

U. S. GEOLOGICAL SURVEY
UNIVERSITY OF WASHINGTON
WASHINGTON DEPARTMENT OF NATURAL RESOURCES,
DIVISION OF GEOLOGY AND EARTH RESOURCES

**The Consortium for Geologic and Hazard Mapping in Puget Sound (CHAMPS):
Rationale, Strategy, and Plans for Large-Scale Digital Geologic Maps
in the Central and Southern Puget Lowland, Washington**

By
Ray Wells¹, Derek Booth², Tim Walsh³,
Ralph Haugerud¹, Kathy Troost², and Josh Logan³

- 1) U.S. Geological Survey
- 2) University of Washington
- 3) Washington Department of Natural Resources,
Division of Geology and Earth Resources

Administrative Report to
USGS National Earthquake Hazards Reduction Program
March 1, 2000

Need for New Geologic Mapping

The Olympia-Tacoma-Seattle-Everett urban corridor in the Puget Lowland of Washington is home to a major and rapidly growing segment of the US economy. Because recent research has shown that the earthquake hazard in the Lowland has been significantly underestimated, the engineering community is pressing for more precise evaluation of earthquake hazards, including the locations of crustal faults, the frequency of crustal earthquakes, and the distribution of deposits prone to liquefaction and locally severe shaking. Recent storms and continued development along shoreline bluffs have greatly increased the awareness, and consequences, of landslide hazards. Surface water resources are fully committed, and in some communities further growth is contingent on identification of groundwater resources. Local government is eager for up-to-date geologic mapping to help deal with these and other issues. Geologic mapping in the 1950's and the late 70's through early 90's has been synthesized into regional maps (Table 1), but tremendous increases in population and geologic information now require complete 1:24,000-scale geologic map coverage of the region and updates of the older, existing mapping in selected urban and urbanizing areas.

To date this renewed mapping effort has been addressed through informal coordination of University of Washington scientists (UW), the Pacific Northwest Urban Mapping Project of the USGS, and the Washington Department of Natural Resources, Division of Geology and Earth Resources (WDNR). Funding for the UW portion has largely been by competitive grants from the National Earthquake Hazards Reduction Program (NEHRP). WDNR has been funded in part by grants from NEHRP and the National Cooperative Geologic Mapping Program (NCGMP). In anticipation of increasing local demand and the need to set priorities, we have outlined a stronger framework for cooperation in part based on the implementation of a UW-USGS cooperative agreement for geologic mapping.

Strategy

In six years, assuming anticipated personnel and funding are available, UW and USGS staff can complete seamless, large-scale, digitally based geologic map coverage of the Everett-Seattle-Tacoma urban corridor, the rest of urban King County, suburban Tacoma, and Kitsap County. Much of the rest of Pierce County, together with part of Mason and Thurston counties, could be covered by WDNR given adequate state and Federal funding. This would accomplish several interrelated objectives:

- Production of maps at a nominal scale of 1:24,000 (larger in key urban areas);
- Use of a regionally-consistent stratigraphy;
- Pursuit of analytic studies necessary to develop an adequate stratigraphy and chronology for older unconsolidated deposits, and for dating of structural deformation;

- Geologic maps of sufficient detail and quality to support derivative hazard maps;
- Expansion of a geotechnical database, now being constructed for Seattle, into areas where sufficient data exist and population densities are high enough to warrant the effort; and
- Development of consistent digital databases for use by local government, the private sector, and other earth scientists.

