

The California Watershed Assessment Guide



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Irrigated fields east-side Sierra Nevada
Muir Woods

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Big Sur Coast – back page (courtesy California Coastal Commission, 2005, Coastal Art
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See the full Manual at <http://cwam.ucdavis.edu>

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Guide to the California Watershed Assessment Manual

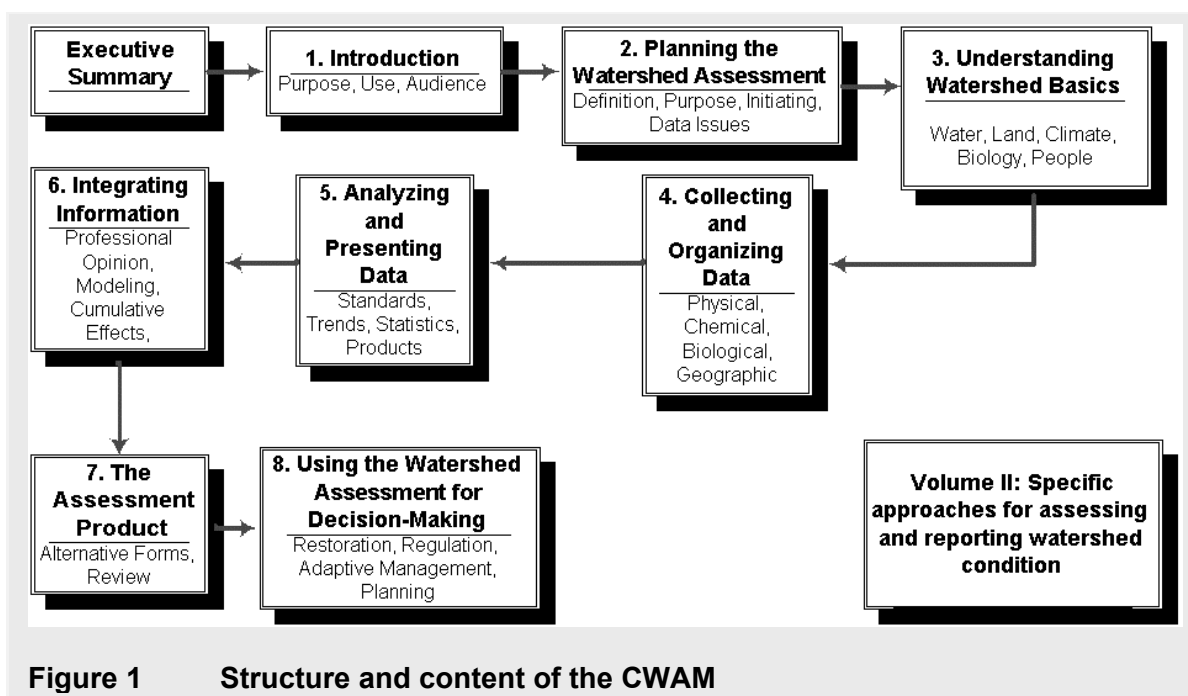
Preface

The California Watershed Assessment Manual (CWAM) provides information and guidance to assist watershed assessors. This information should be useful to a variety of watershed stakeholders, including members of watershed groups, agency representatives, landowners, scientists, members of the academic community, business representatives, and consultants. The California Watershed Assessment Guide (CWAG) summarizes key ideas and processes for conducting a watershed assessment, while the Manual describes in detail the mechanics for conducting one. All references have been omitted from this Guide; they are included in the Manual. The CWAG follows the same structure as the Manual. The CWAG should be used as a primer and brief introduction to conducting watershed assessments in California.

Manual Structure

The Manual contains eight chapters and an appendix (see Figure 1). These flow from an introductory chapter (1), a chapter on planning and conducting your assessment (2), background material on watershed processes (3), through chapters describing the details of data collection (4), data analysis (5), and data integration (6). Chapter 7 gives details on how to structure an assessment report and chapter 8 describes connecting the assessment with decision-making in a watershed adaptive management cycle. A second volume of the Manual is under construction and will consist of a selection of tools for collecting new data about specific natural or human processes or conditions.

The Manual will be available in three formats: as a loose-leaf printed manual, as a CD, and on a website. The website



(<http://cwam.ucdavis.edu>) also provides access to relevant technical and spatial information.

1. INTRODUCTION

The State of California is responsible for protecting and managing many aspects of the natural environment. One of California's most valuable natural assets is its water and waterways. Watersheds, also known as catchments or drainage basins, provide a useful, natural unit for better understanding and protecting our lakes, rivers, and streams. Assessing a watershed to understand its current condition, and how it got there, is usually the first step taken in developing a strategy toward improving and protecting the watershed's condition. A relevant watershed assessment addresses the sources of watershed impacts rather than just their symptoms, which is key to achieving effective watershed protection and restoration.

An assessment is far more than an encyclopedic collection of information about the watershed—it must analyze why the watershed is in its current condition. Watershed assessments can be relatively comprehensive or be focused on several specific issues. However, watershed practitioners must make a choice between a broad assessment and a focused assessment after thoroughly discussing the advantages and disadvantages of each in light of the watershed's needs and the purpose of the assessment.

A watershed assessment is: “a process for analyzing a watershed's current condition and the likely causes of these conditions.”

A watershed assessment report is: “a report documenting the findings of the watershed assessment process.”

2. BACKGROUND INFORMATION ON WATERSHEDS AND ASSESSMENTS

A “watershed” is defined as “the region draining into a river, river system, or other body of water upstream of a particular point.” Within a watershed common zones, often used for management purposes, are: 1) upland (land above the zone inundated by floods or above the transition between riparian and terrestrial vegetation), 2) riparian (vegetated area between the waterbody edge and the upland area), and 3) waterbody (any stream, river, abandoned channel, pond, lake, wetlands, estuary, or ocean). The term “watershed” is not synonymous with terms such as “stream” or “riparian corridor” or another single feature of the watershed.

Chapter 3 of the Manual provides an overview of relevant natural and social science disciplines and describes the main types of issues that emerge during a watershed assessment. It provides important basic information about the technical subjects likely to be addressed in a watershed assessment including geography, hydrology, climate, flooding and stormwater, geology, soils, sediment erosion and deposition processes, water quality, aquatic ecosystems, wetlands and riparian habitats, human land uses and water management. Because the material in Chapter 3 is already condensed to a fairly fundamental level, this Guide will not attempt to distill it any further, but only suggests that chapter as an introduction to some important watershed topics.

Watershed Assessment: What It Is and What It Is Not

Coming to a common understanding of what watershed assessment is—and what it is not—is important for the users of this Guide. “Watershed assessment” definitions include the following:

- The analysis of watershed information to draw conclusions concerning the conditions in the watershed. (Nehalem

River Watershed Assessment, Washington, 1999).

- A process for evaluating how well a watershed is working. (Oregon Watershed Assessment Manual, WPN, 1999)
- A process that characterizes current watershed conditions at a coarse scale using an interdisciplinary approach to collect and analyze information. (NCWAP & CDF 2002)
- The translation of scientific data into policy-relevant information that is suitable for supporting decision making and action at the watershed level. (Watershed Academy, U.S. EPA).

Despite their differences, what is common to each definition is a process composed of actions—analysis, integration, translation—that leads to the interpretation of information about the watershed’s current condition. It is critical that the watershed assessment effort lead to a better understanding of watershed processes and conditions and why the watershed is in that condition. That way, the assessment can serve as a compass to help direct further actions.

Your assessment should move beyond a simple description of what a watershed looks like, or what historical activities took place in the watershed. While those are some of the building blocks of an assessment, your assessment must connect past and current human activities and land uses (causes) to watershed processes and current condition (effects). (Watershed processes refer to the natural processes, such as hydrologic and nutrient cycles, that influence the waterways’ conditions). With an understanding of dominant watershed processes and potential causes of watershed condition, watershed practitioners can propose solutions to problems. Without this understanding, proposed solutions may address only the symptoms. A successful watershed assessment leads to the implementation of actions that benefit watershed processes and conditions—the ultimate “performance measure”.

What an Assessment Is

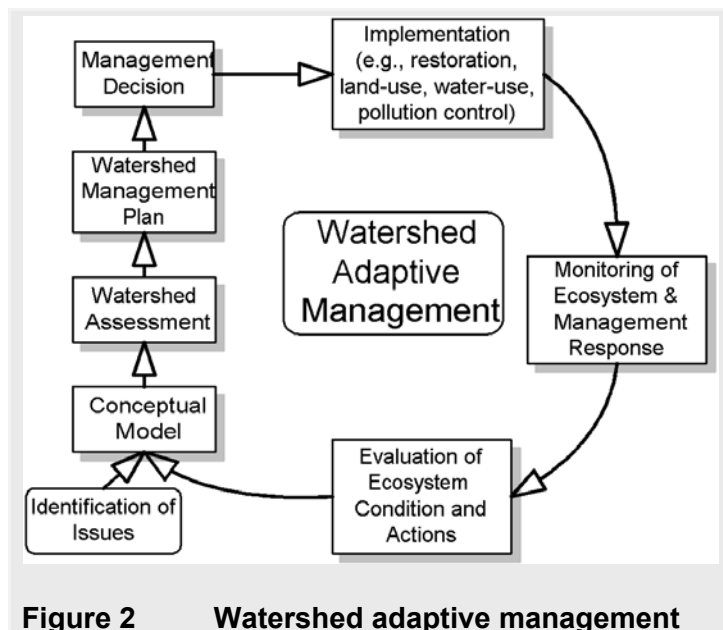
- The scientific interpretation of watershed information and data, leading to conclusions about watershed condition
- An objective problem-solving tool that identifies the potential causes of problems
- A tool to help identify available data or information gaps
- Analysis and findings that can be used to develop appropriate actions
- A component of a watershed management package that leads to planning, implementation, evaluation, and additional monitoring
- A product that is useful for its audience

What an Assessment Is **Not**

- Monitoring and data collection only
- A list of data only
- A consolidation or summary of existing information only
- Historical conditions or “baseline” conditions only
- An identification of symptoms of problems only
- A plan
- An endpoint

Watershed Adaptive Management

Adaptive management is a systematic process of modeling, experimentation, and monitoring to compare the outcomes of alternative management actions. Management actions are treated like “experiments”. When actions are taken, it is recognized that there are hundreds of factors that influence a watershed. Management and restoration activities are designed with the best available knowledge at the time. However, much can be learned from these activities and future actions should be shaped by the knowledge gained from the original effort or “experiment”. The sequence in Figure 2 describes this process, involving a cycle of monitoring data collection, analysis and evaluation, conceptualization of issues, planning,



decisions, actions, and more monitoring. This is the adaptive management cycle, because it implies that management decisions will be adapted to fit and respond to new information about a system; new information that is gained from monitoring and assessment. Feedback loops that include assessing whether watershed's problems are improving – at the project or action level and at the watershed level – are important for gauging management effectiveness.

In this Guide, it is assumed that the assessors and watershed managers will use an adaptive management approach to evaluate actions and make decisions about how to proceed. The watershed assessment is key to the success of this watershed adaptive management approach.

3. USING THIS GUIDE AS AN AID TO CONDUCTING A WATERSHED ASSESSMENT

This Guide reviews the basic process for conducting a watershed assessment, following these steps:

- 1) Organize the assessment team
- 2) Define the purpose and develop a plan for the assessment
- 3) Collect data and information

- 4) Analyze the data
- 5) Integrate and report the data to inform decision-making

The assessment team should identify cause-and-effect relationships to the extent possible with existing information. Additional monitoring is often needed so that issues can be analyzed with more confidence.

