NEW MEXICO ENVIRONMENT DEPARTMENT
SURFACE WATER QUALITY BUREAU

Completion of Nutrient Threshold Development for New Mexico Streams and Rivers and Begin Development of Lake and Reservoir Nutrient Threshold

Submitted to:
U.S. Environmental Protection Agency
Region 6

Submitted by:
New Mexico Environment Department
Surface Water Quality Bureau
1190 Saint Francis Drive
Santa Fe, NM 87502

April 28, 2006
REVISED: April 9, 2008

Title and Approval Sheet

Project Title: **Completion of Nutrient Threshold Development for New Mexico Streams and Rivers and Begin Development of Lake and Reservoir Nutrient Threshold – Phase 3**

New Mexico Environment Department Surface Water Quality Bureau

Program Manager: _____ Date: _____
Jane DeRose-Bamman, Staff Manager

Project Manager: _____ Date: _____
Seva Joseph, Environmental Specialist

QA Officer: _____ Date: _____
Stephanie Stringer, Environmental Specialist

United States Environmental Protection Agency Region VI

EPA Quality Assurance Officer: _____ Date: _____
Arlene Gaines

EPA Project Officer: _____ Date: _____
Tim Herfel

TABLE OF CONTENTS

LIST OF ACRONYMS 4
SECTION 1 PROJECT MANAGEMENT 5
1.1 Project Definition/ Background 5
1.2 Project/Task Description 6
1.3 Proposed timetable 7
1.4 Data Quality Objectives (DQOs) 8
SECTION 2 DATA GENERATION AND ACQUISITION 10
2.1 Sampling Process Design 10
2.2 Field Measurement and Sampling Procedures 17
2.3 Sample Handling and Custody Requirements 18
2.4 Analytical Methods Requirements 19
2.5 Quality Control Requirements 19
2.6 Instrument/ Equipment Testing, Inspection, and Maintenance Requirements 20
2.7 Instrument Calibration and Frequency 20
2.8 Inspection and Acceptance Requirements for Supplies 21
2.9 Data Acquisition Requirements 21
2.10 Data Management 21
2.11 Assessments and Response Actions 21
2.12 Reports 22
SECTION 3 DATA VALIDATION AND USABILITY 22
3.1 Data Review, Validation and Verification Requirements 22
3.2 Validation and Verification Methods 22
3.3 Reconciliation with Data Quality Objectives 22
REFERENCES 23

LIST OF ACRONYMS

AFDM	Ash free dry mass
APHA	American Public Health Association
CFR	Code of Federal Regulations
cm^2	Square centimeters
CWA	Clean Water Act
DO	Dissolved Oxygen
ft/s	Feet per second
GIS	Geographic Information Systems
GPS	Global Positioning System
mg	Milligram
mg/L	Milligrams per liter
NMED	New Mexico Environment Department
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Units
ºC	Degrees Celsius
QA	Quality Assurance
QAP	Quality Assurance Program
QAPP	Quality Assurance Project Plan
QC	Quality Control
RBP	Rapid Bioassessment Protocol
RTH	Richest-Targeted Habitat
SCI	Stream condition index
SLD	Scientific Laboratory Division
SOP	Standard Operating Procedure
STORET	Storage and Retrieval
SWQB	Surface Water Quality Bureau
TDS	Total dissolved solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

SECTION 1 PROJECT MANAGEMENT

1.1 PROJECT DEFINITION/ BACKGROUND

Excessive nutrients are one of the top three causes of impairment to the nation's waters. The federal Clean Water Action Plan of March 1998 requires that EPA and States develop and implement numeric criteria for nutrients. In January of 2001, EPA recommended that states develop a plan for nutrient criteria development by the end of the year and make substantial progress in this plan by the end of 2004. In January of 2002, the Surface Water Quality Bureau (SWQB) submitted a letter to EPA Region 6 stating that development of nutrient criteria would be based on the nutrient assessment protocol. In 2004, SWQB submitted a Nutrient Criteria Development Plan and draft Nutrient Assessment Protocol to EPA for review and comment. SWQB submitted a revised Nutrient Criteria Development Plan in 2005 and in early 2006 this plan was "mutually agreed upon" by EPA. As outlined in the plan, nutrient data were collected from streams in 2004 and 2005 for the refinement of threshold values in the draft Stream Nutrient Assessment Protocol. In 2006, the process of refining the Stream Nutrient Assessment Protocol will continue and collection of nutrient data from rivers, lakes, and reservoirs will begin.

The state of New Mexico has a narrative nutrient criterion which states that, "Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state" (NMAC 2005). This narrative nutrient criterion is challenging to assess, as the relationships between nutrient levels and impairment of designated uses are not defined, and distinguishing nutrients from "other than natural causes" is difficult. To meet this challenge, SWQB developed a nutrient assessment protocol. It was developed for streams, which represent the majority of assessed surface waters in the state. This protocol was successfully applied and used to develop non-point source Total Maximum Daily Loads (TMDLs). However, it lacked impairment thresholds and quantitative endpoints needed to develop TMDLs with both non-point and point sources. There is a need to define the narrative nutrient criterion, so in 2004 a revised assessment protocol was drafted with threshold values. The assessment uses a weight of evidence approach in order to conduct a more robust assessment accounting for diverse lotic systems and dynamic nutrient cycling. There is now the need to test and refine the threshold values with regional data and an appropriate classification system and to develop assessment protocols and associated numeric translators for rivers as well as lakes and reservoirs.

Nutrient criteria work funded under 2003 and 2004 104(b)(3) developed a dataset to define the relationships between the cause and response variables and impairment thresholds and to test and refine literature threshold values for streams. However, more data is needed for rivers, lakes, and reservoirs. The primary nutrient criteria variables suggested by EPA in the Nutrient Criteria Technical Guidance Manual (EPA 2000a) are: water column concentrations of total nitrogen (TN) and total phosphorus (TP) (causal parameters), algal biomass (as chlorophyll *a*), and turbidity or transparency (response parameters). Additional response variables such as dissolved oxygen (DO), pH, plankton and periphyton biomass and community composition, and benthic macroinvertebrate community composition will also be considered. While the SWQB monitored

nutrient concentrations for many years, response variables such as plankton and periphyton community composition and biomass and benthic macroinvertebrate community composition have been monitored infrequently. Cause and response variables were rarely monitored concurrently. These types of data are needed to define relationships between causal and response variables, quantitative endpoints, and impairment thresholds.

