Proposal to
North Pacific Coast Marine Resources Committee

Geologic Hazards and Rapid Terrace Erosion at Rialto Beach, Olympic National Park, WA

November 8, 2021

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(NPC MRC)
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1. **Title**: Geologic Hazards and Rapid Terrace Erosion at Rialto Beach, Olympic National Park, WA

2. **Lead Organization and Contact:**
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3. **Start and end dates for your project:**
Begin January 1, 2022; End December 31, 2023

4. **Deliverables:**
Reports and database: December 31, 2023
5 quality photos: September 30, 2023
MRC newsletter: September 30, 2023
Presentations: September 30, 2023
Refer to Table 1 for details.

5. **Project staff:**
PI: Kathy Goetz Troost, PhD, LG; UW Associate Teaching Faculty (resume available)
Lead Scientist: Elizabeth Davis: UW PhD Candidate (resume available)
Team of graduate and former graduate students from UW ESS: Mary Alice Benson, Sam Bartish, Chelsea Bush, Katelyn Card, and Elise Freeman

6. **Partners:**
Brian Sherrod, PhD, US Geological Survey (USGS). Providing radiocarbon dating and high-resolution dendrochronology.
Matthew Dubeau, Olympic National Park. Providing our permit and connections to other scientists and data.
Ian Miller, PhD, UW SeaGrant**.** Providing beach surveys on a quarterly basis and consulting on coastal processes and changes.
Tim Abbe, PhD, Natural Systems Design. Providing sediment transport expertise.

7. **Geographic Area:**
Rialto Beach and upland from the parking lot to Hole-in-the-Wall.

8. **Permits:**
We will renew our research permit (OLYM-2021-SCI-0009) with the Olympic National Park. We plan to amend our permit by adding dendrochronology (tree coring) and hand-dug pits.

Table 1. Objectives, Tasks, and Deliverables

Objectives/Tasks	NPC-MRC Funding Request	No. of Field Days	No. of trips	In-Kind Support Available	No. of Field Days	No. of Trips	Other Funding Needed	No. of Field Days	No. of Trips	Deliverables	Field Dates	Due Dates
Totals		50	16		11	5		28	6			
Objective 1: Evaluate the Potential for Uplift										**Report, Master's Thesis**		**6/1/2023**
Detailed stratigraphic map	yes	5	1	no			no			Map	summer 2022	
Map and date organic soils	yes	3	1	yes	0	0	no			Radiocarbon dates	summer 2022	
Hand dig small pits on terrace	yes	5	1	no			no			Map	summer 2022	
Sample for diatoms, prep and count slides	yes						no			Tables	autumn 2022	
Map and evaluate knickpoints	no			no			yes	5	1	Map	summer 2023	if funded
Objective 2: Determine the Ages of Landslides and Debris Flows										**Report, Master's Thesis**		**6/1/2023**
Map two more landslides and ravines	yes	5	1	no						Map	summer 2022	
Radiocarbon sampling and dating	yes	3	1	yes	0	0	no			Radiocarbon dates	autumn 2022	
Dendrochronology on landslides	yes	5	1	yes			no			Tables	summer 2022	
Slabs and wiggle matching	no			yes	3	1				Tables	autumn 2022	
Objective 3: Monitor and Measure Erosion										Memo		**12/31/2023**
Continue beach topographic profiles	no	0	0	WA Sea Grant	8	4	no			Data, graphs	quarterly	
Repeat measurements at selected trees	yes	16	4	no			no			Data, graphs	2x year	
Objective 4: Reconstruct Historical Changes to Beach-River-Spit System										**Report, Master's Thesis**		**12/31/2023**
Find and compile photographs	no			no			yes	5	1	Compilation	spring 2023	if funded
coastal maps and aerial imagery	yes	2	2	no			yes	5	1	Maps	autumn 2022	
Collect and compile construction information	yes	2	2	no			yes	5	1	Maps, tables	winter 2023	
Recommedations for monitoring	no			no			yes			Text	summer 2023	if funded
Objective 5: Repository										**Compilation**		**12/31/2023**
Find an appopriate repository for data and maps	no			no			no			Memo	autumn 2022	
Populate repository	no			no			yes			Compilation	spring 2023	if funded
Objective 6: Outreach and Education										**Presentations**		**9/30/2023**
Presentations to NPC MRC	yes	4	2	no			no			Presentations and article for newsletter	autumn 2022, 2023	9/30/2023
Conference presentation	no			no			yes	3	1	Presentations and abstracts	autumn 2023	9/30/2023
Public workshop	no			no			yes	5	1	Workshop materials, interpretive brochure	autumn 2022	9/30/2023

9. Project Narrative

a) Abstract

The beach and adjacent low-elevation marine terrace and upland at Rialto Beach are providing critical data regarding earthquakes in the Cascadia Subduction Zone, landslides, vegetation changes, and rapid erosion. Our work to date, funded by the NPC MRC, UW, and USGS suggests that:

the terrace may have been uplifted between 500 and 200 years ago,
multiple landslides may have accompanied the uplift,
subsequent debris flows have locally inundated the terrace,
the terrace is eroding rapidly,
the forest on the terrace is dying, and
tree health reflects rapid erosion and climatic events.

