DOI Strategic Sciences Working Group
Mississippi Canyon 252/Deepwater Horizon Oil Spill
Progress Report 2

April 2012

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Executive Summary

The U.S. Department of the Interior (DOI) has established a small Strategic Sciences Working Group, with the objective of rapidly providing DOI leadership with science-based analyses of how the MS252 oil spill may impact the ecology, economy, and people of the Gulf of Mexico. The Working Group convened its first session 25-28 May 2010 in Mobile, Alabama, and published its first progress report in August 2010. Building on the experience from the first session, the Strategic Sciences Working Group met again 20-24 September 2010 in New Orleans, Louisiana. This progress report describes the second session and contains: 1) the organizing framework, 2) methods used, 3) two developed scenarios with potential interventions, 4) lessons learned, and 5) recommendations. The Working Group consisted of a group of federal and non-federal scientists (see Appendix 1 for a list of current group participants). The Working Group reported to Dr. Marcia McNutt, Director, U.S. Geological Survey, and was led by Dr. Gary Machlis, Science Advisor to the Director, National Park Service.

Organizing Framework

The Working Group treated the region of potential impact as a *coupled natural-human system.* The human ecosystem conceptual model was used in both the first and second scenario-building sessions. The Working Group expanded the conceptual model and identified a list of biophysical variables to cover conditions specific to the MS252 oil spill in the first scenario-building session and used the same list in the second session. In addition to a coupled natural-human system conceptual model, the Working Group developed a scenario framework adapted from the scientific literature on natural hazards response.

Methods

The approach taken by the Working Group in the second session were substantially the same used in the first session and involved four main steps: 1) establish a matrix of alternative scenario parameters; 2) using a specific subset of the scenario parameters, develop a detailed "chain of consequences" that illustrates important cascading effects; 3) for each element in the chain of consequences, assign a qualitative level of scientific uncertainty; and 4) identify a set of potential "interventions" at points in the scenario when scientists, policy makers, and other responders might most effectively take action to alter the outcomes of the cascade such that a sustainable recovery is accelerated.

The Working Group used three key scenario parameters for the second session: 1) persistence of toxicity of the oil and dispersants remaining in the general environment of the Gulf region, 2) time horizons, and 3) geographic and spatial units of interest. During its first session, the Working Group established several geographic or spatial units to help focus the alternative scenarios and provide useful information to decision makers. These units were also used in the second session and include 1) vertical life zones, 2) major ecosystem types, 3) socio-political and administrative units, and 4) Gulf of Mexico Biodiversity Quadrants. The Working Group assumed that there would be at least one major tropical storm or hurricane landfall in the Gulf Mexico during recovery. The Working Group considered the remaining oil in the system as a baseline amount and used the Georgia Sea Grant definition of remaining oil, which assumed 3.2 million bbl of oil as of August 2010.

Limitations

The scenario-building technique employed by the Working Group has several limitations. The scenarios are not quantitative risk analyses or predictive models. This approach does not include detailed linkages and feedback loops among different components and does not use environmental endpoints and values. All possible trajectories cannot be anticipated. The assigned scientific uncertainties reflect the scientific literature and expert opinion for each individual consequence in a chain; summary uncertainties for a full chain of consequences or a scenario were not assigned. The scenarios are not spatially specific at scales other than the identified GOM quadrants and spatial units used as a parameter. Like most scenario-building, the scenarios are constrained by available expert opinion, information, and theory.

Preliminary Results

The first work session resulted in the development of three scenarios (reported in the first progress report, http://www.usgs.gov/oilspill/docs/SSWG_Progress_Report_09june10.pdf):

- Scenario 1 examined the time period from oil flow containment to the beginning of recovery, during which it was expected that stress in the system would continue to build (though at a slower rate).
- Scenario 2 examined the time horizons for short-term and long-term recovery, when MS252 oil spill-related stress to the system was expected to be declining.
- Scenario 3 examined the time horizons for short-term and long-term recovery, when MS252 oil spill-related stress to the system was expected to be declining. This scenario used the oil release estimates established by the DOI Flow Rate Technical Group, which were released while the Working Group session was underway.

The second work session created two additional scenarios, scenarios 4 and 5 (reported here).

Scenario 4

Scenario 4 examined the time period from the mid-term to long-term recovery/reorganization, during which it is expected that stress in the system would be declining. Numerous potential direct consequences were identified, including 1) contaminated Gulf seafood, 2) continuing human exposure to oil and dispersant, 3) contamination of coastal wetlands, 4) fish mortality, 5) contamination of the benthic life zone, 6) contamination of pelagic life zone, 7) depletions of marine/estuary populations, 8) behavioral response by animals, 9) continued contamination of beaches, 10) stressed wetland flora, 11) continued contamination of barrier islands, and 12) diverse post-spill activities. Several illustrative highlights emerge from this scenario:

- Of the twelve direct consequences, scientific certainty levels were high for eleven, with fish mortality deemed probable.

- Stressed wetland flora was linked to flora mortality via root kill, which leads to a reasonably certain decrease in habitat and plausible increase in severity of landfall storms' impact.
- Post-spill activities may produce a wide range of consequences; for example, a reasonably certain consequence of institutional changes is increased economic pressure on Gulf fisheries.
- Insufficient information is available regarding the likelihood of berm construction, but it is probable that berm construction, if undertaken, would lead to selected habitat degradation and reduced water quality.
- Heightened sensitivity to health issues for vulnerable populations such as the young, elderly, pregnant, or chronically ill, as a consequence of continued human exposure to oil and dispersant, has a high level of scientific certainty.
- Closure of commercial fisheries and oyster beds is likely to have substantial consequences for the coupled natural-human system. It is plausible that closures would lead to increases in select populations of specific species of fish and oysters and loss of traditional knowledge.

The scenario includes numerous potential interventions identified by the Working Group that could accelerate recovery. These interventions are listed below (in no order of priority).

Scenario 4 Interventions:

1. Provide comprehensive assistance to commercial and subsistence fishermen.
2. Increase and improve monitoring techniques for seafood safety.
3. Provide targeted healthcare support for oil-related physical and mental health issues.
4. Prepare for and implement increased scientific monitoring and documentation.
5. Create networks of no-take marine reserves for critical natural resources.
6. Subsidize fishermen not to overfish based on fisheries data and externally peer-reviewed models.
7. Reevaluate and implement appropriate oil barrier booming strategies, technology, and maintenance.
8. Ensure science-based sustainable restoration.
9. Implement a policy or program for relocation and reestablishment of oyster beds.

10. Create a permanent Federal cooperative Gulf of Mexico science center.
11. Institute a sampling and toxicity testing program for oil plumes.
12. Increase transparency of all data related to event.
13. Support research and design of technology for oil spill monitoring, containment, and science.
14. Educate political leaders about the hazards of oil and dispersants for animals and people
15. Develop a local leadership and strategic recovery program.
16. Conduct post-event review of the Natural Resource Damage Assessment (NRDA) process.
17. Provide assistance to tourism and seafood industry marketing.
18. Expand or establish long-term monitoring of long-lived fish and wildlife populations that reproduce in the northern Gulf.
19. Fund independent research on impacts of oil and dispersant in the Gulf.
20. Provide comprehensive assistance to affected marginalized communities.
21. Include marginalized/coastal communities in recovery process.

Scenario 5

Scenario 5 examined the mid-term and long-term recovery when spill-related stress to the coupled natural-human system is expected to be declining. This scenario focused upon the possibility of the remaining oil being entrained in the sediment. The scenario identified several direct consequences: 1) oil in the beaches, 2) oil in estuarine sediment (both in soluble and non-soluble phases), 3) oil in near shore sediment (soluble and non-soluble phases), and 4) oil in offshore sediment (soluble and non-soluble phases).

Several illustrative highlights emerge from this scenario:

- Due to oil in the beaches, it is reasonably certain that fauna will have some difficulty burrowing due to contact with or avoidance of solid-phase oil, which could lead to a probable altered sand ecosystem.

- Consequences of oil in estuarine sediment include such probable occurrences as altered regional food webs and destabilization of human communities dependent on oysters.
- It is reasonably certain that oil in near-shore sediment will lead to reduction in commercial and recreational fishing and localized economic and social impacts. It is plausible that oil in near-shore sediments could lead to a bloom of oil-eating microbes, which could lead to a probable reduction of oxygen.
- Increasing oil in offshore sediment has several significant potential consequences, including a probable loss of habitat and biodiversity for deep-water corals and probable decreased resilience and increased mortality for epibenthic communities.

The scenario includes numerous potential interventions that could accelerate recovery identified by the Working Group. The interventions are listed below (in no order of priority).

<u>Scenario 5 Interventions</u>

1. Map the presence of oil across the northern Gulf of Mexico.
2. Create a long-term citizen science effort to monitor and map oil in sediment.
3. Establish a beach safety monitoring and alert system.
4. Develop absorbent booms and anchoring systems that can withstand moderate storms.
5. Assess the potential of barrier protection for coral reefs.
6. Implement a program to stabilize oyster fisheries compatible with freshwater diversions.
7. Conduct research on degradation processes (and fate) of MS252 oil.
8. Conduct targeted restoration of affected oyster beds.
9. Develop and apply new, less invasive cleanup techniques for sensitive habitats.
10. Conduct ecotoxicological research on the fates and accumulation of hydrocarbons throughout the Gulf of Mexico ecosystem.
11. Improve and extend seafood monitoring.
12. Implement a coral reef propagation and restoration program.

13. Assess reorganization of oyster bed leasing to minimize risk to individual lease holders.
14. Create no-take marine reserves for novel habits.
15. Test effectiveness of depuration of oysters for consumption.
16. Conduct research on toxicity of metabolites.

Lessons Learned

The Working Group suggested a wide range of lessons learned relevant to both continued work related to the MS252 oil spill and future emergencies and events. These are listed below (in no order of priority)

1. Selection of a diverse range of appropriate expertise remains an essential element of success in developing robust and interdisciplinary scenarios.
2. Additional members to the Working Group would be helpful.
3. Establishing scenario parameters in advance would allow Working Group members to do preliminary research before each session.
4. Displaying a scenario online in real time would allow group members to see the full scenario with better functionality of the graphic software.
5. The 5-day work schedule and Gulf venue (New Orleans) used in the second session worked well.

Applications

The products of the Strategic Sciences Working Group can have specific application to both the MS252 oil spill and to future emergencies and events.

1. Help identify critical decision points for DOI leadership and resource managers during late emergency, response, and recovery phases of an event.
2. Help identify and prioritize possible interventions by decision makers and resource managers to mitigate negative impacts and foster positive recovery responses.
3. Help identify critical information needs and knowledge gaps for decision makers and resource managers.
4. Provide useful insight and information to decision makers conducting risk analyses associated with emergency incidents and events.

5. Inform decision makers and resource managers of “potential surprises” associated with cascading effects of emergency incidents and events.
6. Help identify future monitoring requirements, techniques, and technologies to inform inventory and monitoring programs, NRDA, Incident Command Teams, Operational Leadership preparation, and research programs.
7. Help prioritize immediate, mid-term, and long-term future research needs.
8. Provide the conceptual framework for development of quantitative predictive models of coupled natural-human system response to major disruptions.

Recommendations

1. The Unified Command in New Orleans should be briefed on the second session of the Working Group as soon as possible.
2. While select DOI leadership were briefed on key elements of the second session scenarios, the broader DOI leadership should be briefed on the Working Group’s results as soon as possible.
3. The Working Group should be convened in a third (and final) session to a) further advance the existing scenarios based on additional input and new information, b) complete additional scenarios focused on long-term recovery and interventions appropriate to DOI mission and responsibilities, and c) prioritize interventions identified. Several aspects were not explored in the scenarios to date—such as the dispersal of oil through aerosolization, resuspension of sediments, and the persistence of tar balls—and could be considered in future scenarios.
4. Additional scientists from relevant disciplines should be added to the Working Group, including scientists from agencies outside DOI.
5. As Gulf coast restoration proceeds over the next few decades, the resources and results of this Working Group should be available and accessible to future Working Groups and decision makers.
6. The proposal to establish a long-term capacity for strategic sciences should be presented to DOI leadership.

Conclusion: A Strategic Sciences Approach to Major Environmental Incidents

The strategic sciences working group technique is useful for dealing with the challenges of the MS252 oil spill. A strategic science response to a disruptive event can provide more immediate assessment of the range of system stresses and the priorities for effective restoration and reconstruction. An accelerated restoration response has the beneficial impact of shifting the stress level below the level anticipated with a slower restoration response. If the stress level is lower at the time of a secondary event, emergency, restoration, and reconstruction responses will contend with less severe conditions. The strategic sciences working group technique is well suited to provide scientific assistance in preparations, emergency response, and recovery efforts related to other emergency incidents, including large-scale oil spills, bioterrorism attacks, hurricanes, earthquakes, significant wildfires, floods, and other hazard events.

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Introduction

The Mississippi Canyon 252/Deepwater Horizon (MS252) oil spill resulted in an extraordinary and complex engineering and scientific effort. This effort continues as the spill has ended and recovery efforts are underway. Multiple agencies and disciplines continue to apply science to understanding the spill, developing responses, and planning for recovery. Department of the Interior (DOI) bureaus require significant scientific input to the immediate, mid-term, and long-term restoration and management of DOI natural and cultural resources affected by the spill, and the DOI is a critical partner in the overall Federal Government's response.

Objectives and Tasks

On 19 May 2010 the Department of the Interior established a small Strategic Sciences Working Group with the objective of rapidly providing DOI leadership with science-based analyses of how the MS252 oil spill might impact the ecology, economy, and people of the Gulf of Mexico. The Working Group was not established to conduct a scientific investigation but rather to provide a rapid science-based assessment of potential consequences of the spill that could provide usable knowledge to decision makers. The Working Group had several tasks: 1) quickly gather relevant scientific information, 2) use this information and expert scientific opinion to develop alternative scenarios concerning the cascading consequences of the MS252 oil spill during the emergency response, mid-term, and long-term recovery/restoration period, 3) share the results of this work with DOI leadership, and 4) test the usefulness of such strategic science working groups for other major environmental events. The Working Group convened its first session 25-28 May 2010 in Mobile, Alabama, and published its first progress report (http://www.usgs.gov/oilspill/docs/SSWG_Progress_Report_09june10.pdf) in August 2010, along with an overview paper in *Science* (Machlis and McNutt 2010).

The first work session resulted in the development of three scenarios:

- Scenario 1 examined the time period from oil flow containment to the beginning of recovery, during which it was expected that stress in the system would continue to build (though at a slower rate).
- Scenario 2 examined the time horizons for short-term and long-term recovery, when MS252 oil spill-related stress to the system was expected to be declining.
- Scenario 3 examined the time horizons for short-term and long-term recovery, when MS252 oil spill-related stress to the system was expected to be declining. This scenario used the oil release estimates established by the DOI Flow Rate Technical Group, which were released while the Working Group session was underway.

Building on the methods and results from the first work session, the Strategic Sciences Working Group met again 20-24 September 2010 in New Orleans, Louisiana. During this second session, the Working Group developed two additional scenarios for mid- to long-term recovery and possible interventions to accelerate the sustainable recovery of the Gulf of Mexico as a coupled natural-human system. This progress report contains 1) the organizing framework, 2) methods used, 3) two developed scenarios with potential interventions, 4) lessons learned, and 5) recommendations. Material from the first progress report is included in this report where appropriate. The members of the Working Group are listed in Appendix 1. During the workgroup session, daily briefings were provided to DOI leadership; these briefings are included in Appendix 2. A special briefing report to the Environmental Protection Agency on potential public health concerns (see Scenario 4) is included in Appendix 3.

Structure of the DOI Strategic Sciences Working Group

The Working Group consisted of a group of federal and non-federal scientists. Scientists from a wide range of relevant disciplines participated, as well as a mix of Federal, academic, and non-governmental organizations. The Working Group reported to Dr. Marcia McNutt, Director of the U.S. Geological Survey, and was led by Dr. Gary Machlis, Science Advisor to the Director, National Park Service.

The Working Group performed its duties independent of the Incident Command System (ICS), the Natural Resource Damage Assessment (NRDA), and British Petroleum (BP). Members of the Working Group participated as individuals and provided independent expert opinion. Participants declared no conflict of interest or appearance of conflict of interest.

Organizing Framework

The MS252 oil spill has potentially significant consequences for the ecological, economic, and social systems of the Gulf of Mexico (GOM). The Working Group treated the region of potential impact as a *coupled natural-human system* (Machlis and McNutt 2010; Liu et al. 2007; Gunderson and Holling 2002), and approached the task of scenario building from this interdisciplinary view. Hence, the Working Group did not limit the scenarios to separate biological, economic, or social consequences but included how these consequences interact in shaping possible trajectories of the overall system.

Many alternative conceptual models of coupled human/natural systems exist in the literature, including, for example, state-and-transition models (Bestelmeyer et al. 2009). For the purposes of the Strategic Sciences Working Group, the human ecosystem model (Machlis et al. 1997) was used in both the first and second scenario-building sessions. Reasonably detailed, the human ecosystem model includes both biophysical and socioeconomic variables, is explicit regarding flows, and has an emerging record of application (Machlis et al. in press). The model has been applied to a variety of complex environmental challenges, including United Nations “state of the environment reporting,” National Science Foundation Long-Term Ecological Research (LTER) projects, Asian mega-city response to natural hazards, and environmental consequences of warfare. The general human ecosystem model includes sets of critical resources, social institutions, timing cycles, and social order as well as key flows between subsystems (see Figure 1).

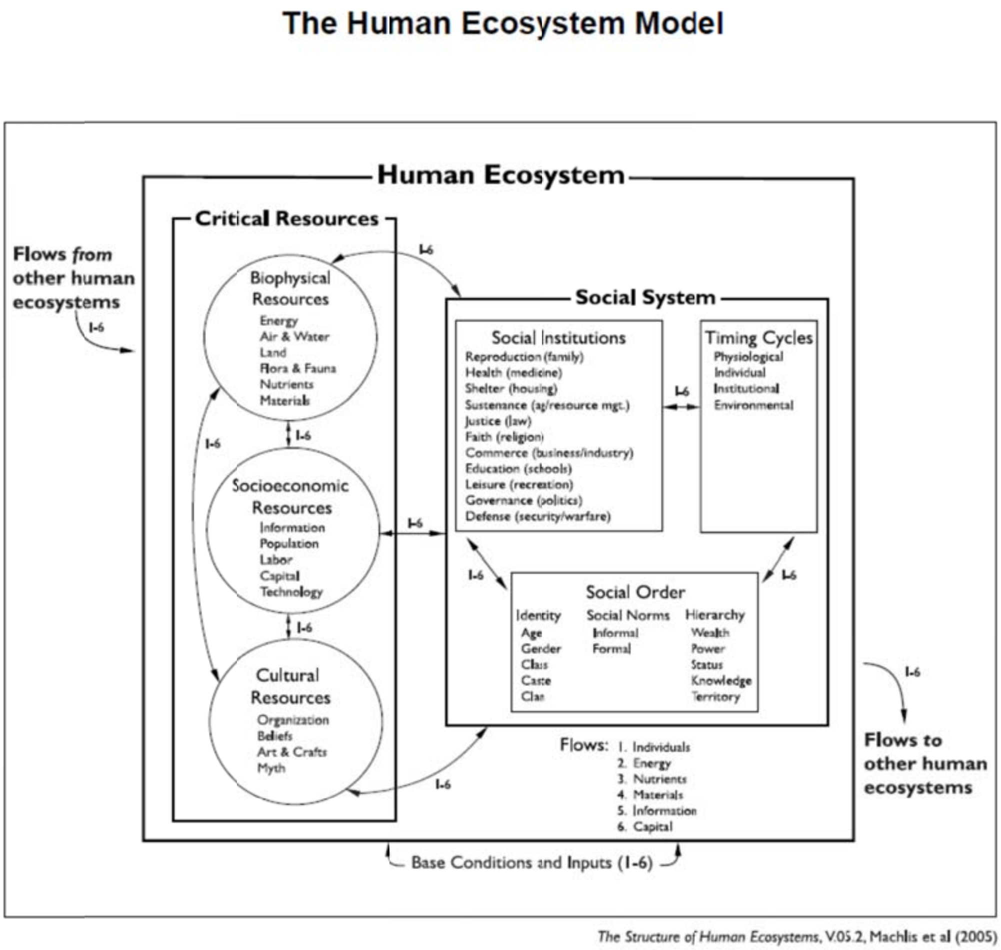


Figure 1: Human Ecosystem Conceptual Model.

The Working Group expanded the list of biophysical variables to cover conditions specific to the MS252 oil spill in the first scenario-building session and used the same list in the second session. This list (which includes several overlapping categories) is shown in Table 1. The Working Group used the conceptual model as an informal checklist of possible relationships to ensure consideration of key elements of the coupled natural-human system for inclusion in the scenarios.

Table 1: Selected Additions to the Human Ecosystem Conceptual Model, Biophysical Resources.

Flora/Fauna	Energy	Land
plankton	wind	wetlands
nekton (all kinds)	solar	uplands
megafauna	tidal	beaches
picoplankton	electricity/natural gas	barrier islands
birds	current	
fish	wave energy	
submerged aquatic vegetation	Water	Materials
marine mammals	fresh water	wood
turtles	salt water	soil
coral	surface	rock
terrestrial wildlife	salinity	metal
terrestrial animals	temperature	calcium carbonate
domesticated animals	depth	plastic
insects	turbidity	
forests		
mangroves		
grass beds		

In addition to a coupled natural-human system conceptual model, the Working Group developed a scenario framework adapted from the scientific literature on natural hazards response (see for example, Haas et al. 1977; Kates et al. 2006). The scenario framework includes a general trend line of coupled natural-human system stress over time divided into several key time horizons (Machlis and McNutt 2010). The scenario framework is an idealized, conceptual framework; other potential trajectories exist. The framework is shown in Figure 2.

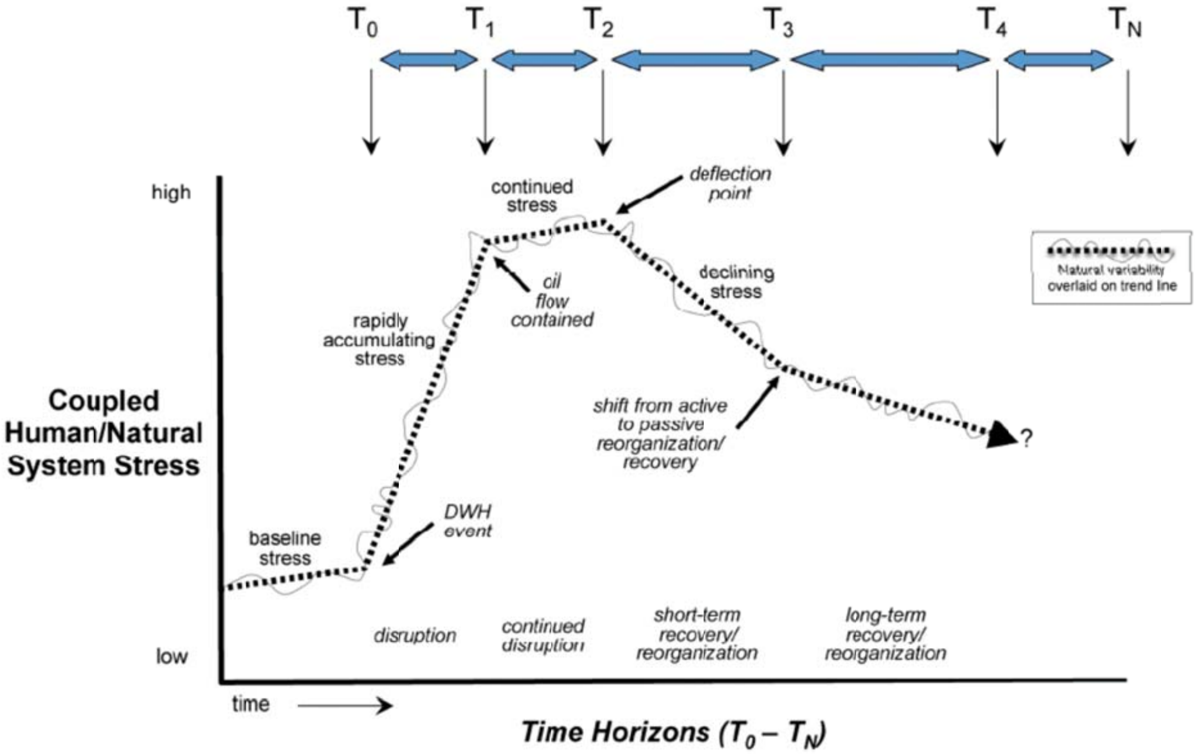


Figure 2: Scenario Conceptual Framework.

