Appendix C

Seismic Design Criteria Update Technical Memo

King County

TECHNICAL MEMORANDUM

DATE August 28, 2020 **Project No.** 1420076.002

TO Mr. Phil Coughlan
Herrera Environmental Consultants

FROM Alan Hull, PhD and Frank Shuri, PE, LG, LEG **EMAIL ahull@golder.com**

EARTHQUAKE GROUND MOTIONS AT CEDAR HILLS REGIONAL LANDFILL, KING COUNTY, WASHINGTON

This technical memorandum contains information used to estimate the horizontal peak ground acceleration (PGA) at the Cedar Hills Regional Landfill (CHRLF) site in King County, Washington (47.471227ºN 122.048421ºW). The PGA has a 10% probability of exceedance in 250 years (equivalent to 2,475-year return period) and has been obtained from the US Geological Survey (USGS) 2014 conterminous dynamic seismic hazard model (v.4.2.0) of the 2014 national seismic hazard map (NSHM).

Introduction

Golder Associates Inc. (Golder) understands that King County is preparing an Environmental Impact Statement (EIS) for a proposed expansion of its existing CHRLF. This facility is located about 7.5 miles (12 km) east of Renton in King County, Washington. Part of the technical analysis for the EIS includes an estimate of the PGA at the CHRLF site used to support present and future engineering analyses. In particular, mean PGA values are used as inputs to the assessment of the stability of existing and proposed permanent and temporary landfill slopes. It is important, therefore, that up-to-date assessments of earthquake ground motions are used for landfill development.

In 2008, Golder estimated earthquake ground motions for the CHRLF Area 7 expansion project (Golder 2008) from interpolation of the 2002 USGS NSHM. Key seismic information reported by Golder (2008):

- The CHRLF is located about 4 miles (6.5 km) south of the Seattle fault zone.
- The 2,475-year return period mean PGA was 0.56 g for an outcropping weak rock site.
- The total mean 2,475-year return period mean PGA had contributions from crustal earthquake sources (faults and background earthquakes), and deep and interface sources from the Cascadia Subduction Zone (CSZ).
- A moment magnitude **M**7.2 earthquake at a distance of 4.6 miles (7.3 km) was the modal magnitude-distance pair for the 2,475-year return period mean PGA at the site.

Since 2008 there have been several updates to the USGS NSHM with new geological information available for the history of crustal earthquakes in the Puget Lowland (e.g., Nelson et al. 2014) and particularly for the Seattle Fault Zone (SFZ) (e.g., Pratt et al. 2015). The earthquake ground motion analysis discussed in this memo has, therefore, been undertaken to update the mean 2,475-year return period PGA estimate and other information on potential earthquake hazards at the CHRLF site.

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Work Scope

Golder's work scope for the update was developed from discussions with Herrera Environmental Inc. (Herrera) on May 29, 2020 and with a Herrera/King County/Golder teleconference meeting on June 4, 2020. The key work objective is to update the information and recommendations in Golder (2008) with the most recent readily available information from public science agencies, peer-reviewed published literature, and other credible sources. Key tasks undertaken by Golder for this update are:

- Compilation of an up-to-date earthquake catalog based on the hypocenters identified by Pacific Northwest regional seismic network (PNWSN), including information on any earthquake strong motions and large regional historical earthquakes (Figure 1A)
- Review of recent information on the tectonic setting, location, and activity of major crustal faults, including recent models of the geometry of the Juan de Fuca-North American plate boundary to the west and beneath Puget Sound (Figure 1B)
- Review of the 2014 USGS NSHM to evaluate the mean PGA with a 10% probability of exceedance in 250 years (i.e., 2,475-year return period) at the CHRLF site
- Use of online USGS tools to deaggregate the 2014 NSHM for PGA at a 2,475-year return period to identify the earthquake source contributions to the PGA hazard
- Preparation and internal review of this technical memorandum that explains the data, methods, and results of the PGA hazard update, including recommendations for earthquake ground motion values and scenario earthquakes suitable for seismic stability analysis of the CHRLF

Regional Tectonic Setting

Figure 1A illustrates the major tectonic elements and the epicenters of historical earthquakes in the Pacific Northwest of the United States, including those near Vancouver, Canada. These tectonic features confirm that the CHRLF is located in an active tectonic region associated with the ongoing interaction of the North America and Juan de Fuca tectonic plates (Figure 1A inset). The Juan de Fuca plate is located offshore of the coasts of California, Oregon, Washington, and Vancouver Island, British Columbia, Canada. At the latitude of the CHRLF, the Juan de Fuca plate converges northeast toward the North America plate at a present-day velocity of about 0.8 inches/year (20 millimeters/year, North America fixed) based on the GSRM v2.1 plate velocity model of Kreemer et al. (2014). Farther east, the Juan de Fuca plate sinks beneath the North America plate at the Cascadia Trench as it is subducted beneath North America in the region known as the CSZ (Figure 1B).