Our findings support a hypothesis that the 1700 Cascadia Earthquake not only caused coastal subsidence to the south, but also caused uplift on the north coast. To date, no scientific findings have been published regarding uplift, however the USGS (Dr. Brian Sherrod) is actively researching this hypothesis and the data at Rialto Beach could provide a key confirming element.

Rapid erosion is seen by monitoring trees on the seaward side of the terrace and surveying the beach/terrace profile. Did that erosion begin after uplift and/or has it been exacerbated by the anthropogenic changes to the spit/jetty at the mouth of the Quillayute River? We have collected more than six detailed beach/terrace surveys to begin to quantify those changes. The monitoring data should identify trends in beach position, beach slope beach grain size, position of large woody debris, and erosion of the terrace edge.

We propose to collect data to constrain the date of uplift, determine the timing of landslides, monitor the rate of erosion and beach/terrace change, and analyze historical shoreline change. In addition, we propose to build a data repository to catalog the critical information being gathered. Then, we plan to prepare graphics that could be used in an interpretive brochure about geologic significance of the beach and terrace at Rialto Beach.

b) Background and Context

Marine terraces and beaches can provide important insights into 1) uplift history related to subduction zone earthquakes, 2) timing of landslides and bluff/slope stability, 3) long-term and short-term erosion rates, 4) landform history, and 5) coastal evolution. A low elevation (1 to 2 meter tall) marine terrace at Rialto Beach may have been uplifted during a subduction zone earthquake. Landslides resting on older beach gravels in the terrace may have been triggered by the same earthquake.

Rialto Beach is a dynamic environment with frequent and extensive relocation of the modern beach berm and erosion of the face of the terrace. Over the few years we have been working at Rialto Beach we have seen over 5 meters of headward erosion of the terrace edge in at least one location. Good exposures have been buried and some have been eroded. Therefore, timely sample collection is critical with respect to understanding the origin of the terrace, the history of

landsliding, and the magnitude of changes occurring on the beach and terrace edge. The long-term shoreline morphology dataset contributes to understanding how extreme storms, climate variability, and long-term sea level changes affect Olympic coast beaches.

In our first three years of MRC funding we were able to collect wood samples for radiocarbon dates (12 funded by the NPC-MRC and 5 by the USGS), map part of the terrace edge, determine that multiple landslide deposits comprise part of the terrace, date some of those landslides, map part of the slope above the terrace, evaluate the paleoecological setting of several strata using pollen analyses, survey the beach and terrace edge six times, collect grain size photographs, and develop a conceptual geological model of terrace formation and beach changes.

In the last half of 2021, we continued research at Rialto while unfunded. We began a tree monitoring program to help track terrace erosion. We also collaborated with the USGS to collect slabs of trees in landslide deposits to determine tree age and year that the trees died. Those results should be available in the next few months. The USGS is also going to fund 6 more radiocarbon dates.

c) MRC Benchmarks

The work proposed herein is appropriate for MRC funding because it meets several of the six benchmarks: Marine Habitats, Sound Science, Education and Outreach, and Costal Communities.

We propose to continue surveying the beach and terrace edge north of the parking lot at Rialto Beach. In addition, we propose to compile information about the historical changes at Rialto Beach, specifically erosion. We will provide data to support the following specific goals of the **Marine Habitat** benchmark:

- surveying and mapping marine and estuarine resources to better define physical and biological characteristics of marine habitats
- providing data to make scientifically based recommendations about management tools to protect marine and estuarine habitats
- understanding and evaluating erosion to promote sound sediment management practices

We propose to collect high quality data and promote its dissemination as described in the **Sound Science** benchmark.

- We have and will continue to use established scientific protocols for data collection and analysis. Dr. Ian Miller established the scientific protocol for the beach surveying and our partners are available for data evaluation with respect to evaluating our chronologic and geomorphic findings.
- We have identified a gap in the understanding of earthquake-derived uplift on the outer coast and are working to fill that data gap. And we plan to make our findings available to the public and other scientists via a database, presenting at conferences, and at workshops.
- Our reports will undergo peer review and our findings will be included in scientific publications.

