Risk Informed Decision Framework for Louisiana Coastal Protection and Restoration (LACPR)

24 April 2007

The Need for Risk-Informed Planning:

The Risk-Informed Decision Framework (RIDF) is proposed as a planning tool for LACPR. The five main purposes of the RIDF are to:

1) identify, assess, communicate and manage risks to life, health, the environment and economics associated with hurricane-induced flooding and residual risks associated with risk mitigation plans;
2) account for the major uncertainties in the planning environment that could affect the performance of plans in the future;
3) identify data gaps that could influence decisions;
4) provide the basis for ranking the performance of alternative plan formulations based on risk metrics correlated to planning objectives and stakeholder values;
5) establish confidence levels for planning decisions and recommendations.

History has shown that storm and flood risks change over time. This is a result of changes in weather patterns, changes in land use patterns, or perhaps changes in project performance. Over the course of a project's life, conditions may differ from the expectations that were anticipated during pre-project planning. The RIDF described here is being developed to guide planning decisions by providing information to decision-makers on a plausible set of future conditions. The risks and uncertainties are characterized with respect to the multiple objectives and metrics relevant to hurricane-induced flooding. These multiple objectives and metrics include issues related to human health and safety, national economic development, regional economic development, environmental quality, national security, among others. The RIDF augments standard planning approaches by incorporating scenario analysis, risk analysis, and multi-criteria decision analysis (MCDA) to accomplish risk-informed planning. This augmented planning process provides the means to structure and integrate information about multiple, diverse objectives, stakeholder values and uncertainty in the evaluation of plans. What follows below is a brief description of the six major elements of the RIDF (Figure 1).

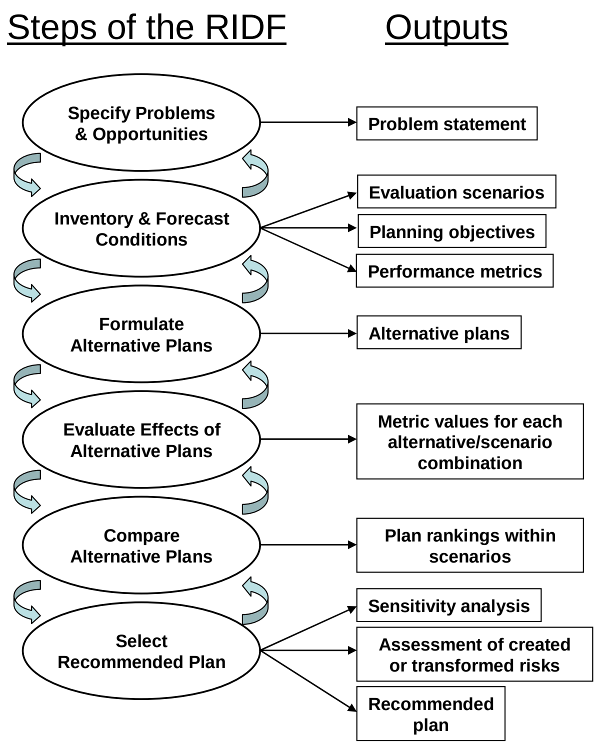

Figure 1. Steps and Outputs of the RIDF.

Risk-Informed Decision Framework

Step One: Specify Problems and Opportunities

The first step of the RIDF identifies the specific problem(s) being addressed by the planning process. Developing a clear and comprehensive understanding of the problem is a critical anchor point for the planning process because plans will be formulated, evaluated, and compared based on this understanding. Characterizing the problem includes identifying the events or sequences of events posing risks to life, property, economics, and the environment. Problem identification is a deliberate process that considers past and future events shaping the understanding of the problem.

Figure 2 is an influence diagram that represents one conceptualization of the problem being addressed by the LACPR in terms of the relationships among sources, stressors, human and environmental responses and endpoints measured. Hurricanes, sea level rise, and subsidence are the contributing sources of rain, surge, and wind stressors that result in the human and environmental responses. The overall aim of the LACPR is to minimize, to the extent feasible, residual risks to people, property, economic interests, the environment, and cultural resources resulting from these various sources and stressors. The term *residual risk* is used here to refer to the risk that will remain after action is taken and a plan is fully implemented. Risks can only be reduced, not eliminated. This is true for any range of problems, including such problems as infectious disease transmission, human transportation, as well as storm and flood protection.