Geologic processes associated with the ongoing development of the CSZ result in three general types of earthquakes that can produce moderate to strong earthquake shaking at the CHRLF site. These earthquake types are:

1. Shallow (i.e., <20 miles or ~30 km), great-magnitude earthquakes (i.e., **M**8 to **M**9$^+$) generated by sudden slip along the boundary between the Juan de Fuca and North America plates. The epicenters of these great earthquakes are expected to be offshore or beneath the coast. The great earthquakes have thrust-type (i.e., contraction) rupture mechanisms and typically result in major land movements offshore and at the coast. Based on the record of buried marshes in the southwest Washington (Atwater and Hemphill-Haley 1997), these earthquakes have an average return period of 500 to 540 years, but have recurred in periods as short as 100 to 300 years and as long as 1,000 years over the last 3,500 years. Major

tsunamis are generated by the seafloor movements accompanying these great earthquakes as recorded from the last great earthquake (**M**9) in January 1700. This earthquake generated a major trans-Pacific tsunami affecting both the Pacific Northwest coast of North America and Japan as described by Atwater et al. (2015).

2. Intermediate- and deep-focus (>20 miles or 30 km) strong- to major-magnitude earthquakes (i.e., **M**6.5 to **M**7.9) located within the downgoing Juan de Fuca plate beneath the coast and Cascade Range (Figure 1B). These deeper earthquakes typically have normal-slip mechanisms (i.e., extension) and can be felt widely as in the 1949 **M**6.75, 1965 **M**6.73 Seattle, and 2001 **M**6.8 Nisqually earthquakes. These historical earthquakes were felt strongly and caused damage throughout the greater Seattle area.
3. Shallow-focus strong- to major-magnitude crustal earthquakes generated by slip on faults in the North America plate as it accommodates contraction and internal rotation along its boundary with the Pacific plate to the south and Juan de Fuca plate to the west (Figure 1B). Shallow-focus earthquakes also include those associated with periodic activity of the volcanic centers within the Cascade Range.

Cascadia Subduction Zone

The regional tectonic setting of the Pacific Northwest is dominated by tectonic processes associated with the ongoing subduction of the Juan de Fuca plate beneath North America. The CSZ "megathrust" is an approximately 600-mile (1,000-km) -long fault that extends from northwest Vancouver Island to Cape Mendocino, California (Figure 1A inset). Continued subduction of the Juan de Fuca plate has resulted in the accretion and deformation of marine sediments on the overlying North America plate and the development of the periodically active volcanoes within the Cascade Range.

Figure 1A shows depth contours (in km) developed by Hayes et al. (2018) for the top of the Juan de Fuca plate as it is subducted beneath North America. Figure 1B is a cross-section extending eastward from the Cascadia Trench through the CHRLF site to central Washington. Earthquake hypocenters for 60 miles to the north and south have been projected onto the cross-section line. Key tectonic features illustrated in Figures 1A and 1B are:

- The eastward dip of the Juan de Fuca plate is initially relatively shallow to a depth of about 40 miles (~60 km), but the plate dip steepens under the Cascade Range
- Relatively few historical earthquakes have been recorded in the deeper parts of the Juan de Fuca plate and offshore regions of overlying North America plate
- Shallow-and intermediate-focus earthquakes beneath the Olympic Range and Puget Lowland. The concentration of earthquakes hypocenters appears to be associated with the change in orientation and dip of this part of the Juan de Fuca plate
- Crustal and CSZ inslab earthquakes are common beneath the Puget Lowland

Historical Earthquakes

The historical record of strong earthquake ground shaking and damage experienced in the Puget Lowland surrounding the CHRLF site over about the last 100 years is dominated by the three **M**6.7^{+} earthquakes originating within the Juan de Fuca plate (Figures 1A, 1B). Information on the damage from the major historical events is described in many online summaries provided by the USGS, State of Washington and other public agencies (e.g., WDGER 2008).

Eight deaths, many injuries, and up to $25 million in property damage were caused by the **M**6.75 earthquake on April 13, 1949 that had an epicenter near Olympia, Washington (WDGER 2008). At Olympia, nearly all large buildings were damaged, and water and gas mains were broken. Property damage was caused by falling parapet walls, toppled chimneys, and cracked walls. Electric and telegraphic services were interrupted. A large portion of a sandy spit jutting into Puget Sound north of Olympia disappeared during the earthquake. Near Tacoma, a rockslide on the seacliff collapsed into Puget Sound. The earthquake was felt from western Montana in the east, to Cape Blanco, Oregon in the south, and western Canada to the north.

An **M**6.73 earthquake occurred on April 29, 1965, with an epicenter and felt area close to the 1949 earthquake. (WDGER 2008). Three people were killed by falling debris, and the deaths of four elderly women from heart failure were attributed to the earthquake. The damage caused about $12.5 million in damage, with the strongest shaking and damage recorded in Seattle and Issaquah. In 188 West Seattle city blocks, 1712 of 5005 chimneys were damaged. Two schools in West Seattle and two brick school buildings in Issaquah suffered substantial damage consistent with the damage pattern experienced during the 1949 earthquake.

