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Weathering the Storm - Climate Resilience at Airports

October 7, 2020

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Learning Objectives

1. Discuss the practical use of climate forecast data for airport decision making

2. Describe how to develop useful risk information

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ACRP Report 199

Climate Resilience and Benefit-Cost Analysis: A Handbook for Airports

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ACRP AIRPORT COOPERATIVE RESEARCH PROGRAM

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- Expert on economics and financing of airlines and airports
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ACRP Report 199 Oversight Panel

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Introduction

Project Overview

- ACRP 199 is a Handbook with Illustrative Case Studies and software showing how airports can evaluate the risks of climate change and develop financial and benefit-cost analyses of possible mitigations.

- The main contribution is demonstrating methods that airports can use to assess vulnerability to climate change while accounting for the large degrees of uncertainty in future climate projections.

- The techniques can be used to answer a number of relevant questions:
  - *Will a mitigation project pay off over the long run?*
  - *What percent of the time will it pay off given the uncertainty?*
  - *What are the chances of a potentially catastrophic loss with and without the mitigation project?*

Introduction

Focus on Two Specific Types of Climate Change

- Q Given the threat of sea level rise, does it make sense to try to physically raise various pieces of airport infrastructure or build a physical barrier?

- Q Given the threat of global warming, does it make sense to extend a runway to allow takeoffs when surface temperatures are unusually high?

Approach to Problem

- Recommended method focuses on how to extend standard benefit-cost framework to account for uncertainty in climate projections
- Approach employs Monte Carlo simulations that produce a *range of estimates* for possible impacts on airports
- Results presented in a “value-at-risk” format focusing on net dollar impacts and risks associated with undertaking a mitigation project

Quick Refresher on Benefit-Cost Analysis

- Define relevant time horizon
  - Typically 20-30 years (but may be longer for, say, a runway project)
- Estimate stream of costs associated with undertaking the project
  - Typically a large upfront cost followed by annual maintenance costs
- Estimate stream of benefits
  - Benefits often represent *avoided costs* if the project were not to be undertaken (e.g., avoided aircraft/passenger delays if, say, very high temperatures caused flights to be delayed or cancelled)
  - But avoided costs may be much more extreme in the case of sea level rise (e.g., a storm due to sea level rise causing severe flooding that damages airport infrastructure)
- Compute discounted benefit-cost ratio: > 1 suggests project is worthwhile

Inadequacy of Simple Benefit-Cost Ratio

- Standard analysis breaks down when benefits (avoided costs) are highly uncertain and time horizon is long

Scenario	Severe storm Year 5		Severe storm Year 45		Moderate storm Year 5	
B/C Ratio @7%	3.57		0.24		1.07	
B/C Ratio @3%	3.94		1.21		1.18	
Year	Benefits	Costs	Benefits	Costs	Benefits	Costs
1	$0	$10,000,000	$0	$10,000,000	$0	$10,000,000
2	$0	$50,000	$0	$50,000	$0	$50,000
3	$0	$50,000	$0	$50,000	$0	$50,000
4	$0	$50,000	$0	$50,000	$0	$50,000
5	$50,000,000	$50,000	$0	$50,000	$15,000,000	$50,000
6	$0	$50,000	$0	$50,000	$0	$50,000
7	$0	$50,000	$0	$50,000	$0	$50,000
8	$0	$50,000	$0	$50,000	$0	$50,000
...	...	...	...	...	...	...
42	$0	$50,000	$0	$50,000	$0	$50,000
43	$0	$50,000	$0	$50,000	$0	$50,000
44	$0	$50,000	$0	$50,000	$0	$50,000
45	$0	$50,000	$50,000,000	$50,000	$0	$50,000
46	$0	$50,000	$0	$50,000	$0	$50,000
47	$0	$50,000	$0	$50,000	$0	$50,000
48	$0	$50,000	$0	$50,000	$0	$50,000
49	$0	$50,000	$0	$50,000	$0	$50,000
50	$0	$50,000	$0	$50,000	$0	$50,000
PV @ 7%	$35,649,309	$9,989,103	$2,380,674	$9,989,103	$10,694,793	$9,989,103
PV @ 3%	$43,130,439	$10,946,682	$13,221,931	$10,946,682	$12,939,132	$10,946,682