This Guide gives a brief overview of these steps. For more detailed information, see the Manual.

Step 1: Organize the Assessment Team (Chapter 2, CWAM)

Step 1. Initiate Assessment Planning as a Group and with the Community

Your organization has decided that it wants to do a watershed-scale assessment. In some cases, there are conditions and impacts in your watershed that have raised concerns. You are interested in finding out why these impacts have occurred. In other cases, your watershed may be relatively pristine and you want to maintain its character. You are interested in assessing conditions and analyzing potential sources of degradation so you can prevent or minimize future problems. Whether you are performing a retrospective study (the first scenario) or a prospective one (the second scenario), the basic process is similar.

You may have already obtained funding as part of a grant or in-house budget, or you are scoping the topic to determine assessment requirements in order to prepare a grant or budget proposal. Once you've reached this point, complete the following tasks to get your watershed assessment underway.

❖ *Assemble the Team and Committees*

No one has all the expertise required to do an assessment, not consultants, agencies, academics, or watershed groups.

Accordingly, your assessment team should include people with a wide variety of expertise and interests. Putting together such a team is described in detail in the Manual.

Some things to keep in mind

- Mix the disciplines on the team and support committees
- Identify the disciplines needed for your assessment
- Keep the groups as small as possible
- Establish technical and public advisory committees
- Identify a team coordinator

It is important to assign responsibility for decision making at the beginning of the process to avoid problems down the road.

❖ *Contract Analysis and Coordination Work If Necessary*

Your assessment team will likely consist of people in your watershed group, for the most part. However, conducting most watershed assessments in California requires additional expertise from outside the group. You may need to hire experts through a contracting process. This person could fill a management and coordination role, be a technical analyst, or bring the information you have collected together in an integrated assessment. Take the time to find and contract with the right person or group—their expertise is important to the success of your effort, and contracting expenses can be considerable.

❖ *Keep Costs Under Control*

The cost of doing a watershed assessment can vary greatly, depending on the scope, scale, time, and use of paid consultants. A few groups have kept their costs low by

using experts (agency staff and consultants) who have contributed their time at no cost to the group, as well as by receiving volunteer time from their members and the community. Minimizing scale, scope, time, and consultant use can reduce costs. However, each assessment effort has certain minimum built-in costs no matter what the scale: project management, public participation, data and information collection, analysis, report writing, and draft and final report publication. To reduce costs, do as much of the advance planning and thinking as possible within your watershed group or similar decision-making body.

❖ *Create a Realistic Schedule*

It's important to be realistic about how much time it takes to perform a watershed assessment, but estimating time required can be challenging. Experience has shown that simpler assessments performed in-house with sufficient expertise and information may take four to eight months. More complicated or comprehensive assessments or assessments where the process is not under tight scheduling control can take as long as 36 months. Use milestones to stay on track. Here are some sample milestones (adapted from Coastal Conservancy 2001):

- Start-up
- Initial project team meeting (define approach)
- Public meeting #1 (review issues, concerns)
- Technical Advisory Committee (TAC) meeting #1 (review strategy)
- Begin assessment
- TAC meeting #2 (mid-progress review)
- Draft assessment complete
- Review results—TAC and Public Advisory Committee
- Release revised draft to public
- Revise and deliver final assessment

❖ *Involve the Community*

Those who will be making decisions using information contained in the assessment should be included, consulted, or at least considered when designing an assessment. From start to finish, the assessment should make clear how and why various steps were taken. This approach has the benefit of getting all-important buy-in—stakeholders and decision-makers are more likely to trust the assessment’s conclusions if they understand the reasons various approaches were taken or they were involved in gathering data and information for each step.

Summary of Tasks for Step 1

- Assemble the assessment team and committees.
- Appoint a coordinator and seek contractors, if necessary.
- Encourage community participation through public meetings, the media, and outreach to other relevant local organizations (e.g., Farm Bureau, resource conservations districts, etc.).

Once you have your watershed team assembled, you can actually begin the work. One way of organizing a watershed assessment is to break it into four main parts:

- Defining the problem and planning the assessment
- Collecting information and data
- Interpreting results: data analysis and synthesis
- Preparing the report

The next section of the Guide will provide an overview of each of these steps.

Step 2: Define the Purpose and Scope and Develop a Plan for the Assessment (Chapter 2, CWAM)

The first formal phase of a watershed assessment consists of clearly identifying the issues of concern, identifying the purpose of the assessment, developing a conceptual diagram of the key components of the watershed, and developing a plan for carrying out the assessment. For this Guide and Manual, the term “purpose” is basically synonymous with “goal”.

Step 2A. Formulate the Important Questions and State the Purpose of the Assessment

Watershed assessments may be motivated by one or more influences:

- to evaluate watershed conditions from a neutral perspective, i.e., with no prior assumptions;
- to address identified watershed issues or problems;
- to meet a particular purpose, e.g., identify conditions that need to be improved in order to increase drinking water quality;
- to meet a particular goal, such as educating the public about natural and human features of the entire ecosystem and assist in planning and decision-making.

For many assessments, one or more issue-based questions usually drive the process. The question may be as generic and general as, “What is the condition of our watershed, and why is it that way?” More specific questions might be along the lines of, “Why did the salmon stop spawning in our stream? Why did such a big flood come from such a small storm? Why can’t we drink the stream water any more?” or “How can we protect our pristine watershed from the degradation we see in neighboring watersheds?” Questions

based on observations and community concerns will direct the watershed assessment, which will in turn provide the basis for addressing the important issues.

❖ *Issues to Consider*

- If there are no fundamental questions or concerns guiding a watershed assessment, you may wish to make explicit the perceived need for the assessment.
- The questions should be stated clearly enough to capture the prevailing concerns that led to wanting or needing a watershed assessment.
- Clearly write out the questions and/or issues use them to guide future data collection and analysis.

❖ *State the Purpose*

Watershed assessors should develop a **clear statement of purpose**. A “fuzzy,” or implied purpose statement that never gets clarified, or an absent purpose statement can lead to bigger and bigger problems (such as getting off target, or creating misunderstandings due to different expectations of the product) as the assessment process continues.

It is also important to clearly identify **who really wants the watershed assessment, and why** they want it. Otherwise, misunderstandings can occur. For example, the impetus may come from the local level—from a cooperative group (e.g., a watershed council), a local agency (e.g., a resource conservation or water district), or other private or public stakeholders—for a variety of reasons.

On the other hand, the driving force often comes from the state or federal level as a requirement of a grant program or a regulation. For example, funding agencies may require that a watershed assessment be done as a condition of funding a watershed plan or restoration projects.

Another aspect of defining the purpose of the assessment is **to identify the target audience**. Having a clear sense of the target audience is important both for refining the assessment’s purpose and for developing and writing the assessment. Watershed assessors should agree to and clearly state the assessment’s intended audience at the beginning of the process. Otherwise, the product might not be very useful when completed.

Another factor to consider when defining the purpose is how specific the assessment will be. There are two ways to approach the content of your watershed assessment: 1) comprehensive, or broad, and 2) focused. Each offers strengths and weaknesses.

❖ *Level of Detail: Comprehensive vs. Focused*

The **comprehensive approach** assesses the conditions of all processes and features in a watershed. The advantages are that this broad approach gives an overview of the watershed’s condition, may expose previously unknown problems in the watershed, and may identify the interconnections between various problems or issues. On the other hand, “comprehensive” may sound desirable, but a focused product may prove more useful.

In the **focused approach**, the assessment process chooses the most critical issues in the watershed, and then focuses the assessment effort on these. The benefit to this approach is that it makes the assessment potentially more useful for future decision making about specific problems or areas. Groups identify upfront the issues—of all those possible—that most need to be addressed because the assessment cannot address all issues in depth. The watershed’s problem(s) drive the assessment. The risks of this approach are that the focus can become too narrow, miss critical issues, and overlook connections among problems/issues, resulting in a

failure to correctly identify the root cause of problems.

Other options may help you achieve the best of both comprehensive and focused approaches. The incremental approach is one that can be quite practical, particularly considering the harsh realities of cost and time in doing an assessment. Add other components to your focused assessment over time. Ideally, the critical, interrelated components of an incrementally produced watershed assessment need to be integrated as the work is completed over time.

❖ *Determine How the Assessment Will be Used*

Finally, consider carefully how the assessment might be used. A watershed assessment can be prospective or retrospective, or both. Most are retrospective in that the assessors seek to identify the causes of perceived problems or changed conditions. Some assessments are prospective, seeking to anticipate how human activities might degrade the present conditions. Focused assessments could be both retro- and prospective. The assessment could be used to develop a management plan, meet regulatory responsibilities, or restore degraded habitat. Regardless of the specific needs, the same basic process applies.

Summary Tasks for Step 2a

- Write out a *draft* purpose statement that identifies the main questions or perceived problems in the watershed.
- Seek agreement on the draft and finalize a purpose statement
- Identify the degree of specificity of the assessment (broad vs. focused) and experts needed to assist with certain aspects of the work.
- Identify the intended audience for the assessment. If the audience is not involved in the assessment, state how

they will be informed of the findings and their significance.

- Identify the decision-making processes the assessment may inform and how the assessment is intended to be used in these processes.

Step 2B. State What the Watershed Assessment Will Be Used For

Assessments generally serve to inform certain functions:

- General watershed management planning with multiple purposes
- Regulatory concerns
- Restoration or enhancement planning
- Monitoring program development
- Management of areas at risk and practices resulting in risk
- Land use activities

❖ *Connecting watershed assessment with watershed management*

To encourage implementation of effective management actions, a watershed assessment that will inform watershed management planning should include the following components:

- Connections between individual assessment findings and potential watershed management plan (WMP) elements. Example: Analysis of erosion potential in connection with road construction, maintenance, and upgrade practices.
- Specific findings for geographic sub-areas within the assessment area for individual impacts or cumulative effects of disturbances. Example: “The impervious surface area for Urban Creek is very high relative to standards for stormwater runoff management and impacts downstream waterways.”
- Assessment of processes at scales appropriate for the scales at which decisions are made. Example: Waterway effects of licensed water management occur on hourly to

centuries-long timeframes, so multiple timeframes during hydroelectric project analysis are important for licenses with fixed time periods. Effects need to be measured at the timeframe over which they occur, not at some arbitrary interval such as daily or monthly.

❖ *Regulatory Concerns*

Some regulatory processes require watershed assessments. Under the federal Clean Water Act, for example, states must identify impaired water bodies and begin describing “total maximum daily loads” (TMDLs) (<http://www.epa.gov/region09/water/tmdl/>) for pollutants causing the impairment. Establishing TMDLs requires that Regional Water Quality Control Boards in California analyze pollutant loads entering waterbodies on a watershed scale.

California’s Forest Practice Rules (FPRs) require watershed assessment for Sustained Yield Plans (SYP), the optional, long-term, large-scale management plans for logging operations on private lands. These assessments are usually focused on habitat concerns for endangered salmonids in waterways affected by the operations. Typically, the analyses are restricted to those parts of watershed functioning where impacts are known to limit salmon spawning and rearing habitat (e.g., riparian retention and erosion risk). However, there are currently no state-prescribed analysis methods.

