US Army Corps
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Mobile District

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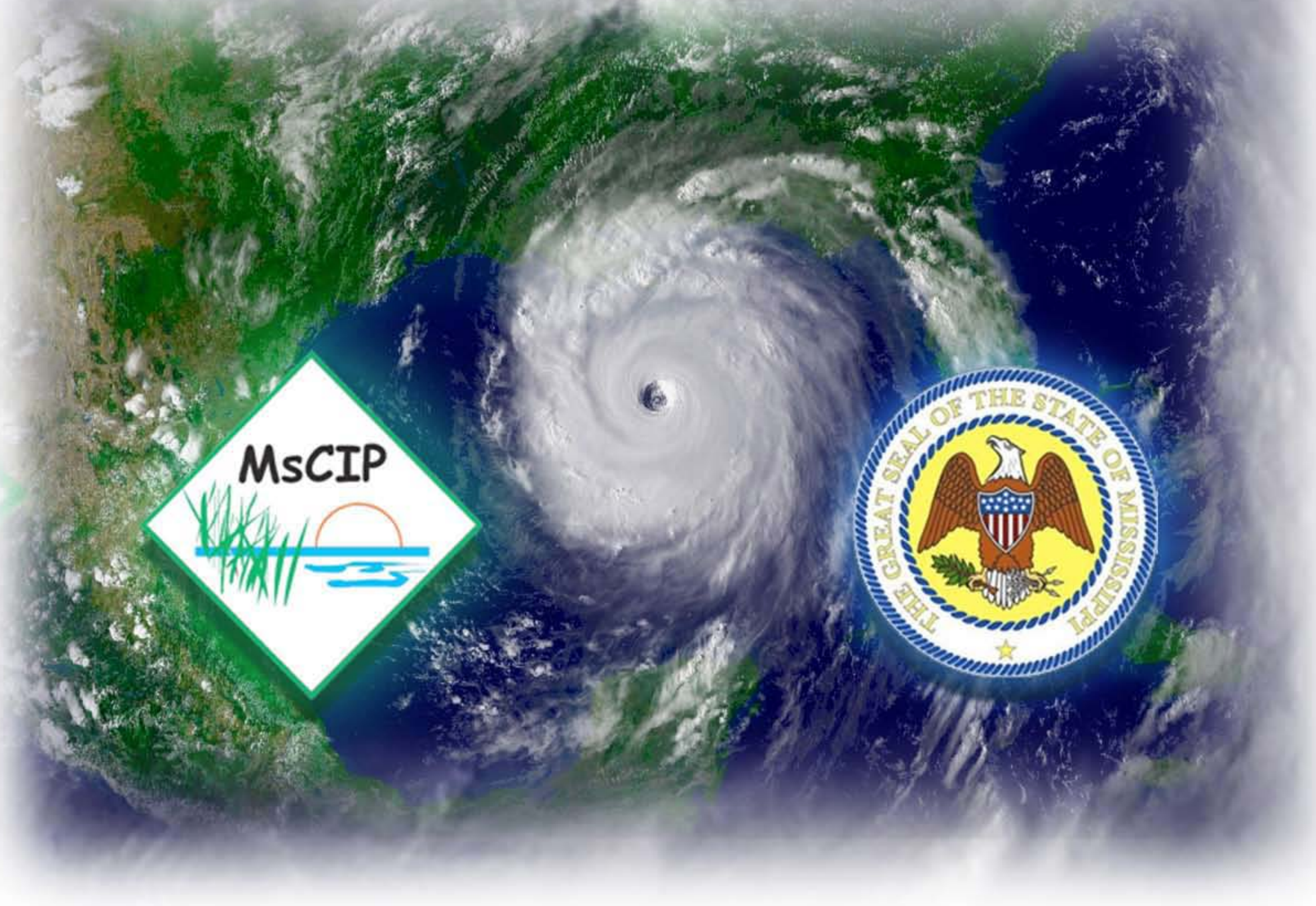
Mississippi Coastal Improvements Program (MsCIP) Hancock, Harrison, and Jackson Counties, Mississippi

Appendix G Risk Appendix



Appendix G

Risk Appendix

Mississippi Coastal Improvements Program (MsCIP)

Comprehensive Plan Report
and
Integrated Environmental Impact Statement

AUGUST 2008

Planning, Environmental, Engineering, and Economics Sections; Mobile District;
Planning, Environmental and Economics Sub-CoPS; South Atlantic Division; and,
Engineer Research and Development Center
U.S. Army Corps of Engineers

FOREWORD

This document is one of a number of technical appendices to the *Mississippi Coastal Improvements Program (MsCIP) Comprehensive Plan and Integrated Feasibility Report and Environmental Impact Statement*.

The *Mississippi Coastal Improvements Program (MsCIP) Comprehensive Plan Integrated Feasibility Report and Environmental Impact Statement* provides systems-based solutions and recommendations that address: hurricane and storm damage reduction, ecosystem restoration and fish and wildlife preservation, reduction of damaging saltwater intrusion, and reduction of coastal erosion. The recommendations contained in the Main Report/EIS also provide measures that aid in*:* greater coastal environmental and societal resiliency, regional economic re-development, and measures to reduce long-term risk to the public and property, as a consequence of hurricanes and coastal storms. The recommendations cover a comprehensive package of projects and activities, which treat the environment, wildlife, and people, as an integrated system that requires a multi-tiered and phased approach to recovery and risk reduction, irrespective of implementation authority or agency.

The MsCIP Study Area

The purpose of the Comprehensive Plan Report is to present, to the Congress of the United States, the second of two packages of recommendations (i.e., the first being the "interim" recommendations funded in May 2007, and the second, this "final" response, as directed by the Congress), directed at recovery of vital water and related land resources damaged by the hurricanes of 2005, and development of recommendations for long-term risk reduction and community and environmental resiliency, within the three-county, approximately 70 mile-long coastal zone, including Mississippi Sound and its barrier islands, of the State of Mississippi.

This appendix, the Main Report/EIS, and all other appendices and supporting documentation, were subject to Agency Technical Review (ATR) and an Independent External Peer Review (IEPR). Both review processes will have been conducted in accordance with the Corps "Peer Review of Decision Documents" process, has been reviewed by Corps staff outside the originating office, conducted by a Regional and national team of experts in the field, and coordinated by the National Center of Expertise in Hurricane and Storm Damage Protection, North Atlantic Division, U.S. Army Corps of Engineers.

The report presents background on the counties that comprise the Mississippi coastline most severely impacted by the Hurricanes of 2005, their pre-hurricane conditions, a summary of the effects of the 2005 hurricane season, problem areas identified by stakeholders and residents of the study area, a summary of the approach used in analyzing problems and developing recommendations directed at assisting the people of the State of Mississippi in recovery, recommended actions and projects that would assist in the recovery of the physical and human environments, and identification of further studies and immediate actions most needed in a comprehensive plan of improvements for developing a truly resilient future for coastal Mississippi.

This Risk Appendix contains a discussion of the risk-based planning approach used by the MsCIP study team, for the analysis and characterization to the public and stakeholders of risks associated with existing and future without-project conditions, the potential risks, uncertainties and consequences associated with potential problem-solving measures (also known as "with-project" conditions), the incorporation of, and use of a stakeholder-involved risk-aware "weighting" process, referred to as a "Risk-Informed Decision Framework", or RIDF, that elicited stakeholder preferences on specific metrics used in the analysis, evaluation, and comparison of alternatives; and finally, the incorporation and consideration of all information received as stakeholder input, and a full consideration of all factors, in the screening of the final array of alternatives, and ultimately, the selection of recommendations contained in the Main Report/EIS.

The use of the Risk-Informed Decision Framework (RIDF) in the Mississippi Coastal Improvements Project, comprehensive plan development, was done better inform and involve stakeholders in the planning process, with the ultimate goal of creating solutions to reduce the potential for continued residual risk from flood and storm surge inundation, coastal wetlands loss and degradation, erosion, and saltwater intrusion, in ways that would promote greater resiliency in the future. The RIDF provided procedures that have aided decision makers in identifying planning objectives, performance metrics, and stakeholder priorities, in a transparent format. The RIDF utilizes techniques from the fields of risk and decision analysis to simply and clearly show decision makers and the public the risks, costs and consequences of flood control, coastal restoration, and hurricane protection by accommodating multiple objectives, conflicting stakeholder values, both qualitative and quantitative assessments of performance, and uncertainty in the natural, social, and economic environment.

Each appendix functions as a complete technical document, but is meant to support one particular aspect of the feasibility study process. However, because of the complexity of the plan formulation process used in this planning study, the information contained herein should not be used without parallel consideration and integration of all other appendices, and the Main Report/EIS that summarizes all findings and recommendations.

EXECUTIVE SUMMARY

This Risk Appendix outlines the approach taken in the Mississippi Coastal Improvements Program (MsCIP) Comprehensive Plan study effort, to evaluating, communicating, and incorporating consideration of risks, uncertainties, and consequences, in the comparison, screening, and selection of alternative plans.

The MsCIP approach utilized a multi-step process, which incorporated:

1) Evaluation and assessment of potential risks, uncertainties and consequences associated with existing conditions, future "without-project" conditions, and numerous "with-project" plans;

2) Application of the Corps' "Risk and Uncertainty" analysis procedures, which assess and incorporate probabilities and uncertainties in the technical evaluation process;

3) Education of the public, agencies and other interests, in the inherent risks, uncertainties and potential consequences or any course of action, (including doing nothing), in various public forums and workshops;

4) Incorporation of the newly-implemented "Risk-Informed Decision Framework" (RIDF) methodology, that considered the factors (or "metrics") of greatest importance to the stakeholders and technical evaluators, solicitation of public and agency input on potential plans, and their prioritization (i.e., "Stakeholder Preferences") and potential selection of Locally-Preferred Plans, and finally;

5) Comparison of alternative plans, including all risk factors, in a "System of Accounts" format, screening, and selection of Federally-recommended plans, as part of the full consideration of all economic, environmental, technical, societal, risk factors, and explicit requirements (including Congressional) directed at the study effort.

Risk Analysis using this set of procedures was a new approach for a Corps of Engineers study, as it required a more thorough assessment of all the risk factors involved, but also integration of more public and agency involvement in the discussion of, and prioritization of risk factors, in a better articulated explanation of how risk may determine alternative recommendation in the plan selection process, in some cases with clear direction resulting from the risks and consequences possible under various plans.

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PART 1 – EVALUATION AND ASSESSMENT OF RISKS, UNCERTAINTIES, AND CONSEQUENCES

Evaluation and assessment of risk, uncertainties and consequences was the first step in the MsCIP risk assessment process.

The MsCIP team used standard conventions and definitions used in risk assessment, although some leeway was incorporated into the overall use of risk terminology, due to the on-going use of certain terms, such as "risk", in ways that are much broader than those in the risk assessment arena might use them. The broadest use of the term "Risk", as used in the MsCIP study, could be characterized as the potential for negative outcomes, under certain action and no-action conditions, both now and in the future. The public uses this term to refer to their own personal risks, be it risks to their health, income, residences, cultural integrity, or community, and thus, the MsCIP team had to adopt this convention. The MsCIP team also had to similarly use this term to characterize risks of environmental outcomes, such as functional damage to ecosystems, loss of species (or multiple species) integrity and survival, and many other negative outcomes. Because the public and stakeholders had to understand the nature of their risks and potential consequences for a large range of possible future conditions that by their nature were, in many cases, only qualitatively defined, the use of "risk" in this broader framework was by necessity, adopted.

"Risk ", in a narrower definition also used in the MsCIP study, could be defined as the probability of a certain outcome, under certain conditions. An example of this would be the probability (5% in any given year, for example) of a certain damage level, expressed in dollars ($10,000,000, for example), occurring in the event of a certain-sized hurricane-caused surge and wave depth and extent event. This could be expressed both as a probability of a certain outcome given a certain event, but can also be expressed as a sum of damages expected under a range of events, such as an average of all damages expected, over a time horizon such as fifty years, were nothing to be done to prevent those damages.

Risk, or the probability of certain events or outcomes, was more readily defined for some type of outcomes, such as hurricane-caused surge and wave depth, than for other types of outcomes, such as human reactions, or the number of deaths caused, by an oncoming hurricane. For some factors, probabilities were defined quantitatively; in many other cases, they could only be estimated qualitatively, as a range of possible outcomes.

The first phase of the data collection and characterization step involved the collection of all data associated with human and environmental outcomes to past hurricanes in this area of the Gulf Coast. Data collected included damages caused by various events, environmental conditions created by hurricanes and other large storm events, salinity and freshwater effects, erosion effects, and the human impacts of events, including deaths caused, human health and mental health effects, and human and environmental responses over time, economic (local, regional and national outcomes), response over time to relative sea level rise and developmental pressures, income and minority community responses, and many other probabilistic outcomes.

Most difficult to determine, were the hypothetical outcomes, both positive and negative, expected under future "without-project" conditions. This involved the development of outcomes in consideration of the numerous technical and environmental studies being developed in the course of the MsCIP study. In some cases, "risk" data were developed in express direction to expected negative outcomes resulting from certain course of action, particularly those concerned with human impacts as a result of certain plans being implemented.

The MsCIP study team used data furnished by a broad range of sources, to define risks associated with a large number of existing and future conditions, including the “No-Action”, and future with-project conditions for a large number of alternative plans. Many potential outcomes were developed in detailed discussions as to the nature of conditions under many future scenarios, and what the effects might be on the large array of resources. This data was used to populate a database, summarized in the System of Accounts tables given in the Main Report, where both quantitative and qualitative determinations of positive and negative outcomes are displayed, and the risks, uncertainties, and potential consequences of each, are compared.

“Uncertainty” as used in Corps studies, refers to the degree of uncertainty expressed by technical evaluators (or even in some cases by the public), that a certain outcome will occur under and certain condition. This could be expressed as a range of outcomes given a certain condition, an example being that experts predict that water depth may be as much as 20 feet and as little as 12 feet deep, under circumstances of a certain-magnitude hurricane event, at a certain location. In many cases, however, uncertainties regarding a certain outcome, could only be expressed in the broadest of terms. An example of this would the uncertainties regarding threats to human life under conditions such as the implementation of ring levees or surge barriers. It is, of course, highly uncertain as to how human beings will react to the approach of a hurricane event, given the uncertainties as to landfall, intensity, and other factors. This is complicated by the intervention of certain conditions like a surge barrier, behind which people may feel “protected”, or alternatively, very mush at risk. These determinations of risk and uncertainty played a large, although heavily dependent on qualitative assessment, role in decision-making on the part of the Federal response.

Assessment and characterization of risk and uncertainties led, as expected, to their incorporation in the technical analyses conducted under the MsCIP study effort, the second step of this process.

PART 2 – TECHNICAL RISK AND UNCERTAINTY

The second step of the risk assessment process was the incorporation of what the Corps refers to as “Risk and Uncertainty Analysis”. This aspect of the risk analysis focuses on the evaluation of technical aspects of potential plans that includes not only estimation of probabilities of certain outcomes, but also the determination of uncertainties in any estimated outcome. Technical risk and uncertainty also included a measure of risk and uncertainty inherent in cost estimation.

Risk and uncertainty analysis is a comprehensive, statistically-based approach directed at identifying and incorporating uncertainties associated with key factors that are inherent in the determination of plans addressing flooding, hurricane surge, waves, and other destructive events, as well as those comprising key elements of ecosystem restoration planning, economic analysis, and cost estimating.

Key factors evaluated in the Risk and Uncertainty analysis conducted under the MsCIP study include: evaluating uncertainties in estimating surge (water surface) elevations and wave contributions to surge height, the extent of surge inundation by frequency of event (by use of multiple event modeling), the first floor elevation of structures, the magnitude of damages to both structures and contents, and risks in the estimation of costs associated with future events, including those of project or program implementation. In addition, uncertainty was an inherent factor in the environmental processes used to identify possible restoration sites. This uncertainty was primarily related to the scale of the existing data used to populate the GIS based Spatial Decision Support System (SDSS). In addition there is uncertainty in the benefit evaluation system used, the Hydrogeomorphic Methodology (HGM), due to the lack of time to completely ground truth the sites in question.

Risk and Uncertainty is a rigorous part of Corps of Engineer analyses and the planning process. Engineer Regulation 1105-2-101 defines risk as, “The probability an area will be flooded, resulting in undesirable consequences,” and uncertainty as, “A measure of imprecision of knowledge of parameters and functions used to describe the hydraulic, hydrologic, geotechnical, and economic aspects of a project plan.”

For the Mississippi Coastal Improvements Program (MsCIP) Comprehensive Plan, both risk and uncertainty played a vital role throughout the planning and selection process as well as the work conducted by each of the various technical aspects. While this section will paint a broad picture of the application of techniques used to address risk and uncertainty, the engineering, environmental, real estate, and economic appendices go into greater detail on how each discipline addressed these issues.

Estimation of risks and uncertainties associated with the MsCIP Comprehensive Plan study area, as defined by Congress, included estimation of physical outcomes across the three coastal counties of Mississippi; Hancock, Harrison and Jackson Counties from west to east respectively. Hancock, Harrison, and Jackson Counties include over 1,361 square miles, roughly 100 square miles larger than the state of Rhode Island and populations of 40,421, 171,875, and 130,577 respectively. The Maximum Probable Intensity (MPI) footprint, or the estimate of the maximum surge footprint, includes over 138,000 residential and commercial structures. Within these areas, surge from Hurricane Katrina significantly destroyed (50% or more structural damage) 32,446 structures, with another 15,000 to 25,000 sustaining moderate to minor damage. The sheer magnitude and scale of this area, along with the extent of the damage sustained, set the stage for much larger degrees of risk and uncertainty than exist in typical Corps Feasibility Studies.

Forecasting future scenarios is an important part of the Corps planning process. In order to evaluate the true risk and impacts over the period of analysis, all forecasts were created based on historic and existing information, as well as quantitative and qualitative assessments of what is most likely to happen within the study area in the future. One method used was to identify the ‘most likely’ future, or the best guess about what may happen based on observed variables and assumptions of both natural and human behaviors. Another method used was to conduct scenario planning, where multiple future scenarios are created in order to evaluate what would happen if observed variables or assumptions do not happen as projected. Scenario planning attempts to answer the ‘what if’ questions that arise when making forecasting assumptions and predictions. For the MsCIP Comprehensive Study, the former method was chosen due to the size, scope, and complexity of the overall analysis, but with scenario testing used for the multiple possible futures possible under sea level rise and re-development possibilities.

The use of scenario planning allowed the MsCIP PDT the ability to evaluate the impacts of large uncertainties such as varying redevelopment types and the effects of relative sea level rise. Four future without-project scenarios were developed based on two redevelopment scenarios and two potential relative sea level rise scenarios. Redevelopment was assumed as either the rebuilding of the study area exactly as it was pre-Hurricane Katrina (residential redevelopment) or rebuilding similar to pre-Hurricane Katrina levels except for the vast waterfront coastline, which would rebuild as either condominiums or casinos (commercial redevelopment). Sea level rise and land surface subsidence have been taken into account as part of this study and is reported as “relative sea level rise” which accounts for both as a single value.

After the identification of the four potential future without-project scenarios, the next step was the evaluation of those scenarios using hydrodynamic and economic models. Hydraulic and hydrologic modeling efforts by a team of USACE, FEMA, NOAA, private sector and academic researchers have been working toward the definition of a new system for estimating hurricane inundation probabilities. Their work includes the use of multiple models such as the Planetary Boundary Layer Model (TC-96) which evaluates wind pressure fields, the Wave Attenuation Model (WAM) which evaluates offshore waves, the STWAVE near shore wave model, and the Advanced Circulation (ADCIRC) model which incorporates output from the other models into the storm surge modeling effort. Modeling inputs included a storm suite of over 150 storms covering ranges in variable drivers such as central pressure, radius to maximum winds, and forward speed. Outputs of the models were statistically analyzed using a modified Joint Probability Method with Optimal Sampling (JPM-OS). The underlying concept of the JPM-OS methodology is to provide a good estimate of the surge in as small a number of dimensions as possible, while retaining the effects of additional dimensions by including a $\boldsymbol{\varepsilon}$ term within the estimated Cumulative Distribution Function (CDF) for surges. The $\boldsymbol{\varepsilon}$ term is considered to include, at a minimum, tides, random variations in the Holland B parameter, track variations not captured in storm set, model errors (including errors in bathymetry, errors in model physics, etc.), and errors in wind fields due to neglect of variations not included in the Planetary Boundary Layer model winds. More detail on the JPM-OS method can be found in the Engineering Appendix (Appendix E)

The output of the JPM-OS modeling effort was provided to the Mobile District Engineering Division for the estimation of exceedence probability functions that were incorporated into the Hydrologic Engineering Center – Flood Damage Analysis (HEC-FDA) program. The HEC-FDA program uses risk-based analysis methods for evaluating flood damage and flood damage reduction alternatives. The program relies on hydrologic, hydraulic, and economic data input. Uncertainties in these data are input and used by the model for computing expected annual damages. HEC-FDA input variables that include uncertainty are the exceedence probability functions, depth damage relationships, first floor elevations, and structure and content values. The program’s risk-based analysis methods conform to Corps of Engineers policy regulations. Outputs of the HEC-FDA program for each of the future without-project scenarios are detailed in the Economic Appendix

(Appendix B), and are included in the Risk Informed Decision Framework (RIDF) process outlined in later sections of this appendix.

Although there is some uncertainty associated with the environmental restoration evaluation process it is felt that these uncertainties are within the ranges of values used within the various models. The environmental team ground-truthed a portion of each of the recommended sites to ensure that the proposed restoration activities would be achievable and that the restored sites would function as designed. The project is also recommending implementation of an adaptive management process and monitoring for all the proposed environmental restoration project elements. The techniques being proposed for restoration, e.g. excavation of fill, filling man-made ditches, mowing and burning etc., are tried and true proven restoration methods. Further only sites that contain wetland soils and are in the near vicinity of water courses are proposed for restoration. This will increase the probability of success for those sites proposed for restoration as tidal fringe wetlands.

Risk and Uncertainty outcomes were also incorporated into the risk database, summarized in the System of Accounts tables given in the Main Report. All of this data was used in the later phases of risk assessment and screening of alternatives ultimately leading to the selection of recommended actions.

PART 3 – EDUCATION OF STAKEHOLDERS

The third step of the risk assessment process was the characterization of risk, in terms that everyone could understand, and the dissemination of this information to the stakeholders. This was an extremely important part of the process, since the stakeholders were so interested in the planning process and its potential outcomes, but was doubly important given their participation in the next phase of study, the integration of Risk-Informed Decision Framework (RIDF), in which they would very actively participate, and for which good information on risks, uncertainties, and consequences was so important.

Data on the potential risks and consequences of the no-action plan, and the large number of potential alternatives plans addressing numerous identified problem areas and sites, was assembled and discussed by members of the study team, agency participants, and technical experts in each field. It was recognized that much of the data would be confusing to the public, and in fact, could actually cause the public to believe information that would run contrary to what the study team believed was in the best interests of the stakeholders. Key among this was the discussion of “protection” and “100-year” storms. Both these concepts have negative outcomes, as the public interprets them. Early attempts at educating the stakeholders on risk led the study team to the recognition that the public would believe themselves to be “protected” from storm events, in the event of various structural plans being implemented, and that the concept of a “100-year level of protection” was guaranteed to result in many members of the public believing that a “100-year” hurricane was only possible 100 years in the future, since “we just had one.”

The study team convened a group to re-characterize event frequency, and the risks and consequences of various magnitude events occurring, in terms that everyone in the study area could relate to. Frequency-inundation mapping was developed, to characterize events in terms of their depth, and re-occurrence based on past events the community has suffered, rather than an arbitrary frequency that the public could not understand. Risks and consequences associated with many other factors were also discussed and then re-characterized in simple, easy to understand terms.

The MsCIP team shared this information, through a series of public workshops. These workshops are discussed in greater detail in the Public Involvement Appendix. The key outcome of the initial public workshops, in regards to the education of stakeholders on risk issues, was the better understanding of all the factors involved in the eventuality of either no action, or any number of potential plans, in terms of both human and environmental impacts, risks or probabilities of certain outcomes given certain circumstances, and what that might mean to the individuals concerned, their institutions, and communities.

Education of the stakeholders was understood to be one important part of the process, but requiring additional tools to enlist greater public participation, and expression of stakeholder preferences on plans, in a risk-aware environment. This led to the following step in this process.

PART 4 – RISK INFORMED DECISION FRAMEWORK

Risk-Informed Decision Framework (RIDF) refers to a guided process by which stakeholders can "weigh in" on their preferences, in regards to concepts, measures, and alternative plans, in a manner that leads to group decision-making, at least in regards to stakeholder preferred actions.

The RIDF provides a robust and comprehensive approach toward identifying plans that the public and agencies feel best achieve the particular goals and objectives of that population, and draws from current practice in the fields of multi-criteria decision analysis (MCDA) and risk and uncertainty analysis. The RIDF is solidly grounded in and supports the Corps of Engineers' six-step planning process closely, in augmenting this planning process by incorporating specific techniques and methods from risk analysis and MCDA, to solicit and incorporate public and agency preferences in plan evaluation and selection. RIDF is the logical next step in the process of evaluating and incorporating risk in the planning process, in that it involves the public in the evaluation of potential measures that might be used to address problems, further educates them to the risks and consequences of each potential action, including a No-Action scenario, and allows them to weigh-in on a prioritization process that allows local decision-makers to see what the public desires, and how that might be used in the determination of preferred plans and activities.

