North Coast LRMP

Background Report

Implementing adaptive management through the North Coast LRMP

Prepared by

Brenda Taylor

September 2000

BRITISH COLUMBIA

This report was prepared by independent consultant, Brenda Taylor, as background information on implementing adaptive management in the North Coast LRMP area. The information in this report was collected from a wide range of sources and was reviewed by government staff for accuracy and completeness. The final product is presented as the professional judgement of the authors and does not necessarily reflect the view of the Province.

Table of Contents

1.0 Introduction

Ecological and social systems are complex, dynamic and inherently unpredictable. It can be extremely difficult to predict what will happen if we follow a certain pathway, or which of several possible pathways will lead us to our goal. Developing an LRMP is particularly challenging because we are dealing with a large landbase, multiple objectives (values), and a wide variety of management activities.

Adaptive management is a pro-active approach to managing in the face of this uncertainty. It is "…a systematic, rigorous approach for learning from our actions, improving management and accommodating change" (B.C. Ministry of Forests brochure). In conventional management, we try to decide which action is "best" (a futile and frustrating exercise when information and understanding are limited); in adaptive management we design plans to *reveal* which action is best. At a minimum, plans and monitoring strategies are carefully designed so that they will provide reliable feedback about whether or not a strategy "worked". This approach, sometimes referred to as "passive" adaptive management, is the typical approach used in LRMPs. In contrast, "active" adaptive management involves actively generating information by deliberately designing plans as "management experiments". Management experiments involve comparing alternative actions (and testing alternative assumptions) in the "real world". Where it is appropriate and feasible, active adaptive management generates more reliable feedback and leads to more rapid learning and improvement that passive adaptive management.

This background report provides some ideas and suggestions for how adaptive management (and active adaptive management in particular) could be incorporated into the LRMP from the outset. It is intended to provide the government technical team with a foundation on which to build a more specific and detailed adaptive management framework for the North Coast LRMP. The report addresses five specific questions about how to incorporate adaptive management into the LRMP:

- What are the criteria to assess the resources/values that would benefit from adaptive management? I.e., How do we identify situations where uncertainty masks our ability to make good decisions?
- How might the planning table approach its negotiations within an adaptive management framework?
- How can the LRMP provide language through objectives and strategies to identify and enable testing of resource management assumptions?
- What are the criteria for identifying indicators to test resource management assumptions?
- What types of analysis would support an Adaptive Management approach? How should these analyses be incorporated into a decision support system for the process?

For those who want additional information on adaptive management and its application, a short reading and reference list has been included at the end of the report.

2.0 Implementing adaptive management in the LRMP

2.1 Criteria to assess the resources/values that would benefit from adaptive management

The principles of adaptive management (e.g., acknowledging uncertainty, exploring alternative scenarios, being willing to adjust strategies in response to new information, monitoring outcomes) can be beneficial throughout the LRMP. The real question is: when should the LRMP table go the next step and deliberately design management actions themselves so that they will generate information? When is it worthwhile to probe the system for information and to design actions as management experiments?

The two fundamental preconditions for adaptive management are: 1) significant uncertainty must be present, and 2) resolving that uncertainty must lead to better management. Flowing from these is a third: that the potential value of the information gained through adaptive management must exceed its cost (both direct and indirect). The questions below expand on these fundamental preconditions and can be used to identify situations that might benefit from adaptive management.

a. Is there uncertainty about the best action?

Uncertainty typically manifests itself as indecision and/or disagreement about how to proceed. Once uncertainty has been acknowledged, the next step is to identify its source. Is it uncertainty about the goal (i.e., the desired future condition), the current state of the system, or the best way to reach the desired future condition?[i] The negotiating table is the appropriate place for defining the desired future conditions[ii]; inventories are the most efficient method for resolving uncertainties over the current condition[iii]. Adaptive management focuses on resolving uncertainty about the best way to reach a desired future condition. It can help resolve questions such as "in order to achieve the desired future condition, X, should we do A, B, or C?. Or, stated another way, " if we do A, how will values X, Y and Z respond?"

---

[i] Stochasticity (inherent unpredictability) is another potential source of uncertainty. Adaptive management cannot resolve uncertainties stemming from stochasticity. For example, it may lead to better strategies to reduce the amount of timber infested with beetles, but it cannot predict where infestations will occur.

[ii] Decision analysis (see Section 5) can help to resolve disagreements over objectives. Essentially, this involves repeating the decision analysis using different objectives, to see how the optimal decision changes (i.e., sensitivity analysis).

[iii] There will always be some uncertainty over the current state of the system (because inventories are only estimates of what is out there and are subject to measurement error, bias etc). Further inventories are useful ***only if*** the factor preventing a decision is uncertainty over the current state of the system. That is, if you knew what the current state was, you would *know* which management strategy to recommend. Be careful not to fall into the trap of delaying decisions until you have a better inventory, in the hopes that the inventory will resolve the uncertainty. Assess how sensitive the decision or outcome is to the current state before investing in further inventories.

Often, disagreements over which action to adopt stem from different assumptions about the way the system functions. For example, one person may assume that water quality is linearly related to the width of a riparian buffer. Someone else may assume that there is an S-shaped relationship. Each assumption would suggest a different best option or set of trade-offs. One could deliberately design management actions (in the short term) to resolve which assumption best reflects the "true" way the system functions, and then adjust future actions to reflect this new knowledge.

b. How significant and how big is the uncertainty?

In general, a management experiment is worthwhile when different actions would lead to different outcomes (i.e., the outcome is sensitive to the action). In resource management, there are a lot of uncertainties, but not all of them are significant in terms of management decisions. We don't need to understand *everything* about the system and how it functions in order to choose the best management action. In some cases, the effects of management actions may be overwhelmed by other factors (e.g., natural variability, actions beyond the control of the LRMP) and any uncertainty is insignificant. Adaptive management focuses on resolving those uncertainties that make it difficult to decide between alternative actions.

In general, management experiments are worthwhile when uncertainty is relatively big (i.e., no one action or assumption is substantially more likely than the others). The degree or magnitude of uncertainty is determined by the quality and quantity of the evidence supporting alternative assumptions.

c. What is the best way of resolving this uncertainty?

Management experiments are only one way of reducing uncertainty. Existing information (e.g., historical information, information from other areas) and small-scale or process-based research may be adequate for answering some types of questions (e.g., those dealing with a very similar system or scale) and for building the models used to explore alternative scenarios. Caution must be exercised, however, in extrapolating results to a different system or scale, and from the simplified model world to the complex real world. Management experiments are the best way of resolving uncertainty when:

- there is uncertainty about the cumulative and emergent effects of a strategy when it is applied at a large scale and/or in conjunction with other strategies;
- it is impractical or costly to postpone decisions until the results of research become available;
- the costs and risks of applying one strategy everywhere are unacceptably high (because of the probability and cost of undesirable outcomes); or
- one strategy is not obviously better than the others, where "better" takes into account both the value of the outcome and its probability.

d. Is it practical, possible and worthwhile to design an informative management experiment?

In some cases it may simply be impossible or impractical to design an informative experiment. In general, informative management experiments are possible when:

- response can be distinguished from the background noise of measurement error, natural variability, and the confounding influence of other factors;
- response occurs quickly, or at least within a time frame that is relevant for management;
- opportunity exists to apply the principles of experimental design (e.g., replication of treatments, random allocation of treatments, comparison to untreated controls); and
- the risk (probability and cost) of undesirable outcomes is acceptable (e.g. where outcomes are reversible, only affect a small area, or do not impose unacceptable costs).