Within this scenario framework, the Working Group identified increasing baseline (pre-event) stress in the GOM prior to the MS252 oil spill. This reflects numerous known trends of stress: nutrient loading, expansion of the seasonal hypoxic area ("dead zone"), wetland loss and land subsidence, invasive floral and faunal species, climate change, increased fishing pressures, continuing effects of major hurricane damage in previous years, national and regional economic recession, and other factors (Burley et al. 2007; Castillo and Moreno-Asasola 1996; Rabalais et al. 2001; Tibbetts 2004).

At the time of the MS252 spill (20 April 2010 T_0, identified in Figure 2 as the "DWH event"), system stress is hypothesized to accumulate rapidly, initiating a period of significant system disruption. After the oil flow was contained (15 July 2010 T_1), system stress is hypothesized to continue to rise due to a series of lagged effects such as landfall of previously released oil, re-release of sequestered oil and dispersant, or chronic toxicity to sensitive ecosystem components. At some time in the future (T_2), system stress begins to decline (the "deflection point") due to a combination of reduced inputs of stressors, natural and social resilience in the coupled natural-human system, active emergency and recovery responses by national, state, and local entities, and other factors.

Further along the time horizon (T_3), the stress trend further deflects, as short-term recovery/reorganization (with its active and adaptive responses) gives way to long-term recovery and passive response. Examples of passive responses might include water quality improvements or economic redevelopment without substantial government or industry intervention. T_4 and T_N represent longer-term time horizons over which recovery processes may persist. These time horizons are not necessarily linear and may vary significantly in duration (measured in days, months, years, or decades).

Within this framework, there is an assumption that recovery often involves some reorganization of the system rather than full return to a pre-existing state (Holling 1973). Baseline stress in these future horizons is largely unknown at present. Figure 2 illustrates that natural variability (both spatial and temporal) is overlaid upon general stress trends, and thus care should be taken to distinguish between responses to the MS252 event and natural variability or "noise" in a system (Adger et al. 2005).

Methods

Numerous alternative approaches to constructing science-based scenarios exist (for a review, see Chermack et al. 2001); scenario planning has been widely used in the oil industry (see for example Schoemaker et al. 1992). During major incidents and natural hazard events (in which response time is critical and many key factors are unknown), scenario planning offers several advantages, particularly its capacity to rapidly, systematically, and creatively examine possible futures that are complex and uncertain. Peterson et al. (2003:360) note:

> "…Scenarios are alternative, dynamic stories that capture key ingredients of our uncertainty about the future of a study system. Scenarios are constructed to provide insight into the drivers of change, reveal the implications of current trajectories, and illuminate options for action."

The approach taken by the Working Group in the second session involved four main steps: 1) establish a matrix of alternative scenario parameters (parameter is defined as a selected scope condition that constrains a scenario); 2) using a specific subset of the scenario parameters, develop a detailed "chain of consequences" that illustrates important cascading effects; 3) for each element in the chain of consequences, assign a qualitative level of scientific uncertainty; and 4) identify a set of potential "interventions" at points in the scenario when scientists, policymakers, and other responders might take action to alter the outcomes of the cascade such that a sustainable recovery is accelerated. In this use, "chain of consequences" refers to a set of cascading causal relationships*; it does not imply that all possible relationships have been identified*. Step 4 emerged from the potential applications identified during the initial session (23-29 May 2010) and was approved as an additional Working Group task by DOI leadership. "Sustainable recovery" is defined, following the International Strategy for Disaster Reduction (United Nations 2004), as decisions and actions taken after a disaster for restoring or improving the pre-disaster conditions following sustainable development principles appropriate to the region.

The steps for building the scenarios are described below.

1. *Establish a matrix of alternative scenario parameters and define assumptions.*

During the initial session of the Working Group (23-29 May 2010), the MS252 oil spill had not been contained, nor had an accurate flow rate been established. Hence, estimated time to containment and rate of oil flow were necessary scenario parameters. Both uncertainties had been resolved at the time of the second session (20-24 September 2010) and were not treated as alternative parameters for scenario building. The Working Group used three key scenario parameters for the second session: a) persistence of toxicity of the oil and dispersants remaining in the general environment of the Gulf region, b) time horizons, and c) geographic and spatial units of interest.

The persistence of toxicity of the oil and dispersants involved in the MS252 oil spill is not fully understood. The Working Group (which included an expert marine toxicologist) established three alternatives based on the longevity of toxicity in the environment. Persistence of toxicity was considered to potentially be measured in 1) months, 2) years, or 3) decades.

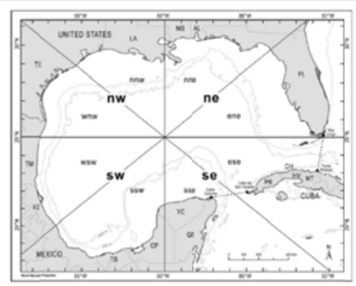
During the first session (23-29 May 2010), the Working Group established distinct time horizons (T_1-T_4, T_N) to help focus the first three scenarios on specific time periods during the emergency response, short-term recovery, and long-term recovery. The time horizons are shown in Figure 2 and could be applied to a specific scenario's construction in varying combinations (i.e. T_0-T_2, or T_2-T_4). Since the oil flow was halted in mid- to late July 2010, during the second session (20-24 September 2010) the Working Group focused on the mid- to long-term recovery time horizons.

During its first session, the Working Group established several geographic or spatial units to help focus the alternative scenarios, incorporate distinctive consequences associated with the different units, and provide useful information to decision makers. These units were also used in the second session and included a) vertical life zones (adapted from Robison 2009), b) major ecosystem types (adapted from Maguire 2005), c) socio-political and administrative units from local village to parish, county, and state (adapted from Sheppard and McMaster 2004), and d) Gulf of Mexico Biodiversity Quadrants (Felder and Camp 2009). Table 2 identifies the specific units of analysis and illustrates the Biodiversity Quadrants.

Table 2: Geographic/Spatial Units for Scenario Parameters.

Vertical Life Zones (Robison 2009)	Administrative Boundaries (Sheppard and McMaster 2004)
above surface/terrestrial	village
surface	parish/county
epipelagic	state
mesopelagic	national
epibenthic	international
benthic	
underlying geology	

Ecosystem Types (Maguire 2005)	Biodiversity Quadrants, Gulf of Mexico (Felder and Camp 2009)
open ocean	northwest
shelf	northeast
littoral	southwest
estuaries	southeast
coastal	
inland/terrestrial	



The combination of these alternative scenario parameters created a matrix shown in Table 3. For a particular scenario, the Working Group selected a specific combination of parameters, varying persistence of toxicity, time horizon, and spatial unit as appropriate. This approach also allowed for continued adaptation to new information, as was the case when more accurate flow rate estimates became available or when oil landfall patterns shifted.

Table 3: Matrix of Alternative Parameters.

Persistence of Toxicity (months, years, decades)	Time Horizon (T_0-T_N)	Geographic/Spatial Units
months	T_1	vertical life zones
years	T_2	ecosystem types
decades	T_3	administrative boundaries
	T_4	biodiversity quadrants
	T_N	

In addition to the scenario parameters, two assumptions were made. First, the Working Group assumed that there would be at least one major tropical storm or hurricane landfall in the Gulf of Mexico during recovery. This is a conservative estimate following NOAA frequency predictions (National Weather Service Climate Prediction Center 2010). Second, the Working Group considered the remaining oil in the system as a baseline amount as of August 2010. The Working Group established that discrepancies in various estimates stemmed from the definition of "remaining" and not from significant differences in actual estimates (Lubchenko et al. 2 Aug 2010; Hopkinson 17 Aug 2010; Miller 22 Jul 2010). The estimated balance of remaining oil agreed upon by the Working Group followed the Georgia Sea Grant definition of remaining oil and converted to 3.2 million bbl of oil as of August 2010 (Hopkinson 17 Aug 2010). The Georgia Sea Grant estimate included a range of 2.9 to 3.2 million bbl, and the Working Group chose to use the upper end of the estimate.

2. Using a specific subset of the alternative scenario parameters, develop detailed "chain of consequences" scenarios that illustrate important cascading effects of the MS252 oil spill upon the coupled natural-human system.

The Working Group established a common method of scenario building during the first session. First, scenario parameters were selected from the matrix shown in Table 3. Next, an initial condition resulting from the selected scenario parameters was established, such as "persistence of oil and dispersant in months in the mid-water life zones in the NE biodiversity quadrant." From the initial condition, the group developed a set of cascading consequences via sharing of expert opinion, scientific literature, and in-depth discussion. Lead Scientist Machlis facilitated the work. Working Group members used their own expert knowledge and consulted the scientific literature via the Internet and additional experts via phone and email as the cascading consequences were being developed. These cascades were informally drawn on whiteboards and simultaneously entered into a graphic program called SmartDraw[1] (Hemera Technologies, Inc. San Diego, CA). SmartDraw enabled the Working Group to quickly modify and expand upon existing cascades.

During the first session in Mobile reported in the earlier Progress Report, the Working Group developed three scenarios (S1-S3). Building on the experiences of the first session, the Working Group selected two scenarios to develop using the method described above. Given that the matrix of parameters could result in a large number of possible scenarios (too many to construct given time constraints), Working Group members selected a general scenario of mid- to long-term recovery (S4). The additional scenario (S5) reflected the request by Director of the U.S. Geological Survey Marcia McNutt to develop a scenario considering possible consequences of oil remaining in the sediment.

3. For each element in a chain of consequences scenario, assign a level of scientific uncertainty.

A key element of the Working Group's task was to assign preliminary levels of scientific uncertainty to each of the cascading consequences. These reflect the state of knowledge for complex and significant disruptions in coupled human/natural systems (which can vary from substantial scientific certainty to unstudied and unknown relationships), the state of knowledge for the specific system (GOM) and its system functions and processes, and the need to provide decision makers with a practical method of assessing levels of uncertainty for policy and decision making.

Following Weiss (2003), several alternative scales were considered in the first Working Group session: a) legal standards of proof, b) informal scientific levels of uncertainty, c) Bayesian probabilities, and d) the climate change-specific scale adopted by the Intergovernmental Panel on Climate Change (IPCC). The

[1] Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Working Group adapted the Weiss scale of informal scientific uncertainty, as it is well suited to scenario building and allows for systematic refinement as new information becomes available (a key characteristic of the MS252 event). In the Working Group adaptation, several of the Weiss scale categories were aggregated for clarity and to allow for rapid assessment. Table 4 illustrates Weiss' original scale and the Working Group's adaptation.

Table 4: Levels of Scientific Uncertainty.

DOI Strategic Sciences Working Group Categories	Weiss's (2003) Informal Scientific Categories
5 – certain	certain
4 – reasonably certain	very probable + reasonably certain
3 – probable	likely + probable
2 – plausible	possible + probable (more info needed for firm conclusions)
1 – unlikely	unlikely (supported, but not entirely ruled out)
0 – not possible	not possible (violates established laws, theories, principles)
nk – not known	insufficient information to ascribe level of certainty

Following the development of a specific scenario, the Working Group established uncertainty levels (0-5 and not known) for each cascading consequence within the scenario. Individual Working Group members with appropriate expertise provided opinion bolstered by review of the available literature and contacts with additional subject matter experts. Lead Scientist Machlis established the preliminary level of uncertainty based on these individual opinions and, in cases where there was professional disagreement among Working Group members, applied the precautionary principle and selected the lower level of uncertainty. As new information was developed or became available during the Working Group session, uncertainty levels were revised as appropriate.

4. Identify potential interventions at points in the scenario at which scientists, policy makers, and other responders might take specific actions to significantly alter the outcomes of the cascade.

The scenarios provide decision makers and resource managers a set of possible intervention points where they can focus attention on key interventions likely to have substantive effect on reducing negative impacts (such as re-release of sequestered oil). Interventions may also offer the ability to increase resilience and positive recovery responses (such as improved monitoring and targeted income support). This is particularly useful during the long-term recovery period and could help accelerate sustainable recovery. DOI leadership requested that the Working Group identify possible interventions as recommended in the first progress report.

The Working Group established a technique for identifying potential interventions. Each Working Group member identified one or more possible alternatives and intervention points in the chain of consequences. The Working Group identified the place along the chain of consequences at which the intervention might be most effective, but it did not prioritize them or create alternative scenarios to demonstrate efficacy. Each intervention was presented individually to the group for 1) consideration, 2) clarification if necessary, 3) possible revision, and 4) potential inclusion in the scenario. Only those interventions identified and discussed by the Working Group are included here; we recognize there are other potential scenarios and interventions that were not discussed.

Limitations

The scenario-building technique employed by the Working Group has several limitations. The scenarios are not quantitative risk analyses or predictive models. This approach does not include detailed linkages and feedback loops among different components and does not use environmental endpoints and values. All possible trajectories cannot be anticipated. The assigned scientific uncertainties reflect the scientific literature and expert opinion for each individual consequence in a chain; summary uncertainties for a full chain of consequences or a scenario were not assigned. The scenarios are not spatially specific at scales other than the identified GOM quadrants and spatial units used as a parameter. Like most scenario building, the scenarios are constrained by available expert opinion, information, and theory (Machlis and McNutt 2010; Peterson et al. 2003).

Preliminary Results: Two Scenarios

During the second scenario-building session, the Working Group developed two scenarios (S4 and S5). Each is summarized below and represented in full in a series of graphic displays (Figures 3 and 4). The assumptions and parameters (a selected scope condition that constrains a scenario) are given for each scenario and shown in a grey box. Individual consequences (the dependent effects of precedent conditions) in a chain are shown in grey boxes with the assigned scientific uncertainty. Only those consequences identified and discussed by the Working Group are included; this does not include all possible trajectories. Interventions (potential actions that can mitigate negative consequences and accelerate a sustainable recovery) are shown in green ovals and were inserted within the chain of consequences where the Working Group determined they would be most effective. Again, not all possible interventions are illustrated; only those identified by the Working Group are shown.

Figures 3 and 4 represent the visual display of the scenarios developed by the Working Group. Again, the scenarios are limited by the expertise of the individuals, the state of knowledge at the time of construction, and the time available. The output represents an experimental use of the visualization software selected for Working Group use (SmartDraw).

Scenario 4

Scenario 4 examined the time period from the mid-term to long-term recovery/reorganization, during which it is expected that stress in the system would be declining. Scenario assumptions were 1) 3.2 million bbl of oil remaining in the Gulf System and 2) at least one major landfall tropical storm or hurricane during recovery. The scenario parameters chosen by the Working Group were 1) toxicity of oil and dispersant persisting for years in the northern biodiversity quadrants of the GOM, 2) coastal communities as the spatial unit, and 3) T_2-T_4 as the time horizon. The scenario is shown in Figure 3.

Numerous potential direct consequences were identified, including 1) contaminated Gulf seafood, 2) continuing human exposure to oil and dispersant, 3) contamination of coastal wetlands, 4) fish mortality, 5) contamination of the benthic life zone, 6) contamination of the pelagic life zone, 7) depletions of marine/estuarine populations, 8) behavioral response by animals, 9) continued contamination of beaches,

10) stressed wetland flora, 11) continued contamination of barrier islands, and 12) other post-spill activities.

Several illustrative highlights emerge from this scenario:

- Of the twelve direct consequences, scientific certainty levels were high for eleven, with fish mortality deemed probable.
- Stressed wetland flora was linked to flora mortality via root kill, which leads to a reasonably certain decrease in habitat and plausible increase in severity of landfall storms' impact.
- Post-spill activities may produce a wide range of consequences; for example, a reasonably certain consequence of institutional changes is increased economic pressure on Gulf fisheries.
- Insufficient information is available regarding the likelihood of berm construction, but it is probable that berm construction, if undertaken, would lead to selected habitat degradation and reduced water quality.
- Heightened sensitivity to health issues for vulnerable populations such as the young, elderly, pregnant, or chronically ill, as a consequence of continued human exposure to oil and dispersant, has a high level of scientific certainty. Because this potential chain of consequences raises health issues of significance and complexity, an additional briefing report was prepared that provides important background and basis for the scenario. This preliminary report was presented to DOI leadership and sent to the Environmental Protection Agency (EPA), as that agency has primary responsibility for environmental health issues associated with the Deepwater Horizon oil spill. A copy of the report to EPA is in Appendix 3.
- Closure of commercial fisheries and oyster beds are likely to have substantial consequences for the coupled natural-human system. It is plausible that closures would lead to increases in select populations of specific species of fish and oysters and loss of traditional knowledge.

The scenario includes numerous potential interventions that could accelerate recovery identified by the Working Group. These interventions are identified in the figure and listed below (in no order of priority).

Scenario 4 Interventions:

1. Provide comprehensive assistance to commercial and subsistence fishermen.
2. Increase and improve monitoring techniques for seafood safety.
3. Provide targeted healthcare support for oil-related physical and mental health issues.
4. Prepare for and implement increased scientific monitoring and documentation.
5. Create networks of no-take marine reserves for key or critical natural resources.
6. Subsidize fishermen not to overfish based on fisheries data and externally peer-reviewed models.
7. Reevaluate and implement appropriate oil barrier booming strategies, technology, and maintenance.
8. Ensure science-based sustainable restoration
9. Implement a policy or program for relocation and reestablishment of oyster beds.
10. Create a permanent Federal cooperative Gulf of Mexico science center.
11. Institute a sampling and toxicity testing program for oil plumes.
12. Increase transparency of all data related to the oil spill event.
13. Support research and design of technology for oil spill monitoring, containment, and science.
14. Educate political leaders about the hazards of oil and dispersants for animals and people.
15. Develop a local leadership and strategic recovery program.
16. Conduct post-event review of the NRDA process.
17. Provide assistance to tourism and seafood industry marketing.
18. Expand or establish long-term monitoring of long-lived fish and wildlife populations that reproduce in the northern Gulf.
19. Fund independent research on impacts of oil and dispersant in the Gulf.
20. Provide comprehensive assistance to affected marginalized communities.
21. Include marginalized coastal communities in the recovery process.

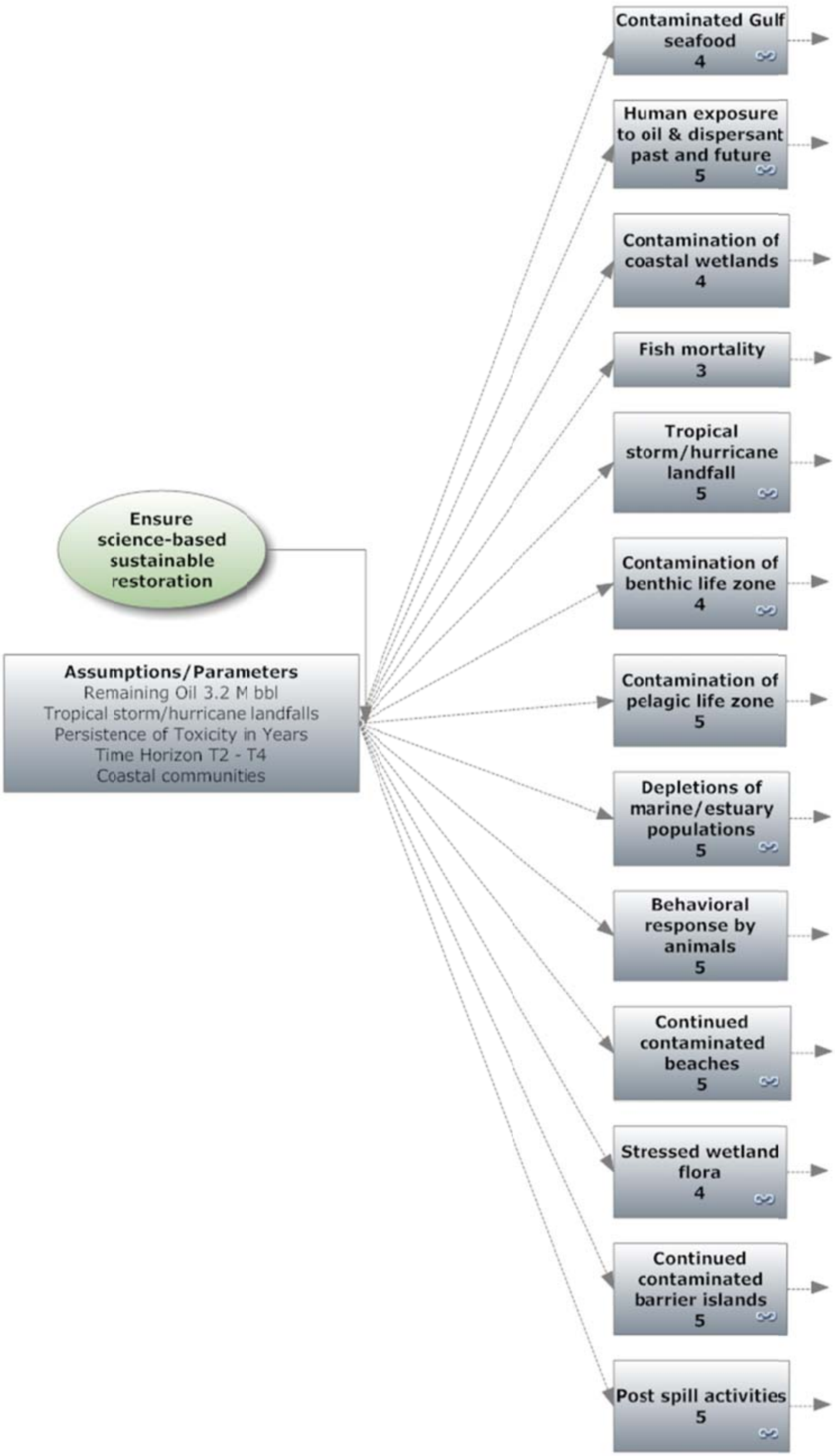


Figure 3: Illustration of chain of consequences associated with scenario 4.

