Final Report

OWEB Coastal Storm Assessment Project

Prepared by
The Institute for Natural Resources
Oregon State University

Marine Resource Management Program and Oregon Sea Grant
Oregon State University

for the
Oregon Watershed Enhancement Board

January 2009

OWEB Coastal Storm Assessment Project

January 2009

Prepared by

The Institute for Natural Resources
210 Strand Agricultural Hall
Oregon State University
Corvallis, Oregon 97331
http://inr.oregonstate.edu/

for the
Oregon Watershed Enhancement Board
http://www.oregon.gov/OWEB/

Project Team

Listed in alphabetical order

Glenn Ahrens	OSU Extension
Jenna Borberg	OSU Marine Resource Management
Cyrus Curry	Oregon Watershed Enhancement Board
Robert Emanuel	OSU Sea Grant Extension
Erik Endrulat	Oregon Watershed Enhancement Board
Lisa Gaines	OSU Institute for Natural Resources
Guillermo Giannico	OSU Fisheries and Wildlife
Michael Harte	OSU Marine Resource Management
Josh Lambert	OSU Institute for Natural Resources
Kathy Maas-Hebner	OSU Forest Science Laboratory
Melissa Murphy	OSU Marine Resource Management
Peter Parsons	Oregon Department of Agriculture
Stacy Polkowske	OSU Institute for Natural Resources
Marv Pyles	OSU Forest Engineering

The Institute for Natural Resources

Created by the Oregon Legislature through the 2001 Oregon Sustainability Act, the Institute for Natural Resources' mission is to provide Oregonians with ready access to current, relevant, science-based information, methods, and tools for better understanding natural resource management challenges and developing solutions.

The Institute for Natural Resources is an Oregon University System institute.

Institute for Natural Resources
Oregon State University
210 Strand Agricultural Hall
Corvallis, Oregon 97331

http://inr.oregonstate.edu/

For more information about this report please contact Lisa.Gaines@oregonstate.edu.

Acknowledgements

We wish to thank all of the landowners in the North Coast Range who granted us access to their restoration sites and the many people who generously and patiently provided their time and insights to make this report possible. We would specifically like to thank:

Liz Dent, Oregon Department of Forestry
Maggie Peyton, Upper Nehalem Watershed Council
Ray Monroe, Tillamook County Soil and Water Conservation District
Doug Ray, Carex Consulting
Tom Shafer, Oregon Watershed Enhancement Board

Disclaimer

The contents of this report reflect the view of the authors who are solely responsible for the facts and accuracy of the material presented. The contents do not necessarily reflect the official views of the Oregon Watershed Enhancement Board.

This report does not constitute a standard, specification, or regulation.

Executive Summary

In the winter of 2007-2008 the Oregon and Washington coasts, from Newport to Hoquiam, received the most significant winds since the Columbus Day storm of 1962. While the wind event was not as significant as the 1962 storm in terms of top wind speeds and geographic expanse, the duration and potential for damage from the recent storm was greater. Rainfall associated with the storm was accompanied by near-record temperatures. Rainfall amounted to as much as 14 inches in just a 24-hour period, sending many rivers in northwest Oregon and southwest Washington from well below flood stage to flood stage in a matter of hours. Because the storm varied in intensity and artifact (i.e., wind, rain, or both) throughout the region, it provides an opportunity to evaluate the impacts to various river basins particularly focusing on restoration actions implemented over the last ten years.

In summer 2008, the Oregon Watershed Enhancement Board (OWEB) asked the Institute for Natural Resources (INR) lead the *OWEB Coastal Storm Assessment* project. The purpose of this time-limited project was to provide the scientific context that would assist OWEB in determining if its restoration project guidelines are robust enough to take into account potential increases in storm magnitude, frequency and/or intensity associated with climate change. This report characterizes the December 2007 storm and long-term storm variability along the Oregon and Washington coast, presents the results of a rapid assessment of randomly selected OWEB restoration projects (restoration activities including large wood placement, culverts, and riparian planting), and based on the characterization and field assessment provides an assessment of the robustness of OWEB guidelines.

Summary of Findings

Climatological Assessment
Though the coastal sections of Oregon and Washington are among the wettest and stormiest in the country, an evaluation of precipitable water, percentage of 100-year precipitation, and sustained wind speeds concluded that the December 2007 storm was an unusual combination of very wet and very windy. Using a new rating system, it is one of the highest ranked storms ever experienced in the Northwest. Precipitation trends for three western Oregon stations revealed an apparent increase in the intensity and frequency of large rain storms; however, changes in intensity or frequency of storms in the future are very difficult to predict.

Rapid Assessment
Rapid assessment protocols were developed to assess the pre- and post-storm condition and effectiveness of three restoration activity types (large wood placement, fish passage, and riparian restoration) on the Oregon North Coast. A total of 86 randomly selected individual projects/sites from 19 OWEB Grant numbers were surveyed in September and October 2008.

Of the 86 sites surveyed 89% were subject to precipitation amounts associated with a significant storm event and wind levels were classified as significant at 63% of all sites. Consistent with these metrological observations, evidence of torrent and debris flow damage was present at 51% of sites. Evidence of wind damage was found at 33% of sampled sites.

The overall condition of surveyed sites nine months after the December 2007 storm was very good or excellent. Although all sites surveyed experienced a significant rain and/or wind event, 83% of sites showed no adverse change in the pre- and post-storm measures of condition. Minor adverse change in the pre- and post-storm measures of condition was found at 14% sites. One site showed moderate adverse impacts and two sites showed evidence of severe impact. The patterns and change in condition are generally consistent across all project types. Large wood placement projects exhibit more severe changes in condition attributed to the storm than the other two surveyed restoration activities.

The generally minor impact of the December 2007 storm on the surveyed restoration sites/projects can be attributed to at least three factors. First, the impact of the 2007 storm was evaluated in relation to baseline site conditions. Second, Oregon's North Coast encounters frequent moderate to severe wind and/or precipitation events, meaning that projects/sites are likely impacted by significant events on a periodic basis. Third, landowners, watershed council employees and volunteers, and agency staff have considerable experience designing and implementing restoration projects that are resilient to North Coast storm conditions, and are quick to maintain projects, particularly riparian planting projects, that show wear and tear after a major storm event.

OWEB Restoration Practices and Guidelines

Building the capacity to efficiently manage climate impacts before and as they occur is the primary objective of planning for climate variability and change (Climate Integration Group [CIG], 2008c). This, in turn, could require adjusting existing policies, practices, and procedures to provide the flexibility necessary to adapt to short- and long-term changes in climate. Though OWEB does not appear to have explicit guidelines for restoration activities, as a proxy, its document *Instructions for Completing Restoration Grant Applications* (2008) allows for the use of wide range of approaches to restoring salmon habitat and watersheds. A review of these proxy guidelines shows that they too appear to be robust enough to take into account potential increases in storm magnitude, frequency and/or intensity associated with climate change, if one were to assume increases were a trend. First, OWEB requires compliance with restoration guidelines that represent the best available science for project design. Second, grant applicants are required to describe how the project planning and design take into account extreme events (e.g., floods, fire, drought, etc.) that are known to be of concern in the area.

A key to planning for climate change is asking whether the policies and decisions being made are robust given what is known about, and the uncertainty around, climate change in the Pacific Northwest. Though we can not speculate about the intensity and frequency of future storms, engaging in a rapid assessment of how resilient OWEB restoration projects were to the December 2007 storm is one way in which OWEB is positioning itself to better meet restoration objectives that might be compromised as a result of climate change.

Table of Contents

Figures and Tables

Figures

Tables

Introduction

In the winter of 2007-2008 the Oregon and Washington coasts, from Newport to Hoquim, received the most significant winds since the Columbus Day storm of 1962. While the wind event was not as significant as the 1962 storm in terms of top wind speeds and geographic expanse, the duration and potential for damage from the recent storm was greater. Rainfall associated with the storm was accompanied by near-record temperatures. Rainfall amounted to as much as 14 inches in just a 24-hour period, sending many rivers in northwest Oregon and southwest Washington from well below flood stage to flood stage in a matter of hours. Because the storm varied in intensity and artifact (i.e., wind, rain, or both) throughout the region, it provides an opportunity to evaluate the impacts to various river basins particularly focusing on restoration actions implemented over the last ten years.

In summer 2008, the Oregon Watershed Enhancement Board (OWEB) asked the Institute for Natural Resources (INR) lead the *OWEB Coastal Storm Assessment* project. The purpose of this time-limited project was to provide the scientific context that would assist OWEB in determining if its restoration practices/projects are robust enough to take into account potential increases in storm magnitude, frequency and/or intensity associated with climate change. This context would facilitate a dialogue about OWEB's restoration investments and their relative success through time given a variety of potential climate-change scenarios, along with an evaluation of the robustness of past and current OWEB restoration practices/projects to determine how well they fared the intense storm event.

The project had four major components:

- Component 1: Framing the question: Information gathering;
- Component 2: A field assessment;
- Component 3: A meteorological/climatological evaluation; and,
- Component 4: A review of OWEB restoration practices and guidelines.

The purpose of this report is to characterize the December 2007 storm and long-term storm variability along the Oregon and Washington coast, present the results of a rapid assessment of randomly selected OWEB restoration projects (restoration activities including large wood placement, fish passage, and riparian planting), and based on the characterization and field assessment provide an assessment of the robustness of OWEB restoration practices relative to the December 2007 storm.

It is beyond the scope of this report to suggest changes to restoration practices if patterns or trends can be discerned.

1.0 An Analysis of Storm Characteristics and Long-Term Storm Variability along the Oregon-Washington Coast

This chapter examines trends in storm data in the Pacific Northwest and places the December 2007 storm in this context. It is adapted from a full report by George Taylor, certified Consulting Meteorologist, which can be found in Appendix A. The report was reviewed by Peter Parsons, Meterologist for the Oregon Department of Agriculture. His comments were submitted to George Taylor who addressed the comments.

1.1 Introduction

The coastal sections of Oregon and Washington are among the wettest and stormiest in the country. Stretching along Oregon's Pacific border, the coastal zone is characterized by wet winters, relatively dry summers, and mild temperatures throughout the year. Coastal terrain features include a coastal plain (extending from less than a mile to a few tens of miles in width), numerous coastal valleys, and the Coast Range, whose peaks range from 2,000 to 5,500 feet above sea level and extend down the full length of the state. Rivers such as the Coquille, Umpqua, and Yaquina dissect the Coast Range and drain its slopes. The area's heavy precipitation results from moist air masses moving off the Pacific Ocean onto land, especially during winter months.

Occasional strong winds strike the coast, usually in advance of winter storms. Wind speeds can exceed hurricane force, and in rare cases have caused significant damage to structures or vegetation. Damage is most likely at exposed coastal locations, but it may extend into inland valleys as well. Such events are typically short-lived, lasting less than one day.

1.2. Changes in the Frequency of Precipitation

To study changes in the frequency of extreme precipitation events, it is necessary to analyze precipitation trends over time using “time series” analysis. Three long-term weather stations were chosen for this analysis: Tillamook (data beginning 1948); Astoria Airport (data beginning 1953); and Laurel Mountain (data beginning 1978). The first two stations are near sea level on the northern Oregon coast. Laurel Mountain is at 3,590 feet in elevation in the central Oregon Coast Range. All three stations are Cooperative Stations administered by the National Oceanic and Atmospheric Administration (NOAA). Data were obtained from the Oregon Climate Service.

The analysis here is not intended to be systematic; rather, it uses several reliable, high-quality stations to illustrate trends at those locations. It is believed (but not proven) that these sites are representative of the central and northern Oregon coast.

1.2.1 One-day precipitation

The twenty highest one-day precipitation observations for Tillamook, Astoria and Laurel Mountain appear in Figures 1, 2 and 3, respectively.

Tillamook and Astoria show no significant change in the magnitude or frequency of one-day events. However, Laurel Mountain data show an increasing frequency of extreme one-day events.

1.2.2 Two-day precipitation

The twenty highest two-day precipitation observations for Tillamook, Astoria and Laurel Mountain appear in Figures 4, 5 and 6 respectively.

Tillamook and Astoria show an increasing magnitude of two-day precipitation events. Laurel Mountain data show an increased frequency of extreme events.

1.2.3 Three-day precipitation

The twenty highest three-day precipitation observations for Tillamook, Astoria and Laurel Mountain appear in Figures 7, 8 and 9 respectively.

Neither Tillamook nor Laurel Mountain data show significant change in the frequency or magnitude of extreme three-day events. However, Astoria data show increases in both the magnitude and the frequency of extremes.

1.3 Precipitable Water

Long-term trends in precipitable water were examined using the Salem, Oregon upper-air site. Data from 1966 through 1996 are shown in Figure 10, which is limited to the largest events (with a cutoff of 20 mm). No long-term trend is suggested in the data.

1.4 Storm Intensity Rating

A storm intensity rating system for the Oregon-Washington coast was developed using historical information from Taylor (1999) and other sources. The parameters used in the rating system were (Table 1):

1. Precipitable water. As measured at the Salem upper-air site, this provides an estimate of “potential precipitation.”
2. Percent of 100-year precipitation. The actual amount of precipitation reported is compared to estimated 100-year precipitation at that location.
3. Maximum wind gusts observed along the coast.

