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Climate Change and the Puget Sound: Building the Legal Framework for Adaptation

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Climate change and the Puget Sound: Building the legal framework for adaptation

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Abstract. Regardless of the efforts governments may take to mitigate the impacts of greenhouse gas emissions and other human activities on climate change, the need for society to adapt to climate change is unavoidable. Adapting to the myriad impacts of climate change will require actions at all levels of government. This article focuses on the anticipated impacts of climate change on the Puget Sound region in the northwestern United States as an example of the range of problems climate change will present and of the solutions available to governments and others interested in avoiding or minimizing the adverse impacts of climate change. As a guide for policy-makers, the article offers general principles for formulating climate change adaptation policies, suggestions for changes in decision-making processes that make them more suitable for addressing the unpredictable impacts of climate change, and strategies for adapting to three specific categories of climate change effects: impacts on the hydrologic cycle, sea-level rise, and altered meteorological conditions. The strategies and recommendations analysed in the article can provide a model for climate change adaptation policies, both in the Puget Sound region and more broadly, that are both environmentally protective and socially equitable.

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I. Introduction

The projected scope of climate change impacts is extraordinary, reaching every ecosystem on the planet and affecting human interactions with the natural and built environment. From increased surface and water temperatures to sea-level rise, climate change promises vast and profound alterations to our world. Yet the daunting scope and unpredictability of these impacts cannot become an excuse for paralysis and inaction. Although the focus has long been on mitigation, past and ongoing emissions guarantee certain changes, regardless of future reductions in emissions. Moreover, these changes are likely to last for at least a century or two, if not more. Thus, the need to adapt to a changing climate is crucial. The longer we wait to adopt a framework and laws for climate change adaptation, the more costly and painful the process will be.

Adapting to climate change will require actions at all levels of government. This article focuses on the anticipated impacts of climate change on the Puget Sound region in the northwestern United States as an example of the range of problems climate change will present and of the solutions available to governments and others interested in avoiding or minimizing its adverse impacts. As a guide to policy-makers at all levels of government, but particularly at the state, tribal, and local levels, the article offers general principles for formulating climate change adaptation policies, recommendations for changes in decision-making processes that reflect uncertainties about the precise location, timing, and extent of climate change impacts, and strategies for adapting to three important categories of climate change impacts: impacts on the hydrologic cycle, sea-level rise, and altered meteorological conditions. Policy-makers at the state, tribal, and local levels in Washington State have become leaders in addressing the effects of climate change, recognizing the need both to assess the likely impacts of climate change and to identify and implement adaptation strategies. Various state agencies, tribal governments, counties, and municipalities have already undertaken important adaptation actions. The state has conducted extensive studies on the impacts of climate change in the region and has assessed the vulnerabilities and basic capacity of the state to adapt to these impacts. With this information, Washington is in the early stages of identifying and assessing adaptation options to respond to the impacts that have already occurred and are expected to result from climate change.

Regardless of what path the federal government chooses to take in adapting to climate change, state agencies, public and private organizations, and grassroots advocates in Washington and other states have an opportunity to contribute to the development of climate change science, law, and policy by adopting and promoting adaptation strategies that are environmentally protective and socially equitable. This article identifies some of these strategies, identifies overarching themes for addressing major impacts, and lays the foundation for the future discussion, exploration, and implementation of environmentally protective, socially equitable, and innovative approaches to climate change adaptation. The article is not designed to reflect a comprehensive analysis of all anticipated climate change impacts, or of the legal tools needed to address them. Instead, it focuses on key principles for choosing adaptation strategies, selected examples of how existing law enables or foils adaptation, and new proposals to enable adaptation in a climate-altered world. The focus is on climate change impacts and solutions in the Puget Sound

region. We believe, however, that the analysis provides useful models for the identification and implementation of adaptation policies both for other locales facing similar problems and for addressing impacts different than those facing Puget Sound. In particular, the general principles for climate change adaptation policy and the descriptions of the roles that different levels of government and other interested stakeholders may play in dealing with climate change should be broadly applicable.

II. Climate Change Initiatives in Washington State

Climate change adaptation policy, like environmental policy generally, must be crafted on the basis of scientific knowledge that is applied within relevant legal frameworks. Washington's great advantages in planning for climate change adaptation are the active scientific community and the many assessments of the impacts of climate change it has produced. In 2009, the University of Washington's Climate Impacts Group (CIG) published an initial but fairly thorough report on climate change impacts on the state's major natural resources and economic sectors.[1] Washington also has a preliminary legal framework for climate change adaptation, which includes two executive orders that focus on mitigation by reducing state-wide greenhouse gas emissions and on adaptation within the Departments of Ecology and Health.[2]

State law also requires agencies to adopt an integrated climate change response strategy by December 2011 to help state and local agencies, public and private businesses, non-governmental organizations, and individuals to prepare for, address, and adapt to the impacts of climate change.[3] The strategy must address "the impact of and adaptation to climate change, as well as the regional capacity to undertake actions, existing ecosystem and resource management concerns, and health and economic risks".[4] Finally, the law encourages state agencies to prioritize the development of adaptation plans when planning or designing agency policies and programs. Agencies must consider this response strategy when developing infrastructure projects and must incorporate natural-resource adaptation actions and alternative energy sources when designing and planning infrastructure projects.[5]

Within the Puget Sound region, King County has been on the front lines of taking climate change adaptation actions and preparing the county for future adaptation efforts. To date, King County has acquired repetitive-loss properties and other at-risk properties in the floodplain and has invested in maintenance and repair of flood-control structures.[6] The county has also begun to

[1] *The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate*, The Climate Impacts Group University of Washington (June 2009) [hereinafter *CIG Report*].

[2] Wash. Exec. Order No. 07-02 (7 February 2007) and Wash. Exec. Order No. 09-05 (21 May 2009). Between 2005 and 2008, the state's GHG emissions increased by 3.4 per cent, and those emissions are expected to continue to increase, requiring additional policy responses in order to meet the state's reduction goals.

[3] Wash. Rev. Code § 43.21M.010.

[4] Wash. Rev. Code § 43.21M.020.

[5] Wash. Rev. Code § 43.21M.040.

[6] *King County 2009 Climate Report*, Interdepartmental Climate Team (1 February 2010).

assess climate impacts on the built infrastructure and on public health. Nearby, the Swinomish Indian Tribal Community has also begun planning for climate change impacts, which may alter not only their natural environment but also their very sense of cultural identity that is closely tied to the historical abundance of shellfish, salmon, and other natural resources. In 2010, the Tribe released its *Climate Adaptation Action Plan*, which identifies specific and unique impacts on the tribal members and resources and outlines specific actions for addressing these impacts, such as establishing incentives for relocation away from high-risk flood plains.[7] These efforts provide a foundation on which a set of effective climate change adaptation policies can be built.

III. Framework and Principles of Adaptation

The mainstream discussion of climate change has long focused on *mitigation*—that is, what humans can do to reduce the emissions of, or increase the sinks for, greenhouse gases.[8] More recently, however, discussion of *adaptation* has been added to the policy mix. After describing the challenges posed by, and the need to adapt to, climate change, this part describes fundamental principles that adaptation policy should reflect.

1. What is Adaptation?

Adaptation is defined by the IPCC as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects".[9] The goal of adaptation efforts is to lessen the magnitude of these impacts on humans and the natural environment through proactive or pre-planned actions. As the IPCC said, "Mitigation will always be required to avoid 'dangerous' and irreversible changes to the climate system. Irrespective of the scale of mitigation measures that are implemented in the next ten to twenty years, adaptation measures will still be required due to inertia in the climate system".[10]

Despite the overwhelming consensus on certain effects from climate change, the process of climate change adaptation presents a number of difficult challenges. From a scientific and technical perspective, the location and extent of climate change impacts are extremely uncertain. For example, climate models generally agree that climate change will impact the water cycle, but the exact impacts may be very different in western and eastern Washington. Models, moreover, cannot precisely predict specific events, such as floods or droughts. Climate change also undermines the reliability of historical data in predicting future phenomena such as extreme weather events. Incorporating this uncertainty into adaptation planning is crucial, but inherently difficult, because the extent and timing of these impacts remain unknown.

[7] *Swinomish Climate Change Initiative: Climate Adaptation Action Plan*, Swinomish Indian Tribal Community, Office of Planning and Community Development, at 37 (October 2010) [hereinafter *Swinomish Action Plan*].

[8] IPCC, Climate Change 2007: Mitigation of Climate Change 818 (B. Metz et al., eds., 2007) [hereinafter *IPCC Mitigation Report*].

[9] IPCC, Climate Change 2007: Impacts, Adaptation and Vulnerability 6 (M. L. Parry et al., eds., 2007) [hereinafter *IPCC Adaptation Report*].

[10] *IPCC Mitigation Report*, *supra* note 8, at 101.

Institutionally, the existing fragmentation of authority at the federal and state government levels to manage natural resources may impair development of a holistic approach to climate change adaptation.[11] For example, water resources management may involve federal agencies like the US Environmental Protection Agency, the US Fish and Wildlife Service, and the US Army Corps of Engineers, state agencies like the Washington Department of Ecology, and local governments that design comprehensive land-use plans. In addition, adaptation efforts, much like mitigation efforts, may suffer from a lack of long-term funding and, at times, a lack of political will to support the necessary changes. Thus, successful climate change adaptation will depend upon public education and outreach and strong advocacy efforts by community organizations, which must be independent of, and yet occur simultaneously with, the adoption and use of legal mechanisms that support adaptation.

Despite these obstacles, focusing on adaptation is imperative because of what scientists call the "inertia" of the climate. Regardless of any future reduction in emissions, past and current emissions have set into motion a series of changes that will very likely occur because of the long-lived nature of carbon dioxide and other greenhouse gases and the absorption of heat by the oceans.[12] Existing environmental and natural resource management laws tend to equip agencies with the tools to address only the variations that fall into a mostly predictable and limited range based on historical records. Climate change upends this legal paradigm because of the unprecedented nature of the changes it has begun to induce, leading scientists and scholars to look for a new policy-making paradigm.[13] In addition, non-climatic factors such as demographic changes and population growth, invasive species, and habitat degradation may further exacerbate the impacts of climate change or create destructive feedback loops.

2. Foundations of the Adaptation Framework

The overarching goal of adaptation should be to adopt and employ the most environmentally protective and socially equitable policies. Several principles are critical to achieving this goal. First, policy-makers must truly acknowledge and accept the uncertainty associated with climate change impacts. The strength of climate models is their ability to predict general trends in average surface temperature, sea-level rise, or other global impacts. However, regional or local models are unable to predict the precise extent of these impacts at localized scales, which are more useful for planning. Although the ability to downscale climate impacts is improving, uncertainty surrounding the precise impacts should be acknowledged and accommodated through scenario-based planning and other tools discussed below, rather than used as an excuse for inaction. Once

[11] Alejandro Camacho, *Adapting Governance to Climate Change: Managing Uncertainty through a Learning Infrastructure*, 59 Emory L.J. 1, at 26-7 (2009).

[12] *Progress Report of the Interagency Climate Change Adaptation Task Force: Recommended Actions in Support of a National Climate Change Adaptation Strategy*, White House Council on Environmental Quality, at 15 (5 October 2010).

[13] See Robin Kundis Craig, *Stationarity is Dead! Long Live Transformation: Five Principles for Climate Change Adaptation Law*, 34 Harv. Envtl. L. Rev. 1 (2010).

uncertainty is acknowledged, it becomes important to collect as much information and data as possible and to conduct vulnerability assessments and mapping.

Policy-makers must also take steps to increase the resilience of natural systems and human communities. The IPCC defines "resilience" as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.[14] An important way to increase the resilience of natural systems is to remove to the extent possible existing stressors such as invasive species and air and water pollution. For human communities, increasing resilience may include improving public health or socio-economic conditions before a disturbance occurs and ensuring access to rebuilding resources after a disturbance.

In selecting adaptation strategies, policy-makers should rely as much as possible on natural infrastructure. Ecosystems provide natural buffers against variations in climate and meteorological activity, and this natural or green infrastructure should be incorporated into any overall climate change adaptation strategy. Green infrastructure prolongs the natural ecosystem, whereas grey and other human-made infrastructure often destroy natural buffers. In many places, however, human development and encroachment have permanently eliminated this capacity or rendered the ecosystem much less resilient. Where possible, climate change adaptation strategies should use the natural buffering capacity of forests, shorelines, and wetlands to absorb the impacts of climate change, whether by designating protected areas, restoring natural features, or removing existing stressors.[15]

Adaptation strategies should also strive to achieve an equitable allocation of the burdens of climate change and reduce personal and community vulnerability. Climate change impacts, akin to natural disasters, are likely to highlight social and economic fractures by disproportionately affecting vulnerable groups, such as low-income populations or racial minorities. Although disasters appear to be "social equalisers" that are blind to race, creed, and colour, long-term recovery efforts are nearly always accompanied by patterns of unfair social distribution.[16] Thus, some communities will be subject to more danger and hardship than others, creating obvious social injustice and less obvious social wedges that inhibit recovery efforts.[17] A first step in promoting social equity, therefore, is to dispel the notion that disasters such as those related to climate change will necessarily affect all segments of the community equally. As Robert Verchick notes, "Catastrophe is bad for everyone. But it is especially bad for the weak and disenfranchised".[18]

[14] *IPCC Mitigation Report*, *supra* note 8, at 818.

[15] See Craig, *supra* note 13, at 39.

[16] Robert R.M. Verchick, Facing Catastrophe: Environmental Action for a Post-Katrina World 107 (Harvard Univ. Press 2010).

[17] Ibid.

[18] Ibid., at 106.

Effective adaptation strategies should anticipate the effects of climate change and take a preventive approach to dealing with them. Adaptation strategies can be either *proactive* or *reactive*. Proactive strategies are designed to reduce future harms before those harms occur. In contrast, reactive strategies are contemporaneous responses to observed climate change impacts, typically through emergency and disaster response.[19] This wait-and-see approach is generally perceived as inefficient and unsuccessful in addressing irreversible damage, though it may be appropriate for some climate-related impacts that are highly uncertain and difficult to anticipate.[20] While designing proactive strategies may be information-limited, these strategies allow decision-makers to assess baseline capacities, fill gaps, and consider major impacts before they occur.

