SUMMARY

CLIMATE CHANGE SCENARIO PLANNING WORKSHOP

JOSHUA TREE NATIONAL PARK AND KALOKO-HONOKOHAU NATIONAL HISTORICAL PARK

November 13-15, 2007
Joshua Tree National Park Headquarters

This report summarizes the processes and outcome of a scenario planning workshop held in November 2007 at Joshua Tree National Park. It was produced by the National Park Service (NPS) in collaboration with the National Center for Landscape Fire Analysis (NCLFA) at the University of Montana. Most of the content in the report was written by NCLFA staff, which organized and facilitated the pre-workshop exercises as well as the workshop itself. The workshop was conducted for the NPS using a task agreement through the Rocky Mountain Cooperative Ecosystems Studies Unit at the University of Montana. Funding was provided by the National Park Service Division of Fire and Aviation Management. The report reflects the major elements of the processes leading up to the workshop and the workshop results. It is intended to provide guidance on scenario planning with particular applications to resource management and to inform the development of scenario planning as tool for adaptation planning in the NPS.

Workshop Purpose:

To explore the use and effectiveness of scenario planning for climate change in national park units by:

1. Understanding the principles and applications of scenario planning.
2. Developing a scenario planning process and applying it to two case study parks.
3. Identifying climate change scenarios that lead to robust management actions that could be initiated at the two parks.
4. Identifying lessons learned and areas of needed refinement.

Meeting Participants:

See Attachment 1: Participant List.

INTRODUCTION

This report summarizes the results of the pilot climate change scenario planning project conducted in 2007 using Joshua Tree National Park (JOTR) and Kaloko-Honokohau National Historical Park (KAHO) as case studies. The report describes the process and the results of the project through the following six sections: Background, Methodology, Process, Results, Lessons Learned, and Recommendations.

BACKGROUND

The Issue: Climate Change

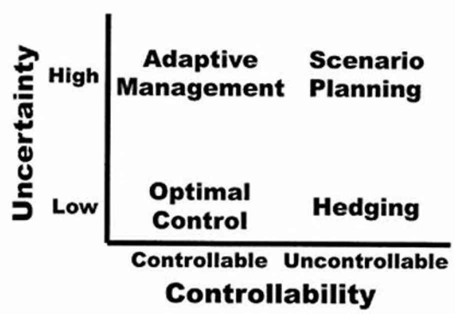
Climate change likely poses the most significant threat to global ecosystems and landscapes in modern human history. Effects of climate change are far-reaching and profound, and include species extinction; altered distributions of species; community shifts; increased disturbance from wildfires, droughts, pathogen infestations, and invasive species; changes in growing season length and timing and duration of phenological events; increase in extreme weather events such as thunderstorms, hurricanes, and windstorms; increased ocean temperatures and acidification; and rising sea levels (IPCC 2007). Natural and cultural resources in the national park system are similarly at risk from the effects of climate change – America's parks may experience severely altered landscapes and habitats; loss of key species; species invasions; increased severity, frequency, and size of wildfires; damage to infrastructure and resources; and inundation by sea water. Although evidence for climate change is unequivocal, in many cases the timing and magnitude of events and their effects on complex ecosystems cannot be precisely predicted. Therefore, parks cannot forecast exactly how climate changes will alter park resources and may struggle to develop appropriate management responses. Alternatively, park planners can explore possible effects of climate change and begin to plan for a variety of outcomes. The development of multiple future scenarios allows for more adaptive, flexible, effective and far-reaching management responses than current one-dimensional plans.

Why Should National Parks Take Action on Climate Change?

- Climate changes and associated ecosystem impacts have already been observed.
- Reduction of greenhouse gas emissions is possible, but there is a long lag time between emissions reductions and change in the levels of atmospheric CO_2.
- Climate change will result in irreversible changes to the world as we know it.
- Proactive planning is easier and less expensive than quick reactions.
- Although scientists concur that climate change is occurring, uncertainty exists about the timing, magnitude, and extent of changes. Multi-dimensional planning strategies are necessary to manage this uncertainty.

Why Use Scenario Planning?

- Scenario planning offers a tool for developing a science-based decision-making framework in the face of high uncertainty and low controllability.



Peterson 2003

- Scenario planning highlights action steps and policy changes that can address a range of possible future outcomes (single decisions that can have multiple results).
- Scenario planning creates prepared awareness by pointing out potential future surprises.
- Scenario planning incorporates alternative perspectives into conservation planning.
- Managers can build into the scenarios monitorable indicators to assess the validity of the scenarios over time and to adjust plans according to the actual levels of change.
- Scenario planning improves capacity for adaptive management.

What is Scenario Planning?

Scenario planning is used to create and assess alternate futures in a systematic fashion, and then make decisions that are effective in a variety of futures. To cope with uncertainty, scenario planners envision decisions and management strategies that are robust given a range of possible futures (Bennett 2003).

> “Scenarios are powerful planning tools precisely because the future is unpredictable. Unlike traditional forecasting or market research, scenarios present alternative images instead of extrapolating current trends from the present. Scenarios also embrace qualitative perspectives and the potential for sharp discontinuities that econometric models exclude. Consequently, creating scenarios requires decision-makers to question their broadest assumptions about the way the world works so they can foresee decisions that might be missed or denied.” (Global Business Network 2007)

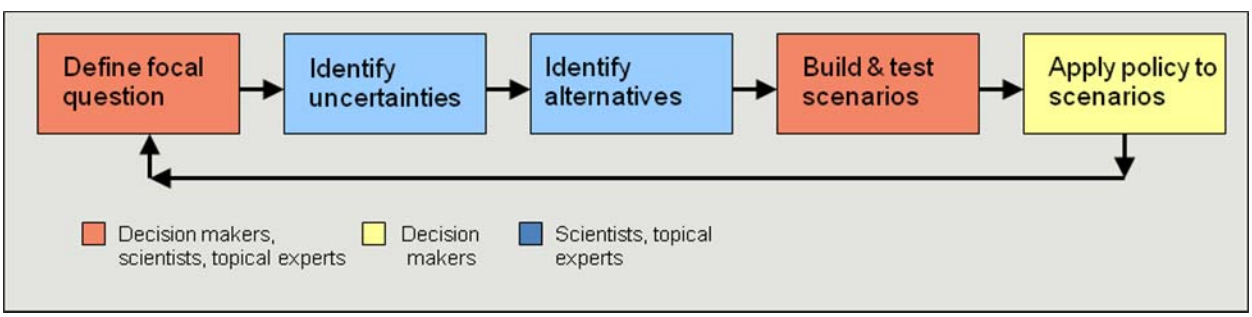
Scenario planning has been used formally in various arenas since post-World War II, initially as a method for military planning. The Shell Oil Company used scenario planning in the late 1960s by envisioning, against conventional wisdom, a future where oil prices might skyrocket. In 1973, oil prices did indeed rise dramatically and Shell Oil was one of the only oil companies prepared to react to the increase. Since that successful application, scenario planning has become widely used by business planners, political decision makers, local community managers and global environmental thinkers (Bennett 2003). More recently, natural resource planners and ecologists have used scenario planning to better understand environmental change (Baker 2004, Bennett 2003, and Peterson 2003). Ecological systems are complex and are capable of great change and function over long time scales; predictive modeling, forecasting, and projections offer only short-term, narrow outcomes (Bennett 2003). Scenario planning can incorporate potential sudden changes in current trends and can address the complex, interwoven, and long-term issues associated with the impacts of climate change on an ecosystem.