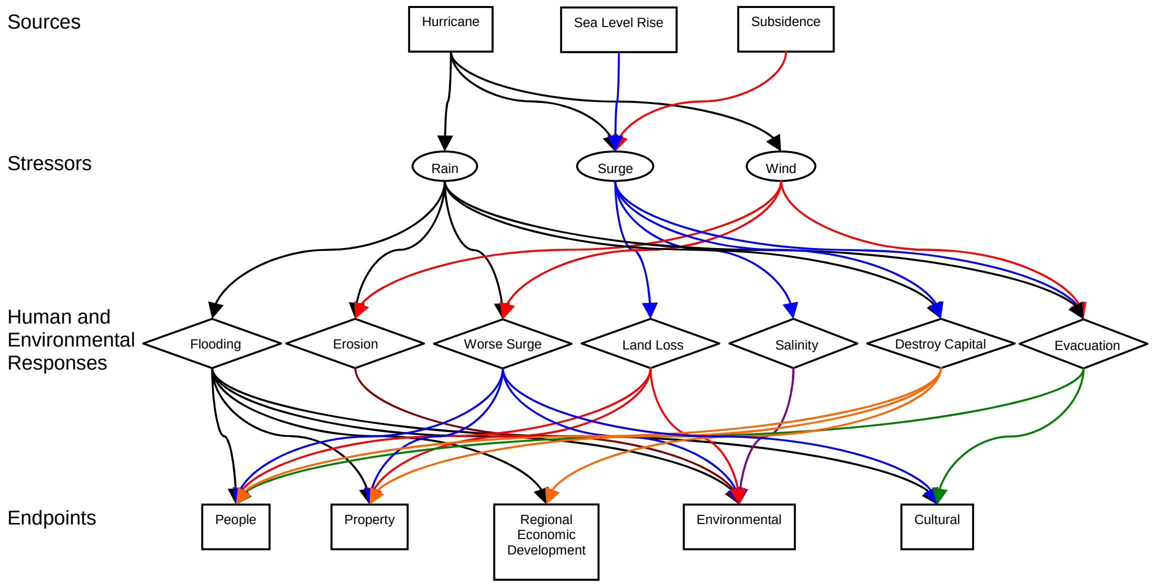

Figure 2. LACPR Influence Diagram Showing Sources, Stressors, Responses, and Endpoints.

The following problem statement will guide risk-informed planning within the LACPR:

The people, economy, environment, and culture of south Louisiana, as well as the Nation, are at risk from severe and catastrophic hurricane storm events as manifested by:

- Increasing risk to people and property from catastrophic hurricane storm events.
- Increasing vulnerability of coastal communities to inundation from hurricane induced storm damages due to coastal subsidence, wetland losses, and relative sea level rise.
- National and regional economic losses from hurricane flooding to residential, public, industrial, and commercial infrastructure / assets.
- Losses to high levels of productivity and resilience of south Louisiana coastal ecosystem due to natural conditions and coastal storm disturbances.
- Risks to historic properties and traditional cultures and their ties and relationships to the natural environment due to catastrophic hurricane storm events.

Step Two: Inventory and Forecast Conditions

The second step of the RIDF develops an inventory and forecast of critical resources (physical, demographic, economic, and social, etc.) relevant to the problems and opportunities under consideration in the planning area. This step of the RIDF includes three major components: scenario development, definition of planning objectives, development of performance metrics.

Scenario Development

The plans that will be formulated and evaluated in the LACPR are intended to address both present and future risks associated with flood and storm inundation events. Evaluating plans with respect to the no action alternative requires making predictions about conditions that will exist in the future.

There are significant sources of uncertainty that relate to future conditions. Scenario analysis is being used within the RIDF to include consideration of uncertainties associated with future conditions in the planning process. Scenarios are developed to:

- address planning elements that are difficult to quantify, e.g., subjective interpretations of facts, shifts in values, new regulations or inventions.
- combine a number of uncertain factors in a manner that facilitates evaluating the robustness of a plan.

Scenarios are descriptions of alternative future conditions that are developed using information provided by technical experts (e.g., in climatology, geology, statistics, economics, etc.). They are not predictions or strategies. Instead, they represent hypotheses about different futures that are designed to highlight the risks and opportunities involved in planning. The use of scenarios within the plan evaluation process provides decision-makers and stakeholders with the opportunity to evaluate the robustness of proposed plans with respect to these uncertain future conditions.

The four principal factors around which scenarios are being developed for the LACPR are: sea level rise, subsidence, storm intensity, and redevelopment patterns within local communities in south Louisiana. The scenarios under development combine high and low levels of sea level rise with high and low levels of regional redevelopment (societal and economic recovery from Hurricanes Katrina and Rita).