Similarly, policy-makers should incorporate longer-term temporal scales into their planning efforts. Because the impacts of climate change are likely to occur over several decades, if not centuries, adaptation planning must extend over an equivalent timeframe. The exact timeframe will vary from sector to sector but should generally encompass the lifespan of the proposed action.

Planning at an early stage allows policy-makers to select "win-win" strategies that provide multiple benefits for other sectors and for climate change mitigation. Adaptation approaches have been described as "low regrets", "no regrets", or "win-win".[21] "Low regrets" actions result from moderate additional investments in planned projects to increase the ability to adapt to climate change impacts.[22] "No regrets" actions provide benefits regardless of whether or not a projected climate change impact occurs. These actions, for example, address non-climatic driven changes but, if climate impacts occur, provide additional adaptation benefits. Finally, "win-win" strategies reduce the magnitude of a particular impact and also provide additional environmental, social, or economic benefits.[23] Restoring or preserving coastal wetlands would buffer inland areas from sea-level rise while also generating environmental and economic benefits through recreation and tourism. Some adaptation strategies, such as reforestation, may also benefit mitigation efforts.

As a complementary principle, policy-makers should avoid maladaptive actions. The IPCC defines "mal-adaptation" as an action that increases vulnerability to the impacts of climate change.[24] These actions tend to deliver short-term gains or economic benefits but lead to increased vulnerability in the medium- to long-term and may foreclose future adaptation options or have negative impacts on mitigation efforts. Sea walls may provide temporary protection for coastal development, for example, but they lead to complete erosion of the shoreline and thus

[19] J. B. Ruhl, *Climate Change Adaptation and the Structural Transformation of Environmental Law*, 40 Envtl. L. 363, at 383 (2010).
[20] Ibid.
[21] *CIG Report*, *supra* note 1, at 393.
[22] Ibid.
[23] Ibid.
[24] IPCC, Climate Change 2001: Impacts, Adaptation and Vulnerability 990 (James M. McCarthy et al., eds., 2001).

foreclose the ability to restore the shoreline as a natural buffer. Policy-makers should identify and deliberately avoid these maladaptive strategies.

Finally, recognizing that the current and future political and economic situation in the United States, and many other countries, may not be favourable for passing new legislation or financing new programs, the adaptation framework discussed here emphasizes the use of existing legislation and legal tools to achieve adaptation goals where possible. Some existing laws simply need better, stronger, and more consistent enforcement, whereas others require some reinterpretation or stronger emphasis on overlooked provisions. Where these laws do not adequately address adaptation, this article proposes new solutions.

3. Summary

By using these principles to adopt and implement climate change adaptation strategies, policy-makers and advocates can maximize the likelihood that adaptation actions will be both effective and equitable. Building on this basic framework, the remainder of this article focuses first on the procedural strategies to address climate change adaptation and then discusses some specific impacts of climate change, the sectors that will be affected by each such set of impacts, and substantive adaptation strategies.

IV. Overarching Considerations for the Legal Framework

The impacts of climate change present a fundamentally new problem for the United States, confounding the existing paradigm of environmental laws that environmental changes will occur gradually over a relatively long period. The projected scope of climate change impacts will erode the natural resiliency of many ecosystems and make them more vulnerable to both anthropogenic and natural disturbances. These impacts are expected to occur on an accelerated, unpredictable timeline that will make accommodation to the impacts extremely difficult, if not impossible, for many ecosystems and species. The uncertainty in predicting the timing, scale, and location of adverse climate change impacts arises from the complex and non-linear interactions among the factors that influence climate.

How can governments act in the face of such great uncertainty, and what overarching features of law might be useful in accommodating and managing uncertainty? Alejandro Camacho and others suggest using *procedural* strategies to allow governments to simultaneously deal with uncertainty and move forward on necessary adaptation measures.[25] Substantive strategies, addressed in Parts V to VII of this article, respond directly to the effects of climate change by, for example, using building codes to address sea-level rise or water law to ensure adequate water supplies for the environment. The procedural strategies discussed in this part focus on the decision-making process and can both help manage the uncertainty surrounding the effects of climate change and maximize the efficacy of substantive adaptation responses. For example,

[25] Camacho, *supra* note 11, at 25.

an adaptive approach to managing a species affected by climate change would allow resource managers to make immediate management decisions and then reevaluate those decisions as climate change impacts occur. Procedural strategies that disseminate information and encourage widespread participation may also increase the willingness to act in the face of uncertainty.[26]

This part first discusses the impact of climate change on the legal infrastructure and proposes features that build flexibility and resilience into the legal process to better address uncertainties. It then touches on new decision-making strategies that will facilitate effective responses to climate change despite uncertainty. Ultimately, in light of the inevitable uncertainty climate change presents, developing and implementing adaptive procedural strategies may be the best precautionary actions that communities in Washington and around the world can take right now.

1. Establishing Principled Flexibility

In the face of climate change, many existing environmental laws premised on a stable environment will prove ineffective as currently interpreted and applied. If natural systems become more dynamic and baseline conditions change, the US Endangered Species Act of 1973 will be unable to protect species, and existing water rights will be unable to allocate water effectively. The law itself will need to become more flexible and adaptive in the face of climate change. Although other areas of law such as energy, national security, or immigration may become increasingly pressing drivers of climate change adaptation, the existing environmental laws and legal structures are likely to remain in the spotlight.[27] To maximize responsiveness to climate change impacts, it is important to consider how these laws can incorporate flexibility and thus manage uncertainty.

A. Features of Principled Flexibility

Traditional environmental laws are based on concepts of preservation and restoration and tend to assume stationarity—that natural systems fluctuate but within a bounded, predictable range.[28] These laws seek to restore natural systems to a selected baseline, usually by reference to historical data or levels.[29] For example, the US Clean Water Act contains an anti-degradation provision that requires states to maintain existing water quality, but that goal may become unachievable in the future as a result of the impacts from climate change. The projected impacts from climate change will upend environmental laws premised on the concept of stationarity, increasing the discrepancy between the overwhelming need to respond to climate change impacts and the limited ability of environmental law to respond to this need.

The flexibility needed in climate change adaptation laws must, as Robin Kundis Craig proposes, involve principled flexibility, meaning that flexibility should not translate into open-ended

[26] Ibid.

[27] See Ruhl, *supra* note 19.

[28] Craig, *supra* note 13, at 9.

[29] See J. B. Ruhl and James Salzman, *Gaming the Past: The Theory and Practice of Historic Baselines in the Administrative State*, 64 Vand. L. Rev. 1 (2011).

discretion to do nothing or to deviate materially from the overarching regulatory and management goals.[30] Rather, flexibility needs to be accompanied by measures to hold policy-makers accountable for acting. Communities should be required to develop adaptation strategies but should have the flexibility to decide how to select and tailor these strategies to local circumstances.

Incorporating this concept of principled flexibility into particular laws could include elements such as planning, scenario planning, triggering mechanisms or benchmarks, periodic review of adaptation actions, and redundancy. For example, planning is a key tool in responding to climate change impacts. Planning for available options before a disaster or emergency situation occurs will likely reduce the chaos of post-disaster recovery, when the rush to provide assistance may ignore crucial needs or prevent public participation. Washington law requires local governments to plan for future growth under both the Growth Management Act and the Shoreline Management Act, and communities should fully consider pre- and post-disaster adaptation strategies in these plans.

Plans should also account for a variety of scenarios to integrate scientific considerations into the policy-making process. Scenario planning can capture uncertainties by establishing the likelihood or probability of a given impact. Using quantitative and qualitative models, scenario planning can help policy-makers visualize future outcomes based on various decisions, policies, or societal pathways.[31] The scenarios should include a worst-case outcome and not focus exclusively on the most likely outcome.[32] Akin to adaptive management, scenario planning identifies key uncertainties and allows decision-makers to explore those uncertainties, understand their implications, act, and monitor the outcomes.[33] Under Washington law, state agencies are already required to include a "range of scenarios for the purposes of planning ... to assess project vulnerability and, to the extent feasible, reduce expected risks and increase resiliency to the impacts of climate change".[34]

Another mechanism for establishing principled flexibility is to set thresholds or benchmarks that, if reached, trigger a pre-determined course of action. Unbounded flexibility creates a risk that agencies will abuse their discretion by failing to act when necessary. Triggers promote accountability by forcing agency action at specific times or occurrences. For example, property severely damaged or destroyed by flooding in a certain number of years could trigger a no-rebuild provision, or disqualify the property owner from participating in publicly subsidised flood insurance. These benchmarks could also trigger a different decision-making scheme that is detailed in advance. This element is particularly relevant in the adaptive management context, discussed below.

[30] Craig, *supra* note 13, at 17.

[31] Leigh Welling, *A Tool for Decision-Making in an Era of Uncertainty*, National Park Service Climate Change Response Program (December 2010).

[32] Daniel Farber, *The Challenge of Climate Adaptation: Assessing Current Planning and the Need for Action-Forcing Requirements*, 23 J. Envt'l L. (forthcoming August 2011).

[33] Ibid.

[34] Wash. Rev. Code § 43.21M.020.

Flexibility in the adaptation context will also require the ability to review and adjust strategies as climate change impacts occur. Current US environmental laws, such as the National Environmental Policy Act (NEPA) and the Clean Air Act (CAA), depend heavily on predictions and standards made as a part of an initial determination, such as the environmental assessment required by NEPA, or based on historical data, such as attainment status under the CAA. Introducing follow-up mechanisms or requiring periodic review and revision of decisions to incorporate new information or data will unbuckle environmental laws from this front-loaded process, allowing management adjustments to tailor decision-making to changing and realistic conditions.[35] Similarly, climate change strategies should include a certain amount of redundancy or back-up options in case primary strategies are ultimately ineffective or overwhelmed by the scope of the impact.

The uncertainty of climate change impacts can provide a superficial excuse for delaying action, particularly when policy-makers face tough political situations or economic constraints. Because these features of law provide workable mechanisms for managing uncertainty, the existence of uncertainty will become a less compelling justification for inaction.

B. Adaptive Management

The concept of adaptive management illustrates many of the features of principled flexibility. In the climate change adaptation context, adaptive management is appealing because it specifically recognizes the uncertainty of climate change impacts but provides a structured approach to addressing and attempting to reduce this uncertainty. By applying the process of scientific inquiry to a natural-resources management problem, adaptive management can reduce uncertainty and generate new knowledge and information. It requires resource managers to design management actions as scientific experiments, monitor the outcomes, and adjust the management actions depending on the outcomes produced by the experiments. When designed and implemented correctly, adaptive management can provide the principled flexibility necessary to accompany adaptation strategies for managing natural resources.

Although the definitions of adaptive management differ, the term generally includes four elements: (1) the articulation of clear goals and measurable indicators of progress toward achieving those goals; (2) an iterative approach to making decisions and the opportunity to adjust strategies; (3) the continual monitoring of outcomes and impacts; and (4) the explicit acknowledgement and characterization of risks and uncertainties.[36] Adaptive management is well suited for natural resource management problems affected by climate change because they are inherently dynamic and often poorly understood. These problems will benefit most from the deliberate learning generated by adaptive management.

[35] J. B. Ruhl, *General Design Principles for Resilience and Adaptive Capacity in Legal Systems: Applications to Climate Change Adaptation Law*, 89 N.C.L. Rev. 1373, 1396 (2011). See also Robert L. Glicksman and Sidney A. Shapiro, *Improving Regulation Through Incremental Adjustment*, 52 Kan. L. Rev. 1179 (2004).

[36] Holly Doremus et al., *Making Good Use of Adaptive Management* 2, CPR White Paper Pub. No. 1104 (April 2011) [hereinafter *Adaptive Management*].

However, the widespread application of adaptive management may reflect hope rather than reality. Holly Doremus notes that documented instances of successful adaptive management are rare, and in practice natural-resources managers have not exhibited sufficient adherence to the principles of this approach.[37] Agency cultures and funding structures often pose barriers to the learning component. In addition, adaptive management can provide cover for agencies to avoid politically controversial limits on economic activity through the open-ended or vague promise of future action after more knowledge is accumulated.[38]

In determining whether adaptive management is the best strategy, resource managers should carefully assess whether it suits a natural-resources problem. Adaptive management is not a panacea for all resource-management problems, such as those limited to a single decision point. At the outset, resource managers should carefully assess whether a particular problem has the requisite elements and can benefit from this approach: (1) information gaps exist, leading to (2) good prospects for learning and (3) opportunities for adjusting the management strategy after new information is acquired.[39] For natural resources affected by climate change, these prerequisites are likely to be met.

Once adaptive management is selected, resource managers must ensure accountability and enforceability for acting on the new knowledge generated through the adaptive management process. As noted earlier, adaptive management can provide cover for delayed agency action or even inaction, particularly in high-profile or controversial situations. Thus, agencies should set clear benchmarks or trigger points—such as the sea level reaching a given point—for further action or incorporation of new information. Mandatory actions under the management plan should also be enforceable by interested citizens.[40]

The management plan should be designed to elicit new information about the natural resource or otherwise promote directed learning. At the outset, resource managers should identify the needed data and articulate the ways that the data, once collected, will be useful and used.[41] For example, forest managers could design experiments to test the effects of climate-induced increased temperatures, or burning frequency, on forest regeneration, and apply the results to forestry management.

Finally, the adaptive management approach must be sufficiently funded with dedicated, guaranteed resources. Properly implemented, adaptive management requires more resources than conventional management strategies, particularly when used to address the long-term impacts of climate change. It involves technical and scientific resources to conduct monitoring, and

[37] Ibid. at 1. See also Holly Doremus, *Adaptive Management as an Information Problem*, 89 N.C.L. Rev. 1455 (2011).
[38] *Adaptive Management*, supra note 36, at 1.
[39] Doremus, *supra* note 37, at 1467-77.
[40] *Adaptive Management*, supra note 36, at 11.
[41] Ibid., at 12.

personnel resources to analyse the results, and can thus be quite expensive to implement.[42] Policy-makers committed to adaptive management should provide sufficient resources to give the approach an opportunity to work as intended.

