Review of the Diavik and EKATI Adaptive Management Plans

Prepared for:

Fisheries and Oceans Canada
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Central and Arctic Region
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Abbreviations

AEMP	Aquatic Effects Monitoring Program
AM	Adaptive management
AMI	Adaptive management initiative
AMP	Adaptive Management Plan
DDMI	Diavik Diamond Mines Inc.
DFO	Fisheries and Oceans Canada
EEM	Environmental Effects Monitoring
WLWB	Wek'èezhìi Land and Water Board

1.0 Introduction

Fisheries and Oceans Canada, Central and Arctic Region asked ESSA to review the 2007 *Diavik Diamond Mine Adaptive Management Plan for Aquatic Effects* (Diavik Diamond Mines Inc. 2007) and the 2008 *EKATI Diamond Mine Watershed Adaptive Management Plan* (Rescan 2008). The following questions guided the review of each adaptive management plan (AMP):

Question 1: Is the AMP consistent with the current practice of adaptive management (AM)? i.e., does it define AM correctly, and does the process outlined in the AMP align with how AM should be done?

Question 2: Does the AMP contain all of the components described in the recent Guide for Preparation of Adaptive Management Plans (Grieg et al. 2008) developed for DFO, and does it appear adequate? If not, what is missing?

Components of an AMP, summarized from the Guide; the full list is provided in Appendix 1):

1. A clear statement of the management goals and objectives for the adaptive management initiative (AMI), in measurable terms.
2. A list of the key uncertainties (management questions) to be addressed by the AMI.
3. A description of the alternative management actions to be employed in the AMI, and how they relate to the uncertainties listed above.
4. A graphic (map based) and textual description of the spatial / temporal bounds of the AMI.
5. Documentation of any conceptual models used to describe the hypotheses to be tested.
6. A description of the indicators that will be measured to assess the effects of management treatment(s).
7. A description of the sampling design for collecting any baseline data used to develop or inform the AMI, and a presentation of the results of the baseline monitoring.
8. A description of how what is learned from the AMI will be used to change management policy or practice.
9. A description of the involvement of stakeholders, scientists, and managers in the development of the design of the AMI.
10. A description of the contrasts, replications, controls to be employed in the AMI (if "active" AM is planned).
11. Predicted outcomes of the management treatments, and a description of the next steps to be taken in response to each of the alternative outcomes.
12. A data management plan.
13. A monitoring plan, including a description of implementation and effectiveness monitoring.
14. A description of the plan for implementation of the treatment(s) to be explored in the AMI.
15. A description of the plan for data analysis, evaluation and reporting.

Question 3: Will the AMP as described achieve the goals and objectives it claims it will? If not, why? What are the shortcomings? [This question is intended evaluate whether the AMP will meet its stated goals / objectives regardless of whether it follows the current practice of AM.]

Question 4: What recommendations can be offered that might improve the AMP?

Question 5: How do the two AMPs compare?

Our review focused on the Adaptive Management Plan for each mine. For some questions we also scanned their Aquatic Effects Monitoring Program (AEMP) documentation for specific answers, as time allowed. This report contains the results of our review.

2.0 Context

The following information will help the reader understand our approach and interpret our findings.

2.1 CURRENT PRACTICE OF ADAPTIVE MANAGEMENT

Adaptive management (AM) is commonly misunderstood and misused (Murray and Marmorek 2004, Gregory et al. 2006, Marmorek at al. 2007; and discussions with numerous practitioners including Brenda Taylor and Brian Nyberg during our work with them in developing AM training courses in 1999-2000 and again with Brian in 2007-2008), and is often erroneously assumed to refer to any process involving the adaptation of management ("managing adaptively") to changing conditions (regulatory, environmental, institutional or social). AM is in fact a **systematic and rigorous** approach for **learning** through **deliberately** designing and applying **management actions** as **experiments**, as defined and used by leading practitioners (Murray 2008). It was first developed under the name "Adaptive Environmental Assessment and Management" in the 1970s by Drs. C.S. Holling, C.J. Walters and associates at the University of British Columbia and the International Institute for Applied Systems Analysis in Vienna (Holling 1978).

AM is more than just better monitoring[1] and response to unexpected impacts (Walters 1997). True AM involves significant work up front, including the identification of management objectives and key uncertainties about how to best achieve them, expressing them as hypotheses to be tested, exploring alternative actions for testing them, and making explicit predictions of their outcomes; and then selecting one or more actions to implement, monitoring to see if the actual outcomes match those predicted, and using these results to learn and adjust future management plans and policy (Walters 1986, Taylor et. al 1997, Stankey et al. 2003, Stankey et al. 2005). Using management actions as experiments is a key component of AM (Bormann et al. 1999, MacDonald et al. 1999, Stankey et al. 2003, Stankey et al. 2005, Bunnell et al. 2007); important gaps in knowledge and the need for learning from planned experimental comparisons in the field was what led to the development of the AM approach (Walters 2007).

A simple diagram illustrating this process is shown in Figure 1. Recent work with leading AM practitioners in Canada and the U.S. (Marmorek et al. 2006), including George Stankey, Bernard Boorman, Brian Nyberg and Bill Beese, led to a comprehensive list of what each step should entail. This list is provided in Appendix 2 (and informed the components in the Guide for Preparation of AMPs).

Adaptive management can be categorized into two types: "passive" and "active". In active AM, managers explicitly recognize in step 1 that they are uncertain about which activities will best meet management objectives, and select several as alternatives to test according to the steps and elements in the cycle.[2] In passive AM, the management action believed to be best (e.g. best practice) is taken through the cycle, still following the elements in each step (e.g. in step 1 the rigour of identifying objectives, uncertainties, hypotheses, assumptions and indicators, and making predictions, would still occur); the only thing missing with good passive AM is the design and implementation of *alternative* treatments. (Note: passive AM looks similar to, but is not the same as, active AM where the contrasting treatments occur over time instead of space. For example, if experimenting with different magnitudes and durations of water releases from a dam to maintain fish habitat, contrasting treatments would need to be applied sequentially rather

[1] This does not mean that "monitoring and reacting" is not useful; it simply means that it is not the same as adaptive management (although monitoring is a key component of AM). There are many ways to learn, and AM is just one of them – one that happens to be particularly systematic and rigorous and has been designed to increase rates of learning over some other approaches.

[2] Fred Bunnell defines active AM a bit differently; to him, "active" AM means experimenting with new methods that have not yet been tried elsewhere (Bunnell, pers. comm., February 2008).

than concurrently, but this is still considered active AM if more than one treatment is being tested and compared.)