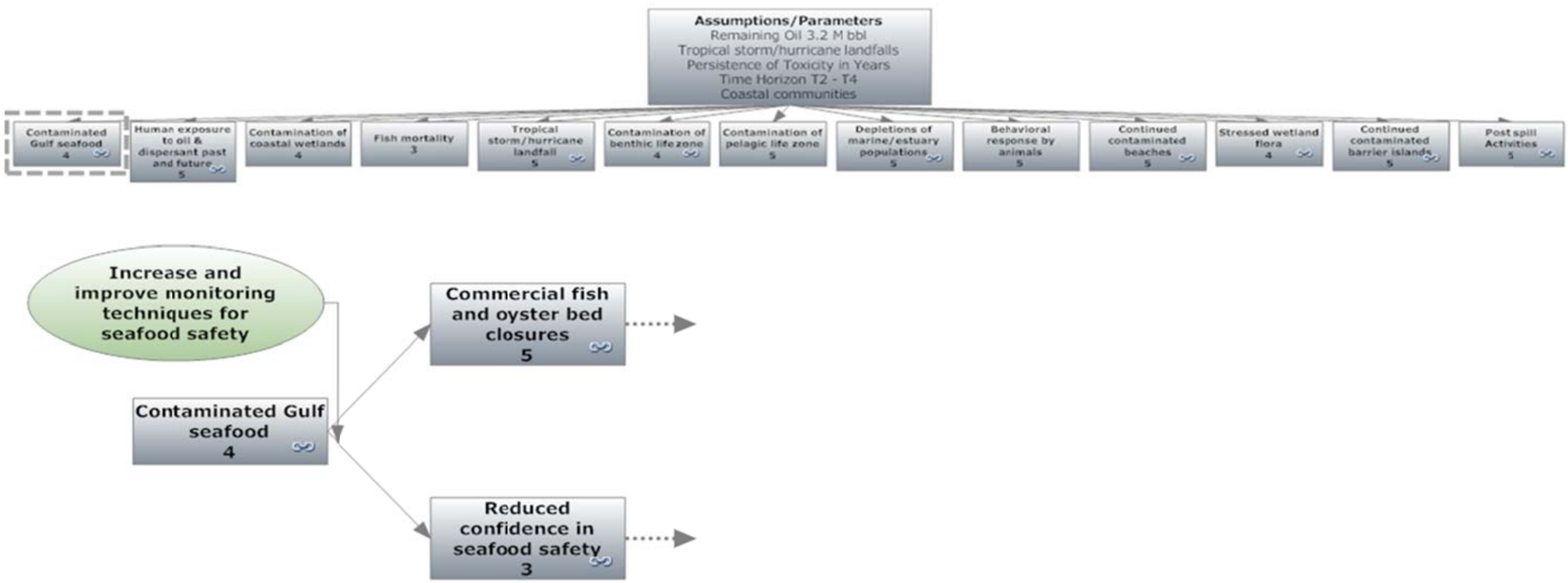


Figure 3a: Contaminated Gulf seafood.

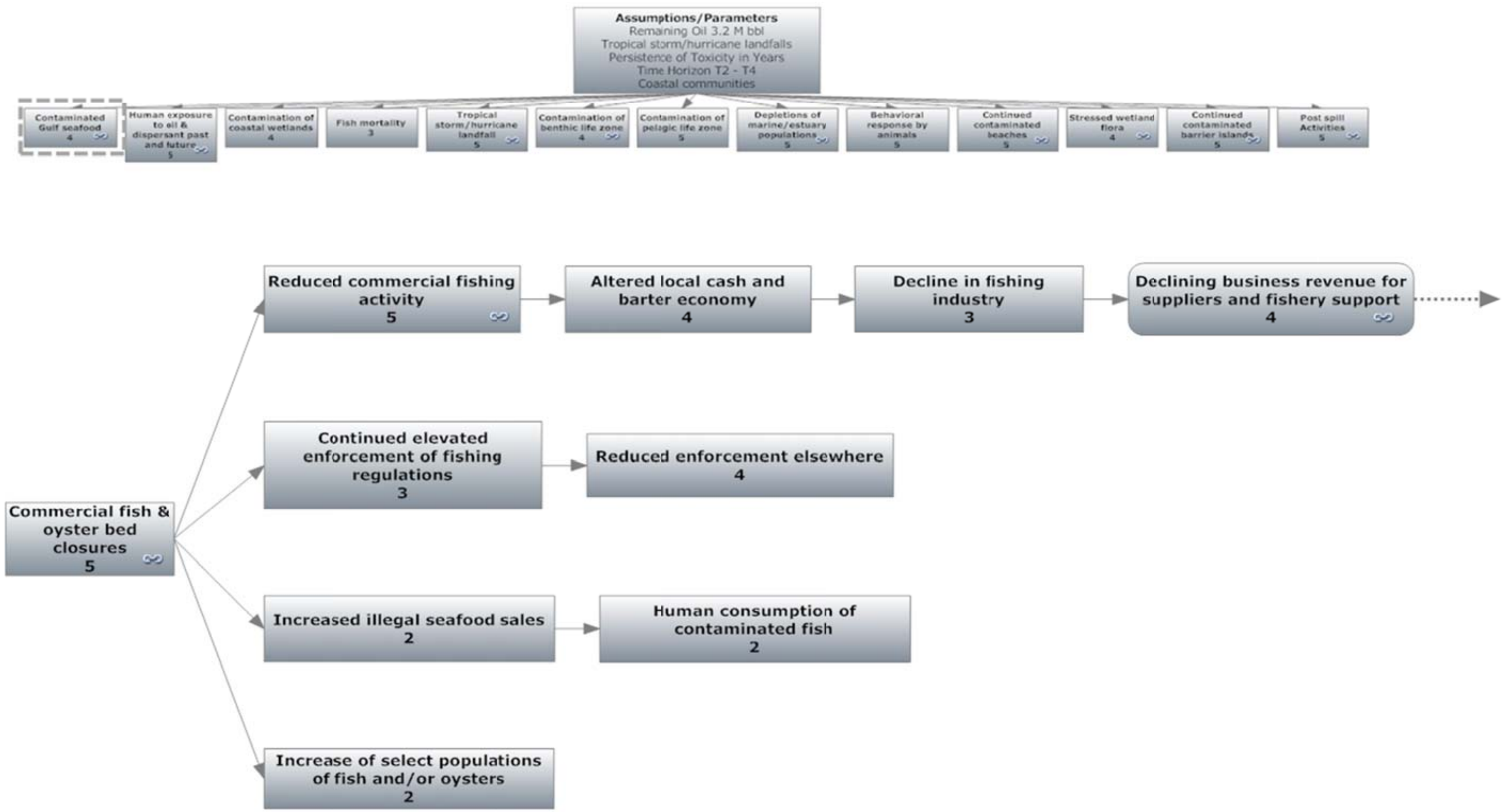


Figure 3b: Commercial fish and oyster bed closures.

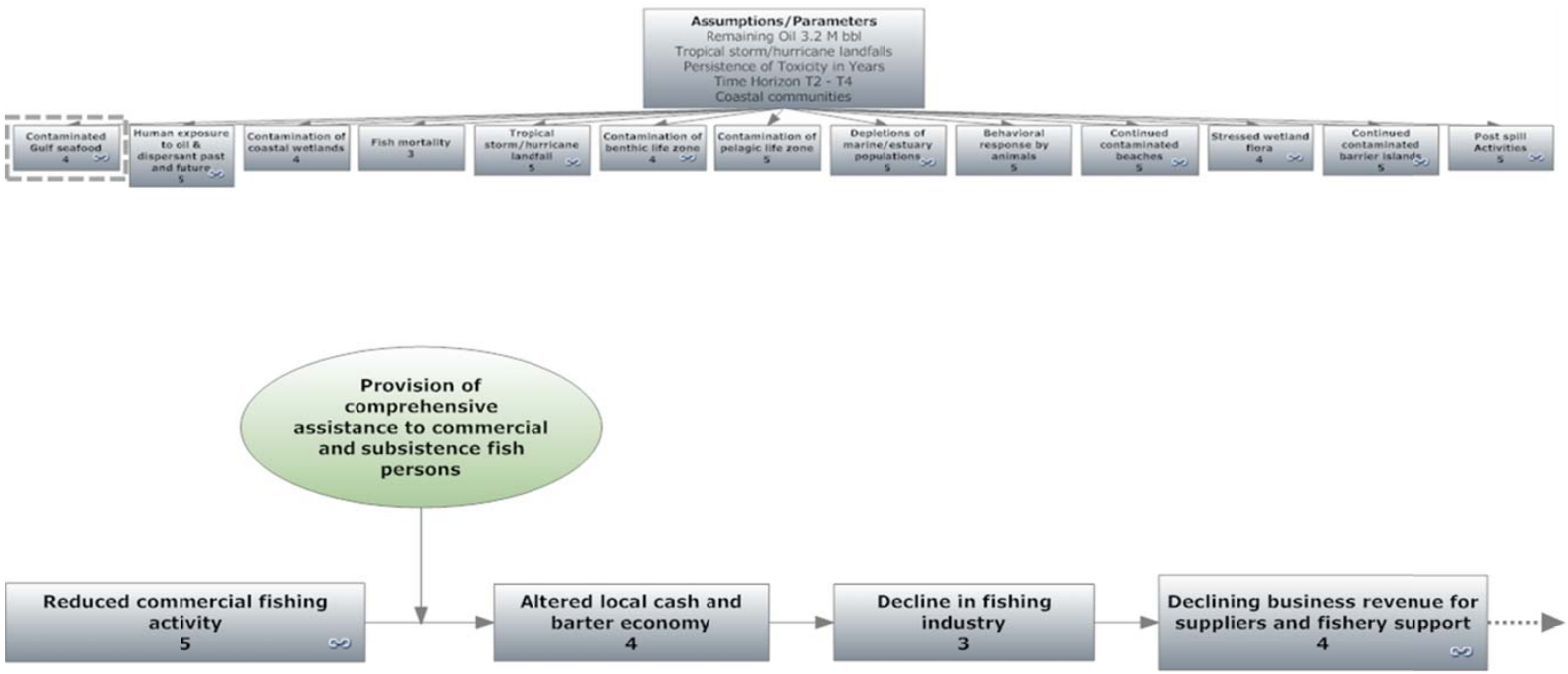


Figure 3c: Reduced commercial fishing activity.

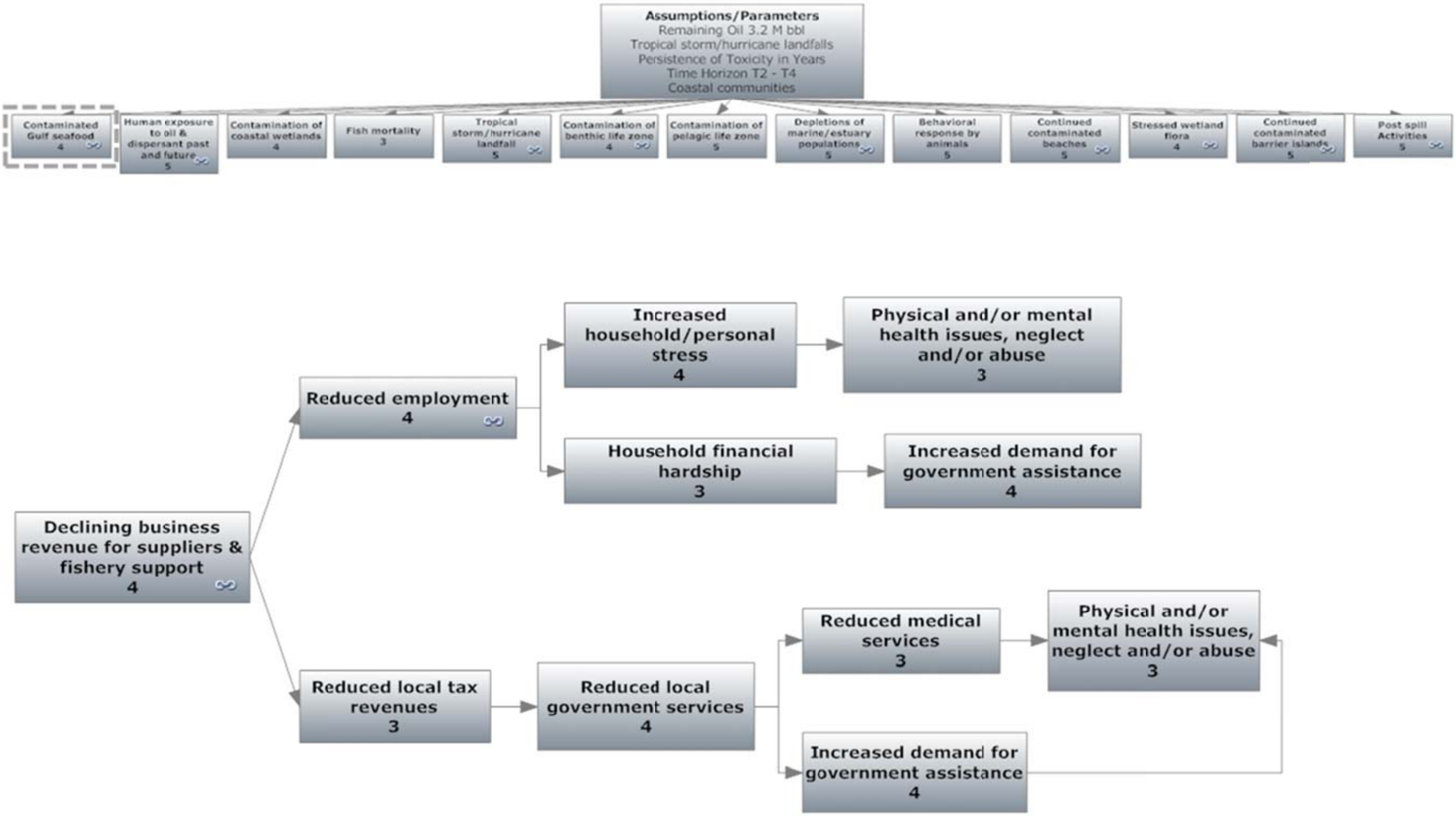


Figure 3d: Declining business revenue for suppliers and fishery support.

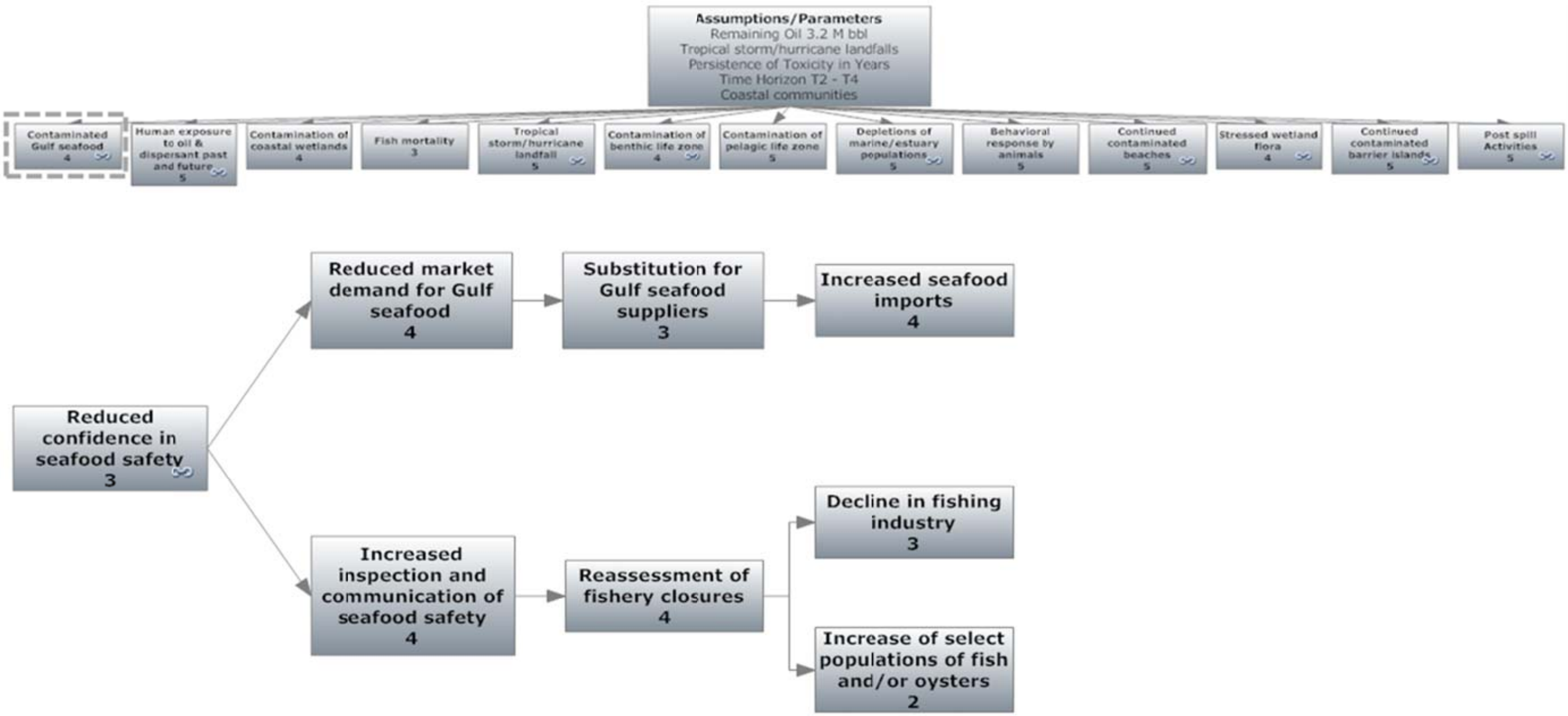


Figure 3e: Reduced confidence in seafood safety.

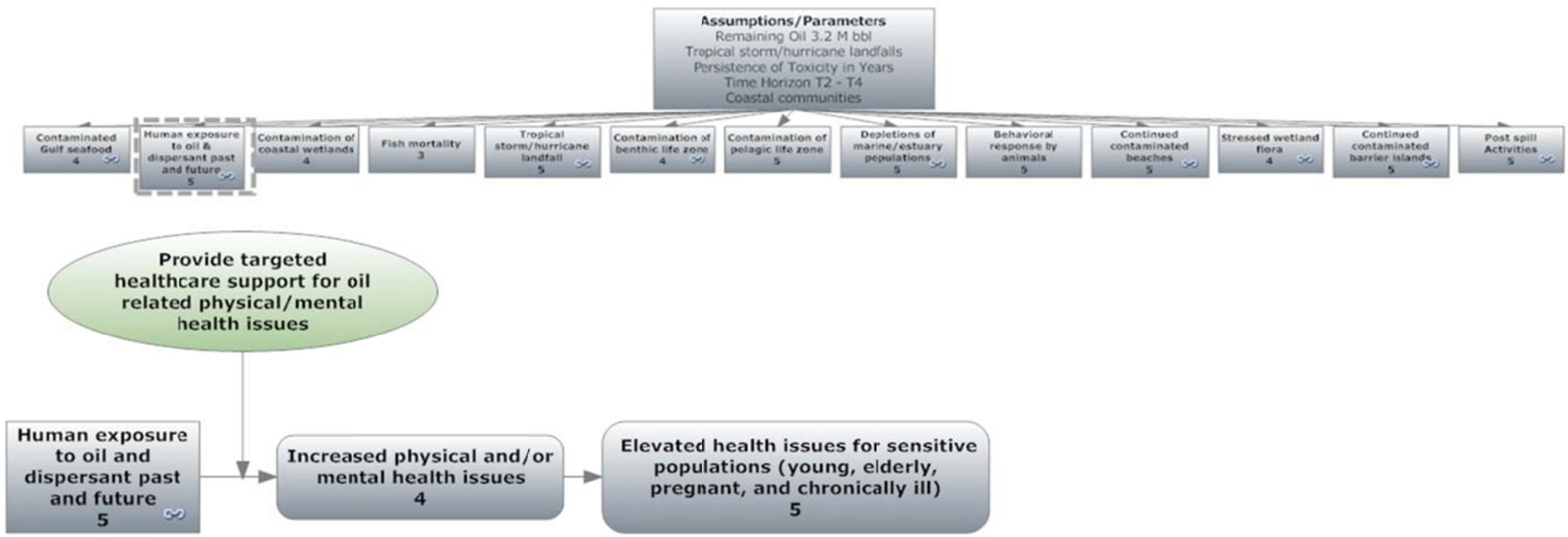


Figure 3f: Human exposures to oil and dispersant past and future.

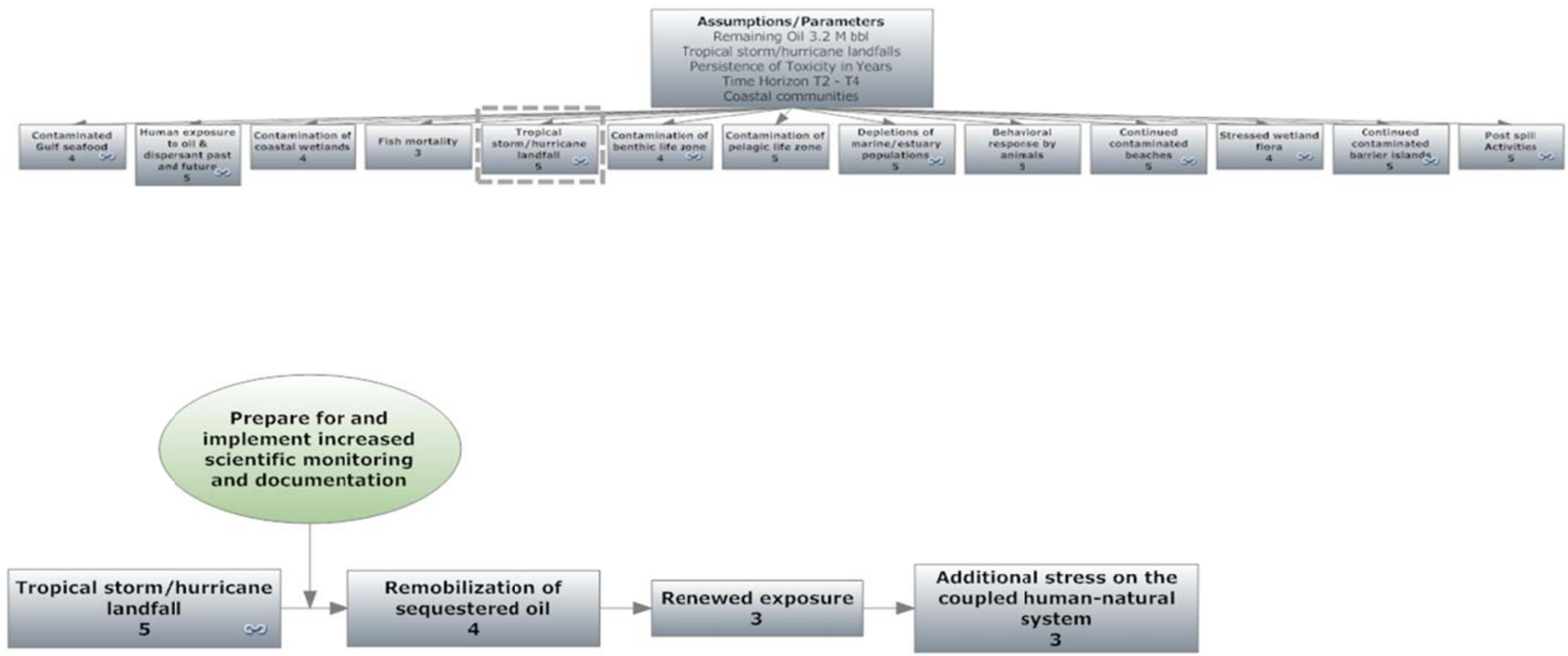


Figure 3g: Tropical storm/hurricane landfall.