The **M**6.8 Nisqually earthquake occurred in the mid-morning of February 28, 2001, with an epicenter in southern Puget Sound northeast of Olympia (WDGER 2008). About 400 people were injured but no direct deaths. Most of the property damage occurred very near the epicenter or in unreinforced concrete or masonry buildings in the older neighborhoods of Seattle. The Fourth Avenue Bridge in downtown Olympia was heavily damaged and was later torn down and re-built. In Seattle, the Alaskan Way Viaduct and its seawall were damaged, forcing the viaduct to close for emergency repairs. Approximately $305 million of insured losses and a total of $1 to $4 billion worth of damage occurred in the state of Washington.

Resurveying of the bathymetry of the shallow deltas near the Nisqually earthquake epicenter revealed multiple submarine failures on the Puyallup River and Duwamish River delta fronts. In other areas, liquefaction, sand boils, landslides, and soil slumping occurred. Soil liquefaction was also observed at the Nisqually National Wildlife Refuge causing damage to the some of its buildings.

Crustal Faults of the Puget Lowland

Figure 2 shows the major faults within and surrounding the Puget Lowland and Olympic Peninsula in western Washington. These fault traces are those included within the 2014 NSHM fault source model of Petersen et al. (2014) and represent their general rather than precise locations.

Seattle Fault Zone

Location

The east-west striking SFZ has been mapped to extend for approximately 43 miles (70 km) (Figure 2). Three principal fault strands have been identified from the interpretation of high-resolution seismic reflection and aeromagnetic surveys. The northernmost strand is sub-parallel to Interstate 90 and extends under Lake Sammamish (Figure 2). The locations of the middle and southern traces of the Seattle fault are based on the interpretation of seismic-reflection profiles by Johnson et al. (1999) and Brocher et al. (2001); high-resolution aeromagnetic surveys from Blakely et al. (2002) and Pratt et al. (2015); and by local surface geologic mapping. Maps included in Nelson et al. (2014) and Pratt et al. (2015) provide more detailed locations of the SFZ along most of its mapped length.

Golder (2008) reported that the most significant crustal fault for the CHRLF site is the nearby middle trace of the SFZ located about 4 miles (6.5 km) north of the CHRLF site at its closest approach. The southern trace terminates about 5 miles (8 km) to the northwest of the CHRLF site. The SFZ trace locations used in the 2014 NSHM are the same as in 2008.

The Washington Geologic Information Portal indicates that the inferred southern trace of the SFZ trace extends eastward to be directly north of the CHRLF site, and is mapped to extend farther east than mapped by the USGS. The location of the inferred eastward extension of the SFZ southern fault trace is based on a geophysical lineament mapped by Liberty and Pratt (2008). Thus, based on the inferred fault location from WDNR (2020), the southern trace of the SFZ is located approximately 1 mile (1.6 km) to the northeast of CHRLF and 2 miles (3.2 km) northeast of the Renton site (WDNR 2020). No maps or databases, however, indicate that any trace of the SFZ extends into or beneath the CHLRF or Renton sites.

Structure

The SFZ (Figure 2) marks the geological boundary between 50 to 60 million year old uplifted basalt rocks on the south and younger northward-tilted sedimentary rocks of the Seattle Basin to the north. The basalt rocks underlying the Seattle Basin have been buried under at least 4.3 miles (7 km) of sedimentary rocks less than 30 million years old and, most recently by glacial and post-glacial sediments since about 20,000 years ago. The continued development of the SFZ has created a 2.5- to 4.3-mile (4- to 7-km) -wide zone of geological deformation, where three main south-dipping thrust faults have been recognized (e.g., Johnson et al. 1999; Liberty and Pratt 2008; Pratt et al. 2015). Most of the fault planes do not reach the ground surface (i.e., they are "blind"), which makes them often difficult to locate on the ground because they form broad zones of warping that are commonly obscured by a thick vegetation cover or modified by urban development.

The south, hanging wall of the SFZ contains a number of north-dipping “back-thrust faults” ─ thrust faults opposite in dip to the main south-dipping SFZ that accommodate contraction during folding of the southern hanging wall. The Toe Jam Hill fault on Bainbridge Island and Waterman Point faults on Pt. Glover Peninsula are interpreted to be back-thrusts of the Seattle fault (e.g., Blakely et al. 2002; Nelson et al. 2003; Nelson et al. 2014). These back-thrust faults are not considered to be independent sources of major earthquakes. Instead, the they are interpreted to accommodate slip on the main, south-dipping SFZ, and therefore only move with the SFZ.

Pratt et al. (2015) interpreted the shallow, south-dipping thrust faults imaged on seismic-reflection profiles within the SFZ to model the Seattle fault as a fault-propagation fold where the main SFZ thrust faults reach shallow depths to reproduce the morphology of uplifted terraces and cause subsidence north of the fault. Pratt et al. (2015) argued that their interpretation of seismic-reflection profiles provides evidence that the northernmost thrust fault and synclinal axial surface forming the deformation front of the SFZ may project to the surface beneath the downtown area of Seattle. The back-thrust scarps and terrace uplifts indicate that approximately 17 m of north-south shortening has been accommodated beneath the Puget Lowland in the last 3,500 years. This cumulative shortening is about half of the total expected in the Cascadia forearc and indicates that the SFZ has been one of the most active faults, if not the most active fault, in the region.