The following questions are useful when deciding whether AM is the right approach for solving any given environmental management problem:

- Is there significant uncertainty regarding what management actions will best achieve the desired outcomes? (Uncertainty is the driver for AM; if there is little or no uncertainty about the effects of management actions, there is no need to use AM, although some degree of monitoring is prudent to confirm assumptions and provide early warning of surprises.)
- Is a management experiment the best way to reduce this uncertainty? (E.g. could you instead do retrospective analyses on data previously collected for some other purpose to find the answer?)
- Can you design a powerful enough management experiment to discern the effects of different management actions (i.e. to confidently detect cause-and-effect)?
- Is sufficient monitoring (i.e. measuring enough indicators, and for long enough, to discern treatment effects from natural variability and confounding factors) feasible?
- Can there be 'safe failures' (i.e. if the management experiments 'fail' or result in outcomes that are different from those desired, is this acceptable, or reversible)?
- Is there support (institutional, stakeholder, partner) to implement adaptive management?

If the answer to any of these questions is "no", then AM may be unnecessary, inappropriate, or unsuccessful.

Determination in this review of how well the AMPs align with "current practice" of AM was done with this information in mind.

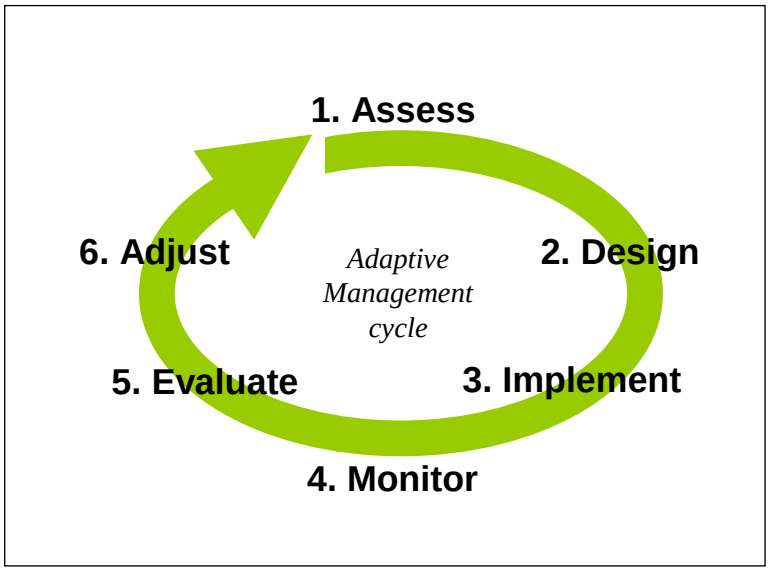

Figure 2.1. The adaptive management cycle.

2.2 REQUIREMENTS FOR PREPARING AN AMP

We understand that both of the mines have been operating for several years, that each have previously developed and periodically revised AEMPs as required in their water licences, and that these water licences have also recently included an adaptive management requirement. According to information provided in the AMPs, these plans have been prepared in response to the following directives:

Diavik: *"In their letter of July 18, 2007 the WLWB directed DDMI to prepare this AEMP Adaptive Management Plan. Specifically the WLWB Directive states that: 'The Plan should describe, in sufficient detail, how data in the AEMP will be used to identify the need for additional mitigation strategies to minimize the impacts of the project on the aquatic environment'."*

EKATI: "*Water Licence MV2003L2-0013, under Part H, item 7, requires that BHP Billiton develop: 'a management plan that describes a way of managing risks associated with uncertainty and provides a flexible framework for the mitigation measures to be implemented.' Part H, item 7, of the water licence further requires:*

- *monitoring and research programs to meet the needs of the AMP;*
- *identification of contaminants of interest for adaptive management planning;*
- *derivation of numerical thresholds in the receiving environment for the contaminants of interest;*
- *appropriate triggers for the numerical thresholds for the contaminants of interest;*
- *response procedures, mitigation measures and treatment options if triggers are activated;*
- *linkage with the Aquatic Effects Monitoring Program (AEMP) and other management*
- *plans as appropriate; and*
- *annual reporting to the Wek'èezhìi Land and Water Board."*

In February 2008 DFO asked ESSA to craft a guideline for what a good AMP should contain, and our product (Grieg et al. 2008) was informed by our AM expertise/experience and the key AM steps and elements in Appendix 2. Question 2 in this review specifically addresses the degree to which the AMPs adhere to this guideline. It should be noted however that this guideline was not available when the two AMPs reviewed here were written. It was therefore up to the proponents to determine how to best use AM to meet the directives.

3.0 Diavik AMP Review Results

3.1 Alignment with current practice of AM

Question 1: Is the AMP consistent with the current practice of AM? Does it define AM correctly? Does the process outlined in the AMP align with how AM should be done?

AM is defined in the Diavik mine AMP (DDMI 2007) as "*a systematic process for continually improving mine operation practices by learning from the outcomes of performance monitoring and review programs. It is a cyclical process of plan ➔ monitor ➔ review ➔ revise plan ➔ monitor etc.*" While this information is not incorrect, a subsequent statement that "*the notion of adaptively managing applies to many activities in an operation*" and the actual content of the Diavik AMP suggests that AM is being viewed with either much less rigour than required to be done properly, or is being misunderstood as "managing adaptively". (The difference between formal Adaptive Management and the idea of managing adaptively is discussed in Section 2.1 of this review).

The parts of AMP Figure 1-1 (DDMI 2007) that are below the line (i.e. outside the AEMP) are specified as being the focus of the AMP, but are the subject of only 5 pages at the end of the Plan, and do not contain sufficient information to confirm an understanding of – or adherence to – how AM should be done. The whole of Figure 1-1 in the AMP (both above and below the line) suggests that AM is being viewed primarily as a monitoring tool (featuring the AEMP), with management reaction occurring if monitoring results reveal a problem. This is not the same as AM. Further discussion of the difference is provided in Section 6 of this review.

AMP Figure 1-1 also suggests that the proponent intends to only consider a "passive" approach to management responses, as the second and third boxes outside the AEMP are labelled "Evaluate Possible Management Options" and then "Apply Appropriate Management Option". (A "passive" approach is not identified as such in the AMP, so it is unclear if the authors are aware of the distinction.) An "active" approach whereby different options are tested would provide much greater opportunity to learn which was best; this is also discussed further in Section 6.

3.2 Alignment with DFO Guide for preparing an AMP

Question 2: Does the AMP contain all of the components described in the recent Guide for Preparation of Adaptive Management Plans developed for DFO, and does it appear adequate? If not, what is missing?

