.

This page intentionally left blank.

8. References

ACGIH. 2007. American Conference of Governmental Industrial Hygienists.

Edelson, C. R., Holmstrom, F. R. Magnetic Field Study – Impact of Impact of Proposed Light Rail Line on University of Washington Physics Laboratories, August 30, 1998.

Enertech Consultants. 1998. Survey of Personal Magnetic Field Exposure – Phase II: 1,000-Person Survey, EMF Rapid Program, Engineering Project #6. Prepared by Enertech Consultants, Lee, Massachusetts for Lockheed Martin Energy Systems, Oak Ridge, Tennessee.

Federal Railroad Administration. 1993. Safety of High Speed Guided Ground Transportation Systems, EMF Exposure Environments Summary Report. (FRA/ORD-93/28.) Washington, DC.

International Commission for Non-Ionizing Radiation Protection. 1998. Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields. Health Physics 74:494-522.

NIEHS. 1999. NIEHS Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields. National Institute of Environmental Health Services, National Institutes of Health. NIH Publication No. 99-4493.

NIEHS. 2002. EMF, Electric and Magnetic Fields Associated with the Use of Electric Power. National Institute of Environmental Health Services, National Institutes of Health. http://www.niehs.nih.gov/emfrapid.

Porter, Dennis and Thomas Helig. 2003. Light Rail Electrification - *One Break Point is Enough Traction Power Simulation in Portland.* Transportation Research Circular E-C085: 9th National Light Rail Transit Conference.

Santa Clara Valley Transportation Authority. 2005. Capitol Expressway Corridor Final Environmental Impact Report. State Clearinghouse #2001092014

WHO 2005. World Health Organization. What are Electromagnetic Fields? Website: www.who.int/peh-emf/about/WhatisEMF/en/print.html.

This page intentionally left blank.