2. Reallocating Decision-Making Authority

Climate change also will require flexibility and fluidity in the decision-making processes within and among agencies that manage natural resources. The boundaries of traditional jurisdiction will be stretched, if not wholly reconfigured, by climate change impacts, requiring discussions now about how governments and agencies will operate and how to allocate authority in a new climate. Climate change adaptation requires a fluid decision-making process that incorporates public participation, collaboration among differing interests, decentralization of governance structures, and integration of policy across different sectors.[43]

A. Recalibrate the Allocation of Traditional Authority

Because the acute impacts of climate change will manifest locally, states and local governments should naturally exercise significant control over developing and implementing adaptation strategies. Governments operate on both vertical and horizontal planes. The vertical planes represent the hierarchical nature of government, from the federal, tribal, and state levels down to the municipal level. The horizontal plane represents the network of agencies that work at the same level of government, such as the state departments of environment, health, and transportation. In many of the areas that are key to adaptation—water policy and land-use planning, for example—federal, state, tribal, and local governments have traditionally had distinct and largely separate jurisdiction.

As communities in the Puget Sound and Washington and the federal government consider climate change adaptation strategies, they should reexamine the allocation of authority in a way that does not rely solely on traditional, sector-by-sector divisions of power and jurisdiction. Different levels of government should exercise their authority to best meet adaptation needs without ignoring the wider public interest of neighbouring counties or states, or of the United States as a collective. Under this framework, attempts to ignore this broad public interest may invite displacement of authority by the federal or state government, regardless of traditional spheres of jurisdiction.

For example, if the response or adaptation strategy of a local government adequately addresses the relevant climate change impact and does not cause negative impacts to a neighbouring municipality or tribal reservation, state government involvement should be secondary, perhaps limited to gathering and distributing information and financial resources. Similarly, the federal government may harmonize adaptation responses to prevent states from acting in conflict with other states'

[42] Ibid., at 13.
[43] Ruhl, *Resilience*, *supra* note 35, at 1397.

or Tribes' interests or to establish processes that facilitate inter-jurisdictional communication and planning.

State or local adaptation strategies that ignore or harm the public interest may require more involvement by higher levels of government.[44] For example, an upstream region in an interstate watershed may decide against enacting water conservation measures despite climate-induced changes to the water supply, reducing the amount of water available to downstream regions. Uniform state-wide standards for conservation may be appropriate to prevent this kind of harm. Such a uniform "floor" can also help counter the free-rider effect—that is, the risk that some counties or cities will fail to act, relying instead on benefitting from adaptation strategies adopted by others.

The strongest role for the federal or state government—complete displacement of lower-level government regulations—is appropriate only when individual, overzealous, state or local regulations are unlikely to produce the optimal result from a collective perspective due to divergent incentives and interests, thereby harming the public interest.[45] For example, a state could decide to construct canals to block salt water intrusion from sea-level rise within its jurisdiction even though the canals fragment important habitat or drain wetlands, with adverse environmental consequences in other states. The federal government may step in to prevent these negative environmental consequences. A stronger role would also be appropriate if local adaptation strategies created either too much variation or unequal footing among states. Robert L. Glicksman suggests that this situation may justify uniform rules for interstate water transfers to prevent states from adopting laws to hoard scarce water supplies.[46]

B. Integrate Decision-making Vertically and Horizontally Among Agencies and Institutions

State and local governments have a significant role to play in implementing and supplementing federally established policies. In addition, responsibility to address particular environmental problems is often dispersed among multiple agencies at the same governmental level. This kind of dispersed decision-making authority has many benefits, including enhancing public participation and facilitating experimentation by different government actors. To maximize synergies and avoid the risk of uncoordinated decisions and conflicting policies and authority, however, relevant government agencies and non-governmental organizations should engage in coordinated and, where appropriate, collaborative adaptation-planning efforts.

C. Build Trans-governmental Networks Among Agency Personnel

Strengthening the relationships among individuals at various government agencies will help promote the flow of information among agencies. This information exchange will produce decisions

[44] Robert L. Glicksman, *Climate Change Adaptation: A Collective Action Perspective on Federalism Considerations*, 40 Envtl. L. 1159, 1183 (2010).
[45] Ibid., at 1191.
[46] Ibid., at 1189.

that are better informed and consider a range of multi-sector impacts and influences.[47] While these interpersonal networks do not have the authority to pass legislation or dictate policy, they can more adeptly transfer information, confer about trends, and identify potential obstacles to adaptation strategies.[48] For example, public-health officials could discuss transportation and siting decisions with transportation and land-use officials to coordinate the health response in an emergency situation and to consider new joint initiatives across their respective agencies or institutions.

3. Conclusion

The impacts of climate change are not limited to the human and natural environment. Climate change will test the resilience and flexibility of the law itself, raising serious questions about the current legal framework and governance structure to address the profound changes in natural-resources management and response. Deliberately incorporating processes such as adaptive management can address the inherent uncertainties associated with climate impacts and will improve the resiliency of both the law and the human and natural environments under its protection. Building principled flexibility into the existing law is a necessity, and transforming the governance space into a fluid, dynamic web will help communities better respond to climate change.

Even if policy-makers change the processes for making decisions that allow society to adapt to the impacts of climate change, they will face significant challenges in designing and implementing effective substantive responses to new problems, or to old problems whose pace or scope has changed. The remainder of this article discusses, by way of example, substantive climate change adaptation strategies that focus on three of the impacts most likely to be significant in the Puget Sound region: changes to the hydrologic cycle, sea-level rise, and increased average temperatures and extreme weather events.

V. Changes to the Hydrologic Cycle

The Pacific Northwest and the Puget Sound Basin are famous for their verdant, lush landscape, a result of ample precipitation throughout much of the year. Because water plays such a central role in shaping human communities and ecosystems across the Sound, the impacts of climate change on the hydrologic cycle will be significant. The most perceptible and dramatic long-term impact will likely be a shift in the timing of the hydrologic cycle.[49] While this shift may not significantly affect water supplies for human uses, it may be disastrous for salmon and other aquatic ecosystems. Because humans interact with these resources, they too will be affected. This part identifies the major impacts to the hydrologic cycle on water availability and aquatic

[47] Ruhl, *Resilience*, supra note 35, at 107–8, and idem, *Climate Change, Dead Zones, and Massive Problems in the Administrative State: A Guide for Whittling Away*, 98 Calif. L. Rev. 59 (2010).

[48] Ruhl, *Massive Problems*, *supra* note 47, at 108.

[49] *CIG Report*, *supra* note 1, at 86.

habitat and discusses general principles for adaptation strategies. It also identifies specific legal tools for climate change adaptation.

1. Climate Change, the Shifting Hydrologic Cycle, and the Puget Sound Basin

The Puget Sound basin drains nearly 30,000 square kilometres of land, ranging from sea level to the Cascade Mountains in the east and to the Olympic Mountains in the west. The basin is home to nearly seventy per cent of Washington's population. Historically, precipitation patterns range from sixty millimetres to more than three thousand annually; most of the precipitation occurs between October and March.[50] Many of the major rivers in Washington drain into the Sound, including rivers that are the primary sources of drinking water for residents in the metropolitan areas of Seattle, Tacoma, and Everett: the Cedar, Green, Tolt, and Sultan.[51]

The Puget Sound area is a transient basin, meaning that the drainage is a mix of rain and snow with a characteristic biannual peak runoff for both snowmelt and precipitation. Snow accumulation acts as a natural reservoir, releasing water as the seasons change. According to the Climate Impacts Group, modelling shows a consistent shift in the hydrograph towards higher runoff during the cool season and lower runoff during the warm season. This shift could ultimately lead to a single peak runoff as a result of precipitation increasingly falling as rain rather than snow. Snowmelt may also occur earlier and faster.

The 2009 CIG report concludes that for the Puget Sound, the "primary hydrologic manifestation of climate change... will be the decline and eventual disappearance on average of the springtime snowmelt hydrograph peak, and its replacement with an elevated winter runoff peak".[52] Figure 1 below shows a gradual shift in water runoff for the Cedar River between 2000 and 2075. Most notably, the peak flow rate changes from two peaks in December and May in 2000 to a single peak in January 2075.

Analysis of water security for human consumption in light of this climate-change-induced impact indicates that water availability will remain relatively stable for the major metropolitan areas in Puget Sound basin, which have in the past benefitted from strong conservation measures and an overall decrease in demand despite population growth.[53]

For the iconic but dwindling salmon populations, however, the changes in timing could be devastating, with ripple effects for the many Native American Tribes that depend on salmon and have rights to take salmon according to treaties with the United States. The waters in and around Puget Sound provide migration routes and breeding grounds for many species of salmon and trout, which spend parts of their lives in both fresh and marine waters. Already the destruction

[50] Ibid., at 82.

[51] Some of these major rivers include: the Nooksack, Samish, Skagit, Stillaguamish, Snohomish, Cedar, Green/Duwamish, Puyallup, Nisqually, Deschutes, Skykomish, Dosewallips, Dungeness, and Elwha Rivers.

[52] *CIG Report*, *supra* note 1, at 128.

[53] Ibid., at 120.

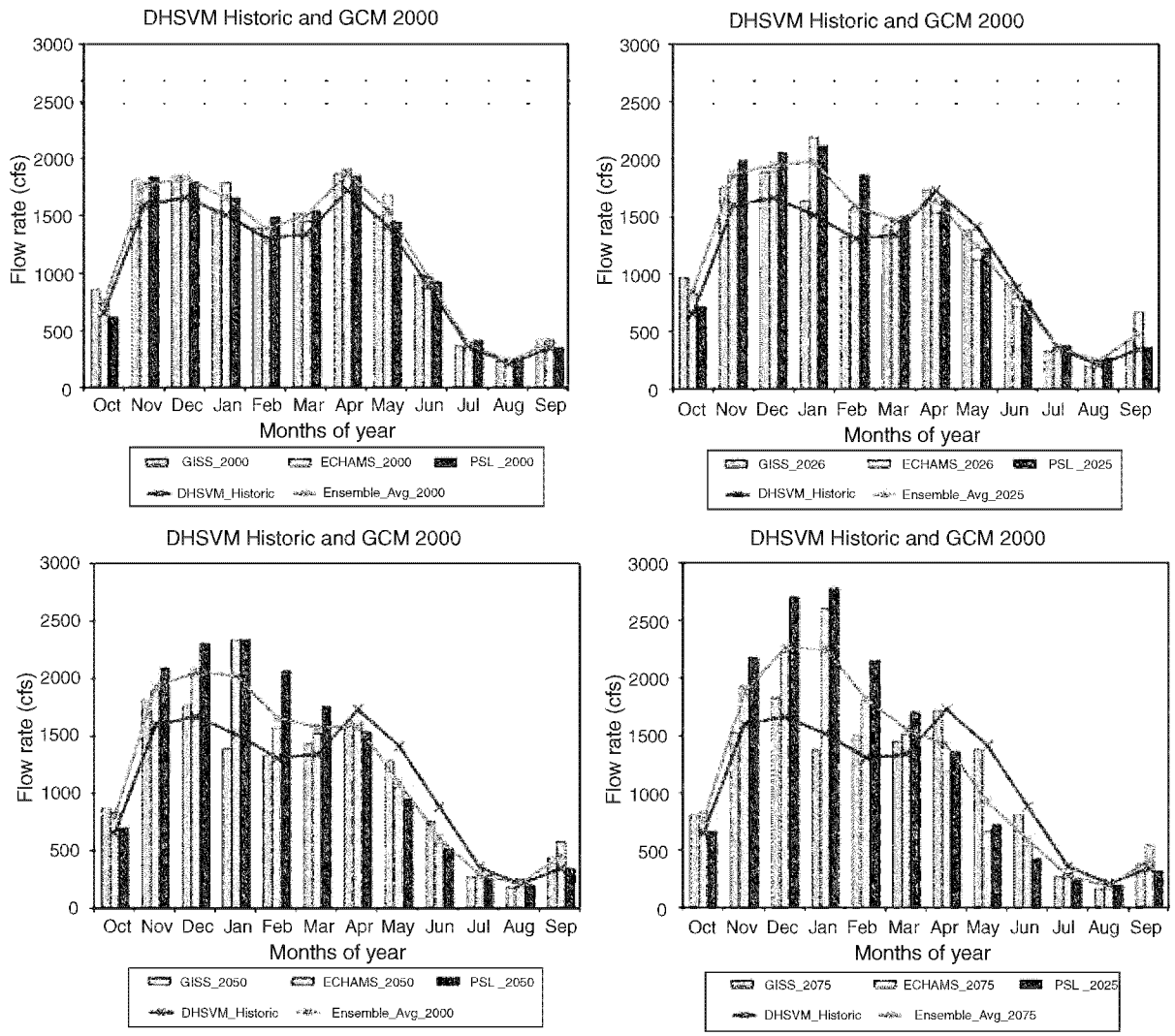

Fig. 1. Hydrographs of the Cedar River projecting the convergence of runoff peaks by 2075. (A. Polebitski, L. Traynham, and R. N. Palmer, Climate Change Technical Subcommittee of the Regional Water Supply Planning Process, *Technical Memorandum no. 5: Approach for Developing Climate Impacted Streamflow Data and its Quality Assurance/Quality Control*, at 41 (13 December 2007)).

of wetlands and estuaries by human activities has jeopardized the habitats and breeding grounds of these fish (Fig. 2). Evidence of climate change impacts on the marine environment, such as current marine patterns and ocean acidification, will likely further harm anadromous fish species.[54]

[54] For more on the impact of ocean-atmosphere climate on salmon, see N. J. Mantua et al., *A Pacific Interdecadal Climate Oscillation with Impacts on Salmon Production*, 78 Bulletin of the Am. Meteorological Soc'y 1069 (1997); US Fish and Wildlife Service, "Salmon Research and Climate Change", available at <http://www.fws.gov/endangered/news/bulletin-summer2009/salmon-research-and-climate-change.html> (last visited April 12, 2011).

