A gap analysis of water quality data in a gold mining region of Nicaragua

by

Katherine Chambers
B.Sc., University of Western Ontario, 1996

A Thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of

MASTER OF SCIENCE

in the Department of Geography

© Katherine Chambers, 2011
University of Victoria

All rights reserved. This thesis may not be reproduced in whole or in part, by photocopy
or other means, without the permission of the author

.

Supervisory Committee

A gap analysis of water quality data in a gold mining region of Nicaragua

by

Katherine Chambers
B.Sc., University of Western Ontario, 1996

Supervisory Committee

Dr. Stephen Lonergan, Department of Geography
Supervisor

Dr. Jutta Gutberlet, Department of Geography
Departmental Member

Dr. Rick Nordin, Department of Biology
Outside Member

Brian Wilkes, M.E.S., R.P.Bio.
Additional Member

Abstract

Supervisory Committee
Dr. Stephen Lonergan, Department of Geography
Supervisor

Dr. Jutta Gutberlet, Department of Geography
Departmental Member

Dr. Rick Nordin, Department of Biology
Outside Member

Brian Wilkes, M.E.S., R.P.Bio.
Additional Member

Communities in the vicinity of the Mico River, located in Chontales, Nicaragua, suffer from periodic dry season water shortages. The Mico River is impacted by artisanal and industrial mining, cattle ranching, effluent from local dairies and tanneries, and poor waste management practices in the watershed. Available water quality data consists of short term assessment studies and monitoring data for a mine operating in the headwaters, but to date this information has not been collated and interpreted as a whole. Communities in the vicinity of the Mico River have expressed an interest in having this data reviewed to verify information they have received from government and industry with regards to impacts from the La Libertad Mine. A gap analysis of existing water quality data in the headwaters of the Mico River is presented, with interpretation of current data and identification of further data needs. Recommendations are provided for future water quality monitoring in the region.

The study area was defined as the Mico River watershed upstream of the town of Santo Tomas. A total of 14 studies were identified with information about the Mico River in this area. Individual study reliability was assessed, and study data were compiled to assess conditions in comparison to water quality guidelines and any spatial or temporal trends. Both water chemistry and bioassessment studies were assessed.

The major gaps in existing information are: insufficient baseline/ reference information, insufficient information on impacts from contaminants other than metals, insufficient coverage of streams not directly impacted by the La Libertad Mine, poor quality and reliability of data, and poor coordination/ continuity between studies done to date. Cyanide concentrations were found to be below drinking water criteria at the majority of sample locations. Metals concentrations were elevated throughout the study area but it cannot be determined if this is due to natural background levels or anthropogenic sources. Water quality conditions with regards to other parameters (e.g., dissolved oxygen, temperature, pesticides and bacteria) and bioassessment data cannot be assessed due insufficient data quality and quantity.

Existing monitoring in the region should be expanded to include reference locations. It is recommended that a benthic invertebrate bioassessment program designed for tropical mountain streams be implemented to supplement existing monitoring and identify areas where stream function is impaired, as bioassessment is cheaper and requires less equipment and logistical coordination than water chemistry monitoring programs. Whatever future work is done, care must be taken that study design and implementation is of a higher quality than that done to date, so that results are comparable and reliable. Coordination and cooperation between bodies involved in monitoring is essential for efficient use of scarce resources.

Table of Contents

Table of Contents

List of Appendices

List of Tables

List of Figures

List of Figures

List of Acronyms

ADB	Asian Development Bank
ANA	(Nicaraguan) National Water Authority (*Autoridad Nacional del Agua*)
ANZECC	Australian and New Zealand Environment Conservation Council
ARD	Acid Rock Drainage
AUSRIVAS	Australian River Assessment System
BMP	Best Management Practice
BOD	Biological Oxygen Demand
BCAWQG	British Columbia Approved Water Quality Guidelines
BCWWQG	British Columbia Working Water Quality Guidelines
CABIN	Canadian Aquatic Biomonitoring Network
CAPRE	Regional Coordinating Committee for Drinking Water and Sanitation Institutions in Central America, Panama and the Dominican Republic (*Comité Coordinator Regional de Instituciones de Agua Potable y Saneamiento de Centroamérica, Panama y República Dominicana*)
CCAD	Central American Commission for Environment and Development (*Comisión Centroamericana de Ambiente y Desarrollo*)
CCME	Canadian Council of Ministers for the Environment
CEPIS	Pamamerican Centre for Enviromental Engineering and Sciences (*Centro Panamericano de Ingeniería y Ciencias del Ambiente*)
CEPREDENAC	Coordination Centre for the Prevention of Natural Disasters in Central America (*Centro de Coordinación para la Prevencion de los Desastres Naturales en América Central*)
CEO	Chief Executive Officer
CFU	Colony Forming Unit
CIRA	Nicaraguan Centre for Inland Water Research (*Centro para las Investigaciones en Recursos Acuáticos*)
COD	Chemical Oxygen Demand
CONAPAS	Commission on Water and Sanitation
COOPELMICH	Cooperative of Small-Scale Miners of La Libertad, Chontales (*Cooperativa de Pequeños Mineros de La Libertad, Chontales*)

List of Acronyms

DESMINIC	Mining Developments of Nicaragua (*Desarrollo Minero de Nicaragua*)
DFO	Fisheries and Oceans Canada
DO	Dissolved Oxygen
EC	Environment Canada
EEM	Environmental Effects Monitoring
EIA	Environmental Impact Assessment
ENACAL	National Water Supply and Sanitation Company (*Empresa Nicaragüense de Acueductos y Alcantarillados*)
EPA	(United States) Environmental Protection Agency
EU	European Union
EVR	Environmental Viability Report
IMF	International Monetary Fund
INAA	Nicaraguan Institute of Water Supply and Sanitation (*El Instituto Nicaragüense de Acueductos y Alcantarillado Sanitario*)
INEC	(Nicaraguan) National Census and Statistics Institute (*El Instituto Nacional de Estadisticas y Censos*)
INETER	Nicaraguan Institute of Territorial Studies (*El Instituto Nicaragüense de Estudios Territoriales*)
INIFOM	Nicaraguan Institute of Municipal Development (*El Instituto Nicaragüense de Fomento Municipal*)
IWRM	Integrated Water Resource Management
km	kilometre
L	litre
m	metre
masl	metres above sea level
mg	milligrams
MINSA	(Nicaraguan) Ministry of Health (*Ministerio de Salud*)
MPU	Most Probable Number
n	sample size
NGO	Non-Governmental Organization
MAC	Mining Association of Canada

List of Acronyms

MARENA	(Nicaraguan) Ministry of the Environment and Natural Resources (*Ministerio del Ambiente y los Recursos Naturales*)
MMER	(Canadian) Metal Mining Effluent Regulation
MoE	(British Columbia) Ministry of Environment
PROCUENCA	Strategic Action Plan for the Integrated Management of Water Resources and the Sustainable Development of the San Juan River Basin and its Coastal Zone (*Plan Estratégico de Accíon para la Gestión Integrada de los Recursos Hidricos y Desarrollo Sostenible de la Cuenca del Río San Juan y su Zona Costera*)
QA/QC	Quality Assurance/Quality Control
RCA	Reference Condition Approach
RISC	Resources Information Standards Committee
SNV	Netherlands Development Organization
SRK	Steffen Robertson & Kirsten Inc.
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
UCA	Central American University (*Universidad Centroamericana*)
ug	microgram
UN	United Nations
UNAG	(Nicaraguan) National Union of Farmers and Ranchers (*Unión Nacional de Agricultores y Ganaderos*)
UNAN	Autonomous University of Nicaragua (*Universidad Nacional Autónoma de Nicaragua*)
UNDP	United Nations Development Programme
UN GEMS	United Nations Global Environment Monitoring System
UNESCO	United Nations Educational, Scientific, and Cultural Organization
WHO	World Health Organization

Acknowledgments

I would like to thank Dr. Steven Lonergan for his supervision and guidance throughout the research process. I would also like to thank Dr. Rick Nordin, Dr. Jutta Gutbertlet, Mr. Brian Wilkes and my external examiner, Kevin Riesberger, for sharing their insight, expertise and feedback.

My biggest debt of gratitude is to the many individuals in Nicaragua who made my research possible. Antionette Kome of SRK and Francisco Flores of ENACAL pointed me in the direction of a research project that would be both interesting and practical. Jose Dolores and others at the alcadía of La Libertad, Yelba Flores at CIRA, Graham Speirs and Humberto Kaufmann at Central Sun, Alfredo Mendoza at UNAN, and Jiron Rubner of COOPELMICH endured my terrible Spanish and generously shared their data and knowledge with me. I would not have had a project without these individuals. I also would have been lost without the help of Katie Mitchell of the US Peace Corps, who acted as translator and introduced me to La Libertad. A special thanks to Mercedes and her family for their hospitality, and to Christian and Essa of the US Peace Corps for their support and assistance.

My warmest thanks go to Lily Filipow in Granada, for providing me with a home base in Nicaragua that genuinely felt like home. I'd also like to thank my employer for giving me the flexibility to finally complete this thesis, with an especial thanks to Jay Rourke for all of his database wisdom. Finally, I would like to thank my friends and family for their encouragement, love and support.

Chapter 1. Introduction

As human populations grow so too does the demand for adequate supplies of clean water. Freshwater supplies are stressed around the planet, both in quantity and quality. The United Nations (UN) estimates that by 2015, two-thirds of the world's population could be living under water stress conditions (UN 2006).

Clean water is essential for human health and economic development, and performs vital ecosystem functions (Brauman *et al*. 2007; Hassan *et al*. 2005). Waterborne illnesses kill three million people a year, and impede countless others from full productivity and quality of life (UN 2009). The services provided by intact aquatic ecosystems include: habitat for many endemic species that contribute to biodiversity, filtering of pollutants from water, buffering the effects of storm events and natural disasters, protection against erosion, regulation of hydrological flow, and aesthetic, cultural and recreational values. It is estimated that the value of these ecosystem services adds up to over 2 trillion dollars per year (Hassan *et al*. 2005).

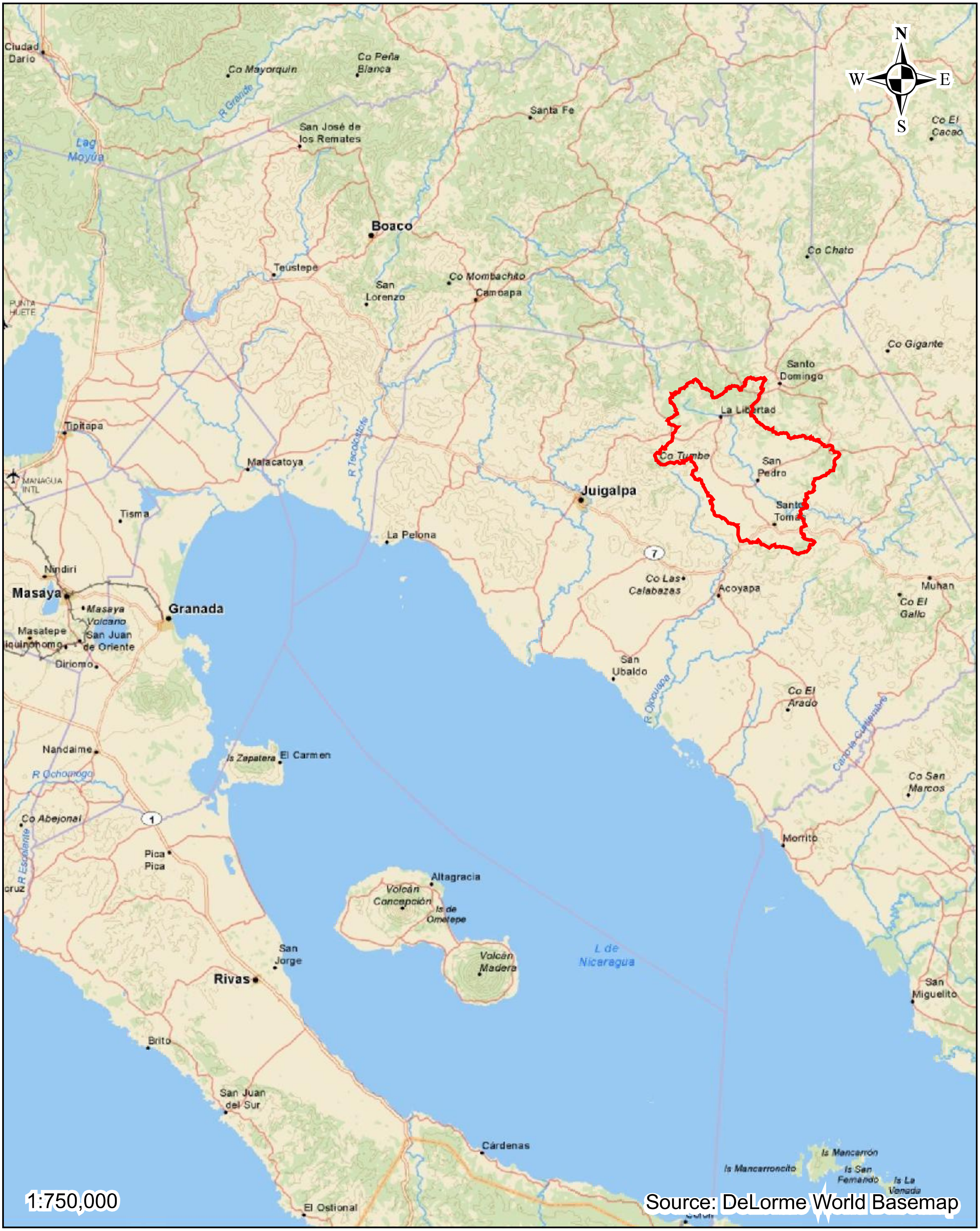
Although Latin America is relatively well-supplied with freshwater, rapid population growth and environmental pressures are creating a shortage of usable water in some areas (Ascencio 2002; CCAD 2005). Poverty plays a role in creating these conditions. Although the relationship is complex and poverty itself does not inevitably create environmental degradation (Nunan *et al*. 2002; Ravnborg 2003), poverty is often associated with social and political forces (e.g., insecure land tenure) that drive individuals to actions creating environmental damage. Impoverished governments typically lack the resources and infrastructure to either protect natural resources or provide a reliable supply of treated water to their citizens (Soares *et al*. 2002; UN 2010).

One of these insufficient resources is a shortage of information about existing water quantity and quality. There is a real need for research and technical expertise in documenting both surface and groundwater flows in the global South[1]. Water quality data for most countries are even more patchy (UN GEMS 2006). In Nicaragua, government agencies lack the capacity for effective water quality monitoring throughout the country (Montenegro 1997). While non-profit organizations, private stakeholders and research institutions fill in some of the gaps, their efforts are not always coordinated with government or each other in purpose and design. Issues of trust and accountability also come into play when stakeholders with vested interests are the only sources for such data.

This study focuses on water quality issues in the Mico River. The Mico River begins northeast of Lake Nicaragua in the department of Chontales. It is part of the Escondido River system, ultimately draining into the Atlantic Ocean (INETER 2010). The department of Chontales suffers from periodic dry season water shortages and aquifer depletion (INETER 2004). As a result, communities in the region are looking to the Mico River as a possible means of supplementing their water supply (**Figure 1-1**)

.

[1]In the context of this report, the South refers to countries in receipt of development aid (Economist 2010).



0 3 6 12 18 24 30
km

Study Location	
September 2011	Figure 1-1

Gold mining has been conducted in the headwaters of the Mico River since at least 1850 (Belt 1911; Lazo 2005). Gold mining is often associated with contamination of surface waters by cyanide, mercury, and other heavy metals (MAC 2000; May *et al*. 2001; M. Veiga *et al*. 2009; UN 2002). This has made people leery of the Mico River as a potential drinking water source. Other potential sources of contamination in the region include the effects of cattle ranching and insufficient human sanitation infrastructure.

A number of short term assessment studies of water quality have been conducted by the private sector, academics, government agencies and non-government organizations (NGOs) in the headwaters of the Mico River, and there is a large mine operating in the region that has been monitoring effluent and receiving water quality for years. This information has not, as yet, been collated and stored in one place for local government and the public to view. The Nicaraguan Ministry of Environment and Natural Resources (MARENA) conducted an environmental assessment of the region in 2006 as a precursor to an "Environmental Action Plan" for the headwaters of the Mico River and neighbouring Siquia River. This study is publicly available, but the results have not been universally accepted (Jiron 2008; F. Flores 2008), in part due to reasons of trust described below.

There is a history in La Libertad of broken promises and conflict with the previous mine owners (Tolvanen 2003), and of national government support for large mining interests over local people (Aiyer 2004). MARENA has been implicated in corruption in the past (Castro 2008), and public trust in government is not high (Brown & Cloke 2005; Transparency International 2010). The result is mistrust of MARENA and the mine by many in Chontales. Local municipalities and the small miners' union want an impartial third party to review the available data and develop a community monitoring plan (F. Flores 2008).

The objective of this research was to assist the community in its water quality monitoring and management efforts, by collating and reviewing available data, and identifying water quality data needs. My study asks three questions:

1. What water quality information for the Mico River is a priority? What are the potential uses of the water, and what are the potential contaminants that might hinder that use?
2. What water quality information is already available for the Mico River? What can that information tell us about the status and trends of water quality with regard to the contaminants identified in question #1?
3. What are the gaps in water quality information identified as a priority in question #1? How might they best be filled?

