Wadeable Stream Conditions in Oregon

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EXECUTIVE SUMMARY

This report describes the ecological conditions of wadeable, perennial streams throughout Oregon, and relates indicators of chemical and physical conditions to the conditions of the biological communities. The results of this 5-year study are part of the Western States Environmental Monitoring and Assessment Program (W-EMAP), which was designed to summarize stream conditions for 12 western states and across the entire western United States. W-EMAP utilized a random sampling design to ensure that the results were unbiased and represented conditions across Oregon. Results are based on surveys of 118 randomly selected streams throughout Oregon during the summer months of 2000-2004. Streams were sampled for chemical, physical habitat, and multiple biological communities--fish and amphibians, macroinvertebrates, and algae—although only the results of macroinvertebrates are presented here.

We feel it is important to be clear about what the results presented here actually represent. For a given parameter, the extent of stream kilometers in each of the three condition classes adds up to 100%--but these results are only representative of the percentage of the resource that was actually surveyed. A certain percentage of the targeted stream resource (wadeable and perennial streams only) was not assessed, and this percentage varies by each parameter. We are thus unable to make an assessment of conditions of all wadeable, perennial stream kilometers in Oregon. Additionally, due to the inability to assess conditions on a large percentage of stream miles on private lands, the results presented in this report largely reflect the conditions of public lands.

Oregon results indicate that 51% of assessed wadeable, perennial stream kilometers are ecologically similar to least disturbed, or reference conditions, 23% of assessed stream kilometers are in moderately disturbed ecological condition, and 26% of assessed kilometers are in most disturbed ecological condition. These results are representative of 59% of the total wadeable, perennial stream kilometers—we cannot determine the ecological condition of 41% of the targeted resource. The chemical and physical habitat parameters found to most commonly fail to meet water quality standards or reference benchmarks are human disturbances in riparian zones, alteration of slow water and fast water habitats, and increased fine sediments. The parameters found to pose the greatest risk to ecological condition are total suspended solids, loss of pool habitat, relative bed stability, and increased phosphorus levels.
ACKNOWLEDGEMENTS

W-EMAP was directed by USEPA staff from the Western Ecology Division—Office of Research and Development. They were instrumental in developing the protocols, training and resources, sample processing for chemistry and macroinvertebrate samples, data management, and guidance in data analysis. (Due to the risk of inadvertently leaving an individual out, I express gratitude to the entire staff.) Gretchen Hayslip, Lilian Herger, and Peter Leinenbach from USEPA Region 10 (Seattle, Washington) ensured the needs of the state agencies were represented during the planning stages of W-EMAP, performed audits of ODEQ field crews, performed field sampling with ODEQ field crews, and GIS support for and reviews of this report.

A large number of individuals from the Oregon Department of Environmental Quality (Portland, Oregon) were critical to the successful completion of W-EMAP in Oregon. Adam Coutu provided budget support. Rick Hafele and Mike Mulvey provided project guidance, planning, and reviews of this report. Finally, I would like to thank the following field crew members that worked very hard to ensure the data collected for W-EMAP was of the highest quality. The success of this project was a direct result of their efforts.

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INTRODUCTION

The Oregon Department of Environmental Quality (ODEQ) was one of 12 western states that partnered with the United States Environmental Protection Agency (USEPA) to measure the chemical, physical, and ecological conditions of all perennial and wadeable streams in the western United States (Figure 1). Participating agencies included: USEPA, ODEQ, Washington Department of Ecology, Idaho Department of Environmental Quality, California Department of Fish & Game, Nevada Division of Environmental Protection, Utah Division of Water Quality, Montana Department of Environmental Quality, Wyoming Department of Environmental Quality, North Dakota Department of Health, South Dakota Department of Game Fish and Parks, Colorado Division of Wildlife, Arizona Game and Fish Department, Utah State University, Michigan State University, Portland State University. This cooperative research effort was a part of the Environmental Monitoring and Assessment Program (EMAP), developed by USEPA scientists to provide an unbiased assessment of the condition of stream resources. The results presented in this report are based on stream surveys conducted throughout Oregon during the summer months of 2000-2004.

Under Section 305(b) of the Clean Water Act (CWA) each state is responsible for reporting to the USEPA on the conditions of water quality, aquatic life and recreational uses of state waters. Traditionally, states relied on chemical and physical measures of water quality collected at non-randomly selected sites to summarize stream conditions for CWA reporting. The use of non-random samples makes meaningful statewide assessments difficult, as there is an unquantifiable bias in the data used for the reports.

The EMAP program utilizes a probability site selection process that enables the conditions of state waters to be interpreted from a randomized subsample of locations. Also, the EMAP program incorporates the direct assessment of ecological stream conditions in addition to the traditional chemical and physical indicators water quality indicators. Fish, macroinvertebrates, and algae communities are useful for understanding watershed health because they integrate the effects of the chemical and physical properties of the stream over time. A measure of biological conditions provides a more complete picture of overall stream conditions than a water sample alone.

The goal of this report is to present to citizens, resource managers, and policy makers an unbiased account of the current status of the ecological conditions of wadeable streams throughout Oregon. This information should be useful in setting future priorities for stream resource management in the state.
Figure 1. W-EMAP study area covering 12 western states. Random sampling locations are shown as black dots. Special study areas, where random sites were intensified, are highlighted. (Reprinted from Stoddard et al. 2005a.)
METHODS

Sampling Design

W-EMAP used a probabilistic sampling design to select survey stream segments throughout Oregon. This means a subsample of stream sites are selected at random to represent the population of streams in a region (in this case, all perennial and wadeable stream kilometers in Oregon). With probabilistic sampling designs, each sampling site has a known probability of being selected, and thus represents a portion of the total stream population in Oregon. A detailed description of W-EMAP’s study design can be found in Stoddard et al. (2005b).

The random sites surveyed in Oregon as part of W-EMAP are shown in Figure 2. Several classes of streams were excluded from the target population. Intermittent streams and tidally influenced streams were not surveyed. While non-wadeable streams (large streams and rivers) were originally surveyed as part of W-EMAP, the results presented in this report are only representative of the wadeable perennial streams. The sites in Oregon are densified in the “Blue Mountains” ecoregion (red dots, Figure 2) because ODEQ conducted a focused study area in this region (the John Day and Lower Deschutes River basins). These sites were included in the statewide assessment, but were down weighted to adjust for higher density sampling. An assessment of conditions in this intensified study area will be completed in the near future.

Extent of Resource Assessed

Random sample locations were selected from EPA’s River Reach file (RF3). RF3 is comprised of digitized USGS topographic maps (1:100, 000 scale). The total length of stream kilometers in the RF3 stream network in Oregon was 86,067 km, which includes all streams and rivers of the state. The targeted extent of stream resources for this assessment, which includes only perennial and wadeable streams, was 55,091 kilometers (Figure 3). This represents 64% of the total stream and river resources in Oregon.