Paleoseismology

Most evidence of surface deformation during earthquakes of the past few thousand years in the SFZ has come from studies of fault scarps and deformed shorelines on Bainbridge Island and the Point Glover peninsula to the south. Nelson et al. (2014) provide a detailed summary of the locations, evidence, and dates from detailed paleoseismological investigations of the SFZ from fault scarp trenching and uplifted shore platform investigations. Nelson et al. (2014) identified at least four past surface ruptures indicating moderate to large earthquakes that originated on the SFZ in about the last 3,500 years. The age range for the earthquakes are, in years before present:

- 940–380
- 1040–910
- 1350–1170
- 2650–1940

Earthquake dates all have age ranges because of the uncertainties associated with the radiocarbon dates used to estimate the age of sediments that were offset and/or deformed by coseismic movement on the SFZ.

Nelson et al. (2014) report a new inferred surface-rupturing earthquake along the Waterman Point back-thrust at 940 to 380 years ago. It remains unclear, however, whether the mapped fault scarps are a record of moderate-magnitude shallow earthquakes (i.e., **M**5.5 to **M**6.0) or larger (**M**6.5 to **M**7.0) magnitude earthquakes. Kinematic modeling of SFZ earthquakes by Pratt et al. (2015) supports a model where the shallow back-thrust scarps formed in the forelimbs of major thrust faults that most likely ruptured with earthquakes on the main faults. They argue that the paleoseismic record of the back-thrust ruptures reflects moderate or larger earthquakes on the main thrust faults. The slip on back-thrusts of the SFZ may occur during moderate to large earthquakes every few hundred years over periods of 1000 to 2000 years, and then not slip for periods of at least several thousands of years (Nelson et al. 2014).

It is important to note that the paleoseismic record is a minimum record only. As noted by Pratt et al. (2015), paleoseismic studies date only those earthquakes preserved as surface ruptures or uplifted marine terraces. The paleoseismic record does not include earthquakes rupturing the blind thrust faults that did not cause surface rupture and/or were not large enough to cause strong ground shaking to trigger secondary events such as landslides and liquefaction.

Seismic Hazard Assessment

This section describes the information on the CHRLF site ground condition and the results from the USGS 2014 NSHM used to develop the PGA estimate.

Site Ground Condition

Golder (2008) assumed a site ground condition for earthquake ground motion estimation at the CHRLF site with a time-averaged shear-wave velocity of 2,500 ft/s (760 m/s) for the 100 ft (30 m) below the ground surface. This parameter is V_{S30} and is used in earthquake ground motion assessment to characterize the near-surface ground condition. A site condition with a V_{S30} of 2,500 ft/s (760 m/s) is equivalent to an outcropping weak rock site. Geological and borehole information from the CHRLF site indicates that in general, it is underlain by a veneer (less than 12 ft [~ 4 m]) of fill overlying glacial till. This site stratigraphy suggests that a V_{S30} of 2,500 ft/s)(760 m/s) is a reasonable estimate for the CHRLF site soil condition. Accordingly, this update uses this same site condition assumption as in Golder (2008).

Peak Ground Acceleration Estimate for a 2,475-year Return Period

Probabilistic seismic hazard analysis (PSHA) is used to estimate mean-value earthquake ground motions for regions and for sites. PSHA provides a probabilistic estimate for a specified earthquake ground motion at a specified return period or annual exceedance probability (AEP). The earthquake ground motions can be a horizontal peak ground acceleration (PGA) or spectral accelerations (accelerations at a specified period), as commonly used in the 2019 International Building Code and American Society of Engineers (ASCE) 7-16 standard.

The USGS developed probabilistic national seismic hazard maps (NSHMs) in 1996, 2002, 2008, and 2014. The NSHM provides mean PGA and spectral accelerations for sites throughout the conterminous United States. The 2014 NSHM reported by Petersen et al. (2014) was partially updated in 2018. Each NSHM update has revised the national probabilistic source model so that each new NSHM incorporates the latest information on historical earthquake locations and recurrence rates, the locations and activity of major faults, the fault rupture characteristics, and application of ground motion models (GMM) that model the source-to-site attenuation of earthquake accelerations from the earthquake hypocenter to the site of interest.

For Washington State, the probabilistic seismic source model is based on the geometry and earthquake activity of the shallow and deep parts of the CSZ (Figures 1A and 1B), distribution and frequency of historical crustal earthquakes (Figures 1A and 2), and the location and activity of the major crustal faults of the Puget Lowland such as the Seattle fault (Figure 2).