❖ *Restoration and Enhancement Planning*

Not all watershed assessments are intended to inform restoration planning, but this is a common goal of most watershed partnerships. Restoration is defined here as the renewal of a natural process (e.g., natural fire regimes) or habitat (e.g., measurably functional riparian corridors) through human actions. These actions could include changing permitted land or water uses (e.g., modification of dam releases), or removing structures that are suspected or

known to cause damage (e.g., roads or fish migration barriers).

The ideal situation is for restoration planning to take place in the context of watershed assessment for the upslope and in-stream area surrounding the proposed restoration area. Taking a watershed approach to restoration planning is essential in order to determine how upstream or downstream processes and land uses may affect the restoration area. If the restoration is focused on an area of a hill-slope or a reach of a river, the essential unit for assessment and planning is the watershed. For this reason, watershed assessment can support subsequent decision making about where, when, and how to restore natural processes at specific sites or in larger areas (e.g., sub-watersheds) to benefit native wildlife. It can also inform decisions about how to monitor the effectiveness of the restoration action and how to maintain the action over time.

❖ *Monitoring Programs*

Watershed assessments are closely tied to past and current monitoring in watersheds. The assessor relies on data and conclusions drawn from monitoring programs to analyze watershed processes and conditions. In turn, the assessment can form the basis for developing or updating monitoring programs. This iterative process is part of an adaptive management and assessment approach that incorporates new information as it becomes available in order to make decisions.

From the watershed assessment point of view, it’s important to find areas in the watershed that might impact waterway condition (e.g., water quality). These areas will include both human-created and natural features that have the potential or are known to be releasing material into a waterway or otherwise influencing in-stream processes. At one end of the impact spectrum might be ridgeline roads that connect to streams through impacts to hillslope geomorphology or pollutant runoff.

At the other end of the spectrum might be riparian developments (e.g., in urban settings) that have direct connections to channels and dominate the relationships between watershed hillslopes and waterways.

Summary of Tasks for Step 2b

- Identify the decision-making process that the assessment will or may inform.
- State how the assessment findings would be used in the particular decision-making process(es).

Step 2C. Define the Watershed Boundary

Establishing the boundaries of your watershed assessment or the spatial limits of the area to be analyzed is a critical early step. The only watersheds defined by nature are those with a low point at the ocean or a closed-basin lake. All others (including those contained within a “naturally-defined” watershed) are defined by a human choice of the lowest point. Agreeing on the assessment area at the outset so that everyone knows exactly what piece of ground is under discussion can head off many problems and arguments.

Choosing a point along a stream or river that then defines the lowest point or downstream end of your watershed is the sole decision that defines a watershed. Once you choose that point, everything upstream of it becomes your watershed. Your watershed includes all land that drains downhill (or could contribute water via gravity) to the point of your choosing. So, how do you choose this all-important point? That depends largely on the objectives of your assessment and the general area in which you are interested. Common points to select are the mouth of a stream at an ocean or lake, the confluence of a stream of interest with another stream or a much larger river, a point immediately upstream of a major water diversion, a stream-gaging station where flows have

been measured for several years or decades, or a location where water quality samples have been consistently obtained. Sometimes, another entity (e.g., a funding agency) will pick the point for you. Also consider using the state’s CalWater system of delineated watersheds if your watershed approximates one of the CalWater watersheds (<http://www.ca.nrcs.usda.gov/features/calwater/>).

Step 2D. Develop a Basic Picture of the Watershed

This step involves pulling together information on the ecological system within the watershed based on the knowledge of each member of the assessment team and other readily-available information. This process will help organize your thoughts and provide some clues about which parts of a more thorough assessment will be relatively easy to perform and which will be more difficult. An adaptive watershed assessment approach will usually be an efficient use of personnel and finances. With this approach, as more information is gathered, the plans for the assessment could change to reflect the new information. You need to learn some basics about an issue before deciding how to and how hard to tackle the problem. As you learn more, you will begin to get a sense of whether the path you are on will yield a definitive answer or will provide limited information with considerable uncertainty.

Your assessment team should gather information that allows you to get a general picture of conditions in the watershed today and to the degree possible, in the past. Gaining an understanding of the changes that have occurred in the ecological system over time will provide the most accurate picture on which to base the assessment. The information you gather at this point will be incomplete, but it serves as a starting point and will be necessary for the next two steps.

Step 2E. Identify the Watershed Processes and/or Valued Ecosystem Components that Will Be the Focus of the Assessment

“Watershed processes” refers to the natural physical, chemical, or biological processes that interact to form the terrestrial and aquatic ecosystems (the water cycle, for example). “Valued ecosystem components” refers to the things within the watershed that stakeholders value, such as fish, clean water, trees, or open space. In other words, these components may be structural (population of a certain species of fish) or functional (such as the return frequency of fire). It is not necessary in every case to directly measure a component or process. Frequently, surrogates or indicators can be used to get an idea of the condition of the selected watershed component. Looking at a simple example, you might not be able to directly measure the population of the splittail fish, but by measuring different habitat and water quality characteristics (e.g., water temperature), you can get a good idea of whether or not this fish could survive in these conditions.

There are many possible watershed processes and attributes. These include, for example, the distribution of benthic macroinvertebrate communities, drinkable water, presence of a species of fish or a plant that is important to the stakeholders, or, more generally, the overall riparian corridor or upland areas.

Some criteria that are often used to select the watershed processes or components that could be the focus of the assessment are:

- Importance to the health and sustainability of the watershed;
- Related to the assessment’s purposes;
- Sensitive to those activities or factors you suspect might be causing changes in the watershed;
- Have societal value.

Additional criteria might include watershed processes for which the natural variability is known; attributes required by a regulation; and the availability of data, models, or knowledge about the particular endpoint.

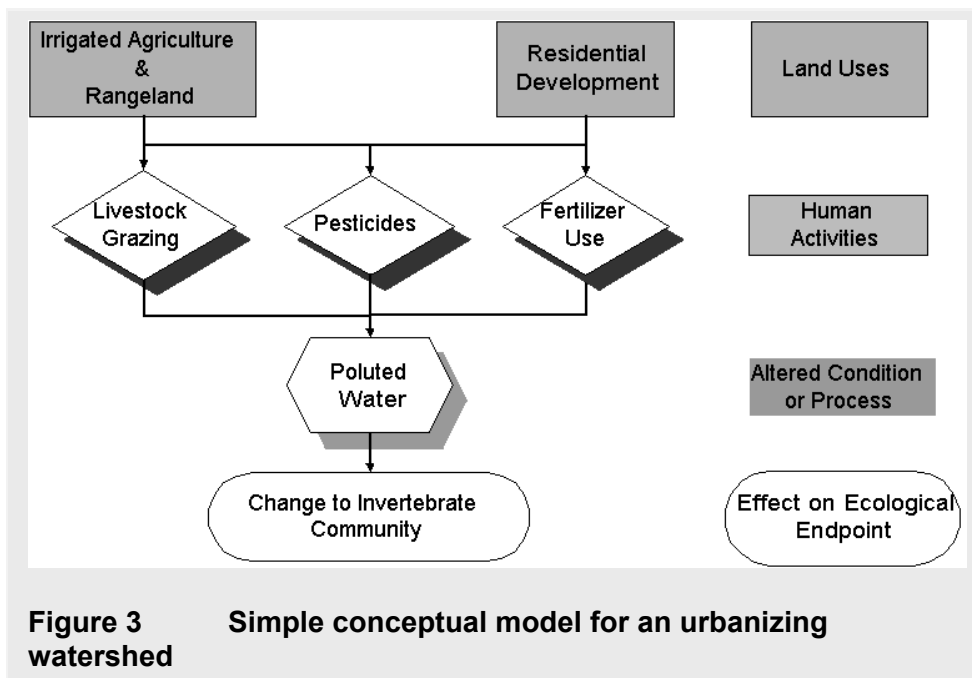
Step 2F. Identify the Temporal Scale of the Assessment

When you defined the boundaries of the watershed, you identified the spatial scale of the assessment (Step 2B). You also need to define the temporal scale. How far into the past and into the future do you plan to collect data? Ideally, having data that extends over a period of many years is best because you can get the clearest picture of the changes that have occurred. Also, year-to-year variability is inevitable. Having data that extends over many years will permit you to distinguish between natural variability and a real alteration or change.

Step 2G. Develop a Conceptual Model

A conceptual model is a graphical representation of potential relationships among the watershed’s components and processes. Once you have identified the watershed processes you are most interested in, you will need to think about how they are impacted by changes in regional and watershed processes and the stress, or impacts, that may result from human activities. The relationship between human activities, watershed processes, potential impacts or sources of stress and the effects on ecosystem function are depicted in the conceptual model. Watershed assessments typically focus on those alterations that are human-induced since these are the ones we can influence.

Developing a conceptual model is an iterative process. The model you develop at the beginning of your effort may look different from the one you finally adopt because you will modify it as your knowledge of the conditions and processes within the watershed grows. The knowledge



Clearly, the knowledge required to draw accurate conceptual models can be significant. That is why having a team of people with varied technical backgrounds is very helpful. These are just two examples of the way you might construct a conceptual model. Regardless of how yours looks,

needed to develop a conceptual model will come from familiarity with the particulars of your watershed as well as from general knowledge about watershed science.

Chapter 3 of the Manual reviews watershed basics. Additional sources of information include scientific articles and books as well as reliable sources of online information (<http://cwam.ucdavis.edu>).

Conceptual models can be developed in a variety of ways. These models will help you understand the possible relationships that are important to consider when you collect and/or analyze data. Figure 3 is an example of a simple conceptual model of an urbanizing watershed. In this example, the assessors were interested in the health of the benthic macroinvertebrate community in their local creek. They were concerned that runoff from agricultural fields and new development was impairing the diversity and viability of the insects.