1.2 PROJECT/TASK DESCRIPTION

Data will be collected and analyzed to develop nutrient assessment protocols for rivers, lakes, and reservoirs. Monitoring protocols will be developed and/or refined as needed. Threshold values for each waterbody class will be defined for both cause and response variables and contained within the appropriate assessment protocols. Suitable classification systems will be developed for waterbody types, e.g. sub-ecoregional classes based on classification variables such as designated use, lake type, size or depth, watershed size, and geology. A literature review will be conducted to develop monitoring protocols, classification systems, and to define potential threshold values for TN, TP, DO, pH, and algal biomass.

SWQB is distinguishing rivers from streams by defining systems that cannot be monitored effectively with the biological and habitat methods developed for wadeable streams. These rivers also generally meet the Simon and Lyons (1995) definition of great rivers as those having drainage areas greater than 2,300 square miles (mi^2). There are many systems is in New Mexico that meet the great river definition but are suitable to wadeable streams monitoring methods due to the arid nature of the region. The systems included in the "rivers" waterbody type are:

1. The San Juan River from below Navajo Reservoir to the Colorado border near Four Corners,
2. The Rio Grande in New Mexico,
3. The Pecos River from below Sumner Reservoir to the Texas border, and
4. The Rio Chama from below El Vado Reservoir to the Rio Grande.

The only river listed above that does not meet the great rivers definition is the Rio Chama, which has a drainage area of only 880 mi^2 below El Vado Reservoir. However, the flow of the Rio Chama is augmented with water diverted from the San Juan River drainage via the San Juan/Chama Project. The Rio Chama reaches a drainage area of 2300 mi^2 below Abiquiu Reservoir.

Lake and reservoir waterbodies have been divided into four general classes (cirque lakes, sinkhole lakes, and large and small reservoirs). Cirque lakes are defined as natural lakes that occur in a steep bowl-shaped hollow occurring at the upper end of a mountain valley, especially one forming the head of a glacier or stream. In New Mexico these lakes are generally small (less than 8 acres) and at high elevations (greater than 8000 feet). Sinkhole lakes are those occurring in a natural depression in the surface of the land caused by the collapse of the roof of a cavern or subterranean passage, generally occurring in limestone regions. In this document, reservoir refers to **man-made** ponds or lakes used for the storage and regulation of water. Large reservoirs are those greater than 100 acres and small reservoirs are those 100 acres and less.

Other lake classification systems will be explored once classification parameters are collected and analyzed. Fifteen stream reference sites (Table 1) that were monitored in 2004 and 2005 will be monitored again in 2006 to examine year-to-year variability.

Threshold values will be tested and refined with regional data. In order to accomplish this, SWQB will survey sites from rivers (Table 2), reservoirs (Table 3), and lakes (Table 4). A nutrient survey will be conducted at each site including measurement of both cause and response variables as well as classification parameters. The variables to be monitored include: 1) algal biomass, 2) periphyton or phytoplankton community composition, 3) nutrient concentrations (TP, nitrate + nitrite, ammonia, and total Kjeldahl nitrogen (TKN)), 4) field parameters (DO, pH, turbidity, temperature, and conductivity), 5) benthic macroinvertebrate community composition, and 6) a number of habitat and classification parameters. Methods and parameters will vary between rivers and lakes and reservoirs.

In rivers, water column (planktonic) and benthic (periphyton) chlorophyll *a* concentration will be determined. Habitat parameters will be monitored including velocity, canopy cover, width and depth, and substrate composition. Sondes will be deployed to take 3-7 days of hourly recordings of field parameters (DO, pH, turbidity, temperature, and conductivity) to examine diurnal fluctuation.

In lakes and reservoirs, algal biomass will be determined from water column samples collected from the euphotic zone. Algal community composition will focus on plankton and periphytic diatoms. Field parameters will be measured along depth profiles and water quality samples will be collected from a depth-integrated sample. The euphotic zone, total depth, and secchi depth also will be determined.

Additional site information will be collected to aid in classifying waterbodies and defining reference sites. Classification parameters to be added to the dataset include ecoregion, watershed size and dominant geology, elevation, percent of different land uses, designated use, and depth. All of the data will be analyzed to test the applicability of literature threshold values, refine waterbody classifications, and where possible define impairment thresholds and adjust threshold values. Nutrient assessment protocols will be drafted for rivers and lakes and reservoirs, and will include waterbody classification systems with their associated threshold values.

1.3 PROPOSED TIMETABLE

Date	**Task**
Sept 1, 2005	Meeting to plan lake/reservoir and river nutrient project
Sept 30, 2005	Continue collection of nutrient data for streams and rivers
Dec 31, 2005	Refine Nutrient Assessment Protocol for streams
Mar 31, 2006	Complete compilation of lake/reservoir dataset and identify data gaps
Apr 30, 2006	Complete QAPP and study design for lakes/reservoirs project
Jun 15, 2006	Begin monitoring of reservoirs. Complete SOP for river monitoring.

Aug 15, 2006	Begin 2006 collection of nutrient data for streams and rivers.
Nov 15, 2006	Complete monitoring of 2006 streams, rivers, and lakes/reservoirs
Apr 30, 2007	Complete processing of water and add to existing dataset
Jun 15-Nov 15, 2007	Monitoring of 2007 lakes and reservoirs
Aug 15-Nov 15, 2007	Monitoring of 2007 rivers
Apr 30, 2008	Complete processing of 2007 water and biota samples and add to existing dataset
July 31, 2008	Complete compilation and review of lake and reservoir nutrient indicator dataset
	Compile river nutrient indicator dataset
Aug 15-Nov 15, 2008	Monitoring of 2008 rivers
Dec 31, 2008	Initial data analysis and draft lake and reservoir classification system
	Add diatom-nutrient index to Nutrient Assessment Protocol (AP) for Streams
Apr 30, 2009	Add 2008 river data to river dataset and complete compilation and review
July 31, 2009	Outline Nutrient AP for Lakes and Reservoirs with provisional threshold values
	Initial data analysis and draft river classification system
Dec 31, 2009	Test provisional threshold values for lakes and reservoirs
	Outline Nutrient AP for Rivers with provisional threshold values
July 31, 2010	Refine lake and reservoir threshold values
	Test provisional threshold values for rivers
Dec 31, 2010	Draft Nutrient AP for Lakes and Reservoirs
	Refine river threshold values
July 31, 2011	Draft Nutrient AP for Rivers

