# Appendix H: Geology and Soils Discipline Report

# Point Defiance Bypass Project


# Soils and Geology Discipline Report

Washington State Department of Transportation

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# Summary

## Affected Environment and Effects

The Project lies within the southern Puget Sound Lowland, an elongated topographic and structural depression filled with a complex sequence of sediments deposited by glacial processes and non-glacial geologic processes similar to those of the present day. Soil originating from the Vashon Stade of the Fraser Glaciation is present across most of the project alignment. This soil is relatively dense and typically has high strength. Since the retreat of the Vashon glacial ice, fluvial and lacustrine sediments have been deposited along rivers and streams and in closed topographic depressions. The fluvial and lacustrine deposits are less dense and have lower strength than the glacial deposits and are considered to be susceptible to liquefaction.

### No Build Alternative

No construction effects are anticipated for the No Build Alternative.

Operational effects of the No Build Alternative include continued instability of steep slopes along the existing rail alignment and effects related to earthquake activity. Liquefiable soil is present along the existing rail alignment from TR Junction near the Puyallup River to about Old Town Tacoma and in scattered areas along the BNSF alignment along Puget Sound. Soil liquefaction can result in settlement and lateral deformation of the tracks in areas where liquefiable soil is present. Liquefaction occurs when vibrations within a soil mass cause the soil particles to temporarily lose contact with one another. As a result, the soil behaves like a liquid, has an inability to support weight, and can flow down slopes (lateral spreading). Damage as a result of earthquake activity would likely result in temporary discontinuation of train traffic until repairs can be made. Soil and organic debris from steep slopes along the tracks could potentially block drainage ditches, resulting in erosion and possibly contributing to continued landsliding along the No Build Alternative alignment, which may also disrupt train operations.

### Build Alternative

Potential construction effects as a result of the Project include increased wind and water erosion from land clearing operations and from cuts into existing slopes; sloughing and shallow landsliding on overly steep temporary excavation slopes; poor drainage control, which could affect temporary excavation slopes and adjacent properties; and damage to pavements as a result of heavy construction traffic.

Potential physical effects as a result of the Project include changes to the topography and landscape along the alignment.

Potential operational effects as a result of the Project include damage to the tracks and structures as a result of soil liquefaction and lateral spreading. Areas of concern include:

- The vicinity of I-705 (Rail MP 2.1 to Rail MP 2.2);
- Between about Tacoma Avenue South (Rail MP 2.7) and South "M" Street (Rail MP 3.2); and
- The portion of the alignment east of East "G" Street (Rail MP 1.8)

Liquefaction can result in significant settlement and lateral deformation of the tracks in areas where liquefiable soil is present. Embankment failure, especially east of Freighthouse Square, may also occur due to a loss of underlying soil strength and lateral spreading displacement of the soil toward the Puyallup River. Damage as a result of earthquake activity would likely result in temporary discontinuation of train traffic until repairs can be made.

The track sections between Pacific Avenue (Rail MP 2.3) to about East "M" Street (Rail MP 3.2) and the steep hillside traversed by the BNSF main line south of I-5 (Rail MP 20.0) are located in landslide hazard areas. In these sections, landsliding could result in blocked drainage ditches and possibly temporarily block the tracks with debris, disrupting train operations.

## Recommended Minimization

### No Build Alternative

No minimization is proposed for the No Build Alternative.

### Build Alternative

Potential effects as a result of the Project are generally minor in nature and most can be easily addressed using proper construction means and methods and employing Best Management Practices (BMPs) during construction.

To address the potential construction effects of the Project , a *Temporary Erosion and Sediment Control Plan* will be prepared for approval in accordance with BMPs included in WSDOT's *Highway Runoff Manual*

(WSDOT 2010a) and procedures in the National Pollutant Discharge Elimination System (NPDES) guidelines administered by the Washington State Department of Ecology (Ecology website, 2011). Other controls that may be implemented include restriction of work activities to the dry season and limiting access to the site. Areas disturbed during construction would be paved or permanently restored as soon as possible. Trucks hauling soil would be covered to prevent material from being deposited onto roadways.

Temporary excavation slopes would be evaluated and designed by experienced structural and geotechnical engineers and sloped accordingly to prevent surface sloughing and shallow landsliding. Proper erosion control and surface water runoff BMPs would be implemented to prevent sedimentation and destabilizing temporary excavation slopes. Permanent cut slopes would be no steeper than two horizontal feet to one vertical foot (2H:1V) and vegetated as soon as possible. Properly designed retaining walls would be used where permanent cut slopes cannot be constructed at 2H:1V or flatter.

All fill and pavement areas would be sloped to drain away from construction areas and prevent ponding of water and softening of sub-grade soils. Drainage water from construction areas would be directed into suitable drainage features in accordance with BMPs. No water would be allowed to drain out over existing slopes, into excavations, or onto sub-grade areas.

Damage to pavement would be minimized by choosing construction traffic routes that avoid areas of potential soft sub-grade and/or inadequate pavement thickness. If no alternative exists, portions of existing roadways with pavement sections inadequate for handling construction traffic may be removed and replaced with pavement sections of appropriate thickness. Alternatively, pavement damage caused by construction traffic could be mitigated by replacing the damaged pavement following completion of construction. New pavement would be designed by a qualified civil or geotechnical engineer in accordance with American Association of State Highway and Transportation Officials (AASHTO) guidelines.

Potential operational effects of the Project related to the soil conditions along the project alignment would be mitigated by proper design of Project elements. The Project would be designed considering the seismicity of the site and the design guidelines presented in WSDOT's *Highway Runoff Manual* (WSDOT 2010a), *Design Manual* (WSDOT, 2010b), and *Bridge Design Manual* (WSDOT, 2011), AASHTO's Load and Resistance Factor Design Bridge Design Specifications (AASHTO, 2010), the AREMA *Manual for Railway Engineering* (AREMA, 2011), and the International Building Code (ICC, 2009).

Permanent drainage facilities for slopes, walls, or fills would be designed for anticipated water flows. All permanent drainage systems would be installed so that water does not overflow and is not directed onto slopes or other areas that may be sensitive to erosion or landsliding. The Project includes drainage features, such as ditches, that are not currently present or are inadequate along the existing rail. Such features would likely reduce the effects of uncontrolled or undesirable surface water runoff.

# Chapter 1 – Project Description

## Introduction

Under the High-Speed Intercity Passenger Rail (HSIPR) Program and pursuant to a programmatic Tier I Environmental Assessment (EA) the Federal Railroad Administration (FRA) has approved an application from the Washington State Department of Transportation (WSDOT) to improve the Pacific Northwest Rail Corridor (PNWRC), a federally designated high-speed rail corridor. One project included in the PNWRC application is the Point Defiance Bypass Project (the Project), which would respond to deficiencies in the existing rail operations around Point Defiance. This Discipline Report has been prepared in support of the project-specific EA for the Point Defiance Bypass project.

The Project is located in Pierce County along an existing approximately 20-mile rail corridor between Tacoma and Nisqually.1 The Project would provide for the re-routing of Amtrak passenger trains from the BNSF rail line that runs along the southern Puget Sound shoreline (Puget Sound route) to the Point Defiance Bypass route, an existing rail corridor that runs along the west side of I-5. The Project would consist of railroad track and support facility improvements, and relocation of the Tacoma Amtrak Station to Freighthouse Square in Tacoma.

## Purpose and Need

As described above, the Point Defiance Bypass route is part of the larger PNWRC. Within Washington State, the vision for the PNWRC is to "…improve intercity passenger rail service by reducing travel times and achieving greater schedule reliability in order to accommodate growing intercity travel demand…"[2].

The purpose of the Project is to provide more frequent and reliable high-speed intercity passenger rail service along the PNWRC between Tacoma and Nisqually. In conformity with the decisions under the Tier 1 Programmatic EA, the PNWRC Improvement Program has reduced the overall environmental effects of providing improved passenger rail service

[1] *The three owners of the project corridor are Sound Transit, Tacoma Rail, and BNSF.*
[2] *WSDOT 2009*

with the use of an existing transportation corridor and associated infrastructure, rather than creating a new corridor.

The Project is needed to address the deficiencies in the existing rail alignment around Point Defiance. The existing alignment (Puget Sound route), shared by freight and passenger rail traffic, is near capacity and is therefore unable to accommodate additional high-speed intercity passenger rail service without substantial improvements. In addition, the existing alignment has physical and operational constraints that adversely affect both passenger train scheduling and reliability.

Improving intercity passenger rail service in the project area and meeting the Project needs would be accomplished by:

- Enhanced Frequency: Increasing Amtrak Cascades round-trips from four to six by 2017 to meet projected service demands.
- Improved Reliability: Reducing scheduling conflicts with freight trains that often result in delays, and by minimizing or avoiding operational delays (e.g., drawbridge openings) and weather-related delays (e.g., mudslides), and improving on-time performance from 68 percent to 88 percent.
- Enhanced Efficiency: Enhancing the efficient movement of people by decreasing trip times by 10 minutes, and reducing the amount of time passenger trains spend yielding to freight movements.
- Improved Safety: Constructing at-grade crossings with upgraded safety features, including wayside horns, median barriers, advance warning signals, and traffic signal improvements.

## What alternatives are being considered for the Point Defiance Bypass Project?

FRA and WSDOT conducted an evaluation of three build alternatives: the Point Defiance Bypass Alternative, the Shoreline Alternative, and the Greenfield Alternative. Two of the alternatives (the Shoreline Alternative, and the Greenfield Alternative) were eliminated from further study. Although both alternatives could meet the Project's purpose and need, they were determined to be impracticable and unfeasible due to technical constraints, high construction costs, and significant environmental effects. Grade separations were also evaluated for further consideration. FRA and WSDOT's preliminary analysis revealed that current and projected future traffic volumes do not warrant the construction of new grade-separated crossings.

## What's happening in the bypass corridor today?

The rail line between TR Junction and East "D" Street in Tacoma hosts both freight and commuter trains, including freight operators Tacoma Rail and BNSF, and Sound Transit's *Sounder* commuter rail service. Freight train traffic between TR Junction and East "D" Street averages under two trains per day, while Sound Transit currently operates 18 trains per day between Freighthouse Square and Seattle each weekday, and also offers occasional special event trains, usually on weekends, to serve sporting and other events in Seattle. *Sounder* service to Lakewood begins in late 2012.

## What would happen if the Project were not built?

If the Project were not built (the No Build Alternative), Amtrak's Cascades and Coast Starlight passenger train service would continue to use the existing Puget Sound route. The No Build Alternative includes only the minor maintenance and repair activities necessary to keep the existing Puget Sound route operational. With the No Build Alternative, it would be expected that as freight traffic increases, congestion would adversely affect Amtrak service reliability, and the travel time for Amtrak trains between Seattle and Portland would increase.

Along the Point Defiance Bypass route, the Tacoma Rail and BNSF freight services would continue. The at-grade crossings at Clover Creek Drive Southwest, North Thorne Lane Southwest, Berkeley Street Southwest, 41st Division Drive, and Barksdale Avenue Southwest would not be upgraded.

Sound Transit's *Sounder* commuter passenger trains will become operational in late 2012 between the Tacoma Dome Station at Freighthouse Square in Tacoma and Sound Transit's Lakewood Station (on the Point Defiance Bypass route) with as many as 18 *Sounder* trains per day.

## What are the proposed improvements and related activities of the Point Defiance Bypass Project?

The Project consists of railroad track and support facility improvements, and the relocation of Amtrak's Tacoma Station. Exhibit 1 shows the components of the Build Alternative. The following details specific components of the Build Alternative.

- **Construct New Track Adjacent to the Existing Main Line –** A new 3.5-mile track adjacent to the existing main line would be constructed from South 66th Street (Rail MP 6.9) in Tacoma to between Bridgeport

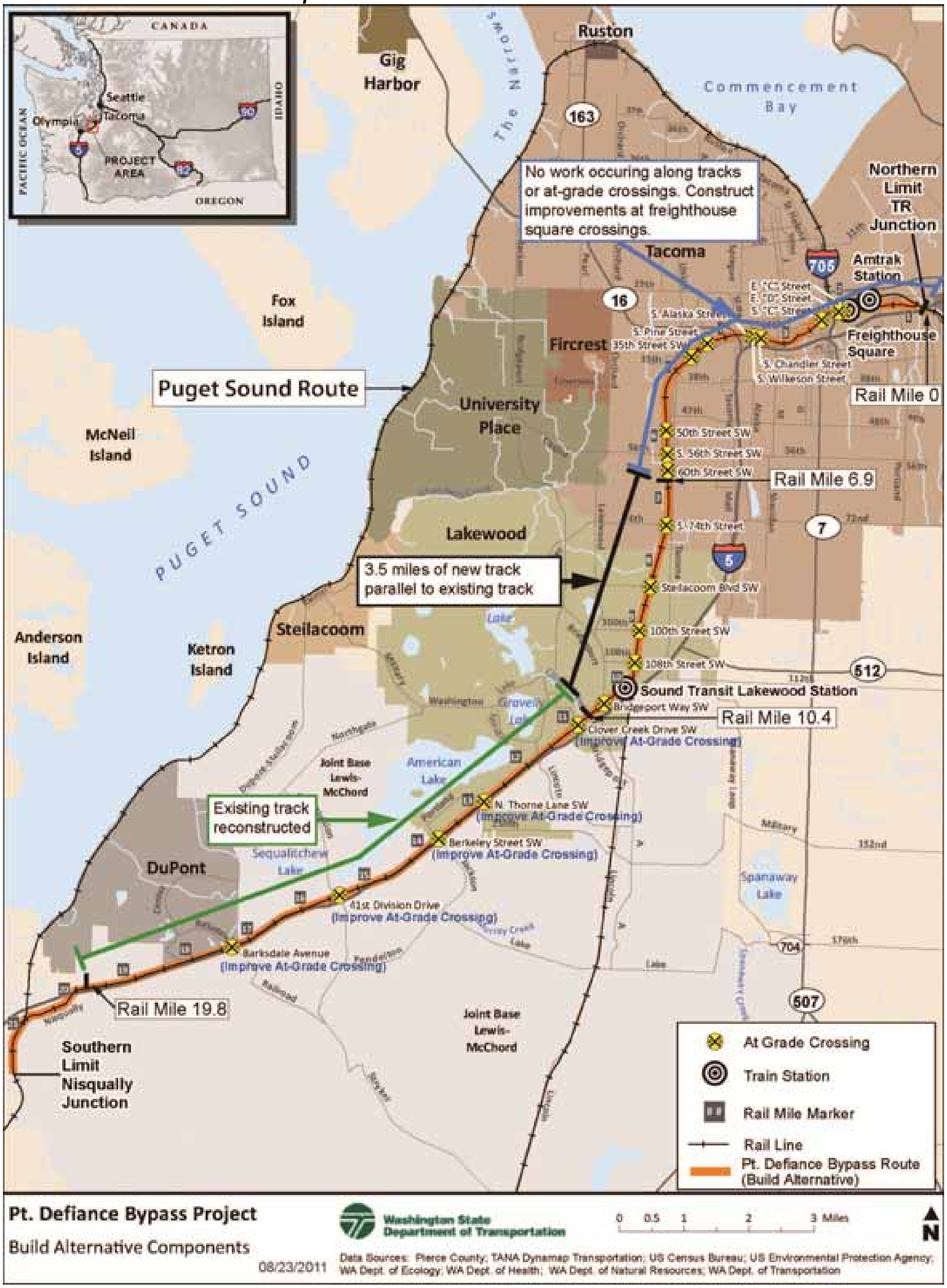
Way SW (Rail MP 10.4) and Clover Creek Drive SW (Rail MP 10.9) in Lakewood.

- **Reconstruct and Rehabilitate the Existing Main Line** – Starting just southwest of Bridgeport Way Southwest (Rail MP 10.4) in Lakewood, the existing track would be reconstructed to a location southeast of the I-5/Mounts Road Southwest interchange (Rail MP 19.8) at Nisqually Junction.
- **Improvements at at-Grade Crossings** – Several grade crossings would be improved with wayside horns, gates, traffic signals and signage, sidewalks, median separators, and warning devices. These crossings include Clover Creek Drive Southwest, North Thorne Lane Southwest, Berkeley Street Southwest, 41st Division Drive and Barksdale Avenue.
- **Tacoma Amtrak Station Relocation** – The existing Tacoma Amtrak Station would be relocated from its Puyallup Avenue location to the Tacoma Dome Station at Freighthouse Square, at 430 E. 25th Street in Tacoma.

## What are the proposed operational changes that would result from the Point Defiance Bypass Project?

Amtrak's existing Cascades and Coast Starlight passenger train service would be rerouted from the Puget Sound route along the Puget Sound shoreline to the Point Defiance Bypass route. The Project would also provide for additional Amtrak Cascades service by increasing the number of round trips provided from 4 to 6, or a total of 12 Cascades service train trips. Amtrak Coast Starlight would also travel on the Point Defiance Bypass route for a total of two Coast Starlight service train trips. The speed of these passenger trains would be up to 79 mph.

***Exhibit 1. Build Alternative Components***



# Chapter 2 – Methodology

The purpose of this *Soils and Geology Discipline Report* is to identify soil and geologic conditions and associated potential hazards, assess the potential effects of the Project with respect to soils and geology, and if found appropriate, identify measures to mitigate potential adverse effects.

## What was the methodology for this analysis?

Geologic and soil conditions were reviewed because the Project would involve the movement and alteration of soil and rock materials. Geologic information of the study area was obtained by collecting and reviewing existing data, and conducting geologic and geotechnical reconnaissance to assess surface conditions, geologic hazards, and likely subsurface conditions. Understanding the geology and soils in the study area is necessary to understand and limit potential environmental effects.

Information was collected from Pierce County Critical Areas Mapping, City of Tacoma Critical Areas Mapping, Pierce County Soil Survey (NRCS, 1979), US Geological Survey (USGS) Geology Maps, Washington Department of Natural Resources Geology Maps, and previous geotechnical reports.

Project files and archives from several sources were reviewed to obtain site-specific geotechnical subsurface information along the Project corridor. These efforts were concentrated on sources where large amounts of information were already stored and easily accessed. Data, primarily consisting of boring logs, were collected from the following sources:

- Consultant project files
- WSDOT
- City of Lakewood
- Sound Transit

Sources of existing subsurface information are listed in the Reference section of this report. In addition, information contained in the previous *Soils and Geology Discipline Report* (WSDOT, 2007) was incorporated into this report as appropriate.

In addition, between November 2006 and May 2011, Project teams conducted field visits to the study area to assess surface conditions, geologic hazards, and likely subsurface conditions. The site reconnaissance completed in May 2011 was restricted to public rights of way between 100th Street Southwest (Rail MP 9.1) and Gravelly Lake Drive (Rail MP 11.7) and between North Thorne Lane Southwest (Rail MP 12.8) and Berkeley Street Southwest (Rail MP 13.7). No subsurface information investigations were conducted as part of this study.