The RIDF enhances the level of communication and collaboration among decision-makers and stakeholders by providing structured opportunities for interaction. The RIDF uses the information gained through the initial steps involving the public and agencies to develop a set of factors of importance (referred to as "metrics") in the analysis of specific problems and sites, for which the Study team then develops units of measurement for which to compare each metric later in the process, and solicits publically-, and agency-determined "weights" or preferences that reflect stakeholder priorities. This provides an analytically sound, defensible, and quantitative approach to aid in local decision-making. In this way, decision outcomes can more adequately satisfy the interests, values, and objectives of most importance to the individuals and agencies weighing in on each alternative plan.

Metrics evaluated during the MsCIP RIDF process included measures of the total cost as well as local implementation costs, acres of habitat lost or restored by No-Action or various restoration plan opportunities, potential impacts to physical and mental health, impacts to cultural integrity, regional economic well-being, residual risks and risk of failure of a given plan, and other factors.

The RIDF also incorporated information about uncertainty into the decision process and facilitates discussion of residual risks, which include the expected damages or consequences resulting from events, and which might result even in the event of construction of a large project or implementation of a program. Accurate forecasts about the future are difficult, and decisions that ignore these uncertainties may differ from and perform less well than those that do not. The MsCIP RIDF process also incorporated uncertainty originating from two additional sources of particular importance in this area, those of relative sea level rise (resulting from both global sea level rise and sinking of the land relative to the sea's surface) and the future potential patterns of re-development. Information about these uncertainties manifests itself in the outcome metrics and in the scoring and ranking of alternative plans.

Ultimately, the optimality of a prospective public and agency decision outcome depends upon values and beliefs that can vary across different stakeholder groups. Since the MsCIP decision process involves a broad spectrum of stakeholders, the RIDF evaluates the sensitivity of the recommendations to these values and beliefs to help decision-makers and stakeholders understand the prioritization of factors by any group or individual, and their emotion about each plan and its potential outcomes. Use of RIDF may further help to identify what additional studies may be needed and what communication and negotiation efforts could be improved. These efforts help to build confidence in the planning process, involve the public and agencies in decision-making, and may enhance commitment to selected alternatives. RIDF also educates and obtains input on the role that adaptive management can play in the long-term outcomes of potential plans, and incorporates public and agency input on monitoring and maintaining the performance of projects and programs over longer planning horizons.

Detailed discussion on the models used, the creation, selection and characterization of metrics used, and the outcome of stakeholder weighting sessions, is contain in the attachment to this appendix.

PART 5 – COMPARISON, SCREENING, AND CONSIDERATION OF RISK, IN THE PLAN SELECTION PROCESS

The Fifth and final phase of Risk Analysis in the MsCIP Study process involved comparison of no-action and alternative plans, in a side-by-side trade-off presentation of plan outcomes, potential inherent and residual risks, associated with various No-Action and with-project scenarios, through display in a System of Accounts format. Screening of alternatives, by use of the System of Accounts tables, and consideration of all apparent risks, uncertainties, potential consequences and outcomes, led to screening of alternatives, weighing of the outcomes of each alternative, and identification, by Stakeholders, of a "Stakeholder-Preferred" (where applicable) Plan, and "Federally-recommended" courses of action for each problem area, based on the best-balance of objective outcomes, achievement of high cost-effectiveness, and inclusion as a key element of a comprehensive package of recommendations, directed at achieving a lower-risk, higher sustainability environment. The goal of this process was to generate a full range of tiered recommendations aimed at achievement of the study objectives, and identification of those measures for immediate or longer-term action as a result of the decision document being acted upon by Congress.

The Accounts displayed and used in this final part of the process, included the standard four accounts identified in the USACE Plan Formulation Guidance: "National Economic Development" (NED), "Regional Economic Development" (RED), "Environmental Quality" (EQ), "Other Social Effects" (OSE). In addition a "Risk" (RISK) account was added to fully identify the inherent risks associated with no action or the implementation of any one of the measures. The System of Accounts tables also display the Stakeholder Preference "scores" resulting from the public and agency RIDF process, as well as a final discussion of the selection result, based on those factors of greatest importance in that selection, for both "Stakeholder", and "Federally-Recommended" actions.

The stakeholder "scores" from the public and agency RIDF process, presented in the System of Accounts tables, resulted from a summary of the most recent series of public/agency workshops, and the application of the multi-criteria decision analysis. The summary of those scores was presented as the Stakeholder Preference score, for each of the final array of plans. This number rates each alternative, in concept, as a percentage of a theoretical "perfect plan" (in the eyes of the stakeholder group). The higher the score reflects the stakeholder belief that the alternative provides the best fit to their value judgments of the metrics. In other words, the higher the score, the more acceptable the alternative should be to that stakeholder group.

Because the stakeholders may possess very different life experiences and also may not have possessed full information on the nature and magnitude of potential risks associated with any plan of action, the MsCIP study application of the planning process required that the Corps' study team have ultimate responsibility for a Federally-recommended plan selection, based on full consideration of risk factors and potential consequences of plan implementation. This was determined to be especially important in the consideration of alternatives that had potentially negative outcomes under various future scenarios.

The study team engaged Corps and outside experts, to characterize residual or inherent risks, and to potentially recommend actions based on these over-riding criteria, in meeting the original mission as detailed by the Congress. This final part of the process was considered to be the key final level of input to the planning process, particularly in this high-risk situation.

An example of the evaluation, comparison, and rationale leading identification of plans recommended for implementation, as formulated to deal with a particular problem set at a specific site, is illustrated below, and also provided for each recommendation, within the body of the Main Report.

The Barrier Islands of the Gulf Coast form an important attribute in the system of islands, water bodies and mainland features of the coast of Mississippi. They function as a barrier to saltwater intrusion, maintaining a delicate salinity balance on which many species depend for survival within Mississippi Sound. The barrier islands attenuate wave and surge height. They also provide for a host of unique environmental conditions, both terrestrial and aquatic, and create unique conditions on which mainland values depend. Most of the barrier islands are managed by the National Park Service, with some being designated Wilderness Areas, and protected by stringent regulation.

Analysis of the effects of hurricanes Katrina, Rita, and others indicated a large number of problems caused by their erosion and degradation. Loss of the barrier islands has led to increased salinity within Mississippi Sound, increased potential wave and surge effects within the study area, and loss of aquatic species viability. Degradation of the many functions and values provided by the barrier islands, and their identification as a large focus of study effort, lead to the creation of a large number of potential measures by which restoration of the islands, and protection of resources might be achieved.

Many potential measures would be intrusive, and would violate Wilderness Act protections, due their active interference in natural processes. The list of potential measures was rapidly screened by the joint interagency sub-committee created to evaluate barrier islands options, to a shorter list containing only a No-Action Plan, restoration of the pre-hurricane island footprint plan (Plan A), a sand replenishment plan (Plan C), restoration of Ship Island breach only (Plan G), and a combination plan that would address sand replenishment and repair of Ship Island (Plan H).

Data on costs, benefits (both monetary damages prevented and ecological damages prevented), environmental quality issues, societal effects, “Stakeholder Preference” scores generated during the RIDF stakeholder involvement process, and risk factors assessment, were entered into the System of Accounts table shown below. This information was discussed with stakeholders, ranging from members of the public, to the State, and Federal agencies.

The final phase of risk incorporation in the MsCIP planning process, leading to plan selection for the barrier islands element, began with the side-by-side comparison of No-Action and action plan outcomes, with no one factor taking precedence. Examination of possible outcomes indicated that Plan H appeared to provide the most complete, effective, efficient and acceptable alternative plan. Plan H would achieve a high degree of restoration benefit, at less than half the cost of Plan A, and virtual identical damage reduction and protection of fisheries. It is a more complete solution than plans C or G, particularly in regards to protection of fisheries and restoration of tidal and non-tidal habitat. Plan H also would create positive monetary net benefits, demonstrating its cost-effectiveness (one of the primary charges given by Congress), with damage reduction benefits of approximately $18.8 million annually, protection of fisheries benefits of approximately $44 million annually, and restoration of 456 acres of tidal, and 694 acres of non-tidal habitat. Plan H would provide similar cultural, environmental quality, societal, and community benefits, at a lesser cost than Plan A. Stakeholder preference scores for Plan A and Plan H were almost identical, with Plan H receiving a marginally higher mean score. Evaluation of risks indicate that Plans A and H would provide similar reductions in several risk factors, including reduction of residual damages (primarily to reduction of wave effects on mainland development), will be minimally impacted by relative sea level rise, and have a low risk of failure (of plan outcomes). While no plan provides for significant positive benefits to life and safety, those are not factors that would be influenced strongly by this element of the comprehensive plan, but by others included in the package of recommendations.

Weighing of all considered factors above provided a clear indicator that Plan H provides the best balance, and indeed, the greatest number and magnitude of positive outcomes, of all plans considered, including the No-Action Plan.

System of Accounts table for Barrier Islands

Ecosystem Restoration and Hurricane and Storm Damage Reduction

Problem Area: Barrier Island Restoration, Hancock, Harrison, and Jackson Counties, Mississippi					
Problems ID: Damages suffered by hurricane-induced surge and wave attack; Potential future damages from storm and hurricane events.					
		Plan A	**Plan C**	**Plan G**	**Plan H**
A. PLAN DESCRIPTION	No Federal Action	Restore Island Footprint	Replenish Sand in Littoral Zone (Off-Shore & Inland River Sand Source)	Restoration of Ship Island Breach	Combination of C + G
B. IMPACT ASSESSMENT					
1 National Economic Development					
a. Beneficial Impacts					
(1) Damages Prevented	$0	$18,866,000	$10,468,000	$7,616,000	$18,866,000
(2) Emergency Costs Avoided	$0				
(3) Recreation	$0	$466,000	$117,000	$466,000	$466,000
(4) Total Beneficial Impacts	None.	$19,332,000	$10,585,000	$8,082,000	$19,332,000
b. Adverse Impacts					
(1) Project Cost	$0	$942,200,000	$147,400,000	$181,400,000	$328,800,000
(2) Interest During Construction	$0	$119,317,000	$18,667,000	$22,972,000	$41,639,000
(3) Average Annual First Cost	N/A	$58,376,000	$9,133,000	$11,239,000	$20,372,000
(4) Annual O&M	$0	$0	$0	$0	$0
(5) Total Avg. Annual Costs	$0	**$58,376,000**	**$9,133,000**	**$11,239,000**	**$20,372,000**
2. Environmental Quality (EQ)					
(1) Ecosystem Restoration	No benefit	Restoration of 644 acres of tidal habitat and 2036 acres of nontidal habitat.	Restoration of 326 acres of tidal habitat and 217 acres of nontidal habitat.	Restoration of 130 acres of tidal habitat and 477 acres of nontidal habitat.	Restoration of 456 acres of tidal habitat and 694 acres of nontidal habitat.

Problem Area: Barrier Island Restoration, Hancock, Harrison, and Jackson Counties, Mississippi

Problems ID: Damages suffered by hurricane-induced surge and wave attack; Potential future damages from storm and hurricane events.

		Plan A	Plan C	Plan G	Plan H
(2) Protection of Fisheries	**Loss of $43,618,143** in average annual fishery landings	Avoidance of **$43,618,143** in lost fishery landings.	Avoidance of **$6,542,721** in lost fishery landings.	Avoidance of **$21,809,072** in lost fishery landings.	Avoidance of **$43,618,143** in lost fishery landings.
(3) Water Circulation	Area would become more open Gulf in nature as islands erode	No anticipated effect.	No anticipated effect.	No anticipated effect.	No anticipated effect.
(4) Noise Level Changes	No change in noise levels	Temporary increase in noise levels during construction	Temporary increase in noise levels during construction	Temporary increase in noise levels during construction	Temporary increase in noise levels during construction
(5) Public Facilities	Loss of the barrier islands would result in loss of National Parks	National Parks would be preserved.	National Parks would be enhanced by supplemental sand supply.	National Parks would be enhanced by supplemental sand supply.	National Parks would be preserved.
(6) Aesthetic Values	Continued degradation of aesthetic values	Significant aesthetic improvement	Moderate aesthetic improvement	Moderate aesthetic improvement	Significant aesthetic improvement
(7) Natural Resources	Continued degradation of islands and loss of function of MS Sound.	Significant reduction in loss of island and function of MS Sound.	Minor reduction in loss of island and function of MS Sound.	Moderate reduction in loss of island and function of MS Sound.	Significant reduction in loss of island and function of MS Sound.
(8) Biological Resources	Continued degradation and loss of biological resources.	Significant improvement in biological resources.	Moderate improvement in biological resources.	Moderate improvement in biological resources.	Significant improvement in biological resources.
(9) Air Quality	No anticipated effect on air quality	Air emission would be *de minimus*	Air emission would be *de minimus*	Air emission would be *de minimus*	Air emission would be *de minimus*
(10) Water Quality	Water quality is anticipated to deteriorate with future loss of the island system (salinity increase will decrease size of estuarine zone).	Temporary negative impacts to water quality due to construction but overall long-term improvements to water quality are anticipated.	Temporary negative impacts to water quality due to construction but overall long-term improvements to water quality are anticipated.	Temporary negative impacts to water quality due to construction but overall long-term improvements to water quality are anticipated.	Temporary negative impacts to water quality due to construction but overall long-term improvements to water quality are anticipated.

Problem Area: Barrier Island Restoration, Hancock, Harrison, and Jackson Counties, Mississippi

Problems ID: Damages suffered by hurricane-induced surge and wave attack; Potential future damages from storm and hurricane events.

		Plan A	Plan C	Plan G	Plan H
(11) Public Services	Possible increase in interruption of services as islands continue to erode	Increased stability of barrier islands would reduce likelihood of interruption of public services.	Increased stability of barrier islands would reduce likelihood of interruption of public services.	Increased stability of barrier islands would reduce likelihood of interruption of public services.	Increased stability of barrier islands would reduce likelihood of interruption of public services.
(12) Cultural and Historical Preservation	Alternative would result in future loss of important cultural resources at Ship Island.	Alternative would preserve cultural and historical artifacts, including Fort Massachusetts and the French Warehouse.	Alternative would provide some reduction in impact to cultural and historical artifacts, including Fort Massachusetts and the French Warehouse.	Alternative would preserve cultural and historical artifacts, including Fort Massachusetts and the French Warehouse.	Alternative would preserve cultural and historical artifacts, including Fort Massachusetts and the French Warehouse.
(13) Total Quality of the Environment	Significant negative impact on the total quality of this environment if the islands erode away	Significant positive impacts on the total quality of environment (i.e. future production of Mississippi Sound)	Significant positive impacts on the total quality of environment (i.e. future production of Mississippi Sound)	Significant positive impacts on the total quality of environment (i.e. future production of Mississippi Sound)	Significant positive impacts on the total quality of environment (i.e. future production of Mississippi Sound)
3. Regional Economic Development (RED)					
(1) Impact on Sales Volume	No impact to the local economy.	Increase of **$2,289,546,000** in additional sales volume.	Increase of **$358,182,000** in additional sales volume.	Increase of **$440,802,000** in additional sales volume.	Increase of **$798,984,000** in additional sales volume.
(2) Impact on Income	Negative impact to individuals involved in fishing industry as islands erode and MS Sound environment changes.	Increase of **$480,984,800** in additional local income.	Increase of **$75,246,410** in additional local income.	Increase of **$92,603,120** in additional local income.	Increase of **$167,849,530** in additional local income.

Problem Area: Barrier Island Restoration, Hancock, Harrison, and Jackson Counties, Mississippi

Problems ID: Damages suffered by hurricane-induced surge and wave attack; Potential future damages from storm and hurricane events.

		Plan A	Plan C	Plan G	Plan H
(3) Impact on Employment	Negative impact to individuals involved in fishing industry as islands erode and MS Sound environment changes.	Increase of **14,100** new jobs.	Increase of **2,206** new jobs.	Increase of **2,714** new jobs.	Increase of **4,920** new jobs.
(4) Tax Changes	Possible negative impacts as islands erode and chance of storm damage increases	None	None	None	None
4. Other Social Effects (OSE)					
a. Beneficial Impacts					
(1) Security of Life, Health, and Safety	Continued risks to life, health and safety	Significant decrease in risks to life, health and safety.	Moderate decrease in risks to life, health and safety.	Moderate decrease in risks to life, health and safety.	Significant decrease in risks to life, health and safety.
(2) Community Cohesion	Negative impacts as islands continue to erode and damages from waves and storms increase above the existing level.	Positive impact as community observes coastal resources being restored and stability of barrier islands and MS Sound increased.	Positive impact as community observes coastal resources being restored and stability of barrier islands and MS Sound increased.	Positive impact as community observes coastal resources being restored and stability of barrier islands and MS Sound increased.	Positive impact as community observes coastal resources being restored and stability of barrier islands and MS Sound increased.
(3) Tax Values	Negative impacts as islands erode and chance of storm damage increases	Moderate increase in tax values due to decreased risk to properties.	Small increase in tax values due to decreased risk to properties.	Small increase in tax values due to decreased risk to properties.	Moderate increase in tax values due to decreased risk to properties.

Problem Area: Barrier Island Restoration, Hancock, Harrison, and Jackson Counties, Mississippi

Problems ID: Damages suffered by hurricane-induced surge and wave attack; Potential future damages from storm and hurricane events.

		Plan A	Plan C	Plan G	Plan H
(4) Community Growth	Could have negative impact on growth as islands continue to erode	Moderate positive impact to community growth	Small positive impact to community growth	Small positive impact to community growth	Moderate positive impact to community growth
(5) Property Values	Negative impacts as islands erode and chance of storm damage increases	Moderate increase in property values due to decreased risk to properties.	Small increase in property values due to decreased risk to properties.	Small increase in property values due to decreased risk to properties.	Moderate increase in property values due to decreased risk to properties.
(6) Displacement of Businesses	Potential impacts to businesses from increased risk of surge damage.	Reduced risk of displacement of businesses.	Reduced risk of displacement of businesses.	Reduced risk of displacement of businesses.	Reduced risk of displacement of businesses.
(7) Public Facilities	Negative impacts to public facilities from increased risk of surge damage.	Reduced risk to public facilities.	Reduced risk to public facilities.	Reduced risk to public facilities.	Reduced risk to public facilities.
(8) Injurious Displacement of Farms	N/A	N/A	N/A	N/A	N/A
b. Preservation of life	Not anticipated to contribute to loss of life.	Not anticipated to contribute to loss of life.	Not anticipated to contribute to loss of life.	Not anticipated to contribute to loss of life.	Not anticipated to contribute to loss of life.
C. PLAN EVALUATION					
1 Contributions to Planning Objectives					
a. Flood, Hurricane and/or Storm Damage Reduction	Increased risk in damage reduction from further degradation of islands.	Significant avoidance of increased risk.	Minor avoidance of increased risk.	Moderate avoidance of increased risk.	Significant avoidance of increased risk.

Problem Area: Barrier Island Restoration, Hancock, Harrison, and Jackson Counties, Mississippi

Problems ID: Damages suffered by hurricane-induced surge and wave attack; Potential future damages from storm and hurricane events.

		Plan A	Plan C	Plan G	Plan H
b. Recovery of lost environmental resources	Alternative will result in continued loss of environmental resources.	Barrier Island restoration will accrue unquantified benefits.	Barrier Island restoration will accrue unquantified benefits.	Barrier Island restoration will accrue unquantified benefits.	Barrier Island restoration will accrue unquantified benefits.
2. Response to Planning Constraints					
a. Avoid environmental impacts and minimize induced damages	Continued loss of pre-Katrina environmental resources.	Beneficial effect on environmental resources.	Beneficial effect on environmental resources.	Beneficial effect on environmental resources.	Beneficial effect on environmental resources.
b. Institutional Acceptability	Is not supported by state or local government	Is supported by local and state governments	Is supported by local and state governments	Is supported by local and state governments	Is supported by local and state governments
3 Response to Evaluation Criteria					
a. Acceptability	NO	No, does not meet all Federal policies and regulations (i.e. Wilderness Act)	YES	YES	YES
b. Completeness	NO	YES	NO, it does not avoid all of the future degradation.	NO, it does not avoid all of the future degradation.	YES
c. Effectiveness	NO	YES	NO, not a completely effective solution.	NO, not a completely effective solution.	YES
d. Efficiency (Cost-Effectiveness; i.e., most efficient use of Federal and Non-Federal Funds)	NO	No, over 2 1/2 times as expensive as plan H	No, less efficient than plan A and H.	No, less efficient than plan A and H.	YES, most efficient / cost effective plan.
e. Integration	N/A	Seamless addition to system.	Seamless addition to system.	Seamless addition to system.	Seamless addition to system.

Problem Area: Barrier Island Restoration, Hancock, Harrison, and Jackson Counties, Mississippi

Problems ID: Damages suffered by hurricane-induced surge and wave attack; Potential future damages from storm and hurricane events.

		Plan A	Plan C	Plan G	Plan H
f. Reversibility	This issue does not apply	Alternative could be reversible, given means to remove sand.	Alternative could not be reversible, given placement in open-water.	Alternative could be reversible, given means to remove sand.	A portion of this alternative could not be reversible, given placement in open-water.
4. Stakeholder Preference Score (From MCDA weightings analysis)					
a. Summary Score	**15.53%**	**71.69%**	**62.28%**	**41.70%**	**72.03%**
Cluster Group A	27.16%	67.62%	63.08%	47.53%	73.93%
Cluster Group B	18.82%	70.58%	63.58%	45.57%	73.93%
Cluster Group C	11.83%	74.03%	63.92%	41.81%	73.58%
Cluster Group D	4.30%	74.51%	58.55%	31.90%	66.66%
b. Stakeholder Preference	All groups ranked this plan lowest	Plan ranked very high, but less than H.	Plan ranked lower than A and H.	Plan ranked lowest of all action plans.	Plan ranked highest overall
D. Implementation Responsibility	Does not have any implementation responsibilities	Elements would be joint Federal/Non-Federal implementation responsibility.	Elements would be joint Federal/Non-Federal implementation responsibility.	Elements would be joint Federal/Non-Federal implementation responsibility.	Elements would be joint Federal/Non-Federal implementation responsibility.
E. State and other Non-Federal Coordination	Would require no State or other Non-Federal coordination activities	Would require significant State or other Non-Federal coordination activities	Would require significant State or other Non-Federal coordination activities	Would require significant State or other Non-Federal coordination activities	Would require significant State or other Non-Federal coordination activities
F. Risk Evaluation					
1 Risk and Vulnerabilities					
a. Risk of Failure	N/A	Low	Moderate	Moderate	Low

Problem Area: Barrier Island Restoration, Hancock, Harrison, and Jackson Counties, Mississippi					
Problems ID: Damages suffered by hurricane-induced surge and wave attack; Potential future damages from storm and hurricane events.					
		Plan A	**Plan C**	**Plan G**	**Plan H**
b. Residual Risk	All barrier islands will overtop during large surge events, and will not provide significant reduction of surge and waves.	All barrier islands will overtop during large surge events, and will not provide significant reduction of surge. Plan A would provide a significant reduction to waves.	All barrier islands will overtop during large surge events, and will not provide significant reduction of surge and waves.	All barrier islands will overtop during large surge events, and will not provide significant reduction of surge and waves.	All barrier islands will overtop during large surge events, and will not provide significant reduction of surge. Plan A would provide a moderate reduction to waves.
c. Reliability	N/A	Plan A would provide a moderate level of reliability, would be resistant to damage from storm events, and would not require significant maintenance.	This plan would provide a low level of reliability, would receive damage from storm events, and would require significant maintenance.	This plan would provide a low level of reliability, would receive damage from storm events, and would require significant maintenance.	Plan A would provide a moderate level of reliability, would be resistant to damage from storm events, and would not require significant maintenance
d. Relative Sea Level Rise	Problems will be substantially exacerbated by an increasing relative rise of sea level	This Plan will be minimally impacted by an increasing relative rise of sea level over the period of analysis	This Plan will be moderately impacted by an increasing relative rise of sea level over the period of analysis	This Plan will be moderately impacted by an increasing relative rise of sea level over the period of analysis	This Plan will be minimally impacted by an increasing relative rise of sea level over the period of analysis
e. Risk of Ecosystem Damage	Ecosystem damage will continue to accrue at a rate at least that of recent history with substantial negative	Risk of ecosystem damage will be minimal throughout the period of analysis.	Risk of ecosystem damage will be moderate throughout the period of analysis.	Risk of ecosystem damage will be moderate throughout the period of analysis.	Risk of ecosystem damage will be minimal throughout the period of analysis.