Scenarios and scenario planning have been defined in a variety of ways by a range of planners. The term *scenario* can refer simply to a continuation of the current situation or, as used in systems models, can be a structured result of various input parameters. The IPCC uses the term scenario to reflect its assumptions about emissions levels given different assumptions about demographics, economics, and technological innovations. The approach to scenario planning described in this report defines scenarios as a narrative account of alternative plausible yet imagined futures resulting from interactions between external drivers and internal feedbacks.

The end result of scenario planning is a collection of scenario narratives: generally two to five stories about plausible future realities in a park, region, community or other area of interest. The scenario narratives can contain both qualitative and quantitative information and may contain realistic projections of current trends or be based on quantitative models, but are ultimately imaginative and incorporate a wide range of possibilities (Peterson 2003). The range of plausible future events emerges from the interaction of external drivers and the resulting feedbacks in internal systems. For example, a scenario narrative might trace the story of a) a temperature increase resulting from climate change as an external driver, which b) alters the viability of a native species that is strongly associated with the park's identity, and c) an exploration of how visitor experience and park management of that species might be affected. Scenario narratives are not simply an extension of current reality, but instead incorporate realistic imaginings about future surprises or possible outcomes from processes not currently seen as normal.

METHODOLOGY

The overall approach for scenario planning for this pilot project generally followed the process identified by Petersen et al. (2003) (see figure below), but was adapted based on guidance from Ogilvy and Schwartz (2004) and The Climate Impacts Group (2007).



Peterson 2003

PROCESS

Summary

The National Park Service (NPS) initiated the climate change scenario planning pilot project in the summer of 2007. Two case study parks were selected: Joshua Tree National Park (JOTR) and Kaloko-Honokohau National Historical Park (KAHO) for the project. An interdisciplinary team of scientists, managers, other stakeholders and scenario planning facilitators (see Attachment 1 for a list of participants) defined the focal issue, conducted research, and created tools to facilitate the scenario planning process. The team met via conference call and web conferencing on multiple occasions to review and discuss the scientific information needed to write the scenarios. A 3-day workshop was held in November 2007 at Joshua Tree National Park to build the scenarios.

Step-By-Step

The scenario planning process took place over the course of 10 weeks. Below is a summary of the tasks accomplished each week, followed by a step-by-step description of the major planning elements. Results, lessons learned, and recommendations are discussed in subsequent sections.

Week 1:	Engage interdisciplinary scenario planning and stakeholder team (ID teams)
Week 2:	Distribute introductory reading; Begin planning workshop
Week 3:	Conference call 1: introductions to each other and to concept of scenario planning
Week 4:	Conference call 2: discuss readings, brainstorm focal issue; Conference call 3: decide on focal issue
Week 5:	Conference call 4: identify uncertainties
Week 6-7:	Complete scenario planning tools and tables
Week 8:	Conference call 5: review tables, begin to create connections for flow diagram; create flow diagrams
Week 9:	Conference call 6: review flow diagrams, discuss possible scenario outlines
Week 10:	Scenario planning workshop – build scenarios

<u>Step 1: Engage scenario planning and stakeholder team (ID team)</u>
An ID team was developed that consisted of scientists, managers, other stakeholders, and scenario planning facilitators (Attachment 1). The University of Montana's National Center for Landscape Fire Analysis (NCLFA) organized and facilitated the process through a task agreement of the Rocky Mountain Cooperative Ecosystem Studies Unit (RMCESU).

The ID team familiarized themselves with the topic of scenario planning and the science of climate change by reading and discussing:

- *Scenario Planning: a Tool for Conservation in an Uncertain World* by Garry D. Peterson, Graeme S. Cumming, and Stephen R. Carpenter from <u>Conservation Biology</u> 17, no. 2 (2003): 358-366.
- *Plotting Your Scenarios* by Jay Ogilvy and Peter Schwartz from the Global Business Network, 2004.
- Intergovernmental Panel on Climate Change documents about climate change, particularly the *Working Group I Report: The Physical Science Basis, Summary for Policymakers* and the *Emissions Report* and *The Regional Impacts of Climate Change: An Assessment of Vulnerability.*

Several examples of scenario narratives were also reviewed and discussed.

<u>Step 2: Plan workshop logistics</u>
While the ID team was being assembled and team members were reviewing the readings, the facilitators and a core group from the NPS coordinated the details and logistics of the workshop. A workshop agenda (see Attachment 2) was developed and background materials were assembled and placed into a binder for the workshop. Binder materials included sample scenario narratives, copies of the tables and graphs (tools) that were developed in the pre-planning process, and specific information on the two case study parks.

<u>Step 3: Identify focal issue and critical uncertainties/drivers</u>
Four conference calls were held with the ID team during weeks 3-5. The first call was a kick-off call for the project that focused on introductions of the team members and their areas of expertise.

The second call was held one week later to discuss the concept of scenario planning and the readings. During the 2nd call, the facilitator encouraged the team to start brainstorming possible focal issues. The focal issue is the key decision that needs to be made in order to set the scope of the following activities (e.g. Ogilvy 2004).

On the third call the ID team discussed and decided upon the focal issue - *How can NPS managers respond to climate change impacts?* At the close of the 3rd call the facilitator requested that the ID team brainstorm external drivers that influence the focal issue.

During the fourth conference call the ID team evaluated which uncertainties have the largest impact on the focal issue to identify the external drivers that impact the focal issue and other implications. Scenario planners generally look at five categories of forces and trends: social, technological, economic, environmental and political (Ogilvy 2004). To identify the key uncertainties, or external drivers, the team brainstormed a large list of all the possible external influences impacting the park and then ranked those by their potential impact. Forces that seemed inevitable or pre-determined were eliminated. The two to four forces that were considered most uncertain and most important to the park were retained as the primary drivers.

The ID team utilized WebEx, a collaborative meeting software system that allows viewing and sharing of each other's computer desktops over an online connection, and CMap Tools, a concept mapping software application that creates flow diagrams, as tools to accomplish the objectives of the conference calls.

<u>Step 4: Develop drivers and impacts tables</u>
Using the critical uncertainties identified in the previous step, the team identified key drivers of climate change uncertainty and documented their potential impacts to park resources, facilities, and visitor use. Several conference calls were conducted with subject matter experts on the ID team to develop, review, and refine these products.

<u>Step 5: Develop flow diagrams</u>
Flow diagrams that depicted the relationship between the drivers and potential impacts were developed to graphically illustrate the complex relationships and to assist in the development of scenarios. The flow diagrams were created, reviewed, and refined in weeks 8-9.

<u>Step 6: Conduct scenario building workshop</u>
A 3-day workshop was held to build the park-specific scenarios. Scenarios are stories of plausible alternative futures that could occur based on differences in the local effects of climate change. See the Results section for a more detailed description of the scenarios produced for the two case study parks.

RESULTS

A number of important findings resulted from the pilot scenario planning process and from the workshop held in November 2007. A more-detailed version of these results is included in the original workshop report produced by the University of Montana, but this report summarizes the most pertinent of these findings below. Key products that resulted from the workshop and the project are included as attachments to this report and are referenced below.