The answers to these questions will inform development of a community monitoring plan. This study forms one component of required information for development of a successful monitoring plan. Clear understanding of capacity and the socio-cultural setting are also necessary, as are strategies to address site-specific challenges and to improve cooperation and trust amongst stakeholders.

This situation is not unique to Chontales, nor is it only of concern to local communities. As requirements for corporate social responsibility gain momentum, foreign companies wishing to exploit resources in the South are learning the value of building trust and engaging with local communities (Canada 2006; Clark 2003; Hassanein *et al*. 2006). This process is not always easy, especially in the wake of past poor corporate practices and/or corrupt governments. The Mico River headwaters could serve as a relevant case study for extractive industries operating in foreign cultures and jurisdictions, particularly in Latin America.

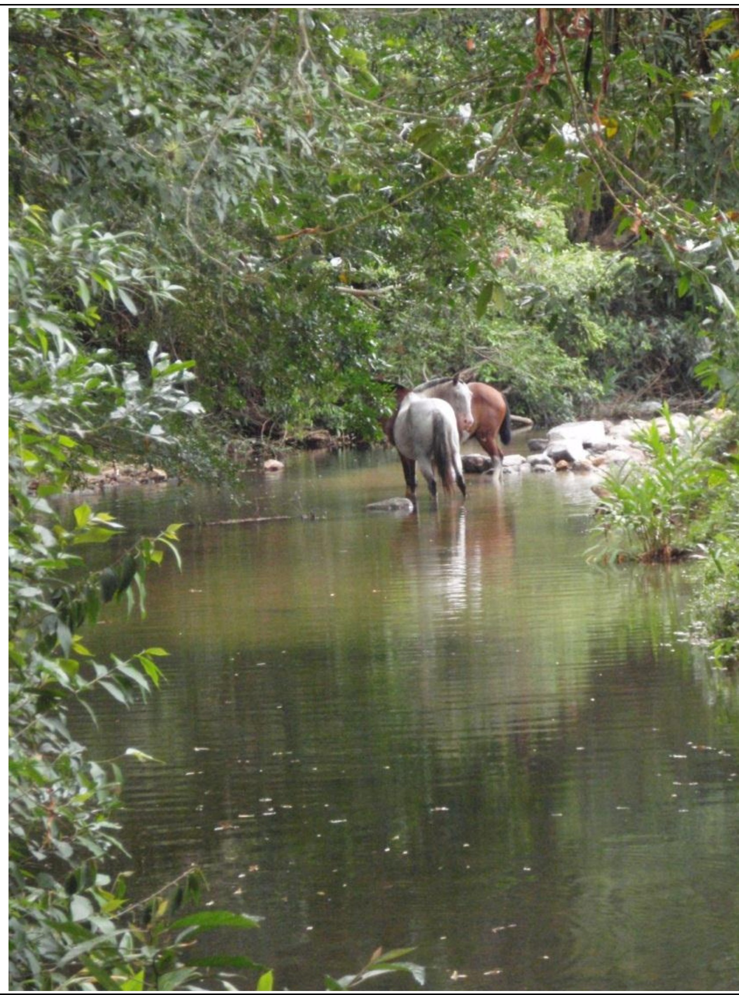


Figure 1-2. Horses in Mico River

Chapter 2. Background

2.1 Water Quality Assessment

Water quality is a subjective term. It means different things depending on the desired use of the water resource. Ecological function, drinking water, agriculture and industrial use all have different criteria for safe concentrations of various substances. Drinking water quality is commonly determined by comparison of contaminant concentrations to set standards or guidelines determined to pose an acceptable risk to human health (Boyd 2006). Water quality for healthy ecological function is similarly determined by comparison to toxicological risk, but may vary dependent on natural background levels and tolerance of native flora and fauna (UN GEMS 2006). Both reliable baseline data and ongoing monitoring are required in order to see trends, identify pollutant sources and assess the effectiveness of mitigation activities.

A water quality monitoring program's design is dependent upon its purpose (Cavanagh *et al*. 1998; UNEP & WHO 1996). The goals of water quality monitoring may include, but are not limited to:

- Baseline/survey information;
- Compliance with regulations;
- Trends;
- Impact Assessment; and,
- Design of regulations or standards.

The number and location of sampling sites, and the intensity, duration and type of sampling activity will vary depending on the purpose of the monitoring program. It is critical to identify the goals of a monitoring program at an early stage in order to avoid wasted money and effort, and/or insufficient data for the task at hand (Cavanagh *et al*. 1998; Ongley 1997). When designing a monitoring program, the following questions should be asked:

1. What is the management goal? How will meeting this goal be measured?
2. What are the potential water quality impacts that need to be measured?
3. What is already known?

The answers to these questions, along with cost and available institutional/ technological capacity, will determine the best sampling methods. Choice of parameters, frequency of sampling, and the spatial and temporal scope of the program cannot be determined until these questions have been answered.

2.1.1 Bioassessment

Measuring chemical and physical components of water only tells the story of what is occurring at the moment in time when the sample was taken. Sampling must be done at regular intervals for extended periods of time in order to legitimately extrapolate what kind of exposure to potential contaminants is actually occurring for organisms drinking or living in the water. This is expensive and labour intensive, and is one step removed from actually measuring the impacts to the receiving environment. Comparison to set standards also allows little flexibility to account for local background conditions. For these reasons, the use of environmental effects monitoring has become commonplace in recent years in the North, although it is still rare in the South (Hart *et al*. 2001; Ongley 1997). Examples include the determination of Total Maximum Daily Load (TMDL) in the United States (EPA 2010), the Environmental Effects Monitoring (EEM) program in Canada (EC 2010) and the derivation of trigger values in Australia and New Zealand (ANZECC 2000).

Environmental effects monitoring focuses effort on the receiving environment and any changes therein, rather than compliance with a generic numerical standard. Monitoring is generally focused on comparison to a reference condition as well as observable changes at the subject site over time. Numerous guidance documents exist in the literature detailing the necessary study design (ANZECC 2000; Barbour *et al*. 1999; Reynoldson *et al*. 2001). Biological effects are measured by studying populations of fish, periphyton, and/or benthic invertebrates. Benthic invertebrates are the most commonly used indicator. They are relatively easy to identify, immobile, sensitive to impact, and show impacts sooner than fish (Barbour *et al*. 1999; Reynoldson *et al*. 2001).

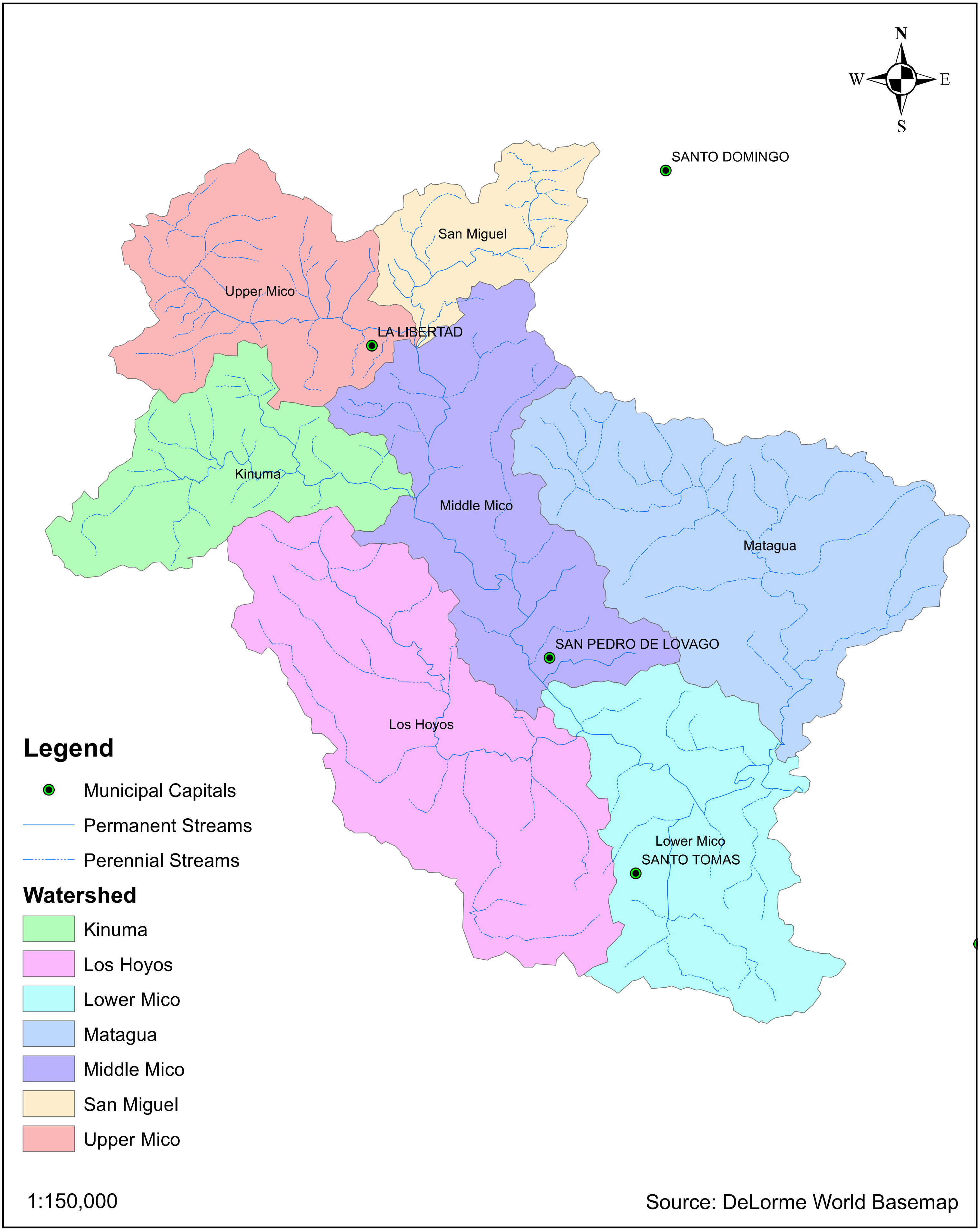
Bioassessment of benthic invertebrates is well suited for use by community stewardship groups and non-scientists (DFO & EC 1997). Sampling for benthic invertebrates is relatively inexpensive and does not require specialized equipment. It is not necessary to identify benthic invertebrates beyond family for the most commonly used invertebrate metrics. (Fore *et al*. 2001) found that properly trained volunteer monitors could collect benthic invertebrate data comparable in reliability to that of professionals. Combined with the use of hand-held water quality meters, a monitoring plan utilizing bioassessment techniques seems well-suited for use in regions where both technical and capital resources are in short supply (Soldner *et al*. 2004).

2.2 Study Area

The study area is located in the department of Chontales, to the east of Lake Nicaragua (**Figure 1-1**). The study area was defined as the drainage of the Mico River upstream of Santo Tomás, encompassing an area of 400 km^2. The Mico River forms part of the Escondido River system, which ultimately drains to the Caribbean Sea. Major tributaries within the study area include the San Miguel River, Kinuma River, El Pastal - Los Hoyos River and the Matagua River (**Figure 2-1**).

Elevation of the study area ranges between 400 and 800 metres above sea level (masl), and the terrain is mountainous (**Figure 2-2**). There are distinct dry (December to April) and wet (May to November) seasons, with average annual rainfall close to 1700 mm, and average temperatures ranging from 24°C to 27°C. The study area is located on the edge between the dry and wet tropical broadleaf forest ecosystems, and includes areas of coniferous tropical forest at higher elevations (CEPREDENAC 2006).

Nicaragua is uniquely positioned on the land bridge between North and South America, where the southernmost and northernmost extent of several species overlap. The region is also home to a large number of endemic species (Andraka 2001; A. Perez 2001). Dry tropical broadleaf forest is under intense pressure from human impacts (Gillespie *et al*. 2000), and the World Wildlife Fund has ranked it as a high priority for conservation (Dinerstein 1995).



0 1 2 4 6 km

Major Watersheds in Study Area
September 2011 | Figure 2-1

Figure 2-2. View of La Libertad area, facing west from location just north of town

Major communities in the study area include Santo Tomás (pop. 15,000), San Pedro de Lovago (pop. 2,000) and La Libertad (pop. 2,500). Approximately 15,500 additional people live in small villages and farms throughout the study area. Cattle ranching and gold mining are the primary economic activities in the area (INEC 1995). Although Chontales is one of Nicaragua's most prosperous departments, a significant number of its people live in poverty. Infrastructure and resources related to education, water, sanitation and other development indicators are inadequate in many parts of the study area (Dolores 2008; INETER 2004; SRK 1995).

Water shortages are chronic in Chontales during the dry season. Municipal water is available only two or three days a week in La Libertad during this time of the year, as little as once per week in communities such as Santo Tomás. It is likely that a great deal of water is lost to leakages and deteriorating infrastructure. It is estimated that non-revenue water (i.e., water lost to leaks or not invoiced) accounts for the loss of a third of water production in many developing countries (ADB 2011; Kingdom *et al*. 2006). Extensive deforestation in the region has also affected hydrology, reducing recharge to aquifers and drying up smaller streams in the dry season (Webster *et al*. 2001).

2.2.1 Mining

History

There has been gold mining in the La Libertad region for over a century (Belt 1911), the first 50 years of which were dominated by small mining[2]. This changed in 1940, when the first incarnation of the current La Libertad Mine began operation. Cattle ranching began to gain importance under the Somoza government, in part due to government policies encouraging its development (Aiyer 2004; Lazo 2005).

As in other parts of the world, small miners have historically faced challenges with recognition and legitimacy (Hentschel *et al*. 2003; M. Veiga 1997). Even the Sandinista government of the 1980s, of which many small miners were supporters, was keen to "modernize" the small miners and use Nicaragua's gold as a source of foreign revenue. Conflict has arisen more than once over different perspectives on the right to mine. The La Libertad Mine has changed hands several times, but most operators have shared the perspective that once they paid for the concession they had exclusive rights to exploit it.

[2]Small miner (pequeňo minero) is the colloquial term in Chontales for small-scale or artisanal miners, also known as güiriseros. The International Institute for Environment and Development (IIED) defines this type of miner as "[using] minimal or no mechanization, often in the informal (illegal) sector of the market" (Hentschel *et al*. 2003), which certainly applies to many of the small miners in Chontales.

The small miners believed that they had a historical right to the gold; that it was part of the cultural patrimony of the town and they had the right to work the deposit (Aiyer 2004; Tolvanen 2003).

In recent times, this conflict flared up in an armed standoff between the small miners and a Canadian mining company called Greenstone Resources Canada Inc. (Greenstone). As a result of the standoff, the small miners formed the Cooperative of Small-Scale Miners of La Libertad, Chontales (COOPEMILICH) and negotiated an agreement that allowed them to work within the concession as long as they dismantled their *rastras*[3] and sold their ore to Greenstone at world prices.

Greenstone was primarily an exploration company, and was not prepared for the business of operating a gold mine. Greenstone entered La Libertad with promises of a social fund and infrastructure improvements; however by 1999 the company was effectively bankrupt and unable to deliver on these promises. Greenstone's facility for processing ore had far less capacity than the *rastras* it replaced, and when Greenstone left, La Libertad small miners had nowhere to take their ore. As a result, there was considerable anger on the part of the community for the manner in which Greenstone had operated (Tolvanen 2003). This legacy of mistrust has persisted to this day, complicating relations between the community and the current mine owners (Jiron 2008; Speirs 2008).

At the time of my site visit, the La Libertad Mine was undergoing upgrades to a new processing system (Central Sun 2008) and was not producing gold. The La Libertad Mine re-opened in 2010, with a collective bargaining agreement in place between Desarollo

---

[3]*Rastras* = small mills which use mill mercury amalgamation in order to extract gold from ore

Minero de Nicaragua S.A. (DESMINIC) / BG2 Gold (the current mine owners), its employees and COOPEMILCH (B2Gold 2010). This agreement commits BG2 Gold to processing 5,500 tonnes of ore per year for COOPEMILCH.

Environmental Impacts

Artisanal gold mining is known for causing environmental degradation and being marked by a poor health and safety record for workers and communities (Hinton *et al*. 2003; M. Veiga 1997). The most common environmental impacts from artisanal gold mining are sediment inputs (Mol & Ouboter 2004) and heavy metals, particularly mercury contamination (Tarras-Wahlberg *et al*. 2001).

Mercury amalgamation is the most common method of gold extraction (**Figure 2-3** & **Figure 2-4**), and due to the informal and poverty-driven nature of the industry, techniques for mining and processing ore are often rudimentary and labour intensive (Hentschel *et al*. 2003). Many small miners have limited economic capacity or formal training, and the dangers of mercury are not always well-understood (Spiegel & M. Veiga 2010).

Figure 2-3. A *rastra* in La Libertad

Figure 2-4. Close up view of a *rastra*

The informality and marginalization of small miners has not helped improve this track record. Legal procedures to formalize mining operations are often bureaucratic and costly, and regulations written with medium to large-scale mining interests in mind. Nicaragua's *Mining Law* (Nicaragua 2001) faced opposition from artisanal miners for just this kind of bias towards industrial mining (Tolvanen 2003; Velasco 2001). Small miners often do not have the economic or technical resources to meet these requirements (Hruschka & Echavarria 2011). Without legal status, it is difficult for small miners to acquire and maintain rights to their concession, or to be seen as a feasible risk for financial investment and development.

