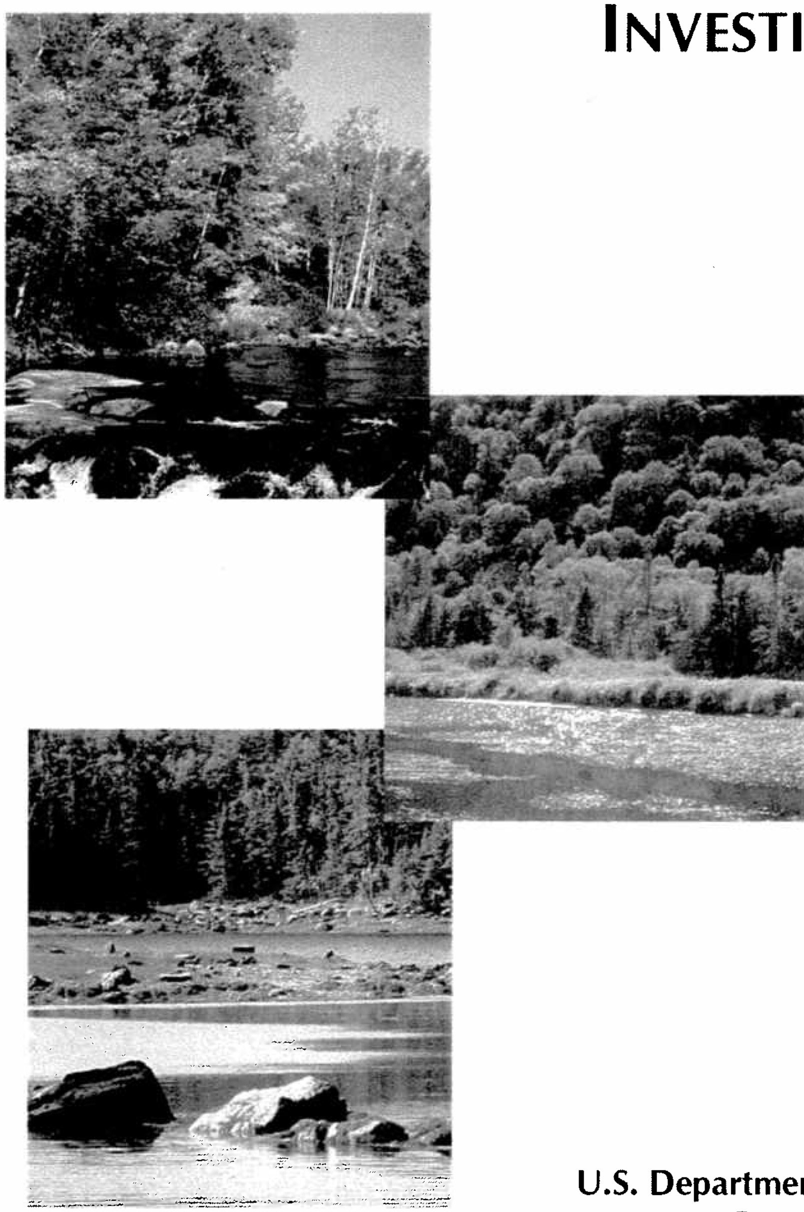
TECHNICAL GUIDELINES FOR WATER QUALITY INVESTIGATIONS



U.S. Department of the Interior
Bureau of Reclamation

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ACRONYMS AND ABBREVIATIONS

BLM	Bureau of Land Management
BMPs	Best Management Practices
CCCs	Criterion Continuous Concentrations
CMCs	Criteria Maximum Concentrations
DO	dissolved oxygen
DQOs	Data Quality Objectives
EA	environmental assessment
EC	electrical conductivity
EIR	environmental impact report
EIS	environmental impact statement
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
FWS	Fish and Wildlife Service
IRIS	Integrated Risk Information System
MCLGs	maximum contaminant level goals
MCLs	maximum contaminant levels
meq/L	milliequivalents per liter
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRCS	Natural Resources Conservation Resources
NTU	nephelometric turbidity unit
QAP	quality assurance plan
QAPP	Quality Assurance Project Plan
QA/QC	Quality assurance/quality control
QMP	Quality (Assurance) Management Plan
Reclamation	Bureau of Reclamation
SAP	Sampling and Analysis Plan
SAR	sodium adsorption ratio
TDS	total dissolved solids
TMDL	total maximum daily load
TOC	total organic carbon
UIC	Underground Injection Control
USFS	United States Forest Service
USGS	United States Geological Survey

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CHAPTER I

INTRODUCTION

These guidelines were developed to assist the Bureau of Reclamation (Reclamation) employees responsible for resource management in meeting national water quality goals and implementation of water quality aspects of Reclamation's strategic plan. The strategic plan has three mission goals. Mission Goal 1 is: "Manage, develop, and protect water and related resources to meet the needs of current and future generations." To meet commitments under Mission Goal 1, Reclamation plans, develops, and completes water projects that increase availability and improve the efficient use of limited water supplies, including reclaimed water and other low quality water. Reclamation manages and protects water resources by managing stored water to maintain or improve water quality, implement conservation practices, and improve water use efficiency to assure water is available and usable for agricultural, municipal, industrial, rural, hydropower, tribal, recreational, and fish and wildlife purposes.

Mission Goal 2 is: "Operate, maintain, and rehabilitate facilities safely, reliability, and efficiently to provide project benefits." Under Mission Goal 2, Reclamation conducts oversight reviews and planning to implement timely replacements, upgrades, or modifications to assure safe and efficient operation to continue providing project benefits for agriculture, power, municipal and industrial, recreation, fish and wildlife, and flood control. By ensuring that Reclamation facilities are safe, cost-effective, and reliable, they can best be operated to provide project benefits while protecting public health and safety and providing timely and economical services to customers while sustaining environmental values.

Mission Goal 3 is: "Advance Reclamation's Organizational Effectiveness." Under Mission Goal 3, benefits to water quality would be through the maintenance and recruitment of additional staff with water quality expertise to meet identified priorities related to water quality.

To effectively implement the Strategic Plan, effective planning and investigation, including a water quality component, is required. These guidelines are designed to help Reclamation's managers and planners give water quality concerns proper emphasis. The strategic plan goals that support water quality are based on the Clean Water and Safe Drinking Water Acts. The Clean Water Act (CWA) is implemented by the Environmental Protection Agency (EPA) and State agencies approved by EPA. The implementing agencies set stream and lake water quality standards and goals based on criteria provided by EPA. Reclamation and other Federal agencies are required to meet these standards in their day-to-day activities. The CWA goals are to maintain and/or improve water quality at a level that will maintain "fishable and swimable" conditions in the Nation's rivers and lakes.

The Safe Drinking Water Act (SDWA) was established to assure that water providers would supply water that maintains the health of water users. As Reclamation project water is converted from the more traditional agricultural uses to drinking water, meeting the requirements of this act becomes more important. Reclamation must meet the SDWA requirements for water supplies at facilities, visitor centers, and recreation areas that meet the minimum service requirements. Application of the SDWA to drinking water supplies requires specific levels of treatment for ground and surface water sources. In certain instances, a drinking water source may implement protection activities to prevent contamination of the supply and can limit some activities in the source area.

These guidelines can be used by Reclamation staff to guide them in obtaining usable water quality data from available data sources, collection of additional water quality data as needed to determine if water quality requirements are met for specific water uses, analysis of water quality data to predict project impacts, determine environmental impacts of project alternatives, and predict water quality changes due to changes in project operation. These guidelines also provide general information on available water quality models that can be used to predict water quality changes in streams and reservoirs from project implementation and/or modification. The study purpose and needs statements are developed and used to define the water quality concerns and objectives, identify expected water quality impacts that may occur, and determine the water quality data needed to accomplish the required analysis. Data quality objectives should be tied to the project purpose and will depend on what water quality questions need to be answered. Collection of additional water quality data should be based on available data and whether it can be used to satisfy project water quality concerns. If the concerns cannot be answered adequately, then a data collection plan must be developed and implemented. The level of water quality detail and range of analysis should be tailored to study purposes, objectives, and the complexity of identified water quality issues or concerns. The sensitivity of the identified water quality issues will influence the amount of data needed, the level of data quality control, and the list of water quality parameters for analysis.

CHAPTER II

BASIC TYPES OR LEVELS OF INVESTIGATIONS

Reclamation has developed directives and standards for several levels of project investigations. A different level of detail for water quality analysis is usually required for each level of study. The project investigations can range from appraisal, feasibility, and special studies. Typically, each level of investigation requires different amounts of water quality data to accomplish the required analysis. Feasibility studies and studies that require water quality modeling or quality impact determination analysis frequently require the collection of additional data specific to the identified water quality problem.

