

Science Question 4: What are the major research and monitoring needs for urban and rural-residential landscapes?

There are many research and monitoring needs directly related to urban and rural-residential areas, some of which overlap with the research and monitoring needs for other land use types (e.g., Wenger *et al.* 2009). Given the marked effects developed areas can have on surface and ground waters, the continued expansion of development in Oregon, the proportion of the human population residing in these areas, and the limited amount of research and monitoring conducted on them, IMST believes that the following research and monitoring needs warrant greater attention from Oregon Plan partners.

Section 11.0: Research and Monitoring Needs

The needs IMST has identified in this section range in scale from basic research and monitoring needed on statewide variation in urban effects to more focused studies on specific parameters and structures (e.g. low impact development effectiveness, identification and removal of fish passage barriers). ***These needs are not listed in priority order.*** Overall, the effectiveness of policy and management practices needs more research and evaluation. A great challenge lies in the understanding of how toxic chemicals affect the aquatic environment and how effective rehabilitation strategies for salmonid habitat and salmonid populations are in urban and rural-residential watersheds, riparian areas, streams, floodplains, rivers, wetlands, and lakes. A better understanding of how to effectively communicate and engage the public to increase their awareness and knowledge of watershed health and salmonid recovery is crucial to successful implementation of the Oregon Plan in urban and rural-residential areas.

The IMST recognizes that various entities at the federal, state, or local levels may be engaged in addressing some of these needs listed below in ways we were not aware of during the development of this report. This possible lack of knowledge in itself, however, illustrates the communication problem we have in a state as large and varied as Oregon. Given that agencies in various municipalities and counties in Oregon (e.g. City of Portland, Clean Water Services in Washington County) are actively working to address many of these needs, the IMST spells out this list in hopes that it will generate discussion and coordinated responses throughout the State. Ideally individual entities would work together to share experiences, data, and create emergent knowledge regarding the research, monitoring, and management needs listed below as well as a “toolkit” of cost-effective remedies to be shared throughout Oregon.

The IMST further recognizes that this list of research needs is not complete. Other areas needing further research include, but are not limited to, processes of urban impacts that are unique to estuaries, knowledge regarding air quality relationships with water quality, and better knowledge of socio-ecological dynamics (see also Wenger *et al.* 2009 for other urban-related research needs developed for the US). It is the nature of science to raise additional questions in the process of answering others. The potential for unknowns expands significantly given the complexity of dealing concurrently with numerous aspects of biology, human systems, and their interactive effects. The high likelihood that the landscape is also going to change through time because of demographic pressures, economic growth, and climate change further expands the difficulty of anticipating information gaps for the future.

Section 11.1: Needs Related to General Effects of Urban Development

Evaluate the major factors that impair aquatic ecosystems and limit salmonid populations in urban and rural-residential areas. This information could be used to set priorities for addressing the sources of such impairments, whether future, contemporary or historical. In Section 8 we summarized research that reported on the variability in biological indices measured in aquatic ecosystems affected by development. These results suggest that multiple factors associated with development alter the composition of aquatic communities. This research need incorporates three sub-components.

- 1) **Assess how effective impervious area (including its proximity and connectivity to streams), landscape development indices (e.g., Brown & Vivas 2005; McMahon & Cuffney 2000), and measures of traffic or road density affect aquatic ecosystem responses to varying degrees.** By determining the major landscape sources of ecological variability, it may be possible to determine how to minimize the effects of current and future development on aquatic ecosystems.
- 2) **Insure that research on water quality (e.g., toxic chemicals) is integrated into other inter-related landscape-level factors that affect entire aquatic ecosystems (i.e., from headwaters to estuaries and near-shore marine environments) and salmonid recovery.** In general, there has been a recent tendency by aquatic scientists to focus attention on the physical and hydrological stressors of aquatic ecosystems. This is a natural consequence of largely ignoring such physical and hydrological stressors during the 1970s, but such swings in attention ignore the need to consider all the multiple stressors outlined in Figure 2-1. For example, how land use affects toxic chemicals may be just as important as how it affects hydrology, and mitigating one stressor without attending to the others means that aquatic ecosystems will remain impaired.
- 3) **Consider large-scale, long-term changes and anticipate at least 50–100 years of future human population and economic growth in salmonid-supporting watersheds, through the use of futuring and systematic analyses.** Current conditions and short-term, site-scale changes are often considered in risk assessments, but increasingly landscape ecologists are emphasizing temporally and spatially greater perspectives and long-term systematic changes (e.g., Parmesan & Yohe 2003; Baker *et al.* 2004; Steel *et al.* 2010b). Such perspectives often reveal fundamentally different risks than those evident from short-term, site-scale studies. For example, how predicted climate and land use changes will affect future hydrologic regimes and water quantity in basins affected by development needs more research, but cannot be addressed with short-term, reach-scale studies.

