

Challenges of Adapting to a Changing Climate

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“Organizations increasingly face adaptive challenges requiring them to abandon the familiar and routine. Instead, they need to develop the capacity to harness knowledge and creativity to fash-

* Department of Agricultural Economics and Agricultural Business, New Mexico State University, Las Cruces, New Mexico 88003, (505) 646-2674, bhurd@nmsu.edu. I would first like to thank the sponsors, organizers, and participants of the UCLA Law School’s 2007 Frankel Symposium, in particular Sean Hecht for his efforts to organize such a stimulating program. Next, this paper reflects many ideas and thoughts accumulated throughout past collaborations with many colleagues, including William Easterling, Joel Smith, Richard Adams, Bruce McCarl, Mac Callaway, and Robert Mendelsohn, all of whom have stimulated my research and thoughts. Finally, my appreciation extends to the Agricultural Experiment Station of New Mexico State University for their ongoing support of my research program.

ion unique responses, stimulate organizational learning and sometimes embrace transformational change.”

Carl Sussman (Management and Community Development Consultant),¹

I.

INTRODUCTION

The consensus among many climate scientists is that reducing greenhouse gas (GHG) emissions from current levels can be expected to slow and, eventually, lower atmospheric concentrations if efforts are sufficiently aggressive. Over time, reduced GHG emissions and concentrations will lessen both the likelihood and the severity of adverse climatic changes and impacts.² Recent trends and observations indicate that warmer temperatures and hydrologic changes associated with elevated GHG levels may already be occurring. These changes are likely to endure for some period, even beyond the time when emissions are reduced, because of the longevity of the atmospheric carbon cycle – about thirty years.³ As a consequence, measurable warming and hydrologic changes are likely unavoidable – at least for the remainder of the century. Faced with this prospect, communities, organizations, and institutions that are particularly vulnerable to warming and hydrologic changes might prudently consider strategies that will enhance adaptive capacity. Such adaptive strategies could potentially forestall or limit adverse impacts and, in some cases, harness new and changing opportunities for economic growth and development.⁴

This paper intends to provide a non-technical overview that describes several key concepts and issues related to climate change adaptation. Drawing insights from varied studies, including those on climate change impacts, vulnerability assessment, and adaptation capacity building, the paper focuses on strategies to bolster adaptive capacity within societal systems. In order to illustrate the concepts of adaptation, the paper utilizes the pro-

1. Carl Sussman, *Building Adaptive Capacity: The Quest For Improved Organizational Performance* 1-20 (Sussman Associates 2004).

2. Intergovernmental Panel On Climate Change [IPCC], *Climate Change 2007: The Physical Science Basis, Summary For Policymakers, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Feb. 2007).

3. *Id.*

4. William E. Easterling III et al., *Coping With Climatic Change: The Role Of Adaptation In The United States* (Pew Center on Global Climate Change 2004).

jected changes in water resources as an illustrative example. In addition, the paper also identifies strategies and projects that are general starting points for efforts to build adaptive capacity. These strategies are attractive starting points because they offer benefits beyond those stemming from climate change preparedness and can be characterized as “no regrets” or “win-win” tactics. For example, additional research into the management and technology associated with water use could potentially raise water-use efficiencies, and thus provide benefits for regions experiencing long-run drought and increased water demands, independent of climate change. These additional benefits, thus, effectively lower the action threshold for project implementation. Finally, the paper turns toward the critical issues of timing adaptation projects and policy changes. Uncertainty about the timing, location, and severity of climate change impacts introduces complexity into both the decision-making process and the traditional rules for optimal investment timing.

II.