Even when it is possible to set up a management experiment, it may not be worthwhile. Management experiments have costs associated with them (e.g. direct costs of set-up, monitoring and data analysis; indirect costs of suboptimal outcomes). In some cases, the value of information that can be gained from a management experiment may not be high enough to offset its cost. In general, the value of the information is high when the uncertainty is large, different strategies lead to outcomes with different values, and it is possible to design a management experiment that yields reliable information. (Note that it *can* sometimes be worthwhile resolving a relatively small uncertainty if the costs of gaining the information are low.) Tools for assessing the potential value and cost of a management experiment are briefly summarized in Section 5.

e. Is it within the scope and jurisdiction of the LRMP to resolve this uncertainty?

Developing the LRMP may uncover uncertainties that are significant and substantial (i.e., they affect choices made by the LRMP table), but that are beyond the ability or jurisdiction of the LRMP to address. The most the LRMP can do is identify these external uncertainties and use a tool such as decision analysis (see Section 5) to assess which is the best option, given the uncertainty. It cannot resolve the uncertainty itself. For example, there are significant uncertainties about global warming and its implications. The LRMP table can do little to address uncertainties about global warming itself, but it *can* explicitly address the uncertainty it creates about which action to choose (i.e., by looking at the outcomes of various options under different assumptions about climate and using decision analysis to assess which is the best option given the uncertainty, or by adopting a precautionary

Summary

To identify issues that are suitable for adaptive management, ask the following questions:

<u>Is there agreement (at least in general terms) about the goal or desired future condition?</u>

Is there uncertainty?

- Is there uncertainty (manifest as disagreement or indecision) about which option will best achieve the desired future condition?

How significant or big is the uncertainty?

- Does the uncertainty concern large scale or cumulative impacts?
- Is the outcome sensitive to the action? Are the predicted outcomes of each option different?
- How big is the uncertainty? How well are different assumptions supported by existing evidence?

What is the best way of resolving this uncertainty?

- Is the uncertainty within the scope and jurisdiction of the LRMP?
- Can the uncertainty be resolved by other means?
- Has this been tried elsewhere and if so, can the results be extrapolated reliably?

Is designing a management experiment practical, possible and worthwhile?

- Can the uncertainty be resolved by small-scale or process-based research (are there resources to support that research and can we wait for the results)?
- Does the potential value of the information outweigh the cost of getting it?
- Is it possible and practical to design an informative management experiment? Are there opportunities for replicating and randomly allocating treatments? For comparing treated areas to control areas? Is the response distinguishable from background noise? Are potentially suboptimal outcomes reversible? Can the costs be shared across participants?
- Can useful information be gained in timeframe that is relevant to management?

As a rule-of-thumb, adaptive management is probably useful for dealing with:

- complex and dynamic systems,
- cumulative impacts,
- impacts over large areas and time frames,
- trade-offs between values,
- new ecosystems and/or new strategies,
- existing information that is limited or of poor quality; and
- questions where results are applicable beyond a single site.

2.2 How might the planning table approach its negotiations within an adaptive management framework?

Approaching the negotiations within an adaptive management framework involves two related aspects: adopting an adaptive management attitude and applying adaptive management methods.

2.2.1 Adopting an adaptive management attitude

Establishing a clear, shared understanding of what adaptive management is, what it is not and how and when it can help is a critical prerequisite for applying adaptive management effectively. Adaptive management has become a buzzword, and like many buzzwords it is often used (and misused) without being clearly understood. Often, people have widely different interpretations of adaptive management and how to apply it. These differences can lead to misunderstanding, increased conflict and "wheel-spinning". It is worthwhile spending some time upfront defining, discussing and coming to a shared understanding of what adaptive management is and how it can be used. The participants' handout on adaptive management will certainly help, but it is probably not enough. A short presentation and discussion will go further to answer questions, clear up any misconceptions and uncover different interpretations. From there, participants should develop a clear, shared definition of adaptive management and how it will be used.

Recognizing and acknowledging uncertainty are key elements of an adaptive management attitude. Unless participants are willing to acknowledge uncertainty, they will not be willing to invest in resolving it. Rather than ignoring uncertainty, people with an adaptive management attitude say "right, we don't know what the best strategy is, or what the outcomes of this particular strategy might be, but this is how we are going to find out." Rather than seeking the best solution (which is a futile and frustrating exercise when key information is missing), participants seek a strategy that will *reveal* the best solution. Throughout the process, the facilitator and participants can be on the look-out for the following indicators of uncertainty:

- disagreement over the best strategy or over predicted outcomes;
- indecision (resulting from difficulty in predicting outcomes, or lack of confidence in those predictions);
- desire to postpone decisions "until further information is available";
- use of words such as "assume", "in principle", "theory", "opinion" (for example, the Conservation Area Design is based on "principles" of reserve design, many of which are untested assumptions).
- extrapolating results from other areas or other spatial scales; and
- assuming linear and/or stable relationships between variables (between actions and indicators); assuming that what worked in the past will continue to work in the future or basing decisions on anecdote, conventional wisdom or rules-of-thumb that are only weakly supported by evidence.

Valuing learning (but only insofar as it can lead to better management) is another key element of an adaptive management attitude. In adaptive management, the value of learning arises from the reduced costs or increased benefits that can result from better management. Strategies that are unnecessarily restrictive, overly lenient or ineffective all have costs (either direct costs or opportunity costs). Delaying decisions until "more information is available" also has a cost. Adaptive management is a worthwhile investment when the value of the learning (in terms of improved management) exceeds its cost.

2.2.2 Applying Adaptive Management methods

The key steps in adaptive management are outlined in Figure 1. The question is how and where do these steps fit into the existing LRMP process? To some extent, the two processes overlap. For example, both processes involve defining the problem boundaries (i.e., terms of reference), developing clear goals (i.e., desired future conditions), identifying indicators (with which to compare scenarios and measure progress towards goals), developing strategies for meeting objectives, and exploring the potential outcomes of scenarios. Both involve implementation, monitoring, evaluation and adjustment (i.e., review and amendment).

The typical LRMP process is already a form of passive adaptive management: alternative scenarios are explored, one is implemented (the one considered most likely to meet goals), effectiveness is monitored, and adjustments to the LRMP are made as necessary. With adaptive management, however, there is more explicit recognition of uncertainty and its implications, which then leads to more direct ways of addressing that uncertainty. Key uncertainties (i.e., those that affect decisions about what to implement) are explicitly identified, underlying assumptions are exposed and articulated, and plans are designed to test these assumptions and resolve key uncertainties (where feasible). In a conventional LRMP, a choice is made based on the best available information; in adaptive management, plans are designed to *reveal* the best choice.

Active adaptive management involves a learning phase (during which the options are tested in a "management experiment"), followed by an adjustment. During the learning phase, options could be tested on a *portion* of the landbase (e.g., part of a zone or watershed), with the rest managed according to (presumed) "best management practices" or deferred. The best action would then be applied more widely during the adjustment phase. Alternatively, the management experiment could involve partitioning the *whole* landbase into a few large units where different actions are applied (e.g., partitioning a watershed into subwatersheds). After the learning phase, actions would be adjusted on those units where the "best" option was not initially used. Which set-up is better will depend on the scale at which indicators respond, whether outcomes are reversible, and the quality, reliability and relevance of the information that could be gained under each option[iv] (see Section 5).