Planning objectives

The planning objectives developed for the LACPR are:

- Reduce risk to public safety from catastrophic storm inundation;
- Reduce damages from catastrophic storm inundation;
- Promote a sustainable ecosystem;
- Restore and sustain diverse fish and wildlife habitats, and;
- Sustain the unique heritage of coastal Louisiana by protecting historic sites and supporting traditional cultures.

Performance metrics

Performance metrics are being developed within the RIDF that will be used to evaluate plans to establish the degree to which they satisfy the planning objectives. Performance metrics developed for projects such as the LACPR involve quantification of a complex array of human and natural system drivers. Therefore, any set of metrics will not be representative of all the decision factors that could be brought to bear on the problem. For this reason, metrics are often referred to as indicators, to emphasize the representational relationship metrics have to the state of complex systems. They are indicative – but not definitive – gauges, and consequently must be interpreted with their limitations in mind.

The list of current metrics being developed to conduct plan evaluations are presented in Table 1. These metrics will be used to score and then rank flood and storm damage reduction measures and plans within each scenario. In selecting this set of metrics, the LACPR project team is striving to represent the best available information for evaluating alternatives, keeping in mind the characteristics of effective metrics. Effective metrics will be: scientifically verifiable; cost-effective; easy to communicate to a wide audience; credible; scalable; relevant; sensitive enough to capture the minimum meaningful level of change; minimally redundant; and transparent.

Metric estimates can be derived from mathematical models, empirical data, or expert opinion. Metric estimates within the RIDF will be supported by descriptions of the important underlying assumptions associated with their use. In addition, estimates of uncertainty for metric values will be quantified (e.g., in terms of the variance or range associated with the estimate) to support risk-informed decisions.

Table 1. LACPR Objectives and Metrics.

Plan Performance Objectives for Risk Reduction		Metrics	(Units)	Description	Data Source
People	Protect public health and safety from catastrophic storm inundation.	Resident Population / Exposed Population	Number of people	Expected future evacuation behavior will be based upon a post-Katrina and post-Rita analysis provided by the Louisiana Department of Homeland Security and Emergency Preparedness. The results of this study will be used to establish a set of expected evacuation rates for future storms.	Models and Empirical Data
Economy	Reduce damages from catastrophic storm inundation.	Expected Annual Damages	$	Measures the dollar damages to assets in the study area. Damages will be expressed in expected annual equivalent terms, which are the product of the annual probability of a particular storm's occurrence times the damages that would be caused by a storm of those characteristics and are summed across the full frequency curve to arrive at expected annual damages for a geographic region.	Models
		Regional Economic Development (RED): Gross Regional Output, Number of People Employed, and People's Earned Income	$ for Output and Income; Number of individuals employed in the workforce for Employment	Will be modeled with a regional forecasting model assembled specifically for this region by Regional Economic Model, Inc. (REMI).	Model
		Cost of Implementation and Operations/Maintenance	$	These costs will occur at different times during the planning horizon for each of the different alternatives.	Empirical Data
		Residual risk	$	EAD with project in place	Model

Plan Performance Objectives for Risk Reduction		Metrics	(Units)	Description	Data Source
Environment	Promote a sustainable ecosystem.	Sustainability Index	Unitless	Acreage loss with project divided by acreage loss without project (0-1 scale)	Empirical Data and Expert Opinion
	Restore and sustain diverse fish and wildlife habitats.	Habitat Relative Abundance	Acres	Acres by habitat type	Empirical Data and Expert Opinion
	Reduce surge and waves	Surge or wave reduction	Unitless	Percentage change in surge and wave elevations with the presence or absence of coastal wetlands and marshes.	Models, Empirical Data & Expert Opinion
Culture	Sustain the unique heritage of coastal Louisiana by protecting historic sites and supporting traditional cultures.	Cultural sites protected	Number of sites	Includes the number of sites, properties, and structures to be protected. Cultural resources are sites, properties, and structures that are especially noteworthy with respect to the culture of communities. Location information will be compiled for all such sites, properties, and structures and mapped against areas protected or not protected from flooding by a particular project alternative.	Empirical Data

Step Three: Formulate Alternative Plans

Plan formulation is the process of building plans that meet planning objectives and avoid planning constraints. During early phases of the LACPR, many structural, non structural and coastal landscape stabilization measures were identified through public and stakeholder workshops and interagency consultation. Measures were also gathered from several other sources including other coastal area plans and programs; local, parish, and landowner plans; study workshops; the NEPA scoping process; and other public input. These management measures have been identified for implementation at specific geographic sites to address one or more of the planning objectives. These measures will form the building blocks to develop alternative plans.