IDENTIFYING CLIMATE CHANGE VULNERABILITY AND IMPACTS AND DESCRIBING APPROACHES TO ADAPTATION

Rising concentrations of greenhouse gases in the atmosphere are widely believed by climate scientists to contribute to warmer temperatures, rising sea levels, decreasing snow packs, earlier snowmelts, and changing spatial and temporal patterns of rainfall.² Such changes can have many significant and profound impacts on the functioning of many vulnerable systems found within communities, institutions, and ecosystems.⁵

Accurately characterizing the range of possible impacts – both economic and non-economic – on various systems and resources is complicated by uncertainty about the magnitude, rate, and nature of climate changes, as well as uncertainty about the nature and timing of adaptive responses and their subsequent feedback on impacts. Adaptations are designed to alter and affect the type and magnitude of impacts. Therefore, understanding and portraying likely adaptive responses is fundamental to the assess-

5. James J. McCarthy et al., *Climate Change 2001: Impacts, Adaptation, and Vulnerability* (Cambridge Univ. Press 2001); Robert Mendelsohn & James E. Neumann, *The Impact of Climate Change on the United States Economy* 1-331 (Cambridge Univ. Press 1999); Robert Mendelsohn, *Global Warming and the American Economy* 1-209 (Edgar Elgar Publishing, Inc. 2001).

ment and projection of impacts. For example, the earliest climate change studies that attempted to measure potential impacts on agricultural systems made strong assumptions about the behavior of farmers. These studies, driven largely by the biophysical crop data that was available, assumed that farmers would act naively by failing to adjust their practices even in the face of observed changing conditions.⁶ These so-called myopic or naive farmer assumptions provided for "worst-case-scenario" estimates that did not require researchers to guess about farmer behavior. However, in spite of these limitations, the studies did yield some insights about the range and the upper-bound magnitude of economic impacts and the regional distribution of potential impacts.⁷

Perhaps even more importantly, these studies uncovered the necessity of including adaptation in the measurement process. Researchers had to move beyond the question of whether farmers (or people in other vulnerable sectors) would adapt to questions about how, when, and where they would adapt, the degree of effectiveness of the adaptations, and how to best portray adaptations in subsequent impact models.

III.

SETTING THE STAGE WITH SOME USEFUL DEFINITIONS

To better understand the context and role that underlies the processes of adapting to climate changes, it is helpful to define the following terms:

Sensitivity describes how climate changes can affect a system and its ability to function. Consider an agricultural example – as compared to wheat, corn is much more physiologically sensitive to climate change because corn is more susceptible to hot and dry

6. P. Waggoner, *Agriculture and a Climate Changed by More Carbon Dioxide*, in CHANGING CLIMATE 383-418 (National Academy Press 1983).

7. Richard M. Adams et al., Effects of Global Climate Change on Agriculture: An Interpretive Review, 11 CLIMATE RESEARCH 19-30 (1998); Richard M. Adams et al., The Economic Effects of Climate Change on U.S. Agriculture, in THE IMPACT OF CLIMATE CHANGE ON THE UNITED STATES ECONOMY 18-54 (Robert. Mendelsohn & James E. Neumann eds., Cambridge Univ. Press 1999); Richard M. Adams et al., Impacts on the U.S. Agricultural Sector, in CLIMATE CHANGE: SCIENCE, STRATEGIES, AND SOLUTIONS 25-42 (Eileen Claussen et al. eds., Pew Center on Global Climate Change 2001); J. M. Reilly & D. Schimmelpfennig, Agricultural Impact Assessment, Vulnerability, and the Scope for Adaptation, 43 CLIMATIC CHANGE 745-88 (1999); B. Smit et al., Agricultural Adaptation to Climatic Variation, 33 CLIMATIC CHANGE 7-29 (1996).

conditions and is less able to take advantage of higher carbon dioxide (CO₂) levels.

Exposure describes the extent of climate-change sensitive resources or societal systems that are potentially at risk. It is a critical element of vulnerability, and is one that is often influenced by institutions and policies. For example, coastal populations and the value of coastal developments are exposed to rising sea-levels and storm surges. As populations and developments grow in these areas so does the level of exposure to the risks of climate change. Although people are drawn to coastal areas largely by the aesthetics and recreational opportunities of these areas, the growth and ensuing vulnerability of coastal populations may be exacerbated by relief, rebuilding, and insurance institutions that facilitate the transfer of associated costs and risks to the broader population.