Section 11.2: Needs Related to Variation in Effects of Development across Oregon

Assess how the effects of development on aquatic ecosystems vary across Oregon regions (e.g., Coast, Valley, Central, East). The IMST found very few published studies reporting on the effects of urban and rural-residential areas on aquatic biota and their habitats throughout Oregon's varied environments. Most assessments were limited to the Willamette Valley and therefore may be unrepresentative of urbanization effects in other ecoregions (e.g., in more arid

regions or in estuaries). By using a scientifically rigorous sampling design (such as a probability-based design using consistent physical, chemical, and biological indicators and sampling methods, see IMST 2009) with stream sites distributed throughout Oregon's urban and rural residential areas, the State would be able to assess the degree to which those land uses alter aquatic ecosystems. That is, given such a probability-based design, one can assess the proportions and extents of stream length that are meeting desired conditions, and relate those to the stressors associated with those conditions. Such a survey would help establish management and rehabilitation priorities by clarifying the magnitude and effects of stressors. Lacking such a survey, Oregon can only guess about the effects of urban and rural-residential development on stream ecosystems (e.g., Oregon Progress Board 2000). This need incorporates two sub-components.

- 1) **Assess the proportion of urban and rural-residential stream length that is 303(d) listed, the proportions of those with TMDLs, and the proportions of the streams with reduced biological condition that are not listed.** Waterways with 303(d) listings and TMDLs offer insights into the more extreme parts of the water quality picture, but may ignore flow, passage, and habitat structure for salmonids. A more thorough consideration of the effectiveness of water quality standards goes beyond water chemistry and sediment analysis and would include an assessment of biological condition and the role of multiple stressors. However, 303(d) listings depend on sampling (with sometimes either frequency or spatial limitations), and not all urban/rural-residential streams have been rigorously sampled. A state-wide assessment of the proportion of stream lengths that merit 303(d) listing in urban and rural-residential areas would indicate which streams, rivers, or estuaries warrant more water quality monitoring and assessment.
- 2) **Assess the current capacity of Oregon streams and rivers within urban growth boundaries to support salmonids (in terms of parameters such as physical habitat, seasonal flows, storm flows, water temperature, dissolved oxygen, fine sediments, and biota).** A probability-based survey such as that described earlier could be used to assess the proportion of urban and rural-residential streams that support, or that has the potential to support, viable salmonid populations. By sampling in both summer and winter, the State could determine the proportion of stream miles in developed or developing areas that support or could support salmonid spawning, rearing, or both. Recent research in Oregon agricultural streams in the Willamette Valley indicates that intermittent streams may support spawning and rearing of native fish (Colvin *et al.* 2009). Some small urban streams in western Oregon also support small salmonid populations (Friesen & Ward 1996; Hughes *et al.* 1998; Waite *et al.* 2008), but the distributions and sizes of such populations have not been rigorously evaluated.

Section 11.3: Needs Related to Stormwater Runoff

Determine the adequacy of methods currently implemented in Oregon for alleviating or mitigating the adverse effect of stormwater runoff (e.g., by increasing on-site retention) in both urban and rural-residential areas. Impervious surfaces such as roofs, roads, and parking areas rapidly deliver stormwater runoff to streams rather than allowing precipitation to infiltrate into the soil (Section 4.11 of this report). Low impact development methods have the goal of increasing on-site water retention that may better mimic natural hydrologic and vegetation patterns (Section 9.23 of this report). It would be useful for the State of Oregon to determine where and how often low impact development methods are implemented in Oregon's urban and rural-residential areas and their overall effectiveness in protecting Oregon's aquatic ecosystems. This need incorporates two sub-components.