Due to the inability to access a large percentage of stream miles on private lands, the results presented in this report largely reflect the conditions of public lands. Our assessment of the conditions of perennial wadeable streams throughout Oregon represents 64% of targeted kilometers. We were unable to assess approximately 36% of the perennial wadeable streams (19,783 km) in Oregon—primarily due to access denials from private land owners (33%) and a smaller portion were not sampled due to unsafe conditions or inaccessibility (3%).

Some indicators had higher percentages of stream kilometers not assessed due to an inability to collect samples at all sites or compromised samples. For example, with temperature only 22% of the total wadeable, perennial stream miles were surveyed. However, we list 54% of stream kilometers as failing to meet the water quality standard. This should be interpreted as:

- 22% of all wadeable, perennial streams were surveyed for temperature.
- We found that 54% of the surveyed stream kilometers failed to meet the water quality standard.

Alternatively, we could have assumed that conditions at the locations not sampled were similar to conditions observed at locations we did sample. Using this approach, the 64% of perennial wadeable stream kilometers we did survey would be used to represent conditions for the entire wadeable stream resource. However, this approach may introduce unknown biases. It would only be reasonable to take this approach if we could show that land uses and management protocols
were similar between public lands (the majority of stream sites sampled) and private lands (the majority of locations we were not able to sample).

**Indicators of Ecological Condition**

W-EMAP collected information on three biological assemblages: aquatic vertebrates (fish & amphibians), macroinvertebrates (insects, clams, snails, etc.), and algae (diatoms). Due to Endangered Species Act restrictions in Oregon, we were unable to adequately sample aquatic vertebrates throughout Oregon. Also, data for algal assemblages were unavailable for analysis in time for inclusion in this report. The exclusion of aquatic vertebrate and algal assemblages could mean that we have not identified all the potential risks to ecological integrity throughout Oregon. However, macroinvertebrate assemblages are useful indicators of ecological health.

Macroinvertebrates occupy a central role in food chains and the ecosystem. They are easy to collect, are relatively cheap to process and analyze, and respond to a variety of stressors. Macroinvertebrates are the most commonly used aquatic assemblage for assessing stream biological integrity. For a thorough examination of the role of macroinvertebrates in assessing biological integrity, see Rosenberg and Resh (1993) and Wright et. al (2000).

Macroinvertebrate samples were collected from erosional (riffle) habitats. Samples were collected using a D-frame kicknet, with a mesh size of 500 μm. Eight randomly collected 1-ft² kicks, one from each of eight different riffle habitats, were composited into a single sample. Samples were randomly sub-sampled to 500 individuals in the laboratory at 10x magnification. For full details of macroinvertebrate sampling procedures see ODEQ (2004a).

We used a “Taxa Loss” model to assess macroinvertebrate integrity. This model uses multivariate statistics to predict the expected macroinvertebrates that would be found at a random site if the site were in reference conditions (least impaired). The number of expected taxa (E) was compared to the observed taxa (O) at reference sites with similar environmental characteristics (elevation, stream size, gradient, etc.). The ratio of observed to expected taxa (O/E) is thus a measure of the loss of taxa commonly observed at reference sites. An O/E less than 1.0 means that fewer taxa were observed than were expected.

For consistency with other Region 10 states, we assessed random samples using the same predictive model as was used in the Western States EMAP report (Stoddard et al. 2005a). This model was built with reference samples from all 12 participating states. DEQ’s internally developed predictive models (Hubler 2007) were not used in this assessment.
Figure 2. EMAP-West sampling locations for Pacific Northwest states. Only random sites (red dots) in Oregon were used to determine extent of condition, while reference sites were aggregated by Level III ecoregion across state boundaries. Aggregated ecoregions share the same color coding.
Figure 3. The extent of stream resources in Oregon as determined using EPA’s RF3 digitized 1:100,000 topographic maps.

**Indicators of Stress (Water Quality & Physical Habitat)**

The water quality and physical habitat features of a stream naturally occur over a range of conditions throughout Oregon’s streams. Some variables occur within a narrow range, while others exhibit great variability across the landscape. Human activities throughout a watershed may alter the conditions within a stream beyond what is naturally observed for these variables. Because the biological communities have adapted to these natural conditions, alteration of the chemical and physical habitat characteristics may depress the ecological condition of streams.

**Water Quality:**

Water samples were typically collected at the downstream end of the study reach, at the beginning of daily activities, usually between 9:00 and 10:00 AM. Parameters measured in the field were dissolved oxygen, temperature, and conductivity. All other parameters were analyzed at the EPA laboratory in Corvallis, Oregon. For full details of water chemistry sampling methods, see Peck et al. 2006.

*Temperature*—Temperature is a very important water quality parameter in aquatic habitat in determining species presence and viability. This is especially true for salmonids which require relatively low water temperatures compared to many other aquatic species. Water temperature was collected using continuously-recording thermistors during the late spring to early fall time period.
The temperature value used in this assessment was the seven-day average of the daily maximum temperatures for the summer season. The water quality standard for this indicator depends on the fish use designation for each stream segment (ODEQ 2003). The water quality standard ranges from 12 °C to 20 °C.

**Dissolved Oxygen**—Dissolved oxygen is essential to all life that depends on aerobic respiration. The amount of oxygen in water is determined by a number of factors. The solubility of oxygen in water decreases as water temperature increases. The amount of oxygen dissolvable in water also decreases with decreasing barometric pressure. Barometric pressure decreases with increasing elevation and changes with the weather. In addition, the biological activity in the water, particularly aquatic plant and algal photosynthesis, can have a tremendous influence on the dissolved oxygen. As a result dissolved oxygen can vary daily and seasonally as photosynthesis, respiration, and water temperature vary. Turbulent, fast-moving water can restore depleted dissolved oxygen through aeration. Human activities can affect dissolved oxygen in a number of ways. Removal of riparian vegetation and decreased shading can lead to increased water temperatures and decreased dissolved oxygen. Stream bank destabilization can cause wider, shallower stream channels with increased exposure to solar energy. Increased organic material to streams through soil erosion or other pollution can also deplete dissolved oxygen through aerobic decomposition by bacteria.

Dissolved oxygen was determined in the field using the Winkler titration method (ODEQ 2004a). The dissolved oxygen criterion for each site was determined by fish use designations and spawning codes for the stream reach (ODEQ 2004b).

**Chloride**—Natural sources of chloride anions (Cl\(^-\)) in water are derived from widely distributed chloride compounds such as sodium chloride (NaCl) and potassium chloride (KCl). Chloride is highly soluble in water and occurs as anions paired with oppositely charged cations. Human sources of chloride include fertilizers, a suite of industrial chemical, sewage and irrigation drainage. The EPA does not have a standard for chloride concentrations in water but it does have a recommended limit of 250 mg/l in drinking water. Chloride concentrations are important for individuals on low salt diets and water with concentrations higher than 250mg/l has a detectably salty taste.