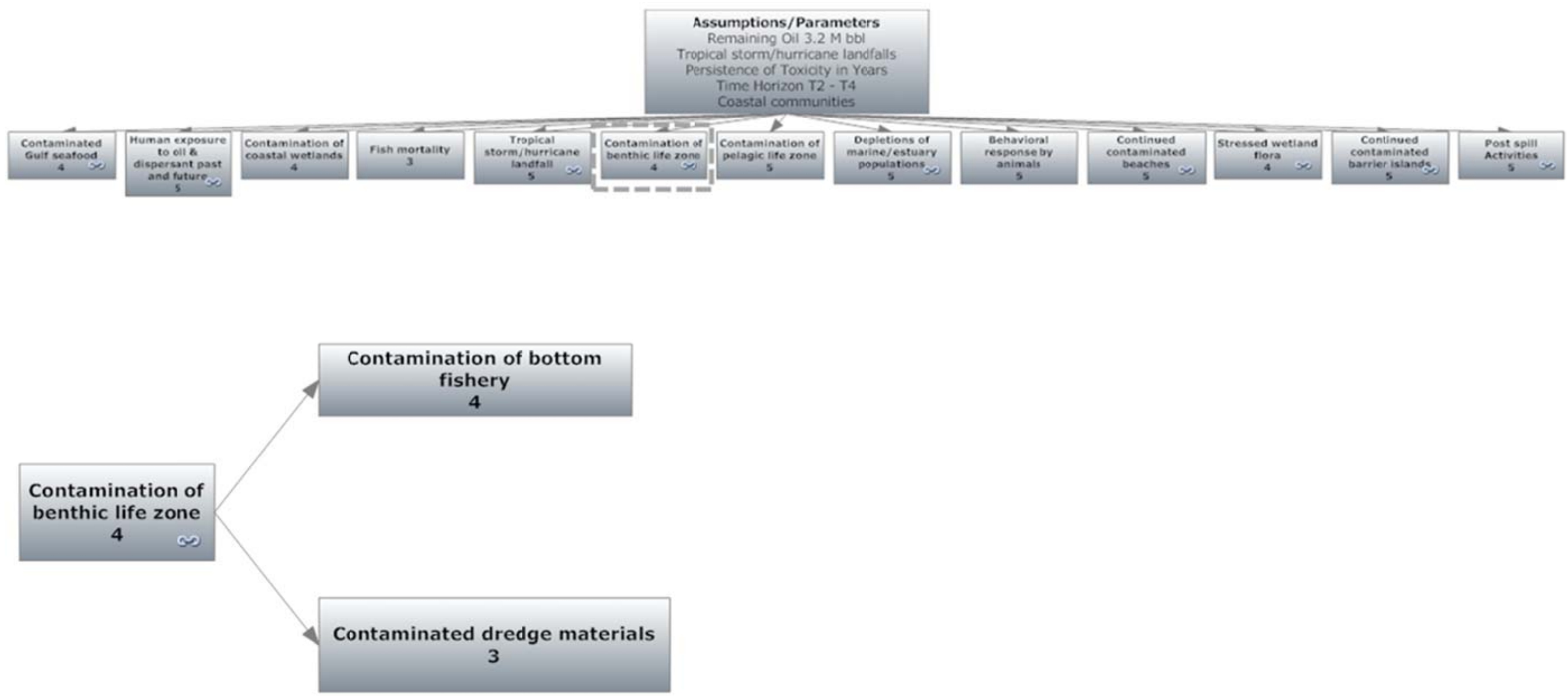


Figure 3h: Contamination of benthic life zone.

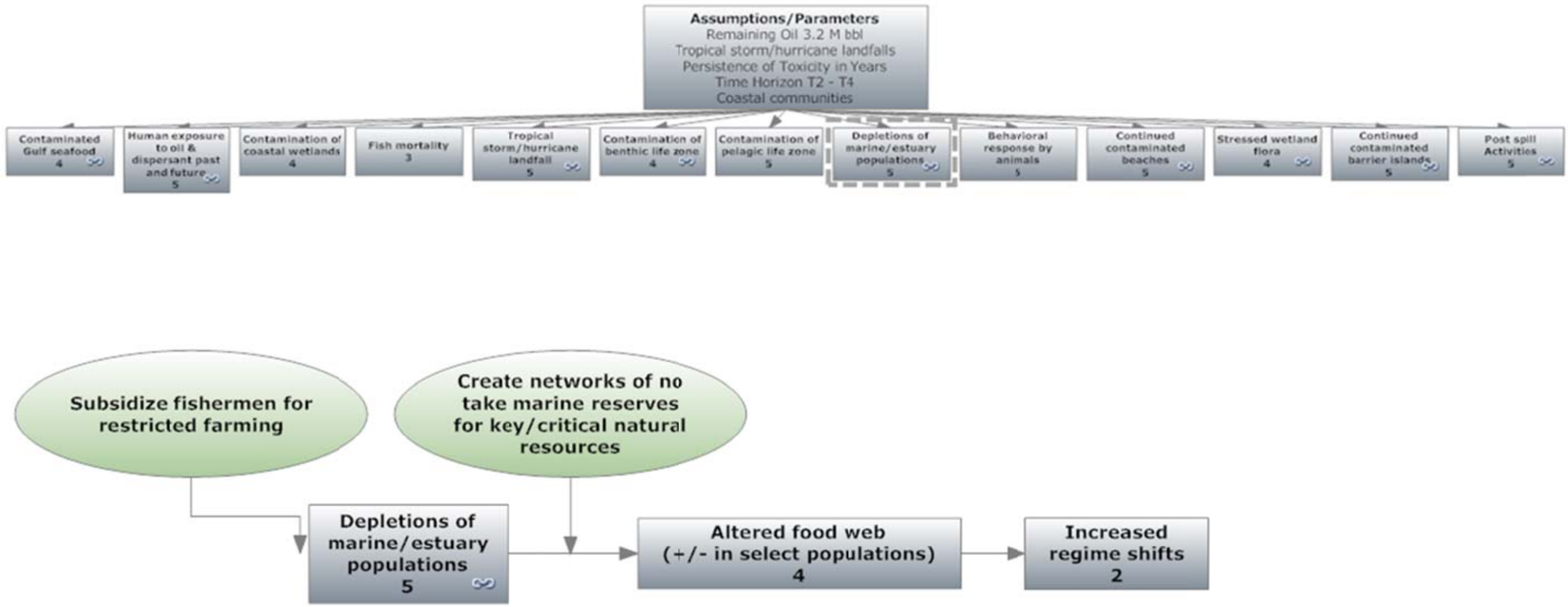


Figure 3i: Depletions of marine/estuary populations.

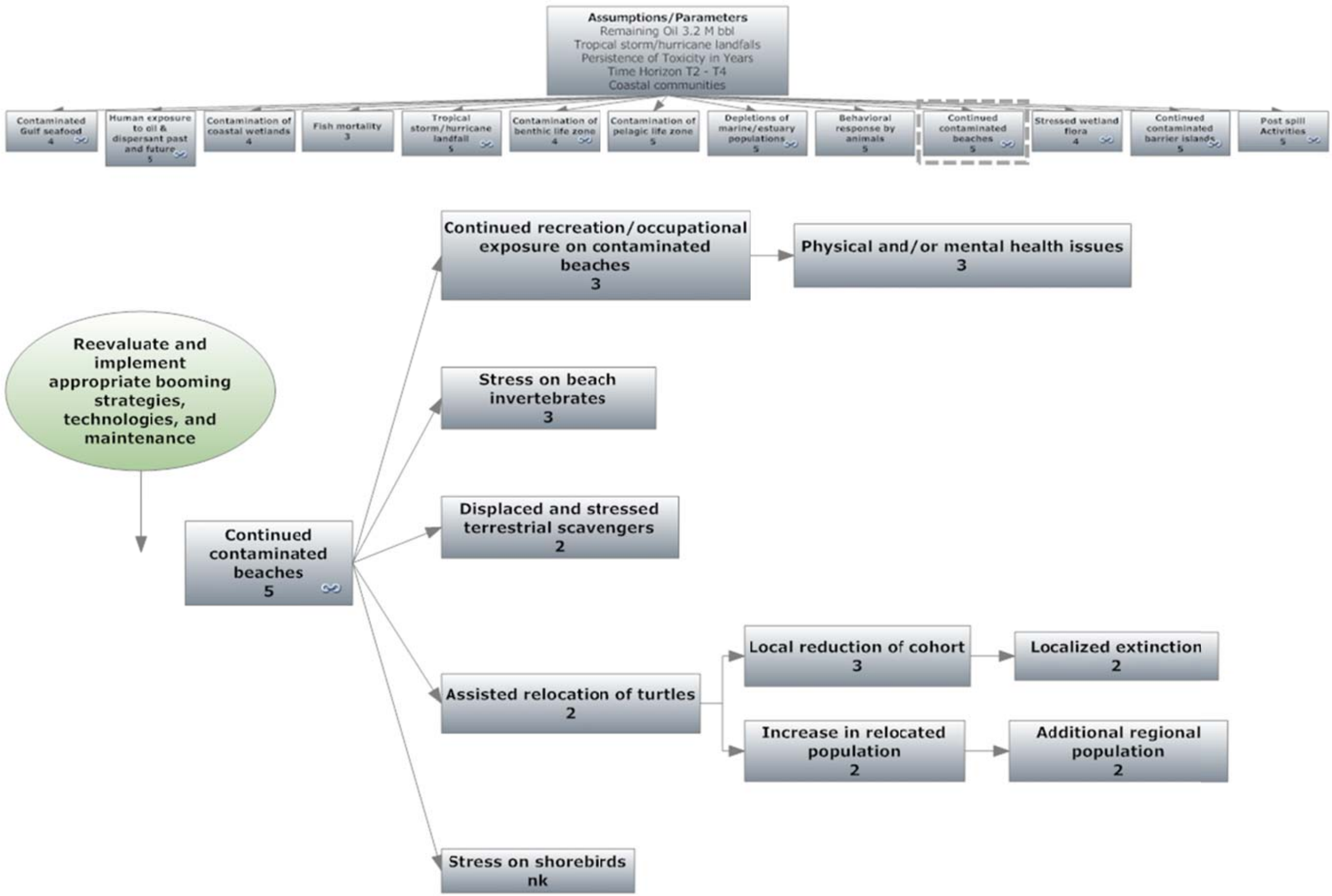


Figure 3j: Continued contaminated beaches.

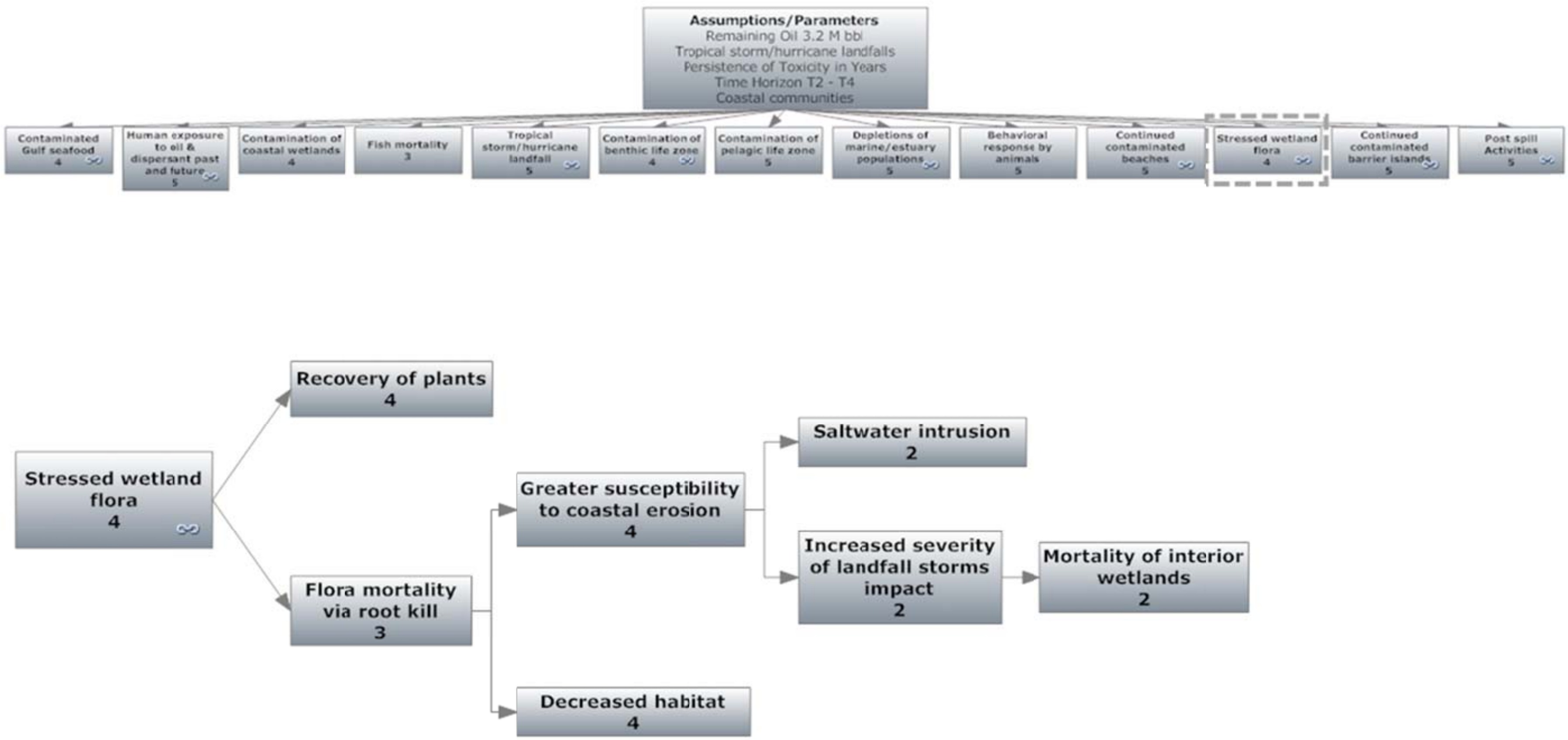


Figure 3k: Stressed wetland flora.

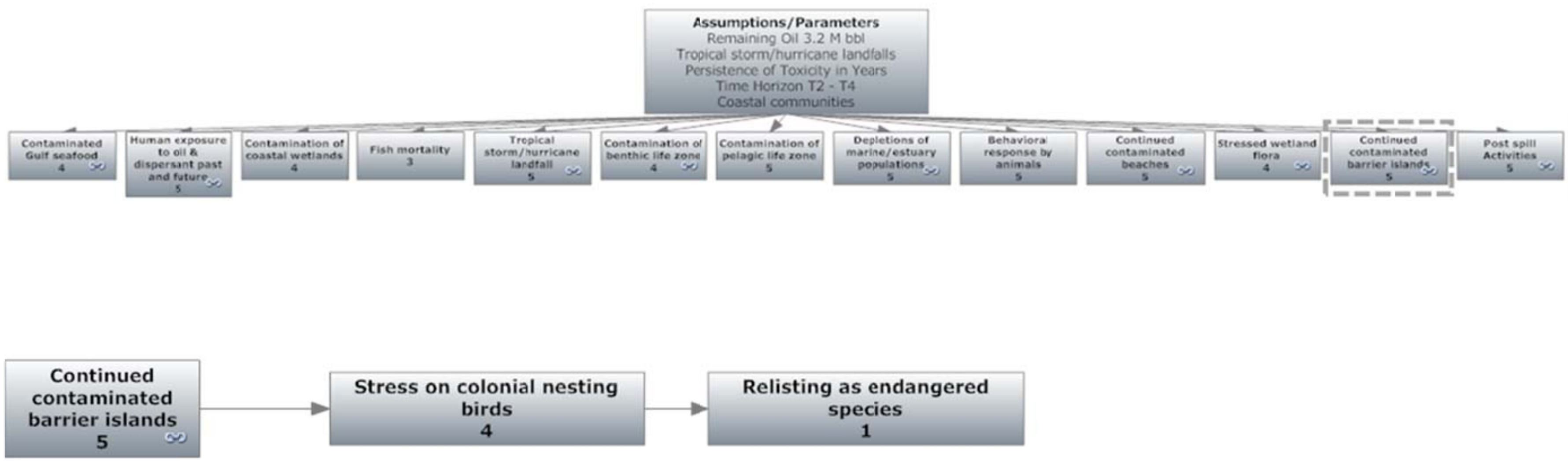


Figure 3l: Continued contamination of barrier islands.

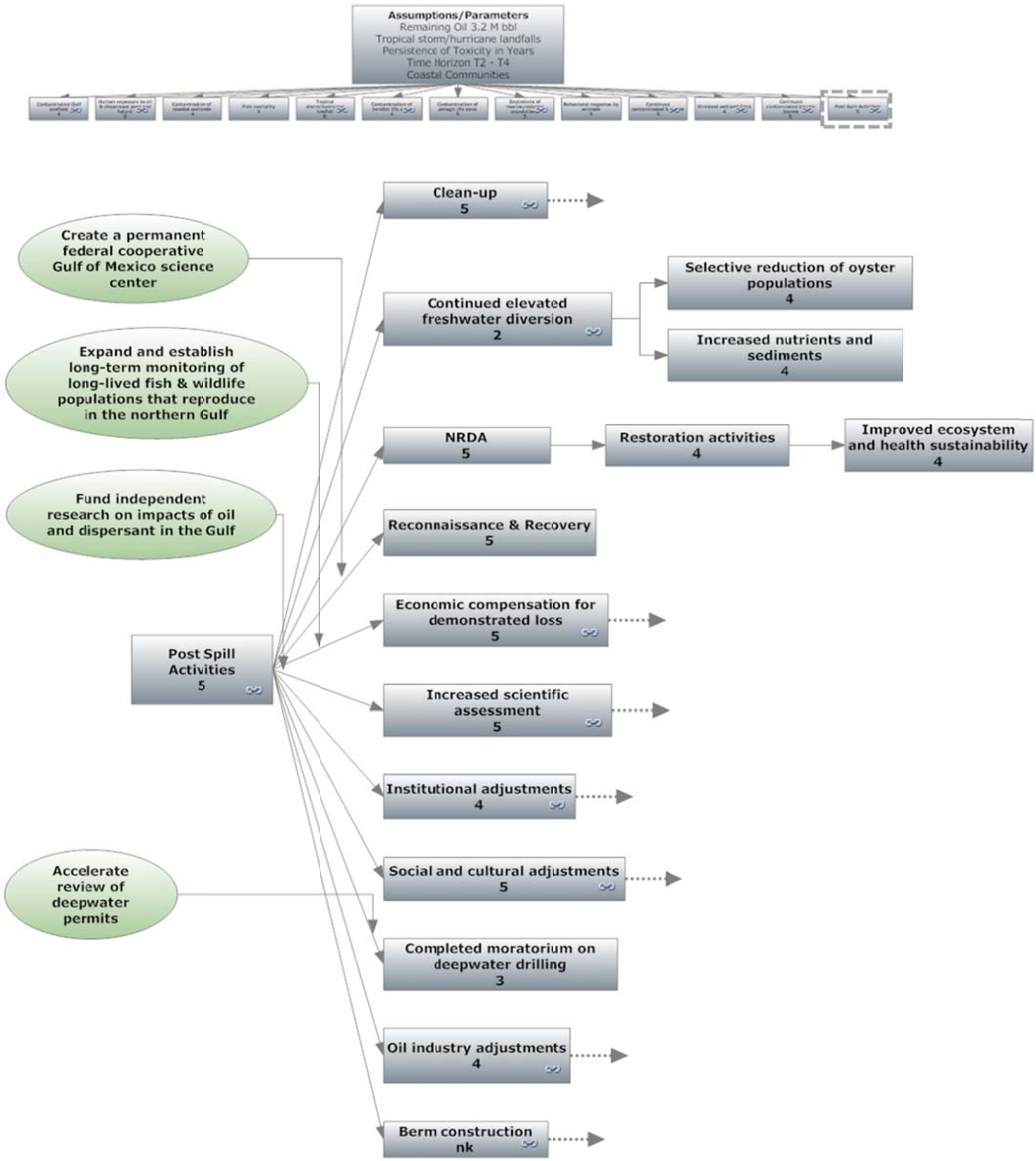


Figure 3m: Post-spill activities.

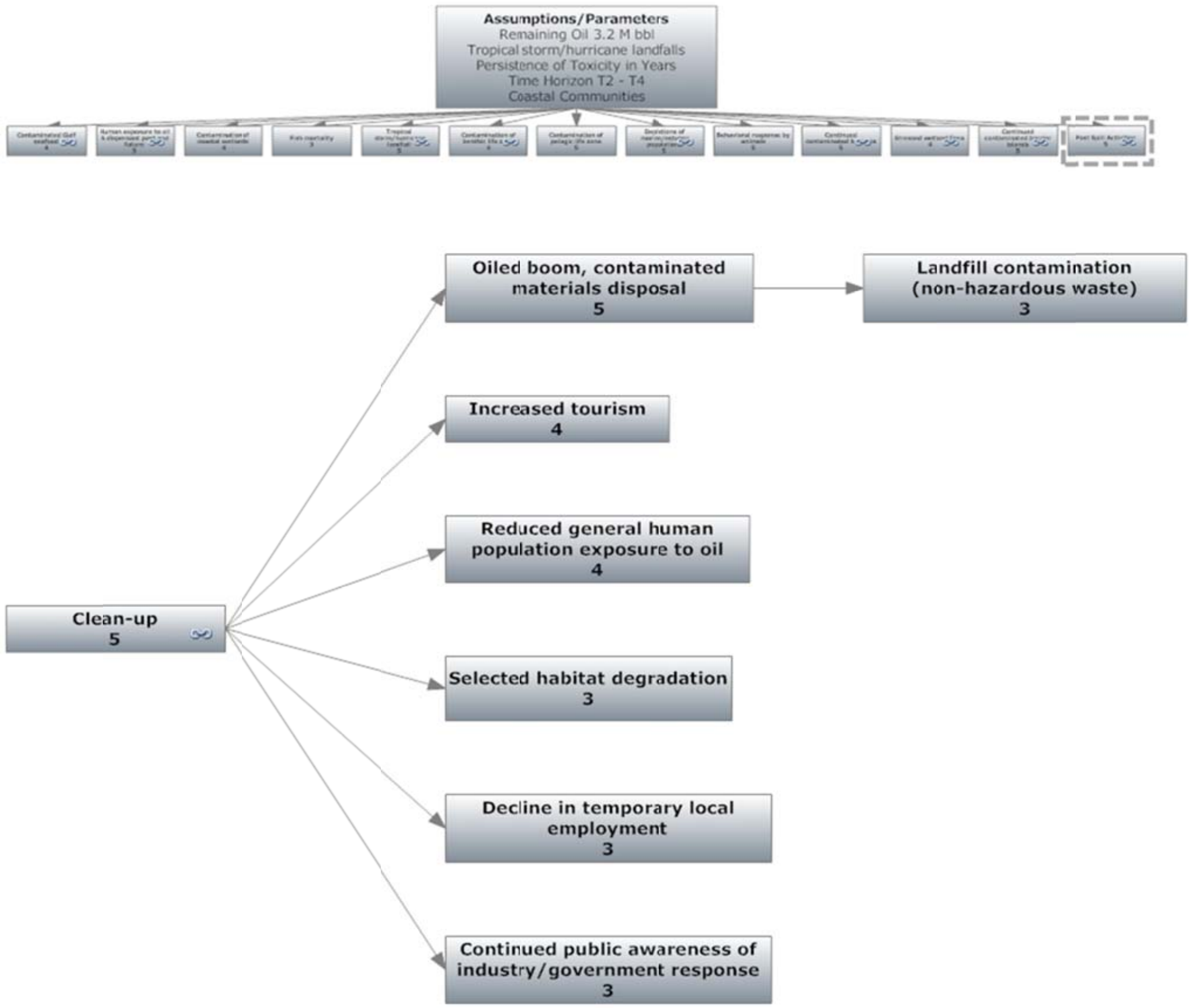


Figure 3n: Clean up.