Problem Area: Barrier Island Restoration, Hancock, Harrison, and Jackson Counties, Mississippi					
Problems ID: Damages suffered by hurricane-induced surge and wave attack; Potential future damages from storm and hurricane events.					
		Plan A	**Plan C**	**Plan G**	**Plan H**
	outcomes.				
f. Risk to Life and Safety	Significant threats to Life and Safety from storm surge will continue to rise due to continued deterioration of the Barrier Islands.	Significant threats to Life and Safety from storm surge will still exist, but this plan will provide the least risk to life and safety.	Significant threats to Life and Safety from storm surge will still exist, but this plan will provide less risk to life and safety than the No Action Plan.	Significant threats to Life and Safety from storm surge will still exist, but this plan will provide less risk to life and safety than the No Action Plan and Plan C.	Significant threats to Life and Safety from storm surge will still exist, but this plan will provide the least risk to life and safety, except for Plan A.
g. Risk to Mental and Physical Health	Significant threats to Mental and Physical Health from storm surge will continue to rise due to continued deterioration of the Barrier Islands.	Significant threats to Mental and Physical Health from storm surge will still exist, but this plan will provide the least risk to Mental and Physical Health.	Significant threats to Mental and Physical Health from storm surge will still exist, but this plan will provide less risk to Mental and Physical Health than the No Action Plan.	Significant threats to Mental and Physical Health from storm surge will still exist, but this plan will provide less risk to Mental and Physical Health than the No Action Plan and Plan C.	Significant threats to Mental and Physical Health from storm surge will still exist, but this plan will provide the least risk to Mental and Physical Health, except for Plan A.
2 Recommendations and Preferences					

Problem Area: Barrier Island Restoration, Hancock, Harrison, and Jackson Counties, Mississippi					
Problems ID: Damages suffered by hurricane-induced surge and wave attack; Potential future damages from storm and hurricane events.					
		Plan A	**Plan C**	**Plan G**	**Plan H**
a. Federal Recommendation					This Plan has the highest NED benefits, substantial RED benefits, substantial EQ benefits, the greatest achievement of OSE outcomes, does not violate any local, state, or Federal statues, laws, and regulations, and is the most cost effective and efficient recommendation of the Barrier Island component of the Comprehensive Plan
b. Stakeholder Preference					This Plan has the highest stakeholder preference score, and creates a low risk environment.

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ATTACHMENT 1

Risk-Informed Decision Framework for the Mississippi Coastal Improvements Program (MsCIP)

Prepared for Mobile District, US Army Corps of Engineers

January 2008

Engineer Research and Development Center
U.S. Army Corps of Engineers
Vicksburg, MS

Table of Contents

GLOSSARY

Cluster: A set of data that share a common trait.

Eustatic: Changes in sea-level that are caused by global forces such as climate change.

Isostatic: Changes in sea-level that are caused by local forces such as land subsidence and glacial rebound.

Measure: A component of plans for risk reduction. Categories of risk reduction measures include structural, non-structural and coastal restoration.

Metric: A parameter for quantifying the performance of plans in respect to planning objectives.

Natural variability: The heterogeneity of some attribute in a population.

Plan: Any detailed scheme, program, or method worked out beforehand to accomplish an objective. A plan could incorporate structural, non-structural, and/or coastal restoration measures or combination of measures for risk reduction. Plans emerge from the plan formulation process.

Residual risk: The portion of risk remaining after the recommended plan has been implemented.

Risk: Risk is fully defined by an event probability, a set of factors on which that event probability is conditioned (scenarios), and the consequences of that event.

Uncertainty: A lack of knowledge that originates from an incomplete understanding of the structure and function of natural or manmade systems, the choice of a model to represent those systems, and the choice of the input values for the parameters of the chosen model.

Variance: A measure of statistical dispersion, averaging the squared distance of its possible values from the expected value (mean). Variance captures the mean's scale or degree of being spread out.

EXECUTIVE SUMMARY

This part of the Risk Appendix outlines a Risk-Informed Decision Framework (RIDF) for the Mississippi Coastal Improvements Program (MsCIP) effort. The RIDF provides a robust and comprehensive approach toward identifying plans that the public and agency stakeholders feel best achieve the particular goals and objectives of that population and draws from current practice in the fields of multi-criteria decision analysis (MCDA) and risk/uncertainty analysis. The RIDF is solidly grounded in and follows closely the Corps of Engineers six-step planning process closely, but augments this planning process by incorporating specific techniques and methods from risk analysis and MCDA. There are numerous advantages to this approach.

The RIDF enhances the level of communication and collaboration among decision-makers and stakeholders by providing structured opportunities for interaction. The RIDF uses the information gained through this process to define a set of decision objectives, outcome metrics, and preference weights that reflect stakeholder priorities and provide an analytically sound, defensible, and quantitative approach to decision making. In this way, decision outcomes can more adequately satisfy the interests, values, and objectives germane to the decision. The RIDF also incorporates information about uncertainty into the decision process and facilitates discussion of residual risks, which are the expected damages from storms that will remain after a storm defense is built. Accurate forecasts about the future are difficult, and decisions that ignore these uncertainties may differ from and perform less well than those that do not. Therefore, the RIDF explicitly considers uncertainty originating from two sources including relative sea level rise and the future pattern of development. Information about these uncertainties manifests itself in the outcome metrics and in the scoring and ranking of alternative plans.

The optimality of a prospective decision outcome depends upon values and beliefs that can vary across different stakeholder groups. Since the MsCIP decision process involves a broad spectrum of stakeholders, the RIDF evaluates the sensitivity of the recommendations to these values and beliefs to help decision-makers and stakeholders understand the robustness of recommendations and anticipated outcomes. In this way, the RIDF helps to identify what further studies may be needed and what communication and negotiation efforts could be improved. These efforts also build confidence in the planning process and commitment to the selected plans. We also recognize the role that adaptive management can play in connection with the RIDF as a mechanism for monitoring and maintaining the performance of decisions over longer planning horizons.

1. INTRODUCTION

1.1 Background

This report summarizes the results of a risk-informed decision framework (RIDF) as applied in the Mississippi Coastal Improvements Project (MsCIP) as part of the development of a comprehensive plan to reduce the residual risks from flood and storm surge inundation and coastal wetlands loss and degradation. The intent of the RIDF is to "**develop a decision framework in such a manner as to simply and clearly show to decision makers and the public the risks, costs and consequences of flood control, coastal restoration, and hurricane protection measures...[and] recommendations…will be supported…using the risk informed decision framework.**"

A comprehensive plan addresses a full range of risks to people, environment, property, and economy as well as infrastructure construction, operations, and maintenance costs. Risk is fully defined by an event probability, a set of factors on which that event probability is conditioned (scenarios), and the consequences of that event (Kaplan and Garrick 1981). With respect to flood risk management, residual risk has been defined by the National Research Council (2000) as that risk that remains after a flood damage reduction project is implemented.

This part of the Risk Appendix develops the risk-informed decision framework (RIDF). The RIDF has been developed by the Engineer Research and Development Center (ERDC) to integrate risk and decision science methods into the US Army Corps of Engineers (USACE) planning process while emphasizing consistency with existing USACE planning guidance.

The MsCIP decision process must consider a comprehensive set of planning objectives that include: 1) the reduction of risks to human life, property, and the regional economy; 2) the protection of the region's natural resources, and environmental quality; and 3) the construction, operations, and maintenance costs associated with any particular alternative. In addition to these numerous diverse interests that must be addressed through the planning process, the Mississippi coastal area is a dynamic environment that is rapidly changing in ways that are difficult to predict. Prudent decision makers will therefore take account of the uncertainty regarding economic, environmental, and other conditions that may affect the outcome of a project during the planning horizon.

The MsCIP decision problem is to recommend a comprehensive plan that will reduce the risks of flooding caused by storm surge and coastline degradation while considering a full range of risks to people, environment, property, and economy as well as infrastructure construction, operations, and maintenance costs. The RIDF is responsive to these and other decision support needs of MsCIP for which conventional decision support methods are poorly suited. The RIDF offers a decision approach that accounts for a comprehensive set of coastal assets in Mississippi and acknowledges the presence of a diverse group of stakeholders who exhibit conflicting interests and objectives. The RIDF approach also addresses uncertainty in certain environmental, social, and economic trends over the planning horizon that can affect the desirability of risk reduction strategies.

Conventional approaches to decision making have emphasized cost-benefit analysis, which is suitable only when decision outcomes can be fully monetized. There is now an increasing level of consideration given to assets that are difficult to quantify in economic terms, such as wildlife habitat and cultural diversity, and tend to confound the application of that approach. Conventional decision methods have also emphasized a single decision objective built around national economic development objectives. However, the MsCIP planning guidance requires an accounting of regional economic development, environmental, and other social effects objectives as well. Therefore, a multi-attribute decision analysis method is needed. In addition to presence of multiple objectives, there is diverse set of stakeholders whose interests must also be taken into account. Conventional approaches to decision making have also tended to ignore uncertainty. By evaluating and communicating uncertainty during the planning process, RIDF helps lead decision makers to more well-reasoned and rational choices. The RIDF attempts to addresses all of the shortcomings of conventional decision approaches in a manner that is consistent with the USACE planning guidelines.

1.2 Overview of the Risk-Informed Decision Framework

1.2.1 RIDF is based on the Corps Planning Process, Outfitted to Incorporate Risk Analysis and Decision Analysis

The Risk-Informed Decision Framework (RIDF) is rooted in the Corps' standard approach to planning, but augments that approach with insights and techniques drawn from the fields of decision and risk analysis. RIDF provides procedures to help decision makers identify planning objectives, performance metrics, and stakeholder priorities.

RIDF draws on multi-criteria decision analysis (MCDA) techniques (specifically, multi-attribute utility theory (MAUT), because plan selection involves multiple, competing objectives denominated in in-commensurate terms. For example, this is the case when some attributes of an objective such as life-cycle infrastructure costs can be expressed in monetary terms and others, such as environmental quality, cannot.

RIDF draws on risk analysis (RA) techniques to characterize and assess the uncertainties that complicate the MsCIP decision. These include uncertainties in the economic and environmental conditions that will influence the outcome of a decision (such as the rate of sea-level rise) as well as the stochastic nature of storm surge events. The objective is to help planners characterize the critical uncertainties most important to the choice among plans and to identify robust risk reduction strategies, which are decision alternatives that perform relatively well across a wide range of future conditions.

1.2.2 Why is RIDF "Risk-Informed?"

RIDF is risk-informed because it:

- accounts for the consequences of low-probability storms including expected property damages, population at risk, and regional economic impacts.

1.2.3 What are the Advantages of RIDF?

The RIDF has several advantages.

- The framework engages stakeholders and decision makers in a process of issue identification and priority setting to formally establish project goals. The process helps decision makers to:
    - Identify and reveal hidden agendas
    - Identify, acknowledge and, when possible, fill data gaps that, if filled, could influence decisions;
- Objectives are expressed in the form of a multi-attribute utility function that:
    - gives objectives that are difficult to monetize the same consideration as monetary objectives, enabling environmental and social decision objectives to receive equal consideration with economic objectives.
    - allows decision makers to make explicit tradeoffs between objectives because progress on one objective can be used to compensate for lack of progress on another objective.

1.3 Scope of Risk Informed Decision Framework

Part 2 of the Risk Appendix provides an overview of the six planning steps in terms of the MsCIP risk-informed decision framework including:

- Introduction, background and scope
- Methods used to implement MCDA and the RIDF
- Detailed descriptions of metrics and scenarios
- Results of rankings and uncertainty
- Discussion
- Tables and figures showing outputs

2. BACKGROUND

2.1 Planning in the USACE – The Six-Step Planning Process

The *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (also known as Principles and Guidelines or P&G) and Engineering Regulation (ER) 1105-2-100, *Guidance for Conducting Civil Works Planning Studies* sets out a six-step planning process:

1. Specify problems and opportunities;
2. Inventory, forecast and analyze conditions relevant to the identified problems and opportunities;
3. Formulate alternative plans;
4. Evaluate the effects of the alternative plans;
5. Compare alternative plans;
6. Recommend a plan from the compared alternatives.

Since publication of the P&G in 1983, U.S. Army Corps of Engineers (USACE) planning and decision-making have been based, primarily, on a comparison of alternatives using economic factors (USACE 2003a). Planners have also been confronted with the challenge to provide for integrated systems that serve multiple objectives (e.g., a coastal system that provides for flood and storm damage reduction, navigation, and ecosystem restoration).

2.2 Changes to the Planning Landscape

In response to a USACE request for a review of P&G planning procedures, the National Research Council (1999) provided recommendations for streamlining planning processes, revising P&G guidelines, analyzing cost-sharing requirements and estimating the effects of risk and uncertainty integration in the planning process. Implementation guidance of the Environmental Operating Principles (EOP) (http://www.hq.usace.army.mil/cepa/envprinciples.htm) within USACE civil works planning directs that projects adhere to a concept of environmental sustainability that is defined as "a synergistic process whereby environmental and economic considerations are effectively balanced through the life of project planning, design, construction, operation and maintenance to improve the quality of life for present and future generations" (USACE 2003a). While adhering to the overall P&G methodology, USACE (2003b) advises project delivery teams to formulate acceptable, combined economic development/ecosystem restoration alternatives through use of multi-criteria/trade-off methods.

2.3 Corps Efforts to Address Planning Needs

Over the last several years, the Corps has been developing approaches and guidance for implementing multi-criteria decision analysis (MCDA) approaches for planning (Yoe, 2002; Linkov et al. 2004; Kiker et. al. 2005). This approach utilizes a comprehensive decision analytic framework that considers a broad array of objectives and criteria/metrics, including those associated with ecosystem restoration (Males, 2002). Guidance contained in *Trade-Off Analysis Planning and Procedures Guidebook (2002)* lays out a multi-criterion decision analytic approach for comparing and deciding between alternative plans and relates the P&G six-step planning process described above to outputs of the RIDF, as depicted in Figure 2-1.

Over the last several years, the Corps has been developing approaches and guidance for implementing multi-criteria decision analysis (MCDA) approaches for planning (Yoe, 2002; Linkov et al. 2004; Kiker et. al. 2005). The challenge has been to select and implement an analytical approach that best serves the Corps' needs and provides outputs that can be incorporated into existing decision-making processes, which are laid out in the Corp's *Trade-Off Analysis Planning and Procedures Guidebook (2002)*. In addition to serving the needs of Corps planning, the decision framework should provide structure and tools for interacting and communicating with partners, stakeholders, and the public about planning and risk. The approach utilizes a comprehensive decision analytic framework that considers a broad array of objectives and criteria/metrics, including those associated with ecosystem restoration (Males, 2002).

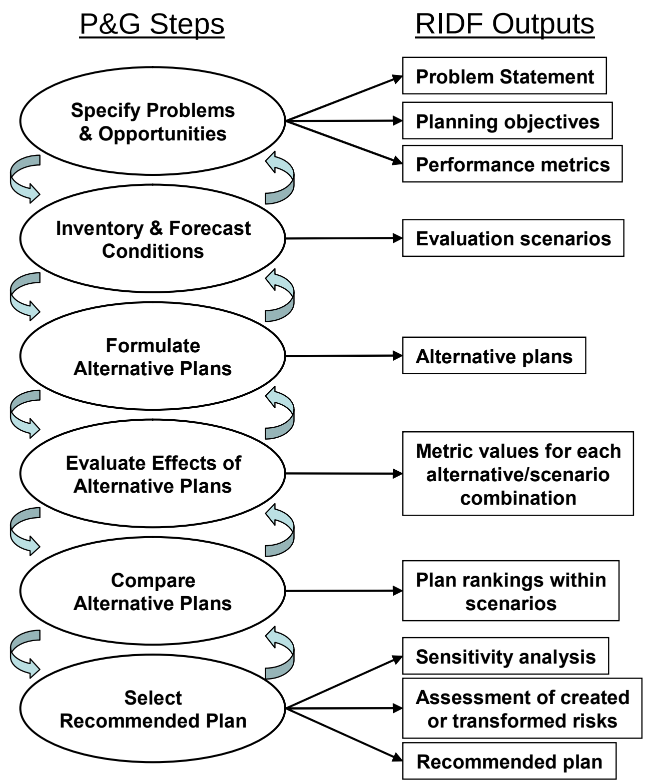


Figure 2-1: The 6 steps of the P&G and resultants outputs of the risk-informed decision framework.

2.4 How is RIDF an Incremental Improvement in Addressing Planning Needs?

Making effective and credible flood and storm damage reduction planning decisions requires an explicit structure for jointly considering the positive/negative impacts and risks, along with associated uncertainties, relevant to the selection of alternative plans. The complexity of flood and storm damage reduction and coastal landscape stabilization in south Mississippi requires integration of multiple models and tools as well as expert judgment. Integrating this heterogeneous and uncertain information demands a systematic and understandable framework to organize complex and often limited technical information and expert judgment.

Having the right combination of ***people*** is the first essential element in the decision process. The activity and involvement levels of three basic groups of people (decision makers, scientists and engineers [e.g., the MsCIP technical team], and stakeholders) are symbolized in Figure 2 by dark lines for direct involvement and dotted lines for less direct involvement. While the actual membership and function of these three groups may overlap or vary, the roles of each are essential in maximizing the utility of human input into the decision process. Each group has its own way of viewing the world, its own method of envisioning solutions, and its own societal responsibility. Policy- and decision-makers spend most of their effort defining the restoration planning context and the overall constraints on the decision. In addition, they may have responsibility for final plan selection and implementation. Scientists and engineers, including the MsCIP technical team, have the most focused role in that they provide the measurements for metrics that quantify the degree to which the various alternatives satisfy the objectives of the project; while they may take a secondary role as stakeholders or decision-makers, their primary role is to provide the technical input necessary to inform the decision process. Stakeholders contribute the most input in helping formulate performance metrics and making value judgments for weighting the various metrics. Depending on the problem and restoration context, stakeholders may have some responsibility in ranking and selecting the final option.

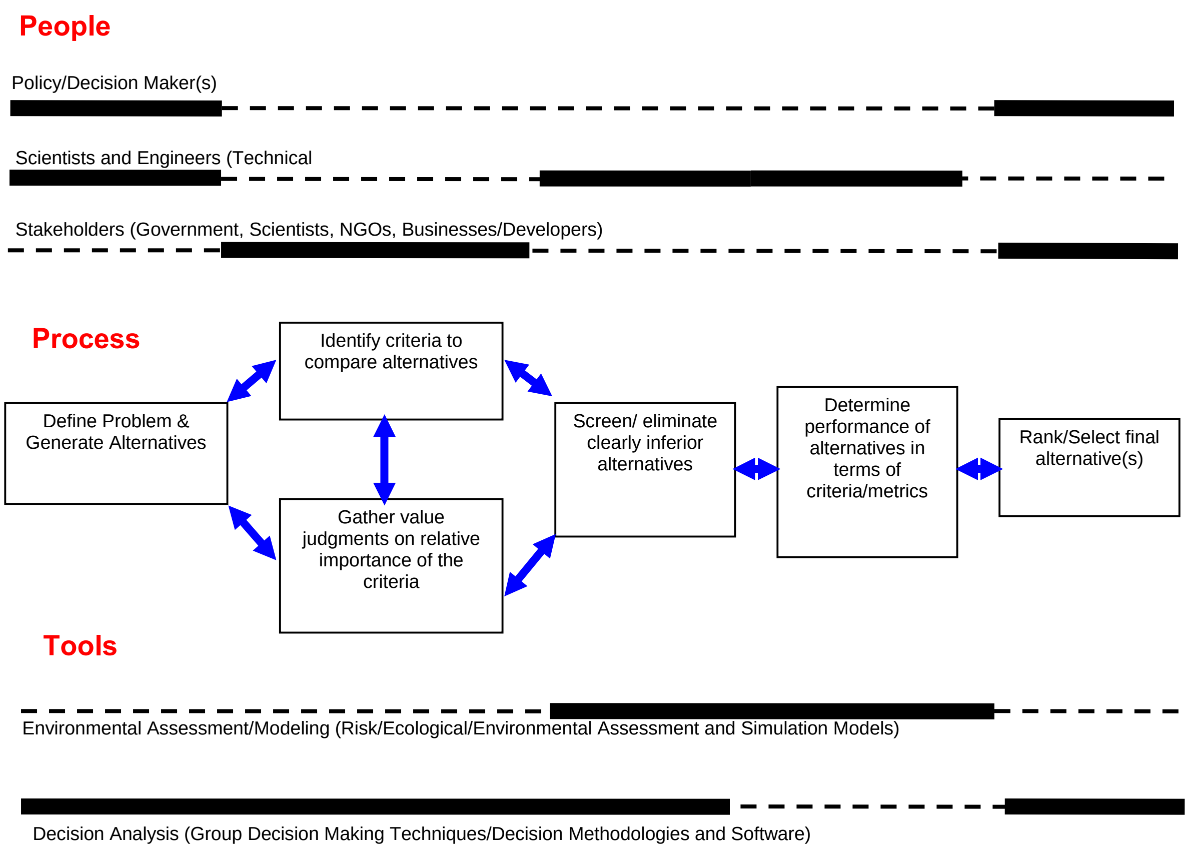


Figure 2-2: Proposed decision process (adapted from Linkov et al. 2004 and Kiker et al. 2005). Dark lines indicate direct involvement / applicability and dotted lines indicate less direct involvement / applicability.

The ***process*** depicted in Figure 2-2 is composed of two major elements: (i) generating alternative restoration scenarios, performance metrics, and value judgments and (ii) ranking the alternatives by applying value weights. The process generates and defines choices, performance levels, and preferences. The process also methodically screens non-feasible alternatives by first applying screening mechanisms (*e.g.*, excessive cost, performance below minimal levels or unacceptable social consequences) and then evaluating, in detail, the remaining alternative restoration plans through the use of decision criteria/metrics that are parameterized with data from engineering models, experimental data, or expert judgment and then ranking those plans through use of MCDA techniques. MCDA separates out judgments about scaling the relative performance of alternatives using a metric from judgments about weighting those metrics (Clemen, 1995). We discuss scaling and weighting in subsection 3.5.1. While it is reasonable to expect that the process may vary in specific details for different planning projects (i.e., based on project needs), the planning accomplished through use of this framework operates within an overall adaptive management structure whereby learning, accomplished through additional study and monitoring, is being used to ensure that the process is responsive to changes in decision priorities or new knowledge that can affect alternative selection or implementation strategies.

The ***tools*** used within group decision making and scientific research are essential elements of the overall decision process. The applicability of the tools is symbolized in Figure 2-2 by solid lines (direct involvement) and dotted lines (indirect involvement). Decision analysis tools help to generate and map technical data as well as individual judgments into organized structures that can be linked with other technical tools from risk analysis, modeling, monitoring, and cost estimations. Decision analysis tools can also provide useful graphical techniques and visualization methods to express the gathered information in understandable formats. When changes occur in the requirements or the decision process, decision analysis tools can respond efficiently to the new inputs. Flood and storm damage reduction planning requires the use of multiple mechanistic, empirical, and stochastic models, and combinations thereof, for examining flood and storm inundation stage-frequencies to assess the performance of alternatives under several uncertain future conditions. Output from these models has been combined to calculate specific risk factors affecting coastal Mississippi. Finally, decision models incorporated individual risk model predictions and reconciled conflicting priorities expressed by different stakeholder groups through transparent and reproducible valuation protocols. The decision analysis tools were used to compare the alternative plans and conduct sensitivity analysis to assess the robustness in relative performance across future scenarios of the resulting rankings.

The entire process results in a comprehensive, structured process for selecting the optimal alternative in any given situation, drawing from stakeholder preferences and value judgments as well as scientific modeling and risk analysis.

2.5 Adaptive Management

The consequences of Hurricane Katrina have motivated the Corps to examine both its processes and institutional culture. The Corps' must be responsive and reliable, and change will be required to ensure that Corps remains so. Actions for Change were identified that will serve as catalysts for that change (see http://www.hq.usace.army.mil/cepa/releases/News_Release_-_USACE_12_Actions_for_Change.pdf). Key to the successful implementation of these actions is use of integrative and comprehensive systems-based approaches, adaptive planning, stakeholder involvement and risk communication.

3. IMPLEMENTATION OF THE RIDF

The Risk-Informed Decision Framework (RIDF) assists decision makers by condensing the decision process into a transparent and tractable format. RIDF can be described in terms that are closely aligned with the standard Corps approach to planning, but utilize techniques from the fields of risk and decision analysis to accommodate multiple objectives, conflicting stakeholder values, both qualitative and quantitative assessments of performance, and uncertainty in the natural, social, and economic environment in which decisions will be played out.

As implemented for MsCIP, the RIDF procedure can be summarized as follows. Decision makers and stakeholders establish an objectives hierarchy to fully and uniquely characterize the important outcomes of each decision alternative. A set of outcome measures of performance is then chosen to represent the performance of each alternative in terms of achieving each of the decision objectives. The outcomes of the alternative plans is modeled and, to the extent there are uncertainties present that may significantly affect performance outcomes, this evaluation of plans would be replicated over a set of scenarios that represent a range of possible conditions during the performance phase. Once all of these evaluations are complete, a multi-attribute utility function is developed to assess the overall utility of each plan given its performance in terms of achieving the objectives.

The relationship between the six steps of the Corps planning process and RIDF is illustrated in Figure 2-1. In general, RIDF activities are closely related to the six step Corps planning process as follows:

1. Specify Problems & Opportunities: Frame the decision by developing a problem statement and identifying the spatial and temporal boundaries of analysis. Establish planning objectives and choose outcome measures of performance, or metrics, which reflect progress toward achieving the planning objectives.

2. Inventory and Forecast Conditions: Select models of physical and economic systems or other appropriate tools to simulate decision outcomes in terms of the selected performance metrics. Identify important sources of uncertainty in physical and economic models.

3. Formulate Alternative Plans: Formulate decision alternatives by identifying potential measures for flood risk reduction and environmental restoration, pre-screening infeasible measures, and formulating coast-wide plans from remaining measures.

4. Evaluate Effects of Alternative Plans: Model the outcome measures of performance for each alternative and each scenario.

5. Compare Alternative Plans: Obtain weights on objectives from the decision maker and/or stakeholder groups. Calculate multi-attribute utility and implement the decision analysis for each alternative, each scenario, and each stakeholder group. Screen out plans that are consistently dominated.