Active adaptive management will not always be necessary, appropriate or possible (see Section 1). It may be useful to compare the pros and cons of: a precautionary approach, passive adaptive management (i.e., the conventional LRMP approach) and active adaptive

[iv] Management experiments that involve partitioning whole systems into a relatively small number of experimental management units "… reduce the risk of failing to identify processes that only become important at larger spatial scales, allow some replication in comparisons among policy alternatives, and avoid committing the entire system to any single policy option that might prove ineffective in the long run." (Walters, 1993).

management. In some cases, the comparison can be done formally, using a technique such as decision analysis (see Section 5); in other cases, the choice may be obvious.

Where adaptive management is helpful, what might it look like? In general terms, it would involve:

- identifying areas of likely uncertainty;
- developing different management options;
- exploring the options (using a model/decision support system);
- assessing the sensitivity of the outcome and choice to different assumptions (using the DSS);
- assessing the feasibility of a management experiment (active AM), implementing the "best" option (passive AM) or applying the precautionary approach;
- if a preliminary assessment indicates that a management experiment might be useful and acceptable, then developing and comparing different "experimental designs" (with the help of a biometrician to make sure that the "experiment" would generate useful, reliable data; and
- developing implementation, monitoring, evaluation and adjustment strategies.

Figure 1: The Adaptive Management Framework

Adaptive management involves a basic framework of 6 steps. These steps are common to all problems, although the details of how they are applied will depend on the characteristics of the problem and the creativity of the participants.

Step 1 *Assess:* Define the problem. Define measurable management objectives and indicators. Explore the effects of alternative strategies. Document predicted outcomes. Identify key uncertainties and assumptions. Document the basis for decisions.

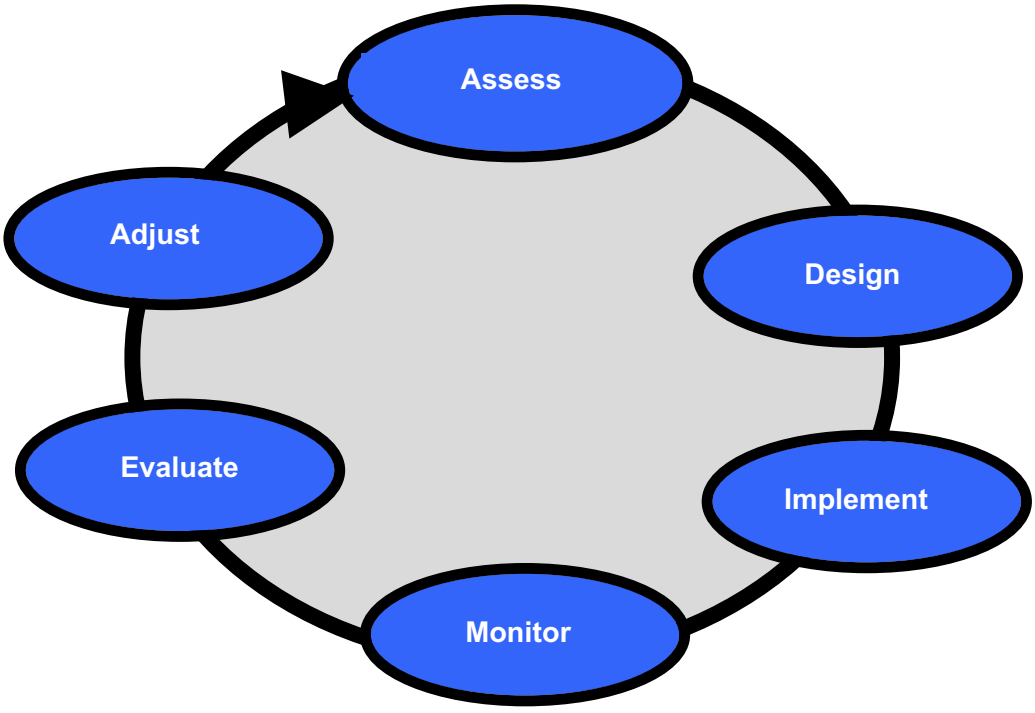
Step 2 *Design:* Ask yourself "how can we learn from what we are about to do?". Design a management plan to test key assumptions/resolve key uncertainties (apply the principles of experimental design to design of management actions). Define details of monitoring plan.

Step 3 *Implement:* Follow the plan. Document deviations from the plan.

Step 4 *Monitor:* Monitor implementation and effectiveness, according to the plan.

Step 5 *Evaluate:* Compare actual outcomes to predicted outcomes. Assess which assumption is supported by data. Document and communicate results.

Step 6 *Adjust:* Close the loop! Revise assumptions as necessary. Update models (mental models and computer models). Confirm or adjust management actions/strategies. Identify further uncertainties that should be resolved.



2.2.3 Where to apply adaptive management

Exactly how and where would adaptive management fit into the LRMP? This really involves identifying the areas of the LRMP process where uncertainties are most likely to arise, and then assessing whether adaptive management is the best way of resolving them.

Goals: Goals describe a general, desired future condition (Brown, 1996). They are central to both the LRMP and adaptive management: you first need to define where you are going before you worry about how to get there. While there may be uncertainty and disagreement at this stage, it probably arises from differences in values, rather than gaps in knowledge or information. Adaptive management will not help to resolve this type of uncertainty or disagreement. Once the desired future conditions have been agreed upon, adaptive management can be used to reveal the best pathway for reaching them. Essentially, these pathways are defined by zoning, objectives and strategies.

Zoning: Zones are areas of specific land use allocation or areas that have a defined resource management direction. The LRMP planning table identifies a number of "resource management zones" with associated objectives and strategies, that, combined, represent the social choices about priorities for the use and management of Crown land in the plan area.

For some values or resources, zoning may be straightforward, with little uncertainty (i.e., we are pretty certain that zoning works and what that zoning should look like). For other resources, there may be uncertainties around whether zoning is the best approach, what type of zoning is best, and where those zones should be located. Is there more than one plausible zoning option? If so, what are the assumptions underlying each option (i.e., what are the reasons for zoning this way)? Is it feasible to test these assumptions and options in the LRMP?

For example, there might be uncertainties around zoning for grizzly bears. Is it better to have large "special management zones", where some human activity is allowed? Or is it better to have protected areas with no human activity (even if those areas are smaller than the special management zones)? The first option might be based on the assumption that bears are most sensitive to habitat loss; the second might be based on the assumption that bears are most sensitive to human interaction. The next step would be to see if there is any existing information that strongly supports one of these assumptions over the other. If not, is it possible to design zoning to test the assumptions and the options that arise from them (e.g., by testing the two different zoning options on different areas within the LRMP, or by trying one type of zone for 10 years, and the second type for 10 years, and then choosing the best)? The next step would be to compare this active adaptive management approach, with a passive approach (where only one zoning option is implemented) and a precautionary approach (e.g., designating large zones with no activity).