1.4 DATA QUALITY OBJECTIVES (DQOS)

This project is intended to produce data to draft Nutrient Assessment Protocols for Rivers and Lakes and Reservoirs by defining classification systems and defining nutrient translator values for the select nutrient variables. The nutrient variables under consideration for rivers are: water column concentrations of TN and TP (causal parameters), periphyton and/or plankton biomass (as chlorophyll *a*), dissolved oxygen, pH, and periphyton and benthic macroinvertebrate community composition (response parameters). For lakes and reservoirs the nutrient variables under consideration are: water column concentrations of TN and TP (causal parameters), plankton biomass (as chlorophyll *a*), dissolved oxygen, secchi depth, and plankton and benthic diatom community compositions (response parameters). The data quality objectives for this project include the following:

1) <u>To collect water quality, habitat, and biological data that are representative of rivers, lakes, and reservoirs from various aquatic life uses, and ecoregions within New Mexico</u>. **Representativeness** will be achieved by selection of sites, training of sampling staff, and adherence to SWQB standard operating procedures (SOP) and the quality assurance project plan (QAPP). All of the data will be collected and processed in accordance with methods documented in our EPA-approved QAPP (NMED/SWQB 2005) and associated SOP (NMED/SWQB 2004).

2) <u>To collect data that are comparable</u>. **Comparability** will be achieved through the use of standardized data collection methods and sample handling and analysis. Standardization

will be attained by: 1) using standardized field forms (Appendix B), 2) utilizing standardized benthic macroinvertebrate, water quality, habitat, and periphyton sampling and processing methods, and 3) ensuring consistent data handling and reporting.

3) To collect data with a high degree of precision. **Precision**, or reproducibility among duplicate observations, will be addressed by collection of duplicate water quality samples. The water quality duplicates will be subjected to a thorough QA review with the relative percent difference calculated for each parameter and those that are outside of the control limits flagging as described in the SWQB QAPP Section No. 4 (NMED/SWQB 2005). The QA/QC procedures in the QAPP include the collection and analysis of 10% of water samples as duplicate and blanks, adherence to calibration methods, and taxonomic verification of a subset of periphyton and benthic macroinvertebrate samples as well as a thorough QA review of all site and analytical data, and flagging of all parameter that are outside of the control limits.

4) To collect data with a high degree of accuracy. **Accuracy** is the closeness of agreement between an observed value and an accepted reference value. Bias is assessed by comparing a measured value to an accepted reference value in a sample of known concentration or by determining the recovery of a known concentration spiked into a sample (USEPA 1998). Bias due to matrix effects based on a matrix spike is calculated as:

$$\%R = \frac{100\,(x_s - x_u)}{K}$$

where,

%R = percent recovery
x_s = measured value for spiked sample
x_u = measured value for unspiked sample
K = known value of the spike in the sample

This technique quantifies accuracy in terms of percent recovery of the added spike and takes into account matrix effects specific to a particular sample. USEPA (1998) stipulates those constituents appropriate for spiking and subsequent measurement, and defines the %R required for proper QA/QC to meet method requirements. The QA Director at the SLD is responsible for establishing measurement criteria for precision and accuracy of the analytical procedures used in projects where water quality data are collected. Data for these QC procedures are obtained by analyses of replicate, split and spiked samples and blanks. Appendix A lists laboratory measurement criteria for precision, accuracy, and completeness. Acceptable %R is evidence of accuracy in laboratory data measurements. Additionally, the use of field and equipment blanks can also provide an estimate of bias due to effects outside of the laboratory and therefore serves as an additional check on the quality assurance of field collection and transportation techniques of water quality samples.

5) To collect data with a high degree of completeness. **Completeness** is the percentage of samples that are actually collected compared to the sampling plan that also meet the QA/QC field and laboratory requirements detailed in this QAPP. Completeness will be calculated as:

$$\text{Completeness} = \frac{\text{valid data obtained}}{\text{total data planned}} \times 100$$

The completeness requirement will be to routinely achieve 80 percent completeness.

SECTION 2 DATA GENERATION AND ACQUISITION

2.1 SAMPLING PROCESS DESIGN

SWQB will survey river, lake, and reservoir sites (Tables 2, 3, and 4). For lakes and rivers the best available sites will be surveyed. For reservoirs where even the best available sites are highly impacted, examination will focus on impairment of the designated uses and both best available and highly impacted sites will be monitored. Selection of the best available sites was based on examination of historic data and best professional judgment. Best available sites that are distributed over different ecoregions and aquatic life uses were selected. The general aquatic life use (ALU) was assigned by grouping the designated or existing uses of each waterbody into a warmwater aquatic life use (WWAL) or a coldwater aquatic life use (CWAL). The WWAL consists of warmwater, marginal warmwater, and marginal coldwater uses while the CWAL consists of coldwater and high quality coldwater uses. The marginal coldwater use was included in the general warmwater use as it indicates support of a seasonal coldwater fishery and waterbodies often have both warmwater and marginal coldwater uses. During the summer when nutrient surveys and assessments will be conducted, systems with marginal coldwater uses will have warmwater conditions.

A nutrient survey will be conducted at each site. The monitoring will be done according to the methods described in the SWQB SOP (NMED/SWQB 2004). For streams and rivers, the *Guidance for Nutrient Surveys Of Streams and Rivers* (SWQB 2006) and the Physical Habitat Monitoring portion of the SWQB SOP (NMED/SWQB 2004) will be used. For lakes and reservoirs, monitoring methods are described in *Protocols For The Limnological Evaluation and Water Quality Assessment of New Mexico Lakes and Playas* section of the SOP. Habitat monitoring methods to be used in rivers will be developed and added to the SOP before the start of the biological and habitat field season (August 15). During the survey, a number of nutrient and habitat variables will be measured at each site.
For rivers, a late summer/fall index period (August 15 – Oct 15) was selected based on review of benthic macroinvertebrate life cycles, their relationship to the hydrograph, monitoring logistics, and various EPA and state guidance documents (Rosenberg and Resh 1993, EPA 1999). Monitoring will be conducted at least 3 weeks after a high flow event as determined by gage data

or on-site evidence. Lakes and reservoirs will be monitored later in the algal growing season (June 15 to Sept 15) once algal biomass has some time to develop. Given the short duration of this project, sampling frequencies will be once per year for rivers and lakes and twice per year for reservoirs. However, a subset of sites will be selected as long-term monitoring stations, which represent regional reference sites that have the best available conditions and will be monitored yearly. Long-term monitoring stations will be used to add to the dataset and to explore seasonal and year-to-year variability.