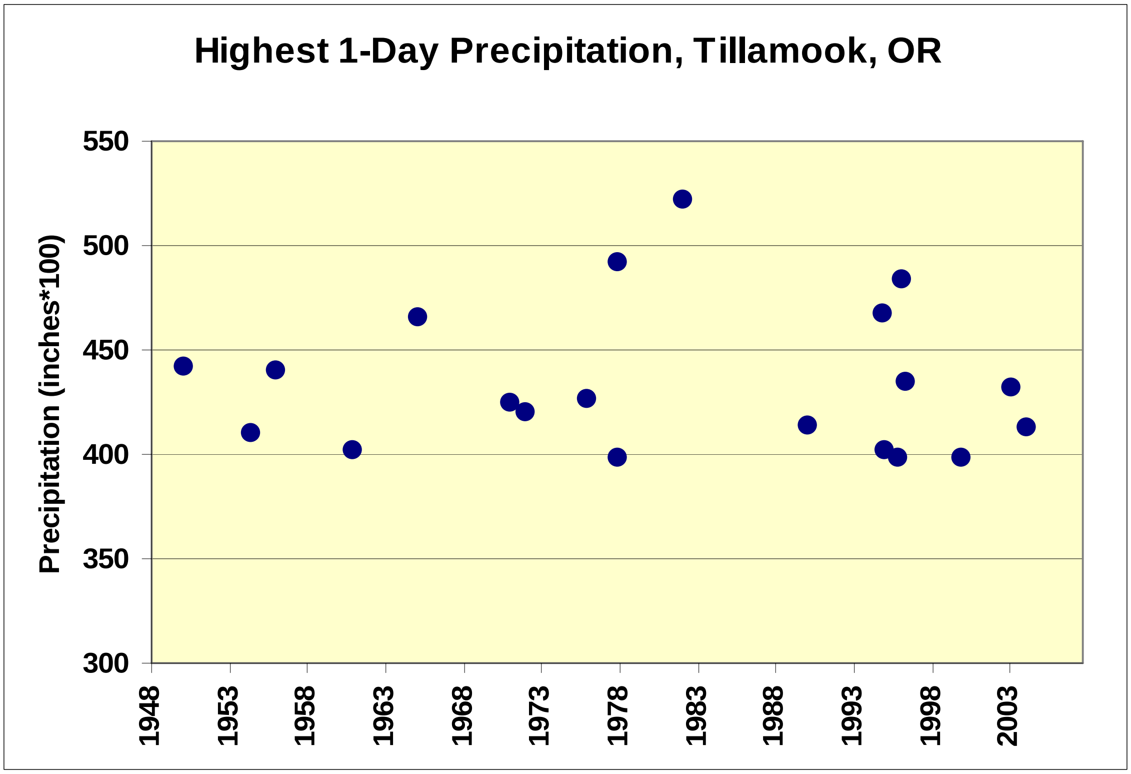


Figure 1. Twenty highest one-day precipitation totals, Tillamook, 1948-2007

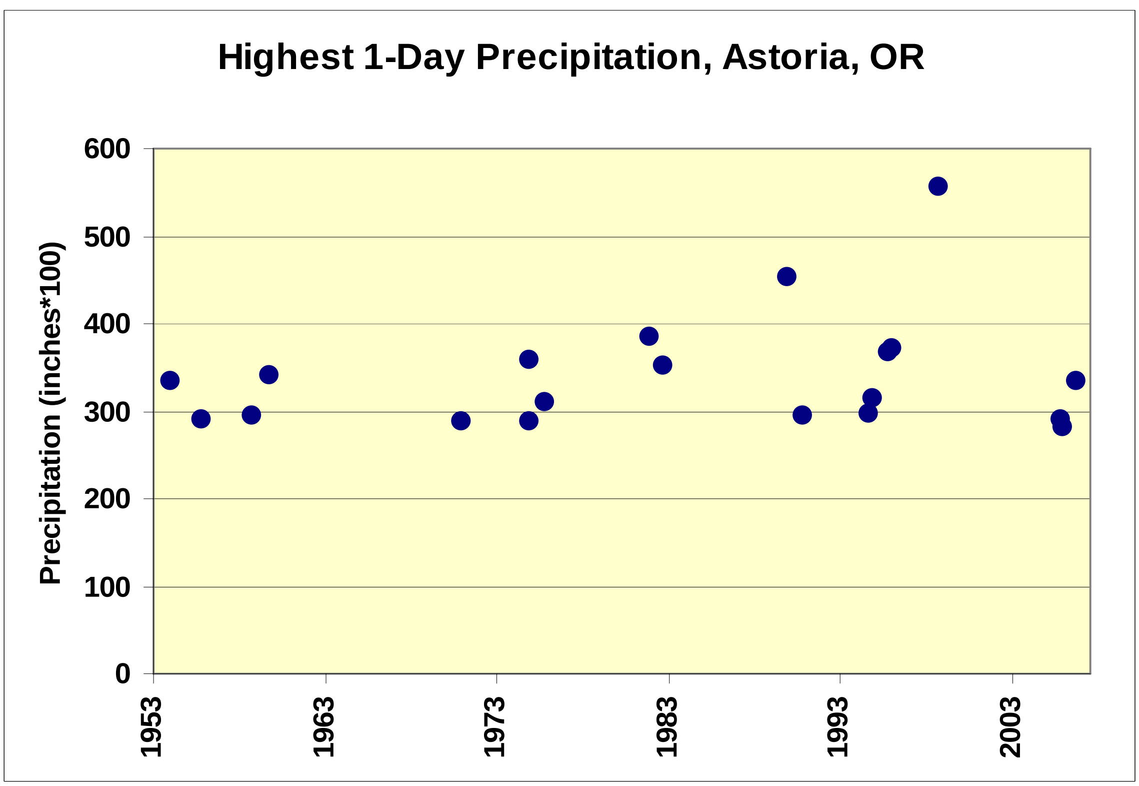


Figure 2. Twenty highest one-day precipitation totals, Astoria, 1953-2007

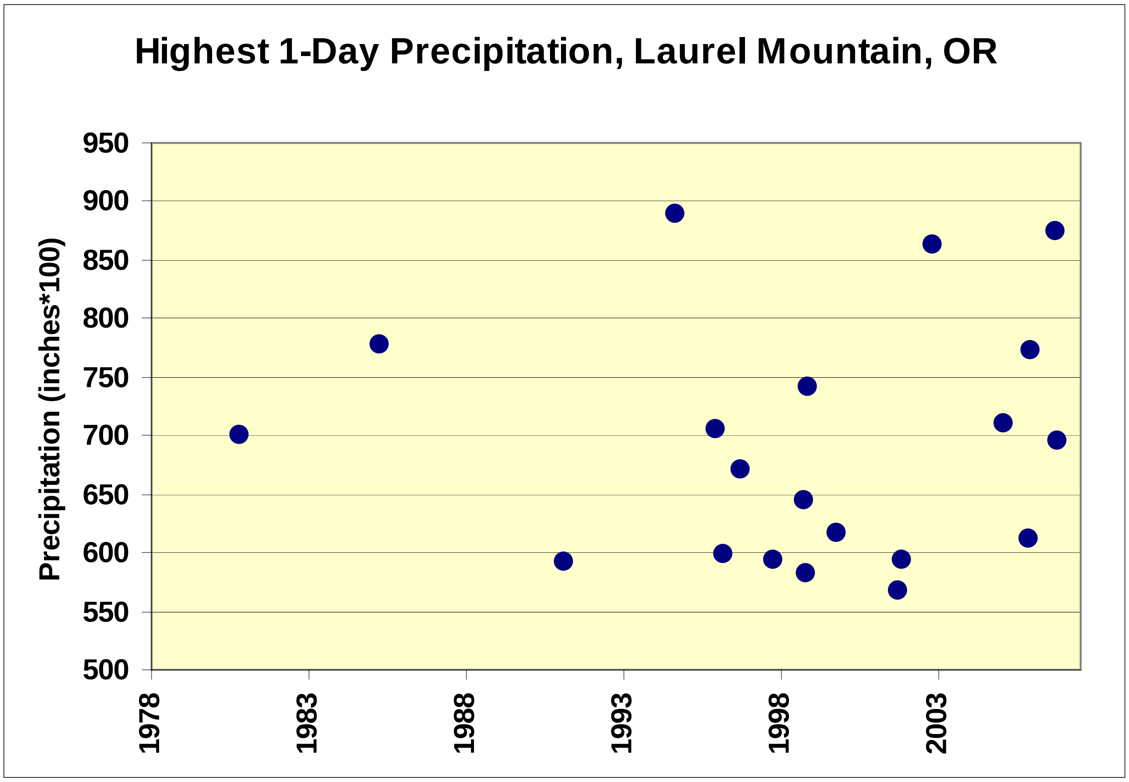


Figure 3. Twenty highest one-day precipitation totals, Laurel Mountain, 1978-2007

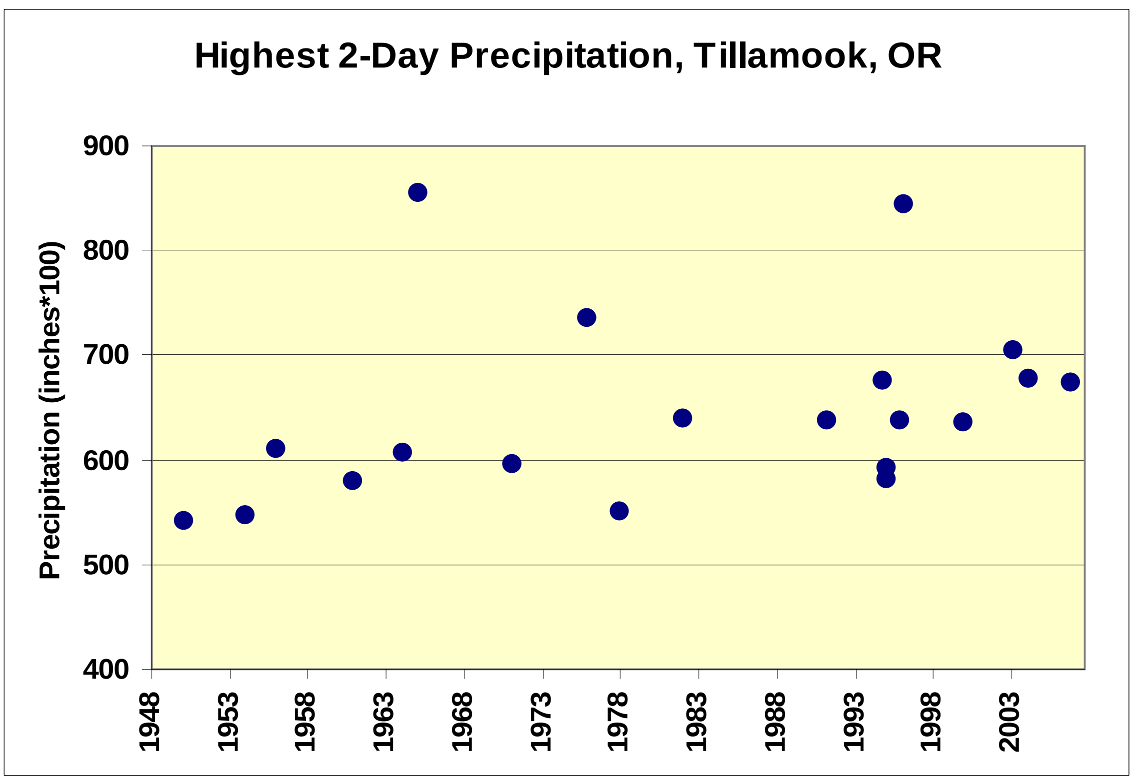


Figure 4. Twenty highest two-day precipitation totals, Tillamook, 1948-2007

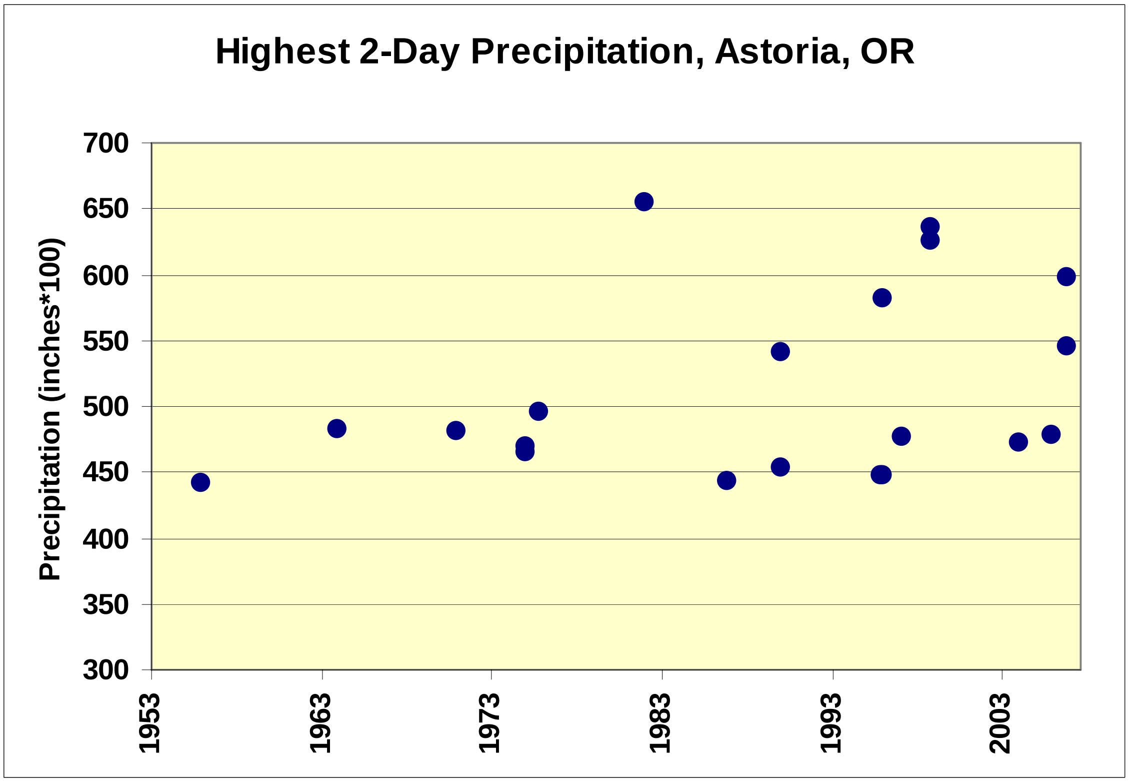


Figure 5. Twenty highest two-day precipitation totals, Astoria, 1953-2007

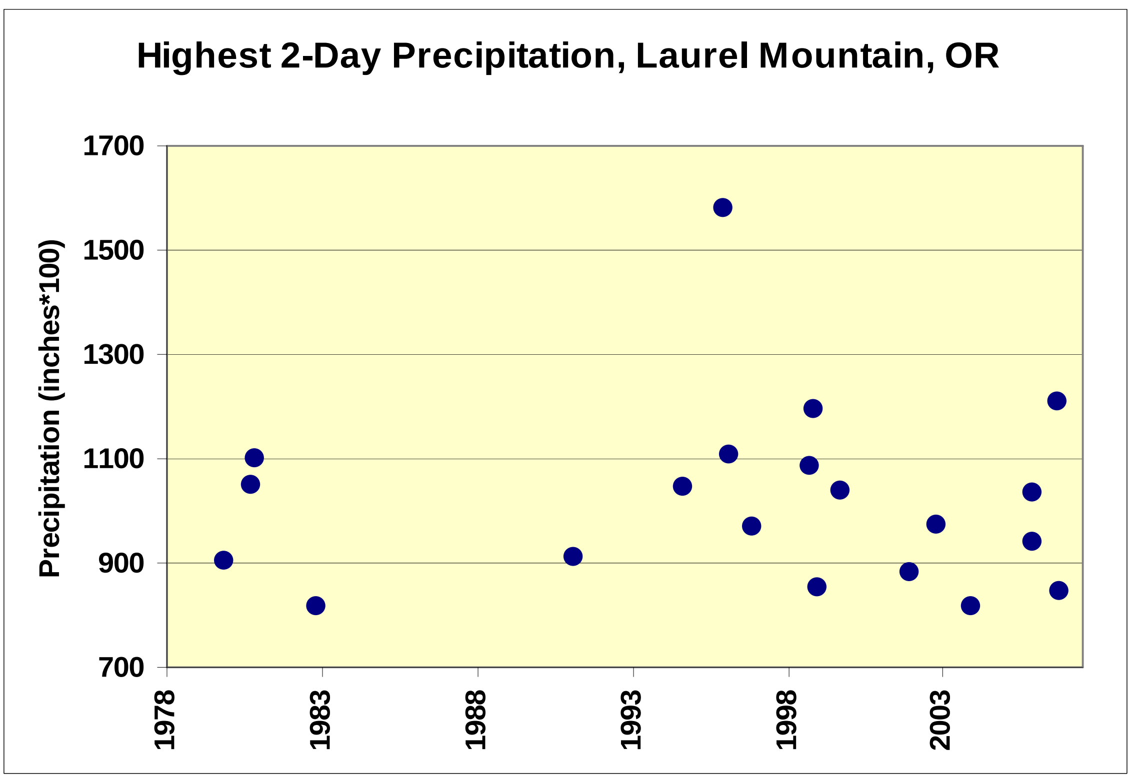


Figure 6. Twenty highest two-day precipitation totals, Laurel Mountain, 1978-2007