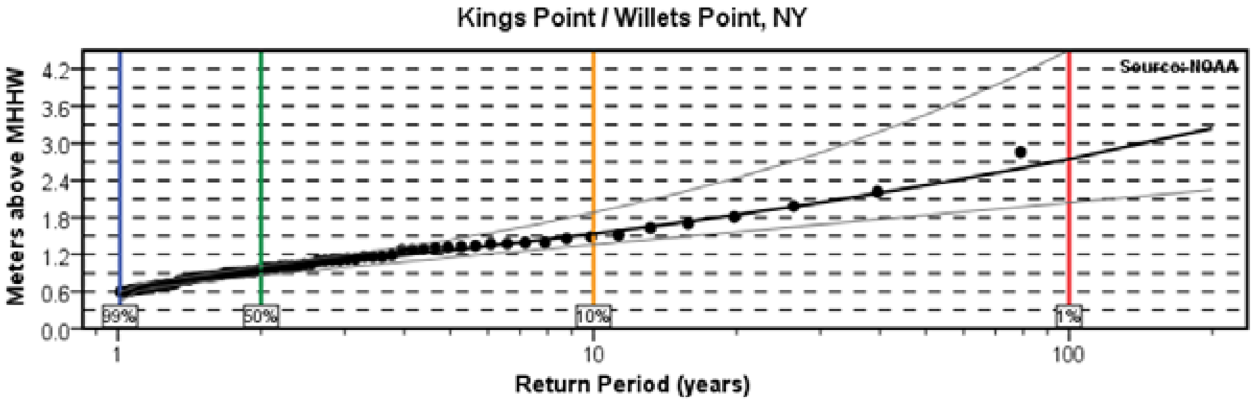
Solution: Account for Uncertainty

- Suggested alternative is to use Monte Carlo simulations and "value-at-risk" (VaR) approach
  - Monte Carlo – Run benefit-cost analysis many times, each time using a different assumption about size and incidence of storm or extreme temperatures
  - Value-at-Risk – Rather than focus on simple benefit-cost ratio, consider the net dollar impacts under both the Base Case and Scenario Case

- Required inputs
  - Knowledge about probable likelihood of storm severity or extreme temperatures now and well into the future
  - Estimates of and allowance for partial mitigations (i.e., even if project is completed, damages may not be reduced to zero)

Creating a Projection for Sea Level Rise: Two Primary Measures of Uncertainty

- Annual probability of storm surge based on historical data
  - *Exceedance Probability Curve from NOAA for 112 coastal locations*