Artisanal mining in Chontales is well-established and more stable than in rush areas such as the Amazon or parts of Africa. In addition to a 100-year tradition of mining in the community, many small miners in La Libertad have either worked in the large mine themselves or have family members who do (Aiyer 2004). These miners are experienced in artisanal techniques and have varying levels of modern technical training and background. Many are aware of the environmental and safety risks of artisanal operations. During my time in La Libertad, I observed one *rastra* where the owner/operator had constructed a settling pond to mitigate sediment inputs into the river (**Figure 2-5**). I also heard from COOPELMICH that they wished to open an independently operated cyanide leach plant with which to process ore, which would be independent of the La Libertad Mine and offer miners an environmentally superior alternative to mercury amalgamation (Jiron 2008; M. Veiga *et al*. 2009). With the proper financial and technological support, I believe La Libertad is relatively well-situated to improve working conditions and reduce environmental impacts amongst small miners.

Figure 2-5. Settling pond downstream of a rastra in La Libertad. The pond was dry as the photograph was taken during the dry season.

Industrial large-scale mines tend to have a smaller externalized environmental cost per unit of product than do artisanal operations, but due to their size they do have a large overall impact (**Figure 2-6**). Multinational mining companies generally are required to conduct environmental impact assessments as part of pre-project planning, have environmental management and monitoring plans in place during operation, and closure and restoration plans for the end of the project. Many conform to international or home country standards more stringent than those of the host country (Hentschel *et al*. 2003; Kumah 2006). However, large mining companies have also been implicated in human rights violations and environmental destruction in parts of the world with corrupt or weak governments. Industrial mines can create very large environmental impacts. When tailings dams fail or leak, catastrophic poisoning of surface and groundwater can result.

Large-scale deforestation and open pit mining can create significant hydrological changes and erosion (Clark 2003; Earthworks & Oxfam America 2007; Kumah 2006).

Figure 2-6. La Libertad Mine

Tailings from the La Libertad Mine were discharged to surface water until 1988 when a dam and facility was constructed to process and contain the tailings. Embankments of this tailings facility had minor failures on more than one occasion under Greenstone's operation, and tailings and supernatants spilled into El Tigre and Santa Fe Creeks (Knight Piesold 1997). Given Greenstone's poor financial and social record, it is unsurprising that they were in violation of environmental requirements as well. A second tailings facility has since been built, and the recent upgrades to facilities at the mine are intended to address engineering issues in one of the tailings dams identified in a more recent MARENA audit (Alfaro & Ortiz 2009).

2.2.2 Cattle Ranching

Chontales is popularly known as the place where "*los ríos son de leche y las piedras de cuajadas*[4]", and with good reason. Ranching is one of the region's largest economic activities; the majority of Nicaragua's dairy products originate from this part of the country (Wood 2010). Cattle ranching became an important part of the local economy in the 1950s, when Somoza-era policies encouraged land privatization (Aiyer 2004; Montambault 2004). Cattle herds in Chontales shrunk during the Sandinista revolution and conflict with the contras in the 1970s and 1980s (Gibson 1996; Nietschmann 1990), but once the fighting ended ranchers returned. Chontales currently consists of almost 80% pasture or former pasture, and forested areas are highly fragmented (Montambault 2004; Vanmen & Y. Flores 2006).

Unfortunately, sufficient pasture rotation is rare and overgrazing is typical (**Figure 2-7** & **Figure 2-8**). Cattle ranching is one of the primary causes of deforestation and erosion in Nicaragua (Esquivel *et al*. 2007; European Commission 2007). Few fences keep cattle out of waterways, and even fewer protect riparian vegetation (personal observation 2008). Environmental impacts to water quality from cattle ranching can include erosion and sedimentation, faecal contamination and changes in stream hydrology due to deforestation.

[4]the rivers are made from milk and the rocks from cheese

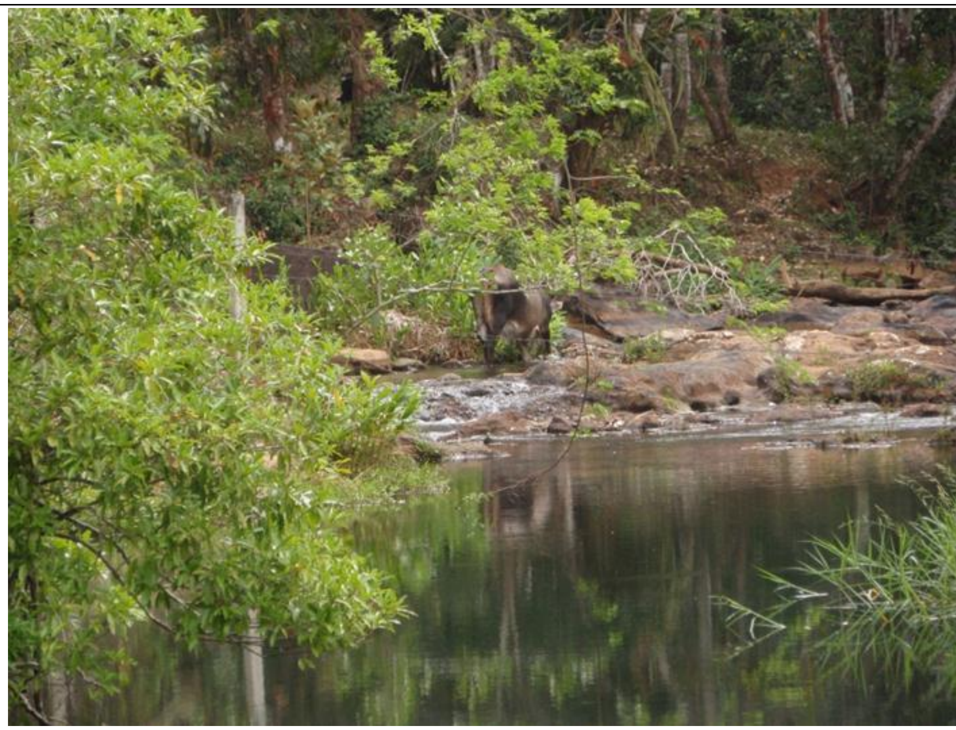


Figure 2-7. Cow in Mico River approximately 200 m upstream of La Libertad water intake

Figure 2-8. Access point for cattle on Mico River downstream of La Libertad

The National Union of Farmers and Ranchers (UNAG) are working in Chontales to modernize the cattle industry. This has included reforestation efforts and education on best management practices. Ranchers in Chontales tend to be relatively prosperous and generally have the financial capability to make changes in their farming practices. Convincing them of the benefits of reforestation (Yamamoto *et al*. 2007) and controlled access to water (Davidson & Gulka 2007) on cattle health and productivity will hopefully lead to positive results for water quality.

2.2.3 Household Waste

Wastewater treatment is inadequate in many parts of Chontales. Gastrointestinal diseases associated with fecal contamination of drinking water are common throughout the region (Ascencio 2002). Pit latrines are ubiquitous even in larger centres such as Santo Tomás, while in rural areas many people rely on open-air defecation. Although in many ways pit latrines are a good solution to sanitation in areas with unreliable water and wastewater infrastructure, in high densities they may contaminate groundwater with nitrates and pathogens (Banks *et al*. 2002; UNESCO 2006). Open-air defecation can contaminate surface runoff with pathogens and excess nutrients, resulting in eutrophication and high biological oxygen demand (BOD) in receiving waters.

Garbage collection is, for the most part, non-existent in rural areas of Chontales. Littering is commonplace, and waterways are choked with plastics and other garbage (**Figure 2-9**).

Figure 2-9. Garbage in the Mico River

2.2.4 Other Industry

Several dairy processing plants and tanneries are located in Santo Tomás and throughout the region. Untreated dairy effluent creates conditions of low pH and dissolved oxygen as lactose is converted to lactic acid (Karadima *et al*. 2010). Other pollutants include dissolved and suspended solids. Like dairy effluent, tannery effluent contains dissolved and suspended solids, and creates high biological and chemical oxygen demand in receiving waters. It also may contain elevated levels of chromium and other metals (Bosnic *et al*. 2000). *Decreto 33-95* regulates effluent discharge from these industries (Nicaragua 1995), but enforcement is limited.

Other impacts to water quality include the common practice of washing vehicles and clothes directly in the river (**Figure 2-10**).

Figure 2-10. Women from La Libertad washing clothes in the Mico River. Note the soap-stained rocks in the foreground

2.3 Regional Challenges

Adequate hydrological and water quality data are essential for effective water resource use planning (UN GEMS 2006) and protection. Such data informs receiving environment capacity, identifies critical water-related issues and aids in allocation of funds. Lack of water data has been identified as a major obstacle in achieving water-related Millennium Development Goals (Hassan *et al*. 2005; UN 2010) in the global South.

Water quality monitoring in Nicaragua has for the most part been limited to site-specific studies. The government has identified the need for a national information system for water quality and hydrological data (Montenegro *et al*. 1999), but at the current time such information is scattered across various agencies and private actors (F. Flores 2008). This data is difficult to track down, and not all is available to the general public (Mendoza 2008).

In the global North, governments have had water quality and hydrological monitoring programs in place for decades. A body of literature has since developed on water quality assessment and monitoring methods, primarily developed under temperate conditions with the assumption of ample technical and financial capacity. Conditions are often quite different in tropical parts of the world. Ecology and climate, funding and capacity, and cultural norms can all affect the efficacy of methods designed in North America or Europe. Understanding these differences is essential in adapting methods to be effective in a particular location.

2.3.1 Capacity

Capacity is a commonly used word in development, but a definition can be difficult to pin down. It is used to describe technical expertise, good governance and effective institutions, sufficient funding, adequate infrastructure: everything from enforcement of regulations to office supplies. In essence, it refers to the ability of individuals or institutions to perform required functions and solve problems (UNDP 1997).

Nicaragua is the second poorest country in the western hemisphere (IMF 2010). It has a recent history of dictatorship and civil war and suffered heavy damage from Hurricane Mitch in 1998. Infrastructure is poor, especially in the eastern half of the country. Government agencies are strapped for cash and lack qualified personnel and equipment (A. M. Larson 2002). Compounding these problems, the government in recent years has not been free from corruption and scandal (Anderson 2008; Brown & Cloke 2005; Transparency International 2010).

Nicaragua is a relatively young democracy; the current parliamentary system was formed in 1984. There are currently seven political parties in Nicaragua, however the political landscape is dominated by the Sandinistas[5] and the Liberals[6]. Nicaraguan politics are heavily partisan, often resulting in staff turnover and/or loss of support for programs initiated under one political party when another gains power (Anderson 2008). This not only makes it difficult to implement government-led change, but it reduces public confidence in government agencies.

A history of corruption in government creates similar problems with public perception. Many people simply do not pay their taxes (Lopez 2008), with little repercussion when they have family connections in government and/or the government has no capacity to enforce tax laws. However, people are often willing to contribute money to a particular project when there is some guarantee that their money will be used as it should (Calderón 2008; Dolores 2008; Mitchell 2008). Although confidence in political institutions in Nicaragua is low (Calderón 2008), civil engagement and public

[5] FSLN - *Frente Sandinista de Liberación Nacional*
[6] PLC - *Partido Liberal Constitucionalista*

participation in politics is relatively strong when compared to the rest of Latin America (Anderson 2008; Booth & Richard 2008).

Design of a community monitoring plan for rural Nicaragua should involve some discussion of what capacity is required to implement it, and how those needs might be met. Training of personnel, sustainable funding, effective management and coordination with other agencies will be necessary for successful implementation of such a plan.

2.3.2 Regulation

Governance and planning in the Mico River watershed are complicated by the multiplicity of government agencies with jurisdiction in the area. Not until recently has Nicaragua created a single agency or comprehensive policy dealing with water. The Nicaraguan *Water Law* was passed in 2007, with the intention of improving water resource management and water rights allocation. The law calls for the creation of a National Water Authority (ANA) to perform the regulatory, management and control functions of the new law, however this authority has not yet been established (Nicaragua 2008; Novo & Garrido 2005). Numerous NGOs and the private sector are also involved in water-related issues. **Table 2-1** shows these players and their roles.

Table 2-1. Current Water-Related Agencies in Nicaragua (from Novo & Garrido 2005)

Actor		Water Institution	Water Use				Key Role					Spatial Scale	Local	
			Agriculture	Environment	Energy	Drinking & sanitation	Regulatory	Planning & management	Conflict resolution	Pricing & financing	Consult & research	National	Urban	Rural
Government	Ministry	MARENA	■	■	■	■	■	■	■			■		
		MAGFOR	■	■			■	■				■		
		MINSA				■	■					■		
		MIFIC	■		■		■	■	■			■		
		MEM			■		■	■				■		
	Autonomous government body	INAA				■	■	■	■	■		■		
		ENACAL				■		■		■			■	
		ENEL			■			■				■		
		INETER									■	■		
		INTA	■								■	■		
		FISE				■		■		■				■
		CONAPAS				■		■			■	■		
		CNRH						■			■	■		
		Local Governments	■	■	■	■	■	■	■	■			■	■
		Reg. Governments	■	■	■	■	■	■	■	■			■	■
		Courts	■	■	■	■			■			■		
		Env. Attorney		■					■			■		
		Police		■					■			■		
		National Assembly	■	■	■	■	■					■		
International community		Inter. Banks			■	■				■				
		Dev. Agencies/NGO		■		■		■	■	■	■	■		
Civil organization		Nicaraguan NGOs	■	■	■	■		■			■		■	■
		CAPS				■		■	■	■				■
		Municipal Assoc.						■			■		■	■
		Basin Committees	■	■	■	■		■			■		■	■
		Farmers Unions	■								■			■

Source: Authors' own elaboration.

MARENA = Environment and Natural Resources Ministry; MAGFOR = Agriculture and Forestry Ministry; MINSA = Health Ministry; MIFIC = Infrastructure and Trade Ministry; MEM = Energy and Mines Ministry; INAA = Nicaraguan Institute for Water and Sanitation; ENACAL = National Water Supply and Sanitation Company; ENEL = Nicaraguan Electricity Company; INETER = Institute Territorial Studies; INTA = Institute of Agricultural Technology; FISE = Social Investment Fund; CONAPAS = Commission on Water and Sanitation; CNRH = National Water Resources Commission; Reg. Governments = regional governments; Env. Attorney = environmental attorney; Inter. Banks = international banks; Dev. Agencies = development agencies; CAPS = water and sanitation committees; Municipal Assoc. = municipal associations.

2.3.3 Tropical Freshwater Ecology

Water quality in a water body is shaped by the geology and precipitation regime of its catch basin (UN GEMS 2006; WHO 2011). As a result, acceptable concentrations of chemical constituents cannot always be measured by generic standards developed in distant locations.

Similarly, bioassessment techniques of measuring aquatic ecosystem health are intimately linked to the ecology of the region in which they are conducted. Tropical streams are less homogenous in character than are temperate ones (Boyero *et al*. 2009; Ramírez *et al*. 2006), and so less generalizable. Bioassessment techniques developed in temperate regions are insect-based and focus on substrate sampling, while in tropical streams other invertebrates such as shrimps may make up a higher percentage of macroinvertebrates, requiring drift sampling to properly assess the stream (Boyero *et al*. 2009; Pringle & Ramirez 1998).

Tropical rivers show different hydrological characteristics than do temperate ones do, reflective of wet and dry season. Tropical mountain streams often have small watersheds (WHO 2011) and many are ephemeral during the dry season. There may be no unimpacted reference sites available. In Chontales, the entire watershed of the Mico River has been altered by anthropogenic influences. There is no "upstream" of cattle impacts, for example, as stream headwaters are located within cleared pasture land rather than in forested uplands. Reference sites may need to be chosen in a similar, adjacent watershed or in a relatively unimpacted area (e.g. well-vegetated riparian fenced off from cattle access).

Despite these difficulties, a reference condition approach (RCA) to bioassessment (e.g. CABIN, AUSRIVAS (EC 2010; Land & Water Australia 2011)) is preferable to comparison with a pollution index developed in a temperate part of the world. If adopted, these methods should be critically examined for appropriateness, and adapted to local conditions if necessary. Tropical streams are relatively well-studied in Costa Rica

(Boyero *et al*. 2009). This research may be applicable in establishing a taxonomic base for invertebrates in Chontales, as well as understanding ecological functions and processes in streams in this part of the world.