Objectives: Objectives are statements of measurable desired conditions (Brown, 1996). They define, in general terms, the pathway for reaching a goal. Most objectives will have relatively little uncertainty, either because they are quite straightforward or because they are stated in general terms. There may be some objectives, however, that generate a lot of discussion and disagreement, or where the LRMP table is reluctant to make a decision. These are candidates for active adaptive management.

Strategies: Strategies are a means of achieving a goal, objective or interest (Brown, 1996). Most of the uncertainty in an LRMP will likely centre around the strategies. As the LRMP table works through each objective or resource value developing strategies, it will be helpful to keep track of those that are uncertain, articulate the assumptions underlying them, and recommend the best option for addressing them (passive, active, precautionary).

Cumulative effects: Substantial uncertainty will probably surround the cumulative effects of zones, objectives and strategies. Even if there is little uncertainty about each zone, objective or strategy when considered separately, uncertainty will likely arise when they are considered as a package. Effects of different individual strategies or objectives may counteract, nullify or exaggerate one another. This can lead to unexpected outcomes when they are considered as a package. Moreover, we typically have little good information about cumulative effects (in part because they are difficult to address through research). Cumulative effects are prime candidates for adaptive management because they typically represent large and significant uncertainties that are difficult to resolve through other approaches.

Uncertainties around zoning and objectives are "strategic" uncertainties that would need to be addressed in the LRMP itself. That is, the LRMP would define the options to be compared, how they would be compared (i.e., the specifics of the "experimental design"), and at what point adjustments to the LRMP would be made. Uncertainties around strategies are "operational uncertainties" (i.e., they deal with actions that are implemented at an operational level). The LRMP could identify these operational uncertainties and enable resource managers to address them in lower level plans. The LRMP could define whether a management experiment should be done on a portion of the landbase (with the rest being deferred or managed according to best management practices), or whether it should involve the whole landbase. It could provide explicit direction on how to design the management experiment (e.g., recommend treatments, indicators, where it should be done, length of learning phase etc) or it could leave the details up to resource managers responsible lower level planning.

2.2.4 Implementation, monitoring, evaluation and adjustment

Implementation, monitoring, evaluation and adjustment are critical to adaptive management and should be built into the LRMP. All LRMPs include direction for developing an implementation strategy, for effectiveness monitoring, and for evaluating the plan and adjusting actions at predetermined times. Under adaptive management, the LRMP should state the predicted outcomes of each action, the assumptions that are being tested, and how actions might be adjusted, depending on the actual outcome and which assumption is supported by the monitoring data. For example it may be helpful to develop statements in the form of "if A, then B" (i.e., "if data support assumption A, then we will adjust actions in the following way…"). Adjustments might occur at several potential times, depending on the strength of the data[v]. For example, preliminary data that strongly support one assumption or suggest that the system may be crossing a threshold may result in early adjustment.

[v] This is often done in medical trials that involve comparing a treated group to an untreated (control) group. If early evidence strongly supports the efficacy of the treatment, the trial is stopped and the treatment given to all patients. It would be important to define the quality of data and magnitude of "effect" that would lead to

It may be helpful to develop a timeline for each objective and strategy that shows when it will be implemented, when it will be monitored, when the data will be analysed and evaluated, and when adjustments might occur. The timelines for individual objectives and strategies could then be aggregated into a timeline for the LRMP as a whole.

2.2.5 Building a legacy of knowledge

Throughout the LRMP, participants can look for opportunities for building a legacy of knowledge. This could include:

- identifying opportunities for replicating treatments (in space and in time) and for designating control areas;
- identifying opportunities for building on existing research trials, by testing results and recommendations in the LRMP;
- identifying opportunities to build on or use existing monitoring; and
- documenting predicted outcomes and reasons for decisions (even when no management experiment is planned).

2.2.6 Summary

Approaching negotiations within an adaptive management framework involves:

Adopting an adaptive management attitude:

- developing a cleared, shared definition of adaptive management;
- recognizing and acknowledging uncertainty; and
- valuing learning, if it leads to better management.

Applying adaptive management methods:

- exploring different options for meeting a goal;
- identifying key uncertainties (using sensitivity analysis);
- comparing different approaches (passive adaptive management, active adaptive management, precautionary approach) and different "experimental designs";
- monitoring, implementation, evaluation and adjustment; and
- searching for opportunities to build a legacy of knowledge.

---

an early adjustment, in order to avoid arbitrary changes in strategy based on the latest "bandwagon" or on political pressure.

Active adaptive management will likely be most useful (and practical) when applied to strategies, but it may also be useful when applied to zones and objectives. Cumulative impacts (of zones, objectives and/or strategies) are prime candidates for adaptive management. For strategic uncertainties (those dealing with zones, objectives or cumulative impacts), the adaptive management plan should be written into the LRMP. For operational uncertainties (those dealing with strategies), the LRMP could provide support and direction for incorporating adaptive management into lower level plans.

2.3 Implementing adaptive management through LRMP objectives and strategies

This section describes various ways that the LRMP can provide language through its objectives and strategies to identify and enable testing of resource management assumptions. These include: providing general support for adaptive mangement; incorporating adaptive management into the General Management Direction; and ensuring that the language in the management direction does not preclude or contrain opportunities for learning.

a. General support for adaptive management

The LRMP can explicitly acknowledge uncertainty and support adaptive management. For example, it could include an introductory section in which uncertainty, as a general characteristic of managing complex systems, is acknowledged and its implications for decision-making, implementation and outcomes are reviewed. This section could explain (in general terms) how the LRMP addresses uncertainty (i.e., under what conditions it uses adaptive management, the precautionary principle, or other methods). It could include a clear definition of adaptive management and how to apply it, drawing on material from this report and the participants' handout.

The purpose of this section would be to provide general direction on how to deal with uncertainty, and specifically how and when to apply adaptive management. It would lay the foundation for more specific direction on adaptive management in the rest of the LRMP. It would also provide explicit support for implementing adaptive management in lower level plans. Without this explicit support, managers may be reluctant to step beyond the boundaries of traditional management to test alternative treatments, particularly where those treatments may have suboptimal outcomes. Just as resource managers look to the LRMP for general direction on how to manage for biological diversity, recreation or timber, they can also look to the LRMP for general direction on how to deal with uncertainty.

b. Adaptive management as part of the General Management Direction

The General Management Direction should " provide a baseline for addressing uncertainty on Crown land within the LRMP area". It should highlight key uncertainties that need to be resolved/assumptions that need to be tested and include or suggest strategies for testing them. In some cases, the strategy might include actively testing assumptions; in other cases it might be a more "passive" approach where a single treatment is implemented and monitored. For a particular uncertainty identified in the GMD, the strategy could suggest the range of treatments that would be informative (and acceptable), indicators to monitor, and other

aspects of design. The challenge will be to provide direction and support, without unduly constraining opportunities for learning.

