WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
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Models of Bedrock Elevation and Unconsolidated Sediment
Thickness in the Puget Lowland, Washington
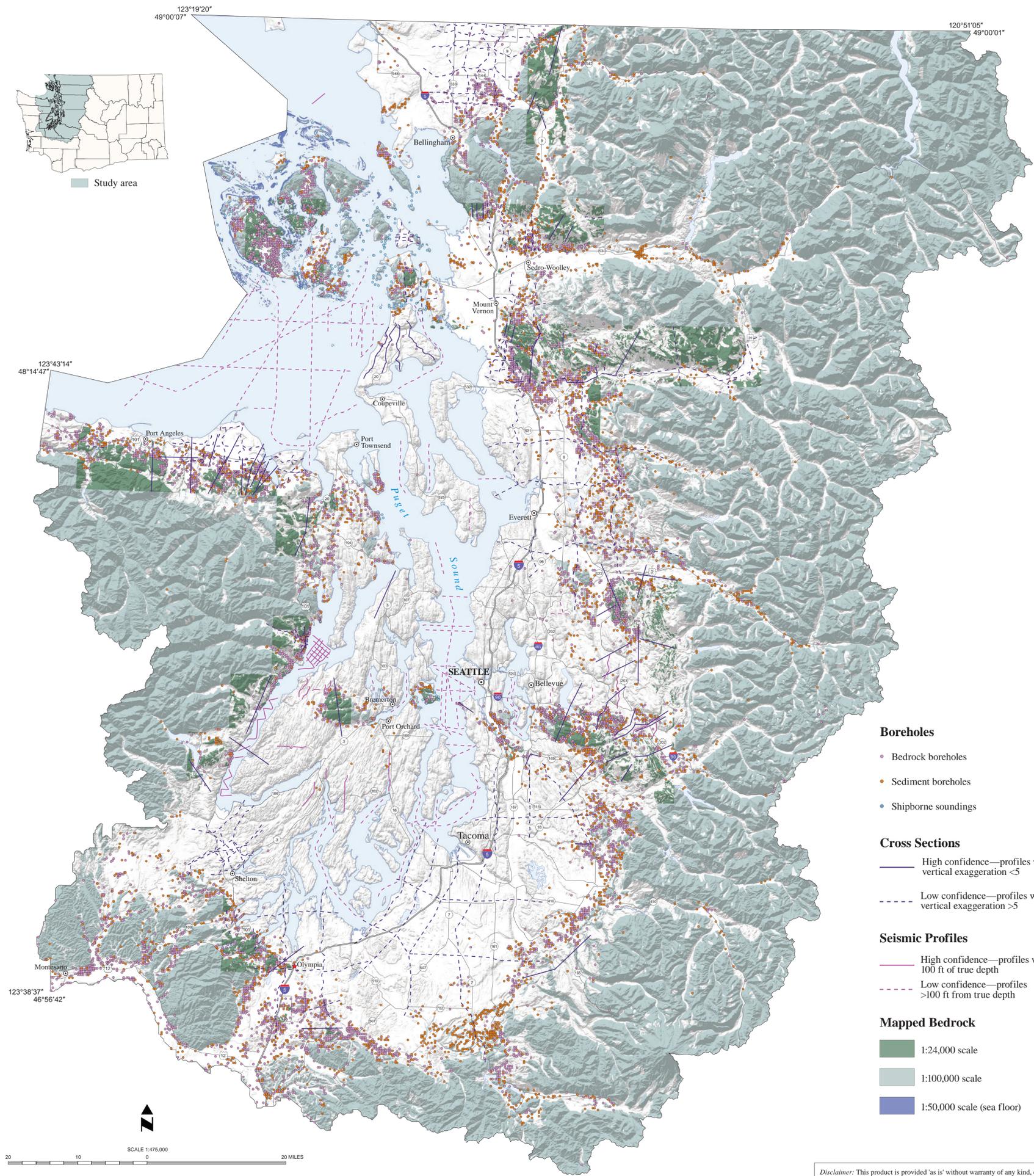Plate 2 of 2
*Pamphlet accompanies plate*

# Data Sources for the Puget Lowland
# Bedrock Elevation Model

by
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Study area

**Boreholes**
- Bedrock boreholes
- Sediment boreholes
- Shipborne soundings

**Cross Sections**
High confidence—profiles with vertical exaggeration <5
Low confidence—profiles with vertical exaggeration >5

**Seismic Profiles**
High confidence—profiles within 100 ft of true depth
Low confidence—profiles >100 ft from true depth

**Mapped Bedrock**
1:24,000 scale
1:100,000 scale
1:50,000 scale (sea floor)

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SCALE 1:475,000
20  10  0  20 MILES
20  10  0  20 KILOMETERS

Lambert conformal conic projection
North American Datum of 1983
Shaded relief generated from U.S. Geological Survey 30-meter digital
  elevation model; sun azimuth 340°; sun angle 45°; vertical exaggeration 1.4
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Digital cartography by Ian J. Hubert, Anne C. Olson, and Jessica L. Czajkowski
Editing and production by Jessica L. Czajkowski

## DATA PREPARATION METHODS

To generate elevation and thickness models for the Puget Lowland (Plate 1, Maps A and B), we integrated bedrock elevations from geologic maps, geologic cross sections, borehole data, and seismic profiles. Ten-meter DEMs compiled by Gesch and others (2002), merged with 10-m bathymetry data from Finlayson (2000) and 90-m bathymetry from the NOAA National Geophysical Data Center (2014), provide elevations for both the land and seafloor. This study did not use lidar-based elevation data, despite its greater elevation precision, due to the scale of the study, incomplete lidar coverage, and file-size limitations. Geographic Information System (GIS) modeling of bedrock elevations from these data sources provided an estimate of bedrock elevation and thickness where little to no bedrock control exists.