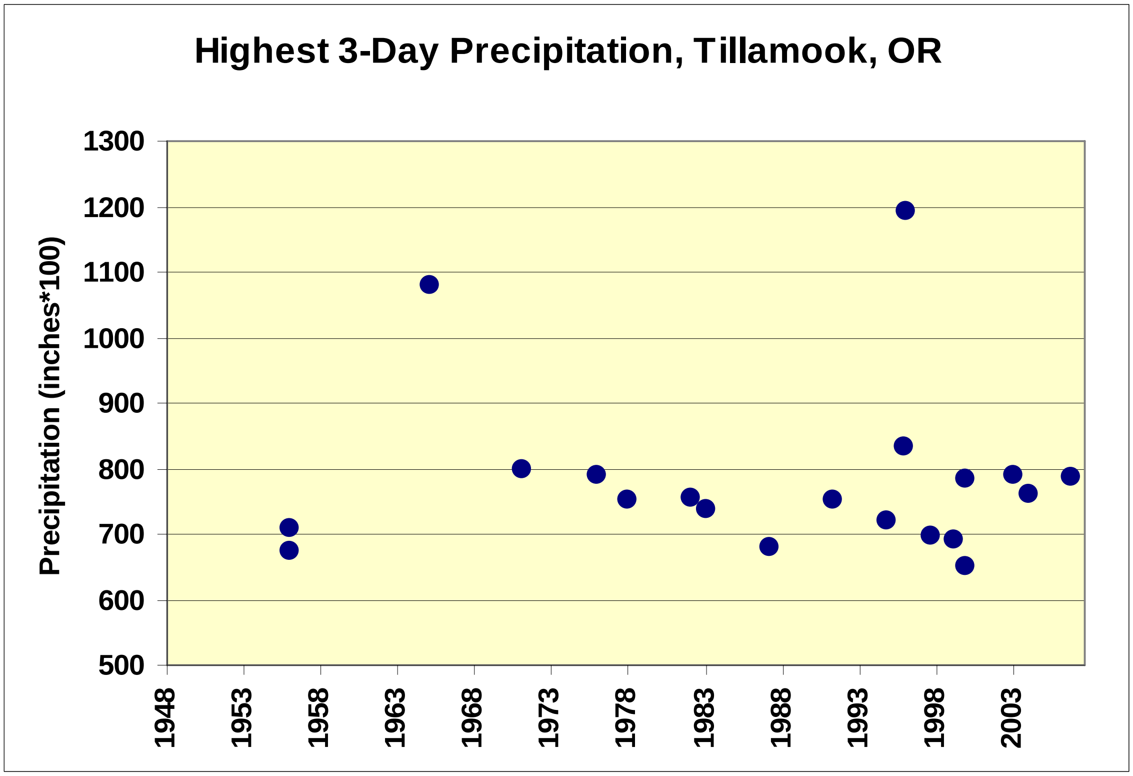


Figure 7. Twenty highest three-day precipitation totals, Tillamook, 1948-2007

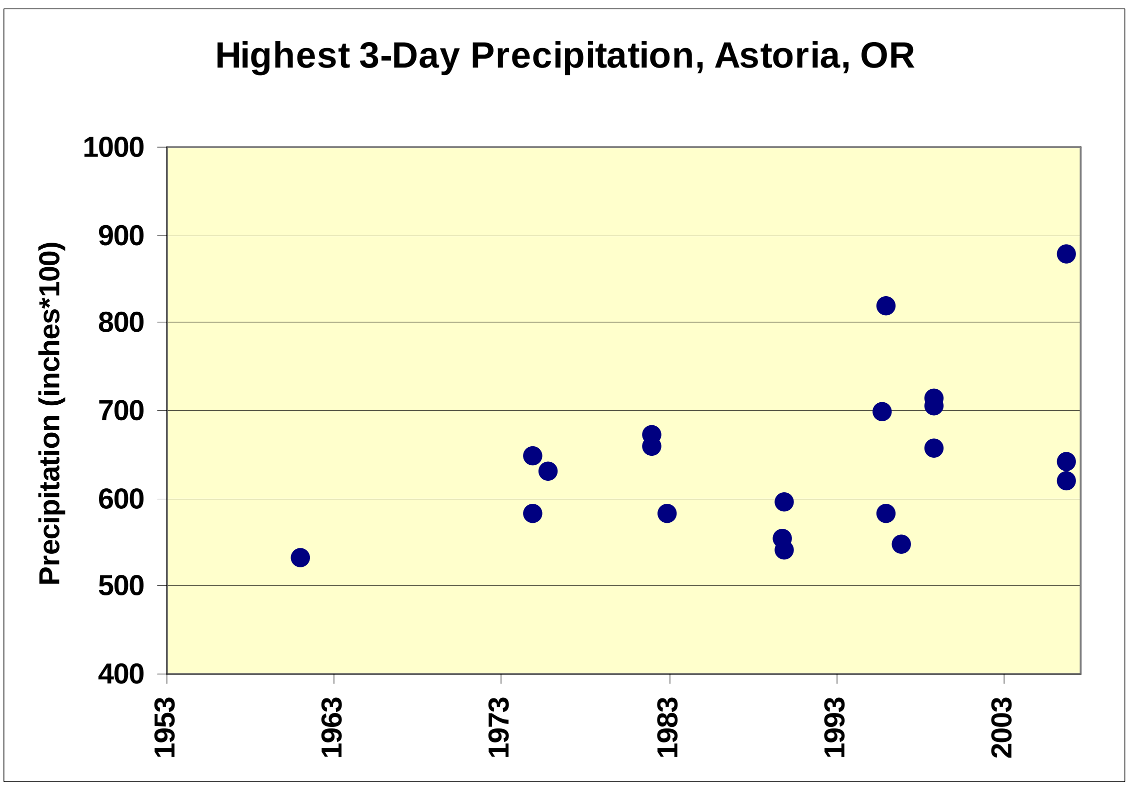


Figure 8. Twenty highest three-day precipitation totals, Astoria, 1953-2007

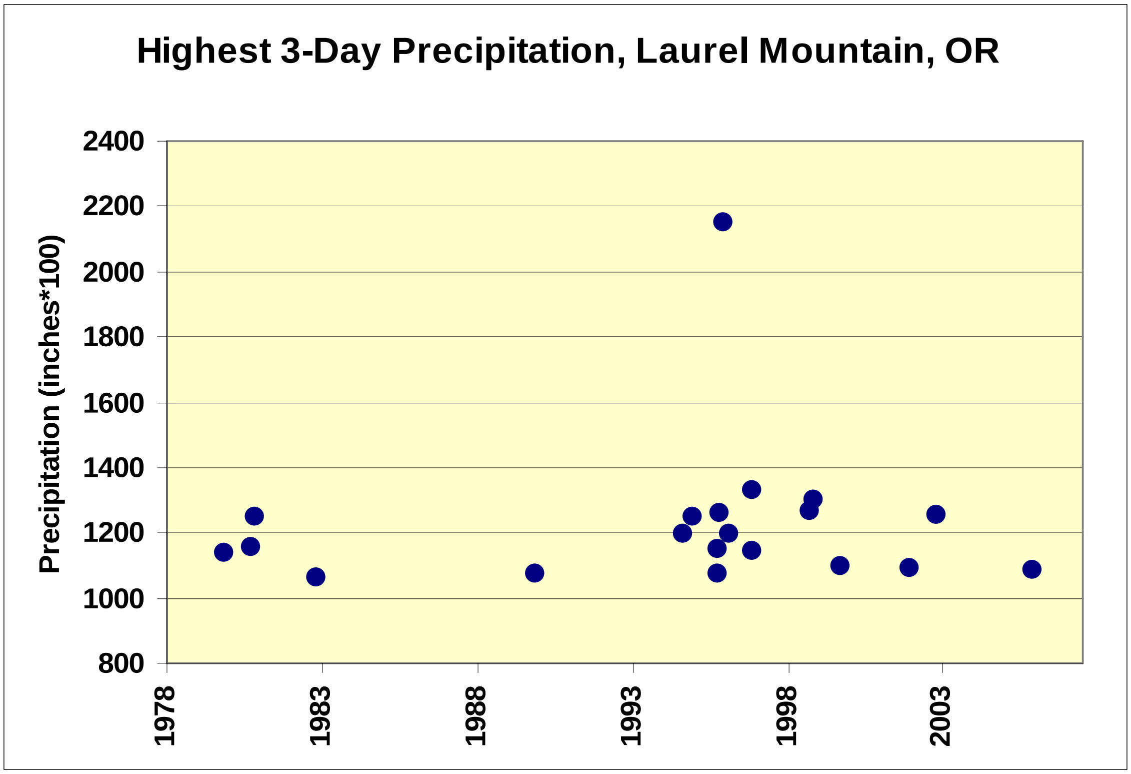


Figure 9. Twenty highest three-day precipitation totals, Laurel Mountain, 1978-2007

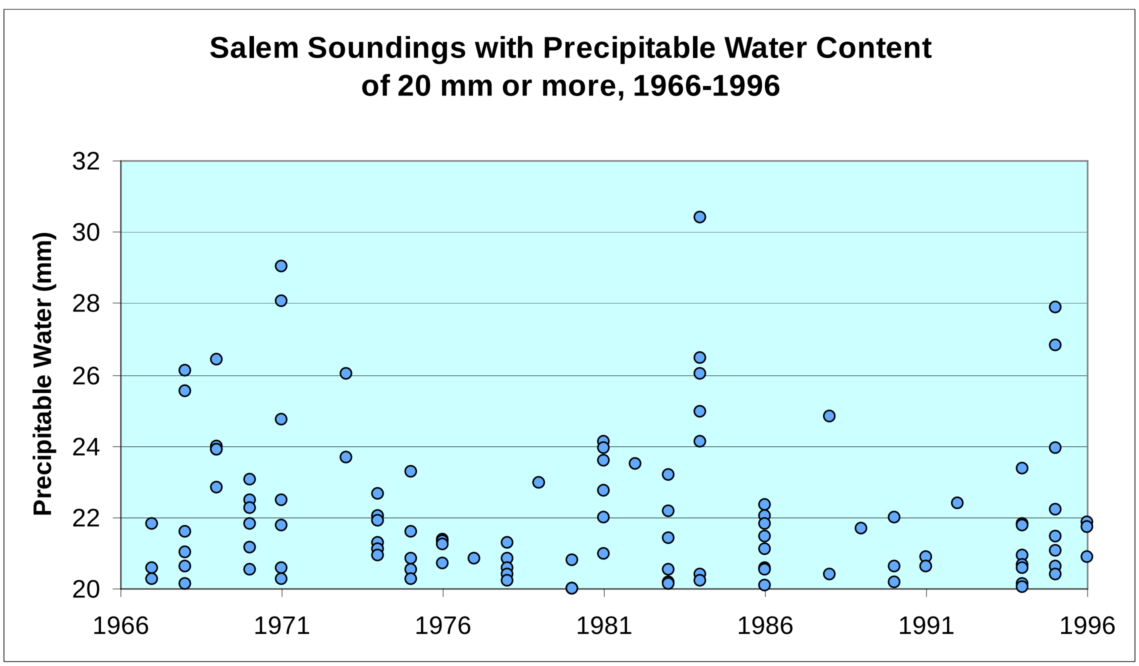


Figure 10. Salem soundings with precipitable water of 20 mm or more, 1966-1996

Table 1. Storm Intensity scale using five categories

Parameter	Units	Likert Scale*				
		1	2	3	4	5
Precipitable Water, Salem	mm	20	22	24	26	28
Precipitation, Percent of 100 year, maximum observed	percent	100	110	120	130	140
Maximum wind gust, Oregon-Washington Coast, sea level	mph	80+	90+	100+	110+	120+

* A value of 1 represents the smallest or weakest significant storm, 5 the highest. The parameters are mutually exclusive.

Most historical storms are either "wet but not especially windy" or "windy but not especially wet." The December, 2007 storm was an exception: a very wet storm which was also very windy.

1.5 The Storm of December 2007

A large and very damaging storm affected all of the Pacific Northwest during the first week in December. Winds exceeding 100 mph were accompanied by intense rains, which led to flooding. Damage was severe in many locations, mostly near the Oregon and Washington coasts.

The storm began as a large, but not particularly strong, mid-latitude storm in the mid-Pacific. Moisture from several decaying typhoons moved eastward and was absorbed by the storm, causing rapid enhancement. The storm deepened and grew in size, eventually reaching a diameter of several thousand miles; at one point, it stretched from western Idaho to the International Date Line, or about the size of the continental United States.

The moisture-enhanced deepening is what led to the very strong winds. The sheer size of the storm allowed it to reach well down into the tropics and tap abundant tropical moisture, which formed an "atmospheric river" – warm, moist air from the southwest.

At 12:45 pm on December 3 the National Weather Service issued the following announcement:

> *A strong Pacific system continues to rock the coastal region this afternoon...*
>
> *A very strong storm over the northeast Pacific continues to hold a tight pressure gradient along the Pacific Northwest coast. This is resulting in very strong winds. The storm peaked early this morning on the coast though strong winds will continue today and may see some peaks in the valley through early Tuesday morning as the cold front pushes onshore.*
>
> *Much damage has been reported. Coastal communities have reported many trees that have been blown down...blocking highways and taking out power lines. Damage has also been reported to homes. Major power outages are reported along the coast from Lincoln County to the Long Beach Peninsula. In*

addition to the wind...heavy rains have saturated most of northwest Oregon resulting in flooding and landslides.

1.5.1 Wind reports

Wolf Read, a Northwest wind storm expert, produced a retrospective on the wind storm for the Oregon Climate Service. The description below comes largely from Wolf's report.

"Historic" is a good descriptor of the coastal gale of December 1-3, 2007, especially for the counties of Lincoln, Tillamook and Columbia. At two key official weather stations, at the Newport Municipal Airport and the Astoria Regional Airport, wind gusts were the strongest in 45 years. A gust to 83 mph occurred at Newport and a burst to 85 mph at Astoria. While these values fall short of the Columbus Day Storm's 138 mph and 96 mph, respectively, it is good to keep in mind that the 1962 storm was unprecedented in raw wind velocity. Table 2, showing Astoria peak gusts, reveals that most big windstorms produce maxima of 65 to 80 mph at that location; anything above 80 mph is quite unusual. Roughly speaking, speeds of 85 mph and above appear to belong to a 50-year storm.

Peak gusts at some unofficial weather stations during the December storm resemble accounts of the Columbus Day Storm. Speeds of 125 mph were clocked on a well-exposed anemometer located at 70-feet above ground level in southern Lincoln City. At the Bay City Fire Station, a blast to 111 mph was observed at 1:10 AM on December 3rd, closely followed by a gust to 114. Then, at 1:30 AM, a 129 mph surge was observed. Nearby, a church steeple toppled, crashed through a power pole and was demolished on the street below. A wood-frame garage lifted from its foundation and flew to pieces, and a modern metal-framed storage building had its roof peeled off and walls disrupted. Two houses had wooden portions of their roofs yanked off, while many lost a flurry of shingles. Some windows shattered, siding peeled off and stop signs with metal poles were bent strongly toward the north. Trees at all points from the fire station toppled, some tearing through power lines and blocking roads. Clearly winds reached extreme levels at Bay City. This kind of damage appeared in many areas of the coast, with the heaviest destruction occurring from about Lincoln City northward.

The peak gust map (Figure 11) shows the narrow focus of the storm. The Pacific shoreline of Oregon and Washington bore the brunt of the winds, and a heavy gale tore through the Coast Range northward, producing an extreme gust of 147 mph on Naselle Ridge, a place subject to local wind enhancement where gusts of 160 mph occurred during the Columbus Day Storm. Eastward, beyond the coastal hills, the ferocity of the December 2007 gale quickly waned. Wind gusts in the Willamette Valley ranged from 35 mph at Troutdale to 54 mph at Salem. While it was a forceful storm, it paled in comparison with other Valley windstorms.

Table 2. Historic Peak Winds at Astoria. Peak gusts from 1995-2006 are adjusted upward to account for a 5-second averaging period

Storm Event	Peak Gust at Astoria (mph)	Other Name
12-Oct-62	96	Columbus Day Storm
03-Dec-07	85	"Great Coastal Gale"?
14-Dec-06	82	Hanukkah Eve Storm
15-Jan-51	80	
16-Jan-00	78	
03-Mar-99	78	
13-Feb-79	76	Kitsap Blowdown
17-Dec-61	76	
20-Dec-61	76	
16-Jan-86	75	
03-Nov-58	75	
15-Dec-95	74	Big Blast
15-Dec-97	74	
20-Jan-93	72	Inauguration Day Storm
27-Apr-62	71	
27-Dec-02	70	
26-Mar-71	70	
09-Jan-53	70	
14-Nov-81	68	Friday-the-13th Storm
07-Jan-53	66	
27-Oct-50	65	

Peak gust is one of a number of important ways to measure wind. The Columbus Day Storm may outclass all windstorms in terms of maximum wind speed; however, the December, 2007 storm is perhaps the longest-lasting high-wind event on record. The Columbus Day Storm sprinted through the Northwest, typically delivering its lively gale over a period of about two to three hours at most locations. The 2007 storm proved to be a very long-lasting event. Allowing for a few brief lulls, high-wind criteria gusts of 58 mph (50-knots) and higher lasted nearly two days.