A. APPRAISAL STUDIES

Appraisal studies primarily utilize existing water quality data to determine the nature of the water quality and how it relates to the project problems and needs. Appraisal studies include a preliminary assessment of alternatives and a recommendation to either proceed to a feasibility investigation which includes development of a draft feasibility study plan or terminating the study.

In determining potential impacts of the alternatives, identify potential water quality changes and estimate the potential project impacts. State stream water quality standards can sometimes be used in the determination if the standard meets project purposes. If the project is expected to cause adverse quality impacts, especially if the water quality standards are likely to be exceeded with project implementation, actual water quality data is usually required. It is better to have actual data that covers the parameters needed to determine water usability and the potential of the project to exceed stream water quality standards. Through an examination and analysis of existing water quality data, answers to the following project related questions are usually developed:

- What water quality data are available?
- Are the data adequate to complete the necessary analysis as outlined below to determine if the source is of adequate quality for the project use, to estimate project impacts, and to identify potential water quality problems in the watershed? If no data exists, data collection may be required before water quality issues are resolved. A possible exception to data collection is to use data from a similar nearby watershed. However, a water quality data collection program would still be needed if the project goes to the feasibility level of investigation.
- Can a determination be made of water quality conditions in the proposed project water supply to assure water quality standards or criteria that apply for project uses will be met?
- Do water quality problems exist in the basin for other water uses? This can sometimes be determined from State 303(d) listings and other available data and water use information.

- Will the project water use cause quality problems for other water uses? This would be determined based on expected project water quality changes or impacts.
- If the data are not adequate, what additional water quality data are needed to complete the require project analysis and determinations? The identification of additional data needed to complete a feasibility study and a data collection plan for the feasibility study would be developed. It may be that significant amounts of additional water quality data would need to be collected prior to the initiation of the recommended feasibility study.

B. Feasibility Level Investigations

Typically, feasibility level studies follow the completion of appraisal studies generating sufficient interest so that a more detailed look at alternatives is warranted and a need or desire to seek congressional authorization for the project exists. A feasibility study includes the following determinations:

- Is there sufficient water available to meet project requirements?
- Is the quality of the potential water sources adequate to support the proposed use?
- How will the water quality of the area be impacted by the project?

This level of study often requires collection of additional water quality data to better quantify current water quality conditions and to adequately quantify any expected water quality changes due to each alternative. Meeting stream water quality standards is an important aspect of the alternatives analysis. Additional water quality data may be needed to determine what water quality mitigation might be required for project implementation if negative environmental impacts occur. The feasibility investigation usually will develop an array of alternatives that meets all, or most, of the project goals. A determination also will be made to determine if the project is economically and environmentally feasible. Feasibility studies are normally integrated with and provide project National Environmental Policy Act (NEPA) compliance. Water quality investigations are generally required to accomplish this level of project planning. The water quality activities that are usually performed in feasibility investigations are summarized below.

New water quality data collected between the appraisal level and feasibility studies are reviewed to insure that the data are valid statistically, temporally, and spatially.

Evaluation and analysis of the water quality data are presented in a way that can be understood by management and others to determine if water quality impacts must be mitigated.

The locations of possible project impacts are identified through the analysis of the water quality data and the project configuration. Plans are developed for the impacted areas that would result in reducing the pollutant loadings to the stream and assuring that the established stream standards will be met. Water quality mitigation solutions are identified for each alternative, as needed, to correct any identified water quality problems.

Typically, an environmental impact statement (EIS)/environmental impact report (EIR) or environmental assessment (EA) is required in conjunction with feasibility level investigations. The water quality impacts and benefits for each alternative are compared to the current water quality conditions. Current conditions usually define the no action alternative. If it is determined that significant adverse environmental impacts are expected to result from the project, mitigation measures probably will be necessary to mitigate the adverse impacts of project implementation.

C. Special Studies

Special studies address activities that are required for responsible resource management decisions; however, these studies sometimes lead to Federal actions requiring subsequent EIS/EA analysis and/or additional authorizations by the Congress. The measures usually address specific problems that have been identified and may be at the request and assistance of non-Federal partners. Reclamation, as a participant, has the obligation to explore the Federal role in the study. For Reclamation to participate in special studies, a Federal interest or responsibility must be demonstrated.

The identified water quality issues that require a special water quality study can be diverse and involve reservoir operations, changing quality of reservoir inflows, and/or more restrictive water quality standards. These special studies address what needs to be done to correct or mitigate the identified water quality problem. If the water quality analysis cannot be completed with existing data, then additional water quality data, specific to the issues, must be collected. The water quality analysis may be straight forward or complex, often requiring the use of complex water quality models.

1. Ground Water/Surface Water Studies

Special studies involving ground water only or conjunctive use studies of surface water and ground water are common. When performing special ground water studies, Reclamation's *Ground Water Manual* can be used as a guide. The manual provides information on the analysis necessary to determine the quantity of water available and the yield potential of an aquifer to supply project water. Also, general water quality information is provided in the manual as it relates to water use. Expected project impacts to the existing ground water quality is usually needed and must be projected from soil chemistry and irrigation water quality. These quality aspects are not discussed in the *Ground Water Manual.* Most aquifers in the United States do not have formally established water quality standards, nor is detailed water quality data available unless they been have designated as sole source aquifers for domestic water supplies. The primary water quality protection activity for ground water is in preventative actions that are designed to prevent pollution of the aquifer and protect them as a potential drinking water source. The potential uses of ground water are based on the water quality of the ground water and are determined by the same methods used for surface water. Existing ground water quality data have been collected by the U.S. Geological Survey (USGS) or other local entities for some aquifers. However, ground water quality data is usually limited; and, frequently, water quality samples need to be collected from the aquifer and analyzed to determine acceptability of the ground water source for the proposed use. Usually, this can be accomplished at the same time the potential aquifer yield is determined by collecting water samples for quality analysis. Care must be taken to assure the results represent the aquifer quality.

The primary ground water quality concerns usually relate to use as a drinking water source. The general contaminants of concern include bacterial contamination, nitrates, pesticides and herbicides, industrial chemicals, petroleum products, elevated trace elements, and total dissolved solids (TDS), or salinity. Naturally occurring trace elements that may be present in sufficient concentrations and may be of concern are usually boron, selenium, arsenic, iron, and manganese. Bacterial contamination of ground water originates from improperly designed and operating septic systems, animal waste discharges, and infiltration losses from waste water treatment lagoons. Nitrate contamination can be from septic systems, agricultural and urban fertilizer use, and animal wastes. Typically, industrial chemical pollution occurs from industrial manufacturing water use, waste water disposal, or accidental spills by the manufacturer and in transportation activities. Petroleum pollutants usually originate from leaking storage tanks at service stations, oil wells and refineries, waste water discharges from the refining process, or through accidental spills. Further, any potential pollutant from spills or from waste water discharges, including naturally occurring substances that are readily dissolved in water, can interact with existing surface water resources and may percolate into existing ground water aquifers, possibly resulting in an adverse affect on surface and ground water quality. The potential for contamination from pollution spills and/or waste water discharges need to be prevented and/or minimized in all of Reclamation's activities.

a. Conjunctive Use of Ground Water and Surface Water

Conjunctive use of ground water and surface water usually occurs when one of the potential sources alone cannot provide an adequate water supply to meet the user's needs. However, facilities can be constructed to obtain water supplies from both sources and mixed prior to use. The combined water quantity and quality for the two sources of supply must meet the use quantity needs and be of acceptable quality for the intended use, assuming economical adequate water treatment is possible. If ground water is mixed with surface water or the aquifer is under the direct influence of surface water and will be used for a domestic water supply, the water treatment requirements must follow the surface water treatment regulations of the SDWA. Sometimes, ground water and surface water is blended to meet the required water quality for a specific use, if the most readily available source will not meet the needed quality by itself.

b. Underground Injection Control (UIC) Regulations

Underground Injection Control (UIC) regulations are applied when water or waste water is injected into aquifers or geologic formations through injection wells. EPA regulates the injection of water or waste water into underground formations and ground water aquifers. This includes surface water, agricultural drain water, waste water, or any other water that may be injected for disposal or recharge purposes. Typically, these waters require treatment to drinking water standards prior to injection to prevent contamination of any potential drinking water source. Formal injection of any irrigation return flows and urban drainage probably would have to meet EPA's injection requirements, including obtaining an injection permit prior to proceeding. The injection permit usually requires detailed information on geology and geochemistry in the area where injection will occur, including the location and quality of all ground water (aquifers) that could be impacted. Injected water may not need treating if it can be demonstrated that the injection point is isolated from useable water and would not impact usable ground water.