There are two options for structuring the GMD to incorporate adaptive management. In one option, learning could be included as a specific value or activity within the LRMP/GMD, in the same way that access management, timber or biodiversity might be included, with a defined goal, objectives and strategies. The goal might be something like " to reduce key uncertainties that limit the ability to make informed decisions". The objectives would be specific uncertainties that need to be resolved or assumptions that need to be tested. The strategies would be management experiments (or suggestions for management experiments). The second option would be for the GMD to highlight the uncertainties and describe the strategies for resolving them for each resource value/activity in turn (as part of the GMD for that value/activity). Under either approach the GMD could also explicitly identify objectives and strategies where adaptive management could be implemented as part of lower level plans.

c. Use language that does not preclude or constrain opportunities for learning

Not only should the LRMP provide specific direction on where, when and how to apply adaptive management, it should also use language that does not preclude or unduly constrain opportunities for learning. It must allow managers the flexibility to test a range of treatments (even some that may have suboptimal outcomes)[vi]. Where uncertainties are large, the objectives could define a range of acceptable outcomes (rather than a single outcome) and the strategy could provide a range of acceptable treatments, as well as recommend a management experiment. Care should be taken to avoid wording objectives and strategies too narrowly or restrictively. Throughout, the LRMP should include language that conveys that it is a "living" document, subject to change, but where changes must be supported by reliable evidence.

Summary

The language of the LRMP can support and enable testing of assumptions in five ways:

- in general terms, by explicitly recognizing uncertainty and its implications and supporting adaptive management;
- by explicitly identifying uncertainties and recommending strategies for resolving them (e.g., as part of the General Management Direction and/or for each zone);
- by providing direct support, encouragement and direction for implementation of adaptive management in lower level plans;
- by using language that does not preclude or constrain opportunities for testing assumptions in lower level plans, and provides the flexibility necessary to actively probe the system for knowledge (where appropriate); and

[vi] To protect against potential abuse of this flexibility, the LRMP could also define the circumstances under which probing is justified.

- by identifying zones (geographic areas or types of areas) where testing a range of actions is acceptable and those where it is not, and by identifying areas that would be suitable as untreated control areas.

2.4 Criteria for identifying indicators to test resource management assumptions

Indicators are things we can measure to answers questions such as "did we meet our management objectives?" or "which assumption best reflects the "real" world?" Clearly formulated questions (objectives and assumptions) are prerequisites to identifying meaningful indicators. They allow us to separate indicators that provide information that we "need to know" (in order to make decisions) from those that provide information that is simply "nice to know" (interesting, but irrelevant to decision-making). Remember that adaptive management focuses on providing answers that will allow us to manage better; it is not intended to provide a complete picture of the way the system works. Beware of the tendency to think that more information is better. Too much data can be overwhelming and confusing, rather than enlightening. Moreover, there is a cost to collecting, storing, analysing and interpreting all that data. A few carefully chosen indicators can provide as much (or more) useful information at a lower cost than a long list of indicators.

Criteria for indicators used in adaptive management

Useful indicators are both MEANINGFUL and MEASURABLE. Meaningful indicators are *relevant* to management objectives or to the assumptions being tested. In general, the more closely related an indicator is to an objective (or assumption), the better; however, in some cases it may be necessary or advantageous to select an intermediate or surrogate indicator. Surrogate indicators are useful where the "real" indicator is impossible or impractical to measure. Intermediate indicators are useful where the "real" indicator responds slowly, or where you want an "early warning" of potential problems. It is critical to be clear about why these surrogates or intermediate indicators are being included, in order to avoid the trap of goal displacement. Goal displacement occurs when the surrogate is mistaken for the final answer. For example, measures of habitat suitability are often used as surrogates for population indicators. But where the population is limited by factors other than habitat, habitat suitability may not reflect the real state of the population or the ultimate impact of management actions on that population.

Meaningful indicators are *responsive* to management actions (and that response is detectable): a management action will result in a measurable change in the indicator. In addition, the indicator should respond in a time frame and at a spatial scale that is meaningful for decision-making. Is an indicator whose response is only detectable after 100 years useful? The answer may be yes, where there is value in building a legacy of knowledge for future managers and where the cost of monitoring is low. In other cases, you may want to search for an intermediate indicator that responds more quickly.

Measurability is the second main criterion for selecting indicators. Can the indicator be measured with an acceptable level of precision and accuracy at a reasonable cost? Some indicators may be essentially unmeasurable because high levels of natural variability or

measurement error make their response indistinguishable from background noise. Cost is another key element of measurability. Indicators that are very expensive and/or difficult to measure for practical purposes may be unmeasurable if the resources required to measure them are unavailable. Equipment, time, skill, and monitoring frequency all affect cost.

The ideal indicator is relevant to management objectives/assumptions; responds to management actions quickly, with a large magnitude and at an appropriate spatial scale; can be measured using cheap, easy to use equipment; and has low levels of measurement error and natural variability. Inevitably, however, trade-offs will need to be made between meaningfulness and measurability. In making these trade-offs, consider the potential value of the information (higher value may make higher costs acceptable) and the level of precision and accuracy necessary to decide between management options or alternative assumptions (i.e., it may be possible to lower costs by accepting a lower level of precision or accuracy). In some cases, it may be possible to reduce costs by building on existing monitoring (provided the data being gathered are meaningful for your purposes). Finally, look for (or develop) new, innovative monitoring methods that are cheaper and/or provide more meaningful data.

Summary

Asking the following questions can help in identifying a list of informative indicators.

<u>Is it RELEVANT to the objective or the assumption?</u>

- How closely linked is it to the objective or the assumption? Is it a direct measure? Or an intermediate or surrogate measure?
- Does it provide information you NEED to know in order to assess whether 1) the strategy was implemented; 2) the strategy was effective; or 3) which assumption best reflects the way the system really works? Does it answer a key question?
- Is it relevant at the appropriate spatial scale?

Is it RESPONSIVE to management actions?

- Does it respond at a spatial scale that is meaningful/relevant to the objective or to the assumption being tested?
- Does it respond within a time frame that is meaningful?
- Is the response detectable above background noise?
- Does it signal when you are about to cross a threshold?

Is it MEASURABLE?

- Can it be measured (with an acceptable level of precision and accuracy) with resources that are/could be available?
- Does it require expensive equipment? Equipment that is not readily available? Equipment that can only be operated by skilled people?
- Is it time-consuming to monitor? Does it require repeated field visits?
- Are the method and equipment robust? (i.e. do they still provide data with acceptable precision and accuracy when operated by less-skilled, less conscientious or less experienced people, or by a variety of different people?)
- Can you develop innovative measurement methods that are cheaper or that yield better data?
- Does the value of the information outweigh the cost of obtaining it?

The key question to ask when selecting indicators is: "what do I want to know about in order to decide whether to do A or B (or decide whether A "worked" or not)? What drives your decision?

2.5 Types of analysis to support an adaptive management approach

Three main types of analysis would support an adaptive management approach to the LRMP: scenario analysis (including sensitivity analysis), decision analysis, and statistical analysis of data.

a. Scenario analysis

Scenario analysis is already a central element of the LRMP process, where it is used to document and evaluate the potential outcomes of scenarios developed by the LRMP table. For a problem that is as complex as developing an LRMP, scenario analysis will require a computer simulation model. As part of an adaptive management approach, scenario analysis, using a simulation model, has the following functions:

1. Allows LRMP participants to "see" the potential impacts of proposed actions (e.g., zoning, objectives and strategies). By managing and integrating large amounts of information, the model can help participants "see" the potential impacts of proposed

actions when they are applied over a large landbase and long time frames. It can reveal cumulative impacts and impacts that only emerge at a large scale. The model may reveal that actions that may make sense when they are applied at a small scale or independently may have quite unexpected impacts when they are applied as a package or over large areas.