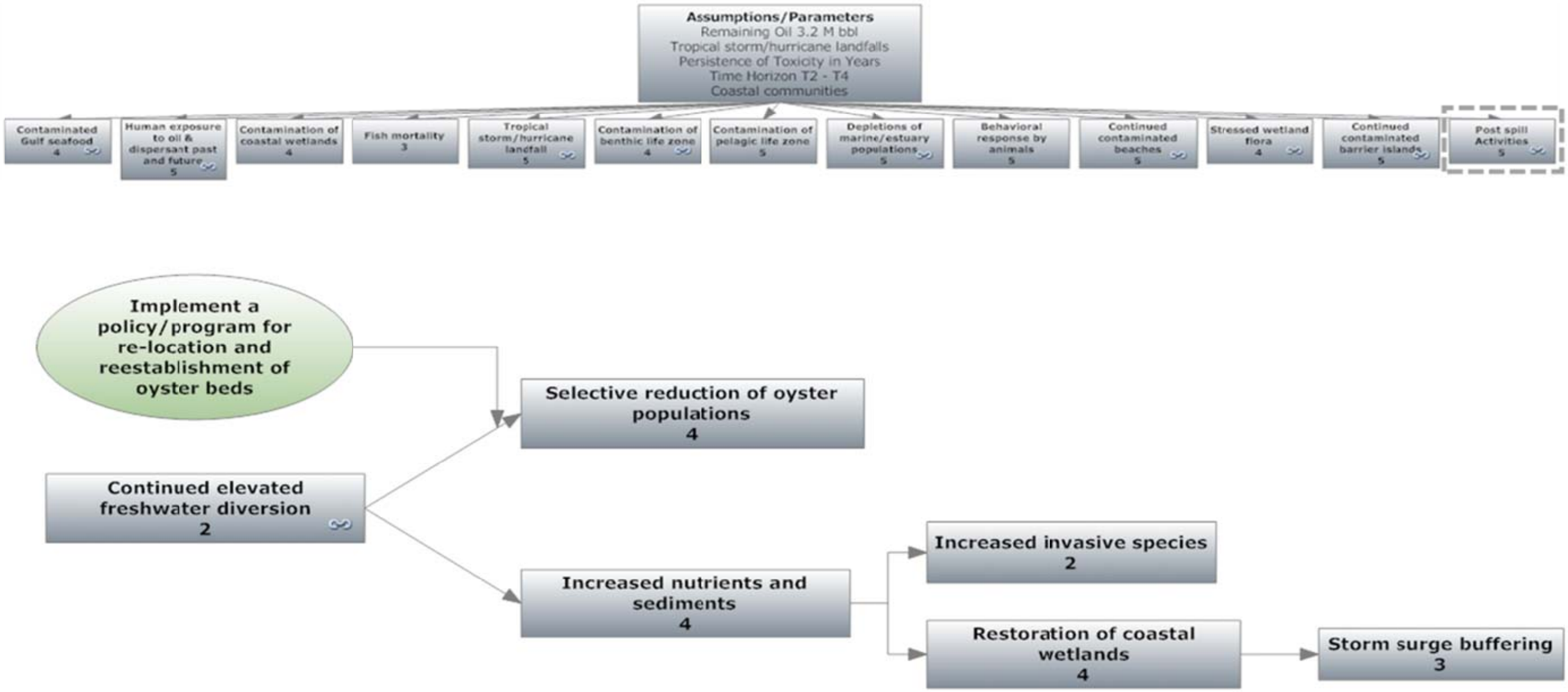


Figure 3o: Continued elevated freshwater diversion.

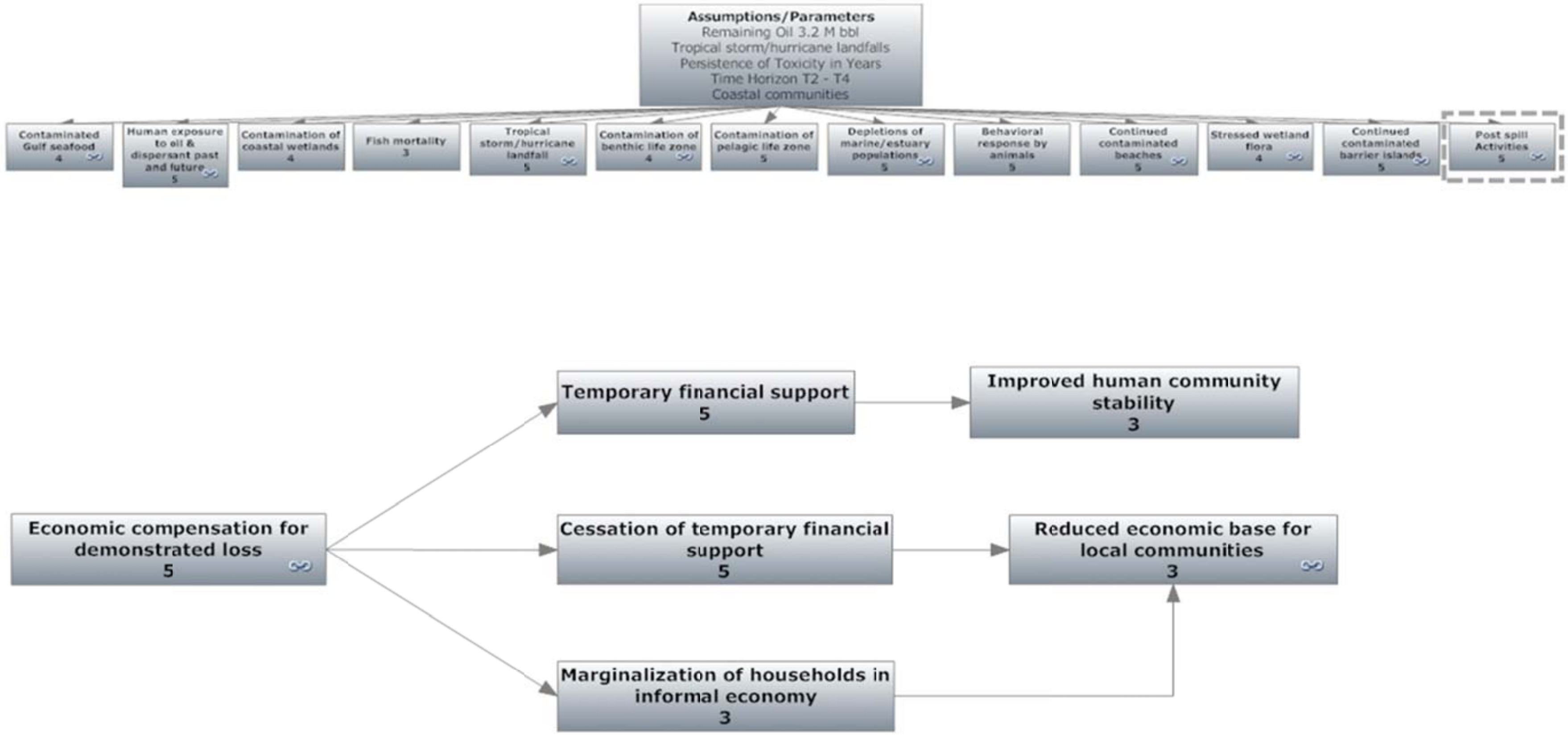


Figure 3p: Economic compensation for demonstrated loss.

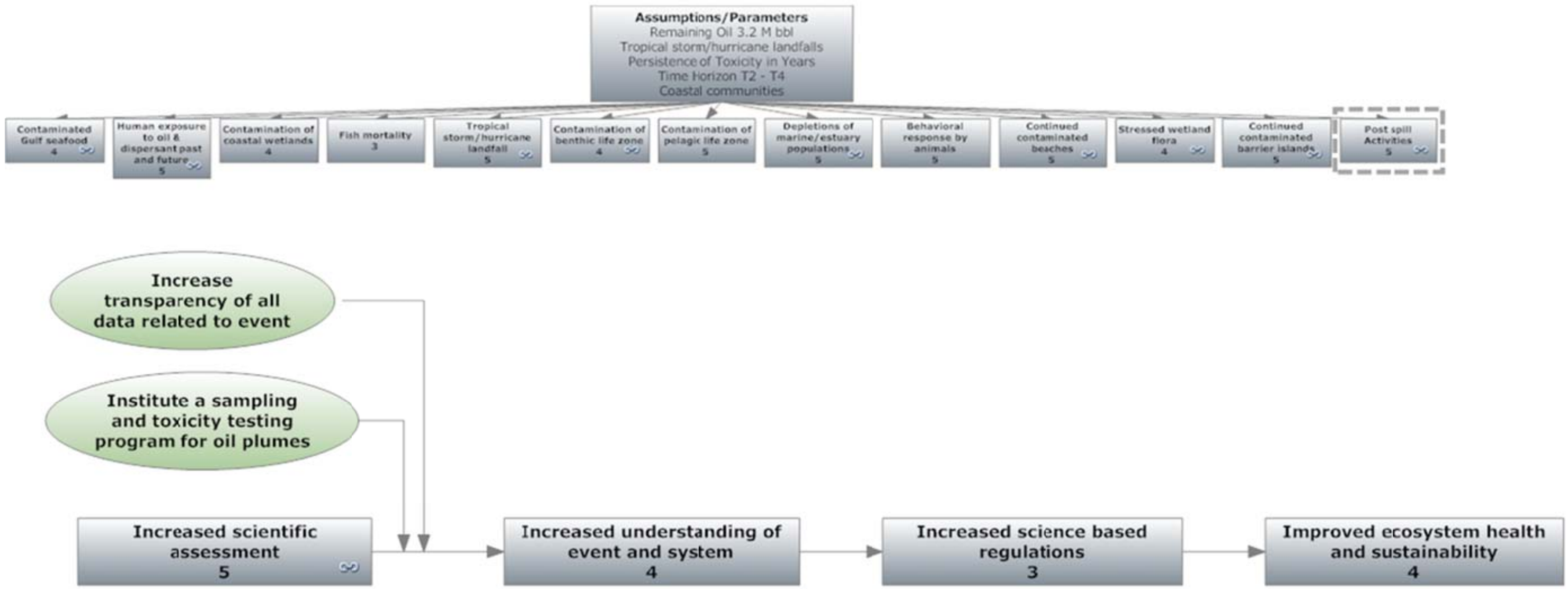


Figure 3q: Increased scientific assessment.

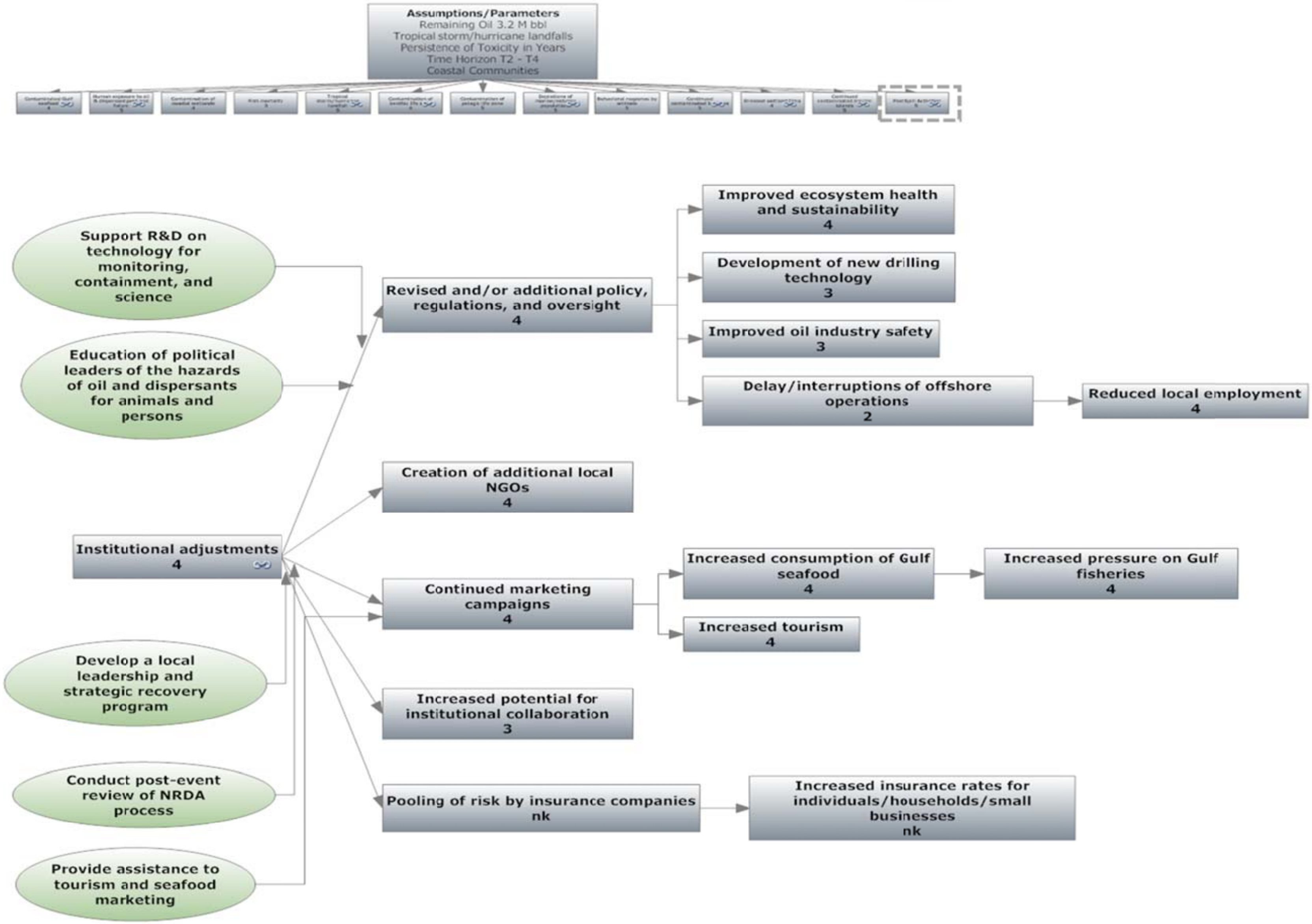


Figure 3r: Institutional adjustments.

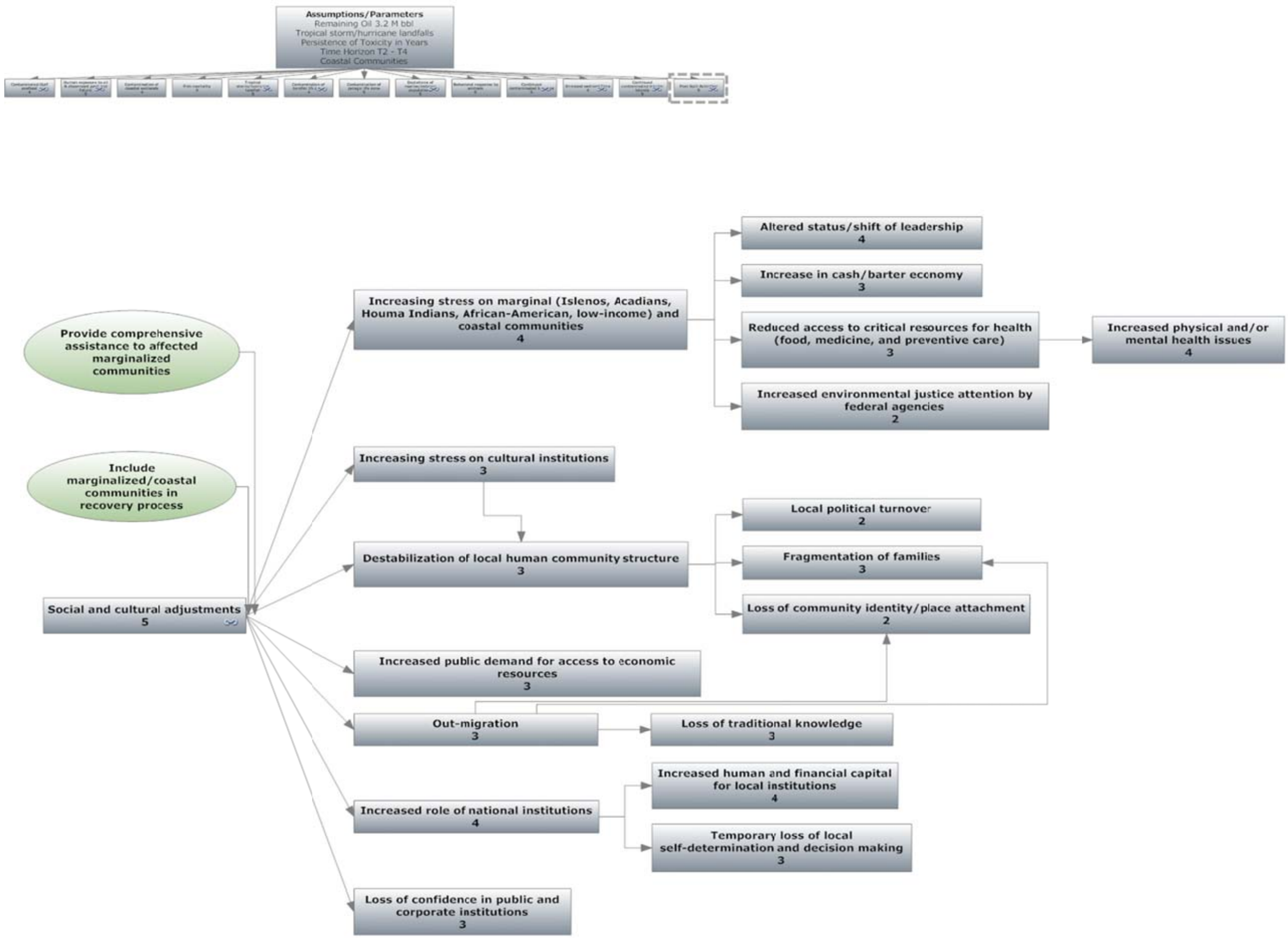


Figure 3s: Social and cultural adjustments.

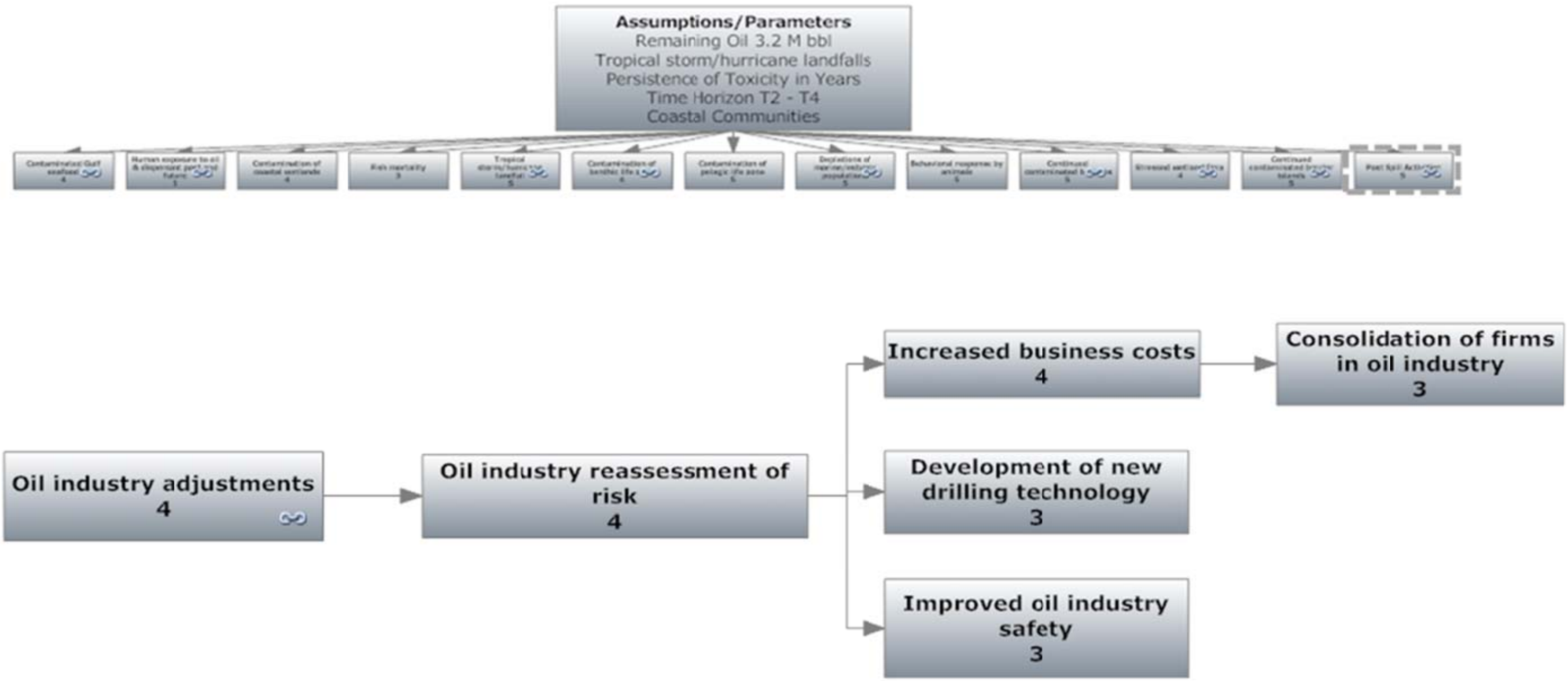


Figure 3t: Oil industry adjustments.