Based on the information obtained from the studies above, both the Build and the No Build alternatives were evaluated with respect to their potential geologic effects. Preliminary evaluations were made related to geologic hazards, earthquakes, and other geologic issues. The evaluations were made based on experience with similar projects and similar soil conditions, and conceptual engineering analyses. Potential operational effects were identified including seismic hazards, steep slope hazards, erosion, and ground vibrations. Potential construction effects were identified including erosion, excavation, and fill stability; groundwater effects; settlement; and ground vibration. Potential secondary and cumulative effects were also identified.

If the potential for effects to these resources was found, recommended BMPs were developed for each effect identified. The recommended BMPs were selected based on experience with similar projects and accepted industry standard engineering practices.

# Chapter 3 – Affected Environment

## What is the study area?

For the purposes of this report, the study area is defined as the corridor that lies within 1,000 feet both left and right of the centerline of the Project, including relocating the Tacoma Amtrak Station to the Tacoma Dome Station at Freighthouse Square.

## What are the existing conditions in the study area?

### Geologic Setting

The study area lies in the southern portion of the Puget Lowland, an elongated topographic and structural depression filled with a complex sequence of unconsolidated sediments deposited during the Pleistocene (from approximately 2 million to 12,000 years ago). These sediments were deposited by glacial processes associated with the incursion of large, glacial ice sheets into the Puget Lowland and by non-glacial geologic processes similar to those of the present day. These unconsolidated deposits overlie bedrock, which lies approximately 1,000-1,700 feet below the ground surface in the study area (Jones, 1996).

The Puget Lowland was glaciated six or more times during the Pleistocene. The last glaciation, known as the Vashon Stade of the Fraser Glaciation, receded from the area about 13,500 years ago. This ice sheet is estimated to have been about 3,000 feet thick in the vicinity of the study area. Since retreat of the Vashon glacial ice, fluvial and lacustrine sediments have been deposited along rivers and streams and in closed topographic depressions.

### Topography

From TR Junction (Rail MP 1.0) to East “G” Street (Rail MP 1.8), the topography along the rail line is of low relief and lies along the southern side of the Puyallup River Valley between approximately elevation 10-30 feet above sea level. From East “G” Street, the topography begins to rise upward from the Puyallup River Valley to a broad upland plateau with relatively low relief that lies between approximate elevations of 200-400 feet to the I-5 crossing (Rail MP 20.0) then decreases to about elevation 70 feet at the southern terminus of the study area.

Most of the rail line is situated on the broad upland plateau. Coastal bluffs that descend to waters of Puget Sound bound the west side of the upland plateau. Steep bluffs that descend to the lowland floodplains of the Puyallup and Nisqually rivers bound the northeast and southwest sides of the upland plateau, respectively. The east side of the plateau is bounded by the Cascade foothills.

The upland surface comprises numerous north-trending ridges and swales and numerous large topographic channels that trend westerly, which control the orientation of many of the upland stream channels. The upland is also occupied by numerous closed depressions, some of which are occupied by small lakes and poorly drained areas.

The portion of the rail line along the Puyallup River to about East “G” Street (Rail MP 1.8) lies within a low-relief alluvial plain. The orientation of surface features is generally controlled by the Puyallup River.

The existing rail line extends westward from the Puyallup River Valley to about Pacific Avenue (Rail MP 2.3), then climbs upward to the Nalley Valley at South “M” Street (Rail MP 3.2), then turns southward and traverses across the upland plateau to the southern edge of the plateau along the Nisqually River Valley. With the exception of the portion of the rail line between Pacific Avenue and South “M” Street, most of the study area is flat, with a few moderately sloped depressions. Hillside slopes along the portion of the rail line between Pacific Avenue and South “M” Street are moderate to very steep. Hillside slopes at the southern end of the study area, south of the I-5 crossing (Rail MP 20.0), are also moderate to very steep.

### Study Area Geology

Geologic mapping in the vicinity of the study area includes work by Smith (1972, 1976) and Walsh (1987). The geology in the vicinity of most of the study area has been recently remapped by Troost (in review), Troost et al. (in review) and Walsh et al. (2003).

The generalized geology in the vicinity of the study area is depicted in Attachment A, Figures A-1 through A-10, which is adapted from Troost (in review), Troost et al. (in review), Walsh (1987), and Walsh et al. (2003). Descriptions of the geologic units used in the geologic map are presented in Exhibit 2

***Exhibit 2. Surficial Geology in the Study Area***

| Unit Designation | Geologic Unit | Description |
|---|---|---|
| af | Fill and Modified Land | Clay, silt, sand, gravel, organic matter, riprap, and debris or a mixture of. Includes engineered and non-engineered fills. Mapped only where fill placement is extensive, sufficiently thick to be of geotechnical significance, and readily verifiable. |
| Qal | Alluvium | River or creek deposits, normally associated with historical streams, including overbank deposits. Sand; silty sand; gravelly sand; very loose to medium dense. |
| Qmw | Colluvium and Alluvial Fan Deposits | Loose soil and glacial sand and gravel deposited by soil creep and shallow raveling on hill slopes and alluvial fan deposition, some of which occurred during the waning stages of the Vashon Stade of the Fraser Glaciation. |
| Qp | Peat | Depression fillings of organic materials. Peat; peaty silt; very soft to medium stiff. |
| Qgof, Qvr | Recessional Glacial Outwash | Recessional Outwash – Recessional Lacustrine (Qgof) and Glaciofluvial sediment (Qvr) deposited as glacial ice retreated. Lacustrine deposits of clayey and sandy silt associated with glacial Lake Russell and other lakes of Vashon glacial recession; soft to medium stiff. Glaciofluvial deposits include Steilacoom gravel; sand, gravelly sand or sandy gravel; medium dense to dense. |
| Qvi | Ice Contact Deposits | Heterogeneous soils deposited against or adjacent to ice during the wasting of glacial ice; commonly reworked; stratified to irregular bodies of gravel, sand and silt; loose to dense. |
| Qvie | Eskers | Sinuous, steep-walled mounds of loose gravel and sand deposited in ice-confined channels by glacial meltwater. |
| Qvt | Glacial Till | Lodgment till laid down along the base of the glacial ice. Gravelly, silty sand or gravelly, sandy silt; very dense; "hardpan;" boulders and cobbles common. |
| Qva | Advance Outwash | Glaciofluvial sediment deposited as glacial ice advanced, sand, gravelly sand, or sandy gravel; dense to very dense. |
| Qpogc | Pre-Olympia | Coarse-grained pre-Olympia glacial deposits. |

The topography and near-surface geology of the study area is largely the product of the last glaciation (Vashon). The Vashon glaciation left a prominent pattern of north-trending ridges and swales as the glacial ice crossed the upland plateau, and left deposits of sand and gravels that mantle the upland surface. The Vashon and older deposits in the Tacoma area form a sequence of permeable sand and gravel layers separated by finer-grained layers of clay and silt or other low permeable soils, which are exposed in places along the steep slopes that border the upland plateau. The Vashon and older deposits comprise several aquifers (a geologic formation that contains sufficient saturated permeable material to yield water to wells and springs) and aquitards (geologic formations that may contain groundwater but are incapable of transferring that water to a well or spring) within the subsurface, which control subsurface water movement from the upland to the lowland as well as the locations of streams and creeks that occupy former outwash channels (Jones et al., 1999).

On the hillside areas on both sides of the alignment corridor, a complex series of glacially overridden soils (soils that were compacted by the weight of overriding glacial ice) layers are present. These soils were deposited during glacial events and during interglacial periods (periods where no glaciers were present) that were similar to the present-day environment.

In general, most of the alignment crosses the low relief, upland surface, where most existing cuts into the subsurface along this portion of the current alignment are relatively small. The portion of the track section from TR Junction (Rail MP 1.0) to the upland area is generally at grade, with the exception of the portion from East “K” Street (Rail MP 1.5) to Freighthouse Square, which is elevated on a trestle. No adjustments to the track or changes in operational speed are planned as part of the Project. As such, only near-surface geologic materials are pertinent to an understanding of potential effects to the environment from the Project.

The predominant geologic unit along the rail line corridor is mapped as Vashon-age recessional outwash, which was deposited as the glaciers retreated. Ice contact deposits, advance outwash, pre-Fraser deposits, alluvium, and fill are mapped east of about South “M” Street (Rail MP 3.2). Ice contact deposits are mapped near DuPont and advance outwash is mapped along the rail line south of the I-5 overpass (Rail MP 20.0).

Recessional outwash rivers scoured channels in the landscape and deposited sand and gravel. The most significant recessional event was that relating to the Steilacoom gravel, a geologic formation of coarse gravel deposited in south- and west-trending channels carved by torrential floodwaters released from a former proglacial lake that occupied the Puyallup River Valley. The proglacial lake was created by a stagnant ice sheet.

Along the rail line corridor, Steilacoom gravel is commonly about 20 feet thick but locally can be much thicker. In the study area, this deposit chiefly consists of openwork gravel with abundant cobbles. Openwork gravel is coarse gravel deposited in high-energy streams and rivers, resulting in the removal and subsequent absence of fine-grained particles from the void spaces between the gravel particles. Steilacoom gravel was not overridden by glacial ice, so it is generally medium dense. These highly permeable deposits at or near the ground surface are significant aquifer recharge areas and are highly susceptible to environmental contamination of groundwater.

Glacial till from the Vashon glaciation mantles much of the upland area to the east and generally underlies the recessional deposits along the rail line, with the exception of the portion of the rail line through the Nalley Valley. The torrential floodwaters released from the former proglacial lake that occupied the Puyallup River Valley scoured through the glacial till and into the advance outwash, exposing glacial till and advance outwash on the Nalley Valley sides. Glacial till is an unstratified and unsorted mixture of sand, gravel, silt, and clay deposited at the base of a glacier and subsequently overridden by the ice and compacted to a very dense state by the weight of the overriding ice. Glacial till has very low permeability and typically acts as an aquitard, restricting the downward flow of groundwater and reducing recharge of deeper aquifers. Till occurs at or near the ground surface within the study area and makes up the core of low hills that are present in the vicinity of the alignment. Where till is exposed at the ground surface, runoff is likely to be rapid, with very little infiltration of precipitation.

Glacial till is commonly covered by a relatively thin layer of sediments that were deposited during retreat of the ice sheet. These recessional deposits include ablation till, ice contact deposits, glacial outwash, and recessional lacustrine (lake environment) deposits. These materials were deposited away from the ice by meltwater streams that flowed from the retreating glacier or deposited in place as the stagnant ice melted.

Post-glacial deposits in the vicinity of the study area include alluvium, depression fillings, and fill. Alluvium is sediment deposited by water flowing in streams. Alluvium is likely to be present along present-day streams and rivers, such as Murray Creek (Rail MP 13.9), Clover Creek (Rail MP 10.8), and the Puyallup and Nisqually rivers. Where encountered, alluvium is likely to consist of loose sand and gravelly sand to silt and sandy silt. A thick accumulation of alluvium is present along the Puyallup River east of TR Junction (Rail MP 1.0) and along the Nisqually River, west of the existing rail line, as shown in Attachment A, Figures A-1 and A-10.

Depressions in the ground surface following retreat of the Vashon glaciation became lakes and ponds that slowly filled with fine-grained (silt and clay) soil. Organic material and peat also accumulated as these lakes turned into bogs and marshes. These organic deposits are commonly associated with existing wetlands or a previous marsh environment. These deposits are present on either side of the Tacoma/Lakewood city boundary line. Localized deposits too small to have been mapped may be crossed by the alignment.

Fill is mapped along the project alignment between TR Junction (Rail MP 1.0) and East “G” Street (Rail MP 1.8) and is present along numerous other places along the alignment. Fill is soil placed by humans, and it can have widely varying properties, depending on the material used as fill and whether the fill was placed in an engineered or non-engineered fashion.

Fill is present along portions of the existing rail alignment. The fill was placed during construction of the existing Sound Transit-owned rail line and the BNSF main line to provide a uniform grade. Such areas of fill are likely to be of limited depth and extent.

The embankment fill that supports the rail line at about Rail MP 20.3 appears to be unstable. Based on field observations (Shannon & Wilson, 2009a), an approximately 300-foot-long section of the embankment has moved slightly downward. This movement may reflect settlement or failure of the fill or of the relatively soft or loose soils inferred to underlie portions of the embankment.

At the Freighthouse Square station location, the surficial geology has been mapped (Troost in review) as generally consisting of ice contact deposits, Vashon glacial till, and pre-Fraser deposits. Though not shown on the geologic map of the area, surficial fill is present at the site. The mapped geology in the study area is generally consistent with conditions observed in the borings completed in the vicinity of the site (Landau Associates, 2008a), though glacial till was not encountered in the borings.

There are no unique or protected geologic resources, or geologic resources of specific local interest, identified in the study area.

### Soils

According to the US Department of Agriculture Soil Conservation Service Soil Survey of Pierce County Area, Washington, the predominant soils in the study area are Spanaway gravelly sandy loam (NRCS, 1979). The soil survey does not map soils within cities or military reservations; therefore, soils along portions of the alignment within the Tacoma city limits and JBLM have not been mapped. Spanaway gravelly sandy loam soils are formed in glacial outwash on uplands and are described as somewhat excessively drained with moderately rapid permeability. In areas underlain by these soils, runoff is slow and there is little erosional hazard. These soils are generally a good source of sand and gravel for construction purposes.

Within the broad area of mapped Spanaway soils, localized depressions in the upland area are mapped as being underlain by DuPont muck. The only area of these soft soils within or very near the study area is south of 84$^{th}$ Street S (Rail MP 8.0). Infiltration is slow in these soils.

The slopes that border the plateau in the northern and southern portion of the study area are not included in the soil survey because of their location within the City of Tacoma and within JBLM, respectively.

Extrapolating from the closest adjacent areas that were mapped, Puyallup fine sandy loam soil is likely present in the area along the Puyallup River to about East “G” Street (Rail MP 1.8). Puyallup fine sandy loam is derived from sandy alluvium, infiltration is moderate to rapid, and there is only a slight erosion hazard. West of about East “G” Street to the upland area west of South Chandler Street (Rail MP 3.4), the soils are likely of the Alderwood and Kitsap Series. Alderwood gravelly sandy loam is derived from glacial till and permeability is very slow. The erosion hazard varies from slight for gentle slopes to moderate to severe for steeper slopes. Kitsap silt loam is derived from fine-grained, glacial lacustrine deposits and permeability is very slow. The erosion hazard varies from slight for gentle slopes to severe to very severe for steeper slopes. On steep slopes, these soils are susceptible to landsliding.

Extrapolating from the closest adjacent areas that were mapped, Spanaway gravelly sandy loam, Nisqually loamy sand, and Kitsap silt loam soils are likely present in the southern portion of the study area within JBLM. Nisqually loamy sand is derived from sandy glacial outwash and has a high permeability. In areas underlain by these soils, infiltration is rapid and there is only a slight erosion hazard. Kitsap silt loam is derived from fine-grained, glacial lacustrine deposits and permeability is very slow. In areas underlain by these soils, the erosion hazard is moderate. These soils are susceptible to landsliding.

There are no unique or protected geologic resources, or geologic resources of specific local interest, identified in the study area.

### Surface Water and Groundwater

Surface water and groundwater over most of the rail alignment are controlled primarily by soil conditions and topography. In the northern portion of the rail alignment, groundwater is controlled primarily by the Puyallup River. The topography across the upland portion of the study area is generally flat and the soils are coarse-grained and permeable. Rather than flowing overland and forming streams, most of the precipitation falling in the vicinity of the study area infiltrates directly into the highly pervious soils (Steilacoom gravel). The only streams within the study area are Murray Creek (Rail MP 13.9) and Clover Creek (Rail MP 10.8). Flett Creek lies just outside of the study area.

Water that infiltrates into the ground migrates laterally through the shallow groundwater system. The groundwater table over most of the upland area is approximately 10-40 feet below the ground surface. The water table commonly intersects larger depressions in the upland surface resulting in standing bodies of water in these depressions, such as American Lake and Gravelly Lake. Because of rapid infiltration and the shallow groundwater system, the aquifer formed by Steilacoom gravel is highly susceptible to contamination. From TR Junction (Rail MP 1.0) to Freighthouse Square, groundwater is generally shallow and is highly susceptible to contamination.

### Geologic Hazards

Washington State's Growth Management Act (Chapter 36.70A RCW) requires all cities and counties to identify critical areas within their jurisdictions and to formulate development regulations for their protection. Among the critical areas designated by the Growth Management Act are geologically hazardous areas, defined as such because of their potential susceptibility to erosion, sliding, earthquake, or other geologic events, or because of their past use (e.g., landfill). These areas may not be suitable for development consistent with public health and safety concerns without conducting specific studies during the design and permitting process. Potential geologic hazards that may affect the study area are discussed below. Some of these hazards are identified as regulated critical areas of Pierce County (PALS, 2011), which also includes the City of Lakewood, and the City of Tacoma (2010), and are discussed in a separate section. Geologic hazards and critical areas may be regulated differently within different jurisdictions within the study area.