6. Select a Recommended Plan: Develop recommendations based on the analysis.

3.1 Step 1: Specify the problem and opportunities

Framing the problem to be solved is often one of the most difficult and critical tasks in the planning process because it forces planners to clarify their objectives. Framing also helps to identify what attributes should be considered in judging decision outcomes and what metrics should be used in assessing progress toward objectives. Framing helps to establish what spatial and temporal scales are needed for modeling decision outcomes. For example, the preferred alternative may change with the spatial resolution chosen for an analysis; therefore, factoring such spatial variation into how the framework is used along the coast should be considered. Similarly, the most preferred decision may vary as a function of the timeframe under consideration: a longer planning timeframe may lead to a preference for alternatives with higher fixed costs and lower operational/maintenance costs.

3.1.1 Problem Statement

Catastrophic impacts of the 2005 Atlantic Tropical Cyclone season in the Gulf of Mexico identified the need for investment in flood and storm damage risk reduction and coastal ecosystem restoration.

Traditional investigation methods were recognized as insufficient to identify plans for action in averting future disasters directly impacting major metropolitan centers, strategic regional national assets, and significant coastal resources located in south Mississippi. A new planning methodology based on risk and uncertainty would be required to augment traditional approaches, addressing direct adverse impacts as well as large indirect adverse effects of coastal disasters in Mississippi on the rest of the United States. A multi-objective, long range, comprehensive system-scale analysis is needed to identify a full range of measures for risk reduction and coastal landscape stabilization in the event of moderate/frequent and severe/rare storms.

The following problem statement was drafted with the above issues in mind: The people, economy, environment, and culture of coastal Mississippi, as well as the Nation, are at risk from severe and catastrophic hurricane storm events as manifested by:

1. Storm impacts to residential, public, and commercial infrastructure.
2. Storm impacts to people’s quality of life.
3. Habitats damaged by saltwater intrusion.
4. Storm-caused erosion of coastal shoreline.
5. Degradation of fish and wildlife habitats that support an array of commercial and recreational activities coast wide.

The risks associated with the problem can rarely be eliminated or entirely prevented. Thus, residual risk remains and must be considered. The nature of the risks to the planning area is identified in the problem statement.

3.1.2 Planning Objectives

The purpose of this section is to delineate the objectives appropriate to a sound solution to the MsCIP decision problem that can be readily articulated to an array of audiences.

As a group, a good set of planning objectives must be collectively exhaustive. That is, nothing that really matters can be left out. However, and again with an eye to simplification, the list must be limited to only the ones that really do matter. A hierarchical arrangement of objectives (e.g., a principal objective branching to a tier or two of sub objectives) is often useful for structuring a complex decision. Each objective should be specific and succinct (Keeney and Raffia 1976). An objective must be unambiguous yet still succinctly stated, as brevity helps communication and clarifies thinking. Each objective must be amenable to measurement using one or a few metrics so that predictions can be quantified and performance ultimately can be assessed. Simultaneously, objectives must be realistically achievable and relevant. Finally, there must be concordance with practical time frames (Hobbs and Meier 2000). In other words, predictions must be possible within the planning time frame or monitoring of performance must be possible within a useful time frame.

The planning objectives for MsCIP are:

- Reduce risk to public health and safety from catastrophic storm inundation;
- Reduce storm damages to infrastructure from catastrophic storm inundation;
- Restore and protect upland and tidal wetland habitats, and;
- Reduce residual risk from catastrophic storm damage.

The objectives identified in the preceding paragraph were organized within the RIDF framework using the USACE P&G System of Accounts (Yoe and Orth 1996), which guides an evaluation of the effects of a project with respect to National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE). Establishing the system of accounts 1) shows all effects important to decision-making, 2) explicitly shows the NED effects as the basis for establishing the economic feasibility of the plan, 3) offers a rational, organized framework for presenting the results of the MsCIP analysis, and 4) provides a means for comparing plan effects. The plans' effects presented in the system of accounts relate to the plans' contributions toward planning objectives. The effects of the plans are arranged such that the differences among the plans are easily discerned.

In recent history, USACE planners have been guided to select the NED plan (the one maximizing national economic development benefits) as the preferred alternative, while still meeting National Environmental Policy Act requirements. The Mobile District has received slightly different and more flexible guidance for the critical MsCIP project. Namely, choice is not constrained to an NED plan but rather more broadly to a cost-effective plan that best meets objectives across the NED, RED, EQ, and OSE accounts. Metrics proposed in the subsequent section for evaluating project effects in MsCIP are categorized according to these four accounts.

3.1.3 Outcome Metrics of Performance

Metrics to be used to guide the MsCIP evaluation are presented in Table 1A-1E. These metrics were used to score and then rank flood and storm damage reduction and environmental restoration measures and plans. In selecting this set of metrics, we strove to represent the best available information for evaluating alternatives in the MsCIP, keeping in mind the characteristics of effective metrics (see Roy, 1985; Seager et al. 2007, Graedel and Allenby 2002, Seager and Theis 2004; Yoe 2002). Effective metrics are:

- **Comprehensive and complete:** The metric set should capture the entire range of the decision maker's priorities. No relevant priorities should be unaccounted-for.
- **Preferentially independent:** Changes in one attribute or metric should not affect the decision maker's preferences for another attribute or metric.
- **Verifiable:** Two independent assessments yield similar results.
- **Cost-effective**: Evaluation of the metrics should not require an intensive deployment of resources or unavailable technology.
- **Easy to communicate to a wide audience**: The public understands the scale and context of the metric and can interpret the metric with little additional explanation.
- **Changeable by human intervention**. The metric has a causal relationship between the state of the system and the variables that are under the decision-maker's control. Metrics that are independent of human action do not inform a management, policy-making, or design process.
- **Credible**: Stakeholders perceive that the metric accurately measures that which it is intended to measure.
- **Appropriate scale:** The metric is applicable at the spatial and temporal scales chosen for analysis.
- **Directed**: Metric scales whether they are qualitative or quantitative, are bi-directional polar scales,
- **Relevant**: The metric reflects stakeholder priorities and enhances the ability of managers and regulators to faithfully execute their stewardship responsibilities. There is no point assembling a metric no one cares about.
- **Sensitive:** enough to capture the minimum meaningful level of change or make the smallest distinctions that are still significant, and it would have uncertainty bounds that are easy to communicate.
- **Minimally redundant:** A smaller metric set is preferred to a larger metric set to avoid interactions or correlations with other metrics.
- **Transparent:** The metric should not be designed to serve a "hidden agenda."

It is important to acknowledge here that there will be "conflicts" among metrics, resulting in the need to make tradeoffs. For example, a tradeoff exists between achieving any significant benefit from a project and minimizing cost. The tradeoff concept is discussed in Step 5. As a consequence of such "conflicts", a given measure or alternative may not take clear precedence over other measures or alternatives in respect to every metric for evaluating performance. This may present a dilemma to decision-makers, who are trying to choose a single measure. It is important to place development of metrics prior to the development of measures because the "hard thinking" that goes into developing the metrics can create an improved set of measures; this in turn permits stakeholders to focus on thinking about the objectives rather than anchoring themselves to favored measures (Keeney and Raiffa 1976).

In the following sections and in Tables 3-1A thru 3-1E the metrics for the MsCIP are listed and described.

3.1.3.1 Environmental Quality (EQ) Metrics

Table 3-1A.
MsCIP Objectives and Metrics for Environmental Quality

					Data Source
Environmental Quality	Restore and protect tidal and non-tidal habitats.	Tidal Habitat Restored	Functional units	This metric measures positive changes to the tidally-influenced wetlands that result from the implementation of a measure or plan.	Models
		Tidal Habitat Lost	Functional units	This metric measures adverse impacts to the tidally-influenced wetlands that result from the implementation of a measure or plan.	Models
		Non-tidal Habitat Restored	Functional units	This metric measures positive changes to the non-tidal ecosystem that result from the implementation of a measure or plan.	Models
		Non-tidal Habitat Lost	Functional units	This metric measures adverse impacts to the non-tidal ecosystem that result from the implementation of a measure or plan.	Models

1. Tidal Habitat Restored - This metric measures positive changes to the tidally-influenced wetlands that result from the implementation of a measure or plan. These are positive benefits from implementing a restoration plan or a combination of plans. Ecosystem components included in this metric are tidal wetlands (i.e., tidal fringes), associated threatened and endangered and other species associated with essential fish and other tidal habitats, and related losses that require mitigation due from implementation of structural plans. Units are in acres.

2. Tidal Habitat Lost - This metric measures adverse impacts to the tidally-influenced wetlands that result from the implementation of a measure or plan. Ecosystem components included in this metric are tidal wetlands (i.e., tidal fringes), associated threatened and endangered and other species associated with essential fish and other tidal habitats, and related losses that require mitigation from the implementation of structural plans. Units are in acres.

3. Non-tidal Habitat Restored - This metric measures positive changes to the non-tidal ecosystem that result from the implementation of a measure or plan. These are positive benefits from implementing a restoration plan or a combination of plans. Ecosystem components included in this metric are maritime forests, wetland pine savannah, beach and dune habitats, and associated threatened, endangered and other species in non-tidal habitats. Units for this metric are the percentage increase of quality fish and wildlife habitat in acres.

4. Non-tidal Habitat Lost- This metric measures adverse impacts to the non-tidal ecosystem that results from the implementation of a measure or plan. This has a negative impact of implementation of an array of alternatives as part of the comprehensive plan. Ecosystem components included in this metric are maritime forests, wetland pine savannah, beach and dunes, threatened, endangered and other species and their non-tidal habitats, and related losses that require mitigation due to implementation of structural plans. Units for this metric are the percentage decrease of quality fish and wildlife habitat in acres.

3.1.3.2 National Economic Development (NED) Metrics

Table 3-1B.
MsCIP Objectives and Metrics for National Economic Development

					Data Source
National Economic Development	Reduce damages from catastrophic storm inundation.	Expected Annual Damages Avoided	$	The amount of storm damages reduced/avoided by a plan expressed as annualized dollars. Annualized dollars are calculated by comparing a future without a project in place versus a future with a project in place.	HEC-FDA Model
		Residual Damage	$	This metric describes what a plan does not account for (or what happens if a plan is exceeded). Residual damage is defined as the storm damage that is not prevented with the implemented plan in place (expressed as annualized dollars).	Model
		Cost of Implementation	$	The amount of money in dollars needed to implement the plan. This metric measures the cost in today's dollars to local and Federal governments to implement the recommended plan.	Empirical Data

1. Expected Annual Damages Avoided - The amount of storm damages reduced/avoided by a plan expressed as annualized dollars. Annualized dollars are calculated by comparing a future without a project in place versus a future with a project in place.

2. Residual Damage – This metric describes what a plan does not account for (or what happens if a plan is exceeded). Residual damage is defined as the storm damage that is not prevented with the implemented plan in place (expressed as annualized dollars).

3. Cost to Implement Plan – The amount of money in dollars needed to implement the plan. This metric measures the cost in today's dollars to local and Federal governments to implement the recommended plan.

3.1.3.3 Other Social Effects (OSE) Metrics

These OSE metrics focus on the preservation of people's quality of life. OSE metrics were developed addressing impacts to cultural heritage and preservation of historical structures, disruptions to public service and infrastructure and impacts to personal effects.

Table 3-1C.
MsCIP Objectives and Metrics for Other Social Effects

					Data Source
Other Social Effects	Protect public health and safety from catastrophic storm inundation.	Cultural and Historical Heritage Impacts	Unitless	This metric addresses impacts to social groups, church congregations and groups with common heritages. This metric also includes impacts to aesthetics and the destruction of the human-created landscape such as historical structures.	Expert Judgment
		Public Service and Infrastructure Disruptions	Unitless	This metric includes post-flood event disruptions to schools, fire and police service, access to hospitals, libraries and community centers, and use of roads, bridges, and utilities.	Expert Judgment
		Personal Impacts	Unitless	This metric includes loss of family possessions, photographs, and impacts to people's emotional and mental health.	Expert Judgment

1. Cultural and historical heritage impacts – This metric addresses impacts to social groups, church congregations and groups with common heritages. This metric also includes impacts to aesthetics and the destruction of the human-created landscape such as historical structures. Units are presented as a quantitative scale where a score of 10 is best, 1 is worst. (i.e., 10 is least impacts to structures, 1 is most impacts).

2. Public service and infrastructure disruptions – This metric includes post-flood event disruptions to schools, fire and police service, access to hospitals, libraries and community centers, and use of roads, bridges, and utilities. Units are presented as a quantitative scale where a score of 10 is best, 1 is worst (i.e., 10 is least disruption, 1 is most disruption).

3. Personal impacts – This metric includes loss of family possessions, photographs, and impacts to people's emotional and mental health. Units are presented as a quantitative scale where a score of 10 is best, 1 is worst. (i.e., 10 is least impacts to people, 1 is most impacts).

3.1.3.4 Regional Economic Development (RED) Metrics

The RED metrics measure both positive and negative impacts to the regional economy. Positive impacts are captured by impacts to sales volume, personal income and employment and negative impacts by local cost burdens. Sales volume, income and employment will be sub-metrics under RED, and will be equally weighted. This metric is termed Positive regional economic benefits and will combine these 3 sub-metrics. The local cost burdens metric is also a sub-metric under RED and will receive a weight equal to combined weighting of the positive metrics under regional economic benefits.

Table 3-1D.
MsCIP Objectives and Metrics Regional Economic Development

					Data Source
Regional Economic Development	Reduce damages from catastrophic storm inundation.	Local Cost Burden	Unitless	This metric assesses the costs that will be born locally. This includes the local cost-share with the Federal government to implement the alternative and local costs for ongoing operations and maintenance (O&M) related to the alternative. It also accounts economic impacts on the gross sales volume, personal income, and number of individuals employed in the workforce. These measures are incorporated into unitless scale.	Model/Expert Judgment
		Positive Regional Economic Benefits	Unitless	Economic benefits to the region with regards to sales volume, income and employment. This metric assesses the potential impacts of sales volume change and personal income in dollars and regional employment change in number of jobs to the local economy.	Expert Judgment

1. Local Cost Burdens – This metric represents costs born locally. This includes cost-sharing with the Federal government to implement the recommended plan and local costs for ongoing operations and maintenance (O&M) related to the implemented plan. The local cost burdens may include costs associated with maintenance workers needed to maintain infrastructure of the recommended plan. Units are a unitless quantitative scale where a score of 10 is best, 1 is worst.

2. Positive regional economic benefits – Economic benefits to the region with regards to sales volume, income and employment. This metric assesses the potential impacts of sales volume change and personal income in dollars and regional employment change in number of jobs to the local economy. Units are a unitless quantitative scale where a score of 10 is best, 1 is worst.

3.1.3.5 Comprehensive Risk Metrics

The following risk metrics serve as additional information to decision makers. They are a way to address extreme cases of uncertainty.

Table 3-1E.
MsCIP Objectives and Metrics for Comprehensive Risk

					Data Source
Comprehensive Risk	Reduce plan risk.	Long-term Sustainability of Plan	Unitless	The risk that features associated with the recommended plan will not perform as intended (over time) due to factors such as cost, human behavior, technical level of maintenance required, political concerns, resource availability, local funding per year, and operational reliability.	Expert Judgment
		Residual Risk	Unitless	This metric describes what a plan does not account for (or what happens if a plan is exceeded). Residual risk is defined as the storm damage risk that remains with the implemented plan in place (expressed as annualized dollars).	Empirical Data/Expert Judgment
		Consequences of Plan Failing	Unitless	This metric describes what happens if a plan does not work as intended. It describes consequences to humans and the environment due to a catastrophic failure of an implemented plan under design conditions or other sets of circumstances from a storm event.	Expert Judgment

1. <u>Long-term Sustainability of Plan</u> – The risk that features associated with the recommended plan will not perform as intended (over time) due to factors such as cost, human behavior, technical level of maintenance required, political concerns, resource availability, local funding per year, and operational reliability. Units are a unitless quantitative scale where a score of 10 is best, 1 is worst (i.e., 10 is least risk, 1 is most risk).

2. <u>Residual Risk</u> – This metric describes what a plan does not account for (or what happens if a plan is exceeded). Residual risk is defined as the storm damage risk that remains with the implemented plan in place (expressed as annualized dollars). It accounts for the following factors: erosion, wildlife species, wildlife habitat, salt water intrusion, surge damages, drainage, wind, maximum probable intensity (MPI) plan (accounts for more intense storm), cultural heritage, and infrastructure. Units are a unitless quantitative scale where a score of 10 is best, 1 is worst.

3. Consequences of Plan Failing – This metric describes what happens if a plan does not work as intended. In other words, it describes consequences to humans and the environment due to a catastrophic failure of an implemented plan under design conditions or other sets of circumstances from a storm event. The greatest risk is risk of failure to structural measures, such as levees, flood gates, etc. Consequences and likelihood of failure vary depending on the line of defense. For example, risk of Line 2 failure is more likely, but consequences are relatively low; risk of Line 4 failure is highly unlikely, but consequences are very high. It includes the following factors: injuries to population, loss of infrastructure, loss of habitat, and loss of wildlife species. Units are a unitless quantitative scale where a score of 10 is best, 1 is worst.

3.2. Step 2: Inventory and Forecast to Establish Baseline Conditions

In this step of the planning process, models and tools are selected to simulate decision outcomes in terms of the selected performance metrics. There is often uncertainty in projecting decision outcomes and, when planning horizons are long, a considerable amount of uncertainty may be unavoidable. Nominal forecasts of decision outcomes, those forecasts made assuming baseline conditions or "business as usual" conditions, should therefore be qualified by considering what implications uncertainty in these assumptions may have for the decision recommendations. Uncertainty is a lack of knowledge that originates from an incomplete understanding of the structure and function of natural or manmade systems (*e.g*., coastal hydraulics at the mouth of the Mississippi).[1] Uncertainty is often classified as either model uncertainty or parameter uncertainty. Model uncertainty is a lack of knowledge about the proper structure of a model (*e.g.*, choice of a two vs. a three dimensional model to simulate hydrodynamics). Parameter uncertainty is the lack of knowledge about the best value to use as an input parameter value for the chosen model.

One of the advantages of decision analysis is its ability to assist decision makers to make rational decisions in the face of uncertainty. A full uncertainty analysis of the decision would culminate in a probability distribution over the utility of decision outcomes. However, considerable effort may be needed to reach such a conclusion. Often, a sensitivity analysis that considers how the decision recommendations might change under different assumptions may be adequate. Neither sensitivity nor uncertainty analysis of this decision were undertaken for MsCIP at this point.

1 Although he mathematics used to describe variability and uncertainty is essentially similar, uncertainty is widely recognized as being distinct from natural variability. Variability describes the heterogeneity in an inherently random value. For example, the heterogeneity of some size attribute within a population. This variability is, in principle, not reducible (Morgan and Henrion 1990). In contrast, uncertainty can be thought of as a lack of knowledge about what parameter value to use in a model or how to represent a process in a mechanistic model. This lack of knowledge might in principle be reduced, although reducing some uncertainties can often be difficult in practice.

3.3 Step 3: Formulate alternative plans

3.3.1 Plan Formulation

Plan formulation is the process of building plans that meet planning objectives and avoid planning constraints. It requires the knowledge, experience, and judgments from many professional disciplines, as well as the views of stakeholders, other agencies and non-governmental organizations (NGOs), and the public. Plan formulation capitalizes on imagination and creativity wherever it is found, across technical backgrounds and group affiliations. Formulating plans includes developing management measures (e.g., structural and non-structural), identifying planning units, conducting screening of measures, and combining measures into alternative plans. Plans include abilities to be modified into the future within the adaptive management framework. For more details on the formulation of plans and planning units for MsCIP, refer to the Main Report.

3.4 Step 4: Evaluate effects of alternative plans

Once the plans have been formulated, the performance of each plan with respect to each metric is estimated for each decision alternative and scenario. The SAM Technical Team accomplished this step using mechanistic or empirical models of physical, economic, and social systems where available and expert judgment where such models were not available. Sources of metric data are presented in Tables 3-1A thru 3-1E.

3.5 Step 5: Compare alternative plans

In this step, the objective is to rank the decision alternatives (plans) using an abstract utility measure that integrates information about anticipated performance outcomes and stakeholder interests. The MCDA approach used for MsCIP is multi-attribute utility theory (MAUT) (Keeney and Raiffa 1976). With respect to its applications in MCDA, the advantage of MAUT is that it converts a multi-objective decision with competing objectives to a single objective problem for which the objective is to maximize utility given information about the decision maker’s preferences. The purpose of this section is to provide an overview of the approach. Sub-section 3.5.1 describes how information on stakeholder preferences is brought into the decision making process. Sub-section 3.5.2 describes the calculation of a multi-attribute utility score, the ranking of decision alternatives, and decision analysis. Sub-section 3.5.3 describes how sensitivity and uncertainty analysis can be used in conjunction with MCDA specifically to support risk-informed decision making. Specific details about this application of RIDF are provided in Section 4.0.

3.5.1 Stakeholder Preferences

The first step toward developing a multi-attribute utility function is to collect information on stakeholder preferences by finding out how much importance stakeholders place on the various decision objectives. Information about stakeholder preferences is obtained through workshops during which stakeholders participate in a series of assessments designed to obtain information on their preferences. These preferences are expressed as relative weights on decision objectives. These weights are subsequently incorporated into a multi-attribute utility function that is then used to calculate the utility score by which decision alternatives are ranked. This process gives stakeholders an active role in the decision making process because, if stakeholder weights are used in the utility function, the ranking of plans is then tied directly to their preferences.

Since stakeholders can exhibit a diverse set of preference patterns, it is important to consider how this diversity of preference will be treated in the decision analysis. If there are many stakeholders, their sheer number may make it very difficult to consider each ones preferences individually. In addition, there would be much redundancy in such an approach because most stakeholders appear to have some recognizable preference patterns. On the other hand, aggregating stakeholders into a single group and averaging their weights to represent an amalgamated public interest is also not a good strategy, particularly if diverse values have been expressed in the stakeholder population. An averaged set of weights would tend to converge on an equal distribution of weights across the decision objectives and/or a set of weights that is not likely to represent anybody's interests in particular.

The approach used in this analysis is to analyze the sets of weights obtained from individual stakeholders and then classify them based on their expressions of common preference patterns. For classification purposes, we rely on a set of multivariate statistical techniques known as cluster analysis to identify distinct preference patterns that exist within the stakeholder population. Once stakeholders have been segregated based on their preferences, the patterns of preference that are characteristic of each group can be represented by averaging their weights on decision objectives. At this time, no particular consideration is given to the prevalence of each preference pattern in the MsCIP project area. The primary concern is to understand what patterns of preference exist in the project area and what affect these different patterns of preference might have on the choice of a risk-reduction plan.

3.5.2 Multi-attribute Utility and MCDA

The multi-attribute utility function transforms the metrics for the several objectives to a single, aggregate measure of utility. The utility function is compensatory in the sense that it allows progress on one objective to substitute for lack of progress on another objective. The rate of compensation depends upon the relative weight on each objective, which depends upon the preferences of the decision maker. Multi-attribute utility (*U*) is the weighted sum of *L* outcome measures of performance,

$$V(m_{jkl}) : U_{jk} = \sum_{l} w_l V(m_{jkl}) .$$

Outcome measures of performance are evaluated through modeling studies for

$$j = \{1,2,3,..., J\}$$

decision alternatives and

$$k = \{1,2,3,..., K\}$$

planning scenarios. Planning scenarios represent the range of possible futures under which plan performance may be realized. A set of weights (*w*) that reflects the relative importance of each decision objective is elicited from the decision maker and/or stakeholders using a direct weighting procedure (see Section 3.5.1). Weights may take any value between zero and one, but must sum exactly to one. Value scores are then calculated from a linear utility function for each metric,

$$V(m_{jkl}),$$

that is either increasing or decreasing with that metric, m_{jkl}. For an economic "good" (*i.e.*, more is better):

$$V(m_{jkl}) = \frac{m_{jkl} - \underset{jk}{MIN}(m_{jkl})}{\underset{jk}{MAX}(m_{jkl}) - \underset{jk}{MIN}(m_{jkl})}$$

and for an economic "bad":

$$V(m_{jkl}) = 1 - \frac{m_{jkl} - \underset{jk}{MIN}(m_{jkl})}{\underset{jk}{MAX}(m_{jkl}) - \underset{jk}{MIN}(m_{jkl})},$$

where the *MIN* and *MAX* functions are over all decision alternatives and scenarios. Each scenario is represented by a set of possible values for uncertain variables in hydrologic and economic models used to simulate outcome measures of performance. Value and utility scores, which are bounded by 0 and 1 so that scores closer to 0 indicate less desirable outcomes, are calculated for the outcome of each alternative and scenario, including a "No Action" alternative.

In MCDA without uncertainty, the objective is to maximize the multi-attribute utility function for a set of stakeholder preferences by choosing the "best" decision alternative. Results of the analysis can also be presented more comprehensively by ranking the alternatives by their utility score. This is useful because much can be learned about the alternatives themselves by observing how the utility score varies from one alternative to another. For example, it is possible that some alternatives may yield as much utility as the preferred alternative, but do so because they accentuate performance on a different set of objectives. Just as results of a decision analysis are conditioned on the assumptions used to simulate performance outcomes, the results of the decision analysis and plan rankings also depend in part upon what set of stakeholder weights are used in the multi-attribute utility function. Thus, it is also useful to examine the sensitivity of plan rankings to the weights on decision objectives. If plan rankings are not sensitive to the weights, this may suggest that the alternative may have a broad base of support among stakeholders.