Within the central and southern Puget Lowland, we have evaluated each 7.5' quadrangle on the basis of these objectives, and on the degree to which existing mapping (if any) has already satisfied these needs. To organize our anticipated future efforts, six "themes" have motivated the choices for additional geologic mapping (Table 2 and Figure 1):

1. Seattle fault zone
2. Urban areas/critical lifelines
3. Coastal zones and landslides
4. Other crustal structures/fault zones
5. Contiguous coverage, particularly of cities or counties
6. Derivative maps for landslide, liquefaction and ground response, hydrology and groundwater, growth management, and economic resources

On the basis of existing efforts, thematic expertise, and geographic continuity, we have identified a lead agency (UW, USGS, WDNR) for each quadrangle. The USGS focus is on geologic structures that are critical to understanding geologic conditions and hazards in the urban lowland: the Seattle fault, the Kingston arch, and the White River fault (themes 1, 4). The UW team is focused on the Seattle urban core, the coastal expression of Quaternary deformation and regional stratigraphy in the Tacoma-south Kitsap area, and older stratigraphy in the Mukilteo-Kingston area (themes 2, 3, 4). WDNR is focused on urban and urbanizing areas in the southern Lowland, coastal-zone landsliding, and the production of liquefaction maps (themes 2, 3, 6). These themes significantly overlap; based on experience to date, we expect productive collaboration and shared mapping efforts, particularly along the trace of the Seattle fault through the Seattle-Bellevue urban area, coastal areas of the Kingston arch, and structural deformation associated with the west end of the Tacoma structure.

WDNR has a long history in geologic and hazard mapping throughout the entire State, tending to focus on the periphery of urban growth where urban planning and resource extraction are both feasible and effective. STATEMAP, funded as a cost-share between the USGS and WDNR, promotes 7.5' mapping to meet broad societal needs, including resources as well as hazards. WDNR's hazard-mapping program is broadly tailored to providing geologic assistance to smaller jurisdictions for planning purposes. In the next six years, WDNR priorities for geologic mapping are the urbanizing areas of Thurston and Mason counties in the southern Puget Lowland, Clallam and Jefferson Counties in the northeasternmost Olympic Peninsula, and the transition from the Cascade foothills to Puget Sound in Skagit County and northern Snohomish County. Other WDNR priorities

for mapping include the Kelso-Longview area of Cowlitz County and the Aberdeen-Hoquiam area of Grays Harbor County, where hazard mapping for landslides and tsunamis requires a more thorough understanding of the local geology.

In the context of this Puget Sound mapping effort, we have identified two other geologic-mapping efforts that would require additional staff, money, and/or time. First, a number of quadrangles could be usefully updated without complete remapping. These updates would include more-accurate contacts based on new LIDAR topography (see below), revised age assignments of older deposits using focused analyses of key outcrops, and compilation of subsurface data into a geotechnical database where warranted. UW and USGS scientists are the most likely candidates to jointly undertake this effort. Second, mapping could be expanded into areas of the Puget Lowland not presently addressed, including southern and eastern Pierce County, most of Snohomish County outside of the immediate Everett area, most of Island County, and eastern King County.

Approach

The mapping and associated digital databases use a stratigraphic framework based on a century of studies in the Puget Lowland, confirmed and extended by modern process-based models of ice advance and retreat, and tested by continuing field work. Stratigraphy of the older Quaternary deposits is being constrained by a variety of newly applied dating techniques, including thermoluminescence, magnetostratigraphy, paleosecular variation, fission track, tephrochronology, and AMS and conventional radiocarbon dating.

To assure mapping of a uniformly high quality, we are conducting workshops to address mapping techniques, field observations, and regional stratigraphy. The first such workshop, held in the field in June 1999, addressed criteria for distinguishing tectonic from glacial and gravitational deformation, and was attended by scientists from the USGS, UW, WDNR, and Geological Survey of Canada. We expect the next field workshop to address mapping techniques (density of observations, nature of map units, use of remote-sensing data, and field identification of key stratigraphic units). This spring the UW team, assisted by scientists from the USGS, WDNR, and Western Washington University, is hosting a symposium at the Geological Society of America's Cordilleran Section meeting on the Quaternary geology of the Puget Lowland.