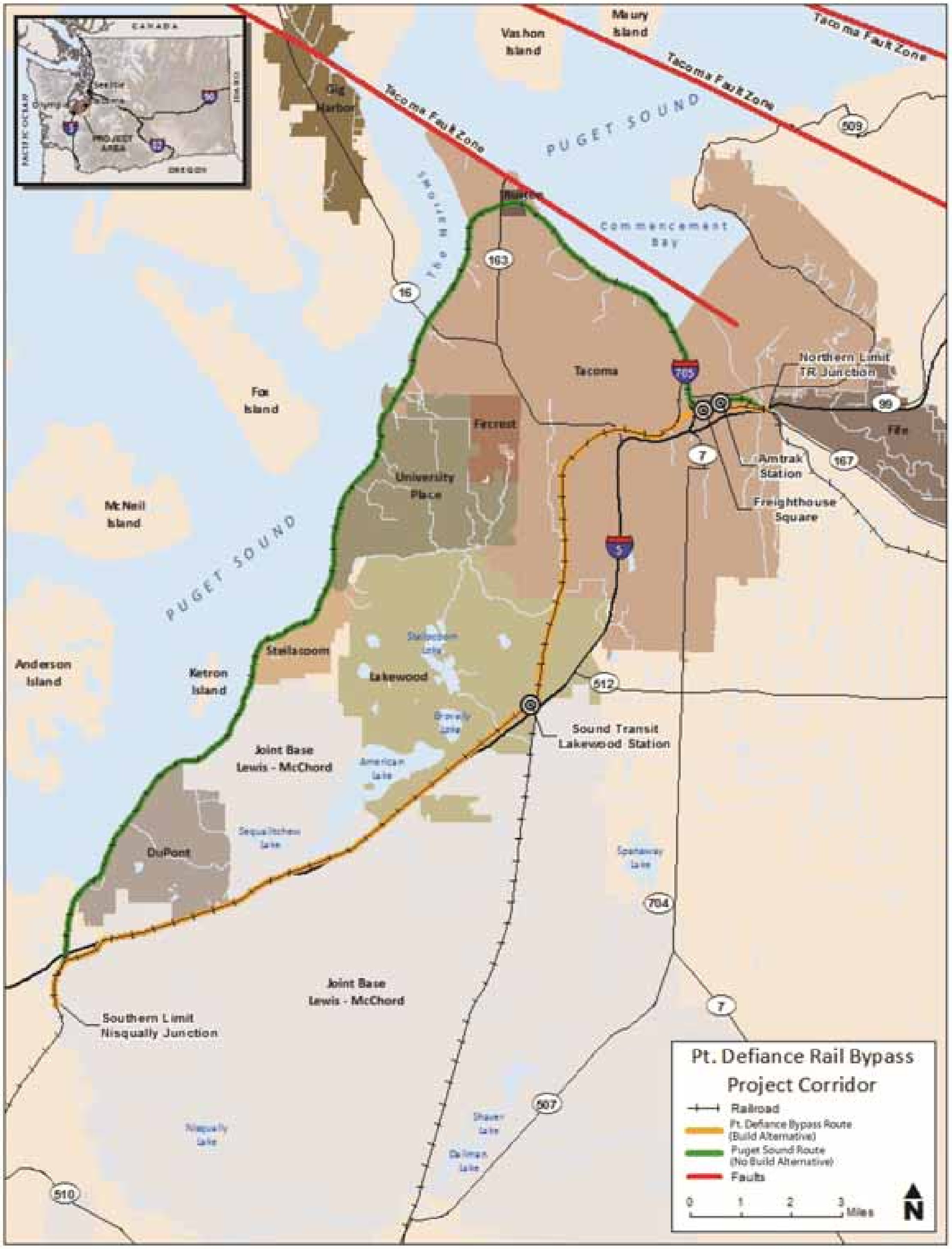
#### Seismicity

The study area is located in a moderately active tectonic province that has been subjected to numerous earthquakes of low to moderate strength and occasionally to strong shocks during the brief 170-year record in the Pacific Northwest. Some of the largest historical earthquakes in the Puget Lowland include the magnitude 7.1 Olympia earthquake of April 13, 1949; the magnitude 6.5 Seattle-Tacoma earthquake of April 29, 1965; and the recent magnitude 6.8 Nisqually earthquake that occurred on February 28, 2001. Geologic evidence indicates that a magnitude 9 earthquake on the Cascadia Subduction Zone occurred approximately 300 years before present.

#### Faulting

The nearest potentially active fault to the study area is the Tacoma Fault, which lies approximately 5 miles north of the northern end of the Project (Exhibit 3). This northwest-trending fault zone consists of several fault splays in an area as wide as 7 miles (Brocher et al, 2001). The locations of the fault splays are largely determined from overwater seismic reflection profiles within Puget Sound; the location of the fault splays on land have been extrapolated and are not precisely known. Recent studies indicate late Holocene movement on this fault (Sherrod et al, 2004).

***Exhibit 3. Fault Map***



### Liquefaction and Lateral Spreading

Soil liquefaction is a phenomenon in which pore water pressure in loose, saturated, granular soil increases during ground shaking to a level near the initial effective stress, thus resulting in a reduction of shear strength of the soil (a quicksand-like condition). As a result of this reduction in shear strength during liquefaction, lateral spreading (ground movement on very gentle slopes) and landsliding may occur. Because of the reduced soil strengths, vertical and lateral foundation restraint may also be significantly reduced.

Lateral spreading is a phenomenon where lateral ground displacements occur as a result of soil liquefaction. Lateral spreading is typically observed on very gently sloping ground or on virtually level ground adjacent to slopes. Lateral spreading tends to break the upper soil layers into blocks that progressively move downslope during an earthquake. Large fissures at the head of the lateral spread are common, as is compressed or buckled soil at the toe of the soil mass. Lateral spreading displacements can range from a few centimeters to meters, depending on the magnitude and duration of the seismic event (Kramer, 1996). From accounts of recent large earthquakes, including the relatively recent Kobe earthquake, lateral spreading at waterfront facilities typically appears to be more prevalent in upland areas within about 300 feet of the shoreline; however, case histories have documented lateral spreading occurring up to about 1,200 feet from the free-face of the soil mass.

Soils susceptible to liquefaction and lateral spreading include non-engineered fills and loose Holocene alluvium below the groundwater table, such as present in the Puyallup River Valley (east of Rail MP 1.8) and the Nisqually River Valley (located northwest of Rail MP 21.0). Alluvium deposited along small streams such as Clover Creek (Rail MP 10.8) and Murray Creek (Rail MP 13.9) may also be susceptible to liquefaction.

Several localized areas of potentially liquefiable soil were identified in the project corridor (Shannon & Wilson, 2006; Shannon & Wilson, 2009b). These areas include just west and east of Interstate 705 (I-705) (Rail MP 2.1 to MP 2.2) and between about Tacoma Avenue S (Rail MP 2.7) and South “M” Street (Rail MP 3.2).

### Slope Stability

Areas of potential slope instability within the study area comprise localized steep slopes (slopes greater than 40 percent) along the track section between Pacific Avenue (Rail MP 2.3) and about South “M” Street (Rail MP 3.2) and immediately north of the I-5 overcrossing (Rail MP 20.0) and a broad area of steep slopes south of the I-5 overcrossing.

Slopes that have been identified as having a relatively high risk of instability by Pierce County and the City of Tacoma are shown in Attachment A, Figures A-11 through A-20. Most of these slopes are relatively stable under static conditions, but some areas may be susceptible to failure. Slopes identified as having a relatively high risk of slope instability under static conditions are more likely to fail during a large earthquake.

Two areas of instability were reported in the area (Shannon & Wilson, 2009b) within the study area. Both of these areas are south of the I-5 overcrossing at Rail MP 20.0. One area of past landsliding is just north of the junction between the Lakeview Subdivision and the BNSF main line at about Rail MP 20.9. At this location, slopes as steep as 65 degrees are located close to the track along the uphill (east) side. The soils at this location consist of fine-grained silt and clay. Blocks of soil at the top of the slope have slumped downward, with some soil falling onto flat ground adjacent to the track. Shannon & Wilson (2009b) indicates that shallow failures have also occurred on the slope below the rail line, south of Rail MP 21.0.

The other area of observed instability is a side hill embankment where the rail line is not constructed on a full bench cut (approximately Rail MP 20.3). At this location, the rails of the track were reported (Shannon & Wilson, 2009b) to be displaced slightly toward the downhill (west) side of the embankment. The embankment soils adjacent to the track appear to be slightly lower than adjacent areas of the embankment to the north and south. This section of the line likely would require ongoing, periodic maintenance to keep the rails aligned. The movement of these embankment soils may be the result of failure of the embankment itself or of a bearing capacity failure of underlying soft, weak sediments. Poor drainage conditions were reportedly observed along this portion of the track (Shannon & Wilson, 2009b).

### Critical Areas

Many areas along the rail line are designated as environmentally critical by Pierce County (PALS, 2011) and the City of Tacoma (2010). Ordinances pertaining to these environmentally critical areas regulate development within or adjacent to such areas to protect the environment and proposed development. The soils-related critical areas comprise seismic, volcanic, landslide, erosion, and aquifer recharge hazard areas. Pierce County, including City of Lakewood and City of Tacoma hazard areas in the vicinity of the Project are shown in Attachment A, Figures A-11 through A-20.

### Seismic Hazards Areas

Seismic hazard areas are those areas that are subject to severe risk of damage as a result of seismic-induced settlement, shaking, lateral spreading, surface faulting, slope failure, or soil liquefaction. These conditions occur in areas underlain by non-cohesive soils of low density, usually in association with a shallow groundwater table.

The floodplains of the Nisqually River and Puyallup River are designated potential seismic hazard areas (Attachment A, Figures A-11 and A-20) because of the susceptibility of the soil to undergo liquefaction during an earthquake. The track section between TR Junction (Rail MP 1.0) and about East "G" Street (Rail MP 1.8) crosses through a designated seismic hazard area. The track located adjacent to the Nisqually River Valley (Rail MP 20.7 to MP 21.0) is located outside of the designated seismic hazard area.

### Volcanic Hazard Areas

The City of Tacoma and Pierce County define volcanic hazard areas as those areas subject to pyroclastic flows, lava flows, and inundation by lahars, debris flows, or related flooding resulting from geologic and volcanic events on Mount Rainier. The Puyallup River Valley is mapped as a volcanic hazard area (Attachment A, Figure A-5). The track is located within this mapped volcanic hazard area from TR Junction (Rail MP 1.0) to about East "G" Street (Rail MP 1.8). The Nisqually River Valley is also mapped as a volcanic hazard area (Attachment A, Figure A-20). In this portion of the alignment, the track is located outside of the volcanic hazard area. Pierce County hazard maps show volcanic hazard areas along the Puyallup and Nisqually rivers as high as elevation 80 feet.

### Landslide Hazard Areas

The City of Tacoma and Pierce County define landslide hazard areas as those areas potentially subject to mass movement due to a combination of geologic, seismic, topographic, hydrologic, or man-made factors.

Landslide hazard areas in the study area are shown in Attachment A, Figures A-11 through A-20. Numerous areas designated by Pierce County as landslide hazard areas are present within the City of Lakewood. These steep slope areas are generally associated with cut or fill slopes at freeway interchange ramps, bridges across I-5, or grade-separated crossings of the existing rail line. Most other designated landslide hazard areas are localized steep slopes that are not much more than 20 feet high.

The most extensive landslide hazard areas designated by the City of Tacoma in the study area are along the track section between about Pacific Avenue (Rail MP 2.3) and South "M" Street (Rail MP 3.2).

The steep hillside traversed by the BNSF main line south of the I-5 overcrossing (Rail MP 20.0) has not been mapped as a steep slope hazard area because of its location within JBLM. Other steep slopes may be present within JBLM. These hillside slopes are potentially prone to instability and are subject to regulation under Pierce County's critical areas ordinance.

#### Erosion Hazard Areas

Erosion hazard areas are those areas where the combination of slope and soil type makes the area susceptible to erosion by water flow, either by wave action, channel migration, or surface runoff. Mapped erosion hazard areas are present within the study area but not immediately adjacent to the proposed improvements (Attachment A). The mapped erosion hazard areas in the study area are primarily associated with potential erosion from channel migration of rivers or streams. Soil susceptible to erosion is present along the railroad corridor when cleared of vegetation or exposed on cut or fill slopes.

#### Aquifer Recharge Areas

The Steilacoom gravel together with the deeper Vashon advance outwash composes what is known as the upper aquifer. This aquifer is a highly used source of groundwater, and is tapped by public and private wells as a source of drinking water. Because of rapid infiltration and the shallow groundwater system, the aquifer formed by the Steilacoom gravel is highly susceptible to contamination. To protect this critical resource, these highly permeable surficial deposits along with wellhead protection areas are designated as aquifer recharge areas by the City of Tacoma and Pierce County. The study area from north of the I-5 DuPont Interchange (Rail MP 18.5) to Yakima Street (Rail MP 2.8) is mapped as an aquifer recharge area by Pierce County and the City of Tacoma. Regulations associated with these aquifer recharge areas provide standards to protect critical groundwater resources.

The portion of this aquifer recharge area that lies within the City of Tacoma is also regulated by the South Tacoma Groundwater Protection District. The South Tacoma Groundwater Protection District is an overlay land use control district designed to prevent the degradation of groundwater in this aquifer system by controlling the use and handling of hazardous materials.

#### Timber and Mineral Resources

There are no timber or mineral resources present within the study area.

# Chapter 4 – Potential Project Effects

This chapter discusses possible direct effects that could result from the No Build Alternative, and the direct and indirect effects that could result from the Build Alternative, to the geology- and soils -related aspects of the environment.

The Build Alternative effects would be related to the operation and construction of new or rehabilitated structures in the Project alternative on the existing features in the study area. Potential effects to geology and soils have been differentiated as construction effects, permanent physical effects, and operational effects, using the geology and soils identified in the existing conditions section.

Construction effects, usually temporary, are those that are resolved or mitigated by the end of construction activity. Permanent physical effects are those permanent topographic changes to the landscape caused by construction of a project. Operational effects are those caused by changes in railroad operations—not only the logistics of train travel, but also the daily activities on, and maintenance of, railroad facilities.

The Project alternatives consist of a No Build Alternative and a Build Alternative. The No Build Alternative assumes that Amtrak trains would remain on the Puget Sound route and would not be shifted to the project corridor, the Point Defiance Bypass. The tracks on the Tacoma Rail/BNSF- and Sound Transit-owned corridor would remain in their current condition and have the same or similar train usage as they currently do.

Sound Transit Sounder service would be in place between Tacoma and Lakewood, an existing condition for this analysis.

## What are the potential effects of the No Build Alternative?

The No Build Alternative would not require any construction, such as that being considered under the Build Alternative. However, existing conditions under the No Build Alternative would persist and have the following effects.

### Construction Effects

With the No Build Alternative, there would be no construction effects.

### Physical/Operational Effects

There is a history of landsliding and unstable slopes between about North 36th Street (approximately Rail MP 33.1 on the Point Defiance Bypass Route line) in Tacoma to Nisqually Junction (approximately Rail MP 24.7 on the Point Defiance Bypass route). Unless slope inclinations are reduced or other measures employed, soil and organic debris from failures of steep slopes along the tracks are expected to continue, which would affect regular train schedules and speeds and occasionally result in the potential to block train traffic. The existing embankment at Rail MP 20.3 on the BNSF main line appears to be moving or has moved in the past. The embankment could continue to move if it is not stabilized. If not stabilized, slope failure could occur and as a result, train traffic could be blocked, and sediment could be delivered to adjacent drainages and streams.

If a seismic event occurs, the stability of existing structures, slopes, and fill embankments along the No Build Alternative rail alignment could be affected. Liquefiable soil is present along the existing rail alignment from TR Junction to about Old Town Tacoma and in scattered areas along the BNSF alignment along Puget Sound. Liquefaction can result in widespread damage to the tracks. Damage would be expected to consist of settlement and lateral deformation of the tracks in areas where liquefiable soil is present. Embankment failure may also occur due to a loss of underlying soil strength and the lateral displacement of soils toward the Puyallup River and Puget Sound. The magnitude of settlement, soil movement, and loss of strength is a function of the soil thickness, soil quality, groundwater level, location and magnitude of the seismic event, and the specific foundation system of the structure.

Soil liquefaction, should it occur, would likely lead to consolidation of loose, saturated soil deposits, resulting in some surface settlement at the site. Since subsurface conditions vary, overall settlement would vary, leading to differential settlements along the track alignment. The track section between the Puyallup River to TR Junction (Rail MP 1.0) is within the zone of potential lateral spreading as a result of soil liquefaction. Damage as a result of soil liquefaction and lateral spreading would likely result in temporary discontinuation of train traffic.

The No Build Alternative would not result in any indirect or cumulative effects because the Point Defiance Bypass Project would not be constructed.

## What are the potential effects of the Build Alternative?

Following are the geology- and soils-related effects of the Build Alternative.

### Construction Effects

No construction is planned for the track section between TR Junction (Rail MP 1.0) and the new station at Freighthouse Square (Rail MP 2.0). The existing track would be used in its current condition. Therefore, no construction effects are expected for this track section.

The track section between Freighthouse Square to about 225 feet east of South Chandler Street (Rail MP 3.4) is being prepared for *Sounder* service by Sound Transit and would be finished before commencement of the Project. This new commuter service is considered an existing condition, and no construction effects would be attributed to the Project for this track section.

The track section between 225 feet east of South Chandler Street (Rail MP 3.4) to South 66$^{th}$ Street (Rail MP 6.9) has been constructed and no alterations to the track section are planned, although upgrades to the warning systems are planned at several crossings. No construction effects are anticipated from upgrading the crossing warning systems.

Sub-grade preparation and placement of the track sub-ballast has been completed for the track section between South 66$^{th}$ Street (Rail MP 6.9) to about 700 feet beyond the Lakewood Station (Rail MP 10.1). Anticipated construction activities for this track section include placement of the track ballast material and the rail.

The track section between about 700 feet beyond the Lakewood Station (Rail MP 10.1) to the southern terminus of the Project would be reconstructed. The anticipated construction activities for the Project for the track section would include:

- Clearing and grubbing the existing ground of vegetation when new fill would be placed for the improved track sections
- Cutting into existing slopes to allow for track structure widening
- Excavating ditches to allow for drainage of surface water
- Placing fill for new embankments, and widening existing embankments

- Placing track sub-ballast and ballast material
- Hauling away and disposing of excavated material.

Additional construction activities along the rail line include possibly extending the bridge abutment wing walls with retaining structures for the two bridges crossing I-5 near Rail MP 20.0. For the track section in the vicinity of the Mounts Road overpass (Rail MP 19.8), additional construction activities may include regrading slopes to flatten inclines where needed and building new retaining structures to accommodate track widening. South of I-5 (Rail MP 20.0), additional construction activities may include protecting the track from upslope debris and removal of existing loose fill.

Construction activities for the new station in the vicinity of Freighthouse Square would include:

- Clearing and grubbing the existing ground of vegetation
- Removing existing improvements such as underground utilities, pavement, and buildings
- Removing unsuitable soils for the site
- Placing and compacting fill to establish final site grades
- Paving.

The construction activities for the Build Alternative would result in short-term geology- and soils-related effects to the study area. Construction of the Build Alternative would not affect unique or protected soil or geologic resources because none are present in the study area. The construction effects are discussed in the following paragraphs.

#### Erosion and Sediment Control

Reconstruction of the existing track and construction of new track requires land clearing, removal of soil and ballast, and other site preparation work. Because the study area would be located within an existing railroad corridor (except for portions of the study area required to accommodate the Tacoma Amtrak Station relocation to Freighthouse Square), construction in these areas would temporarily disturb soils. Relocating the Tacoma Amtrak Station to Freighthouse Square may also require land clearing, removal of soil, and other site preparation work.

In areas of proposed new construction, soil beneath proposed fills and structures would be cleared and grubbed of all vegetation and debris, and stripped of all organic topsoil. In areas where the existing track is to be reconstructed, the sub-grade would be graded to meet the design roadbed elevation, width, and slopes. Minor grading work would be required in areas where the track would be rehabilitated.

The high permeability of the coarse granular soils that dominate along the study area, particularly north of the I-5 overcrossing (Rail MP 20.0), indicates that the likelihood of erosion is small. However, soil exposed in sloped excavations or fills may be susceptible to erosion locally until vegetation is established. The soil at the new Freighthouse Square Station is susceptible to erosion. Any areas that are disturbed during construction would be subject to increased erosion if proper erosion control measures are not incorporated in the design. Surface water flow across exposed soil would remove sediment and deposit it in downslope areas. If the exposed soil is allowed to dry out, the soil can also be susceptible to wind erosion. The amount of erosion and sedimentation would depend on the amount of soil exposed and/or disturbed, weather conditions, groundwater conditions, and the erosion control measures implemented. The eroded soils could be carried into stormwater drains, existing culverts, adjacent streets, or adjacent properties. During construction, the tires of construction vehicles could also carry soil onto roadways when leaving construction areas, which could then be carried into ditches or stormwater drains. However, through the use of Best Management Practices (BMPs) and minimization measures these effects would be minimized or avoided.