We are dedicated to science-based **Education and Outreach** to promote stewardship and understanding. Troost and Davis give frequent talks to the public and to scientific audiences. WE and our partners take active roles in the following:

- informing the public about threats to living resources and coastal communities and presenting them with practical measures they can take to prevent further harm especially regarding land use, erosion control, and individual homeowner decisions
- informing citizens and governmental agencies about ocean energy activities and associated effects on coastal communities
- coordinating outreach and education programs with other organizations, including local community colleges, and evaluating their effectiveness
- translating and disseminating scientific information about the status of Washington's coastal habitats, resources, and communities to regional policy makers, resource managers, and the public in a timely manner
- expanding partnerships with tribal governments and continuing to foster respect for tribal cultures and treaties
- striving to maintain and improve coordination and communication among stakeholders and all managers

We are also dedicated to promoting sustainable and resilient **Coastal Communities** by engaging in education about hazards so that communities can minimize damage from and prepare for geologic hazards. We also want to engage tribal members and other community members to help reconstruct the history of changes to the beach-river-spit system at Rialto Beach.

d) Project Objectives

We have 6 specific objectives for our proposed work, each aimed at better understanding the natural geologic hazards and consequences of human interactions on the north coast of the Olympic Peninsula. Table 1 provides more detail about each objective. Note that we are not seeking funding for every task listed on Table 1 but have included those tasks to show the extent of our proposed research. We will be pursuing additional funding sources for the tasks not designated for our NPC-MRC funding request.

1. **Evaluate the Potential for Uplift.** We propose to conduct detailed mapping and sampling to delineate and date the older (potentially uplifted) beach surface and overlying strata. Our mapping would include gathering information along the face of the terrace and at several transects perpendicular to the terrace. It is crucial that we evaluate the back terrace area by hand digging small pits to determine depth to the older beach surface, track the extent of back terrace paleo marsh deposits, and collect small samples for radiocarbon dating and diatom analyses. The diatom analyses may tell us if abrupt sea level change has occurred and if that change can be attributed to the 1700 Cascadia Subduction Zone earthquake.

2. **Determine the Ages of Landslides and Debris Flows.** We have made great progress on determining the ages of two of the landslide complexes and one debris flow. But the slope above the terrace is full of evidence of landslides and debris flows. It is important to continue to work on one or two landslides per year to build a catalog of such events

and to determine the extent of geologic hazards that have impacted and will continue to impact the Rialto Beach area. We propose to map two more landslides and obtain ages for the landslides. The USGS will fund the radiocarbon dating. We also propose to collect age dating via dendrochronology by coring trees on the landslides. We estimate that we will be able to core about 25 more trees with the time allotted. If ample wood is found in the landslide deposits, we hope to collect slabs to view the growth rings, date the outer layer, and determine when the tree died. We were able to get a permit for such sampling in the last half of 2021 and are awaiting the "wiggle match" results (Figure 1).

Figure 1. Sliced in-place root in landslide deposit.

3. **Monitor and Measure Erosion.** Over the past few years, we have seen evidence of rapid erosion of the terrace. At one tree fall location we measured 3 m of erosion in one year. At one isolated tree, we were able to track the tree back in time using air photos and determine that approximately 5m/yr of erosion has occurred in the last 15 years (Figure 2). While the terrace edge is clearly eroding, trends in changes to the beach topography are not so clear. Dr. Ian Miller has been and will continue to survey the beach surface about 4 times year to monitor changes. This summer we started a tree monitoring program to help quantify the rate of terrace erosion. We propose to obtain geospatial data at each selected tree and determine the distance from the center of the tree to the terrace edge. We propose to collect these measurements two times a year for the foreseeable future. So far, we have selected twelve trees to monitor representing different settings, different tree sizes, and different distances from the parking lot to Hole-in-the Wall.

Figure 2. Image of "Boris" through time, indicating erosion of ~25 m of terrace since 2006.

4. **Reconstruct Historical Changes to Beach-River-Spit System.** We want to determine the cause of the rapid erosion of the terrace and the apparent increase in the rate of erosion. Determining the cause could lead to mitigation measures or at least an understanding of risks from geologic hazards such as an increased potential for landslides at Rialto Beach (assuming steady erosion at current rates). We have several hypotheses to test including abrupt sea/land level change such as from an earthquake (addressed in objective 1), steady increases in sea level or uplift of the Olympic Peninsula (work by Dr. Ian Miller, changes in sediment supply, and/or changes in climate (such as an increase in storminess). To address changes in sediment supply, we need to evaluate the impacts of the anthropogenic changes at the mouth of the Quillayute River, particularly the jetty/spit. This requires that we obtain historical information about armoring, dredge spoil placement, beach nourishment, and breaches in the spit. We also propose to compile and geo-rectify old coastal maps and serial photographs to determine changes over time. Another task of this objective is to gather photographs and information from tribal members and the community. We aren't seeking funding from the NPC-MRC for this task currently. We expect that this could be a very time-consuming task and therefore need to obtain additional funding and/or volunteer efforts.