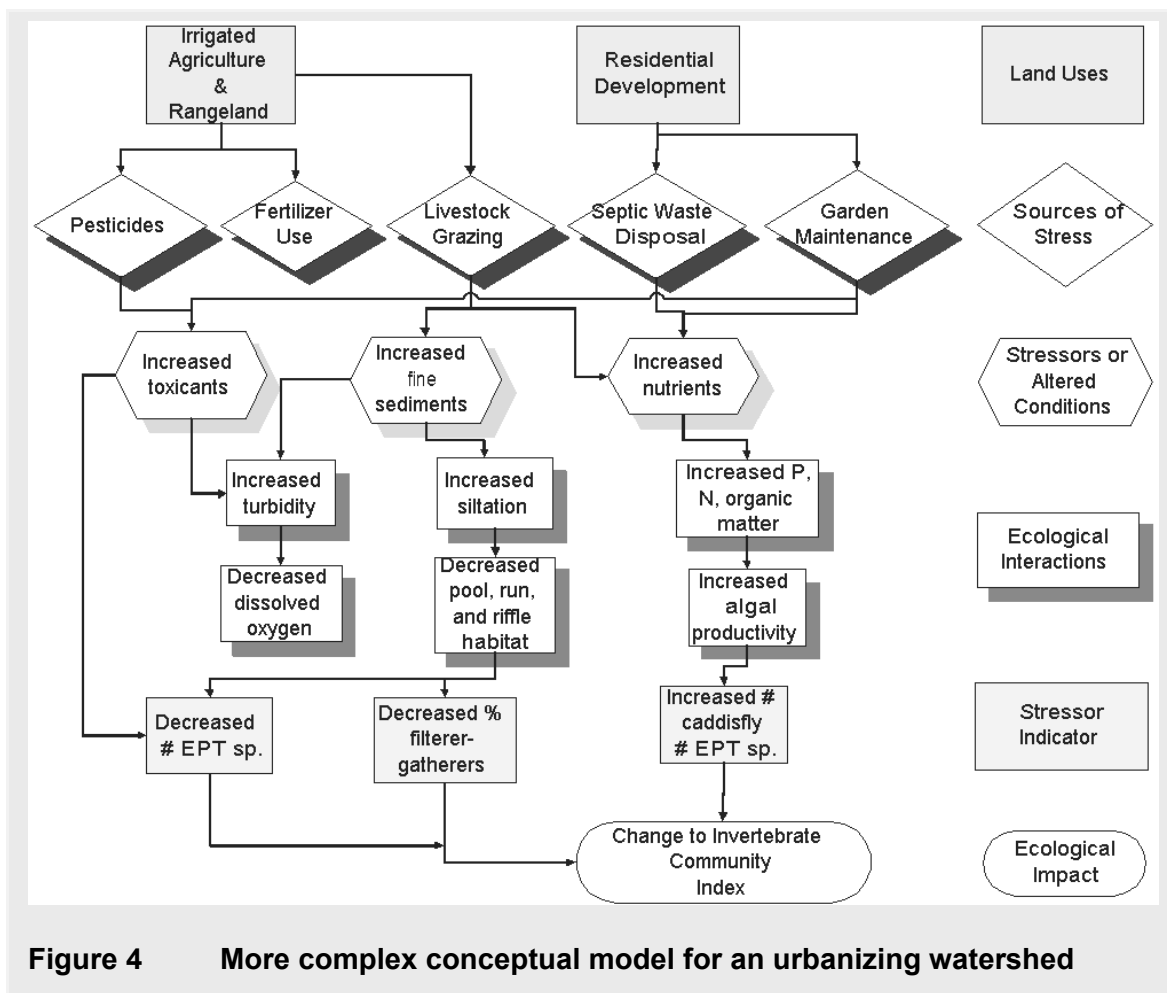
The more complex model shown in Figure 4 is a refinement that reflects more detail as the group's understanding of the watershed components and processes increased.

the key point is that the conceptual model diagrams should identify hypothesized relationships between human activity, changed conditions or processes in the watershed, and the potential effects of these changed conditions on the selected watershed processes and/or components. These relationships can serve as the basis for data collection and analysis.

Overview

Now that you have figured out what your assessment questions are, developing and implementing an "analysis plan" for collecting and analyzing information and data is typically the next step. Data collection and analysis constitutes the heart of the watershed assessment. The conceptual model or diagram you constructed can serve as a guide. Accordingly, as you prepare for the analysis phase of your assessment, you should identify the data and information that must be gathered and outline the process for organizing and analyzing this material.

The watershed assessment focuses in part on the potential harmful effects of human activities on watershed components and



functions. These effects occur when human activities cause changes in the watershed's physical, chemical, or biological characteristics and processes.

- Physical changes include water temperature and flow rate, generation and transport of sediment, stream channel shape and connectivity with the floodplain, erosion and incision of the streambank, and any other physical habitat characteristic
- Chemical changes include the introduction of pesticides, excess nutrients, oil/grease, effluent from industry, or other contaminant to the targeted habitat
- Biological alterations that might be associated with harm could include invasive species and pathogens.

Step 3: Collect Watershed Data and Information (Chapter 4, CWAM)

Step 3A. Determine the Kind of Data You Want to Collect

The data you collect should correspond in type and substance to the questions raised at the beginning of assessment planning and refined in the conceptual model. Types of data include spatial or geographic data for understanding things taking place on the landscape (such as land use) and water quality or quantity data for understanding a waterway.

The conceptual model can serve as a guide to what data you need to collect. The following list includes key classes of information that typically are useful.

- Data on human activities and land uses – the location, type, intensity, areal extent (acreage), and proximity to or linkage to the waterways (such as via storm drains)
- Data on the physical, chemical, and biological properties and potential sources of impacts in the watershed – in-stream and riparian habitat characteristics, water quality data, animal/plant population abundance and diversity, etc.
- Data on alterations in watershed processes – changes in the hydrological cycle, nutrient cycling, etc., particularly as they are affected by past and current water and land use and by climate change.
- Data on potential effects of potential impacts on watershed functions

These and other data can come in a variety of forms: digital and non-digital spatial data, quantitative or qualitative data, and anecdotal information. All these data types can be useful in a watershed assessment. Specific types of data include quantitative water quality data, geomorphological surveys, biological surveys, maps, and other similar data. These data may be presented in various formats and at varying levels of detail of analysis. For example, data might be presented in spreadsheets, tables, and graphs; as spatial data within or separate from a computer-based geographic information system; in internal agency memoranda; in field surveys, in narrative or historic descriptions of a place and past processes and events, such as floods, landslides, or contaminant spills; and products of computer models developed to illustrate specific processes (e.g., storm-water runoff). Consider collecting any type of data that would be useful for the goals of your assessment.

Anecdotal information may be one of the most difficult data types to record and store, but may also provide knowledge about watershed processes that might otherwise be lacking. Common types of anecdotal data include:

- 1) The extent of salmon runs in rivers now lacking these runs due to dams or other barriers,
- 2) Increasing turbidity of streams and rivers over time due to upstream activities,
- 3) Encroachment of roads and human structures into previously undeveloped landscapes,
- 4) Growth of nuisance vegetation (e.g., benthic algae, riparian weeds, or invasive exotic weeds), or
- 5) Increased rate of flooding in river valleys due to landscape modification.

Although not the same as quantitative information, anecdotal data can provide very useful information and help you develop hypotheses about historic conditions in the watershed and the effects of human activities.

Step 3B. Identify Sources and Collect Existing Watershed Data and Information

The following section references sources of watershed information and data that are already available.

3B.1. Waterway data

The availability of hydrologic and water-quality data on the Internet has thoroughly transformed the hunt for watershed data in recent years. Rather than conducting long searches and even longer copying and transcription sessions in libraries of distant universities and archives of local agencies, an amazing amount of material is now accessible from any computer connected to the Internet. Online resources do not eliminate the need to seek specialized and unpublished information from a variety of sources, but your office computer is now a

convenient place to start your search for data.

The U.S. EPA's "Surf Your Watershed" Web site (<http://cfpub.epa.gov/surf/state.cfm?statepostal=CA>) is a good place to begin. An interactive map will direct you to your region. This site provides links to a variety of other Web sites and resources that may be useful in your search for watershed data. The number of links on EPA's site varies tremendously, depending on the watershed.

The Department of Forestry and Fire Protection has compiled 1:24,000 hydrography GIS data for the North Coast region (<http://www.frap.cdf.ca.gov/data/frapgisdata/select.asp>).

The U.S. Geological Survey is a repository for the nation's water data. Your search for USGS data can begin at <http://ca.water.usgs.gov> or <http://waterdata.usgs.gov/ca/nwis/nwis>. The USGS Web site primarily contains flow information, although for some sites, there is water quality data as well. Water quality data include information on both the water column and sediment. The primary source for water quality data is the U.S. EPA's STORET system (<http://www.epa.gov/storet/dbtop.html>). STORET has recently been split into two separate entities: the Legacy Data Center (LDC), a static archive containing historical data collected through 1998, and STORET, the modern system.

Water quality data from discrete samples are accessible from the U.S. Geological Survey's Web site <http://waterdata.usgs.gov/ca/nwis/qw>. Under the "Tutorial" button are instructions for accessing water quality data in watersheds. You can get to your watershed of interest quickly if you already know the USGS hydrologic unit code. Otherwise, navigate to your watershed by starting with your county. Depending on what, if any, data are available for sites in your watershed, you can specify a variety of output formats to meet your needs. The USGS has a good summary of its

procedures for sample collection and onsite measurements at <http://ca.water.usgs.gov/archive/waterdata/text/onsite.html>. More detailed information can be found in the USGS reports, "Techniques of Water-Resource Investigations", at <http://water.usgs.gov/pubs/twri/>.

The State Water Resources Control Board has implemented a program required by Water Code Section 13192 to study the physical, chemical, and biological condition of California's waterways <http://www.swrcb.ca.gov/swamp/>. At its current level of funding, the program focuses in a limited way on water quality, which is conducted by the USGS, Department of Fish and Game, and the Regional Water Control Boards. The protocols and data management systems is described at: <http://www.swrcb.ca.gov/swamp/qapp.html#appendixi>. Currently, the system does not hold data, but the program is assisting in collecting and providing data for the Bay-Delta and Tributaries (BDAT) project, which is part of the California Environmental Data Exchange Network (<http://baydelta.ca.gov/>).

Water quality data from the Central Coast Regional Water Quality Control Board's Central Coast Ambient Monitoring Program is available at <http://www.ccamp.org>. Here you can navigate to a sampling location or water body and then view a summary table of attributes and values.

3B.2. Hydrology and Flooding Data

Information and data about your watershed's hydrology are obviously critical to your watershed assessment. The availability of hydrologic data largely depends on whether some agency thought the water in your stream had some utility, either locally or for export. If there are major or formerly proposed water-engineering projects in or near your watershed, then there is a high likelihood of current or historic stream-gaging stations.

Flow data

Streamflow data come from three basic types of measurements: 1) continuous records of stage (water level) and discharge at a calibrated cross-section, 2) spot measurements, and 3) crest-stage gages (where only the highest water level is recorded).

The U.S. Geological Survey is the federal agency with primary responsibility for the nation's water data, including streamflow. Navigating USGS streamflow data is easiest when you have the USGS gage numbers, which have a structure similar to the USGS hydrologic unit codes for watersheds. From the USGS entry portals <http://ca.water.usgs.gov> or <http://waterdata.usgs.gov/ca.nwis/nwis>, you can easily get to a site selection page and enter your county or a pair of latitudes and longitudes to begin your search for stream gages in your watershed.

Although the USGS portal <http://ca.water.usgs.gov/> provides annual tables (flat files) of daily discharge values for gages operated between 1996 and 2001, you may wish to obtain more data in a format that can be manipulated on your computer. For access to more thorough data after you know what sites and periods of record are available, go to: <http://waterdata.usgs.gov/ca.nwis/sw> or <http://nwis.waterdata.usgs.gov/ca/nwis/disc> harge.

In addition to daily streamflow values, USGS also publishes data of the highest annual flows over the period of record for selected sites. Access the peak streamflow database at <http://waterdata.usgs.gov/ca/nwis/peak>.

Other sources of streamflow data include water districts, municipal utility districts, irrigation districts, hydroelectric generating companies, the U.S. Forest Service, and any other local entity that needs to measure streamflow. Data from such sources may not be available online and may require a

personal inquiry to the agency or company. Some records are not considered public information and may not be available. In cases where the data are not public records, be prepared to make a good case for your need, demonstrate that release of the data will not be harmful to the supplier, and be prepared to pay for staff time to copy or otherwise prepare the data for you.

Climate data are available from CDEC at <http://cdec.water.ca.gov>. Select "Precipitation/Snow" from the menu "CDEC Resource Directory" for a list of precipitation stations. From there you can select an individual station and obtain the latest data. At the bottom of a page for a particular station, select "Historical Data" to get to the "Bulk Data Selector". Using the three-letter station code from the previous page, specify the data, period of record, and output format. A pair of interactive maps for locating stations with available data can be found at <http://cdec.water.ca.gov/cgi-progs/mapper>.