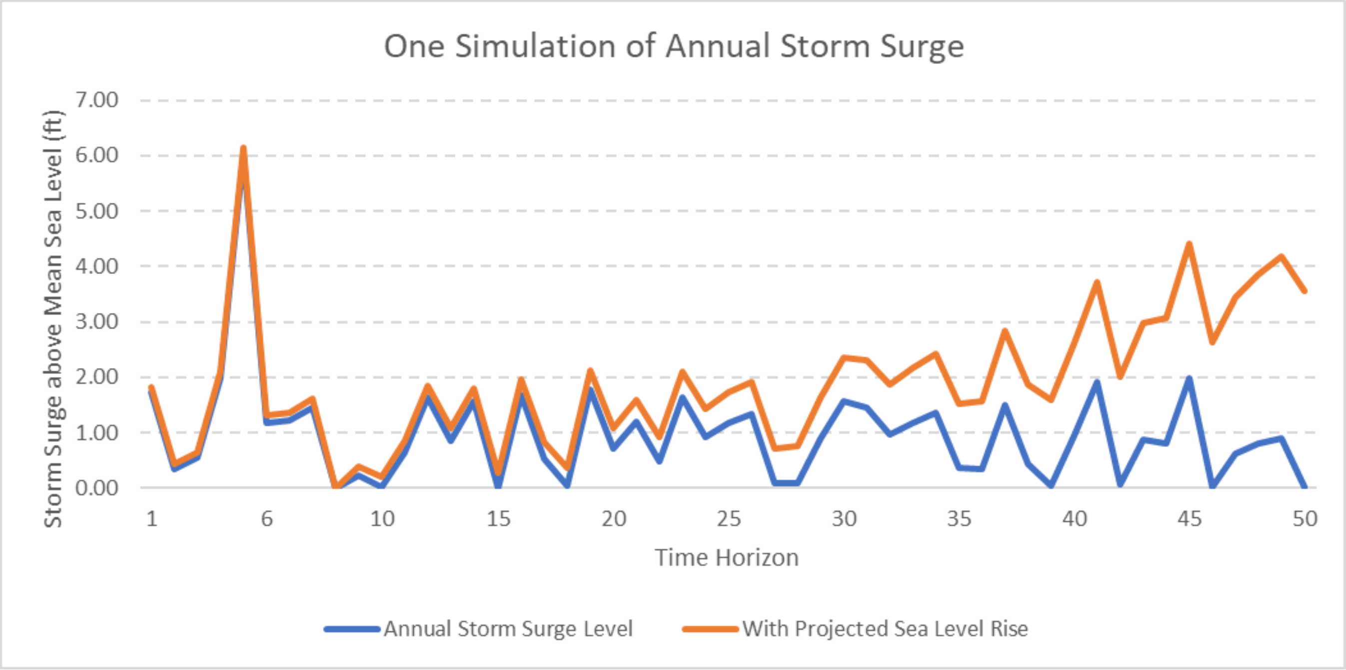


  - Probability of future sea level rise by 2081-2100 (columns represent different assumptions about path of global greenhouse gas emissions over time)

GMSL rise Scenario	RCP2.6	RCP4.5	RCP8.5
Low (0.3 m)	94%	98%	100%
Intermediate-Low (0.5 m)	49%	73%	96%
Intermediate (1.0 m)	2%	3%	17%
Intermediate-High (1.5 m)	0.4%	0.5%	1.3%
High (2.0 m)	0.1%	0.1%	0.3%
Extreme (2.5 m)	0.05%	0.05%	0.1%

Creating a Projection for Sea Level Rise

- Create a Monte Carlo simulation out to 2100 by combining historical probabilities with future projections



Value-at-Risk Approach to Assessing Impacts

- Net dollar impacts from one simulation (same numbers as a traditional benefit-cost analysis, just split out differently)

Year	Total Water Level (ft)	Net Impacts w/o Project: Damages without Project	Net Impacts with Project: Remaining Damages with Project*	Net Impacts with Project: Project Costs
1	1.82	$0	$0	$10,000,000
2	0.43	$0	$0	$50,000
3	0.66	$0	$0	$50,000
4	2.11	$100,000	$0	$50,000
5	6.14	$20,000,000	$4,000,000	$50,000
6	1.32	$0	$0	$50,000
7	1.36	$0	$0	$50,000
8	1.61	$0	$0	$50,000
...	...	$0	$0	...
42	2.01	$100,000	$0	$50,000
43	2.98	$100,000	$0	$50,000
44	3.07	$250,000	$0	$50,000
45	4.41	$1,000,000	$200,000	$50,000
46	2.64	$100,000	$0	$50,000
47	3.45	$250,000	$0	$50,000
48	3.86	$250,000	$0	$50,000
49	4.19	$1,000,000	$200,000	$50,000
50	3.55	$250,000	$0	$50,000
PV @7%		**$14,584,962**	**$2,867,634**	**$9,989,103**

**Assumes 100% mitigation if < 4 ft storm surge, 80% mitigation otherwise*

- *Without project, net impacts = -$14.6M*
- *With project, net impacts = -$12.9M*
- *Savings to airport = +$1.7M*