Table 1. Long-term stream monitoring stations.

Site ID	LOCATION	Latitude (DD)	Longitude (DD)	Size (mi^2)	Elevation (ft)	Omernik Level 3 Ecoregion
05Rayado033.8	Rayado Creek at Philmont near USGS gage	36.37222	-104.96944	59.1	6795	Southern Rockies
29RChama143.8	Rio Chama 2mi below La Puente Gage	36.66726	-106.66360	482.0	7136	Southern Rockies
28RSanBa017.9	Rio Santa Barbara @ S. B. Campground	36.08540	-105.60880	33.4	8868	Southern Rockies
28RGRanc013.1	Rio Grande del Rancho @ gage near Talpa	36.29778	-105.58194	84.0	7264	Arizona/New Mexico Plateau
50PecosR670.3	Pecos R abv Tecolote Creek	35.23865	-105.16340	709.3	5500	Arizona/New Mexico Plateau
27RPinos007.3	Rio de los Pinos near Ortiz	36.96000	-106.09000	167.0	8120	Arizona/New Mexico Plateau
77WFkGil010.0	West Fork Gila @ wilderness and cliff dwellings	33.22904	-108.26272	108.6	5746	Arizona/New Mexico Mountain
77GilaRi088.0	Gila River 300 meters above Turkey Creek	33.07618	-108.48818	1790.1	4754	Arizona/New Mexico Mountain
77IronCr009.7	Iron Creek at Forest Trail 151	33.37806	-108.56584	8.6	7884	Arizona/New Mexico Mountain
78BlueCr000.9up	Blue Creek 0.5 mile abv Gila River-upper	32.662660	-108.829980	139	3960	Chihuahuan Desert
41Anima029.3	Las Animas Creek above box	33.04120	-107.55476	89.9	5100	Chihuahuan Desert
78GilaRi025.5	Gila River blw Blue Creek @USGS gage	32.64927	-108.84679	3196.9	3871	Chihuahuan Desert
16Seneca000.1	Seneca Creek abv Clayton Lake	36.58837	-103.31560	117.0	5344	Southwestern Tablelands
06Canadi322.5	Canadian River at Mills Canyon	36.06694	-104.37215	3777.6	5151	Southwestern Tablelands
10UteCre104.3	Ute Creek abv Hwy 102 near Bueyeros	35.95094	-103.69657	768.4	4505	Southwestern Tablelands

Table 2. River sites. The yellow highlighted stations may be monitored in 2008, if SWQB resources permit.

Site ID	WATERBODY NAME AND LOCATION	Latitude (DD)	Longitude (DD)	Size (mi^2)	Elevation (ft)	Omernik Level 3 Ecoregion
	San Juan River					
64SanJua144.8	San Juan River at bridge in Blanco	36.724572	-107.812904		5535	Arizona/New Mexico Plateau
66Animas027.8	Animas R upstream of HWY 512 bridge in Aztec	36.827523	-107.999926		5596	Arizona/New Mexico Plateau
USGS 09365500	San Juan River near Archuleta					
USGS 09365000	San Juan River at Farmington					
USGS 09357000	San Juan River at Bloomfield					
USGS 09368000	San Juan River at Shiprock					
	Upper Rio Grande					
28RGrand725.5	Rio Grande @ Ute Mountain below Rio Costilla	36.93133	-105.73575	7988	7403	Arizona/New Mexico Plateau
USGS 08276500	Rio Grande below Taos Junction Bridge					
	Rio Grande above the Rio Pueblo de Taos	36.34040	-105.73110		6113	Arizona/New Mexico Plateau
USGS 08313000	Rio Grande at Otowi Bridge					
	Middle Rio Grande					
USGS 08317400	Rio Grande below Cochiti Dam					
USGS 08319000	Rio Grande at San Felipe Pueblo					
USGS 08329918	Rio Grande at Alameda Bridge					
USGS 08330000	Rio Grande at Albuquerque					
USGS 08331000	Rio Grande at Isleta Pueblo					
USGS 08332000	Rio Grande near Bernardo, NM					
USGS 08361000	Rio Grande below Elephant Butte Dam					
28RGrand550.9	Rio Grande blw Pojoaque Creek (EMAP)	35.901126	-106.12568		5510	Arizona/New Mexico Plateau
32RGrand458.9	Rio Grande on Sandia Pueblo (EMAP)	35.28863	-106.591637	16834	5039	Arizona/New Mexico Plateau
	Lower Rio Grande					
32RGrand258.0	Rio Grande at San Marcial (near USGS gage)	33.6803	-106.9924		4500	Chihuahuan Desert
42RGrand115.0	Rio Grande near Rincon at NM 140	32.654448	-107.075838		4300	Chihuahuan Desert
USGS 08355000	Rio Grande at San Acacia, NM					
USGS 08362500	Rio Grande below Caballo Dam					
USGS 08364000	Rio Grande at El Paso, TX					

Site ID	WATERBODY NAME AND LOCATION	Latitude (DD)	Longitude (DD)	Size (mi^2)	Elevation (ft)	Omernik Level 3 Ecoregion
	Lower Pecos River					
52PecosR430.0	Pecos River at USGS gage blw Taiban Creek	34.332320	-104.181210		4000	Southwest Tablelands
52PecosR311.7	Pecos River at pipeline upstream of Salt Creek (EMAP)	33.64238	-104.35678		3700	Chihuahuan Desert
USGS 08386000	Pecos River below Sumner Dam					
USGS 08385630	Pecos River near Dunlap					
USGS 08384500	Pecos River near Acme					
USGS 08407500	Pecos River at Red Bluff					
USGS 08396500	Pecos River near Artesia					
	Lower Rio Chama					
29RChama079.5	Rio Chama above Abiquiu Reservoir @ USGS gage	36.318333	-106.597222	1576	6500	Southern Rockies
29RChama038.3	Rio Chama @ Hwy 554	36.216670	-106.247505		5869	Arizona/New Mexico Plateau
USGS 08287000	Rio Chama below Abiquiu Dam					
USGS 08287500	Rio Chama below Abiquiu, NM					
USGS 08290000	Rio Chama near Chamita, NM					
	Canadian River					
USGS 07211500	Canadian River near Taylor Springs					
USGS 07221500	Canadian River near Sanchez					
USGS 07227000	Canadian River near Logan					
USGS 07224500	Canadian River below Conchas Dam					
	Gila River					
USGS 09431000	Gila River near Cliff					
USGS 09432000	Gila River below Blue Creek near Virden, NM					
USGS 09431500	Gila River near Red Rock					
	Rio Puerco					
USGS 08353000	Rio Puerco near Bernardo					
USGS 08352500	Rio Puerco at Rio Puerco, NM					

Table 3. Reservoir sites. The green highlighted stations will be monitored in 2006 the other waterbodies will be monitored in 2007.