2. WATER CONSERVATION ISSUES

Irrigated agriculture uses a large amount of water when compared to other types of use, particularly in the arid Western United States. In recent years, considerable attention has been focused on agricultural water conservation. Whenever water is diverted from streams or lakes and is used for any beneficial purpose, the quality of the water is altered in some way, and this includes the use of water for irrigation. Water quantity and water quality benefits have been attributed to water conservation measures. However, water quality changes, due to implementation of water conservation measures to facilitate water use reductions, are dependent upon site specific conditions and can either be positive or negative. Water conservation efforts, which results in less water being diverted for irrigation, may result in increased concentrations of selected water quality parameters of importance in the return flows, albeit at lower flow rates. Conservation could also improve water quality between the diversion point and where the return flow discharges back to the stream by leaving more good quality water in the stream to dilute any pollution inputs between the diversion and the return point. Water quality loads under the implementation of field water conservation measures are usually about the same downstream of the return point. If the conserved water is utilized for other consumptive uses, then the impact to the stream is usually negative with increased concentrations between the diversion point and the return flow point, as well as below the return point, due to reduced flows, because less water would return to the stream with nearly the same pollution load.

Two important points should be understood concerning water conservation in general. The first is that excess water remaining on or below the land surface after the initial use is usually recoverable for subsequent reuse and is not truly lost from the system. In contrast, water lost to the atmosphere by evaporation and transpiration and water that ends up in saline sinks is irrecoverable and is truly lost from the system for reuse. This recovery and reuse of water as it relates to agriculture is termed the reuse of irrigation return flows and occurs extensively in the West. A second point is that reducing recoverable water loss generally saves water locally or on the farm but not for the entire river basin or State. Reducing irrecoverable water loss would truly save water for additional uses. In many river basins, the truly salvageable water may only be 10-15 percent of the total water use.

As has been indicated, implementation of water conservation measures can result in different impacts on in-stream water quality, depending on the site specific conditions. Further, State water laws and how and where conserved water is used have impacts to the in-stream water quality. In order to predict or determine water quality impacts due to water conservation, the hydrology of the project, the stream system, and the eventual use of the conserved water must be fully understood. The following presents a few examples of water conservation.

a. Examples of Water Conservation

An irrigation project improves irrigation efficiency by replacing flood or row irrigation with a more efficient system, such as sprinkler or drip system, resulting in a decrease in the amount of water needed to meet current irrigated acreage demands. Further, assuming that the State water law or water contract doesn't allow irrigation of additional acreage with the conserved water, then the streamflow would increase in the area of the stream between the diversion point and where the irrigation return flows discharge back to the stream. With additional water in the stream, the aquatic habitat would probably improve and the water quality would probably also show some improvement, assuming that pollutant discharges are unchanged in the reach of increased flows. Downstream of where project return flows enter the stream, the water quality improvement could have reduced sediment and maybe nutrients. If sediment traps were already being used on project returned flows, sediment and phosphorus improvement would not be expected. However, the total salt load may not be changed significantly as long as the soil salt balance is maintained in the project.

Assuming the conserved water in the above case is allowed to be used on new or additional lands in the project, then the conserved water would remain in the project and not increase the streamflow or quality below the diversion point. This use of the conserved water would result in increased consumption of diverted water, reduce return flows back to the stream from the irrigated area, and probably increase the salt load in the stream as the salt balance in the irrigated soils is maintained. This use of conserved water could also reduce the streamflow downstream of the project returns due to an increase in the irrigated acreage and associated consumptive use. The irrigation of additional lands would result in an increase in the salt concentration downstream of the project and an increase in other pollutants in the stream due to reduced return flows. A possible benefit could be a reduction of sediment and phosphorus loads in the return flows, but the extent of the benefit would depend on site specific conditions and would have to be evaluated for each project.

Many municipal and industrial users conserve water by using treated waste water to replace or supplement their existing domestic water supply. The treated waste water is usually used on parks, golf courses, and other public grassed areas. Waste water reuse reduces the water being returned to the stream, which can have an adverse impact on the flow levels and the in-stream water quality. The reuse of waste water provides for transfer of the original water supply used on the grassed areas to service the growing municipal demands. Reducing waste water return flows to the stream can result in an increase in pollutant concentrations in the stream downstream from the waste water discharge point due to reduced flows, even though certain total pollutant loads might be reduced. It is possible that other downstream pollutant loads from point and nonpoint sources might show an increase in pollutant concentrations in the stream because of the reduced flows due to waste water reuse. Water conserved through the implementation of water conservation methods by homeowners reduces per capita consumption and would add to the total available domestic water supply for additional users or reduce the overall demand. The reductions in outside watering at individual residences could result in reducing the runoff from urban surface water drainage and in shallow ground water recharge. Typically, TDS concentrations could increase in the ground water and surface drains that receive shallow ground water discharges from lawn drainage.

Water conservation measures can have complex impacts on the water quality of a watershed or river system. A good understanding of the hydrology of the basin, water uses, and how the applied conservation will impact the basin hydrology is needed as well as what impacts water conservation will have on the return flows and existing pollutant loading in the stream system. The implementation of water conservation methods undoubtedly will change the water quality parameter concentration and the quantity of return flows. These impacts should be determined and understood in any decision to implement water conservation measures.

3. Constructed Wetlands

Wetlands can be constructed to improve wildlife habitat and/or water quality of irrigation return flows. The wetlands must be properly designed and located to meet the intended purpose, which usually is to improve water quality and provide wildlife habitat. In some cases, Reclamation may be required to construct wetlands to mitigate adverse impacts of a water resource project development. The purpose of any proposed wetlands project needs to be well defined so that wetlands can be properly designed to provide the needed wetland functions to accomplish the project goals. Long-term operation and maintenance must be accounted for in the wetland design and planning for continued benefits to occur. A firm or dedicated water supply should be committed to each constructed wetland. It is also important to take advantage of existing land forms (gravity flow systems, if possible) in the wetland design to minimize operation and maintenance costs and to assure that the wetlands blend in with the natural environment. Soft sinuous edge designs of wetland are recommended with variable depths created for diversity. Both open water and marsh features are important to wetland diversity and functionality. Additional wetland design information can be found in the wetlands literature.

It is important to consider the watershed when developing a treatment wetland and to define its role in the watershed and the larger regional ecosystem context. Aspects of this role include:

- Potential water quality improvements (chemical, physical, biological, thermal) to the surface and ground water

- Surrounding and upstream land uses
- Location of the wetland in relation to wildlife corridors or flyways
- Potential threats from the introduction of non-native plant or animal species; and local citizens' perception of the appropriateness of the treatment wetland in their watershed

If possible, the wetland project should be planned in the context of any community-based watershed programs.

a. Treatment Wetlands

Treatment wetlands are constructed to improve the quality of waste water (if applicable) and irrigation return flows to assure that in-stream water quality standards are met downstream from the wetlands discharge point. Treatment wetlands should be constructed, when possible, in upland areas away from natural wetlands. The wetland should be similar to natural wetlands of the area by using native species and as natural a transition zone as possible. If sediment removal is part of the objective, the sediment trap or basin should be built upstream of the wetland and physically accessible to equipment for cleanout operations. The wetland design should meet the primary purpose of the wetland for improvement of water quality. The wetlands design should ensure that stagnant water areas are minimized to reduce the potential mosquito habitat. A section 402 permit (National Pollutant Discharge Elimination System [NPDES]) may be required, if the discharge from the wetland will be into a stream or waters of the United States. If the constructed wetland will be in an existing wetland, a section 404 dredge and fill permit from the U.S. Army Corps of Engineers (Corps) will probably be required.

b. Construction of a Wetland for Wildlife Habitat Purposes

Construction of a wetland for wildlife habitat purposes can be built in the flood plain if polluted water is not used and the wildlife usage is controlled so that pollutants are not added to the discharge back to the stream. A 404 permit will be needed for any construction work in the flood plain, and a NPDES permit is typically required to regulate the discharge back to a stream or natural wetland. Native species should be used with an emphasis on species preferences of the target wildlife uses.

c. Construction of Combination Wetlands for Water Treatment and Wildlife Habitat

Construction of combination wetlands for water treatment and wildlife habitat needs to be constructed and placed away from existing wetlands and streams. The components of both types of wetlands need to be included in the design with the treatment process as early as possible, especially the sediment removal. Proper habitat must be built for the targeted wildlife species.

D. Water Quality Modeling

Water quality modeling may be a tool that is needed to fully evaluate environmental impacts related to the project alternatives, changes to existing structures, such as multiple outlets for temperature control, and to determine ways to implement water project operational changes to improve identified water quality problems. An appropriate level of investigation and a proper water quality model should be selected and used to address the water quality problems and where they are expected to occur. The following paragraphs summarize some considerations that will assist in the selection of an appropriate water quality model and the level of investigation.