2. Provides a consistent framework for comparing scenarios. The model can be used to evaluate and refine scenarios. It can be used to screen out options (either entire scenarios or elements of a scenario) that are obviously ineffective or undesirable.

3. Can be used to identify key uncertainties. This is a key function in adaptive management. Resource management is rife with uncertainties; it is futile (and unnecessary) to try to resolve all of them. The model can be used to identify those uncertainties that limit our ability to choose between alternative actions. It can separate information that we "need to know" in order to make a decision, from information that is simply "nice to know".

   Models are essentially simplifications of reality. They are based on current information and assumptions about how the system works (i.e., about the relationships between actions and outcomes). Some of these relationships are well-understood; others have a great deal of uncertainty around them. Often, existing information only describes how an indicator responds or how well an action works under a very limited range of conditions. What happens beyond that range? In the absence of good information, we must make assumptions. The model cannot tell us what *will* happen, it can only tell us what *might* happen, if the model assumptions are true. Changing the model assumptions will in some cases change the outcomes and thus the choice about which action will best meet desired future conditions. Sensitivity analysis is used to assess how sensitive the modelled outcomes (and LRMP decisions) are to different model assumptions. Resources can then be focussed on resolving those uncertainties (i.e., testing those assumptions) to which outcomes and choices are sensitive. Using management actions to resolve these key uncertainties is what distinguishes adaptive management from conventional management.

4. Used for "gaming" participants. In the "classical" approach to adaptive management[vii], the model is used for "gaming". Participants themselves use the model to explore various "what ifs" (i.e., different scenarios and assumptions). This not only uncovers key uncertainties (as described above), but it has the added value of making the participants

---

[vii] In the "classical" approach to adaptive management, termed "Adaptive Environmental Assessment and Management (AEAM)" (Holling, 1978), participants are actually involved in developing the model. Together, they define the model scope and the relationships between actions and indicators that are used to build the model. Proponents of the AEAM approach argue that it enhances communication between participants, develops a common understanding of the problem, and can often stimulate creative approaches to the management problem (Walters, 1986). The disadvantages are that AEAM workshops are time, energy and money intensive; some participants find the model-building process frustrating and/or boring; and workshop success is highly dependent on the skill of the modelling/facilitating team.

Involving participants directly in model-building would add another layer of complexity to an already complex LRMP process, making it more cumbersome, time-consuming and expensive. Moreover, the LRMP process may already provide a number of the benefits of AEAM-style workshops. If participants are not involved in model-building, it is important that they understand both the value and limitations of whatever model is used, so that they treat the model outputs with the appropriate combination of trust and skepticism.

themselves familiar with the model, its assumptions and its limitations. They may then be more inclined to invest in testing the model assumptions. In addition, "gaming" can sometimes stimulate creativity and lead to innovative suggestions.

In order to fulfill these functions the model should have the following characteristics:

- project outcomes over a large landbase and long time frames;
- be capable of modelling the cumulative impacts of a "package" of actions, but also allow exploration of what happens if different elements of that package are changed (to assess sensitivity of outcome to different actions);
- allow sensitivity analysis of model assumptions about which there is uncertainty or disagreement;
- provide outputs relatively quickly, in order to facilitate exploration of alternatives. A model that is takes a long time to generate outputs will limit the number of alternatives that can be explored and the amount of sensitivity analysis that can be done. For purposes of adaptive management, where model exploration is at least as important as model accuracy, a simple model is usually preferable to a more complex model. Moreover, complex models are not necessarily more accurate or reliable reflections of reality;
- consider building stochasticity into the model. Natural variability and stochasticity are inherent to the real world and can dramatically influence the actual outcomes of management actions. Ideally, they should be taken into account in evaluating management options since the "best" choice when natural variability (and the uncertainty it creates) is taken into account may be different than the "best" choice when that uncertainty is ignored. The potential disadvantages of including it are that it may increase model cost, complexity and runtimes.

b. Decision analysis

Decision analysis is a quantitative method of evaluating management options that formally takes uncertainty into account. Most methods for comparing management options only assess the (potential) values of each option. Uncertainty about the outcomes of these options is either ignored or taken into account crudely (e.g., by "hedging our bets"). This can lead to decisions that are overly lenient or unnecessarily restrictive. Decision analysis takes into account both the value of different outcomes *and* their probabilities of occurring (based on the probability of different assumptions being true). For example, decision analysis can be used to compare an option that has big (potential) benefits, but is less probable, with one that is has small (potential) benefits, but is more probable. Whether it is better to go with the one or the other will depend on the relative size of the benefits and the probabilities. This type of comparison is very difficult to make "in your head".

Combining sensitivity analysis with decision analysis can provide a quantitative assessment of how sensitive the "best decision" is to different objectives and to different assumptions. In this way it can help to resolve conflicts over objectives and identify priorities for management experiments.

As part of adaptive management, decision analysis can also be used compare different management approaches (i.e., passive vs. active vs. precautionary) and different designs for management experiments. For example, it can be used to compare different designs based on their cost and ability to generate useful, reliable information (and thus meet management objectives in the long term). It can help to answer questions such as: is the value (i.e., reliability and importance) of the information we will get from comparing two "treated" units with two "control" units enough to offset the cost? Or are we better off trying one treatment everywhere? Do we get enough good information if we try a treatment for 5 years, or are we better off trying it for 10 (taking into account the extra cost of monitoring for 10 years)?

Decision analysis can be a very powerful and useful tool but it does have limitations (related to the amount of quantitative data it requires). It should be used judiciously, where it will have the most benefit (e.g., where data are available, costs of incorrect decisions are potentially large and objectives can be stated quantitatively). Even if a quantitative decision analysis is not completed, structuring a decision using the principles of decision analysis can help to clarify the options, uncertainties, and trade-offs.

c. Experimental design and statistical analysis

Good experimental design and statistical analysis are critical for generating the reliable feedback that is essential for learning and adaptive management. Poor designs are at best a waste of money and resources and, at worst, can lead to costly management mistakes. There are a number of tools available that can aid in the design of cost-effective and informative designs. To avoid costly mistakes, and to get the most return on your monitoring investment, it is wise (and probably essential) to design any management experiment and monitoring program in consultation with a biometrician.

Adaptive management draws on the same principles of experimental design (e.g., replication of treatments and controls, randomization, blocking) and statistical methods (e.g., ANOVA) developed for research; however, because the focus of adaptive management is different from that of research, these methods may be applied differently. For example, scientists are typically most concerned with avoiding the error of saying that something happened (i.e., had an effect) when it really didn't. Resource managers may be equally (or more) concerned about making the opposite error (i.e., saying something didn't have an effect when it really did). In addition, management decisions may not require the same standard of rigour and confidence demanded by scientific publications. In fact, that level of rigour, because it typically comes at a higher cost, may be inappropriate for making management decisions.

Decision-makers or resource managers will need to compare alternative experimental/monitoring designs, to weigh the trade-offs between the reliability and value of feedback and its cost. This can be done by considering the relative probabilities of making different types of errors (measured by the statistical parameters α and β) and by assessing the statistical power of a design (i.e., its ability to detect a biologically significant effect). A variety of software packages are available for calculating statistical power. Judith Anderson (a research associate at Simon Fraser University) has recently developed two models (based on Excel spreadsheets) that allow users to explore different experimental designs, varying a range of parameters (e.g., number of replicates, effect size, statistical significance (α),

statistical power, length of "learning phase", cost). These tools are an extremely useful and relatively simple way of developing an experimental and monitoring design that is both informative and cost-effective.

