SUPPORT DOCUMENT FOR DEVELOPMENT OF THE REGIONAL STORMWATER MONITORING STRATEGY

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Prepared for:

Bay Area Stormwater Management Agencies Association (BASMAA)

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Executive Summary

This report presents the authors' opinions based on the results of an in-depth examination of urban storm water monitoring activities and special studies carried out by BASMAA and its member agencies. The review focuses intensively on the relationship between monitoring and management/ regulatory decision making. BASMAA understands that any Regional Monitoring Strategy should not only coordinate the monitoring activities of its member agencies, but should also help program managers:

- make more informed decisions
- prioritize problems based on their regional importance and tractability
- share responsibility and expertise among programs
- remove redundancy
- make better use of accumulated knowledge
- use pooled resources to better advantage
- create and take advantage of synergism among programs.

The remainder of this report describes the authors' opinions on the contents of a Strategy along with its rationale.

BASMAA's Regional Monitoring Strategy shall develop regionally consistent and integrated information to help all BASMAA members assess compliance with MEP, identify and evaluate impacts on beneficial uses in receiving waters, decide on appropriate actions to protect and enhance those beneficial uses, and document the effectiveness of their programs.

BASMAA should recognize that accomplishing this mission may require changes to existing monitoring efforts in terms of how they are planned, financed, executed, managed, analyzed, and reported. While a Regional Monitoring Strategy should ultimately replace current routine monitoring efforts, it is important to realize that this shift must be implemented in phases over the next few years. This will provide an opportunity to make needed adjustments to existing practice on a realistic timetable. It will also enable the Strategy to build on incremental successes, thereby reinforcing both the experience and commitment needed for its long-term viability.

A Regional Monitoring Strategy should be envisioned as a set of objectives and monitoring approaches for achieving these, combined with a management process for periodically evaluating and modifying objectives as necessary. *The core principle guiding the development of the Strategy is that monitoring should produce information with the potential for changing or confirming management practices.* The following set of objectives has been developed based on an intensive discussion of past monitoring approaches and future management information needs. They address both management and technical issues because of the necessity for coordinating monitoring activities throughout the region.

Management objectives

- Develop an Implementable system that assures consistent, long term administrative support for and implementation of the Regional Monitoring Strategy.
- Develop core policies on funding, information sharing, and methods standardization.
- Build and/or enhance useful relationships with other regional monitoring and management entities.

Technical objectives

- Design and implement standard methods for understanding MEP.
- Design and implement standard protocol for evaluating priority BMPs.
- Encourage and support efforts to assess the relative contributions of anthropogenic and geological sources to regional metals loadings.
- Design and begin a regional survey of patterns and trends in toxicity, particularly due to diazinon.
- Design and begin a regional survey of beneficial uses (particularly locally).

These objectives are ones that BASMAA currently considers to be of regional concern and ones that can be effectively addressed by the coordinated efforts of its member agencies. The rationale for each is described more fully in Sections 4 and 5, along with suggested steps to implement the monitoring associated with each one. The management processes described in Section 5 provide a suggested approach for reevaluating the technical objectives as monitoring information improves, and continuing, modifying, or replacing them as appropriate. The proposed concepts for the Strategy thus intend that the processes of problem identification and prioritization should be ongoing, guided largely by the analysis and interpretation of monitoring information.

BASMAA's member agencies are connected not only by geography but also by an overlapping set of environmental issues and processes and a common regulatory structure. It is only natural that the evolution of their individual storm water management programs has led toward increasing amounts of information sharing, cooperation, and coordination. The Regional Monitoring Strategy described here reflects BASMAA's recognition of the common themes that underlay storm water management in the region and of the collective benefits to be gained from coordination and collaboration.

Preface

Defining goals

The purpose of the Regional Monitoring Strategy is to provide clarity and focus for BASMAA agencies' monitoring programs. In order to effectively do so, the Strategy must be based on an unambiguous understanding of the core questions (or goals) motivating monitoring as well as the rationale underlying these questions. As part of the development of the Regional Monitoring Strategy, a survey was conducted in early 1997 of the BASMAA program managers to identify the questions they wanted their monitoring programs to answer. Two primary issues emerged:

- Is my storm water program complying with the intent of MEP (maximum extent practicable)?
- Is my storm water program helping to protect and improve local streams and receiving waters?

A well-known management principle is that clearly measurable goals enhance any endeavor's chance of success. BASMAA recognizes that one of the major difficulties with the storm water regulations is that the term "maximum extent practicable" (MEP) has not been defined in a concise and measurable (not necessarily quantitative) way that helps program managers determine if the goal (i.e., MEP) has been achieved. Storm water programs are asked (indeed required) to comply with the goal of MEP without agreement among the legislators, regulators, or the regulated community as to the activities or level of effort this entails.

Storm water programs have become increasingly dissatisfied with this obviously vague approach to problem solving. They are attempting to set meaningful goals for themselves consistent with the water quality-based approach described above by asking, "What are we trying to accomplish locally?" They are finding that the Clean Water Act's goals of "fishable, swimable" and "restoring the physical, chemical, and biological integrity of our nation's waters" provides a much needed focal point for these efforts. As a result of this focus on local problem solving, BASMAA's members recognize that, if their storm water management programs are to be productive and cost-effective, they must address three basic purposes:

- to identify and implement those activities that appear to be reasonable and consistent with their peers
- to identify measurable local goals consistent with the intent of the Clean Water Act and implement activities specifically designed to make progress towards these goals
- to develop information on how urban storm water runoff may (or may not) inhibit the accomplishment of these local goals.

These practical goals reflect BASMAA's recognition that MEP will remain an elusive, ever-changing target until it is formally defined nationally. Until such time, BASMAA believes the best approach for setting meaningful and achievable management goals is to shift a portion of the storm water program resources into defining local water quality-based goals and implementing activities to accomplish those goals.

This management context thus provides the needed structure and focus for the Regional Monitoring Strategy and is reflected in the Strategy's Mission Statement (see page 6). It furnishes a logical basis for reconsidering and reorganizing BASMAA's current monitoring efforts and improving their ability to provide useful information to guide decision making. As a result it supports the individual storm water programs as well as efforts to coordinate and streamline them regionally.

1.0 Introduction

The Clean Water Act Amendments of 1987 specified both the need for NPDES permits to address urban storm water runoff as well as the broad outlines of the components that storm water management programs should contain. Within the San Francisco Bay area, NPDES storm water permits have been issued in all counties except Marin and Sonoma.

Monitoring has been an integral part of these storm water management programs. It initially focused on confirming the results of the nationwide, but necessarily more generic, NURP (Nationwide Urban Runoff Program) study by gathering locally pertinent information about the characteristics of runoff from different land uses and estimating overall pollutant loads to receiving waters. While not exhaustive, these initial monitoring efforts provided data that were sufficient for program planning and for implementing specific storm water management actions. In addition to documenting the general storm water quality, these data also improved the essential knowledge base about the sources and pathways of pollutants, the nature of flows in the system, and the technology of field measurement.

Monitoring efforts to date have succeeded in meeting several early objectives of the region's storm water management programs. To take the next step toward fulfilling the intent of the Clean Water Act Amendments ("fishable, swimable" and "restoring the physical, chemical, and biological integrity of our nation's waters"), it is necessary to expand the storm water programs' fundamental approach toward watershed management, both locally and regionally. The BASMAA agency program managers' realized that their respective monitoring programs needed to provide different information and more of it. This lead, logically, to the recognition that a regionalized approach to monitoring would:

- help program managers make better informed decisions
- prioritize problems based on their regional importance and tractability
- share responsibility and expertise among programs
- remove redundancy
- make better use of accumulated knowledge
- use pooled resources to better advantage
- create and taking advantage of synergism among programs.

The suggestions made in this report, dubbed the BASMAA Regional Monitoring Strategy (BRMS), can accomplish these goals and thereby improve the effectiveness of storm water management programs in the region, both individually and collectively.

The BRMS provides a structure for assessing knowledge on a regional basis in order to identify useful mid-course corrections to existing programs. Given that monitoring was initially developed in the absence of detailed information about storm water, its characteristics, and its impacts, this is a logical evolutionary step at this stage of development.

The BRMS presents an opportunity to pool program resources to answer important management questions, especially regarding the cost effectiveness of both pollution reduction/prevention activities and of monitoring itself. This information will aid programs in reassessing the appropriateness of resource allocation among different kinds of program activities (including monitoring). In addition, it provides an opportunity to fill important gaps in our knowledge about whether expenditures are producing concomitant benefits in terms of reductions in loads and/or changes in behavior.

The BRMS helps to coordinate related efforts across programs and in the process realize substantial improvements and efficiencies. Existing monitoring efforts could be better coordinated and information could be shared more effectively. Substantial efficiencies could be achieved from regional standardization, cost sharing, and selection of a few regional status and trends sites. In addition, carefully planned special studies could benefit programs throughout the region.

The BRMS assists BASMAA in responding to shifts in regulatory philosophy, particularly the growing interest in watershed management and in moving away from "command and control" approaches.

The BRMS focuses on creeks because they tend to be the dominant waterbody in Bay Area watersheds. However, the use of the term creeks in the BRMS should be interpreted more broadly to include other waterbodies of interest in watersheds such as lakes and rivers.

The BRMS assists BASMAA in taking advantage of partnership opportunities with other monitoring and assessment activities in and around San Francisco Bay. There are fruitful opportunities for more fully developed partnerships with others such as volunteer monitoring efforts, USGS studies, the RMP (Regional Monitoring Program for Trace Substances in the San Francisco Estuary), various watershed management initiatives, and the Bay Area Air Quality Management District's (BAAQMD) air monitoring network.

BASMAA developed this Strategy to meet the mission statement irrespective of jurisdictional boundaries and purviews. Therefore, BASMAA fully expects, through implementation of the Strategy, to identify situations that should be evaluated to determine whether BASMAA members are the appropriate agencies to take any corrective action at this stage, whether additional information is needed, or whether other agencies should be notified and opportunities for partnerships explored. In this way, the BRMS promotes achieving these benefits through a series of specific actions. These include:

- organizing information about present program and monitoring activities as a starting point for evaluation and redirection
- clarifying a mission statement and a set of strategic objectives to link monitoring activities to management, environmental, and regulatory priorities
- prioritizing problems and related program actions and monitoring efforts as a basis for allocating program resources
- describing a structured set of monitoring efforts, based on knowledge gained in the last several years
- balancing monitoring efforts direct at improving best management practices (BMPs) with those to identify environmental impacts from urban storm water
- establishing principles for ongoing decision making about the scope and focus of the Regional Monitoring Strategy
- establishing procedures for necessary standardization of methods across programs
- identifying potential partnership opportunities with other monitoring organizations.