3.6 Step 6: Select recommended plan

Analysis of the project selection decision using the risk-informed decision process should provide a basis for recommending a risk-reduction plan for each planning unit. This recommendation will be based on all of the information assembled during the planning process including information on stakeholder preferences, performance outcomes, and both risk and uncertainty. An advantage of the RIDF is that the process of plan selection is a transparent and rational one. Decision makers should be able to rely on the results of RIDF analysis as long as all of the factors, issues, and concerns of relevance have been accounted for among the decision objectives. Care should be taken to minimize the number of factors germane to a decision that remain outside the formal scoring and ranking process. In other words, the decision model implemented using MAUT should include as many of the concerns, objectives, and factors that are relevant to decision-making as possible. Given the large number of parties relevant to the decisions under consideration (The Corps, other Federal agencies, Congress, state, counties, cities, stakeholders, the public), great care must be taken to ensure that the planning process is comprehensive in its approach to the interests and values of these parties.

4. APPLICATION OF RIDF TO MSCIP PROJECT SELECTION

4.1 Stakeholder Workshops Activities Summary

The purpose of the weight elicitation workshop held on 10-11 September 2007 was to develop a transparent process to provide decision makers with key stakeholder group perspectives (traditional process used mainly NED and RED criteria to select a plan). We wanted to capture stakeholder value information that guides the ranking of plans and recommendations. We also wanted to document differences among stakeholders so that we can identify consensus areas and potential compromises. This makes it easier to find common ground in selecting a plan. We documented these differences by comparing the performance of different plans by looking at different metrics for each plan. A common set of metrics was used to facilitate negotiation. Stakeholders were actively engaged in weighting the metrics during the workshop.

The workshop involved using questionnaires (survey instruments) to elicit weights of individuals from key stakeholder groups. The objective of the workshop was to conduct sessions with key stakeholders where their weights were elicited and their weight judgments summarized. Both the direct score and swing weight methods were used to elicit these weights. The workshop was held in Biloxi, MS at the Mississippi Department of Marine Resources building, Room 205.

Stakeholder groups were selected for participation in this effort based on their participation in previous MsCIP stakeholder meetings. These groups and individuals were selected by the MsCIP team in advance to ensure diversity of opinions. Key stakeholder groups included individuals from government (Federal, state, and local), non-governmental organizations (NGOs), and individuals representing various environmental, business, development, and academic institutions. The Corps (MsCIP technical team and the ERDC) also submitted weights.

To kick off the stakeholder session, the MsCIP technical team and ERDC described the background and purpose of the workshop and answered questions or concerns that arose. We discussed the metric set, its importance and clarified metric definitions as appropriate. We also described through specific hypothetical examples the swing weight process and how stakeholder weights will be generated using this method. Draft data for the set of 15 metrics were included in the matrix. Weights were obtained for the final set of 15 metrics (see Tables 4-1). We elicited and received input from each of the stakeholder groups on the metric set and its completeness.

A series of “polls” were conducted. In the first of these, participants were asked to provide an ordinal ranking of the 15 individual metrics from most to least important, where each participant was asked to "wear the hat" of their job within their organization. The results were shared and discussed briefly. Next, the stakeholders were asked to allocate points to each metric, thus providing finer distinction of the relative importance of metrics. Allocation was done with three rules. First, no individual metric could be given more than 70 points. Second, 100 points was available for the sum total of points given to all metrics. Third, all 100 points must be used. The same process was used of first ranking and then allocating points to the "categorical" metrics (NED, RED, OSE, and EQ). Thus, each of the stakeholder sessions progressed according to the following weight elicitation activities:

- Round 1: ranks were obtained for the list of 15 metrics.
- Round 2: rate (allocate) 15 metrics using 0-100 scale.
- Round 3: rank 15 metrics from 1-15.
- Round 4: rate (allocate) these metrics using 0-100 scale.

An intranet-based system was used to gather weight data from participants. Each participant accessed a dedicated PC to rank metrics. These results were compiled real-time and shared with the group so that weights could be discussed.

The RIDF and SAM Technical Team members attended to answer technical questions that arose and to document the process. Group Solutions, a Corps contractor, facilitated each session and electronically elicited the weights from each of the stakeholder groups. Group Solutions compiled the resultant weights and submitted all results electronically to ERDC for analysis and reporting.

Following the workshops, input values for metrics were combined with information about values and weighting functions for the various metrics to generate an overall score for each plan being considered. These scores will allow for direct comparisons to be made across all measures/plans and to rank plans in relation to each other in terms of the degree to which they satisfy the objectives the MsCIP metrics represent. Such scores can be used to evaluate measures or plans against the without project condition, as well as to compare the performance of individual measures or plans (see more detailed discussion below).

Session Participants and Organizations

Tables A1-1 to A1-6 in Annex 1 list in alphabetical order the people (and corresponding affiliation) who participated in the MsCIP stakeholder sessions. Some of those listed in the tables collaborated while others started but did not complete the weighting process.

4.2 Stakeholder Weightings

The MsCIP weight elicitation sessions yielded 45 complete sets of weights on fifteen metrics. We used a cluster analysis, an exploratory data reduction technique, to classify stakeholders with similar preference patterns expressed through their allocation of weights to metrics. These results enable us to identify and characterize patterns of preferences that exist in the project area.

Several different clustering techniques are available and applications of these methods would lead to alternative cluster solutions. The standard for evaluating solutions is whether or not the resulting solutions can be explained and are meaningful in the context of their purpose. In this case, the objective of the analysis is to identify and document the existence of distinct patterns of preferences within the subject population and characterize preference patterns. Characteristic preference patterns are then used to analyze the sensitivity of the decision to stakeholder preferences. This enables the sensitivity analysis to focus only on those preference patterns that have been observed, while excluding from the analysis those that have not been observed. The data reduction also eliminates the duplication of effort associated with carrying out sensitivity analysis for preference patterns that are essentially similar.

A number of clustering techniques were tested to evaluate the sensitivity of clusters to the choice of clustering method. The selected method employs a hierarchical agglomerative clustering technique called Ward's minimum variance method. In this method, an initial cluster of two individuals is formed by considering all possible clusters of size two and combining those individuals that produce the least impairment in an objective function. In the subsequent stage, all possible combinations of two individuals and all possible combinations of three individuals that include the initial cluster are formed and the cluster that results in least impairment of the objective function is accepted. At each level of the hierarchy, the objective function is minimized over all partitions of the data (Dillon and Goldstein 1984, SAS 2004). Although slightly different methods might produce clusters consisting of somewhat different individuals, we found that different methods identified a set of clusters that differed in similar ways.

Clusters were tested using two versions of the weight data. We used the raw weights that were allocated through direct weight elicitation to the fifteen metrics and we also used an aggregate weight statistic in which the fifteen metrics were aggregated into four metrics that correspond to the USACE system of accounts. Aggregate weights by planning objective are the sum of weights allocated to individual metrics associated with National Economic Objectives (NED), Regional Economic Objectives (RED), Environmental Objectives (EQ), and Other Social Effects (OSE). When the weights are aggregated this way, the data have fewer dimensions and the clusters are more clearly delineated. For this analysis, the comprehensive risk metrics that were identified in Section 3.1.3.5 were subsumed into one of the system of accounts. Long-term sustainability (Metric 13) and consequences of plan failing (Metric 14) are subsumed into the RED account. Residual risk (Metric 15) was subsumed into the NED account.

4.2.1 Analysis of Stakeholder Weights

The MsCIP weight elicitation sessions yielded 45 complete sets of stakeholder weights on the set of fifteen metrics (Annex 2). Four clusters emerged from the weight elicitation results. Mean weights are summarized in Table 4-1 for each metric and in Table 4-2 for each aggregation of weights by planning objective. The smallest cluster, D, contains six individuals and the largest cluster, B, contains 15 individuals. The formation of each cluster explains at least five percent of the variation in respondent's allocation of weights to the aggregate planning objectives. Five respondents were classified as outliers and therefore are not included in any particular cluster. Figure 4-1 shows the mean weight for each aggregate planning objective and each cluster. This graph can be used to help develop explanations for why the different clusters emerged. For example, group A places the highest weight on RED and Group D places the highest weight on EQ.

Table 4-1.
Mean Weight for each Metric by Cluster

Metric Description			Cluster			
		Category	**A**	**B**	**C**	**D**
1	Tidal Habitat Restored	EQ	0.02	0.07	0.12	0.21
2	Tidal Habitat Lost	EQ	0.02	0.09	0.17	0.18
3	Non-Tidal Habitat Restored	EQ	0.02	0.05	0.09	0.13
4	Non Tidal Habitat Lost	EQ	0.02	0.06	0.12	0.18
5	Damage Reduced/Avoided	NED	0.14	0.11	0.05	0.04
6	Residual Damages	NED	0.06	0.07	0.03	0.04
7	Cost to Implement Plan	NED	0.10	0.09	0.06	0.02
8	Local Cost Burden	RED	0.12	0.07	0.05	0.02
9	Regional Economic Benefits	RED	0.08	0.06	0.03	0.02
10	Cultural and Historical Heritage	OSE	0.05	0.04	0.05	0.02
11	Public Service Disruptions	OSE	0.08	0.06	0.04	0.02
12	Personal Impacts	OSE	0.05	0.05	0.03	0.02
13	Long-Term Sustainability	RED	0.13	0.08	0.09	0.05
14	Consequences of Plan Failure	RED	0.08	0.07	0.06	0.03
15	Residual Risk	NED	0.04	0.06	0.02	0.03

Table 4-2.
Mean Weight for each Aggregate Planning Objective by Cluster

Cluster	Respondents (Number)	Aggregate Planning Objective			
		NED	**RED**	**EQ**	**OSE**
A	9	0.34	0.42	0.07	0.17
B	15	0.32	0.27	0.27	0.15
C	10	0.17	0.24	0.48	0.12
D	6	0.12	0.12	0.70	0.06

(5 respondents are outliers)

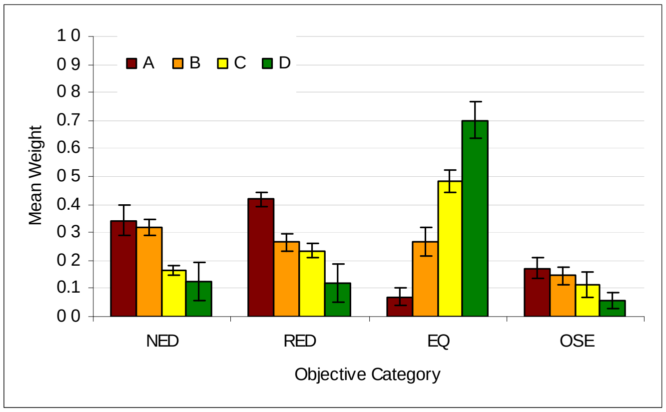
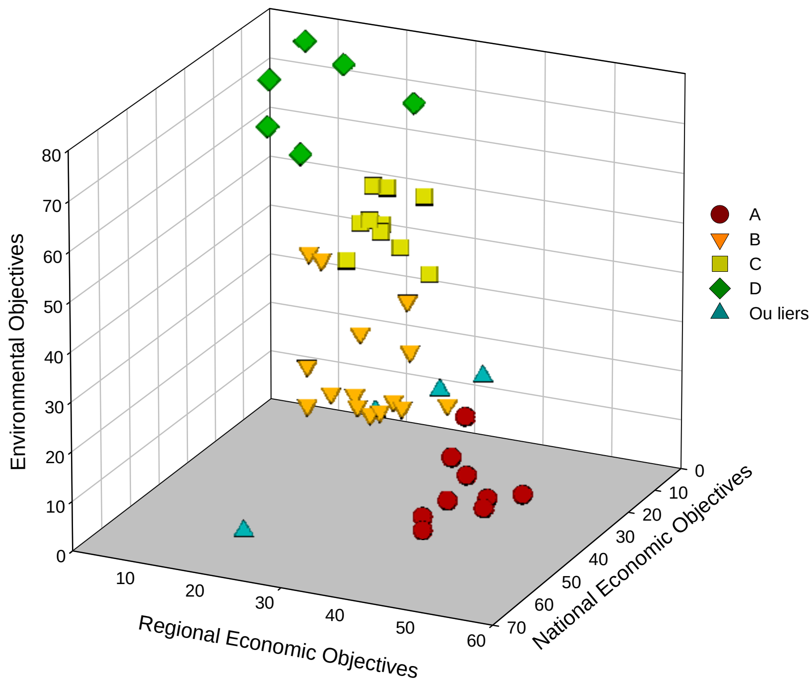


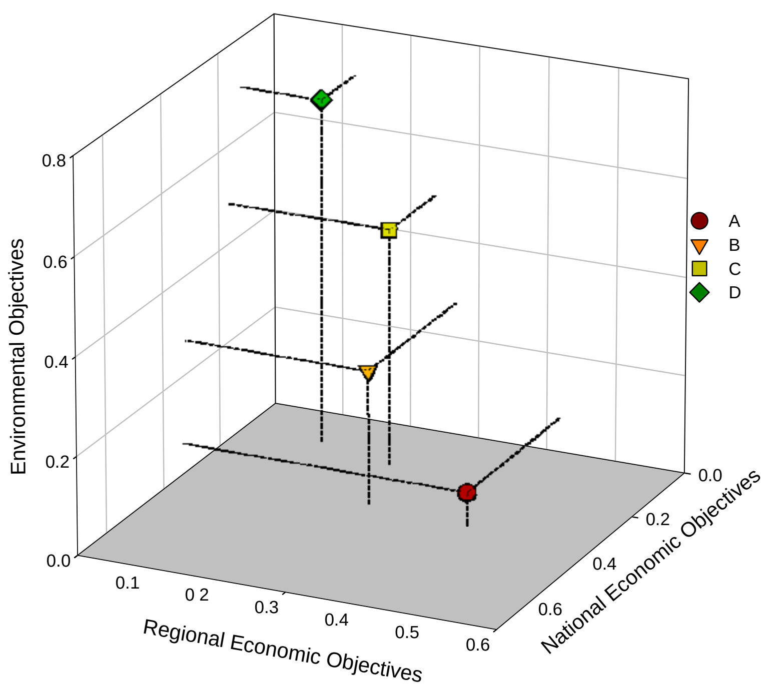
Figure 4-1. Mean weights by aggregate planning objective for four clusters, A through D. Uncertainty bounds represent 95% confidence limits on the estimated mean weight.

Differences among the clusters are further illustrated in Figures 4-2(a) and 4-2(b) which show the individual respondent weights arrayed in three-dimensional space. These results are not displayed in the OSE dimension because of relatively small differences in that dimension.

Performing the cluster analysis in this manner identifies distinct stakeholder group preferences across the Mississippi coast. These four groups represent differing stakeholder values and each will be used to rank alternative plans. This will permit us to document differences among stakeholders and identify areas for consensus and potential compromise. This information guides the ranking of plans and recommendations, as described below.



(a)



(b)

Figure 4-2: Weight allocation arrayed in three dimensions showing four clusters (a) and mean weight allocation for each cluster (b)

4.2.2 Cluster Groups

The cluster analysis identified four (4) distinct groups (or clusters) of stakeholders using stakeholder's allocation of weights across the fifteen metrics. Each group is described below relative to each of the four system of accounts, or objective categories on a 0-1 scale (see Table 4-2 and Figure 4-1).

- Cluster A: This group's focus was on economic development at both the regional and national levels. It had the highest NED weighting of 0.42 and the highest RED weighting of 0.34. This group also had the highest OSE weight (0.17) and the lowest weight for EQ (0.07).
- Cluster B: This group was intermediate (not highest or lowest weight for any category), allocating at least a weight of 0.15 to each category. It was unique in that it provided the second-highest weights for three categories: NED (0.32), RED (0.27) and OSE (0.15).
- Cluster C: While this group focused on EQ, giving it the second-highest weight (0.48), this group also weighted (balanced) each of the other categories with at least a 0.12 weighting, which sets it apart from Cluster D.
- Cluster D: This group is the most focused on the EQ category, showing the highest EQ weight of 0.70. This high EQ weighting comes at the expense of the other 3 categories, yielding the lowest weights for RED (0.12), NED (0.12) and OSE (0.06).

4.3 Plan Rankings by Multi-attribute Utility (MAU) Score

In this analysis, an MAU score is calculated and plans are ranked by the MAU score. Plans with higher MAU scores are preferred, but these ranks assume a particular set of stakeholder preferences and planning assumptions.

4.3.1 Ranking of Measures

MAU scores were calculated for each of the measures and the no-action alternative using a full set of fifteen weights and metrics. The alternatives are then ranked by MAU score, with the alternative having the highest MAU score being most preferred given the preferences under consideration. However, these ranks should be interpreted with more caution than this because there are many uncertainties that have not been fully addressed in this analysis. Therefore, rather than focusing on identifying the top-ranked plan and choosing this as the "best" alternative, it may be more useful to consider other types of questions. For example:

- How much do the MAU scores vary across the alternatives?
- Is there a group of plans at the top that have MAU scores that are relatively close to one another? What are the similarities and differences of the plans that form this "top tier?"
- How sensitive are plan rankings to planning assumptions and stakeholder preferences?
- Do stakeholders with different preference patterns prefer one particular plan but for different reasons?

Results of the analysis are presented in the form of numerous tables and graphs that summarize the results for each planning unit so that they can be used to support these types of deliberations among decision makers and stakeholders.

4.3.2 Summary of Results

Results of the MCDA are summarized in Table 4-3 for each cluster group of preference pattern. An independent MCDA was completed in each of the nine subdivisions. Stakeholder preferences are assumed to be consistent across subdivisions and the preferred plan in one subdivision is assumed to be independent of choices in every other subdivision or project alternatives (see Chapter 5 of Main Report for discussion of alternatives). Therefore, when aggregated, the combination of preferred plans in Table 4-3 represents a comprehensive suite of projects for each preference pattern. For example, stakeholders with preferences consistent with those of preference pattern A are best-served by a plan that consists of a suite of projects including the Barrier Islands Comprehensive Plan, Option K in LOD2, Bayou Cumbest Acquisition, Forrest Heights Plan 2, the High-risk Homeowner's plan. These stakeholders prefer no action in Turkey Creek, Admiral Island, Dantzler, and Franklin Creek subdivisions. Although Table 4-3 suggests that, in some cases, some stakeholders would prefer the no action alternative in some subdivisions, each subdivision has at least one preference pattern for which an action plan is preferred by at least one preference pattern.

Table 4-3.
Summary of Decision Analysis Results by Preference Pattern and Subdivision

Subdivision	**Preference Pattern**			
	A	**B**	**C**	**D**
Barrier Islands	Comprehensive Plan	Comprehensive Plan	Option A	Option A
LOD2	Option K	Option K	Option K	Option K
Turkey Creek	No Action	No Action	No Action	Ecosystem Plan 1
Bayou Cumbest	Acquisition	Acquisition	Acquisition	Ecosystem Plan 1
Admiral Island	No Action	No Action	No Action	Ecosystem Plan 1
Dantzler	No Action	No Action	No Action	Ecosystem Plan 1
Franklin Creek	No Action	No Action	No Action	Ecosystem Plan 1
Forrest Heights	Plan 2	Plan 2	No Action	No Action
Non-Structural	High Risk HARP	Long-term HARP	High Risk HARP	Long-term HARP

HARP = Homeowner's Relocation and Assistance Plan

The calculation of the MAU score is summarized for each of the four preference patterns in Annex 3. In most subdivisions, at least one of the fifteen metrics did not vary across the decision alternatives. If a metric did not vary, it was dropped from the calculation of MAU and the weights for all preference patterns in that subdivision were re-scaled to sum to one. The consequence of this re-scaling is that MAU scores cannot be compared across subdivisions. For example, the Barrier Island Comprehensive Plan has an MAU score of 0.7393 for preference pattern A. This score should not be compared to an MAU score in Dantzler or any other subdivision. There are fifteen outcome metrics of performance associated with each decision outcome. If none of the decision alternatives being considered in a subdivision would have any impact on an outcome measure of performance, that outcome measure is irrelevant to the decision because it cannot affect the choice. Moreover, if the maximum value of an outcome metric for a set of alternatives is the same as the maximum value of that outcome metric (the case of non-varying metrics), it is impossible to calculate a value score using the equations on lines 6 and 8 on page 41 and a multi-attribute utility score cannot be calculated. Therefore, non-varying metrics are dropped. Dropping these metrics will have no effect on the decision (*i.e.,* which alternative is chosen) because there is a linear utility function.

Figures 4-3 through 4-11 illustrate project rankings and show the relative contribution of each metric to the overall multi-attribute utility (MAU) score. This is illustrated by the color banding of the vertical bar in each figure. A larger color band for a metric indicates that metric contributes more to multi-attribute utility than metrics with smaller bands. One of the results of this study is that in some subdivisions, stakeholders with different preference patterns may prefer similar measures for different reasons. For example, in Figure 4-4, LOD2 Option K is associated with the highest MAU for all preference patterns. It is sometimes the case that stakeholders with different preference patterns prefer the same plan, but they prefer the plan for different reasons. In these cases, MCDA can serve as a way to recognize these situations, help focus the debate and discussion on only the issues that matter, and promote consensus within a diverse group.

In the Barrier Islands (Figure 4-3), the Comprehensive Plan and Plan A are preferred by all preference patterns, but their ordering depends upon preferences. In LOD2 (Figure 4-4), Option K is preferred by all preference patterns. In Turkey Creek (Figure 4-5), the No Action plan is preferred by preference patterns A, B, and C. Preference pattern D prefers Plan 1. In Bayou Cumbest (Figure 4-6), Acquisition is the preferred alternative for preference patterns A, B, and C with the No Action plan coming in ahead of the other plans for preference patterns A and C. For preference pattern B, the No Action plan is least preferred. For preference pattern D, the preferred plan in Bayou Cumbest is Plan 1. For Admiral Island (Figure 4-7), Dantzler (Figure 4-8), and Franklin Creek (Figure 4-9), the No Action plan is preferred for preference patterns A, B, and C. Plan 1 is preferred for preference pattern D. In Forrest Heights (Figure 4-10), Plan 2 is preferred by preference patterns A and B. The No Action plan is preferred by preference patterns C and D. Among the Non-structural program alternatives (Figure 4-11), the High-risk Homeowner’s Plan is preferred by preference patterns A and C and Long-term Homeowner’s Plan is preferred by preference pattern B and D.