The Western Regional Climate Center in Reno is the other major source for precipitation, temperature, and other climate data. Begin your search at <http://www.wrcc.dri.edu/CLIMATEDATA.html>. Interactive maps with locations of climate stations are available for Northern California (<http://www.wrcc.dri.edu/summary/climsmnc.html>) and Southern California (<http://www.wrcc.dri.edu/summary/climsmnc.html>). After selecting a particular site, you will obtain a monthly summary over the period of record and a menu for accessing more detailed information for the site.

3B.3 Riparian Vegetation and Wetlands Data

The riparian zone is where the aquatic and terrestrial landscapes come together and where species from both environments benefit. As a result, riparian data sources come from both the aquatic and terrestrial areas of environmental responsibilities and interests. Attributes of riparian data include:

canopy cover, species, tree size, plant community (e.g., cottonwood riparian, mixed conifer riparian), large woody debris, bank erosion, and others. Another quality describing riparian areas is “proper functioning condition,” which can be evaluated on the adequacy of vegetation, landform, or large woody debris to serve certain functions. Data about riparian vegetation and other characteristics of riparian areas are likely to be scarce for your watershed, however. In the past, there has been little demand for systematic surveys of riparian areas.

The California Riparian Habitat Conservation Program was created within the Wildlife Conservation Board (WCB) in 1991 (http://www.dfg.ca.gov/wcb/california_riparian_habitat_conservation_program.htm) One of its objectives is to assess the current amount and status of riparian habitat throughout the state. However, this extensive mapping effort has not yet occurred. This program is partnering with the state-federal-private Riparian Habitat Joint Venture, which was instigated for riparian bird habitat purposes. The Joint Venture also aims to identify riparian areas in the state, but it has not yet compiled a database (<http://www.prbo.org/calpif/htmldocs/rhvjv>). Challenges include the difficulty of mapping land cover statewide with sufficient resolution of the narrow riparian zone and cost.

Aerial photography is a potential source of raw data about riparian vegetation (primarily vegetative cover and human disturbances), although it requires a lot of rather tedious effort to interpret the images (e.g., Nelson & Nelson 1984, Grant 1988). Sources of archived aerial photography include offices of the U.S. Forest Service, the Bureau of Land Management, the California Department of Forestry and Fire Protection, county planning departments, the Earth Science and Map Library at U.C. Berkeley, and the Map and Imagery Library at U.C. Santa Barbara.

The National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service provides information about wetlands throughout the United States. About 90% of the wetlands of the continental United States have been mapped, with much of the information available in digital form online (<http://www.nwi.fws.gov>). With the exception of southern desert areas, most of California has been mapped as of November 2003, with digital information available for about half the state. Other potential sources of wetlands information and data include county planning departments, the Natural Resources Conservation Service, and the U.S. Army Corps of Engineers.

3B.4 Physical Watershed, Channel, and Habitat Conditions Data

Geologic and topographic information are essential components of watershed assessment. Data collected should be used to help identify the dominant physical processes active within the watershed. California maps are readily available from a variety of agency and private sources—and are always useful in an overview-scale assessment. Data that provide a physical overview of watershed characteristics are available from USGS topographic maps (<http://ask.usgs.gov/maps.html>) and geologic maps from various agencies.

The Department of Forestry and Fire Protection and the USDA Forest Service's California Land Cover Mapping and Monitoring Program has mapped most of the state's vegetation from satellite imagery (http://www.frap.cdf.ca.gov/projects/land_cover/index.html). This information can be used on its own to evaluate vegetation. Watershed wide, or it can be overlain with hydrography data in a GIS to analyze riparian data.

The Department of Forestry and Fire Protection also maintains a number of other watershed physical attribute GIS data sets that are useful for watershed assessment

(<http://www.frap.cdf.ca.gov/data/frapgisdata/select.asp>).

Historic and current aerial photographs are another valuable source of watershed-scale data that helps characterize a watershed's physical character (as well as vegetation and land use character). Topographic data and photographs are available online from <http://terraserver-usa.com/> sponsored by USGS and other groups. County planning departments, museums, Caltrans, NRCS, and a variety of agencies and private firms can sometimes provide historic and current aerial photographs that may be used to evaluate trends and changes in physical watershed characteristics over time.

Step 3C. Identify Sources and Collect Spatial Data for the Watershed

The majority of the area in any California watershed is the terrestrial landscape. Landscape data are often collected for areas. They may also have been collected initially at individual survey sites (e.g., soil or vegetation) and then subsequently generalized to areas. Currently, most contemporary data about a watershed landscape is collected with a geographic reference point. In contrast, historic data may be very valuable, but lack easily usable or identifiable reference points.

- *Non-digital Spatial Data*

Many professional opinion-based approaches to decision-making rely on paper maps, or local knowledge, to decide where projects should go. Many local, state, and federal agencies have archives of paper maps. You could collect copies of these, make digital versions of them (e.g., by scanning), or summarize and interpret them somehow for later use. Paper maps are probably most useful when they show high-resolution information about local occurrences. For most watershed assessments, collecting all paper maps available isn't feasible. You may want to collect maps for select areas where, for

example, you are interested in the historical condition or for features where digital information is not available.

- *Digital Spatial Data and GIS*

Digital spatial data are electronic versions of a paper map and show the relative positioning of mapped features (e.g., roads, rivers) in a geographical location (e.g., a watershed). These data are often used in watershed mapping for watershed assessments and plans. However, they are useful for much more than just cartography (mapping). They can be used in modeling and understanding the distribution of features across a landscape and how things interact with each other.

There is a wide variety of sources for data about landscapes. However, these sources are not always easy to find. Large agencies or institutions may hold data, which may be available online. Local agencies or private organizations are other data sources. However, these organizations and agencies may require a more direct approach to explore their databases and retrieve information (i.e., negotiating in person). A list of potential data sources is in the CWAM, but this list is not exhaustive—there are hundreds of different possible sources of data in California. In all cases, when you access and organize data, maintain a log of where you got the data, make sure you get the metadata (the description of the data, such as how it was collected and when), and try to file likes with likes to make retrieving the data more intuitive.

A list of Web sites is available at the CWAM Web site: <http://cwam.ucdavis.edu>. Also, the state is currently developing the "California Watershed Portal" to help direct assessors to watershed-relevant data sources (<http://cwp.resources.ca.gov>).

The term "GIS" (geographic information system) gets used a lot in the watershed world. To some it means a single digital map; to others it refers to a series of maps on a computer and includes analysis of spatial data. The spatial data often originate

from remote sensing of the earth, from digitization of features from paper maps, or from using global positioning system (GPS) units to geo-reference points or lines on the ground. The history of GIS includes people taking pictures of battlefields from balloons (remote sensing), putting pins in maps for the locations of features (geo-referencing), overlaying multiple layers of transparencies with different spatial attributes delineated on each layer, and the development of rapid automated calculations (computers). Computer-operated GIS was created when these capacities were refined, and paper maps could no longer capture processes on earth. If you are responsible for conducting a watershed assessment that involves GIS, you should become familiar with the relevant terms and system descriptions below in order to understand the opportunities and limitations of this approach.

However, as a starting point, ask yourself, "What questions do I intend to answer with this GIS?" and "How much money do I have to spend?" Answers to the first question will tell you the scope of your GIS project and help inform the second question. Costs for a GIS can vary widely, and this is where there may be the least amount of information available for the watershed group to make fiscal decisions. For example, you may decide you want to collect digital spatial data and do simple analyses (e.g., where roads cross streams), with an emphasis on visual presentation of map information. In that case, your least expensive route is to use free GIS software on a donated computer, taking advantage of spatial data online and printing on a color inkjet printer. Being able to do this requires a basic education in GIS, which you can get inexpensively or for free online. At the other end of the spectrum, you may want to spend \$10,000 to \$100,000 hiring staff or a consultant to do all of this for you on a purchased computer, using licensed software, and present your maps in large printed format and online using a map server. A likely outcome of hiring a

consultant is that a GIS professional will do a good job more quickly than someone local having to learn GIS. At the same time, if GIS is likely to be part of your planning, monitoring, and management work for several years, it may make more sense to train a volunteer or staff person to carry out the GIS in order to increase local capacity.

Step 3D. Develop a System for Archiving and Managing Your Data

As data are collected, they should be organized in a manner that suits the questions being asked and the users' needs. Because watershed assessment usually involves the collection of several different types of data (e.g., maps, water quality, and field surveys), consider developing file organizational systems for each type of data that conform to a single standard for categories (e.g., wildlife habitat, water quality, land use). One way to keep track of information collected is to make a database of the category types. If you will be collecting data for aquatic and terrestrial systems and of various different types (i.e., from text to digital spatial data), then keeping track of the types of data and the areas they cover will help in both organizing the data and describing how much of the watershed they cover.

For most watershed assessments of modest scale, you don't need to become a database expert, but you should learn enough to choose an adequate structure for your data needs. Existing environmental data will be stored in some sort of file structure or database, with the particular details dependent on the type of data, the agency archiving the data, and the needs of data users. An introduction to data management appears in Chapter 4 of the Manual.

Step 3E. Identify Data Gaps and Collect New Data, If Needed

As you collect and organize your data, you will quickly identify important areas of concern for which you have no or very little data. For example, you might be concerned with alterations in the hydrological cycle in your watershed, but don't have any data or information on stream morphology (% pools and their size, % fine sediment, etc.) except for anecdotal information. If in-stream habitat is an important factor in your assessment and you are not in a position to collect this data, you will have to identify it as a data gap in your report and consider the uncertainty that results when you analyze the data you have. It will be a limitation in your assessment – but there are limitations on just about everything anyone does so this may not be a fatal flaw. You might identify the lack of data on stream morphology as a priority when future funds become available and explain how this information might help provide a more complete picture of watershed conditions.

Alternatively, if you have the resources and time to fill the identified data gaps, the uncertainty of the assessment can be minimized with the addition of the new information. If your budget is limited, many times there are less sophisticated methods to collect the same information; methods that volunteers or high school students can learn with a short orientation. Typically these methods won't be highly quantitative, but at least they can provide you with a first approximation of the condition about which

you have no data. Frequently, watershed groups will partner with a local community college or university to collect selected types of data on their watershed. In the best-case scenario, you will have funds available to collect the information you need to fill in the data gaps.

Step 4: Analyze the Data (Chapter 5, CWAM)

This section suggests ways you can move from the raw data you have collected to interpreting its meaning and importance. You might be data rich, but information poor staring at a bunch of numbers that do not yet tell a story. The material presented here and in Chapter 7 of the Manual will assist you in making your assessment more complete and accurate. In moving from raw data to integration and interpretation, you may encounter a few stumbling blocks along the way. Suggestions to overcome these problems can be found in this section.

Step 4A. Overview

The last phase of your watershed assessment is in many ways the most important because it involves trying to make sense of the data and information you have collected. Using the analogy of the physician trying to diagnose a disease, in this phase the doctor sits down with the results of the tests and X-rays and makes a differential diagnosis. The doctor tries to interpret the results based on a number of

CHECKLIST FOR STEP 3: Collect Watershed Data and Information

- Determine the kind of data you need to collect
- Identify sources and collect existing watershed data and information
- Identify sources and collect existing spatial data about the watershed
- Develop a system for archiving and managing your data
- Identify data gaps and collect new data, when needed

factors: which tests are most 'out of whack' with normal values, does a group of tests seem to be pointing to the same problem, which diseases are most commonly associated with the results obtained from the tests, and a variety of other criteria. The physician looks at all the evidence to test the hypothesis that conditions x or y are most likely the cause of the problem while conditions a or b are less likely causes. Perhaps other conditions are 'long shots'. This process of elimination as applied to watershed analysis is known as limiting factor analysis, watershed risk assessment, or a number of other names. But regardless of name, the process is very similar. The assessment team needs to interpret the results and identify the factors most likely associated with the issues that gave rise to the assessment in the first place.