WATERBODY NAME	WATERBODY TYPE	General ALU	LATITUDE (D/M/S)	LONGITUDE (D/M/S)	SIZE (ACRES)	ELEV (FT)	OMERNIK LEVEL 3 ECOREGION
Heron Reservoir	Reservoir (Lg)	CWAL	36 41 09	106 42 07	4741.9	7186	Southern Rockies
Lake Maloya	Reservoir (Lg)	CWAL	36 59 21	104 22 14	117.6	7511	Southern Rockies
Maxwell Lake 13	Reservoir (Lg)	CWAL	36 34 56	104 34 52	301.6	6150	Southwestern Tablelands
McAllister Lake	Reservoir (Lg)	CWAL	35 31 19	105 10 33	183.8	6433	Southwestern Tablelands
Navajo Reservoir	Reservoir (Lg)	CWAL	36 48 24	107 36 18	13151.2	5900	Arizona/New Mexico Plateau
Charette Lake (Lower)	Reservoir (Lg)	WWAL	36 11 06	104 48 11	300.0	6500	Southwestern Tablelands
Conchas Reservoir	Reservoir (Lg)	WWAL	35 25 37	104 11 55	4218	4215	Southwestern Tablelands
Ute Reservoir	Reservoir (Lg	WWAL	35 21 06	103 31 03	3760.8	3760	Southwestern Tablelands
Brantley Reservoir	Reservoir (Lg)	WWAL	32 34 31	104 23 28	3058.7	3267	Chihuahuan Desert
Elephant Butte Reservoir	Reservoir (Lg)	WWAL	33 15 03	107 10 05	6517	4347	Chihuahuan Desert
Bonito Lake	Reservoir (Sm)	CWAL	33 27 25	105 43 59	39.1	7377	Arizona/New Mexico Mountain
Canjilon Lake (a)	Reservoir (Sm)	CWAL	36 33 45	106 19 44	5.9	10100	Southern Rockies
Fenton Lake	Reservoir (Sm)	CWAL	35 52 59	106 43 33	23.8	7500	Southern Rockies
Shuree Pond (South)	Reservoir (Sm)	CWAL	36 46 21	105 11 34	1.5	9300	Southern Rockies
Tres Lagunas (Northeast)	Reservoir (Sm)	CWAL	34 57 21	104 38 37	37	4695	Southwestern Tablelands
Bill Evans Lake	Reservoir (Sm)	WWAL	325200	1083430	74.4	4800	Arizona/New Mexico Mountain
Bitter Lake NWR - Unit 16	Reservoir (Sm)	WWAL	332508	1042444	82.9	3471	Chihuahuan Desert
Lake Van	Reservoir (Sm)	WWAL	331137	1042124	12.0	3429	Chihuahuan Desert
Bosque Redondo Lake	Reservoir (Sm)	WWAL	342611	1041319	15.0	3965	Southwestern Tablelands

Table 4. Lake sites. These will be monitored in 2007.

WATERBODY NAME	WATERBODY TYPE	General ALU	LATITUDE (D/M/S)	LONGITUDE (D/M/S)	SIZE (ACRE)	ELEV (FT)	OMERNIK LEVEL 3 ECOREGION
Bitter Lake (Bitter Lake NWR)	Sink Hole	WWAL	33 28 30	104 24 53	149.4	3491	Chihuahuan Desert
Lea Lake	Sink Hole	WWAL	33 19 09	104 19 48	17.5	3450	Chihuahuan Desert
Perch Lake	Sink Hole	WWAL	34 55 33	104 39 50	2.0	4595	Southwestern Tablelands
Figure Eight Lake	Sink Hole	WWAL	33 20 03	104 19 54	2.2	3458	Chihuahuan Desert
Lake Katherine	Cirque Lake	CWAL	35 50 02	105 45 06	11.8	11742	Southern Rockies
Trampas Lake (East)	Cirque Lake	CWAL	35 59 33	105 38 05	6.0	11255	Southern Rockies
Middle Fork Lake of Rio de la Casa	Cirque Lake	CWAL	35 59 31	105 31 46	2	12000	Southern Rockies
Serpent Lake	Cirque Lake	CWAL	36 02 47	105 32 30	3.0	11740	Southern Rockies

2.2 FIELD MEASUREMENT AND SAMPLING PROCEDURES

The following variables will be monitored at each river and stream site in accordance with the SOP and recorded on standardized field forms: 1) periphyton (as benthic chlorophyll *a* concentration, AFDM, and community composition), 2) nutrient concentrations (TP, nitrate + nitrite, ammonia, and TKN), 3) ions - sulfate, chloride, total dissolved solids (TDS) and total suspended solids (TSS) concentrations, 4) DO, pH, turbidity, temperature, and conductivity readings and at select sites 3-7 days of hourly recordings of these field parameters, 5) benthic macroinvertebrate community composition, and 6) a number of habitat parameters (velocity, canopy cover, wetted width and depth, approximate gradient, substrate character, and a qualitative habitat and geomorphic assessment). At the larger river sites, planktonic chlorophyll *a* concentrations will also be measured. A summary of the monitoring methods is provided below. For a more detailed description refer to SWQB SOP (NMED/SWQB 2004) and *Guidance for Nutrient Surveys of Streams and Rivers* (SWQB 2006). The river habitat methods will be added to the SWQB SOPs at the next revision.