The management measures identified to date fall broadly into three categories: structural measures (e.g., levees, floodwalls, surge gates, pump stations, bank and shoreline armoring), non-structural measures (e.g., buyout of property and permanent evacuation of population at risk, wet and dry flood proofing, raising-structures-in-place, relocation of structures and population into clusters at flood-free sites), and coastal restoration (e.g., land/marsh building diversions, bank gapping and crevasse management, mechanical marsh creation, barrier island/shoreline restoration, bank /shoreline stabilization, and ridge restoration). For purposes of plan formulation, the southern part of Louisiana was divided into 5 planning units based on social and physical characteristics and hydrology. An inventory and graphical documentation of the coastal protection and restoration measures being considered for southern Louisiana are presented in the LACPR Plan Formulation Atlas.

The Corps is partnering with a State agency, the Coastal Protection and Restoration Authority (CPRA), to study and recommend implementation of hurricane risk reduction strategies. The CPRA is developing a master plan to provide a long-term vision for project features that implement the recommended strategy. The LACPR technical team has participated in screening workshops with the state and other stakeholders to produce the alternative recommended in the master plan. Example screening criteria include: extraordinarily high construction and operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) costs; excessive time of construction; unproven engineering design/methods; increased wetland loss; excessive real estate acquisition issues. The aim of applying these initial screening criteria is to eliminate clearly inferior choices from further consideration. Much of this screening task has been completed during the development of the master plan.

The LACPR technical team will continue to work with the CPRA and others to define plan features that are not addressed or refined in the master plan. The team's objective is to formulate and evaluate a sufficient number of alternatives to illuminate the trade-offs (in inputs and outputs) between strategies that emphasize structural, nonstructural, and coastal features. The final array of plans would include differing combinations of these features.

Each alternative plan will then be refined through an iterative process of continued formulation that is coupled with technical evaluations. The formulation process will provide opportunities for continued coordination with stakeholders and the general public through the completion of the final technical report.

Step Four: Evaluate Effects of Alternative Plans

The performance of each formulated plan will be evaluated with respect to each metric and scenario developed in Step 2 of the RIDF.

The base condition for planning is 2010, which is defined as the status of the protection system and the assets and people that will be present in 2010. Plans will be evaluated with the economic and demographic conditions of 2010 and the levee alignments expected to be in place in 2010 as a starting condition for the 50-year period of analysis. Conditions are expected to change, over the period analysis, within the parameters outlined by the differing scenarios developed to describe plausible sea level rise and redevelopment/population trends.

Plans will be designed and evaluated based on flood stage frequencies derived from the maximum stages generated by the Advanced Circulation (ADCIRC) model. In ADCIRC, numerous storms having various intensities, sizes, tracks and forward speeds are simulated and data on the maximum stages and wave characteristics at points of interest are generated. These data form the basis for calculating metric values.

Once a levee system has been designed to protect against a certain level of storm surge and waves, the flooding effects of larger surges and waves will be analyzed to ascertain the residual risk of flooding to the area behind the levee or floodwall. What is needed to conduct this analysis is an estimate of the volume of water that overtops a given levee design and its frequency of occurrence. This information will be developed from hydrographs generated in the ADCIRC simulation, coupled with the statistical analysis to produce storm surge hydrographs. Estimates of overtopping frequencies can then be obtained from the hydrographs and the estimates are used for evaluating each protection plan. The surge levels outside the levee system and interior flood levels caused by rainfall and/or overtopping combine to represent the flood risk across south Louisiana. Changes to flood risk and associated consequences will be estimated for each alternative through each of the metrics described in Table 1.

The next step within the evaluation is to translate the output we obtain for each metric into a performance score for each evaluated plan. This will be accomplished using MCDA methods which are based on Multi-Attribute Utility Theory (MAUT). Using this approach, input values for metrics are combined with information about stakeholder and decision-maker values and weighting functions to generate an overall score for each plan being evaluated. These scores allow for direct comparisons to be made across all the alternatives plans being evaluated for a planning unit and to rank plans in relation to each other in terms of the degree to which they satisfy the objectives the LACPR metrics represent. Such scores can be used to evaluate measures or plans against the without/with project condition.

MCDA will be implemented in several steps. The first step in the MCDA process is the creation of a single criterion utility function for each metric. The utility function normalizes the performance estimate for each metric by describing preferences regarding different levels of each metric. They translate the physical metric into a measurement of value, and are scaled between 0 and 1, representing the worst and best values, respectively. Although several methods can be applied to reflect how an individual's degree of satisfaction changes across the scale, we will use a simple additive and linear value scale. After a single utility function is developed separately for each metric, the utility values, along with estimates of uncertainty in those values, will be weighted and aggregated into a multicriteria utility function to allow an overall comparison of the alternatives. This weighting judgment and aggregation process occurs in Step 5.

