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Good morning! Contemplating what to discuss this morning, I settled on offering the lens of a former policy maker on conundrums that mark the future of ecosystem management. It is tempting to set forth the oft-cited portfolio of resource challenges—water, energy, habitat degradation, declining fisheries, the list goes on. But I want, instead, to look at the decision context itself. I will examine effects of a changing climate on lands, water, wildlife, people, and their communities as springboard for this exploration.

During my nearly 8-year tenure at the U.S. Department of the Interior, perhaps no challenge was more complex than climate change and its effects on people and places. Those effects cut a broad swath across the landscape. Those gathered here today are acutely aware of that medley of potential effects—sea level rise; permafrost thawing; changes in precipitation patterns; increased frequency of high-intensity rainfall events; impacts on flora and fauna; and other changes unfolding globally. I will not enumerate these effects in detail, as we are all familiar with them.

At the Interior Department, I chaired the Department's first-ever Climate Change Task Force. The Task Force examined how climate effects might unfold across 500 million acres of Interior-managed lands and how these effects might impact Interior Department's management at 2,400 locations with some 165,000 facilities. Our deliberations were situated at the confluence of science, technology, communities, management, and policy.

There is a passage in the children's book, *Alice in Wonderland*, by Lewis Carroll, in which the heroine Alice stands at a fork in the road. Alice looks up to see the grinning Cheshire Cat. She asks the Cat, "Tell me, please, which way ought I to go from here." The Cat replies: "That depends a good deal on where you want to get to."

For communities grappling with a changing climate and its effects, perhaps the response to the Cheshire Cat might be: "Communities are striving for risk reduction and sustainability (however defined)."

The challenge is, of course: How? Where? What? Who? When?

Many communities have launched climate action plans. There is much outstanding scientific research underway to better understand climate change effects. Many collaborative efforts are emerging to develop options for addressing risks to communities.

This morning I will offer a few thoughts from the vantage point of a policymaker on the intersection of science, communities, and decision making. Through that lens, I'll highlight four features of the climate change tableau. These features complicate decision making and affect how we think about institutions, information, and actions. These features are not wholly unique to addressing the effects of climate change. But, perhaps, they are distinctive in the breadth, depth, pace, and scale at which they are manifested in climate context.

These four features include:

- The multiple spatial and temporal scales of the climate change problem set;
- High levels of uncertainty about these effects, particularly regionally and locally;
- The interconnected complexity of the changes underway. This complexity results from multiple variables, non-linear interactions, and what a former colleague of mine at the Interior Department referred to as the hyper-volume of interacting axes. This complexity results from interconnectedness—among issues, across landscapes, between people and place, even across time.
- Persistent—and possibly dramatic—change. Climate change effects intersect with demographic change, economic, and land use changes.

Let us consider the first feature: the multiple spatial and temporal scales of change. Many climate effects transcend boundaries of political institutions. Sea level rise, for example, along the Gulf of Mexico, affects multiple communities, even multiple states. Climate effects transcend boundaries and span different time horizons. Some effects are significant and near-term, such as we see with sea-ice melting in the Arctic region. Others are long-term, iterative, and ongoing, as we see, for example, in the responses of some wildlife to climate change.

What are the implications of this first feature for decision-makers? We need institutions and decision processes that facilitate coordination across jurisdictional boundaries. We also need both horizontal and vertical interaction among multiple governing units.

Such interaction is not new. Indeed, the governing framework in many nations involves some sharing of public decision making and a vertical distribution of governing roles and responsibilities among levels of government. But these forms of federalism and regional decision-making may require a different character to respond effectively to the challenges of a changing climate.

Social scientist Kirk Emerson describes “collaborative federalism,” with joint decision making among multiple governing units. The governing form she describes is one of “shared governance”, not divided and distributed decision making. The concept of shared or collaborative governance may be applicable at the regional scale among local, interacting jurisdictions that are striving to coordinate policy and action where responding to climate effects requires cross-jurisdictional action.

But collaborative federalism presents challenges. How might one convene and motivate a cross-jurisdictional polity? And policy makers face practical challenges associated with limits on their authorities to expend funds outside jurisdictional boundaries. Yet such expenditures may be important. Consider source water protection in which relevant lands may lie outside a city’s boundaries. Or consider the need to sustain cool, instream water temperatures along an entire watershed. Or consider beach replenishment along coasts, in which sediment deposition may be required outside a city’s boundaries to secure the desired protections.