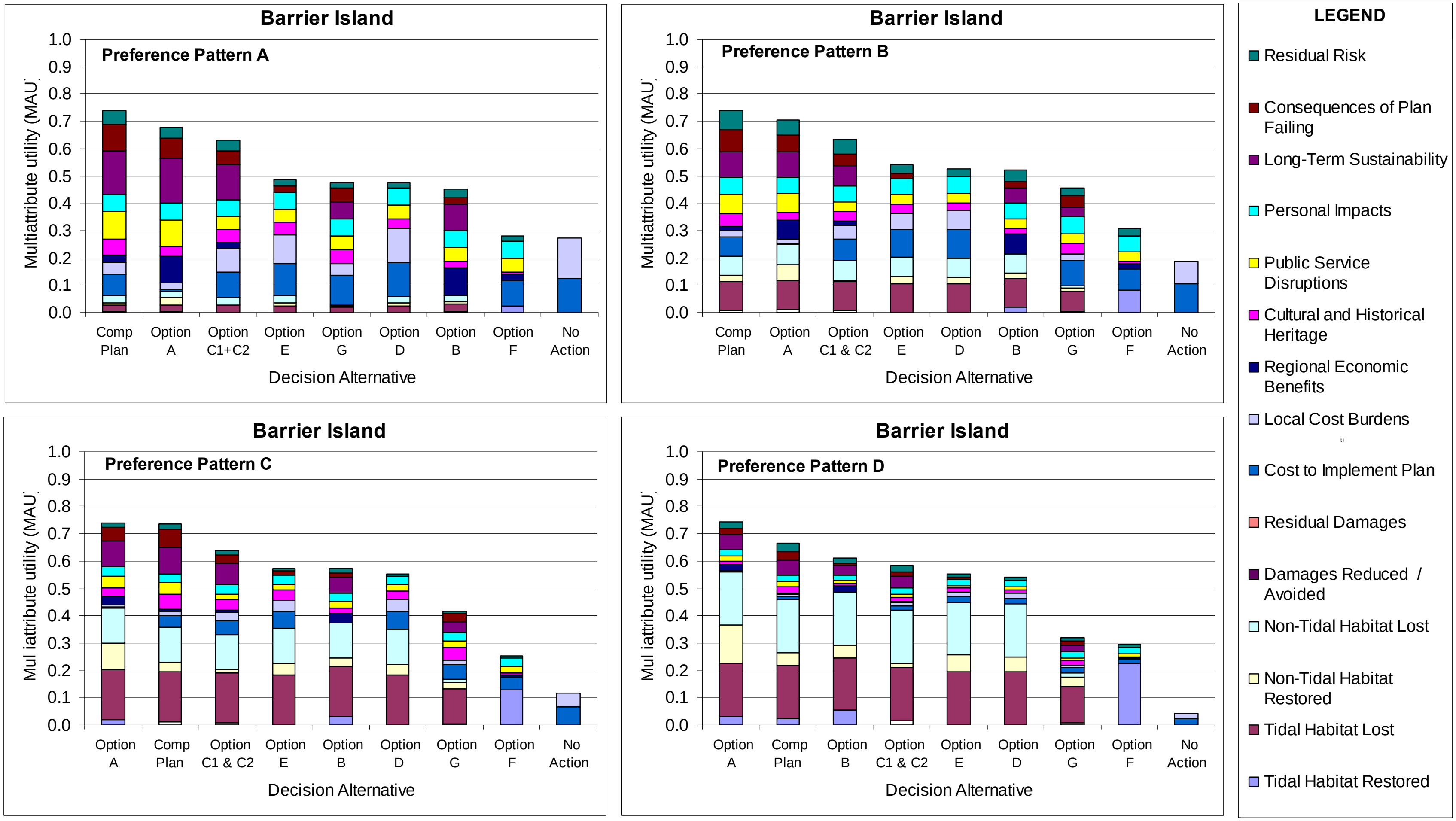


Figure 4-3: Contributions of the Metrics to Multi-attribute Utility Scores for Barrier Islands Ecosystem Restoration

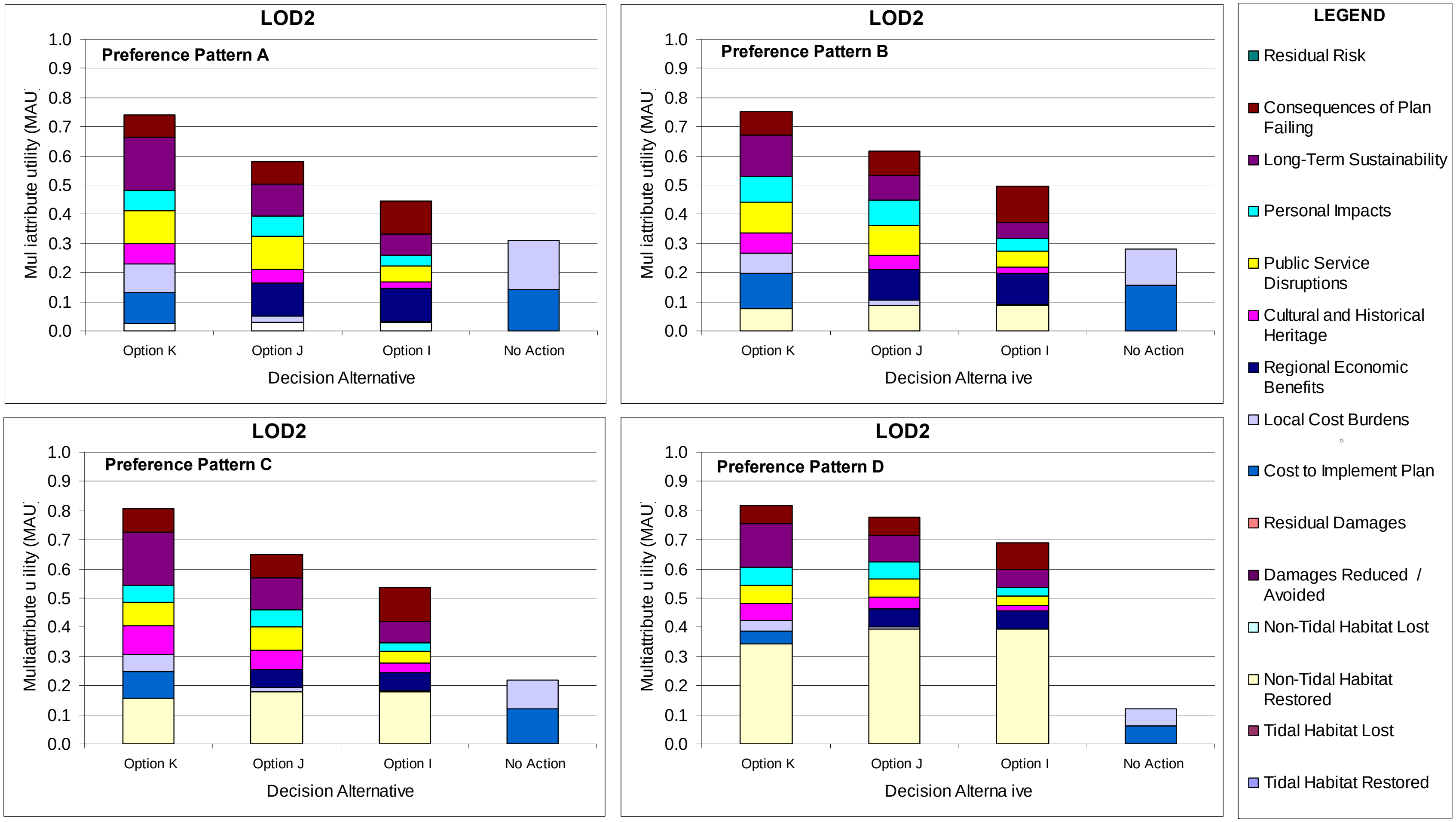


Figure 4-4: Contributions of the Metrics to Multi-attribute Utility Scores for LOD2, Beach and Dune Restoration

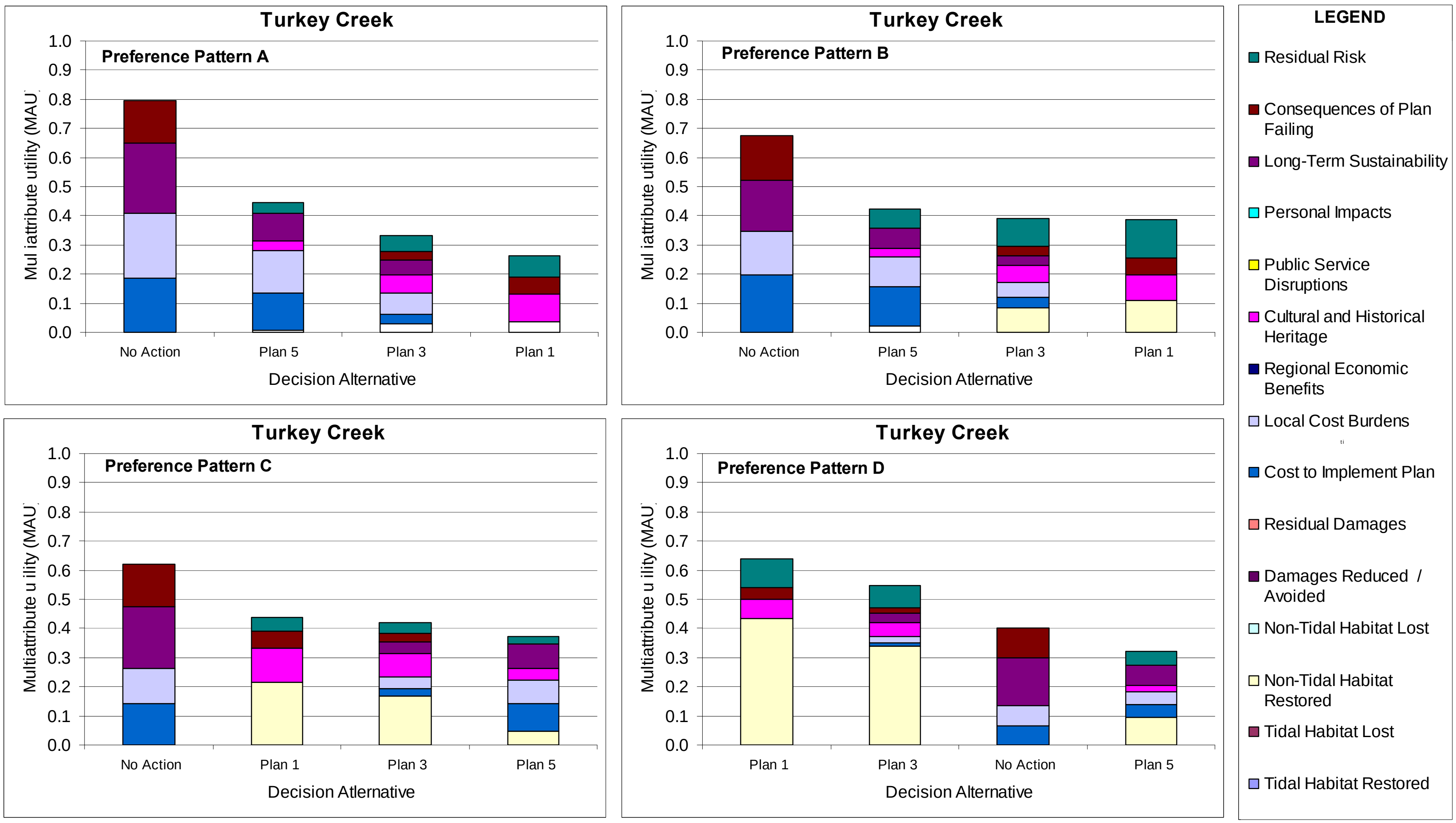


Figure 4-5: Contributions of the Metrics to Multi-attribute Utility Scores for Turkey Creek Ecosystem Restoration

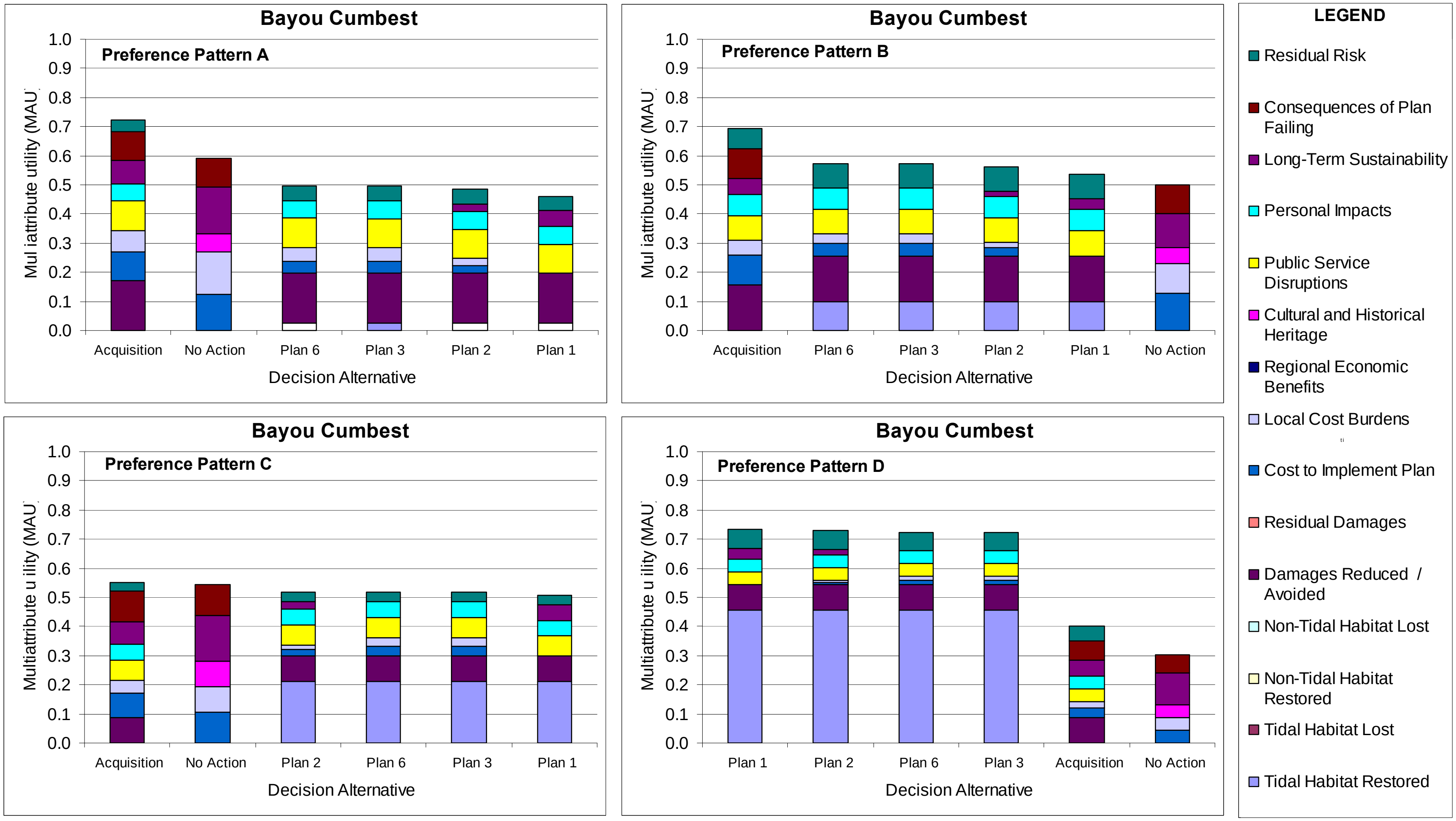


Figure 4-6: Contributions of the Metrics to Multi-attribute Utility Scores for Bayou Cumbest Ecosystem Restoration

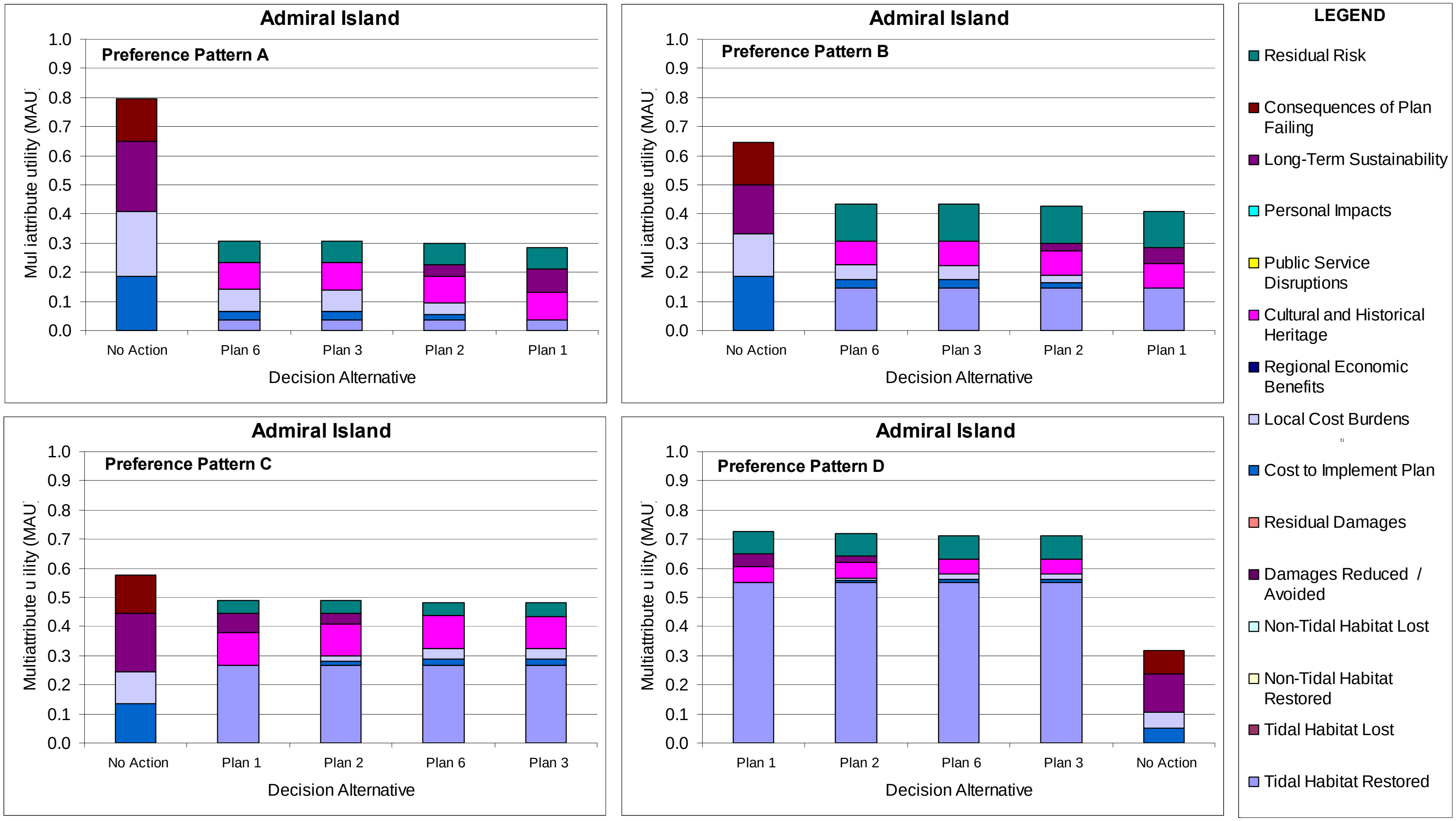


Figure 4-7: Contributions of the Metrics to Multi-attribute Utility Scores for Admiral Island Ecosystem Restoration

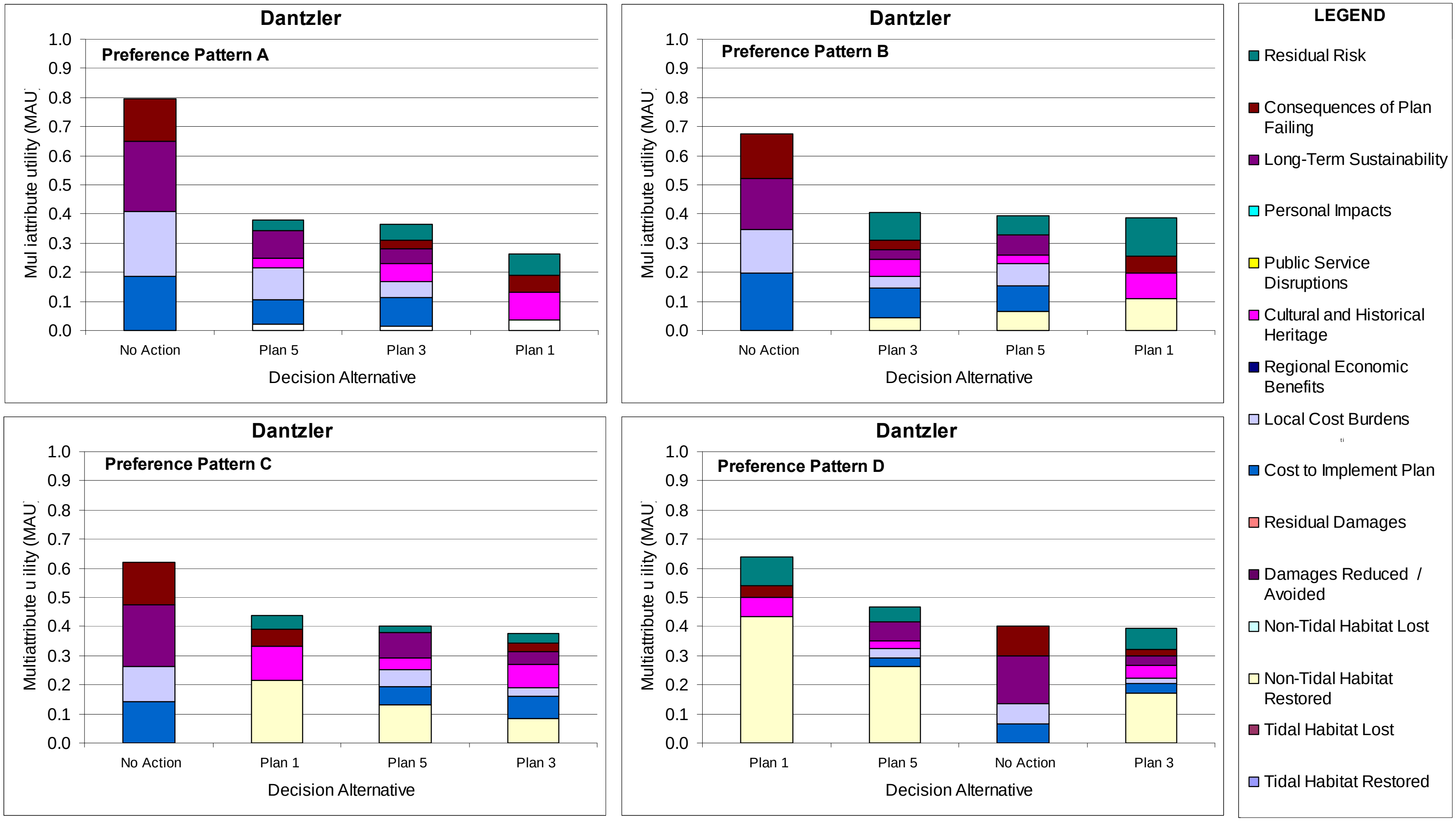


Figure 4-8: Contributions of the Metrics to Multi-attribute Utility Scores for Dantzler Ecosystem Restoration

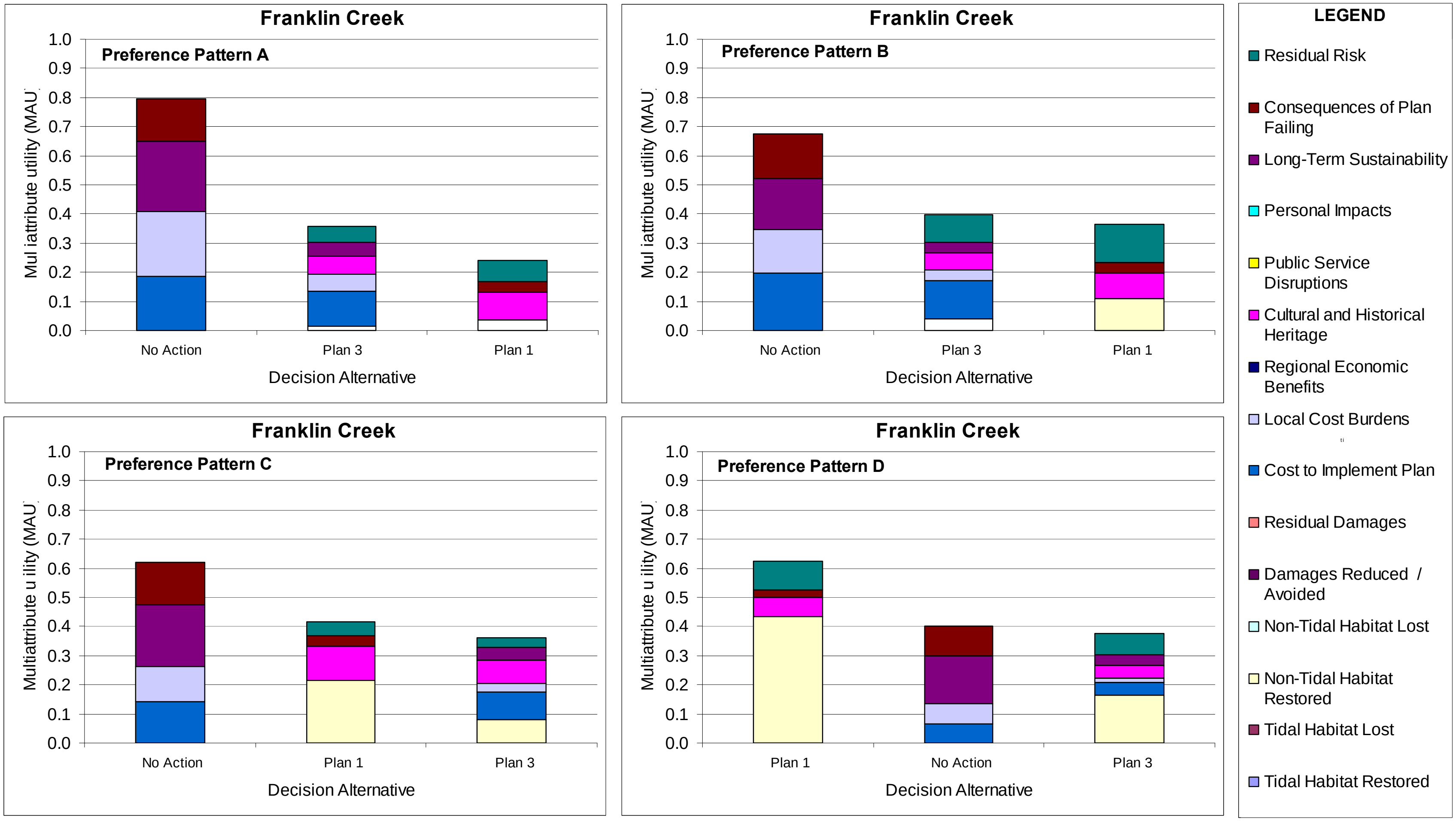


Figure 4-9: Contributions of the Metrics to Multi-attribute Utility Scores for Franklin Creek Ecosystem Restoration