This section describes a variety of approaches to exploring and analyzing typical watershed data sets. As discussed in previous sections and in Chapter 2 of the Manual, assessments can and should be performed in progressively more detailed stages, and this approach applies especially to data analysis.

Step 4B. Summarize and Explore the Data

Before beginning any formal statistical analysis, you should explore the data informally. This can be done with descriptive statistics. Descriptive statistics refers to simple calculations including calculating the mean or average value, calculating the standard deviation (or range of variation), and making a frequency distribution if you have sufficient data points. For example, if you've collected water temperature data once a month for three years, you might decide to summarize the data for each month, based on the value you collected over the three years, by calculating the mean and standard deviation. You can then construct a graph or table that reflects the average temperature each month.

A frequency distribution plot is another way to look at data variability. If you collected data on temperature from 15 sites in the watershed in the month of September, you might plot the data to see how similar or different the sites are. Plotting the data in a frequency distribution (see Figure 5) gives you a visual picture of the variability in temperature throughout the stream. It helps give more meaning to the average.

Overall, descriptive statistics give you a better feel for the data. These simple statistics are sometimes all that is needed for the watershed assessment, especially if you have a small dataset.

4C. Perform Statistical Analyses, If Warranted.

Once you have summarized your data, you will need to determine whether it would be useful to perform a statistical analysis to identify significant changes over time or between different places within the watershed. Here are some questions to consider to get an overall feel for the data.

- Is the data of sufficient quality to use? Do the data meet appropriate official standards and practices for collection? Are data collection methods documented adequately so that you can assess their quality?
- Are the gathered data and information useful for your needs?

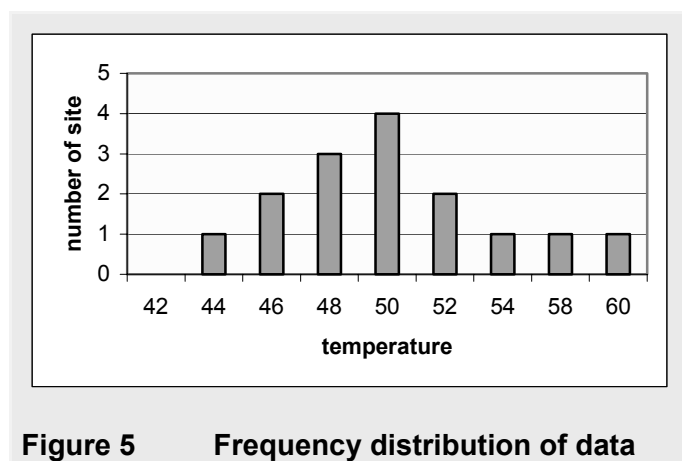


Figure 5 Frequency distribution of data

- Do all the potential users and detractors of the watershed assessment accept the raw data?
- Do all the stakeholders support the choice of analyses?
- Are you thinking in ranges rather than single values for the data?
- Are you making comparisons to natural variability, which requires determining or estimating baseline and reference conditions?
- What statistical tests, if any, do you plan to use? Some screening level assessments do not necessarily require statistics. Also, if the datasets you have collected are limited in scale (either temporally or spatially) then they might not be suitable for statistical analysis.

You might want to analyze your data using more complex, multivariate methods. These methods permit you to estimate which factors contribute the most to minimizing variability in the results. In most cases, those factors that reduce variability in the data are usually the most important regarding meaningful relationship. Principal components analysis is one method to determine, for example, which stressor out of six might contribute the most toward the change in habitat that you might have observed.

Another way to approach data analysis is to do spatial analysis or time series analysis. An example of an analysis over a spatial scale is the measurement of extent of development (e.g., human population or parcel density) in watershed areas that erode more rapidly than other areas. An example of analysis over a temporal scale is determining whether changes in water temperature over time are meaningful (or whether they just reflect natural variability).

The methods used to analyze things that change over space are different from those used for things that change over time. There is an extensive technical literature on how to measure each of these types of changes,

depending on what needs to be measured (e.g., analysis of trends over time). Two cautionary notes are that most analyses involve assumptions about the nature of the process being analyzed and that sometimes analysts have employed inappropriate tools, so copying an approach used elsewhere should be done with caution. In general, it is wise to consult with someone knowledgeable in statistics to get an informed opinion and recommendations.

Geographic information systems (GIS) were created to allow calculations for specific places on the earth. If you have a GIS software program, you can carry out these calculations, too. Examples of common straightforward analyses are densities of things within a certain area of the landscape (e.g., abandoned mine density in a sub-watershed), intersection of lines of different types (e.g., roads crossing streams), and summarizing data for an area (e.g., the number of people in a watershed). Not all spatial analysis needs to involve a computer-based GIS, but that is our focus in this Manual.

Step 4D. Analyze the Data: Comparing Your Findings to Reference Values or Control Conditions

Another aspect of analyzing your data is comparing it to standards that are recognized as supporting the normal functions of biota or watershed processes that you are evaluating. To objectively do this, compare your data either to that from similar watersheds that are widely considered to have well-functioning processes and good conditions OR to values for habitat conditions and water quality standards that are known to be protective for the watershed processes on which your assessment focuses. One critical issue for this analysis is that for many processes the standards for comparison will vary by bioregion (e.g., the North Coast) and by habitat type. So don't expect one statewide standard to be available or to fit your needs.

The following information might be useful in identifying sources of information for making these comparisons.

- **Water Quality Standards that Support Aquatic Life**

U.S. EPA has developed a set of water quality criteria that can be used to compare water quality data from any water body with values that are known to protect aquatic life. EPA's Water Quality Criteria were developed pursuant to Section 304a of the Clean Water Act, which required EPA to develop and publish criteria for water quality that accurately reflect the latest scientific knowledge for a variety of aquatic species. These criteria are based solely on data and scientific judgment on the relationship between pollutant concentrations and environmental effects. They do not reflect consideration of economic impact or technological feasibility (U.S. EPA, 2002). EPA categorizes pollutants into three major categories: priority pollutants, non-priority pollutants, and pollutants with "organoleptic" effects (those that affect water's taste or odor). Priority pollutants include pesticides, PCBs, and a variety of anthropogenic chemicals. Non-priority pollutants include conventional water quality parameters, such as pH, dissolved oxygen, turbidity, and temperature. Pollutants with organoleptic effects are primarily important relative to drinking water.

The criteria that U.S. EPA uses for aquatic life protection are the same as those contained in each California Regional Water Quality Control Boards' Water Quality Goals. Each of the nine Regional Boards prepares a Basin Plan, which designates the beneficial uses of the region's waters, as well as water quality objectives for a wide variety of constituents that will support the identified beneficial uses. The Water Quality Goals contain numeric criteria that, for aquatic life protection, are the same as U.S. EPA's criteria. Each Regional Board's Basin Plan identifies beneficial uses of the water, water quality objectives, and a plan

for implementation of these objectives. Each Basin Plan's Chapter 3 contains the water quality objectives, including criteria values for conventional and priority pollutants. There are also non-numeric standards for certain waterway or water quality attributes. Some Regional Boards attach relevant documents, including recommended numerical limits for pollutants, to their Basin Plans. The Central Valley Regional Board has prepared "A Compilation of Water Quality Goals," a staff report that "contains numerical water quality limits from the literature for over 800 chemical constituents and water quality parameters" (http://www.swrcb.ca.gov/rwqcb5/available_documents/wq_goals/index.html). The companion document "Recommended Numeric Limits", available at the same URL, is an Excel spreadsheet with a list of water quality criteria for a wide variety of conventional and priority pollutants. It is an excellent reference document.

- **Sediment Quality Standards that Support Aquatic Life**

Criteria values for contaminants in sediment are not readily available from the Regional Boards. In many cases, sediment contaminants are a greater problem than those in the water column. This is the case because metals and many organic contaminants are not highly water-soluble. One of the best sources of reference data on sediment contaminants is the NOAA Fisheries Screening Quick Reference Tables which are posted at: <http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html>. Additionally, the US EPA document "Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems" is also another source of information. It is a three-part manual and is posted at: <http://www.epa.gov/glnpo/sediment>. Please refer to Chapter 5 of the Manual for additional details.

- **Habitat Conditions**

It is difficult to identify information on standards for habitat conditions relevant to a particular species. Quantifying these conditions is not simple to do, so reference values similar to the Water Quality Criteria do not exist for habitat conditions. For salmonid species, some of this information is available. The California Department of Fish and Game has developed a Salmon Stream Restoration Guide that contains what many experts consider to be preferable conditions. It can be used as a guide to compare conditions in your stream and is posted at: <http://www.dfg.ca.gov/nafwb/manual.html>. Information on preferable habitat conditions for other species of fish is not as readily available. Scientific studies containing this type of information can be found using a database such as Aquatic Sciences and Fisheries Abstracts. This database contains searchable lists of hundreds of thousands of scientific articles relevant to watershed assessment. This scientific literature search engine can be used at the library of most universities.

Step 5: Identify the Influences on Condition: Data Integration and Synthesis (Chapter 6, CWAM)

Once you have collected all the data needed or available to answer your watershed assessment questions, you face the challenging step of incorporating or integrating all the information into a common analysis. Information integration

here means combining or linking information about various watershed processes and attributes in a way that leads to conclusions about overall watershed condition and the possible causes. You could integrate information for particular processes, like the movement of sediment from hill-slopes through waterways until it is deposited and the impacts of that transport and fate, for example. You could also combine multiple processes and potential impacts in a system using indicators for potential impacts (e.g., land use), system stressors (e.g., water temperature), and impacts (e.g., aquatic biota). Without linking individual processes (or separate disciplines or specialties), watershed assessments may fail to identify potential causes of the watershed's condition and important linkages among watershed processes.

In this section, we describe a variety of ways that you can carry out this step, depending on your needs and available resources. There is no single 'correct' way to do this. We give several examples of approaches that scientists and watershed partnerships have tried in California. None of them is necessarily right or always usable; they are listed here to inform you of the range of choices. The methods range from relatively simple conceptual tools to modeling tools.

The relative condition of watersheds and waterways can be expressed in a variety of ways, but it is commonly measured using such indicators as drinking water standards, aquatic community composition, terrestrial and riparian vegetation condition, and constraints on the free flow of water. A majority of watershed or waterway monitoring and restoration projects are based upon definitions of "health" that are

CHECKLIST FOR STEP 4: Analyze the Data

- Summarize and explore the data
- Decide if statistical analyses are needed or possible with the data available
- Compare your data to standards, historical, and/or reference conditions

either explicit (e.g., water quality standards) or implicit (often expressed as deviation from “historical condition”). Any risk or condition assessment scheme designed to support monitoring or restoration programs should make these watershed health definitions explicit so that stakeholders understand and support the relevance of the findings or products of the assessment activities. Making these overall watershed assessments will require the development of a scheme for integrating the information.

There are many possible ways to integrate information, from qualitative to highly quantitative, from informal to formal. Many watershed partnerships have a group of experts from different disciplines evaluate information and form professional opinions about watershed condition(s) and the potentially interrelated causes of those conditions. Other watershed assessments rely on computer modeling for most of information processing and then base conclusions on the products of these models. Some assessment programs develop models that return evaluations of watershed condition as the product.