I want to mention two central challenges of multi-jurisdictional governance. Fundamentally, policy makers face the challenge described in a report by the Lincoln Institute for Land Policy of how to achieve a decision scale “big enough to surround the problem, but small enough to tailor the solution.” Second, policy makers face a challenge of how to share both goal-setting and financing across governing units—and with the private-sector.

Within this context of shared governance, national agencies may shift their roles from that of provider to facilitator to what some have called the “Home Depot Model”—“you do it, we help.”

Cross-boundary governance options include both structural and non-structural tools. Structural tools include the creation of dedicated agencies, districts, and institutions. Nonstructural tools include service agreements, partnerships, joint programs, and other informal coordinating arrangements. Both may be relevant depending on issues and circumstances.

In the United States, we see many emergent models.

- In southeastern Wisconsin, 28 municipalities with separate stormwater management authorities have joined in a public-private partnership to create a nonprofit organization to coordinate stormwater management in an area encompassing six watersheds.
- In the Tualatin Basin, water managers combined four wastewater permits and one stormwater permit into a single cluster. They partnered with the farmers in the county and the U.S. Department of Agriculture to plant trees within the watershed to reduce water temperatures. Rather than spending $60 million on refrigeration systems to cool the water outflows from the

wastewater and stormwater facilities, they paid $6 million to farmers to invest in “nature”—trees along the river banks.

Both of these partnerships are issue specific. Very few U.S. examples present models of multi-purpose, cross-jurisdictional government—and yet, to address interconnected issues, we may need governing forums that simultaneously consider drinking water, stormwater, flood management, waste water, urban tree cover, transportation systems, and other infrastructure.

Let us turn now to the second feature of climate effects—the high level of uncertainty regarding these effects, particularly at regional and local scales. This characteristic makes ongoing learning imperative. It highlights the significance of adaptive management. The ubiquity of uncertainty underscores the need for flexibility, iteration, and adaptive responses in decision tools and action options. High uncertainty also underscores the central role of science and technical expertise in decision making about whether, when, and how to respond to the effects of a changing climate.

The centrality of science and technical expertise raises a conundrum--what some have referred to as the “technocracy versus democracy” quandary. Climate change issues are highly technical and complex. But policies and adaptation decisions may significantly affect people and involve trade-offs. These differential effects on people heighten the relevance of community collaboration and present a fundamental question: How is it possible to increase public involvement in decision making when the scientific and technical issues associated with some climate effects challenges are so complex? What are the roles of scientists and technical experts?

I suggest that the role of science in decision making is fluid and varying. The relationship of scientists to decision making unfolds along a continuum of low engagement to high engagement. That continuum can be described as clustering into five potential roles for scientists. At an end of the spectrum with minimal engagement is a reporting role in which scientists report research to decision makers. A slightly more active engagement includes reporting and interpretation of scientific information. Third is a role in which scientists report, interpret, and then integrate their scientific information and analysis into policy or management options. Beyond this integration, some scientists may actually advocate particular options. At the far end of the spectrum are circumstances in which scientists participate in making policy choices.

What is the appropriate role of scientists? How can relevant science inform policy and management decisions? I am intrigued by the joint fact-finding model described and used by the U.S. Geological Survey and others. Under that model, scientists, decision makers, and citizens collaborate in the scoping, conduct, and employment of technical and scientific studies to improve decision making. Studies on knowledge use show the importance of iterative dialogue. They show the importance of decision contexts and mechanisms (such as joint fact finding) that link researchers to users.

The user context can significantly affect whether and how scientific and technical information are used. Substantial research indicates that mere reception of knowledge by users does not imply use. Lack of interaction between researchers and intended audiences can present a significant problem that limits relevance and can also limit the perceived credibility of research intended to inform public policy decisions.

The very context of uncertainty invokes other important questions about science and policy. How much certainty about a particular cause/effect sequence or about projected futures is enough? Scientists use a protocol of a 95% confidence level as a bar necessary to affirm scientific results. Policymakers use a different bar—for policymakers or managers, how much uncertainty is acceptable invokes the reply: “It all depends.”

What is acceptable depends on the legal or policy context that might dictate immediate action despite uncertainties. Think of water management in the West. We don’t know with certainty the timing, amounts, and storm frequencies that a changing climate might bring to the West. But water managers may need to take steps to alter water management despite uncertainties. Thus, the question of what level of certainty is sufficient to take management action is, in part, a policy decision.

Though much more might be said of the science-policy interface, let me turn now to the third feature of the climate change problem set: the interconnected complexity of climate change effects.

