Prepared in cooperation with the U.S. Environmental Protection Agency

Conceptual Plan for Long-Term Monitoring of Surface Water in the Cheyenne and Belle Fourche River Basins of Wyoming and South Dakota

U.S. Geological Survey

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Introduction

This monitoring plan describes a conceptual data-collection network for surface-water quality and quantity in the Cheyenne and Belle Fourche River Basins of Wyoming and South Dakota. The plan was prepared by the U.S. Geological Survey (USGS) at the request of the U.S. Environmental Protection Agency (USEPA) in consultation with stakeholders in the basins.

Purpose of Monitoring Plan

The purpose of the plan is to identify critical sites in a watershed-scale monitoring network and to describe general features of a long-term systematic operational design. The plan is intended to assist water resources managers in evaluating how their own agency priorities can be integrated into a larger watershed view. Integration of monitoring activities among various agency programs will be necessary to sustain the long-term operation of a comprehensive network. Data generated from a watershed-scale monitoring network can be used by multiple agencies having various resource-management responsibilities to make informed environmental assessments and decisions.

This monitoring plan is intended to have an objective design capable of providing high quality data that represents “collective” impacts on water quality from multiple natural or human sources over a broad geographic area. The network is not intended to monitor site-specific inputs, localized impacts, or compliance with regulatory standards. Rather, it is designed to function as a starting point for systematic, long-term information on stream condition that can serve as the basis for detecting impairment and identifying changes over time. It is recognized that there currently are a number of sampling programs independently being conducted by Federal, State, Tribal, and private entities. All of these programs contribute to an overall characterization of water quality in the basins. Because these programs have their own specific objectives and requirements, this monitoring plan does not seek to replace any of the sampling programs currently in operation. The network design incorporates a review of the types of monitoring being done and seeks to identify either data gaps or a subset of currently active sites that could be utilized in a unified watershed-scale network.

A primary goal of this plan is to advocate for the operation of a long-term monitoring network in a consistent manner over time, and to provide recommendations on data-collection strategies to meet various objectives. Ongoing operation of a network of key sites can provide current data that may be critical when immediate resource-management decisions need to be made. Uninterrupted, long-term information is also necessary to document changes over time in a manner that can support statistical analysis of trends and enhance the confidence of conclusions on environmental impacts.

Securing funds to implement and maintain long-term operation of a watershed-scale network will be a difficult challenge. Although this conceptual monitoring network does not identify a specific funding process, development of an objective monitoring plan that has stakeholder support is an essential first step toward articulating goals and tasks needed to achieve objectives that benefit multiple agencies and the public interest. Therefore, it is hoped that this plan can be a reference for groups evaluating data needs and priorities in the Cheyenne and Belle Fourche River Basins, and can enhance opportunities for collective efforts from multiple funding sources to support a watershed-scale monitoring effort.

Process of Monitoring Plan Development

The development of this monitoring plan was modeled after a similar process used to develop a conceptual monitoring plan for the Tongue and Powder River Basins in Wyoming and Montana. A review of current and former sampling programs was initiated to understand what types of data are available for use as historic reference to previous conditions, and what types of data currently are being collected. This effort was achieved by an in-house review of the sampling histories of USGS stations as well as a survey (in July 2004) of sampling programs being conducted by Federal, State, Tribal, and private data-collection entities. The results of the sampling-program surveys were compiled into tables and maps that were used to review locations, types of data, and periods of record. This information was used to define the historical and current monitoring status in the Cheyenne and Belle Fourche River Basins.

The next major step in the process of network design was to convene a meeting of stakeholders from the Cheyenne and Belle Fourche River Basins in Wyoming and South Dakota. On September 14, 2004, a meeting was held in Spearfish, South Dakota to allow approximately 26 participants to provide input on important monitoring locations, sampling strategies, and desired outcomes from monitoring efforts. Summaries of monitoring programs compiled from the survey were distributed to stakeholders to provide an overview of the numerous sampling efforts in the basins. Site locations, sampling intensity, and parameters were discussed and a general consensus was achieved on what sites best represent a “core” network to provide stream data on an ongoing basis and at a practical scale of operation. Data gaps were identified, as well as existing programs that currently satisfy numerous monitoring objectives. Additional sampling and data-interpretation issues were raised that are beyond the scope of this network effort, but represent important considerations that warrant further discussion and examination of possible approaches to meet issue-specific or site-specific objectives (see “Supplemental Studies”).

Following the meeting of stakeholders, the USGS assembled the recommendations on network design into tables listing the core sites and levels of sampling intensity needed to meet various environmental assessment objectives. A “draft” monitoring plan was distributed to USEPA for review and comment in April 2005. Distribution of the final plan is contingent on general acceptance by stakeholders and USEPA. The plan includes lists of sites in the proposed network, as well as discussions on monitoring objectives, sampling strategies, rationale for site selection, technical considerations for operating a network, and issues regarding how agencies can coordinate efforts to share information and pool resources to sustain the network.

Monitoring Goals and Objectives

Resource Management and Protection

The overall goal of long-term, systematic monitoring is to provide reliable and current information to support environmental assessments of stream health and to guide resource-management decisions necessary to protect aquatic resources and their associated beneficial uses. Specifically, the goal of this monitoring plan is to collect surface-water quality and quantity data at key sites on the mainstems and major tributaries in the Cheyenne and Belle Fourche River Basins, as discussed and selected by consensus of the stakeholders.

Environmental Assessment Objectives

Long-term data can be used for a variety of assessment objectives, depending on the intensity of data collection. Some examples of the types of assessments that could be achieved with a systematic program of data collection are:

- Identification of impaired streams that do not fully support beneficial uses;
- Development of objective criteria for decisions on permits and water-quality standards by understanding the range of seasonal and annual variability;
- Assessment of the effectiveness of TMDL watershed plans and Best Management Practices implemented to improve water quality;
- Comparison of ambient water quality with regulatory standards;
- Ongoing tracking of the status of annual water-quality conditions, including average conditions, abrupt changes, or unusual extreme conditions;
- Providing input data to watershed models used to simulate impacts from a range of hydrologic or land-use scenarios;
- Determination of annual loads of constituents input at various points across the watershed that can be used to identify important source areas;
- Detection of statistically significant trends in water quality over time that can be used to identify and quantify long-term degradation or improvement in the condition of the resource;
- Assessment of stream ecosystem health and trends through systematic documentation of aquatic insect and algal characteristics over time; and
- Assessment of reservoir quality through systematic sampling of water quality and algal productivity.

These various assessments can be grouped into general categories of monitoring objectives that describe the types of environmental assessments that can be supported by data obtained from varying levels of sampling intensity (frequency and duration). Table 1 presents a generalized set of guidelines for water-quality sampling intensity necessary to meet a variety of common monitoring objectives. The guidelines in table 1 do not represent formal requirements that have been statistically determined; rather, they represent a general range of sampling intensity that can serve as a starting point for considering the relative scope of data requirements for different objectives.

Table 1. Recommended water-quality sampling intensity for various monitoring objectives

Objective	Assessments supported by data	Recommended sampling intensity to meet objective: *Sampling frequency (per year)*	Recommended sampling intensity to meet objective: *Program duration (years)*
Baseline	General reference to range of conditions (max, min), but resolution is inadequate to support much interpretation.	2-4	2 +
Status	Descriptive statistics (mean, max, min) of stream chemistry; identifies moderate range of seasonal and flow variability; useful to identify relative differences between sites.	4-6	5 +
Source-Area Assessment (Annual Loads)	Mathematical relations (flow vs. conc., flow vs. load, etc.) can be developed to describe response of stream chemistry to flow. Continuous flow gage required to compute annual loads. Higher sampling frequency may be required for basins with variable hydrology dominated by rainfall runoff.	6-8	5 +
Long-Term Trends	Long-term sampling at sufficient frequency to discern seasonal and hydrologic variations in stream chemistry; allows statistical detection of trends to distinguish natural variability from human-induced changes.	8-12	10 +
Compliance Monitoring	Documentation of stream chemistry relative to regulatory standards. May require very high frequency of sampling, or continuous-recording monitors. Typically conducted by dischargers in accordance with permits.	Weekly, daily, continuous	Entire period of discharge

The effectiveness of decisions designed to protect and manage water resources for multiple beneficial uses is directly dependent on the adequacy of available data in terms of quality and quantity. Therefore, it was proposed that a sampling intensity be recommended for this network that is sufficient to generate data capable of meeting a wide range of environmental assessment objectives, yet represents a practical scale of cost and staff resources for long-term operation. The primary monitoring objective considered for this plan is “Long-Term Trends”; however, “Source-Area Assessments” were also considered for several sites in tributary basins.