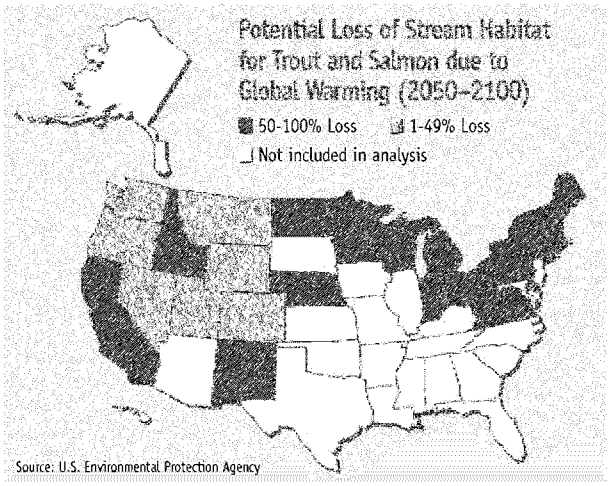

Fig. 2. Map of potential cold-water stream habitat loss due to climate change. (*Ecological Impacts from Climate Change: An Economic Analysis of Freshwater Recreational Fishing*, US Environmental Protection Agency, Pub. No. 220-R-95-004 (April 1995)).

Flow rates are themselves critically important to the timing of salmon runs, during which smolts migrate out to sea and adults return to freshwater to spawn. In addition, flow rates affect water temperature, and water temperature affects salmon at every stage of development, although the specific sensitivities depend on the species and stock-specific adaptations to local conditions. Cold-water fish species in Montana, for example, are already feeling these temperature impacts.[55] For species classified as "of concern", or those already listed as threatened, the impacts of climate change may compound existing stressors such as habitat destruction, requiring additional protections under the Endangered Species Act.[56]

Climate models and research from the CIG project habitat loss for salmonids of between five and twenty-two per cent by 2090, the result of temperature increases that affect their distribution, migration, health, and reproductive capacity. Research has shown, for example, that salmonids have increased vulnerability to predation and displacement when average water temperatures exceed fifteen degrees Celsius. In addition, higher water temperatures increase their vulnerability to disease and infection. Water temperatures that exceed twenty-two degrees Celsius can prevent migration altogether. Communities in the Puget Sound must confront the worst-case scenario possibility that, in a world so altered by climate and continuing human impacts, salmon or other species will not be able to adapt on an accelerated timescale.[57] Given this possibility,

[55] IPCC, Special Report on the Regional Impacts of Climate Change: An Assessment of Vulnerability at Section 8.3.6 (Robert T. Watson et al., eds. 2001).

[56] For example, in 2010 the US National Marine Fisheries Service established a recovery plan for the Puget Sound Chinook salmon that recognises the connected impacts of habitat degradation, historical over-harvesting, and climate change. *Puget Sound Salmon Recovery Plan*, National Marine Fisheries Service, at 122 (2007).

[57] Alec D. MacCall and T.C. Wainwright (eds.), *Assessing Extinction Risk for West Coast Salmon*, US Dep't of Commerce, Nat'l Oceanic and Atmospheric Agency Technical Memo NMFS-NWFSC-58 (2003).

improved projections of climate impacts, adaptive management, and scenario-building are critical to salmonid-related policy and management.

2. General Considerations and Principles for Adaptation to Changes in the Water Cycle

Conflict and controversy over water management is likely to intensify in the Pacific Northwest as climate change advances. The overarching goal of a prudent adaptation strategy, therefore, is to ensure adequate water supplies and flows when and where it is needed for both human consumption and ecosystem use.

In a 2008 *Science* article, a group of scientists and natural resource managers declared, "Stationarity is dead". The concept of stationarity is the idea that natural systems fluctuate within an unchanging envelope of variability. It underlies traditional water-resource management and water law.[58] The authors of the article argued that stationarity no longer applies to water-resource management because the substantial anthropogenic change of the Earth's climate is altering the means and extremes of the hydrologic cycle, sea level, and glacial melt. If stationarity is no longer applicable, significant implications for state-level water law and the federal Clean Water Act (CWA) arise.

Water law governs the allocation of water at the state level and is designed to promote stability and predictability rather than to respond to change.[59] The "first in time, first in right" mantra of prior appropriation regimes demonstrates this underlying guarantee of stability, at least for the most senior users. Prior appropriation thus preserves water uses that may no longer reflect current social values. For example, the value of water for aquatic ecosystems has become increasingly important, but often constitutes a junior use. Under prior appropriation, no junior user gets water until senior appropriators receive the full allocation of their water rights.

Another obstacle to adaptation is the disjointed nature of both water law and environmental law, which creates unscientific and confounding divisions between surface water and groundwater, water quantity and water quality, and intrastate and interstate jurisdiction.[60] This lack of coherence impedes the ability to reallocate or redistribute water supplies to the most desirable or valuable uses as an adaptation strategy. For example, in times of drought, a state may allocate water to sustain existing out-of-stream human uses at the expense of in-stream uses and in violation of the CWA. The ability of water to serve multiple masters—hydropower uses, drinking water supplies, recreational uses, aquatic ecosystems, riparian habitats, and others—in the face of climate change may test traditional jurisdictional boundaries and raise tough questions. What happens if the rivers in the Puget Sound Basin can no longer sustain salmon or other cold-water fish or aquatic species because of uncontrollable changes to the environment to which species cannot adapt? Policy-makers and society at large may face this dilemma, and

[58] P.C.D. Milly et al., *Stationarity is Dead: Whither Water Management?* 319 Science 573 (2008).

[59] Robert W. Adler, *Climate Change and the Hegemony of State Water Law*, 29 Stan. Envtl. L.J. 1 (2010).

[60] Ibid., at 18. See also Christine A. Klein, *On Integrity: Some Considerations for Water Law*, 56 Ala. L. Rev. 1009 (2005).

it is important to begin exploring the legal options and policy responses before these impacts occur.

Climate change will also strain the traditional boundaries between federal and state jurisdiction over water. The artificial division between water quality and water quantity will become even more apparent, as decreased flows result in higher in-stream pollutant concentrations and temperatures, and put endangered and threatened species in greater jeopardy. In the future, the availability of water may determine land use and the growth of urban areas, causing water law, land-use law, and environmental law to become increasingly intertwined rather than remaining separate areas of law.

The goal of adaptation to a changing hydrologic cycle is to ensure that water can be used where it is most needed, however society determines that need. Adapting to these impacts is likely to further highlight the tension between human use of water and ecosystem use of water. Climate change adaptation strategies for human use of water and ecosystem use of water may come into conflict as a result of changes to the hydrologic cycle. Policy-makers should ensure that strategies to protect supplies for human use cause as little impact as possible to the flows needed to maintain a healthy, functioning ecosystem.

Ultimately, achieving this goal requires strictly enforcing the CWA to increase aquatic ecosystem resilience, as well as collecting background information and assessing existing water resources to prepare for future impacts. Stronger implementation and enforcement of the CWA and other traditional environmental laws is imperative. Ecosystems that are under stress from pollution, destruction of wetlands, and the loss of biodiversity are less resilient and more vulnerable to the impacts of climate change than healthy systems. Throughout the country, the federal EPA, states, and Tribes can strengthen regulation of stormwater and enforcement of pollutant-discharge permits. Maximizing these legal and regulatory controls will enhance the resiliency of aquatic ecosystems.[61]

For planning and future allocation purposes, calculating the total amount of water in the Puget Sound basin will facilitate improved water-resource management and can be used to develop a water budget. Models can be used to calculate significant inflows, outflows, and storage capacity under alternative climate change scenarios and to build various climate change scenarios as well. To effectively prioritize uses and conservation goals, the Department of Ecology and other water users must have a clearer understanding of the entire picture of water uses in the Puget Sound basin. From the information gained in this quantification, the Department of Ecology can better target conservation measures, enforce in-stream flows and the beneficial use of water, and plan for an altered hydrologic cycle.

Most fundamentally, policy-makers and scientists must collaborate to integrate science into law by adopting a watershed approach to water-resource management. Water science has long

[61] Craig, *supra* note 13, at 45.

established the interconnections between waters located within the same watershed, both surface waters and groundwater, and between water quantity and water quality. However, existing water laws tend to artificially separate these connections and thus fail to manage water in a holistic way. As climate-change impacts on water highlight these connections, laws should be implemented to reflect the cumulative impacts of climate change on a watershed and to better integrate science and hydrologic data.

3. Specific Adaptation Strategies

With these principles and considerations in mind, this section discusses specific reforms in water law, the Clean Water Act, and the Endangered Species Act to address the impact of climate change on the hydrologic cycle.

A. Reform Prior Appropriation

Water law in the United States is largely a matter of geography. In the eastern states, where water has been plentiful historically, a doctrine known as riparian rights took hold. Under riparianism, water is viewed as a common property to be shared by riparian landowners. Because all riparian landowners have an equal right of reasonable use, the amount and use of water is a matter of individual judgment, barring any court resolution.[62]

Washington—like most states west of the one-hundredth meridian, where water is generally a scarce resource—has adopted the system of prior appropriation as its dominant state water law, with some holdovers from riparian law as well. Prior appropriation is codified in the state code, which provides that waters of the state belong to the public but a right of use "may be acquired only by appropriation for beneficial use and in the manner provided... [and] as between appropriations, the first in time shall be the first in right".[63] The heavy emphasis on the notion of "first in time, first in right," or the priority aspect of prior appropriation, displaces other ingredients of prior appropriation law, such as beneficial use, the rule against waste, and the doctrines of relinquishment or abandonment.

In light of climate change adaptation and potential water shortages, Robert Adler suggests that prior appropriation is in theory better than other forms of water-allocation law because, in times of shortage, it guarantees senior appropriators their full allotment of water, and thus a measure of certainty, albeit at the expense of junior appropriators.[64] However, Adler notes that these protections have not been tested in reality because the extensive network of dams and water infrastructure have largely averted water shortages and thus prevented any harsh outcomes for junior appropriators.[65]

[62] For an overview of state water law and the Clean Water Act, see William L. Andreen, *Developing a More Holistic Approach to Water Management in the United States*, 36 Envt'l L. Rep. 10277 (2006).

[63] Wash. Rev. Code § 90.03.010.

[64] Adler, *supra* note 59, at 24.

[65] Ibid.

Prior appropriation may be beneficial because it treats water rights as concrete property rights, which facilitates water transfer and the overall ability to move water to where it is needed.[66] However, critics of western water law point out that this system freezes certain uses, such as outdated and inefficient irrigation techniques, leaving little water for new uses that may be more efficient or highly valued. While Washington and other western states are highly unlikely to abandon prior appropriation as a system of water law, placing equal importance on elements other than relative acquisition dates of water rights is a crucial adaptation strategy to both identify wasteful and inefficient uses and to conserve existing water supplies.

To reform prior appropriation in light of climate change impacts, Washington should emphasize the co-equal but, to date, ignored aspects of its water law, such as the public-interest and beneficial-use requirements. The public-interest requirement recognizes that water is a public resource that should be used in the overall public interest. To obtain a water right, an applicant must demonstrate that the proposed use is "not detrimental to the public interest".[67] When authorizing new uses, or even use transfers or changes, Washington should consider what constitutes a use that is "detrimental to the public interest" in light of climate change impacts on water timing and availability for both human and ecosystem uses. Uses that decrease ecosystem resilience might be regarded as contrary to the public interest.

To augment water supplies, Washington should enforce relinquishment provisions for abandonment or failure to beneficially use water and provide incentives for water conservation. Prior appropriation water-use rights may revert to the State of Washington if the holder of those rights abandons or voluntarily fails without sufficient cause to beneficially use or withdraw water for any period of five successive years after 1 July 1967.[68] Beneficial use encompasses the idea that uses should not be wasteful and should be efficient. To ensure adequate quantities of water, Washington should consider establishing priorities among beneficial uses, establishing criteria for waste, and enforcing relinquishment provisions for abandoned prior-appropriation rights and failure to use water beneficially.

In addition, water conservation may prove to be one of the most effective ways of ensuring adequate water supplies for human consumption during dry periods. Incentives could range from tiered, seasonal pricing of water for increasing volumes of water usage, such as the scheme used by Seattle Public Utilities, to other financial or regulatory benefits for users who achieve a stated level of conservation.

[66] Ibid., at 25.

[67] Wash. Rev. Code § 90.30.290.

[68] Wash. Rev. Code § 90.14.160. A water right holder can avoid relinquishment only by showing sufficient cause or by demonstrating that an exception applies. For example, nonuse due to drought, military service, or legal proceedings constitutes sufficient cause. In addition, certain water rights are never subject to relinquishment, including trust water rights, municipal supplies, or standby supplies for drought conditions. See *City of Union Gap v. Ecology*, 195 P.3d 580 (Wash. App. 2008), *rehearing denied*, (2009).

A final adaptation strategy for prior appropriation is to increase flexibility to transfer uses and places of use for water. A prior-appropriation water right is granted for a specific point of diversion, a specific use, and a specific time and place for that use. Washington should continue to develop water banks to create a reservoir of water supplies that are available to improve stream flows and in-stream uses during critical drought periods; to offset future development; or to efficiently reallocate water among beneficial uses.

The doctrine of prior appropriation is deeply rooted in western states and in the mindsets of many western water users. Faced with potentially catastrophic changes to aquatic ecosystems, however, countries and regions around the world have reformed their water laws, and the impact of climate change across Washington may provide a similarly pressing impetus. Over-allocated waters and severely degraded aquatic ecosystems prompted significant water-law reform in the Australian state of New South Wales. As a result of this reform, water licenses on regulated rivers provide a right for an annual volumetric amount of water, but only to the extent that water is available. Thus, a typical allocation announcement might say: "Irrigators are advised that sixty-five per cent of allocations are currently available. There is a sixty per cent chance this will rise to seventy-five per cent by December and a forty-five per cent chance of 100 per cent allocations by the same date".[69]

The government of New South Wales regularly determines what percentage of an allocation is available by adding the amount of water in storage to expected inflows, and then deducting environmental requirements and system losses. During times of shortage, the law also prioritizes environmental needs, second only to domestic water uses. To meet the required environmental flows, dams release water in such a way that the downstream river flow will mimic natural variations.[70] By basing allocations on percentages of available flow rather than volumetric allocations, and by prioritizing the environmental uses of water, New South Wales has developed an equitable tool for managing water in times of shortage that may prove extremely useful as a changed climate alters the water cycle.[71]

B. Augment In-stream Flows

Among the most significant impacts to the hydrologic cycle is the disruption of the timing and volume of flows to which salmon and other aquatic species have adapted. Protecting this natural cycle is a key adaptation strategy.