#### Cuts into Existing Slopes

Construction may require temporary and permanent cuts into existing slopes to allow for widening of embankments and construction of drainage ditches. During construction, soils exposed in slope excavations may be susceptible to erosion until vegetation is established. Cuts into slopes for track and culvert construction could result in shallow landslides and sloughing. The higher the cut slope, the more prone the slope is to erosion and slope failure, and the greater the potential effect. Failure of higher slopes could result in greater volumes of failed material, which could block drainages or be eroded and conveyed to streams.

Construction of new abutment wing walls for the I-5 crossing (Rail MP 20.0) may require high cuts into existing slopes. These temporary cuts are likely to be steep and prone to failure until permanent wing walls have been constructed. Failure of these slopes could result in sediment being conveyed in the ditches along I-5 to the Nisqually River. However, through the use of BMPs and minimization measures these effects would be minimized or avoided.

#### Fill Embankments

South of South 66$^{th}$ Street (Rail MP 6.9), the project alignment is underlain by outwash sand and gravel or very dense or hard soils. Localized zones of soft or weak foundation soils may be present in portions of this section of the alignment. Soil at the new Freighthouse Square station is also anticipated to consist of very dense soil. Settlement caused by construction of fill embankments in these areas is anticipated to be minor and would occur as the fill is being placed.

Fill slopes could fail, particularly if constructed too steep or if the underlying foundation soil is loose or soft. The likelihood of failure would increase as the height of the fill increases. Fill slopes constructed on existing slopes are prone to failure if the previous fill surface is not properly benched prior to new fill placement.

The sand and gravel deposits that dominate along the project alignment south of South 66th Street (Rail MP 6.9) are likely to be suitable for use as fill during construction unless they locally contain a relatively high percentage of silt and clay or organic material.

The use of BMPs and minimization measures would result in minimizing and avoiding effects to fill embankments.

#### Drainage in Construction Areas

During construction, poor surface water control practices could result in drainage of surface water onto unstable slopes. This could result in landslides or erosion, or affect adjacent properties. Between the I-5 overpass (Rail MP 20.0) and South 66th Street (Rail MP 6.9), surface water should infiltrate into the pervious soils with little runoff. Therefore, it is unlikely that poor drainage practices would result in landsliding or significant erosion onto adjacent properties. The portion of the project alignment most prone to instability from poor drainage practices is located south of the I-5 overpass where the slopes are steeper and underlain in places by relatively loose, colluvial soils.

#### Pavements

Soil from cuts into slopes, and soil and ballast removed from the existing track would need to be hauled off site. New soil and ballast would need to be imported to rehabilitate and reconstruct the track. Dump trucks would use the existing access roads as haul roads. In places, this could include city or county streets, but would be limited to streets that are rated for truck traffic.

#### Economic Resources

Earthwork that would generate appreciable economic resources (soil that can be used as fill material) is expected to be primarily limited to the portion of the alignment where the existing main line would be reconstructed [i.e., between Bridgeport Way Southwest (Rail MP 10.4) and Clover Creek Drive Southwest (Rail MP 10.9) to just southeast of the I-5/Mounts Road Southwest interchange (Rail MP 19.8)]. Soil generated during soil cutting is anticipated to consist primarily of topsoil and sand and gravel. The topsoil would not be suitable for use as structural fill on the Project and should be disposed of at an approved off-site location. Sand and gravel generated during cutting would likely meet WSDOT's criteria for Common Borrow, and is likely suitable for use as fill during construction unless it locally contains a relatively high percentage of silt and clay or organic material. Soil generated during cutting would not be suitable for use on the Project for other purposes without significant processing.

### Physical Effects

Cuts and fills would be required to construct the Project. These cuts and fills would temporarily disturb soils and other geologic features in the study area. The heights of anticipated cuts into slopes and fills would vary along the project corridor. In areas where there is an insufficient space to accommodate large cuts or fills, retaining walls would be constructed.

### Operational Effects

Long-term geology- and soils-related effects could occur during normal operations of the proposed tracks, depending on design. The Project would be designed based on the available subsurface information, design procedures and criteria approved by WSDOT, and existing site conditions. If subsurface conditions at the site are different from those discovered during field explorations, or site conditions change during the life of the Project, future effects to the site could occur. There would be no long-term operational effects to unique or protected soil or geologic resources because none are present in the study area. Long-term operational effects are discussed below.

#### Seismic Considerations

If a seismic event occurs during the life of the Project, the stability of structures, permanent cut slopes, and fill embankments could be affected. West of East "G" Street in Tacoma (Rail MP 1.8), the project alignment is generally underlain by sandy gravel and gravelly sand, which are not generally susceptible to liquefaction. Localized zones of potentially liquefiable soil are potentially present in the vicinity of I-705 (Rail MP 2.1 to MP 2.2) and between about Tacoma Avenue S (Rail MP 2.7) and South "M" Street (Rail MP 3.2). The portion of the alignment located east of East "G" Street (Rail MP 1.8) is mapped as being within a high liquefaction hazard area (see Attachment A).

Liquefaction can result in widespread damage to the tracks if not properly mitigated. Damage would be expected to consist of settlement and lateral deformation of the tracks in areas where liquefiable soil is present.

Embankment failure may also occur due to a loss of underlying soil strength and the lateral displacement of soils toward the Puyallup River. The magnitude of settlement, soil movement, and loss of strength is a function of the soil thickness, soil quality, groundwater level, location and magnitude of the seismic event, and the specific foundation system of the structure.

Soil liquefaction, should it occur, would likely lead to consolidation of loose, saturated soil deposits, resulting in some surface settlement at the site. Since subsurface conditions vary, overall settlement would vary, leading to differential settlements along the track alignment. The track section between the Puyallup River and TR Junction (Rail MP 1.0) is within the zone of potential lateral spreading as a result of soil liquefaction.

In areas adjacent to steep slopes or in mapped potential landslide areas (see Attachment A), cut slopes could experience shallow landsliding as a result of seismic shaking, which could deposit material onto the tracks.

#### Steep Slopes

The track sections between Pacific Avenue (Rail MP 2.3) to about East "M" Street (Rail MP 3.2) and the steep hillside traversed by the BNSF main line south of I-5 (Rail MP 20.0) are located in landslide hazard areas. In these sections, landsliding could result in blocked drainage ditches and possibly temporarily block the tracks with debris.

#### Cuts into Existing Slopes

Cuts into existing slopes, to allow for reconstruction and rehabilitation of the existing tracks and construction of new tracks, may experience erosion and surface sloughing over the lifetime of the Project. The degree of erosion would depend on near-surface soils, weather conditions, potential seismic events, establishment of vegetation, surface drainage, and other factors. Surface slumps or landslides occurring in the future may result in the deposit of material onto the tracks. Erosion could result in sediment reaching drainage ditches along the tracks.

#### New Fill

Reconstruction and rehabilitation of the existing tracks or construction of new tracks would require placement of structural fill and ballast along the project corridor. Long-term settlement of the new fill could occur. Based on available subsurface data, the portion of the Project located west of East "G" Street in Tacoma (Rail MP 1.8) is underlain by sand and gravel or other very dense or hard soils. Settlement in these soils would be small and occur immediately after the fill is placed. Since site grades are not being changed between TR Junction (Rail MP 1.0) and East "G" Street, settlement in this portion of the alignment is not anticipated.

### Permanent Drainage

Permanent drainage facilities for slopes, walls, or fills could result in increased water flow to existing culverts or drainage ditches. Additional sediment load from slope erosion may result in buildup in ditches, culverts, swales, and other drainage features. Water that overflows or is incorrectly directed could result in drainage onto adjacent slopes and properties. This could cause erosion or landsliding, and affect adjacent properties. However, through the use of BMPs and minimization measures these effects would be minimized or avoided.

### Ground Vibration Amplification

West of East “G” Street (Rail MP 1.8), the near-surface soil is mapped as consisting of outwash sands and gravel or very dense or hard soils. These soil types do not typically transmit or amplify ground vibrations.

A geologic reconnaissance of the portions of the corridor between 100th Street Southwest (Rail MP 9.1) and Berkeley Street Southwest (Rail MP 13.7) was completed on May 16, 2011 to determine if any soil possibly susceptible to amplifying ground vibration (i.e., soft clay or peat layers greater than about 20 feet thick) are present. During the geologic reconnaissance, no deposits of soft clay or peat were observed in the immediate vicinity of the rail line. Consequently, it is unlikely that amplification of ground vibration would occur along this portion of the alignment.

The soil mapped between TR Junction (Rail MP 1.0) and East “G” Street (Rail MP 1.8) consists of fill and alluvial deposits. These soils can transmit and amplify ground vibrations.

## Indirect Effects

The Project is located within an existing rail corridor and urbanized area. The only potential indirect effect tied to the Project is that it may indirectly influence redevelopment near the relocated Amtrak Station at Freighthouse Square (see Land Use Discipline Report[3]). Such redevelopment would be consistent with local zoning and approved by state and local agencies and would take place in previously disturbed areas and would have no effect on geologic or soils resources. Thus, no indirect effects to geologic or soils resources are expected.

[3] *WSDOT 2012*

### Cumulative Effects

The Project would have no direct or indirect effect on geologic resources or high value soils. Thus, the Project would not contribute to a cumulative effect on these resources.

# Chapter 5 – Recommended Minimization Measures

As noted previously, no significant effects to geology and soils are anticipated. This chapter provides Best Management Practices (BMPs) that could be applied during construction and operation to minimize the Project's effects.

## What minimization is required for the No Build Alternative?

No minimization is proposed under the No Build Alternative. Some minimization measures will likely be implemented by the corridor owners in the future if landsliding or embankment failure were to occur along the existing rail alignment.

## What minimization is required for the Build Alternative?

The following minimization measures for the Build Alternative predominantly focus on minimization of potential construction effects.

### Construction Effects

The Project will be constructed in accordance with WSDOT guidelines. The following sections address the minimization for each of the potential construction effects.

#### Erosion and Sediment Control

Best Management Practices (BMPs), such as construction staging, barrier berms, filter fabric fences, temporary sediment detention basins, and use of slope coverings to contain sediment on site, will be effective in protecting water resources and reducing erosion from areas with cuts, fills, or excavations. Erosion control measures suitable to the site conditions will be included as part of the Project design. Temporary erosion and sediment control plans will be prepared for approval in accordance with BMPs included in WSDOT's *Highway Runoff Manual* (WSDOT, 2010a). Erosion control measures will include vegetative and structural controls. Other controls that could be implemented include restriction of work activities to the dry season and limiting access to the site.

Areas disturbed during construction that will not be paved or permanently covered will be revegetated to minimize erosion as soon as possible. Revegetation methods will include covering cleared areas, graded areas, excavation slopes, and embankments. These areas will be covered with netting, mulching, or hydroseeding as appropriate to minimize erosion and encourage revegetation. The exposed soil will be moistened with a water truck in order to control dust and wind erosion in addition to the erosion control measures specified above.

Structural controls are artificial means of preventing sediment from leaving the construction area. Parking and staging areas for vehicles and equipment could be covered with a gravel work pad where appropriate to prevent the disturbance and erosion of the underlying soil. Silt fences will be placed around disturbed areas to filter sediment from unconcentrated surface water runoff. Straw bales will be placed in paths of concentrated runoff to filter sediment. Temporary ditches, berms, and sedimentation ponds will be constructed to collect runoff so that entrained sediment could settle out of the water prior to being released into drainages, streams, or wetlands. Cleaning tires and tracks of heavy equipment before they leave the site will also assist in retaining sediment on site. In addition, truck loads will be covered to prevent sediment deposit onto roadways.

Proposed minimization measures will comply with temporary stormwater design and treatment procedures based on WSDOT's *Highway Runoff Manual* (WSDOT, 2010a). Such procedures follow the National Pollutant Discharge Elimination System (NPDES) guidelines administered by the Washington State Department of Ecology (Ecology website, 2011). WSDOT guidelines require approval of a *Stormwater Site Plan* and a *Temporary Erosion and Sediment Control Plan* prior to construction, which will be prepared as part of Project construction documents. The erosion and sediment control measures will be in place before any demolition, clearing, grading, or construction occurs.

#### Cuts into Existing Slopes

Temporary excavation slopes would typically be no steeper than 1.5 horizontal feet to one vertical foot (1.5H:1V). According to construction drawings (HDR 2010a,b), permanent cut slopes are expected to be no steeper than 2H:1V. Retaining walls such as mechanically stabilized earth (MSE) walls, cast-in-place (CIP) concrete retaining walls, soldier pile, or soil nail walls will be used where cut slopes cannot be constructed at 2H:1V or flatter. Because of the nature of the soils that underlie the study area and the geometry of proposed cuts and fills, the risk of slope instability is relatively small. The risk of slope instability is slightly higher south of the I-5 overpass (Rail MP 20.0) because of higher proposed cut slopes and the potential presence of groundwater perched on top of fine-grained soils that "daylight" on the existing slope faces.

The potential for slope instability and erosion on cut slopes during construction will be reduced by using BMPs. Cut slopes and cut walls will be evaluated and designed by experienced structural and geotechnical engineers. Potential landsliding and erosion could also be reduced by intercepting surface water runoff and conveying it through a tightline to the bottom of the slope. This interception could consist of covering the slope with plastic sheeting, installing drains, and/or restricting construction to dry weather. As soon as possible during or after construction, vegetative controls will be installed. This will include covering the slopes with netting, mulching, or hydroseeding, as appropriate, to minimize erosion and encourage revegetation on the slopes.

#### Fill Embankments

According to the design drawings (HDR, 2010a,b), fills will be constructed with side slopes of 2H:1V, which should be stable for the soils present along the Project. Retaining walls such as MSE or CIP concrete retaining walls will be used where fill slopes cannot be constructed at 2H:1V or flatter. Fill slopes and fill walls will be evaluated and designed by experienced structural and geotechnical engineers. Because of the relatively dense nature of the near-surface soils mapped along the alignment, significant settlement of fill embankments is not anticipated and no minimization is required.

As soon as possible during or after construction, vegetative controls will be installed on all fill embankments. This will include covering the slopes with netting, mulching, or hydroseeding, as appropriate, to minimize erosion and encourage revegetation of the slopes.

#### Drainage in Construction Areas

All fill and pavement areas will be sloped to drain away from construction areas and prevent ponding of water and softening of sub-grade soils. Drainage water from construction areas will be directed into suitable drainage features in accordance with BMPs. No water will be allowed to drain out over existing slopes, into excavations, or onto sub-grade areas.

#### Pavements

Pavement damaged by construction traffic could be replaced following completion of the proposed improvements. New pavement will be designed by a qualified civil or geotechnical engineer in accordance with American Association of State Highway and Transportation Officials (AASHTO) guidelines.

### Physical Effects

Cuts, fills, and retaining walls will be required to construct the Project. Cuts, fills, and retaining walls are generally kept to the minimum necessary to construct the Project using appropriate design based on the site conditions. No minimization of permanent physical effects is required or proposed.

### Operational Effects

Minimization measures for the direct operational effects of the Project are based on the site information and standard design and construction procedures. As part of the final design, the geology- and soils-related features may be evaluated by an experienced geotechnical engineer who will provide appropriate design recommendations. These recommendations will be based on the subsurface conditions in the study area, as indicated by field explorations. The design recommendations will take into account the direct operational effects of the Project alternatives and provide for adequate minimization for these effects.

The Project will be designed based on WSDOT design procedures and criteria, American Railway Engineering and Maintenance-of-Way Association (AREMA) design procedures, the International Building Code, and existing site conditions. To adequately define subsurface conditions for design of the features included in the Project, additional subsurface data may be collected. In general, a geotechnical investigation will be completed to support final Project design. Adequate subsurface information will allow improved evaluation of foundation capacities, estimated settlements, and liquefaction potential.

#### Seismic Considerations

The Project elements will be designed considering the seismicity of the site and the design guidelines presented in WSDOT's *Design Manual* (WSDOT, 2010b) and *Bridge Design Manual* (WSDOT, 2011), AASHTO's *Load and Resistance Factor Design Bridge Design Specifications* (AASHTO, 2010), the AREMA *Manual for Railway Engineering* (AREMA, 2011), and the International Building Code (ICC, 2009).

In the areas west of East "G" Street (Rail MP 1.8), shallow landsliding may occur adjacent to steep slopes or in areas identified as landslide hazard areas (see Attachment A) during a major earthquake. Cut retaining walls such as soldier pile or soil nail walls could be used to stabilize the slopes. Alternatively, a catchment wall could be constructed at the base of the slope to catch any landslide debris. The soldier pile, soil nail, or catchment wall requirements will be evaluated and designed by experienced structural and geotechnical engineers.

Potential liquefaction of loose or soft alluvium and/or fill soil located east of East “G” Street (Rail MP 1.8), in the vicinity of I-705 (Rail MP 2.1 to Rail MP 2.2), and between about Tacoma Avenue S (Rail MP 2.7) and South “M” Street (Rail MP 3.2) is possible during an earthquake. Most railroad agencies consider track distress from seismic events (e.g., liquefaction) to be a maintenance issue and ground improvement below at-grade tracks is typically not performed.

If liquefaction-induced distortion is intolerable, liquefaction could be mitigated by designing the proposed improvements to tolerate the vertical and horizontal movements caused by liquefaction and lateral spreading or implementing ground improvement measures. Ground improvement measures could include stone columns, vibro-compaction, vibro-replacement, deep soil mixing, compaction grouting, and others. Lateral spreading could be reduced by stabilizing the soil adjacent to the Puyallup River by using ground improvement or installing retaining structures at appropriate depths and locations. Selection of the minimization techniques depend upon a number of issues including the soil type, level of improvement required, area and depth to be improved, proximity of existing structures, presence of contaminated soil and groundwater, and cost. The specific method of ground improvement will be determined as part of the design and permit approval process by a qualified geotechnical engineer.

#### Cuts into Existing Slopes

Minimization for the proposed cuts includes performing proper design, defining the location and extent of unstable soils, and using proper construction procedures. To mitigate slope instability in cut areas, slope angles and retaining walls will be designed based on the characteristics of the soils in the cut. The cut wall will be evaluated and designed by experienced structural and geotechnical engineers.

Some of the slopes that are currently prone to instability will be flattened to more stable inclinations. Vegetation will be installed on the slopes to mitigate surface erosion and sloughing. For surficial slides that may occur along the slopes, a catchment area or catchment wall can be constructed at the base of the slope.

#### New Fill

Based on the mapped geology, extensive deposits of loose/soft soil are not present in areas where appreciable fill will be placed. If loose/soft soil is encountered during construction or during site-specific design, settlement due to compression of loose/soft soils could be mitigated by removing and replacing the unsuitable soils or by placing the fill and allowing it to settle prior to construction. Existing utilities near the new fill will be relocated if loads and settlements will cause damage.