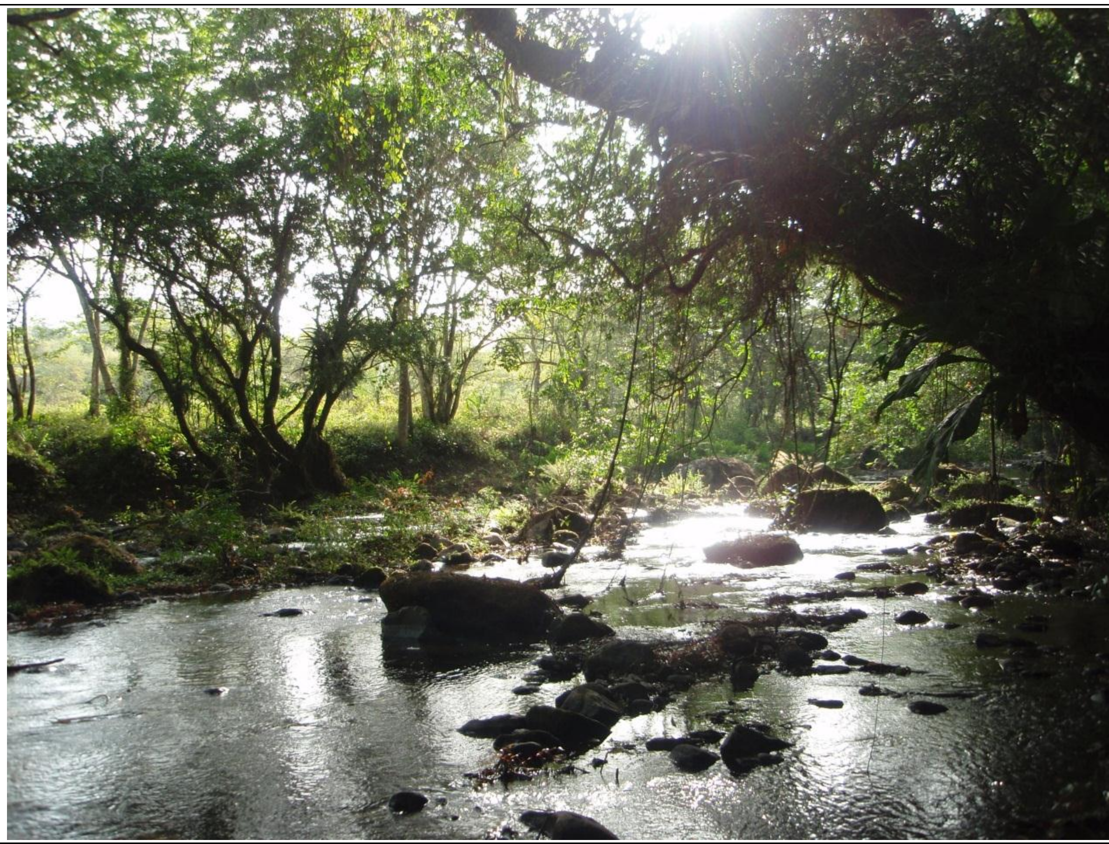


Figure 2-11. Mico River

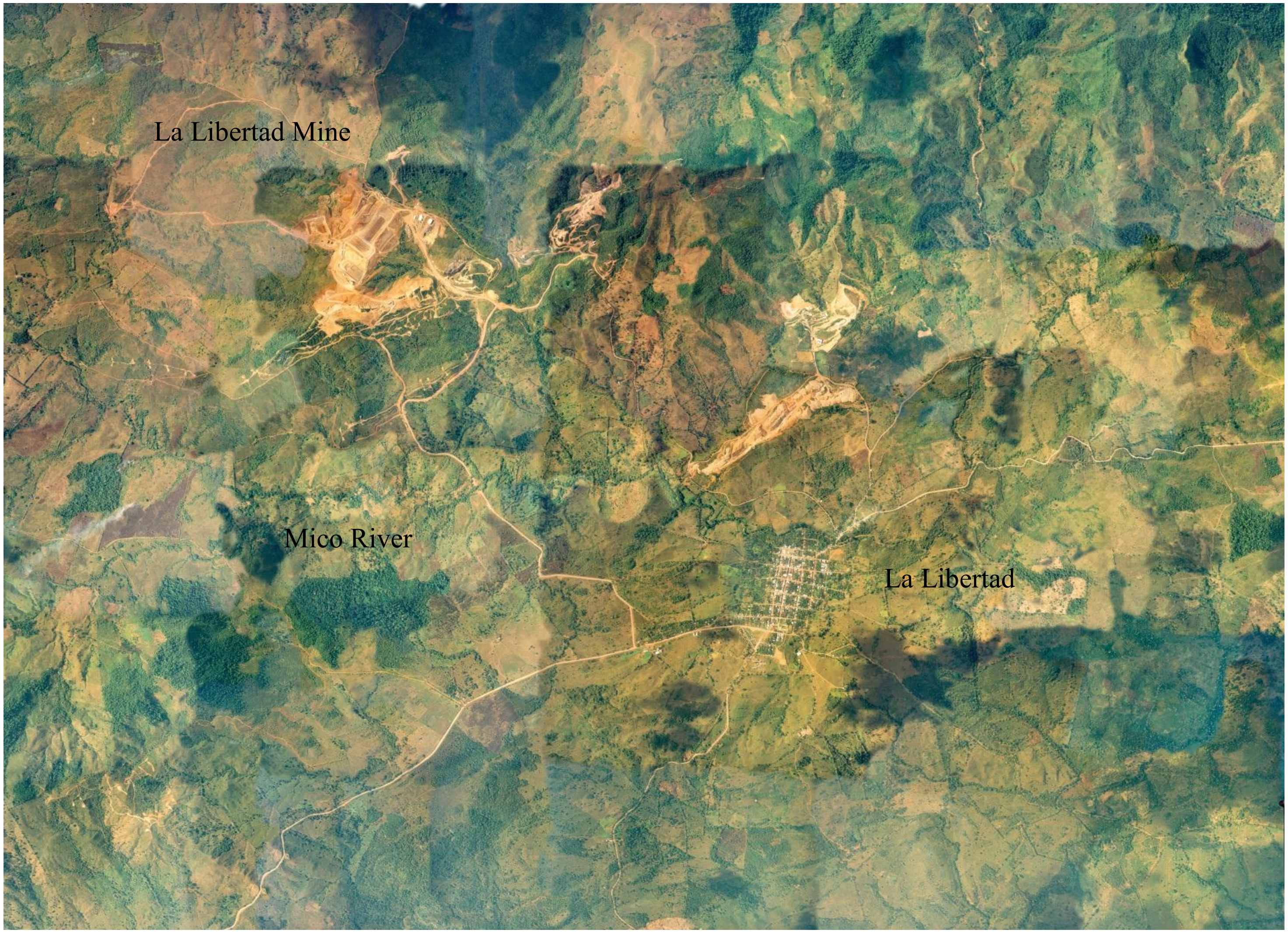


Figure 2-12. Aerial photo of La Libertad and La Libertad Mine. (photo courtesy of Central Sun 2008)

Chapter 3. Methods

3.1 Project Development

I initially looked at land use and water quality issues in and around Lake Nicaragua. Lake Nicaragua is the largest freshwater lake in Central America, and has a number of juicy issues to explore: transboundary watershed management (Montenegro 2006), invasive species (Cermeño 2001; Ocón & Martínez 2001; Stauffer *et al*. 1995), land use and pollution, a population of freshwater sharks (FishBase 2010; Smith 1893) and a once (and future?) plan for a canal to rival Panama's (Smith-Spark 2006; Vidal 2006). Water quality was one of several research needs identified in an action plan developed for the lake's watershed by the governments of Costa Rica and Nicaragua (Montenegro 1997).

My research strategy initially encompassed both qualitative and quantitative methods, and I was guided by an "action research focus", which Wisner *et al*. (1991, p. 271) calls a "solution of social problems rather than the mere compilation of scientific data". I was interested in a project that might be of some practical use in improving the quality of life for people in Nicaragua. As a researcher in a foreign country and culture, I also was careful to keep in mind the tenets of ethnography, which involves being flexible, and capable of changing preconceptions and questions as you go along in the process of your research (Denzin & Lincoln 1998).

I was not formally affiliated with any groups or universities in Nicaragua, so my first task was to contact individuals working on these issues in and around Lake Nicaragua. I began doing so in Canada and this process of networking consumed the first month or so of my time in Nicaragua. This process also produced a change in my research project. When given the opportunity to work on a topic that was both interesting to me and had been identified by a local community itself, I leapt at the chance to produce a thesis that might be of practical use.

Participatory development[7] has been the dominant paradigm in development literature for the past 20 years. Most plans and studies conducted in the South at present have as a core component the participation of local people. The academic literature on participatory research methods is quite extensive (see, for example, ADB 2001; Gaffney 2008; Gonsalves 2005; OECD 1995; Wadsworth 1998; Wisner *et al*. 1991) and covers fields such as health (Khanlou 2010; Kralik & Koch 2006; McKay *et al*. 2010), development (ADB 2001; Bessette 2004; Muraleedharan 2006; Pound *et al*. 2003), watershed management (Castelletti & Soncini-Sessa 2006; Farrington *et al*. 2000; Kerr 2002; Rhoads *et al*. 1999; Williams 2002) and many more.

Participatory research seeks to address specific issues identified by local people, and to apply the results directly to remedying those issues. While participatory methods were not utilized for the actual gap analysis, these ideas of engaging local citizens and better understanding their concerns and issues determined what the focus of my research would be. The research itself was positivist in nature; a quantitative assessment of physical and biological data.

---

[7]Participatory development is difficult to define, but in essence refers to a process through which stakeholders influence and share control over development initiatives, and the decisions and resources that affect them (ADB 2001).

3.2 Qualitative Aspects

My research began before I left Canada. As an outsider in Nicaragua, it was important to me to get as much of a “feel” for the place and people as possible. This process began with actively studying and improving my existing command of Spanish, both in Canada and during my stay in Nicaragua. Fluency in Spanish was not only vital for communication purposes, but in understanding the place and culture (Sherzer 1987).

Prior to beginning my field work, I researched the literature in order to learn not just about my area of research but also about the history, culture, politics and physical surroundings of Nicaragua and Chontales. My reading included a wide range of sources, from peer-reviewed studies to travel writing to fictional works from and about Nicaragua. I also lived and traveled in Nicaragua for several months before spending time in La Libertad. Physically being in the landscape and talking to people who live there gave me a “feel” for the place, and contributed towards a positive experience of living and working in a rural Nicaraguan community.

One of the most important of my initial tasks was the search for a “gatekeeper”. Without the support of an in-country organization I needed someone through whom to gain entrée to the community, an individual who could introduce me to others and vouch for the worthiness of what I plan to do (Denzin & Lincoln 1998; Lofland 2006). To this end I made contact with the Centre for the Investigation of Aquatic Resources of Nicaragua (CIRA), an NGO called the Netherlands Development Organization (SNV), and with several Peace Corps volunteers working in Chontales. Katie Mitchell, a Peace Corps volunteer working and living in La Libertad, became my gatekeeper. She introduced me to members of local government, to COOPELMICH, and to other members of the community.

While in La Libertad, I utilized participant observation and informal interviews to better understand land use and the history of mining in the area. Participant observation has a long history as an appropriate means of gaining understanding of a culture when barriers of language (Friedrichs 1975; Vidich & Shapiro 1955). I spent time walking around town and exploring the countryside and observed *rastras* and ranching operations. I walked up and down the Mico River to get a sense of aquatic and riparian values and stream morphology. I also benefited from the interest that people I met took in my work, and the enthusiasm many Nicaraguans have in talking politics.

In addition to social conversations that turned to the topic of my research, I had the good fortune to have more formal discussions with several people in town. Jose Dolores, the municipal Environmental Coordinator, showed me the town's water source and talked to me about water supply issues and related environmental concerns. Hector Kaufmann, the environmental manager at the La Libertad Mine, took me on a tour of the mine and showed me their mitigation measures and water quality sampling locations. Javier Ocón, the secretary of COOPELMICH, took me to several *rastras* and was a wealth of information on artisanal mining.

Others who took time to talk to me and provide insight on the region included Alfredo Mendoza at the National Autonomous University of Nicaragua (UNAN), Yelba Flores with CIRA, Antoinette Kome at SNV, Graham Speirs at Central Sun and Fernando Flores at the National Water Supply and Sanitation Company (ENACAL) in Juigalpa.

I recorded field notes of my conversations, observations and impressions daily, and took numerous photographs. I also occasionally taped conversations, with permission. Analysis was limited to an introspective re-reading of my notes in order to gain a general sense of meaning. I used several of Baxter & Eyles (1997) criteria for establishing 'rigour' in qualitative work. My findings from informal interviews were confirmed by observation, the literature and my quantitative data. I attempted to speak to a range of different stakeholders, although I was not entirely successful. I did not have opportunity to speak to a rancher, and the majority of people I spoke to were academics and/or professionals.

3.3 Quantitative Analysis

My quantitative analysis began with collation and analysis of existing data. I collected and mapped existing water quality data for the study area, and analysed spatial and temporal coverage for each parameter of interest.

Based on known activities in the watershed and available mapping of watercourses and roads, I created a hypothetical monitoring plan to measure impacts to water quality. I chose parameters to be tested, sampling locations and sampling frequency. I then compared existing data to this monitoring plan to identify where data was missing or insufficient. Finally, I made recommendations for future monitoring requirements.

3.3.1 Data Collation and Analysis

The first step in my gap analysis was to identify and assemble available water quality and aquatic resource data for the Mico River. I searched the following sources for such information:

- Published academic literature;
- CIRA, UNAN and the Central American University (UCA);
- MARENA, ENACAL, CONAPAS, INAA, MINSA and INETER
- Municipal records in La Libertad, San Pedro de Levago and Santo Tomás;
- DESMINIC and B2Gold Mining Corporation (formerly Central Sun);
- The Humboldt Centre and other environmental NGOs involved in Nicaragua; and,
- Literature from the World Bank, United Nations and other international bodies involved in development in Nicaragua.

My search uncovered seven separate studies containing water quality/bioassessment data, three sets of monitoring data and four studies which provided qualitative data on environmental concerns in the region. These are listed in **Table 3-1** below:

Table 3-1. Primary Data Sources

Author	Year	Title	Parameters	Season
Velásquez, G	1993	*Diagnostic study of environmental contamination due to mining activity in the Sucio, Mico and Sinecapa Rivers, Nicaragaua*	Water chemistry, toxicology	Both
Steffen Robertson & Kirsten Inc. (SRK)	1995	*Baseline Study: La Libertad Project, Nicaragua*	Water chemistry, bioassessment	Dry

Table 3-1. Primary Data Sources

Author	Year	Title	Parameters	Season
SRK	1996	*Environmental Impact Assessment: La Libertad Project, Nicaragua*	none	N/A
Knight Piesold	1997	*Environmental Audit: Cerro Mojón*	Water chemistry (refers to DESMINIC data)	Dry
Tolvanen, A	2003	*The Legacy of Greenstone Resources in Nicaragua*	Social effects	N/A
Centro Humboldt	2005	*Resultados del Monitoreo in situ de la actividad minera en los departamentos de Chontales, Boaco, Matagalpa y municipios de Chinandega Norte*	Water chemistry (independent and review of ENACAL, DESMINIC data)	Wet
Central Sun	2006	*DRAFT Environmental Impact Assessment: Chamorro Exploration*	none	N/A
Vanmen, K & Flores, Y	2006	*Diagnostico Ambiental: La Subcuenca Alta de los Rios Siquia y Mico*	Water chemistry, bioassessment	Wet
Galatowitsch, M	2007	*Monitoreo de los Macroinvertebrados en las Partes Altos de los Ríos Mico y Siquia en los Municipios de Santo Domingo, La Libertad, San Pedro de Lovago, Santo Tomás y Villa Sandino, Chontales, Nicaragua*	Bioassessment	Both
DESMINIC	2007	*Estudio Hidrobiológico del Sistema Acuático circundante al Proyecto "Ampliación Cerro Mojón"*	Bioassessment	Dry
Manuel, J	2007	*Estudio geofísico para microlocalización de pozo en el sitio Monasterio Santa María de La Paz*	Water chemistry	Dry
DESMINIC	1995-2008	effluent and watercourse monitoring data, 1996 - 2008	Water chemistry	Both
ENACAL	1998-2008	watercourse monitoring data for La Libertad	Water chemistry	Both
Alfaro, A & Ortiz, F	2009	Estado Actual de la Minería Metálica en Nicaragua e Impactos Ambientales de Algunos Proyectos Mineros Emblematicos	Water chemistry (independent and review of DESMINIC data)	Dry

Data from these studies were entered into Excel and organized in an Access database. As the focus of this report is on surface watercourses, groundwater results were not included. The following information was recorded for each data point:

- Sample location (in NAD27 UTM coordinates and by description)
- Sample date
- Sample type (i.e., sediment, surface water chemistry or bioassessment)
- Parameter tested
- Analytical result

Once data entry was complete, I mapped sample locations using ArcGIS. Several of my data sources did not provide UTM coordinates for sample locations, and these were plotted based on location descriptions. I then binned together sample locations in close proximity (i.e., within 25 m) and measuring the same effects (e.g. downstream of stream confluence, or upstream of a *rastra*) as one data point, in order to show overall spatial coverage of the study area. Surface water and sediment chemistry data from outside of the study area was not included, with the exception of sample locations that coincided with bioassessment sampling locations. Bioassessment data for the entire region was collated and analysed in order to provide a larger database of reference and test sites (Reynoldson *et al*. 2000). **Appendix A** contains electronic copies of the original reports, the database containing raw data, and ArcGIS files used in mapping and spatial analysis.

Each of these new combined data points was then assessed using the JMP statistical software package. Values below detection limit were assigned a value of 0. It is understood that this practice would not be acceptable in determining legal compliance with a standard, but for the purpose of this study (i.e., a general sense of water quality) it allowed the many non-detect values in the data set to be incorporated into the analysis. Descriptive statistics (mean, number of samples (n), standard deviation, etc.) were produced for each parameter analysed at each point. This was done in order to produce an average value for each site to be used for comparison to water quality criteria; standard deviation and n provided a sense of how accurate a description of conditions that average value is. Each parameter was also plotted over time to assess any trends, and compared to effluent, drinking water and aquatic life criteria where available.