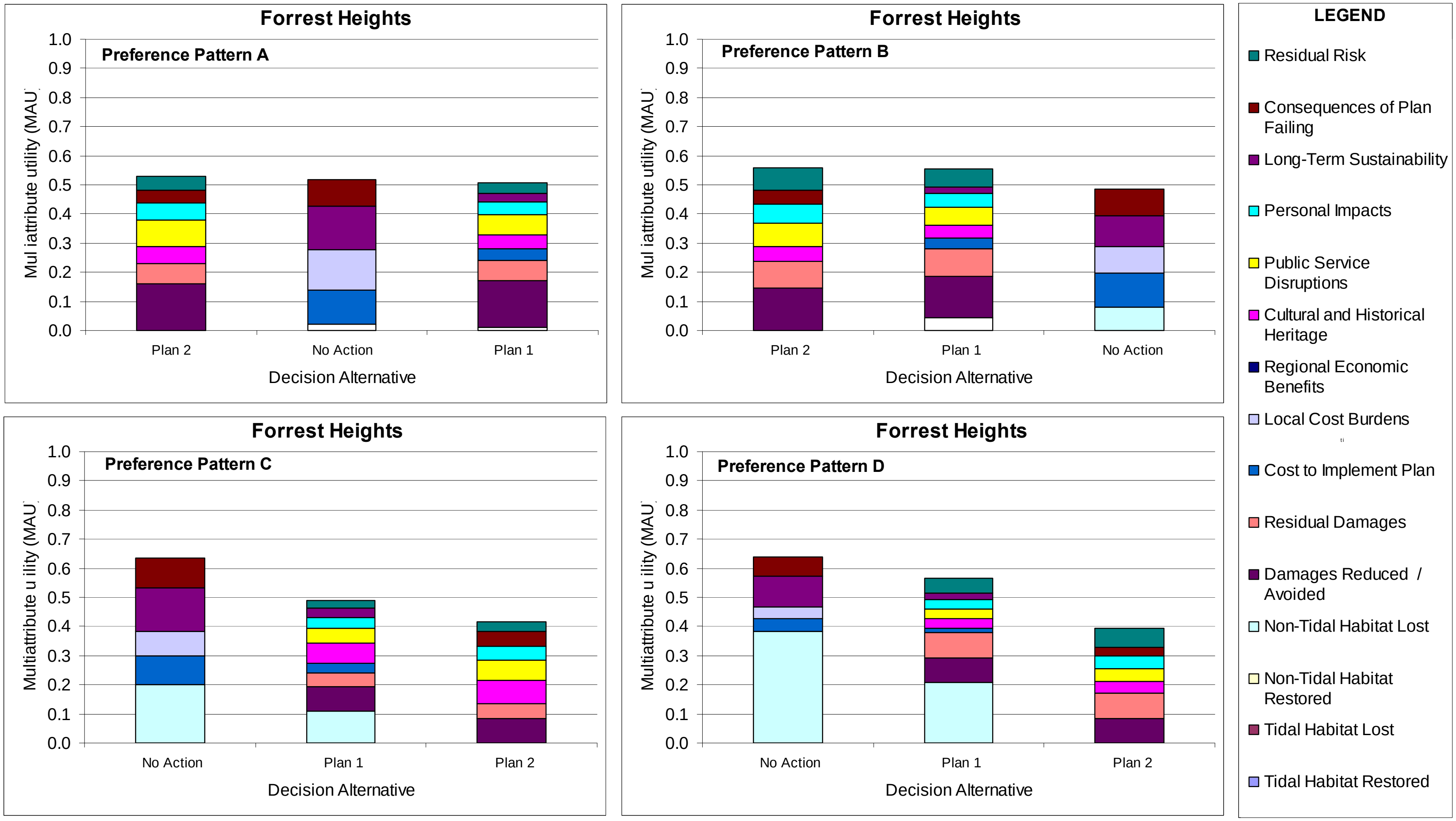


Figure 4-10: Contributions of the Metrics to Multi-attribute Utility Scores for Forrest Heights Hurricane and Storm Damage Reduction

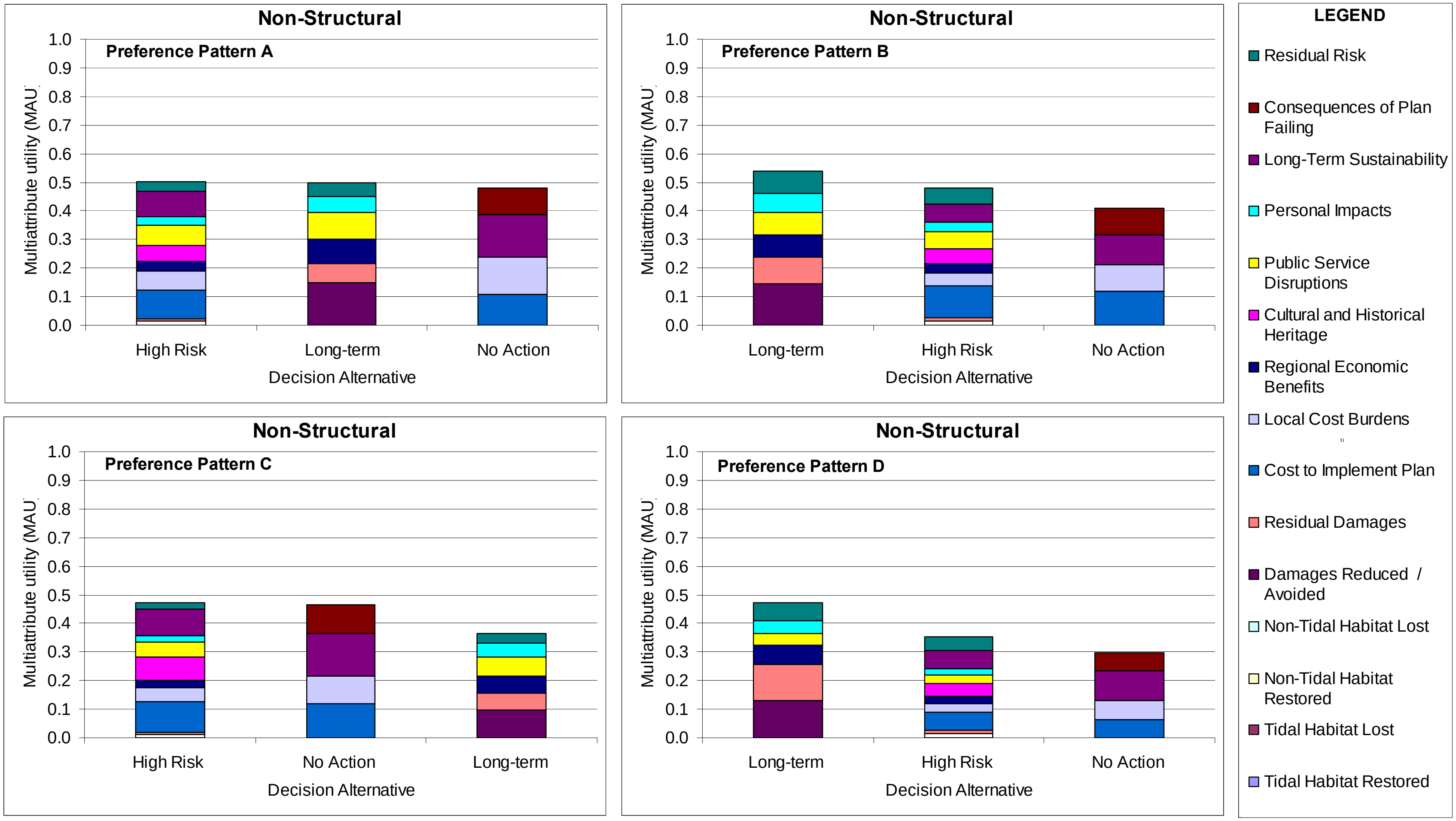


Figure 4-11: Contributions of the Metrics to Multi-attribute Utility Scores for Non-Structural Hurricane and Storm Damage Reduction

5. DISCUSSION

This application of RIDF has focused on developing an objectives hierarchy for MsCIP measures selection, identifying a set of metrics to model performance outcomes, and developing a multi-attribute utility function to rate the relative performance of project alternatives. In the analysis of results, MsCIP measures alternatives are ranked by MAU score using four different sets of attribute weights. Each set of weights characterizes a pattern of preference that is represented by a group of individuals, or cluster, within the stakeholder community. Plans are ranked by MAU score and, in the absence of uncertainty in the assumptions used to model plan outcomes, the preferred measure for each cluster is the measure with the highest MAU score. However, most decisions with long-range planning horizons involve a considerable amount of uncertainty and MsCIP is no exception.

In addition to enhancing the Corps' six-step P&G guidelines by providing a means to consider multiple objectives in the decision process, RIDF also offers a mechanism by which to engage stakeholders more actively in the Corps' planning process. For example, these MCDA procedures help decision makers and stakeholders: 1) systematically structure the decision process; 2) assess tradeoffs among decision objectives; 3) reflect upon, articulate, and apply explicit value judgments concerning conflicting decision criteria; 4) make more consistent and rational evaluations of risks and uncertainties; and 5) facilitate negotiation (Hobbs and Meier 2000). In addition to improving the quality of decisions, RIDF helps decision makers engage stakeholders. Stakeholders assist decision makers to develop an objectives hierarchy and to assess the relative importance of those decision objectives. An obvious benefit of engaging stakeholders during the planning process is that this is likely to engender greater trust and confidence on the part of stakeholders and may enhance the sense of legitimacy of the decision or final outcome. The objectives hierarchy is described in Section 3.1.3 and the stakeholder weight elicitation sessions are described in Section 4.1.

Results of the stakeholder weight elicitation sessions are analyzed using cluster analysis to identify characteristic patterns of preference in the stakeholder population. The rationale for this method is that it provides an objective approach to classifying stakeholders based on psychometric data obtained directly from them. Four characteristic patterns of preference emerged from the results of weight elicitation. These preference patterns can be differentiated by the aggregate weight on EQ objectives, which is the sum of relative weights on individual EQ sub-objectives. The aggregate weight on EQ objectives is negatively correlated with the aggregate weight on each of the remaining higher level objectives: NED, RED, and OSE. Preference pattern A places the greatest emphasis on NED and RED objectives while preference pattern D places the greatest emphasis on EQ objectives. OSE objectives are consistently rated low relative to the other objectives, but preference pattern A gives slightly more emphasis to OSE objectives than EQ objectives.

This study describes why the outcomes associated with some alternatives are preferred by various stakeholders to others. Utility provides a relative measure with which to compare decision outcomes given a set of objectives and the preferences of a subject. The contribution of an attribute to utility is determined by the relative importance placed on a performance objective and the relative performance of the alternative with respect to that decision objective. Plan rankings will tend to be more strongly influenced by those decision attributes that have both a high weight and a large amount of variability in performance outcomes across plans. If relative performance does not vary much across the alternatives, then these metrics should have little impact on the decision. Similarly, an objective that is unimportant (receives a low weight) should also have little impact on the decision, even if the corresponding metric varies a lot from one alternative to another. Metrics that do not vary much do not affect the plan rankings. For MsCIP, at least one metric in each subdivision was eliminated because it exhibited no variation across decision alternatives. Weights on decision objectives were scaled in each sub-division to accommodate the elimination of metrics.

Results of the MCDA are summarized in Table 4-3 and in the ensuing figures. A great deal can be learned by analyzing the MCDA for these four distinctly different patterns of preference. For the Barrier Islands Ecosystem Restoration, Option A and the Comprehensive Plan form a top tier of decision alternatives (Figure 4-3). These plans outrank the seven other plans for each preference pattern. Although preference patterns A and B prefer the Comprehensive Plan and preference patterns C and D prefer Option A, the differences in the MAU scores between these two plans appears relatively small for each preference pattern. This suggests that, while the different preference patterns express wildly different values and priorities, stakeholders could reach consensus around one of these two plans. Each preference pattern prefers the similar decision alternatives, but for different reasons. A similar result is observed in the LOD2 subdivision, where Option K is preferred to other alternatives for all preference patterns (Figure 4-4).

Results in other subdivisions are slightly more complicated. In Turkey Creek (Figure 4-5), Admiral Island (Figure 4-7), Dantzler (Figure 4-8), and Franklin Creek (Figure 4-9), preference patterns A, B, and C all prefer the No Action alternative while preference pattern D, which has a high weight on environmental objectives, prefers Ecosystem Plan 1. A similar pattern is observed in Bayou Cumbest (Figure 4-6) where preference patterns A, B, and C all prefer Acquisition while preference pattern D prefers Ecosystem Plan 1. It is worth pointing out that, in each case, the MAU score for the preferred alternative stands out as apparently higher than the MAU score for the other alternatives. In Forrest Heights (Figure 4-10), Plan 2 has the highest MAU score for preference patterns A and B while the No Action alternative ranks highest for preference patterns C and D. Among the Non-structural alternatives (Figure 4-11), the High Risk Homeowners Assistance Plan has the highest MAU score for preference patterns A and C while the Long-term Homeowners Assistance Plan has the highest MAU score for preference patterns B and D.

One of the benefits of subjecting policy decisions such as those being considered in MsCIP to a multi-attribute decision analysis and stakeholder involvement is that it helps decision makers to identify where common interests exist. It is possible to analyze the results to identify where and how bridges might be built to unite stakeholders who hold competing views, and where more work may be needed to evaluate decision alternatives. The results of this analysis suggest that, given the information that is available at this time, stakeholder consensus is a real possibility in the Barrier Islands and LOD2 subdivisions. For Turkey Creek, Bayou Cumbest, Admiral Island, Dantzler, and Franklin Creek, there is a modal preference for the No Action alternative among the preference patterns considered in this report. More work may be needed differentiate among the alternatives will be needed to develop recommendations for the Forrest Heights and Non-structural subdivisions.

Although a plan may have a high rank over a large number of preference patterns, the utility of that plan for one or more of those preference types may be substantially lower than for others. In this case, consideration should be given to how large these differences in utility are, whether or not these differences represent an inequity, and to what extent this outcome may be the product of having considered only a limited scope of decision alternatives.

6. LESSONS LEARNED FROM IMPLEMENTATION OF THE RIDF

Stakeholder input is being used by US Army Corps of Engineers to inform itself about the interests and values of the stakeholders who will be affected by the planning process. However, the ultimate responsibility for this project selection decision rests solely with the US Army Corps of Engineers. The agency is legally bound to act only within the mission and authority that it was given by Congress.

A number of lessons were learned in this application of RIDF that suggest recommendations for future planning studies that use this method. For example, it is important that sufficient attention be given to developing the objectives hierarchy and selecting the metrics. The time spent structuring an objectives hierarchy will assist in helping the decision maker to clarify his objectives and the use of poorly structured hierarchies can result in recommendations that lead to sub-optimal outcomes. All of the relevant interests of the decision maker should be included in the hierarchy and the lower level objectives should be associated with metrics that clearly represent the extent to which that objective is achieved by a decision outcome.

Ideally, metrics should be quantitative and measurable. Some of the metrics adopted for this study were qualitative because time and resource constraints limited the ability to evaluate the metrics quantitatively through modeling studies or other forms of analysis. Metrics should also be meaningful for the stakeholders who are participating in the weight elicitation session. For example, a decision objective to minimize project cost could be represented by a metric that is an estimate of an individual's additional tax burden rather than an estimate of the total project cost, which may hold less meaning for most stakeholders.

All objectives and metrics should be clearly defined. If definitions are long, complicated, or ambiguous, they will lack clarity. Clarity is needed to avoid confusion in the weight elicitation process and divergent views about what a particular metric represents. Such circumstances could undermine the ability to compare weights elicited from stakeholders.

Many different patterns of preference will commonly exist in populations affected by large planning projects. Therefore, it is important that the group of stakeholders who participate in the weight elicitation sessions provide a representative cross-section of the population. If participants are drawn from too narrow a subset of the population, the interests of the population will not be accurately represented.

Preference assessment is a difficult task and it is important that the level of effort needed to obtain valid results not be underestimated. While much effort went into obtaining information on stakeholder preferences for this project, some improvements in the approach are still possible. Stakeholder engagement sessions, such as those conducted for this project, should incorporate controls during the weight elicitation procedure to qualify the results using internal validity tests. For example, future weight elicitation sessions should include tests to help confirm that participants understand and are implementing the instructions properly. In addition, persons conducting the weight elicitation sessions should follow a script so that the procedures are consistently applied from one session to another and are well documented. It may also be useful to expand the scope of information collected from stakeholders. For example, a set of questions unrelated to the project at hand could assist in developing a more meaningful interpretation of the clusters. This will also provide the ground work for formalizing the MCDA technique and making it more generally applicable to other Corps decision processes.

Finally, there are many uncertainties that can influence a project selection decision. For example, the rate of change in sea-level rise over the life of the project is an obvious and relevant factor to consider in evaluating decision alternatives. Decision analysis assists decision makers in choosing among alternatives despite these uncertainties. Failure to account for uncertainty in the decision can lead to suboptimal outcomes. Therefore, future applications of the RIDF should assess the most important sources of uncertainty and fully analyze their impacts on the decision.

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ANNEX 1. – STAKEHOLDER WORKSHOP PARTICIPANTS

Table A1-1.
State Government Participants 10 September. 15 survey participants

Name	Organization
Margaret Bretz	Secretary of State
Mike Buchanan	MS Dept of Marine Resources
Sonia Carr	MEMA Long-Term Recovery
Kerwin Cuevas	MS Dept of Marine Resources
Dale Diaz	MS Dept of Marine Resources
Ashley Edwards	Governor's Office
Tom Mann	MS Museum Natural Science/MDWFP
David McNeel	MS State Port Authority
Jamie Miller	Governor's Office
Ken P'Pool	MS Dept of Archives and History
George Ramseur, Jr.	MS Dept of Marine Resources
David Seyfarth	MS Dept of Transportation
Kathy Shelton	MS Museum Natural Science/MDWFP
R. Chad Wallace	MDOT, Environmental Division
Nick Winstead	MS Museum Natural Science/MDWFP

Table A1-2.
Federal Government Participants 10 September. 11 survey participants

Name	Organization
Valerie Anderson	FEMA Biloxi
Sabrina Chandler	USFWS Jackson
Tyree Harrington	USDA-NRCS
Ntale Kajumba	USEPA Region 4
Rob Lowe	FEMA Region 4
C. Baxter Mann	FEMA-DELO
Bruce McCraney	National Park Service
Jim Murphy	MARAD
Mickey Plunkett	USGS (MS)
Chris Recceston	FEMA
Mark Thompson	National Marine Fisheries Service (Habitat)

Table A1-3.
Local Government Participants 10 September. 8 survey participants

Name	Organization
Patrick Bonck	Harrison County Zoning
Harrietta Eaton	City of Pascagoula
Les Fillingame	City of Bay St. Louis
Liz Ford	City of Pascagoula
Aneice Liddell	City of Moss Point
Gordon Quesenberry	City of Gautier
Jaclyn Turner	City of Pascagoula
Daphne Viverette	City of Moss Point

Table A1-4.
Business/Developer Participants 11 September. 5 survey participants

Name	Organization
Laura Brown	Gulf Coast Investment Dev (GCID)
Willie Davis	City of Pass Christian
Jim Kelly	Eco-Logic Restoration
Shelby Stevenson	CSX Transportation
Stuart Williamson	Association of Floodplain Managers of Mississippi

Table A1-5.
NGO/Scientist Participants 11 September. 5 survey participants

Name	Organization
Jeff Grimes	Gulf Restoration Network
Buck Lawrence	STEPs Coalition/North Gulfport Commission Land Trust
Mike Murphy	The Nature Conservancy
Stephanie Powell	STEPs Coalition Environmental Justice & Sustainability Piller
Judy Steckler	Land Trust

Table A1-6.
Corps MsCIP and ERDC Participants 11 September: 5 survey participants

Name	Organization
Cynthia Banks	ERDC
Todd Boatman	SAM
Barry Payne	ERDC
Susan Rees	SAM
Burton Suedel	ERDC

ANNEX 2. STAKEHOLDER RANKINGS

Table A2-1.
Allocation of 100 Points to 15 MsCIP Metrics (See Table 1-1 for Definitions of Metrics)

Cluster	Elicitation Session	Metrics														
		Tidal Habitat Restored	Tidal Habitat Lost	Non-Tidal Habitat Restored	Non-Tidal Habitat Lost	Damage Reduced/Avoided	Residual Damages	Cost to Implement Plan	Local Cost Burden	Regional Economic Benefits	Cultural and Historical Heritage	Public Service Disruptions	Personal Impacts	Long-Term Sustainability	Consequences of Plan Failure	Residual Risk
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	Business	1	1	1	1	35	3	5	5	5	4	2	2	15	16	4
A	Business	5	3	5	3	5	4	9	10	10	6	8	8	15	3	6
A	Federal	2	1	2	1	20	4	10	4	10	1	10	4	17	10	4
A	Local	2	2	2	2	7	7	12	24	10	5	10	5	5	2	5
A	Local	1	1	1	1	3	3	25	25	10	10	5	1	7	3	4
A	Local	1	2	1	2	13	8	1	12	13	1	8	5	12	12	9
A	Local	3	4	1	2	15	5	5	3	4	3	12	8	18	13	4
A	Local	1	1	1	1	20	8	12	9	10	6	7	2	15	5	2
A	Local	1	1	1	1	10	10	10	16	3	7	7	7	15	10	1
B	Business	8	6	6	2	15	6	10	8	8	8	5	7	4	3	4
B	Business	10	8	1	1	7	10	10	12	5	3	8	5	9	6	5
B	USACE	12	12	10	10	12	7	2	2	2	5	5	2	7	7	5
B	USACE	10	12	10	14	10	9	8	5	7	3	2	4	2	3	1
B	USACE	5	5	5	5	10	5	10	10	5	5	5	5	7	15	3
B	Federal	6	6	5	5	20	6	6	4	7	4	5	3	9	8	6
B	Federal	5	5	5	5	10	10	10	5	5	5	5	5	10	10	5
B	Federal	10	10	5	5	10	1	10	7	5	1	5	1	5	5	20
B	Local	1	10	1	10	10	12	18	1	8	4	8	3	1	12	1
B	Local	15	9	5	2	8	5	6	8	3	8	5	5	8	5	8
B	NGO	5	10	5	10	17	1	10	5	2	3	3	3	18	7	1
B	State	5	5	5	5	10	10	10	10	10	5	10	5	10	0	0
B	State	7	12	7	12	6	3	11	6	3	3	2	2	16	5	5
B	State	5	4	5	3	9	5	5	7	6	5	10	10	8	6	12
B	State	3	15	2	2	8	10	8	8	7	1	5	12	5	6	8
C	Business	8	30	1	1	5	1	10	10	9	5	5	3	10	1	1
C	USACE	11	12	11	12	5	7	6	6	4	2	3	2	9	8	2
C	Federal	12	12	12	12	5	5	3	3	2	5	5	5	10	5	4

Cluster	Elicitation Session	Metrics														
		Tidal Habitat Restored	**Tidal Habitat Lost**	**Non-Tidal Habitat Restored**	**Non-Tidal Habitat Lost**	**Damage Reduced/Avoided**	**Residual Damages**	**Cost to Implement Plan**	**Local Cost Burden**	**Regional Economic Benefits**	**Cultural and Historical Heritage**	**Public Service Disruptions**	**Personal Impacts**	**Long-Term Sustainability**	**Consequences of Plan Failure**	**Residual Risk**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
C	Federal	10	10	12	15	4	4	1	1	1	15	1	1	5	15	5
C	NGO	16	16	11	11	4	3	3	1	1	2	1	1	18	8	4
C	NGO	10	20	5	20	6	3	5	3	5	2	5	2	5	8	1
C	State	12	14	11	13	9	1	10	9	2	2	1	2	10	2	1
C	State	8	15	8	16	5	5	5	10	2	5	4	4	8	3	2
C	State	15	20	10	10	5	0	10	0	3	2	3	2	10	10	0
C	State	15	15	5	5	5	5	5	5	5	5	10	10	4	4	2
D	Federal	15	20	15	15	10	5	1	2	3	4	2	4	1	1	2
D	Federal	30	25	12	8	1	1	1	1	1	1	1	1	77	5	5
D	Federal	50	1	20	2	6	5	2	2	1	2	2	2	2	1	2
D	NGO	14	20	14	20	1	1	1	3	7	2	1	1	5	88	2
D	NGO	14	25	15	24	2	1	3	2	1	2	2	3	2	3	1
D	State	5	15	2	40	1	10	5	1	1	2	1	1	10	1	5

ANNEX 3. - CALCULATION OF MULTI-ATTRIBUTE UTILITY SCORES BY PREFERENCE PATTERN.