- Critical uncertainties for JOTR and KAHO were: local effects of climate change, budget resources, and public perception of resource values.
- Key drivers of climate change and potential impacts to park resources, facilities, and visitor use were documented by producing the *Drivers of External Change* and *Change-Sensitive Sectors and Potential Impacts* tables (see Attachment 3). These tables were developed specifically for this pilot project, building from tables included in the Climate Impacts Group text *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments* (Center for Science in the Earth System (The Climate Impacts Group) 2007).
- A Cartesian Quadrant Graph was also developed to illustrate the key drivers and form the basis for the development of the park-specific scenario narratives for JOTR and KAHO.
- Park-specific scenarios were developed that illustrate the range of plausible climate change events and conditions that the parks may have to respond to (see Attachment 4 for the scenario narratives).
- A number of common management actions to respond to the effects of climate change were proposed for the two parks:
    - re-locate historical sites and archaeological resources
    - document resources that are vulnerable to destruction
    - work with different user groups to understand how changes in the park might impact their use of the park
    - revise long-term interpretive plans
    - update fire management plans
    - develop relationships with other agencies in the ecosystem around the park – discuss ecosystem management plans for species and other transboundary issues

- develop a schedule to evaluate the need to revise or update the indicators proposed to detect change in key park systems and resources, such as the pervasiveness of invasive non-native annual grasses proposed to evaluate wildland fire severity and frequency at JOTR

LESSONS LEARNED

A number of lessons were learned as a result of this pilot project for assessing the utility of climate change scenario planning for national parks. As described in the Results section, a more-detailed version of these lessons learned is included in the original workshop report produced by the University of Montana, but this report summarizes the most pertinent of these findings below.

Stakeholder Involvement

The stakeholder and scenario planning teams assembled for the JOTR/KAHO case studies included a range of disciplines and interests. However, several key actors were missing from the scenario building workshop. For example, native Hawaiians are a key stakeholder in KAHO, but were not present at the workshop. Managers from KAHO were able to speak about concerns and viewpoints of the native Hawaiians, but a full scenario planning effort for the park would need to include several members of this important stakeholder group. Park staff from KAHO discussed the native Hawaiian's view of history and time and that artifacts created two hundred years ago might not necessarily be considered older or more valuable than artifacts created two weeks ago. This point of view might impact how KAHO can manage its archaeological resources – the native Hawaiian stakeholders might welcome moving or rebuilding historic fishponds, for example. This viewpoint seemingly contradicts what might be expected of a culture interested in preserving its history and it was important for all stakeholders to hear this view at the workshop in order to incorporate it into the scenario planning.

Recommended members of the scenario planning team include the following program/interest areas:

NPS staff

- Chief of interpretation
- Climate change coordinator
- Natural resource manager
- Cultural resource manager
- Education/outreach staff
- GIS staff from the park
- Superintendent

Public / Stakeholders

- Cultural groups that use or access the park's resources
- Member of Park Association or other non-governmental organizations that support the park
- Other members of the public with specialized knowledge of potential external influences on the park (e.g. manager of adjacent public lands, city or county planner, real estate professional or developer)

The Focal Issue

The focal issue should be broad enough to address the complex interactions between the park ecosystem and external forces like climate change, yet should be focused enough to allow for the identification of specific action steps that park managers can implement. If the park is threatened by a specific impact of climate change or is particularly vulnerable to an external force (i.e., sea-level rise, severe storms, or wildland fire) those can be reflected in the focal issue.

Developing the Drivers and Impacts Tables

The scenario planning facilitator should coordinate the completion of these tools by identifying which stakeholders have the expertise to complete the various input fields and then working with those experts to get the information and populate the tables.

Scenario Building Workshop

It is important to adequately review all of the work that has been completed in the weeks and months leading up to the workshop at the beginning of the workshop because many of the workshop participants will not have been involved in every aspect of the scenario planning process and will have different levels of understanding. It is entirely possible that assumptions about key drivers and impacts could change as a result of broad understanding, which will result in greater acceptance of the scenario planning process and its results.

Policy Issues and Scenario Narratives

This pilot project uncovered some complex issues in the process of writing scenario narratives for the two parks – one in a desert ecosystem and one on the Hawaiian coast. These issues included the idea that one park's native species might become another park's invasive species as climate changes force the species to migrate – the definition of a natural community might have to expand to the bioregion level. Current park policy calls for preserving the natural state – does this mean documenting and observing the losses due to climate changes (like inundation of archeological resources due to sea level rise), or does climate change require a new park mandate that allows for active interference, such as re-locating natural and cultural resources?

In order to develop robust scenarios that challenge assumptions and lead to informed planning and decisions, scenario planning teams should create scenarios that represent fundamental shifts in the character of the world, not just intensification of current patterns. These scenarios should be different in character and should not duplicate relationships between external drivers and vulnerable internal sectors.

Indicators of Change

Quantifiable indicators should be developed for each scenario to assist park staff in determining which story and set of climate change conditions is unfolding. Investigate and consider using the Inventory & Monitoring program data and vital signs to assist with this effort. The selected indicators need to be monitored systematically.

Developing Management Responses and Actions

The following guidelines can be used to assist in the development of climate change management responses and actions that may be considered at the park level:

- Determine how current policies and procedures need modification in order to make the park better able to respond to the possible futures outlined in the scenarios.
- Choose possible future events that might occur within the realm of plausibility and determine how the park might respond to those events. A common response across several scenarios will become an action step.
- Identify plausible changes in the vulnerable sectors of the park, identified through the tables and the scenarios, and then determine if the park is currently able to adapt to those increased vulnerabilities and, if not, what steps are required to adapt.
- Create a cost-benefit analysis table for possible management actions, given a future scenario. For example, if one scenario narrative identifies that temperature increases and increased incidence of wildfire will destroy much of an important plant species in the park, managers could examine the costs and the benefits of replanting that species elsewhere in the park.

RECOMMENDATIONS

A number of recommendations were identified as a result of the pilot scenario planning process and workshop.

- The Intergovernmental Panel on Climate Change (IPCC) created emissions scenarios to capture the complex uncertainty of the future levels of greenhouse gas emissions. These IPCC scenarios incorporate assumptions about demographic, socio-economic, and technological development as part of narrative storylines, in which future emissions levels are dependent on the initial set of assumptions. As well as serving as good examples of alternate futures, these scenarios provide park managers with initial data on the range of driving forces associated with anthropogenic climate change, and the potential physical changes associated with each emissions storyline. The IPCC emissions scenarios can serve as the basis for constructing unique, personalized storylines for individual parks using regionally appropriate scientific data, personal knowledge, plausible stochastic events, and other information.

- If the park is unable to engage an external scenario planning facilitator, it should appoint an internal staff person (or persons) with an understanding of workshop facilitation, scenario planning, park management and climate change science to coordinate this process. Ideally, the scenario planning team should consist of a facilitator, a climate change scientist, and a scenario planning expert.

- The pre-workshop reading, research and information gathering should begin about three months before the first workshop.

- The workshop should be held in a conference room inside the park so that participants can view examples of park resources firsthand and because many of the stakeholder attendees will likely work in or near the park. The workshop meeting space should contain projection equipment for showing presentations and should have an internet-enabled computer available.

- Include monitorable environmental indicators in each scenario – these indicators can be used as landmarks through time to highlight the narrative pathway that most closely matches the current reality. Examine if the driving forces are creating environmental pressures to produce an environmental state. These indicators should be aligned with the NPS Inventory and Monitoring program if possible.

- The scenarios that are developed should be tested by applicable outside scientists and others for feasibility and brought back to the scenario planning team for review, revision, and acceptance. One possible aspect of this outside review is for additional scientific testing of the assumptions, climate drivers, models of local climate change conditions and effects, and proposed management responses. The scenario planning facilitator should coordinate testing the validity of the scenario's assumptions by bringing the scenarios to a range of outside peers for evaluation. Those peers might include scientists from a nearby national park or other agency who are familiar with the park's ecosystem, managers from other parks or other public lands, and climate change researchers from universities in the region. Testers should especially examine the responses included in the park to assess whether they think park management, park staff, the public, local politicians and other actors described in the scenario might really respond in the way that the scenario envisions. For example, if a scenario suggests major shifts in visitation habits due to the effects of climate change, those visitors should be sampled to gauge the reality of this shift. This sort of testing will likely require more time.