Local Nicaraguan (i.e., *Decreto 33-95* (Nicaragua 1995) or Comité Coordinator Regional de Instituciones de Agua Potable y Saneamiento de Centroamérica, Panama y República Dominicana (CAPRE) (CAPRE 1994)) criteria were defaulted to, with international (i.e., World Health Organization (WHO) (WHO 2011)) guidelines or Canadian (i.e., *Metal Mining Effluent Regulation* (MMER) (Canada 2002)) standards used for parameters with no local standard. *Decreto 33-95* and the MMER standards are for comparison of effluent quality, where CAPRE and WHO guidelines are drinking water criteria for surface water. No local aquatic life standards or guidelines exist in Nicaragua and so Canadian Council of Ministers for the Environment (CCME) freshwater aquatic life guidelines for surface water (CCME 2011b) were used. Sediment samples were compared to the CCME freshwater aquatic life guidelines for sediment (CCME 2011a). These criteria may not be directly comparable as different organizations may develop criteria to measure different effects (e.g. acute vs chronic exposure), however they give a general sense of water quality with regard to different uses.

Finally, a qualitative assessment was made of individual study reliability. This included documented quality assurance/ quality control (QA/QC) procedures, availability of raw data and study design.

3.3.2 Comparison of existing data to "Ideal" monitoring plan

Introduction

A gap analysis is inherently subjective. What constitutes a data "gap" depends on what you are attempting to measure. As discussed in **Section 2.1**, one should be clear in one's purpose when designing a water quality assessment program.

In order to effectively identify gaps in existing data, I undertook the theoretical exercise of designing a water quality monitoring program for the purposes of establishing baseline conditions and evaluating existing impacts to water quality in my study area. This allowed me to clarify what I was asking of the existing data, and prioritize when thinking about what is possible in future in the Mico River headwaters given existing capacity.

Objectives

The first goal of this thesis is to identify what water quality information is a priority for the Mico River, and this also informs the objectives of my theoretical water quality monitoring program. The communities in the study area have expressed a desire to understand existing water quality conditions, with a focus on determining if the water safe for consumption by humans and livestock. A number of dairies exist in the study area and require clean water for processing milk and cheese. Concern also exists for the ecological health of the aquatic environment. Healthy watercourses provide a number of ecosystem services (see **Chapter 1**), including improved drinking water quality. A non-commercial fishery exists in the region, and is dependent on aquatic ecosystem health.

Surface water quality varies across the landscape, and can change seasonally and year to year depending on natural processes such as precipitation, natural mass movement, flow patterns, and atmospheric conditions. A good baseline survey of water quality should have sufficient spatial and temporal data to account for these variables.

Identifying the source, magnitude and extent of potential impacts to water quality is outside of the scope of this hypothetical study design.

Figure 3-1. Drinking water intake for La Libertad

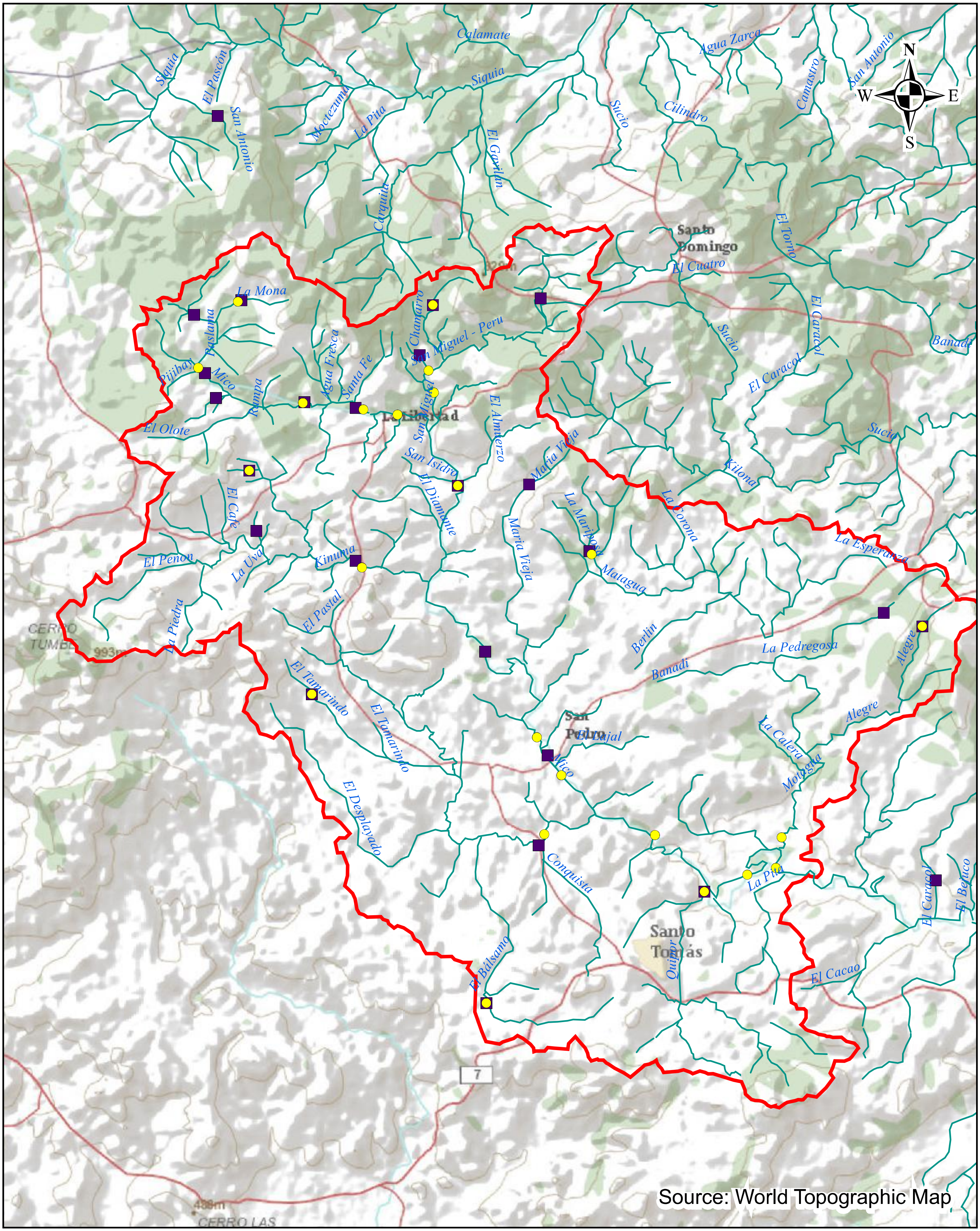
Methods

This hypothetical study includes analysis of surface water chemistry and RCA based bioassessment with benthic invertebrates. Sediment sampling is generally undertaken to identify areas of contamination or as a part of long-term monitoring of industrial activities. Sediment can act both as a sink for contaminants originating from airborne deposition or contaminated surface water, and as a source of contaminants back into the water column when disturbed. A sediment sampling program would be appropriate as a second step should benthic invertebrate populations prove to be in poor condition at impact sites, or in order to delineate areas and gradients of contamination, but is not required for this hypothetical study.

Study Area

A baseline surface water quality survey requires sampling sites located in representative locations in all major drainages in the project area. These locations are shown in **Figure 3-2**.

.



Legend

- "Ideal" Water Quality Sampling Location
- "Ideal" Bioassessment Sampling Location
- Streams
- Study Area

0 1 2 4 km

"Ideal" Sample Locations	
July 2011	Figure 3- 2

RCA based bioassessment requires a range of reference sites indicative of natural variability, in order to create an empirical model that test sites can be compared against. Reference sites should be representative of a variety of habitat types (e.g., altitude, stream order, ecoregion, etc.). A large number of reference sites (i.e., 25 or more, depending on natural variability) are required in order to develop a defensible model (Grey & Stewart 2011). Potential locations for bioassessment reference and test sites are also shown in **Figure 3-2**.

Reference locations shown in this figure are approximate only, as they were based on aerial photos. Actual sites for both water quality and bioassessment should be chosen based on more accurate land use data, and groundtruthing in the field.

Parameters and Timing

Sampling should occur in February, May, August and November, in order to capture seasonal variability. In particular, the May sampling event should be timed to capture first flush of the rainy season (e.g., pushed back to June if necessary). Water quality variables to be analysed are listed in **Table 3-2** below, with a description of selected parameters following (EPA 2008; RISC 1998).

Table 3-2. Priority Water Quality Parameters

Parameter	Activities Potentially Creating Impact	Water Use Impacted
pH	Industrial and artisanal mining, dairies, tanneries, inadequate sanitation	Aquatic life, affects toxicity of other contaminants
Conductivity	Industrial and artisanal mining, dairies, tanneries, inadequate sanitation	Aquatic life
Temperature	Industrial and artisanal mining, ranching, agriculture, deforestation, washing in river	Aquatic life
Dissolved Oxygen (DO)	Industrial and artisanal mining, ranching, agriculture, deforestation, washing in river, dairies, inadequate	Aquatic life

Table 3-2. Priority Water Quality Parameters

Parameter	Activities Potentially Creating Impact	Water Use Impacted
	sanitation	
Turbidity/ Total Suspended Solids (TSS)	Industrial and artisanal mining, ranching, agriculture, deforestation, washing in river	Aquatic life, drinking water, food processing
Hardness	Not applicable	Affects toxicity of other contaminants
Nutrients	Cattle ranching, inadequate sanitation, dairies	Aquatic life (through eutrophication), drinking water, food processing
Bacteria	Cattle ranching, domestic wastewater, dairies	Drinking water, food processing
Cyanide	Industrial mining, fishing	Aquatic life, drinking water, livestock use, food processing
Total Metals	Industrial mining	Aquatic life, drinking water, livestock use, food processing
Mercury	Artisanal mining	Aquatic life, drinking water, livestock use, food processing
Pesticides and Herbicides	Agriculture, ranching	Aquatic life, drinking water, livestock use, food processing
Alkalinity	Not applicable	Affects toxicity of other contaminants
Hydrocarbons	Industrial mining, roads, waste management	Aquatic life, drinking water, livestock use, food processing

Physical/Dissolved Ions

Turbidity/TSS – Turbidity is a measure of the optical properties of a water sample induced mostly by suspended particulate matter which results in a scattering of light as it passes through water, while TSS is a quantitative measure of suspended solids in the water. High levels can reduce biological productivity of the water or prey capture success by visual predators. The relationship between TSS and turbidity depends on the characteristics of the particulate matter (i.e., percentage clay, silt or sand), but once a relationship is established between these parameters at a particular site turbidity can be used as a proxy for TSS.

Dissolved Oxygen (DO) – A measure of the amount of oxygen dissolved in water, essential to the survival and health of most aquatic organisms. Turbulent water contains more dissolved oxygen than does stagnant water. Water also contains more oxygen at saturation at colder temperatures than warmer ones. Anthropogenic inputs such as agricultural runoff and other organic materials use oxygen as they decompose, reducing dissolved oxygen levels.

Temperature – Aquatic organisms have an optimal temperature range outside of which they become stressed, more susceptible to disease and grow more slowly. Increased temperature contributes to algal growth, and is a contributing factor towards eutrophication of a watercourse. Temperature also affects the toxicity of a range of other substances, including ammonia.

pH – Aquatic organisms have an optimal pH range outside of which they become stressed, more susceptible to disease and grow more slowly. pH is a factor in the toxicity of numerous pollutants, including ammonia. Eutrophication may cause a slight rise in pH in watercourses during the daytime due to photosynthesis.

Conductivity – An indirect measurement of the total ion concentration in the water, via measurement of its electrical conductivity. Natural waters vary between 50 and 1500 uS/cm. Conductivity may be used as a measure of dissolved solids, once the correlation is established for a particular body of water.

Hardness – Hardness is primarily due to the presence of calcium and magnesium in the water, although other metallic ions may contribute. Hardness affects the toxicity of some metals. Anthropogenic sources of hardness include mining and some industrial effluents.

Alkalinity – A measurement of the water's ability to neutralize acids. High alkalinity is associated with excessive hardness and high concentrations of sodium salts. Low alkalinity water has little capacity to buffer acidic inputs and is susceptible to acidification. Mining and other industrial effluents and acid rain have the potential to destroy alkalinity.

Coliform Bacteria: Escherichia coli (E. coli) – *E.coli* is the the major species of the fecal coliform group of bacteria; as such it is an indicator of fecal contamination from human and animal wastes. Coliform results are reported as Colony Forming Units (CFU) of *E. coli* bacteria counted in 100 millilitres of water submitted or, Most Probable Number (MPN) per 100 mL of water. The general philosophy associated with using an indicator organism such as *E. coli* is that if it can be shown that fecal contamination of the water has occurred, then pathogenic organisms may also be present. Anthorpogenic source include sewage treatment plants, recreation areas, pulp and paper mills, livestock, urban runoff.

Nutrients

Nitrate + Nitrite – Nitrate and nitrite occur naturally but also can be introduced by anthropogenic sources such as agricultural and urban run-off. Both nitrate and nitrite are useable by plants. Nitrite is an intermediate step in the nitrification of ammonia. It is unstable in surface waters and rapidly degrades to nitrate, the most oxidized and stable form of nitrogen in a water body. Nitrate, and nitrate + nitrite, are often discussed interchangeably both in the literature and in this report.

Ammonia – The most reduced inorganic form of nitrogen in water, and an essential plant nutrient. Excess ammonia contributes to eutrophication of water bodies, and is toxic to aquatic life at high concentrations. Ammonia occurs naturally at low concentrations but similarly to nitrate can be introduced by anthropogenic sources such as agricultural and urban run-off.

Total Phosphorus – Both inorganic and organic forms of phosphorus present as dissolved or particulate matter. Phosphorus is generally the most limiting nutrient to plant growth in fresh water, and is found in very low concentrations in natural waters. Anthropogenic inputs of phosphorus include agricultural and urban run-off, and industrial effluents. Such inputs are often responsible for eutrophication of freshwater systems

Cyanide **-** A toxic substance that renders tissues incapable of oxygen exchange. Cyanide may exist in different forms dependent on pH, temperature, DO, salinity and the presence of other ions. It is more toxic in water below pH 8. Anthropogenic sources of cyanide include industrial effluents and mining, especially gold mining.

Hydrocarbons – Some types of hydrocarbon can be toxic, and oils and grease in water increase biological and chemical oxygen demand as they break down, reducing DO.

Metals (total and dissolved) – Total metals are the concentration of all metals in the water column, including those adsorbed to sediment particles. Dissolved metals are an indicator of bioavailable metals in the water column and provide a better determination of toxicity.

Aluminum – Aluminum is the most abundant element on earth, and occurs naturally in soil, water and air. Its presence may be indicative of acid rock drainage. **Iron** and **sulphate** are also indicative of acid rock drainage. Aluminum can adversely affect the nervous system of humans and other animals.

Cadmium – Cadmium has cumulative and highy toxic effects on aquatic life. It is closely associated with zinc and lead in the natural environment, and these heavy metals are known to increase cadmium's toxicity. It generally is found in trace concentrations of less than 0.1 µg/L. Anthropogenic sources include industrial effluent and mining.

Chromium – Chromium is toxic primarily to lower trophic levels, and does not bioaccumulate, but is very persistent in sediments. Chromium exists in two oxidation states in the environment: trivalent (+3) and hexavalent (+6), the latter of which is more toxic. Trivalent chromium is found naturally in rock deposits and is essential for plant and animal nutrition in trace amounts. Anthropogenic sources are primarily industrial processes; especially chrome plating, dyes and pigments, and leather and wood preservation.

Copper – Copper is essential for plant and animal nutrition, but is acutely toxic to most forms of aquatic life at relatively low concentrations. Background levels are usually in the range of 1 – 10 µg/L. Anthropogenic sources include industrial effluent, mining and copper plumbing in urban developments.

Lead – A toxic element generally found in low concentrations due to its low solubility. Lead is more soluble in soft waters than in hard waters, and is less toxic to fish as hardness and dissolved oxygen levels increase. Anthropogenic sources include industrial effluent, mining and urban developments.

Mercury – Mercury forms highly toxic compounds that bioaccumulate in the body. Atmospheric deposition is the major pathway to aquatic ecosystems. Mercury occurs in very small quantities (i.e., 1-2 ng/L) in natural waters, making it difficult to measure accurately in surface water samples. Measurement of tissue samples is preferable as concentrations will be higher and contamination less likely. Anthropogenic sources include mining (especially artisanal mining), smelting and fertilizer production.

Molybdenum – a low-toxicity essential micronutrient. Anthropogenic sources include steel alloy and electronics manufacturing, mining and agricultural fertilizer.

Silver – Silver is toxic to aquatic organisms, and occurs in only trace amounts in natural waters. Anthropogenic sources include mining, photography, coin and jewelry production and manufacture of chemicals and inks.

Zinc – Zinc is an essential element for plants and animals. While it is relatively non-toxic to terrestrial organisms, it is acutely and chronically toxic to aquatic organisms. Zinc toxicity decreases with increasing hardness, and increases with increasing temperature and decreasing dissolved oxygen. Anthropogenic sources include mining, agricultural fertilizers and pesticides, industry and urban runoff.

Pesticides – A number of different chemicals belong to this category, many of which are highly toxic to aquatic life and persistent in sediments. These compounds bioaccumulate in food webs and can show bioconcentration in higher trophic levels such as fish. Their toxicity is related to the disruption of oxygen uptake, which leads to suffocation and death.

Sampling Methodology

"Ideal" sample collection and QA/QC methodology for water chemistry was considered to be British Columbia Ministry of Environment (MoE) and Resources Information Standards Committee (RISC) standards for surface water quality sampling. "Ideal" bioassessment sample collection and QA/QC was considered to be CABIN and AUSRIVAS methodologies, or the United States Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour *et al*. 1999), as appropriate.

3.3.3 Identification of future water quality monitoring needs

Based on the results of the gap analysis, future water quality monitoring needs were identified and recommendations made for future work.