2.0 Objectives

Reasonable, clearly articulated objectives are the crucial link between monitoring activities and management decision making. Without clear objectives, monitoring can all too easily fall into the trap of collecting data for its own sake without regard for its usefulness in addressing high-priority problems. The Regional Monitoring Strategy is, therefore, based on a clearly articulated set of desired outcomes that can be reevaluated periodically and adjusted as needed. These outcomes are structured in four levels of increasing technical detail and specificity -- mission statement, strategic objectives, specific goals, and tactics.

2.1 Structured objectives

The following four levels of structured objectives reflect BASMAA's belief that monitoring should:

- focus on important concerns and identified problems
- develop information that will help resolve these
- respond to regulatory requirements
- address fundamental environmental values that are important both to the programs and the public.

Mission statement

(a statement of underlying purpose that is revised rarely)

BASMAA's Regional Monitoring Strategy will develop regionally consistent and integrated information to help all BASMAA members assess compliance with MEP, determine impacts on beneficial uses in receiving waters, decide on appropriate actions to protect and enhance those beneficial uses, and document the effectiveness of their programs.

Strategic objectives

(statements of targeted outcomes that are reviewed and revised yearly)

Management *(achieving these objectives is crucial to developing the capability to meet the technical objectives)*

- Develop a management structure for the Regional Monitoring Strategy.
- Develop core policies on funding, information sharing, and methods standardization.
- Build and/or enhance useful relationships with other regional monitoring and management entities.

Technical

- Design and implement standardized methods for understanding MEP.
- Design and implement a standard protocol for evaluating priority BMPs.
- Encourage, support, and participate in Regional efforts to assess the sources and fates of metals loadings to the San Francisco Estuary.
- Design and begin a regional survey of patterns and trends in toxicity, particularly due to diazinon.
- Design and begin a regional survey of impacts on beneficial uses (particularly locally) and the role storm water runoff plays in these.
- Support continuing efforts to obtain baseline water quality information for the San Francisco Estuary (this objective addresses BASMAA's commitment to continued support for the Regional Monitoring Program).

Specific goals

(interim steps needed to accomplish the objectives; reviewed and revised every 6 - 12 months)

See Section 4.0 Monitoring Activities for recommended actions and milestones involved in achieving the strategic objectives

Tactics
(short-term implementation actions; reviewed and revised quarterly)

These actions are developed in response to immediate circumstances. Because of their flexibility they are not specified in any detail in the Strategy.

2.2 The origin of the technical objectives

The six technical objectives address the two fundamental questions implicit in the Mission Statement:

- Is my storm water program complying with the intent of the Clean Water Act?
- Is my storm water program helping to protect beneficial uses?

These objectives stemmed largely from a series of structured brainstorming and prioritization exercises in which the BASMAA managers and Regional Board staff reviewed past monitoring results, discussed what they wanted the Strategy to accomplish, and identified specific regulatory and management requirements. Table 2.1 presents questions that were used to systematically evaluate and prioritize possible alternative objectives. They helped organize existing information, identify gaps in these, and critically examine how and whether additional monitoring information could contribute to decision making. An important part of this effort was its examination of how well existing monitoring addresses the full range of concerns over potential storm water impacts, and not just those associated with strict compliance with regulatory demands.

These discussions also focused on how monitoring information could help quantify measures of success that would be directly meaningful, especially to elected officials and the public. Ideally, the program managers would like to be able to answer questions such as:

- How are we doing - are our efforts making a difference?
- Are there healthy populations of fish in the creeks?
- Are creeks being used as community resources?
- What is storm water's relative contribution to problems in the creeks?

By fulfilling these requirements, the Regional Monitoring Strategy attempts to address both the letter of the law (e.g., Clean Water Act, Basin Plan) with its specific permit requirements, and the intent of the law with its emphasis on the preservation and enhancement of beneficial uses. As part of the effort to identify and address both the letter and the intent of the law, BASMAA examined the relationship of their existing program and monitoring activities to the set of problems known to impact beneficial uses. This subjective analysis (Table 2.2) was intended to assess whether the preponderance of their existing monitoring effort was appropriately weighted toward the identified problems. Table 2.2 shows that monitoring concentrates primarily on the first two issues, related to whether creeks are polluted and whether habitat is being protected. However, an examination of monitoring effort at a greater level of detail revealed that the majority of monitoring related to habitat protection concentrates on sedimentation. Not addressed is a range of other important issues related to maintaining and/or restoring habitat and to riparian vegetation. As a result, BASMAA determined that the Regional Monitoring Strategy should begin to address this imbalance by including a strategic objective specifically related to creek habitats.

Table 2.1. Questions used to help systematically evaluate and prioritize possible strategic objectives for the Regional Monitoring Strategy.

Issue	**Analytical questions**
Major concern	• What are the key beneficial uses? • Are there major threats to these? • If so, what are the threats? • Are there beneficial uses not considered by the present system?
Identified problems	• What is the evidence for the problem? • Is this evidence still valid? • Does evidence need to be improved for decision making? • What is our understanding of the processes that create the problem? • What are the relative natural and human contributions to the problem? • To what degree is storm water contributing to the problem? • Has the problem gotten better, worse, or stayed the same? • How is the problem expected to change in the future and over what time period? • What should be done to better characterize the problem? • How does this problem rank compared to other problems?
Program actions	• What actions are being taken, or could be taken, to address the problem? • What specific part of each problem will such actions address? • How will each action "work?" • How long will it take to see any effects of the action? • What indicators will be used to see the effects? • How large will the effects of program actions be? • What is the evidence that actions work as intended? • How do program actions rank compared to each other?

Table 2.2. Summary of the subjective analysis of how the preponderance of monitoring effort relates to identified problems impacting beneficial uses. Monitoring related to creek habitat in the Key Questions column focuses almost exclusively on sedimentation.

Public concern	Key questions	Public education	Illicit connec-tions	Industrial commer-cial	Public agency activities	New develop-ment
Are creek habitats being protected?	Are they polluted?	X	X	X	X	X
	Is habitat being protected?	X		X	X	X
	Does flow create problems?					
	Are natural communities functioning normally?					
Are Bay habitats being protected?	Is the Bay polluted?	X				X
	Is habitat being protected?					X
	Are natural communities functioning normally?					

3.0 Monitoring Design Principles

The Regional Monitoring Strategy is both a management strategy and a monitoring strategy. As discussed in Section 2.0 (Objectives), it must serve to focus monitoring effort on problems that concern regulators, managers, and the public. However, it must also ensure that any such monitoring efforts are technically sound and have a high likelihood of producing useful information. This section describes basic principles of monitoring design that underlie the specific elements of the strategy described in the next section (4.0 Monitoring Activities). If consistently applied, these principles will help ensure that subsequent activities needed to implement the Regional Monitoring Strategy will result in effective monitoring programs.

3.1 Monitoring as a feedback mechanism

Monitoring is intended as an aid to decision making. It can provide feedback directly about the results of specific management activities. It can also be used in a reconnaissance mode to furnish advance warning about issues with significant management implications. In either case, actual monitoring activities (the specific goals and tactics referred to in Section 2.1 above) must be directly related to the Strategy's mission statement and strategic objectives (see Section 2.1). Expressed another way, *monitoring should produce information with the potential for changing or confirming management practices. Monitoring activities without such potential should not be conducted.*

This view of monitoring, which reflects the current state of practice in environmental monitoring in general, will result in important benefits during the upcoming implementation phase of the Strategy. It provides the foundation for determining the scope and complexity of proposed monitoring activities and for evaluating the utility of any information produced. Similarly, it furnishes a basis for deciding when particular monitoring activities are no longer needed and can be concluded, thus freeing resources for other priorities.

3.2 The Strategy as a self-renewing process

While the term "environmental monitoring" in the past has often been synonymous with long-term, ongoing measurement programs, the Regional Monitoring Strategy is based on the view that monitoring should:

- respond to specific, current management issues
- end when these issues have been resolved or are no longer of concern
- be able to switch to new issues as they become relevant
- contain a "scouting" or "reconnaissance" function to help identify such issues.

The monitoring activities described in the next section (4.0 Monitoring Activities) represent the first, high-priority group of regional issues identified by BASMAA as an appropriate focus for monitoring. They reflect the process of problem identification and prioritization that has occurred over the last several months. However, *the Strategy also intends that the processes of problem identification and prioritization should be ongoing, guided largely by the analysis and interpretation of monitoring information.* Thus, the Strategy defines a process for annually reevaluating the set of strategic objectives (see Section 2.1) and modifying monitoring activities as needed.

The Strategy seeks to ensure that monitoring is responsive to management decision-making needs without falling into either of the traps that can bedevil environmental monitoring programs. The first of these is the tendency to lose touch with management priorities and to go on "automatic pilot," simply collecting data because they have been collected in the past. The other is to become so sensitive to management concerns that monitoring continually shifts its focus, moving from one issue to the next without ever creating the truly useful information needed to resolve these issues. The Strategy achieves this balance through its ongoing process of evaluating and adjusting the strategic objectives in a structured manner (see Sections 2.1 and 5.0 Management for more detail).

3.3 Technical design approaches

The Strategy described here serves to focus management and monitoring attention on a distinct set of key priorities. In addition, it outlines a series of program design steps necessary for developing the monitoring program's needed technical detail about, for example,

- what indicators to measure
- where measurements should be taken
- how many samples should be taken at each location
- how long monitoring should continue
- and how monitoring data should be analyzed and interpreted.

Decisions about such details will be made as part of a formal design process that ensures monitoring will address the Strategy's strategic objectives and will maximize both scientific validity and the information "bang" achieved for each monitoring "buck" spent. Appropriate monitoring design processes have been described elsewhere, most relevantly in Managing Troubled Waters (1990), and need not be repeated at length here. However, in brief, such a process specifies that, at a minimum,

- monitoring attempts to answer clear questions stemming directly from the strategic objectives
- planning makes effective use of available knowledge and information
- study designs be based on explicit conceptual and statistical models that describe basic assumptions
- data analysis and interpretation methods be specified ahead of time and be suited to the study design
- the study be designed to detect a specified "signal," or amount of change in indicator values
- statistical methods be used to demonstrate that this "signal" can actually be detected.