Washington has two primary programs to ensure the continued flow of in-stream water. In 1967, the state legislature adopted the Minimum Water Flows and Levels Act to give the Department of Ecology the authority to promulgate rules that set flow levels for the state's rivers to protect

[69] Brian Haisman, *Impacts of Water Rights Reform in Australia*, *in* Water Rights Reform: Lessons for Institutional Design, 113 (Bryan Randolph Bruns et al., eds., 2005).

[70] Ibid., at 132.

[71] Ibid. William L. Andreen, "Water Law and the Search for Sustainability: A Comparative Analysis," in Water Resources Planning and Management (R. Quentin Grafton and Karen Hussey, eds., 2011).

fish and other aquatic resources, as well as recreational and aesthetic values. Setting flow levels is crucial to determining the amount of water available for out-of-stream allocation, establishing salmon and other aquatic resource recovery plans, and determining overall watershed and water-resource management.[72] To assist salmon and other aquatic species to adapt to climate change, the Department of Ecology should administer water law and in-stream flows to mimic the natural hydrograph to allow species to survive disruptions in the hydrologic cycle.

The second in-stream program is the Trust Water Rights program, whereby the state may acquire water rights through sale, donation, or lease, and hold them in trust for in-stream flow or other beneficial uses.[73] The trust water right retains the same date of priority as the original water right.

Adaptation strategies to augment and maintain in-stream flows involve a combination of existing laws and new approaches. For example, the Department of Ecology must ensure that in-stream flows are set at environmentally protective levels and are strictly enforced consistently with the spirit of the law. Under current law, enforcement of an in-stream flow is limited by its priority date, which tends to be more recent compared to existing water rights, and thus fulfilled only after all prior water rights are fulfilled. The Washington legislature should further protect water for environmental use by passing legislation to guarantee a certain minimum volume or percentage of flow for in-stream use that must be fulfilled before water is appropriated for non-domestic uses. The legislature should prioritize in-stream or environmental use of water.

One of the biggest problems with the in-stream flow program in many states, including Washington, is the low priority date for these flows. Thus, although the Department of Ecology may set minimum flow levels to protect certain species or aquatic ecosystems, the flows typically remain unfulfilled. To enhance these flows, the Department of Ecology should establish seasonal, dynamic flows using numeric water-quality criteria under section 303 of the CWA.[74] At the federal level, the EPA could also encourage and eventually require states to adopt numeric flow standards under its authority in section 303(c). Similarly, these flows must be maintained below dam impoundments. Many private hydroelectric dams are currently undergoing, or will in the near future undergo, relicensing from the Federal Energy Regulatory Commission. Washington should use its authority under the CWA to ensure that flow regimes below these impoundments meet water-quality standards for flow regimes to offset the changes to the water cycle.

Finally, the Washington legislature should establish incentives to encourage participation and more permanent transfers of water rights. The Trust Water Rights program allows the acquisition of water rights by lease, which allows the water-rights holder to recover the right at the expiration of the lease. This provision is helpful in encouraging the donation of rights to the state. To increase participation, the Department of Ecology should agree not to use information gained through participation against the interests of a good-faith participant, or should agree to provide certain

[72] *A Guide to Instream Flow Setting in Washington State,* Department of Ecology, Pub. No. 03-11-007 (March 2003).

[73] Wash. Rev. Code § 90.42.040.

[74] Clean Water Act, 33 USC § 1313.

assurances in status or rights prior to participation and for achieving specific conservation goals.[75] To encourage more permanent retirement of water rights, the state legislature should consider establishing tax benefits or other incentives.

C. Improve Water Quality under the Clean Water Act

The CWA is the primary legal mechanism for protecting the quality of the waters in the United States. The heart of the Act's implementation and enforcement strategy is the National Pollution Discharge Elimination System (NPDES) program.[76] All point sources—discernible conveyances such as pipes or ditches[77]—through which pollutants are added to waters of the United States must obtain a NPDES permit and comply with the conditions set forth in the permit.[78] Among those conditions are uniform technology-based effluent limitations by industrial category, which are generally set by the federal EPA.[79] Additionally, more stringent permit limits are established when necessary to meet state water-quality standards.[80] The EPA has delegated authority to Washington and some Tribes to administer the NPDES permit program.

Whereas state water law focuses on the quantity and allocation of water, the CWA has generally focused on the quality of water. Climate change impacts will highlight the relationship between water quantity and water quality because the maintenance of a healthy ecosystem depends upon both clean water and a natural flow of water. Nevertheless, as Washington has already established in the US Supreme Court, the CWA itself provides mechanisms for linking considerations of water quality and water quantity to protect aquatic ecosystem health.[81]

Climate change will exacerbate existing stressors and alter water quality by causing an increase in water temperatures, changing the timing and flow of water, and lowering the pH of marine environments. Thus, the EPA, Washington, and the Tribes should use the water-quality standards to reduce existing stressors. For example, they could establish water-quality standards for flow, incorporate more stringent thermal-effluent discharge limits in NPDES permits for any waters projected to be impaired by climate-induced warmer waters,[82] or adopt marine-water pH criteria to address ocean acidification.[83]

[75] *Walla Walla Watershed Management Partnership: A Proposal for a Pilot Local Water Management Program in the Walla Walla Basin*, Washington Department of Ecology, Pub. No. 08-11-061 (2008).

[76] Clean Water Act, 33 USC § 1342 (2006).

[77] Clean Water Act, 33 USC § 1362(14) (definition of a point source).

[78] Clean Water Act, 33 USC § 1311(a), 1342(a).

[79] See Clean Water Act, 33 USC § 1314(b).

[80] State water quality standards are governed by section 303(c) of the Clean Water Act. See also Clean Water Act, 33 USC § 1311(b)(10)(C) (requiring compliance by point sources with effluent limitations more stringent than those established by EPA, including those necessary to comply with state water quality standards).

[81] *PUD No. 1 of Jefferson County v. Wash. Dep't of Ecology*, 511 US 700 (1994).

[82] Robin Kundis Craig, *Climate Change Comes to the Clean Water Act: What Now?* 1 Wash. & Lee J. Climate, Energy, & Envt. 7 (2010).

[83] As a result of a settlement with environmental groups in 2010, EPA began grappling with the question of how to address ocean acidification under the CWA. This question is particularly difficult to answer because the dischargers that ultimately cause ocean acidification are emitters of carbon dioxide and are regional, if not global.

Another adaptation strategy under the CWA is to adopt a holistic, watershed approach to restoration. According to a 2002 assessment of Washington's waters, more than fifty per cent of the streams in the Puget Lowlands ecoregion failed to meet their designated use.[84] For these impaired waters, the CWA contains a powerful but relatively little used tool to limit the discharge of pollutants into water: the Total Maximum Daily Load. A TMDL represents the total amount of a pollutant that all sources may add to a water body without exceeding the water quality standards for that pollutant.[85] This pollutant cap may be used to establish limits in NPDES permits for point sources that are more stringent than the EPA's technology-based effluent limitations. For non-point sources, which are not required to have NPDES permits, the TMDL may serve as a basis for inducing the use of voluntary best-management practices or increased mandatory regulation of these sources pursuant to state law. Restoration of a watershed or water system cannot be achieved on a piecemeal basis. When establishing TMDLs, a state should ensure that a TMDL not only helps to restore the individual impaired water, but also contributes to the overall restoration of the watershed.

Finally, non-point source pollution remains the largest source of water pollution around the world, and the problem is particularly acute in the United States.[86] While the CWA does not regulate non-point sources, it provides funding for state programs that encourage voluntary practices. The EPA should encourage states to adopt implementation plans for TMDLs, as it has done in the Chesapeake Bay.[87] States may also enact legislation to regulate these sources and require pollution-reduction controls and practices. Reducing water pollution from these sources is an important adaptation strategy because it provides a way to increase the resiliency of aquatic ecosystems to the likely consequences of climate change, such as lower summer flows, increased water temperatures, and increased levels of sedimentation arising from erosion linked to more frequent and severe wet-weather events.

D. Use the Endangered Species Act to Assist Adaptation of Species

A changed hydrologic cycle, combined with changed marine currents in the northeastern Pacific Ocean, will severely stress Pacific Northwest salmon and other aquatic species if they are unable to adapt. Another tool for specifically protecting anadromous fish species is the Endangered Species Act (ESA). The critical habitat, recovery plan, and consultation provisions of sections

(Footnote 83 Continued)
Nonetheless, EPA concluded in a November 2010 memorandum that states should list waters not meeting marine pH water quality criteria on their 2012 impaired waters list. Memorandum to Water Division Directors, Regions 1-10, from Denise Keehner, Director, Office of Wetlands, Oceans and Watershed, on Integrated Reporting and Listing Decisions Related to Ocean Acidification (15 November 2010).

[84] *Washington State Water Quality Assessment, Year 2002, Section 305(b) Report*, Washington Department of Ecology, Pub. No. 02-03-026 (June 2002).

[85] See Clean Water Act, 33 USC § 1313(d) (2006).

[86] See Robert L. Glicksman et al., Environmental Protection: Law and Policy 656–60 (6th ed., 2011).

[87] *Final Chesapeake Bay Total Maximum Daily Load*, US Environmental Protection Agency, at 1–9 (29 December 2010) [hereinafter *Final Bay TMDL*].

4 and 7[88] may be applied to assist species in adapting to climate change and thus ensure their survival.

The Washington Department of Natural Resources and the US Fish and Wildlife Service should use critical habitat designation to enable migration. Climate change will require many species to move as their habitat shifts. One proposal to ameliorate the problem is through assisted migration. The term has been applied to actions that range from increasing the permeability of landscapes to the intentional transfer of species to a new region.[89] Although it is gaining some currency among natural-resource managers, the more active approach is quite controversial because it represents a dramatic departure from traditional natural-resource management and raises ethical, practical, and legal questions. Assisted migration exemplifies how climate change may fundamentally alter the traditional tenets of natural-resource management.

The ESA authorises the federal wildlife agencies to designate critical habitat *outside* of a species' current habitat if it is essential for the conservation of the species.[90] Section 10 of the ESA may provide the legal basis for this intentional translocation of listed species, either as an experimental population[91] or for other general scientific purposes. As climate change alters habitat, it may be necessary either to make landscapes more permeable so that species can respond by moving through them, or to physically move species, based on criteria such as conclusive evidence of a threat of extinction, a quantitative model showing the likelihood of success once transferred with minimal impact on other species, and dedicated resources for long-term monitoring and adaptive management.[92]

Recovery plans under the ESA can be a useful source of information for natural-resource managers as well. The plans are intended to guide conservation actions necessary for the recovery of listed species.[93] Although the plan is not generally regarded as enforceable,[94] its primary value may be in providing a wealth of information about a species that can help inform other adaptation measures.[95] State and local policy-makers can enact legislation or regulations that are more protective of species than federal actions, and should therefore craft

[88] Endangered Species Act, 16 USC §§ 1533, 1536 (2006).

[89] See Alejandro E. Camacho, *Assisted Migration: Redefining Nature and Natural Resource Law Under Climate Change*, 27 Yale J. Regulation 171 (2010).

[90] Endangered Species Act, 16 USC § 1532(5)(A)(ii) (2006).

[91] Endangered Species Act, 16 USC § 1539 (j) & (a)(1)(A).

[92] J.B. Ruhl, *Climate Change and the Endangered Species Act: Building Bridges to the No-Analog Future*, 88 Boston Univ. L. Rev. 1, 60 (2008).

[93] Endangered Species Act, 16 USC § 1533(f) (2006).

[94] See, e.g., *Center for Biological Diversity v. US Bureau of Land Mgmt.*, 746 F. Supp. 2d 1055, 1103 (N.D. Cal. 2009), *vacated in part*, 2011 WL 337364 (N.D. Cal. 2011) (stating that "the ESA does not require that a Recovery Plan be fully implemented"). But see *Friends of Blackwater v. Salazar*, 772 F. Supp. 2d 232, 242. (D.D.C. 2011) (concluding that the ESA clearly makes the obligation to develop and implement recovery plans mandatory and that § 4(f) requires the FWS to include "objective and measurable" criteria for delisting in the plans).

[95] One recent district court appears to treat the recovery plans as mandatory, *Friends of Blackwater*,772 F. Supp. 2d at 241–245. (D.D.C. 25 March 2011).

effective adaptation measures by making the most they can of the information provided in the plans.

Lastly, the consultation requirement in section 7 also will apply to a federal agency's response to climate change if its actions might affect the species. The response cannot jeopardize "the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [the critical] habitat of such species".[96] At the federal level, this consultation requirement and the no-jeopardy prohibition provide concrete tools for adaptation efforts to protect salmon and other endangered or threatened species.

3. Conclusion

Overall, the climate-induced changes to the hydrologic cycle portend serious environmental implications for salmon and other aquatic species. While the direct impacts to human uses of water are relatively manageable, aquatic ecosystems are likely to change—perhaps substantially—in response to previously unknown fluctuations in water supply and increases in water temperature. These effects on aquatic ecosystems will have indirect impacts on humans, particularly on Tribes that depend on and have treaty-secured rights to salmon, and on others who depend on fish for food or for their livelihoods. Communities in Puget Sound and across Washington should consider implementing existing water laws in new, dynamic ways to enhance the resiliency of these aquatic systems and to reflect the profound impacts caused by climate change.

VI. Sea-Level Rise

Picturesque shorelines and productive estuaries and wetlands are among the major attractions in Puget Sound. Like thousands of coastal communities around the world, however, Puget Sound faces significant challenges as a result of sea-level rise caused by climate change. Stronger storm surges and coastal erosion have motivated these communities to plan for adapting to the encroaching water. This part describes the impacts of sea-level rise and identifies specific tools for addressing it. Other cross-cutting issues related to sea-level rise are discussed later in this article.

1. Climate Change, the Shifting Pacific Coast, and the Puget Sound Basin

The coastline along Puget Sound spans close to 2,400 kilometres and is densely inhabited, with 90 per cent of the coastline lined with single-family housing or available for development. Even though the predominant land use is low-density housing, much of the development has permanently altered or even destroyed natural ecosystems that could help buffer the impact of sea-level rise. Hard-armouring of the shoreline with sea walls, bulkheads, and riprap inevitably

[96] Endangered Species Act, 16 USC § 1536(a)(2) (2006).

lead to encroachment of the ocean and elimination of the naturally dynamic near-shore habitat.[97] Around the Puget Sound, retention of shallow-water habitat and beaches is important for juvenile fish, shellfish, and shorebirds.