**Sulfate**—Sulfate (SO\(_4\)) is a naturally occurring anion in water. Sources include magnesium sulfate, sodium sulfate and calcium sulfate which are typically associated with volcanic rock types. Other natural sources include the decomposition of organic materials and sea salt. Human activities may also contribute sulfates to water. Combustion of fossil fuels, mining activities, paper and textile production all produce sulfate byproducts which can end up in water sources. There is no federally enforceable standard for sulfate, but the EPA has a guideline for sulfate based on taste and odor of 250 mg/L. High levels of sulfate in drinking water may cause diarrhea. This is a concern for sensitive portions of the population such as children, transients or the elderly because of the potential for dehydration (USEPA 1999).

**Nutrients (Nitrogen and Phosphorous)**—The biological productivity of streams depends on a combination of nutrients and energy. Nutrients can enter the stream dissolved in ground water and surface water run off. Nutrients can also enter the stream through the decomposition of solid material such as terrestrial plant leaves and wood falling into the stream, and animal bodies, such as salmon carcasses. Human activity in a basin often greatly increases nutrient input to streams over the normal levels through fertilization of agricultural and residential land, animal and human wastes, and increased soil erosion. Conversely, human activity also leads to decreased stream
nutrients in some areas when there is a decrease in decomposing salmon carcasses due to reduced salmon populations.

Algae, like all plants, require many different nutrients for normal growth. Most of these nutrients are available in aquatic systems in excess of the algal nutritional requirements. Nitrogen and phosphorus are exceptions in that the availability of these nutrients frequently limits algal growth in lakes and streams. The growth of algae feeds insects that are eaten by fish. Too little nitrogen and phosphorus may mean a reduced food supply for juvenile salmonids and overall reduced stream productivity. Too much nitrogen and phosphorus leads to excess algal growth causing pH and dissolved oxygen problems unhealthy to salmonids and other species.

Nitrogen and phosphorus can exist in water in a number of different forms. Some are more biologically available than others. Total nitrogen is made up of nitrogen in particulate and organic material and dissolved forms of nitrogen such as ammonia, nitrate, and nitrite. Total inorganic nitrogen is made up of the dissolved forms of nitrogen: ammonia, nitrate, and nitrite. Total phosphorus is made up of phosphorus contained in particulate and organic material and dissolved ortho-phosphate. Total inorganic nitrogen and dissolved orthophosphate are in forms readily available for algal uptake and growth. Total nitrogen and total phosphorus contain forms of these nutrients relatively unavailable for growth by algae.

**Conductivity**—Conductivity is the ability of a substance to conduct an electrical current. Pure water is a very poor conductor of electricity and has a very low specific conductance. Specific conductivity increases with increasing ions in solution. Soluble ions include nitrates, chloride, phosphate, sulfate, magnesium, calcium and iron. Because many of these ions are produced as byproducts of human activities such as agriculture and industry, conductivity can be an indicator of water pollution, particularly when conductivity deviates from natural levels. The specific conductivity of streams is measured in units of micromhos (μmhos) or synonymously microsiemens (μS/ cm).

**pH**—pH is an important and frequently measured water quality parameter that is critical for the growth and survival of aquatic life. It affects the toxicity of heavy metals and ammonia. Like dissolved oxygen and temperature, pH often varies daily and seasonally. In most waters pH is determined by the dissolved carbon dioxide gas which forms carbonic acid, a weak acid. Algal photosynthesis and respiration in areas with abundant algal growth would decrease dissolved carbon dioxide and increase the pH. At night, pH in those same waters would decrease as a result of carbon dioxide excretion during respiration. Such diel swings in pH can be very stressful to salmon and other aquatic life.

The pH was measured in the field on a freshly collected sample using a meter with a glass pH electrode. The water quality standard for freshwaters allows for pH values from 6.5 to 8.5.

**Total Suspended Solids**—The detrimental effects of excess fine sediment on juvenile salmon and other aquatic life are well known. Fine sediment can clog spaces between gravel and cobble, smothering salmon eggs and emerging fry. Excess fine sediment in the water column interferes with gill function and the ability of young fish to forage for food. Human activities such as road building, logging and agriculture can lead to increased fine sediment in streams.

Total suspended solids are measured by evaporating a known volume of water sample and then weighing the remaining residue for a filtered and unfiltered sample. Total suspended solids have units of milligrams solid material per liter of water. Like many other water quality parameters,
measures of water column sediment can vary tremendously depending on flow conditions. A single sample collected during summer low-flow conditions may not capture water column fine sediment problems for many streams.

_Turbidity_—Turbidity is the opacity or clarity of the water due to dissolved, colloidal and suspended material in the water sample. Turbidity is measured using a turbidity meter. Turbidity is measured in Nephelometric Turbidity Units (NTU). Existing water quality standards for turbidity were not applicable to our studies (ODEQ 2004b), so the distribution of turbidity at reference sites was used to set benchmarks.

**Physical Habitat:**
Instream and riparian habitat was surveyed over a stream reach of 40-times the wetted width. The habitat assessment includes both quantitative and qualitative measures of instream and riparian habitat characteristics. Detailed descriptions of field methods are listed in Peck et al. (2006) and habitat metric calculations are shown in Kaufmann et al. (1999).

_All Human Disturbances_—Human disturbances are often associated with alterations in water quality and biological communities. The measure used for this analysis combines a wide range of human disturbances observed by the field survey crew into a single score and weights disturbance based on the proximity of the disturbance to the stream reach. Types of disturbances included in this measurement are the presence and proximity of roads, logging, agriculture, residences, pipes, and mining.

_Agricultural Disturbances_—This metric is calculated in the same way as All Human Disturbances (above), but is limited to only those disturbances associated with agricultural practices observed by the field survey crew. The isolation of different types of stressors by landuse type, especially this metric, has shown significant correlations with biological condition in previous studies.

_Fast Water Habitat_—Fast water is characterized by broken surface water and typically occurs in steeper sections of the stream reach. Fast water is important for providing well oxygenated water for salmon and other cold water adapt species. In addition, fast water flushes fine sediment downstream and provides spawning areas with sufficient hydraulic pressure to keep redds well oxygenated. Fast Water Habitat is measured at 100-150 points along the reach and includes, “Riffles”, “Rapids”, “Cascades” and “Falls”. This habitat metric is the percent of the stream reach classified by the field survey crew as being in these four types of stream habitat.

_Slow Water Habitat_—Slow water habitat provides important areas for salmonid rearing and refuge during freshets. However, disproportionate slow water habitat, particularly the relatively less complex glide habitat, can be the result of anthropogenic channel simplification and can be detrimental to aquatic species diversity. Instream habitat conditions are characterized at 100-150 points within the stream reach. Slow Water Habitat combines “Glide” and “Pool” habitat types into a single metric as a percent of the stream reach.