Table A3-1.
Calculation of Multi-attribute Utility Scores for Preference Pattern A

CLUSTER A

Metric	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	MAU
Overall Weights	0.02	0.02	0 02	0.02	0.14	0.06	0.1	0.12	0.08	0.05	0.08	0.05	0.13	0.08	0.04	
Barrier Island Comp Plan	0.0026	0.0247	0.0084	0 0247			0.0811	0.0423	0 0247	0 0617	0.0988	0.0617	0.1605	0 0988	0 0494	0.7393
Barrier Island Option A	0.0036	0.0247	0.0247	0 0247			0.0087	0.0212	0 0988	0 0353	0.0988	0.0617	0.1605	0 0741	0 0395	0.6762
Barrier Island Option C1 & C2	0.0018	0.0247	0.0026	0 0247			0.0951	0.0847	0 0247	0 0441	0.0494	0.0617	0.1284	0 0494	0 0395	0.6308
Barrier Island Option E	0.0000	0.0247	0.0110	0 0247			0.1187	0.1058	0 0000	0 0441	0.0494	0.0617	0.0000	0 0247	0 0198	0.4845
Barrier Island Option G	0.0007	0.0172	0.0058	0 0023			0.1096	0.0423	0 0000	0 0529	0.0494	0.0617	0.0642	0 0494	0 0198	0.4753
Barrier Island Option D	0.0000	0.0247	0.0099	0 0247			0.1217	0.1270	0 0000	0 0353	0.0494	0.0617	0.0000	0 0000	0 0198	0.4742
Barrier Island Option B	0.0058	0.0247	0.0083	0 0247			0.0000	0.0000	0 0988	0 0265	0.0494	0.0617	0.0963	0 0247	0 0296	0.4504
Barrier Island Option F	0.0247	0.0000	0.0000	0 0000			0.0912	0.0000	0 0247	0 0088	0.0494	0.0617	0.0000	0.0000	0 0198	0.2803
Barrier Island No Action	0.0000	0.0000	0.0000	0 0000			0.1235	0.1481	0 0000	0 0000	0.0000	0.0000	0.0000	0 0000	0 0000	0.2716
LOD2 Option K			0.0244				0.1077	0.0966	0 0000	0 0704	0.1127	0.0704	0.1831	0 0751		0.7404
LOD2 Option J			0.0282				0.0000	0.0241	0.1127	0 0469	0.1127	0.0704	0.1099	0.0751		0.5800
LOD2 Option I			0.0282				0.0034	0.0000	0.1127	0 0235	0.0563	0.0352	0.0732	0.1127		0.4452
LOD2 No Action			0.0000				0.1408	0.1690	0 0000	0 0000	0.0000	0.0000	0.0000	0 0000		0.3099
Turkey Creek No Action			0.0000				0.1852	0.2222		0 0000			0.2407	0.1481	0 0000	0.7963
Turkey Creek Ecosystem Plan 5			0.0080				0.1260	0.1481		0 0309			0.0963	0 0000	0 0370	0.4464
Turkey Creek Ecosystem Plan 3			0.0290				0.0334	0.0741		0 0617			0.0481	0 0296	0 0556	0.3316
Turkey Creek Ecosystem Plan 1			0.0370				0.0000	0.0000		0 0926			0.0000	0 0593	0 0741	0.2630
Bayou Cumbest Acquisition	0.0000				0.1728		0.0978	0.0741		0 0000	0.0988	0.0617	0.0802	0 0988	0 0395	0.7237
Bayou Cumbest No Action	0.0000				0 0000		0.1235	0.1481		0 0617	0.0000	0.0000	0.1605	0 0988	0 0000	0.5926
Bayou Cumbest Ecosystem Plan 6	0.0247				0.1728		0.0394	0.0494		0 0000	0.0988	0.0617	0.0000	0 0000	0 0494	0.4962
Bayou Cumbest Ecosystem Plan 3	0.0247				0.1728		0.0393	0.0494		0 0000	0.0988	0.0617	0.0000	0.0000	0 0494	0.4961
Bayou Cumbest Ecosystem Plan 2	0.0247				0.1728		0.0263	0.0247		0 0000	0.0988	0.0617	0.0267	0.0000	0 0494	0.4851
Bayou Cumbest Ecosystem Plan 1	0.0247				0.1728		0.0000	0.0000		0 0000	0.0988	0.0617	0.0535	0.0000	0 0494	0.4609
Admiral Island No Action	0.0000						0.1852	0.2222		0 0000			0.2407	0.1481	0 0000	0.7963
Admiral Island Ecosystem Plan 6	0.0370						0.0298	0.0741		0 0926			0.0000	0.0000	0 0741	0.3076
Admiral Island Ecosystem Plan 3	0.0370						0.0294	0.0741		0 0926			0.0000	0.0000	0 0741	0.3071
Admiral Island Ecosystem Plan 2	0.0370						0.0194	0.0370		0 0926			0.0401	0.0000	0 0741	0.3003
Admiral Island Ecosystem Plan 1	0.0370						0.0000	0.0000		0 0926			0.0802	0.0000	0 0741	0.2840
Dantzler No Action			0.0000				0.1852	0.2222		0 0000			0.2407	0.1481	0 0000	0.7963
Dantzler Ecosystem Plan 5			0.0225				0.0827	0.1111		0 0309			0.0963	0 0000	0 0370	0.3806
Dantzler Ecosystem Plan 3			0.0145				0.0995	0.0556		0 0617			0.0481	0 0296	0 0556	0.3646
Dantzler Ecosystem Plan 1			0.0370				0.0000	0.0000		0 0926			0.0000	0 0593	0 0741	0.2630
Franklin Creek No Action			0.0000				0.1852	0.2222		0 0000			0.2407	0.1481	0 0000	0.7963
Franklin Creek Ecosystem Plan 3			0.0139				0.1227	0.0556		0 0617			0.0481	0 0000	0 0556	0.3576
Franklin Creek Ecosystem Plan 1			0.0370				0.0000	0.0000		0 0926			0.0000	0 0370	0 0741	0.2407
Forrest Heights Plan 2				0 0000	0.1609	0.0690	0.0000	0.0000		0 0575	0.0920	0.0575	0.0000	0 0460	0 0460	0.5287
Forrest Heights No Action				0 0230	0 0000	0.0000	0.1149	0.1379		0.0000	0.0000	0.0000	0.1494	0 0920	0.0000	0.5172
Forrest Heights Plan 1				0 0125	0.1607	0.0689	0.0383	0.0000		0 0479	0.0690	0.0431	0.0299	0 0000	0 0368	0.5070
High Risk Homeowners Assistance Plan					0 0161	0.0069	0.1010	0.0645	0 0344	0 0575	0.0690	0.0287	0.0897	0 0000	0 0345	0.5022
Long-term Homeowners Assistance Plan					0.1505	0.0645	0.0000	0.0000	0 0860	0 0000	0.0920	0.0575	0.0000	0 0000	0 0460	0.4965
No Action Homeowners Assistance Plan					0 0000	0.0000	0.1075	0.1290	0 0000	0 0000	0.0000	0.0000	0.1494	0 0920	0 0000	0.4779

Table A3-2.
Calculation of Multi-attribute Utility Scores for Preference Pattern B

CLUSTER B

Metric	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	MAU
Overall Weights	0.07	0.09	0 05	0.06	0.11	0.07	0.09	0 07	0.06	0.04	0.06	0.05	0 08	0.07	0.06	
Barrier Island Comp Plan	0.0085	0.1059	0.0201	0 0706			0.0695	0.0235	0 0176	0 0471	0.0706	0.0588	0.0941	0 0824	0 0706	0.7393
Barrier Island Option A	0.0121	0.1059	0.0588	0 0706			0.0075	0.0118	0 0706	0 0269	0.0706	0.0588	0.0941	0 0618	0 0565	0.7058
Barrier Island Option C1 & C2	0.0061	0.1059	0.0063	0 0706			0.0816	0.0471	0 0176	0 0336	0.0353	0.0588	0.0753	0 0412	0 0565	0.6358
Barrier Island Option E	0.0000	0.1059	0.0262	0 0706			0.1018	0.0588	0 0000	0 0336	0.0353	0.0588	0.0000	0 0206	0 0282	0.5398
Barrier Island Option D	0.0000	0.1059	0.0237	0 0706			0.1044	0.0706	0 0000	0 0269	0.0353	0.0588	0.0000	0 0000	0 0282	0.5244
Barrier Island Option B	0.0193	0.1059	0.0198	0 0706			0.0000	0.0000	0 0706	0 0202	0.0353	0.0588	0.0565	0 0206	0 0424	0.5198
Barrier Island Option G	0.0024	0.0739	0.0138	0 0066			0.0940	0.0235	0 0000	0 0403	0.0353	0.0588	0.0376	0 0412	0 0282	0.4557
Barrier Island Option F	0.0824	0.0000	0.0000	0 0000			0.0783	0.0000	0 0176	0 0067	0.0353	0.0588	0.0000	0.0000	0 0282	0.3073
Barrier Island No Action	0.0000	0.0000	0.0000	0 0000			0.1059	0.0824	0 0000	0 0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.1882
LOD2 Option K			0.0761				0.1207	0.0702	0 0000	0 0702	0.1053	0.0877	0.1404	0.0819		0.7523
LOD2 Option J			0.0877				0.0000	0.0175	0.1053	0 0468	0.1053	0.0877	0.0842	0.0819		0.6164
LOD2 Option I			0.0877				0.0039	0.0000	0.1053	0 0234	0.0526	0.0439	0.0561	0.1228		0.4957
LOD2 No Action			0.0000				0.1579	0.1228	0 0000	0 0000	0.0000	0.0000	0.0000	0 0000		0.2807
Turkey Creek No Action			0.0000				0.1957	0.1522		0 0000			0.1739	0.1522	0 0000	0.6739
Turkey Creek Ecosystem Plan 5			0.0235				0.1332	0.1014		0 0290			0.0696	0 0000	0 0652	0.4219
Turkey Creek Ecosystem Plan 3			0.0852				0.0353	0.0507		0 0580			0.0348	0 0304	0 0978	0.3923
Turkey Creek Ecosystem Plan 1			0.1087				0.0000	0.0000		0 0870			0.0000	0 0609	0.1304	0.3870
Bayou Cumbest Acquisition	0.0000				0.1571		0.1019	0.0500		0 0000	0.0857	0.0714	0.0571	0.1000	0 0686	0.6919
Bayou Cumbest Ecosystem Plan 6	0.1000				0.1571		0.0411	0.0333		0 0000	0.0857	0.0714	0.0000	0 0000	0 0857	0.5744
Bayou Cumbest Ecosystem Plan 3	0.1000				0.1571		0.0410	0.0333		0 0000	0.0857	0.0714	0.0000	0 0000	0 0857	0.5743
Bayou Cumbest Ecosystem Plan 2	0.1000				0.1571		0.0274	0.0167		0 0000	0.0857	0.0714	0.0190	0 0000	0 0857	0.5631
Bayou Cumbest Ecosystem Plan 1	0.1000				0.1571		0.0000	0.0000		0 0000	0.0857	0.0714	0.0381	0 0000	0 0857	0.5381
Bayou Cumbest No Action	0.0000				0 0000		0.1286	0.1000		0 0571	0.0000	0.0000	0.1143	0.1000	0 0000	0.5000
Admiral Island No Action	0.0000						0.1875	0.1458		0 0000			0.1667	0.1458	0 0000	0.6458
Admiral Island Ecosystem Plan 6	0.1458						0.0302	0.0486		0 0833			0.0000	0.0000	0.1250	0.4329
Admiral Island Ecosystem Plan 3	0.1458						0.0297	0.0486		0 0833			0.0000	0.0000	0.1250	0.4325
Admiral Island Ecosystem Plan 2	0.1458						0.0197	0.0243		0 0833			0.0278	0.0000	0.1250	0.4259
Admiral Island Ecosystem Plan 1	0.1458						0.0000	0.0000		0 0833			0.0556	0.0000	0.1250	0.4097
Dantzler No Action			0.0000				0.1957	0.1522		0 0000			0.1739	0.1522	0 0000	0.6739
Dantzler Ecosystem Plan 3			0.0426				0.1051	0.0380		0 0580			0.0348	0 0304	0 0978	0.4068
Dantzler Ecosystem Plan 5			0.0661				0.0874	0.0761		0 0290			0.0696	0 0000	0 0652	0.3933
Dantzler Ecosystem Plan 1			0.1087				0.0000	0.0000		0 0870			0.0000	0 0609	0.1304	0.3870
Franklin Creek No Action			0.0000				0.1957	0.1522		0 0000			0.1739	0.1522	0 0000	0.6739
Franklin Creek Ecosystem Plan 3			0.0409				0.1296	0.0380		0 0580			0.0348	0 0000	0 0978	0.3991
Franklin Creek Ecosystem Plan 1			0.1087				0.0000	0.0000		0 0870			0.0000	0 0380	0.1304	0.3641
Forrest Heights Plan 2				0 0000	0.1447	0.0921	0.0000	0.0000		0 0526	0.0789	0.0658	0.0000	0 0461	0 0789	0.5592
Forrest Heights Plan 1				0 0429	0.1445	0.0920	0.0395	0.0000		0 0439	0.0592	0.0493	0.0211	0 0000	0 0632	0.5556
Forrest Heights No Action				0 0789	0 0000	0.0000	0.1184	0.0921		0.0000	0.0000	0.0000	0.1053	0 0921	0 0000	0.4868
Long-term Homeowners Assistance Plan					0.1447	0.0921	0.0000	0.0000	0 0789	0 0000	0.0789	0.0658	0.0000	0 0000	0 0789	0.5395
High Risk Homeowners Assistance Plan					0 0154	0.0098	0.1113	0.0461	0 0316	0 0526	0.0592	0.0329	0.0632	0.0000	0 0592	0.4813
No Action Homeowners Assistance Plan					0 0000	0.0000	0.1184	0.0921	0 0000	0 0000	0.0000	0.0000	0.1053	0.0921	0 0000	0.4079

Table A3-3.
Calculation of Multi-attribute Utility Scores for Preference Pattern C

CLUSTER C

Metric	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	MAU
Overall Weights	0.12	0.17	0 09	0.12	0.05	0.03	0.06	0 05	0.03	0.05	0.04	0.03	0 09	0 06	0.02	
Barrier Island Option A	0.0189	0.1828	0.0968	0.1290			0.0046	0.0077	0 0323	0 0307	0.0430	0.0323	0.0968	0.0484	0 0172	0.7403
Barrier Island Comp Plan	0.0134	0.1828	0.0330	0.1290			0.0424	0.0154	0 0081	0 0538	0.0430	0.0323	0.0968	0.0645	0 0215	0.7358
Barrier Island Option C1 & C2	0.0096	0.1828	0.0103	0.1290			0.0497	0.0307	0.0081	0 0384	0.0215	0.0323	0.0774	0.0323	0 0172	0.6392
Barrier Island Option E	0.0000	0.1828	0.0431	0.1290			0.0620	0.0384	0.0000	0 0384	0.0215	0.0323	0.0000	0.0161	0 0086	0.5723
Barrier Island Option B	0.0302	0.1828	0.0326	0.1290			0.0000	0.0000	0.0323	0 0230	0.0215	0.0323	0.0581	0.0161	0 0129	0.5707
Barrier Island Option D	0.0000	0.1828	0.0390	0.1290			0.0636	0.0461	0.0000	0 0307	0.0215	0.0323	0.0000	0.0000	0 0086	0.5536
Barrier Island Option G	0.0038	0.1275	0.0227	0.0120			0.0573	0.0154	0.0000	0 0461	0.0215	0.0323	0.0387	0.0323	0 0086	0.4181
Barrier Island Option F	0.1290	0.0000	0.0000	0.0000			0.0477	0.0000	0 0081	0 0077	0.0215	0.0323	0.0000	0.0000	0 0086	0.2548
Barrier Island No Action	0.0000	0.0000	0.0000	0 0000			0.0645	0.0538	0 0000	0 0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.1183
LOD2 Option K			0.1561				0.0917	0.0571	0 0000	0.1000	0.0800	0.0600	0.1800	0.0800		0.8050
LOD2 Option J			0.1800				0.0000	0.0143	0 0600	0 0667	0.0800	0.0600	0.1080	0.0800		0.6490
LOD2 Option I			0.1800				0.0029	0.0000	0 0600	0 0333	0.0400	0.0300	0.0720	0.1200		0.5383
LOD2 No Action			0.0000				0.1200	0.1000	0 0000	0 0000	0.0000	0.0000	0.0000	0.0000		0.2200
Turkey Creek No Action			0.0000				0.1429	0.1190		0 0000			0.2143	0.1429	0 0000	0.6190
Turkey Creek Ecosystem Plan 1			0.2143				0.0000	0.0000		0.1190			0.0000	0.0571	0 0476	0.4381
Turkey Creek Ecosystem Plan 3			0.1680				0.0258	0.0397		0 0794			0.0429	0.0286	0 0357	0.4200
Turkey Creek Ecosystem Plan 5			0.0463				0.0972	0.0794		0 0397			0.0857	0.0000	0 0238	0.3721
Bayou Cumbest Acquisition	0.0000				0 0877		0.0834	0.0439		0 0000	0.0702	0.0526	0.0789	0.1053	0 0281	0.5501
Bayou Cumbest No Action	0.0000				0 0000		0.1053	0.0877		0 0877	0.0000	0.0000	0.1579	0.1053	0 0000	0.5439
Bayou Cumbest Ecosystem Plan 2	0.2105				0 0877		0.0224	0.0146		0 0000	0.0702	0.0526	0.0263	0.0000	0 0351	0.5195
Bayou Cumbest Ecosystem Plan 6	0.2105				0 0877		0.0336	0.0292		0 0000	0.0702	0.0526	0.0000	0.0000	0 0351	0.5190
Bayou Cumbest Ecosystem Plan 3	0.2105				0 0877		0.0335	0.0292		0 0000	0.0702	0.0526	0.0000	0.0000	0 0351	0.5189
Bayou Cumbest Ecosystem Plan 1	0.2105				0 0877		0.0000	0.0000		0 0000	0.0702	0.0526	0.0526	0.0000	0 0351	0.5088
Admiral Island No Action	0.0000						0.1333	0.1111		0 0000			0.2000	0.1333	0 0000	0.5778
Admiral Island Ecosystem Plan 1	0.2667						0.0000	0.0000		0.1111			0.0667	0.0000	0 0444	0.4889
Admiral Island Ecosystem Plan 2	0.2667						0.0140	0.0185		0.1111			0.0333	0 0000	0 0444	0.4881
Admiral Island Ecosystem Plan 6	0.2667						0.0214	0.0370		0.1111			0.0000	0 0000	0 0444	0.4807
Admiral Island Ecosystem Plan 3	0.2667						0.0211	0.0370		0.1111			0.0000	0 0000	0 0444	0.4804
Dantzler No Action			0.0000				0.1429	0.1190		0 0000			0.2143	0.1429	0 0000	0.6190
Dantzler Ecosystem Plan 1			0.2143				0.0000	0.0000		0.1190			0.0000	0 0571	0 0476	0.4381
Dantzler Ecosystem Plan 5			0.1302				0.0638	0.0595		0 0397			0.0857	0 0000	0 0238	0.4028
Dantzler Ecosystem Plan 3			0.0840				0.0767	0.0298		0 0794			0.0429	0 0286	0 0357	0.3771
Franklin Creek No Action			0.0000				0.1429	0.1190		0 0000			0.2143	0.1429	0 0000	0.6190
Franklin Creek Ecosystem Plan 1			0.2143				0.0000	0.0000		0.1190			0.0000	0.0357	0 0476	0.4167
Franklin Creek Ecosystem Plan 3			0.0805				0.0947	0.0298		0 0794			0.0429	0 0000	0 0357	0.3629
Forrest Heights No Action				0 2000	0 0000	0.0000	0.1000	0.0833		0 0000	0.0000	0.0000	0.1500	0.1000	0 0000	0.6333
Forrest Heights Plan 1				0.1087	0 0832	0.0500	0.0333	0.0000		0.0694	0.0500	0.0375	0.0300	0 0000	0 0267	0.4888
Forrest Heights Plan 2				0 0000	0.0833	0.0500	0.0000	0.0000		0.0833	0.0667	0.0500	0.0000	0 0500	0 0333	0.4167
High Risk Homeowners Assistance Plan					0.0105	0.0063	0.1106	0.0490	0 0235	0.0833	0.0500	0.0250	0.0900	0 0000	0 0250	0.4732
No Action Homeowners Assistance Plan					0 0000	0.0000	0.1176	0.0980	0 0000	0 0000	0.0000	0.0000	0.1500	0.1000	0 0000	0.4657
Long-term Homeowners Assistance Plan					0 0980	0.0588	0.0000	0.0000	0 0588	0 0000	0.0667	0.0500	0.0000	0.0000	0 0333	0.3657

Table A3-4
Calculation of Multi-attribute Utility Scores for Preference Pattern D

CLUSTER D

Metric	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	MAU
Overall Weights	0.21	0.18	0.13	0.18	0.04	0.04	0.02	0 02	0.02	0.02	0.02	0.02	0 05	0 03	0.03	
Barrier Island Option A	0.0330	0.1935	0.1398	0.1935			0.0015	0.0031	0 0215	0 0123	0.0215	0.0215	0.0538	0.0242	0 0258	0.7451
Barrier Island Comp Plan	0.0234	0.1935	0.0476	0.1935			0.0141	0.0061	0 0054	0 0215	0.0215	0.0215	0.0538	0.0323	0 0323	0.6666
Barrier Island Option B	0.0528	0.1935	0.0471	0.1935			0.0000	0.0000	0 0215	0 0092	0.0108	0.0215	0.0323	0.0081	0 0194	0.6096
Barrier Island Option C1 & C2	0.0167	0.1935	0.0149	0.1935			0.0166	0.0123	0.0054	0 0154	0.0108	0.0215	0.0430	0.0161	0 0258	0.5855
Barrier Island Option E	0.0000	0.1935	0.0623	0.1935			0.0207	0.0154	0.0000	0 0154	0.0108	0.0215	0.0000	0.0081	0 0129	0.5540
Barrier Island Option D	0.0000	0.1935	0.0563	0.1935			0.0212	0.0184	0.0000	0 0123	0.0108	0.0215	0.0000	0.0000	0 0129	0.5405
Barrier Island Option G	0.0067	0.1350	0.0327	0.0180			0.0191	0.0061	0.0000	0 0184	0.0108	0.0215	0.0215	0.0161	0 0129	0.3190
Barrier Island Option F	0.2258	0.0000	0.0000	0.0000			0.0159	0.0000	0 0054	0 0031	0.0108	0.0215	0.0000	0.0000	0 0129	0.2953
Barrier Island No Action	0.0000	0.0000	0.0000	0 0000			0.0215	0.0215	0 0000	0 0000	0.0000	0.0000	0.0000	0.0000	0 0000	0.0430
LOD2 Option K			0.3417				0.0463	0.0346	0 0000	0 0606	0.0606	0.0606	0.1515	0.0606		0.8166
LOD2 Option J			0.3939				0.0000	0.0087	0 0606	0 0404	0.0606	0.0606	0.0909	0.0606		0.7763
LOD2 Option I			0.3939				0.0015	0.0000	0 0606	0 0202	0.0303	0.0303	0.0606	0.0909		0.6883
LOD2 No Action			0.0000				0.0606	0.0606	0 0000	0 0000	0.0000	0.0000	0.0000	0.0000		0.1212
Turkey Creek Ecosystem Plan 1			0.4333				0.0000	0.0000		0 0667			0.0000	0.0400	0.1000	0.6400
Turkey Creek Ecosystem Plan 3			0.3397				0.0120	0.0222		0 0444			0.0333	0.0200	0 0750	0.5467
Turkey Creek No Action			0.0000				0.0667	0.0667		0 0000			0.1667	0.1000	0 0000	0.4000
Turkey Creek Ecosystem Plan 5			0.0937				0.0454	0.0444		0 0222			0.0667	0.0000	0 0500	0.3224
Bayou Cumbest Ecosystem Plan 1	0.4565				0 0870		0.0000	0.0000		0 0000	0.0435	0.0435	0.0362	0.0000	0 0652	0.7319
Bayou Cumbest Ecosystem Plan 2	0.4565				0 0870		0.0093	0.0072		0 0000	0.0435	0.0435	0.0181	0.0000	0 0652	0.7303
Bayou Cumbest Ecosystem Plan 6	0.4565				0 0870		0.0139	0.0145		0 0000	0.0435	0.0435	0.0000	0.0000	0 0652	0.7240
Bayou Cumbest Ecosystem Plan 3	0.4565				0 0870		0.0139	0.0145		0 0000	0.0435	0.0435	0.0000	0.0000	0 0652	0.7240
Bayou Cumbest Acquisition	0.0000				0 0870		0.0344	0.0217		0 0000	0.0435	0.0435	0.0543	0.0652	0 0522	0.4018
Bayou Cumbest No Action	0.0000				0 0000		0.0435	0.0435		0 0435	0.0000	0.0000	0.1087	0.0652	0 0000	0.3043
Admiral Island Ecosystem Plan 1	0.5526						0.0000	0.0000		0 0526			0.0439	0 0000	0 0789	0.7281
Admiral Island Ecosystem Plan 2	0.5526						0.0055	0.0088		0 0526			0.0219	0 0000	0 0789	0.7204
Admiral Island Ecosystem Plan 6	0.5526						0.0085	0.0175		0 0526			0.0000	0 0000	0 0789	0.7102
Admiral Island Ecosystem Plan 3	0.5526						0.0083	0.0175		0 0526			0.0000	0 0000	0 0789	0.7101
Admiral Island No Action	0.0000						0.0526	0.0526		0 0000			0.1316	0 0789	0 0000	0.3158
Dantzler Ecosystem Plan 1			0.4333				0.0000	0.0000		0 0667			0.0000	0 0400	0.1000	0.6400
Dantzler Ecosystem Plan 5			0.2634				0.0298	0.0333		0 0222			0.0667	0 0000	0 0500	0.4654
Dantzler No Action			0.0000				0.0667	0.0667		0 0000			0.1667	0.1000	0 0000	0.4000
Dantzler Ecosystem Plan 3			0.1700				0.0358	0.0167		0 0444			0.0333	0 0200	0 0750	0.3952
Franklin Creek Ecosystem Plan 1			0.4333				0.0000	0.0000		0 0667			0.0000	0 0250	0.1000	0.6250
Franklin Creek No Action			0.0000				0.0667	0.0667		0 0000			0.1667	0.1000	0 0000	0.4000
Franklin Creek Ecosystem Plan 3			0.1629				0.0442	0.0167		0 0444			0.0333	0 0000	0 0750	0.3765
Forrest Heights No Action				0 3830	0 0000	0.0000	0.0426	0.0426		0 0000	0.0000	0.0000	0.1064	0 0638	0 0000	0.6383
Forrest Heights Plan 1				0 2082	0.0850	0.0850	0.0142	0.0000		0.0355	0.0319	0.0319	0.0213	0 0000	0 0511	0.5640
Forrest Heights Plan 2				0 0000	0.0851	0.0851	0.0000	0.0000		0.0426	0.0426	0.0426	0.0000	0 0319	0 0638	0.3936
Long-term Homeowners Assistance Plan					0.1290	0.1290	0.0000	0.0000	0 0645	0.0000	0.0426	0.0426	0.0000	0 0000	0 0638	0.4715
High Risk Homeowners Assistance Plan					0.0138	0.0138	0.0606	0.0323	0 0258	0 0426	0.0319	0.0213	0.0638	0.0000	0 0479	0.3537
No Action Homeowners Assistance Plan					0 0000	0.0000	0.0645	0.0645	0 0000	0 0000	0.0000	0.0000	0.1064	0.0638	0 0000	0.2992