5. **Repository.** We propose to research the best method for storing all our data, maps, and photographs. The repository needs to be easy to use and accessible by a wide set of users. We will obtain reviews and opinions from the potential data users to help guide the decision. Once a selection is made, we will seek funding to compile all our data.

6. **Outreach and Education.** We are committed to sharing our findings to a wide audience and have already begun doing so through presentations at various conferences and symposia, reports, and newsletter articles. For the next two years, we propose to make at least two presentations to the NPC-MRC members, write another newsletter article,

and attend a conference. If we can obtain additional funding, we would like to begin working on a community workshop and an interpretive brochure for future dissemination of information.

e) Timeline

We propose to begin this work as soon as we are notified of approval of our proposal and the availability of funds, hopefully in January of 2022. We propose to complete our tasks by submitting a report and repository by December 31, 2023. Interim deadlines include providing photographs, an article, and a presentation to the NPC MRC by the end of September 2023. Updates on our progress can be provided upon request. Some of tasks will be started under this proposal but not completed until additional funding is obtained from other sources, see Table 1.

f) Methods and Equipment

Objective 1, Evaluate Potential for Uplift. For this element we will be mapping and surveying using a combination of high-resolution GPS units and surveying transits. These methods will be following the same protocols we have already used at Rialto Beach. We will collect wood samples for radiocarbon dating by an outside laboratory (to be paid for by the USGS). We will collect sediment samples of organic-rich layers to determine if diatom assemblages can discern specific environments. Sampling involves taking small amounts of freshly cleaned material using a small scraper while preventing contamination. Samples are stored in Ziplock bags, cleaned, then shipped to the appropriate laboratories. We hope to get a permit to hand dig small pits on the terrace along perpendicular transects from the front to the back of the terrace to establish a profile on the top of the older beach surface and to map the extent of a back beach marsh. We also propose to map, and field verify, knickpoints to determine if a signal of uplift is present (funding dependent). This involves using LiDAR data and then traversing the gullies and Ellen Creek drainages to document the nature of the knickpoints. For this, standard bushwhacking equipment is required.

Objective 2, Determine Ages of Landslides and Debris Flows. For this element we will map more landslides (two were already mapped under previous NPC MRC funding) and collect samples of wood in the landslide deposits for radiocarbon dating (to be paid for by USGS) (Figure 3). Field mapping includes traversing the landslides and adjacent gullies to gain insights into the subsurface and geomorphology. This is best done in late winter, after some of the underbrush has gone dormant. For this, standard bushwhacking equipment is required. To further evaluate the age of landslides we will determine the age of some of the trees by using an increment borer to view the rings. We will follow the procedure established by Bush in 2019 (Figure 4). If we find large sections of trees (say over 6-inch diameter), we will obtain slices of the trees for wiggle matching to determine the year of tree death. This analysis will be funded by the USGS. Samples are obtained with hand saws then wrapped in plastic for transport to a laboratory. Slices are then dried, mounted on a flat surface, sanded, and then scanned to count and view growth rings. Ring patterns can then be matched to a reference set of tree rings for the Pacific Northwest, to determine when the tree died.