Step Five: Compare Alternative Plans

This step combines performance data with weighting information to rank evaluated plans within each scenario. The utility function developed in Step Four is combined with data that define the relative importance or value assigned to each metric (i.e., the metric's weight). Weightings will be developed through an iterative process within the LACPR team and through interaction with stakeholders. The likely outcome of weighting and alternative scoring and ranking will be the identification of a subset of alternatives from which decision-makers will make their final selections. It is critical that final scores and rankings for alternatives be presented to decision-makers in a format that makes the comparisons clear and concise.

Step Six: Select Recommended Plan

The final step in the planning process is to select a recommended plan for each planning unit. The plan will be based on all the assembled information collected in the planning process, including all the values, weights, and metrics used to score and rank the measures. The comparison of ranked scores will produce outputs similar to the example provided in Figure 3 where the overall utility scores for competing plans, within a scenario, are presented along with the uncertainty associated with those scores.

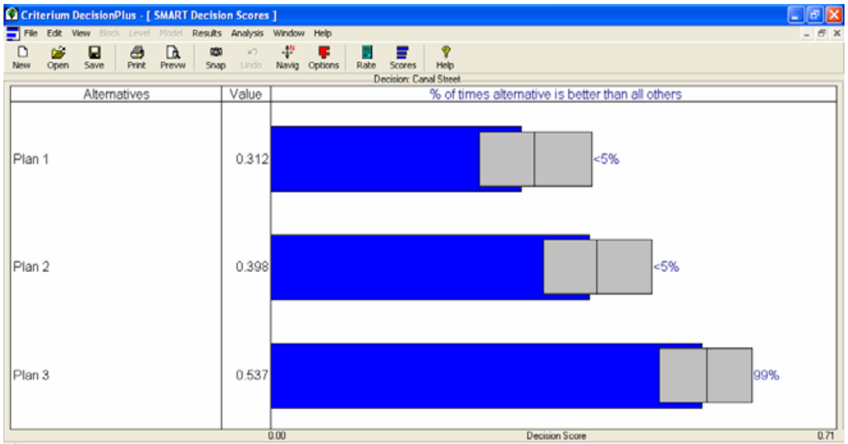

Figure 3. Hypothetical Example of a Comparison of Plans.

Sensitivity analysis will be performed to offer decision-makers and stakeholders a tangible understanding of the relative importance of the metrics and the robustness of the ranking of plans in terms of their cumulative scores. Such sensitivity analyses can be driven by key questions of interest. When used to answer questions of particular interest to decision-makers and stakeholders, sensitivity analysis can be an effective tool for establishing confidence in rankings and, ultimately, the decisions the planning process and rankings inform. It is important to note here that the decision-making process will be transparent to the degree that all the factors, issues, and concerns of relevance are included in the set of metrics used to score the measures.

Once a plan has been selected, a qualitative or quantitative assessment of any risks created or transformed by the plan will be conducted. A transformed or created risk would include increases in lives and property at risk attributable to the levee construction.

For the LACPR, tradeoffs will play a key role in decision-making, because the alternative plans will produce a range of services that are valued in diverse ways by societal groups. The analysis conducted within the RIDF will support decisions to balance tradeoffs among the planning objectives and resolve conflicts that may result from a lack of consensus on the desired future condition. One of the primary benefits of using the structure and quantitative approaches offered by MCDA is that these approaches can be used together as an exploratory/negotiation tool for considering the full range of issues germane to a problem/solution in a systematic, structured, rational, and efficient manner, resulting in more credible decisions. In cases where disagreement exists among decision-makers and stakeholders, the MCDA framework will be used to discover the nature of the disagreement which can then be identified and explored as a starting point for additional analysis, study and negotiation

Role for Adaptive Planning and Engineering

The Corps' Twelve Actions for Change recognize the need for applying a comprehensive systems approach to storm and flood protection projects based on adaptive planning and engineering principles. Adaptive planning and engineering acknowledges at the outset that uncertainty is inherent to any natural or engineered system. It seeks to address this uncertainty by learning about the system over time. The sequencing, scaled implementation, and monitoring of individual projects implemented as a part of a plan provide opportunities to update our knowledge of the system, address uncertainties, and adapt plans. A management strategy founded on the principles of adaptive planning and engineering will be key to successful execution of the LACPR.