Please refer to the Guide, or Appendix 1, for greater detail regarding the listed components.

Table 3.1. Components from the AMP Guide that are present in the Diavik AMP.

AMP Component in the Guide	Present?	Comments on adequacy, gaps
1. A clear statement of the management goals and objectives for the adaptive management initiative (AMI), in measurable terms.	No	No clear statement as such, which is a gap – the purpose of AM is to reduce uncertainty about what actions will best achieve desired management objectives/outcomes – and these objectives must be stated in measurable terms so it is possible to determine if they are being met. For example, is the objective to determine if there have in fact been adverse impacts on water quality, water supply, and fish (the three key issues from the EA)? If so, this should be clearly stated and "adverse" impacts must be defined in measurable terms. AMP Table 1-1 comes close, but the link

AMP Component in the Guide	Present?	Comments on adequacy, gaps
		between management objectives, indicators and desired endpoints should be more explicit.
2. A list of the key uncertainties (management questions) to be addressed by the AMI.	No	No clear uncertainties are identified, and the AMP does not seem to be driven by uncertainties about how mine activities affect the environment. As further discussed in Section 6 of this review, AM is driven by uncertainty, and an explicit desire to reduce this uncertainty, and therefore an AMP should specify what management questions/uncertainties are the focus of the plan.
3. A description of the alternative management actions to be employed in the AMI, and how they relate to the uncertainties listed above.	Somewhat	Some generic management actions are listed, although they are not explicitly linked to the cause-effect pathway they might help mitigate, nor to specific uncertainties (see row above). Potential management actions must be explicitly linked to endpoints, in order to be able to explore feasible options for mitigating impacts on endpoints.
4. A graphic (map based) and textual description of the spatial / temporal bounds of the AMI.	Yes and No	There is a map of the mine site, but there is no specific AM initiative to be bounded in space or time. The AMP does consider spatial and temporal extent in classifying effects levels in the risk characterization process, but this is different from identifying the spatial and temporal bounds of an AM project (management experiment) deliberately designed to reduce specific uncertainty.
5. Documentation of any conceptual models used to describe the hypotheses to be tested.	Yes and No	The AMP contains numerous linkage diagrams from the EA, which are an excellent and commonly-used type of conceptual model for identifying potential impact pathways, but they do not appear to have been used to identify hypotheses to be tested (e.g. hypotheses about the nature/extent/magnitude of impact pathways, or about the effectiveness of management or mitigations actions in minimizing the impact along a particular pathway).
6. A description of the indicators that will be measured to assess the effects of management treatment(s).	Yes and No	There is a list of measurement endpoints, but these are only generally expressed, and part of ongoing monitoring not specific to any particular AM initiative/question/experiment. The AEMP may provide more detail about the measurement endpoints, but the AMP should put these (or a subset) into the context of the management question that AM is intending to address.
7. A description of the sampling design for collecting any baseline data used to develop or inform the AMI, and a presentation of the results of the baseline monitoring.	No	Some baseline monitoring is described in the AEMP (e.g., various water quality monitoring in Lac De Gras since 1994), although the reliance in the AMP on differences between monitoring results near the mine and at reference sites for early warning and determination of effects levels suggests a limitation in pre-project baseline monitoring across multiple variables of interest.
8. A description of how what is learned from the AMI will be used to change management policy or practice.	Somewhat	The AMP states that mitigation strategy options will be considered if warranted by the AEMP results and risk characterization, but because the AMP is not describing any particular AM project/question/experiment no specifics are provided.
9. A description of the involvement of stakeholders, scientists, and managers in the development of the design of the AMI.	No	The AMP contains no information about participants involved in its development. (Section 2 of the AMP mentions issues raised by the public during the EA process, but this is pre-project information.) This may reflect the fact that the AMP is not focused on any particular AM project/question/experiment.
10. A description of the contrasts, replications, controls to be employed in	Partially	Reference areas are mentioned in AMP Table 1-1, but no information is provided about them. The AEMP identifies multiple

AMP Component in the Guide	Present?	Comments on adequacy, gaps
the AMI (if "active" AM is planned).		reference locations for all sampling components of interest (e.g., water & sediment quality, phytoplankton, fish, dust, fish tissue chemistry). Far-field locations within Lac de Gras are used as reference locations since no appropriate control lakes could be identified. There is no discussion of replication or contrasting treatments in the AMP (Note: the ability to detect changes compared with reference sites requires a very robust monitoring design).
11. Predicted outcomes of the management treatments, and a description of the next steps to be taken in response to each of the alternative outcomes.	No	No specific management treatments are proposed. (It does contain predictions from the EA, and compares these to the current status from monitoring results to date, however it does not address situations where current status is different from that predicted (e.g. for the higher dust deposition rates). This would be a perfect opportunity for AM; using the AM cycle to explore why this is happening, and then undertake mitigation experiments to try to reduce dust deposition.
12. A data management plan.	No	There is no data management plan in the AMP. Quality Assurance / Quality Control procedures are described in the AEMP to ensure data are of consistent and known quality, and that data collection matches intended use.
13. A monitoring plan, including a description of implementation and effectiveness monitoring.	Yes and No	There is a separate AEMP although as part of what appears to be an EEM process rather than an AM process (see Section 6 of this review for further discussion). It does not appear as though the AEMP provides guidance on implementation monitoring.
14. A description of the plan for implementation of the treatment(s) to be explored in the AMI.	No	No specific management treatments are proposed in the AMP.
15. A description of the plan for data analysis, evaluation and reporting.	Somewhat	The AMP states that most analysis and reporting under the AMP will be internal to DDMI, and that the primary external reporting mechanism will be through the water licence requirement for an annual AEMP report that must include a summary of activities under the AMP.

3.3 LIKELIHOOD OF ACHIEVING AMP GOALS

Question 3: Will the AMP as described achieve the goals and objectives it claims it will? If not, why? What are the shortcomings?

The goal and objective of the Diavik Adaptive Management Plan are not clearly articulated. However, based on guidance stated in the introduction and provided by the Wek'èezhìi Land and Water Board the AMP:

"*…should describe, in sufficient detail, how data in the AEMP will be used to identify the need for additional mitigation strategies to minimize the impacts of the project on the aquatic environment*".

Thus, we infer that the goal of the AMP is to "*minimize the impacts of the project on the aquatic environment*" (specifically water quality, water supply, and fish) and the objective is to "*identify the need for additional mitigation strategies*" to achieve this goal.