Consider a case in the Netherlands regarding sea level rise and river flows. In their Room for the River project, they indicate that, on one hand, they need to plan for higher river flows through improved drainage. On the other hand, sea level rise interferes with water drainage. Improved flood protection and water management, therefore, require considering both river flows and sea level. One issue cannot be addressed independently of the other.

This interconnectedness raises challenges of agency silos in which responsibilities for issues are divided. It also raises challenges for metrics. How might managers develop cross-issue indicators to measure outcomes on an integrated basis?

I want to mention two issues. Ecosystem management metrics are often calculated in terms of location-specific targets for, say, species populations. Are these the right metrics? Do location-specific population targets cause us to lose sight of the forest for the trees? Many metrics are focused on particulars rather than the integrated whole. Quantum physicist David Bohm once observed:

“To fragment is to divide things up that are at a more fundamental level actually connected.”

Perhaps we need a combination of system process indicators and population metrics. We also need interpretation—what do indicators mean?
In this regard, I am reminded of the caution of US economist Thomas Sowell, who once wrote: “Information everywhere but knowledge is rare.”

But let us now turn to the last feature of climate change effects: dynamism. Climate effects are highly dynamic, with the pace of change sometimes dramatic, as in current trends with Arctic sea-ice melting.

Like the characteristic of uncertainty, the highly dynamic nature of climate change effects may heighten the need for policy options centered on resilience. More specifically, we may need management options that provide functionality across a broad range of operating conditions.

Consider water management and flood protection. In the case of coastal protection, traditional flood and storm surge protection has relied on “gray” infrastructure such as dikes and levees. This infrastructure may perform well under certain conditions. Increasing performance of this grey infrastructure to withstand more frequent and more intense storms may be exorbitantly expensive relative to solutions that supplement existing gray infrastructure with green infrastructure like beach nourishment, wetlands restoration, sea marsh protections. The latter mix may provide greater functionality and more resilience across a broader range of conditions than traditional infrastructure.

Or consider reservoirs, which, traditionally, have been built for dual purposes of water storage and flood control. We are seeing an increased frequency of high-intensity rainfall events or prolonged droughts, which may warrant revising reservoir operations to maximize water storage capacity in combination with restoring flood plains to serve the flood protection role. Such an approach may offer communities greater resilience than building ever-larger reservoirs that operate as dual-purpose systems.

Comparing these options renders consideration of “Nature’s Capital”—ecosystem services—especially relevant. I offer no answers to the governance, information, and adaptation challenges presented by issues of climate adaptation, but I suggest that risk reduction and sustainability will result from a confluence of science, collaboration, and new forms of governance.

These three dimensions of problem-solving are important for effectiveness, accountability, and legitimacy of decisions. Twenty-first century governance may reveal a new lexicon of collaboration, shared power, networks, consensus, and iteration. All these features, for policy makers, make decisions provisional, and they diffuse responsibilities. This sort of diffuse, provisional decision making is difficult to reconcile with traditional notions of accountability.

With this backdrop, I conclude by exploring a bigger question. Let's look at the broad relationship of science and decision making. Science is critical to understanding causes and effects. It is essential to filling knowledge gaps, projecting future outcomes, modeling alternative options, and assessing restoration results. Many issues are sufficiently scientifically complex that engaging scientists at the decision-making table may help pinpoint the possible and define the doable. Such engagement may help decision makers and managers shape and evaluate options through iterative conversations. It may help decision makers define the "problem set."

The intersection of science and management may need some rethinking. I believe we need to strengthen iterative processes by which information needs are articulated and information is generated, communicated, and used. But what information is needed? Scientists ask: "how does the world work"? Science reputations are often built upon the dissection and discernment of complexities and new frontiers. Policy makers and managers have a different set of tasks. Policy makers ask: "what values do we care about? What priorities should we set? What actions should we take to address those priorities?"

At one level, the very nature of these questions invokes the importance of citizen engagement. The values nature of these questions requires decision making processes of coordination, partnerships, and collaboration. But, in other respects, managers (and policy makers) need information that allows for nimble, sometimes quick action. They need a general sense of progress or of impending problems. They need easily accessible, readily comprehended information. This often means policy makers and managers need general benchmarks and easy-to-use models or decision support tools.

Within a resource management context, this tension between the aims of the scientist and the needs of the manager sometimes eludes resolution. As we ponder these issues, we do well to keep in mind the words of Bertrand Russell: "Sometimes it is important to hang a question mark on things long taken for granted."