Determine what the modeling objectives are and what are the water quality issues that must be addressed by the model study. A good understanding of how the pollutants to be modeled behave in the environment is very useful. Are the pollutants conservative? How do they react with other environmental parameters such as temperature, nutrients, sediment, flow rate, other dissolved parameters, and do the pollutants change in time and space (nonconservative)? The complexity of the model needed and the data requirements will depend on the answers to the above questions. Model selection is most effectively accomplished by someone familiar with available water quality models, their data requirements, and the simulation processes used in the model to simulate natural processes needed to represent and predict water quality changes.

The model needs to be able to simulate the basic physical and chemical processes that are occurring in the water resource environment relating to the pollution problems, utilize the available data, and correlate with the environmental conditions of the resource and sources and sinks of the pollutants. The model should be able to simulate how changes in project operations will effect water quality. Specifically, will reducing pollution loading and/or changing project operation result in water quality improvements?

The water quality data must be adequate to meet the needs of the model and be able to define the pollution sources and loadings. Model data must be available to verify and calibrate the model selected for use. Many biological modeling functions require daily and/or hourly simulations. Hourly data is needed when diurnal fluctuations are important in the modeling. Hence, the data time period must support the model time requirements and allow for adequate model verification and calibration. Adverse water quality conditions frequently occur during extreme hydrologic events such as droughts. It is good to have data that covers dry, wet, and average conditions.

Data may need to be collected along the water body to identify where a pollutant is entering. The samples should be obtained at well-mixed sections that are easy to access and are convenient to sample. Sometimes nonpoint pollutant sources can be identified by reviewing the land uses and the type of chemicals used. If the chemicals used and the pollutants in the water body match, then you probably have identified the source of the pollutant. If surface runoff or drains can be found from the land use area, usually a water quality sample will contain elevated pollutant concentrations.

Frequently, additional data will be necessary to adequately support the model and define the pollutant loading sources. Sometimes, data gaps can be filled by regression or correlation methods using existing data or data from similar adjacent watersheds. Reservoir models usually require temperature profiles in the reservoir to assist in model calibration. It also would be useful to have dissolved oxygen (DO), electrical conductivity (EC) and pH profiles. If additional temperature data is needed and collected, other parameters that can be measured in the field should also be collected with the temperature data, such as DO, pH, and EC. In planning the collection of additional water quality data, the timing and frequency of data collection needs to match the model requirements. The modeling of reservoir eutrophication processes is complex and requires significant water quality data and a thorough understanding of the involved physical and chemical processes. It is recommended that an expert in that area be involved in the planning of any additional data collection. Nutrient and algae data are usually required; meteorologic data (radiation, wind speed, temperature and cloud cover), temperature and DO profiles are needed in the reservoir. These data are needed to verify the model in simulating historic conditions before management actions can be simulated.

A partial list of available water quality models is contained in appendix A. The list includes commonly used public domain models. Websites are indicated below where a more extensive list can be found, that includes a more complete description of each model, information on the developer, available documentation, and a current technical contact person. These websites should be useful in obtaining additional water quality model information.

EPA – www.epa.gov/waterscience/wqm/

USGS – smig.usgs.gov/SMIC/

CORPS – www.wes.army.mil/el/elmodels/index.html#wqmodels

CHAPTER III

FACTORS AFFECTING DATA NEEDS OR DATA ANALYSIS

There are many factors that affect water quality data needs. These factors relate to the quality of water needed for each potential use or the water quality standards that have been established for the resource. The amount, timing, quality, comprehensiveness, and use of the data will determine if additional data might be required. Water quality data that reflect the current status of water pollution may need to be collected at appropriate times of the year to adequately define the pollution problems and identify the critical time periods for when these problems occur.

A. DATA SOURCES

Water quality data can be obtained from several sources. Each data source can have limitations depending on the intended purpose of collected data. Some of the limitations are related to time period of collection, the water quality parameters, detection limits, and quality control/quality assurance implemented during the field sample collection, including sample preservation and transporting and laboratory analysis. The project or investigation purpose usually defines the water quality parameters of concern that will be evaluated during water quality related studies. The project purpose needs to be determined prior to initiating a data collection program, unless the data is for general pollution parameter screening.

After defining the project purpose and the water quality parameters of concern or interest, the available data sources can then be investigated to determine the availability of water quality information pertinent to the study. The data sources can be local, State, and Federal agencies. Local sources can be potable drinking water treatment agencies and the data of interest from these sources is the raw or untreated water quality data. Waste water treatment plant effluent water quality data is a good source of pollutant loading/concentration data for conducting total maximum daily loads (TMDLs) and represents a point source to the water body. State agencies that may have water quality data include the Departments of Natural Resources, Departments of Environmental Quality, and Departments of Health. Their data may also be stored in EPA's STORET data system. If the data is not in STORET, it may or may not be available via electronic media. Universities could also have water quality data; however, it will probably be of limited scope and coverage and probably has been collected for specific research purposes.

The two main Federal agencies where water quality data can be obtained is the USGS and EPA. Other agencies that have data specific to their mission are U.S. Forest Service

(USFS), Bureau of Land Management (BLM), National Resources Conservation Service (NRCS), Reclamation, National Park Service (NPS), and Fish and Wildlife Service (FWS). USGS data currently is obtained from the individual State Water Resource Districts of the USGS. More than one office contact may be needed if the watershed is located in more than one State.

B. Methods of Analysis

Water quality data analysis and interpretation are usually tied to streamflow and changes in streamflow. When streamflows are diverted and used for project purposes, the streamflow is usually reduced in downstream portions of the watershed and can result in changes in the water quality. Diversions can reduce the flow available for dilution of existing downstream pollution sources. Return flows from beneficial uses of water usually carry high concentrations of pollutants due to consumptive use and/or additions of pollutants during the use process, which have adverse impacts to the receiving water. The analysis tools and types of data analysis will depend on the expected project impacts and the answers required for proper project evaluation.

Hydrological studies of flow and water quality covering periods of records are commonly used to determine the available water supply and water quality for existing and proposed uses. The studies determine the quantity and quality of water remaining in the stream to support in-stream uses. Adjustments may have to be made to the historic flows and water quality data to account for impacts of development that occurred in the basin after data was collected to extend usable periods of record back in time. The data can also be modified, based on expected project impacts, to better evaluate environmental consequences.

Reviews of inventories of existing streamflow and water quality data are made to determine adequacy of meeting project development requirements and purposes. If existing water quality data is not adequate to determine the applicability for specific uses and determine project environmental impacts, then additional data will need to be acquired. A water quality data collection program must be developed and a determination made if a short-term data collection program will provide adequate data for the project needs and purposes. If not, a longer data collection period will be needed to supply the data, and the detailed data analysis phase will need to be delayed.

Data analysis typically includes statistical analysis of the existing and newly collected water quality data to provide descriptive statistics, regressions relationships, histograms, probability plots, box and whisker plots, and chemical characteristic plots, such as stiff and piper diagrams. The data analysis should describe existing water quality conditions and problems, determine if water treatment is needed prior to use for any identified project water uses, determine how the project might affect the existing water quality, and determine if any mitigation and/or operational constraints will be required by the project.

The water quality data analysis results can be presented in tables and by graphical representations with the data shown spatially and temporally in appropriate plots. The presentation of the data analysis is important to show acceptable project water quality and to indicate possible or probable project water quality and quantity impacts.

Selected analytical tools should be used to develop interrelationships between chemical, physical, hydrological, biological, and geological processes that interact with the project water resource.

For projects that consume water through evaporation and evapotranspiration, the concentration of conservative parameters are important, such as TDS and chloride. Where chemical equilibrium is important—especially between the soils and irrigation water—chemical equilibrium models can be used to assist in the predictions of potential chemical reactions and resulting water quality.

Individual water quality model applications may be required to adequately evaluate project impacts. Information on potential models have been provided earlier in this text. Application of most models will usually require collection of additional site specific data before the water resource can be modeled.

When needed data cannot efficiently be collected to replace missing data, statistical and correlation methods can sometimes be used to fill data gaps. The methods include regression against existing data in the watershed or data from adjacent watersheds with similar geology, environment, and water uses. Sometimes the water quality analysts must reach the required conclusions based on inadequate data and analysis due to limited resources and scheduled completion dates. If this occurs, a data collection plan should be developed and implemented to monitor and evaluate potential project impacts after the project is built and operational.

WATER QUALITY STANDARDS AND CRITERIA

Water quality standards and criteria are used to regulate in-stream water quality and regulate water quality for specific beneficial uses. Standards are enforceable levels of contaminant concentrations that are set to provide general or specific water quality protection. Stream standards are established to protect aquatic biota and other beneficial uses of the water resource such as water contact recreation. Stream standards are established by the regulating authority (usually the State) and are based on the CWA and amendments. Drinking water standards are based on the SDWA and subsequent amendments that are applied to public drinking water supplies. Drinking water standards are applied to the treated water that is supplied to the consumer and are based on an acceptable level of human health risk and the economics of meeting the established standards. Violations of stream standards caused by point sources are enforceable and usually carry enforcement penalties. Point sources of pollution are regulated through the Clean Water Act's NPDES permits. Nonpoint pollution control activities are generally voluntary, and incentives are frequently used to encourage generators of nonpoint source pollution to apply "Best Management Practices"(BMPs) to reduce pollutant discharges to help meet water standards in general watershed area.