It is clear from the Adaptive Management Plan that the process for achieving this goal and objective draw heavily upon information provided in previous efforts. For instance, the AMP relies on data collection, analyses, and risk characterization as outlined in the Aquatic Effects Monitoring Program (AEMP), while the AEMP relies on an understanding of impact pathways as developed in the Environmental Assessment (EA). To provide a confident determination about whether the AMP will achieve the above goal / objective, these other documents must also be reviewed thoroughly which was beyond the scope of this review. We did, however, provide a cursory review of the AEMP and noted the following three observations which relate to whether the AMP will achieve its goal / objective.

First, the AEMP provides a process for identifying impacts of the project that pose a risk on the environment and human health – i.e., identifying triggers and the need for additional management action / mitigation. A risk characterization process distinguishes between tolerable and intolerable "effects sizes" or "changes in the environment". It does not represent a process for identifying any effects / changes in the environment. Determinations of tolerable and intolerable "effects sizes" can be provided through scientific studies / rationale. For instance, in the AEMP water quality endpoints are compared against benchmarks as recommended, in part, by the Canadian Council of Ministers of the Environment (CCME) guidelines for protection of aquatic life. A determination of intolerable levels of change can also be based on social / cultural values which depend on a person's risk tolerance. For instance, other endpoints in the AEMP (sediment chemistry, zooplankton biomass, fish population health), rely on statistical deviations from reference areas (e.g., beyond 2 standard deviations) and are open to much more interpretation. Therefore, given the potential for remaining debate about appropriate thresholds, and the importance of such thresholds for triggering action within the AMP, **all benchmarks and/or effect sizes in the AMP / AEMP should be scientifically defensible where possible, and if not, should be acceptable to all relevant audiences / stakeholders based on an agreed upon tolerance of risk.**

Second, related to the issue of identifying defensible benchmarks, thresholds for triggering action (e.g., Tables 1-1 and 3-1 in AMP) have not been described in enough detail. For instance, it's not clear from the Monitoring Program whether background levels of "exposure" will include pre-development years of data or if reference sites will only be used. In relation to "effects", it is not clear which statistical parameters (e.g., average, 90^{th} percentile, maximum observation) and what time period (daily, monthly, annual) would be used to determine whether effects are within / outside the range of natural variability. A lack of clarity here leaves too much open for interpretation. Therefore, to ensure transparency and minimize debate during latter stages of data analysis and interpretation, it will important to **clearly articulate agreed upon parameters and time periods for describing exposure and effects that will be used to summarize rules for pursuing additional mitigation.**

Finally, in Section 4.2 the list of mitigation strategy options and the associated benefits-costs / impacts is too vague to determine whether the AMP will be effective. For instance, it's not clear from this list whether it will be possible to mitigate against any and all potential risks. Are there any adverse environmental outcomes for which the mine cannot reduce impacts on the environment? As well, prior to implementation of any management action / mitigation there is a need for an evaluation of the benefits and costs / impacts of taking action. Such an evaluation is a value-laden process that requires input from all relevant / affected parties. **No clear statements or descriptions of values are provided. Proactive clarity on this topic would be beneficial to avoid unnecessary conflicts during a time when actions might require evaluation on short notice.**

Overall, it appears the AMP provides the general structure for minimizing impacts on the environment by identifying additional mitigation strategies. However, as described above much greater clarity is needed to ensure risks and mitigation strategies are adequately characterized to ensure the plan will be effective in achieving its goal / objective. The recommendations above are not reiterated in Section 6 as they do not directly relate AM.

3.4 RECOMMENDATIONS

Question 4: What recommendations can be offered that might improve the AMP?

The AMP should have much more information on what would happen if the risk characterization process flags a possible or likely risk, including a more explicit commitment to use steps and elements of the AM cycle, and greater detail on how this would be applied. More information is provided in Section 6 of this review, as it applies to both the Diavik and EKATI AMPs.

4.0 EKATI AMP Review Results

4.1 Alignment with current practice of AM

Question 1: Is the AMP consistent with the current practice of AM? Does it define AM correctly? Does the process outlined in the AMP align with how AM should be done?

The EKATI Adaptive Management Plan (Rescan 2008) contains a summary of AM that is extracted from reputable sources in the domain. While it begins with a loose definition of "learning by doing", which does not reflect the rigour of the approach, the subsequent information conveys key characteristics of AM including deliberately experimenting with management policies and practices for the explicit purposes of reducing uncertainty regarding ecosystem management, and provides a diagram of the AM cycle. (In this context the subsequent statement that "*the theory of AM is continually being refined through its application, in itself an experiment in AM*" (underline added) seems incongruent as it suggests a looser interpretation.)

The bulk of the AMP focuses on thresholds and triggers used to evaluate data collected under the AEMP, and less then 3 pages are devoted to what would be done if such results indicated a problem requiring mitigation. The main link offered in the AMP between the steps in the AM process and the contents of the Plan is the observation that *"numerical thresholds and triggers play a role in the evaluation step of adaptive management as signals of when management should initiate actions."* This suggests that either (a) the AEMP and the thresholds/triggers are being viewed as Steps 4 and 5 in an AM cycle that is already way, or (b) AM is being viewed as a reactionary approach driven by monitoring results rather than a proactive approach driven by management uncertainty. If (a) is true, then the AMP does not provide evidence of (or results from) key elements from Steps 1-3 in the AM cycle, most notably the uncertainty-driven management experiments that characterize AM. Text in the introduction of the AMP suggests that the mine itself might be viewed as an AM experiment, but if so this would fall outside current practice of AM for several reasons, including the fact mine developments are not environmental management actions, they would not allow for 'safe failures', and they are not built for the express purpose of reducing uncertainty about how actions affect the environment. If (b) is true, as AMP Figure 3.2-1 suggests, then this is not the same as AM. Further discussion of the difference between both (a) and (b) and AM is provided in Section 6 of this review.

In Section 4 the AMP states that *"The inherent nature of an adaptive management plan is that the most appropriate response can only be developed at the time, based on the information at hand"* and offers little else regarding what will be done if a trigger is activated. While it may be true that the best mitigation options cannot be identified until the nature of the problem is known (i.e. when a trigger is activated), it is certainly possible to commit to a more rigorous methodology for using AM to solve the problem and to identify what steps will be taken (such as those listed in the Guide).

4.2 Alignment with DFO Guide for preparing an AMP

Question 2: Does the AMP contain all of the components described in the recent Guide for Preparation of Adaptive Management Plans developed for DFO, and does it appear adequate? If not, what is missing?