Even formal design processes can produce flawed monitoring programs if they pay insufficient attention to articulating detailed monitoring objectives or boundary conditions for the design itself. It is important to specify, in as clear a manner as possible, monitoring's relationship to management goals as well as certain key design criteria for the program. Table 3.1 presents a six-step model for constructing detailed monitoring objectives for each of the Strategy's broader strategic objectives. While some elements of this model have already been determined as part of developing the Strategy, others must await more precise implementation work to be carried out in the near future.

Basing the implementation of the Strategy on a formal study design process will provide important structure to what could otherwise be a disorganized and inefficient process. Such a process can be applied even when time, money, information, and other resources are limited. This is because each step can provide value to the overall study design, even if performed at a fairly simple level of sophistication. Perhaps most importantly, a formal design process acts as an effective adaptive mechanism, ensuring that needed changes to the Strategy are carefully considered and thoughtfully implemented.

Table 3.1 A six-part model for developing detailed monitoring objectives, with possible alternatives for each part. Answers to the six questions can be combined in any order to create objectives. Adapted from Bernstein et al. (1993).

Components of detailed objectives	**Possible choices**
What is the management goal?	• no effects from this activity/source/contaminant • no effects greater than a set amount • no change from present conditions • no change greater than natural variability • return to pristine conditions • resource/ecosystem remains in a particular condition • resource/ecosystem returns to particular condition after disturbance
What monitoring strategy is suitable?	• measure actual effect • use one indicator to represent change or effect • use a suite of indicators to represent effect • use model estimates of effects • qualitatively identify the resource/ecosystem condition • quantitatively measure resource/ecosystem parameters • measure key processes or rates • focus on key events/disturbances of overriding importance
What degree of certainty/precision is possible/desired?	• qualitative information only • minimal certainty or precision • moderate certainty or precision • extreme certainty or precision
What reference conditions are appropriate?	• reference location(s) • reference time(s) • model prediction • compliance standards • other populations of indicator species • similar species or communities • analogous situations
What spatial scale is appropriate?	• site specific • local area • entire region
What temporal scale is appropriate?	• immediate • months • year-to-year • long-term (several years to decades)

4.0 Monitoring Activities

This chapter describes the main features of monitoring activities intended to address each of the six technical strategic objectives listed in Section 2.0:

- Design and implement standardized methods for understanding MEP.
- Design and implement a standard protocol for evaluating priority BMPs.
- Encourage, support, and participate in Regional efforts to assess the sources and fates of metals loadings to the San Francisco Estuary.
- Design and begin a regional survey of patterns and trends in toxicity, particularly due to diazinon.
- Design and begin a regional survey of impacts on beneficial uses (particularly locally) and the role storm water runoff plays in these.
- Support continuing efforts to obtain baseline water quality information for the San Francisco Estuary (this objective addresses BASMAA's commitment to continued support for the Regional Monitoring Program).

These descriptions include the rationale for each monitoring activity as well as recommendations for further detailed study design work needed for implementation. Recommendations for near-term implementation steps are relatively specific, and become less well defined for implementation steps further "downstream."

The implementation phase of the Strategy will be guided by BASMAA's Monitoring Committee and carried out by a series of technical workgroups with expertise appropriate to each issue. A key assumption underlying the descriptions of all six monitoring activities is therefore that the Monitoring Committee will validate the importance of these strategic objectives and take responsibility for implementing them. In scheduling implementation of the various aspects of the Strategy, the Monitoring Committee will develop a critical path to meet the mission statement. The critical path will show linkages and dependent relationships among activities being conducted to achieve the strategic objectives.

The description of each monitoring activity to a large extent follows a standard format that involves stating basic questions; reviewing available information and identifying key gaps in existing knowledge; developing more detailed study designs; and gathering, analyzing, and reporting on monitoring data. There are two additional elements, however, that aim to improve the overall utility and cost effectiveness of these efforts. First, the implementation steps are placed in decision trees that ensure that subsequent steps will be carried out only when previous steps have established the need and/or the necessary groundwork for moving forward. Second, each element of the Strategy is intended to contain a set of explicit "stopping rules" that will bring it to an end once it accomplishes its purpose. These stopping rules will be evaluated during the periodic program review that is an essential part of the Strategy's management structure (see Section 5.0 for more detail).

4.1 Standardized Methods for Understanding MEP

The primary goal of this monitoring activity is to help answer the fundamental question of whether storm water programs are complying with MEP. Although MEP has not been defined nationally, or even statewide, storm water programs are beginning to develop agreement about a locally reasonable working definition of MEP. For example, several of BASMAA's member agencies are developing performance standards that define an appropriate level of effort for each program component. As performance standards take shape over the next few years, they could be used to help define a regional understanding of MEP for the San Francisco Bay area.

This monitoring activity will focus and expedite this process by defining a set of procedures for developing regional performance standards and then gathering, over the next several years, the data needed to implement these standards regionally.

Regional performance standards will:

- put storm water programs throughout the Bay area on an equitable footing
- build the credibility of participating programs
- facilitate regional coordination and compliance
- provide a foundation for evaluating programs' long-term progress toward protecting beneficial uses.

The monitoring plan described below is incremental and includes decision points where BASMAA can adjust the scope of the effort or decide to suspend any further monitoring based on explicit stopping rules (see Figure 4.1 for summary).

4.1.1 Develop and implement evaluation process

Each of BASMAA's member agencies has necessarily made numerous decisions over the past several years about which BMPs to implement. This process has been largely subjective but nonetheless valuable, in that it reflected the collected knowledge and judgment of program managers and their technical staffs.

A first step in developing effective regional performance standards is to identify these loosely connected sets of program actions and then compare and evaluate them with a common set of criteria. These criteria should include not only descriptions of program actions themselves but also explanations of their rationale and the decision-making process(es) that led to their selection. This will provide a systematic basis for examining the similarities and differences of existing BASMAA members' performance standards.

The Monitoring Committee will develop a formal process to evaluate existing BMPs and determine if they are suitable candidates for inclusion in the regional performance standards. The evaluation process should address, at a minimum, the following sorts of questions:

- Are other municipal programs similar to mine implementing this BMP?
  - within the countywide storm water program?
  - within the region served by BASMAA?
  - within the state?
  - the nation?
- Why are others implementing this BMP?
- What are the storm water benefits of this BMP?
- Is it a reasonable activity to add to my current set of activities?
- Is this activity already being performed for other purposes, and, if so, can it be readily modified for inclusion in the storm water program?
- Does the Regional Water Quality Control Board require this BMP?
- Are there benefits other than storm water that would be achieved with implementation of this BMP?
- Are there any studies indicating this BMP is effective at removing pollutants from storm water?
- Does this BMP remove pollutants known to be of special concern to the Regional Board?

The Monitoring Committee should then apply this completed evaluation process to the set of BMPs currently being performed by BASMAA's member agencies. The goal of the evaluation process should be to prepare a "report card" that ranks BMPs in terms of their suitability on a range of explicit rating criteria.

4.1.2 Recommend next steps

The Monitoring Committee will review the results of this evaluation and summarize the advantages and disadvantages of drafting a set of regional performance standards for each program component. This will form the basis for a framework of recommendations about which regional standards should be developed, the order in which they should be addressed, and an assessment of the key issues involved in each. Special attention will be paid to performance standards already developed locally by several BASMAA members. These local performance standards will be reviewed as models to be considered for these regional performance standards.

It will be important to categorize potential performance standards in terms of the kinds of situations they apply to. For example, performance standards applicable to more industrialized urban settings would not be completely applicable to residential settings with large amounts of open space. An important outcome of this step will thus be a preliminary description of the specific settings for which distinct sets of performance standards might need to be developed.

4.1.3 Develop standard record keeping

Until regional performance standards are defined, BASMAA will develop and utilize a standard record keeping system for each storm water program component recommended for inclusion in the regional standards. Such a record keeping system will ensure that each member agency utilizes a common set of indicators to report on their activity and, ultimately, to document progress toward measurable goals.

The Monitoring Committee will review indicators currently used to measure progress, and identify similarities and differences across programs, as well as gaps where indicators have not yet been defined. To the greatest extent possible, this effort should build on existing indicators and should focus on filling gaps and reconciling differences among the various programs. However, the Committee should also examine, using the evaluation criteria, the extent to which all indicators conform to the newly articulated goal of developing regionally accepted performance standards and suggest adjustments to current practice where needed. Each municipal storm water program currently submits annual reports to the Regional Water Quality Control Board. This reporting effort requires a large amount of effort on an annual basis. The Monitoring Committee will use this opportunity to explore more efficient methods and schedules for reporting. This will allow more of each program's resources to be devoted to implementing control measures to improve the environment.

The standard record keeping approaches should be designed to present a readily understandable picture of current status. While it will not be possible to track progress toward measurable goals until the regional standards are defined, the record keeping formats should make allowances for including clear measures of progress once the standards become available. As regional performance standards are developed, the standard record keeping will be folded into the procedures for each such standard.

4.1.4 Develop regional performance standards

Developing regional performance standards will involve synthesizing information from the preceding steps. It will also depend on information from the other five monitoring activities that make up the Regional Strategy. For example, information from the systematic evaluation of BMPs (Section 4.2) will necessarily contribute to any decisions about which BMPs should be included in the standards and how much effort should be devoted to each. In a related vein, information about the distribution and severity of toxicity problems (Section 4.4) and about urban storm water impacts on aquatic resources (Section 5.5) will also provide similar guidance.

Based on the recommendations from step 4.1.2, the Monitoring Committee will prepare draft performance standards. Depending on the priorities developed in 4.1.2, it may be appropriate to combine standards into groups that can be addressed simultaneously. At this stage, it will be necessary to carefully consider implementation issues associated with each standard. For example, some standards may mean that some programs adjust their existing practices. The Monitoring Committee should therefore prepare a thorough analysis of both technical and implementation issues (e.g., logistics, cost, available expertise) when developing the standards for review and approval.

4.1.5 Summary

Section 4.1 describes how a working regional definition of MEP will be established through the process of developing the details of regional performance standards. This element of the Strategy addresses an issue of clear regional significance. It uses available information to evaluate, categorize, and prioritize potential standards so they can be addressed in a systematic, cost-effective way. It establishes standard record keeping for all programs to help lay a foundation for the performance standards and to provide useful information while the standards are being developed. In addition, it examines reporting formats and schedules to identify ways these can be made more efficient and useful.