Models are often helpful in this process. When you developed a picture, or conceptual diagram, of your watershed’s processes and influences, you were modeling, even if the picture was only in your head. A model in watershed or environmental assessment is a scaled representation of a system, just as a model boat is a scaled model of a real boat. The term “model” covers a lot of conceptual and computational territory. You could model using only mental processes, or you could rely on a physical model intended to represent a system, such as a watershed. There are many types of models. The main four are: a) conceptual, b) verbal, c) mathematical, and d) physical or mechanical. Conceptual models are pictures of how a particular system works, which often get put into a diagram (Chapter 2 of the Manual). Verbal models are narrative explanations of systems.

Mathematical models are equations or series of equations that describe rate processes (amount of something over unit time) or relationships among processes. Physical models are based on measured rules driving a system and data from the system and are intended to represent the system. Physical models must be calibrated using data that accurately describe existing conditions. Following calibration, and periodically throughout their useful life, models must be verified by demonstrating that they accurately predict existing conditions based on background data.

One part of demystifying modeling is explaining its limitations. Probably one of the best rules for any kind of modeling is “garbage in, garbage out.” This means that a model is only as good as the modeler’s knowledge of the system used to construct the model and the data supplied to run the model. A system where there is very little overall understanding of function and not much data available is not a good candidate for computer modeling. However, if it is similar in some ways to nearby systems, then you may be able to develop a conceptual model sketch for it. Models also can be perceived as “black boxes,” where the assumptions made are hidden from the viewers. This can inhibit public trust or confidence in the results.

A model is:

- A representation of a system
- Based on understanding the types and magnitudes of relationships
- Done mentally, visually, or with computers
- An aid for evaluation and decision-making
- Dependent on the quality of inputs

A model is not:

- A replacement for understanding a system
- Independent of experts

- A substitute for good science and field work
- The answer

With this perspective in mind, there are a number of approaches you can take to analyze your data and understand the cause-and-effect relationships at work in your watershed. They range from mental team integration to simple and complex mathematical models.

Regardless of the model or approach used, the overall goal is to identify the link between the adverse effects and their causes. Being able to attribute a cause to an effect is one of the major values of doing an assessment. It also can be quite difficult. As noted above, historical, hidden, or multiple factors can be involved as causes of a problem. Be careful in making assumptions about cause and effect, even when they might seem obvious: streambank erosion caused most of the sedimentation, housing development caused more frequent flooding, or log jams blocked fish passage. Your data might show instead that roads caused most of the sedimentation, channel aggradation (from sedimentation due to multiple causes) increased flooding, and culverts blocked fish passage much more often than log jams.

Option 1. Team Mental Integration: Weighing the Evidence

Most watershed assessments involve convening a team of experts from several disciplines to discuss the data collected and conclusions reached. The team mental integration method is really nothing more than the assessment team and appropriate experts systematically reviewing the data and, using their best professional judgment, assessing the impacts of various alterations in the watershed on the ecological endpoints on which the assessment focuses. In many watersheds, a collection of true experts about the watershed may provide more detailed and accurate knowledge about influential processes than

the best computer model. This may be partly due to the absence of adequate data, partly due to the lack of a model that truly represents the system, and partly because expert knowledge is still pretty good compared to modeling. Watershed processes are complex, and all models contain simplifying assumptions, some of which may preclude investigation of relevant issues.

Fortunately, there are some guidelines that can be used to help guide this process. The U.S. EPA has developed guidance on methods for identifying cause and effect (U.S. EPA Stressor Identification Guidelines, 2000; posted at: <http://www.epa.gov/ost/biocriteria/stressors/stressorid/pdf>). This document reviews various methods, based on scientifically valid principles, for identifying causal relationships. The approach EPA recommends is based on the weight-of-evidence, i.e., the greater the number of factors that support a relationship, the more confidence you have that the relationship is real.

On the other hand, the team mental integration approach has certain limitations. There is not a single, widely-accepted approach for evaluating the weight of the evidence for an assessment. Also, it may be difficult to ascertain whether team members have sufficient knowledge to thoughtfully interpret the data. If your team does not have the right qualifications, the insight gained from integrating their knowledge and information will be limited. Competency is best measured by assessing the amount of formal training in one or more scientific disciplines, field experience, the amount of time spent understanding the watershed or watersheds like it, and the ability to see watershed functioning from more than one perspective.

The suggestions in the following list address some of the potential benefits and pitfalls of the expert team integration approach:

- Record whatever approach you use in a way that will allow a reader of your assessment, or a future assessor, to understand exactly what you did. This means describing both the details of the data considered and the analyses chosen and rejected, as well as providing a summary of the approach your team took.
- The composition of your team determines the quality of your assessment. Include team members' qualifications, experience, and training as part of the assessment so readers can assess for themselves how much confidence to put in the conclusions drawn.
- Comparing professional judgment can be done in various ways, with the most common (and possibly easiest) being to turn each set of information into rank values, using the criteria for establishing cause-and-effect relationships.
- Because you will rarely get a group of experts together again to discuss your watershed, take advantage of the opportunity and make sure they stretch their brains. Encourage them to think about novel ways that data and knowledge about individual processes can be brought together. Record the full spectrum of information, from speculation with little data to sturdy conclusions based on a lot of data, analysis, and expertise.
- Find ways to express professional judgment graphically so people can see what the experts are thinking. This will help make your analysis understandable to a wider audience.
- Promote diversity in your team by including members from a wide range of disciplines, backgrounds, ages, and organizational origins. This is bound to lead to critical questions, a range of approaches, and interesting discussions.

Remember that at some point, your team must produce an integrated assessment.

Your watershed assessment will not be complete if it consists of a series of chapters that have no obvious connection to each other and no actual integration step for the information gathered and the knowledge gained. It might help to have a group of authors who can write effectively together, or a single author who can pull all the parts together and have the product checked by the rest of the team.

Option 2. Use Statistics

You might wonder how statistics relates to identifying cause-and-effect relationships. Statistics can help identify associations, the magnitude of differences and other patterns. However, statistics alone cannot determine causation from observational data. The correlation between two factors does not necessarily mean that one caused the other. An excellent example of this pitfall can be seen with the story of *Pfiesteria*, the dinoflagellate (algae) whose toxin is thought to be responsible for killing thousands of fish on the East Coast of the U.S. Dead fish and *Pfiesteria* have often been detected in the Chesapeake Bay at the same time – they are highly correlated with each other. Many people assume that the toxin produced by *Pfiesteria* is the cause of the fish kills. But there could also be another factor that both causes blooms of *Pfiesteria* and kills the fish. Correlation does not necessarily mean causation. The same principle applies to watershed assessment.

Looking for significant correlations (e.g., regression analysis, r-squared) between various factors (such as percent of impervious surface vs. peak flows, or population vs. average annual flood) with available data in your watershed could be performed by following the methods described in user-friendly books based on watershed research (e.g., Leopold 1994; Gordon et al. 1992; Center for Watershed Protection 1998). However, a sound statistical approach can be difficult to apply in a non-research setting due to lack of controls and inadequate data, funding, or

resources. If the analysis you perform is inconclusive or the uncertainty too great, reevaluate your procedures and your available data.

Quite often, sample sizes are just too small to provide definitive answers. In such cases, if there is no clear alternative means of analysis, don't be afraid to admit that you don't know or that you are unsure or that there is a lot of uncertainty. It is quite common to have an indefinite outcome from analysis of environmental data sets where tight experimental control is not feasible or cost-effective. Don't let it bother you; just be honest about the limits of the data and analysis and carefully qualify any conclusions you develop.

Option 3. Relative Risk Model

The relative risk model (RRM) is another method for analyzing watershed data. The RRM is a simple mathematical method for ranking stressors and altered conditions in a watershed and the likelihood that they are associated with adverse impacts. It is a useful tool for prioritizing which factors appear to pose the greatest risk to the ecological endpoints of interest. Most of the process for conducting a relative risk assessment follows the suggested steps for any type of environmental assessment, including what has been outlined in this Guide.

The RRM relies on identifying key stressors or altered processes in the conceptual model. Data related to these factors is compared to data on reference conditions, as previously described. The integrative aspect of the RRM is that stressors and sources of stress (land use/human activities) can be prioritized based on their relative rank. To assign ranks:

- Each stressor (altered process or condition) is assigned a rank based on the difference between the observed value (your watershed data) and the

threshold above which an unacceptable effect is likely to occur.

- Risk is calculated by comparing ranks for all stressors. The assumption here is that stressors with the highest ranks are more likely than others to be linked to the adverse effects.

The result of this analysis is a ranking of the types of human activities that are likely to be linked to the harmful impacts and/or a list of stressors likely to be linked to these impacts. This model does not prove cause and effect, but suggests tenable hypotheses about likely causes and effects. In most cases, follow up studies are needed to obtain more definitive data. However, the value of using the RRM is that it focuses efforts on scientifically credible hypotheses that can lead to improved decision-making and management activities.

Option 4. Knowledge-base Models: Ecosystem Management Decision Support

One process for evaluating watershed condition involves using a new modeling approach designed both to reflect inexact knowledge about natural processes and to be based upon expert knowledge of a system. This approach is embodied in the software tool "Ecosystem Management Decision-Support (EMDS). EMDS has been used in the North Coast Watershed Assessment Program (NCWAP) to evaluate restoration potential for salmon habitat in several North Coast watersheds, to evaluate watershed condition and risk to that condition in the Yuba River watershed (<http://snepmaps.des.ucdavis.edu/snner/yuba/StateYubaLands.pdf>) and to prioritize restoration sites for mercury remediation in the Sacramento River basin (http://www.sacriver.org/subcommittees/dtmc/documents/DTMC_MSP_App5.pdf).

The EMDS model is a computer-based model that can be used to compare the observed conditions to reference values for a variety of watershed components and

processes in order to assess the present conditions. EMDS is an integrative approach to assessment, in that it combines data about a place or concern. Because of this, the product can be one form of watershed condition assessment. At the same time, imperfections in data knowledge about aspects of the watershed processes and features will be reflected in the certainty of the assessment. This is true of any model.

The Manual (Chapter 6) provides more details on using EMDS. Review these descriptions carefully before deciding to use either of these methods. Consulting with someone familiar with its use would be worth the investment of time. Other models are also available for data analysis, the Manual reviews some of these.

Option 5. Assessing Cumulative Watershed Effects

Cumulative watershed effects (CWE) or impacts, refers to two or more individual effects that, when combined together, make a significant, usually adverse change to some biological population, water quality, or other valued environmental attributes, or that compound or increase other environmental effects (CEQA Guidelines, Section 14 CCR 15355). Considering how the effects of human activities may combine to have greater consequences than the individual effects is central to the watershed approach. Thinking about processes and impacts in the watershed context usually involves combining individual, seemingly isolated events. Evaluating CWE typically involves assessing the impacts that might occur in the *future* as a consequence of certain human activities or changes in land use. This contrasts with the previously described methods, which focus on analyzing present conditions that are the consequences of *past* activities. Following are a few examples of different approaches you might consider if you want to analyze cumulative watershed effects.

Example 1: Equivalent Roaded Areas analysis for forested watershed

One of the most common approaches to evaluating cumulative watershed effects with respect to logging is the Equivalent Roaded Area (ERA) procedure. The ERA method was developed for and has been widely applied to national forests in California.