Adaptive capacity is the ability of systems, organizations, and individuals to: (1) adjust to actual or potential adverse changes and events; (2) take advantage of existing and emerging opportunities; and/or (3) cope with adverse consequences, mitigate damages, and recover from system failures. Adaptive capacity is an indicator of how well a system could or would adjust to external changes. For example, a community's adjustment opportunities and adaptive capacity are founded on its capability to protect and secure vital physical and social infrastructure, to access financial resources, to harness information and "know how" (human capital), and to deploy appropriate technology in the face of or anticipation of adverse events or changes.

Vulnerability identifies and indicates how susceptible a system is to climate changes. It is integrative of sensitivity, exposure, adaptive capacity, and measures the overall extent to which a particular human or natural system is exposed to the climate, the degree of its sensitivity to changes, and the level of its capacity to respond to adverse changes with the least disruption to essential functioning – otherwise termed as its adaptive capacity.⁸

Adaptation is a deliberate change in system design, function, or behavior, either in response to or anticipation of changing conditions and/or external events. When the deliberate system change is

8. For example, in 1999, a study by Hurd, Leary, Jones, and Smith developed an approach to identify and measure the relative vulnerability of U.S. water resource regions to climatic changes as shown in Figure 1. See: Brian Hurd et al., *Relative Regional Vulnerability of Water Resources to Climate Change*, 35 J. AM. WATER RES. ASS'N. 1399-1409 (1999). More recently, Hurd, Brown, Greenlee, Grandados, and Hendrie applied this approach to the assessment of water resource vulnerability at a much higher resolution using bi-national data in the borderlands of the Southwest. See: Brian H. Hurd et al., *Assessing Water Resource Vulnerability for Arid Watersheds*, 44 N.M. J. OF SCI. 39 (2006).

in response it is often referred to as reactive or autonomous adaptation, whereas when it is in anticipation it is referred to as proactive or anticipatory adaptation. For example, in a natural ecosystem where reactive adaptation processes are likely to be dominant, a climatic change that brought about a sustained precipitation increase across a grassland ecosystem could stimulate a reactive adaptation by encouraging the growth of shrubs and trees and the adaptive transformation of the grassland into a chaparral or woodland ecosystem. In contrast, an anticipation of increasing storm and flood frequency could bring about a proactive response associated with building higher, stronger levees and improved evacuation procedures are indeed adaptations to increasing storm and flood frequency or severity.

Adaptation success is said to follow a change or disturbance, if the level of system services and functionality is approximately maintained or restored. For example, adaptation is successful if it offsets most agricultural income loss, even though it may leave a farmer with a small loss. The farmer may need to adjust his/her profit expectations, but otherwise remains sufficiently solvent and flexible to change production and marketing strategies for the future.

Portraying adaptation in behaviorally-sensitive models of climate change impacts is as much art as it is science. In both human and natural systems adaptation is a highly complex and dynamic process, often entailing feedback and interactions that depend on factors such as prevailing environmental conditions, available technologies, government policies and programs, and even perceptions and experience with prior events. The limited level of applied research conducted thus far on adaptation is best explained by the complexity, scale, and lack of experience in understanding the dynamic nature of climate change. Moreover, the continued reliance on mechanistic assumptions and the widespread appeal of scenarios and historical analogies has also inhibited applied research on adaptation.⁹ While characteristics such as increased population and wealth can increase exposure to climate change risks, greater wealth and improved technology also extend the resources and the capabilities needed to enhance adaptive capacity. These trends must be taken into account.

9. William E. Easterling III et al., *Coping With Climatic Change: The Role Of Adaptation In The United States* (Pew Center on Global Climate Change 2004); Michael H. Glantz, *Societal Responses To Regional Climatic Change: Forecasting By Analogy* (Westview Press 1988).

when evaluating the nature and scale of future adaptive responses and the likelihood of their success.

The implications of climate change and the potential roles for adaptation are more severe for ecosystems than they are for managed systems like agriculture. For example, fractured migration pathways limit mobility – the most immediate adaptive strategy available to wildlife. While many biological systems might accommodate minor (or slowly occurring) perturbations in a smooth continuous fashion, even minor changes in climate may be disruptive for many ecosystems and individual species. Prevailing environmental conditions such as urban development and pollution, as well as the introduction of invasive species and the isolation of habitats can place great stress on indigenous organisms. Furthermore, the relatively rapid rate of anticipated climate change could pose insurmountable challenges for many species, given their lack of resiliency and difficulty adapting to the changing environment.