4.2 Evaluate priority BMP effectiveness

The primary purpose of this monitoring element is to develop a prioritized list of BMPs based on specific criteria and to implement evaluation studies to determine pollutant removal effectiveness and relative importance in protecting or enhancing beneficial uses. These results will help program managers make more informed decisions about which specific BMPs are most appropriate for their community.

BASMAA's member agencies conducted many studies in the past several years to assess BMP effectiveness. These proved useful in some instances in improving and/or redirecting storm water program management. However, as a whole, these studies have suffered from a lack of regional standardization, formal results distribution, and, in a few cases, rigorous study design. In addition, because of the lack of an explicit Regional Monitoring Strategy, these studies did not reflect a common purpose or a common outlook about storm water regulation and management. This portion of the Regional Strategy is designed to improve BMP effectiveness studies by addressing these and other issues.

4.2.1 Define problem

The specific aim of this step is to organize and summarize available knowledge about the range of BMPs currently used, their effectiveness in terms of a variety of criteria, and appropriate methods for designing and carrying out further effectiveness studies. This information will help focus effort on high-priority BMPs and provide a basis for designing technically rigorous and cost-effective evaluations.

4.2.1.1 Frame specific questions. BMP effectiveness studies typically evaluate a specific BMP's ability to remove a particular set of constituents. While this information is critical to determining effectiveness, environmental managers need other kinds of information to decide whether a BMP is effective at protecting beneficial uses and therefore appropriate for implementing in their community.

The BASMAA Monitoring Committee will develop a set of questions that define information needed to determine if BMPs are protecting beneficial uses. These questions will include, at a minimum:

- What beneficial uses does this BMP address?
- How is this beneficial use being impacted?
- What is the relative contribution storm water pollution plays in the impact?
- What portion of urban pollution is reduced if this BMP is implemented region-wide? (i.e., sensitivity analysis)
- What portion of the pollution coming from the entire watershed is reduced if this BMP is implemented region-wide?
- What is the cost of implementing this BMP region-wide?
- What other BMPs address the impact to this beneficial use?
- How does the cost and effectiveness of implementing this BMP compare with the cost and effectiveness of these other BMPs?

4.2.1.2 Summarize and evaluate existing knowledge. Some of this information is available from previous studies conducted by BASMAA and its member agencies, as well as by other agencies elsewhere in the country. Available knowledge has been summarized to some extent in various reports and also exists as an inherent part of the professional experience of BASMAA managers. Before embarking on any further effectiveness studies, it will be beneficial to summarize this available information in terms of the questions defined in the previous step and for each of the major BMPs being considered.

4.2.1.3 Define standard evaluation criteria. While answers to the list of questions in 4.2.1.1 should be developed for each BMP being evaluated, there is a range of factors that will affect the level of detail needed and/or possible in each specific case. These include:

- the specific BMP
- its mode of action
- the nature of the affected beneficial uses
- the type and severity of storm water impacts on these

- the amount and reliability of existing data
- the time and cost required to gather additional information
- the decision consequences and, therefore, the relative need for conclusive information.

Because of the variability in these factors, it will not be either possible or appropriate to demand that the effectiveness of each BMP be evaluated to the same level of detail. However, it is possible to establish a common set of evaluation criteria to help ensure that all BMP evaluations are credible, well documented, and make the best possible use of existing data and expertise. These criteria can be represented as a series of questions.

Does the evaluation:
- address each of the questions listed above in Section 4.2.1.1?
- utilize available data and information and document its use?
- describe and justify study designs?
- ensure that results are applicable to the region as a whole?
- identify sources of uncertainty, their relative importance, and how they might be resolved?
- explain the use of conceptual models, and, where appropriate, statistical models, underlying analyses and conclusions?
- identify important assumptions and their basis?
- justify the choice of analysis approaches?
- clearly explain models, algorithms, and other analysis approaches?
- assess the relative strength/reliability of important conclusions (where appropriate, with power analysis or sensitivity analysis)?
- incorporate outside reviews of the study design, analysis approaches, and analysis results/interpretation?

These questions reflect evaluation criteria that are commonly used to review environmental studies. Others may be developed by the Monitoring Committee. They are generic enough that each can be usefully applied to the full range of study types, from "back of the envelope" calculations to tightly designed and elaborate field sampling and/or modeling efforts.

4.2.2 Develop priority list of BMPs to be studied

The fundamental questions (Section 4.2.1.1), evaluation criteria (Section 4.2.1.2), and summary of existing information (Section 4.2.1.3) provide a basis for selecting and then prioritizing the BMPs for evaluation. The list of BMPs to be studied will include existing BMPs for which the questions described above remain to be answered as well as any new BMPs of interest. BMPs that focus on pollution prevention/reduction as well as those addressing habitat impacts will be included.

The Monitoring Committee will develop an explicit process for this prioritization exercise. It will define a set of rating measures drawn from the information developed in previous steps and then apply these systematically to the set of available BMPs. The outcome of this procedure will be a table that summarizes the relative priority of each BMP. It will be necessary to repeat this process periodically in order to take account of new technical information and to respond to longer-term shifts in management priorities.

4.2.3 Perform BMP effectiveness studies

The Monitoring Committee will develop study designs for the priority list of BMPs identified in the previous step. Study designs will conform to the standard evaluation criteria specified above in Section 4.2.1.3 and will clearly specify the approach to be used (e.g., controlled experiment, empirical measurements, modeling, professional judgment) and the expected reliability of the results. It will be important to ensure the regional applicability of study results; this is fundamental to the success of this element of the Strategy. This may require that study sites be located throughout the region (for those studies that involve field measurements). Similarly, it may require that studies be explicitly designed to include a representative of conditions that reflect those present throughout the region.

The Monitoring Committee will also assign studies to the individual program or programs best suited to carry them out. In some cases, programs' specific areas of expertise may be the basis for effective teaming arrangements. In addition, the Monitoring Committee will make provisions for ensuring that the final results, as well as the raw data, are readily available to all BASMAA members.

4.2.4 Summary

Section 4.2 describes a process for prioritizing BMPs and designing studies to evaluate their effectiveness. This element of the Strategy uses available information as the basis for prioritization and describes a procedure for making clear the basis of the resultant priorities. It recognizes that the wide range of BMPs will result in an equally wide range of study designs. It therefore lays out a set of explicit criteria for ensuring that effectiveness studies are both technically rigorous and cost effective.

4.3 Metals loadings to the San Francisco Estuary

The primary goal for this element of the regional monitoring strategy is to actively participate with other involved parties in determining sources of metals loading to the San Francisco Estuary, quantify urban storm water's contribution to these sources, and evaluate the likely fate(s) of these contributions once they enter the Estuary. Exceedances of water quality criteria in the region occur almost exclusively for metals, and large efforts are being devoted region-wide to reducing urban runoff of these constituents. Results of monitoring and other studies strongly suggest that natural processes may contribute significant amounts of metals. A regional picture of the relative contributions of metals from anthropogenic and natural sources can provide a useful context for decision making about monitoring, BMP implementation and evaluation, and other program activities.

Past efforts have made some progress toward resolving this issue. However, the information produced to date is neither conclusive enough nor regionally comprehensive enough to support effective decision making. This portion of the regional strategy therefore identifies a series of standard study design steps, to be completed in the near future, that will result in a coordinated regional assessment of this issue.

4.3.1 Define problem

The specific aim of this step is to organize and summarize locally produced available knowledge about the sources of metals loadings to creeks and to the Bay. It is possible that this information will be sufficient, if integrated and analyzed for this purpose, to resolve the relative contribution issue. If available data are not adequate, then they should be evaluated further in order to provide an appropriate basis for technical design decisions about needed monitoring (e.g., about station locations and monitoring frequencies).

4.3.1.1 Frame (and answer) specific questions. The central problem for this element of the regional strategy can be framed as the primary question:

- What are the overall relative contributions of anthropogenic and natural sources to metals loadings to creeks in the region and to the Bay?

Further detail is necessary in order to determine if existing data are sufficient to answer this question, and to design effective monitoring if they are not. This detail can be expressed as a set of additional questions:

- How big a difference between the two kinds of sources should monitoring be able to detect (i.e., what should the detection limit of the monitoring effort be?)?
- How precise must the measurement of this difference be (e.g., plus or minus 10, 20, or 50%)?
- What degree of spatial resolution is needed?

Answers to these questions should come from decision makers and will provide the essential "design criteria" for the data analysis and monitoring effort. For example, a willingness to act regionally based on clear-cut results from only a few watersheds in the region will lead to a very different monitoring effort than a requirement to have results confirmed from a majority of the watersheds in the region.

To some extent, answering these questions also depends on judgments about what is possible. Thus, a desire to resolve very small differences between the two kinds of sources may be impossible to fulfill, given inherent variability in the system. This step should therefore be performed in parallel with the next (Summarize and evaluate existing knowledge).

4.3.1.2 Summarize and evaluate existing knowledge. Past studies by several of the BASMAA agencies, as well as by other agencies and academic researchers, have provided some insight into the questions listed above. In general, these studies found that loadings of metals from natural erosion can be a large portion of total loads, exceeding that from anthropogenic sources for some constituents in some instances.

However, studies performed by the BASMAA agencies were focused primarily on estimating loadings from the urban portions of watersheds. In addition, studies done by other agencies and academic researchers on natural erosion processes were not intended to draw comparisons between the urban and non-urban segments of watersheds. As a result, with the partial exception of the Santa Clara Valley

Metals Control Measures Plan, the locally produced data have never been integrated and analyzed with the intent of addressing the primary question listed above. Therefore, before gathering any additional data, the regional strategy should determine whether available data on the region are sufficient to resolve the issue of the relative overall contributions of urban anthropogenic sources to metals loadings.

- If the available data are sufficient, then a report presenting the findings of the analysis should be prepared according to the guidelines described in Section 5.0. If the available data are not sufficient, then the regional strategy should review the usefulness for study design purposes of previous studies by estimating the range of differences in loadings from natural and anthropogenic sources consistent with current data
- identifying the variation in metals loadings from urban watersheds of different types
- identifying geologically distinct areas that are likely to produce natural runoff with different characteristics.

The regional strategy should then use these results to help design a monitoring effort that can answer the question of overall relative contributions.