- Thresholds should be identified for each sector or vulnerable resource. After reaching a certain level, impacts from climate change will be exacerbated or magnified; this threshold shift can mean that changes happen more quickly, more erratically and more unpredictably. It might be impossible to identify all thresholds in the park's systems, but by identifying the most important change-sensitive sectors, managers can determine which of those sectors and their potential thresholds need more research.

- Develop a plan to conduct more research. The scenario planning process may reveal that the park does not have enough data about certain resources to adequately examine their relationship to climate change. An action step to identify and fill those research gaps might be the first step the park needs to take before it can shift its management priorities to respond to climate change.

- Park managers should develop a strategy for proposing management actions in the park. This strategy might include: educating all park staff on climate change and management action strategies through a series of seminars; initiating a management action team to start implementing action steps; and creating a climate change task force for the park to lead climate change research, adaptation, and mitigation efforts.

LITERATURE CITED

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ATTACHMENT 1: PARTICIPANT LIST

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ATTACHMENT 2: MEETING AGENDA

Scenario Planning for Climate Change in the National Parks Workshop

November 13 – 15, 2007
Joshua Tree National Park

Day 1: Tuesday, November 13

8:00 - 8:30 am	Introduction – Lee Macholz
8:30 - 9:00 am	Overview of Climate Change Impacts to National Parks – Leigh Welling
9:00 - 9:30 am	Introduction to Climate Change & Interaction with Fire –Tim Brown
9:30 - 10: 00 am	Introduction to Sea-Level Rise – Eric Grossman
10:00 - 10:30 am	Scenario Planning: Concept & Application – Holly Hartmann
10:30 - 11:00 am	Break
11:00 - 11:30 am	The Joshua Tree Scenarios
11:30 am - 12:15 pm	Lunch, discussion. Lunch provided.
12:15 - 1:00 pm	Walk in the Park
1:00 - 5:00 pm	The Joshua Tree Scenarios (cont.)
7:00 - 9:00 pm	Working session, if needed

Day 2: Wednesday, November 14

8:00 - 8:30 am	Welcome, summary of Tuesday's work – Lee Macholz
8:30 am - 12:00 pm	The Kaloklo-Honokohau Scenarios
10:00 - 10:30 am	Break
12:00 - 12:30 pm	Lunch. Lunch provided.
12:30 - 3:00 pm	Policy Screening
1:40 - 2:00 pm	Break
3:00 - 5:00 pm	Next Steps: Joint PWR-AKR Managers Meeting – Leigh Welling

Day 3: Thursday, November 15

8:30 am - 12:00 pm	Field trip through Joshua Tree National Park. Optional.

ATTACHMENT 3: DRIVERS AND IMPACTS TABLES

Table 1a – Climate Drivers: Joshua Tree National Park (JOTR)

Table 1b – Budget Drivers: JOTR

Table 1c – Value Drivers: JOTR

Table 2 – Impacts: JOTR

Table 3a – Climate Drivers: Kaloko-Honokohau National Historical Park (KAHO)

Table 3b – Budget Drivers: KAHO

Table 3c – Value Drivers: KAHO

Table 4 – Impacts: KAHO

Table 1a –Drivers of External Change for Joshua Tree National Park: Climate Change

SUMMARY OF PROJECTED CLIMATE CHANGES FOR JOSHUA TREE						
Climate Variable	**General Change Expected**	**Specific Change Expected & Reference Period**	**Size of Expected Change Compared to Recent Changes**	**Seasonal Patterns of Change**	**Confidence**	**Source & Context**
Temperature	Increase	2050: +2 +/-0.6°C 2100: +3.1+/- 1.1°C	Large	More pronounced in summer and early fall	>99.9% *Virtually certain*	Abatzoglou and Brown*
Precipitation	No Change / Decrease	2050: 0 +/- 2% 2100: -2.5 +/- 2.5%	Similar	More pronounced in winter and spring	Spring 99% Other seasons non-significant *Likely*	Abatzoglou and Brown*
Relative Humidity	Decrease	2050: -0.8% (-3.2 to +0.7%) 2100: -1.2% (-5.2 to 0.7%)	Large	More pronounced in spring	Spring and Summer 95% *Likely*	Abatzoglou and Brown*
Wind Speed	Increase	2050: +2% +/- 0.7% 2100: +3% +/- 1%	Large	More pronounced in winter and spring	>99% Spring, >95% Annual *Likely*	Abatzoglou and Brown*
Extreme Events: Temperature	Warm Events Increase / Cold Events Decrease	2050: increase 3-6 times present; decrease to 1/5-1/3 of present 2100: increase 5-8.5 times present; decrease 1/12 to 1/8 of present	Large	Increase in frequency and length of extreme hot events (summer) greatest relative exceedances in summer; decrease in extreme cold events (winter)	Modeled and observed *Very Likely*	Abatzoglou and Brown*
Extreme Events: Precipitation	Decrease/Increase	2050: -20% to +50% 2100: -20% to +50%	Large	Increase in frequency and contribution especially in winter. Largest increase in autumn (large intermodel differences).	Modeled and observed *Uncertain*	Abatzoglou and Brown*

				Decreases in spring. Percent of annual precipitation falling as extreme events increases.		
Extreme Events: Storms	Increase	2050: 2100:		Severe winter coastal flooding, more frequent flooding at higher flood levels	Very high confidence	Rachel Loehman IPCC WG2AR4[1]
Extreme Events: Wind Speed	Seasonal Dependant Decrease/Increase			2x to 5x increase in extreme wind speed events during spring and summer, 2x decrease in winter by 2100.	Uncertain need more models	Abatzoglou and Brown*
Other						

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Input by: Tim Brown, Rachel Loehman

*Values extracted from nine climate models used in the IPCC AR4; values based on SRES-A1B.

[1] Field, C.B., L.D. Mortsch,, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running and M.J. Scott, 2007: North America. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 617-652.

Table 1b – Drivers of External Change for Joshua Tree National Park: Budget

SUMMARY OF PROJECTED BUDGET CHANGES FOR JOSHUA TREE						
Budget Variable	**General Change Expected**	**Specific Change Expected & Reference Period**	**Size of Expected Changes Compared to Recent Changes**	**Patterns of Change**	**Confidence**	**Source & Context**
Base NPS Funds[2]	Significant Increase	2006-2016: 15%	Greater	Will appear as a variety of Centennial initiatives	Moderately high[3]	NPS plans for Centennial and Congressional support to date.
Base NPS Funds	Flat or Slow Decrease	2016-2026	Flat or slow decrease	No or few new PMIS statement accepted	Low	U.S. budget in tatters from deficit spending
Project-Specific Funds	Significant Increase	2006-2016: 20%	Greater	Hard to say. Annual initiatives on interpretation, cultural resources, maybe no more I&M, more weed. CC $$ dependent upon planning and perception of effectiveness. The significant increase in project funds proposed here may not be true for fuels funding. Available fuels dollars are likely to decrease over this period of time and few projects are currently funded at JOTR.	Moderately high. Sensitive to perceived ability to mitigate CC effects with $$.	NPS Centennial plans and support to date.