_Residual Pools_—This represents the available refugia available to aquatic organisms during low-flow conditions. This metric has advantages over flow-dependent metrics (like fast water or slow water habitat) for comparisons among streams by factoring out flow conditions.

_Canopy cover_—Canopy cover, or shade, is a direct measure of the overhead steam cover. It includes cover provided by all sources, both natural and anthropogenic. The canopy cover metric
used in this report is the percent of stream cover from vegetation or land forms measured in the center of the channel on eleven transects spaced evenly throughout the stream reach. Shade provides important protection from solar radiation which can cause increases in stream water temperature, excessive algal production, and diel fluctuations in pH and dissolved oxygen.

**Riparian Vegetative Cover**--The riparian zone acts as a buffer zone to protect streams from disturbances, both natural and human. Disruptions to riparian vegetative communities can alter a stream’s ability to maintain natural temperatures, substrate composition, and food webs for instream organisms. The riparian vegetative cover metric measures the proportion of a stream reach with vegetative cover present in each of three layers: canopy, mid-layer, and ground-layer.

**Habitat complexity**--Ecologically sound streams typically exhibit complex physical habitat features. These large features provide refugia for fish and macroinvertebrates, as well as formation of stream morphological units (riffles, pools, falls, etc.). Human activities in streams often result in reduced habitat complexity and cover features. The habitat complexity metric is comprised of visual estimates of large woody debris, boulders, undercut banks, and riparian vegetation near the water surface.

**Large Woody Debris**--The Large Woody Debris measurement is a combination of all wood categories in the stream channel and bridging above the bankfull channel. The measurements are summarized as the wood volume per one hundred meters (m³/100m). Large wood is important because it creates a diversity of pool habitats which provide critical habitat for salmonids. In addition, wood provides substrate for a variety of macroinvertebrate species, which can provide food for salmonids.

**Fine Sediments**--Fine sediment is important because excessive fine sediment can clog spaces between coarse substrate and seriously impact salmon spawning and early life history rearing habitat. In addition, interstitial spaces provides habitat for a variety of macroinvertebrate, cold water fish and amphibian species. Visually estimated size classes of the streambed substrates were made using a modified Wolman pebble count at five points across each of 21 transects along the stream survey reach. Fine sediment was assessed as the percentage of substrate composed of particles smaller than 2mm in diameter; the equivalent of “fines” (particles smaller than 0.6mm in diameter) plus “sand” (particles between 0.6 and 2mm).

**Embeddedness**--Embeddedness is a measure of the percentage of substrate particle surfaces surrounded by fine sediments (< 2mm). Fine sediments reduce available habitat for macroinvertebrates and smother salmonid spawning particles. Embeddedness was visually estimated as part of the modified Wolman pebble count, for a total of 105 particles in each stream reach.

**Relative Bed Stability**--Some streams naturally have high levels of fine sediment due to water velocity and slope of the stream channel, while other streams have high levels of fine sediment due to human disturbance. It can sometimes be difficult to understand what the substrate of a stream should be like. The Relative Bed Stability (RBS) calculation helps to understand stream reach substrate characteristics in terms of the physical and hydrological characteristics of the watershed. Relative Bed Stability evaluates the ability of a stream of a particular size, steepness, discharge and roughness to move substrate downstream. Values less than zero indicate the median substrate particle size at the stream reach was smaller than the expected particle size based on the Relative Bed Stability calculation, meaning that the stream has a higher level of fine sediment than it should have. Values greater than zero indicate the median particle size is larger than expected, and means
the stream channel has less fine sediment than it should have. RBS values near zero indicates the stream channel has about the right amount of fine sediment based on its physical characteristics and hydrology.

**Setting Expectations: The Reference Condition Approach**

**Selecting Reference Sites:**
In order to make an assessment of stream condition, one must define what constitutes acceptable conditions for each indicator. The reference condition approach has been widely used to identify least-disturbed conditions and set expected values or benchmarks for specific parameters, especially for parameters without clearly defined standards or criteria. Least-disturbed conditions represent “the best of what’s left” for any given region. In some parts of Oregon much of the landscape is relatively undisturbed, while in other regions the landscape has been altered more extensively by human activities. Our expectations of what constituted a natural range for an indicator of stress were based on regional reference sites within Level III Ecoregions (Omernik 2004). Ecoregions combine elements of geology, climate, elevation, and vegetative communities. Similar physiographic and biological characteristics make Level III Ecoregion a useful scale for deriving benchmarks based on reference condition.

To achieve an adequate sample size within each Level III Ecoregion, we aggregated reference sites across Oregon, Washington, and Idaho where ecoregions crossed state boundaries. Each state used slightly different protocol for selecting reference sites, however each protocol was based on a set of defined criteria for identifying the lowest levels of human disturbance in a region. ODEQ methods screen prospective reference sites at the local (reach) and watershed scales for the lowest levels of human activities (Drake 2004). USEPA methods employed aerial photos at the watershed scale, as well as including chemical and physical screens for reference identification (Stoddard et al. 2005a). Idaho DEQ (Grafe 2004) and Washington DOE (Plotnikoff 2001) combine reference selection procedures similar to both ODEQ and USEPA. Besides hand-picked reference sites, random W-EMAP sites that met reference site screening criteria were also used as reference sites. The hand-picked reference sites were not used in making population estimates.

A total of 181 reference sites (Table 1; Figure 2) were used to establish indicator benchmarks (Table 2) for the assessment of perennial wadeable streams in Oregon. We aggregated some Level III Ecoregions due to the low number of available reference sites in the individual Ecoregions and the basic similarity of the aggregated Ecoregions. The Puget Lowlands and the Willamette Valley Ecoregions were aggregated, as were the Columbia Plateau, Snake River Planes and Northern Basin and Range Ecoregions.
### Table 1. Level 3 Ecoregions in Oregon and the number of sites used to establish reference benchmarks.

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**Setting Assessment Benchmarks:**

Oregon and other states set water quality standards and criteria to protect the beneficial uses of streams and rivers. For this assessment, we used Oregon’s water quality standards to evaluate statewide conditions for those indicators with established numeric standards (dissolved oxygen, temperature, and pH; Table 2). When the standard was met, the water quality condition was considered “least disturbed”, and when the standard was not met, the water quality was considered “most disturbed”. For water quality and physical habitat indicators without a standard, we used reference site values to establish three classes of stream condition (Table 2, Appendix A). Where increasing indicator values were associated with a declining biological indicator response, the upper 75<sup>th</sup> and 95<sup>th</sup> percentiles of reference values were used to distinguish “least disturbed” (<75<sup>th</sup>), “moderately disturbed” (75<sup>th</sup>-95<sup>th</sup>), and “most disturbed” (>95<sup>th</sup>) classes. Where decreasing indicator values were associated with a declining biological indicator response, the lower 5<sup>th</sup> and 25<sup>th</sup> percentiles of reference values were used to distinguish “least disturbed” (>25<sup>th</sup>), “moderately disturbed” (5<sup>th</sup>-25<sup>th</sup>), and “most disturbed” (<5<sup>th</sup>) classes. The 5<sup>th</sup>/25<sup>th</sup> and 75<sup>th</sup>/95<sup>th</sup> benchmarks are consistent with the benchmarks used in USEPA’s EMAP-West report (Stoddard et al. 2005).
Table 2. Ecological integrity and stress indicators and the direction change of each indicator associated with increasing stress. Condition class benchmarks were derived from upper and lower percentiles of reference populations within each ecoregion. WQS = existing water quality standards were used instead of reference benchmarks.