In streams and rivers, a representative reach is selected that covers approximately two meander lengths or a maximum of 400 meters. Water quality, biological, and habitat monitoring are conducted within this reach. Water quality monitoring consists of measuring field parameters (DO, pH, turbidity, temperature, and conductivity) and collection of water samples to be analyzed for nutrients and ions. Concentrations of hardness, chloride, fluoride, and sulfate as well as TDS and TSS are determined during the ion analysis. Concentrations of TP, nitrate and nitrite, ammonia, and TKN are determined during the nutrient analysis. An YSI® multi-parameter Sonde is used to measure DO, pH, turbidity, temperature, and conductivity on site. Habitat monitoring focuses on parameters that influence the growth of periphyton and channel stability and consists of qualitative and quantitative components. The qualitative components are the Rapid Habitat Assessment (RHA) from EPA's Rapid Biomonitoring Protocols (RBP) (EPA 1999) and the Rapid Geomorphic Assessment (RGA) developed by the USDA National Sedimentation Lab (see forms in Appendix A). The quantitative parameters are cross-sections, canopy cover, pebble counts, average velocity, and an estimate of gradient.

Biomonitoring of streams and rivers consists of collection of benthic macroinvertebrate and periphyton samples. A richest targeted habitat approach is used to collect periphyton. For wadeable systems, a representative riffle is selected and 10 cobbles are collected along a transect running diagonally through the riffle. For small streams (less than 1 meter wide), 5 cobbles are collected from each of two transects through riffles. If no cobble is present, then woody debris or finer substrate is sampled for periphyton. In rivers, substrate or woody debris is collected from the wadeable portion of the river or by using an Eckman dredge. The periphyton is removed from a known area at each location and composited into a single sample (Moulton *et. al* 2002) for each site. For benthic macroinvertebrate collection in wadeable, coarse substrate waterbodies, three Hess samples are collected from the riffle, avoiding the periphyton transect location and composited into a single sample (EPA 1999). In rivers, benthic macroinvertebrates will be collected using a D-net and a multiple habitat approach. For examination of planktonic chlorophyll *a* concentration, a ½ to 2 liter sample of water will be filtered onto a glass fiber filter.

Lake and reservoir nutrient monitoring will be conducted in the following manner. Large lakes are defined as lakes greater than 100 acres and are sampled at a minimum of two stations, one deep and one shallow. Smaller lakes are sampled at one deep station only. At each station, dissolved oxygen concentration, specific conductance, temperature, and pH are measured at one-meter intervals from the surface to within one meter of the bottom using a field-calibrated multi-parameter Sonde and data

logger. Secchi depth and total depth will also be measured. An underwater photometer is used to determine the euphotic zone, or the upper layers of a body of water to a depth at which 1% of surface illumination remains. Five-liter samples from the top, middle, and bottom of the euphotic zone are mixed to form a 15-liter, composited, euphotic zone sample. However, in the presence of a thermocline, 5-liter samples from the top, middle, and bottom of the entire water column are composited. Samples for analyses of ions, chlorophyll, phytoplankton, and total and dissolved nutrients are taken from the composite sample. For chlorophyll analysis, one half to two liters of composited euphotic-zone water are filtered through a Whatman GF/A glass fiber filter until substantial color development is present on the filter. Periphytic diatom communities are sampled by collecting epiphytic scrapes from multiple substrates, e.g., aquatic plants, rocks, submerged wood and materials on sandy or gravelly sediments.

2.3 Sample Handling and Custody Requirements

All samples will be preserved and labeled in the field near the sample location except periphyton samples, which may be processed at the end of the day. Minimum information on the labels includes the date, waterbody name, and sampling location. Periphyton sub-samples will also include the total sample volume and sub-sample volume. This information will also be on all field collection data sheets.

Stream and river periphyton samples are subsampled and preserved with formalin for community composition determination and the remainder of the sample is either frozen on site with dry ice or kept in the dark immersed in ice until the end of the day, with a maximum holding time of 10 hours (Biggs and Kilroy 2000). At the end of the day, the periphyton samples are either processed or frozen. Periphyton samples are processed by collection of sub-samples that are filtered onto glass fiber filters and frozen for chlorophyll *a* and AFDM analysis. The periphyton and filtered samples are kept frozen until they are processed or analyzed. For lakes, once a subsample of composited euphotic zone water is filtered, the glass fiber filters are placed in a 60 milliliter (mL) light-proof septum vial with 35 mL of 90% acetone. This sample is kept on ice and in the dark until it is processed between 24 and 48 hours after collection

Water samples for nutrient and ion analysis are collected, cooled to 4°C, stored on ice, and transported in ice chests to the analytical laboratory at the end of the two to five day sampling trip. Samples for nutrient analysis are preserved with 2.5 mL of sulfuric acid per liter.

Phytoplankton samples consist of a composited euphotic zone sample placed in a one-liter container and preserved with acid Lugol's solution. Samples are concentrated according to the settling method and counted by the Sedgwick-Rafter method (APHA *et. al*. 1998). Periphytic diatom samples are cleaned using 30 percent hydrogen peroxide and potassium dichromate (Van der Werff 1955).

Benthic macroinvertebrate samples are preserved by adding 95 percent ethanol to the sample container to produce a final concentration of approximately 70 percent ethanol with dilution coming from water in the sample matrix and invertebrates. Samples that fill the sample container by more than 50 percent should then be refrigerated overnight, drained, and re-preserved in 95 percent ethanol the next day. A label made from 100 percent cotton fiber bond paper marked by soft pencil or alcohol-proof pen (Pygmy®) accurately describing the sampling location, date, replicate number, sample type (HESS, Kicknet), sample habitat (Riffle, Pool, Microhabitat) and collector is added to the inside of the bag or jar. The outside of the container should be similarly labeled using a waterproof felt pen (Sharpie®).