### Geologic Maps and Cross Sections

Bedrock units mapped at the surface at 1:100,000 scale and, where available, at 1:24,000 scale, provide the best available elevation control. The intersections of geologic contacts for bedrock units and digital elevation models provide the elevation of the surficial extent of bedrock units. For smoother transition between the interpolated bedrock elevation of the model and the true elevation in areas where bedrock exists at the surface, points (capturing elevation data) were generated with 328-ft spacing along the boundaries of the bedrock polygons to ensure that there was at least one elevation point in each raster cell where bedrock was mapped. See Appendix B (pamphlet) for a complete list of geologic maps used in this study.

Geologic cross sections produced by geologists for mapped 1:24,000-scale quadrangles provided additional estimates for bedrock depths. Depths to hydrogeologic units representing bedrock were also obtained from cross sections within hydrogeologic

studies. While geologic and hydrogeologic cross sections both provide interpretations of bedrock depth, they provide far better bedrock control in areas of complex structure than point data alone. We retrieved bedrock elevations from the cross sections and converted the bedrock elevations to points at 328-ft intervals along the line of cross sections (Plate 2). The 328-ft resolution used for these points matches the resolution of the final model.

More restricted in availability, seafloor mapping data were incorporated into the bedrock elevation modeling for the Puget Sound. Seafloor mapping using multibeam bathymetry and remotely operated vehicle (ROV) video analyses is extensive in the area surrounding the San Juan Islands (Picard and others, 2011). Seafloor outcrop polygons designated as sediment-covered bedrock, fractured bedrock, and pinnacle or boulder were included in a single bedrock layer and added to the 1:24,000-scale map compilation. In undersea areas where no bedrock mapping was available, sounding points and nautical maps created by the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and University of Washington (NOAA Ocean Service, Office of Coast Survey, 2001) show the location of potential bedrock outcrops in Puget Sound and the Strait of Juan de Fuca. Locations on nautical maps labeled as 'rocky' or 'rky' and nearby soundings with matching designations were included into the model dataset.

### Borehole Data

Water wells, geotechnical boreholes, and oil and gas exploration data provide bedrock control for the depth and lithology of subsurface geologic units. Locations and data for the boreholes originate from three distinct datasets. The distinction is the precision at which the source agency located the boreholes. The Washington State Department of Ecology (WSDOE, 2013) water well records and locations use township-range coordinates. This method of locating water wells generally places them within the centroid of a

quarter-quarter section; the actual location of these wells may be as much as 935 ft from the reported location. The Washington Division of Geology and Earth Resources (WADGER) Subsurface Database (SSD)(unpub. database, 2014) is a compilation of data from agencies such as the Washington State Departments of Transportation (WSDOT), Health (WSDOH), WSDOE, the USGS, and geotechnical firms. The SSD locations generally have a locational precision of 100 ft or better.

Oil and gas well data (WADGER, 2012) provided locations and digital records for a number of permitted oil and gas borings within the Puget Lowland. A review of additional data in the form of geophysical logs, driller reports, and permit documents on file at the WADGER was performed, which provided bedrock depths particularly useful in areas of thick sediment accumulation. However, several boreholes were excluded as: (1) no interpretation of geophysical logs was performed and (2) the documentation on file did not provide any useful lithology information.

The SSD and WSDOE databases produced a number of duplicate records within the model data. Several rounds of quality checks performed on well records identified duplicates and resulted in the removal of numerous boreholes from the WSDOE-sourced part of the model borehole database. (Due to the lack of detail in some of the well records, it is likely that some amount of duplication remains within the model input data.) We then reviewed the well logs, identifying bedrock depths. Wells that had ambiguous logs or questionable descriptions underwent a secondary review for quality control. By comparing the questionable wells to nearby boreholes with definitive bedrock depths, we re-evaluated the reliability of those wells and removed wells with unreliable lithologic descriptions or depths unlike other nearby wells in the model dataset.

When necessary, we used wells that did not penetrate bedrock to provide a minimum estimate of potential bedrock depth in areas where data was sparse. The minimum bedrock elevation for each borehole was determined by subtracting the bedrock depth—or total

well depth for 'sediment' wells (wells not encountering bedrock)—from the surface elevation provided through either digital elevation model (DEM) or bathymetry rasters.

### Seismic Reflection Data

Both marine- and land-based seismic reflection analyses provided profiles that aided in determining bedrock depths for many areas within Puget Sound, the Strait of Juan de Fuca, and onshore areas near south-central Puget Sound and Hood Canal. While numerous seismic profiles exist, this study considered only those with bedrock 'picks' that were also publicly available, excluding the use of proprietary information found with industry profiles. Project constraints also limited the study to using processed seismic data available in scientific literature.

Building a bedrock surface from marine- and land-based seismic profiles used the same methods as employed with the geologic cross sections. The vertical units provided in the source seismic profiles vary in that some provided interpreted depths for the cross section in kilometers, while others provided the depth in terms of two-way travel time (twt) in seconds. In order to convert the profiles given in twt to kilometers, we calculated the distance to bedrock based on the time given and P-wave seismic velocities. Soil and rock velocities range from 1600 m/sec to 3500 m/sec. For seismic profiles where the author provided no velocity estimates, we used an average value of 1800 m/sec. Table A1 (pamphlet) provides a list of each seismic section, velocity used in the depth calculations, and then determined the bedrock elevation for every 328 ft along the line of transect of a given profile.