Please refer to the Guide, or Appendix 1, for greater detail regarding the listed components.

Table 4.1. Components from the AMP Guide present in the EKATI AMP.

AMP Component in the Guide	Present?	Comments on adequacy, gaps
1. A clear statement of the management goals and objectives for the adaptive management initiative (AMI), in measurable terms.	Somewhat	The objectives of the AMP are stated, but not for any particular AMI as none are described in the AMP, and these are not stated in measurable terms. The thresholds could be inferred as measurable objectives, but are not stated as such.
2. A list of the key uncertainties (management questions) to be addressed by the AMI.	No	The AMP is not driven by uncertainties or management questions; it focuses on establishing thresholds and triggers. As further discussed in Section 6 of this review, AM is driven by uncertainty, and an explicit desire to reduce this uncertainty, and therefore an AMP should specify what management questions/uncertainties are the focus of the plan.
3. A description of the alternative management actions to be employed in the AMI, and how they relate to the uncertainties listed above.	No	It provides a very general list of generic types of management responses that might be possible if a trigger is activated, but hypothetically and not within the context of a specific problem or question.
4. A graphic (map based) and textual description of the spatial / temporal bounds of the AMI.	Yes and No	There is a schematic of a site-wide water balance, but for the whole operation and not for any specific AM initiative/project/question. The AEMP also provides a map of the mine site and surrounding sampling locations, as well as a table with temporal frequency of sampling, although no information on the spatial-temporal bounds of any management experiments.
5. Documentation of any conceptual models used to describe the hypotheses to be tested.	No	Regression models to detect trends over time[3] were used to define triggers, and numerical models are being used to predict water quality changes, but their purpose is to identify triggers, not to explore or describe hypotheses about what management actions might cause these changes.
6. A description of the indicators that will be measured to assess the effects of management treatment(s).	Yes and No	Specific indicators (including units) are listed for 17 contaminants, but as part of the ongoing monitoring under the AEMP and not in relation to any specific AM project/question/experiment.
7. A description of the sampling design for collecting any baseline data used to	Yes and No	The sampling design is not presented in the AMP. A map with sample locations, as well as a series of tables with components

[3] The AMP states that the regression models "*replace the simple Before-After Control-Impact (BACI) comparisons testing only for differences between the current year and baseline data*", and explains that the primary advantage of the regression analyses is that "*they incorporate data from all years of monitoring*". As explained by Schwarz (1998) in Statistical Methods for Adaptive Management Studies (Sit and Taylor 1998) – a report cited in the AMP – a good BACI design is not a simple one-year comparison, and that an enhanced BACI paired (BACI-P) design is one of the best for detecting both acute and longer-term impacts because it can *"show that observed differences in ecological variables between the control and impact sites are neither artifacts of sampling nor due to temporal trends unrelated to the impact."* He further states that "*the strength of the inference is directly related to the design issues directly under the control of the managers such as the frequency of sampling and number of control sites."* Regression analysis is not a replacement for a BACI-type design, but rather one of the methods by which results from these types of designs might be analyzed. However, Schwarz also notes that *"in regression of the characteristics versus time, the estimated slope is often used as evidence of a longterm change. However, data collected over time violate the assumption of independence required for ordinary regression. The estimate of the slope remains unbiased, but typically the estimated standard error of the slope is too small. The results appear to be statistically significant when, in fact, there is no evidence of a change."* A similar problem of correlation among the measurements exists for ANOVA methods, and he suggests time-series methods that incorporate temporal correlation instead.

AMP Component in the Guide	Present?	Comments on adequacy, gaps
develop or inform the AMI, and a presentation of the results of the baseline monitoring.		of interest, station coordinates, and sampling frequencies are provided in the AEMP. The graphs presented show baseline monitoring data for 3 years prior to mine development.
8. A description of how what is learned from the AMI will be used to change management policy or practice.	Somewhat	The AMP lists some possible management responses if a trigger is activated, but because the AMP is not describing any particular AM project/question/experiment no specifics are provided.
9. A description of the involvement of stakeholders, scientists, and managers in the development of the design of the AMI.	No	The AMP contains no information about participants involved in its development
10. A description of the contrasts, replications, controls to be employed in the AMI (if "active" AM is planned).	Partially	Three reference areas (two external and one internal) are mentioned in the AMP but there is no description of contrasts or replications because the AMP is not focused on any particular AM project/question/experiment. The AEMP summarizes the number of replicate samples collected across the study area. No information on contrasting treatments are provided in the AEMP. (Note: the ability to detect changes compared with reference sites requires a very robust monitoring design.)
11. Predicted outcomes of the management treatments, and a description of the next steps to be taken in response to each of the alternative outcomes.	No	No specific management treatments are proposed.
12. A data management plan.	No	There is no data management plan in the AMP, and no data management plan has been provided in the 2006 AEMP.
13. A monitoring plan, including a description of implementation and effectiveness monitoring.	Yes and No	There is a separate AEMP although as part of what appears to be an EEM process rather than an AM process (see Section 6 of this review for further discussion). No information is provided to describe implementation monitoring in the AEMP.
14. A description of the plan for implementation of the treatment(s) to be explored in the AMI.	No	No specific management treatments are proposed.
15. A description of the plan for data analysis, evaluation and reporting.	Yes	The AMP contains information on the thresholds, and how triggers will be activated; and also states that a score card for water quality that compares monitoring values, three-year predictions and threshold values will be reported annually.

4.3 LIKELIHOOD OF ACHIEVING AMP GOALS

Question 3: Will the AMP as described achieve the goals and objectives it claims it will? If not, why? What are the shortcomings?

The stated goal / objective of the EKATI Adaptive Management Plan is to:

"meet the requirements of Water License MV2003L2-0013, and to provide BHP Billiton with a methodology to initiate action when contaminants of concern measured in the aquatic receiving environment approach threshold values"

Seven requirements under Part H, item 7 of the water license specify:

(i) monitoring and research programs to meet the needs of the adaptive management plan;
(ii) identification of contaminants of interest for adaptive management planning;
(iii) derivation of numerical thresholds in the receiving environment for the contaminants of interest;
(iv) appropriate triggers for the numerical thresholds of interest;
(v) response procedures, mitigation measures, and treatment options if triggers are activated;
(vi) linkage with the Aquatic Effects Monitoring Program (AEMP) and other management plans as appropriate; and
(vii) annual reporting to the Wek'èezhìi Land and Water Board.