In July 2020, Golder accessed the Dynamic Conterminous US 2014 (update v4.2.0) NSHM for the CHRLF site location at 47.471227°N, 122. 048421°W (https://earthquake.usgs.gov/hazards/interactive/). We obtained a 2,475-year return period mean PGA of 0.58 g for an assumed site ground condition with a V_{S30} of 2,500 ft/s (760 m/s).

Deaggregation Analysis

Deaggregation analysis of seismic hazard is used to identify the distribution of earthquake magnitude-distance pairs that contribute to the mean hazard at a given return period and for a given spectral acceleration. In general, hazard sources are either those associated with a known fault or fault segment or those arising from background earthquakes not associated with a known fault (i.e., gridded-area, or background point sources). Deaggregation is used to confirm the earthquake magnitude-distance pairs that contribute the most to the site hazard, particularly if further deformation-based analysis of slope stability is to be undertaken.

The USGS website provides the results of PGA deaggregation analysis at the CHRLF site for a 2,475-year return period mean PGA as shown in Figure 3. The colors bars in Figure 3 indicate how much of the hazard contribution is above the median PGA for each magnitude-distance pair for what is known as the epsilon parameter. An epsilon of 0 indicates a median value. Lighter colors (yellow) indicates an epsilon indicating a near-median value to 0.5 of a standard deviation below median. Darker blue colors indicate epsilon values increasingly above median from pale blue at 0.5 standard deviation above median and darkest blue between 2 and 2.5 standard deviations above median. Review of the deaggregation source contributors in Figure 3 indicates that the 0.58 g mean PGA for a 2,475-year return period has four main earthquake sources with percentage contributions:

- Deep Juan de Fuca plate inslab sources beneath the CHRLF site—33%
- Distributed regional crustal sources in the Puget Lowland and surrounding region—32.4%
- Three sections of the SFZ located from 4 miles to 6.9 miles (6.4 km to 11 km) from the CHRLF—27%
- The Juan de Fuca-North America “megathrust” plate interface earthquake—7.6%

These results show that the 2,475-year return period mean PGA at the CHRLF site has about a third contribution from each of deep Juan de Fuca plate earthquakes, earthquakes associated with regional faults and background sources, and the SFZ, while the **M**9+ Cascadia megathrust earthquake makes only a small (7.6%) contribution. These relative contributions will change when spectral periods other than PGA are considered. The most common earthquake magnitude-distance pair (mode) contributing to the total PGA hazard at the site is an **M**7.1 earthquake located within the Juan de Fuca plate about 40 miles (65 km) beneath the CHRLF site.

Comparison to Mean PGA Estimate from Golder (2008)

The results of this analysis and that presented in Golder (2008) reveal only a very minor increase (4%) in 2,475-year return period mean PGA from 0.56 g (Golder 2008) to 0.58 g in this assessment. Both this assessment and Golder (2008) estimates are for a site ground condition with a V_{S30} of 2,500 ft/s (760 m/s). Both assessments indicate that earthquakes from the SFZ, background sources, and CSZ inslab and interface sources all contribute to the total 2,475-year return period mean PGA hazard at the site.

Similarly, the modal earthquake for the mean PGA shows a minor decrease from the **M**7.2 reported in Golder (2008) to **M**7.1 in this assessment. The modal distance and earthquake, however, have changed substantially from 4.6 miles (7.3 km) from an earthquake on the SFZ (Golder 2008) to 40 miles (65 km) from an CSZ inslab Juan de Fuca earthquake in this assessment. The change in modal earthquake source and distance increase reflects changes in how earthquake activity rates in the Puget Lowland and regional sources are modeled for the 2014 NSHM.

The change in modal earthquake from an **M**7.2 earthquake on the SFZ in the 2002 NSHM to a deep Juan de Fuca inslab earthquake in 2014 reflects improved knowledge of the SFZ earthquake history and the relative importance of the deep CSZ inslab earthquakes experienced in the Puget Lowland from the **M**6.7^{+} earthquakes in 1949, 1965, and 2001.

Conclusion

This assessment shows that since completion of Golder (2008) there has been only a very minor increase of 4% in the 2,475-year return period mean PGA for the CHRLF site, despite two major revisions to the USGS NSHM in 2008 and 2014, and one minor update in 2018. A change in total hazard of less than 5% is considered to be within the normal uncertainties associated with earthquake hazard models and of little or no engineering significance for slope stability assessment at the CHRLF site.