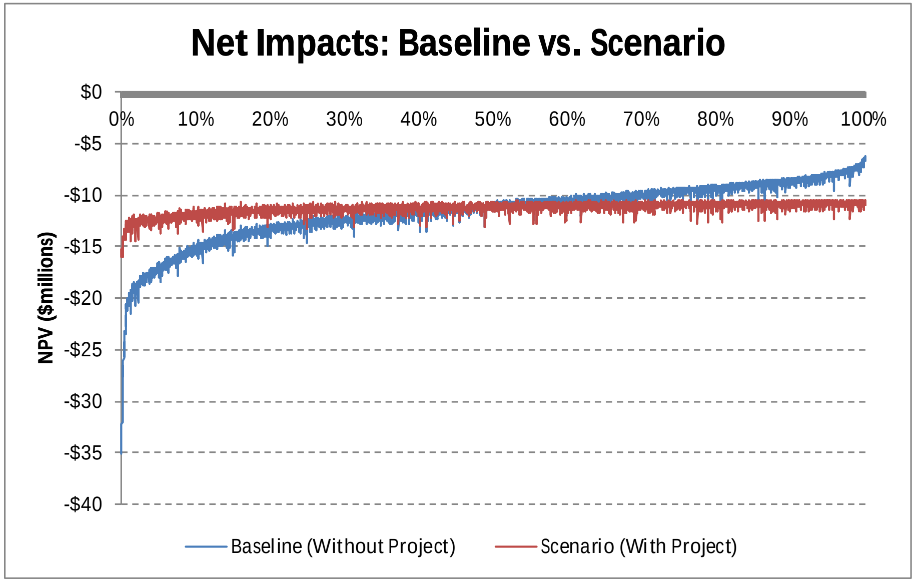
Value-at-Risk Approach to Assessing Impacts

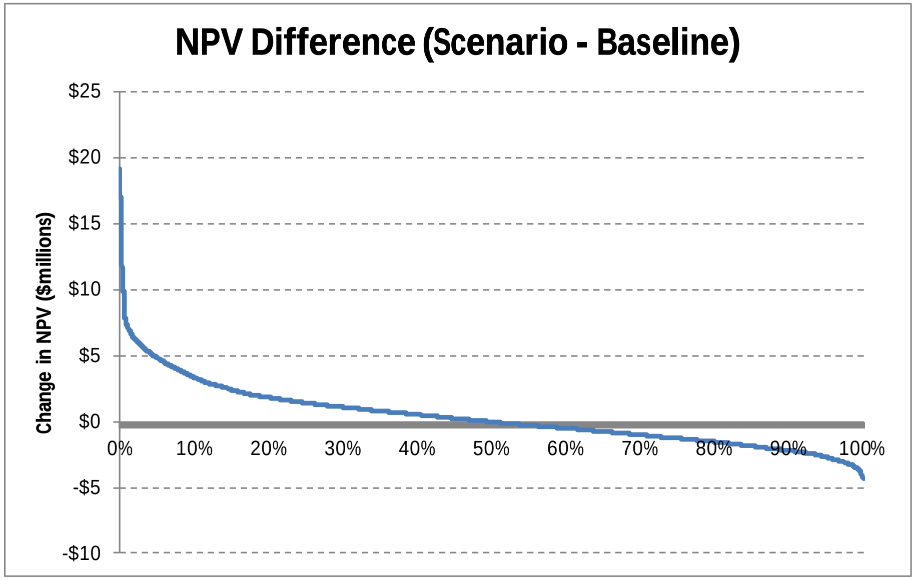
- Repeat analysis many times (Monte Carlo – Excel model does 5,000 simulations)
- Project costs will be the same each time, but overall net impacts will be different due to variations in when/if more extreme storm surges occur
- Will get mix of positive and negative net impacts
- Plot all the net impacts from the simulations on a graph – order the results from worst to best in dollar terms

Value-at-Risk Approach to Assessing Impacts

- Two ways of presenting results

	Mean	Std Deviation
Avg NPV of Project	$316,577	$2,365,522
Avg B/C Ratio	1.03	0.23





Practical Applications of Value-at-Risk

- Value-at-Risk provides a different perspective than simply focusing on the average NPV or average benefit-cost ratio from the simulations