A general description of each monitoring objective is provided in the following sections. A feature that should be noted is that with each increasing level of sampling intensity to meet objectives, the data requirements for the previous objective also will be met.

Baseline

Baseline characterization of water quality is a minimal representation of environmental conditions. Although very limited in the degree of interpretation that can be done with the data, baseline sampling is a very useful screening tool that can be used in a reconnaissance effort to help design a sampling program of greater scope, or in comparing conditions between sites under very specific flow conditions or seasons. Baseline sampling is sometimes conducted at a large number of sites across large geographic areas to provide a measure of the spatial differences among different landscapes or geologic settings for the specific time period of sampling. A sampling frequency of 2-4 times per year for a couple of years will provide a very general reference to short-term conditions. Although not useful for developing descriptive statistics such as minimum, maximum, or average conditions, it can be used to detect stream impairment if the few samples reveal a consistent occurrence of elevated concentrations. Such an indication of impairment can then be used to target the site for more intensive sampling.

Status

Status is a representation of the current or recent stream condition that is described by an ongoing, systematic data-collection program. A sampling intensity of about 4-6 times per year typically can provide information that is sufficient to document an annual range of conditions that represents a general measure of seasonal and hydrologic variability. If the sampling is adequately distributed through the year, the range of conditions might be fairly well described. Continuation of sampling for 5 or more years will eventually allow accumulation of enough data to generate reasonable measures of minimum, maximum, and average conditions. This level of characterization is well-suited to identifying relative differences in environmental condition between sites. Although somewhat insufficient for quantifying water-quality response to streamflow or land-use activities, it is useful to detect seasonal impairment of streams or to indicate the relative magnitude of impairment compared to other streams. The data intensity that is sufficient to determine status is also sufficient to characterize "baseline" conditions.

Source-Area Assessment

Source-area assessments are achieved by identifying the relative percentage of a constituent load passing a mainstem site that is contributed by a particular area of the basin upstream of the site. These assessments require the determination of annual loads passing various points within a basin in order to account for the downstream routing of loads and identification of major sources contributing to the increase between mainstem sites. To be most effective, annual loads need to be determined for multiple years to obtain an average annual load. Loads should be determined for concurrent years among a network of sites to ensure that similar hydrologic conditions are represented. The average annual loads can then be compared among sites to identify any portion of the basin contributing a large or disproportionate amount of constituent load. The benefit of identifying important source areas is that these subbasin areas can either be examined in greater detail to pinpoint discrete sources, or they can be prioritized for remedial actions to decrease their input to the mainstem.

The determination of annual loads requires a continuous streamflow gage and moderately intense sampling (6-8 per year) that is conducted for enough years (5 or more) to develop mathematical relations (regressions equations) between associated variables such as flow and concentration. These relations, if statistically significant, enable the estimation of annual constituent loads by incorporating the daily record of streamflow. Application of the regression model to a daily record of flow is necessary to account for the high degree of hydrologic variation, especially during runoff periods. It is during these relatively short periods of high flow that the bulk of the annual load typically is transported past a sampling site; thus, data on the magnitude and duration of flow conditions, especially high flow, is essential for quantifying the seasonal variations in load. For some constituents, better load estimates are obtained by operating continuous water-quality monitors (e.g. specific conductance) at a site. Regression models are developed relating the constituent concentration to the continuous water-quality parameter. The estimated continuous constituent concentrations are used with the continuous streamflow data to provide a better constituent load estimate. All sites sampled at the intensity sufficient to estimate annual loads will generate data sufficient to document "status."

Long-Term Trends

Evaluating long-term trends is one of the most desirable—yet most difficult—monitoring tasks to accomplish. It is very useful for assessing effects of land-use practices on water quality or aquatic biota and can often infer linkages between cause and effect. Trend detection is a useful tool, whether for examining degradation of stream quality or effectiveness of remediation activities in improving stream conditions. But trends can be difficult to statistically verify because they are often very gradual and can be masked or misinterpreted by the effects of natural variations in environmental conditions such as streamflow (Helsel and Hirsch, 1992).

"Statistically" detecting water-quality trends is difficult because water quality can vary to a great degree, both within a given year and between years, due to shifts in random natural phenomena such as rainfall, temperature, or streamflow. These natural variations can be cyclical and give the appearance of a trend (apparent trend) in concentrations or loads that can be misleading and erroneously attributed to various land uses. Human activities also can cause either subtle or distinct changes in water quality that are superimposed on the natural variations of water quality, thereby making it difficult to discern the extent of effect from either cause.

Distinguishing the effect of human activities on water quality from natural variations requires a substantial amount of data. Within a given year, sufficient data need to be collected to characterize seasonal variations associated with streamflow conditions, instream biological productivity, and changes in land-use activities. Between years, data need to be collected for a sufficient number of years to encompass a wide range of annual flow conditions so that the response of water quality to drought, floods, and normal flows is adequately characterized. Therefore, a rigorous assessment of trends is most beneficial when flow conditions and water-quality conditions are evaluated simultaneously. It is recommended that the sampling intensity for water-quality trends is a frequency of 12 per year for a duration of 10 or more years. The advantage of an intense level of sampling is that the data are suitable for meeting almost all environmental assessment objectives common to most sampling programs. The disadvantage is the high cost associated with the intensive data-collection effort.

Long-term trends in stream ecology provide very useful supporting evidence to confirm long-term patterns in stream chemistry. Stream ecology represents a complementary type of sampling that is recommended to be implemented at water-quality trend sites, wherever possible. Determining stream ecosystem health requires systematic documentation of the biological taxa present at the site and their relative abundance. Sampling of two components of the aquatic ecosystem—benthic macroinvertebrates and algae—provides information on basic components of the aquatic food chain. Aquatic biota present in the stream continually are exposed to ambient stream conditions (flow, water chemistry, temperature, substrate condition, etc.) and consequently are excellent indicators of sustained stream health or impairment. Annual sampling of aquatic biota that represent the base trophic level of the food chain should be adequate to identify long-term trends in stream ecology if conducted for 10 or more years. Coupling monitoring information on biology, streamflow, and water quality can provide a strong case for definitive assessments of stream health and help to identify factors that may be causing biological impairment.

Similar to streams, long-term trends in reservoir quality can be assessed through both chemical and biological sampling. Due to the physical dynamics of reservoir processes, such as thermal stratification, nutrient cycling associated with seasonal turnover, sedimentation, and phytoplankton production and die-off, water quality can vary at different locations and at different depths within a reservoir. Documentation of these variations can describe the current condition of the reservoir system and help to understand the patterns of seasonal variation. A long-term record of reservoir quality can identify trends in water-quality or algal productivity which may be useful for understanding or predicting the response of the fishery to seasonal and annual variations. Also, because reservoirs are depositional environments, estimates of annual loads from input and outflow stations can be used to determine the mass of constituents that accumulate in the reservoir. These data can be used to determine whether the long-term accumulation of constituents pose a potential risk for future water quality degradation or biological impairment.

Compliance Monitoring

Monitoring to evaluate compliance with regulatory standards is the most intense level of data collection and is designed to ensure that exceedances of standards promptly are identified so that the suspected cause or causes of the exceedances can be remediated. The rapid response to exceedances is necessary to protect human health or the beneficial uses of a water body before significant short-term or long-term impairment occurs. Such intense monitoring is typically done at the source of a discharge in accordance with a State- or Federally-issued discharge permit. Point sources of discharge expected to have the potential for impairment in a receiving body of water generally are monitored by the entity producing and controlling the discharge. Similar intense monitoring of a receiving body of water, such as a river or lake, may be warranted in some cases where a water-use is especially vulnerable to degradation. Identifying short-lived spikes in constituent concentrations may require daily or weekly sampling frequencies, which would be a very expensive undertaking for a large network of sites. Additionally, continuous-recording monitors might be employed to measure values of surrogate parameters (such as conductance, pH, etc.) to provide a real-time indication of potential changes in water quality. The operation and maintenance of continuous monitors at a large number of sites also is an expensive and difficult undertaking.