2.4 ANALYTICAL METHODS REQUIREMENTS

Refer to detailed SOPs for all methods used in field surveys (NMED/SWQB 2004). Laboratory analytical methods are listed in Appendix A of the SWQB QAPP (NMED/SWQB 2005). AFDM will be analyzed using Standard Method 10300C(5) - Dry and ash free weight (APHA *et. al* 1998). Chlorophyll *a* concentration will be determined using either the spectrophotometric, trichromatic method (APHA *et. al* 1998) or a modified EPA Method 445.0, *In Vitro Determination of Chlorophyll a and Pheophytin a in Marine and Freshwater Algae by Fluorescence* (http://www.epa.gov/microbes/m445_0.pdf). Generally, the trichromatic method will be used for lakes to be comparable to the historic dataset. For stream and river samples, chlorophyll is extracted and analyzed using methods described in *Stream Periphyton Monitoring Manual (*Biggs and Kilroy 2000) and EPA Method 445.0. In the modified version of EPA method 445.0, an ethanol extraction is used rather than acetone as ethanol is a more efficient and less toxic extractant. The ethanol extraction consists of placing the filter with the periphyton sub-sample in a sealed test tube with 90% ethanol and immersing the tubes in a 78°C water bath for 5 minutes. A proportion of samples will be analyzed with both the spectrophotometric and fluorometric methods to evaluate the comparability of the two methods. Use of an *in situ* YSI chlorophyll probe will also be explored. For additional laboratory methods information refer to the *Quality Assurance Project Plan Scientific Laboratory Division Chemistry Bureau Services* (SLD 2005).

For physical habitat measures, general references used as background for developing SOPs include *Applied River Morphology (*Rosgen 1996), *Stream channel reference sites: an illustrated guide to field technique* (USFS 1994), and *Environmental Monitoring and Assessment Program Surface Waters: Field operations and Methods for Measuring the Ecological Condition of Wadeable Streams* (USEPA 1997). For periphyton collection and sample handling the general references were *Stream Periphyton Monitoring Manual* (Biggs and Kilroy 2000) and *Revised Protocols for Sampling Algal, Invertebrate, and Fish Communities as Part of the National Water-Quality Assessment Program* (Moulton et. al. 2002). For water quality analyses *Standard Methods for the Examination of Water and Wastewater, 20th Edition* (APHA *et. al* 1998) and Code of Federal Regulations (CFR), Title 40: Protection of the Environment, Chapter 1 – Environmental Protection Agency, Part 136 – "*Guidelines Establishing Test Procedures for the Analysis of Pollutants*" (EPA 2000) were used.

2.5 QUALITY CONTROL REQUIREMENTS

Field and laboratory quality control measures include training sessions in habitat monitoring methods prior to each field season rotation, cross-checks between observers in paired teams to ensure uniformity in how parameters are measured and recorded, supervisor oversight of all technicians, use of standardized data forms for all records, and availability of written protocols for all procedures. Replicate and blank water samples are collected and checks of field data forms are made at the end of each survey. Contract laboratories for benthic macroinvertebrates, phytoplankton, and periphyton processing will adhere to QA procedures provided to and approved by SWQB. Voucher and reference collections will be maintained in designated and centralized collections.

QA replicates (i.e., duplicate samples) for all chemical samples are collected at 10% of the sampling sites. The analytical results of replicate sampling are entered into the SWQB Water Quality Database and identified as QA replicates.

The relative percent difference (RPD) between field replicate results is calculated to evaluate the level of precision associated with the entire sample collection and measurement process. A comparison of the RPD between replicates is conducted during the data validation process. After the validation process is completed, qualifiers are assigned to the data points that are outside control limits. To the data user, qualifiers indicate that the analyte concentrations may be unusable or estimated because of QC deficiencies that reduce confidence in the results. If precision is poor (i.e., outside control limits), positive results are qualified as estimated (i.e., assigned a validation code of D2, which indicates the results are estimated based on RPDs outside control limits).

Control limits on replicate RPDs are based on information from the U.S. Fish and Wildlife Service, Patuxent Analytical Control Facility, Laurel, Maryland and are as follows:

Analyte Concentration[1] **(multiples of method detection limit)**	**Maximum Acceptable RPD**
< or = 2	200%
>2 - 10	20%
> 10	10%

Note: If each result falls into a different category (i.e., one result is 2 times the MDL and one is 5 times the MDL), use the larger control limit.

2.6 INSTRUMENT/ EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE REQUIREMENTS

The primary equipment employed in the field that require maintenance include: Marsh-McBirney® flow meters, YSI® multi-parameter Sondes and data loggers (YSI Model 6920 Sondes and YSI 650 MDS and 610 Data loggers), Nalgene® manual vacuum pumps, and GPS units. As needed, this equipment is inspected for proper function, replacement of parts, batteries, and stored at room temperature and dry conditions. All field equipment will be inspected and refurbished as necessary prior to each sampling trip. Results of equipment inspections will be noted in the file for each instrument. Any deficiencies in equipment will be noted in the equipment log in the file and reported immediately to appropriate staff that will recheck the equipment and arrange for repair by the manufacturer or for purchase of a replacement. If the condition of the equipment is in doubt, it is not used. In the field, extra parts and supplies are carried to attend to malfunctions. Benthic macroinvertebrate collection nets will be checked for tears and repaired as needed. Any damage to the nets will be repaired prior to sampling.

2.7 INSTRUMENT CALIBRATION AND FREQUENCY

Prior to use, instruments are inspected to ensure all components are clean and in good working order. All appropriate probes are activated and set to report. All probes are calibrated prior to sampling trip (at least weekly), and the DO probe is recalibrated to altitude once in the field, as needed (at the first site of the day and after every 1000 foot change in elevation). The DO probe membrane is checked for bubbles and the electrode is examined for corrosion prior to calibration. The membrane and clean silver electrode are replaced as per manufacturer's instructions, as needed (see manual). While operation remains normal, other probes should not require further calibration.

2.8 Inspection and Acceptance Requirements for Supplies

All shipments are checked to be certain the packing slip is complete and matches the materials ordered (supplies or equipment). Standard supplies are stored in designated areas. Most ordering is from the following sources: VWR International, Fisher Scientific International Inc., Forestry Supplies Inc., and YSI Incorporated.

2.9 Data Acquisition Requirements

Most results obtained pursuant to this QAPP involve new data acquired using procedures enumerated in this document and its references and appendices. External and/or historical data acquired for inclusion in these analyses must be referenced and must meet the QA/QC requirements outlined in this document.

All methods of sample collection, preservation, and analysis used in determining water quality shall be in accordance with approved test procedures published in 40 CFR 136 or any other test procedure(s) accepted by EPA. Test procedures approved under 40 CFR 136 or otherwise accepted by EPA must be referenced.

2.10 Data Management

Data records are taken on standardized forms for all field and laboratory procedures. Data will be entered into spreadsheets (Microsoft® Excel) and/or a database (Microsoft® Access or New Mexico's version of EDAS). Once entered into spreadsheets, a QC check will be performed by comparing the spreadsheet values to those on the field sheets. Incorrect values will be corrected and suspect values flagged. Site and sample information will also be checked (e.g. latitude and longitude, elevation, date, etc.). Water quality data will be entered directly into the SWQB Water Quality Database and the QC check preformed as described in the SWQB QAPP.