<table>
<thead>
<tr>
<th>Indicator Type</th>
<th>Indicator</th>
<th>Indicator direction with increasing stress</th>
<th>Condition Class Benchmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological Indicator</td>
<td>Taxa Loss (O/E)</td>
<td>Decreasing</td>
<td>5th and 25th</td>
</tr>
<tr>
<td></td>
<td>Dissolved Oxygen</td>
<td>Decreasing</td>
<td>WQS</td>
</tr>
<tr>
<td></td>
<td>Chloride</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td></td>
<td>Sulfate</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td></td>
<td>Nitrogen</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td></td>
<td>Phosphorous</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td></td>
<td>Conductivity</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td>Water Quality</td>
<td>pH</td>
<td>Decreasing and Increasing</td>
<td>WQS</td>
</tr>
<tr>
<td>Indicators of Stress</td>
<td>Temperature</td>
<td>Increasing</td>
<td>WQS</td>
</tr>
<tr>
<td></td>
<td>Total Suspended Solids</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td></td>
<td>Turbidity</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td>Physical Habitat</td>
<td>All Human Disturbances</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td>Indicators of Stress</td>
<td>Agricultural Disturbances</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td></td>
<td>Fast Water Habitat</td>
<td>Decreasing</td>
<td>5th and 25th</td>
</tr>
<tr>
<td></td>
<td>Slow Water Habitat</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td></td>
<td>Residual Pools</td>
<td>Decreasing</td>
<td>5th and 25th</td>
</tr>
<tr>
<td></td>
<td>Canopy Cover</td>
<td>Decreasing</td>
<td>5th and 25th</td>
</tr>
<tr>
<td></td>
<td>Riparian Vegetative Cover</td>
<td>Decreasing</td>
<td>5th and 25th</td>
</tr>
<tr>
<td></td>
<td>Habitat Complexity</td>
<td>Decreasing</td>
<td>5th and 25th</td>
</tr>
<tr>
<td></td>
<td>Large Woody Debris</td>
<td>Decreasing</td>
<td>5th and 25th</td>
</tr>
<tr>
<td></td>
<td>Fine Sediment</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td></td>
<td>Embeddedness</td>
<td>Increasing</td>
<td>75th and 95th</td>
</tr>
<tr>
<td></td>
<td>Relative Bed Stability</td>
<td>Decreasing</td>
<td>5th and 25th</td>
</tr>
</tbody>
</table>
Ecological integrity benchmarks for the macroinvertebrate community scores were as follows: “least disturbed” = < 10% reference taxa loss, “moderately disturbed” = 10-25% taxa loss, and “most disturbed” = > 25% taxa loss (O/E values of > 0.90, 0.75 – 0.90, and < 0.75, respectively). These criteria match benchmarks established for ODEQ’s internally developed biocriteria assessments and predictive models (Hubler 2006, ODEQ 303d Assessment Methodology 2007).

Relative Risk
Two factors were used for assessing which indicators pose the greatest threat to ecological integrity: 1) the extent or number of stream kilometers in poor condition for each indicator, and 2) the relative risk each chemical and habitat indicator poses to ecological integrity when it is in poor condition. The assessment of “relative risk” is frequently used to communicate medical and health information. It is a useful tool for summarizing complex information and relationships in an easy to understand format. Relative risk can be defined as the probability of getting a poor response when a poor indicator value is present, divided by the probability of getting a poor response when a good indicator value is present (Lachin 2000).

A hypothetical risk of cigarette smoking is shown in Figure 4. This example shows that someone who smokes two packs of cigarettes a day has a 7.6 times greater risk of lung cancer than someone who doesn’t smoke.

<table>
<thead>
<tr>
<th>Response</th>
<th>Stressor = Smoking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>Good = No Lung Disease</td>
<td>A (0.45)</td>
</tr>
<tr>
<td>Poor = Lung Disease</td>
<td>B (0.05)</td>
</tr>
<tr>
<td>Total</td>
<td>A+B (0.50)</td>
</tr>
</tbody>
</table>

Risk of poor response given poor stressor = D (0.38) / C+D (0.50)
Risk of poor response given good stressor = B (0.05) / A+B (0.50)

Relative Risk = Risk of poor response given poor stressor D/C+D (0.38/5) = 7.6
Risk of poor response given good stressor B/A+B (0.05/5)

Figure 4. Example Relative Risk calculation.

For these analyses, indicators with a relative risk value greater than 1.5, and where the 95% confidence interval is greater than 1.0, are considered significant. Relative risk values of 1.0 or less indicate no indicator effect on biological condition.
RESULTS

The extent of stream kilometers in each of three condition classes was assessed for ecological condition based on macroinvertebrates, as well as for various chemical and habitat indicators. Appendix A provides the benchmark values used to summarize the extent of wadeable stream kilometers in each of the three condition classes. Appendix B provides the extent of stream kilometers in each condition class.

Ecological Condition

The macroinvertebrate “Taxa Loss” model (Figure 5) shows that approximately 51% of stream kilometers of the assessed wadeable streams in Oregon were in “least disturbed” ecological condition. These streams retained > 90% of expected macroinvertebrate taxa. Samples with 75-90% of expected taxa present are designated in “moderately disturbed” condition, and represented 23% of assessed target stream kilometers. Sites with more than 25% of expected taxa missing fall into the “most disturbed” category. This study shows approximately 26% of the assessed perennial and wadeable stream kilometers in Oregon were in “most disturbed” ecological condition. Forty-one percent of wadeable stream kilometers were not assessed for ecological integrity. Thus, the 26% of kilometers in poor ecological condition represents the minimum amount of stream kilometers in poor condition.

Figure 5. Ecological integrity of wadeable streams in Oregon. (Error bars are 95% confidence intervals.) The pie chart to the right shows the percentage of all perennial, wadeable stream kilometers actually assessed (dark blue) and the percent of kilometers not assessed (grey).
Water Quality Indicators of Stress

Physical:

The condition of physical water quality indicators in Oregon streams is shown in Figure 6 and Appendix B. Oregon water quality standards were used to identify condition classes for pH, temperature, and dissolved oxygen. Conductivity does not have a water quality standard, so condition classes were based on ecoregional reference distributions (Appendix A). The majority of assessed wadeable stream kilometers in Oregon are in “least disturbed” condition for conductivity (67%), pH (95%), and dissolved oxygen (89%). Relatively few assessed stream kilometers were in “most disturbed” condition (12%, 5%, and 11%, respectively). A significant proportion of targeted stream kilometers was not assessed (36%, 36%, and 39%, respectively) and are of unknown condition.