The response to a water-quality exceedance in a mainstem river or large tributary can be complicated by the fact that a large body of water receives the collective inputs from numerous upstream sources. It might not necessarily be clear what specific source is causing the exceedance, thereby limiting the ability to remediate the input. For that reason, larger bodies of water are usually not sampled for regulatory compliance, but rather are sampled at a frequency that can describe water quality sufficiently to assess the overall ability to support beneficial uses. Those portions of a basin exhibiting consistently poor water quality or impaired biological communities may warrant further examination to determine if a compliance-monitoring sampling intensity is needed at selected sites to identify the possible cause of impairment.

Limitations of Network Data

The level of data obtained from a broadly distributed network of sites cannot answer all questions regarding cause and effect of environmental conditions. This conceptual network is not designed to address site-specific issues such as localized effects, discrete source contributions, ground water-surface water interactions, or other complex environmental processes such as detailed geochemical or biological interactions. To answer these types of questions requires a data-collection effort specifically designed to generate data of sufficient resolution to address the issues in question. Long-term systematic data from key locations in a watershed network, however, can benefit detailed investigations by providing quantitative information and illustrating patterns over time to supplement research efforts. Long-term data at key sites can reveal temporal patterns or other features that can be used to extrapolate potential trends to other sites or calibrate models to fit observed conditions. Therefore, systematic data from a distributed network can be coupled with data from targeted, site-specific studies to facilitate interpretation of multiple water-quality effects over a broad geographic area. Potential types of supplemental studies to address specific hydrologic or geochemical processes are described in the section “Supplemental Studies.”

Sampling Strategy to Meet Objectives

Sampling Type and Intensity

Different approaches to sampling are required to meet objectives for various types of water-quality assessments (Averett and Schroder, 1994). For example, increased sampling frequency is required if there is a need to identify the duration and magnitude of short-term variations in water quality. Increased sampling frequency can improve characterization of temporal variations in water quality that may be missed if samples are widely spaced in time. Many factors can lead to water-quality fluctuations, such as changes in flow conditions, land-use activities, and seasonal variations in biological productivity. Where such variations in flow or water quality are continually integrated into a system response—such as in the composition and abundance of biological communities, a lower sampling frequency is required. Regardless of the within-year sampling frequency, the continuation of sampling over multiple years is essential to describe a wide range of hydrologic conditions associated with climatic cycles. Because these hydrologic variations can exert a predominant influence on water quality and annual loads, short-term data programs potentially can misrepresent longer-term average conditions.

A brief description of the various sampling strategies for stream chemistry, stream ecology, and reservoir quality considered to be adequate for a long-term watershed monitoring network is provided in the following sections.

Type I – Stream Chemistry (Trends)

To accommodate a broad range of environmental assessment objectives within a practical and affordable scale of operation, sampling to monitor for “long-term trends” in water quality is recommended for most sites in this watershed network. The sampling strategy for “stream chemistry (trends)” is referred to as Type I in this monitoring plan. Type I sampling is recommended for all mainstem locations on the Cheyenne and Belle Fourche Rivers, as well as for sites near the mouths of major tributaries that were identified by stakeholders as having the greatest importance from a watershed perspective. Continuous streamflow gages are recommended to identify cyclical variations in hydrology and provide the necessary data on streamflow magnitude and duration for computing annual loads.

The intensity of water-quality sampling considered adequate to statistically detect long-term trends in streams in the Cheyenne River and Belle Fourche River Basins is a frequency of 12 times per year for a duration of at least 10 years. Although determination of adequate sampling intensity is somewhat subjective, the proposed frequency and duration are similar to the intensity used in other trend studies (Lurry and Dunn, 1997; Smith and others, 1982; Smith and others, 1987; Schertz, 1990; and Vecchia, 2000). The temporal distribution of the 12 per year frequency is recommended to be once-monthly because of the potential for year-round discharge of coalbed natural gas (CBNG) production waters, municipal wastewater, or subsurface irrigation return flows. Although it is common to reduce sampling during the low-flow winter months, a uniform frequency throughout the year is recommended to characterize natural hydrologic variation as well as capture any year-round inputs that may be associated with land uses that are independent of seasonal hydrologic cycles.

Type II – Stream Chemistry (Annual Loads)

Several sites on major tributaries were considered useful to characterize changes in water quality and loads over relatively short reaches where differences might be significant. In addition, these sites might also serve as reference sites to provide information on stream conditions controlled primarily by natural features such as local geology and hydrology. True reference sites that are unaffected by human activities are rare or nonexistent; but, it was considered important to attempt to identify at least several sites that could provide some information on reference conditions. The sampling strategy for “stream chemistry (annual loads)” at selected tributary sites is referred to as Type II in this monitoring plan.

Similar to the Type I sites, streamflow gages would be required to compute annual loads at the tributary Type II sites. Loads at these sites could be compared to loads at other Type I and II sites to determine the net difference. The difference in loads over short distances could be used to better understand the natural evolution of water quality in the local geologic and hydrologic setting, or the effect of changing land use on water quality.

The intensity of water-quality sampling considered adequate to generally characterize seasonal variability in the Cheyenne and Belle Fourche River Basins and develop statistical relations between streamflow and constituent loads is a frequency of about 6 times per year for a duration of at least 5 years. A sampling frequency of 6 per year may be inadequate if the runoff is flashy and events are difficult to capture, or if flow-constituent relations are complex. These types of considerations may need to be evaluated on a case-by-case basis. The temporal distribution of the 6 per year frequency is recommended to follow the annual hydrograph, with somewhat greater intensity during the runoff period of spring and early summer (April-June). Low flows of late summer and fall (July-November) would be sampled to characterize conditions during periods when constituent concentrations may be elevated due to the lack of dilution. Winter sampling (December-February) would be done occasionally to document conditions during extended periods of low flow and ice cover.

Sampling frequency at some Type II sites might be less than 6 per year depending on streamflow conditions. During the summer and fall, some smaller tributaries flow only as a result of runoff from rainfall. The ephemeral nature of sites on these streams might result in no sample being collected some years. Changing land use in some subbasins might result in decreased streamflows downstream. For example, with the closing of Homestake Mine and the changing of some water rights, flows in Spearfish Creek and Whitewood Creek might change resulting in no flow at times (Driscoll and others, 2002; Goddard, K.E., 1989). These types of considerations may need to be evaluated on a case-by-case basis.

Type III – Stream Ecology

To supplement long-term trend assessments based on stream chemistry, complementary sampling of stream ecology is recommended at all Type I and II sites. Biological data provide an additional line of evidence that can support or refute conclusions on stream condition drawn from stream chemistry data, which relies on a statistical summarization of instantaneous measures of ambient conditions at the time of sampling. Valid water-quality assessments, therefore, are highly dependent on the sampling frequency and the ability of the data distribution to adequately represent the variations and extreme conditions throughout a year. In contrast, stream ecology sampling can be limited to a once-annual frequency because the composition of biological communities represents an integration of continual, year-round exposure to ambient instream physical and chemical conditions. The sampling strategy for stream ecology is referred to as Type III in this monitoring plan.

The important feature in annual sampling of stream ecology is to obtain samples during the same season under similar hydrologic conditions every year in order to provide equivalent data for comparison between years. The typical types of biological data collected for baseline reference are taxonomic composition and relative abundance of the benthic macroinvertebrate and attached algae (periphyton) communities. The timing of the annual sampling for stream ecology would typically be during the July-September base flow period, which is commonly the period of peak algal production. The ongoing sampling of stream biota every year for at least ten years can provide a concurrent measure of biological conditions during the same period and under the same hydrologic conditions described by the water-quality and streamflow data. A time series of biological data for consecutive years can provide insight on the range of variation exhibited by base-level food chain organisms relative to natural cycles of flow and temperature, or to variations in land-use activities.