- 1) **Assess the degree to which current technical methods that have been shown to be effective in increasing on-site water retention have been implemented by local development codes.** The implementation frequency of flow retention methods can likely be assessed by surveys of households and of city planning departments. A second tier of assessment could use field studies of paired sites to evaluate the effectiveness of such retention measures on local flow regimes.
- 2) **If methods increasing on-site water retention are not effective, or are not consistently implemented by local governments and residents, determine why.** Assuming that many urban and rural-residential properties lack flow retention measures, city planner and household surveys could indicate possible reasons. The reasons may include current and historical lack of awareness of the importance of storm flow retention for protecting natural stream structure and function, the initial economic costs of such measures, the notion that such features are not attractive, uncertainty concerning the cost-effectiveness of alternative retention methods, or the contrasting values of citizens (e.g., Lakoff 2002; Graham *et al.* 2009; Steel *et al.* 2010a)

Section 11.4: Needs Related to Groundwater

Assess future groundwater hydrologic responses to population pressures and the extent of groundwater contamination in Oregon's urban and rural-residential areas. Better knowledge of both groundwater hydrology and groundwater quality is needed. Further knowledge is needed concerning how groundwater quality, location and supply could be affected as population and economic pressures on groundwater increase. Knowledge needed includes better understanding of the connections between urban surface and groundwater hydrology, the effect of groundwater withdrawals on groundwater supply, and the current and potential effects of groundwater contamination from waste discharges and land use.

Toxic chemical mixtures from urban and rural-residential areas may leach into groundwater and the degree to which this happens and the potential consequences for aquatic ecosystems are unknown (see Section 11.6 for more needs related to toxic chemicals). The use of low impact development techniques to increase stormwater detention and soil infiltration (as well as the potential to inject surface water into dry wells which were not addressed in this report) create the

potential for increased groundwater contamination depending on the sources of the runoff. Further, there is a need to assess the extent to which present and historical landfill, industrial, and commercial facilities leach toxic chemicals into groundwater.

Section 11.5: Needs Related to Fish Passage Barriers

Determine the extent and number of physical fish passage barriers in urban and rural-residential areas, especially concerning prioritization of removal. Removal of fish passage barriers has been found to be an effective stream rehabilitation technique because barrier removal opens up habitat otherwise inaccessible to migratory fishes. Oregon Department of Transportation and the Oregon Department of Fish and Wildlife both have databases with information on fish passage barriers. Better integration of information on all existing barriers is needed in terms of how they are distributed and how they may be prioritized for removal.

Section 11.6: Needs Related to Toxic Chemicals

Determine the effects of, and possible treatment/remediation/elimination methods for, urban toxic substances and mixtures of toxic substances. Our current understanding of the role of the many varied toxic chemicals prevalent in urban and rural-residential areas is poor and needs much work. Generally, much needs to be learned both regarding conveyance systems of toxic chemicals in urban watersheds and regarding the aquatic chemistry and biological response of aquatic organisms to the cumulative and interactive effects of toxic chemicals. The known and potential ways in which toxic mixtures may impair aquatic ecosystems is summarized in Section 7.6 of this report; however, the individual and cumulative effects of toxic chemicals remain an area of major scientific uncertainty. Sewage and stormwater treatment systems already in use in Oregon and elsewhere do not remove many of the toxic chemicals of concern before treated water is discharged into the environment. The Oregon Department of Environmental Quality considers this issue a major concern because deleterious effects on aquatic organisms are often apparent despite sub-toxic concentrations of individual chemicals. Also, little is known how differences in water quality parameters, such as pH, hardness, and temperature, alter the cumulative chemical interactions and their effects on biota. This need incorporates 6 sub-components.

- 1) **Determine how, when, where, and how often to screen for and identify levels of contaminants and mixtures in aquatic ecosystems affected by urban and rural-residential developments.** Chemicals and their breakdown products are released to the environment on a daily basis from urban and rural-residential areas. These releases create a difficult and expensive monitoring challenge.
- 2) **Evaluate the ecologically relevant and chronic toxicities of a wide range of chemicals on salmonids, and compare those toxicities with those that may occur at the concentrations found in the aquatic environment.** If chronic toxicities (i.e., long-term toxicity of a substance in small, repeated doses) are known for pesticides, pharmaceuticals and personal care products, and other commonly used products, they can be compared against concentrations found in urban water bodies. It is likely that toxicities

of many of these chemicals, are unknown, and even more likely that the toxicities of mixtures are unknown. Given the large number of potentially toxic chemicals determining those present in low concentrations but with high frequency would be a priority over those that occur infrequently. Higher priority chemicals could then be evaluated for their endocrinological effects on salmonid physiology and potential consequences at the population level.