- Airport can use the results to help it decide between the risky, but higher potential payoff of doing nothing, and the certain cost of investing in the mitigation project which reduces but does not completely eliminate its exposure

- Examples
  - Airport CFO might want to know the probability of a loss that exceeds the facility’s current insurance limits
  - Decision makers might want to assess relative positions in best-case and worst-case scenarios (e.g., in best case airport could save $10 million, but in worst case it could lose $50 million)

Other Uses of Climate Projections

- The climate simulations themselves can be used to assess the likelihood that specific pieces of existing airport infrastructure would remain safe
  - Many airports utilize infrastructure design standards based on adding 1 to 3 feet of freeboard to the 100-year (1%) storm projection

- Example: If a particular asset has been designed to withstand inundations up to, say, 5 feet above sea level, then one could estimate the cumulative probability that at least one event at or above 5 feet would occur by 10, 20 or 30 years out based on the Monte Carlo simulations

- The Excel models can provide direct estimates of these probabilities based on the simulations

Other Uses of Climate Projections (cont.)

- To go a step further, an airport could develop a complete inventory list of relevant assets and their corresponding critical elevation levels, and then assess the likelihood of inundation

			Cumulative Probability of Inundation (from 2020)					
	Critical Elevation above Sea Level (ft)	End of Useful Life	2025	2035	2045	2055	2065	2075
TSA Building	8.0	2045	3.4%	9.3%	17.0%			
Fire Station	10.0	2050	1.6%	3.8%	7.4%	11.3%		
Utility Tunnel	12.0	2055	0.8%	1.9%	3.8%	5.8%		
Terminal	15.0	2070	0.4%	1.0%	1.8%	2.5%	3.4%	4.6%

Sea Level Rise Example using Excel Model at Boston-Logan Airport

- User inputs

State_Locid	MA_BOS						
Name	GENERAL EDWARD LAWRENCE LOGAN INTERNATIONAL						
Elevation (ft)	19.1						
Historical extreme water levels (EWL) based on:			*EWL Curve Parameters*			*Implied Water Levels based on historical data (ft)*	
EWL_Station	BOSTON		Location	0.764		100-yr event	4.60
EWL_Distance (miles)	2.39		Scale	0.133		50-yr event	4.27
			Shape	0.019		10-yr event	3.51
						1-yr event	1.85
Projected relative sea levels (RSL) based on:							
RSL_Station	BOSTON		Click here for map				
RSL_Distance (miles)	2.40						
RCP_Scenario	8.5		RCP stands for Representative Concentration Pathway:				

Sea Level Rise Example using Excel Model at Boston-Logan Airport

- User inputs

Analysis_Start_Yr	2020	
Analysis_End_Yr	2099	
Discount_Rate	3.0%	
Mitigation_Project_Type	Simplified	
Project_Start_Yr	2020	
Mitigation_Start_Yr	2021	
Simplified Mitigation Project Costs		
Construction_Cost	$5,000,000	
Annual_Maint_Cost	$500,000	
Rehab_Interval_Yrs	25	
Rehab_Cost	$2,000,000	
Flooding Event Damage Costs		
EWL above MHHW (ft)	Without Project	With Project
0-1	$0	$0
1-2	$0	$0
2-3	$100,000	$0
3-4	$500,000	$0
4-5	$1,000,000	$0
5-6	$1,000,000	$200,000
6-7	$5,000,000	$1,000,000
7-8	$10,000,000	$2,000,000
8-9	$10,000,000	$2,000,000
9+	$20,000,000	$4,000,000