In addition to annual sampling of macroinvertebrates and algae, biological data can be further supplemented with periodic sampling of fish populations (about every 3 years) to document the condition of the highest trophic level among the aquatic biota. Long-term fisheries data could be important to assess the stability of populations and the extent to which the abundance and diversity of long-lived organisms such as fish vary relative to populations in the lower trophic levels. Periodic documentation of fish community structure (taxonomic composition, abundance, size, weight, age class, etc.) using electroshocking methods and habitat assessments may identify changes that can be evaluated relative to hydrologic cycles of drought and flood, variations in water-quality conditions, or changes in land-use activities.

Some trace elements that accumulate in fish tissue are not detectable in water-column samples. Accumulation of these constituents can be toxic to fish as well as pose a health concern to humans and other animals that consume the fish. Many of these trace elements have an affinity for fine sediments. As such, their occurrence can be documented by targeting depositional areas in streams for periodic sampling. Periodic sampling of bed sediments concurrent with fish sampling (about every 3 years) can provide additional information on the occurrence of trace elements in the system.

Complete assessment of the ecological health of a stream includes an assessment of the physical characteristics of the aquatic ecosystem—habitat. Habitat assessment is critical in determining the limiting natural and human factors affecting stream quality (Fitzpatrick and others, 1998). Habitat can be assessed at multiple scales—basin, segment, and (or) reach. For this plan, habitat assessment refers to segment or reach scale monitoring. Periodic assessment of stream habitat concurrent with fish and bed sediment sampling (about every 3 years) can provide additional information on the overall health of the ecosystem.

A final component in the assessment of the ecological health of a stream includes an inventory of amphibians. Amphibians are indicators of general ecosystem health because of their association with aquatic habitats and sensitivity to various environmental stresses. Decline of amphibian populations generally is acknowledged as a serious worldwide issue. Periodic inventories of amphibians concurrent with fish and bed sediment sampling and habitat assessment (about every 3 years) can provide additional information about the overall health of the ecosystem.

Level IV – Reservoir Quality

A less-frequently encountered hydrologic setting in the Cheyenne and Belle Fourche River Basins is that of a large reservoir that is used to store irrigation water, support a lake fishery, and provide public recreation. Because of their importance to various water uses, large reservoirs are recommended for systematic, long-term sampling to assess possible effects from upstream land uses. The sampling strategy to characterize reservoir quality is referred to as Type IV in this monitoring plan.

To document potential spatial differences in water quality that could be associated with deposition of influent sediment and irregular mixing patterns, it is recommended that two sites within the reservoir be sampled – one at the shallower end of the lake near the inflow to the reservoir and one at the deeper end of the lake near the dam and the outflow from the reservoir. In addition, because reservoirs can thermally stratify into layers of water having distinctly different temperature and density, circulation patterns can be non-uniform, resulting in varying water quality with depth. Thus, it is recommended that water-quality samples be collected at two depths at each site to characterize differences that may exist between the near-surface and near-bottom water layers. A depth profile of field parameters (water temperature, pH, specific conductance, and dissolved oxygen) from water surface to reservoir bottom in uniform increments of depth also should be done at each sampling location to characterize depth-dependent variations in water quality. Water transparency, as measured qualitatively by a secchi disk, is also an important parameter to track between seasons and over time. Because of the potential recreational contact with water at reservoirs, bacteria samples should also be collected near the surface to evaluate potential human-health risks.

A sampling frequency of twice per year is proposed to characterize seasonal variability associated not only with variations in inflow volumes, but also with internal circulation patterns within the reservoir that can affect nutrient cycling, vertical mixing, biological productivity, and potential geochemical reactions. The initial distribution of the two samplings would coincide with stratification and turn-over of the reservoirs. Should the data reveal unusual patterns in spatial and vertical water chemistry, or indicate excessive bacterial concentrations, additional summer sampling may be warranted during the periods of maximum human exposure.

Parameters Proposed for Analysis

This section describes various parameters that would meet the most prevalent needs of various monitoring programs. The list of parameters is not all-inclusive, and could vary from site to site, depending on funding availability and local concerns. To achieve a base level of consistency among sampling programs, it is useful to identify a “core” group of parameters that would likely be utilized by almost every program. In addition, other parameters that would be important for local characterization, or for systematic sampling at a less intensive frequency, also are identified based on stakeholder comments. A list of proposed parameters and sampling frequency associated with each sampling strategy is provided in Table 2.

Core Parameters

The stream-chemistry parameters of concern routinely indicated through various meetings, agency communications, landowners, and citizen groups generally include the common ions (dissolved) associated with salinity and sodium adsorption ratio (SAR), nutrients (dissolved and total recoverable) associated with stream enrichment and nuisance algal growth, and suspended sediment which controls the concentrations of many particulate constituents and can be of concern regarding streambed habitat impacts. Common ions, nutrients, and suspended sediment, therefore, constitute the primary constituents of concern in the Cheyenne and Belle Fourche River Basins and would represent the “core” group of chemical parameters to be analyzed at every stream and reservoir site in the network.

A consistent set of onsite field measurements also is useful to characterize the physical properties of the water body at the time of sampling. It is recommended that a core set of field measurements (water temperature, specific conductance, pH, and dissolved oxygen) be measured at every stream and reservoir site. In addition, streamflow should be determined (either by a current-meter measurement or from a stage-discharge rating with the applicable shift available at gaging stations) at the time of sampling for every stream site.

Continuously-recorded streamflow provides a high level of temporal resolution where rapid variations of short duration may not be adequately described by periodic flow measurements. A continuous record of streamflow is considered to be essential to quantify the magnitude and duration of hydrologic conditions, which have a significant effect on water quality. Continuous streamflow, therefore, is recommended for all stream sites in the network (all Type I and II sites).

Other Parameters

Interest is often expressed regarding trace-element concentrations in the water, partly because of concern about potential toxicity to aquatic life and partly because there is uncertainty on the potential inputs directly associated with various geologic units and land uses. Therefore, analysis of a broad suite of trace elements is recommended for Type I and II sites for a period of several years to obtain baseline data that can be used to evaluate concentrations. After an initial period of several years, a decision could be made on whether to continue sampling for trace elements or on what specific elements to continue to analyze. It is also recommended that both the dissolved and total-recoverable concentrations of trace elements be analyzed in order to accommodate various bioavailability and regulatory considerations.

Water temperature can be a critical stressor to aquatic biota. Because temperature exhibits substantial seasonal and diurnal variation, it is best quantified through continuous monitoring, at least seasonally through the warm-weather months. Consequently, continuous water temperature is recommended for all Type I sites because of relative ease in operation, minimal expense, and general utility for assessing biological stress.

A continuous record of specific conductance is important at sites where salinity is a critical issue with regard to suitability of water for irrigation, or for preventing impacts to the aquatic or riparian ecology. Real-time display of continuous conductance on the Internet for selected sites can provide an alert to a potentially serious water-quality condition. Consequently, continuous conductance monitors are recommended for selected Type I sites that have naturally high salinity, represent an important decision point in the basin (State boundaries), or receive inflows from areas where land uses may substantially increase the concentration of salts in water draining from those areas. More extensive use of continuous conductance monitors is precluded only because of the fact that these instruments are very labor intensive, prone to drifting or other malfunctions due to harsh instream environments, and can be very expensive to operate and quality assure. As technological advances in probe accuracy and durability occur, electronic conductance monitors could be utilized at a larger number of sites.

A continuous record of turbidity can be useful as a surrogate for describing suspended-sediment characteristics in streams. Suspended-sediment occurring in streams as a result of both natural and anthropogenic factors is a concern in the Cheyenne and Belle Fourche River Basins. The periodic samples for suspended-sediment included at Type I and II sites might not adequately describe the variability in concentration. For example, for a number of streams in the Belle Fourche River Basin, suspended-sediment concentrations do not peak with streamflows; rather, suspended-sediment concentrations peak on the recession of the hydrograph. For other streams, suspended-sediment concentrations peak without a noticeable change in streamflow (Williamson and Carter, 2001). While collecting more frequent (daily) suspended-sediment samples would provide the best data for characterizing the issue, collecting such data is expensive. A surrogate such as turbidity can be useful for characterizing temporal variability in suspended-sediment when collected continuously. Continuous turbidity monitors are recommended for selected Type I and II sites.