Bayesian statistical analysis is another method that can be applied to adaptive management. Unlike the classical "frequentist" approach to statistics, it allows direct computation of the probability of a particular assumption (hypothesis) being true, and it allows that probability to be updated as new information becomes available. In this way, "bayesian methods provide a way of explicitly integrating a manager's accumulated knowledge with experimental data.." (Bergerud and Reed, 1998). Bayesian statistical methods are often used as part of decision analysis.

Summary

Three main types of analysis are used in adaptive management. All will require input from experts to be used effectively and appropriately.

Scenario analysis (using a computer simulation model)

As part of adaptive management, scenario analysis is used to:

- show the potential impacts of actions when they are applied over large scales, and as a "package";
- provide a consistent framework for comparing scenarios;
- identify key uncertainties (by exploring the sensitivity of model outputs to different model assumptions); and
- involve participants in exploration of scenarios and identification of key uncertainties (as a way of building a shared understanding of the problem and stimulating creative solutions).

Decision analysis

Decision analysis is a method for formally addressing uncertainties in decision-making. Options are ranked taking into account both the probability and value of the (potential) outcomes. The value of potential outcomes under different assumptions are derived using a computer simulation model. As part of adaptive management, decision analysis can be used to:

- identify key uncertainties (by calculating the how sensitive the "best choice" is to different assumptions);
- compare alternative management approaches (passive adaptive management, active adaptive management, precautionary approach); and
- compare the (potential) value of different designs for a management experiment.

Experimental design and statistical analysis

Experimental design and statistical analysis are critical for generating reliable information, and thus are a critical elements of adaptive management. Various tools are available for comparing the relative informativeness and cost of different designs.

3.0 Conclusion

Adaptive management is a useful approach for managing resources in the face of uncertainty. Where existing information is simply inadequate for making a decision, adaptive management provides a way of generating that information from management actions themselves. But adaptive management is not a panacea — to be effective, it should be applied judiciously, where it will offer the most benefit.

This background report outlines ways that adaptive management can be incorporated into an LRMP. The next step is to discuss these suggestions and develop a more specific and comprehensive adaptive management framework for the North Coast LRMP.

There are six steps in adaptive management. To realise the full benefits of adaptive management, plans must be implemented and followed through to evaluation and adjustment. It is pointless to collect data but not analyse it, or to generate new information and then not apply it. The ultimate, long-term success of any adaptive management project depends on the level of commitment to adaptive management and to following through on plans. An "institutional champion", someone in the lead agency who supports adaptive management and is in a position to see it through, can play a key role in generating this commitment, overcoming any obstacles that may arise, and steering the project through to completion.

4.0 References and Further Reading

B.C. Ministry of Forests. Adaptive management: learning from our forests. (brochure)

Bergerud, W. and W. Reed. Bayesian statistical methods. Pages 89-104 *in* V. Sit and B. Taylor, editors. Statistical Methods for Adaptive Management Studies. Research Branch, BC Ministry of Forests, Victoria, B.C. Land Management Handbook No. 42. [online] http://www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh42.htm.

Brown, Daryl W. (1996). Strategic Land Use Planning Source Book. Commission on Resources and Environment, Victoria, British Columbia.

Holling, C.S.(editor). 1978. Adaptive environmental assessment and management. John Wiley and Sons, London, U.K.

McAllister, M. K. and R. M. Peterman. 1992. Experimental design in the management of fisheries: a review. North American Journal of Fisheries Management 12:1-18.

Sit, V. and B. Taylor (editors). 1998. Statistical Methods for Adaptive Management Studies. Research Branch, BC Ministry of Forests, Victoria, B.C. Land Management Handbook No. 42. [online] http://www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh42.htm.

Taylor, B., L. Kremsater and R. Ellis. 1997. Adaptive Management of Forests in British Columbia. B.C. Ministry of Forests.

Walters, C.J. 1993. Dynamic models and large scale field experiments in environmental impact assessment and management. Australian Journal of Ecology 18:53-61.References

Appendix One: Adaptive Management Decision tree

Purpose

This decision tree will help the LRMP table, GTT or AM SWAT team identify where adaptive management (active adaptive management) would be helpful and appropriate. It is intended as a decision *tool*, to augment, not replace, good judgement and careful thinking.

This decision tree can be used where there is uncertainty (indecision) or disagreement over how to proceed (e.g. over how to zone or what strategies to recommend in order to achieve a stated goal)[viii]. Most of the questions can be answered, at least in a preliminary way, by the LRMP table. Some questions, particularly questions 5 and 6, will require more careful review and analysis by the AM SWAT team.

The decision tree could be used:

- as an initial screening tool (to quickly go through and identify those LRMP issues where AM might be most helpful);
- when there is disagreement or uncertainty over how to meet a particular goal, or over a particular strategy;
- after scenario analysis/modelling to determine whether a management experiment is a useful approach for dealing with key uncertainties identified by the model/decision support system.

[viii] Note: in some cases the LRMP table may agree on how to proceed, but may have overlooked an important uncertainty. For example, they may be assuming that what worked in one area or at one spatial scale will work here, overlooking important differences between the areas or spatial scales. Similarly, they may be assuming that what worked in the past will continue to work in the future, even if conditions are different. It will be important for the GTT and facilitator(s) to be aware of this possibility and to point out the uncertainty and its potential implications.

Decision tree

1. **Is the goal clearly defined and agreed upon?**

   _ If no, define goal.

   _ If yes, go to 2

2. **Is the uncertainty about how to proceed a result of uncertainty about the current state of the system**

   (i.e., if you were certain about the current state, you would be certain about how to proceed?)

   _ If no, go to 3.

   _ If yes, is outcome or decision sensitive to different assumptions about current state? I.e. does the outcome or decision change if the assumptions about current state change?

   _ If no, stop here (doesn't matter which option you choose).

   _ If yes, is it practical and worthwhile to invest in further inventory (is there time, money, resources etc to improve inventory? Would that improvement be enough to reduce uncertainty?)

   _ If no, assess risk of different management options, given uncertainty about the current state (e.g., using quantitative decision analysis).

   _ If yes, proceed with inventory.

3. **Is there uncertainty about the best course of action to meet goal or objective?**

   _ If no, uncertainty may be due to "inherent" unpredictability in the system (e.g., natural variability). Compare management options, given this "inherent" uncertainty (e.g. using quantitative decision analysis).

   _ If yes, is the outcome sensitive to the action (i.e., do different actions lead to different potential outcomes)?

   _ If no, stop here (doesn't matter which option you choose).

   _ If yes, is one option significantly more likely than others to lead to the goal (based on existing evidence)?

   _ If no, go to 4

   _ If yes, stop here (choose that option). *BUT* consider investigating potential cost of being wrong (i.e., if the most likely option turns out to be wrong and the cost of being wrong is unacceptably high, you may still want to reduce uncertainty. Go to 4)

4. Is it within the scope and jurisdiction of the LRMP to resolve this uncertainty?

_ If no, compare the potential outcomes of different options, given this uncertainty (e.g., using quantitative decision analysis).