1.5.2 Rainfall

Moisture from the remains of two typhoons, Hagibis and Mitag, was entrained in the monster-sized second low of the series. The tropical genesis of the storm, coupled with very fast mid-level (850 mb) airflow sweeping the moisture-filled air into the coastal mountains, resulted in a significant rainstorm to go with the powerful, hurricane-force winds. The resulting storm thus closely resembled the typhoons that provided much of the original moisture.

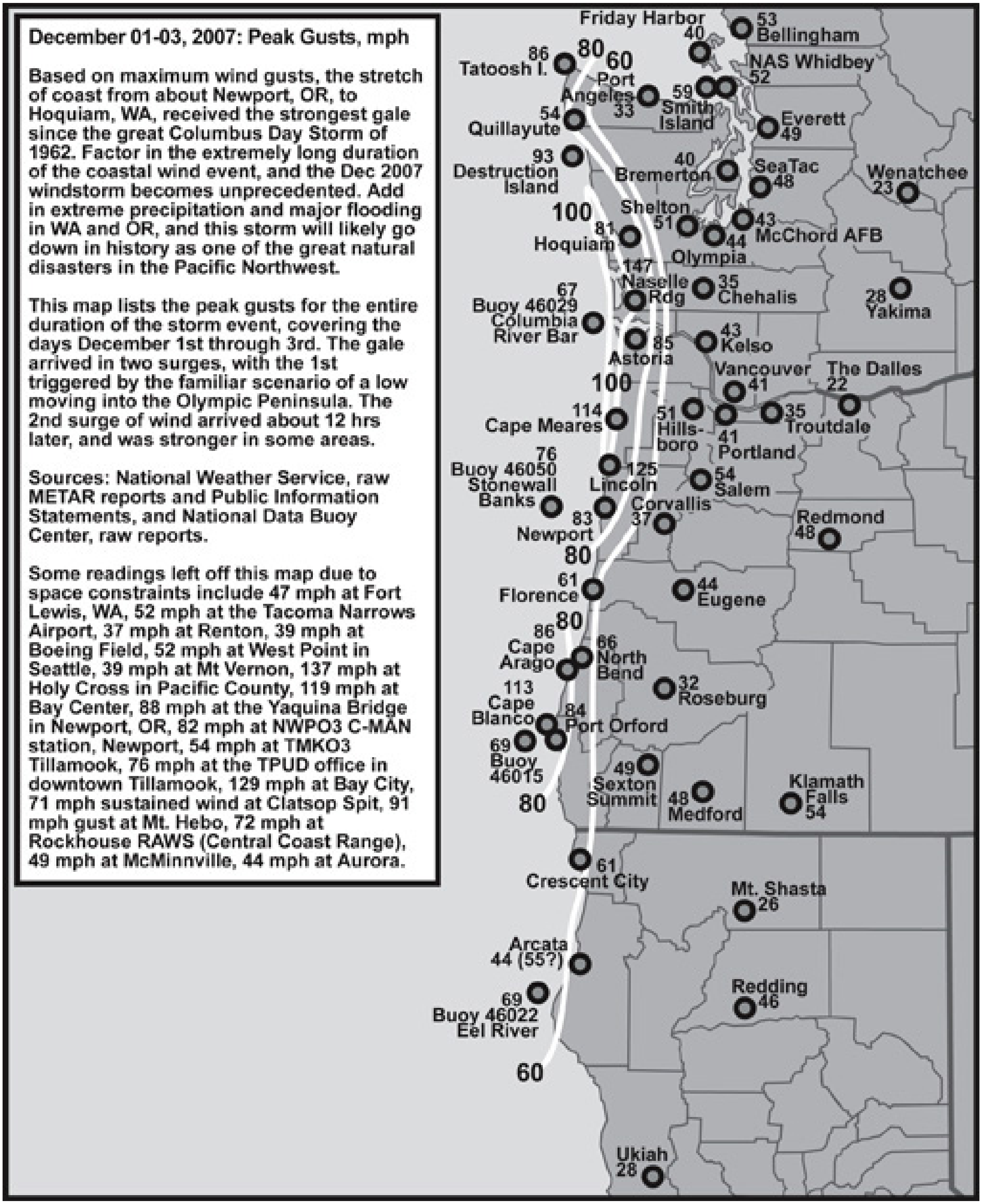


Figure 11. Peak gust map for December, 2007 wind storm

Figure 12 is an enhanced infrared satellite image for 4:00 am PST on December 3, during the height of rainfall intensities. Table 3 lists precipitation observations reported by the National Weather Service at the time of the storm. Several locations exceeded 10 inches for the event, led by Lees Camp at more than 14 inches.

Figure 13 is a preliminary map of maximum one-day precipitation published by Oregon Climate Service. Figure 14 shows the percent of 100-year precipitation represented by the values in Figure 13. Several areas in northwest Oregon and southwest Washington saw daily totals exceeding 140% of the historical 100-year values: in other words, the rainfall totals were truly unusual, if not unprecedented.

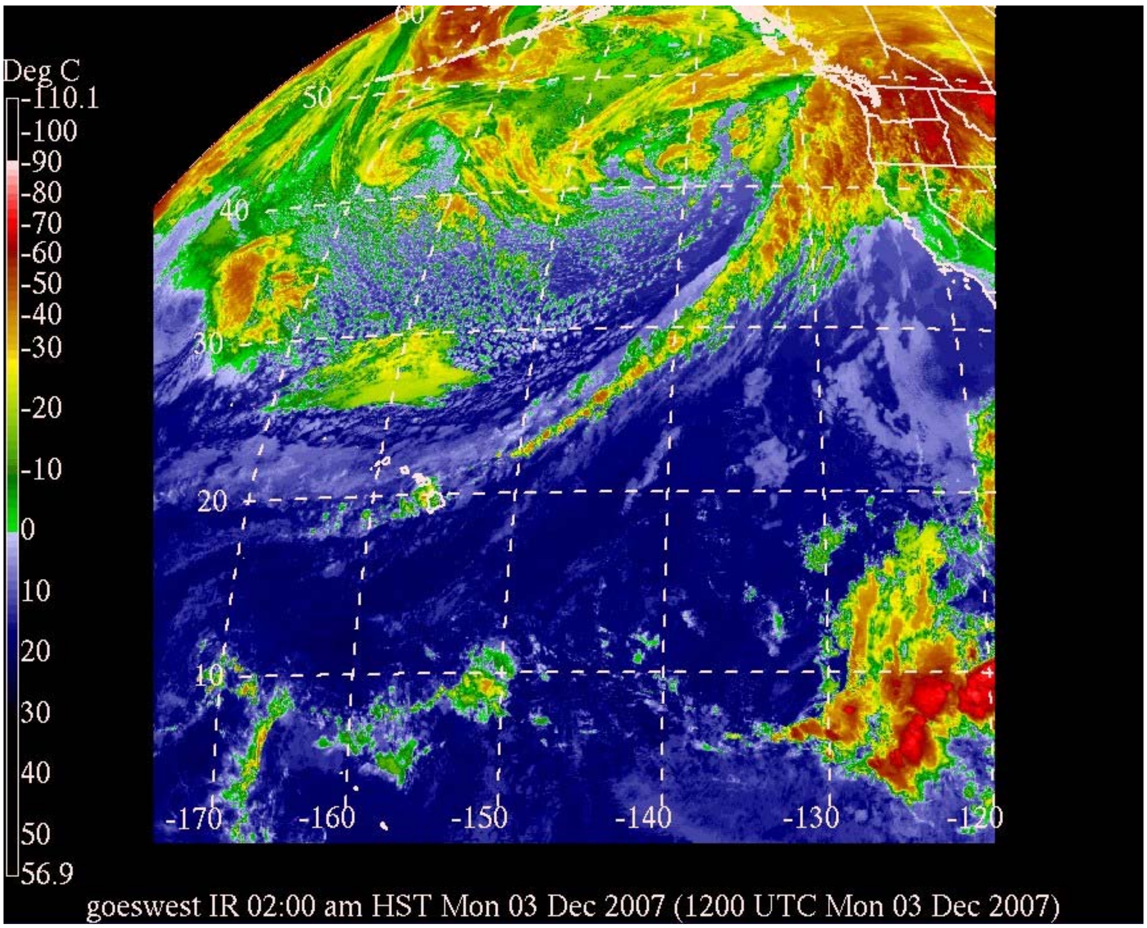
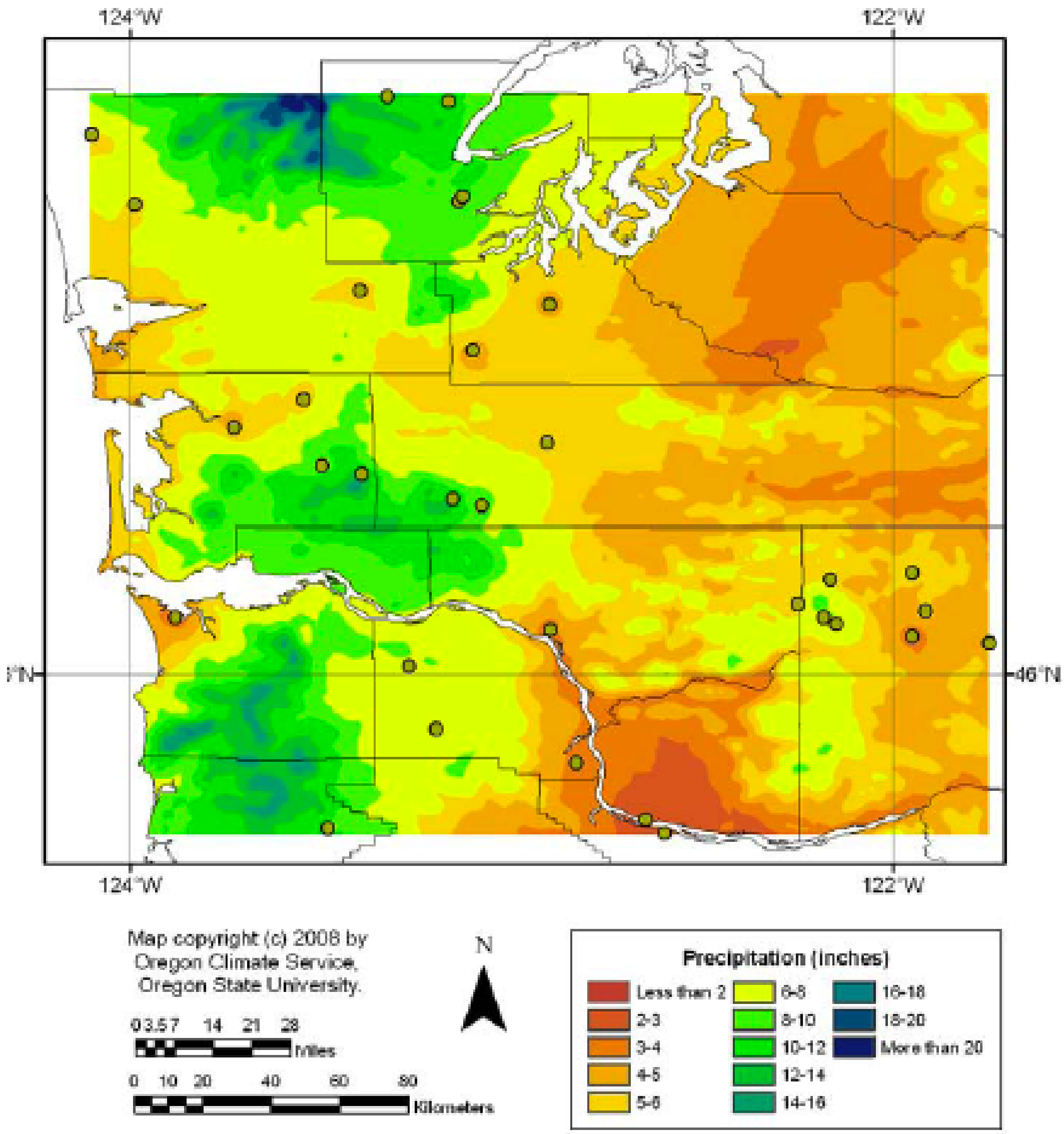


Figure 12. Enhanced infrared satellite image for 4:00 am PST on December 3

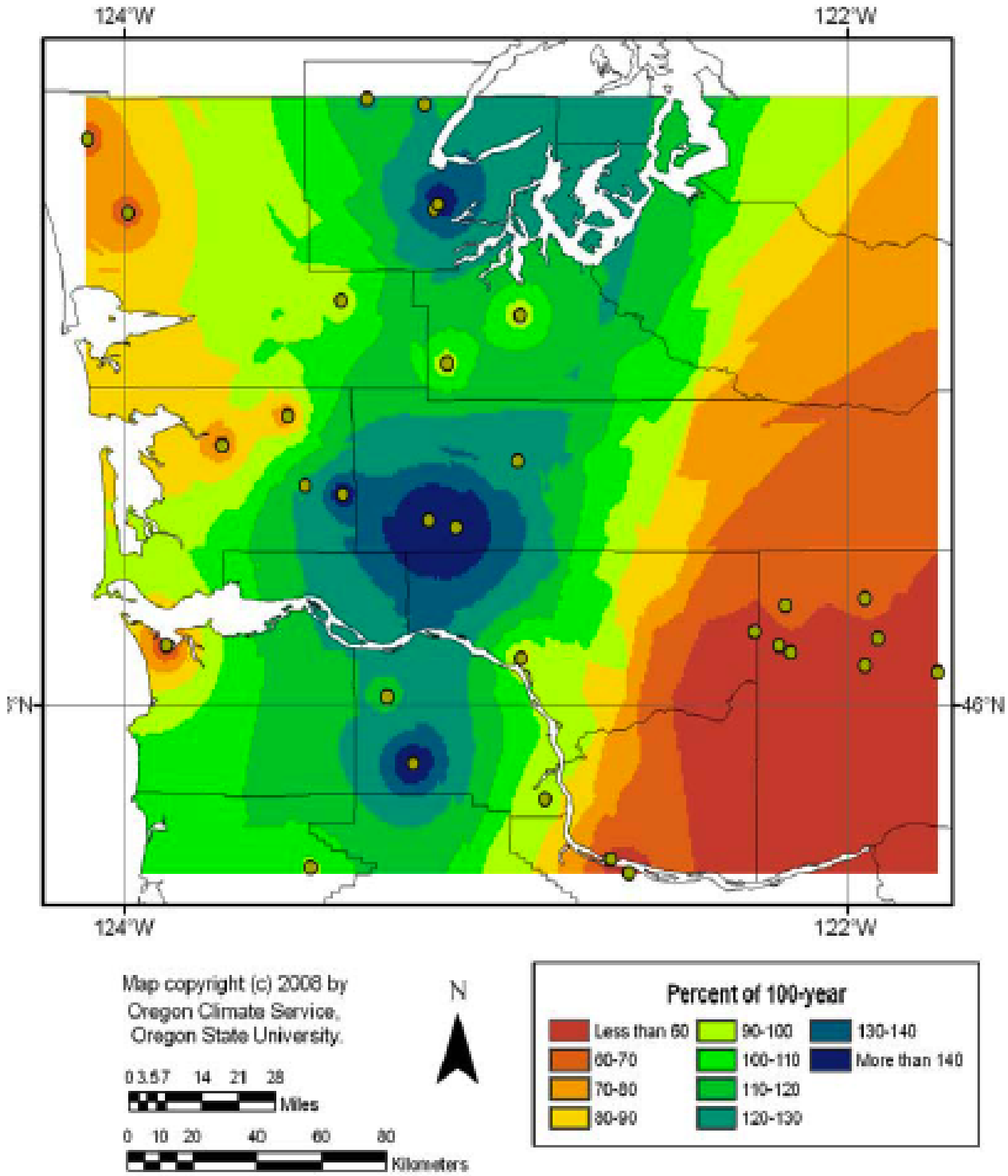
Table 3. Storm Total Precipitation, Dec. 1-3, 2007