IV.

BUILDING ADAPTIVE CAPACITY: WHAT, HOW, AND WHERE TO BEGIN?

Significant changes in the nature and pattern of many types of resources are expected to accompany climate change. An important example is the anticipated changes to the hydrographs of many of the worlds' rivers.¹⁰ Atmospheric warming, fluctuations in rates and patterns of precipitation, and changes in snow pack accumulation as well as the timing of its release can have profound implications for rivers and water delivery systems. Ultimately, these impacts affect the ecosystems, farmers, and cities that rely on the rivers, particularly those in the arid regions.

Figure 2 illustrates what might be a typical pattern of hydrographic change for many river systems as a result of climate change. This shows current and projected average seasonal streamflow for two future time periods, 2050 and 2100, under the influence of climate change in the Rio Grande as it flows down from the mountains of Colorado. The streamflow at this gauge represents roughly 65 percent of the renewable, recurring water supply serving the farmers, cities, and ecosystems of Southern Colorado, Central New Mexico, and West Texas. These results

10. Daisuke Nohara et al., *Impact of Climate Change on River Discharge Projected by Multimodel Ensemble*, 7 J. HYDROMETEOROLOGY 1076-1089 (2006).

indicate the strong likelihood of an earlier and more concentrated pattern of snowmelt, possibly with significantly greater peak flows and much lower mid to late summer streamflows.

The implications of such a change can be considerable for many river systems and water users. Farmers account for more than 85 percent of the use in this system and their greatest water use occurs from mid to late summer. However, river system change will likely result in a substantial drop of natural streamflow during this period, thus putting a greater strain on water reservoir and storage systems. Many reservoir and irrigation systems throughout the West, particularly those found in California's Sierra Nevada, rely in part on the high mountain snow pack for seasonal water storage. Reduced snow pack duration and an earlier and higher peak snowmelt could result in less overall summer water storage as well as a rise in evaporative losses and flood control releases. Changes in streamflow temperatures and hydro-dynamics can also substantially alter aquatic and riparian ecosystems, shifting the timing and lifecycles of many important benthic invertebrates at the foundations of riparian communities.

Successful adaptation generally stems from sufficient and appropriate adaptive capacities that have been harnessed and directed to make deliberate changes in the design, function, and behavior of potentially affected systems. Building adaptive capacity to cope with climate change impacts can, in some cases, entail developing strategies and capabilities that are desirable whether the anticipated impacts occur or not. Such "win-win" or "no-regrets" strategies for developing adaptive capacity are often the ones for which early action is most appropriate. Other strategies, especially those with substantial costs, might best be delayed or postponed, perhaps awaiting better information or better technologies, or else could be developed and deployed more slowly and incrementally. Such timing issues are addressed in the next section.

There are a variety of potential strategies that governments, institutions, and organizations can adopt that could contribute to adaptive capacity and which may yield additional benefits.

A. Improve scientific capabilities and research

In addition to the research needed to gain a more complete understanding of the processes that relate climate and human activities, significant gaps remain in understanding the nature and consequences of impacts and adaptation. The need for improved

environmental monitoring, data, and information is important for climate change, as well as for the management of other environmental stresses. For example, adapting to a shift in a river's hydrograph requires better integration of experts across the scientific fields of climatology, hydrology, and resource management. This might be accomplished by strengthening institutional scientific capacity, cooperation, and collaboration by increasing the use of strategic partnerships such as those between state and local governments, universities, national laboratories, and selected stakeholders.

B. Develop appropriate risk management institutions and policies

As recent disasters such as Hurricane Katrina illustrate, systems of emergency management, government relief, insurance, long-term recovery, and land use planning can be complex – and not always consistent or rational. Major insurers, such as Swiss RE, are looking at the risks of climate change regarding property damage in addition to human health and liability.¹¹ Greater understanding of the interactions of commercial and government insurance programs and their incentive effects on damage exposure and liability harmonization is likely needed. Shifts in river hydrographs can directly impact flood protection systems, exposing system operators to liability, insurers to property damage risks, and citizens to health and property loss.