A hardcopy file with raw data and field notes is maintained by SWQB for no less than ten years. This file contains all SLD analytical forms, all non-privileged field notes concerning the investigation, and all QA results for the survey. In addition to water quality data, this file also contains all hard copies of benthic macroinvertebrate, habitat, fish, pebble count, cross sectional, and periphyton data. Data will be stored on computers and saved to storage media (zip disks or CD). Water quality data will be uploaded to Modernized STORET.

2.11 Assessments and Response Actions

Field sampling and measurement techniques will continually be reviewed in order to determine if changes and/or modifications to the sampling protocols are needed. Decisions to change or alter any protocols or QA/QC measures detailed in this QAPP will be made through consensus of the project team and will be provided to EPA as a revision to this QAPP.

2.12 REPORTS

A final report will be drafted following the completion of data collection efforts, receipt of all data from laboratory and other contractors, and completion of QA/QC analyses. The draft report will be peer reviewed and considered final after incorporation of all comments received and submittal to the funding agency.

SECTION 3 DATA VALIDATION AND USABILITY

3.1 DATA REVIEW, VALIDATION AND VERIFICATION REQUIREMENTS

The Project Manager oversees data review and qualification. All site, benthic macroinvertebrate, periphyton, and habitat data acquired will be reviewed by the Project Manager using best professional judgment, knowledge of stream ecology, and the QAPP for defining acceptance and qualification (i.e. assignment of validations codes).

3.2 VALIDATION AND VERIFICATION METHODS

Refer to Appendix B of the SWQB QAPP for a detailed description of the data validation process. The Project Manager will be responsible for developing and reviewing data sheets as well as dates, times, reported units, and comments. The Project Manager will screen inaccurate data before they are entered in the database by analyzing all quality control data, including replicates, equipment conditions, and sampling conditions. Quality control sample results will be evaluated individually by performing appropriate mathematical analysis for precision of each sample. All data reports shall include QA/QC information.

3.3 RECONCILIATION WITH DATA QUALITY OBJECTIVES

Correspondence of data produced with the data quality indicators specified in the QAPP will be reviewed during analysis of data sets. Various corrective actions, as specified in the QAPP and preceding sections, will be used to address any problems detected. Established data quality objectives (DQOs) (Section 1.4) will be compared with the results of all QA/QC samples. The Project Manager will evaluate completeness, precision, representativeness, and comparability. Data that do not meet DQOs will be flagged in the database. The raw data will be left in the database because it can provide valuable information. If revisions of the QAPP are necessary, this document will be re-drafted and submitted to the appropriate agency QA officers for approval.

REFERENCES

American Public Health Association, American Water Works Association, and Water Environment Federation (APHA *et. al*). 1998. *Standard Methods for the Examination of Water and Wastewater*, 20th Edition.

Biggs, B.J.F. and C. Kilroy. 2000. *Stream Periphyton Monitoring Manual*. NIWA, Christchurch, New Zealand.

Moulton, S. R. II, J. G. Kennen, R. M. Goldstein, and J. A. Hambrook. 2002. Revised Protocols for Sampling Algal, Invertebrate, and Fish Communities as Part of the National Water-Quality Assessment Program. USGS Open-File Report 02-150

New Mexico Administrative Code (NMAC). 2005. *State of New Mexico Standards for Interstate and Intrastate Streams*. 20.6.4. New Mexico Water Quality Control Commission.

New Mexico Environment Department/ Surface Water Quality Bureau (NMED/SWQB). 2004. *State of New Mexico Surface Water Quality Bureau Standard Operating Procedures for Sample Collection and Handling.* Santa Fe, NM

_____. 2005. *Quality assurance project plan for water quality management programs*. . Santa Fe, NM.

New Mexico Scientific Laboratory Division/ Chemistry Bureau Services (SLD). 2005. *Quality Assurance Plan Scientific Laboratory Division Chemistry Bureau Services*. Revision 8, May 18, 2005.

Omernik, J.M. 1987. Ecoregions of the Conterminous United States. *Annals of the Association of American Geographers* 77(1):118-125.

Rosenberg, D.M. and V.H. Resh (eds). 1993. *Freshwater Biomonitoring and Benthic Macroinvertebrates*. Chapman and Hall, New York, NY. 487 pp.

Rosgen, D.L. 1996. *Applied River Morphology*. Wildland Hydrology. Pagosa Springs, Colorado.

_____. 1998. The Reference Reach Field Book. Wildland Hydrology. Pagosa Springs, Colorado.

Simon, T.P. and J. Lyons. 1995. Application of the index of biological integrity to evaluate water resource integrity in freshwater ecosystems. Pages 245-262 *in* Davis, W.S. and T.P. Simon (editors): Biological assessment and criteria: tools for water resource planning. CRC Press, Boca Raton, FL.

U.S. Environmental Protection Agency (USEPA). 2000a. Nutrient Criteria Technical Guidance Manual: Rivers and Streams. EPA-822-B-00-002.

_____. 2000b. Code of Federal Regulations (CFR), Title 40: Protection of the Environment, Chapter 1 – Environmental Protection Agency, Part 136 – "*Guidelines Establishing Test Procedures for the Analysis of Pollutants*."

_____. 1999. Rapid bioassessment protocols for use in wadeable streams and rivers: Periphyton, benthic macroinvertebrates, and fish. EPA 841-B-99-002. Second edition. Office of Water. Washington, D.C

_____. 1998. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*. Publication SW-846, Revision 5. April.

_____. 1997. Environmental Monitoring and Assessment Program Surface Waters: Field operations and Methods for Measuring the Ecological Condition of Wadeable Streams. J. M. Lazorchak and D. J. Klemm (Editors). EPA/620/R-94/004.

United States Forest Service (USFS). 1994. *Stream channel reference sites: an illustrated guide to field technique.* General Technical Report RM-245. Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO.

Van der Werff, 1955. A new method of concentrating and cleaning diatoms and other organisms. Assoc. Theor. Appl. Lim. 12:276-2771.

Wolman, M.G. 1954. A Method of Sampling Coarse River-Bed Material. Transactions of American Geophysical Union 35: 951-956.