The original ERA concept focused on channel destabilization in relation to increased peak flows caused by soil compaction. Accordingly, it used area covered by roads (thoroughly compacted surfaces) as an index of watershed disturbance. Other types of impacts were expressed as some equivalent to a road.

For example, one acre of fresh clear-cut might be equivalent to 0.3 acres of road; one acre of five-year-old clear-cut might be equivalent to 0.1 acres of road; and one acre of one-year-old 50% selection logging might be equivalent to 0.1 acres of road. These coefficients are highly subjective and site-dependent. The coefficients are multiplied by the area in the corresponding disturbance type (e.g., clear cut), and those products are added together. The resulting sum is the Equivalent Roaded Area. The ERA is usually divided by the watershed area to obtain a percentage of the watershed disturbed compared to the equivalent of a road (%ERA). In many applications, this percentage is compared to another percentage called the Threshold of Concern, an index of watershed's sensitivity to disturbance. The threshold is compared to the %ERA to aid in judging whether the watershed can handle further disturbance or is in need of rest and restoration. Despite the subjectivity and uncertainty in the values, the ERA method has proven to be a useful accounting procedure for watershed disturbance.

Example 2: Relative Risk Model

The relative risk model can also be used to anticipate the potential effects of alterations in land use. An evaluation scheme is developed for each land use/human activity, stressor, and habitat that allows the calculation of relative risk to the ecological endpoints. A rank, such as 0, 2, 4, and 6, is assigned to each land use based on the areal extent (acreage) of: 1) each land use that contributes potential physical, chemical, or biological stressors; and 2) each habitat type. The underlying assumption of this approach is that the greater the extent of sources of stress, the more likely they are linked to or will cause an adverse effect.

The relative risk is calculated using a simple mathematical model that considers the areal extent of each land use and habitat. Those land uses that have higher ranks than others are assumed to be more likely causes of the adverse effects. Like the ERA, this approach has a high degree of uncertainty because many fine-scale details are not factored into the analysis.

Limitations of Data Integration Methods*Caveat #1: Data integration might not be the best route*

Some watershed experts interviewed during the development of the Manual argued against the integration of watershed data. Their position was based on the fact that frequently the functioning of many natural systems in California is poorly understood and the data and knowledge available to most assessors doing the integrating are inadequate. They also believed that by doing a good job of investigating individual processes in a watershed, the typical assessor and group or agency would find out enough to make good decisions about management and restoration. By pursuing an integrative component, the assessor may get in too deep and waste resources producing a useless product. The argument

against integrating has merit and deserves acknowledgement.

Here are several suggestions for deciding whether or not to integrate information when describing watershed condition:

- 1) If you decide to perform information integration, do so carefully and consult with someone who is knowledgeable about its use, if possible.
- 2) Integrate only if you have adequate information about the component systems and knowledge about how they interact with each other.

Caveat #2: Consider uncertainty of your results

Uncertainty is a given in the use of environmental data. Sometimes important decision-making is paralyzed by the extent of uncertainty and sometimes, poor decisions are made despite high levels of uncertainty. It is critical that you describe uncertainty in your assessment, both in terms of the data quality and the analysis or use of the data. There are ways of measuring uncertainty and ways to buffer decisions and programs against the negative impacts of uncertainty (e.g., use adaptive management). One example is given below of an approach to assess the impacts of particular types of data on model output.

Sensitivity analysis is a technique that helps us better understand how models work and, hence, how we should go about using them. Sensitivity analysis involves changing the input parameters of a model over a reasonable range and examining how this change affects the model outputs, i.e., how “sensitive” the model outputs are to the model inputs. By clarifying how the model outputs respond to changes in the inputs, sensitivity analysis can help us better understand the level of confidence we should have in the model. With information derived from sensitivity analysis, we can better consider which parameters in the model have the greatest influence on the

CHECKLIST FOR STEP 5: Identify the Influences on Condition: Data Integration and Synthesis

- Choose an integration approach(es)
- Consider team mental integration
- Consider using statistical models and tools
- Consider using a relative risk model
- Consider using a knowledge-base approach
- Consider assessing cumulative effects

model outputs. If we are uncertain about the magnitude, or sign of the coefficient, for a model parameter, and the model is relatively sensitive to that parameter, it may be worth taking steps to reduce that uncertainty, e.g., through additional research. The more sensitive a model is for a given parameter, the more concerned we should be with the quality (accuracy and variability) of the data we have for the independent variable associated with that parameter. If the model is highly sensitive for a parameter, and the quality of the input data for the associated independent variable is poor, it might be worth investing more money or effort into improving the quality of the input data.

Sensitivity analysis can be applied to conceptual model approaches, as well as to computer-intensive quantitative models. If your watershed assessment does not involve computer modeling, you can still conduct the same exercise of iteratively leaving out certain types of information (e.g., intensive land use) from your conceptual model and seeing how that impacts your condition assessment. You may find that certain processes have greater potential impact on your findings than others. You can then determine whether data quality is high for the processes that have the greatest impact on your condition assessment.

Step 6: Prepare an Assessment Report (Chapter 7, CWAM)

A critical component of watershed assessment is describing how you conducted the assessment, what you found out, and how people can use the information to help them with decision-making.

A. Watershed Assessment Report

The Manual defines a watershed assessment report as: “a *report documenting the findings of the watershed assessment process.*” There are several primary components to a well-written report:

- Concise and accurate descriptions
- Use of structural elements like sub-sections, pull-out boxes, appendices and indexing
- Visuals (photos, maps, charts)
- Clear distinctions between how you did something, what you found, and what it means

The report can be published in a variety of ways:

- On a CD with hyperlinks to relevant material on the CD and the Internet
- Online, with links to other online resources

- In hard-copy, which in some ways feels more tangible

With electronic publication, consider associating the watershed assessment report with maps and other data types on the same Web site. Maps can be served using Internet map server software. Data can be shared as stand-alone tables for download, or as an online searchable database. Photographs of parts of the watershed or issues of concern can be linked from a map or from the report itself.

B. Report Evaluation

It is a good idea to build product review into your schedule and budget. Decision-makers and others using the product may have more confidence in it if it has gone through review. The outline or framework for the assessment, an interim draft report, and the final draft report can all be peer or expert reviewed.

Some evaluation criteria that can be used for this process are:

- The flow from assessment questions through data collection and analysis to findings and recommendations makes sense and is explicit.
- Data are presented clearly and analysis methods are described.
- Conclusions are based on scientific and statistically valid approaches.

C. Make Recommendations

Many watershed assessments make recommendations for particular restoration, management, policy, or monitoring actions that could or should be taken in a watershed. We recommend that you keep most action-oriented recommendations in a watershed plan (e.g., a watershed management plan).

Here are examples categories that the Manual team considers appropriate for assessment recommendations:

- How to deal with data or knowledge gaps
- What assessment findings can be linked to elements in a watershed management plan
- How the assessment could inform future watershed decision-making

Here are examples of recommendations that fit well in a watershed plan:

- Certain restoration actions in specific sub-watersheds would benefit watershed function.
- Changing specific land and water management policies and implementation would benefit watershed function and condition.
- Prioritized actions and places for action
- Description of the relative benefits of carrying out specific management and land/water use actions for watershed function and condition.

D. Use in Decision Making

A watershed assessment that is not used in decision-making has lost an important function. The type of decision may range from “more needs to be learned about the system” to “land use designation or pollutant discharge must be tied to watershed impacts.” Decisions may be combined as planned actions in a watershed management plan, or occur separately in different decision-making venues (e.g., local government). There are many types of decisions that can be informed by watershed assessments; here are a few:

1) Restoration planning, from action at a single site to changes in permitted land-use within a watershed, is best done in the context of watershed assessment. Natural and human processes will affect the efficacy of the restoration action and should be

taken into account by the restoration planner. In turn, a watershed assessment intended to support restoration planning should make explicit connections between watershed processes and/or sub-watershed condition and potential restoration actions.

2) Regulation of human activities on the landscape or in waterways is a critical part of environmental management. Regulation of these activities should be informed by watershed assessment when the activities can cause watershed-wide impacts or originate from large portions of a watershed (e.g., non-point source pollution). Examples include: permitted discharges from point sources, permitted discharges from diffuse sources (e.g., under an agricultural discharge waiver), timber harvest plans, housing development, parcel subdivision and zoning, road or highway construction or enlargement, water diversion and storage, public lands grazing or logging, and channel or floodplain modification.

3) Land use planning is carried out by local agencies in California and affects how and where we impact the environment. General plans, zoning ordinances, and parcel subdivisions are important land-use decisions that could be informed by watershed assessment. General plans describe how much new development is desired and where it will be placed in a city or county, and therefore in a watershed. Zoning decisions show what kinds of development – industrial, commercial, residential, agricultural – are permitted in specific areas and thus in sub-watersheds. Subdivision of parcels by landowners, which must be approved by local governments, affects future development patterns (including roads, water delivery, and

sewage treatment). Aspects of watershed assessment, such as water quality analysis, erosion modeling, and habitat degradation, are useful to inform the where and how much of land-use decisions.

4) Water management is a fundamental driver of condition in many watersheds. Water may be stored, diverted, or pumped from underground. How much of it is moved around, when it is moved, and where it ends up can all affect the health of waterways. As California's population grows and increases pressure on surface and ground water supplies and as climate change increases the chance of dramatic shifts in weather and the need for science-based water management increase. Watershed assessment can inform water management by describing the natural volumes and timing of flows, showing locations of current and restorable aquatic habitat, and making the links between surface and sub-surface water quality and quantity.

5) Monitoring of watershed conditions should both inform and be informed by watershed assessment. Monitoring programs can be designed, or modified based on the findings in a watershed assessment. Monitoring can be allocated to sub-watersheds already under pressure, or at risk of future pressure from human activities. The type of monitoring occurring (e.g., water quality, aquatic biology, geomorphology) should be dictated both by what you find in your assessment and what remained as questions about watershed functioning. The location of sample sites, the sampling frequency, the parameters chosen, and the way the data is analyzed can all be informed by your watershed assessment.

CHECKLIST FOR STEP 6: Write the Watershed Assessment Report

- Outline the report and its key elements
- Choose form(s) of publication (e.g., CD, Web site)
- Get outside review of the outline, draft, and final report
- Make recommendations within the report
- Describe the use of the assessment and report in decision-making

RULES OF THUMB FOR ASSESSING A WATERSHED

DEVELOP your watershed assessment to:

- Answer fundamental questions—let the problem drive the assessment
- Address the cause and not the just the symptoms of your watershed's problems
- Understand **why** the current watershed condition seems to be the way it is
- Interpret the physical, biological, and social interconnections within the watershed
- Be useful for later decisions and actions

CLARIFY the:

- Purpose of the assessment—Who wants it and why? Who will use it?
- Structure of who will be involved and what their roles will be
- Decision making—Who are the decision-makers? How are decisions made?
- Recording of the process—Who, how, when, where?
- Best options that will meet your needs
- Reasonable expectations of the assessment product
- Watershed boundaries you will be using

FOCUS on:

- Your most critical or key issues, so the product is useful and not too general
- Effects and processes occurring within your watershed boundaries
- Using consensus effectively in your partnership group
- Keeping costs under control and meeting timelines
- Working with the public through two-way communications
- Satisfying and helping the ultimate users of the assessment



Kristen Dorsey, Grade 11, courtesy of the California Coastal Commission, 2004 Coastal Art & Poetry Contest