Sample Results for BOS

- Projected Climate Inundation Results

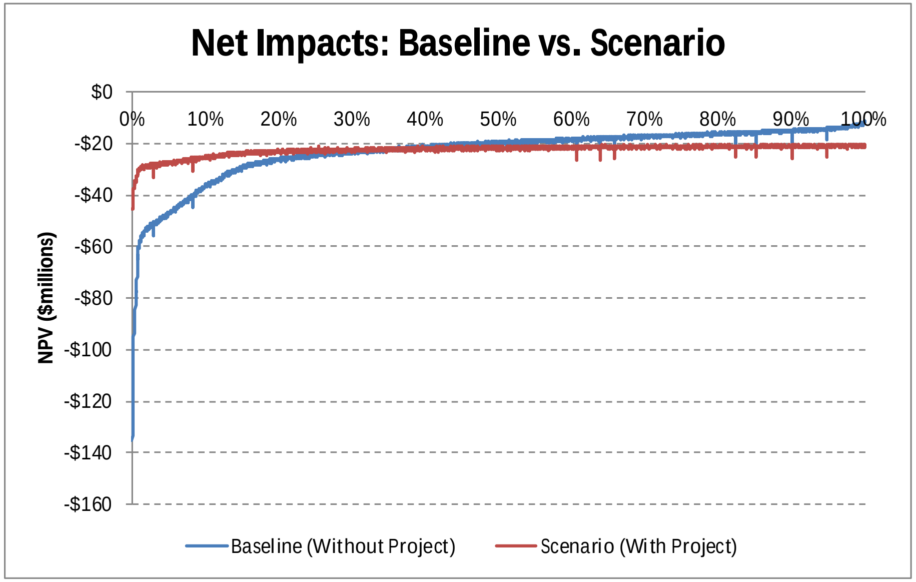
BOS Extreme Water Level Event Probabilities from 5,000 Simulations (RCP 8.5)									
Water Level Rise above MHHW (ft)	Historical	2025	2035	2045	2055	2065	2075	2085	2095
0-1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1-2	3.88%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2-3	68.46%	45.28%	24.68%	8.84%	1.76%	0.40%	0.12%	0.04%	0.00%
3-4	24.16%	46.46%	60.06%	61.94%	48.16%	28.04%	15.24%	9.52%	4.38%
4-5	2.98%	7.24%	13.34%	24.90%	40.38%	50.00%	47.64%	37.10%	29.00%
5-6	0.40%	0.80%	1.76%	3.66%	8.58%	17.68%	27.32%	34.06%	34.94%
6-7	0.12%	0.12%	0.16%	0.52%	1.02%	3.34%	7.72%	13.76%	19.38%
7-8	0.00%	0.02%	0.00%	0.14%	0.10%	0.48%	1.48%	4.20%	8.66%
8-9	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%	0.44%	1.00%	2.76%
9+	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.04%	0.32%	0.88%
TOTAL	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Median (ft)	*2.66*	*3.06*	*3.32*	*3.63*	*4.00*	*4.37*	*4.72*	*5.07*	*5.45*
100-Yr Event (ft)	*4.63*	*4.98*	*5.29*	*5.66*	*6.06*	*6.74*	*7.38*	*8.14*	*8.88*

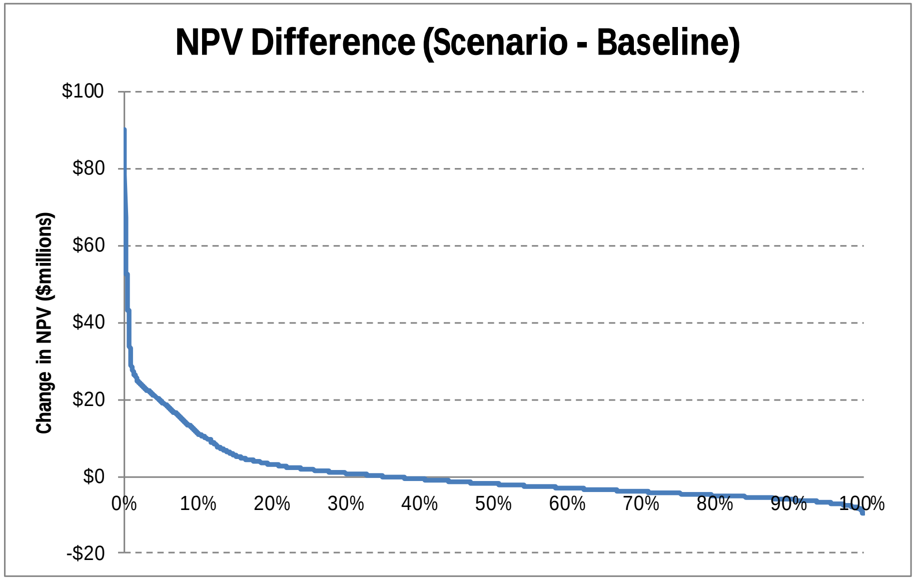
		Cumulative Probability of Inundation above MHHW (from 2020)							
Height Above MHHW (ft)		2025	2035	2045	2055	2065	2075	2085	2095
8.0		0.02%	0.06%	0.12%	0.18%	0.52%	2.78%	9.51%	29.11%