Due to the high cost of the placement of continuously recording temperature probes, which requires additional visits to each site, a large proportion of stream kilometers were not assessed for summer maximum temperature (78%). However, of the 22% of wadeable stream kilometers assessed, 54% did not meet the temperature standard and were designated as “most disturbed” condition.

Figure 6. Extent of physical water quality indicators in each condition class. (Error bars are 95% confidence intervals.) The pie chart to the right shows the percentage of all perennial, wadeable stream kilometers actually assessed (dark blue) and the percent of kilometers not assessed (grey).
Ions

The condition of water chemistry ion indicators in wadeable Oregon streams is shown in Figure 7. Water quality standards do not exist for sulfate or chloride, so regional reference benchmarks were used to designate streams into condition classes (see Appendix A). The majority of assessed stream kilometers were in “least disturbed” condition for both chloride (70%) and sulfate (84%). Only 5% of assessed stream kilometers exceeded reference benchmarks for chloride, while 12% were in “most disturbed” condition for sulfate. A much higher amount of the assessed stream length was classified as “moderately disturbed” for chloride (25%) than for sulfate (4%). For both parameters 36% of stream kilometers were not assessed.

Figure 7. Extent of water chemistry ions in each condition class. (Error bars are 95% confidence intervals.) The pie chart to the right shows the percentage of all perennial, wadeable stream kilometers actually assessed (dark blue) and the percent of kilometers not assessed (grey).
Nutrients

Results of the assessment of nutrient indicators are shown in Figure 8. Because water quality standards do not exist for nitrogen and phosphorous, we used reference sites to establish benchmarks for assigning condition classes (Appendix A). Total nitrogen and total phosphorous showed nearly identical amounts of assessed stream kilometers in each condition class across Oregon. The percentage of assessed stream kilometers in “least disturbed” condition were 80% for nitrogen and 78% for phosphorous. Phosphorous showed a slightly higher percentage of assessed stream kilometers (12%) in “moderately disturbed” condition, compared to nitrogen (9%). The extent of assessed stream length in “most disturbed” condition was 11% for nitrogen and 10% for phosphorous. For both parameters 36% of stream kilometers were not assessed.

Figure 8. Extent of water chemistry nutrients in each condition class. (Error bars are 95% confidence intervals.) The pie chart to the right shows the percentage of all perennial, wadeable stream kilometers actually assessed (dark blue) and the percent of kilometers not assessed (grey).
Sediment load

The assessment of water chemistry sediment is based on turbidity and total suspended solids (Figure 9). Reference site results were used to establish benchmarks for each condition class (Appendix A). Total suspended solids and turbidity showed nearly equivalent amounts of assessed stream length in “most disturbed” condition, 13% and 12% respectively. A greater extent of stream kilometers were in “least disturbed” condition for turbidity (73%) than for total suspended solids (60%). For both parameters 36% of stream kilometers were not assessed.

Figure 9. Extent of sediment load indicators in each condition class. (Error bars are 95% confidence intervals.) The pie chart to the right shows the percentage of all perennial, wadeable stream kilometers actually assessed (dark blue) and the percent of kilometers not assessed (grey).
Physical Habitat Indicators of Stress

Physical habitat indicators were grouped into five categories: human disturbances, stream morphology, riparian condition, habitat structure, and substrate. No water quality standard exists for any of these indicators, so regional reference sites were used to determine condition classes (Appendix A).

Human disturbances

Human disturbances were grouped according to all types of disturbances, and only those pertaining to agricultural practices (Figure 10). We examined agricultural activity separately because this metric has shown a strong linkage to biological integrity in past studies. Throughout Oregon, 56% of assessed stream kilometers were in “least disturbed” condition for agricultural disturbances, while only 30% of stream kilometers were “least disturbed” condition for all disturbances. A high percentage of assessed stream kilometers were in “most disturbed” condition for all types of disturbances (46%) and agricultural disturbances (42%). Since reference sites are selected in watersheds that are relatively undisturbed by human activity, it is not unexpected that the random population would have more extensive disturbances than the reference population. For both parameters 36% of stream kilometers were not assessed.

Figure 10. Extent of human disturbance indicators in each condition class. (Error bars are 95% confidence intervals.) The pie chart to the right shows the percentage of all perennial, wadeable stream kilometers actually assessed (dark blue) and the percent of kilometers not assessed (grey).
Stream morphology

Residual pool depth, slow water habitat, and fast water habitat were measured to characterize stream morphology factors that influence aquatic life (Figure 11). Residual pool depths show that the majority of assessed stream kilometers in Oregon were in “least disturbed” (47%) or “moderately disturbed” (39%) condition. The extent of assessed stream kilometers in “most disturbed” condition was 13%. Fast water habitat and slow water habitat show similar amounts of stream kilometers in each condition category. Fast water and slow water show 57% and 60%, respectively, of perennial wadeable stream kilometers in Oregon were in “least disturbed” condition. These two indicators had similar amounts of stream resource in “most disturbed” condition (19% and 24%, respectively). All three parameters had between 36% and 38% of stream kilometers not assessed.

Figure 11. Extent of stream morphological indicators in each condition class. (Error bars are 95% confidence intervals.) The pie chart to the right shows the percentage of all perennial, wadeable stream kilometers actually assessed (dark blue) and the percent of kilometers not assessed (grey).

This interpretation of slow water as a stressor to biological condition may be at odds with other EMAP assessments. We based our decision to use the upper 75th and 95th percentiles of reference condition on significant correlations between increasing slow water habitat and decreasing biotic integrity (as measured by macroinvertebrate taxa loss; $r^2 = 0.19$). This may not seem intuitive.
when considering habitat utilization by fish, which typically show increased integrity with increasing pool habitat. However, the slow water habitat indicator used in this assessment combines both pool and glide habitats. It is possible that assessments using fish assemblages may show the opposite response, where increased slow water habitat is related to higher biological integrity. However, we hypothesize that the inclusion of the relatively less complex glide habitat as part of the overall slow water habitat indicator may be a confounding factor. Based on our field observations, diversity and abundances of both fish and macroinvertebrates tend to be lower in glide habitats (compared to riffles and pools). Perhaps summarizing slow water habitats to exclude glide habitat would be a more effective indicator of stress.