4.3.2 Design and implement monitoring effort

If the preceding step has determined that available data are insufficient to adequately address the question of relative contributions, then a field monitoring effort will be designed and implemented. The goal of this effort will be to satisfy the "design criteria" established above in Section 4.3.1.1. The data evaluation described in the preceding step (Section 4.3.1.2) should permit an approximate estimate of the duration of monitoring needed to produce useful results. Monitoring data will be analyzed at that point in time and periodically thereafter to determine when an appropriate stopping point has been reached.

Since it is focused on determining the relative contribution of urban anthropogenic sources, this monitoring activity will be structured to allow comparisons of:

- points upstream and downstream of urbanized areas
- areas with different geological (and therefore different runoff) characteristics
- different types of urbanized areas
- wet and dry weather flows.

4.3.2.1 Develop monitoring design. The basic structure of the monitoring design will be to compare points upstream and downstream of specific urbanized areas. Information from the preceding step will be used to define the range of specific conditions in which these paired comparisons will be carried out. The relative contributions of anthropogenic and natural sources will depend (at a minimum), in each particular situation, on the nature of upstream soils, their susceptibility to erosion, the size and character of the urbanized area, the duration and intensity of rainfall events, and the season of the year. Available data from the region strongly suggests that comparisons between upstream and downstream points are likely to differ widely as a result of these and other sources of variability. Thus data from only one or a few conditions may well present a biased picture of the overall regional relationship between anthropogenic and natural sources of metals.

An important part of the study design will therefore be determining which specific conditions to include in the design and in what combinations (e.g., soil types A and B in both wet and dry weather) in an attempt to control and partition out some of the inherent variability in the system. These decisions will be based on readily available information about the range and prevalence of potential conditions. For example, soil types that cover only a small portion of the region might be excluded unless they are situated upstream of one or more large urban areas. Similarly, smaller urbanized areas might be excluded from the design if it appears they contribute only a minor amount to aggregate regional loads. More formal, statistical design steps (such as optimization and power analysis) are not possible because there is no data to work with on the actual dependent variable in this study (i.e., the difference in loads between upstream and downstream stations).

The end result of these design activities will thus be a description of the range of conditions the monitoring will focus on along with the preferred levels of sampling effort in each condition and

combination of conditions. The duration of the study will depend on the results of the data analyses described below.

Parameters will include a standard suite of metals and other external parameters (e.g., flow, total suspended solids) needed to calculate and interpret loadings data.

Throughout these study design steps, coordination will be maintained with the RMP, volunteer monitoring efforts, and other groups whose monitoring and/or research efforts can support BASMAA's regional monitoring strategy.

4.3.2.2 Implement monitoring design. Once the overall structure of the design has been established, the specific technical details of sampling and measurement must be finalized. These include:

- methods for field data collection and laboratory analysis
- exact timing of sampling events
- exact locations of sampling stations
- regional standardization of field and laboratory methods
- data management procedures, including regional standardization of data handling, recording, QA, integration, etc.
- assignment of responsibility to specific programs and/or volunteer monitoring efforts
- project management
- data summarization, analysis, and presentation.

4.3.2.3 Analyze data. Once data are available, standard analysis approaches will be used to estimate the difference in upstream and downstream loads for each paired comparison. Each set of similar comparisons will be evaluated to determine if the results meet managers' decision-making needs as defined above in Section 4.3.1.1. If so, then all or part of the study should be concluded. If results are equivocal, then the study may be continued for a specified period of time and the analysis and evaluation of results repeated.

Efficient data analysis will depend to a large degree on the success of data management activities. These activities will ultimately determine whether data from the regional sampling/measurement effort has been collected and recorded in a consistent way, whether they have been integrated into an easily used format, and whether the integrity and quality of the data have been maintained throughout.

4.3.3 Summary

Preceding sections have described a series of steps involved in developing the details of regional monitoring to assess the relative contributions of anthropogenic and natural sources to metals loadings to creeks and to the Bay. This description is intended to provide insight into the rationale for design decisions. However, it is also helpful to have an overall summary of the main aspects of this element of the Strategy and the schedule for their completion. This is presented in Figure 4.6.

This monitoring activity addresses a well-defined question of regional significance. It uses available information to determine if further studies are needed and proposes a straightforward study design for such studies. In particular, this element of the Regional Strategy requires that data be periodically analyzed and evaluated to determine if management needs have been met and the effort can be concluded.

4.4 Chemical toxicity

There are two primary goals for this monitoring element: first, to identify chemical toxicity caused by urban runoff in order to better target program actions to reduce this toxicity, and, second, to measure regional trends in toxicity to determine the success of these program actions. This element of the Regional Strategy will concentrate principally on pesticide toxicity, using diazinon screening as a cost effective surrogate for toxicity levels and will use data from a few representative stations to document regional trends in toxicity levels. The early stages of implementation focus on evaluating existing knowledge and filling any important knowledge gaps before proceeding with any more comprehensive region-wide sampling.

More specific goals of this element are to:

- develop higher-resolution data on creeks that are of special concern because of their societal and/or ecological value
- identify and track specific sites where toxicity levels are abnormally high.

Past efforts have made progress toward generating such information. However, the information produced to date is not yet sufficient to support the design of an effective regional monitoring effort. This portion of the regional strategy therefore identifies a series of standard study design steps, to be completed in the near future, that will result in a coordinated regional monitoring activity for chemical toxicity. The primary benefits of a regional approach to this problem are the reduced cost of monitoring a reduced number of longer-term status and trends stations and the ability to better target program actions to areas where toxicity problems are the most severe. In the longer run, monitoring data will provide valuable feedback about whether program actions have measurably reduced the toxicity problem.

The monitoring plan described below is incremental and incorporates decision points where BASMAA can choose to stop, wait, or proceed with further monitoring. Incorporating decision points and stopping rules improves the program's ability to respond to new information as it appears (see Figure 4.4 for summary).

4.4.1 Define problem

The specific aim of this step is to organize and summarize locally produced available knowledge about the spatial and temporal patterns of toxicity and the processes that lead to these. This information will help ensure that technical design decisions (e.g. about station locations and monitoring frequencies) will be appropriate. For some aspects of the regional toxicity problem, existing knowledge is sufficient to support more detailed monitoring design efforts. For others, it will be necessary to gather additional information. Identifying such information gaps is an important aim of this first step.

4.4.1.1 Frame specific questions. There are specific kinds of information needed to support the design of an effective regional monitoring effort for toxicity. These can be framed as a set of questions:

- What is the spatial extent of toxicity?
- Is toxicity correlated with external variables?
- How representative are the available Alameda and Contra Costa data of other areas in the region?
- What data will help identify the specific practices and processes that lead to toxicity?
- What data will help identify how these can be changed, modified, or eliminated?

Answers to each of these questions can be qualitative or quantitative, and can be based on subjective judgment of selected professionals and managers or actual sampling data. The Monitoring Committee will determine the appropriate level of effort to put into answering these questions based on the review of existing knowledge and the results of subsequent monitoring design steps.

4.4.1.2 Summarize and evaluate existing knowledge. Past studies, primarily by Alameda and Contra Costa Counties, have provided some insight into the questions listed above. In general, these studies found that

- chemical toxicity is principally associated with urban watersheds and with residential land uses within these
- chemical toxicity is predominantly due to diazinon and chlorpyrifos
- diazinon is more consistently present and at higher levels during wet weather than dry weather flows
- diazinon levels are usually highest during the earlier part of each storm event and decline thereafter.

This information should be reevaluated to
- determine the extent to which existing data satisfactorily answer the questions in 4.4.1.1 above
- review the usefulness for study design purposes of statistical analyses in previous studies
- evaluate the extent to which available data can be used to quantify important sources of spatial variability.

The specific goal of this evaluation should be to identify information gaps and decide on the need for and scope of the additional mapping effort described below.

4.4.2 Perform one-time regional mapping and gather baseline data

This step of the Regional Monitoring Strategy focuses on filling the information gaps described in the preceding section. Such additional data gathering is envisioned as a one-time, or at most periodic, effort that will improve the foundation for the longer-term monitoring in the Regional Strategy. The rapid pace of development in some parts of the region may require that the survey, or parts of it, be repeated at some interval. The specific objectives of this step are to:
- develop a more comprehensive regional picture of diazinon levels throughout the region
- identify any creeks of special concern
- identify any specific sites where toxicity levels are abnormally high.

4.4.2.1 Design and implement mapping and baseline sampling effort. Once results from the analyses described in Section 4.4.1.2 are available, the mapping and baseline sampling effort should develop a design with the following basic structure:
- widespread grab samples for diazinon in creeks throughout the region
- station locations that permit replicated comparisons between urban and non-urban watersheds as well as between residential and other land uses within urban watersheds
- station locations that permit estimation of spatial variability at the watershed, land use (within watershed), and within land use scales
- repeated sampling during several storm events to document how spatial patterns change over time
- additional toxicity testing and screens for toxic chemical constituents at a restricted subset of stations.

Specific numbers and locations of stations will be determined as part of the Strategy's monitoring design activities. Additional such activities will include a survey of information sources to identify creeks that are of special concern because of their societal and/or economic value and coordination with the Regional Monitoring Programs (RMP) in-Bay toxicity monitoring.

Once the overall structure of the mapping and baseline data gathering program is established, the specific technical details of sampling and measurement must be established. These include:
- methods for field data collection and laboratory analysis (where needed)
- exact timing of sampling events
- exact locations of sampling stations
- regional standardization of field and laboratory methods
- data management procedures, including regional standardization of data handling, recording, QA, integration, etc.
- assignment of responsibility to specific programs and/or volunteer monitoring efforts
- project management.

4.4.2.2. Analyze data. Once data are available, they will be analyzed to address the key issues listed at the beginning of this section. Efficient data analysis will depend to a large degree on the success of data management activities. These activities will ultimately determine whether data from the regional sampling/measurement effort has been collected and recorded in a consistent way, whether they have been integrated into an easily used format, and whether the integrity and quality of the data have been maintained throughout.

Analyses will include a variety of mapping techniques to display spatial patterns, statistical tests to determine the strength of such patterns, and variance components analyses to quantify sources of variability important for the further design of the status and trends monitoring effort (Section 4.4.3).