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Attachment:
Figures

https://golderassociates.sharepoint.com/sites/131956/project files/6 deliverables/final/14220076-tm-rev0-cedar hills sha_08262020.docx

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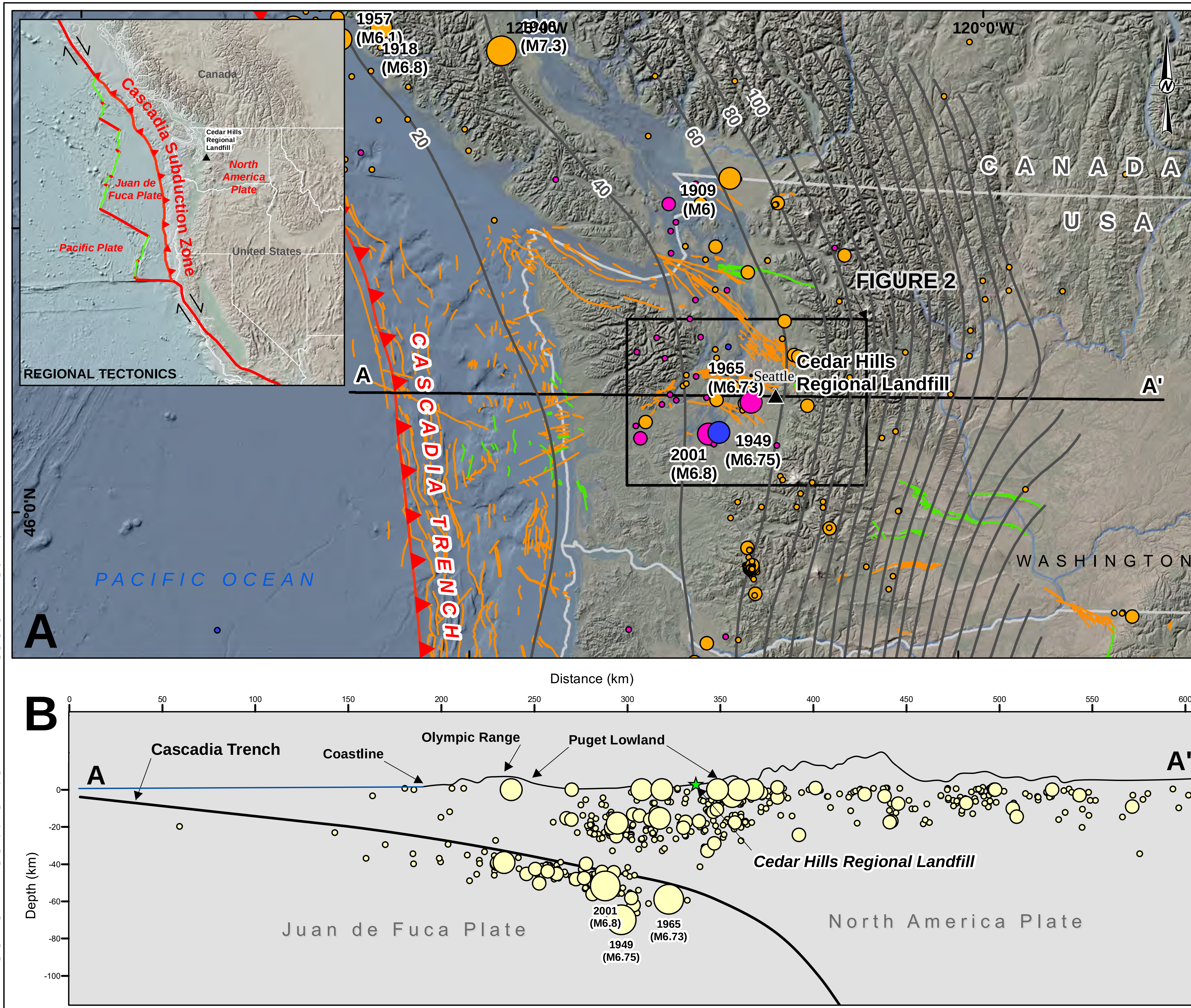
Figures



LEGEND

▲ Cedar Hills Regional Landfill

Historical Earthquake Epicenters

Magnitude	Depth (km)
3.0 - 4.9	0 - 30 km
5.0 - 5.9	30 - 60 km
≥ 6.0	≥ 60 km

Faults

Age of Most Recent Activity

- Historic (<150 years)
- Holocene (<15,000 years)
- Late Quaternary (<130,000 years)
- Cascadia Trench
- Depth Contour to Top of Juan de Fuca Plate (Kilometers)

0 25 50 100 MILES

0 25 50 100 KILOMETERS

REFERENCE(S)
1. EARTHQUAKE EPICENTERS (PNSN, ANSS ACCESSED 7-1-2020)
2. FAULT LOCATIONS: USGS, 2018
3. DEPTH CONTOURS:USGS SLAB2
4. COORDINATE SYSTEM: NAD 1983 UTM ZONE 11N

CLIENT
HERRERA ENVIRONMENTAL CONSULTANTS

PROJECT
CEDAR HILLS REGIONAL LANDFILL SEISMIC DESIGN CRITERIA UPDATE

TITLE
A. HISTORICAL EARTHQUAKES AND MAJOR FAULTS IN THE VICINITY OF CEDAR HILLS REGIONAL LANDFILL, KING COUNTY, WASHINGTON
B. SEISMICITY AND GEOMETRY OF CASCADIA SUBDUCTION ZONE BENEATH CEDAR HILLS REGIONAL LANDFILL SITE