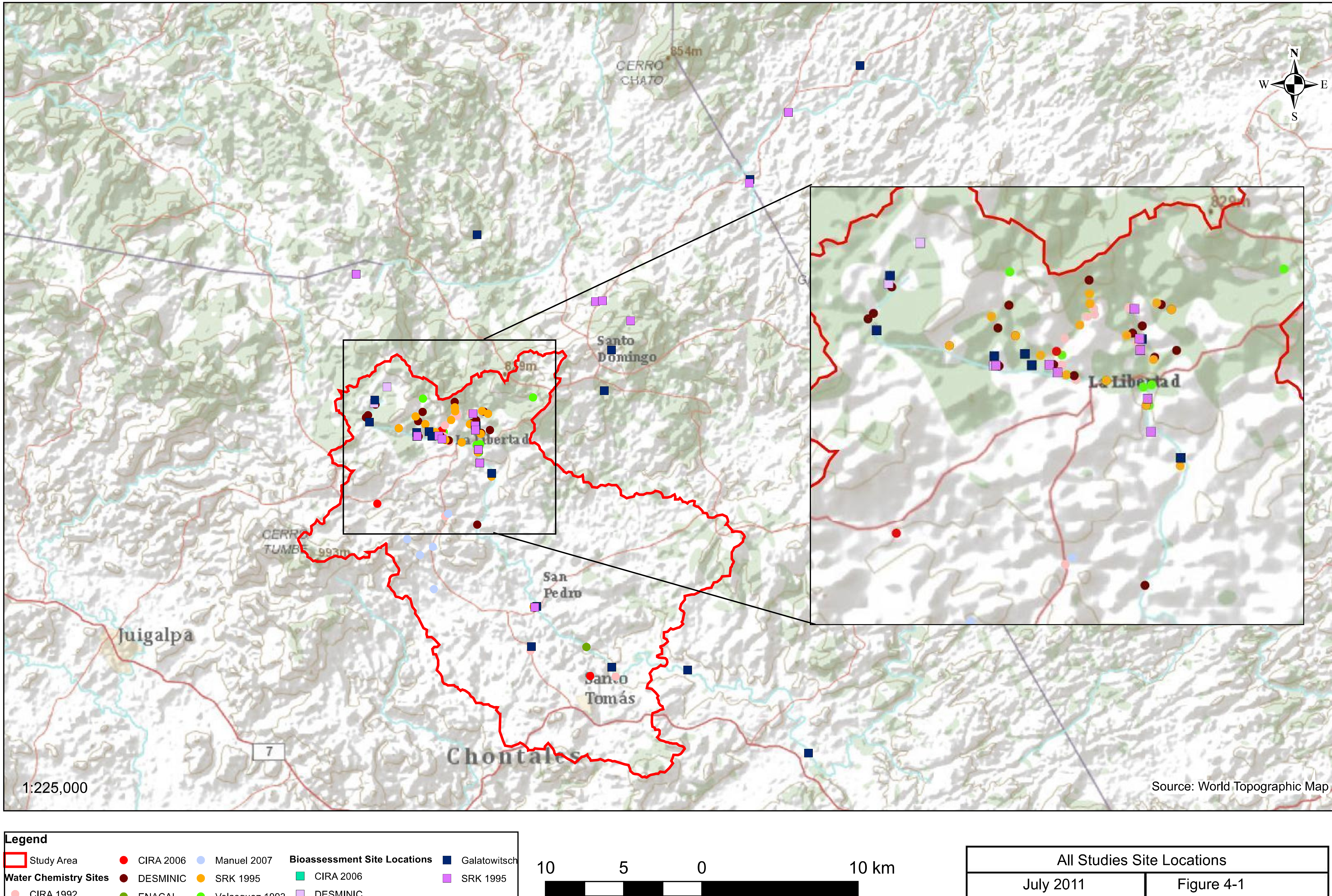
nk

Chapter 4. Results

4.1 Summary of Data Sources

As described in **Section 3.3.1**, I located ten studies containing quantitative data and four containing qualitative data regarding surface water condition and impacts in the study area. The area in and around the La Libertad Mine, unsurprisingly, has the best data coverage, as shown in **Figure 4-1.**

Most available studies had poor quality of data. QA/QC sections were universally weak; none of the studies indicated that duplicate samples had been taken, and few had detailed methodology sections or reference to standard guidelines for sampling. Several studies contained inaccurate or missing coordinates, and none explicitly stated which projection their coordinates were in. As a result, some data could not be assigned a location and had to be discarded. Other locations, and the projection used for described coordinates, were assigned based on deduction, site description, and available shapefiles and mapping. **Table B-1** in **Appendix B** contains a list of location errata and rationale used in assigning locations. A discussion of individual studies follows below.



All Studies Site Locations	
July 2011	Figure 4-1

Velásquez, G, 1994, *Diagnostic study of environmental contamination due to mining activity in the Sucio, Mico and Sinecapa Rivers, Nicaragua* (Velásquez 1994)

This is a MSc thesis looking at mercury, lead and cyanide contamination of surface water and sediment in three watersheds in two mining regions of Nicaragua: the La Libertad – Santo Domingo area and Santa Rosa del Peñón. Sampling was conducted in the Mico, Sucio and Sinecapa Rivers over two events: one during the 1993 rainy season and one during the 1993/1994 dry season. Hair samples were also collected to assess human health impacts of mercury use.

With a few isolated exceptions, mercury and lead concentrations in the Mico River were below 1 μg/L, however mean concentrations of these parameters in sediments exceeded background levels. Over a quarter of the small miners' hair samples showed concentrations of mercury above tolerance levels established by WHO. Cyanide levels were also generally low, with a couple of anomalous samples, and effluent appeared to be quickly diluted and/or degraded in downstream samples. Velásquez concluded that water in the Mico River was safe to drink, given conventional treatment, however evidence of environmental degradation and human health impacts related to small mining practices were apparent.

No duplicates were taken and descriptions of sample locations are very poor (i.e., no coordinates given, nor are all sample locations shown on the maps provided. These maps show very little detail and only approximate locations can be ascertained from them. Velásquez compares the calculated dilution of effluent collected during one time period to a sample collected downstream on a different date to verify the accuracy of her calculations. Correlation is calculated on two sample locations located upstream and downstream of each other, on the basis of two sampling events during one year. Finally, Velásquez attributes anomalous results to factors such as "use of cyanide in fishing" with no evidence that this has occurred in the area or explanation of why other impacts are unlikely.

Steffen Robertson & Kirsten Inc. (SRK), 1995, *Baseline Study: La Libertad Project, Nicaragua* (SRK 1995)

This was a baseline study in support of Greenstone's re-opening of the La Libertad Mine. The study consisted of background research, and two field visits during the start of the dry season of 1994/1995. There is minimal data to support a true "baseline" study here, as only one season in one year is covered, although limited surface water and sediment quality data provided by CIRA for the previous two years was also assessed. The study included surface water, soil, sediment, benthic invertebrate, periphyton and fish sampling. The study also characterized vegetation, wildlife, climate, air quality, geology, hydrogeology and socioeconomic values.

Water quality results showed low levels of TSS, TDS and nutrients. Background levels of metals characteristic of regional geology (i.e., Al, Ca, Fe, Mg, Mn, K, Na and Z) were present throughout, although in higher concentrations in waters immediately downstream of tailings. Other metals and cyanide were present in tailings but generally below detection limits in other samples. Pesticides were analyzed in only two samples; 2-4-D was detected in one of these. Sediment samples all had high metals content. Hg and Pb in sediment were associated with areas of small mining, CN with industrial mining, and other metals were concluded to be the results of natural mineralization. Metals results for both sediment and surface water showed markedly higher concentrations in the 1992 and 1993 CIRA data. It was speculated that the drop in these concentrations may have been due to the removal of several rastras from the Mico River watershed since the time of that study.

Benthic invertebrate and periphyton results seemed to indicate better environmental conditions above La Libertad than below. However, only five locations were sampled over the entire study area (including the watersheds of the Sucio and Siquia Rivers), and the results were not analyzed according to any established index or methodology.

Original laboratory analytical results are provided, and an adequate description is given as to which sample locations were analyzed for which parameters and the rationale. No duplicate samples are reported nor are QA/QC procedures detailed. The report acknowledges that further work should be done during other seasons of the year to get a more accurate representation of conditions.

SRK, 1996, *Environmental Impact Assessment: La Libertad Project, Nicaragua* (SRK 1996)

This is the environmental impact assessment (EIA) based on the baseline study described above. It details potential environmental impacts as a result of proposed mining activities, and environmental mitigation measures to avoid these impacts. Impacts discussed include topographic changes, visual impacts, geological and seismic stability, air quality, noise, soil resources, waste management, surface and groundwater, aquatic and terrestrial vegetation and wildlife, and socioeconomic values. Mitigation measures are described for the above impacts and include specific measures to address acid rock drainage (ARD), chemical storage, erosion and sediment control, emissions control and monitoring, effluent and receiving water monitoring and health and safety measures.

Impact evaluation appears less stringent regarding what is considered “significant” and rationale provided, and mitigation less extensive and detailed than comparable recent Canadian mining EIAs, however this may be a function of the age of the document. Notably lacking from the document are detailed mitigation monitoring plans. An environmental management plan is referenced in an audit performed the following year, but I was unable to locate and review this document.

Knight Piesold, 1997, *Environmental Audit: Cerro Mojón* (Knight Piesold 1997)

This is an environmental audit conducted of Greenstone by Knight Piesold and Co. (Knight Piesold) to assess the effectiveness of the mitigation measures detailed in the 1996 SRK environmental impact assessment. Knight Piesold found that while the engineering designs for the Cerro Mojón (now La Libertad) mine conformed to regulatory standards, field changes made during construction and operation had circumvented environmental controls, and as a result practice did not match commitments outlined in the Environmental Viability Report (EVR)[8]. Compliance concerns included: engineering design and construction of mine facilities; solution management practices; waste, chemical and fuel handling and disposal methods; and a general lack of best management practices. Successes included aggressive reforestation, exploration reclamation and surface water monitoring programs that met or exceeded industry standards in these areas.

---

[8] environmental management plan

Surface water quality is discussed, but refers to existing DESMINIC monitoring (i.e., no new sampling specifically for this study). Results are discussed for two sampling rounds: March and July 1997. A total of 11 locations were sampled, and these locations are referenced with maps and by stream name in the report. Parameters measured included TSS, total metals, pH, TDS and oil and grease. TSS exceeded Nicaraguan and WHO standards at several locations during the July sampling event. Cyanide was not measured. Other exceedances during July were associated with these TSS exceedances and interpreted to be due to contaminants associated with suspended matter.

Knight Piesold acknowledges that the water quality results are limited, but indicate that local tributaries have the potential to impact water quality in the Mico River, mainly due to the amount of TSS. They recommend adding filtered sampling to the monitoring program in order to get a better sense of true concentrations of contaminants in receiving waters.

Tolvanen, A, 2004, *The Legacy of Greenstone Resources in Nicaragua* (Tolvanen 2003)

This report was produced by a non-profit group called MiningWatch and is based on a series of interviews done with community members in 2003. It describes the community's view of Greenstone's impact on the community. The general consensus is that the company broke promises, and overall had a negative impact on the economy and social structure of La Libertad. There is also some discussion about how Nicaragua's *Mining Law* favours large corporations and does not represent the interests of small miners.

Centro Humboldt, 2005, ***Resultados del Monitoreo in situ de la actividad minera en los departamentos de Chontales, Boaco, Matagalpa y municipios de Chinandega Norte*** (Centro Humboldt 2005)

This report provides an assessment of environmental impacts in the upper and middle portions of the Rio Mico watershed, with a focus on water quality with regards to heavy metals. Centro Humboldt reviewed water quality and sediment data from ENACAL for the period 1992-2000 and from the municipality of Santo Tomás from May 2003. Centro Humboldt also sampled surface water at five locations in August 2005. Results were compared to EPA, CAPRE and *Decreto 33-95* water and sediment quality standards. The report also contains the results of interviews with local residents regarding their perceptions of institutional effectiveness in protecting natural resources, and identifies local economic activities with the potential to impact water quality.

Review of the ENACAL data showed exceedances of cyanide and lead in surface water at four locations, including as far downstream as Santo Tomás. Similar results were found in sediment samples at two locations near Santo Tomás. Elevated levels of aluminum and manganese were observed at several locations in 2003 and 2005.

Interviews with local residents indicated that most had a poor perception of institutional efficacy in protecting natural resources in the region. More than half mentioned problems with cattle becoming sick after drinking the river water, and all the interviewees mentioned health problems such as swimmer's itch and ear infections.

Economic activities identified with the potential to negatively impact water quality were mining, milk and cheese production, tanneries and slaughterhouses, as well as poor waste management and practices such as washing clothing in the river. Centro Humboldt calls for better monitoring and enforcement of environmental regulations from government agencies, with a moratorium on new mining concessions in the region. They recommend that monitoring results be made more readily available to the public, and for increased investment in water and sanitation infrastructure in the region.

The methodology for sample collection is sound, although, again, there is no mention of duplicates or other QA/QC procedures. The guidelines results were compared to are somewhat vaguely identified. For example, while I assume that the EPA standard Centro Humboldt is using is the freshwater acute standard (EPA 2011), this is not explicitly stated. EPA criteria are for dissolved metals (EPA 1996b), but it is not specified whether results are for total or dissolved metals, although my assumption is that samples were analysed for total metals (see **Section 4.2.1** for rationale). Similar to several other reports reviewed, sample locations are not well identified (i.e., no UTM coordinates nor mapping to show their locations. More troubling is that the results and discussion section of the report present only the exceedances, and do not mention results that were within the above-noted guidelines.

Similar problems exist with the interview results. A copy of the interview form is included, but little discussion is given to how interviewees were chosen, how the data was analysed, and what QA/QC was done to avoid/account for bias and representation of a variety of viewpoints in the community. Based on my own, far less formal observations and conversations with community members, I suspect that the interview results are reasonably accurate, however; without a rigorous interview methodology presented they are not very defensible.

Vanmen, K & Flores, Y, 2006, *Diagnostico Ambiental: La Subcuenca Alta de los Rios Siquia y Mico* (Vanmen & Y. Flores 2006)

This report is an environmental assessment, intended to inform an action plan for environmental management of the headwaters of the Mico River and Siquia River. The study mapped geology, hydrogeology, and land use. It also sampled surface water, groundwater, sediment and benthic invertebrates over one sampling event during the rainy season. As with the SRK environmental assessment, this is not a true baseline study as it only captures one event during one season in one year. Original laboratory analytical reports were not provided, nor were a discussion of QA/QC protocols. No duplicate samples appear to have been taken.

Results indicated that dairy processing was having a negative impact on surface water quality, specifically to DO, pH, and total dissolved solids. Overall levels of heavy metals were low. One exceedance of lead was associated with a small mining processing plant, as was one very high mercury reading. Cyanide was low overall, with no exceedances. Pesticides were detected at two locations, with one of these showing very high levels. Bacterial contamination was ubiquitous, except for in protected wells. Groundwater showed sufficiently high arsenic levels in two wells such that it could potentially be a health risk during the dry season. All sediment samples showed lead and mercury, with the highest numbers in association with areas of small mining.

No analysis was done of benthic invertebrate results with regards to an index or methodology; merely a description of results is given. Little description is given of study design (i.e., which sites are meant as controls, descriptions of sample locations). Analysis is made of effects of different land uses, but it is not detailed which sample locations measured these impacts so the reader can make their own conclusion. The report acknowledges that further work should be done during the dry season to get a more accurate picture of worst case conditions (i.e., maximum concentration of contaminants).

Central Sun, 2006, *DRAFT Environmental Impact Assessment: Chamorro Exploration* (Central Sun & DESMINIC 2006)

This is a draft version of an EIA of potential exploration activities in the Chamarro area. It details potential environmental impacts as a result of proposed exploratory activities, and environmental mitigation measures to avoid these impacts. Activities are limited to exploratory drilling, clearing of drill platform areas and associated access. Mitigation includes no new road construction (i.e., utilizing existing access, by foot where necessary), standard BMPs for erosion control, spill protection and restoration, and siting of platforms to avoid previously unimpacted vegetation where possible. No significant negative impacts were expected as a result of the exploration program, if the mitigation described was followed. No new data collection occurred for this EIA: mitigation measures and determination of impacts were based on the 1995 baseline study (SRK 1995) and CIRA's 2006 study (Vanmen & Y. Flores 2006).

Manuel, J, 2007, *Estudio geofísico para microlocalización de pozo en el sitio Monasterio Santa María de La Paz* (Manuel 2007)

This is a study evaluating hydrogeological characteristics and arsenic distribution in groundwater in the immediate vicinity of the Santa María de La Paz Monastery near Santo Tomás, with the objective of locating a well to avoid arsenic contamination and provide good recharge. Twelve wells in the vicinity were sampled and measured for temperature, pH and conductivity. Samples from five of these were also analyzed for arsenic. ENACAL arsenic results from a 2004 study in the region were also assessed for eight additional wells. Manuel concluded that the monastery was located in a region of high arsenic contamination, and recommended a well site 2.5 km to the southeast.

Sampling took place during the dry season; no date is provided for the data collected in the 2004 study referenced. No duplicate samples are described, nor is methodology for groundwater sampling.