4.4.3 Develop and implement status and trends monitoring design

A long-term regional status and trends monitoring activity is the primary means through which the Regional Strategy will accomplish the objectives listed above in Section 4.4. The status and trends effort will utilize three kinds of sampling stations:

- representative stations that will allow generalization to the region as a whole
- stations in high-priority creeks of special societal and/or ecological concern
- stations in sites where toxicity is abnormally high.

In addition, the status and trends monitoring effort will be closely tied to special studies needed to further investigate anomalous results, identify sources to a greater degree of resolution, and/or examine processes that may affect levels and patterns of toxicity.

4.4.3.1 Develop monitoring design. Information from preceding steps 4.4.1 and 4.4.2 will be used to define the range of conditions the status and trends effort will focus on. This includes decisions about, for example, the need to monitor non-urban watersheds and dry weather flows, as well as the number of land use types within urban watersheds. It will also include decisions about the relative amount of effort to devote to diazinon-based toxicity as opposed to other, less well defined, sources of toxicity. These decisions will be based on the relative levels of toxicity across this range of conditions as well as on management needs for feedback about the effectiveness of specific program actions to reduce toxicity.

Within this overall structure, a key decision will be how to allocate available sampling effort across watersheds, land uses within watersheds, and stations within land uses. This decision depends on the relative levels of variability at each scale and the relative costs of each kind of sampling. The data on sources of spatial variability from steps 4.4.1 and 4.4.2 will be used in optimization analyses to determine the preferred levels of replication needed at each level of spatial resolution. The end result of these design activities will thus be a description of the range of conditions the status and trends program will focus on along with the preferred levels of sampling replication at the watershed, land use, and station levels.

Establishing this design framework creates the necessary context for finalizing decisions about the locations of specific stations as well as the parameters to be sampled at each station. Stations will be of the three types described previously:

- representative stations that will allow generalization to the region as a whole
- stations in high-priority creeks of special societal and/or ecological concern
- stations in sites where toxicity is abnormally high.

Parameters will include levels of diazinon and other potentially toxic contaminants, toxicity, and other external parameters (e.g., flow) that previous studies have suggested are useful in helping to explain toxicity results. The actual set of parameters to be measured at each station will depend on the results of the study design steps described above.

The last step in the monitoring detail is to decide the sampling frequency for each kind of station. This step follows standard study design practice and is intended to ensure that the monitoring design has the ability to detect meaningful amounts of change. Where sufficient data are available, statistical design

tools such as power analysis (a means of determining ahead of time whether the design will work as expected) can assist in these decisions.

A key requirement for completing the design is specifying the kind and amount of change the monitoring effort should be able to detect. Thus, when it is important to detect only large changes in toxicity and/or constituent levels, less sampling is required than if smaller changes must be documented. This essential design criterion will be determined through an iterative process. Data from previous steps will be examined to estimate variability due to the true temporal trends as well as to other sources of variability such as annual, seasonal, and sampling variance. Where necessary, reasonable variance estimates will be developed based on best professional judgment and on an understanding of the basic processes that contribute to variability. In these cases, a range of estimates will be used for planning purposes. Management's information needs will then be defined in terms of the amount of change it is important to detect and the time frame for when such information should be available. These needs must necessarily reflect both management and environmental contexts, particularly the natural processes that control the rates of change in constituent levels. For example, a management desire to detect a 20% reduction in toxicity levels in five years will be infeasible if, in fact, the true underlying trend only changes by one or two percent per year.

Following this reality test, power and optimization tests will be used to determine whether the desired amount of change can actually be detected with reasonable amount of sampling. Thus, for example, if separating an actual 20% reduction of five years from background variability would require an inordinate amount of sampling effort, then the management need must he reassessed. This iterative process will be continued until it identifies a "detection limit" for the sampling design that is both environmentally realistic and feasible to accomplish on the one hand and managerially useful on the other. This process necessarily involves a series of tradeoffs and thus requires the participation of statisticians, scientists/engineers familiar with the system, and managers.

Throughout these study design steps, coordination will be maintained with the RMP, volunteer monitoring efforts, and other groups whose monitoring and/or research efforts can support BASMAA's regional monitoring strategy.

4.4.3.2 Implement monitoring design. As with the preliminary studies described above in Section 4.4.2, successful implementation of the regional status and trends monitoring design will depend on detailed specifications for

- methods for field data collection and laboratory analysis
- exact timing of sampling events
- exact locations of sampling stations
- regional standardization of field and laboratory methods
- data management procedures, including regional standardization of data handling, recording, QA, integration, etc.
- assignment of responsibility to specific programs and/or volunteer monitoring efforts
- project management
- data summarization, analysis, and presentation.

4.4.3.3 Carry out special studies. The results of the long-term status and trends monitoring will produce results that require further investigation. Such investigations may focus on further investigating anomalous results, identifying sources to a greater degree of resolution, and/or examining processes that may affect levels and patterns of toxicity. These studies cannot be defined until data from the status and trends monitoring have been analyzed and interpreted. However, the strategy will make provision for periodic assessment of whether such studies are called for and will contain a procedure for planning and implementing them.

4.4.4 Summary

Preceding sections have described a series of steps involved in developing the details of regional status and trends monitoring of toxicity. This description is intended to provide insight into the rationale for design decisions and thereby furnish a basis for making more detailed decisions about implementing this

monitoring activity. However, it is also useful to have an overall summary of the main activities in this element of the Regional Strategy and the schedule for their completion. This is presented in Figure 4.8.

This element of the Strategy addresses a well-articulated set of logically linked objectives. It specifically builds on available information and uses an evaluation of this information to identify a focused effort to fill important information gaps. It defers decisions about specific aspects of the detailed study design until sufficient information is in hand to make well-informed decisions about these. In particular, the Strategy emphasizes gathering enough preliminary data on sources of temporal and spatial variability to ensure that the finalized monitoring design will not only be statistically valid but will also produce information useful in management decision making.

4.5 Aquatic habitat impact evaluation

The primary goal for this monitoring activity is to describe the current environmental health of urban creeks. This information, particularly on causes of impairment of beneficial uses, will be used to target high-priority areas where beneficial uses can most readily be protected and/or enhanced. It will also provide a basis for tracking trends in creek status over time, thereby providing feedback on the success of any corrective actions. This element of the Regional Strategy will concentrate initially on identifying and implementing straightforward indicators that can be easily measured, where possible as a part of ongoing maintenance and other activities (such as volunteer monitoring). The principal information product of this monitoring element is envisioned as a map of the region that displays the status of key beneficial uses within specific segments of each creek.

The motivation for this monitoring activity is BASMAA members' realization that factors other than pollutants are impairing beneficial uses of urban creeks. As a result, BASMAA has expressed its desire to explore activities (such as creek restoration) with interested organizations that could address these other factors. This could make their programs more accountable to their constituencies and would also respond to the Regional Water Quality Control Board's move towards watershed management.

While some results on creeks in the region are available from other studies (e.g., USEPA's Regional Creek Survey, watershed assessments), until recently there has been little region-wide information to help BASMAA members clarify their role in protecting and enhancing beneficial uses of urban creeks. This portion of the Regional Strategy therefore identifies a series of data gathering and study design steps that will result in a coordinated regional monitoring program for the environmental health of urban creeks. To the greatest extent possible, these steps emphasize utilizing available data and forming partnerships with other groups involved in watershed monitoring and management (such as other resource agencies). This will improve both the cost effectiveness and the scientific validity of the monitoring information.

The monitoring activity described below is incremental and incorporates decision points where BASMAA can choose to stop, wait, or proceed with further monitoring. Incorporating decision points and stopping rules improves the element's ability to respond to new information as it appears (see Figure 4.5 for summary).

4.5.1 Define problem

The specific aim of this step is to organize and summarize locally produced available knowledge about the environmental health of urban creeks in the region. This information will help provide the basis for selecting appropriate indicators, setting the scope of the monitoring design and its information products, and investigating monitoring partnerships with other groups. For some aspects of this element, existing information may be sufficient to support the detailed design and implementation efforts. For others, it may be necessary to gather additional information. Identifying such information gaps is an important part of this first step.

4.5.1.1 Frame specific questions. There are specific kinds of information needed to support the design of an effective regional monitoring effort for aquatic habitats and to scope this so that it accords with the responsibilities of urban storm water programs. These information needs can be framed as a set of questions:

- What are the relevant watershed boundaries?
- What are the land uses within these watersheds?
- Which creeks are the focus of this monitoring activity?
- What is the physical state of the various reaches of these creeks (e.g., underground culvert; concrete, earthen, or natural channels; water diversion structures)?
- What are the beneficial uses in each creek?
- What are the impairments to beneficial uses in each creek?
- What are the key physical/biological characteristics of the various reaches of each creek?

Other questions may be developed by the Monitoring Committee when it convenes to implement this monitoring activity. Each of these questions can be answered in a qualitative or quantitative way, and with a wide range of technical detail. As described below, BASMAA feels that relatively straightforward and easily gathered data will be valuable for decision making. The monitoring design and implementations steps reflect this judgment.

4.5.1.2 Summarize and evaluate existing knowledge. Both past and current studies, particularly by U.S. EPA, county flood control departments, the California Resource Agencies (such as the Department of Fish and Game), and the storm water programs themselves, have provided some insight into the questions listed above. In general, such studies have found that

- structural changes to channel morphology sometimes cause extreme habitat impacts (e.g., increased or decreased flow rates, decreased riparian habitat)
- increased temperature in shallow, unshaded channels is an important barrier to the movement of fish and other organisms
- metals appear to have little impact on creek environments
- depending on its extent (see Section 4.4), toxicity from organophosphate pesticides may affect the food chain within creeks.

These insights, especially the emphasis on structural changes to channel morphology, provide important overall direction to this element of the Regional Strategy. In addition, data from these efforts can provide a basic description of urban creeks. However, such data are not available consistently for the region as a whole. In addition, different studies have emphasized diverse aspects of creeks, with some focusing on fish populations and others on toxicity, for example. In the past, this has made it difficult to identify, categorize, and prioritize impairments to beneficial uses across the region. The lack of coordinated, long-term, and region-wide data also makes it difficult to assess how creek characteristics, including beneficial uses and their impairments, vary over space and time. Knowledge about such variability is an important ingredient for effective monitoring designs. Finally, this information has not been evaluated with the intent of determining how storm water management programs can best respond to these issues.