_ If yes, pass the issue onto the adaptive management SWAT team to answer the questions 5 and 6.

5. Is a management experiment (active adaptive management) the best option for resolving this uncertainty?

For different options for resolving this uncertainty, compare the potential quality/value of information with its direct and indirect costs (e.g., opportunity costs of delaying decision). Other options could include: retrospective analysis of past actions, literature review, research trials, experiences from other locations. In general, adaptive management is *likely* the best option for dealing with: cumulative impacts, impacts over large areas and/or time frames, new strategies, or application of old strategies to a new ecosystem. This analysis of different options for reducing uncertainty could be "quick and dirty" (qualitative) or more thorough and quantitative.

_ If no, proceed with better option(s) for resolving this uncertainty.

_ If yes, go to 6.

6. Is it possible, practical and worthwhile to design a management experiment?

Consider the following:

- are there opportunities for trying different options in different areas, and for comparing these to (untreated) control areas? i.e., can the area be subdivided into units where different treatments could be applied (and would response in one area be independent of what is happening in other areas)? Or, is it a single, unique area, where actions in one part of the area affect responses in other parts?
- can the response be distinguished from background noise? (If not, consider investing in improved monitoring methods.)
- are potentially undesirable outcomes reversible?
- is a response detectable within a time frame that is relevant for making decisions and adjusting future actions? (If not, can you identify indicators that would respond more quickly, provide some information in the short term?)

_ If no. consider precautionary approach or "best management practices" approach.

_ If yes, develop management experiment (proceed with active adaptive management). See Next Steps.

Next steps

Once an issue has been identified by the LRMP table as being suitable for AM, the AM SWAT team would then:

- confirm that active adaptive management is the best approach by doing a more rigorous comparison of a precautionary approach, best management practices and active adaptive management (e.g., using quantitative decision analysis);
- clarify existing information and understanding;
- clarify the assumptions that underlie different management options;
- explore different management options and assumptions using DSS;
- assess the sensitivity of the outcome and decision to different assumptions (using the DSS);
- develop and compare different experimental designs. Consider designs that differ in length of learning phase and in the proportion of land base involved in experiment (i.e., subdividing entire landbase into treatment units vs. testing treatments on only a portion of the landbase, with the remainder deferred or managed according to BMP).

- develop a detailed adaptive management plan. The plan should: describe key uncertainties and assumptions, define alternative actions and their potential outcomes, describe the experimental design, monitoring design and analytical methods, suggest how actions should be adjusted depending on which assumption is supported by data, and include timeline for implementation, monitoring, evaluation and adjustment of actions/decisions.

Appendix 2: Adaptive Management "SWAT Team"

Role

The North Coast LRMP process will incorporate adaptive management as an integral component of the planning process and plan outcomes. A key feature of this strategy will be to establish a team of experts who will provide guidance into the suitability and structure of projects identified for an adaptive management approach by the government technical team or the LRMP planning table.

Specifically, the role of the AM SWAT team is to:

1. Confirm that an issue is suitable for adaptive management (or that adaptive management is a suitable approach for a particular issue referred to them). Where analysis by the AM SWAT team suggests that adaptive management is *not* suitable after all, they would provide the LRMP table or GTT with some recommendations or options for how to proceed. For example, they may find that the goal is not sufficiently well-defined or that the uncertainty could be resolved by a better inventory.

2. *Carry out the next steps, if the decision is made to proceed with adaptive management. These next steps include::*

   - *formal, quantitative comparison of a precautionary approach, "best management practices" or an active management experiment;*
   - investigation and evaluation of existing information and evidence (including literature, research, actions implemented in other areas, retrospective analysis of past actions) which could be used to refine questions and management options;
   - development of a model (or refinement of an existing model) which would then be used to explore alternative scenarios/strategies, identify and clarify key assumptions, refine management options etc;
   - development of a detailed adaptive management plan that specifies key assumptions to be tested, "treatments", experimental design, analytical methods etc.

3. Provide a "sounding board" for the GTT or LRMP table on adaptive management issues.

Composition

1. ***AM SWAT team leader*** would be the initial contact and liaison for adaptive management issues. This person would provide an initial screen and sounding board for issues referred to them by the LRMP table or GTT and would make an initial recommendation of the next steps. The team leader would bring together the rest of the team when and as necessary to identify and carry out the "next steps". The team leader should be familiar and comfortable with:

   - the concepts, steps and tools of adaptive management;

- how adaptive management fits into the spectrum of approaches to learning and management;
- quantitative techniques and tools commonly used in adaptive management (e.g., simulation models, decision analysis, including Bayesian statistics, experimental design); and
- issues that are likely to arise for the North Coast LRMP.

In addition, the team leader must be able to communicate clearly with scientists, managers and the LRMP table.

2. ***Decision analyst*** As part of adaptive management, decision analysis can be used to structure and clarify the decision problem, compare broad approaches (e.g., precautionary approach, best management practices, active adaptive management) and compare alternative experimental designs. Specifically, the decision analyst could:

   - identify where decision analysis would helpful and appropriate (and where it would not);
   - structure the decision problem;
   - recommend the best method(s) or tools to use; and
   - carry out any decision analysis recommended by the AM SWAT team.

   This person should be comfortable with a range of decision analysis tools and methods, including: decision analysis software (such as *Netica*), quantitative decision analysis (including use of Bayesian statistics), simulation models, and simple spreadsheets and graphics. In addition, they should be familiar with the concepts and steps of adaptive management and the role(s) of decision analysis in adaptive management. They should be sensitive to the overall mandate of the LRMP and the constraints (e.g., on time, money, resources) that this may place on the use of some decision analysis techniques.

3. ***Biometrician*** would be responsible for providing advice and recommendations on the design of management experiments and monitoring plans. Specifically, the biometrician could:

   - develop experimental designs for testing key assumptions and treatments;
   - provide insight into the implications (for analysis and interpretation of data and for decision-making) of various design compromises or options; and
   - recommend for or against design compromises or options, taking into consideration the level of knowledge or certainty requested/required by the LRMP table.

   The biometrician should be familiar and comfortable with a range of statistical approaches and methods including: principles of experimental design, impact surveys (e.g., Before-After designs and their variations), retrospective analysis, power analysis,

and Bayesian statistics. This person should be familiar with the concepts and principles of adaptive management, and how the requirements of adaptive management differ from those of research. The biometrician must also able to clearly and effectively communicate the statistical concepts and trade-offs to other members of the SWAT team and to the GTT.

4. ***Modeller/Decision Support Specialist*** As part of adaptive management, simulation models are used to clarify existing understanding of an issue, explore alternative management options, and identify key assumptions/uncertainties. The model may also be used as part of quantitative decision analysis (to provide quantitative estimates of the outcomes of different management options). The modeller should be able to recommend where and how models developed or chosen for the NC LRMP could assist in adaptive management. It may be desirable to modify some of these models to deal with specific issues being addressed through adaptive management.

5. ***Subject area specialists*** would provide expertise on specific subject areas or issues. These subject area specialists would be called upon as necessary, and depending on the issue, could include: wildlife biologists, fisheries biologists, hydrologists, silviculturalists, recreation specialists etc. They would:

    - help to clarify issues;
    - investigate existing information;
    - provide input into decision analysis and modelling;
    - articulate assumptions underlying management options; and
    - suggest monitoring methods and response variables.