LOCATION/STATION	STORM TOTAL (INCHES)	REMARKS
SOUTH WASHINGTON/NORTH OREGON COAST		
ASTORIA	3.94	THROUGH 4 AM MONDAY
TILLAMOOK RAWS	3.76	CENTRAL OREGON COAST
LINCOLN CITY	3.50	THROUGH 6 AM MONDAY
DUNES	3.10	NORTH OREGON COAST RANGE
SOUTH FORK RAWS	12.71	
CEDAR MTN RAWS	12.19	
MILLER RAWS	8.65	
LEES CAMP	14.50	
VERNONIA	11.00	
ABERNATHY MTN	1.84	
RYE MOUNTAIN	9.51	CENTRAL OREGON COAST RANGE
GOODWIN PEAK RAWS	5.59	
ROCKHOUSE MTN	9.12	
VILLAGE CREEK	7.60	
HIGH POINT	4.91	
KELSO	5.16	
BONNEVILLE	5.50	
MIDDLE MTN	5.17	
PARKDALE	3.57	
HOOD RIVER	4.50	
NORTH WILLAMETTE VALLEY/CLARK COUNTY		
GRESHAM	3.70	
FOREST GROVE	6.37	
VANCOUVER	3.73	
TROUTDALE	3.38	
PORTLAND AIRPORT	3.35	
SCAPPOOSE	5.97	
HILLSBORO	4.48	
GASTON	7.65	
CENTRAL WILLAMETTE VALLEY		
SALEM	2.44	
AURORA	2.36	
JEFFERSON	4.58	
MCMINNVILLE	3.50	
STAYTON	1.40	
FALLS CITY	10.70	
EUGENE (AIRPORT)	2.19	
CORVALLIS	1.51	
CANYON CREEK	5.76	
COLDWATER RIDGE VISITOR CENTER	6.42	
TROUT CREEK	1.43	
DETROIT LAKE (AG STN)	6.39	
DEE FLAT	4.96	
EAGLE CREEK RAWS	3.17	
HORSE CREEK RAWS	8.37	
LOG CREEK RAWS	11.23	
SCOTTS MILLS	5.40	



Source: Oregon Climate Service, 2008

Figure 13. Preliminary map of maximum one-day precipitation for the December, 2007 storm



Source: Oregon Climate Service, 2008

Figure 14. Percent of 100-year precipitation represented by the values in Figure 5.5

1.6 Stream flows

Stream flow data are collected by several agencies and reported by the National Weather Service (NWS). Table 4 lists the maximum river crest and flood stage height for Northwest rivers. The Nehalem was more than 10 feet above flood stage, and several other rivers exceeded flood stage by more than 5 feet.

Table 4. Maximum river crest and streamflow volume, northwest Oregon and southwest Washington, December 2007

GAUGE	FLOOD STAGE (ft.)	RIVER CREST (ft.)	FLOW RATE (cfs)	CREST DATE/TIME
COASTAL RIVERS				
WILLAPA NR WILLAPA	21.0	26.6	15,000	5 PM DEC 3
NASELLE NR NASELLE	15.5	14.7	7,200	8 AM DEC 3
GRAYS NR ROSBURG	12.0	16.5	20,100	1 PM DEC 3
NEHALEM NR FOSS	14.0	24.4	52,200	12 PM DEC 3
WILSON NR TILLAMOOK	12.0	20.5	33,300	11 AM DEC 3
TRASK NR TILLAMOOK	16.5	20.8	20,400	10 AM DEC 3
SILETZ AT SILETZ	16.0	19.0	25,800	2 PM DEC 3
ALSEA NR TIDEWATER	18.0	21.8	27,500	10 PM DEC 3
SIUSLAW NR MAPLETON	18.0	21.5	30,200	9 PM DEC 3
...SOUTHWEST WASHINGTON INTERIOR...				
COWLITZ AT CASTLE RK	48.0	47.4	64,600	6 PM DEC 3
COWLITZ AT KELSO	21.7	22.8	N/A	1 AM DEC 4
...WILLAMETTE VALLEY...				
JOHNSON CK IN PORTLAND	11.0	11.9	1,300	10 AM DEC 3
CLACKAMAS NR ESTACADA	20.0	20.3	24,200	11 PM DEC 3
TUALATIN AT DILLEY	17.5	19.0	9,700	9 PM DEC 3
TUALATIN NR FARMINGTON	32.0	32.6	11,100	7 PM DEC 5
MARYS NR PHILOMATH	20.0	21.0	13,000	9 PM DEC 3
LUCKIAMUTE AT SUVER	27.0	29.0	11,000	4 PM DEC 3
S YAMHILL AT MCMINN.	50.0	55.9	31,000	4 PM DEC 4

1.7 Future Trends in Storm Intensity

As for changes in intensity or frequency of storms in the future, these are very difficult to predict. Three factors that could cause such changes include:

a. changes in the tropic-polar temperature gradient
b. changes in moisture content of the atmosphere
c. changes in clouds

NASA's Goddard Institute of Space Science (GISS) provided an excellent summary of how future changes in temperature could affect weather:

> *"The connection between global warming and mid-latitude storms lies in the temperature difference between the poles and the equator. This temperature difference behaves much like the potential difference across an electric battery, the greater the difference, the easier it is for energy to flow between the end points. As global warming continues, the temperature difference*

between the poles and the equator is expected to decrease, making it harder for energy to flow. The poles will warm more quickly, while the already warm tropics will experience small increases, resulting in a smaller temperature difference. This in turn should produce a less energetic jet stream, with fewer disturbances within it. The expectation is that global warming will cause a reduction in the number of mid-latitude storms.

"There is however, an additional factor to consider. Under continued global warming, the average surface temperature of the earth will increase. Warmer air at the surface will be able to hold more water vapor. When this air is lifted into the atmosphere, there will be more water available to form clouds and precipitation. So even though there may be fewer mid-latitude storms in the future, these storms may produce more optically thick clouds and more damage causing precipitation. (Optical thickness is a measure of the total water within a cloud. An optically thick cloud contains a great deal of water and suspended particles, and reflects most of the sunlight hitting it from above. Such a cloud appears dark from below.)

"An almost hidden, third factor is the potential of clouds to reduce or enhance the global warming that is occurring. Lower, optically thicker clouds will reflect more solar energy back into space, and have an overall cooling effect. Higher, optically thinner clouds will allow most of this solar energy to pass through to the earth's surface, but will then absorb and reradiate some of the infrared energy released by the earth's surface, producing an additional warming. Thus, the exact nature of the clouds that will be produced by the storms of the future is of great importance to the climate scientists as they try to predict the magnitude of future global warming."

Recent years, however, have seen observed temperatures diverge from earlier predictions. In fact, global temperatures (from satellite) have dropped in recent years after reaching a peak in 1998 (during the big El Nino of that year). Some have speculated that perhaps "global warming" has paused. And it is possible a continued decline in temperatures will occur. Figure 15 shows observed satellite temperatures in the mid-troposphere (the part of the atmosphere that should be warming the fastest, according to models). Trends from Intergovernmental Panel on Climate Change (IPCC) and Climate Change Science Program (CCSP) modelers are shown. The overall trend since records began (1978) is close to zero.

Even if a clear trend in temperatures were evident, the effects on Pacific Northwest weather are unclear. As described in the GISS narrative above, warmer temperatures could cause storm intensity to rise or fall. The effects of cooling would also be hard to assess.

If, on the other hand, one views trends in recent decades as "likely to continue," the following conclusions can be drawn:

1. extreme rainfall events, which have been increasing in magnitude and frequency, would continue to become stronger and more common in winter;

2. extreme wind events peaked in the late 1950s through mid-1960s and thus would not be expected to increase; and
3. mean annual minimum temperatures in the Northwest have risen in recent decades, and this is likely to continue.

In the end, that is probably as far as we can go.

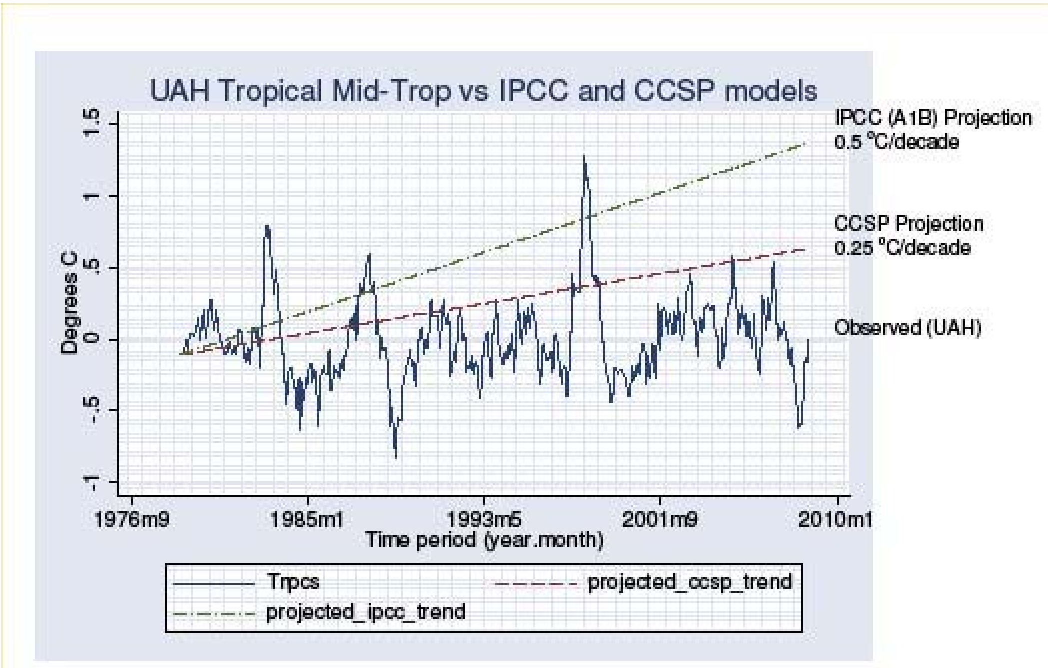


Figure 15. Projected temperature trends from IPCC and CCSP models compared with observed monthly values from the tropical mid-troposphere

1.8 Conclusions

An examination of precipitation trends for three western Oregon stations revealed an apparent increase in the intensity and frequency of large rain storms. This result is tempered by the very small set of data points. The increase was most pronounced in the case of 2-day rainfall totals. Examination of atmospheric moisture for Salem, Oregon showed little or no systematic variation in precipitable water for the period 1966-1996.

A "storm intensity" rating was developed to rank storms according to moisture and wind speeds. Parameters used in the evaluation included precipitable water, percentage of 100-year precipitation, and sustained wind speeds. The December, 2007 storm was an unusual combination of very wet and very windy. As such, it is one of the highest ranked storms ever experienced in the Northwest, using the new rating system. Taken alone the precipitation and wind events of the storm are still significant events but are not unusual for the North Coast of Oregon.

2.0 Storm Impact Assessment

Assessing the severity of the December 2007 storm impact on OWEB–funded restoration projects on the North Coast required:

1. A sampling protocol.
2. Rapid assessment protocols for in field collection of data to assess the condition of large wood placement projects, fish passage projects, and riparian restoration projects. A fourth project type that initially was identified for inclusion—roads—was removed from the study because of a lack of sufficient number of road-related, OWEB-funded projects to assess.
3. A storm impact assessment combing field assessment findings with the climate assessment described in Section 1.

2.1 Sampling Protocol

A random sample design was used to choose candidate sites for inclusion in the field survey. Several queries were conducted in order to select the candidate restoration projects. First, the Oregon Watershed Restoration Inventory (OWRI) database was filtered for only the restoration project activities of interest (riparian planting, in-stream large wood placement, fish passage, or projects with a combination of these types of activities) that occurred between the years 1997 - 2006. The resulting database listed 1,114 individual restoration project activities or sites, each assigned with an OWRI project number.

From this list only OWEB-funded projects with monitoring documentation were selected as possible candidates for this assessment because: 1) the purpose of this assessment was to determine if OWEB's restoration practices are robust enough to accommodate the potential increases in storm magnitude, frequency and /or intensity associated with climate change, and 2) the only project post-implementation/pre-storm monitoring records available were from OWEB's grant files. Under these criteria, there were 103 projects expanding over 158 individual restoration activities (several projects have more than one restoration activity associated with it) that were OWEB-funded and had a monitoring history. Each of these 103 projects had both an OWRI project number and an OWEB grant number. Of the 103 OWEB-funded projects that had a monitoring history, 13 projects were expelled due to either very little monitoring history (no photos) or the file was disposed of. Also, two projects—Blodgett Tract and Gods Valley—were specifically requested to be in the assessment by OWEB personnel.

Initially, a random sample of 60 projects was drawn from the remaining 89 candidate projects by using the OWRI project numbers. The results were: 5 – Combined, 7 – Fish Passage, 6 – Instream, and 42 – Riparian Planting, expanding over 96 individual restoration activities.

Upon further examination, it was discovered that often one OWEB-grant number was associated with more than one OWRI project number. In this example, the 89 candidate projects stemmed from 33 OWEB grants. The problem was that the information obtained from OWEB grant files did consistently include the OWRI project number(s). This meant there was not a convenient or confident way to determine which section of the OWEB grant file aligned with the individual restoration activity as indicated by the selected OWRI project number.

To resolve this issue an alternative random sample was conducted by using the OWEB grant number. In total, 19 OWEB grant numbers were randomly selected from the qualifying pool of 33. The results were: 2 – Combined, 3 – Fish Passage, 3 – Instream, and 11 – Riparian Planting, expanding over 102 individual restoration activities. For this final random sample, it was attempted to assess all individual restoration projects associated with the selected grant number. From this list, individual projects and sites were assessed for data sufficiency and site accessibility. All the sampled restoration activities were treated as unique.

If the total number of discrete sites available for sampling had fallen below 60 or the field teams completed all assessable sites within the field period than additional replacement grant numbers would have been selected from the list of eligible OWEB grant numbers.

2.2 In-field Rapid Assessment Protocol

Given the large area, potential remoteness of restoration sites, the large number of restoration sites and short time period available to complete the assessment project, the only feasible approach was to adopt a rapid assessment framework with context-specific protocols developed for each of the restoration activities.

From the results of the assessment protocols it would be possible to infer whether or not the winter 2007 storm had a detrimental impact on individual restoration projects and whether or not any pattern/trend exists to these impacts that can inform future restoration practices.

Assessment protocols were developed for each of the restoration activities. The protocols were designed to:

- be able to be completed quickly and accurately in the field without the use of specialized equipment or time consuming detailed measurement;
- establish baseline measures of the condition and effectiveness of the restoration projects in achieving its goals and
- identify potential recent wind, torrent and debris damage to the projects.

The assessment protocols were created from existing protocols for monitoring restoration projects and with the guidance and advice of researchers with practical restoration experience on Oregon's North Coast.

The storm damage assessment (Appendix B) noted evidence for and severity of:

- Wind throw within visual range, 10 meters of the stream and within the stream.
- Debris and torrent flow damage to the restoration site.

The large wood placement assessment noted (Appendix C):

- The condition of placed logs and log jams.
- Movement and recruitment of new large wood debris into the treatment reach.
- Stream structure and complexity of stream morphology in the reach in which the large wood was placed.

Riparian plantings (Appendix D) were assessed on the basis of:

- Height.
- Vigor (inter-nodal growth and or height/age).
- Damage extent and type (browsing, storm and/or smothering by invasive plants).