Bacteria represent an important concern for some streams, especially those receiving point discharges from wastewater treatment plants or non-point runoff from areas with various land uses. Used with other water-quality analyses, bacteria can be used to identify possible sources. Some bacteria can pose a human-health risk if those bacteria occur at high concentrations. Bacteria that pose a human-health risk are not part of routine monitoring; however, indicator bacteria that correlate with those pathogens—such as fecal coliform and E. coli—can be included in routine monitoring. The analysis of indicator bacteria is recommended for Type I sites.

Stream ecology (Type III) monitoring is recommended at all Type I and II sites in the current (2005) plan. It is not included as a core parameter because a consistent set of monitoring protocols (methods and parameters) have not been agreed upon. One possible solution is to further categorize stream ecology monitoring into more than one type, each more specific to stakeholder objectives. If so, Type III monitoring would not necessarily be ubiquitous to the network and, as such, would not be a core parameter.

Other parameters could be added at specific sites on a case-by-case basis. If a parameter is subsequently identified as important throughout the watershed, it could be universally added to all sites for consistency. Table 2 below lists the recommended parameters to be analyzed and suggested sampling frequency for each of the proposed sampling strategies.

Table 2. Parameters and sampling frequency for Type I – IV sampling strategies

Type	Parameters	Frequency
I	STREAM CHEMISTRY (Trends):	12/year
	Field measurements: streamflow, water temperature, specific conductance, pH, dissolved oxygen, turbidity	
	Common Ions—Dissolved: calcium, magnesium, sodium, potassium, alkalinity, sulfate, chloride, fluoride, silica. Calculated: sodium adsorption ratio (SAR), total dissolved solids (TDS)	
	Nutrients (dissolved and total): Total nitrogen, nitrite, nitrite plus nitrate, ammonia, total phosphorus, orthophosphate	
	Bacteria: Fecal coliform and E. coli	
	Suspended sediment: water-column concentration	
	Trace Elements (dissolved and total recoverable): aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, zinc	6/year (trace elements)
II	STREAM CHEMISTRY(Annual Loads):	6/year
	Field measurements: (same as for Type I)	
	Common Ions: (same as for Type I)	
	Nutrients: (same as for Type I)	
	Suspended sediment: (same as for Type I)	
	Trace Elements: (same as for Type I)	4/year (trace elements)
III	STREAM ECOLOGY:	1/year
	Benthic macroinvertebrates: taxonomic identification and enumeration	
	Periphyton algae: taxonomic identification and ash-free biomass	
	Chlorophyll A (periphyton): concentration	
	Fish: taxonomic identification, enumeration, size and age characteristics	Every 3 years
	Bed sediment: trace elements (same as Type I; total recoverable only)	
	Habitat: quantitative and qualitative assessment of physical and ecological characteristics	
	Amphibians: inventory	
IV	RESERVOIR QUALITY:	2/year
	Field measurements: depth profiles of water temperature, specific conductance, pH, dissolved oxygen; water transparency	
	Common Ions: (2 depths) Same as for Type I	
	Nutrients: (2 depths) Same as for Type I	
	Chlorophyll A (phytoplankton): (2 depths) concentration	
	Bacteria (E. coli and fecal coliform): near-surface concentration	

Proposed Surface-Water Monitoring Sites

A description of the proposed surface-water sampling sites for long-term monitoring in the Cheyenne and Belle Fourche River Basins are provided in tables 3 and 4 and shown on the attached map.

Table 3. Proposed surface-water sampling sites for long-term monitoring in the Cheyenne River basin.

Sampling Strategy: Type I, stream chemistry at 12/yr (6/yr trace elements); Type II, stream chemistry at 6/yr (4/yr trace elements); Type III, stream ecology at 1/yr (fish, bed sediments, and habitat every 3rd year); Type IV, reservoir quality at 2/yr
Continuous Record: F, flow; T, temperature; C, conductance; S, turbidity

Map Number	Station Name (Identification Number)	Rationale for Site Selection	Proposed Data Collection	
			Sampling Strategy Type	*Continuous Record*
1	Cheyenne River near Dull Center, WY (06365900)	Mainstem site; uppermost site.	I, III	F, T
2	Black Thunder Creek near Hampshire, WY (06376300)	Major tributary to the upper Cheyenne River; multiple and changing land uses.	II, III	F
3	Cheyenne River near Spencer, WY (06386500, 460156)	Mainstem site near the Wyoming-South Dakota state line.	I, III	F, T, C, S
4	Beaver Creek near Burdock, SD (06394500, 460128)	Major tributary to the upper Cheyenne River; characterizes streamflows and water quality from the southern Black Hills.	II, III	F, T, C
5	Cheyenne River at Edgemont, SD (06395000, 460875)	Mainstem site; represents composite of streamflows and water quality of Beaver Creek and the Cheyenne River.	I, III	F, T, C
6	Cheyenne River near Hot Springs, SD (06400500)	Mainstem site; characterizes inflows to Angostura Reservoir	I, III	F, T, C, S
7	Angostura Reservoir near Hot Springs, SD (new site)	Represents composite of water quality of the upper Cheyenne River and inflows from Horse Creek; recreational uses.	IV	None
8	Fall River at Hot Springs, SD (06402000, 460657)	Major tributary to the middle Cheyenne River; consistent streamflows and water quality resulting from thermal springs.	II, III	F, T
9	Cheyenne River at Redshirt, SD (06403700, 460657)	Mainstem site; water quality influenced by minor tributaries downstream of Angostura Reservoir and irrigation return flows.	I, III	F, T
10	Battle Creek at Hermosa, SD (06406000)	Major tributary to the middle Cheyenne River; streamflows and water quality influenced by fire and multiple land uses.	II, III	F, T
11	Spring Creek near Keystone, SD (06407500, 460649)	Major tributary to the middle Cheyenne River; streamflows and water quality influenced by fire and multiple and changing land uses. Site upstream of Madison Aquifer recharge zone; streamflows lost to aquifer often discharge as springs downstream in the Spring Creek and Rapid Creek basins.	II, III	F, T
12	Rapid Creek above Pactola Reservoir at Silver City, SD (6410500)	Major tributary to the middle Cheyenne River; uppermost site.	II, III	F, T
15	Rapid Creek near Farmingdale, SD (06421500, 460910)	Major tributary to the middle Cheyenne River; site near mouth; streamflows and water quality influenced by multiple land uses.	II, III	F, T
16	Cheyenne River near Wasta, SD (06423500, 460865)	Mainstem site; streamflows and water quality influenced by inflows from Battle Creek, Spring Creek, and Rapid Creek; upstream from the confluence with the Belle Fourche River.	I, III	F, T
42	Cheyenne River near Plainview, SD (06438500, 468860)	Mainstem site; upstream of backwater effects from Lake Oahe.	I, III	F, T
43	Cherry Creek near Plainview, SD (06439000, 460131)	Major tributary to the lower Cheyenne River.	II, III	F, T
44	Cheyenne River above Oahe Dam HWY 63 (460133)	Mainstem site; Type IV sampling strategy because the site is often affected by backwater from Lake Oahe.	IV	None

Table 4. Proposed surface-water sampling sites for long-term monitoring in the Belle Fourche River basin.