[2] All budget changes corrected for inflation.
[3] Nobody knows how to forecast agency budgets more than 5 years out with any accuracy or specificity.

Project-Specific Funds	Flat or Slow Decrease	2016-2026	(0 to -5%) Flat or slow decrease	Dependent to some extent on matching extramural funds, hence public support.	Low	U.S. economy looking fragile out there, hence harder to raise private $$ for matching or otherwise.
Mitigation Monies	??	Unknown	Unknown	If development (e.g. dumping, solar electric, etc) near JOTR shows impacts, this could be factor.	Low	Precedents elsewhere and resources recovery act.
Other						

- The simplest solutions are going to be putting $ into what we can fix - rather than investing acquiring more information. This means managers are going to tend to choose the "greening" choices like transportation and energy alternatives, etc. It is easier to focus on the GHG mitigation piece than it is the management adaptation piece.

- Reprogramming of budget may be what happens - this may result in less money for restoration if CC is deemed more important and funds need to come from somewhere; it may be that restoration is seen as futile (i.e. rebuilding roads and structures that are damaged by storms, restoring ecosystems that become degraded, etc.) because it is not effective in the face of CC.

- Adaptive management and funding: Projects funds currently have about a 1-3 year life cycle and we do not get money to monitor the results of an action to evaluate the effectiveness. Monitoring is a critical component of adaptive management and we have to be able to support this somehow. Is this in the realm of I&M?

- There are basically three categories of management response to the impacts of CC.
    - resource manipulation to protect and mitigate resource impacts
    - reduction of greenhouse gases (green practices)
    - changes to planning structure to incorporate climate change thinking and accommodate adaptive management capability

- We can also think about this as a scaling issue:
    - "retooling" at park level
    - think through these issues at regional planning levels
    - promote servicewide change

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Input By: Dave Graber, Leigh Welling

Table 1c – Drivers of External Change for Joshua Tree National Park: National Park Value

SUMMARY OF PROJECTED NATIONAL PARK VALUE CHANGES FOR JOSHUA TREE						
Resource Valuation Variable	**General Change Expected**	**Specific Change Expected & Reference Period**	**Size of Expected Change Compared to Recent Changes**	**Patterns of Change**	**Confidence**	**Source & Context**
Visitor Experience						
Overall Quality	Decrease	Beyond ten years	Moderate	Change in visitation patterns because of 'draws' (wildflowers, climbing during 'cooler' season, increase in extreme, intense heat=disincline visitors, air quality may affect visitation-unclear relationship). Enabling legislation conditions may change, posing the question "Would you visit JOTR w/no Joshua trees?"	Uncertain	Discussion between DePrey and Zarki
Visitation	Increase	10 years, 2006	+0.5% / annum	Shorter visits, more pass-through visits, increasingly non-Anglo.	Quite uncertain. Publicity over centennial may provide some boost.	Overall visits to national parks are flat, but JOTR can be accessed by I-10, a major transit corridor. There is increasing interest in desert parks.
Visitor Education	Uncertain	Increased use of web technologies and some increase in direct visitor	Uncertain, but significant increase by 2016. Beyond 2016,	More seasonals, more web product. Use of increased contact to effect	Moderately high. Likely that NPS will use increasing visitor education	Centennial will include focus on visitor education; education already

		contacts by interpreters. Unclear whether online experiences are ‘acceptable’ or supportable.	there may be more question about how this will be achieved.	changes in valuation of park resources is up to NPS. Spring visitation may be more difficult due to high temperatures and school children.	to inform about climate change impacts.	identified in PWR planning for climate change. Visitor education goes beyond GCC issues, to include enabling legislation topics.
Nature programs in entertainment media, exp. TV	Increased coverage of “nature in peril”	Unknown, but will reflect rate of physical/ecological response to CC.	Depends on many variables, but will be affected to perceived impacts of CC.	More like to appear in PBS-style programming (thus, may not reach younger audiences).	Cautiously positive.	This is how entertainment media function. Sensationalized approach may produce ‘burnout’. Uncertain whether media approach will fulfill an educational role.
Personal contact with nature	Decrease	Slow, indefinite decline.	Similar to recent rates of decline in outdoor activities. More constricted period for exposure—increased, intense periods, with more people. Less solitude, more intense visitation over shorter times.	Less hiking and camping.	Long-term trend.	Louv: Last Child in the Woods
Wilderness Services						
Solitude	More opportunities for wilderness visitors to be alone	Increasing as conditions become less hospitable. Beyond ten years out.	Minor	With anticipated drops in hiking and climbing in the backcountry, it is more likely that those who seek solitude will achieve it.	Uncertain	DePrey

Ecosystem Services						
Biodiversity	Loss of species richness	Range restrictions for niche species may cause some species to no longer be found in the park. Beyond 20 years out.	Significant	Uncertain	Uncertain	DePrey
Hydrologic Cyclic	Less water available both seasonally and permanently	In line with projections related to precipitation	Uncertain	Groundwater pumping may be restricted inside and outside the park due to political pressures.	Uncertain	DePrey
Cultural Services						
Access to cultural services	Increased interest in heritage tourism. Park history program grows to meet demands.	Through 2016; beyond is uncertain	Significant (50% of park visitors have an opportunity to visit Keys Ranch)	Urbanizing populations provide an opportunity to describe desert pioneering. Proximity to growing metropolitan areas	Likely	DePrey
Infrastructure						
Circulation (road/trails)	Increase disruption to legacy infrastructure	Growing and immediate (though intermittent)	Moderate	Storm events are the primary stressor.	Likely	Slaughter
Structures	Cooling needs will increase (a/c, shade structures). Revisiting locations of visitor developed sites. Potential changes to changing visitation needs (more intense, though shorter)	Immediate and ongoing	Moderate	Increase number of campsites with longer ‘mothballing’ periods. Increased capacity for periods of high visitation (as opposed to longer, steady visitation).	Uncertain	DePrey, Slaughter, Zarki
Utilities (convert nature to human benefit)	Waste water management becomes a growing	Increased conversion of desert to solar power.	Could be big.	More desert solar power arrays. More use of desert	Quite uncertain.	Energy and CC crisis.

	concern. Increase photovoltaic production.			for waste disposal.		
Fleet	Increased immediate demand followed by lessening demand	Through 2016, increased fleet use as new staff are brought on. Thereafter (an potentially sooner) fuel costs will require reconsideration of expenditures on fleet	Moderate	Uncertain	Uncertain	Slaughter and DePrey

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Input By: Dave Graber, Paul DePrey, Joe Zarki, John Slaughter

Table 2– Change-Sensitive Sectors and Potential Impacts due to Climate Change and Interactions with Changing Budget Allocations and Resource Values: Joshua Tree National Park

SECTORS AND POTENTIAL IMPACTS TO JOSHUA TREE		
Sector	**Sub-Sector**	**Impacts**
Natural Resources	Hydrology & Water Resources	• Increase in extreme runoff and flooding (especially in winter); decrease in total snowpack; decrease in soil moisture[4]; limited surface and groundwater availability[5] • Increase/decrease water shortage (storage re: storm events), decrease in water quality • Link between high precipitation events and increase in invasive species to increase in fire size and spread (seasonality, changes in native plant recruitment). • Decrease in overall precipitation could lead to drought conditions. Potential to provide additional niches for other invasive species.
	Aquatic Ecosystems	• Nitrogen eutrophication; increased pollution from runoff; lower streamflows in summer; warmer stream temps; loss of habitat and species[2]
	Vegetation	• Changes in phenology and geographic range; increase or decrease in biomass[2] • Increased invasive species • Vegetation community shifts • Stand-replacing fires result in loss of sources for recolonization of burned areas – e.g. it could take hundreds of years for pinyon-juniper woodland to recover (Brooks 158). The inability of these stands to recover may be more accurately explained by the establishment of a grass-fire cycle. The presence of continuous grassy fuels and short fire return intervals may be influencing response more than increased fire severity and size. Still, changes in these fire regime components are having important ecological impacts. • Increased winter temperatures may impact Joshua tree flowering/reproduction
	Wildlife	• Changes in phenology, migration, reproduction, dormancy, and geographic range[2] • Further threats to threatened desert tortoise • Modified habitat for ecosystem transition area species

[4] Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton, 2007: Regional Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[5] Field, C.B., L.D. Mortsch,, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running and M.J. Scott, 2007: North America. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 617-652.