DESMINIC, 2005 -2007, *Estudio Hidrobiológico del Sistema Acuático circundante al Proyecto "Ampliación Cerro Mojón"* (DESMINIC & Glencairn 2005; DESMINIC & Glencairn 2006; DESMINIC & Glencairn 2007)

DESMINIC began a bioassessment monitoring program of areas in and around the mine in 2005, in order to meet the commitments of the EIA (SRK 1996), to determine what, if any effect mining operations were having on the nearby aquatic environment, and to build baseline data for potential future EIAs. The monitoring program included measurement of physical parameters (i.e., DO, conductivity, pH, temperature and turbidity), phytoplankton and benthic invertebrates. Sampling initially was limited to four sites; in the second year of the program this was expanded to five and the reference site was moved further upstream to avoid the potential effects of a sedimentation dam. The first year sampling was done during the rainy season; the following two years sampling occurred in the dry season.

DESMINIC used European Economic Commission (now European Union (EU)) *Directive 2000/60/EC* rankings of aquatic condition (i.e., “moderate”, “good” and “very good”) for physical parameters, phytoplankton diversity and abundance, and benthic invertebrate diversity and abundance (EU 2000). *Directive 2000/60/EC* was used to determine trophic condition, until Year 3 when the CEPIS methodology for tropical lakes (Salas & Martino 2001) was used. Benthic invertebrate sampling was done with a Van Veen drag in Year 1 and Year 2; with an Eckman drag in Year 3.

Results in all three years reviewed were “good” for physical parameters and phytoplankton, and moderate to good for benthic invertebrates. The trophic level of the streams was ranked as between meso- and oligotrophic under the *Directive 2000/60/EC* system during the first two years, and as between oligo- and ultra-oligotrophic under the CEPIS system in the third year. Site-specific substrate and current velocity were described as possible contributing factors to the “moderate” benthic invertebrate ranking.

DESMINIC concludes that the results indicate that the aquatic environment does not appear to be under strong negative stress that would impair the quality and uses of the ecosystem. DESMINIC acknowledges that insufficient data exists to speak conclusively to potential effects of the mine on the aquatic environment, nor on the effectiveness of existing environmental mitigation measures, nor on the potential effects of other activities in the watershed. Recommendations include further monitoring at a minimum of two times per year (rainy and dry season), sampling for phosphorus at the time of the monitoring, and changing sampling methodology for benthic invertebrates to one better suited to the rocky substrate.

This study has a strong methodology section and reasonable conclusions and recommendations. Weaknesses include: the use of a temperate index of aquatic health in a tropical environment and insufficient number of sampling locations to answer to the objectives of the monitoring program. The trophic results from the first two years are not comparable to the third year as the ranking system was changed, nor will benthic invertebrate results be should sampling methodology be changed (unless the two methods are calibrated to each other). The CEPIS methodology refers to lakes, not streams, and the ranking should be qualified appropriately. Finally, descriptions of habitat quality are not included in the methodology, nor taken into account when determining water quality from benthic invertebrate densities and diversity.

Galatowitsch, M, 2007, ***Monitoreo de los Macroinvertebrados en las Partes Altos de los Ríos Mico y Siquia en los Municipios de Santo Domingo, La Libertad, San Pedro de Lovago, Santo Tomás y Villa Sandino, Chontales, Nicaragua*** (Galatowitsch 2006)

This document refers to work done by Mark Galatowitsch in support of graduate research conducted through the University of Michigan and the Peace Corps. Galatowitsch partnered with MARENA, CIRA, and the municipalities of Santo Domingo, La Libertad, Santo Tomás and Villa Sandino to undertake an assessment of stream health in the headwaters of the Mico River utilizing bioassessment methods. Specifically, the study was designed to compare water quality above, in proximity to and below the La Libertad Mine. The major goal of the project was as a training exercise for municipal and MARENA staff with regards to benthic macroinvertebrate sampling rather than as a technically stringent aquatic assessment (Galatowitsch 2008).

Galatowitsch's raw data make reference to fifteen locations sampled during the dry season of 2005/2006, however the above-referenced report only describes a second round of sampling at five of these sites during the rainy season of 2006. Sites were chosen to coincide with CIRA water and sediment sample locations from 2005 (Vanmen & Y. Flores 2006). Galatowitsch used kick net sampling, following methods described in the EPA's *Rapid Bioassessment Protocols* (Barbour *et al*. 1999). Samples were identified to family and the results compared to three indices: the Shannon-Wiener Index (Shannon 1948), the Hilsenhoff Biotic Index (Hilsenhoff 1988) and the Pollution Tolerance Index (EPA 1997).

Galatowitsch interprets his results to indicate moderate water quality and benthic invertebrate diversity both above and below the La Libertad Mine. He acknowledges that too few individuals were collected for proper application of the three indices he used. He justifies using indices developed in temperate areas by arguing that these differences are not noticeable above the family area, but provides no references to back up this statement. The Pollution Tolerance Index is only an indicator of organic pollutants, not metals and other toxins likely to result from mining activities (EPA 1997), and no discussion is given as to why this index is used to determine mining impacts to water quality. More importantly, no discussion is given as to the impact of existing natural conditions on potential benthic invertebrate diversity and total numbers, and no habitat data were collected or analysed.

Galatowitsch does recommend the use of more sample locations in order to properly assess the impacts of mining runoff to the Mico River, and the need for sampling during both rainy and dry seasons. He describes the need for better taxonomic information on local invertebrates and their tolerance to contamination. Like the DESMINIC study, Galatowitsch recommends the use of kick nets or Surber nets rather than drag nets due to the substrate and stream velocities.

DESMINIC, 1995-2008, effluent and watercourse monitoring data, 1996 - 2008

This is raw surface water quality monitoring data provided by B2Gold. Data are recorded daily or quarterly depending on parameters. All seasons and multiple years are represented. Original laboratory analytical results were not provided, nor do duplicate samples appear to have been taken.

ENACAL, 1998-2008, watercourse monitoring data for La Libertad

This is raw surface water and groundwater quality monitoring data provided by ENACAL. All seasons and multiple years are represented. Some original laboratory analytical results are provided, but duplicate samples do not appear to have been taken.

Alfaro, A & Ortiz, F, 2009, *Estado Actual de la Minería Metálica en Nicaragua e Impactos Ambientales de Algunos Proyectos Mineros Emblematicos* (Alfaro & Ortiz 2009)

This study was conducted by the Humboldt Centre. It is a review of current mining activity in Nicaragua, with a focus on the compliance of mining companies with social and environmental standards. The report looks in detail at two mines: the El Limon mine and La Libertad Mine (formerly called Orosi mine). A particular emphasis is given to heavy metal contamination of surface and groundwater.

A literature review was conducted, as well as interviews with applicable government agencies. Water quality samples were taken in the field, and interviews conducted with local stakeholders. Five surface water quality samples were taken in the Mico River headwaters over two days in January and February 2009 and analysed for physical parameters and heavy metals. Described methodology for the sampling program was the most rigorous of any of the reports I reviewed, although once again, no duplicates or trip blanks were taken.

Alfaro and Ortiz describe the recent history of mining and associated regulatory controls in Nicaragua. They discuss the number of mining concessions currently under operation or exploration and the economic and employment impacts of this activity. The case studies of the El Limon and La Libertad Mines include descriptions of recent ownership changes, production and scale. Alfaro and Ortiz also describe the social and physical geography of the surrounding municipalities, and discuss environmental impacts resulting from the above-mentioned mines' activities.

The discussion of the La Libertad Mine references the 2005 Humboldt Centre study (Centro Humboldt 2005), which found heavy metal exceedances in surface water in the Mico River headwaters. The Humboldt Centre presented these results to MARENA and lodged a complaint against DESMINIC. MARENA requested that the Humboldt Centre corroborate their findings by analysing sediment samples as well; this was done in March of 2006 at four locations and returned results of arsenic, copper, chromium and lead above EPA guidelines.

MARENA conducted an inspection of the La Libertad Mine in February 2006 and found several violations of their EMP, including evidence of sedimentation, poor management of hydrocarbons and solid waste and inadequate engineering at one of the tailings dams onsite. DESMINIC was ordered to comply with their EMP and fix the above-noted violations. DESMINIC subsequently halted operations in order to upgrade their processing facilities. The EA for the upgrades included mitigation measures for the above-noted issues and other potential impacts related to mining activities. Alfaro and Ortiz express concern as to the degree of compliance to these measures that will be forthcoming.

Alfaro and Ortiz reviewed DESMINIC surface water quality monitoring data from 2006, 2007 and 2008. The results showed exceedances of *Decreto 33-95* and/or CAPRE standards for oils and grease, total suspended solids, manganese, zinc, aluminum and iron at several locations. The Humboldt Centre surface water quality results from 2009 showed improvement, with only slight exceedances of iron at one location and zinc at another. During the 2009 sampling event, Humboldt Centre personnel found evidence that DESMINIC was still not incorporating BMPs to fix the violations noted during the MARENA inspection of 2006.

Alfaro and Ortiz call for improved monitoring, oversight and regulatory enforcement on the part of central and municipal government. They also recommend increased monitoring and better distribution of monitoring results to local stakeholders on the part of industry.

4.2 Existing Data Coverage

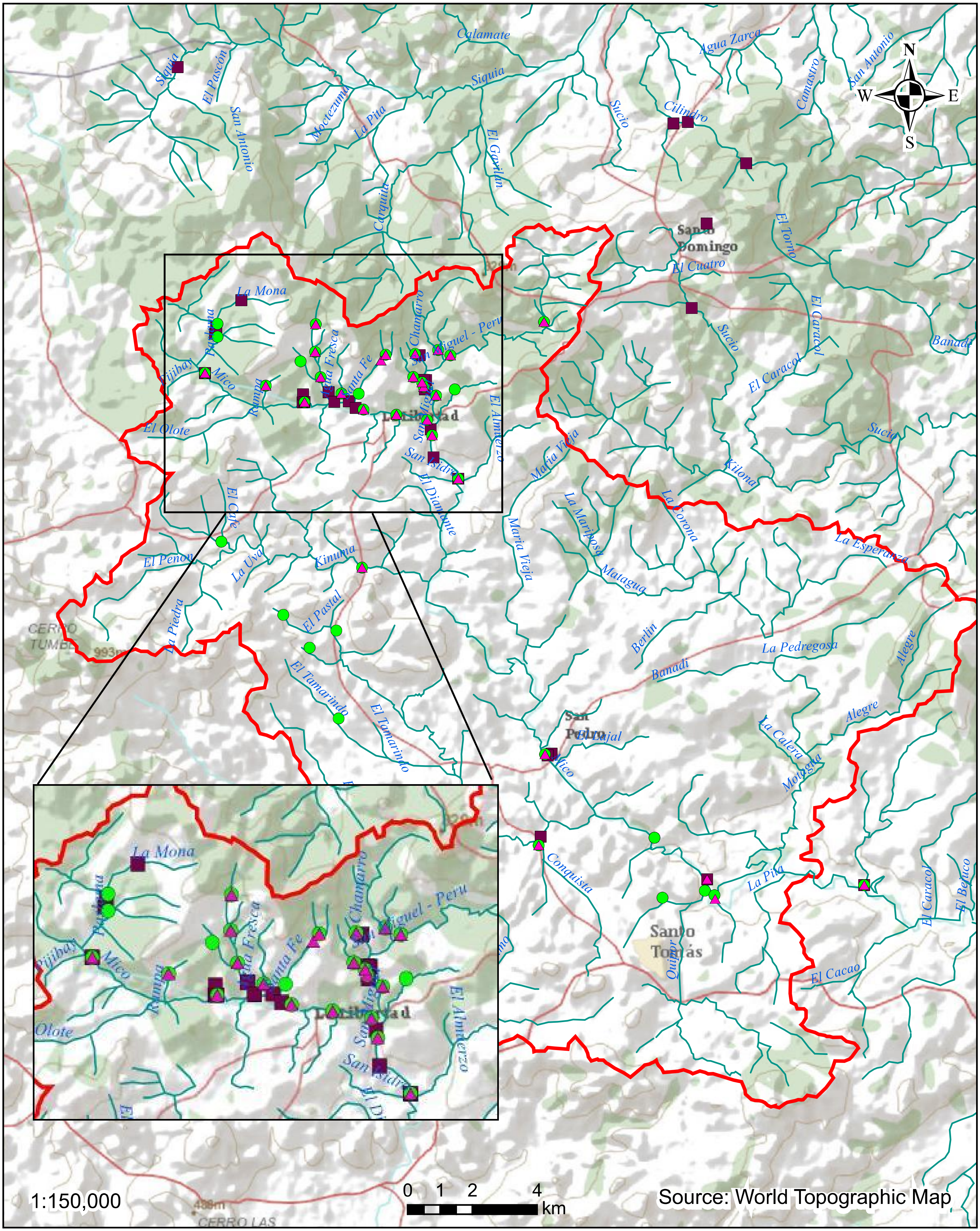
A total of 39 combined data locations were created from the amalgamated existing water quality and sediment data. Twenty-four combined data locations were created from amalgamated bioassessment data. These locations are shown in **Figure 4-2**, below, and in greater detail in **Figures C-1** through **C-7** in **Appendix C**. Bioassessment sites outside of the study area were included, in order to provide a larger number of potential reference sites. Land use data and locations of potential contaminant sources beyond the mine and towns (e.g. *rastras*, dairies) were unavailable and so are not shown on **Figure 4-2**.

4.2.1 Surface Water Chemistry

Data Quality

I located eight sources of surface water quality data for the study area, from which I created 37 unique combined data water chemistry locations. Unfortunately none of these studies contained much in the way of QA/QC procedures for data validation, and original laboratory reports were only available for two of these sources. Descriptions of sampling methodology and exact site location varied from quite rigorous to very poor. The quality of the combined data is poor, and the results cannot be said to be very reliable. I would not recommend relying on available data to make a legal determination of impairment of surface water quality. However, sufficient quantity of data exists to provide an overall general description of water quality issues in selected areas of the study area.

As shown in **Figure 4-2**, areas in and around the La Libertad Mine have the most data points. Overall temporal coverage is quite variable, although again, data points in and around the mine show the most complete and recent data sets. **Table D-1** in **Appendix D** contains descriptive statistics for the combined surface water quality sites.



Legend

- Streams
- Study Area
- Combined Sediment Sites
- Combined Surface Water Sites
- Combined Bioassessment Sites

Combined Data Locations	
July 2011	Figure 4-2

Standard deviation is quite high for some locations and parameters (i.e., over 1,000), likely due to some extremely high concentrations for heavy metals identified in data collected in the early 1990s (SRK 1995). It is possible that an error in transcription occurred between μg/L and mg/L for this data during the writing of the baseline study, as some of these results are several orders of magnitude higher than those collected three years later. It is also possible that these readings are correct, as contamination of surface water from both the large mine and numerous *rastras* was occurring during the early 1990s, to the point where anecdotal evidence exists of cattle becoming ill from drinking the water from the river (Centro Humboldt 2005; Knight Piesold 1997; Tolvanen 2003).

I used a rule of thumb of a sample size of at least ten (Cavanagh *et al*. 1998) to determine which sample locations and parameters had sufficient data to speak reliably to trends and/or exceedances of water quality guidelines. The EPA has more stringent criteria to determine if the sample results are indicative of actual conditions, generally recommending a sample size of 30 or more (EPA & OW 2002). The EPA also gives guidance on determining impairment of water bodies (i.e., where greater than 10% of samples exceed the criteria, and a confidence value of 90% is met) where statistically defensible decision making is required (EPA 1996a).

Only 14 of the combined sample locations had $n \geq 30$, and most of these had a limited number of different parameters meeting a minimum sample size of 30. Given the high standard deviation found for many parameters, meeting a confidence value of 90% would require very large sample sizes. Few, if any, of the combined sample locations would meet such sample size critera. It has been established that the data collected to date in the study area is not of sufficient quality or precision to definitively determine whether or not the Mico River is impaired in comparison to established criteria. As such, the purpose of comparing available data to criteria was to get a general sense of water quality conditions, where enough data existed to do so. A minimum sample size of ten was determined sufficient for these purposes. **Table 4-1** contains a list of combined sample locations and parameters measured which met this criterion.