Sea-level rise causes not only the landward migration of the shoreline along open beaches, but also coastal bluff erosion. This erosion causes slabs to break off from the bluffs above, weakening the structure on which houses or other human infrastructure may be built. Coastal communities may experience stronger storm surges and other extreme weather events as the most immediate impacts of sea-level rise. For example, energy and waste facilities located on the coast are vulnerable to strong storm surges, which may cause both infrastructure damage and public health problems if a storm surge breaches waste containment structures.

The CIG Report concluded that relative sea-level rise in Washington will be greatest in south Puget Sound and least at the northwest tip of the Olympic Peninsula.[98] The climate-induced sea-level rise is augmented by natural land subsidence. Whereas the Olympic Peninsula is rising at two millimeters per year, South Puget Sound is subsiding by an equal amount.

2. General Considerations and Principles for Adaptation to Sea-Level Rise

Adapting to sea-level rise will require planning and action over a long timeframe. Because of the uncertainty associated with specific local impacts, local governments in Washington should follow basic principles that encourage retreat from the coastline where possible, reliance on natural or green infrastructure, and planning that involves scenario-building and identifies broad impacts to other sectors.

In considering actions to adapt to sea-level rise, three general approaches are accommodation, protection, and retreat.[99] Accommodation involves maintaining existing land uses with actions to protect structures or land from flooding by seawater. For example, a coastal community may elevate buildings onto piles but not actively attempt to prevent dry land from flooding. Protection involves maintaining existing land uses by preventing flooding with hard or soft structures. Hard structures, such as seawalls, concrete jetties or bulkheads, or riprap, are generally considered maladaptive because they halt the natural migration of the shoreline, such that erosion eventually eliminates the shallow-water area and the beach.[100] Soft structures, or "green armouring," using rocks, vegetation, and sand or gravel, prolong the natural ecosystem and provide habitat, but require maintenance and generally are not permanent.[101]

[97] *CIG Report*, *supra* note 1, at 291.
[98] Ibid., at 288.
[99] US EPA, "Strategies for Adaptation to Sea Level Rise", available at <http://epa.gov/climatechange/effects/coastal/SLRAdaption.html> (last visited 14 April 2011).
[100] *Report to the Legislature*, New York State Sea Level Rise Task Force, at 26 (November 2010) [hereinafter *Task Force Report*].
[101] Wash. Rev. Code § 36.70A.030(9).

Retreat is probably the most effective of the three approaches, but also the most difficult to implement and the most likely to generate political opposition. Retreat involves eliminating existing land uses by moving development inward and returning the coastal zone to natural ecosystems, which can then shift and migrate as sea levels rise.

If retreat is impossible or impractical, a secondary option is to rely on natural features of the shoreline or other "green infrastructure" to provide a buffer against sea-level rise. The goal of adapting to sea-level rise is to rely, as much as possible, on the natural features of the shoreline to protect ecosystems and human communities. This approach entails a combination of active and passive measures, such as removing infrastructure and designating existing natural areas as "no development zones". Adaptation to sea-level rise requires a fundamental change in the way local governments approach shoreline development, including designating vulnerable areas as "no development" zones and providing incentives or compensation to prevent future development in critical areas. Washington and coastal communities in the Puget Sound should also identify areas where reliance on green infrastructure is not an option—such as ports or high-density coastal developments—and begin identifying feasible accommodation or protection strategies.

From a planning perspective, adapting to sea-level rise requires governments to institute coastal planning and scenario-building based on climate change projections. Climate change adaptation is a continuous process that will span decades, if not centuries. In permitting new structures and renewing permits to modify existing structures, coastal communities in Washington should consider the likely lifespan of the new structure and the range of sea-level rise scenarios over that lifespan. This long-term approach may help minimize future problems. Coastal planning should also include decommissioning requirements or benchmarks for major infrastructure or facilities that handle toxic or hazardous materials and are vulnerable to sea-level rise and storm surges.

During the planning process, governments and planners should identify critical impacts on other sectors, such as public health and transportation. Sea-level rise poses a threat not only to coastal ecosystems and coastal structures but also to public health, transportation, and disaster-management planning. The impact on these sectors may become apparent only with episodic but severe weather events, and may take precedence over adaptation to the more gradual encroachment of water. Identifying and adopting plans for these multiple impacts is critical to adapting to sea-level rise.

Among the important tools that Washington and communities in the Puget Sound should use to adapt to sea-level rise are the existing Growth Management Act and Shoreline Management Act. These acts can be used to identify vulnerable areas and plan for future coastal land use, refine local building codes to increase the resilience of built infrastructure, and apply the public-trust doctrine to protect natural coastlines. In addition, using laws to recognize natural migration and rolling easements would give coastal communities in the Puget Sound and around the world a well-stocked toolbox to address this inevitable impact.

3. Specific Recommendations

Adapting to sea-level rise will require a fundamental reconsideration of the human interaction with the coastline. This section offers some specific strategies for adaptation that may be useful not only to communities on the coast of Washington but more generally to coastal communities around the world.

A. Adopt a State-wide Definition of Coastal Hazard Area

Washington's Growth Management Act requires a county or city to identify critical areas, including "geologically hazardous areas" that "because of their susceptibility to erosion, sliding, earthquake, or other geological events, are not suited to the siting of commercial, residential, or industrial development consistent with public health or safety concerns".[102] Sea-level rise reasonably fits among these events. Thus, a county or city with a comprehensive plan should consider the impacts of sea-level rise in the definition of a hazardous area, either by adopting a new category specific to the shorelines or as a sub-area plan:[103] the coastal-hazard area. Alternatively, the Washington Legislature should amend the Growth Management Act to require a coastal-hazard element.

The scope of this area could be a combination of the geologically hazardous area and the definition proposed by the New York Sea-Level Rise Task Force. Washington state law defines geologically hazardous areas as those areas susceptible to gradual sea-level rise or episodic storm surges and other extreme weather events. The Task Force proposed a definition that includes zones designated by the Federal Emergency Management Agency (FEMA) to include coastal high-hazard areas and any areas defined by FEMA as "areas of moderate wave action", or subject to wave action of fifty to one hundred centimetres. Areas designated as coastal hazard areas would then trigger specific mandatory adaptation strategies to address sea-level rise, such as increased setback lines or other building requirements, as proposed in the Swinomish Climate Action Plan.[104]

B. Adopt Coastal Resilience Plans

Coastal communities around the Puget Sound should adopt coastal resilience plans, as proposed in the Task Force report. The purpose of such a plan is to assess in advance the resiliency of the coast or shoreline by identifying the protection, accommodation, or retreat options for coastal infrastructure and features. The plans should identify several components, such as hard-armouring alternatives to reduce vulnerability in coastal-risk areas; areas where structural protection is needed to protect significant public investment, water-dependent uses, and critical infrastructure; opportunities to further reduce vulnerability through non-structural measures

[102] Wash. Rev. Code § 36.70A.030(9).
[103] Wash. Rev. Code § 36.70A.080.
[104] See *Swinomish Action Plan*, *supra* note 7, at 46.

in the recovery and restoration process following coastal damage or storms;[105] and adaptation strategies to be implemented after extreme storm events, such as land-use controls, infrastructure relocation or abandonment, and restoration of natural features. The plan should also include laws or mechanisms that make the plans enforceable and encourage public participation in identifying and prioritizing strategies to bolster coastal resilience.

C. Use the Washington's Shoreline Management Act to Protect against Sea-Level Rise

Enacted in 1971, the Shoreline Management Act (SMA) emphasizes three basic policies: preferred uses of shorelines, environmental protection of shorelines, and public access to shorelines. In combination, these policies strive to protect against adverse effects to the public health, the land, and its vegetation and wildlife, and the waters and aquatic life of the state, while generally protecting public rights of navigation and related rights. The SMA recognizes that the shorelines are among Washington's greatest and most fragile natural resources and declares that "the public's opportunity to enjoy the physical and aesthetic qualities of natural shorelines of the state shall be preserved to the greatest extent feasible consistent with the overall best interest of the state and the people generally".[106]

The SMA applies to all thirty-nine counties in Washington and more than two hundred towns and cities that contain "shorelines of the state," including all marine waters; streams and rivers above a certain flow; lakes above a certain acreage; upland shorelands extending landward from these waters; and wetlands and floodplains associated with these waters. In addition, the SMA classifies certain shorelines as "shorelines of state-wide significance," which include among others certain Puget Sound shorelines and all waters of the Puget Sound. For these significant shorelines, a preferred use may be a long-term, state-wide interest that preserves the ecology and natural features of the shoreline and promotes public access and recreation.[107]

The SMA is intended in part to protect the natural character of the shoreline and public access for recreational opportunities. Adverse impacts to the shoreline from preferred or allowed uses are supposed to be mitigated to the maximum extent feasible. In addition, local governments that administer the SMA are required to provide for public access to publicly owned shoreline areas and the preservation and enlargement of recreational opportunities.

At the local level, the SMA is implemented through shoreline master programs (SMPs), which are essentially a combination of shoreline-specific comprehensive plans, a permit system for shoreline development, and zoning ordinances that are tailored to the specific geographic, economic, and environmental needs of the shoreline community. Local governments are responsible for administering the SMPs and are required to review them every seven years. The

[105] *Task Force Report, supra* note 100, at 56.
[106] Wash. Rev. Code § 90.58.020.
[107] Wash. Rev. Code § 90.58.020.

Department of Ecology reviews and approves the plans, and provides funding and assistance for plan implementation.

Although the regulations for SMPs do not specifically include consideration of sea-level rise, they encompass a handful of policies that should be used to authorize actions that protect against the adverse consequences of sea-level rise. For example, state regulators could consider the impact of sea-level rise on existing and projected shoreline uses in the shoreline use analysis.[108] Washington regulations specify certain elements that must be included in SMPs, including economic development, public access, recreation, circulation, conservation, and historic and cultural elements. Impacts from sea-level rise can be easily incorporated into the plans, as they have the clear potential to affect each of these elements. For example, the shoreline-use analysis could consider the impact of sea-level rise on existing and projected uses.[109] The conservation element also provides a good opportunity to consider adaptation to sea-level rise by identifying projects to restore natural processes or features such as erosion and sediment transport or vegetated dunes.

State regulators could also consider how to redefine the "no net loss" policy in light of sea-level rise. Washington regulations establish the "no net loss" policy for shorelines, meaning that the "existing condition of shoreline ecological functions should remain the same as when the SMP is implemented". The purpose of the policy is to prevent harm to the ecological functions of shorelines that result from new development. Shoreline functions should be improved where possible, but at a minimum, adverse impacts to shorelines should be avoided or minimized, or the shoreline should be restored where damage has already occurred. Over time, however, sea-level rise and other changes resulting from climate change will likely prompt the Department of Ecology to examine the feasibility of this policy, as rising sea levels erode shorelines to the edge of bluffs or hard-armouring structures, and to decide how the policy should be redefined to ensure resilience in the face of climate change.

Lastly, state regulators could require applicants for conditional-use permits to demonstrate how a proposed use will adapt to sea-level rise. SMPs establish regulations for development and define what uses are "conditional uses" that are not preferred but may be permitted under certain conditions. Conditional Use Permits (CUPs) are approved (or disapproved) by the Department of Ecology depending on whether the use meets certain criteria, including "no significant adverse effects to the shoreline" and "no substantial detrimental effect to the public interest". These criteria provide an opportunity for the Department of Ecology to require an applicant to show, for example, how a proposed use will adapt to changing conditions over the lifespan of the use.

D. Apply Rolling Easements and Selected Retreat

Part of adapting to climate change may entail simply letting natural systems move and adjust as they would without hard, human-built infrastructure. Much has been written about the concept

[108] Wash. Dep't of Ecology, *Appendix A: Addressing Sea Level Rise in Shoreline Master Programs*, in Shoreline Master Program Handbook.
[109] Ibid.

of rolling easements, under which private-property rights yield to a naturally migrating shoreline and the public use on that shoreline. The most prominent state with rolling easements is Texas, which adopted the Texas Open Beaches Act.[110] The purpose of the Act was to guarantee public access to the beach rather than to guarantee the dynamism of the shoreline, but many advocates have since proposed a shift in the fundamental purpose. Under the Act, the public has the right of access to the state-owned beaches along the Gulf of Mexico. The Act further states that the public can, through continual use, easement, or dedication, acquire a right of access up to the landward line of vegetation.[111] Thus, if a party can first establish that the public has a right to use the contested area, the Act authorizes the removal of barriers and other obstructions, even if they exist on private land.[112]

Washington could adopt a similar law because the legal foundations, in part, already exist. For example, the definition of the ordinary high-water mark (OHWM) recognizes that the mark migrates:

> that mark that will be found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual, and so long continued in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland... *as it may naturally change thereafter*, or as it may change thereafter in accordance with permits issued by a local government of the Department of Ecology...[113]

In addition, the Washington Supreme Court has clarified under what circumstances the OHWM shifts in a river or a stream: if the shift "is slow and imperceptible so that it may be classified as accretion or reliction," the OHWM shifts. However, if the shift is avulsive and therefore marks a sudden change, the original line remains.[114] Although no cases that address avulsion of shorelines have been brought in Washington, it is likely that a court would extend this reasoning to coastal avulsion.

With this framework, Washington should implement rolling easements through different methods and levels of restrictions and state actions. First, local governments could simply prohibit the construction of hard structures that block the natural migration of the shoreline. Washington should also pass legislation to specify that rolling easements apply to all shorelines, and require this disclosure in property deeds. In addition, the state could negotiate an option to purchase private property along the shoreline if sea level rises to a certain point.[115]

[110] Other states, including California and North Carolina, have rolling easements as well.

[111] Tex. Nat. Res. Code § 61.011. However, the Texas Supreme Court recently limited the Act to the gradual, landward migration of the line of vegetation. *Severance v. Peterson*, 54 Tex. Sup. Ct. J. 172 (2010), *rehearing granted* (19 April 2011). The court held that the Act does not apply to a sudden, avulsive event that causes the line of vegetation to move landward.