Cooperation and collaboration with paleoseismologists, geophysicists, and hydrologists in other projects and agencies is ongoing. An advisory committee of local consultants and users of geologic data has already been established for the UW's Seattle Geologic Mapping Project. Detailed bathymetry for Puget Sound is planned by the USGS and will help integrate offshore topography and recent seismic surveys with onshore exposures. Onshore, a LIDAR survey over the central Puget Lowland is planned during FY 2000 will provide high-resolution topography for geologic mapping of critical areas along the Seattle fault. USGS mapping staff are part of the consortium that has pursued

this survey, which includes Kitsap County, other USGS staff, NASA, City of Seattle, Puget Sound Regional Council, and King County.

LIDAR and high-resolution bathymetry acquisition are critical to the generation of new geologic maps for the Lowland, but the flood of new LIDAR and bathymetric data and the resulting need for interpretation may prove to be an embarrassment of riches, particularly if additional active crustal faults are revealed. As already demonstrated through recent fault-scarp trenches on Bainbridge Island, additional resources may be necessary to adequately fund any subsequent, detailed explorations.

Organization

Project organization reflects three main objectives: interagency cooperation, coordination through the USGS, and partnership with local agencies (Figure 2). The work is a cooperative, collaborative effort of the three lead entities with geologic expertise in Puget Sound—the USGS, the University of Washington, and the State geological survey (WDNR). Scientific management of the overall geologic mapping effort, on behalf of the USGS and UW, is coordinated by Ray Wells, USGS program manager. The ultimate *users* of the geologic data, namely the cities, counties, other agencies, and consultants of the region, are recognized key participants in the geological investigations, not merely as prospective funding sources but as partners and collaborators in the collection of data and presentation of results.

Support

The USGS mapping team (Pacific Northwest Geologic Mapping and Urban Hazards projects) is supported by the NCGMP, NEHRP, and the Urban Hazards Program. The UW team has successfully competed for NEHRP external grants for two years; it has also received support through contracts and direct analytical and logistic support from the USGS mapping team, and from direct financial contribution from the City of Seattle. WDNR is currently funded in part by the STATEMAP component of the NCGMP, as well as by several external NEHRP grants. It is largely funded, however, from the state general fund, and so its activities may be guided in part by as-yet unrecognized needs. Conversion of NEHRP support for the UW mapping effort to a cooperative agreement in FY 2001 will significantly improve opportunities and options for interagency coordination and assurance of continued funding for a critical element of the USGS-led mapping in the region. Additional support from local agencies with a critical interest in mapping progress is anticipated. To date, the City of Seattle has committed or already supplied over \$250 K to this effort, via direct support to the UW team. Acquisition of more than \$500 K of LIDAR by the Puget Sound Regional Lidar Consortium will provide a base for a new generation of mapping, and additional support for ground truthing of the data is essential.

Table 1. Existing Regional Geologic Mapping of the Puget Lowland

<i>Map and Scale</i>	<i>Lead agency/partners</i>	<i>Status</i>
Lifelines map	USGS-EQE	published OF99-387
King County Geologic Map 1:100,000 (digital compilation)	UW-USGS-WDNR- King Co.	in review
Tacoma 1:100,000	WDNR	field work complete; digitized; DGER Open File FY 2000
Bellingham 1:100,000	WDNR -USGS- West. WA University	field work complete; in review June 2000
Seattle bedrock and surficial 1:100,000	USGS	Published OF91-147; needs major revision
Port Townsend bedrock and surficial 1:100,000	USGS	Published; I-1198
SW Quadrant of State Geologic Map 1:250,000	WDNR	Published 1987; digital 1999
NW Quadrant of State Geologic Map 1:250,000	WDNR	In prep; digital 2001?