C. Increase use of market-based programs for resource management

Decision makers at all levels respond according to the incentives, opportunities, and constraints that they face. When risks and rewards are misaligned, the result is frequently poor planning and decision making, inefficient resource use, and higher costs. Programs and policies that use market-based incentives and prices (like marketable permits for air pollutants) flexibly achieve desired outcomes and behavioral changes with lower costs than alternative regulatory and coerced enforcement approaches.¹²

11. Andrew J. Hoffman, *Getting Ahead Of The Curve: Corporate Strategies That Address Climate Change* 29, 76-87 (Pew Center on Global Climate Change 2006).

12. WILLIAM J. BAUMOL & WALLACE E. OATES, *THE THEORY OF ENVIRONMENTAL POLICY* 1-299 (2d ed., Cambridge Univ. Press 1988) (1975).

D. *Add flexibility and safety to long-lived infrastructure design and improvements*

Long-lived or durable infrastructure that is exposed to potential climate change risks, such as dams, bridges, sea walls and levees, ports, and coastal developments, may be at risk of underperforming or potentially failing if specifications do not account for the stress of climate changes impacts. Sea level rise and shifting river hydrographs can subject infrastructure to acute stress if these conditions are not at least considered during planning and design. Often it is less costly to achieve greater infrastructure flexibility, durability, and safety at the design stage than to attempt retrofit solutions at later stages.

E. *Consider climatic factors in land use planning and building codes*

State and local governments are typically responsible for land use, zoning, and building codes. As such, they have a critical role in strengthening adaptive capacities. As temperatures rise and hydrographs shift, risks to health and property can change. Appropriate land use and zoning can lessen potential flood risks. Also, building codes can be adjusted to better account for future risks and the stresses of people living with higher temperatures.

Unfortunately, there are many potential road blocks and limitations that can confound strengthening adaptive capacity. Among them are the potential for political gridlock and institutional paralysis, a dearth of leadership with long-term perspectives, shortness in political cycles, tax fatigue among the voting populace, and competition for scarce public resources. In combination, these factors highlight the importance of looking for additional ways that adaptive capacity benefits society. Recently, political interest has turned recently to infrastructure needs, as a result of the bridge collapse in Minneapolis and levee failures in New Orleans. Perhaps this is an opportune time to enhance renovations and future planning by considering climatic changes.

V.

TIMING INVESTMENT AND POLICY CHANGES

Building adaptive capacity is not an instantaneous occurrence but, rather, one that develops over time, usually with sustained investment. As adaptation projects diverge from "win-win" and "no-regrets" models to those where benefits are largely condi-

tional on the eventuality of climate change impacts, it becomes increasingly important to justify the investment by estimating the time it will take to begin to realize net economic benefits expected to result from the project (e.g. the value of averted damages).

One of the key differences between reactive and proactive adaptation strategies concerns the timing of investments in adaptive capacity building. Reactive adaptation can result from two situations. First, no consideration is given at all to changing conditions or events, and adaptation occurs as conditions warrant it. Second, a deliberate decision to delay or postpone investment is taken, perhaps because of inherent uncertainty or political reluctance. This results in adaptation actions that may have been anticipated but acted upon too late for their full benefits to be realized. Third, proactive adaptation tries to anticipate changing conditions and prepare for them well in advance. Figure 3 compares two hypothetical and stylized time paths depicting the net economic benefits for reactive and proactive adaptation scenarios. In the case of reactive adaptation, net economic benefits are positive and continue to grow until the time of disastrous change. As with Hurricane Katrina, disaster costs in this case are catastrophic and recovery time is quite long. In contrast, proactive adaptation might anticipate the disastrous event and take prudent and appropriate steps to mitigate damages. For example, strengthening levees around New Orleans prior to disaster, or similarly, taking appropriate actions now to shore up the levees around Sacramento, before some catastrophic event would anticipate and mitigate. In these cases, investments cause an initial drop in economic welfare, after which growth proceeds until the disaster. However, in these cases the adaptations are successful; slight damages occur but are quickly recovered from. Long-run economic welfare is potentially enhanced by proactive adaptation in both of these cases.