This information should be collected, organized, and reevaluated to

- determine the extent to which existing data satisfactorily answer the questions in 4.5.1.1
- review the appropriateness of indicators used in previous studies
- identify data gaps that require additional monitoring
- evaluate the extent to which available data can be used to quantify important sources of spatial and temporal variability.

An important goal of this early stage of this monitoring activity is to develop a method for displaying locally available information in a way helpful to storm water program managers and other decision makers. BASMAA's initial notion is that a simple map illustrating this information for each urban watershed would help evaluate overall creek health and identify factors causing impairment. This map may use different colors to illustrate reaches that are healthy or impaired, as well as the degree and cause of impairment (e.g., pollution, habitat, flow, sunlight). The map may also use icons to locate key physical features (e.g., water diversions, dams, etc.).

A map of this kind will be prepared using readily available information. It will serve three purposes at this stage. First, it will furnish the basis for identifying opportunities for corrective action, as described in the next section. Second, it is intended as the primary tool for identifying data gaps and inconsistencies and will therefore be instrumental in scoping any needed additional monitoring efforts. Third, it will provide an opportunity to test BASMAA's assumption that the visual presentation of straightforward information about creek status will be useful to decision makers. Feedback from managers about the usefulness of this information will be important input to the monitoring design.

4.5.2 Identify and implement corrective actions

This portion of the Regional Strategy concentrates on using the information developed in the preceding step to identify, and then address, easily achievable opportunities for corrective actions to improve

beneficial uses. This can best be accomplished through an iterative process that involves the following steps (see also Figure 4.9):

- identify preliminary opportunities and interested organizations
- develop prototype work plans for corrective actions
- define and gather any additional needed information
- refine work plans as necessary
- implement corrective actions.

The monitoring activities described below (Section 4.5.3) are intended to track the results of these corrective actions and provide feedback about needed adjustments.

4.5.2.1 Identify opportunities. The data evaluation and mapping described above is intended to create a context for identifying situations where the causes of beneficial use impairment are relatively obvious and can be readily addressed. Despite BASMAA's expectation that some causes of impairment will be readily apparent, it will be most prudent to have a systematic approach to identifying such opportunities.

This step of the Regional Strategy should therefore begin by specifying a set of questions and/or criteria that can be used to identify, categorize, rank, and justify alternative opportunities for corrective action. Some issues that might be considered include:

- Where are fish found and of what species?
  What type(s) of channels do fish occur in?
  What level of development is typical in watersheds with fish?
- Where are fish not found?
  What are the reasons for the absence of fish?
- What are the characteristics of the creeks with successful fisheries?
  What is the land use in these watersheds?
  What is the channel type in these watersheds?
- Are there other similar creeks that do not contain successful fisheries?
  If so, what are the reasons for the absence (e.g., concrete channel, barriers, land use)?
- What are the locations for public access?
  What are the main concerns at these locations (e.g., litter, graffiti, safety)?
- Where are there water contact activities?
  What are the main concerns at these locations (e.g., swimming, coliforms, fishing)?
- Where is there water fowl habitat?
  What are the main concerns at these locations (e.g., type of channel, contaminants, food supply)?

This effort should result in a prioritized list of situations where beneficial uses are impaired, the causes of impairment are readily apparent (or not), and potential corrective actions are similarly apparent (or not). These situations should also be evaluated to determine whether BASMAA members are the appropriate agencies to take any corrective action at this stage, whether additional information is needed, or whether other agencies should be notified and opportunities for partnerships explored.

4.5.2.2. Develop and implement corrective action work plans. If BASMAA members determine they are indeed the appropriate agencies to address these opportunities, then detailed work plans for each opportunity will be developed. It is very likely that an iterative process will be required to complete all necessary details for the work plans. Prototype work plans should be sketched out as a "proof of concept." These should be crafted fairly quickly but with enough specificity to suggest the responsible agency (or agencies), the type of approach, the level of effort involved, the chances of success, the expected time frame for success, and the monitoring data needed to document progress. These prototype work plans should also identify potential problems and describe the outcome of similar work elsewhere.

The prototype or "proof of concept" work plans will furnish the basis for a more rigorous evaluation of the potential of each opportunity identified above. These work plans should therefore be used to re-prioritize the list of opportunities. In addition, it is likely that further information will be required in some cases to complete the next, more detailed, version of work plans for the high-priority opportunities. The nature of such information will depend on the specifics of each situation, but may include:

- more detailed maps
- better historical data about biological and/or physical features
- better information about the ranges and variability of key habitat parameters
- a more detailed understanding of the prerequisites for success of the potential corrective actions
- special studies to better understand the causes of impairment.

Such data should be gathered, if they are available at an acceptable cost and within a reasonable time frame. Where this is not possible, the chance of success for that particular corrective action plan should be carefully reevaluated and the priority list adjusted if necessary. While it is impossible at this point in time to specify what kinds and amounts of additional data may be required, the effort to obtain them is envisioned as a focused, one-time activity, not an ongoing monitoring effort.

These data will provide the basis for revising the work plans and producing final versions to guide implementation. Throughout this design and evaluation process, BASMAA should continually assess opportunities for partnerships with other relevant monitoring and management organizations in the region. Given the momentum building behind the watershed management concept, it is very likely that BASMAA could find partners with overlapping interests whose participation would increase the overall cost effectiveness of the this element of the Regional Strategy.

Once the work plans are finalized, any useful partnerships have been formed, and the monitoring element is designed and in place (see following section), the corrective actions should be implemented.

4.5.3 Develop and implement monitoring

Monitoring data will be required for two purposes. The first is to track the results of the corrective actions to provide the feedback for adjusting them as needed. The second is to update the regional assessment of creek status to focus management attention and priorities. These efforts will obtain data in three ways:

- additional basic descriptive data (e.g., watershed boundaries, creek locations) available from existing sources
- data on the environmental health of urban creeks obtained from other monitoring and management organizations
- data collected by BASMAA members themselves to fill gaps not covered by the other two sources of data.

4.5.3.1 Develop monitoring designs. Separate monitoring designs will be developed for tracking results of corrective actions and for updating the regional assessment of creek status.

The details of monitoring to track the results of corrective actions will depend on the specific nature of each action. While these details cannot be defined at this time, it is possible to describe the basic structure of such monitoring efforts and how they should be designed. Each corrective action should be based on a conceptual model that describes how and why the action is expected to improve creek status. (For more detail on the use of conceptual models in monitoring design, see Managing Troubled Waters (NRC 1990), pp. 65-67.) Such models should be initially framed as a simple set of cause and effect statements. For example, one model might state that removing a barrier to flow will increase downstream flow which will in turn reduce temperature spikes which will increase both fish survival and distribution. These initial models should be simple enough to be readily understood but explicit enough to reveal key assumptions and focus monitoring effort.

Monitoring should be directed both at the ultimate outcome of the corrective action (e.g., broader fish distribution) as well as at the intermediate causal mechanism(s) presumed to affect the final outcome. Thus, in the example above, monitoring should be focused not only on the final distribution of fish but also on the relationships between flow and temperature and between temperature and fish distribution. This will provide two important benefits. First, where some time is expected to elapse before the final improvements become apparent, this approach can furnish more timely indications about whether the corrective action is working as planned. Second, it provides insight into whether the cause-effect relationships are really working as assumed. This in turn will improve planning for future corrective actions.

The time frame for monitoring should be based on the expected pace at which the conceptual model predicts changes will occur. In some cases this will entail immediate monitoring while in others monitoring may be delayed or stretched out for months or even years. In each case, monitoring should be designed to document important signals in the predicted restoration process, without necessarily requiring frequent and/or routine monitoring on a set schedule. Indicators should be selected that are unambiguously tied to the results of the corrective action.

A key issue in many efforts to monitor the effects of corrective actions is whether and what kinds of reference conditions to monitor. When the underlying goal is to return a creek to natural conditions, then some independent measure of natural conditions, or reference, is typically used to measure progress towards this goal. While simple in concept, selecting appropriate reference location(s) is complex and problematic in practice. Because of this, the priority list developed in Section 4.5.2.1 should probably concentrate on those situations and kinds of corrective actions that do not depend on rigorous comparisons to reference locations for an evaluation of their progress.

Additional design efforts to finalize sampling locations and frequency for each action should follow the suggestions on technical design approaches outlined in Section 3.3.

Monitoring to update the regional assessment of creek status should build on the initial efforts described above in Section 4.5.1. This monitoring should maintain the emphasis on using readily available and/or easily collected data that can create a broad picture of creek status throughout the region. Preparation of the initial summary of status and the development of the corrective action work plans will provide useful insight into how the regional assessment can be improved and streamlined. The monitoring design should define the frequency at which the assessment should be repeated. Rather than assume an arbitrary frequency (e.g., yearly), the frequency should be based on knowledge about the rate at which meaningful changes occur. Thus, if the overall status of a creek is expected to remain stable for the next several years, monitoring should not be scheduled in the interim unless an unusual event (e.g., major storms or erosion events) occurs.

4.5.3.2 Implement monitoring design. Successful implementation of both kinds of monitoring described above will depend on detailed specifications for

- indicator selection
- methods for field data collection
- exact timing of sampling events
- exact locations of sampling stations
- regional standardization of field methods
- data management procedures, including regional standardization of data handling, recording, QA, integration, etc.
- assignment of responsibility to specific programs and/or volunteer monitoring efforts
- project management
- data summarization, analysis, and presentation.

4.5.4 Summary

Previous sections have described a series of steps involved in developing the details of a regional effort to assess and address the health of aquatic habitats. This description is intended to provide insight into the rationale for design decisions and thereby furnish a basis for making more detailed decisions about implementing this element of the Regional Strategy.

This monitoring element for aquatic habitats is closely tied to developing and implementing easily achievable corrective actions to improve urban creek habitats. Thus, the initial summary and evaluation of existing information is designed to identify opportunities for corrective action. Subsequent monitoring effort is targeted at tracking the results of these corrective actions. Additional monitoring focuses on updating the regional assessment of creek status.

4.6 Obtain baseline water quality information for the San Francisco Estuary

The primary goal for this monitoring activity is to confirm the BASMAA agencies' commitment to and the financial support of the Regional Monitoring Program. BASMAA recognizes that without a clear and realistic understanding of the health of the San Francisco Estuary, regulations governing discharges into the Estuary must, by necessity, be conservative when estimating the impacts associated with the discharge. Regulations that truly reflect the relative impacts of discharges will only be achieved when conditions within the Estuary are clearly understood. BASMAA believes the monitoring activities encompassed by the Regional Monitoring Program will, given time, provide the clarity to make sound regulatory decisions that achieve harmony between a healthy ecosystem and a vital and sound Bay-wide economy.