Sampling Strategy: Type I, stream chemistry at 12/yr (6/yr trace elements); Type II, stream chemistry at 6/yr (4/yr trace elements); Type III, stream ecology at 1/yr (fish, bed sediments, and habitat every 3rd year); Type IV, reservoir quality at 2/yr
Continuous Record: F, flow; T, temperature; C, conductance; S, turbidity

			Proposed Data Collection	
Map Number	Station Name (Identification Number)	Rationale for Site Selection	*Sampling Strategy Type*	*Continuous Record*
17	Belle Fourche River below Rattlesnake Creek near Piney, WY (06425720)	Mainstem site; uppermost site.	I, III	F, T, C
18	Coal Creek near Piney, WY (06425750)	Tributary site; multiple land uses.	II, III	F
19	Caballo Creek at mouth near Piney, WY (06425900)	Tributary site; multiple and changing land uses.	II, III	F
20	Donkey Creek near Moorcroft, WY (06426400)	Tributary site; multiple and changing land uses.	II, III	F
21	Belle Fourche River below Moorcroft, WY (06426500)	Mainstem site; upstream of Keyhole Reservoir.	I, III	F, T
22	Belle Fourche River below Hulett, WY (06428050)	Mainstem site; streamflows regulated by Keyhole Reservoir.	I. III	F, T
23	Beaver Creek above Cook Lake near Alva, WY (new site)	Tributary reference site.	II, III	F
24	Beaver Creek at mouth near Alva, WY (new site)	Tributary site; multiple land uses.	II, III	F
25	Belle Fourche River at WY-SD State Line (06428500)	Mainstem site near Wyoming-South Dakota state line.	I, III	F, T, C, S
26	Sand Creek near Ranch A near Beulah, WY (06429905)	Tributary site; streamflows and water-quality influenced by springs.	II, III	F
27	Redwater Creek at WY-SD State Line (06430500)	Major tributary site near Wyoming-South Dakota state line.	II, III	F, T
29	Spearfish Creek at Spearfish, SD (06431500, 460900)	Lower site on tributary to Redwater Creek; urban land uses.	II, III	F, T
30	Redwater Creek above Belle Fourche, SD (06433000, 460895)	Major tributary site; streamflows and water quality influenced by spring discharges from the Black Hills and by multiple land uses.	II, III	F, T
31	Inlet Canal near Belle Fourche, SD (06434505)	Site on canal that diverts most of the flows in the Belle Fourche River to an off-stream reservoir.	II, III	F, T
32	Belle Fourche Reservoir near Belle Fourche, SD(06435000)	Off-stream reservoir with multiple uses including recreation and irrigation.	IV	None
33	Belle Fourche River near Fruitdale, SD (06436000)	Represents minimal flow maintained in the Belle Fourche River when water is being diverted to Belle Fourche Reservoir	I, III	F, T
36	Whitewood Creek above Vale, SD (06436198, 460682))	Represents tributary inflow	II, III	F, T
37	Horse Creek near Vale, SD (06436760)	Represents major tributary inflow and typically accounts for approximately ¼ of the irrigation non-used water as well as storm and spring runoff.	II, III	F, T, S
38	Belle Fourche River near Sturgis, SD (06437000, 460880)	Downstream of most urban, mining, and irrigation influences.	I, III	F, T
40	Bear Butte Creek at Sturgis, SD (06437400)	Lower portion of tributary with urban influences	II, III	F, T
41	Belle Fourche River near Elm Springs, SD (06438000, 460676)	Mouth of the Belle Fourche River basin and major tributary to the Cheyenne River	I, III	F, T

Technical Considerations for Network Operation

This section describes some basic features of how a comprehensive network might be operated to obtain data of high quality and to disseminate information to the public. Depending on what entity actually performs the data collection, specific practices would need to be documented in appropriate methods reports or project sampling plans. The purpose of this overview is to outline features of network operation that could serve as a general guide for consistency in data quality. Similarity in data-collection methods and sampling intensity will lead to comparable levels of data among sites that can facilitate data interpretation and comparisons of data among sites. Complete consistency can be difficult to achieve when the network represents a combined effort of multiple entities and programs, each having potentially different monitoring objectives. However, an outline of some basic operational features may provide a common basis for network designs among agencies.

Data Collection

The following sections describe some general features of data collection related to sampling and analytical methods, plus quality-assurance practices to evaluate the performance of the methods being used to generate data.

Sampling Methods

Sampling methods can vary greatly among agencies, consultants, university researchers, and volunteer monitoring groups. While each method of sampling may be valid for the specific objectives of the individual group's program, substantial differences in methods can complicate the comparability of the data over a large network of sites. Ideally, a single entity using a standard method of data collection would produce the most consistent data quality over time. Where this is not feasible, multiple entities utilizing identical or very similar methods would produce generally comparable results that would presumably be capable of supporting between-site comparisons necessary for environmental assessments. At a minimum, the entities that are enlisted to conduct sampling should have their methods fully documented and available for outside review in order to evaluate the suitability of the data for meeting various objectives.

The goal of water-quality sampling in streams is to obtain a sample that is representative of the average composition across the entire stream cross section. The most commonly used stream sampling method is "grab" sampling, which provides an easily obtainable aliquot of water in a manner that is inexpensive and requires no specialized equipment or staff training. Although widely used, it should be cautioned that such sampling has limitations when dealing with large rivers or with any stream during periods of high flow. To fully account for potential variability due to incomplete mixing of upstream inflows or unequal distribution of suspended particles, it is necessary to use sampling methods that can provide representative data over the full range of hydrologic and seasonal conditions. This will usually involve obtaining a discharge-weighted sample that represents a composite of depth-integrated (sampled from water surface to streambed) subsamples collected from multiple verticals across a stream. Discharge-weighted sampling methods result in the volume of sample water obtained at each vertical being proportional to the percentage of total flow passing that individual subsection. Discharge-weighted sampling methods and examples of isokinetic sampling equipment can be reviewed in various USGS reports (Edwards and Glysson, 1999; Wilde and others, 1998).

Obtaining a representative water sample from a lake or reservoir also requires specialized methods that are applied consistently at all sampling sites in a reservoir. Depth- integration sampling is not done in reservoirs; rather, water is obtained from known depths and brought to the surface in an unmodified condition using sampling bottles that are capable of opening and closing at discrete depths. Sampling at multiple locations and at multiple depths will provide a three-dimensional view of water-quality variations. The extent of characterization will vary with the number of sampling locations in a reservoir, although the initial sampling design can be a simplified version to obtain a general sense of reservoir mixing dynamics. Examples of sampling methods and lake-sampling equipment are provided in Ward and Harr (1990).

Similar to water sampling, biological sampling methods can also vary according to the entity collecting the samples or the objectives of the particular program. The goal is to obtain a sample of the targeted biota in a manner that provides a representative characterization of the biological community. Sampling methods should be clearly documented and protocols must be followed consistently to obtain data that can produce representative results and that can be compared among sites and over time. Depending on the methods used, the biological data can be either quantitative or semi-quantitative. Multiple habitat types are commonly sampled in order to determine variability within the reach. Specific types of biological sampling equipment will be necessary to obtain results that conform to most standard sampling protocols. In some instances, such as for fish, permits will need to be obtained from appropriate agencies to collect samples. Examples of biological sampling methods, equipment, and processing are provided in Moulton and others (2002).

In addition to the collection of the sample, there will typically be onsite processing of that sample to prepare it for subsequent laboratory analysis. This can involve filtration to remove suspended material, preservation with various chemicals, or chilling to stabilize the constituents. Special handling protocols for all equipment used during sample collection, and of all materials used to process the sample onsite, are necessary to prevent any extraneous contamination that could be erroneously interpreted to represent an environmental concentration. Clean sample collection and processing methods are described in USGS reports (Horowitz and others, 1994; Wilde and others, 1998).

State and Federal habitat assessment programs often vary in objectives and methodologies (Fitzpatrick and others, 1998). As a result, the comparability of the results is not known or not possible. Prior to basin-wide implementation of this plan, stakeholders in the basins should reach a consensus on what habitat protocols should be used.

Analytical Methods

Numerous government and private laboratories can analyze environmental concentrations of a wide range of chemical constituents found in water. Many laboratories either utilize standard EPA water/wastewater methods (Eaton and others, 1995) or use other agency methods that are documented and approved by rigorous testing to produce accurate results for environmental concentrations (Fishman, 1993). Similarly, many laboratories are available to provide taxonomic identification and enumeration of aquatic biota. Whatever laboratory is used, all methods should be documented, analytical capabilities should be available for all constituents of interest, and minimum reporting levels should be adequate to either allow uncensored quantification of ambient concentrations or be substantially lower than any relevant water-quality standard.

Quality Assurance

Quality assurance is essential to produce reliable data of known quality and should be integrated into all aspects of sample collection, laboratory analysis, data management, and data reporting. An important component of quality assurance is to have documented methods that can be referred to as a guide for proper application of procedures. Written methods should supplement formal training of staff in specialized procedures that may be needed to accommodate a wide range of stream conditions.