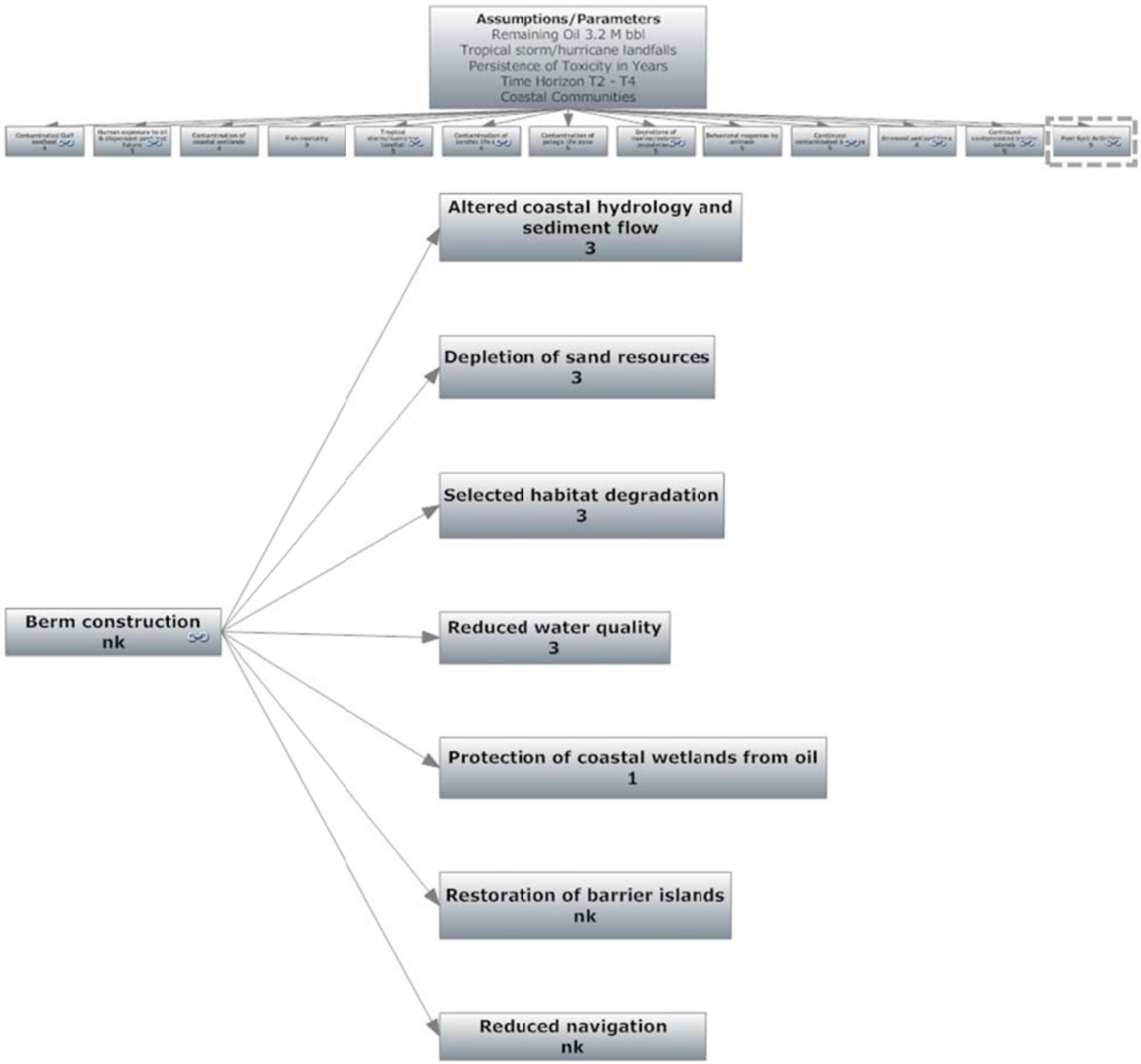


Figure 3u: Berm construction.

Scenario 5

Scenario 5 examined the mid- to long-term recovery when spill-related stress to the coupled natural-human system is expected to be declining. The focus of the scenario was on the consequences of oil entrained in the sediment. The scenario parameters were 1) toxicity of oil and dispersant persisting for decades, 2) the benthic zone of the northern biodiversity quadrants (which includes Florida, Mississippi, Alabama, Louisiana, and Texas) of the Gulf of Mexico as the spatial unit, and 3) T_2-T_4 as the time horizon. Scenario assumptions were: 1) 3.2 million bbl of oil remaining in the GOM system, and 2) at least one major landfall tropical storm or hurricane during recovery. The scenario is shown in Figure 4.

This scenario focused upon the possibility of the remaining oil being entrained in the sediment. The scenario identified several direct consequences: 1) oil in the beaches, 2) oil in estuarine sediment (both in soluble and non-soluble phases), 3) oil in near-shore sediment (soluble and non-soluble phases), and 4) increasing oil in offshore sediment (soluble and non-soluble phases).

Several illustrative highlights emerge from this scenario:

- Due to oil in the beaches, it is reasonably certain that fauna will have some difficulty burrowing due to contact with or avoidance of solid-phase oil, which could lead to a probable altered sand ecosystem.
- Consequences of oil in estuarine sediment include such probable consequences as altered regional food webs and destabilization of human communities dependent on oysters.
- It is reasonably certain that oil in near-shore sediments will lead to reduction in commercial and recreational fishing and localized economic and social impacts. It is plausible that oil in near-shore sediments could lead to a bloom of oil-eating microbes, which could lead to a probable reduction of oxygen.
- Increasing oil in offshore sediment had several significant potential consequences, including a probable loss of habitat and biodiversity for deep-water corals and probable decreased resilience and increased mortality for epibenthic communities.

The scenario includes numerous potential interventions that could accelerate recovery identified by the Working Group. The interventions are identified in the figure and listed below (in no order of priority).

Scenario 5 Interventions:

1. Map the presence of oil across the northern Gulf of Mexico.
2. Create a long-term citizen science effort to monitor and map oil in sediment.
3. Establish a beach safety monitoring and alert system.
4. Develop absorbent booms and anchoring systems that can withstand moderate storms.
5. Assess the potential of barrier protection for coral reefs.
6. Implement a program to stabilize oyster fisheries compatible with freshwater diversions.
7. Conduct research on degradation processes (and fate) of MS252 oil.
8. Conduct targeted restoration of affected oyster beds.
9. Develop and apply new, less invasive cleanup techniques for sensitive habitats.
10. Conduct ecotoxicological research on the fates and accumulation of hydrocarbons throughout the Gulf of Mexico ecosystem.
11. Improve and extend seafood monitoring.
12. Implement a coral reef propagation and restoration program.
13. Assess reorganization of oyster bed leasing to minimize risk to individual lease holders.
14. Create no-take marine reserves for novel habitats.
15. Test effectiveness of depuration of oysters for consumption.
16. Conduct research on toxicity of metabolites.

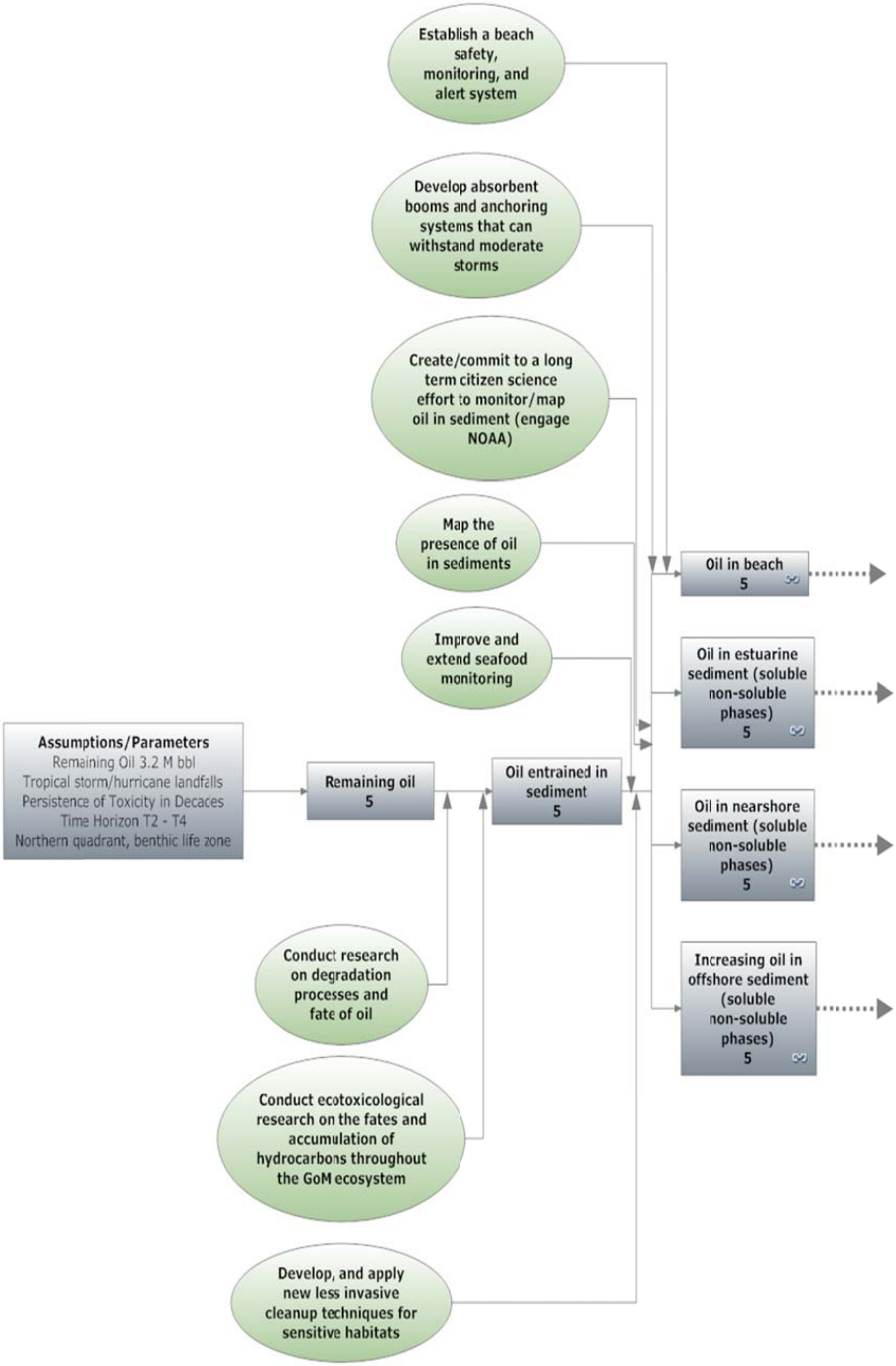


Figure 4: Illustration of chain of consequences associated with scenario 5.

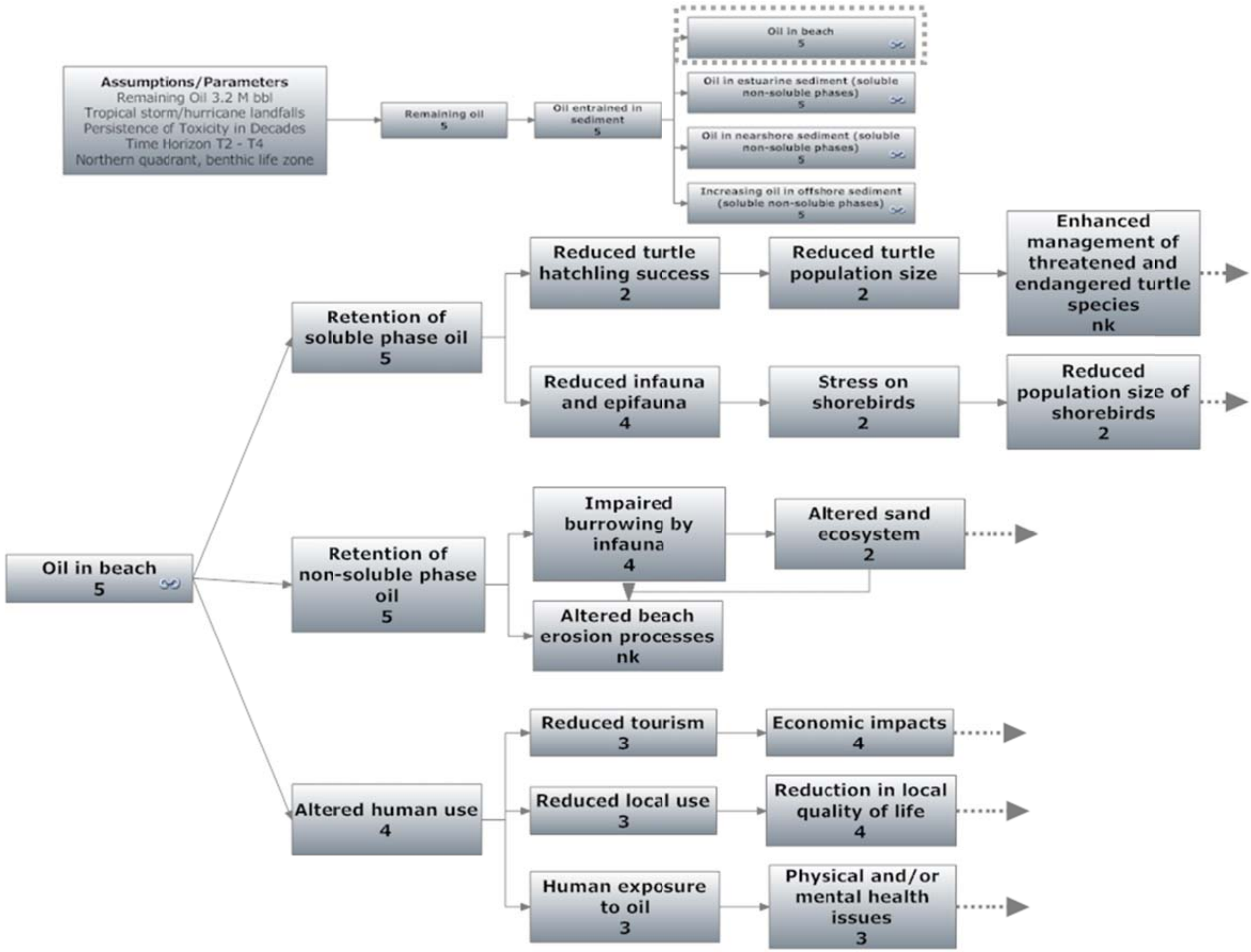


Figure 4a: Oil in beach.

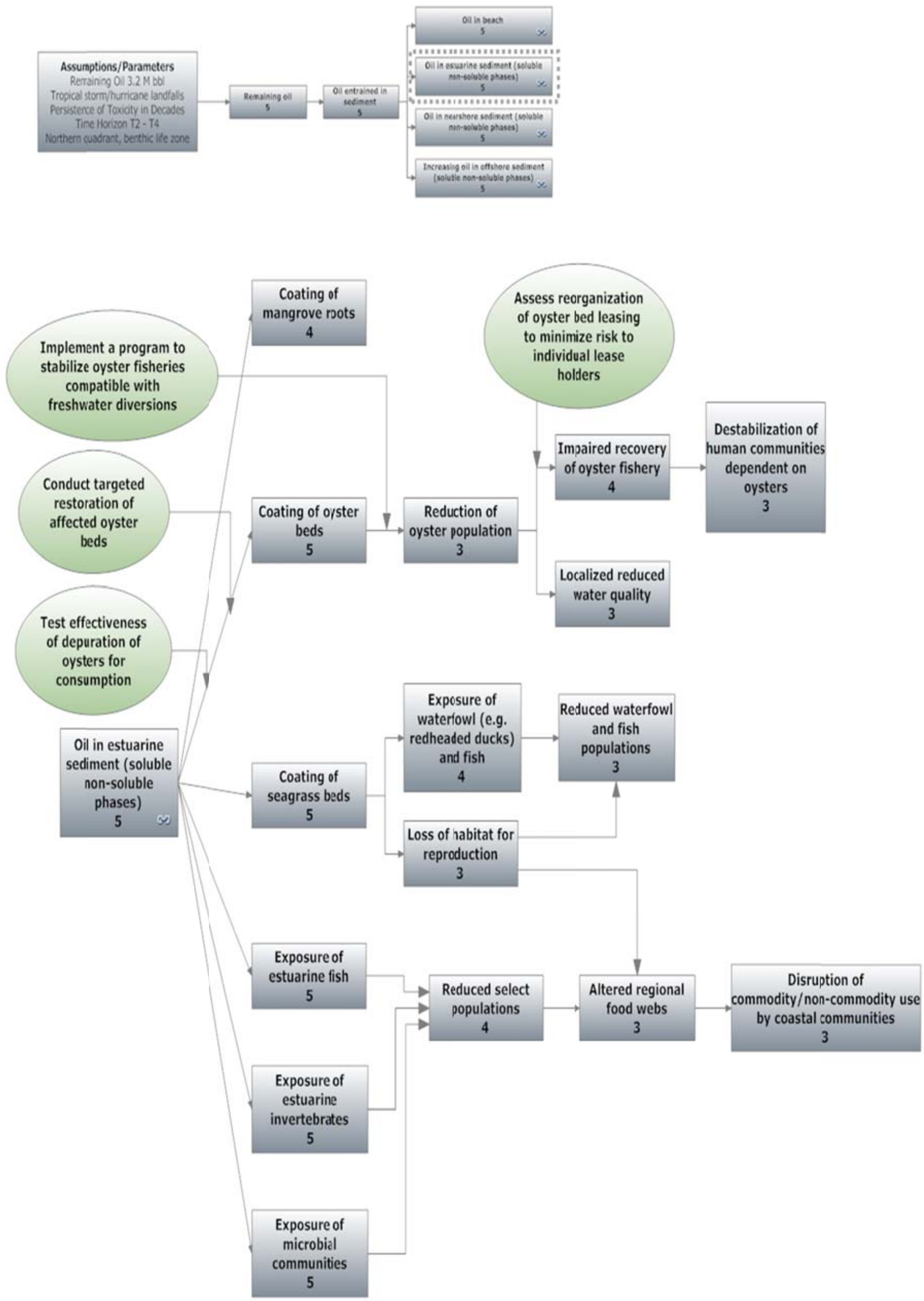


Figure 4b: Oil in estuarine sediment (soluble non-soluble phases).

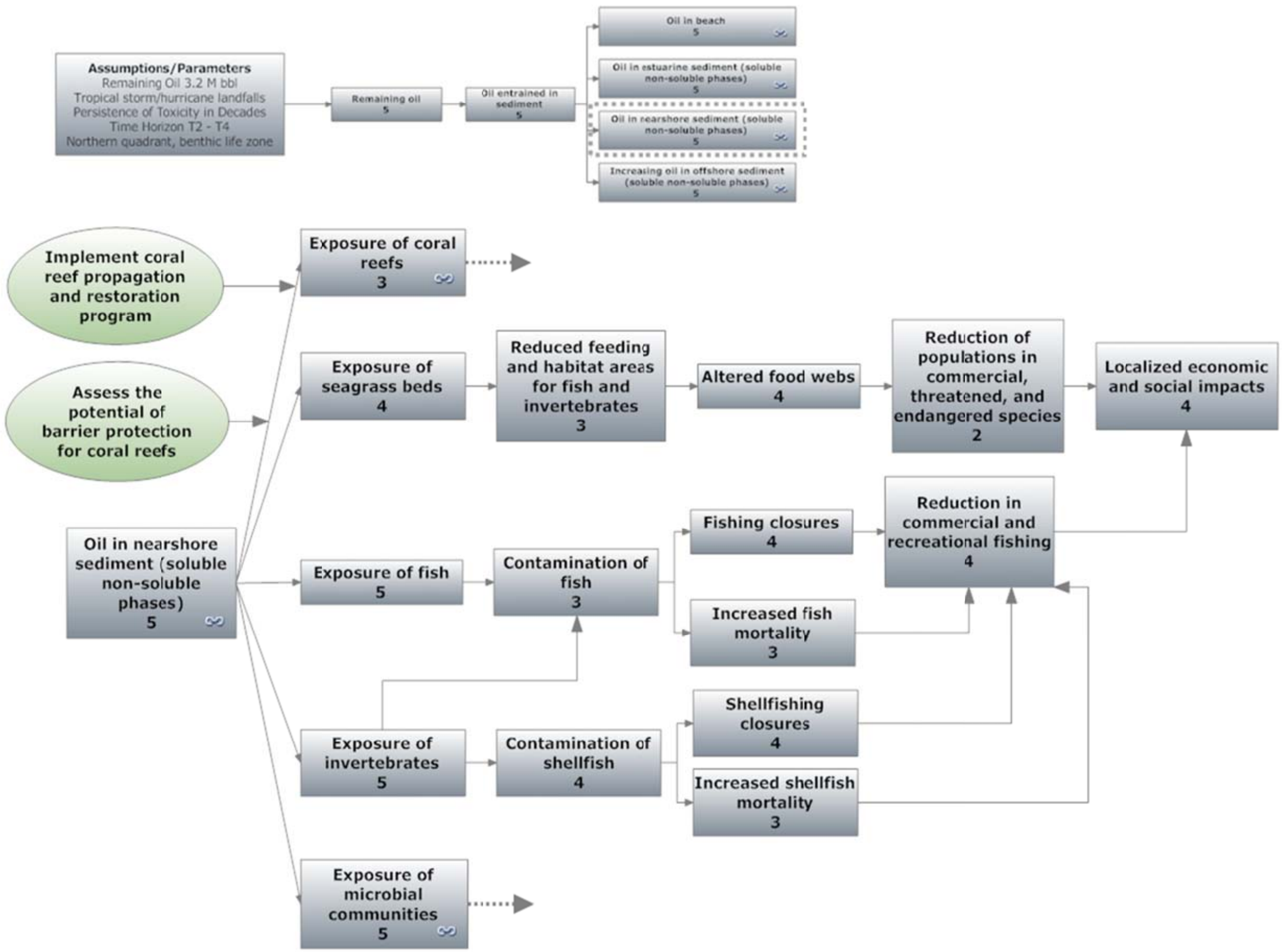


Figure 4c: Oil in near-shore sediment (soluble non-soluble phases).

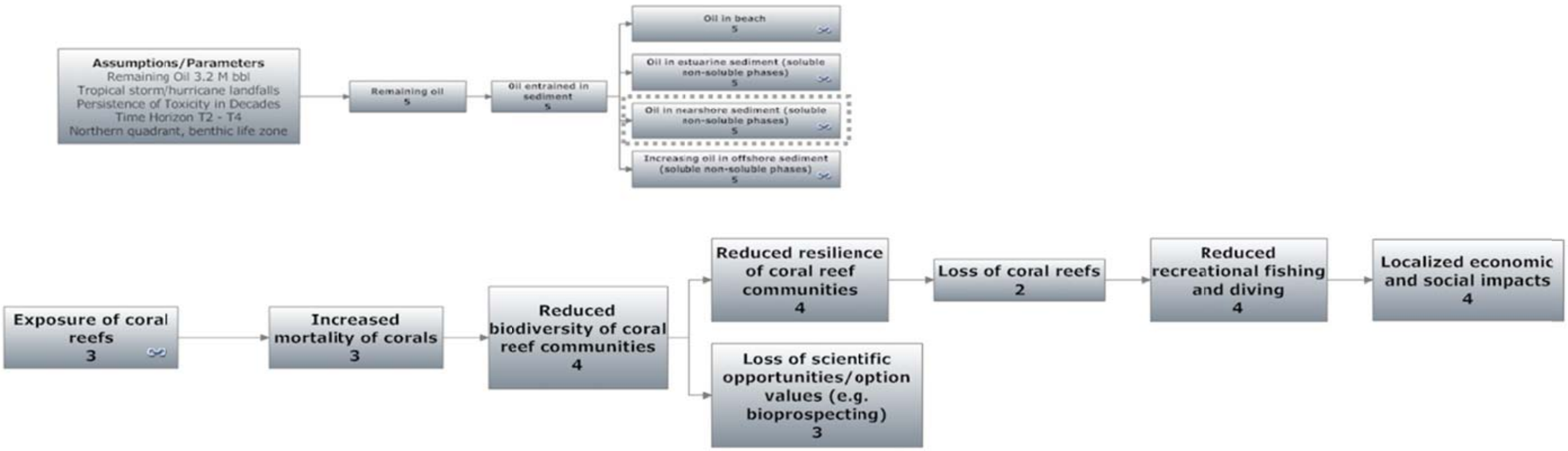


Figure 4d: Exposure of coral reefs.