The AMP provides information to satisfy all seven of these requirements. In regards to requirement (i), the AMP summarizes the general design and parameters of interest within the Aquatic Effects Monitoring Program (AEMP). The AEMP (Rescan 2006) is referenced for further information. Related to requirement (ii), 17 contaminants of interest are provided as an initial list to identify possible future concerns. Related to requirements (iii), (iv), and (v), numerical thresholds are provided for all contaminants of interest, triggers are defined if threshold exceedences are predicted within three years, and a suite of management responses are provided. Finally, linkages to the AEMP have been articulated (requirement (vi)) and commitments for annual reporting to the WLWB have been provided (requirement (vii). Therefore, evaluated on the basis of satisfying these requirements the EKATI AMP achieves its goals and objectives.

Noteworthy are the different requirements / interpretations of an AMP between EKATI and Diavik. For instance, the EKATI AMP does not discuss thresholds and triggers for biological endpoints (e.g., zooplankton, benthic invertebrates, fish, etc.). Management responses within EKATI's AMP range from adding sampling sites to designing mitigation strategies, while Diavik's AMP strategies are more focused on mitigation strategies only. There is also no discussion about the cost-benefit of these options in EKATI's AMP. Thus, if items included in the Diavik AMP also apply to the EKATI AMP, the observations stated in Section 3.3 are also relevant here (i.e., the need for more clearly articulated and defensible thresholds, triggers, and mitigation strategies).

4.4 RECOMMENDATIONS

Question 4: What recommendations can be offered that might improve the AMP?

The AMP should provide much more information on what would happen if a trigger is activated, including a more explicit commitment to use steps and elements of the AM cycle, and greater detail on how this would be applied. More information is provided in Section 6 of this review, as it applies to both the EKATI and Diavik AMPs.

5.0 Comparison of Review Results

Question 5: How do the two AMPs compare?

The EKATI AMP contains more information than the Diavik AMP about what AM is, but neither Plan follows current practice of AM. They both appear to have focused on the process for identifying risks or triggers from the monitoring they are currently doing under their AEMPs, with little of either AMP devoted to what they will do if the monitoring results reveal a problem – which is where we think the best opportunity exists for using adaptive management in the context of these operating mines. (Further discussion of this is provided in Section 6.) This is evident from Table 5.1 which compares the relative attention paid to the main contents of each AMP. Excluding the introductory material, the Diavik and EKATI AMPs devote only 14% and 7% of their content, respectively, to what they will do if monitoring results reveal a problem requiring mitigation.

Table 5.2 compares a summary of which specific AM components in the Guide are included in the AMPs. From this table it is evident that both AMPs are missing many of the key elements of AM, which is not surprising given the finding described above.

Table 5.1. Comparison of the content in each AMP.

Diavik		EKATI	
Main content of the AMP	Relative proportion*	Main content of the AMP	Relative proportion*
Review of potential pathways and impacts from the EA, and actual effects to date	67%	Review of water use and water management activities at the site	20%
Methodology for how effects and risks will be characterized	19%	Review of AEMP sampling design, effects evaluation, and actual thresholds and triggers	73%
Methodology for how likely/possible risks will be addressed, potential mitigation strategy types and how they will be chosen, and what will be reported	14%	Description of common initial responses and possible AM responses if a trigger is activated, and what will be reported	7%

* % of total pages across the different contents listed within each AMP

Table 5.2. Comparison of the components from the AMP Guide that are present in each AMP.

AMP Component in the Guide	Diavik AMP	EKATI AMP
1. A clear statement of the management goals and objectives for the adaptive management initiative (AMI), in measurable terms.	No	Somewhat
2. A list of the key uncertainties (management questions) to be addressed by the AMI.	No	No
3. A description of the alternative management actions to be employed in the AMI, and how they relate to the uncertainties listed above.	Somewhat	No
4. A graphic (map based) and textual description of the spatial / temporal bounds of the AMI.	Yes and No	Yes and No
5. Documentation of any conceptual models used to describe the hypotheses to be tested.	Yes and No	No

AMP Component in the Guide	Diavik AMP	EKATI AMP
6. A description of the indicators that will be measured to assess the effects of management treatment(s).	Yes and No	Yes and No
7. A description of the sampling design for collecting any baseline data used to develop or inform the AMI, and a presentation of the results of the baseline monitoring.	No	Yes and No
8. A description of how what is learned from the AMI will be used to change management policy or practice.	Somewhat	Somewhat
9. A description of the involvement of stakeholders, scientists, and managers in the development of the design of the AMI.	No	No
10. A description of the contrasts, replications, controls to be employed in the AMI (if "active" AM is planned).	Partially	Partially
11. Predicted outcomes of the management treatments, and a description of the next steps to be taken in response to each of the alternative outcomes.	No	No
12. A data management plan.	No	No
13. A monitoring plan, including a description of implementation and effectiveness monitoring.	Yes and No	Yes and No
14. A description of the plan for implementation of the treatment(s) to be explored in the AMI.	No	No
15. A description of the plan for data analysis, evaluation and reporting.	Somewhat	Yes

6.0 Conclusions and Recommendations

It appears as if the process of monitoring under the AEMP, identifying when monitoring results indicate a problem, and then taking action has been mistaken for AM. This is understandable, given the similarities. Monitoring and then acting on the results is certainly **necessary, but not sufficient,** for AM. AM involves much more than is provided in the AMPs; it is driven by **management uncertainties**, and employs deliberate **management experiments** to reduce these uncertainties, neither of which are evident in the Plans. In gaining better clarity about the difference between the AMPs and true AM it may help to think of AM as "experimental management", a term often used to describe AM and one that is perhaps less open to misinterpretation. AM begins with a management uncertainty (i.e. a question about how a certain environmental policy or practice will best meet management objectives) and then follows a systematic, rigorous process for further exploring/defining the question and then trying to answer it, using the six steps and as many elements (see Appendix 2) in each step as possible – because together these steps and elements provide a greater likelihood of actually learning what you need to answer the question than if you leave steps or elements out. Step 1 in the AM cycle involves full exploration of the management question (including hypotheses, assumptions, etc.), Steps 2-5 involve designing, implementing, monitoring and evaluating management experiments that are specifically intended to answer the question, and Step 6 involves changing management policy or practice based on what has been learned.