Fish passage projects (Appendix E) were assessed using:

- Structure characteristics and structure condition.
- Fish passage characteristics
- Impact on upstream and downstream habitat.

Each site assessment was supported by photographic evidence using a photo protocol (Appendix F).

2.3 Storm Impact Assessment

The project/site specific storm impact assessment was designed as a six step process using expert judgment to assign scores. At each step the Principal Investigators assigned a rating based on OWEB monitoring reports, the completed infield rapid assessment sheets, climate data and photographic evidence. Experts on riparian restoration, large wood placement and culvert replacement projects reviewed these "first round "qualitative assessments and site scores were adjusted as necessary.

The six steps are:

1. Assessment of the physical condition of restoration project prior to the storm event relative to best restoration practices

   Based on OWEB documentation and, if necessary, informal conversations with landowners and/or restoration teams, assess on a scale of 1 to 5 the physical condition of the restoration site/project prior to the winter of 2007.

   - A score of 1 would indicate that there was no evidence of restoration activity at the project.

- A score of 5 would indicate that prior to winter 2007 the restoration project/site was in place and was in the best physical condition possible given normally prevailing conditions.

2. Assessment of pre-storm restoration effectiveness

   Based on OWEB documentation and, if necessary, informal conversations with landowners and/or restoration teams, assess on a scale of 1 to 5 the effectiveness of the restoration work prior to the winter of 2007.

   - A score of 1 would indicate that there was no evidence that the restoration activity was having an effect in avoiding, remedying or mitigating the adverse processes it was intended to address.
   - A score of 5 would indicate that the restoration activity was fully effective in avoiding, remedying or mitigating the adverse processes it was intended to address.

3. Assessment of physical condition post-storm event

   Based on field assessment, establish the physical condition of the restoration site/project following the December 2007 storm event. This assessment could be supplemented with information learned from informal conversations with landowners and/or restoration teams, if necessary.

   - A score of 1 would indicate that there was no evidence of restoration activity at the project.
   - A score of 5 would indicate that following winter 2007 the restoration site/project was in place and was in the best physical condition possible given normally prevailing conditions.

4. Assessment of post-storm restoration effectiveness

   Using field assessments and, if necessary, informal conversations with landowners and/or restoration teams, assess on a scale of 1 to 5 the effectiveness of the restoration following the winter of 2007.

   - A score of 1 would indicate that there was no evidence that the restoration activity was having an effect in avoiding, remedying or mitigating the adverse processes it was intended to address.
   - A score of 5 would indicate that the restoration activity was fully effective in avoiding, remedying or mitigating the adverse processes it was intended to address.

5. Assessment of winter 2007 storm event at the site

   Based on available meteorological data and maps of storm intensity assess severity of winter 2007 storm at the restoration site.

Parameter	Units	Likert Scale 1	 2	 3	 4	 5
Precipitation, Percent of 100 year, maximum observed	percent	100	110	120	130	140
Maximum wind gust, Oregon-Washington Coast, sea level	mph	80+	90+	100+	110+	120+

The Storm Intensity scale, uses five categories. A value of 1 represents the smallest or weakest significant storm, 5 the highest.

6. Overall storm resiliency/impact score

   Combining the scores for the previous five elements of the assessments we can come up with an overall storm resiliency scale

   - A score of 0 would indicate that the condition of the site prior to winter to 2007 was too poor to make an inference about the impact of the winter 2007 storm. Or that the winter 2007 storm intensity was assessed below the level to be a significant storm so no inferences can be made about the impact of the winter 2007 on the site. The site would be exposed to these conditions on a regular basis.
   - A score of 1 would indicate that there was no adverse change in the pre- and post-storm measures of condition and/or effectiveness no matter the severity of the storm.
   - A score of 2 indicates a minor adverse change in the pre- and post-storm measures of condition and/or effectiveness and a storm intensity of 1 and above.
   - A score of 3 would indicate a moderate adverse change in the pre and post storm measures of condition and/or effectiveness and a storm intensity of 1 and above.
   - A score of 4 would indicate a severe adverse change in the pre- and post-storm measures of condition and/or effectiveness and a storm event in excess of 2 and above.
   - A score of 5 would indicate a severe adverse change in the pre- and post-storm measures of condition and/or effectiveness and a storm event in excess of 2 and above.

2.4 Results and Discussion

2.4.1 OWEB-requested Sites

OWEB requested that two sites—Blodgett Tract and Gods Valley—be evaluated. As these sites were not randomly selected, they were assessed only during the pre-testing of the relevant protocol and are not included in the results presented in the remainder of section 2.4.

Blodgett Tract
The Blodgett Tract Railroad Throughfill Stabilization project occurred on OSU Research Forest property and involved a culvert improvement project.

The field crew visited the culvert site to test the draft fish passage (culvert) protocol. The culvert joined two mixed alder wetland drainages that had been separated due to the road placement, approximately 20-30 feet above the culvert. OWEB monitoring records indicate that the condition and effectiveness of the culvert to be very good or excellent prior to the December 2007 storm event.

Condition of the site was virtually indistinguishable from pre-storm conditions. There was no indication of road sag or a dip, and the culvert was completely intact. There was no obvious evidence of erosion from the road into the project, which the team thought would have been the most easily predictable storm impact and which was measured by signs of crushed vegetation and occluded culvert openings. There was no (i.e., less than 5%) accumulation of sediment accumulated in the culvert. The vegetation surrounding the culvert was fairly thick indicating that the re-vegetation on the site was successful. Aside from the presence of Himalayan blackberry, no evidence of significant invasive species encroachment was found. Trees on the grade appeared healthy and competitive. In summary, there were no observable changes due to the storm.

However, outside of the sample frame, a bridge over the nearby creek (located upstream and north by northwest of the culvert) showed significant storm damage. Damage included scour and removal of bridge footings and point bars upstream of the bridge, and a one-foot diameter log impaling the bridge. The bridge was under reconstruction at the time the field crew visited the area and another bridge that they were currently working on and putting rip rap along the sides in attempt to minimize impacts from future storms (the bridge was on a bend of the stream).

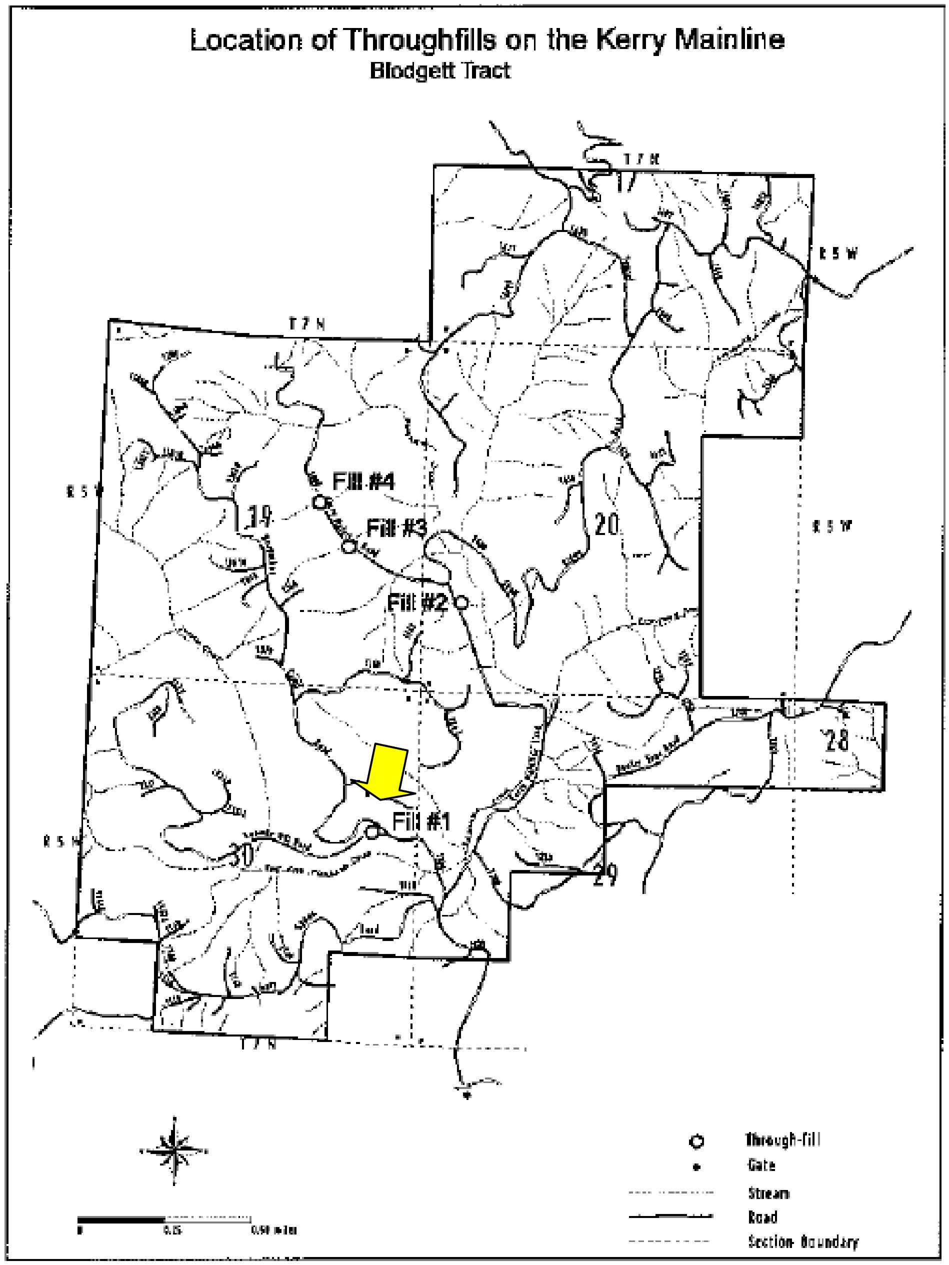


Figure 16: Blodgett Track assessment site location

Gods Valley

The Gods Valley restoration project has several restoration sites within it which have been completed during multiple phases of the project. Assessed were culvert, large wood placements and riparian plantings accessible from Gods Valley Loop Road (Figures 17 and 18). The riparian plantings are not marked on the available maps but were be located throughout the shaded areas on these figures.

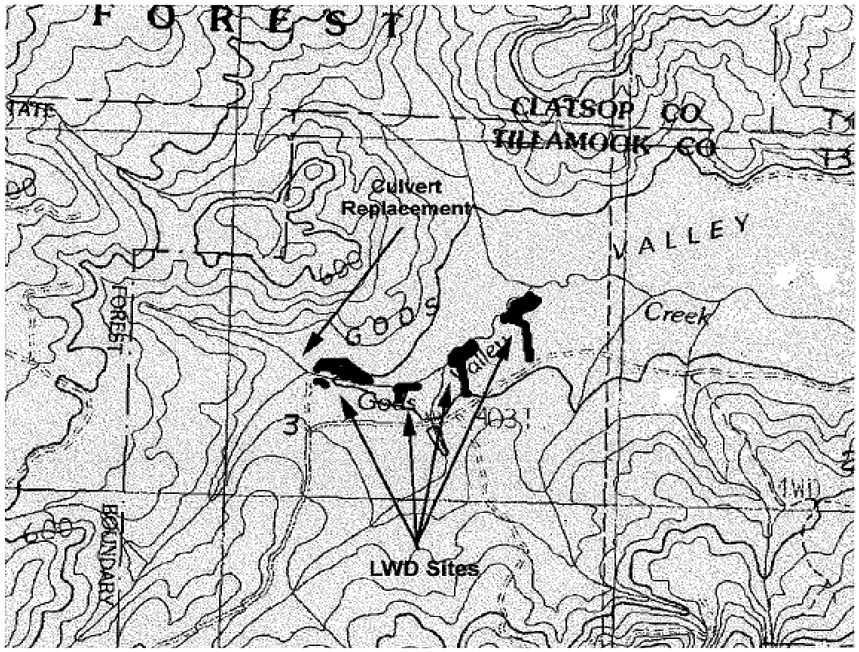


Figure 17: Gods Valley assessment site location

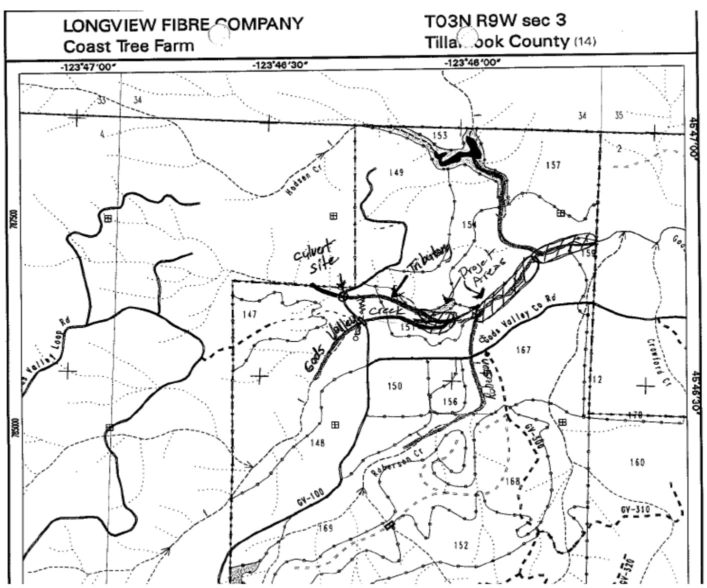


Figure 18: Gods Valley assessment site location

OWEB monitoring records indicate that the condition and effectiveness of the culvert and large wood placement to be very good or excellent prior to the December 2007 storm event. Riparian plantings showed 70-80% survival but monitoring suggested slow growth was an issue as was browsing damage from elk. Based on available information the rainfall event at Gods Valley was a rated as a 100-year event and wind speeds likely reached greater than 80 miles an hour.

The field crew noted recent wind throw (5-10%) of mature trees within both view of the restoration sites and within 10m of the stream channel. No damage from torrent or debris flows was noted.

Post Storm Treatment Condition

Culvert
The survey of culvert condition and effectiveness showed it to be in very good condition with some evidence of erosion at the upstream face of culvert though it could not be ascertained when this occurred or whether or not it was a result on one event or cumulative storms. Overall this damage was minor.

Riparian Planting
As noted above riparian plantings were not noted on project maps but could be deduced from on the ground evidence. Although no significant storm damage was detected the condition of the plantings was generally poor due to shading from mature canopy plants leading to poor vigor and browsing damage from elk leading to the loss of plants and damage to cages and tubing meant to protect the plants. Overall survival rates could not be estimated due to the absence of detailed site records.

Large Wood Placement
The assessed projects were all in excellent condition and were playing an active role in recruitment of additional debris and in the formation of complex stream habitat. There was little or no evidence of storm damage to the placed structures and the effectiveness of the debris placement was not impaired at all.

2.4.2 Field Assessment

A total of 86 randomly selected individual projects/sites from 19 OWEB Grant numbers were surveyed in September and October 2008. Riparian restoration projects made up 70% (60) of projects surveyed and large wood placement (LWP) and fish passage projects each made up 15% (13) of projects surveyed.

Of the 86 sites surveyed 89% (77 sites) were subject to precipitation amounts associated with a significant storm event. Wind levels were classified as significant at 63% of all sites. Table 5 shows that precipitation and wind intensity were classified as significantly sever (severity levels 1 and 2) for 75% and 63% of all sites, respectively. Consistent with these metrological observations, evidence of torrent and debris flow damage was present at 51% of sites. Evidence of wind damage was found at 33% of sampled sites (Table 6).