Quality-assurance practices should include a systematic plan for testing the performance of data-collection and laboratory analytical methods in order to detect, quantify, and evaluate data-quality problems. This is commonly done through a process of routinely collecting quality-control samples (such as blanks and replicates) that are handled and processed in the same manner and with the same equipment used for water samples. These types of samples will generally constitute about ten percent of the sample load and are submitted to the laboratory for analysis of the same constituents analyzed in the routine samples. The results of quality-control samples are used to compile a record of bias and precision associated with the routine samples. The results can be reviewed in context with environmental data to evaluate data quality. In addition to field practices to verify data quality, analytical laboratories should also employ rigorous quality-assurance practices to ensure the quality of analytical results. Precision estimates should be available for each method, and the laboratory should participate in external quality-assurance testing. The laboratory also should provide analytical reruns for questionable results, have documented internal quality-assurance practices, and be able to provide data that documents the analytical performance of internal quality-assurance testing. Ultimately, quality assurance is intended to confirm data quality, prevent or minimize problems, and to provide insight on how to resolve problems when they occur. Examples of quality-assurance practices are provided in various USGS reports (Moreland, 1991; Knapton and Nimick, 1991; Lambing and Dodge, 1993; White and others, 1998; Pritt and Raese, 1995; and Matthes and others, 1991; Wilde and others, 1998).

Data Management and Reporting

The data generated from a large-scale, long-term monitoring program will need to be managed efficiently in order to ensure that the information is accurately recorded, archived in a secure system, and accessible to the public. All primary data should be stored in computerized databases that can be backed up and retrieved upon request or accessed via web pages. All data and ancillary information generated during the sequence of steps from sample collection through laboratory analysis should be stored in either computer or hard-copy files. Organized site files permit the tracking, retrieval, and transmittal of data, as well as maintain a record of station history. The laboratory data need to be reviewed promptly for completeness and technical adequacy, and analytical reruns may be necessary to verify anomalous values. Reviews and approval of laboratory data should incorporate various acceptance criteria, such as completeness, ionic electrical balance, comparison of recent results to historical data to identify outliers or extreme values, comparison of data to that of nearby sites to assess consistency in patterns of variation, and review of field notes to identify any unusual local land-use, climatic, or other factors.

The reporting of data represents the final step in delivering information to resource-management agencies and the public. This is the interface between the data-collection entity and the data users that is crucial to maintaining a system of equal access to information. The lack of such equal access can bear on the credibility of the data and objectivity of the monitoring program. The capabilities of different entities to disseminate data will vary, but ideally, all data should be transmittable via electronic files. Provisional data that have not received final quality-assurance checks and have not been approved for public release may sometimes need to be temporarily withheld, but release of provisional data for preliminary inspection should be accommodated whenever possible. If the private entity or government agency does not have the means to serve the data on a publicly-accessible site, such as on the Internet, it would be beneficial to load the data to the STORET database administered by EPA.

Data also can be disseminated through reports that are published at regular intervals, such as an annual report series. In some instances, it may be preferable to summarize the data in various ways to illustrate data patterns (statistical distributions or time series) that are more descriptive than a simple tabulation of data. Analysis of the data using detailed calculations and statistical relations that are used to support interpretations such as source-area load assessments, long-term trends, modeling of potential impacts, or description of geochemical processes is an ultimate goal for providing meaningful environmental assessments. Such detailed interpretive efforts are generally undertaken after sufficient data have been generated over a number of years to adequately characterize water-quality conditions over a broad range of streamflow.

Supplemental Studies

Stakeholders expressed a need for acquiring data to examine either localized conditions or environmental processes in more detail than can be accomplished with a broadly distributed network of sites. Although the proposed long-term network described in this monitoring plan cannot fully address all environmental issues in these basins, the data from a core set of sites can support other studies having more targeted objectives. If targeted studies establish additional monitoring sites to obtain increased spatial resolution, it should be feasible to modify the sampling intensity of nearby sites in the long-term network, such as increasing sampling frequency or adding parameters, in order to support the objectives of other studies and enhance interpretation of environmental processes.

This type of coordination likely can be accomplished through regular committee meetings and correspondence among agencies.

Further discussions regarding various types of targeted studies, as represented by several examples given below, may be warranted among the stakeholders to evaluate the feasibility and benefits of pursuing additional monitoring. Some examples of the types of targeted studies that could provide valuable information in the basins are:

1) Ephemeral and intermittent tributary monitoring: This approach was predominantly considered for the Cheyenne River Basin where streams flow sporadically and typically for short duration as a result of precipitation runoff. Some of the short-duration runoff is of considerable magnitude and potentially can contribute large salt and sediment loads to the mainstem. Sampling is essentially non-existent due to the unpredictable nature of the runoff. Such sporadic runoff makes systematic sampling difficult and, thus, these types of drainages were not included in the long-term network. Given the recognition that their input may be substantial, albeit infrequent, a study designed to accommodate the irregular flow frequency, such as through automatic pumping samplers, may provide valuable insight on the relative impact of naturally occurring salt and sediment loads on the mainstem relative to those loads draining from basins with perennial flow.

   An alternative or additional approach discussed by stakeholders included a 3-year rotational synoptic sampling of tributaries in the upper Cheyenne River Basin. Ephemeral and intermittent streams are unique in that the biota have adapted to the conditions and can be different from biota in perennial ecosystems. Thus, the primary focus of the sampling would be equivalent to Type III (Stream Ecology) monitoring. A set of tributary segments or reaches could be identified. A subset (1/3) of the reaches or segments could be sampled the first year with the second and third subsets sampled in subsequent second and third years. Even though the sampling focus would be Type III monitoring, stream sampling equivalent to Type I or II monitoring should be included as appropriate.

2) Characterization of local ground-water effects: Similar to load apportionment, a watershed-scale network cannot by itself quantify reach-scale groundwater components. Such a detailed analysis of surface water - ground water interactions would require the installation of monitoring wells to determine local head and flow gradients. Although beyond the scope of this surface-water network, such an approach to characterize shallow groundwater flow paths and water quality might be coupled with synoptic sampling/flow measurement of irrigation ditches and streams to determine irrigation effects within specific valley segments.

   In the Black Hills of South Dakota, the Madison aquifer is a primary source of drinking water. Streams flowing across outcrops of the Madison are important sources of recharge to the aquifer. Tributary monitoring sites were identified upstream of these loss zones in response to concerns by stakeholders concerned about the water quality of the streams. Even though flows at these tributary sites upstream of the loss zones do not represent direct inflows to the Cheyenne or Belle Fourche Rivers, flows at these sites are representative of springs that discharge from the aquifer downstream.

   In addition to irrigation effects on shallow ground water, there are concerns regarding the potential impact of on-channel impoundments being considered to store CBNG production waters. These concerns include the potential for the ponded water to infiltrate through the alluvium and eventually discharge to surface waters or underlying aquifers, the potential for the CBNG-produced water to degrade the quality and diminish the use of surface water or shallow ground water, and the uncertainty of how the chemistry of CBNG- production waters will react with the chemistry of the receiving waters or with the soil and channel materials at the impoundment site.

It appears that there is much interest in quantifying shallow ground-water effects from both irrigation and CBNG activities. A multi-discipline surface-water/ground-water study may offer the best approach to resolving site-specific issues of quantity and quality within the channel alluvium and irrigated segments of the valley corridor. An additional component that could contribute to the understanding of water chemistry evolution is sampling of soils to characterize their chemical composition and potential geochemical response to the application of either irrigation water or CBNG production water.

Relatively few data describing the occurrence of radioactive elements in CBNG-produced waters are available. Radioactivity occurs naturally from the release of energy resulting from the degradation—or decay—of unstable atomic—or nuclear—structures. Most of the radioactivity in natural waters is a result of uranium nuclides decaying to more stable nuclides (Hem, 1989). A synoptic sampling of CBNG-produced waters for radioactive elements could contribute to the understanding of water quality characteristics of ground water as well as surface water in the Cheyenne and Belle Fourche River basins.