Using AM to identify and minimize impacts from a development project is different from what AM is designed to do. The Diavik and EKATI diamond mines are not management experiments and were not undertaken for the purpose of trying to better meet environmental management goals or objectives. They are environmental perturbations that must themselves be mitigated or managed, and therefore mine construction/operation and monitoring for impacts does not fit the AM framework. (This doesn't mean that there is anything wrong with the AEMPs; it simply means that monitoring under the AEMP and reacting to the results is not the same thing as doing AM.) This raises a compelling question*: is AM a useful tool in the context of development projects, and if so, where does AM best fit?*

We believe that the **selection and implementation of mitigations** – activities intended to meet environmental objectives – are the closest fit in this context with the intent and practice of AM. Mitigations are the closest analogy to environmental management actions in a development context, and provide the best opportunity for incorporating AM into the process. Used in this manner, the AM cycle would begin once a risk or a trigger is activated and mitigation is required. The driving uncertainty would relate to how best to mitigate the impact, once discovered; contrasting mitigation options would be applied as different experimental treatments and taken through the AM cycle. This framework is represented in Figure 6.1, and is a different conceptual framework from what appears to be the approach taken in the AMPs. The effectiveness monitoring that would be done under Step 4 would likely be some subset of that already being done under the AEMP, although it will be driven by the specific questions and management experiments and may require different indicators or a modified sampling design from that of the AEMP.

From our review results and conclusions we offer the following recommendations:

For the regulatory agencies:

1. **Decide if AM really is the approach that you want mine operators to use.** Given the information provided in this review, specifically regarding the true nature and intent of AM, is this still a tool you would like them use? Were the most recent water licence directives intending Diavik and EKATI to focus on how to characterize risks and identify thresholds/triggers, or on mitigation experiments driven by specific uncertainties?

2. **If AM is still the desired approach, clarify the intended purpose of AM requirements in the water licences.** This includes clarity regarding the difference between EEM and AM, and where the AEMPs fit in. It is our recommendation that the purpose be to test mitigation options if the AEMP monitoring results reveal a problem that must be mitigated, as per the framework in Figure 6.1.
3. **Provide specific guidance to proponents regarding what you expect to see in an AM Plan.** It is our recommendation that the proponents be asked to follow the components listed in the Guide.

For the proponents:

1. **Use AM to answer specific questions.** Avoid trying to superimpose AM over a process of mine construction/operation → monitoring → responding, as the mines are not management experiments and AM doesn't fit. Instead, focus on using AM to answer specific questions that arise during this process about how operational changes or mitigations might better meet objectives related to minimizing the release of contaminants in the aquatic environment.
2. **Include all of the AM steps and as many AM elements as possible in your AMP.** If writing the AMP in the absence a specific problem or uncertainty (i.e. if describing what you will do if a problem is flagged in the future), use the Guide to describe how the AM cycle would be applied once a problem arises, including commitments to identify the critical uncertainties and to be clear about how the mitigation actions/treatments relate to that uncertainty. A more specific AMP should be prepared once a problem or question arises and begins its way through the AM cycle, containing details about AM elements in each step that are particular to the problem/question being addressed.

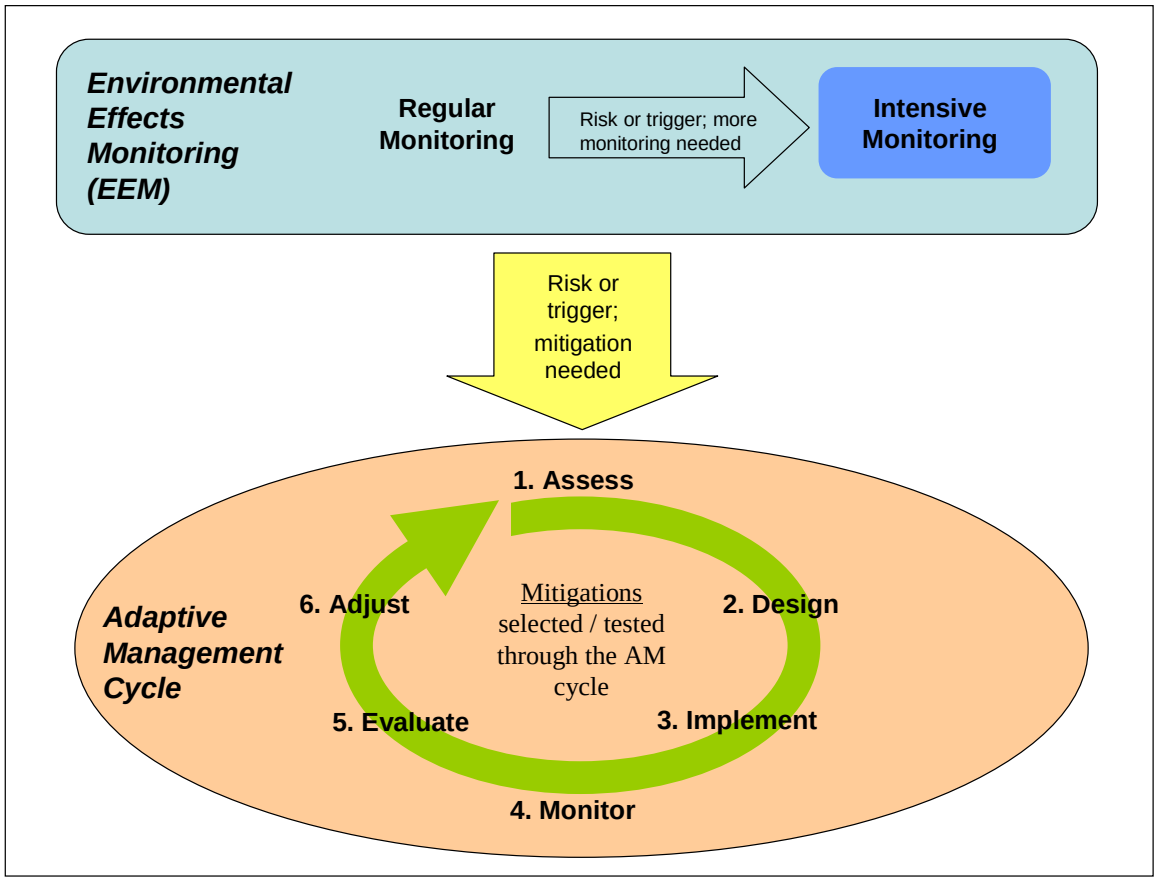

Figure 6.1. A conceptual framework for fitting AM into the current EEM at the mines.
The top box does not attempt to capture the cycles and nuances of the risk assessment (Diavik) or threshold and trigger (EKATI) processes that may lead to further study or monitoring (actions undertaken as part of EEM); but rather to separate those activities from situations where mitigations are clearly needed – which under this framework would be the 'trigger' for using AM and provide a specific set of questions to answer using the AM cycle.