#### Permanent Drainage

Permanent drainage facilities for slopes, walls, or fills, will be designed for the anticipated water flows. All permanent drainage systems will be installed so that water does not overflow and is not directed onto slopes or other areas that may be sensitive to erosion or landsliding. The Project includes drainage features, such as ditches, that are not currently present or are inadequate along the existing rail. Such features will likely reduce the effects of uncontrolled or undesirable surface water runoff.

#### Ground Vibration

It is unlikely that significant ground vibration would occur as a result of increased passenger rail service; therefore, no minimization is required.

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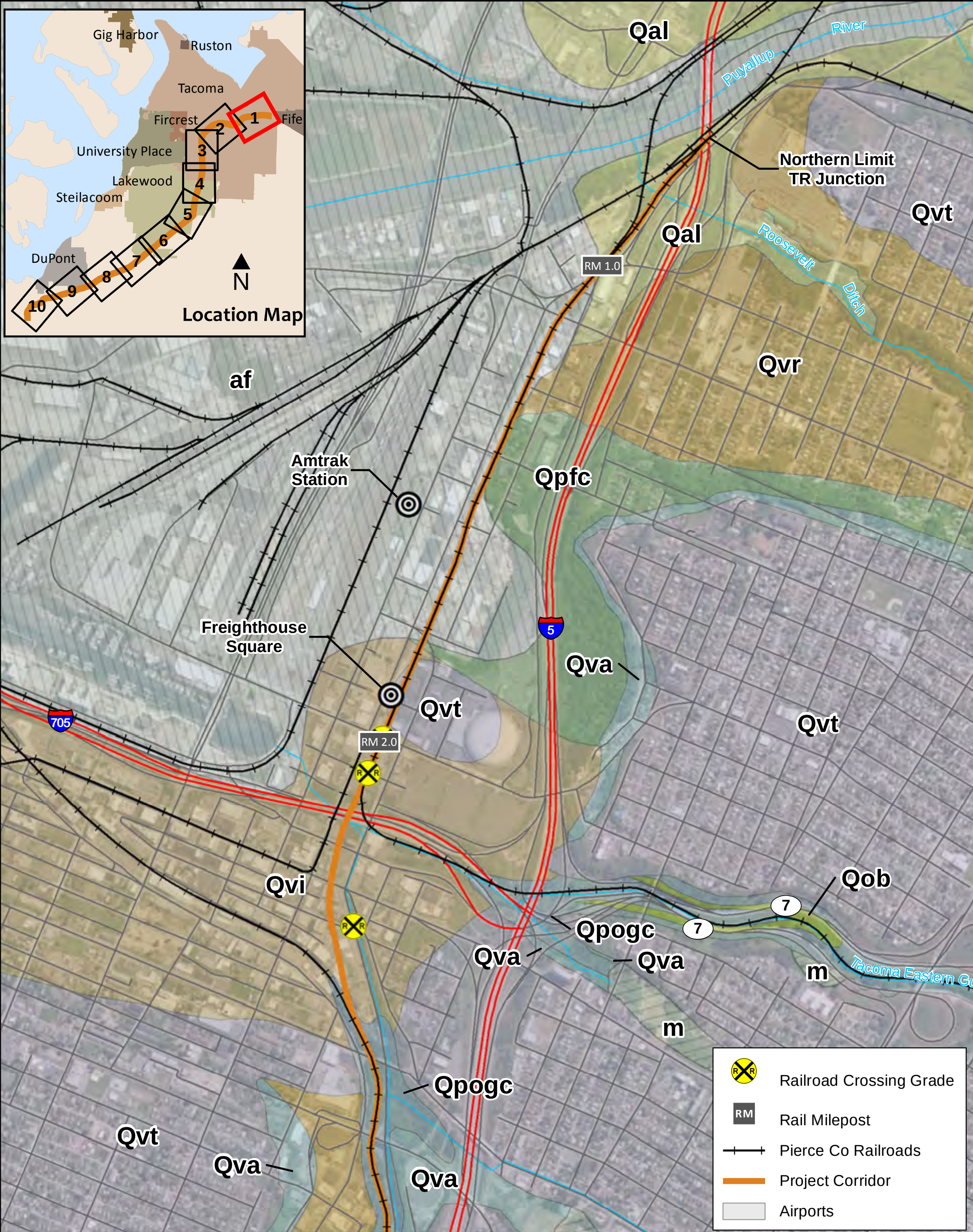
# Attachment A




Pt. Defiance Rail Bypass
Attachment 1: Geology

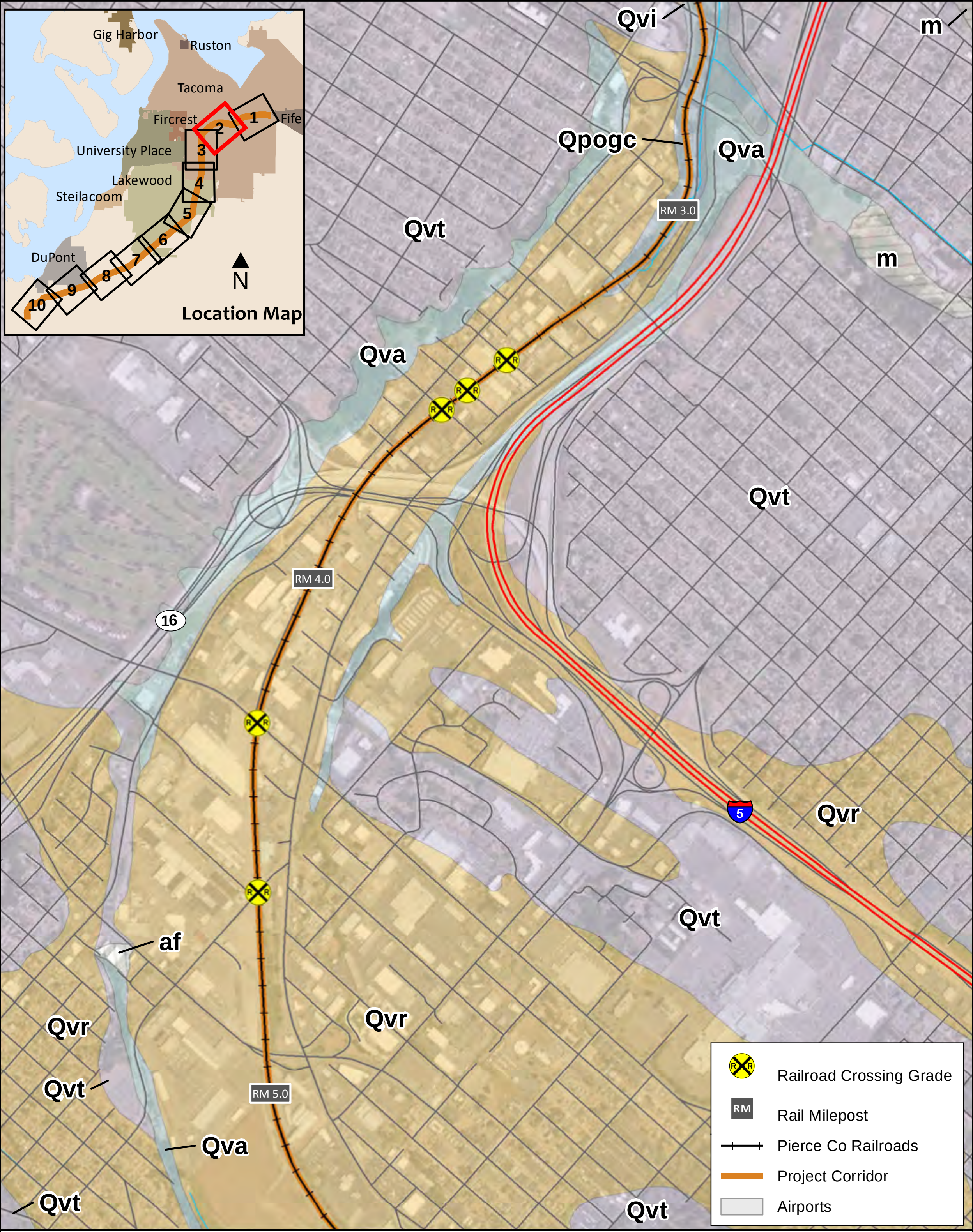
Panel 1 Nov 7, 2011

Note: See Text for Explanation of Geologic Units

Washington State Department of Transportation

0 0.25 0.5 Miles

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation



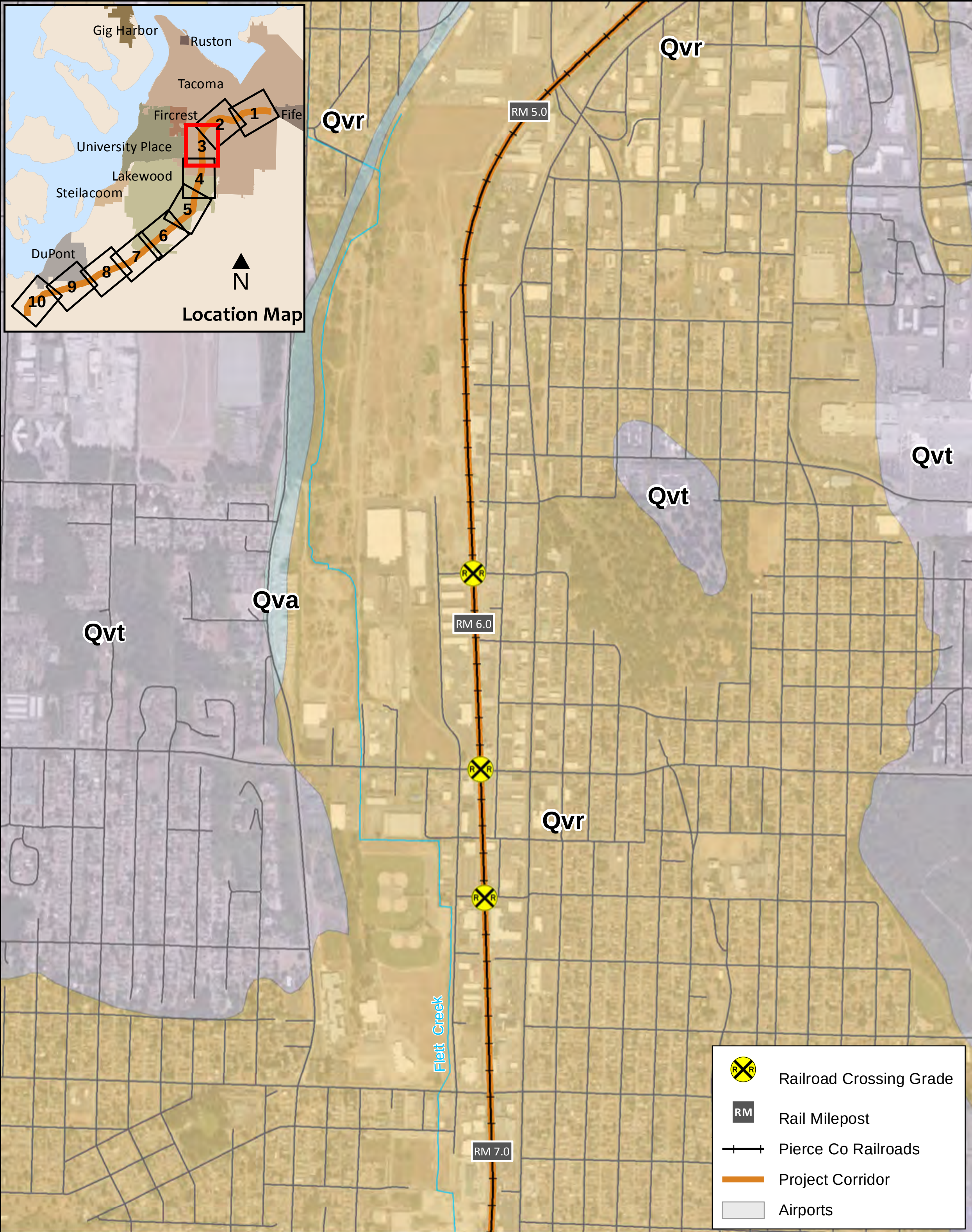

Pt. Defiance Rail Bypass
Attachment 2: Geology

Panel 2 Nov 7, 2011

Note: See Text for Explanation of Geologic Units

Washington State Department of Transportation

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass
Attachment 3: Geology

Panel 3 Nov 7, 2011

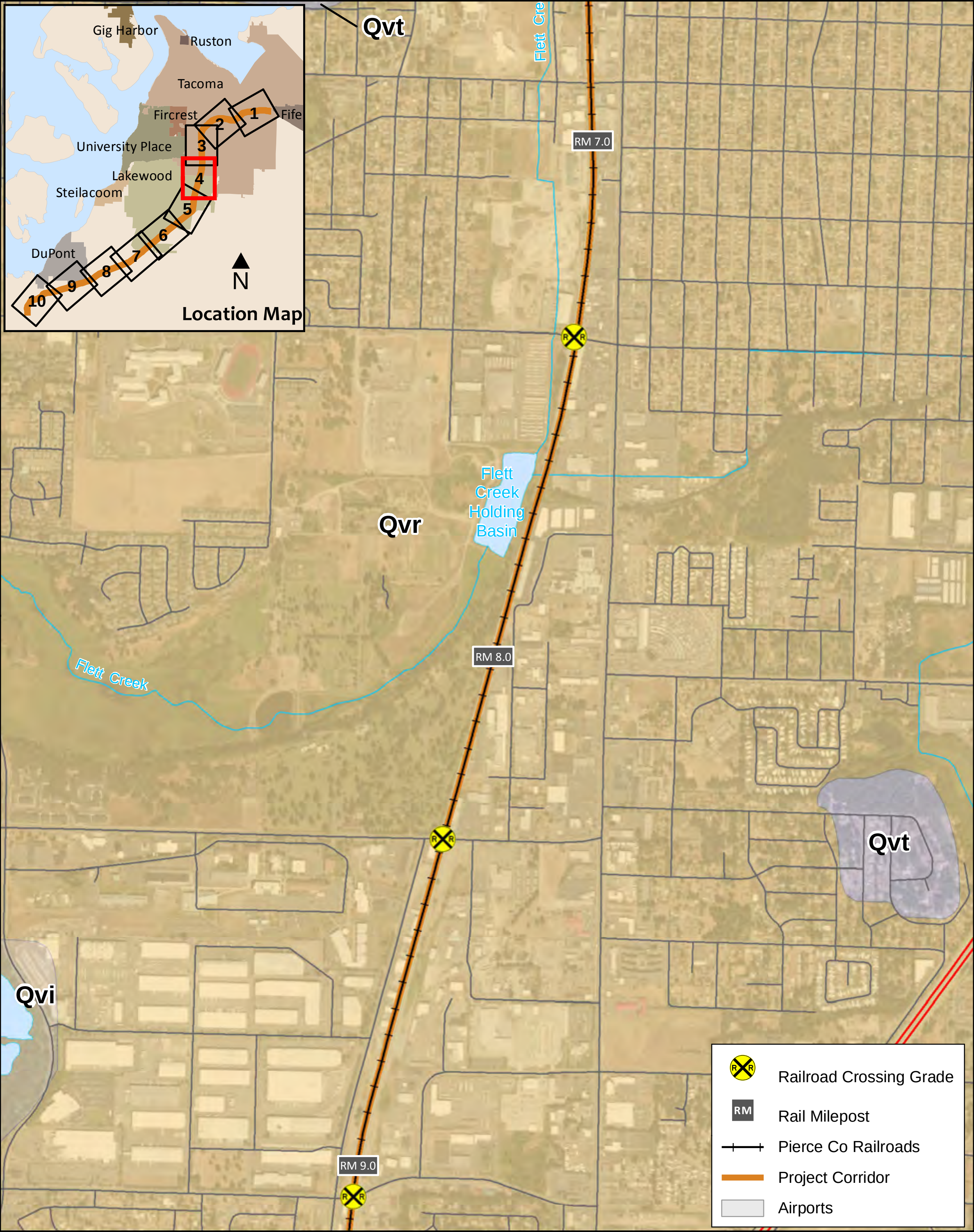
Note: See Text for Explanation of Geologic Units

Washington State Department of Transportation

0 0.25 0.5 Miles

N

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass
Attachment 4: Geology

Panel 4 Nov 7, 2011

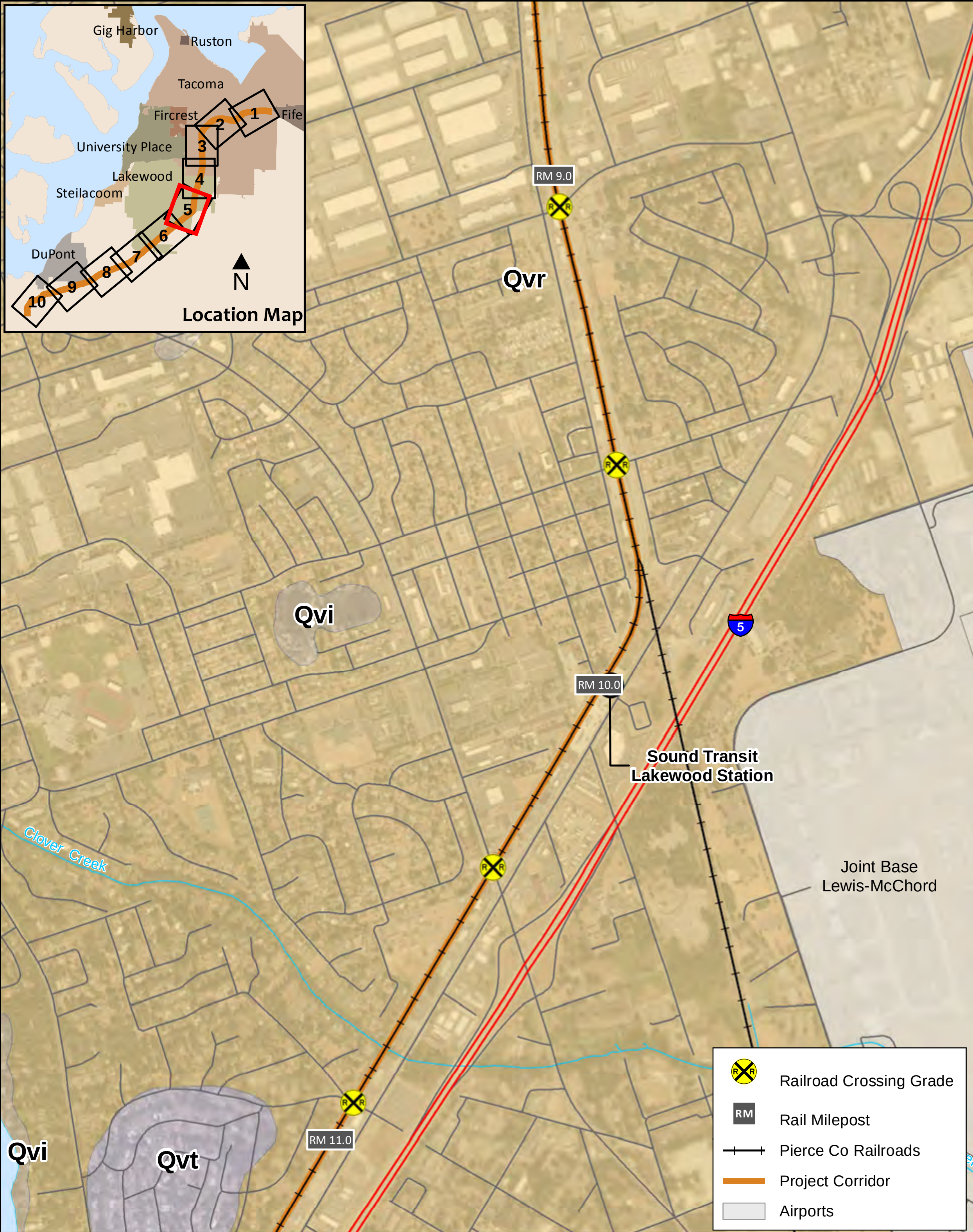
Note: See Text for Explanation of Geologic Units