Water quality criteria are usually considered to be guidelines for water uses, such as irrigation, and are nonenforceable. Agricultural water use criteria cover irrigation and livestock uses and usually cover a range of concentrations for parameters of interest. The criteria can be established by regulatory authorities or from trade groups or user groups to assure safe economic use of the water.

A. STREAM WATER QUALITY STANDARDS

The original Federal CWA was passed in 1972 and required the States to establish surface water quality standards. Since then, the law has been refined and modified by amendments. Most States have adopted standards as recommended by EPA; however, if a State doesn't establish the appropriate standards, EPA is required step in and establish and enforce standards for the State. A general water quality goal that has been developed is to have fishable and swimable water in our lakes and streams. Fishable means that the water body will support a healthy biological community of fish and other aquatic species. This generally means that there should be a total absence of any toxic substances or that the concentrations are at least below the toxic levels to biota in the water resource. Meeting swimable water quality standards in a lake or stream provides for safe primary water contact recreation where some water ingestion is likely and standards are set to prevent adverse health affects by ingestion. All existing water uses of a water body are considered in establishing enforceable water quality standards. However, sometimes a potential use can be used to establish the specific stream or lake standards.

The water quality standards (links to standards and information where available) can be specific values, that vary based on other constituents in the water such as pH and temperature, or can be expressed in narrative form that describe conditions that should be prevented. Sediment standards are frequently narrative and relate to fish spawning habitat and adequate aquatic insect diversity. Some water uses identify criteria for parameters at recommended levels but are not an official requirement. The boron concentration in irrigation water is an example of this type of criteria, where the recommended boron concentration is 0.75 milligrams per liter (mg/L) in the irrigation water; however, exceeding this criteria could limit the production of sensitivity crops that would suffer production loses. However, some States have established a mandatory standard for boron where irrigation of boron sensitive crops are important in the crop rotation.

EPA has the responsibility to set new stream and drinking water standards and to develop recommended water quality criteria for priority pollutants where standards have not been established. As of December 1998, criteria for 157 priority pollutants have been established based on the authority given to EPA as provided in section 304(a) of the CWA. The stream and lake water quality criteria information can be obtained at the following web site:

http://www.epa.gov/waterscience/standards/wqcriteria.pdf

The web site contains an explanation of the criteria development process and presents a table that lists Criteria Maximum Concentrations (CMCs) and Criterion Continuous Concentrations (CCCs) for both fresh and salt water. CMCs are estimates of the highest concentrations of pollutants in surface water to which aquatic biota can be exposed to on a short time basis without resulting in an adverse effect. This is commonly referred to as the acute exposure concentration level. CCCs are estimates of the highest concentrations of a pollutant in surface water to which aquatic biota can be exposed to on a long-term basis without resulting in an adverse effect. This is commonly referred to as the chronic exposure concentration level.

The above criteria are used to establish surface water quality standards to protect aquatic life and provide for safe primary water contact recreation. These recommended criteria provide guidance for States and tribes in adopting water quality standards under section 303(c) of the CWA. Such standards are used in implementing a number of environmental programs, including setting discharge limits in NPDES permits. Usually, when these standards are met, most other water uses are protected. Occasionally, a parameter will be high enough to cause problems for a specific use, such as boron, for irrigation water use and still not affect aquatic life or recreation. The State can adopt concentration limits for elements, such as boron, and establish it as an enforceable standard or as a recommended water quality criteria. The criteria do not impose legally binding requirements on the water users.

EPA also sets mandatory concentrations on chemicals in the environment under the authority of the Drinking Water Standards. These chemical concentration limits apply to water after treatment and before any beneficial potable use by the public. The drinking water standards are set to protect the public from adverse human health risks due to consumption of drinking water while also taking into account food organisms and chemicals that are consumed with food. The human health risk related to the drinking water standards is primarily based on the carcinogenic and toxic nature of chemicals and pollutants that may result from exposure to these chemicals in the drinking water. Detailed carcinogenic and toxic information can be obtained from EPA's "Integrated Risk Information System" (IRIS) electronic database located at the following web site:

http://www.epa.gov/ngispgm3/iris/

The information in the IRIS database is intended for use in regulating chemicals and pollutants to protect public health through the process of risk assessment and risk management. The database includes detailed information on the health effects and risk for many chemicals and pollutants and includes detailed rational on the toxicity levels and how the CMCs and CCCs were developed.

The SDWA and amendments establish standards in the form of maximum concentrations of chemicals in drinking water that will protect human health upon consumption. These standards are set by EPA as maximum contaminant levels (MCLs). State health or environmental agencies that are charged with drinking water regulation by the State can either adopt the MCL or a value that is more restrictive. However, if State agencies establish standards that allow for higher risk levels than specified by EPA, then EPA is required to step in and establish standards for the State and administer the program. The drinking water standards are enforceable standards being applied to the treated water throughout the distribution system that is used to supply the consumer. An evaluation of source water quality is based on normal treatment costs for typical raw water quality. Usually, the drinking water standards are adequately covered by standards established for aquatic species and primary water contact recreation. The current enforceable drinking water standards can be found at the following web site:

http://www.epa.gov/safewater/mcl.html

The web site contains listings of primary regulation standards for inorganic chemicals, organic chemicals, radio nuclides, microorganisms, and secondary standards. The primary standards are MCLs for each regulated chemical and maximum contaminant level goals (MCLGs) which can be lower than the MCL, or as low as zero. The MCL is the enforceable standard. The listing also presents the potential health effects and possible sources of each pollutant. The secondary standards are guidelines or recommendations and are not legally enforceable.

B. Water Quality for Specific Beneficial Uses

Generally, water resource investigations will include an evaluation of the source water quality compared with the applicable water quality standards or criteria for the specific beneficial water use. The purpose of source water quality investigations is to determine if the water quality of the source water is adequate to meet the needs of the specific project beneficial uses. If the source water quality does not meet the required beneficial use water quality, the investigations should further determine if economical treatment is available or if blending of different water sources (if available) can be accomplished to meet the designated water quality. The water quality needs for the major beneficial uses are summarized below.

1. Agricultural Water

The most restrictive agricultural water use is typically for irrigation. The quality of the water needed is dependent on the soils to be irrigated and the crops to be grown. The main concerns for irrigation water are TDS or EC, sodium adsorption ratio (SAR) or percent sodium, and the boron, chloride, and sulfate concentrations. Early irrigation water classification systems can be summarized into a three class system as was done by Mckee and Wolf, 1963. The classes are defined by the following parameters:

- The total concentration of salts, expressed as mg/L or the EC in microsiemens per centimeter at 25 degress Celsius (°C)
- The percentage of sodium (Na) which is equal to (Na*100) divided by (Na+calcium [Ca]+magnesium [Mg]+potassium [K]) when the cation concentrations are expressed as milliequivalents (meq/L) per liter.
- Specific elements, such as boron, chloride (Cl), and sulfate (SO_4) concentrations, are expressed in mg/L or meq/L.

The classifications are shown in the table 1.

Table 1.—Summary of Classifications for Irrigation Water

Class	Percent Sodium[1,2]	Boron[2] (mg/L)	Chlorides[2] (meq/L)[4]	Sulfates[2] (meq/L)[4]	EC[2,3] (microsiemens/cm)	TDS[2] (mg/L)
I	<30–60	<0.5–1.5	<2–2.5	<4–10	<1,000	<700
II	30–75	0.5–2.0	2–16	4–20	500–3,000	350–2,100
III	>70–75	>1.0–2.0	>6–16	>12–20	>2,500–3,000	>1,750–2,100

[1] The percent Na is based on meq/L of concentration for Na with respect to the total cations concentration made up of Na, Ca, K, and Mg.

[2] The lower range of values relate to sensitive crops and the upper to nonsensitive crops.

[3] The EC is an indirect field estimate ofTDS of water.

[4] One meq/L of chloride and sulfate are equal to 35.4 mg/L and 48.0 mg/L, respectively.

The U.S Department of Agriculture (1954) rates irrigation water based on SAR and EC in *Agriculture Handbook No. 60*, titled "Diagnosis and Improvement of Saline and Alkali Soils," which is covered in detail in chapter 5. The handbook also recommends that the concentration of boron be evaluated for irrigation after the salinity and sodium hazards are evaluated. Generally, water with boron concentrations less than 0.75 mg/L are safe for most crops, except for the most boron sensitive plants.

The Food and Agriculture Organization (FAO) of the United Nations (1985) published *Water Quality for Agriculture* where water quality, as it relates to irrigated agriculture, is discussed. The more important aspects are presented in table 2.