Table 5. Severity of December 2007 storm – meteorological data

	Severity*				
Precipitation Intensity	1 (=less)	2	3	4	5 (=more)
All Projects	69%	6%	3%	8%	3%
Riparian	60%	7%	5%	8%	5%
Large Wood Placement	92%	8%	0%	0%	0%
Fish Passage	85%	0%	0%	15%	0%
Wind intensity					
All Projects	50%	13%	0%	0%	0%
Riparian	55%	18%	0%	0%	0%
Large Wood Placement	46%	0%	0%	0%	0%
Fish Passage	31%	0%	0%	0%	0%

* A value of 1 represents the smallest or weakest significant storm, 5 the highest

Table 6. In field storm damage assessment

	Severity*				
Torrent/Debris Evidence	1 (=less)	2	3	4	5 (=more)
All Projects	49%	33%	14%	3%	0%
Riparian	47%	32%	17%	5%	0%
Large Wood Placement	38%	38%	15%	0%	0%
Fish Passage	69%	31%	0%	0%	0%
Wind Fall Presence					
All Projects	67%	14%	9%	2%	0%
Riparian	70%	8%	12%	0%	0%
Large Wood Placement	31%	46%	8%	15%	0%
Fish Passage	92%	8%	0%	0%	0%

* A value of 1 represents no evidence of debris flow or wind damage at the surveyed site, 5 Evidence of very severe torrent & debris flows and/or windfall.

Pre-2007 storm monitoring data was highly variable in its quantity and quality. All fish passage sites surveyed had good to excellent pre-2007 monitoring information. Large wood placement monitoring data were poor to good, but nearly all surveyed sites had some pre-2007 site data. Data for riparian projects ranged from non-existent or cursory to very good. This variability in data meant that for the majority of the surveyed sites, changes in project effectiveness pre- and post-December 2007 could not be used as a criterion for measuring storm impact. In some instances pre-December 2007 monitoring data was also insufficient to estimate change in site condition. In this case, the existing condition of the project, infield storm impact assessment data and site photos were used to determine the impact of the storm on the restoration site or project.

The overall condition of surveyed sites nine months after the December 2007 storm was very good or excellent (Table 7). Although all sites surveyed experienced a significant rain and/or wind event, 83% (71) of sites showed no adverse change in the pre- and post-storm measures of condition. Minor adverse change in the pre- and post-storm measures of condition was found at 14% (12) sites. One site showed moderate adverse impacts and two sites showed evidence of severe impact (Table 8).

Table 7. Field assessment of restoration site condition

	Condition				
	1 (=worse)	2	3	4	5 (=better)
All Projects	1%	3%	14%	50%	31%
Riparian	0%	2%	15%	57%	27%
Large Wood Placement	8%	15%	0%	23%	54%
Fish Passage	0%	0%	23%	46%	31%

A value of 1 indicates that there was no evidence of restoration activity at the site.
A score of 5 would indicate that site/project in the best physical condition possible given normally prevailing conditions.

Table 8. Change in site condition due December 2007 storm

	Change in Condition				
	1 (=better)	2	3	4	5 (=worse)
All Projects	83%	14%	1%	2%	0%
Riparian	85%	15%	0%	0%	0%
Large Wood Placement	85%	0%	0%	15%	0%
Fish Passage	69%	23%	8%	0%	0%

A score of 1 would indicate that there was no adverse change in the pre- and post-storm measures of condition. A score of 5 indicates a severe adverse change in the pre- and post-storm measures of condition

The patterns and change in condition are generally consistent across all project types. Large wood placement projects exhibit more severe changes in condition attributed to the storm than the other restoration activities. At one site no evidence of placement could be found (see Section 2.3, protocol step1). It is not clear whether or not the placed large wood was washed out or not placed as indicated on the site map included in the project file. Some fish passage projects were assessed as having only moderate condition because of culvert embeddedness greater than 20% in two projects. Pre-2007 monitoring data suggests this condition has existed for a number of years for the culverts in question.

The overall minor impact of the December 2007 storm on the surveyed restoration/sites projects can be attributed to at least three factors. First, the method used evaluated the

impact of the 2007 storm relative to baseline site conditions. This meant that although the site/project may have been impacted by the storm, this impact was often determined to have no major detrimental effect at that location compared to normally prevailing conditions and processes. At some riparian sites, for example, flood debris was found several meters above bankfull level and large willows had been undermined and fallen into the streambed. However, the riparian plantings themselves were unimpaired.
The riparian plantings selected for the assessment were fairly young and trees were small. The potential effects of these large storm events on riparian plantings will change as the trees grow and mature. The taller the trees and the more leaf area they carry during a storm event the more susceptible they will be to wind damage. The root systems can affect their vulnerability over time as well. Depending on the site and the tree species, if the trees are shallowly rooted then they can become more susceptible to windthrow in soggy, saturated soils. The 2007 storm had dramatic effects on riparian forests along state highways but those experiencing high windthrow and stem breakage rates were mature trees that caught the brunt of the winds.

Some large wood placement projects exhibited major changes with significant additions or changes in placements. In one case a channel with large wood placement was no longer active. These changes were not considered to be detrimental since large wood pieces and key pieces were still present and available for recruitment should, for example, the channel shift again. In nearly all instances, projects were either functioning effectively in 2007 or there was no evidence of change in effectiveness (for sites where this information was available).

Second, as Chapter One shows Oregon's North Coast is subject to frequent moderate to severe wind and/or precipitation events. This means that projects/sites are likely impacted by significant torrent and debris flows and high winds on a periodic basis. Moreover, though the December 2007 storm was an extreme event, its precipitation and wind intensity impacts were highly localized meaning that in many locations it was not distinguishable from other severe winter storms. In other words, if a site/project had survived other severe storm events intact it was likely to survive the December 2007 storm intact. Sites, especially large wood placement projects, unable to withstand North Coast conditions would have been impacted previously and either not restored or restored to a higher standard. In many instances, the field crew could not determine the age of storm damage. It is highly likely that some of the impacts noted resulted from the severe winter storm of 2006, or other winter storm events in the last two to three years.

Third, landowners, watershed council employees and volunteers and state agency staff have considerable experience in designing and executing restoration projects that are robust and resilient to North Coast storm conditions. They are also quick to maintain projects that show wear and tear after a major storm event. This means that the potential for damage from severe storms maybe mitigated through sound design, project execution, and ongoing maintenance. It also means that some damage from the 2007 storm may have already been repaired, particularly riparian plantings, therefore improving the site condition evaluation score. Where possible this was controlled for by talking to the landowner, Watershed Council representative or state agency staff.

Notwithstanding the limitations of this assessment, it appears that the vast majority of restoration projects on the North Coast came through the December 2007 storm intact. In many instances the field crews noted damage from other sources that was more or equally significant to any storm damage present. This was particularly so for riparian projects. For example, about 6% of plants surveyed were recorded as having a damage rating of moderate to severe (approximately188 out of 2500 trees surveyed). For the damaged plants, the cause of harm was as follows (in descending order): Browse - primarily beaver (41%); storm (19%); suppression from cage or close planting (15%); unknown - protection present but plant missing (12%); disease/insects (6%); mechanical (4%); and smothering by invasive plants (3%).

2.4.3 Other December 2007 storm impact assessments

Assessment of storm-related damage to aquatic, riparian, and terrestrial habitats is very limited and what is known is associated with assessing areas with more significant wind damage (Forest and Debris Recovery Team, 2008). Initial reports indicate significant blowdown in designated marbled murrelet management areas in the God's Valley and Coal Creek areas. Anecdotal reports indicate that severe damage is believed to have occurred to at least three Bald Eagle nests and two Great Blue Heron rookeries, and one marbled murrelet management area (Forest and Debris Recovery Team, 2008).

At the request of Governor Kulongoski and Clatsop, Columbia, and Tillamook counties, the Oregon Department of Forestry assembled a Forest and Debris Recovery Incident Management Team to assist the counties in assessing storm-related damages to forest lands and natural resources. In particular the assessment aimed at identifying the most significant damage and identifying immediate concerns.

The assessment revealed that the majority of the heavy wind damage was limited to an area of northwest Oregon extending from Tillamook to Clatskanie, and Clatskanie to Astoria. Clatsop and Tillamook counties sustained extensive wind damage, a combined gross volume over 390 million board feet across all ownerships. Columbia County's damage was nominal in comparison.

A number of issues and concerns were identified and loosely categorized as public safety, recovery from damage, natural resources, and economics. Natural resource issues and concerns include, but were not limited to, inadequate road drainage and stream crossing structures on legacy forest roads and relic railroad grades. The Forest and Debris Recovery Team noted that further assessment to determine the magnitude of damage to aquatic, riparian and terrestrial habitat (particularly for threatened and endangered species) is needed.

The Weyerhaeuser North Coast timberlands were substantially hit by the December 2007 causing a significant environmental and financial cost. Following the storm, Weyerhaeuser completed a comprehensive assessment of the damages (see Reiter, 2008) and rapidly began timber salvage operations. The vast majority of the damage to Weyerhaeuser lands in the Oregon North Coast was caused by wind damage. Their lands in Washington had a combination of wind and rain damage.

Based on casual observation of Weyerhaeuser stream restoration projects, their fish passage and the new fish passable culverts & bridges, legacy roads, and large wood placement projects have seemed to have held up well since the storm event (Mark

Morgans, Weyerhaeuser, personal communication, 2008). Over the last several years most of Weyerhaeuser's restoration projects have focused on large wood placement. As designed, they moved around a little with the high water flow, but settled back into place.

3.0 Planning for Climate Change

Managing the consequences of climate change requires both understanding how it affects resource management, and integrating near-term operational and long-term strategic planning management approaches (Climate Integration Group [CIG], 2008c). Due to the uncertainty over how to plan for climate change, climate change considerations have not been on public and private institutions' past agendas. Building the capacity to efficiently manage climate impacts before and as they occur is the primary objective of planning for climate variability and change. This, in turn, could require adjusting existing policies, practices, and procedures to provide the flexibility necessary to adapt to short- and long-term changes in climate, or could entail constructing new infrastructure designed to mitigate projected impacts (CIG, 2008c). In planning for climate change a key question is whether the policies and decisions being made are robust given what is known about, and the uncertainty around, climate change in the Pacific Northwest.

Through the filter of climate change scenarios produced by the CIG, this section briefly summarizes the scenarios and examines OWEB's restoration practices and guidelines in the context of storm intensity and frequency.

3.1 Climate Change Scenarios and Impacts

By examining 20 global climate simulation models, the CIG recently produced updated scenarios of future climate for the PNW. All scenarios evaluated project a warmer climate in the Pacific Northwest in the 21st century. Historical record and model predictions regarding climate change's impacts on precipitation, however, are much less consistent due to challenges associated with modeling precipitation at the global and regional scale (CIG, 2008a). In particular:

- the projected change in average annual precipitation for all models combined is near zero;
- existing seasonal patterns of precipitation could be enhanced; and
- average annual precipitation will likely stay within the range of 20th century variability.

The CIG points out that (1) natural year-to-year and decade-to-decade fluctuations in precipitation are likely to be more noticeable than longer term trends associated with climate change; and (2) though average annual precipitation will likely stay within the range of 20th century variability (Figure 16), this does not convey how the intensity of precipitation intensity might change.

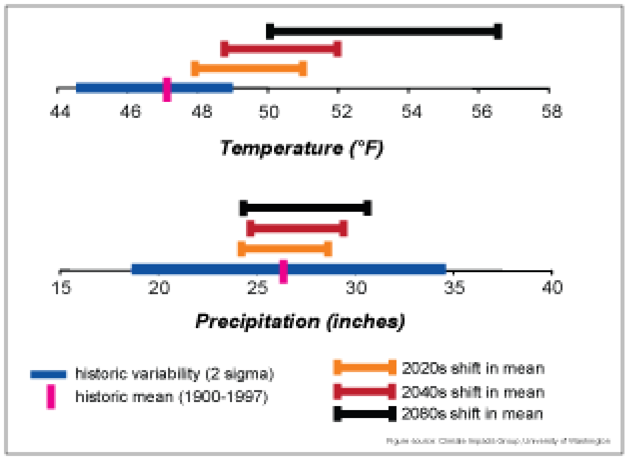


Figure 19. Comparison of observed year-to-year variability and projected shifts in average temperature and precipitation from 20 climate models.

The blue bars represent the year-to-year variability in PNW temperature and precipitation during the 20th century. The pink bar represents the historic average for 20th century PNW temperature and precipitation. The orange, maroon, and black lines indicate the projected shift in the historic average for the 2020s, 2040s, and 2080s, respectively. Average temperature could exceed the year-to-year variability observed during the 20th century as early as the 2020s, while future projected precipitation falls within the range of past variability.
Source: Climate Impacts Group, University of Washington (CIG, 2008a)

Compared to previous scenarios for the Pacific Northwest, the 2008 scenarios indicate somewhat higher increases in temperature in the 21st century than the 2005 scenarios. The 2008 scenarios show only nominal change in average annual precipitation compared to the 2005 ones; however they do indicate that the "range of possible precipitation changes is greater throughout the time periods analyzed" (CIG, 2008a).

Regarding the impact of climate change in affecting extreme events in the Pacific Northwest, the Climate Impact Group states:

> *Because many key aspects of climate (e.g., windstorms, heat waves) either are not well simulated by models or cannot be studied using monthly mean values which are the standard model output, the CIG cannot speculate how they may change in the future. However, droughts may become more common due to the effects of warmer temperatures and reduced winter snowpack on late summer streamflows. Changes in the intensity of precipitation are uncertain, although a preliminary analysis [(Salathé, 2006)* – reference added*] suggests that average monthly (Nov-Jan) winter precipitation could become more intense by the end of the 21st century. Additionally, ongoing work at the CIG suggests that extreme daily precipitation could increase by the end of the century* (CIG, 2008a).

Taylor has shown some evidence for increasing storm intensity in the Pacific Northwest. Work by Salathé (2006) suggests that this trend might continue during the 21st century due to global warming impacts on North Pacific storm tracks. Though we can not conclude with certainty that this shift in the Pacific Northwest is being seen, slight changes in temperature and precipitation have had noticeable effects on snowpack, river flows, salmon abundance, forest productivity, and the quality of nearshore and coastal habitat, among other things (CIG, 2008).

The CIG produced a diagram (Figure 17) that ranks the potential impacts of climate change (for the 2040s). The impacts are categorized based on their confidence level (high, medium, or low) in the projected impacts and their estimation of their relative importance for the Pacific Northwest as a whole. The size of each arrow (small, medium, or large) in the diagram indicates the relative magnitude of the ecological and/or socioeconomic impacts that climate change would have on the region. The diagram also illustrates whether the impacts would be positive or negative. For example, water

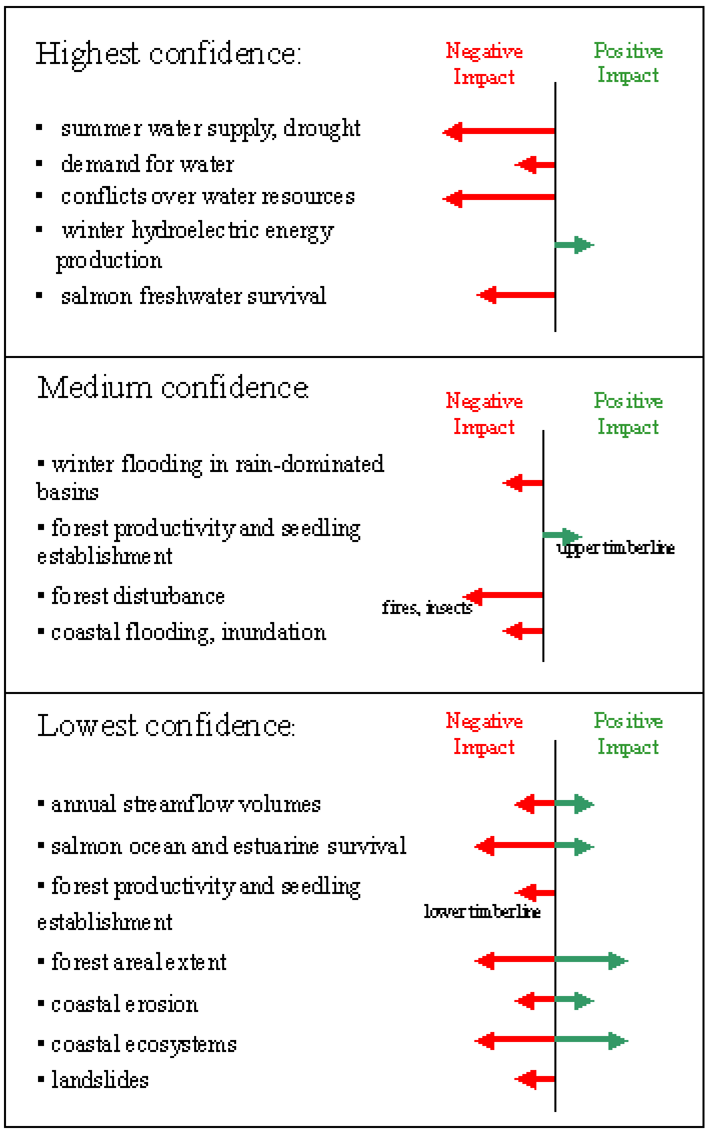


Figure 20. Impacts of climate change on the Pacific Northwest
Source: Climate Impacts Group, University of Washington (CIG, 2008b)

supplies are expected to decrease during the summer when water demand is generally higher. This would be seen as a negative impact of climate change. The ranking accounts for the magnitude of the climate impact itself (either quantified or estimated) and the estimated magnitude of its regional consequence.