Washington State Department of Transportation

0 0.25 0.5 Miles

N

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass
Attachment 5: Geology

Panel 5 Nov 7, 2011

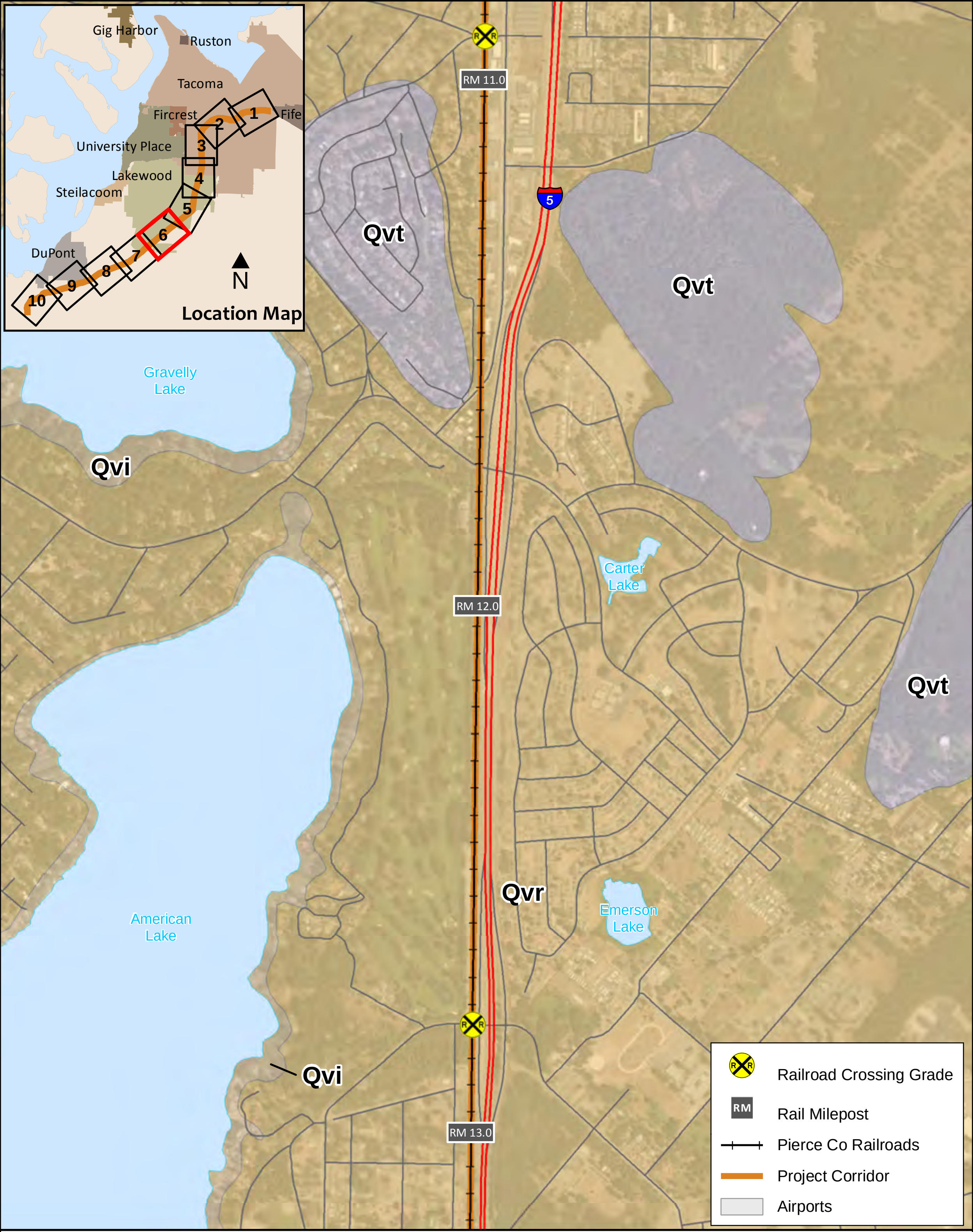
Note: See Text for Explanation of Geologic Units

Washington State Department of Transportation

0 0.25 0.5 Miles

N

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass
Attachment 6: Geology

Panel 6 Nov 7, 2011

Note: See Text for Explanation of Geologic Units

Washington State Department of Transportation

0 0.25 0.5 Miles

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation


Pt. Defiance Rail Bypass
Attachment 7: Geology

Panel 7 Nov 7, 2011

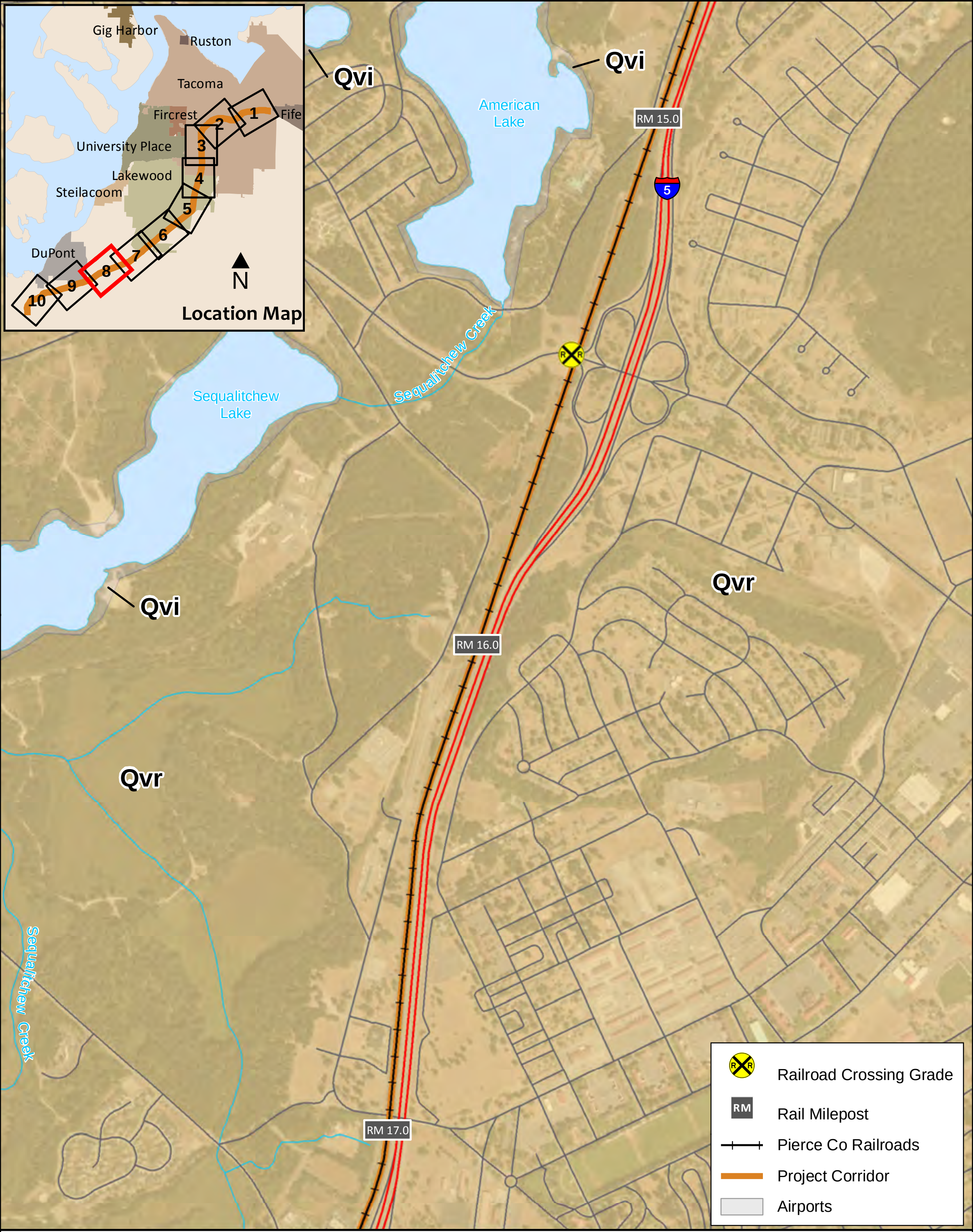
Note: See Text for Explanation of Geologic Units

Washington State Department of Transportation

0 0.25 0.5 Miles

N

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass
Attachment 8: Geology

Panel 8 Nov 7, 2011

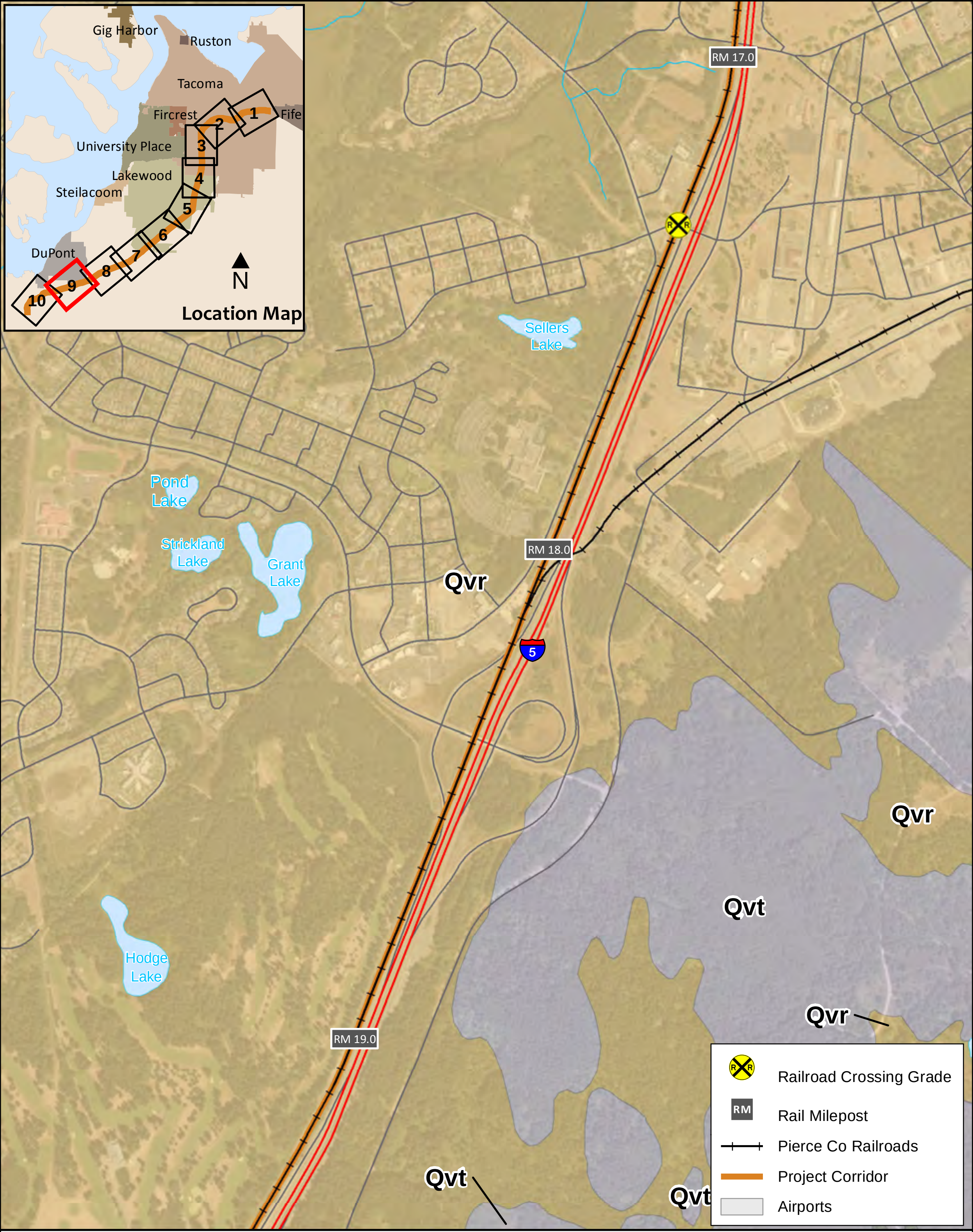
Note: See Text for Explanation of Geologic Units

Washington State Department of Transportation

0 0.25 0.5 Miles

N

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation



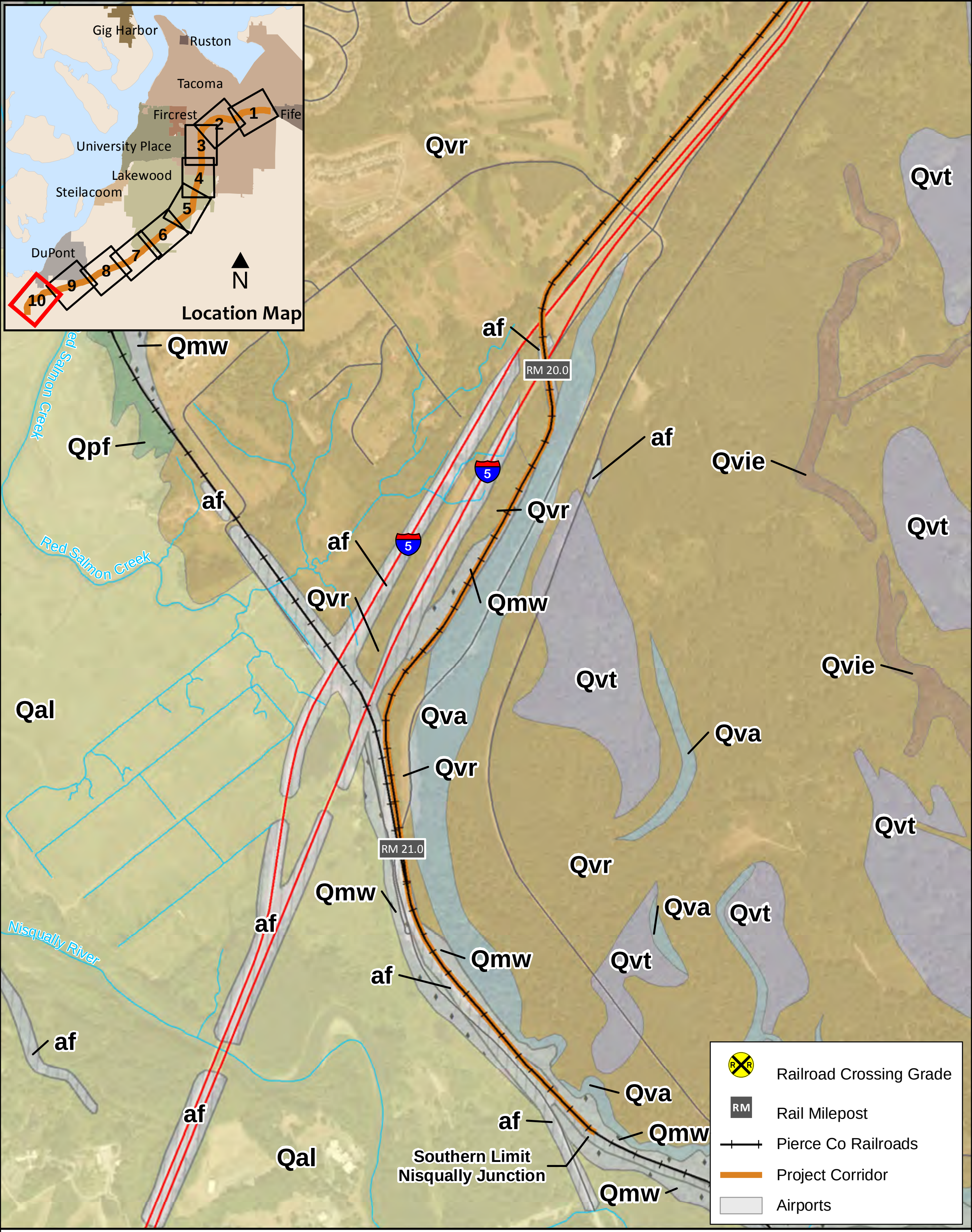

Pt. Defiance Rail Bypass
Attachment 9: Geology

Panel 9 Nov 7, 2011

Note: See Text for Explanation of Geologic Units

Washington State Department of Transportation

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass
Attachment 10: Geology

Panel 10 Nov 7, 2011

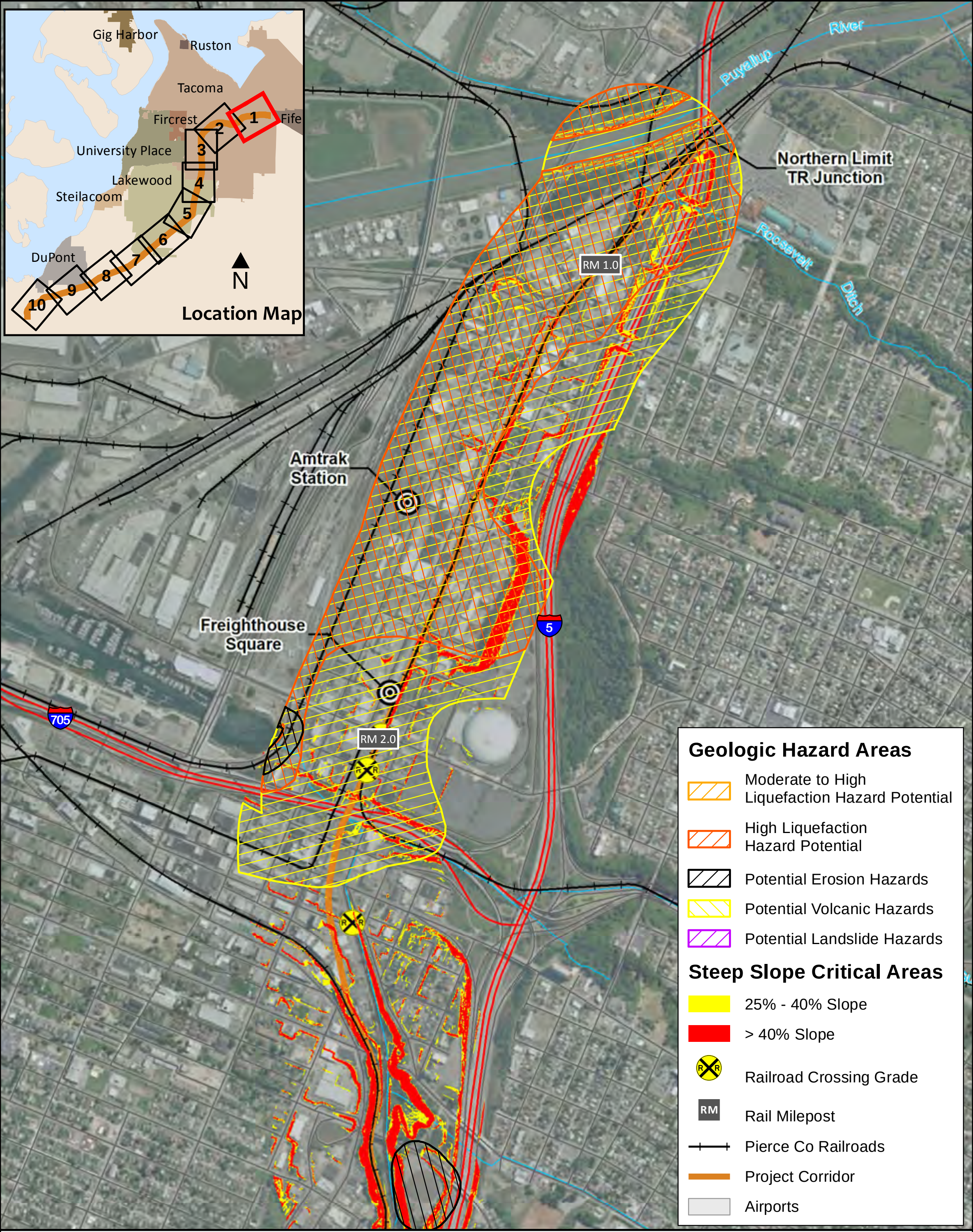
Note: See Text for Explanation of Geologic Units