CONSULTANT
GOLDER

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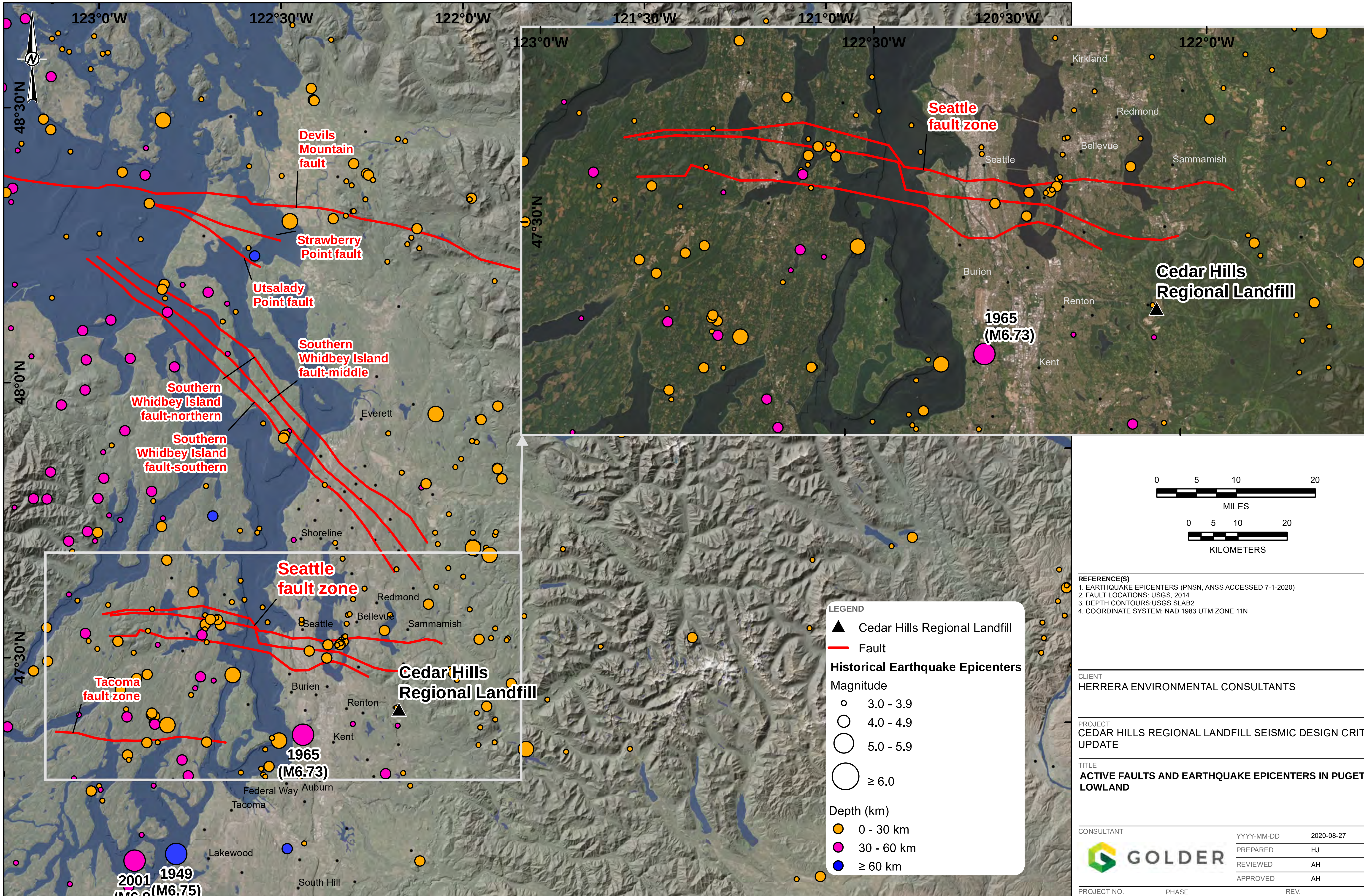
PREPARED	HJ
REVIEWED	AH
APPROVED	-

PROJECT NO.	PHASE	REV.	FIGURE
1420076	002	0	1



REFERENCE(S)
1. EARTHQUAKE EPICENTERS (PNSN, ANSS ACCESSED 7-1-2020)
2. FAULT LOCATIONS: USGS, 2014
3. DEPTH CONTOURS:USGS SLAB2
4. COORDINATE SYSTEM: NAD 1983 UTM ZONE 11N