Sample Results for BOS

- Projected Value-at-Risk results

	Mean	Std Deviation
Avg NPV of Project	$557,444	$8,805,207
Avg B/C Ratio	1.03	0.43





Breakeven = 35.0%

FOR ADDITIONAL INFORMATION

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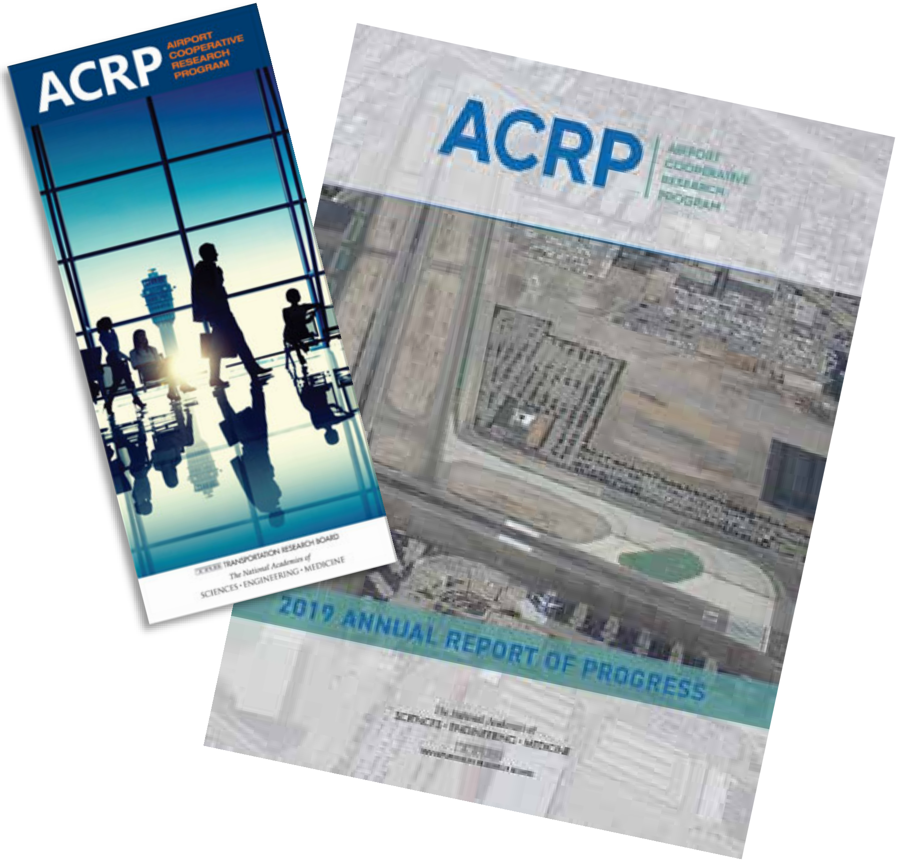

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Report 160: *Addressing Significant Weather Impacts on Airports: Quick Start Guide and Toolkit*

Research Report 188: *Using Existing Airport Management Systems to Manage Climate Risk*

Synthesis 77: *Airport Sustainability Practices*

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October 29
Set the Stage - Estimating Market Values for Small Airports

November 5
Wetland Mitigation at Airports

Today’s Panelists
#TRBWebinar

Moderator: Mary Davis,
Tufts University

William Spitz,
GRA, Inc.

Frank Berardino,
GRA, Inc.

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