Proper timing of investment and policy changes can often make the difference in whether or not adaptation is successful. Standard economic rules apply to proper timing when the time path of benefits is certain. In the ideal case of proactive adaptation, investment outlays are timed so as to maximize the present value of net project benefits.¹³ Therefore, as a rule, project or

13. This is the standard result from economics that optimizes the project's net returns. In other words, the timing and rate of investment is selected so as to maximize the net present value of economic returns, as described by Chu and Polzin,

policy changes should begin when the estimated value of annual benefits begins to exceed annual debt repayment costs. In other words, it is optimal to postpone the project until countable benefits are a significant share of the project costs. Benefits must be currently present, not just projected sometime in the future. For example, when should a bridge be built? The answer is when the willingness to pay of the population served is high enough to pay interest on the debt, and perhaps a share of the principle if the lifetime of the bridge is finite. To use an analogy from residential real estate, the rule is to wait until the benefits can pay the mortgage on an "interest only" loan. Investments made too early effectively add to total project costs, just like creative loan practices result in principle increases and not reductions.

Chu and Polzin¹⁹ also discuss two additional situations for identifying rules for optimal investment timing that are appropriately applied to considering climate change. The first is when the time path of benefits is random rather than certain, and when this randomness is sufficiently well understood so as to be capable of estimating the expected present value of benefits with some degree of confidence. Statisticians describe this type of random process, one with a stable profile exhibiting a constant mean and standard deviation, as "stationary." When the benefit time path of a project or policy change is uncertain and its random nature is stationary, then optimal investment timing cannot be precise. Here, the underlying economic concept is to time investment outlays so as to maximize the *expected* present value of net economic benefits. Investment timing is expected to be optimal when the estimated value of annual benefits exceeds annual debt repayment costs times a fixed constant (> 1.0) that reflects a risk premium for the uncertainty and the growth rate of expected net benefits over time. In other words, it is optimal to postpone the project until countable benefits are an even higher share of project costs than when benefits are certain. Using the real estate analogy again, the rule is to postpone investment until expected benefits are sufficient to pay the mortgage interest plus a risk premium at a minimum and, as before, the level is even higher if the expected project lifetime is finite.

Dixit and Pindyck, and Lempert et al. See: Xuehao Chu & Steven E. Polzin, *Timing Rules for Major Transportation Investments*, 27 TRANSP. 201-219 (2000); AVINASH K. DIXIT & ROBERT S. PINDYCK, *INVESTMENT UNDER UNCERTAINTY* (Princeton Univ. Press 1994); ROBERT J. LEMPERT ET AL., *CAPITAL CYCLES AND THE TIMING OF CLIMATE CHANGE POLICY* 1-60 (Pew Center on Global Climate Change 2002).

The second type of rule, which is arguably even more descriptive of present knowledge regarding climate change, is when the benefit time path not only is random but “non-stationary.” This means that a probability profile is not stable or even changing smoothly. In this case, expectations lack confidence at best, and may even be dangerously unreliable. Standard investment timing rules lose their credibility, requiring the application of less objective and more heuristic approaches for project and policy timing. There is no analogous rule that holds for this case. As such, this type of condition causes real havoc in the insurance industry where stationary random processes are the basis for determining actuarial estimates and competitive insurance premiums.

VI.

CLOSING THOUGHTS

In general, there is considerable uncertainty in understanding the possible trajectories that climate change can take. Possibilities range from gradual and smooth paths to rapid and discontinuous trajectories. To the extent that climate change is rapid or discontinuous, adaptation will be more difficult. Faster rates of climate change necessitate more rapid and costly adjustments associated with any adaptive response and increase the likelihood that necessary adaptive responses will lag behind changes in climate. Also, when the time path of expected adaptation benefits is uncertain, then postponing action may be desirable because more time allows for the accumulation of knowledge and information and the potential resolution of some uncertainty. Moreover, postponing action may also enable more accurate project scopes and timing as well as the emergence of better technologies and potentially lower project costs. On the other hand, there are several risks to delaying action. For example, delay might result in less successful adaptation as the time frame to deploy projects is shortened. Delay could also raise the likelihood of irreversible losses.