Washington State Department of Transportation

0 0.25 0.5 Miles

N

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation



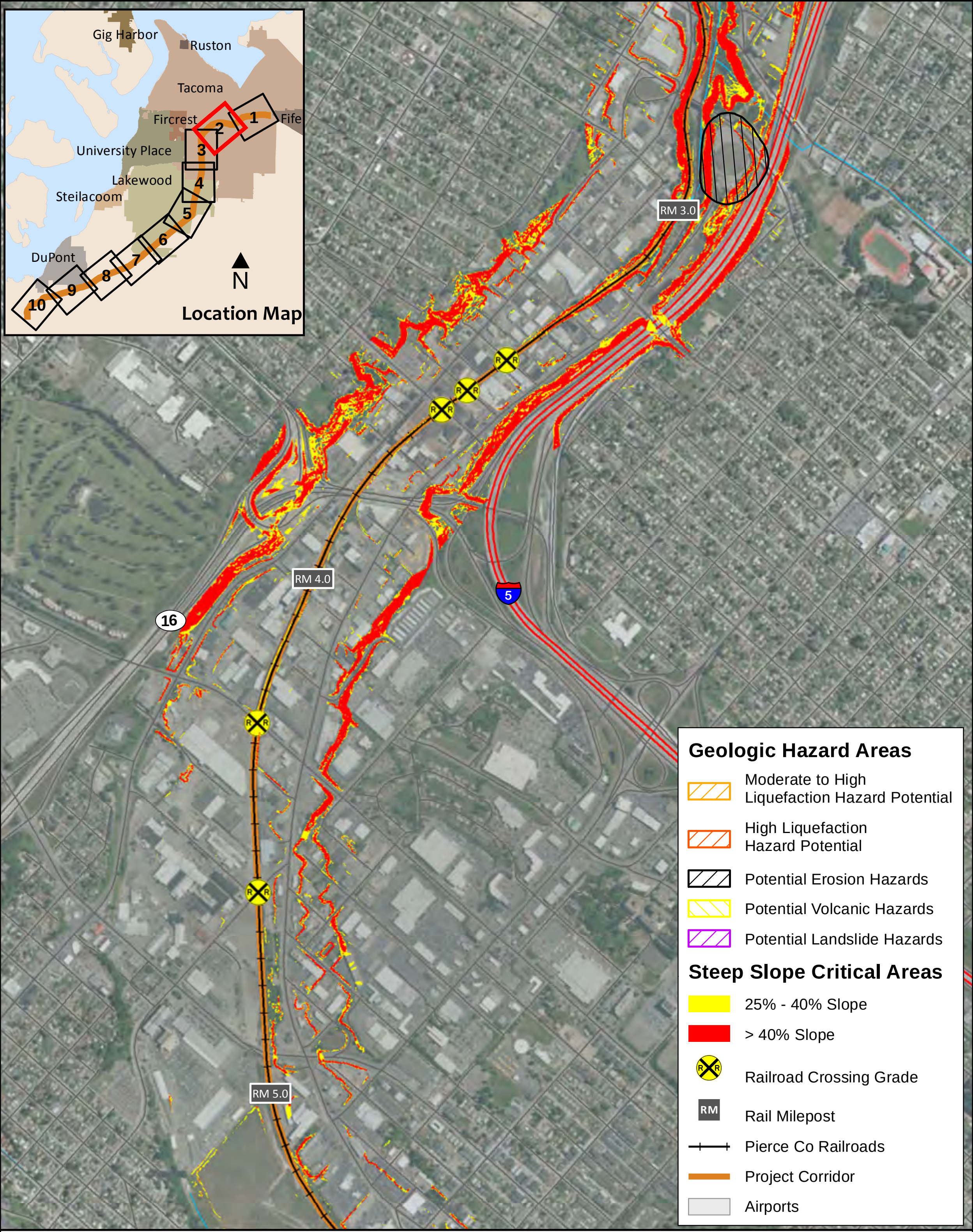

Pt. Defiance Rail Bypass
Attachment 11: Geologic Hazard Areas

Panel 1 Nov 3, 2011

Washington State Department of Transportation

0 0.25 0.5 Miles

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation



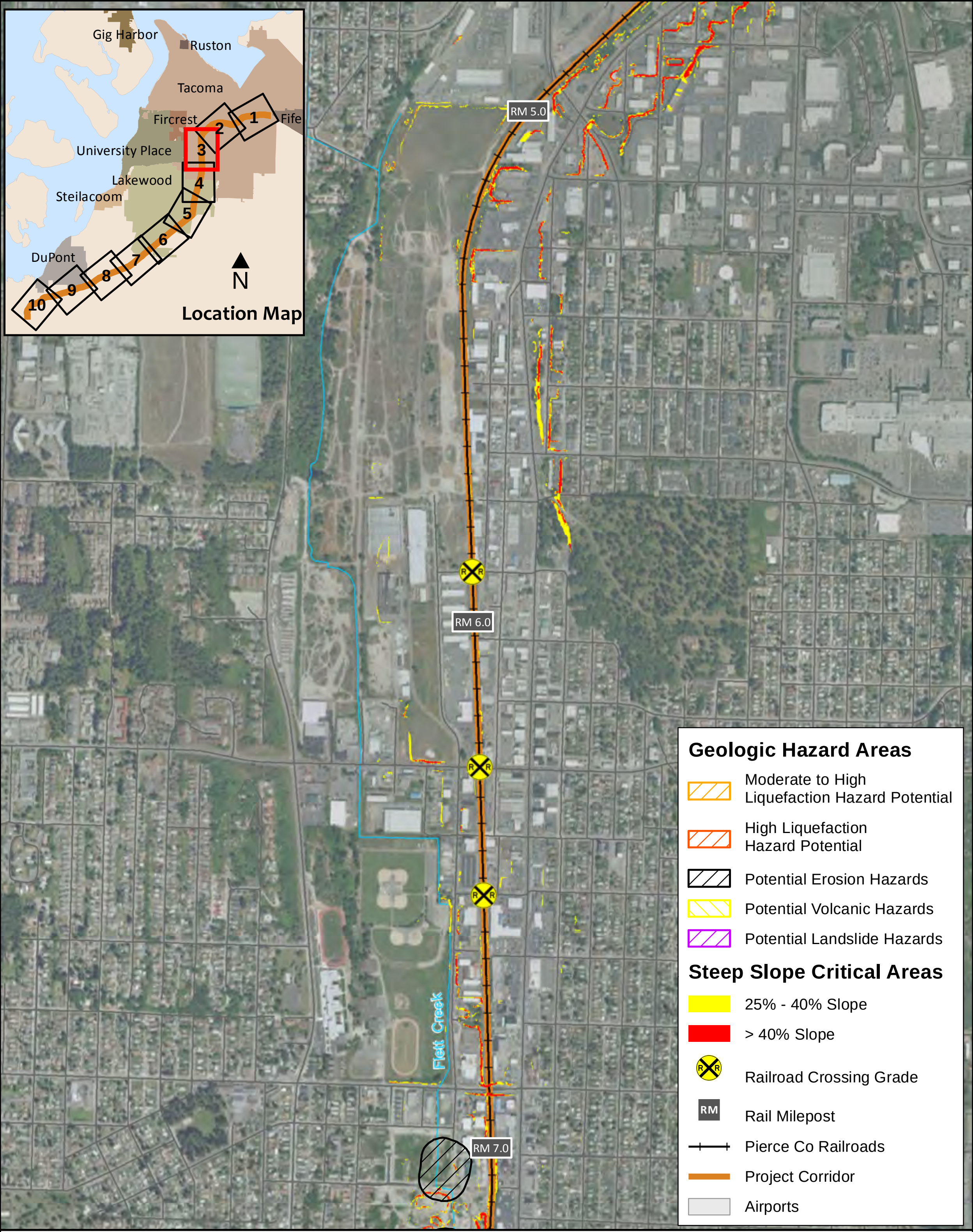

Pt. Defiance Rail Bypass
Attachment 12: Geologic Hazard Areas

Panel 2

Nov 3, 2011

Washington State Department of Transportation

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass
Attachment 13: Geologic Hazard Areas

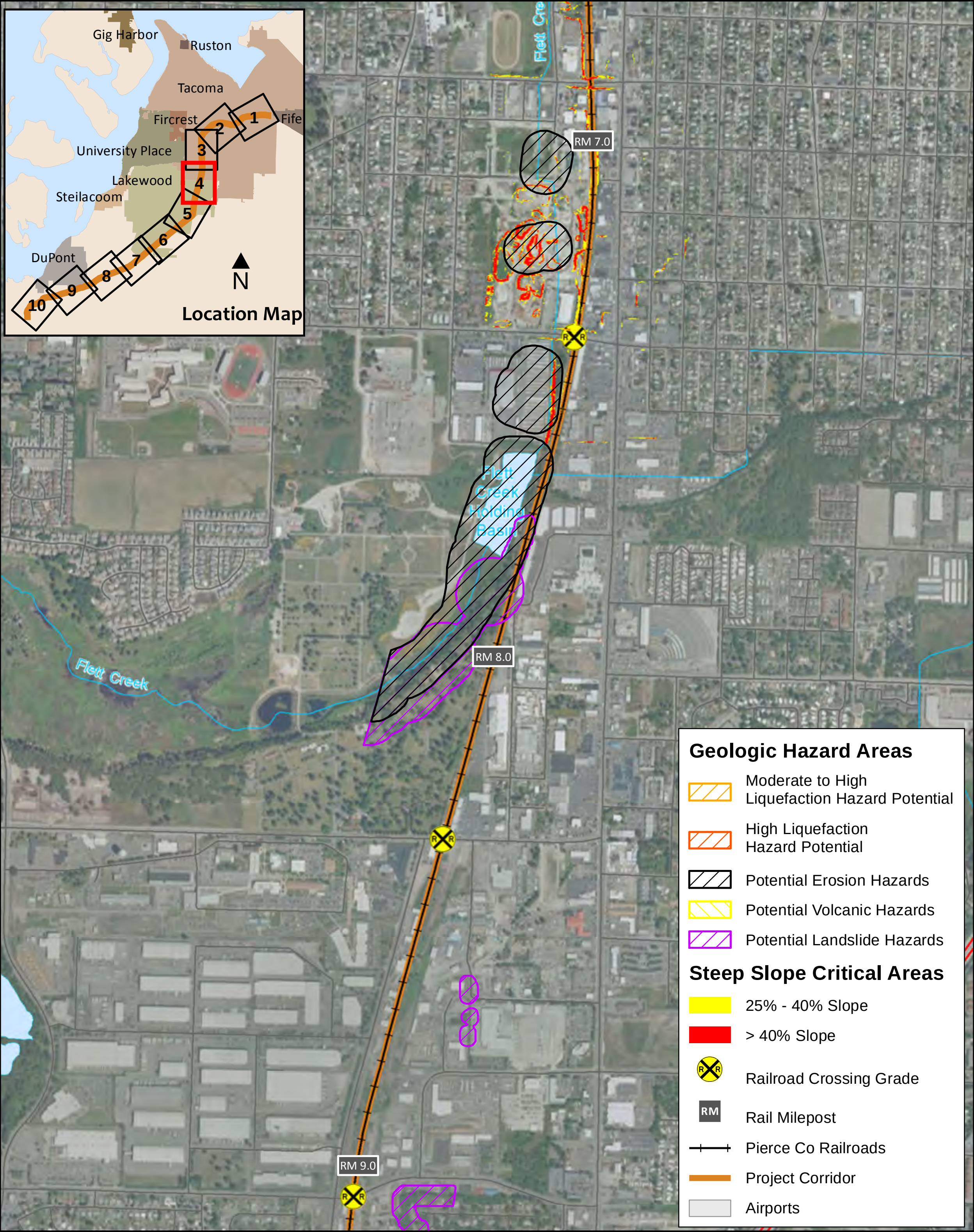
Panel 3 Nov 3, 2011

Washington State Department of Transportation

0 0.25 0.5 Miles

N

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass
Attachment 14: Geologic Hazard Areas