3) Additional surface-water sampling sites important to local monitoring were identified by stakeholders using rationale that were inconsistent with the sampling plan objectives. For example, some sites were included because they bracketed a specific water-quality impact. The purpose of this sampling plan is not to characterize local impacts from any specific sector. Other sites selected as reference sites are downstream of significant water-quality impairments, thus limiting their value as reference sites. Some of these sites also are located on minor tributaries.

Table 5. Additional surface-water sampling sites important to local monitoring, Cheyenne and Belle Fourche River basins.

Sampling Strategy: Type I, stream chemistry at 12/yr (6/yr trace elements); Type II, stream chemistry at 6/yr (4/yr trace elements); Type III, stream ecology at 1/yr (fish, bed sediments, and habitat every 3rd year); Type IV, reservoir quality at 2/yr
Continuous Record: F, flow; T, temperature; C, conductance; S, turbidity

			Proposed Data Collection	
Map Number	**Station Name (Identification Number)**	**Rationale for Site Selection**	***Sampling Strategy Type***	***Continuous Record***
13	Rapid Creek above Canyon Lake near Rapid City, SD (06412500)	Major tributary to the middle Cheyenne River; site upstream of urban influences and downstream of Madison Aquifer recharge zone.	II, III	F, T
14	Rapid Creek below Sewage Treatment Plant near Rapid City, SD (06418900)	Major tributary to the middle Cheyenne River; site downstream of largest urban area in the basin.	II, III	F, T
28	Spearfish Creek above Spearfish, SD (06430900, 46MN35)	Upper site on tributary to Redwater Creek; downstream of mining and upstream of urban land uses; upstream of Madison Aquifer recharge zone.	II, III	F, T
34	Whitewood Creek above Lead, SD (06436150)	Represents upper portion of tributary that has historical contamination problems. Site located above most urbanization.	II, III	F, T
35	Whitetail Creek above Whitewood, SD (06436180, 460684))	Represents lower portion of tributary that has historical contamination problems. Site located at upper end of mine-tailing deposition and previous superfund site. Does provide additional information on urbanization upstream	II, III	F, T
39	Bear Butte Creek near Deadwood, SD (06437020, 460125)	Upper portion of tributary with mining influences upstream	II, III	F, T

Agency Collaboration and Coordination

To successfully implement and operate a watershed-scale monitoring network, it will be necessary to work with the Federal, State, Tribal, and local agencies that have resource-management responsibilities. Monitoring activities will be directed toward meeting the needs of those agencies, whose missions involve serving a diverse range of public interests. Although the broadly distributed network described in this document cannot meet the specific needs of all agencies, it can be a framework of consistent, long-term data spanning a large geographic area that can serve as a foundation upon which other studies can be built.

An example of an inter-agency effort that serves as a forum for government agencies to address and discuss issues of concern regarding potential environmental impacts is the Powder River Basin Interagency Working Group administered by the BLM to assess numerous aspects of CBNG development. The mission of this working group is to collect and integrate the information necessary to protect environmental quality, while providing for sound development of energy resources. It is anticipated that a watershed-scale network of the type described in this document could support many of the objectives of the Powder River Basin Working Group and other groups that have a need to obtain data in specific areas for targeted objectives.

Information Exchange

The primary means of coordinating efforts among numerous agencies is to have a regular exchange of information. This can be accomplished in a number of ways, including periodic meetings where agency personnel and stakeholders provide input on issues of concern, email correspondence of new developments, announcements of recent publications relevant to water quality in the basins, and participation in committee meetings. There are currently a number of committees already established to deal with water-quality issues in the basin and their meetings may be adequate to allow stakeholders to provide input on concerns. To stay abreast of new developments, the stakeholders suggested this monitoring plan function more as a “living document.” Acknowledging that the plan should be periodically evaluated, it was proposed that a mechanism be put in place allowing for the stakeholders to discuss current and changing conditions in the basins. To facilitate such discussion, one possible approach is to form a technical committee comprised of stakeholders and (or) their representatives. Such a committee could meet annually and discuss additions or changes to the plan, progress on implementation of the plan, emerging issues in the basins, and other relevant items.

Funding and Implementation

With this network design to serve as a guidance document for recognizing priority sites and parameters in the basin, the initial challenge will be to secure the funding necessary to begin implementation of the monitoring network. Ultimately, maintaining funding to operate the network over the long term will be an ongoing challenge. It should not be expected that any single funding source will be able to pay for all data types at all of the sites. Realistically, individual sites, or possibly only individual components of data collection, will be funded through a number of different agencies, grant programs, congressional allocations, etc., so that the bulk of the network can be in place and operating in a concurrent time period. With the guidance provided in this document, it is hoped that a consistent set of core parameters will be analyzed, regardless of who provides the funding or who collects the samples. This base level of consistency will eventually allow a coherent set of data to be available for a large geographic area, and potentially for similar time periods, wherein the data from all sites represent a relatively equivalent hydrologic regime that would enhance between-site comparisons of environmental conditions.

At this time (2005), several of the proposed sites in the Cheyenne River and Belle Fourche River Basins have some level of active water-quality sampling and streamflow gaging. Recent developments in the winter of 2005 include funding provided by several agencies to embark on an aquatic monitoring effort in northeastern Wyoming and southeastern Montana. Part of the study area includes the Cheyenne and Belle Fourche River Basins. The USGS will likely be able to provide some matching funds to support streamflow gaging and sampling activities wherever cooperating State, Tribal, or local agencies can secure 50 percent or more of the costs. Various EPA grant programs exist where State, Tribal, and local agencies can submit proposals for short-term funding. Although grant funds may be limited to a single year or a short-term period, the collective effort to secure funds may be patched together for priority sites and possibly result in an uninterrupted period of data collection. At a minimum, short-term funding can provide baseline data for new sites or updated information for former sites. Long-term data collection will be difficult to maintain, but as the benefits to resource management become evident, the chances for sustained funding may increase.

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Appendix

List of stakeholder meeting attendees.

Name	Street	City	State	Zip	Agency
Joyce E. Williamson	1608 Mountain View Rd	Rapid City	SD	57702	USGS
Kirk Miller	2617 E Lincolnway	Cheyenne	WY	82001	USGS
Mike Sweat	2617 E Lincolnway	Cheyenne	WY	82001	USGS
Bud Stewart	PO Box 6249	Sheridan	WY	82801	WY Game & Fish Dept
Andy Bobst	111 Garryeven Rd	Miles City	MT	59301	MT-Dak BLM
Karl Jensen		Whitewood	SD	57793	Lawrence CD
Charlie Trautwein	1408 E. 33rd st	Sioux Falls	SD	57105	USGS
Karen Hamilton	999 18th st suite 300	Denver	CO	80202-2466	USEPA
Heidi Sturman	Box 659	Lusk	WY	82225	Niobrara CD
Lisa Shaw	Box 659	Lusk	WY	82225	Niobrara CD
Cindy Steele	200 4th st	Huron	SD	57350	NRCS
Scott Tangenberg	PO Box 5680	Sundance	WY	82729	USFS - Black Hills
Michelle Cook	PO Box 2577	Gillette	WY	82717	Cambell Co CD
Debbie Hepp	PO Box 2577	Gillette	WY	82717	Cambell Co CD
Gene Stueven	523 E. Capitol	Pierre	SD	57501	SD DENR
Trish Kindt	523 E. Capitol	Pierre	SD	57501	SD DENR
Tom Quinn	1837 5th St.	Belle Fourche	SD	57717	NRCS
Dan Driscoll	1608 Mountain View Rd	Rapid City	SD	57702	USGS
Tate Lantz	2202 West Main St	Sturgis	SD	57785	NRCS
Ed Duke	501 E. St Joseph	Rapid City	SD	57701	South Dakota School of Mines
Dan Hoyer	3824 Jet Dr	Rapid City	SD	57701	RESPEC
Fay Streier	515 9th St. Rm 101	Rapid City	SD	57701	BOR
Joel Brumm	PO Box 268, 13000 Hwy 244	Keystone	SD	57751	Nationa Park Service, Norther Great Plains
Christine Galloway	PO Box 1020	Sundance	WY	82729	Crook County NRD
Elizabeth Reede	Po Box 590	Eagle Butte	SD	57625	Cheyenne River Sioux Tribe, EPP 106