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Appendix 1: Guideline – Contents of Adaptive Management Plans

Adaptive Management plans are developed as part of Step 2 in the AM cycle (element h in Table 2). While there may be iteration between some of the elements in Steps 1 and 2 in the cycle as the design is refined, the AM plan should be prepared and filed when there is a complete draft of the design of the management experiment suitable for peer review. In some cases, where additional baseline information is needed, it may be desirable to conduct the peer review in two phases: 1) an initial review when there is a well developed conceptual outline of the AM experimental approach together with a design for collection of additional baseline information, and 2) a final review when the design has been finalized in light of the baseline information collected during the design phase.

Adaptive Management plans must describe the results of Steps 1 and 2 in the AM cycle in sufficient detail to permit a thorough peer review of the intended experimental design. This description should include not only the design for the management strategies and monitoring to be carried out in Steps 3 and 4 of the AM cycle, but should also include a description of the anticipated analysis to be used in Step 5 and the expected management response in Step 6 of the AM cycle based on what is learned (e.g. what changes in policy or practice would be expected if the outcomes that are *predicted* in Step 2 do indeed occur). The plan should describe the AM initiative (AMI) in sufficient detail that it can be used to guide implementation of the subsequent steps in the cycle. In this regard an AM plan (AMP) should include each of the components listed below.

1. A clear statement of the management goals and objectives for the AMI, in measurable terms.
2. A list of the key uncertainties (management questions) to be addressed by the AMI
3. A description of the alternative management actions (experimental "treatments") to be employed in the AMI, and how they relate to the uncertainties listed above. Management actions considered during the assessment stage but which are not included in the AMI, if any, should also be identified and the reasons for their elimination from the AMI should be documented. In the event that the AMI will employ a Passive AM approach, the plan should indicate the initial management action to be explored, the duration of monitoring required to evaluate that action, and the likely sequence of alternative management actions thereafter depending on the outcome of the monitoring and evaluation steps (i.e. a series of if…then statements). If the sequence of alternatives is not specified, then the criteria for selecting alternatives for subsequent investigation should be described.
4. A graphic (map based) and textual description of the spatial / temporal bounds of the AMI.
5. Conceptual models which describe the hypotheses to be tested, and which thus underlie the design, should be clearly documented. Such models are best presented in terms of diagrams that illustrate the pathways through which the effects of alternative management actions are thought to occur, accompanied by descriptive text to explain the meaning of the linkages in the pathway diagrams. As appropriate to the context of the AMI such models should clearly illustrate the specific spatial / temporal boundaries, and spatial / temporal dynamics of the pathways. The discussion / presentation of the models should clearly state the assumptions made in developing the AMI design.
6. A description of the indicators that will be measured to assess the effects of management treatment(s) (effectiveness indicators).
7. A description of the sampling design (locations, timing / frequency of sampling for each indicator) employed in collecting any baseline data used to develop or inform the AMI, and a presentation of the results of the baseline monitoring (this may be incorporated in the presentation of the conceptual models which describe the hypotheses to be tested).

8. A description of how what is learned from the AMI will be used to change management policy or practice.
9. A description of the involvement of stakeholders, scientists, and managers in the development of the design of the AMI (who was involved, the methods of involvement, and their contributions).
10. If the AMI will employ an active AM approach (preferred) then the AM plan should include a description of the contrasts, replications, controls to be employed in the AMI.
11. Predicted outcomes of the management treatments. This should include not just the most likely expectation, but the possible range of expected outcomes. The next steps to be taken in response to each of the alternative outcomes should be also be described. This is especially important for any designs that may employ a tiered approach (e.g. one in which the initial level of monitoring is designed to detect a problem which if detected would necessitate a subsequent management response – either the implementation of corrective management actions, or increased monitoring to further identify the cause of the problem.
12. A data management plan, including:
    - data formats, locations, backup security,
    - planned design of the statistical / data analysis of the AMI results,
    - planned timing of analysis and reporting
    - planned reporting formats
    - planned methods for data sharing and review
13. A monitoring plan, including:
    - A description of *implementation* monitoring to be done (where, how, by who, how often, for how long) including and reporting formats, in order to track and document the implementation of the prescribed management treatment(s), and any deviations from the intended implementation.
    - A description of the *effectiveness* monitoring to be done (sampling locations, timing / frequency / duration by indicator, methods of data collection, methods for securing, transporting and analyzing samples, etc).
14. A description of the plan for implementation of the treatment(s) to be explored in the AMI. This description should be provided in sufficient detail that persons responsible for implementation of the management action(s) can successfully implement it/them as intended by the architects of the design. This would for example include a sufficiently detailed description of the management methods to be employed, their location and timing (and clear instructions to document any deviations that might be unavoidable; although implementation monitoring as described in the monitoring plan should also be sufficient to catch this).
15. A description of the plan for data analysis, evaluation and reporting (i.e. how will you go from data to decisions?)

From: Grieg et al. 2008

Appendix 2: Elements within Each Step in the AM Cycle

AM Steps	Ideal Elements within each Step
Step 1. Assess and define the problem	a. Clearly state management goals and objectives b. ID key uncertainties (what are the management questions?) c. Explore alternative management actions (experimental "treatments") d. ID measurable indicators e. ID spatial / temporal bounds f. Build conceptual models g. Articulate hypotheses to be tested h. Explicitly state assumptions i. State up front how what's learned will be used j. Involve stakeholders k. Involve scientists l. Involve managers
Step 2. Design	a. Use active AM b. Include contrasts, replications, controls c. Get statistical advice d. Predict outcomes e. Consider next steps under alternative outcomes f. Develop a data management plan g. Develop a monitoring plan h. Develop a formal AM plan i. Get the design peer-reviewed j. Obtain multi-year budget commitments k. Involve stakeholders
Step 3. Implementation	a. Implement contrasting treatments b. Implement as designed (or document unavoidable changes) c. Monitor the implementation
Step 4. Monitoring	a. Implement the Monitoring Plan as it was designed b. Undertake baseline ("before") monitoring c. Undertake effectiveness monitoring
Step 5. Evaluation of results	a. Compare monitoring results against objectives b. Compare monitoring results against assumptions, uncertainties, hypotheses c. Compare actual results against model predictions d. Receive statistical or analysis advice e. Have data analysis keep up with data generation from monitoring activities
Step 6. Adjustment / Revision of Hypotheses & Management	a. Meaningful learning occurred (and was documented!) b. Communicate this to decision makers c. Communicated to others d. Actions or instruments changed based on what was learned

Source: Murray 2008, adapted from Marmorek et al. 2006