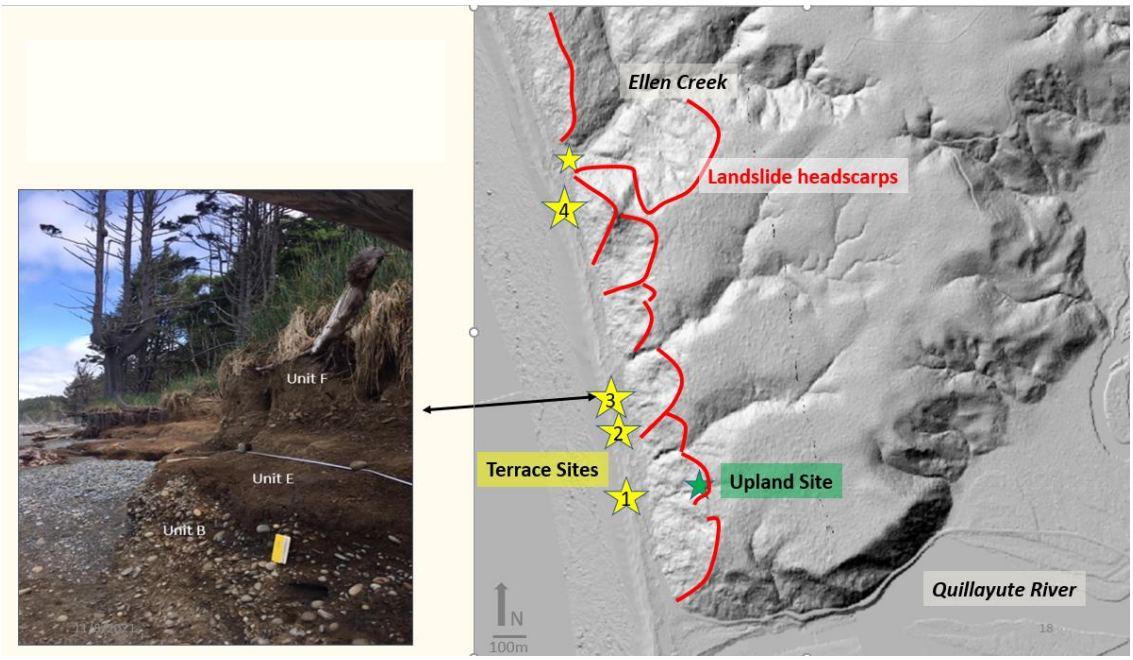

Figure 3. Image showing extent of landslide scarps along portion of Project Site. Also shows where we have focused our radiocarbon dating (yellow stars).

Figure 4. Photo of Bush collecting a tree core from a sitka spruce in 2018.

Objective 3, Monitor and Measure Erosion. The equipment needed for this element includes high-resolution GPS, long tape measures, and an increment borer to establish the age and

position of selected trees. In addition, Dr. Ian Miller will continue his topographic surveying along his established transects using an RTK-GPS system and camera.

Objective 4, Reconstruct Historical Changes to Beach-River-Spit System. Equipment needed for this element includes a computer and scanner, which are available at the UW. Older maps and air photos will be geo-rectified using photogrammetric software and added to an ArcGIS geodatabase. Photographs will be compiled in a geo-spatial program such as Google Earth for ease of access by others.

Objective 5, Repository. We expect that standard internet access and available software will be available for this objective.

Objective 6, Outreach and Education. At this time no additional equipment is needed for this element.

g) Extent and Impact

Although Rialto Beach is a relatively small area, our findings, together with the work of our partners, will have the potential to impact all the coastal communities in northwest Washington. Earthquakes and resulting land level changes are of a large regional nature. Likewise, beach changes resulting from sea level rise and extreme storms will affect the entirety of northwest Washington. The impact of landslides resulting from earthquake shaking would have more of a local impact. We anticipate that our findings would be used to address geologic hazards by informing communities of the range of and possible frequency of coastal impacts. These impacts could include earthquake magnitude, frequency, and possible land level changes; sea level changes; beach morphology changes; and slope changes. These changes could negatively impact infrastructure, ecological environments, and human health and safety.

h) Plans for Continuation

We do plan to continue our work at Rialto Beach into the future. And to do so, we will be looking for additional funding, see Table 1. We have started some monitoring efforts that may require years of data collection before we can interpret the results and determine the presence of robust trends. We also want to develop outreach materials, evaluate paleo environments and their relevance to future climate impacts, and continue to provide a scientific basis for estimating the magnitude of geologic hazards in coastal communities.

10. Project Budget

Category	Objectives	Detail	RT Miles	Quantity	Rate	Cost	MRC Request
Salary	**1-6**	Troost, months		0.4		$4,270.00	$4,270.00
		Benefits on salary		$4,270.00	23.2%	$991.00	$991.00
Supplies/ Equipment	**1-2**	Sampling supplies				$140.00	$140.00
Travel	**1-4, 6**	Mileage	300	18	$0.56	$3,024.00	$3,024.00
		Ferry fares		18	$40.00	$720.00	$720.00
		Meals		100	$74.00	$7,400.00	$7,400.00
		Lodging				$0.00	$0.00
Contracted Services	**1**	Diatom slide prep		20	$100.00	$2,000.00	$2,000.00
	1	Shipping		1	$30.00	$30.00	$30.00
Indirect Expenses	**1-4, 6**	UW F&A on all items above		$18,575.00	55.5%	$10,309.13	$10,309.13
Totals						**$28,884**	**$28,884**