Panel 4

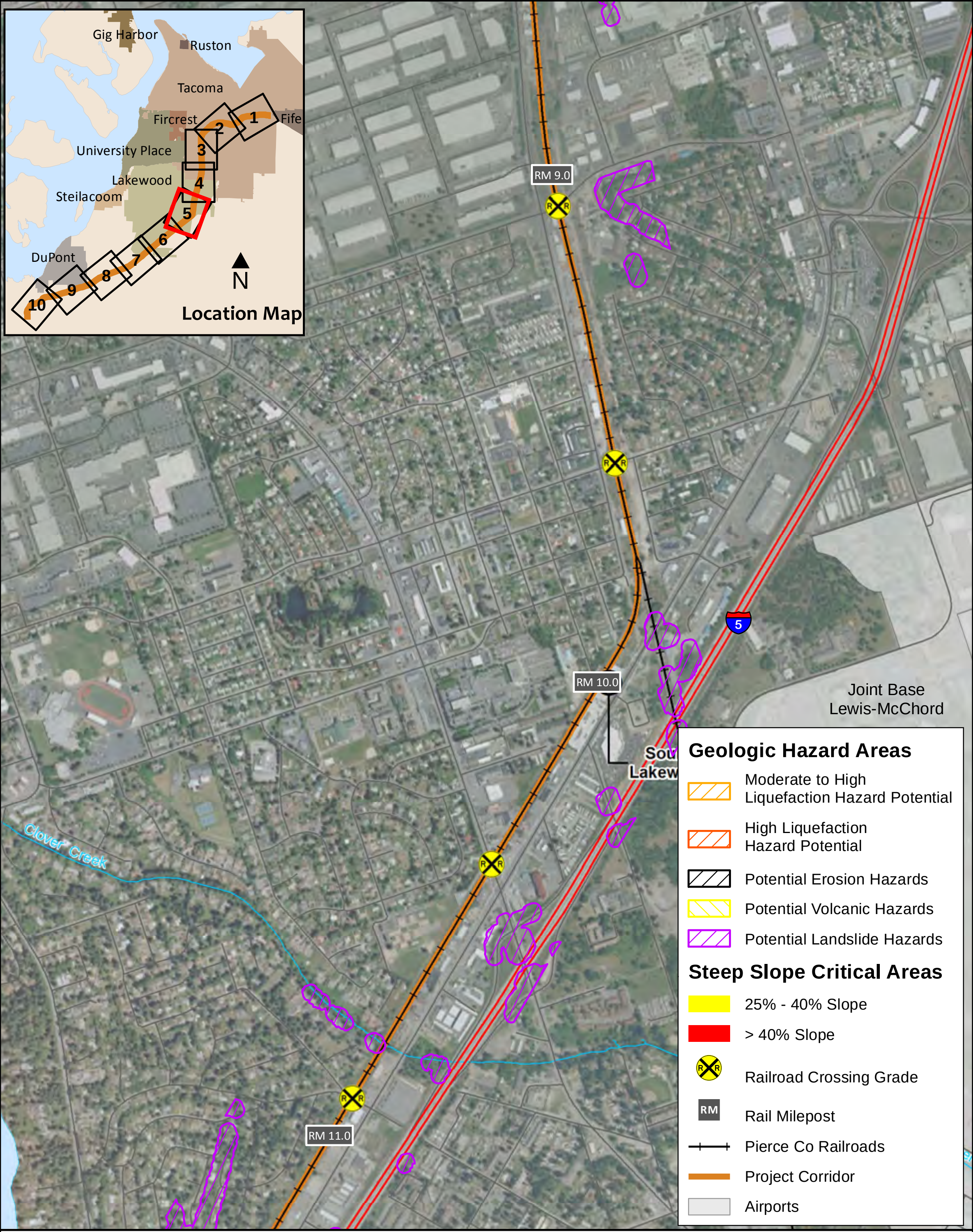
Nov 3, 2011

Washington State Department of Transportation

0 0.25 0.5 Miles

N

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation

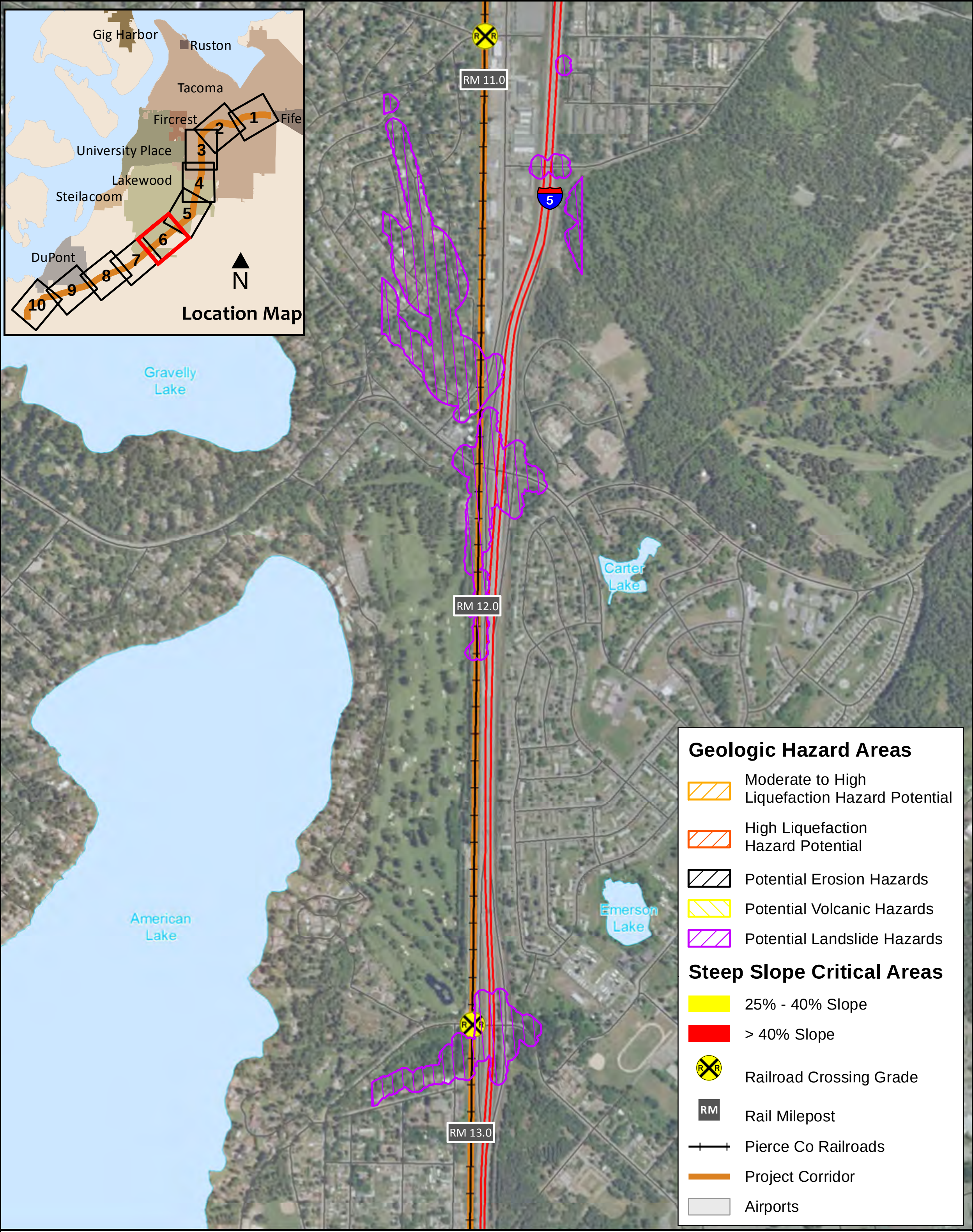



Pt. Defiance Rail Bypass
Attachment 15: Geologic Hazard Areas

Washington State Department of Transportation

Panel 5 Nov 3, 2011

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass

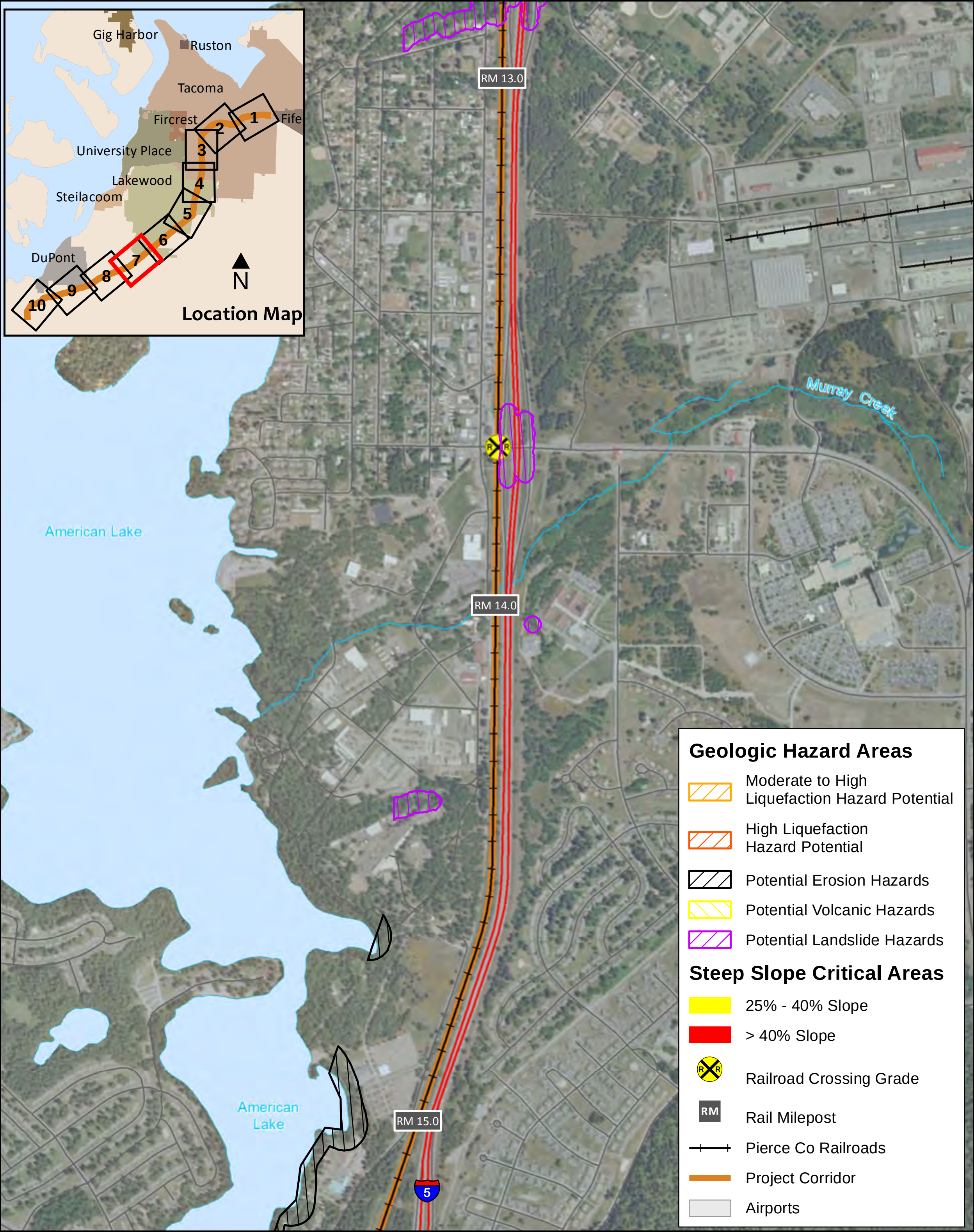
Attachment 16: Geologic Hazard Areas

Panel 6

Nov 3, 2011

Washington State Department of Transportation

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass
Attachment 17: Geologic Hazard Areas

Panel 7

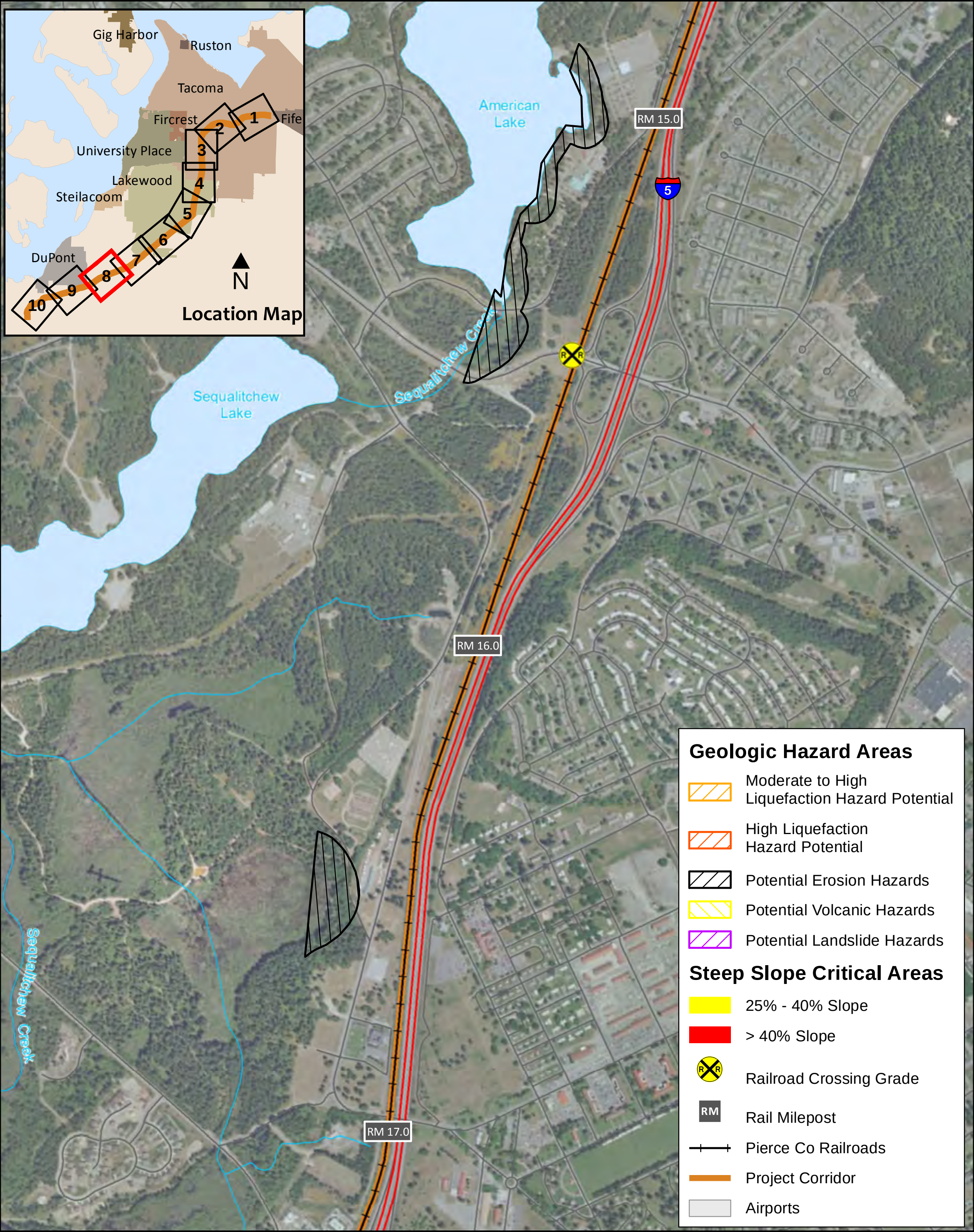
Nov 3, 2011

Washington State Department of Transportation

0 0.25 0.5 Miles

N

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass
Attachment 18: Geologic Hazard Areas

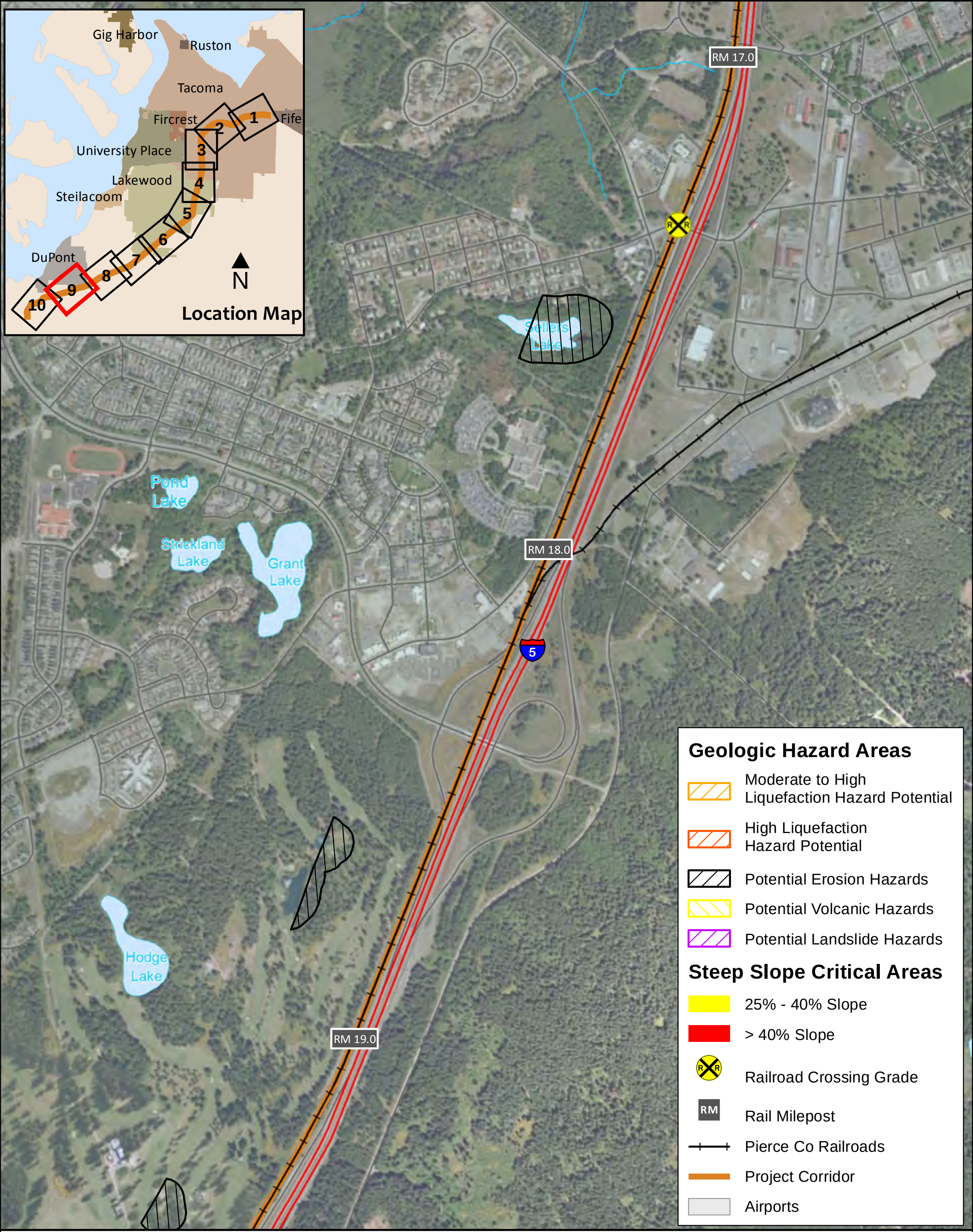
Washington State Department of Transportation

0 0.25 0.5 Miles

N

Panel 8 Nov 3, 2011

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation

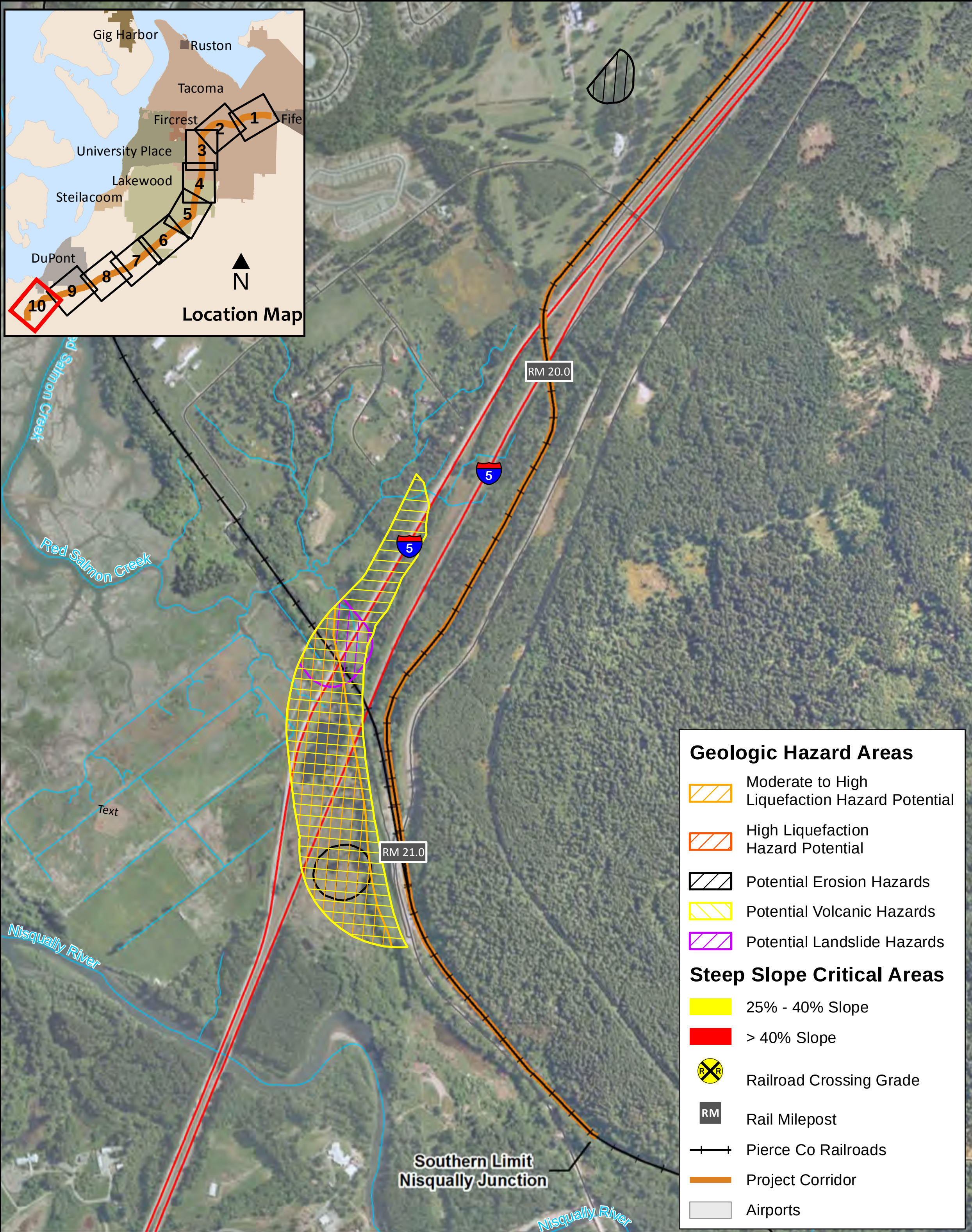



Pt. Defiance Rail Bypass
Attachment 19: Geologic Hazard Areas

Panel 9 Nov 3, 2011

Washington State Department of Transportation

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation




Pt. Defiance Rail Bypass
Attachment 20: Geologic Hazard Areas

Washington State Department of Transportation

0 0.25 0.5 Miles

N

Panel 10 Nov 3, 2011

Data Sources: Pierce County; TANA Dynamap Transportation; US Census Bureau; US Environmental Protection Agency; WA Dept. of Ecology; WA Dept. of Health; WA Dept. of Natural Resources; WA Dept. of Transportation