	Disturbance (fire, pests, pathogens, avalanche)	• Fire: Increase in length of fire season, severity of fires, and number of acres burned[2]; non-native invasive grasses provide continuous fuelbeds and increase wildfire severity.[6] There is high likelihood that this outcome will prove to be true, but some uncertainty still exists. With changes in the pattern of precipitation (more rain in extreme events) there may be variable response from non-native grasses. This could limit the frequency and extent of fires. • Pest/Pathogen: increased winter temperatures facilitate pathogen/pest survival • Storm Events: Energy potential in washes could change (periodicity/season/location)
	Soil	• Geochemical transformations in soil chemistry from pollutants/moisture/UV/invasive plants
Cultural Resources	Historic Structures	• Loss/condition degradation of historic structures from wildfire, erosion, exotic plant invasion • Wooden structures may become more quickly degraded from weathering caused by pollutants.
	Archeological Resources	• Loss/condition degradation of some of the 501 archaeological sites from erosion and exotic plant invasion. • Pictographs and petroglyphs damaged/degraded from chemically reactive pollutants/UV/moisture
	Ethnographic	• Changes in traditional use area utilization by native peoples. Invasive exotic plants impact growth of traditionally gathered/medicinal plants.
	Cultural Landscapes	• Maintenance requirements for cultural landscapes will likely change (easier/more difficult)
Facilities	Circulation	• Design for probably maximum flow (ie 500 yr flood) for new trails and roads. • Legacy trails and roads need to be reconfigured/upgraded to address increase storm events
	Structures	• Retrofit legacy structures to address cooling requirements • New structures will have building envelopes that meet higher design standards
	Utilities	• New photovoltaic generation with the park • Water and waste water management will become a greater concern. Septic systems may need to be phased out to address water quality issues. Water budgets need to be developed as a conservation practice.
	Fleet Management	• Reduction in high GHG emitters • Reduce overall miles driven
Protection & Visitor Services	Recreation	• Decreased rock climbing, hiking because of increased temps during summer. • Increased rock climbing, hiking during shoulder and winter season. • Loss of landscape (to fire) could decrease steady visitation (aesthetics), but could increase wildflower peak visitation.
	Emergency Response	• Increased number of heat-related responses.
Interpretation & Education	Elementary Education	• Changes in themes and curriculum to reflect changing conditions (as appropriate) • Fewer 'in the park' and more 'in the classroom' activities due to extreme temperatures
	Visitor Programs	• Changes in themes and messages. • Increasing reliance on novel media and technology to reach audience/public

Last Updated: 10/24/07

Input By: Dave Graber, Leana Schelvan, Lee Macholz, Rachel Loehman, Leigh Welling, Paul DePrey, Joe Zarki, John Slaughter, Nate Stephenson

[6] Brooks, M.L. and J.R. Matchett, 2006. Spatial And temporal patterns of wildfires in the Mojave Desert, 1980-2004. Journal of Arid Environments 67:148-164.

Table 3a – Drivers of External Change for Kaloko-Honokohau National Historical Park: Climate Change

SUMMARY OF PROJECTED CLIMATE CHANGES FOR KALOKO-HONOKOHAU						
Climate Variable	**General Change Expected**	**Specific Change Expected & Reference Period**	**Size of Expected Change Compared to Recent Changes**	**Seasonal Patterns of Change**	**Confidence**	**Source & Context**
Temperature	Increase	2050: +1.3C ± 0.3C 2100: +2.2C ± 0.6C	Large	Little Seasonal Difference, Late 21st shows greatest increases in autumn and winter	99.9%	Abatzoglou and Brown* Lal et al. 2002[7]
Precipitation	Increase	2050: +3.0% ± 1% 2100: +5.5% ± 2% Intensity: mean intensity increase of 20-30% over tropical oceans with 2x CO2[8]	Large	Largest Increases in autumn	<95% 2050 >95% 2100	Abatzoglou and Brown* Lal et al. 2002[9]
Sea-Level	Increase	By 2100: Rise of up to 0.6m or more[9] Range of rates: Low-mean global rate 3.1 mm/yr High rate (Hilo RSLR) ~3.94 to 4.3 +/- 0.2 mm/yr	1854-1999: mean for period of record is +3.36mm/yr ±0.21mm/yr at Hilo, HI			Nichols et al 2007 and IPCC Summary for Policymakers WG1 AR4
Sea Surface Temperature	Increase	Surface: Annual mean rise of 1.0ºC with 2x CO2[10]	Global mean temps have risen 0.6 ºC since 1950. From			Bindoff et al.[11]

[7] Lal, Murari, Hideo Harasawa, and Kiyoshi Takahashi, 2002. Future climate change and its impacts over small islands states. Climate Research 19: 179-192.

[8] Field, C.B., L.D. Mortsch,, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running and M.J. Scott, 2007: North America. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 617-652.

[9] Nicholls, R.J., P.P. Wong, V.R. Burkett, J.O. Codignotto, J.E. Hay, R.F. McLean, S. Ragoonaden and C.D. Woodroffe, 2007: Coastal systems and low-lying areas. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the FourthAssessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 315-356.

		1961-2003: risen by 0.10ºC from surface to depth of 700m	1993-2003, high warming; but from 2003 onward, some cooling.			
Ocean Acidification	Increase (decrease in pH)	8.16 pH pre-industrial 8.05 pH present[12]	2x CO2 is 7.91 pH 3x CO2 is 7.76 pH			Kleypas, et all. 2006 p22[13]
Extreme Events: Temperature	Increase			Increase in frequency and duration of high temperature events		Lal et al. 2002[9]
Extreme Events: Precipitation	Increase			Increase in heavy rainfall events		Lal et al. 20029
Extreme Events: Storms	Increase			Increase in intensity of tropical cyclones; increase in peak wind speed and precipitation associated with cyclones; more frequent flooding at higher flood levels	Likely	IPCC WG2 SPM[14], IPCC WG2 AR4[15]

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[10] Watson, R.T., Zinyowera M.C., Moss, R.H., IPCC Special Report on The Regional Impacts of Climate Change: An Assessment of Vulnerability. Working Group I. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[11] Bindoff, N.L., J. Willebrand, V. Artale, A, Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D. Talley and A. Unnikrishnan, 2007: Observations: Oceanic Climate Change and Sea Level. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[12] Kleypas, J.A., Feely, R.A., Fabry, V.J., Langdon, C., Sabine, C.L., Robbins, L.L., 2006. Impacts of Acidifcation on Coral Reefs and Other Marine Calcifiers: A Guide for Future Research. Report of a workshop sponsored by NSF, NOAA, USGS.