[112] *Severance v. Patterson*, 54 Tex. Sup. Ct. J. 172 (2010).

[113] Wash. Rev. Code § 90.58.030 (emphasis added).

[114] *Parker v. Farrell*, 445 P.2d 620, 622 (Wash. 1968).

[115] James L. Titus, *Rising Seas, Coastal Erosion, and the Takings Clause: How to Save Wetlands and Beaches Without Hurting Property Owners*, 57 Md. L. Rev. 1279 (1998).

A good example of retreat occurred in California, where sea levels are projected to rise as much as 140 centimetres by 2100 and inundate more than one hundred square kilometres of coastal land. As a result, the city of Ventura has embarked on a managed retreat effort for Surfer's Point, relocating a bike path and parking lot twenty meters inland and extending the life of the Point by fifty years. At a cost of US$4.5 million, the project is the first of its kind in California. Private landowners with property adjacent to the Point agreed to give up some land in order to allow the beach to migrate landward. This project marks a significant departure from the ubiquitous concrete sea walls and other hard-armouring structures favoured to keep the ocean at bay, which provide only short-term relief and create long-term hazards, such as further erosion of coastal shorelines.[116]

E. Enforce and Broaden the Scope of the Public-Trust Doctrine

The public-trust doctrine reflects the idea that certain natural resources belong to the public because of their immense value to the public as a whole, and no private entity can ever acquire the right to monopolize or deprive the public of the right to use and enjoy these resources.[117] Although it originally focused heavily on water and shorelines used for navigation, states like Washington have increasingly applied the public-trust doctrine to protection of environmental values in water.[118]

In Washington, the public-trust doctrine is part of both the state constitution and the Shoreline Management Act.[119] Article XVII of the state constitution declares that the state of Washington owns "the beds and shores of all navigable waters in the state up to and including the line or ordinary high tide, in waters where the tide ebbs and flows, and up to and including the line of ordinary high water within the banks of all navigable rivers and lakes". Washington law also defines aquatic lands as "all state owned tidelands, shorelands, harbour areas, and the bends of navigable waters" and requires the state to manage these lands to encourage public use and access, and to ensure environmental protection.[120] Before leasing land or allowing changes of use, the Department of Natural Resources must consider "the value of state-owned aquatic lands as wildlife habitat, natural area preserve, representative ecosystem, or spawning area".

[116] Tony Barboza, *In Ventura, a Retreat in the Face of a Rising Sea*, L.A. Times (16 January 2011). It is unclear whether the landowners, the Ventura County Fairgrounds, received compensation.

[117] *Illinois Central R. Co. v. Illinois*, 146 US 387 (892); *Nat'l Audubon Soc'y v. Superior Court of Alpine County*, 658 P.2d 709 (Cal. 1983). See also Joseph L. Sax, *The Public Trust Doctrine in Natural Resource Law: Effective Judicial Intervention*, 68 Mich. L. Rev. 471, 484 (1970).

[118] See Alexandra B. Klass & Yee Huang, *Restoring the Trust: Water Resources and the Public Trust Doctrine*, CPR White Paper No. 908 (Sept. 2009) [hereinafter *Restoring the Trust*]; Robin Kundis Craig, *A Comparative Guide to Western States' Public Trust Doctrines: Public Values, Private Rights, and the Evolution Toward an Ecological Public Trust*, 37 Ecol. L.Q. 53 (2010); and Alexandra B. Klass, *Modern Public Trust Principles: Recognizing Rights and Integrating Standards*, 82 Notre Dame L. Rev. 699 (2006).

[119] The Ninth Circuit Court of Appeals noted that "it is beyond cavil that the [doctrine] has always existed in Washington." *Esplanade Props., LLC v. City of Seattle*, 307 F.3d 978, 985 (9th Cir. 2002) (internal citations omitted).

[120] Wash. Rev. Code §§ 70.01.101(1) & 79.105.001.

The public trust, like trust mechanisms generally, includes three primary components: the trustee, the trust principal, and the beneficiaries of the trust. In the public-trust framework, the *state* is the trustee, which manages *specific natural resources*[121]—the trust principal—for the benefit of the *current and future generations*—the beneficiaries. These components allow the doctrine to play a key role in adapting to sea-level rise by dictating that land uses affecting the shoreline be controlled using a forward-looking perspective. Although the doctrine does not give the state any *additional* regulatory authority, it can be used to support and protect natural features of the trust lands, to defend against takings claims that may arise from application of laws and regulations to protect the shoreline, and to protect vulnerable areas in combination with other common-law remedies.[122] However, lawmakers and advocates should be mindful of concurrent trust obligations to Tribes in the Puget Sound region, and should avoid encroaching on these obligations or other treaty rights.[123]

Washington should use the public-trust doctrine as a legal tool to protect trust lands from sea-level rise. Advocates should support efforts by the state to actively fulfil its public-trust duty by protecting shoreline uses, including public access, and protecting the shoreline itself. In the adaptation context, the goal would be to maintain or improve the buffering capacity of shorelines to provide natural defences to sea-level rise and reduce the need for hard-armouring. The public-trust doctrine may also provide a defence for state action taken to protect public-trust lands or resources that affect private property. When Washington is obligated by the public-trust doctrine to act, a court may find that the state does not have to compensate a private landowner.[124]

Other common-law remedies such as dedication or prescription may also be used to protect shorelines and other public trust resources.[125] For example, public rights to a beach may be established by open and continuous public use for a statutory period of time.[126] In addition, a private adaptation action that harms trust resources or endangers public health may constitute a public nuisance. Public trust resources therefore benefit from a variety of common-law doctrines that all promote and preserve the greater public good.

[121] Historically, the natural resources comprising the trust principal were limited to navigable waters and the submerged lands beneath them. The legal definition of "navigable" comes from an early Supreme Court case: a waterway is navigable when it is or could be used in its natural state as a highway for commerce in the customary ways commerce is conducted. *The Daniel Ball*, 77 US 557 (1870). At that time, commerce was dominated by river and other water-dependent transportation.

[122] Tim Eichenberg et al., *Climate Change and the Public Trust Doctrine: Using an Ancient Doctrine to Adapt to Rising Sea Levels in San Francisco Bay*, 3 Golden Gate U. Envtl. L.J. 243 (2009).

[123] See generally Mary Christina Wood, *Tribes as Trustees Again (Part I): The Emerging Tribal Role in the Conservation Trust Movement*, 32 Harv. Envtl. L. Rev. 373 (2008), and *EPA's Protection of Tribal Harvests: Braiding the Agency's Mission*, 34 Ecology L.Q. 175 (2007).

[124] See *Restoring the Trust*, *supra* note 118, and Eichenberg, *supra* note 122; Robert L. Glicksman, *Making a Nuisance of Takings Law*, 3 Wash. Univ. J. L. & Pol'y 149, 174 (2000).

[125] The doctrine of dedication states that a private property owner may explicitly or implicitly grant the property to the public and, if accepted by the public, the property becomes public. The doctrine of prescription is another method for the public to obtain rights to private property if the public openly and continuously uses the property for the statutory period of time. Black's Law Dictionary 412 & 1183 (6th ed. 1990).

[126] See, e.g., *Matthews v. Bay Head Improvement Ass'n*, 95 N.J. 306 (1984).

3. Conclusion

In the Puget Sound, the impacts from sea-level rise will likely manifest as incremental migration of the ordinary mean high-water mark, as well as episodic but forceful storm surges and other extreme weather events. Adapting to these impacts requires advance planning and mapping of vulnerable areas, identifying priority actions for existing structures, and designating natural areas subject to development restrictions. Advocates could also consider legal tools, such as rolling easements and the public-trust doctrine to protect natural areas. As many coastal communities around the country and the world are faced with sea-level rise, communities in Puget Sound can learn from and contribute to the adaptation conversation.

VII. Increased Average Temperature and Extreme Weather Events

Increased average temperature and extreme weather events will be some of the most disruptive impacts resulting from climate change. Increases in average temperature are likely to occur gradually and less perceptibly, but increased frequency of extreme weather events is likely to take the form of episodic but severe temperature or precipitation events. These changes will directly affect human health by exacerbating existing public-health problems and introducing new problems. This section first describes the impact of climate change on human health and then identifies general principles for selecting and identifying adaptation strategies. It emphasizes the importance of pre-disaster planning to protect the public health and the need for strategies to address poor air quality.

1. Climate Change and Public Health in the Puget Sound Basin

The relationship of climate change to human health is multi-faceted. For example, the severity of climate impacts on health is strongly influenced by underlying vulnerabilities, such as low baseline health and income. Failing to address these underlying vulnerabilities will reduce the effectiveness of any climate-specific adaptation efforts. Climate impacts are also likely to widen existing disparities because vulnerable populations are less likely to be able to obtain health care or to access other resources for recovery. As a result, these vulnerable populations will bear the most severe impacts of climate change, triggering a negative feedback loop that often results in long-term poverty.

The Puget Sound Basin benefits from a mild climate, with average temperatures ranging from zero to twenty-six degrees Celsius throughout the year. Thus, some of the most dramatic impacts of climate change on human health will not result from increased average temperature but instead from extreme weather events, in the form of both precipitation and periods of unusual heat. Indeed, in the United States, extreme heat events cause more deaths each year than all other extreme weather events combined.[127] In normally temperate regions such as the Puget Sound,

[127] *A Human Health Perspective on Climate Change*, US Centers for Disease Control, at 40 (2010) [hereinafter *CDC Perspective*].

these periods of heat can be more lethal than in regions accustomed to high temperatures because fewer buildings are designed to provide protection from heat.

The CIG conducted modelling of heat-related morbidity and mortality under three warming scenarios: low, middle, and high, in 2025, 2045, and 2085.[128] In the Puget Sound region, the increase of deaths ranged from 68 to 211 in 2025 under the three scenarios, from 89 to 401 in 2045, and 107 to 988 in 2085.[129] The most vulnerable populations are children; the elderly; the poor; those with existing mental illnesses or chronic diseases; and day labourers. More broadly, the US Centres for Disease Control identified a range of potential climate impacts on human health,[130] which include increased incidence of illness and mortality from asthma and respiratory allergies; cardiovascular disease and stroke; heat exposure; waterborne and vector-borne diseases; and extreme weather events.[131]

Many of these impacts require further study because the direct causal links are uncertain despite the high correlative links. However, the need for further study does not preclude the need for or capacity to take action. Populations in the Puget Sound region could potentially experience increased risk of most of these impacts, and public health officials should be aware of how these health impacts are related to climate change and how they are likely to manifest. For example, shellfish and shellfish aquaculture are vital to the health and well-being of the region's Native American Tribes and are important to the economy of the Puget Sound.[132] However, the toxins in shellfish, which cause a range of effects, from mild gastrointestinal illness to paralysis, are present in higher concentrations in warmer waters.[133] Climate change may therefore lead to the increased risk of food-borne illness for human populations. In addition, the historically mild climate in Puget Sound has meant that relatively few buildings and homes are equipped with air conditioning, increasing vulnerability to morbidity and mortality from extreme heat events.

2. Principles for Adapting to Climate Change in the Human-Health Sector

The determinants of individual health are a complex interaction of genetics, community, socioeconomic status, environment, and education, and are often difficult to isolate. The increased average temperatures and increased frequency of extreme weather events that are driven by climate change will seldom be the sole drivers for negative impacts to human health, but instead will exacerbate underlying conditions.

To begin adaptation efforts in the human-health sector, policy-makers and advocates should adhere to principles that promote socially equitable outcomes for all communities. First, policy-makers should adopt an integrated, holistic approach to increase resilience. Human health is

[128] *CIG Report, supra* note 1.
[129] Ibid., at 360.
[130] *CDC Perspective, supra* note 127, at 7.
[131] See generally *CDC Perspective, supra* note 127.
[132] *Swinomish Action Plan, supra* note 7, at 59.
[133] Washington State Department of Health, "Shellfish Poisoning: Paralytic or Domoic Acid" (January 2011).

complex and dependent on many environmental, social, and economic factors. Addressing only a single factor may not result in an improvement in health outcomes or remove barriers to good public health posed by other factors. For example, building cooling centres as an adaptation strategy may help, but only if those who may need the centres are able to access them during a heat wave. This strategy must be paired with transportation solutions for those who cannot afford cars or public transportation. Thus, climate change adaptation strategies and laws should consider these multiple factors, including profound economic disparities, to increase a community's overall resilience.

Policy-makers should also consider underlying disparities or differences that affect a community's ability to adapt to or recover from an extreme weather event. The impacts of climate change on human health will manifest differently for discrete populations within the same area. For example, immigrant communities that speak little to no English, or communities that view the police or government with suspicion, will need appropriate public-service or emergency announcements, such as announcements in different languages or disseminated by non-governmental organizations. For prolonged increases in temperature, access to and the ability to afford air conditioning is correlated with income. While air conditioning is critical to reducing the health impacts of elevated temperatures, individuals with little income may forego obtaining or using air conditioning if they do not receive financial assistance. For climate change adaptation to be both effective and equitable, these differences and disparities must be acknowledged and accounted for as part of any adaptation strategy.

Finally, policy-makers should prioritize adaptation strategies that have co-benefits for other sectors, or that link to other disciplines. Because of the interconnectedness of factors that impact human health, this area presents a particularly ripe opportunity to promote strategies and laws that provide benefits to other sectors. For example, improving underlying air quality to lessen the existing impacts of heat-induced ozone pollution would have important co-benefits for human health and the environment more generally. At the same time, decision-makers should also consider any negative spill-over effects caused by adaptation strategies in the public-health sector, such as introducing air conditioning that will lead to higher rates of energy consumption and greenhouse gas emissions.

3. Disaster Planning: Preparation is Key

One of the key adaptation strategies to address the episodic but severe weather impacts from climate change is pre-disaster planning. Starting the adaptation conversation early, before the chaos of a disaster, creates an opportunity for broad community participation in planning for post-disaster recovery. Communities in the Puget Sound region should ensure that they are undertaking a thorough review of the existing ability to respond to and recover from disasters.