Table 2.—Summary of Water Quality Relationships for Irrigation Water (Modified from FAO's *Water Quality for Agriculture*)

Potential Irrigation Problem	Units	Degree of Restriction in Use		
		None	Slight to Moderate	Severe
Salinity (affects crop water availability)				
EC_W[1]	**dS/m**	< 0.7	0.7–3.0	> 3.0
TDS[1]	**mg/L**	< 450	450–2,000	< 2,000
Infiltration (affects infiltration rate of water into soil)				
SAR = 0 – 3 and EC_W =		< 0.7	0.7–0.2	< 0.2
3 – 6		< 1.2	1.2–0.3	< 0.3
6 – 12		< 1.9	1.9–0.5	< 0.5
12 – 20		< 2.9	2.9–1.3	< 1.3
20 - 40		< 5.0	5.0–2.9	< 2.9
Specific Ion Toxicity (affects sensitive crops)				
Sodium (Na)	meq/L	< 3	3–9	< 9
Chloride (Cl)	meq/L	< 4	4–10	< 10
Boron (B)	mg/L	< 0.7	0.7–3.0	< 3
pH		Normal Range 6.5–8.4		

[1] ECW means electrical conductivity, a measure of the water salinity, reported in decisiemens per meter at 25 °C (dS/m). TDS means total dissolved solids, reported in milligrams per liter.

[2] SAR means sodium adsorption ratio.

The water quality requirements for irrigation further depends on the soil type, its chemical composition, its drainage characteristics, and the crop's sensitivity to specific ion concentration. The information in table 2 is a general guideline and emphasizes the long-term influence of water quality on crop production, soil conditions, and farm management. More detailed relationships can be found in *Agriculture Handbook No. 60* and the FAO publication. If water quality approaches the above values, generally, additional studies would be needed to evaluate project sustainability. Project soil investigations are required to identify toxic trace elements that maybe leached from the soil in the drain water and result in aquatic toxicity. Selenium found in soil derived from marine sediments is a good example.

Few concerns have been raised concerning water quality for livestock and wildlife watering in the United States; however, efforts in South Africa and Australia have provided information concerning livestock water quality issues. Water meeting water quality criteria for irrigation will meet livestock water quality needs. The Australian Department of Agriculture (1954) has determined that different livestock can tolerate different water quality as measured by TDS before adverse impacts are exhibited. Livestock given water with TDS greater than the acceptable levels generally experience reduced lactation and reproduction problems first, which generally is followed by weight loss and, possibly, death. Table 3 contains standards used in western Australia as the maximum TDS concentration without adverse impacts to the livestock. Some trace elements can be toxic and adversely affect livestock. Toxic trace elements should be investigated if a history of toxicity problems have occurred in local livestock.

Table 3.—Livestock Drinking Water Standards Used in Western Australia

Animal	Threshold Salinity Concentration – Adverse Affects	
	Grains per Imperial Gallon	TDS mg/L
Poultry	200	2,860
Pigs	300	4,290
Horse	450	6,435
Cattle, Dairy	500	7,150
Cattle, Beef	700	10,000
Adult Dry Sheep	900	12,900

2. Domestic Water Supply

Drinking water standards have been developed by EPA based on the Safe Drinking Water Act and subsequent amendments. The standards cover physical, chemical, and bacterial quality and are applicable to all public water supplies. Privately developed drinking water supplies that serve individual households are not regulated by EPA under the SDWA; however, it is recommended that the source water supplies be tested for toxic substances and bacteria. As indicated above, it is important to note that the drinking water quality standards don't apply directly to the water source but they apply to the treated water. However, the better the raw water quality is, the easier and more economically it can be treated to the drinking water quality standards. The parameters that are of most concern include bacteria, turbidity, and total organic carbon (TOC). These parameters are frequently not available in water quality data collected by most agencies and may need additional water quality monitoring of these parameters to determine treatment processes required to meet drinking water standards. The drinking water standards require that all surface water sources require, as a minimum, coagulation and filtration water treatment to meet turbidity levels of less than 0.5 nephelometric turbitity unit (NTU) standard to remove the suspended solids and cysts. After coagulation and filtration treatment, the remaining bacteria and viruses are killed with proper disinfection; however, there are chlorine disinfection byproducts formed when chlorine (the typical disinfectant) is used as a disinfectant through the interaction of chlorine and TOC. If the TOC is greater than about 3.5 mg/L, the disinfection byproducts standard may be exceeded. The byproducts are carcinogens that can cause cancer in humans. Activated carbon filters are one method to remove the TOC after coagulation and filtration, or alternate disinfection methods can be utilized that do not form the hazardous byproducts.

A water quality parameter that may require special treatment in ground water supplies is nitrate. The nitrate standard is 10 mg/L when expressed as nitrogen or 45 mg/L when expressed as nitrate nitrogen (NO_3). If the nitrate concentration in the raw water exceeds the standard, treatment for nitrate removal is required to reduce the nitrate concentration below the drinking water standard to insure that the treated water is safe for use, especially by babies, young children, and expectant mothers. The drinking water standards for all regulated water quality parameters can be obtained from the following two EPA web sites:

http://www.epa.gov/safewater/mcl.html
http://www.epa.gov/ost/drinking/standards/dwstandards.pdf

Table 4 contains the primary drinking water standards that must be met by water providers after treatment.

Table 5 presents EPA's secondary standards that are recommendations to the water providers. Secondary standards assist in the selection of water sources when more than one source is available and may indicate the need for specialized treatment, particularly if the TDS and sulfate concentrations are high; however, treatment to concentrations below the secondary standard recommended concentrations is not required.

3. Industrial

Industrial water quality requirements are highly variable and are dependent on the specific industrial entity. The same industry may use water of differing water qualities, depending on how the water is used. It is impossible herein to describe all water quality variations that are needed in industry. As an example, food and beverage industries typically require better than drinking water quality when it is used in the product, while drinking water quality is adequate for other uses. Normally, if a specific industry requires better quality than local drinking water, special treatment would be necessary; and the industry typically accepts the responsibility to provide for this additional treatment on site.

Table 4.—National Primary Drinking Water Standards

EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Acrylamide	TT[8]	Nervous system or blood problems;	Added to water during sewage/wastewater increased risk of cancer treatment	zero
OC	Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
R	Alpha particles	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010 as of 1/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes	0
IOC	Asbestos (fibers >10 micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
OC	Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta particles and photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
D	Chloramines (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes	MRDLG=4[1]

LEGEND

- D — Disinfectant
- DBP — Disinfection Byproduct
- IOC — Inorganic Chemical
- M — Microorganism
- OC — Organic Chemical
- R — Radionuclides

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
D	Chlorine (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG=4[1]
D	Chlorine dioxide (as ClO_2)	MRDL=0.8[1]	Anemia; infants & young children: nervous system effects	Water additive used to control microbes	MRDLG=0.8[1]
DBP	Chlorite	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT[7]; Action Level = 1.3	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	*Cryptosporidium*	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and fecal animal waste	zero
IOC	Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	0.2
OC	2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
OC	Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
OC	1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	zero
OC	o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
OC	p-Dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075
OC	1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	0.007
OC	cis-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	0.07
OC	trans-1,2-Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	0.1
OC	Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories	zero
OC	1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	Di(2-ethylhexyl) adipate	0.4	Weight loss, live problems, or possible reproductive difficulties	Discharge from chemical factories	0.4
OC	Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	zero
OC	Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	0.007
OC	Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	zero
OC	Diquat	0.02	Cataracts	Runoff from herbicide use	0.02
OC	Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	0.1

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Endrin	0.002	Liver problems	Residue of banned insecticide	0.002
OC	Epichlorohydrin	TT[8]	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	zero
OC	Ethylbenzene	0.7	Liver or kidneys problems	Discharge from petroleum refineries	0.7
OC	Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	zero
IOC	Fluoride	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	4.0
M	*Giardia lamblia*	TT3	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	0.7
DBP	Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	zero
OC	Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	zero
M	Heterotrophic plate count (HPC)	TT3	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment	n/a
OC	Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	zero
OC	Hexachlorocyclopentadiene	0.05	Kidney or stomach problems	Discharge from chemical factories	0.05
IOC	Lead	TT[7]; Action Level = 0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	zero
M	*Legionella*	TT3	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	zero
OC	Lindane	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens	0.0002
IOC	Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	0.002
OC	Methoxychlor	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock	0.04
IOC	Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	10
IOC	Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	0.2
OC	Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories	zero
OC	Picloram	0.5	Liver problems	Herbicide runoff	0.5
OC	Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
R	Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of natural deposits	zero
IOC	Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines	0.05
OC	Simazine	0.004	Problems with blood	Herbicide runoff	0.004
OC	Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
OC	Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	zero
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
OC	Toluene	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories	1
M	Total Coliforms (including fecal coliform and *E. coli*)	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally present in the environment as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.	zero
DBP	Total Trihalomethanes (TTHMs)	0.10 0.080 after 12/31/03	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle	zero
OC	2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
OC	1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.20
OC	1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
OC	Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	zero
M	Turbidity	TT[3]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff	n/a
R	Uranium	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits	zero

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	zero
M	Viruses (enteric)	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

NOTES

1 Definitions

- Maximum Contaminant Level Goal (MCLG)—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
- Maximum Contaminant Level (MCL)—The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- Maximum Residual Disinfectant Level Goal (MRDLG)—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- Maximum Residual Disinfectant Level (MRDL)—The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- Treatment Technique (TT)—A required process intended to reduce the level of a contaminant in drinking water.