[13] Kleypas, J.A., Feely, R.A., Fabry, V.J., Langdon, C., Sabine, C.L., Robbins, L.L., 2006. Impacts of Acidifcation on Coral Reefs and Other Marine Calcifiers: A Guide for Future Research. Report of a workshop sponsored by NSF, NOAA, USGS.

[14] IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[15] Field, C.B., L.D. Mortsch,, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running and M.J. Scott, 2007: North America. *Climate*

Tidal Range[16]			Current mean tidal range: 0.446 m			Classified as very high vulnerability (<1m) with respect to tidal range.
Wave Heights		Last 25 years N Pacific has observed increase in NW Swell[17]	1984-2001: 2.5m averaged annually			National Data Buoy Center, Buoy station 51002 located 215 nautical miles S-SW of Hilo, HI
Shoreline Erosion	Increase in Erosion / Reduction in Shoreline	Bruun model suggests shoreline recession is in the range of 50 to 200 times the rise in relative sea level[18]	1950-2002: -0.3m / year		Application of Buun model is controversial	DOI USGS[19], Nichols et al 2007
Storm Intensity	Increase in intense tropical cyclones	Reduction by 10% in number of tropical cyclones in 21st century, but an increase by 1/3 in intense storms (wind speed greater than 50m/s).			Likely	Bengstsson et al. 2007[20]

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Input By: Rachel Loehman, Leana Schelvan, Eric Grossman

Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 617-652.

[16] Tidal range is the vertical difference between the highest high tide and the lowest low tide.

[17] Komar, OSU

[18] Coastal Change Rates and Patterns: Kaloko-Honokohau National Historical Park, Hawai'I, U.S. Department of the Interior U.S. Geological Survey. Open-File Report 2005-1069

[19] Coastal Change Rates and Patterns: Kaloko-Honohohau National Historical Park, Hawai'i. U.S. Department of the Interior U.S. Geological Survey. Open-File Report 2005-1069

[20] Bengstsson, L., Hodges, K.I., Esch, M., Keenlyside, N., Kornblueh, L., Luo, J., Yamagata, T, 2007. How may tropical cyclones change in a warmer climate? Tellus (2007), 59A, 539–561

Table 3b – Drivers of External Change for Kaloko-Honokohau National Historical Park: Budget

Used Table 1b, *Drivers of External Change for Joshua Tree National Park: Budget*, as reference.

Table 3c – Drivers of External Change for Kaloko-Honokohau National Historical Park: National Park Value

SUMMARY OF PROJECTED NATIONAL PARK VALUE CHANGES FOR KALOKO-HONOKOHAU						
Resource Valuation Variable	**General Change Expected**	**Specific Change Expected & Reference Period**	**Size of Expected Change Compared to Recent Changes**	**Patterns of Change**	**Confidence**	**Source & Context**
Visitation	Increase	10 years, 2006	+0.5% / annum	Shorter visits, more pass-through visits, increasingly non-Anglo	Quite uncertain. Publicity over centennial may provide some boost.	Overall visits to national parks are flat.
Visitor Education	Increase	Increased use of web technologies and some increase in direct visitor contacts by interpreters	Uncertain, but significant increase by 2016	More seasonals, more web product. Use of increased contact to effect changes in valuation of park resources is up to NPS.	Moderately high. Likely that NPS will use increasing visitor education to inform about climate change impacts.	Centennial will include focus on visitor education; education already identified in PWR planning for climate change.
Nature programs in entertainment media, exp. TV	Increased coverage of “nature in peril”	Unknown, but will reflect rate of physical/ecological response to CC.	Depends on many variables, but will be affected to perceived impacts of CC.	More like to appear in PBS-style programming (thus, may not reach younger audiences).	Cautiously positive.	This is how entertainment media function.
Personal contact with nature	Decrease	Slow, indefinite decline.	Similar to recent rates of decline in outdoor activities.	Less hiking and camping.	Long-term trend.	Louvre: Last Child in the Woods
Convert nature to human benefit	Increase	Increased conversion of desert to solar power.	Could be big.	More desert solar power arrays. More use of desert for waste disposal.	Quite uncertain.	Energy and CC crisis.
Wilderness Experience: Personal contact with wilderness						
Wilderness Experience: Wilderness for wilderness sake						

Ecosystem Services	-Biodiversity Value					
Visitor Experience	-Interaction w/ facilities					
Historical / Cultural Services						
Other						

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Input By: Dave Graber

Table 4– Change-Sensitive Sectors and Potential Impacts due to Climate Change and Interactions with Changing Budget Allocations and Resource Values: Kaloko-Honokohau National Historical Park

SECTORS AND POTENTIAL IMPACTS TO KALOKO-HONOKOHAU		
Sector / Sub-Sector	**Specifics**	**Impacts**
Natural Resources		
Hydrology & Water Resources		• Recent 50% decrease in GW flux to coast (due to human withdrawal for municipal uses) increases saline intrusion which will be exacerbated by rising sea level
Native Vegetation		• Warmer temperatures and lower annual rainfall favors invasive species • Sea level rise increases soil salinity through inundation and increased salt spray which leads to replacement of coastal vegetation by more salt tolerant species
Fresh Water Ecosystems	T&ES; Metabetaeus lohena and Palaemonella burnsi shrimp	• Increase in salinity in coastal anchialine ponds/pools impact fresh and brackish habitats and endemic species • Decrease in hydrologic gradient due to SLR, decreases drainage during low tides and increases change of flooding during high precipitation/runoff events
Disturbance (fire, pests, pathogens, avalanche, erosion)		• Erosion: loss of shoreline • Inundation • Sea level rise • Storm surges
Coastal Ecosystems		• Higher sea level increases wave energy over reef and leads to breakage of coral structure • Increased inundation and energy reaching shore may lead to increased erosion of shore and sediment transport to reef inducing (1) higher turbidity and lower light levels[21] and (2) abrasion of coral structure. • Higher sea level will change tidal prism of open fishponds and embayments altering current velocities and circulation patterns that are responsible for erosion, larval transport and contaminant pathways • Coast paralleled by shallow fringing reefs, vulnerable to sea level rise, storm damage, increased water temperature, land runoff, changes in salinity and sedimentation.[1] • Inundation from storm surges; nitrogen eutrophication; changes in heat budget and pH[22]
Inundation Hazards		• Shoreline erosion[1] • Salt water intrusion into groundwater aquifers[1] • Inundation of wetlands & estuaries[1] • Shoreline erosion increases threats to cultural and historic resources and infrastructure[1]

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[21] Coastal Vulnerability Assessment of Kaloko-Honokohau National Historical Park to Seal-Level Rise. USGS Open-File Report 2005-1248

[22] Field, C.B., L.D. Mortsch,, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running and M.J. Scott, 2007: North America. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 617-652.