- 3) **Assess the degree to which cumulative and synergistic effects of commonly-occurring chemicals prevalent in urban areas alter salmonid behavior, reproduction, and mortality.** A combination of whole effluent chronic toxicity and early developmental tests can be used to evaluate salmonid growth, feeding, predator avoidance, parasite/disease loads, endocrine disrupting potential, and hormones. Acute tests will likely focus on juvenile salmonid mortality rates (USEPA 2002a).
- 4) **Assess the degree to which cumulative and synergistic effects of commonly-occurring urban chemicals alter salmonid-supporting food webs.** Research insights in this area may be best attained through use of experimental streams or model ecosystems (with underlying assumptions clearly identified) because of the complexity of potential interactions among predators, prey, and the food base (e.g., Warren & Davis 1971; Belanger 1997).
- 5) **Conduct research on the relative technical and economic feasibility of removing endocrine disrupting chemicals and other toxic chemicals from the waste stream through sewage and stormwater treatment and/or prohibitions on product sales.** Endocrine disrupters are viewed by some as a fundamental threat to the health and sustainability of salmonids and other aquatic vertebrates because they occur throughout our environment. Endocrine disrupters can affect vertebrate endocrine systems at very low doses. These effects can extend to vertebrate embryological development, juvenile development, general health (including immune system dysfunction and increased vulnerability to cancer) and reproductive fitness (either directly or indirectly) (e.g., Colborn *et al.* 1993, 1996; Hayes *et al.* 2006; Colborn 2009). Assays have been, and continue to be, developed for impairment of physiological systems by endocrine disrupting compounds; given the risks of these chemicals and the extent of their occurrence, however, it would be wise to consider ways of substantially reducing their presence in the environment as well as in salmonids.
- 6) **Determine the best available strategies for keeping toxic chemical from pesticides, herbicides, personal care products, pharmaceuticals, metals, and other anthropogenic-derived products out of surface and ground waters.** Given their widespread occurrence and the potential for toxic substances to impair salmonid and human health at extremely low concentrations, it is advisable that Oregon agencies review methods for eliminating these chemicals from use and waste streams. Research and monitoring resources might best be focused on the effectiveness of cost-effective and

scalable (i.e., from reach to basin-level) strategies to control and mitigate toxic contamination. A more thorough assessment of effectiveness would go beyond chemical analyses to include the perspective of biological condition.

Section 11.7: Needs Related to the Evaluation of Effectiveness of Policies and Regulations

Determine the strengths and areas for improvement of measures currently implemented in Oregon to avoid, remedy or mitigate the impact of urban and rural-residential development in headwaters, wetlands, riparian areas, floodplains, and key salmonid-watersheds. The State of Oregon leads the nation in comprehensive land use planning; however, as described in Section 9.0 of this report, much more can be done, especially regarding sensitive aquatic environments and the watersheds that dominate and buffer the flow regimes of urban streams. A review of current county and municipal land use plans and regulations could indicate the degree to which current laws, regulations and programs adequately remedy or mitigate the adverse impacts of development on watersheds and aquatic ecosystems (e.g., Ozawa & Yeakley 2007). This need incorporates four sub-components.

- 1) **Assess whether or not planning measures for protecting streams, wetlands, riparian areas, floodplains, and other sensitive areas are effective.** If current laws are written such that they could provide adequate protection to aquatic ecosystems, then the implementation consistency of protective measures can be assessed by studying the land use plans of local governments and completed projects to determine how frequently sensitive systems are protected. Assessment of these systems could be evaluated through remote sensing and field surveys.
- 2) **If planning measures are failing to mitigate or remedy the adverse effects of development or are inconsistently implemented, determine why.** If sensitive areas (e.g., water bodies, riparian areas, and unstable lands) within urban growth boundaries are not protected or incompletely protected, a survey of county and urban planners could indicate possible reasons. It also appears prudent to assess the long-term ecological effects and monetary costs associated with the implementation and lack of implementation of these measures. In other words, the effects of a “lack of action” may lead to long-term future costs that greatly outweigh costs associated with implementation of mitigation or remedial actions in the first place (NRC 1992; 2002).
- 3) **Assess the most cost-effective low impact development (LID) practices.** Research is needed to determine the effectiveness of major LID techniques for normalizing hydrological regimes and removing toxic chemicals from runoff. Washington State has eastside and west-side best management practices, reflecting the differing hydrologic regimes east and west of the Cascades. Evaluations would include the degree to which LID increases runoff retention and improves fish physical, chemical and biological habitat and fish species and assemblage condition. It also would be useful to study

whether LID can improve stream physical, chemical, and biological conditions relative to preexisting conditions (Brown *et al.* 2009).