Riparian condition

Riparian vegetative cover and shade results were very similar (Figure 12). “Least disturbed” conditions exist across 59% of Oregon’s wadeable stream kilometers for canopy cover and 61% for vegetative cover. “Most disturbed” conditions were found at 15% of stream kilometers for canopy cover and 14% for vegetative cover. Approximately 26% and 25% of stream kilometers were in “moderately disturbed” condition for canopy cover and vegetative cover, respectively. For both parameters 36% of stream kilometers were not assessed.

![Graph showing riparian condition](image)

Figure 12. Extent of riparian vegetation indicators in each condition class. (Error bars are 95% confidence intervals.) The pie chart to the right shows the percentage of all perennial, wadeable stream kilometers actually assessed (dark blue) and the percent of kilometers not assessed (grey).
Habitat Structure

Results of habitat structure indicators are shown in Figure 13. Across Oregon, most of the assessed stream kilometers meet reference expectations (“least disturbed”) for large woody debris (69%) and habitat complexity (64%). Twice as many assessed stream kilometers fail reference expectations (“most disturbed”) for habitat complexity (18%) than for large woody debris (9%). Similar amounts of stream length were in “moderately disturbed” condition for habitat complexity (18%) and large woody debris (22%).

![Graph showing habitat structure indicators](image)

**Figure 13.** Extent of habitat structure indicators in each condition class. (Error bars are 95% confidence intervals.) The pie chart to the right shows the percentage of all perennial, wadeable stream kilometers actually assessed (dark blue) and the percent of kilometers not assessed (grey).
Substrate

Results of substrate indicators are shown in Figure 14. The extent of assessed wadeable stream length in “least disturbed” condition was very similar for fines (44%), sand/fines (43%), and embeddedness (42%). Approximately twice as many stream kilometers in Oregon are in “most disturbed” condition for fines (23%) and embeddedness (20%), than for sand/fines (10%). Relative bed stability shows a higher amount of assessed stream length in “least disturbed” condition (64%) than the other substrate measures. The extent of assessed stream kilometers classified as “most disturbed” for relative bed stability was 17%. Relative bed stability had 38% of stream kilometers unassessed, while the other three variables had 36% unassessed.

Relative bed stability may be a more accurate way to assess substrate conditions than these other substrate indicators. Relative bed stability takes into account such natural factors as gradient, discharge, etc. to determine if the median particle size is smaller or larger than expected. An example of the utility of relative bed stability over % fines would be a stream that is naturally high in fine sediments due to a highly erodible base geology and low gradients. Relative bed stability is likely to classify this site in “least disturbed” sediment condition. On the other hand, % fines is likely to result in the designation of “most disturbed” sediment condition.

Figure 14. Extent of substrate indicators in each condition class. (Error bars are 95% confidence intervals.) The pie chart to the right shows the percentage of all perennial, wadeable stream kilometers actually assessed (dark blue) and the percent of kilometers not assessed (grey).
Ranking of Indicators

Understanding the relative importance of an indicator as a stressor to the biological community can help resource managers determine which environmental factors pose the greatest risk to maintaining healthy aquatic communities. One way to do this is to identify the relative extent of stream resource in “most disturbed” condition for the assessed variables. With this approach it is possible to identify those indicators with the most widespread poor condition throughout Oregon. A second approach is to identify the relative risk each indicator poses to an ecological measure of interest. This approach identifies the severity of an indicator on biological integrity. In other words, if an indicator is beyond a standard or reference benchmark, what is the magnitude of the impact to the biological assemblage?

Relative extent

For the most part, individual indicators of stress within categories showed similar amounts of assessed stream kilometers failing to meet water quality criteria or reference benchmarks (Figure 15). The indicators showing the greatest extent of assessed stream kilometers in most disturbed conditions were temperature (54%), human activities (all disturbances = 46%, agricultural disturbances = 42%). Other extensive indicators included stream morphological indicators (excessive slow water habitat = 24%, reduced available fast water habitat = 19%, reduced availability of residual pools = 13%) and substrate indicators (high % fine sediment = 23%, high embeddedness = 20%, relative bed stability indicating excess fine sediment = 17%).

Indicators with somewhat less extensive assessed stream kilometers in most disturbed conditions were riparian vegetation indicators (reduced stream canopy cover = 15%, reduced riparian vegetative cover = 14%) and water chemistry sediment load indicators (high total suspended solids = 13%, high turbidity = 12%). Physical chemistry and ion indicators ranged from moderately extensive (high conductivity = 12%, high sulfate = 12%, low dissolved oxygen = 11%) to low extent (poor pH levels = 5%, high chloride = 5%) in most disturbed condition. Nutrient indicators exceeded reference population benchmarks in 10% (high total phosphorus) and 11% (high total nitrogen) of assessed perennial, wadeable stream kilometers.

The actual percent of stream kilometers across Oregon listed in “most disturbed” condition is likely significantly under-represented in this report. The percent of stream kilometers that were not assessed for all indicators ranged from 36-41% for all parameters except temperature (78% unassessed). Most of these stream kilometers were not assessed due to private landowners restricting access for the surveys.

Relative risk

Eleven indicators were identified as a significant risk to the biological integrity of macroinvertebrate assemblages in wadeable Oregon streams (Figure 15). Total suspended solids showed the highest risk, with a 9.6 times greater likelihood of a biological impairment occurring when total suspended solids was high. Another water chemistry sediment load indicator, turbidity, also showed a significant risk (4.0). Relative bed stability also showed a high risk (4.6) to macroinvertebrates. High risks were associated with reduced availability of residual pools (5.0) and reduced availability of fast water habitat (4.0). One nutrient indicator (high total phosphorus = 4.4) and two ion indicators (high chloride = 3.5, high sulfate = 2.6) showed significant risks to macroinvertebrates. Other variables showing a significant risk were poor pH levels (3.1), high conductivity (2.9), and low riparian vegetative cover (2.8).
Figure 15. Extent of stream kilometers in most disturbed condition and relative risk of water chemistry and physical habitat indicators to macroinvertebrate assemblages. (The extent of the wadeable, perennial resource actually assessed for each indicator varies from 22% - 64%). Relative risk estimates with lower 95% confidence bounds (error bars) greater than 1.0 (vertical red line) are considered significant risks (light blue) to the ecological integrity of wadeable streams in Oregon.
SUMMARY

Wadeable stream conditions throughout Oregon

Based on 118 randomly selected sites, the overall biological integrity of 64% of Oregon’s wadeable, perennial streams was assessed. We were unable to assess 41% of the targeted resource—predominantly private lands. Thus, the results presented here more accurately reflect conditions on Oregon’s public lands. Using the macroinvertebrate taxa loss model, we observed that 51% of the assessed stream kilometers were in least disturbed condition, while 26% of stream kilometers were in most disturbed and 23% of stream kilometers were in moderately disturbed condition.