		• Increase in magnitude and frequency of flooding due to loss of hydrophobic gradient with higher sea level
Cultural Resources		
Historic Structures	N/A	• N/A
Cultural Landscapes		• Climate change limits ability to maintain cultural landscapes • Sea level rise result in loss or migration up slope of coastal strand vegetation
Archeological Features	Kaloko and Aimakapa fish ponds, Aiopio fish trap	• Sea level rise and increased severity of annual events will damage, destroy, and make fishpond/traps cease to function • Higher sea level will produce greater stress on fishpond walls leading to increased failure
	Pu'uoina, Makaopio & hale o Kane Heiau	• Rise in sea level and extreme storm events erodes Heiau and potentially destroys them
	Petroglyphs	• Sea level rise results in inundation of petroglyphs and associated sediment transport likely abrades (erases) petroglyph etchings
	Burials	• Sea level rise and increased severity of annual events expose burials and other cultural deposits
	House sites, platforms, salt pans, corral walls, etc	• Sea level rise and increased severity of annual events inundate and destroy archeological sites and expose buried cultural deposits along the coast.
Ethnographic	Live-in Cultural Education Center	• Sea level rise and extreme storm events threatens Live-in cultural center complex with destruction
Traditional Cultural Places	Anchailine pools	• Sea level rise elevates water table and increases salinity in brackish anchialine ponds/pools threatening endemic species and cultural habitat and associated cultural uses (value) • Sea level rise AND reduction in freshwater budget (due to reduced rainfall and/or increased air temperature and evapotranspiration may lead to increase in anchialine pond salinity impacting ecosystem services and cultural uses (described above)
Facilities		
Transportation – roads/trails	Coastal Trail – Ala kahakai trail	• Rise in sea level and extreme storm events erode Ala Kahakai National Historic Trail and force park to migrate it inland
Protection & Visitor Services		
Ocean Recreation	Swimming, surfing, fishing, snorkeling, & Scuba	• Rise in sea level & extreme storm events erode sand beaches, less swimming beach areas in park

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Input By: Lee Macholz, Rachel Loehman, Richard Boston, Stephanie Toothman, Eric Grossman

ATTACHMENT 4: SCENARIO NARRATIVES[1]

Joshua Tree National Park

In the ***Summer Soaker*** scenario, annual precipitation does not change but seasonally less rain falls in winter and spring and more during summer monsoons. This scenario was constructed to be consistent with IPCC scenario B1. Because summer rains favor annual native grasses, this could help to curtail invasion by non-native vegetation. Warmer temperatures drive vegetation communities to move upslope, causing the Mojave ecosystem to be reduced and the Sonoran ecosystem to expand. As the transition zone between the two ecosystems is altered, features that occur along the zone would be impacted. For example, a popular feature in the zone is Cholla Garden, a dense growth of cholla cactus. Warmers temperatures and erosion from intense summer rains may threaten the unique nature of the Garden. In addition, as the Mojave ecosystem is reduced, some of the species native to this system, such as the bighorn sheep or the relic, namesake species, the Joshua Tree, would likely become isolated or could be lost altogether from the park. Other species, such as the desert tortoise, may improve as their vegetative browse (summer native grasses) increases, although increased summer moisture may exacerbate the upper respiratory tract disorder in tortoises.

When it Rains it Pours is a scenario in which extreme precipitation events are common, especially during winter, and often follow summers of extreme drought. This scenario was constructed to be consistent with IPCC scenario A1B. Chief concerns are flash flooding events and erosion, causing debris dams in canyons that blow out, increased disruption in traffic and other visitor activities, safety concerns, and higher costs for infrastructure maintenance and emergency response. Flooding and erosion would destroy many easily damaged archaeological sites, although new sites may be uncovered. Conditions would also enhance a positive feedback loop involving drought, invasion by exotic grasses, and fire, effectively converting the system to a grassland ecosystem with a more extreme fire regime (i.e. summer drought kills off native annuals; heavy winter rains follow that promote growth of exotic invasive grasses that act as fuels for fire, which fertilizes the ground for non-native annuals). This shift stresses many native species that occupy small niches and do not thrive on less nutritious non-native grasses.

In the ***Dune*** scenario the park experiences increasing temperature with persistent dryness and drought. This scenario was constructed to be consistent with IPCC scenario A1F1. Wind increases in frequency and intensity. Change in vegetation habitats due to drought and high temperatures leads to a significant loss of woody species. Fire spread increases due to increased non-native vegetation fuel load and increased winds. As more fires occur and consume available vegetation, fires occurrence declines. This was considered to be the most devastating of the three scenarios in that the end result would be near complete loss of vegetative cover due to fire, water mining, wind, and higher temperatures. Resulting wind erosion increases dune formations in the Pinto Basin.

Kaloko-Honokohau National Historical Park

The ***Sink or Swim*** scenario

- KAHO will see a 2-foot sea level rise in 100 years
  - Anchailine pools are inundated but some they migrate naturally inland and though there are fewer pools, those that remain are initially sustainable and species migrate with the pools but become isolated because pools are less connected
    - The cumulative effects of population pressure and development over a period of 100 years causes severe draw-down of groundwater levels to the point that anchailine pools are no longer refreshed/sustained
  - All fishponds within the park are inundated
    - A feasibility study determines that the ponds may be successfully relocated/rebuilt inland with cooperation from native Hawaiian groups
    - If ponds are not relocated, complete loss of native vegetation, thus complete loss of Hawaiian Coot and Stilt habitat

        - Relocation of the ponds would allow for re-creation of bird habitat through planting of native vegetation species
    - Coral Reefs
        - Experience bleaching due to ocean temperature increase
        - Bleaching leaves reef susceptible to effects of wave action, turbidity, and terrestrial runoff (esp. flushing of sediment and nitrogen from fish ponds)
    - Petroglyphs are inundated
        - The park is able to document them before they are inundated so a historical record is preserved
    - Cultural use and recreation potential remains viable in the park in the form of canoe launching, fishing, swimming, scuba, snorkeling, surfing; however sand beaches are reduced and the cultural landscape has been severely and irrevocably changed
- KAHO will see increased frequency of 10-foot and even 30-foot storm surges due to increased intensity of tropical storms and hurricanes
    - 10-foot storm surges regularly inundate park resources and periodic 30-foot storm surges cause significant damage to anchailine pools, vegetation, native species, and park infrastructure
- It is important that park management work together with native Hawaiian groups to determine responses to rising sea level in the park

Water World

- KAHO will see a 4-foot sea level rise in 100 years
    - Coral Reefs
        - Complete loss of coral reefs due to multitude of factors including temperature increase (bleaching), wave action, turbidity, terrestrial runoff, and increased depth
        - Reefs cannot reestablish themselves due to sustained ocean temperature increase
    - Severe decrease in native biodiversity
        - Loss of native terrestrial, freshwater, and marine habitat
        - However, species that were once considered invasive establish in the area and become the new natives
    - Fishponds and Anchailine pools
        - All fishponds and anchailine pools are inundated and sea level rises at a rate that eliminates the ability for the fishponds to be relocated or the anchailine pools to migrate either naturally or otherwise
        - Upon inundation, fishpond walls face destruction because they are now in the primary littoral zone and face constant heavy wave action
    - Petroglyphs and Burials
        - All petroglyphs and burials are inundated
    - The primary form of visitation to the park becomes recreation-based due to:
        - Accessibility of archeological features underwater via interpretive scuba trails and tours;
        - Increased use for surfing;
        - Continued use for boat (canoe) launches
- KAHO will see increased frequency of 10- to 30-foot storm surges due to increased intensity of tropical storms and hurricanes
    - 10- to 30-foot storm surges regularly inundate park resources and cause significant damage to infrastructure, vegetation, and native species
- It is important that park management work together with native Hawaiian groups to determine responses to rising sea level in the park
- Ultimately, mission of the park changes from primarily cultural use to recreational use (based on historic cultural features) and to serve as an Oceanic and Climate Change Research Learning Center for effects of sea level rise. In addition, the park produces Historic preservation guidelines for inundation.

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[1] These scenarios are the result of work done at the Scenario Planning for Climate Change and the NPS Workshop, Nov 13-14, 2007. These scenarios are intended as an exploration of *plausible* futures; they are not forecasts or predictions and they do not represent the official view of the parks.