5.0 The Regional Monitoring Strategy's Management Structure

BASMAA's Regional Monitoring Strategy is a dynamic creation that will evolve over time as current issues are resolved and new ones arise. The first set of monitoring activities in this initial version of the Strategy reflect this basic perspective by incorporating a set of stopping rules that help determine when it is time to conclude each particular element. As a result of its dynamic nature, the Regional Monitoring Strategy must necessarily be much more than simply a list of technical monitoring activities. It must include a set of monitoring principles that can successfully guide the development and implementation of new program elements in the future. It must also include decision-making and management processes that will enable the BASMAA agencies to cooperate effectively on a regional basis without expecting unrealistic levels of consensus or requiring member agencies to abdicate their individual authority.

This section describes management issues that typically arise in multi-agency, regional environmental programs; describes management strategies that have proved successful in situations similar to BASMAA's; and briefly considers BASMAA's current decision-making processes in light of this information.

5.1 Typical problems and issues

The Regional Monitoring Strategy represents a departure for BASMAA's member agencies from their previous approach to monitoring. As the Strategy is implemented, monitoring will shift away from a collection of activities performed relatively independently by each storm water program and toward a set of regionally coordinated efforts planned and implemented cooperatively. This will be a challenging transition because of the number of storm water programs involved; their differences in structure, scope, areas of expertise, and financing; and the geographic size of the region.

This is not a unique situation, however, and there are many instances of efforts to develop larger-scale, collaborative environmental monitoring and management programs such as the Regional Monitoring Strategy. These previous efforts provide valuable insights that can help streamline the further development and implementation of the Strategy. This past experience shows that there is a range of issues that usually arise, almost invariably consisting not just of technical problems but also organizational, regulatory, economic, and behavioral components. They include:

- standardizing field and laboratory procedures
- concepts of data ownership, access, and distribution
- mechanisms for transferring data/information among participants
- maintaining data integrity with multiple data sources and users
- preparing and maintaining adequate documentation
- maintaining technical coordination across agencies
- mechanisms for equitable cost sharing
- ensuring that perceived benefits are distributed equitably
- establishing decision processes that are efficient yet open
- making decisions when consensus cannot be achieved
- coordinating with other regional efforts
- disseminating study results
- periodically reevaluating and updating priorities.

This is by no means an exhaustive list. It is important to be aware that these and other issues are likely to arise and to therefore have realistic expectations about the process of implementing the Strategy. Because of the cooperative nature of its funding and planning, BASMAA has addressed some of these issues in the past. However, none of BASMAA's past efforts have involved the degree of regional integration envisioned by the Strategy, which essentially involves replacing each program's existing routine monitoring with a set of regional efforts.

As the following section discusses, it is not necessary to have formal, detailed policies about every such issue. However, it is important to have common agreement about basic principles that can guide day-to-day decision making. It is also important to know when formal policies are required and to have a process for developing them in a timely manner.

In addition to the list of common issues described above, efforts to develop larger-scale, collaborative environmental monitoring and management programs have certain common themes (NRC 1997, p. 57) that are important to recognize and take account of as the Regional Strategy is developed. Key among these is the fact that most such efforts are chaotic and unpredictable, depending partly on luck and also on the improvisational ability of their managers. A related finding is that organizational and behavioral issues are as important (and often more so) as scientific and technical issues. Thus, BASMAA's management approach to the Regional Monitoring Strategy should emphasize statements of fundamental principles and the development of flexible policies that leave room for adaptation to changing circumstances as the Strategy develops over time.

5.2 Strategies for success

There are many examples of both successful and failed regional programs that are analogous to BASMAA's Regional Monitoring Strategy in many ways. Many of these are reviewed in two recent National Academy of Sciences studies, one of data integration efforts for global change research (NRC 1995) and the other of efforts at regional environmental governance and problem solving (NRC 1997). These and other studies reveal that a set of relatively simple principles underlay virtually all successful efforts at coordination, collaboration, and regional problem solving. These rules of thumb include:

- consistent and visible commitment to a simple core goal that everyone can hold in common
- incremental progress that builds on success
- using practical, reliable technical approaches
- careful planning balanced with a willingness to adapt and improvise
- a minimum of bureaucracy
- using existing institutions where possible balanced with a willingness to create new forums
- collaborative decision making with clear leadership
- producing credible and widely distributed information as a basis for decision making
- attention to the human element (motivation, behavior, etc.)
- producing tangible and relatively immediate benefits for participants.

These and other related principles are discussed more fully in *Finding the Forest in the Trees* (NRC 1995, chapter 8) and *Striking a Balance* (NRC 1997, chapter 4) and the references listed therein.

5.3 Challenges for BASMAA

BASMAA is a cooperative organization that has a good track record of developing and implementing various efforts of benefit to its member agencies. In addition, both BASMAA and its member agencies have a cooperative relationship with the Regional Water Quality Control Board. While the Regional Board has the legal authority to require certain policies and actions, both the Regional Board and the storm water management programs have found that better policies and programs result from joint problem solving within broad boundaries set by the Regional Board. *A major goal of the Regional Monitoring Strategy is to maintain and enhance this cooperative working relationship with the Regional Board.* This section discusses a short list of important management issues that are key to successfully initiating the Regional Monitoring Strategy.

Of the issues listed above in Section 5.1, the following are most relevant to the upcoming initial implementation phases of the Strategy. They all (even Section 5.3.1 Decision making) combine both technical and management aspects in varying degrees. These issues are included here because their successful accomplishment depends on establishing management structures and processes.

5.3.1 Decision making

BASMAA's Monitoring Committee will have direct responsibility for implementing the Regional Monitoring Strategy, under the overall guidance of BASMAA's Board.

As discussed in the preceding paragraph, BASMAA desires to maintain a cooperative working relationship with the Regional Water Quality Control Board. In addition, BASMAA has had success with consensus-based decision making on a range of issues over the past several years. The basis for this management approach is detailed in the Memorandum of Understanding that created BASMAA. In addition, consensus-based decision making proved successful in developing the Regional Strategy and its core objectives described in this report.

However, it is also clear that fundamental disagreement can cause consensus-based decision making to bog down in the absence of any mechanism for cutting through such disagreement. In this case, the Regional Board's regulatory responsibility and authority provide a suitable means of establishing a clear course of action if a consensus cannot be achieved. The Strategy therefore depends for its ultimate success on the Regional Board first articulating clear long-term goals that will provide overall direction for the Strategy and then helping resolve fundamental disagreements if and when they arise.

BASMAA also recognizes that the initial set of strategic objectives and monitoring activities described in this report will necessarily change over time. If designed and implemented as intended, these objectives should be achieved, at which time resources can be freed for other monitoring activities. In addition, new information may change the original set of priorities envisioned in this report. While BASMAA acknowledges the need for flexibility, it also understands the importance of pursuing strategic objectives until they are accomplished, as well as the dangers of shifting too rapidly from one objective to another to another. An important part of the Regional Strategy is therefore a systematic process of reevaluating strategic objectives and adjusting them if necessary.

As described in Section 2.1, the strategic objectives that underlay the specific monitoring activities are intended to provide clear direction year by year. The Monitoring Committee will reevaluate the set of strategic objectives on a yearly basis, taking into account information from both local monitoring and studies performed elsewhere. The strategic objectives should only be changed if a preponderance of evidence strongly suggests the wisdom of doing so. The Monitoring Committee will consider the following questions when deciding whether to include new strategic objectives in the Strategy:

- How important is this issue?
- What is the degree of uncertainty now associated with this issue?
- How likely is it that monitoring will significantly reduce this uncertainty?
- What is at stake?
- Is this issue on the critical path to the Strategy's long-term goals?
- Is there a practical approach to monitoring or is R&D required?
- Is this issue regionally significant?
- Will monitoring information have the potential to change existing management practices?

The Monitoring Committee will communicate the results of this yearly reevaluation to BASMAA's Board in a formal report that, once accepted, will constitute the strategic objectives for the next year's implementation activities.

5.3.2 Standardized implementation

The Regional Monitoring Strategy represents a marked shift away from current monitoring practice, in which each program maintains its own monitoring activities with a loose degree of coordination with other programs' monitoring. Instead, the Strategy envisions a common set of strategic objectives and related monitoring activities, planned and implemented cooperatively by all the storm water programs. In some cases, this will involve cooperating to collect measurements throughout the region. In others, it will entail taking advantage of each program's specialized expertise by parceling out responsibility for different aspects of the monitoring to different programs best suited to perform them.

This more regionalized approach will demand that certain things be standardized to improve performance, compatibility, and overall cost effectiveness. For example, certain field measurement protocols, data quality control standards, and laboratory analysis methods will need to be standardized. On the other hand, an attempt to standardize every aspect of the separate programs' monitoring practices would be unworkable and misguided. The Monitoring Committee will examine the implementation pathway for each monitoring activity and identify those critical aspects that must be standardized across programs in order for the Strategy to succeed. The Monitoring Committee will then establish the necessary technical workgroups to develop standardized monitoring protocols as needed. Past experience with other such efforts has shown that developing regionally standardized monitoring protocols can often be the most time-consuming aspect of implementing regionalized monitoring efforts. The Monitoring Committee will therefore make this particular aspect of the Strategy a high priority as implementation of the Strategy begins.

5.3.3 Information management and data analysis

The strategic objectives (Section 2.1) are regionally significant and therefore of interest to all the storm water programs. All the programs will therefore desire to participate to some extent in the analysis and interpretation of monitoring data and to have ready access to both raw data and final results. While BASMAA has distributed reports of past studies, there is no current mechanism for making raw data and analysis results readily available to the various storm water programs. In addition, past BASMAA studies have often been performed by consultants, which means that there is no well-developed process through which BASMAA's member agencies can participate in data analysis and interpretation.

The Monitoring Committee will identify and evaluate practical alternatives for addressing these two related issues. There is a wide range of technologies for providing distributed access to data and it is premature to attempt to select one at this time. However, any method selected for this purpose must ensure data integrity, furnish links to mapping and other analytical tools, and make provision for future adaptations. Most importantly, the Monitoring Committee's evaluation will also identify the key management issues involved in developing an information management approach to support the Regional Monitoring Strategy.

References

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