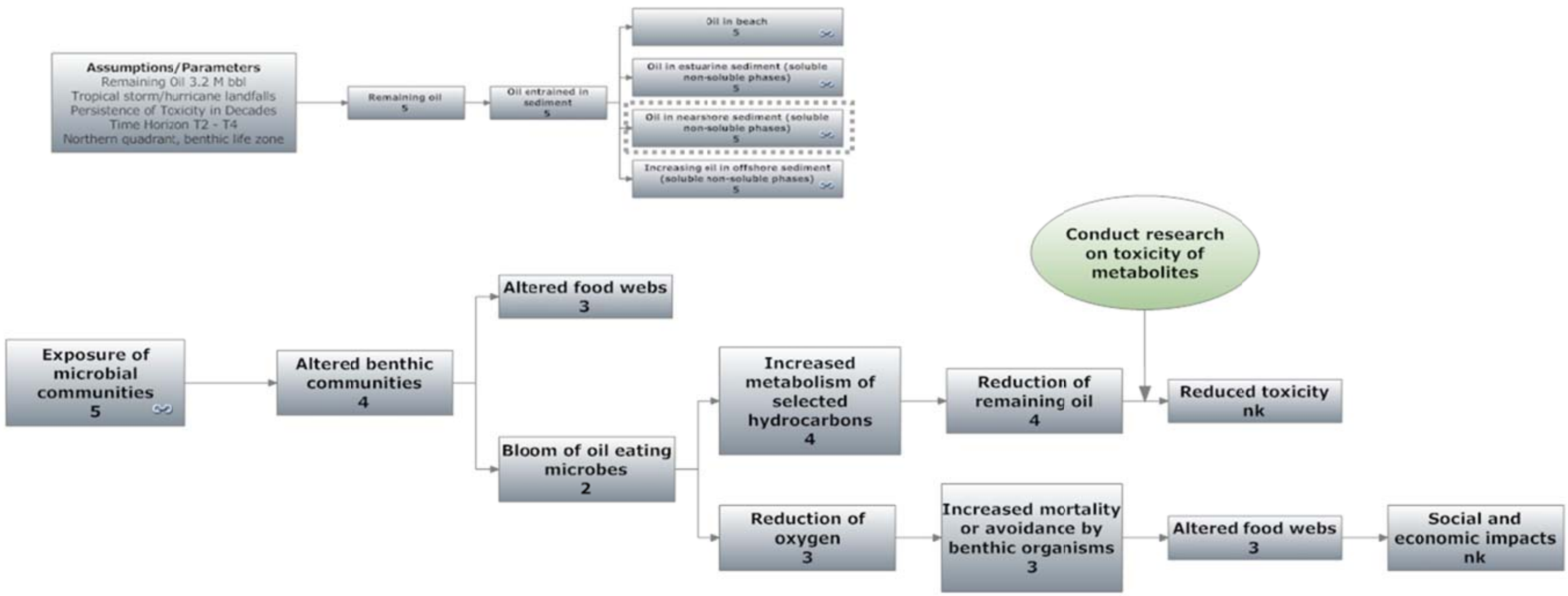


Figure 4e: Exposure of microbial communities.

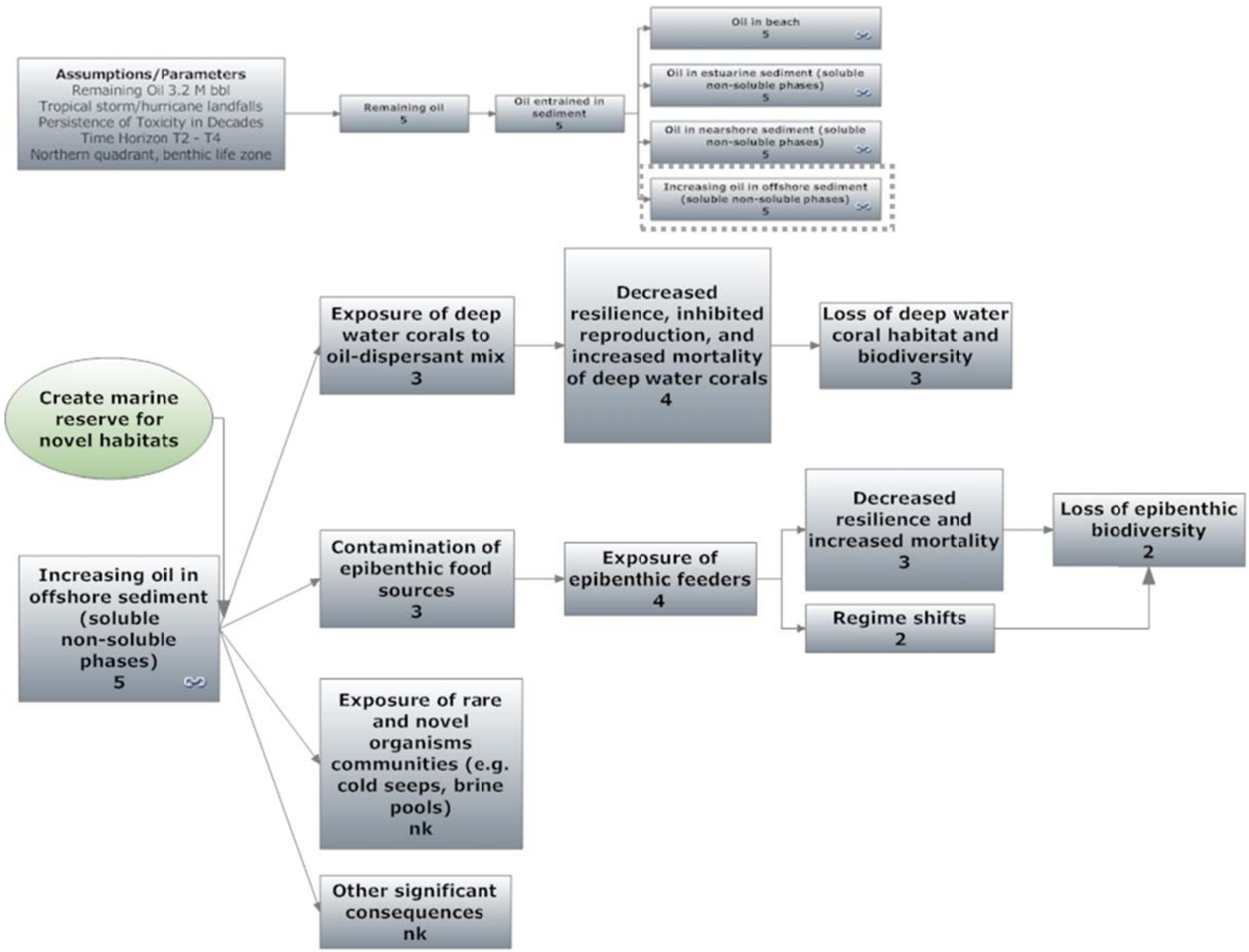


Figure 4f: Increasing oil in sediment (soluble non-soluble phases).

Lessons Learned

At the end of the second session, members of the Working Group suggested a wide range of lessons learned relevant to both continued work related to the MS252 oil spill and future emergencies and events.

1. The Working Group's abilities will always be limited in areas where group knowledge and expertise are lacking. Selecting a diverse range of appropriate expertise remains an essential element of success in developing robust and interdisciplinary scenarios. The addition of new members to the Working Group was highly valued; selected further additions may be beneficial.

2. Adding members to the Working Group such as a microbiologist and a resource economist with both neoclassical and green accounting or environmental services training would be helpful. In addition, staff assistants are extremely valuable. Exposing the next generation of scientists by including graduate students and early career stage scientists in the strategic science process is valuable.

3. Establishing scenario parameters in advance would allow Working Group members to do preliminary research before each session; however, the full Working Group would need to be involved in identifying sound and essential parameters. Video conferencing in advance of the session is an alternative worth exploring.

4. Displaying a scenario online in real time would allow group members to see the full scenario with better functionality of the graphic software. All members of the Working Group should be at least somewhat familiar with the graphic software. Two individuals recording the scenario development would allow one person to develop the chains of consequences in the graphic software, while the other person records background information useful to the scenario building.

5. The 5-day work schedule and Gulf venue (New Orleans) used in the second session worked well. Developing the capacity to have a remote or virtual meeting should be considered. Depending on the type, severity, and location of the event, a Working Group session may have to take place at a different venue; this should be carefully considered.

Applications

The products of the Strategic Sciences Working Group can have specific application to emergency response and long-term recovery efforts associated with the MS252 oil spill. These applications are relevant to both the MS252 oil spill and to future emergencies and events.

1. *Help identify critical decision points for DOI leadership and resource managers during late emergency, response, and recovery phases of an event.*

Each of the scenarios has an associated chain of consequences; the scenarios provide a set of critical decision points with associated levels of scientific uncertainty. DOI leadership and resource managers can use the scenarios to identify key decision points (particularly those impacting response and recovery phases) and focus increased attention on those associated with low levels of scientific uncertainty or those with higher levels of uncertainty and potential impacts for the broader system.

2. *Help identify and prioritize possible interventions by decision makers and resource managers to mitigate negative impacts and foster positive recovery responses.*

The second session of scenario building included the development of over 35 possible interventions and located them in specific scenarios and at specific intervention points in a chain of consequences. The Working Group was not able to prioritize interventions due to time constraints, but, in the future, decision makers and resource managers can evaluate and prioritize these interventions and consider those likely to have substantive impact on reducing negative impacts (such as re-release of sequestered oil) and increasing resilience and positive recovery responses (such as improved monitoring and targeted income support). This is particularly useful during the long-term recovery period and, if shared with decision makers, could help accelerate recovery.

3. *Help identify critical information needs and knowledge gaps for decision makers and resource managers.*

Because each consequence of a scenario is associated with a level of scientific uncertainty, the scenarios can help identify consequences that require additional information, research, monitoring, or scientific assessment. For example, relatively high uncertainty associated with the impact of landfall of tropical storms or hurricanes on the re-release of sequestered oil (and subsequent stress on the coupled natural-human system) would suggest an important research agenda. Similarly, the uncertainty surrounding the impact of oil and dispersant exposure on human health would support heightened consideration of increased health monitoring protocols.

4. *Provide useful insight and information to decision makers conducting risk analyses associated with emergency incidents and events.*

The scenarios can be used (along with the scientific uncertainties associated with each consequence) to inform general and specific risk analyses conducted by decision makers and resource managers. Examples are 1) risk analyses associated with berm island construction, 2) wetlands burning as a tool of marshland recovery, or 3) cumulative occupational exposure to oil and dispersant.

5. *Inform decision makers and resource managers of "potential surprises" associated with cascading effects of emergency incidents and events.*

In some cases, the scenarios can reveal potential surprises that initially might be overlooked by decision makers and resource managers. Examples related to the MS252 event might include 1) potential consumption of seafood that is illegally harvested or does not meet legal standards and its cascading human health effects, 2) fishing closures leading to rebound of previously stressed fish populations, 3) the impact of re-introducing compromised birds into migratory bird populations, and 4) the collapse of fisheries years after the spill as a consequence of trophic cascades.

6. *Help identify future monitoring requirements, techniques, and technologies to inform inventory and monitoring programs, Natural Resource Damage Assessments (NRDA), Incident Command Teams, Operational Leadership preparation, and research programs.*

The scenarios, their chains of consequences, and proposed interventions can be used to identify potential new monitoring requirements as well as techniques and technologies to measure key variables and flows in the coupled natural-human system over time. Related to the MS252 oil spill, this might include 1) development of new storm-resistant boom technology, 2) advanced monitoring techniques and toxicity testing for mid-water pollution, 3) new protocols for monitoring re-release of sequestered oil and loss of traditional knowledge, and 4) long-term health monitoring for occupational exposure and financial stress associated with the spill. Such advances can support ongoing inventory and monitoring programs, help develop future NRDA protocols and contribute to Incident command training.

7. *Help prioritize immediate, mid-term, and long-term future research needs.*

The chains of consequences are identified with approximate levels of scientific uncertainty. These evaluations can help prioritize research needs by identifying important but not yet well-understood relationships. For example, the relationships among the oiling of marshland, resulting ecosystem stress, and future repeated landfall hurricanes are not fully understood but represent a key mid-term and long-term research need. In the case of the MS252 spill, the results can be integrated into the current DOI science planning process and provide input to Federal Government-wide science planning and contribute to regional science plans prepared by and for the academic community.

8. *Provide the conceptual framework for development of quantitative predictive models of coupled natural-human system response to major disruptions.*

The objective and tasks of the DOI Strategic Sciences Working Group did not include the development of quantitative predictive models of coupled human/natural systems; such efforts require significant and additional time, people, and data resources. However, the combination of the organizational framework (the human ecosystem model and the scenario framework) and the chain of consequences can be used as a preliminary step in quantitative model building. Use of basic STELLA modeling techniques (Hannon and Ruth 1994) might be particularly well suited to initial efforts; Bayesian network models (Jenson and Nielson 2007) reflect another possible alternative. Integration of the proposed interventions into such modeling would add significant complexity but should be considered for the added value to decision makers faced with establishing priorities for recovery and restoration actions.

Recommendations

1. The Unified Command in New Orleans should be briefed on the second session of the Working Group as soon as possible.

2. While select DOI leadership were briefed on key elements of the second session scenarios, the broader DOI leadership should be briefed on the Working Group's results as soon as possible.

3. The Working Group should be convened in a third (and final) session to a) further advance the existing scenarios based on additional input and new information, b) complete additional scenarios focused on long-term recovery and interventions appropriate to DOI mission and responsibilities, and c) prioritize interventions identified. Several aspects were not explored in the scenarios to date—such as the dispersal of oil through aerosolization, resuspension of sediments, and the persistence of tar balls—and could be considered in future scenarios.

4. Additional scientists from relevant disciplines should be added to the Working Group, including scientists from agencies outside DOI.

5. As Gulf Coast restoration proceeds over the next few decades, the resources and results of this Working Group should be available and accessible to future Working Groups and decision makers.

6. The proposal to establish a long-term capacity for strategic sciences should be presented to DOI leadership.

Conclusion: A Strategic Sciences Approach to Major Environmental Incidents

In addition to the specific applications described above, the strategic sciences working group technique is useful for developing broad strategies to deal with the challenges of the MS252 oil spill. Colten et al. (2008) provides historical and comparative evidence that recovery of a coupled natural-human system after a disaster generally follows the pre-disaster trajectory with the disaster accelerating or amplifying previous trends. The scenario framework used by the Working Group (Figure 2 above) for the MS252 oil spill reflects this common and repeated pattern.

The system stress model developed by the Strategic Science Working Group (Figure 5) seeks to relate the changes in the stress to a coupled natural-human system in the event of a disruptive event. The model is adapted from Kates' human recovery model from a hazard event (Haas et al. 1977). The initial time period (before T_0) reflects low but increasing stress as human activity produces ongoing and increasing stress on the natural system (A). In the immediate wake of a major disruptive event (such as the Deepwater Horizon well failure and explosion), system stress increases dramatically. Emergency response efforts (B – to control the oil release, cap the well, and remove accessible spilled oil) eventually arrest the steep upward trend, although stress continues to increase at a more moderate rate. Active restoration efforts (C) that seek to repair the damage to the natural-human system commence after the successful control of the disruption's source (in this case, capping the well) and eventually begin to steer the stress on a gradual downward trend. Overlapping with restoration, long-term and more passive reconstruction efforts (D) continue to moderate the stress level.

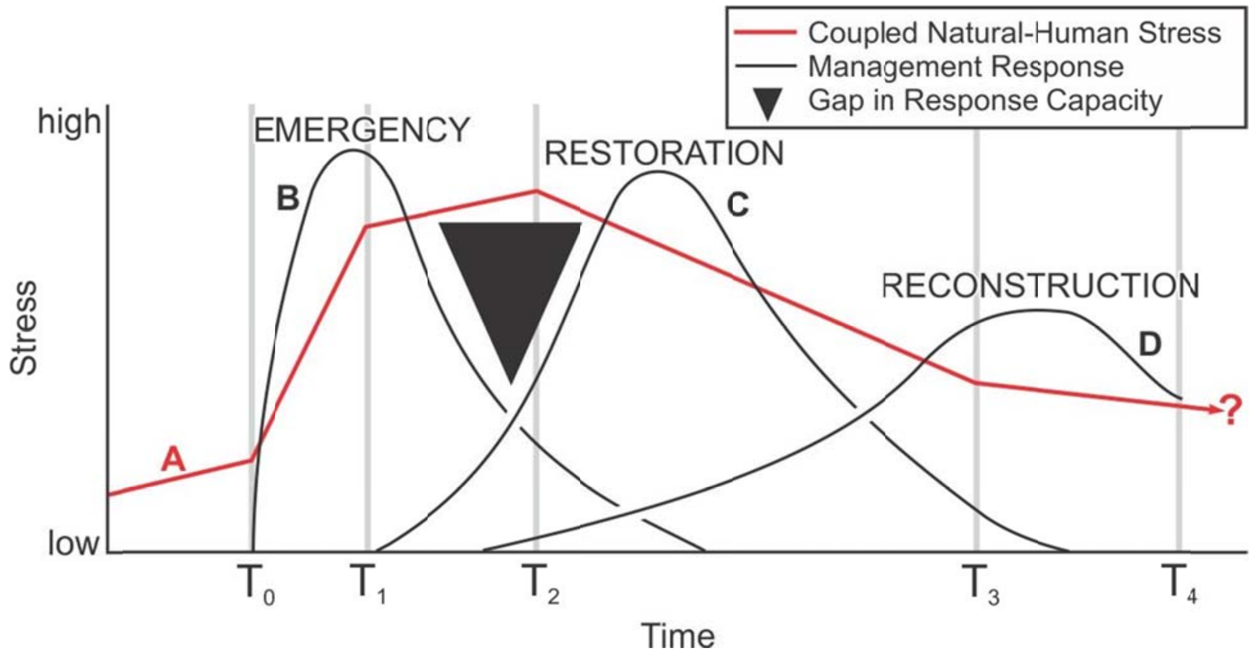


Figure 5: Stress on a coupled natural-human system is potentially or probably low (A) prior to a significant disruptive event, which causes stress to spike (T_0 to T_1). Emergency response efforts (B) contain the disruption, and stress begins to level (T_1-T_2). Active restoration responses (C) begin to reduce stress (T_2-T_3), and reconstruction responses (D) produce a long-term trend towards the pre-event stress level (T_3-T_4). The Gap in Response Capacity reflects the lag between adequate assessment of the event and its impacts and the mobilization of strategic restoration efforts (adapted from Haas et al. 1977).

A strategic science response to a disruptive event can provide more immediate assessment of the range of system stresses and the priorities for effective restoration and reconstruction. This enables a nearly concurrent restoration response, which can lower the peak stress and also accelerate the reduction in stress, which can prove particularly beneficial in the event of a secondary disruptive event (see Figure 6). By initiating restoration activities (C_2) sooner and increasing their overlap with the emergency response (B), the stress level during the T_1-T_2 time period is lowered. The rapid response diminishes the gap in response capacity. An accelerated restoration response has the beneficial impact of shifting the stress level below the level anticipated with a slower restoration response (C_1).

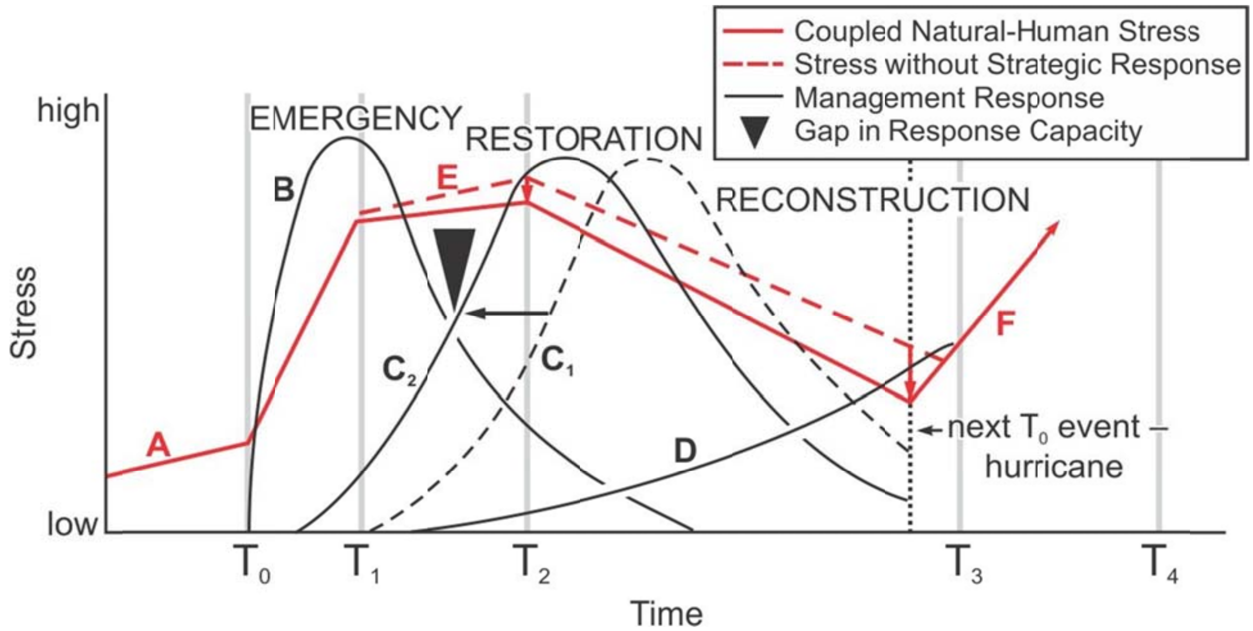


Figure 6: A strategic restoration response (C2) will lower the peak stress (E) and reduce the Gap in Response Capacity. By lowering the stress peak, reconstruction will commence at a lower stress level and lead to an accelerated reconstruction of the natural-human system. In the event of a subsequent T_0 event during restoration, the second spike (F) will begin at a lower level and the response activities will contend with a moderated stress level.

Of equal importance, by lowering the stress trend line following control of the disruption, resource managers would expect a secondary disruptive event (such as a hurricane) to initiate a second stress spike from a lower starting point (F). If the stress level is lower at the time of a secondary event, emergency, restoration, and reconstruction responses will contend with less severe conditions. A response framed by strategic methods can reduce the cost of secondary response in the event of a subsequent event before reconstruction is completed.

In addition, the strategic sciences working group technique is well suited to provide scientific assistance to preparations, emergency response, and recovery efforts related to other emergency incidents, including large-scale oil spills, bioterrorism attacks, hurricanes, earthquakes, significant wildfires, floods, and other hazard events. There may be a unique and valuable role for this concept and technique, as the DOI learns from the MS252 oil spill and prepares for future major environmental incidents.