In Washington, county governments are responsible for disaster mitigation, preparedness, response, and recovery within unincorporated areas, while Tribes and municipalities are responsible for planning within their jurisdictions. The mandatory Washington Comprehensive

Table 1
Elements to consider at various stages of disaster planning. (Created by the authors; based on: University of North Carolina, Center for Law, Environment, Adaptation, and Resources, "Disaster Recovery Plan Evaluation Protocol" Draft (20 December 2010), on file with Yee Huang)

Pre-disaster Planning	Evaluate vulnerabilities of critical infrastructure (such as health care facilities and major evacuation routes) Designate responsibility, including overlap of major areas of concern Identify vulnerable communities Ensure adequate, culturally suitable, pre-disaster warning system
Response during a Disaster	Ensure timely and accessible public announcements Ensure ability to evacuate Ensure access to safe areas or shelters
Post-Disaster Rebuilding and Recovery	Describe process or schema for deciding recovery priorities Identify areas for relocation, redevelopment, or abandonment in rebuilding phase that meet the needs of all communities
Overarching Elements	Communication and dissemination of information Public participation and input in decision making Designate roles and responsibilities, including NGOs as appropriate

Emergency Plan (WCEP)[134] constitutes "a comprehensive, all-hazard emergency plan for the state" that includes an analysis of the natural, technological, or human-caused hazards that could affect the state. Washington defines "emergency" or "disaster" as a situation that either demands immediate action to preserve public health, to protect public property, or to provide relief to any stricken community; or reaches proportions of destructiveness that warrant the governor declaring a state of emergency. The plan also describes the procedures to be used during emergencies, such as the process for administering emergency assistance to victims of disasters.

In the adaptation context, disaster-management planning is crucial because the impacts from episodic but extreme weather events will likely manifest as events that qualify as disasters. As Washington and local communities in the Puget Sound review their disaster-management plans, they should revise their plans with adaptation in mind.

Disaster-management plans should describe future risks and the basic community structure, as well as post-disaster visions and policies for recovery. Thus, a disaster-management plan should consider how climate change impacts will exacerbate existing risks, and should project these

[134] Wash. State Military Dep't, Emergency Mgmt. Division, "Comprehensive Emergency Management Plan" (Mar. 2003); and Wash. Rev. Code § 38.52.030.

new risks. For example, the boundaries of flood plains may expand with more severe storms. The plan should project risks associated with a range of scenarios. A disaster-management plan should include basic information about the community, including the economic and demographic landscape. The plan should focus on identifying vulnerable populations.

For post-disaster recovery, the plan should define "recovery" or include an overarching post-disaster vision that transitions toward a more adaptive environment. This element should also distinguish between areas that should be rebuilt and areas that are unsuitable for rebuilding because of repeated or future risk. The community priorities should be developed through extensive outreach to, and public participation by, all groups, including traditionally marginalized populations. To support that vision, the plan should also include specific goals that lead toward achieving the overarching post-disaster vision and incorporating climate change adaptation strategies as part of any disaster recovery strategy. Ideally, the plan should include goals related to improving resilience; improving equity and social justice in implementing recovery strategies; protecting health and safety; and enhancing economic recovery.[135] The plan should also include policies to achieve these goals, including an overview of available financial, personnel, and technical resources and existing or needed legal tools.

Much as the WCEP describes the role of state agencies in a disaster or emergency, local disaster-management plans should identify the roles of local government agencies, quasi-governmental organizations, and non-profit or non-governmental organizations. The plan should also identify the administrative, technical, and financial resources available to these actors.[136] Plans should also identify the roles of state and federal government agencies and catalogue available resources.

4. The Clean Air Act: Increased Temperatures and Air Quality

Climate change is projected to cause a gradual increase in average surface temperature, which will cause long-term impacts on human health through deteriorated air quality.[137] Two of the air pollutants that will most significantly impact human health are ground-level ozone and particulate matter.

Ground-level ozone is not directly emitted by pollution sources. Instead, it occurs naturally and through photochemical reactions between primary air pollutants known as ozone precursors. These reactions are facilitated by a variety of factors, including temperature. The higher the temperature, the higher the level of ozone resulting from a given level of emissions of ozone precursors. Ozone concentrations tend to be highest during summer months, when sunlight is the most intense.[138] Ground-level ozone pollution is associated with serious health impacts, such

[135] *Disaster Recovery Plan Evaluation Protocol*, University of North Carolina, Center for Law, Environment, Adaptation, and Resources (20 December 2010) (on file with Yee Huang).
[136] *Id.*
[137] *Our Nation's Air: Status and Trends Through 2008*, US EPA, at 39 (February 2010).
[138] *IPCC Adaptation Report*, *supra* note 9, at 401.

as increased incidence of pneumonia, asthma, allergies, and other chronic respiratory diseases and increased mortality.[139]

Similarly, concentrations of air-borne particulate matter (PM) may increase as average surface temperatures increase, because PM formation depends partly on temperature and humidity.[140] Studies link exposure to increased PM concentrations to increased morbidity and mortality.[141]

At the federal level, the Clean Air Act (CAA) is the primary vehicle for addressing the air-quality impacts of climate change. It has been credited with achieving a fifty per cent reduction in the most common air pollutants and with reducing industrial pollutant emissions by more than seventy per cent.[142] More recently, it has become a vehicle by which the US EPA can regulate the emissions of greenhouse gases.[143]

While many have considered how the CAA could be used to reduce GHG emissions, less attention has been focused on the Act's potential role in adaptation. The EPA regulates ground-level ozone and particulate matter concentrations by establishing national ambient air-quality standards (NAAQS),[144] and oversees state plans designed to achieve the NAAQS.[145] In the ozone context, neither the EPA nor the states can rely exclusively on current temperature data to determine the emission levels of ozone precursors that will be needed to ensure future compliance with the ozone NAAQS. Controls on emissions of ozone precursors which would have achieved air-quality standards if temperatures remained constant, could fail to achieve the standards if temperatures—and, consequently the ozone levels associated with a given level of emissions of ozone precursors—increase.

The EPA and Washington should implement the CAA to better achieve current air-quality standards and revise guidance on determining attainment status. Recognizing that climate change will likely worsen background air quality, the Department of Ecology should strive to ensure that, at a minimum, all sources are meeting applicable source-specific emission limitations through increased enforcement efforts and permit oversight.

Currently, the EPA generally recommends that states and Tribes use historical air-quality data to determine attainment status. For example, the EPA guidance on eight-hour ozone and particulate

[139] Ibid., at 402.
[140] Ibid.
[141] Ibid., at 403.
[142] US EPA, "Understanding the Clean Air Act" (last visited April 20, 2011).
[143] In 2010, EPA issued an endangerment finding that greenhouse gases pose a risk to human health, paving the way for regulating the pollutants that contribute to climate change. US EPA, *Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act*, 74 Fed. Reg. 66,496 (Dec. 15, 2009).
[144] The provision that governs the adoption of the national ambient air quality standards is section 109(b) of the Clean Air Act, 42 USC § 7409(b) (2006).
[145] These state implementation plans are governed by section 110 of the Clean Air Act, 42 USC § 7410.

matter attainment demonstrations relies on a historical three-year average.[146] This reliance on historical data assumes that future conditions will remain relatively static—a false assumption given projected temperature increases and their impact on pollution levels. While this method may be viable within the stationary framework of environmental law, the increased frequency of extreme heat events may upend the usefulness of past data in projecting how much emission control is needed to meet the NAAQS and protect public health from air pollution. At the federal level, the EPA should require states to assess not only whether they are in attainment based upon past emissions, but whether they are likely to remain in attainment based on the increased pollutant concentrations that higher temperatures are likely to trigger.

Similarly, states with non-attainment areas must develop state implementation plans that show how they will, by deadlines specified in the CAA, attain the NAAQS. For demonstrating future attainment for ozone and particulate matter, for example, the EPA again recommends in part that states use historical data as a baseline.[147] In light of climate change, states should model future pollution scenarios based on the concentrations likely to arise as a result of higher temperatures, or include worst-case scenario planning in the contingency measures required for areas not in compliance with the national ambient air-quality standards.[148] States should then be required to alter their implementation plans and individual source permits to achieve attainment in light of the increased ozone and particulate concentrations likely to result from higher temperatures.

5. Other Legal Tools and Considerations

In considering adaptation to increased temperatures and increased frequency of extreme weather events, federal, state, Tribal, and local governments should also consider revising building codes and land-use regulations to ensure that they are flexible and respond to adaptation needs. For example, low-impact development requirements could not only enhance water catchment, but also require design features that maximize cooling, such as vented ceilings, site selection, and structure orientation. Hazardous waste treatment or disposal facilities could be subject to additional building codes or stormwater-prevention plans to prevent leakage during flooding events. Major disasters in the past decade, including Hurricane Katrina in the United States and the 2011 tsunami in Japan, demonstrate the importance of such measures.

Ultimately, adaptation in the public health sector involves significant collaboration among local governments, health-care providers, and the public. Socially equitable adaptation strategies require public participation in disaster management planning. To avoid unanticipated surges in air pollution, Washington should begin implementing the Clean Air Act to control emissions at levels that will protect the public from pollution when temperatures increase.

[146] *Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze*, US EPA, EPA -454/B-07/002, at 21 (April 2007).
[147] Ibid.
[148] Clean Air Act, 42 USC § 7502(c)(9) (2006).

VIII. Cross-Cutting Impacts

As noted throughout this article, climate change impacts will not fall neatly into clear, defined boundaries. Instead, the impacts will criss-cross traditional lines of jurisdiction and affect a variety of sectors in countless and unknown combinations. Other important sectors, such as agriculture and hydropower, are primarily concentrated outside the Puget Sound Basin and thus are not addressed in this article. The overarching principles discussed in Part IV are nonetheless applicable. This part briefly highlights particular areas of overlap.

1. The Marine Environment

Greenhouse gas emissions affect both the atmosphere and the oceans. In oceans, climate change produces twin evils: warming and acidification.[149] Studies show that the oceans have absorbed the vast majority of the heat generated since the 1950s, causing deep convective changes in at least one of the world's oceans.[150] The heat and carbon dioxide sequestered by the oceans are cycled into the depths of the large ocean basins; turnover occurs on millennial timescales.[151] The oceans and the Puget Sound are becoming increasingly acidic—a vast change from their natural, alkaline state. The ocean is normally saturated with carbonate and bicarbonate ions, which many marine organisms take up to form their shells and skeletons. However, the oceans are becoming saturated with carbon dioxide, which reduces the availability of these carbonate ions.

These changes will have broad impacts on sea-level rise, marine ecosystems and species, and Washington's aquaculture industry. Changes to the marine environment will impact Washington's 106 commercial shellfish aquaculture areas, which lead the country in commercially farmed bivalve shellfish. The annual economic value of Washington's shellfish industry is valued at roughly US$75 million.[152] Adapting to these changes poses a particular problem because the impact is global and the sources of greenhouse gases are dispersed, falling outside the jurisdiction of Washington and even the United States.

2. Impacts on Flora and Fauna

The combined impacts of increased surface temperatures and changed hydrologic conditions will threaten almost all species in every habitat in the Puget Sound basin. Adaptation efforts should strive to maintain whole ecosystems, recognizing the complex interactions and relationships among species.

[149] Edward L. Miles, *On the Increasing Vulnerability of the World Ocean to Multiple Stresses*, 34 Annual Rev. Envt'l Resources 17, 26 (2009).
[150] Ibid.
[151] Ibid., at 21.
[152] *CIG Report*, *supra* note 1, at 299.

3. Forests

The overall increase in average surface temperature is likely to have significant impacts on forest composition, productivity, and health in the Puget Sound. Both temperature and water availability will impact the distribution of certain species, such as the Douglas fir, and will affect the composition of forests in the inland areas of the Puget Sound Basin. Projected increases in mountain pine beetle outbreaks and forest fires will cause significant disturbances to forest ecosystems. The pine beetle outbreaks are likely to worsen at higher altitudes, due to warmer conditions that are favourable to the insects. The CIG also estimates that the burn area will double or triple by the end of the 2040s, and total burned acres may reach up to two million acres in the 2080s. For all forests across the state, the combination of higher temperatures, decreased water availability as a result of less snowpack and higher rates of evaporation from soil in summer months, and associated ecosystem disturbances suggest that few forests will be immune to adverse changes.

4. Stormwater and Flooding

Flooding poses significant risks both for aquatic ecosystems, by scouring habitat and introducing contaminants, and human-built infrastructure. Projections for extreme precipitation and flooding events are uncertain, but regional climate models generally indicate an increase in extreme rainfall events. The CIG report notes that few statistically significant changes in extreme rainfall have been observed in Washington, except for the Puget Sound. More recent flood events suggest that current infrastructure, using twentieth-century data, may be insufficient for the future climate. For example, the CIG Report noted that the fifty-year storm between 1956 and 1980 became an 8.4-year storm between 1981 and 2005 in the Puget Sound region. Flooding can jeopardize property and human health, for example, by leading to sewage overruns that cause widespread water contamination.

5. Ports

The major ports of Seattle and Tacoma have begun accommodation actions—elevating piers and docks, designing floating terminals—to adapt to projected sea-level rise. These ports are part of a vast transportation hub in the Puget Sound basin, and climate change impacts on them will have reverberating effects on infrastructure, food supplies, public health, and other sectors. Relying on green infrastructure is not feasible for most ports, which are heavily developed.

IX. Conclusion

Adapting to climate change impacts around the world will require an innovative and sustained approach that recognizes the many connections between and among human activities and natural ecosystems. Much as the impacts will affect broad swaths of natural resources and communities, so too must the response be integrated, holistic, and multidisciplinary. Climate change will

challenge the legal status quo, forcing policy-makers to rethink existing tools and how they may apply to heretofore unknown problems.

Although this article focuses on policy prescriptions for the state of Washington, the basic adaptation framework and many of the overarching principles it recommends provide a useful model for policy-makers around the world who are beginning to address adaptation needs. The article poses questions that are broadly applicable, and suggests how policy-makers can analyse those questions and formulate policy to address them.

Facing these tough questions now and laying the foundation for responding to climate impacts, both gradual and episodic, are among the best adaptation strategies that policy-makers around the world can take to ensure environmentally protective and socially equitable adaptation to climate change.