2 Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

3 EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium* (as of 1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- *Giardia lamblia*: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- *Legionella:* No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, for systems servicing >10,000, and January 14, 2005, for systems servicing <10,000, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- Filter Backwash Recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

4 No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E. coli* fecal coliforms, system has an acute MCL violation.

5 Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

6 Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

7 Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

8 Each water system must certify, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05% dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent).

LEGEND

	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

Table 5.—National Secondary Drinking Water Standards[1]

Contaminant	Secondary Contaminant
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	Noncorrosive
Fluoride[1]	2.0 mg/L
Foaming agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor numbers
pH	6.5 to 8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total dissolved solids	500 mg/L
Zinc	5 mg/L

[1] National Secondary Drinking Water Standards are nonenforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, States may choose to adopt them as enforceable standards.

4. Water Recreation

For primary water contact recreation (swimable), the primary concerns are human health and aesthetics. Human health requires that the water be relatively free of pathogenic organisms and toxic substances that, upon ingestion, would prove to be harmful or that, through body contact, are irritating to the human skin. The parameter that is normally used to measure bacterial pollution is fecal coliform count. Stream standards for water recreation can vary from State to State; however, they can not be less restrictive than EPA's recommendations. As an example, Idaho has set the following standard for primary contact recreation for fecal coliform which is enforced during the summer recreation period:

- No more than 500 colonies/100 milliliters (mL) in any sample
- No more than 200 colonies/100 mL in more than 10 percent of samples taken during a 30-day period,
- A geometric mean of 50 colonies/100 mL based on a minimum of samples taken over the 30-day period.

The aesthetic characteristics of water include turbidity, sediment, algae, objectionable odors, and color. The standards for aesthetic characteristics are generally narrative and are more subjective in identification of problems.

5. Aquatic Life

Aquatic life (fishable) standards pertain to the ability of a water body to support a viable diverse community of aquatic organisms and populations of significant aquatic species. The stream and lake standards for aquatic life can be designated as either cold water (has optimum growing temperatures below 18 °C) or warm water habitat (has optimum growing temperature above 18 °C and maximum temperature generally less than 33 °C). Typical water quality standards for cold water species are:

pH – 6.5 to 9.0

Dissolved gas saturation – Shall not exceed 110 percent of saturation.

Water temperature – 22 °C or less with a maximum daily average of 19 °C.

Dissolved oxygen – Greater than 6.0 mg/L at all times except at the bottom of natural lakes and reservoirs.

Ammonia – This standard is a function of temperature and pH based on research and methods developed by EPA. The acceptable concentration decreases as temperature and pH increase and can be stream and site specific. It is best to check with the regulatory authority, which is usually a State agency.

Turbidity – Below any established mixing zone, the turbidity shall not exceed background turbidity by more than 50 NTU instantaneously or more than 25 NTU average for more than 10 consecutive days.

Total chlorine residual – The 1-hour average concentration shall not exceed 19 micrograms per liter (ug/L), or the 4-hour average concentration shall not exceed 11 ug/L.

Warm water fish species can survive higher water temperatures, usually slightly lower dissolved oxygen and higher turbidity. When comparing in-stream or lake water quality to standards for both cold water and warm water conditions, the individual State designates which standard applies for use in the comparisons. For a given water resource, stream, or lake, if the aquatic stream standards are not met, then the State is required to complete a total maximum daily load (TMDL) analysis. The TMDL identifies the pollutant sources and the loading, how much of the load can be assimilated before the standard is exceeded, and how much of the specific pollutant needs to be removed from the stream or what can be done to reduce the pollutant loads from the various sources in order to meet the standard. Reclamation should be a participant in the TMDL analysis when Reclamation facilities are involved and are identified as a contributor. Further, Reclamation should get involved in the TMDL, if the area is located upstream of Reclamation facilities.

C. Inorganic and Organic Parameters

There are many inorganic and organic water quality parameters included in this group of pollutants that are toxic at very low concentrations to aquatic biota and/or humans. In order to obtain usable water quality data for these parameters, laboratory analytical procedures must be able to detect their presence at concentrations below the toxic levels, which can be very low. The water samples for inorganic and organic analysis usually require special handling and preservation techniques to assure that the laboratory analytical data is useable, with sufficient accuracy and precision. The above requirements are necessary for the data to be used for evaluating the significance of the pollutant in the water resource. For proper sampling and handling procedures, reference is made to the Reclamation's *Quality Assurance Guidelines for Environmental Measurements*, 1994, and to the latest edition of *Standard Methods for the Examination of Water and Wastewater*. Analytical methods can also be obtained from *Standard Methods for the Examination of Water and Wastewater*. EPA and the USGS have also published laboratory methods for determining pollutant concentrations of organic and inorganic parameters.

1. The organic contaminates, herbicides, pesticides, and other manmade chemicals are usually found in trace amounts in the water environment. They can be toxic and/or carcinogenic to humans, animals, and aquatic organisms, generally at low concentration levels, in parts per billion (ug/L or ppb) range. The primary sources are from agriculture and urban areas due to the applications of the herbicides and pesticides. Chemical manufacturing industries are also a source of organic pollutants. They are usually found in the watershed near the point of use or near the manufacturing plant The organics that are highly soluble can be found in the ground water as well as the surface water even at some distance from the source of contamination. The low soluble organic chemicals frequently adsorb to sediment and are transported with the sediment. For example, DDT has a low solubility, a long life in the environment, and decomposes at about 5 percent per year when mixed with the soil, attaches to soil particles, and is usually transported with sediment. The use of DDT was outlawed in 1972; however, significant amounts are still found in the environment in areas where it was used on crops.
2. Inorganic materials including common elements and minerals are frequently referred to as metals, trace elements, metalloids, and salts. The trace elements, metals, and metalloids are usually found in small concentrations as with organics and require special sample collection, preservation, and analysis procedures. Inorganics enter the water resource by natural means through leaching from geologic formations or through discharge from use in industry, urban areas, and agriculture. Nutrients from fertilizers, including nitrogen and phosphorus, are inorganics that fit in this category and can pollute both ground water and surface water. The major dissolved elements are the cations—calcium, magnesium, sodium, and potassium—and the anions—chloride, sulfate, carbonate, and bicarbonate and silica. The concentrations of these

major elements are usually determined and expressed in mg/L of concentration. Other inorganic chemicals that can have concentrations in the mg/L range are nitrate and iron. Most other inorganics (trace elements) are measured in ug/L and generally have low solubilities or exist in the environment at low concentrations. The toxic inorganic elements and chemicals are regulated by the CWA and/or the SDWA.

3. Biological interactions with the above parameters can have many different responses due to their presence in the water environment. The responses can range from no affect, to affecting the reproduction and causing deformities, to being toxic to aquatic life, and/or accumulating in the food chain till the parameter concentrates to a level where the predators are adversely effected. The effect depends on the level of toxicity, the parameter concentration, and how the organism reacts to the chemical's concentration level. Excess nutrient concentrations can cause excessive growth of algae that can adversely effect the water environment by blocking sunlight penetration, reducing dissolved oxygen under certain conditions. At times, when blue-green algae are dominant, the blue-green algae can excrete a toxic substance that can poison any biota that utilizes the water. Detailed information on biota effects can be found for individual pollutants from EPA's IRIS database at:

http://www.epa.gov/ngispgm3/iris/index.html

CHAPTER V

SAMPLING PLAN TO OBTAIN CREDIBLE WATER QUALITY DATA

Water quality data collection and analysis studies should follow a definite plan and procedure to assure appropriate and credible data are obtained. Reclamation has developed a report, *Quality Assurance Guidelines for Environmental Measurements*, that can be used in planning the water quality investigations. Each data collection program should start with a quality (assurance) management plan (QMP) that gives the overall vision of any project requiring data collection and providing direction to any data acquisition function. Next, a quality assurance project plan (QAPP) should be outlined. This should be done for any new project following the scoping and funding phase. The QAPP should contain the following four sections: project management, measurement/data acquisition, analysis assessment/oversight, and data verification and validation. The management plan should contain data quality objectives (DQOs) which are formulated and are the responsibility of the project manager and those that provide assistance. With the DQOs adequately defined, the other tasks will be constrained properly. The next step is developing the sampling and analysis plan (SAP). On small projects, the SAP may be the bulk of the project plan; however, ignoring the other elements is usually a mistake. The Data Acquisition and Analysis Assessment and Data Verification and Validation sections follow the SAP. Reclamation project managers should be relatively confident that the field effort will yield the data that is needed to make the proper decisions (based on the QAPP) regarding the water resource project and to implement or design as warranted. Additional information on developing the overall water quality data collection and analysis plan can be found in the Reclamation guidelines referenced above. Finally, it should be emphasized that a well thought out water quality sampling plan is vital to obtaining adequate data that will address the study or project concerns.