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APPENDIX 1

DOI Strategic Sciences Working Group Members

DOI Strategic Sciences Working Group Members

Dr. Gary Machlis
Strategic Sciences Working Group Lead Scientist
Science Advisor to the Director, National Park Service

Dr. Craig Colten
Carl. O Sauer Professor of Geography
Louisiana State University

Dr. Jeffrey Cross
Chief, Ocean & Coastal Resources Branch in the Natural Resource Program Center
National Park Service

Dr. Barry Forsythe
USFWS Liaison to USEPA Region VI
US Fish & Wildlife Service

Dr. James Grace
Senior Research Ecologist
US Geological Survey

Jenny Hay
Doctoral Student
Louisiana State University

Jason Newman
Assistant Team Leader
National Park Service

Joshua Platt
Director of Product Marketing
SmartDraw

Dr. Glenn Plumb
Acting Chief, Yellowstone Center for Resources
Chief, Branch of Aquatic and Wildlife Resources
National Park Service

Dr. Rudy Schuster
Branch Chief, Policy Analysis & Science Assistance
US Geological Survey

Dr. Susan Shaw
Founder/Director Marine Environmental Research Institute (MERI)
MERI

Dr. Edith Widder
CEO, President & Senior Scientist Ocean Research & Conservation Association (ORCA)

ORCA

Rachel Woita
Research Assistant
University of Idaho

APPENDIX 2

Daily Briefing Statements Prepared for DOI Incident Commanders by DOI Strategic Sciences Working Group 21 – 24 September 2010

DOI Strategic Sciences Working Group

Daily Briefing Statement

9:00 PM

20 September 2010

Background

The Department of the Interior DOI Strategic Sciences Working Group (formed in response to the Deepwater Horizon oil spill) is meeting in New Orleans, LA 19-24 September 2010. The Working Group includes representatives from the National Park Service, US Geological Survey, US Fish & Wildlife Service, regional universities, nonprofits, and a software company. The tasks are to develop scenarios for mid- to long-term recovery and possible interventions to accelerate the sustainable recovery of the Gulf of Mexico as a coupled human/natural system.

Day One Activities

The group met and reviewed operational logistics. Lead Scientist Machlis described the assigned tasks of the Working Group and the rules of engagement. The group reviewed scenario-building methods used in the first Working Group session and will continue with the method as previously developed. The group will continue to use the formal levels of uncertainty adapted from Weiss, 2003.

The group spent considerable time sharing information and discussing potential parameters for the upcoming scenarios. Four parameters will be used: (1) time horizons T_1-T_N from Machlis and McNutt 2010, (2) administrative/spatial units of interest (vertical life zones, ecosystem types, biodiversity quadrants, administrative boundaries), (3) remaining oil (oil and dispersed oil in system; 2.57 million bbl/4.0 million bbl, and (4) persistence of general toxicity in the environment (months, years, decades).

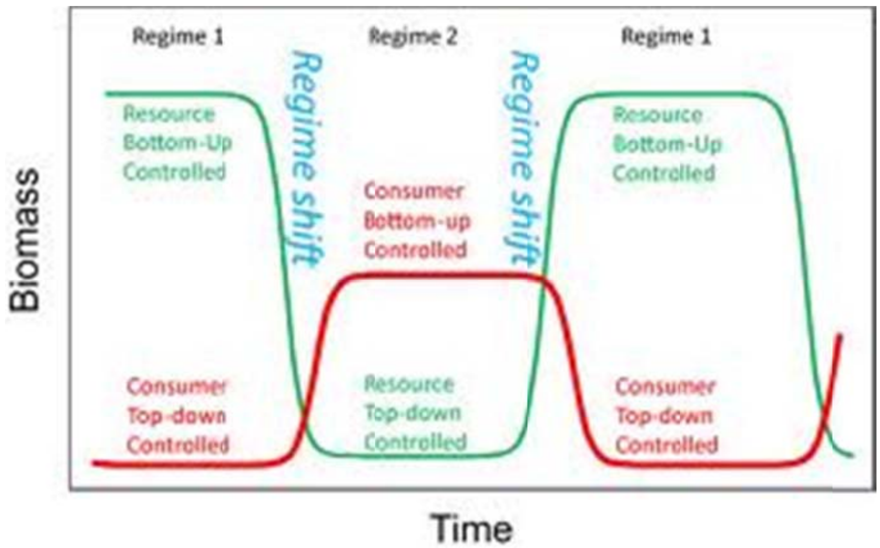
The group began work on Scenario Four using the following parameters: the time horizon T_2-T_4, (mid- to long-term recovery), the spatial unit of coastal communities, 4.0 million bbl oil remaining, and persistence of toxicity in years.

Science Insight

Each day the brief will include an example of scientific insight useful to understanding the consequences of the incident upon the ecology, economy, and people of the Gulf of Mexico.

Impact of increasing stress on Food Webs

The Working Group discussed on-going impacts of the oil spill on food web structure. Examples given were of predators shifting prey choice because of depletion of a primary prey item. Impacts may cascade down a food web. For example, reductions in an herbivore population may lead to increased plant growth (Lubchenco & Gaines, 1981, Estes et al. 1998) or blooms of jellyfish and ultimately "regime shifts" (Daskalov, 2007). A regime shift is like a finger pressing on a light switch, with increasing pressure having little effect until a tipping point is reached and a minimal application of additional force causes a shift into a state that would then require significantly stronger pressures to recover. Regime shifts may have a significant impact on mid- to long-term recovery.



A schematic example of regime shifts

Sources:

Daskalov, G. M., A. N. Grishan, S. Rodionov, & B. Mihneva. (2007). Trophic cascades triggered by overfishing reveal possible mechanisms of ecosystem regime shifts. *PNAS, 104,* 10518-10523.

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Lubchenco, J. & S. D. Gaines. (1981). A unified approach to marine plant – herbivore interactions I populations and communities. *Annual Reviews of Ecological Systems, 12*, 405-437.

Upcoming Briefing of New Orleans Incident Command

Lead Scientist Machlis will brief Rear Admiral Zukunft at the New Orleans Incident Command Tuesday morning, followed by a general briefing for the environmental group at the Incident Command.

Next Steps

Tomorrow's work schedule includes completing Scenario Four (including potential interventions), discussion with USGS Marcia McNutt on selecting Scenario Five, and initiating work on that scenario.

Contact: Dr. Gary Machlis, Lead Scientist, DOI Strategic Sciences Working Group, gary_machlis@nps.gov, 202.746.8877

DOI Strategic Sciences Working Group

Daily Briefing Statement

6:00 PM

21 September 2010

Background

The Department of the Interior DOI Strategic Sciences Working Group (formed in response to the Deepwater Horizon oil spill) is meeting in New Orleans, LA 19-24 September 2010. The Working Group includes representatives from the National Park Service, US Geological Survey, US Fish & Wildlife Service, regional universities, nonprofits, and a software company. The tasks are to develop scenarios for mid- to long-term recovery and possible interventions to accelerate the sustainable recovery of the Gulf of Mexico as a coupled human/natural system.

Day Two Activities

Lead Scientist Machlis briefed Rear Admiral Zukunft and the Environmental Group of the New Orleans Unified Command. Rear Admiral Zukunft recommended that Governor Jindal receive the briefing.

The group met and continued the previous day's work on Scenario Four. More of the scenario was developed and scientific uncertainties added to each of the consequences. Based on the scientific literature, the group revised one of the parameters used in the scenarios. The amount of oil and dispersed oil remaining in the system will now be treated as an estimate of 2.5-3.2 million barrels based on several sources.

A conference call with USGS Director Marcia McNutt was held.

Science Insight

How might remaining oil affect coastal wetland flora?

The oil related to the Deepwater Horizon spill has been described as "sweet crude." Chemical analyses of the source oil indicate that it was low in aromatic hydrocarbons and sulfur content. This particular oil was also found to have high concentrations of asphaltenes. Following evaporation of the light components of this oil (i.e., weathering), the remaining residue is expected to be a tarry asphaltene. This residue is expected to be resistant to degradation and dispersion by biological, chemical, or mechanical means.

Sensitivity of wetland flora to fouling varies among species, age, and season of the exposure. Effects can be classified into two main categories, physical and chemical. From a physical standpoint the oil can coat the stems, leaves, and/or roots. Effects from physical exposure are dependent upon species, thickness of coating, and tide level at the time of exposure, and more. This fouling can prevent plant gas-exchange, causing stress and/or death.

Some plants may produce new leaves and recover from the physical exposure. However, the high asphaltene characteristic could lead to adsorption to organic materials and oil sinking to the root zone. Once the oil is in the root zone, the physical blocking of gas exchange could cause deleterious effects. During clean up actions, there is real potential for the oil in the root zone to be increased by mechanically forcing the oil in and around the roots. With the evaporation of the more acutely toxic light components or the oil, the toxicity of remaining oil is expected to be low to coastal wetland flora as compared to physical stress impacts.

(AP Photo/Gerald Herbert)

Next Steps

Tomorrow's work schedule includes completing Scenario Four (including potential interventions), initiating work on Scenario Five, and revising the conceptual response framework.

Contact: Dr. Gary Machlis, Lead Scientist, DOI Strategic Sciences Working Group, gary_machlis@nps.gov, 202.746.8877

DOI Strategic Sciences Working Group

Daily Briefing Statement

6:00 PM

22 September 2010

Background

The Department of the Interior DOI Strategic Sciences Working Group (formed in response to the Deepwater Horizon oil spill) is meeting in New Orleans, LA 19-24 September 2010. The Working Group includes representatives from the National Park Service, US Geological Survey, US Fish & Wildlife Service, regional universities, nonprofits, and a software company. The tasks are to develop scenarios for mid- to long-term recovery and possible interventions to accelerate the sustainable recovery of the Gulf of Mexico as a coupled human/natural system.

Day Three Activities

The group completed development of the methodology for interventions and completed Scenario Four. Scenario Four used the following parameters: the time horizon T_2-T_4, (mid- to long-term recovery), the spatial unit of coastal communities, 3.2 million bbl oil remaining, and persistence of toxicity in years. The scenario was extended considerably to include biophysical and socioeconomic consequences during mid- to long-term recovery. It also includes over twenty specific potential interventions that could accelerate sustainable recovery.

The group began working on Scenario Five. The scenario will focus on the fate and consequences of oil in the sediment and the process of bioremediation. The scenario will use the following parameters: the time horizon T_2-T_4 (mid- to long-term recovery), the spatial unit of benthic life zone, and persistence of toxicity in decades.

The Working Group also continued work on the revision of the conceptual response framework.

Science Insight

It's Not About Dose

Chemicals in crude oil and dispersants can cause a wide range of health effects in people and wildlife. Highly toxic chemical ingredients such as benzene and polycyclic aromatic hydrocarbons (PAHs) can damage systems in the body (Burns & Harbut, 2010). Exposure to chemicals in crude oil and dispersants occurs through skin contact, inhalation of contaminated air or soil/sand, and ingestion of contaminated water or food. These can occur simultaneously. Crude oil components penetrate the skin and move through cell walls and enter the bloodstream rapidly when they are inhaled or swallowed. Dispersants contain solvents that facilitate rapid entry of oil into cells and organs, and thus oil-dispersant mixtures can be more toxic than either oil or dispersant alone (Burns & Harbut, 2010).

Due to the presence of chemicals in crude oil that are known to cause cancer in humans, and the fact that some of these chemicals can cause DNA damage and mutations, there is no completely safe level of exposure to some crude oil ingredients (Burns & Harbut, 2010). While animals and humans have mechanisms to repair damage, repair does not always occur.

Oil ingredients become more toxic in the body. In fish and vertebrates, including humans, PAHs are rapidly broken down to more toxic metabolites via detoxification processes. PAH metabolites are more carcinogenic and potent than the parent PAH compound itself (Johnson-Restrepo et al., 2008; Kannan & Perrotta, 2008). Over time, PAH metabolites can be eliminated from the body, but even brief exposure during critical life stages may be sufficient to cause serious long-term effects.

References

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Johnson-Restrepo B, Olivero-Verbal J, Lu S, Guette-Fernández J, Baldiris-Avila R, Óbyrne I, Aldous K, Addink R, Kannan K. 2008. Polycyclic aromatic hydrocarbons and their hydroxylated metabolites in fish bile and sediments from coastal waters of Colombia. *Environ. Pollut.* 151, 452-459.

Kannan K, Perrotta E. 2008. Polycyclic aromatic hydrocarbons (PAHs) in livers of California sea otters. *Chemosphere* 71, 649-655.

Next Steps

Lead Scientist Machlis will brief the New Orleans Incident Command on Working Group progress Thursday morning. Thursday's work schedule includes completing Scenario Five (including potential interventions), initiating Scenario Six, and completing revision of the conceptual response framework.

Contact: Dr. Gary Machlis, Lead Scientist, DOI Strategic Sciences Working Group, gary_machlis@nps.gov, 202.746.8877

DOI Strategic Sciences Working Group

Daily Briefing Statement

6:00 PM

23 September 2010

Background

The Department of the Interior DOI Strategic Sciences Working Group (formed in response to the Deepwater Horizon oil spill) is meeting in New Orleans, LA 19-24 September 2010. The Working Group includes representatives from the National Park Service, US Geological Survey, US Fish & Wildlife Service, regional universities, nonprofits, and a software company. The tasks are to develop scenarios for mid- to long-term recovery and possible interventions to accelerate the sustainable recovery of the Gulf of Mexico as a coupled human/natural system.

Day Four Activities

Lead Scientist Machlis briefed the New Orleans Incident Command on progress of the Working Group.

The Working Group completed Scenario Five, including interventions. This scenario focused on the fate and consequences of oil in the sediment. The scenario used the following parameters: time horizon T_2-T_4 (mid- to long-term recovery), spatial unit of benthic life zone, and persistence of toxicity in decades.

The Working Group also continued work on the revision of the conceptual response framework.

Science Insight

Cumulative Impacts to Human Systems

The Gulf of Mexico (GOM) region is a human ecosystem. Resilience is the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes (Resilience Alliance 2007a, 2007b). Resilience in human communities is not about controlling change; resilience is a reflection of the community's ability to cope, adapt, and reorganize in response to change (Magis 2010). Resilience is also influenced by *cumulative* impacts upon a system.

Scenario Five suggests that sediment contamination in the estuarine and nearshore life zones will result in multiple, significant, direct, and indirect impacts to the human system. They are likely to have important cumulative impacts. Impacts are exacerbated in coastal communities that are already have compromised resilience. Well-designed interventions are those that protect human health, quality of life, and local economies in the face of cumulative impacts. Resource managers, scientists (biophysical and social), and policy makers need to work in concert to leverage and sustain social, cultural, human, political, natural, economic, and built resources in response to long-term oil impacts.

References:

Magis, K. 2010. Community Resilience: An indicator of social sustainability. *Society and Natural Resources* 23:401-416.

The Resilience Alliance. 2007[a]. Assessing and managing resilience in social-ecological systems: A practitioners workbook. Volume 1, version 1.0. Available online [http://www.resalliance.org/3871.php]. Accessed July 30, 2010

The Resilience Alliance. 2007[b]. Assessing resilience in social-ecological systems: A scientists workbook. Available online [http://www.resalliance.org/3871.php]. Accessed July 30, 2010

Charlie Neibergall/The Associated Press archive

Next Steps

The second session of the Working Group will conclude at 10:00 AM Friday. Friday's work schedule includes completing revisions to the response framework, outlining the progress report, evaluating the methodology, and assessing the SmartDraw software used in scenario building.

Contact: Dr. Gary Machlis, Lead Scientist, DOI Strategic Sciences Working Group, gary_machlis@nps.gov, 202.746.8877

DOI Strategic Sciences Working Group

Daily Briefing Statement

11:00 AM

24 September 2010

Background

The Department of the Interior DOI Strategic Sciences Working Group (formed in response to the Deepwater Horizon oil spill) is meeting in New Orleans, LA 19-24 September 2010. The Working Group includes representatives from the National Park Service, US Geological Survey, US Fish & Wildlife Service, regional universities, nonprofits, and a software company. The tasks are to develop scenarios for mid- to long-term recovery and possible interventions to accelerate the sustainable recovery of the Gulf of Mexico as a coupled human/natural system.

Day Five Activities

On this final day of Session Two, the group evaluated several revisions to the conceptual framework. These revisions deal with variability and uncertainty in system stress, the potential impact of additional events on an already stressed system, and the response curves reflecting potential interventions that would accelerate recovery.

The group evaluated the second session and developed a list of recommendations and suggestions for future scenario building by the Group. The group completed Session Two and discussed the timing and venue for Session Three.

Science Insight

Losing Traditional Knowledge

A disruptive event like the Deepwater Horizon oil spill can initiate cascading consequences for coastal human communities. For example, closing of fishing areas can result in loss of income, stimulate uncertainty about the future viability of fishing as an occupation, and lead to outmigration of economically stressed fishing individuals and families. The departure of highly skilled and experienced individuals can contribute to loss of important traditional knowledge in coastal communities (Colten & Sumpter, 2008).

This traditional knowledge is a valuable component of the coupled human/natural system in the Gulf of Mexico. For example, “shrimpers” have vital knowledge of environmental cycles, the complex biology of coastal environments, and how to survive common disruptions (such as hurricanes). Migration of these individuals to other regions can erode the base of traditional knowledge and undermine community resilience. Over a long period, loss of traditional knowledge can lessen a community’s ability to effectively respond to future disruptions (Adger et al., 2005).

Sources:

Colten, C. E. & Amy Sumpter, A. (2008). “Social Memory and Resilience in New Orleans,” *Natural Hazards* 48, 355-364.

Adger W. N., Hughes T.P., Folke C., Carpenter S.R., & Rockstrom J. (2005) Social-ecological Resilience to Coastal Disasters. *Science* 308(August 12): 1036–1039.

Next Steps

Lead Scientist Machlis will brief DOI leadership on the scenario work. The progress report will be drafted, peer reviewed following USGS procedures, and published online.

Contact: Dr. Gary Machlis, Lead Scientist, DOI Strategic Sciences Working Group, gary_machlis@nps.gov, 202.746.8877

APPENDIX 3

Briefing Report for Dr. Paul Anastas, Assistant Administrator, EPA Office of Research and Development: Health-related Scenario Result from the Department of the Interior Strategic Sciences Working Group

Briefing Report for Dr. Paul Anastas, Assistant Administrator, EPA Office of Research and Development

Health-related Scenario Result from the Department of the Interior Strategic Sciences Working Group

Introduction

In May 2010, the US Department of the Interior (DOI) established a Strategic Sciences Working Group to assess how the Deepwater Horizon oil spill may impact the ecology, economy, and people of the Gulf of Mexico. It includes scientists from diverse disciplines and federal, academic, and nongovernmental organizations. The Working Group was not to conduct a formal scientific investigation, but to provide a scientific assessment of potential consequences of the spill in the form of scenarios that could provide usable knowledge to decision makers. The Working Group operates independently of the Incident Command System, Natural Resource Damage Assessment, and BP.

The Working Group first met in Mobile, AL May 2010, and developed several scenarios focused on emergency response and short-term recovery. The methods and results were peer-reviewed following USGS guidelines and published online at www.usgs.gov/oilspill and in *Science* (27 August 2010). The second session of the Working Group took place in New Orleans, LA September 2010, and developed two scenarios focused on mid-term and long-term recovery

One of the scenarios in the second session included a key segment on the potential public health effects resulting from occupational and recreational exposure to oil, dispersant, and oil/dispersant mix. An experienced marine toxicologist was included in the Working Group--Dr. Susan Shaw, director of the Marine Environmental Research Institute, ME. Dr. Shaw is an elected member of the International Panel on Chemical Pollution (ICBP), a member of the editorial board of *Reviews on Environmental Health*, and a Fulbright and Woodrow Wilson Scholar.

DOI leadership was briefed on the second session scenarios, and directed that the Working Group provide the EPA with a short briefing or report that summarizes the results.

Methods

The scenarios are constructed based on the available scientific literature, the expert opinion of the Working Group members, and additional input from the review team assembled by the Working Group leader. Each scenario includes: 1) a set of assumptions and parameters, 2) a chain of consequences that emerge from the assumptions and parameters, 3) for each consequence, an assigned level of scientific uncertainty (1=unlikely to 5=reasonably certain), and 4) potential interventions recommended by the Working Group that could accelerate a sustainable recovery. The scenarios are not quantitative risk models or predictions, and do not identify specific locales within the Gulf of Mexico. A full description of the methodology and limitations is provided in the reports referenced above.

Scenario Results

Figure 1 shows the “first tier” scenario consequences for S4. Past and future exposure to oil and dispersant is one of the potential consequences. Figure 2 shows the chain of potential consequences related to past and future exposure to oil and dispersant. *The scenario suggests that there is high potential for increased physical and/or health issues, especially for sensitive populations that include the young, elderly, pregnant, and chronically ill.* An intervention of targeted healthcare support for oil-related physical/mental health issues is suggested.

Rationale

Chemicals in crude oil and dispersants can cause a wide range of health effects in people and wildlife. Highly toxic chemical ingredients such as benzene and polycylic aromatic hydrocarbons (PAHs) can damage systems in the body (Burns and Harbut, 2010). Exposure to chemicals in crude oil and dispersants occurs through skin contact, inhalation of contaminated air or soil/sand, and ingestion of contaminated water or food. These can occur simultaneously. Dispersants contain solvents that facilitate rapid entry of oil into cells and organs, and oil-dispersant mixtures can be more toxic than either oil or dispersant alone (Burns and Harbut, 2010). Due to the presence of chemicals in the crude oil that are known to cause cancer in humans, and the fact that some of these chemicals can cause DNA damage and mutations, there is no completely safe level of exposure to some crude oil ingredients.

In fish and vertebrates, including humans, PAHs are rapidly broken down to more toxic metabolites via detoxification processes. PAH metabolites are more carcinogenic and potent than the parent PAH compound (Johnson-Restrepo et al, 2008; Kannan and Perrotta, 2008). Over time, PAH metabolites can be eliminated from the body, but even brief exposure during critical life stages may be sufficient to cause serious long-term effects.

Next Steps

The scenarios developed by the DOI Strategic Sciences Working Group during its second session deal largely with the ecological and socioeconomic consequences of the Deepwater Horizon oil spill during mid-term to long-term recovery. The second progress report of the Working Group is being prepared for peer-review by the USGS, prior to publication. Additional briefings of DOI leadership and others may be conducted. A third and final scenario session, focused on long-term recovery and potential interventions relevant to the Department of the Interior's mission and responsibilities, will be held in 2011.

For More Information

For more information about the DOI Strategic Sciences Working Group, or to schedule a more detailed briefing for EPA leadership and/or staff, please contact Dr. Gary Machlis, Lead Scientist, DOI Strategic Sciences Working Group at 202.746.8877 or gary_machlis@nps.gov.

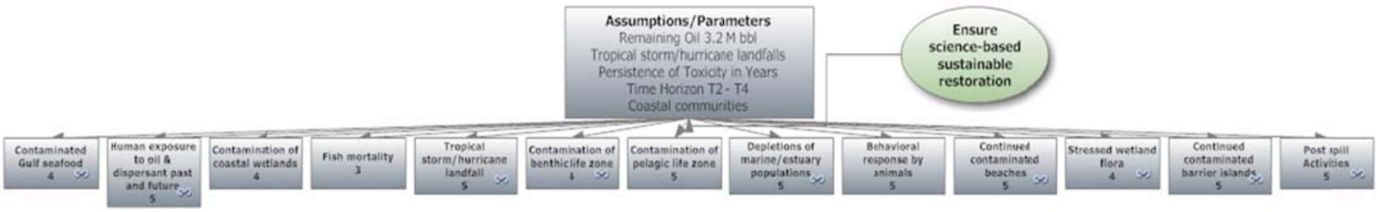

Figure 1. S4 first tier scenario consequences

Figure 2. S4 scenario consequences for human exposure to oil and dispersant

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