Few studies have attempted to examine the impact of climate change on fish habitat restoration activities in the Pacific Northwest. In 2007, Battin et al. investigated the impacts of climate change on the effectiveness of proposed habitat restoration efforts that were designed to recover depleted Chinook salmon (*Oncorhynchus tshawytscha*) populations in the Snohomish River basin. By using a series of linked models of climate, land cover, hydrology, and salmon population dynamics, the results of their Chinook salmon population dynamics model indicate that despite the uncertainty in climate change predictions climate change negatively impacts freshwater salmon habitat and productivity. These impacts were noted as high water temperatures, lower spawning flows, and increased magnitude of winter peak flows. In the Snohomish River basin the negative effects are most prominent in high-elevation streams—streams the authors described as being relatively pristine and where little restoration is possible.

The authors made several points that relate to watersheds in the region that are hydrologically similar to the Snohomish River basin:

- Climate change-related habitat deterioration makes salmon recovery targets much more difficult to attain;
- Climate changes effects on Chinook productivity are likely to be worse in high-elevation areas due to the likelihood of greater “snow-rain transition” during spawning and incubation time periods;
- Projected temperature effects were more detrimental to salmon in the lower watershed;
- Habitat restoration will continue to play an important role through its potential to offset, though not completely mitigate, climate change’s expected impacts; and
- Flexible and adaptive management approaches may have the potential to meet climate change challenges.

Their study, however, did not address climate change-related storm intensity, magnitude, or frequency.

3.2 OWEB Restoration Practices and Guidelines: Planning for Climate Change

As part of the Oregon Watershed Enhancement Board’s support of the Oregon Plan for Salmon and Watersheds, OWEB promotes and funds voluntary actions that aim to restore aquatic habitat, improve water quality, and/or restore biodiversity of Oregon's watersheds. Though OWEB does not appear to have explicit guidelines for restoration activities, as a proxy, its document *Instructions for Completing Restoration Grant Applications* (2008) allows for the use of wide range of approaches to restore salmon habitat and watersheds. In two respects—project descriptions and project design—these proxy guidelines appear to be robust enough to take into account potential increases in storm magnitude, frequency and/or intensity associated with climate change, if one were to assume increases were a trend. As mentioned in sections 1.7 and 3.1 of this report, climate related changes in storm intensity, magnitude, or frequency are difficult to predict.

3.2.1 Project Descriptions

In Section R3 (Project Description), OWEB asks that applicants "identify the specific activities to be conducted to implement that element" of the restoration project and specifies that "this description should provide sufficient information for a reviewer to get a clear understanding of what the project is, how it will be implemented, what the essential elements are and what criteria will be used for implementation" (p. 5). In the examples provided, OWEB mentions two restoration guideline documents: ODFW wood placement guidelines (Example #1) and ODFW and NOAA's culvert sizing and fish passage guidelines (Example #2). OWEB and its partners under the Oregon Plan for Salmon and Watersheds have developed several technical guidance documents for restoration projects (see http://www.oregon.gov/OWEB/publications.shtml#Technical_Guidance_and_Related_Publications); however, it is only in the grant agreements for each successful grant application for restoration work, that it is mentioned that OWEB requires compliance with guidelines such as the ODFW and NOAA guideline documents.

3.2.2 Project Design

Section R6 (Project Design) states that the applicant must:

a. Identify who will do the project design and include their qualifications and experience; and
b. Describe how the project planning and design take into consideration extreme events (e.g., floods, fire, drought, etc.) known to be of concern in the area that have the potential to impact your project (p. 7).

The instructions document provides the following example:

> *The project requires experience and skills in water resource engineering, fluvial geomorphology, fisheries biology and riparian vegetation establishment. The designer(s) will be expected to develop a project that will withstand a 500-year flood and catastrophic fire and be maintenance free while meeting state and federal fish passage standards.*
>
> *The McCall Creek Watershed Council will solicit proposals from qualified consultants. The council has put together a designer selection committee that includes two council members, the NRCS engineer, a tribal fish biologist and a state water resource manager.*

Through the fact that applicants must consider extreme events in their project design, in essence, OWEB is requesting that the applicant accommodates the possibility for extreme events associated with climate change. However, in a review of non-OWEB guidelines for restoration project types included in this study (see list in Appendix G), specific information about how to plan for different magnitudes of storm events is not included in the reviewed large wood placement and riparian plantings guidelines. The *Oregon Road/Stream Crossing Restoration Guide* (1999) designs culverts for a 50-year peak flood flow.

3.3 Discussion and Conclusions

As what constitutes 100-year event has changed with increased storm intensity, design parameters should be reviewed periodically to ensure they are consistent with anticipated increases in magnitude of peak discharge events. For instance, the structural integrity of large wood placement is basically determined by bankfull discharge, as described in ODF/ODFW guidelines (1995). In reference to climate change and storm intensity, existing protocols appear to be sufficient. Each stream's morphology will respond to climate change variability in different ways depending on stream slope and local geology. One caveat to this though is the effect of increasing intensity on stream morphology. Overtime streams will change their depth and width in response to the frequency and magnitude of events. For example, a stream might change from having a bankfull width of 35 feet to having one of 45 feet. In such a case, the ODF/ODFW guidelines would not apply, because a "stream with less than a 40-foot bankfull width and little to moderate stream slope is eligible for the kind of in-channel large woody debris placement work described in this publication" (ODF/ODFW, 1995: 4).

Planning for climate change and extreme events may require providing OWEB-specific parameters to restoration practitioners. OWEB states that restoration grant applicants "take into consideration extreme events". However, OWEB does not specify or define "extreme event" (e.g. 500-year flood event). A definition could have implications for specific design standards or techniques. All of the reviewed guidelines (Appendix G) give preference to activities that mimic or help restore natural processes at the site scale. For large wood placement, however, while ODF and ODFW discourage cabling, they acknowledge that it can be necessary to prevent washout and down stream damage.

> *Natural or artificial anchoring is needed for the placed logs if wood movement cannot be tolerated…* ***It is desirable for the stream to redistribute the wood to some extent, as long as damage is avoided.*** *However, movement of large wood must be limited so it is not carried downstream to damage road culverts, bridges, or other streamside improvements. Cabling may be used if the risk is great of downstream damage from a large debris washout* (p. 12)

If building the capacity to efficiently manage climate impacts before they occur is the primary objective of planning for climate variability and change, OWEB would need to (1) determine if a consistent minimum design threshold is needed; and (2) decide what that threshold would be (e.g., 100-year event, 500-year event, etc.).

4.0 Conclusions

The purpose of this time-limited project was to provide the scientific context that will assist OWEB in determining if its restoration practices are robust enough to take into account potential increases in storm magnitude, frequency and/or intensity associated with climate change. Emphasis can be placed on the following conclusions.

First, OWEB solely does not have a single guidance document for all restoration activities. However, in conjunction with many partner agencies involved with the Oregon Plan for Salmon and Watersheds, OWEB has supported development of and compliance with restoration guidelines. Though this allows for flexibility in project design, the variation in the application of those guidelines seems to lead to inconsistencies in the quality in the condition and the effectiveness of the restoration projects over time. The quality and quantity of information reviewed for this study varied enormously. In the early years of OWEB's monitoring program, the quality of post-project monitoring information was less consistent; however, it appears that with OWEB's recent development of monitoring guidelines there has been an improvement in the quality of monitoring information. At best, this meant there was no consistent basis to compare similar restoration projects and, at worst, that it was very difficult to assess patterns in project condition and effectiveness temporally and spatially.

Secondly, for the study the project team designed, from scratch, a protocol that would enable a rapid assessment to be conducted. We recommend that OWEB consider incorporating this or similar rapid assessment protocols into its monitoring guidelines to enable consistent monitoring over time and space. The application and use of the methodology by our field crew show that this can be done qualitatively and by those with minimal training and experience in monitoring and field work.

Third, although very few of the randomly selected project sites were located in areas of extreme storm intensity, it appears that OWEB projects/sites are resilient. The generally minor impact of the December 2007 storm on the surveyed restoration/sites projects can be attributed to at least three factors. First, the impact of the 2007 storm was evaluated in relation to baseline site conditions. Second, as section one showed, Oregon's North Coast encounters frequent moderate to severe wind and/or precipitation events, meaning that projects/sites are likely impacted by significant events on a periodic basis. Third, landowners, watershed council employees and volunteers, and agency staff have considerable experience designing and implementing restoration projects that are resilient to North Coast storm conditions, are quick to maintain projects that show wear and tear after a major storm event.

Though we can not predict the impact of climate change on storm intensity and frequency, the CIG and other researchers have shown that climate change will impact the Pacific Northwest. Nonetheless, uncertainty about climate change and the changes in weather patterns associated with it makes it difficult to predict how storm events will change through space and time. This uncertainty challenges our ability to predict the conditions to which restoration projects will be subjected and how restoration practices and guidelines might need to be revised. As finer resolution meteorological models are created that predict where and how storm events might be expected to change, this information should be considered during the planning, implementation and maintenance of restoration projects and the future refinement of restoration guidelines.

This rapid assessment has shown that OWEB projects/sites were able to handle the December 2007 storm and that with this effort, along with other OWEB efforts, OWEB is positioning itself to better meet restoration objectives that might be compromised as a result of climate change.

References

Barros, A.P. and D. P. Lettenmaier, 1994: Dynamic modeling of orographically-induced precipitation. *Reviews of Geophysics*, 32: 265-284. [PDF file]

Battin, James, Matthew W. Wiley, Mary H. Ruckelshaus, Richard N. Palmer, Elizabeth Korb, Krista K. Bartz, and Hiroo Imaki. 2007. *Projected Impacts of Climate Change on Salmon Habitat Restoration*. Proceedings of the National Academy of Sciences. Published on-line April 5, 2007; doi:10.1073/pnas.0701685401.

Bennett, and Glenn Ahrens. *A Guide to Riparian Tree Planting in Southwest Oregon.* 2007. Oregon State University Extension Service. E8893-E. September.

Climate Impacts Group. 2008a. *Climate Change Scenarios*. Last updated: 1 August 2008.

Climate Impacts Group. 2008b. *Climate Impacts in Brief* Last updated: unknown.

Climate Impacts Group. 2008c. *Planning for Climate Variability and Change*. Last updated: unknown.

Dettinger, M., 2004. Fifty-Two Years of "Pineapple-Express" Storms Across the West Coast of North America. PIER Project Report for California Energy Commission. Scripps Institution of Oceanography.

Forest and Debris Recovery Team. 2008. *Forest and Debris Recovery Final Report Winter Storm, December 2007 – January 2008*. Clatsop, Columbia, and Tillamook Counties, and the Oregon Department of Forestry. January 11.

Massingill, Chris. 2003. *Coastal Oregon Riparian Silviculture Guide*. Coos Watershed Association, Charleston: OR. December.

Morgans, Mark. 2008. Weyerhaeuser. Person communications. August 8.

Mote, Philip, Eric Salathé, Valérie Dulière, and Emily Jump. 2008. *Scenarios of Future Climate for the Pacific Northwest*. Climate Impacts Group, University of Washington. Seattle: WA. March.

NMFS. 2008. *Endangered Species Act – Section 7 Programmatic Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation: Fish Habitat Restoration Activities in Oregon and Washington, CY2007-CY2012.* National Marine Fisheries Service Northwest Region, Seattle: WA. NMFS Nos.: FS: 2008/03505, BLM: 2008/03506, BIA: 2008/03507. June.

Neiman, P.J., F. M. Ralph, G. A. Wick, Y-H. Kuo, T-K. Wee, Z. Ma, G. H. Taylor and M.D. Dettinger, 2008. Diagnosis of an Intense Atmospheric River Impacting the Pacific

Northwest: Storm Summary and Offshore Vertical Structure Observed with COSMIC Satellite Retrievals. *Monthly Weather Review*, 136: 4398-4420.

Nuss, W. A., and D. K. Miller, 2001: Mesoscale predictability under various synoptic regimes, *Nonlinear Processes in Geophysics*, 8: 429-438.

Oregon Department of Forestry and the Oregon Department of Fish and Wildlife. 1995. *A Guide to Placing Large Wood in Streams*. Oregon Department of Forestry, Salem: OR. May.

Oregon Plan for Salmon and Watersheds. 1999. *Oregon Aquatic Habitat: Restoration and Enhancement Guide*. Oregon Plan for Salmon and Watersheds, Salem: OR. May.

Oregon Watershed Enhancement Board. 2007. *Guide to Photo Point Monitoring*. Oregon Watershed Enhancement Board, Salem: OR. July.

Oregon Watershed Enhancement Board. 2008. *Instructions for Completing Restoration Grant Applications*. Oregon Watershed Enhancement Board, Salem: OR. August.

Pandey, G.R., D.R. Cayan and K. P. Georgakakos, 1999: Precipitation structure in the Sierra Nevada of California during winter. *J. Geophys. Res.*, 104, D10, 12019-12030.

Ralph, F.M., P.J. Nieman, and G.A. Wick, 2004. Satellite and CALJET aircraft observations of atmospheric rivers over the eastern North Pacific Ocean during the winter of 1997/98. *Monthly Weather Review*, 132: 19721-1745.

Reiter, Maryanne. 2008. *December 1-4, 2007 Storm Event Summary*. Weyerhaeuser Western. February 8.

Rhea, J. O., 1978: Orographic precipitation model for hydrometeorological use. Colorado St. Univ., Dept. of Atmospheric Science, Atmospheric Science Paper No. 287, 221p.

Robison, E. George, Albert Mirati, and Marganne Allen. 1999. *Oregon Road/Stream Crossing Restoration Guide*. Spring.

Salathé, E.P. 2006. Influences of a shift in North Pacific storm tracks on western North American precipitation under global warming. *Geophysical Research Letters* 33, L19820, doi:10.1029/2006GL026882.

Shaw, Susan, Jason Hinkle, and John Seward. *2008 Geotechnical Assessment of the December 2007 Debris Flow Complex in Eilertsen Creek, Woodson, Oregon*. Oregon Department of Forestry. Salem:OR. April.

Stockard, W. and R. R. Harris. 2005. *Monitoring the Effectiveness of Culvert Fish Passage Restoration*. Center for Forestry, University of California, Berkeley. 25 pp.

Taylor, George H., 1999. *The Oregon Weather Book*. Oregon State University Press, Corvallis, Oregon.

Appendices

(See files)

Institute
for
Natural
Resources