The indicators with the greatest extent of the assessed stream kilometers in most disturbed condition were temperature (54%) and human disturbances in riparian areas (42-46%). However, these indicators typically showed little risk to the macroinvertebrates. Water chemistry indicators, in general, resulted in fewer stream kilometers in most disturbed condition than physical habitat indicators. Despite low extent, several chemistry indicators did show significant risks to the biology. Indicators showing the greatest combination of extent and risk were related to high levels of fine sediment in the stream bed and high levels of suspended fine sediment in the water, reductions in pool and riffle habitats, and reduction in cover provided by riparian vegetation.

Comparisons to Oregon’s 303(d) list

According to the CWA, water bodies on Oregon’s 303(d) list require a Total Maximum Daily Load (TMDL) be completed to bring the waters in compliance with water quality standards. Direct comparisons between the 303(d) list and this study are not possible for a variety of reasons. First, the 303(d) list covers streams of all sizes, including non-wadeable streams and rivers. Also, the 303(d) list does not represent an unbiased sample, but only those stream segments where DEQ has appropriate data. Finally, data for the 303(d) assessment is compared to Oregon’s water quality standards and evaluations have not been done using benchmarks based on reference sites. Despite these differences, comparisons between the results presented in this report and Oregon’s 2004-2006 303(d) list of water quality limited streams show some similarities and some striking differences.

Temperature is by far the most often listed parameter on the 303(d) list and our study showed 12% of stream kilometers (out of only 22% of targeted stream kilometers assessed) in Oregon exceed water quality standards for temperature. However, in contrast to the number of stream segments on Oregon’s 303(d) list, our study showed a significant extent of the stream resource was in poor condition for biological integrity (macroinvertebrate taxa loss) and fine sediments in both the water column (turbidity and total suspended solids) and bedded sediments (relative bed stability and percent fines). Part of these discrepancies may be explained by the lack of clearly defined listing criteria (water quality standards) for biological criteria and suspended and bedded sediments. Due to funding constraints, DEQ has been unable to tackle the development of standards for these parameters.

Study Limitations

The results of this study have certain limitations, which should be made clear. The results presented here are representative of conditions in perennial (they do not dry up) and wadeable streams and rivers (ones that can be safely walked across during the summer months). While data were collected on larger streams and rivers, there was insufficient data to adequately represent conditions in these larger flowing waters. Also, the results are indicative of conditions during the study period—like a snapshot in time. Future monitoring is required to determine if conditions in perennial wadeable streams in Oregon are improving or degrading.
Estimates of biological integrity were based exclusively on a single biological assemblage, macroinvertebrates. Other assemblages, such as fish and amphibians or algae, often show differing sensitivities to various indicators of stress. Including other assemblages in future assessments may provide a more accurate assessment of ecological conditions across Oregon. Failure to assess these assemblages in this current report likely resulted in an over-estimation of the percent of stream kilometers in good biological condition. For validation of this, one only has to think of the percent of stream kilometers in Oregon that face Endangered Species Act restrictions for salmonids.

Randomly sampled sites were assigned to one of three condition classes (least disturbed, moderately disturbed, or most disturbed) based on conditions observed at least impaired reference sites. Because natural variation occurs in environmental variables (chemical and physical habitat) across the landscape, we used ecoregions to approximate these natural variations. Ecoregions do not perfectly account for all natural variations, but they do approximate natural conditions as well as any other geographic management unit for most environmental variables. The sample sizes of reference sites in several of these ecoregions were low. Future work should involve building up ODEQ’s reference dataset across all ecoregions to ensure an adequate representation of naturally occurring conditions in all ecoregions. With enough effort, in some parts of the state (e.g. the Cascades, Coast Range, and Blue Mountains) it may be possible to utilize Level IV Ecoregions to more adequately account for natural variation. Also, development of models which can make predictions based on continuous variables, and not on categorical variable such as ecoregion, could provide a more robust way of setting expectations (e.g., relative bed stability and taxa loss models).

The scale of this assessment was across the entire state. While informative of conditions across the broader landscape, the results may not reflect conditions at the local scale. For instance, a particular indicator may show a low extent of stream kilometers in poor condition at the statewide scale, but within a given river basin the indicator may be extensively outside of reference conditions. Smaller scale regional assessments should prove more informative of local conditions and thus more appropriate for establishing local monitoring and management priorities. As part of the Oregon Plan for Salmon and Watersheds, ODEQ has completed smaller scale assessments based on probabilistic surveys in the Lower Columbia ESU (report in progress) and the Oregon Coastal Coho ESU (http://nrimp.dfw.state.or.us/OregonPlan/). An assessment of conditions in the John Day and Lower Deschutes basins will be available in 2008 (based on data collected as part of W-EMAP).

Finally, a large percentage of stream kilometers were unable to be assessed due to the inability of crews to survey on private lands. Thus, our overall assessment is more representative of conditions on public lands than on private lands. To achieve a better understanding of the conditions of Oregon’s stream resources on a whole, it is imperative that ODEQ develop better relationships with private landowners. To do this will require building partnerships with other resource agencies, legislators, and private landowners. In future monitoring endeavors, we will expend a greater effort to increase public awareness and acceptance of probabilistic monitoring programs such as EMAP.
LITERATURE CITED


Appendix A. Benchmarks used to determine indicator conditions in wadeable streams. All benchmarks (except for pH and dissolved oxygen) were based on the distribution of indicator values from reference (least disturbed) populations for level III ecoregions in Oregon.

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>Coast Range</th>
<th>Willamette Valley + Puget Lowlands</th>
<th>Cascades</th>
<th>East Cascades</th>
<th>Blue Mountains</th>
<th>Klamath Mountains</th>
<th>Columbia Plateau + Northern Basin and Range + Snake River Plains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity</td>
<td>&lt; 94</td>
<td>&gt; 160</td>
<td>&lt; 102</td>
<td>&gt; 235</td>
<td>&lt; 58</td>
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<td>&gt; 6</td>
<td>&lt; 5</td>
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<td>&lt; 1</td>
<td>&gt; 2</td>
<td>&lt; 1</td>
</tr>
<tr>
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<td>&gt; 26</td>
<td>&lt; 1</td>
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<td>&gt; 14.0</td>
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<td>Total Nitrogen</td>
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<td>&gt; 63</td>
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<td>% Fines</td>
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<td>&gt; 50</td>
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<tr>
<td>% Sand/Fines</td>
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<td>&gt; 75</td>
<td>49</td>
<td>&gt; 77</td>
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<td>&gt; 68</td>
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<td>&lt; 2.1</td>
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<td>&gt; 0.96</td>
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<td>WQ standard: determined by stream segment (based on fish use and spawning)</td>
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Appendix B. Percent of wadeable stream kilometers in Oregon in various condition classes for ecological integrity, water quality indicators, and physical habitat indicators.

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<tr>
<th>Indicators</th>
<th>Least Disturbed</th>
<th>Moderately Disturbed</th>
<th>Most Disturbed</th>
<th>% of Wadeable, Perennial Stream Kilometers Assessed</th>
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