Table 2. Central and Southern Puget Lowland 1:24,000 Geologic Mapping Plan

Quadrangle	Status				Mapping Themes						
	Fieldwork done	Update only	Requested by agency	Current/past funding?	Lead team	Seattle fault (1)	Urban area (Geotech database) (2)	Coastal zone (LS, outcrop) (3)	Other structure (4)	Areal coverage (5)	Derivative maps; Is. liquefaction (6)
Des Moines	X			G, L	UW		X	X		King Co.	WDNR
Poverty Bay	X			G, L	UW		X	X		King Co.	WDNR
Tacoma North	X			G, L	UW		X	X	X	Pierce/King	WDNR
Olalla	X			G	UW			X		Kitsap/Pierce	
Tacoma South	X			G, L	UW		X			Pierce Co.	WDNR
Steilacoom	X			G, L	UW		X	X		Pierce Co.	WDNR
Puyallup	X			G, L	UW		X		X	Pierce Co.	WDNR
Gig Harbor	X			G, L	UW		X	X	X	Pierce Co.	WDNR
Wildcat Lake	X			G	USGS	X				Kitsap Co.	
Uncas	X			G	USGS				X	Kitsap Co.	
Seattle SW (1:12,000)	X		SEA	G	UW	X	X	X		Seattle	
Seattle NW (1:12,000)			SEA	G	UW		X	X		Seattle	
Seattle SE (1:12,000)			SEA		UW	X	X	X		Seattle	
Seattle NE (1:12,000)			SEA		UW		X	X		Seattle	
Mercer Island				L	UW	X	X			King Co.	WDNR
Fox Island					UW			X	X	Pierce Co.	
Burley					UW				X	Kitsap/Pierce	
Belfair					UW				X	Kitsap/Mason	
Lake Wooten					UW			X	X	Mason Co.	
Holly					UW			X	X	Kitsap Co.	
Edmonds West					UW		X	X	X	Snoh. Co.	
Bremerton W				G	USGS	X	X	X		Kitsap Co.	WDNR
Bremerton E				G	USGS	X	X	X		Kitsap Co.	WDNR
Squamish				G	USGS	X		X		Kitsap Co.	
Poulsbo					USGS	X		X		Kitsap Co.	
Seabeck					USGS	X		X		Kitsap/Jeff	
Hansville					USGS			X		Kitsap Co.	
Fall City					USGS	X				King Co.	
Snoqualmie					USGS	X				King Co.	
Quilcene					USGS			X	X	Jefferson	
Lofall					USGS			X	X	Kitsap/Jeff.	
Port Gamble					USGS			X	X	Kitsap Co.	
Enumclaw					USGS				X	King Co.	
Cumberland					USGS				X	King Co.	
Longbranch				G, L	WDNR			X		Pierce/Thurs.	WDNR
McNeil Island				G	WDNR			X		Pierce Co.	
Squaxin Island				L	WDNR			X		Mason Co.	WDNR
Vaughn					WDNR			X	X	Kitsap/Mason	
Shelton					WDNR			X		Mason Co.	
Summit Lake					WDNR			X		Mason/Thurs.	
Tumwater				L	WDNR		X	X		Thurston	WDNR
Lacey				L	WDNR		X	X		Thurston	WDNR
Nisqually				L	WDNR		X	X		Pierce/Thurs.	WDNR
Marysville		X		L	USGS-UW		X			Snoh. Co.	WDNR
Maxwelton		X			USGS-UW			X		Snoh. Co.	
Mukilteo		X		L	USGS-UW		X	X		Snoh. Co.	WDNR
Tulalip				L	WDNR					Snoh. Co.	WDNR
Everett				L	USGS-UW		X			Snoh. Co.	WDNR
Edmonds East		X			USGS-UW		X	X	X	Snoh. Co.	
Bothell		X			USGS-UW					King Co.	
Kirkland		X		L	USGS-UW		X			King Co.	WDNR
Redmond		X		L	USGS-UW		X			King Co.	WDNR
Issaquah		X		L	USGS-UW	X	X			King Co.	WDNR
Vashon		X			USGS-UW			X		King Co.	
Black Diamond		X			USGS-UW				?	King Co.	
Buckley		X			USGS-UW				?	Pierce/King	
Renton		X		L	USGS-UW		X			King Co.	WDNR
Auburn		X		L	USGS-UW		X			King Co.	WDNR

* G = Funded for geologic mapping; L = funded for liquefaction mapping

Figure 2. Project Organization for Central and Southern Puget Lowland Quadrangle Mapping