A. PLANNING

The sampling plan must clearly reflect the stated objectives of the sampling effort and the quality of data required. Planners should identify what can be the allowable sampling error relative to the total error. Sampling error may be reduced through proper selection of sampling methods, types, and devices; field audits; training; and strict adherence to protocols. In planning, determine the methods of analysis that will be used with the water quality data obtained from sampling because the analysis methods will affect, and be affected by, the objectives of the sampling program. The types and numbers of quality control samples to be collected will depend directly on the nature and importance of the potential errors and their impact on the confidence in the decisions that will be made through the analysis of the water quality data. The sampling plan needs to balance the desired DQOs with other factors, such as available time and resources. The water quality sampling plan should describe the location and timing of sampling, type of samples (including quality control), analytes to be measured, record keeping requirements, and sample shipping information.

B. Safety

The act of collecting samples and conducting environmental investigations may expose personnel to safety and health hazards. Sources of risks include the physical sampling environment where the water samples are collected and the handling of the chemicals used in sample preservation. The expected hazards to the sampling personnel and the procedures to reduce accidents and exposures during the sampling should be included in the sampling plan.

C. Sampling Protocols

Sampling protocols are detailed written procedures to be followed for sample collection, handling, storage, and documentation. The sampling plan should identify the sampling locations and all information needed for sampling protocols, including types, numbers, and sizes of containers; labels and tags; field logs; sampling devices; numbers and types of sample blanks, sample splits, and spikes; volumes of samples; specifics on compositing samples; preservation instructions and holding times for each type of sample (see table 1 in *Quality Assurance/Quality Control Guidelines* [QA/QC Guidelines]); field preparations and measurements; timing and the format of reports. The specific protocols should address the responsibilities of the sampling personnel in the collection of the water quality samples, in the use of sampling equipment, and in maintaining written records.

D. Sampling Design

The sampling design must take into consideration what is to be sampled, the required field and laboratory analysis, and area to be sampled. The design needs to minimize the sampling error. Water quality sampling must be tied to the water resource hydrology and reflect the influence of flow conditions, seasonal high and low flow periods, and yearly variations, where possible, for wet, normal, and dry years. The sampling protocols, quality assurance/quality control, and laboratory methods are very important to obtaining credible water quality data. Further information on sampling design can be obtained from the QA/QC Guidelines and other references.

E. Other Samples

Frequently, additional water quality samples are needed to assure that proper interpretation and conclusions are obtained from the data. Control samples can be collected outside the sampling area to determine background conditions if appropriate areas are available. If a project has not been built and/or operated, the samples from the project area would reflect background conditions. Water quality changes would be projected or estimated from this data and the expected project impacts. Later data are collected after the project is in operation to verify the predictions and assure the project impacts are meeting any regulatory requirements.

F. Quality Control

Samples collected or prepared in various ways are used to determine the laboratory accuracy. Water samples collected and split in the field and submitted to the laboratory as separate duplicate samples serve as good laboratory quality control samples. The original sample can be obtained in a large enough quantity to be split. Spiked samples can also be prepared and submitted to the analytical laboratory as quality control samples to check the laboratory accuracy. Spiked samples are usually prepared by another laboratory by adding a known quantity of chemical to a water sample. See QA/QC Guidelines for additional quality control sample information.

G. Field Quality Assurance

The field quality assurance information provides a record of actual work and field activities in a field logbook. Original notes are kept of field observations, calibration records of field equipment, sample information, photos, field data such as water temperature, pH, DO, EC, turbidity, and any other parameters specified in the sampling plan for onsite measurement. It is preferable that the field log be kept by one individual. All entries should be made with permanent ink and each page signed and dated. Additional information and custody records may be required if the data is to be legally defensible. A quick summary of the quality assurance/quality control elements and criteria can be found in table 2, Part I of the QA/QC Guidelines.

CHAPTER VI

LABORATORY GUIDANCE

This section covers general laboratory quality assurance/quality control . The detailed information can be found in the QA/QC Guidelines, Part II. Any laboratory used for analytical purposes should have a written quality assurance plan which should contain the following information: an introduction that contains any pertinent background or historical information, policy statements, limitations and/or quality assurance plan (QAP) data; the organization of the laboratory should be described and contain functional breakdown, contact information, personnel classifications, responsibilities, brief resumes, and other pertinent organizational/personnel data; a section covering the facilities which contains the address, any information specific to the delivery of samples, security measures, and acceptable sample receipt days and times. The sample receipt policy should provide information on unexpected samples, unacceptable sample containers, unacceptable sample shipment containers, and any other unacceptable conditions. It should specify the intended disposition of rejected sample submissions.

The part on instrumentation should list the onsite equipment available for performing sample analysis. The list should include instrument analysis type, instrument name, model manufacture date, and any accessories attached or modifications made. The services provided should be listed, including analytical methods for sample testing that the laboratory can perform, any contract analysis and other services such as consultation; SAP/QAP preparation; referee laboratory services; and supplying of sample containers, blank media, spike samples. A quality assurance/quality control plan assures accurate analytical results from work accomplished. More detail is contained in the QA/QC Guidelines.

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PARTIAL LIST OF WATER QUALITY MODELS

Partial List of Water Quality Models

Model Name/Acronym	Short Description	Scale
ADYN-JRQUAL	Unsteady state hydrological model of water quality for use in rivers	Riverine
AGNPS/Ann-AGNPS	Agricultural Non-Point Source Pollution Model-Annualized version of AGNPS	Watershed
ANSWERS	Areal, Non-Point Source Watershed Environment Response Simulation - Watershed Response	Watershed
BASINS	Better Assessment Science Integrating Point and Non-point Sources - Water Quality	Watershed
BATHTUB/FLUX/ PROFILE	COE empirical eutrofication response model in lakes and reservoirs	Reservoir
BETTER	Box Exchange Transport Temperature Ecology Model - 2D Water Quality Model for Reservoirs	Reservoir
CE-QUAL-R1	Corps of Engineers 1D Water Quality Model for Reservoirs	Reservoir
CE-QUAL-W2	Corps of Engineers Water Quality Model for Reservoirs - 2D	Reservoir
HEC-HMS	HEC-Hydrologic Modeling System - Unsteady state flow model for watersheds and rivers	Watershed Riverine
HEC-RAS	HEC-River Analysis System - Steady state flow model for use in rivers	Riverine
HSPF	Hydrological Simulation Program - FORTRAN Data intensive input water quality program	Riverine
HYDROSS/CRSSAP	Hydrologic and water quality model for use in modeling large river systems.	Riverine
MINTEQA2	Calculates equilibrium chemical balance in water systems	Riverine Reservoir
PHREEQE	pH-Redox Equilibrium Model - Reaction can be maintained in equilibrium	Any Water
QUAL2E	Enhanced Stream Water Quality Model with uncertainty analysis for well mixed streams	Riverine
SWMM	Storm Water Management Model - Water quality analysis for urban runoff	Watershed
WASP5	Hydrodynamic River Water Quality Model - Eutrophication, Metals, and Toxic materials	Riverine
WARMF	Watershed Analysis Risk Management Framework simulates hydrology, nonpoint loading, and water quality of a watershed; predicts changes in water quality due to point and nonpoint source control, land use changes, and best management practices.	Watershed

Additional model information can be obtained from the following websites:

www.epa.gov/waterscience/wqm/

smig.usgs.gov/smic/

www.wes.army.mil/el/elmodels/index.html#wymodels

The Environmental Protection Agency (EPA) sites lists models that they support and links to models from other agencies. Model user technical guidance and EPA program information can be obtained from this web location. They also list available model training and meetings that are scheduled.

The U.S. Geological Survey site contains flow models as well as water quality. The information listed covers model types, dimensions of the model, if it has a geographical user interface, and the domain where it is applicable. It also lists abstracts of projects where the model has been used and the computer system required for its operation.

The U.S. Army Corps of Engineers provides a list of models that relate to their work. They include aquatic plant growth, dredged material management, landfill, and water quality models. The water quality models cover reservoir and riverine environments. A brief description of each model is listed. Additional model information can be accessed from links provided in the site table.