- 4) **Determine how much low impact development (LID) is required in a developed watershed to protect aquatic ecosystems or to improve the condition of already affected streams, rivers and estuaries.** Evaluations are needed concerning whether LID structures in new developments regulated by the NPDES permitting system are sufficient for controlling stormwater and water pollution. Also in need of evaluation are the specific water quality parameters improved by specific forms of LID structures. If sufficient, strategies for integrating LID into existing development need to be determined. It would also be useful to consider assessing LID at site, development, and watershed scales. Here again, a more thorough evaluation of the effectiveness of practices would be evaluated from the perspective of the biological condition of receiving streams.

Section 11.8: Needs Related to Rehabilitation

Assess the effectiveness of efforts to rehabilitate streams in urban and rural-residential areas. A number of projects have been funded to rehabilitate urban streams in Oregon; however to our knowledge, none have been evaluated for their effectiveness in supporting salmonids (Section 10.0 of this report). This need incorporates three sub-components.

- 1) **Assess the effects of urban and rural-residential rehabilitation projects in Oregon on salmonids, aquatic assemblages, and aquatic physical and chemical habitat.** Depending on the number of projects and available funds, project effectiveness could be assessed through a census or survey of sites using a consistent site-scale design and a consistent set of indicators. Incorporating basin coordinators, municipalities and volunteer groups, as well as state and federal agencies, in this monitoring will increase the likelihood of successful salmonid rehabilitation.
- 2) **Evaluate the current technical and implementation processes and estimated costs of removing fish barriers.** Because urban areas are often located downstream of salmonid spawning and rearing streams and because urban areas typically have many barriers (e.g. barriers where roads cross streams), removing these barriers can be an effective way of reducing the effects of developed areas on salmonid production.
- 3) **Assess the ecological and economic costs and benefits that would likely result from rehabilitation efforts directed toward recovering salmonids in developed areas. Evaluate project costs and benefits for households as well as municipalities.** The cost to taxpayers and utility ratepayers is a frequent reason cited for resisting salmonid conservation and water quality improvement. But to IMST's knowledge there has been no rigorous evaluation of those costs, of the costs of incomplete and uncoordinated attempts to comply with state land use and federal ESA and CWA regulations, or of the ancillary benefits to other users and uses if naturally sustainable salmonid populations were attained.

Section 11.9: Needs Related to Communication and Citizen Science

Determine how to communicate science information more widely and effectively to the broadest possible audience via formats that go well beyond technical journal articles.

Citizen science spans a large spectrum, from individual citizens to non-governmental environmental research and management entities (e.g. non-profit organizations and watershed councils). Citizen groups offer the potential to extend the scope of environmental research and to produce a public that is more cognizant of environmental issues. New cross-discipline partnerships (e.g., social scientists, communication scientists, graphic artists, and print and electronic media journalists) are needed to expand the overall effectiveness and social context of citizen science efforts.

Intra- and inter-disciplinary communication on all research gaps is needed. It is critical that government bodies at all levels, including university and agency researchers, work together to ask, evaluate, and answer questions concerning watershed health and the rehabilitation of wildsamonids. While investigator independence and creativity will always be essential to conducting scientific studies, communication and transferability of study outcomes are enhanced by consistency of terminology, methods and indicators. Without consistent and spatially extensive study designs, sampling methods and indicators, the State of Oregon can invest considerable human and fiscal resources and learn little that can be inferred beyond each separate study. If some standardization of experimental designs, methods, and indicators are used by potential investigators and shared through common databases, much more can be learned for the same fiscal and human investments in our common future (e.g. Stranko *et al.* 2005; Paulsen *et al.* 2008; Brown *et al.* 2009; Mulvey *et al.* 2009). In other words, just as spatial and temporal fragmentation limit species richness, fragmented information and management practices limit knowledge and effectiveness.