CLIENT
HERRERA ENVIRONMENTAL CONSULTANTS

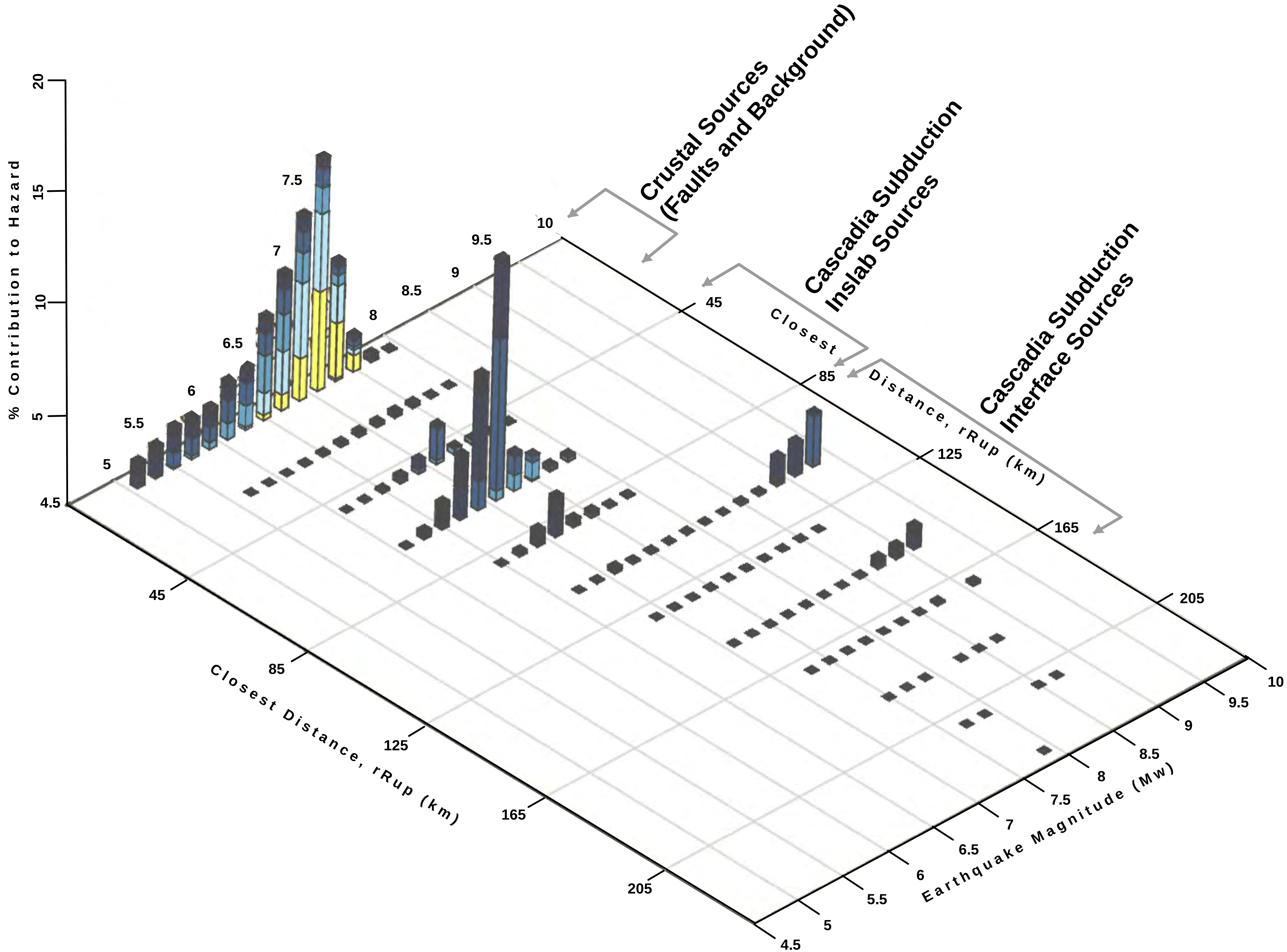
PROJECT
CEDAR HILLS REGIONAL LANDFILL SEISMIC DESIGN CRITERIA UPDATE

TITLE
ACTIVE FAULTS AND EARTHQUAKE EPICENTERS IN PUGET LOWLAND

CONSULTANT
GOLDER

YYYY-MM-DD	2020-08-27
PREPARED	HJ
REVIEWED	AH
APPROVED	AH

PROJECT NO.	PHASE	REV.	FIGURE
1420076	002	0	2



LEGEND

- ε = [-0.5 .. 0)
- ε = [0 .. 0.5)
- ε = [0.5 .. 1)
- ε = [1 .. 1.5)
- ε = [1.5 .. 2)
- ε = [2 .. 2.5)
- ε = [2.5 .. +∞)

NOTE: The colors bars indicate how much of the hazard contribution is above the median PGA for each magnitude-distance pair for what is known at the or epsilon parameter. Lighter colors (yellow) indicates a value from near median level to 0.5 of a standard deviation below median. Darker blue colors indicate values increasingly above median values from pale blue at 0.5 standard deviation above

REFERENCE(S)

1. FROM USGS 2014 UNIFORM HAZARD TOOL.

CLIENT
HERRERA ENVIRONMENTAL CONSULTANTS

PROJECT
CEDAR HILLS REGIONAL LANDFILL SEISMIC DESIGN CRITERIA UPDATE

TITLE
USGS 2014 Deaggregation Plot for 2,475-yr RP Mean PGA of 0.58 g

CONSULTANT
GOLDER

YYYY-MM-DD	2020-08-27
PREPARED	HJ
REVIEWED	AH
APPROVED	AH

PROJECT NO.	PHASE	REV.	FIGURE
1420076	002	0	3