In spite of the challenges this decision environment presents, affirmative steps can be taken by communities, governments, and institutions that inform the decision making process and take into account the nature and types of changes that are more likely than not with a change in climate. Consideration of such changes within planning processes can be expected to result in greater

flexibility in institutional and infrastructure design and greater alignment of the resulting structure or system with the likely trends and changes that are expected with climate change.

FIGURES

Figure 1. Index of Overall Relative Regional Vulnerability of Water Resources to Climate Change from Hurd et al., 1999¹³

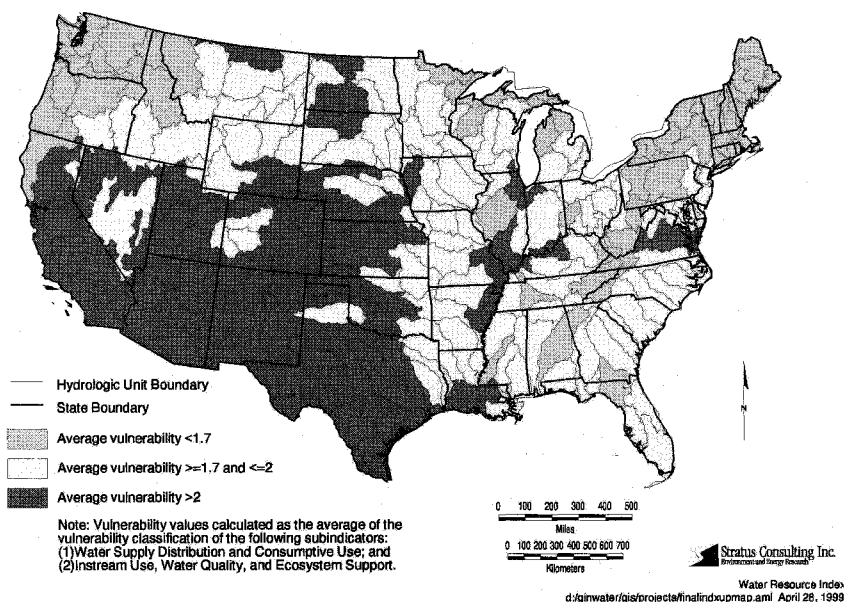


Figure 2. Current and Projected Changes of the Rio Grande Hydrograph under Climate Change

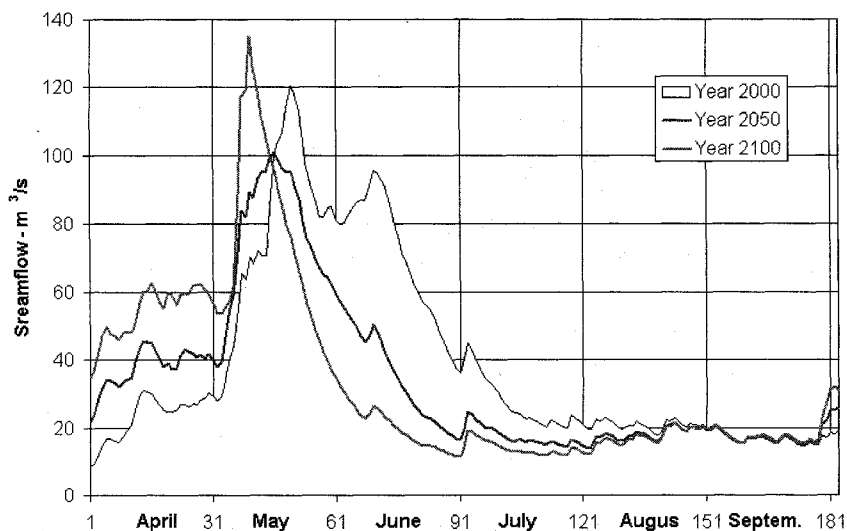


Figure 3. A Hypothetical Comparison of the Relative Cost and Success of Reactive versus Proactive Adaptation