Table 4-1. Surface water quality results with n≥10

ID	Parameter	Description
SW_02	chromium	confluence Paslama and Pijibay
SW_03	silver, aluminum, barium, cadmium, cyanide, chromium, copper, mercury, manganese, nickel, oil and grease, lead, total dissolved solids, total suspended solids, zinc	on Rampa
SW_04	silver, aluminum, barium, cadmium, cyanide, chromium, copper, mercury, manganese, nickel, oil and grease, lead, temperature, total dissolved solids, total suspended solids, zinc	Above the Esmeralda bridge, Mico
SW_05	silver, aluminum, barium, cadmium, cyanide, chromium, copper, mercury, manganese, nickel, oil and grease, lead, total dissolved solids, total suspended solids, zinc	Below Alcantarilla La Victoria, Victoria (Sapo)
SW_07	silver, aluminum, barium, cadmium, cyanide, chromium, copper, mercury, manganese, nickel, oil and grease, lead, temperature, total dissolved solids, total suspended solids, zinc	Below Alcantarilla de Oro, Babilonia
SW_08	chromium	Confluence Victoria (Sapo) and Babilonia
SW_11	silver, aluminum, barium, cadmium, cyanide, chromium, copper, mercury, manganese, nickel, oil and grease, lead, total dissolved solids, total suspended solids, zinc	Above Presa Agua Fresca, Santa Fe
SW_12	lead	at road, Santa Fe above confluence with Mico
SW_14	silver, aluminum, barium, cadmium, cyanide, chromium, copper, mercury, manganese, nickel, oil and grease, lead, temperature, total dissolved solids, total suspended solids, zinc	Mico, below confluence with Santa Fe and above La Libertad
SW_18	silver, aluminum, barium, cadmium, cyanide, chromium, copper, mercury, manganese, nickel, lead, total dissolved solids, total suspended solids, zinc	Tigre above confluence with San Miguel
SW_21	silver, aluminum, barium, cadmium, chromium, copper, silver, aluminum, barium, cadmium, chromium, copper, mercury, manganese, nickel, lead, total dissolved solids, total suspended solids, zinc mercury, manganese, nickel, lead, zinc	Chamorro above confluence with San Miguel, semi-reference
SW_22	silver, aluminum, barium, cadmium, chromium, copper, mercury, manganese, nickel, lead, total dissolved solids, total suspended solids, zinc	San Miguel above confluence with Chamorro
SW_24	silver, aluminum, barium, cadmium, cyanide, chromium, copper, mercury, manganese, nickel, lead, total dissolved solids, total suspended solids, zinc	San Miguel at bridge, road to Santo Domingo
SW_25	silver, aluminum, barium, cadmium, chromium, mercury, manganese, nickel, lead, total dissolved solids, total suspended	Peligo above confluence with San Miguel

Table 4-1. Surface water quality results with n≥10

ID	Parameter	Description
	solids, zinc	
SW_29	silver, aluminum, barium, cadmium, cyanide, chromium, copper, mercury, manganese, nickel, oil and grease, lead, temperature, total dissolved solids, total suspended solids, zinc	Mona, at Paslama sedimentation dam, semi-reference
SW_31	silver, aluminum, barium, cadmium, cyanide, chromium, copper, mercury, manganese, nickel, oil and grease, lead, total dissolved solids, total suspended solids, zinc	Santa Isabel, Mico at confluence with San Isidro
SW_32	chromium, mercury, lead	Kinuma at confluence with Mico
SW_35	silver, aluminum, barium, cadmium, cyanide, chromium, copper, mercury, manganese, nickel, lead, total dissolved solids, zinc	Mico, at bridge into San Pedro de Lovago
SW_37	barium, cyanide, chromium, mercury, lead	Mico above confluence with Quipor

Given the problems with data quality described above, the following discussions of comparison to criteria and trends over time should be taken as a general sense of the state of water quality in the study area, rather than determination of compliance with or failure of relevant criteria. Insufficient QA/QC exists for the existing data to determine which outliers are likely true values and which are bad data that should be removed from analysis.

Comparison to Criteria

The following section discusses specific results and comparisons to *Decreto 33-95* or MMER effluent criteria, CAPRE or WHO drinking water criteria, and CCME aquatic life criteria where such criteria apply. Results discussed below refer to the mean of all results for a particular parameter analysed at each combined sample location. Error! Reference ource not found. contains tables with sample sizes (“n”), standard deviation and other descriptive statistics for surface water and sediment results. **Appendix E** contains figures showing the spatial distribution of selected parameters described below, including which sample locations met the n≥10 criteria.

Physical Parameters

Temperature and hardness were both within specified criteria for all locations. Hardness ranged from 10 – 81 mg/L, although it should be noted that no locations had a minimum sample size of ten. TSS (**Figure E-1**) and TDS generally were within criteria, although SW_05 showed very high results for both parameters, two orders of magnitude higher than the effluent criteria. Turbidity was measured at too few stations, with too few samples to compare to TSS in a meaningful way. pH was between 6 and 9 at all locations, although a few isolated minimums and maximums failed this standard. Two of these were extreme failures, however (pH 12.23 at SW_29 and pH 3.9 at SW_05). Neither dissolved oxygen nor conductivity had $n \geq 10$. Conductivity had one exceedances of the standard; dissolved oxygen failed the standard at nine locations (out of 22 total), although it should be noted that dissolved oxygen was only analysed once at each of these sites.

Inorganics

Cyanide

Eleven sample locations had a minimum of ten samples analysed for cyanide **(Figure E-2)**, and no exceedances occurred in any of these. Two locations with less than ten samples exceeded the CCME criteria; one of these exceeded the *Decreto 33-95* criteria. One of these (SW_12) is located directly downstream of a tailings dam on Santa Fe Creek. The other (SW_32) is located quite far downstream at the confluence of the Mico River and the Kinuma River, lending credence to Velásquez's (1994) theory that use of cyanide by fishermen may be a potential source of contamination.

Nutrients

No sample locations had a minimum of ten samples analysed for any nutrients, and no criteria exceedances occurred at any site.

Other

No sample locations had a minimum of ten samples analysed for calcium, fluoride, or sulphate. No criteria exceedances occurred at any site for calcium or sulphate; two aquatic life exceedances (0.12 µg/L) occurred for fluoride, but it should be noted that the sample size for both these locations was only one. Nineteen sites were analysed for oil and grease; eight of these had a sample size of ten or more and of these all failed the effluent criterion (5 mg/L). Five additional sites with smaller sample sizes also failed the effluent criterion. These exceedances were spread throughout the study area.

Metals

Total metals is a measurement of both particulate (i.e., greater than 0.45 µm particle size) and dissolved (i.e., less than 0.45 µm particle size) metals. CCME and MMER criteria are for total metals (Canada 2002; CCME 2011b), as opposed to EPA criteria which use dissolved metals (EPA 2011). *Decreto 33-95* , CAPRE and WHO criteria do not specify total or dissolved metals (CAPRE 1994; Nicaragua 1995; WHO 2011), but I made the assumption that total metals were implied, as this is the more conservative measure and is more common worldwide. EPA justification for their policy is that dissolved metals is a better reflection of bioavailable metals in the water column than total metals, and hence a better indicator of toxicity (EPA 1996b).

None of the studies reviewed specified whether metals analysis was for total or dissolved metals, with the exception of the SRK baseline study, which looked at total metals (SRK 1995). I have made the assumption that all studies are referring to total rather than dissolved metals, as this is the more common analysis.

Aluminum

Aluminum (**Figure E-3**) concentrations were elevated in all 22 locations where it was analysed, including the reference site SW_01, although this site had a sample size of only two. The sample sites showing the highest concentrations of aluminum (SW-05, SW-12, SW_18, SW_03), were all located immediately downstream of mining activities. Fourteen sample locations had a minimum of ten samples analysed for aluminum, and of these three exceeded the effluent criteria, twelve the drinking water criteria, and all exceeded the CCME aquatic life criteria.

Arsenic

No sites sampled for arsenic had $n \geq 10$ (**Figure E-4**). SW_29, located at the Paslama Dam, exceeded the aquatic life criterion (5 µg/L) with n=8. SW_12, an impacted site on Santa Fe Creek also exceeded the aquatic life criterion, although in this case only three samples were analysed. SW_12 also showed an exceedance of the aquatic life criterion for arsenic in sediment.

Cadmium

Twenty-three sites were analysed for cadmium (**Figure E-5**); 14 of these had ten samples or more. Cadmium concentrations did not exceed effluent criteria (100 µg/L) at any site where it was analysed. The drinking water criterion (3 µg/L) was exceeded at three sites, only one of which had a sample size of at least ten. The aquatic life criterion (0.006 µg/L) was exceeded at 12 sites, half of which had a sample size of ten or more. The highest concentrations of cadmium were found in areas impacted by mining, however aquatic life exceedances were found as far downstream as Santo Tomás and at reference locations.

Chromium

Nine of the 26 sites where chromium **(Figure E-6)** was analysed had ten samples or more. No sites exceeded the effluent (100µg/L) or drinking water (50 µg/L) criteria for chromium. The aquatic life criterion (1 µg/L) was exceeded at 12 sites, ten of which had $n \geq 10$. Exceedances were spread throughout the study area.

Copper

Fourteen of the 24 sites where copper **(Figure E-7)** was analysed had ten samples or more over the study period. No sites exceeded the drinking water (2000 µg/L) or effluent (500 µg/L) criteria. Fourteen sites exceeded the aquatic life criterion (2 µg/L), nine of which had at least ten samples. These exceedances were distributed evenly throughout the study area, including reference locations, although again the highest concentrations were found in immediate proximity to mining areas.

Lead

A total of 32 sites were analysed for lead (**Figure E-8**), 17 of which had ten or more samples. Fourteen sites exceeded the aquatic life criterion (1 µg/L), eight of which had a minimum ten samples. Twelve sites exceeded the drinking water criterion (10 µg/L), seven with $n \geq 10$; five exceeded the effluent criterion (2000 µg/L), three with $n \geq 10$. Lead concentrations were extremely high at certain locations in the early 1990s. SW_14 had a mean lead concentration two orders of magnitude higher than the effluent criterion; SW_12 and SW_17 were both three orders of magnitude higher. Higher lead concentrations appear to be associated with areas of artisanal mining and the Santa Fe tailings facility, although exceedances of the drinking water standard are also found in agricultural areas several km downstream.

Mercury

Seventeen of the 32 sites analysed for mercury **(Figure E-9)** had ten samples or more. All but one site (and all sites where $n \geq 10$) exceeded the criterion for aquatic life (0.026 µg/L). Nine sites (six where $n \geq 10$) exceeded drinking water criteria (6 µg/L) and ten exceeded effluent criterion (2 µg/L), seven of which had at least ten samples. Higher concentrations of mercury followed a similar pattern to that of lead, associated with artisanal mining and Santa Fe Creek, but also found downstream in the Kinuma and Los Hoyos Rivers.

Manganese

Twenty-five sites were analysed for manganese (**Figure E-10**); 16 of these had $n \geq 10$. Six of these sites exceeded the drinking water criterion (500 µg/L); five where $n \geq 10$. Three sites (two where $n \geq 10$) exceeded the effluent criterion (2,000 µg/L). Sites with exceedances were all located immediately adjacent to mining activity.

Silver

Fourteen of the 24 sites analysed for silver (**Figure E-11**) had $n \geq 10$. Eighteen sites exceeded the aquatic life criterion (0.1 µg/L), of which 13 had $n \geq 10$. One site, with $n \geq 10$, exceeded the effluent criterion (200 µg/L). Exceedances were distributed throughout the study area, with no obvious association to mining activity.

Zinc

Fourteen of the 25 sites analysed for zinc (**Figure E-12**) had ten samples or more over the study period. No sites exceeded the drinking water (3000 µg/L) or effluent (2000 µg/L) criteria. Nine sites exceeded the aquatic life criterion (30 µg/L), six of which had $n \geq 10$. These exceedances were primarily found in mining areas, although the reference locations SW_01 and one site downstream on the Kinuma River also showed concentrations over the aquatic life criterion.

Other metals

Nickel had one exceedance of the aquatic life criterion (25 µg/L), located at SW_05 in the immediate vicinity of the La Libertad Mine. This site is one of 14 with $n \geq 10$, out of a total of 23 analysed for nickel. No criteria exceedances occurred for barium, boron, iron, magnesium, molybdenum, selenium, sodium, potassium or thallium in any of the 23 sites where this parameter was analysed. None of these sites had ten samples or more, with the exception of barium (16 out of 23 sites sampled).

Bacteria and Pesticides

Existing data for these parameters was extremely limited, so they were not included in the combined data sets. Both CIRA (Vanmen & Y. Flores 2006) and ENACAL found bacterial contamination at the majority of sites where this was tested. Only one sample was taken at these sites, but this intuitively seems likely, given the poor sanitation infrastructure and access by livestock to watercourses in the study area. Even less information exists for agricultural chemicals. CIRA (n = 1) tested for a suite of pesticides and herbicides at 16 sites (n = 1) in 2005, and SRK did so at two sites (n = 1) in 1994. Both studies found few sites detectable amounts of agricultural chemicals, but given the small sample sizes one cannot interpret these results in a meaningful way. Certainly anecdotal evidence exists that overuse of herbicides and pesticides is commonplace throughout the region (Montenegro 1997) as well as specifically within the study area (Alfaro 2010).

Trends

The majority of the parameters with n≥10 are metals, and few of these show a clear trend over time (**Appendix F)**. Furthermore, the extremely high concentrations of metals reported in the early 1990s and high standard deviations mean that any trends visible in **Appendix E** cannot be confidently said to be indicative of actual trends in concentrations over time. None of the known reference locations have ten or more samples, making it difficult to assess if any visual trends also occur at background sites and hence likely the result of sampling method/ laboratory methods, or are reflective of actual trends.

Most sites exceed the CCME freshwater aquatic life guidelines for many heavy metals throughout the time period reviewed, but mining regions tend to have natural geographies already rich in these constituents. In order to determine whether mining activities are creating heavy metal contamination of surface water adequate background information is required.

Cyanide concentrations have been below the drinking water criterion since about 2000. TSS shows no clear trend over the time period reviewed.

4.2.2 Sediment Chemistry

Five of the surface water chemistry studies also addressed sediment chemistry at a limited number of locations, as shown in **Figure 4-2**. Twenty-nine of the above-noted combined data sample locations contained sediment chemistry results. None of the sediment quality locations had been sampled ten or more times; the vast majority had only been sampled once or twice. The most common analysed parameters were lead and mercury. Similar problems with vague methodology and non-existent QA/QC procedures exist as described in **4.2.1**, although even less data from fewer individual studies are available for sediment chemistry.

Table D-3 in Error! Reference source not found. contains descriptive statistics for the ombined sediment chemistry sites. **Appendix E** contains figures showing the spatial distribution of selected parameters described below. Mercury, arsenic and lead all show exceedances of the CCME freshwater aquatic life standard for sediment. The small sample sizes, especially for parameters other than lead and mercury, and lack of reference locations make it difficult to speak definitively to contamination, however.

Arsenic had six exceedances of the CCME guideline out of 17 locations where it was analysed. These exceedances were clumped in and around known mining areas (**Figure E-13**); however arsenic is naturally present in groundwater in the region (Manuel 2007), and without larger sample sizes and proper reference locations it cannot be said with certainty whether the results are due to contamination or natural elevated background levels.

All 29 locations where sediment samples were taken were analysed for lead (**Figure E-14**); of these only two showed exceedances of the CCME guideline. Both these two sites were located immediately downstream of mining activities.

Mercury had the most exceedances (11 out of 28 locations sampled), mostly clumped downstream of large and small mining activities, but also found downstream as far as the confluence of Los Hoyos and the Mico River (**Figure E-15**). Mercury occurs in very low concentrations naturally (RISC 1998), and it certainly seems likely that the extensive artisanal mining in the Mico River headwaters is contributing mercury to sediment downstream.

4.2.3 Bioassessment

Four separate studies addressed benthic invertebrates: the baseline study in 1994, a multi-year monitoring effort by DESMINIC beginning in 2005, work by Galatowitsch in

2006 and as a part the CIRA investigation in 2006. Results for each combined sample location are presented in **Appendix G**.

It is difficult to aggregate or compare these studies as they used different sampling methodologies (i.e., dredging vs kick net). Moreover, sampling methodology is not well described in many of these studies, making it difficult to quantify or convert the results. For example, the kick net study does not describe the distance covered or time elapsed for each sampling event.

None of these studies included assessment of habitat or even qualitative descriptions of the same, making the results difficult to interpret in terms of whether natural or anthropomorphic factors are influencing the overall richness and diversity of invertebrates collected. Contributing to this problem is the paucity of reference locations in these studies' designs. Only two of the benthic sampling sites (MON01 and SUC02) can be defined as reference locations with any degree of confidence. Based on available mapping and descriptions, four additional sites may function as reference locations, but I had insufficient information to definitively categorize them as such (Grey & Stewart 2011).

The SRK EA contains qualitative descriptions of substrate and other habitat features taken during fish sampling, located within the same river systems but at different locations than the benthic invertebrate sampling. These descriptions largely characterize the substrate as being comprised of rock and coarse sand. This information, combined with the headwater nature of these streams and my own personal observations, would indicate to me that the dominant substrate type in area watercourses is likely erosional rather than depositional. Dredge-type sampling methods are not recommended for erosional stream habitats (Beatty *et al*. 2006), and so the SRK, CIRA and DESMINIC results may under-report some taxa of invertebrates present in the study area. The DESMINIC report speculates that this may be a reason for the low numbers of invertebrates found at the Paslama (MON01) reference site (DESMINIC & Glencairn 2007).

Both the SRK and CIRA studies offer a qualitative interpretation of their results with regard to the richness, diversity and tolerance of species present, but no quantitative definition of ecological health. The DESMINIC study applies EU definitions for high, good and moderate ecological status of rivers to their results; however these definitions depend on comparison to "type-specific communities" (EU 2000). The single reference point used in this study and total absence of habitat data are not adequate to define "type-specific communities".

The Galatowitsch study interprets its results with three different indices, all developed in temperate parts of the world. The Shannon-Wiener Index is a diversity index, and the Hilsenhoff Index and Pollution Tolerance Index are based on tolerance scores. Diversity indices can be useful in describing community structure and changes over time, but have been discredited in some circles as a reliable means to determine pollution levels of water bodies (Washington 1984). Tolerance scores are rarely transferable from one ecoregion to another. Applying tolerance scores at higher classification levels (i.e., family, as Galatowitsch does) has been demonstrated to not work effectively due to species-specific tolerances (Resh 2007).

4.3 Comparison to "Ideal" Plan

4.3.1 Water Quality

Of the 23 sample locations identified in my "ideal" water quality monitoring plan, 11 contain existing data. **Table 4-2** contains a list of these locations, and they are highlighted in **Figure 4-4**, below.

Table 4-2. "Ideal" surface water sampling sites with existing data

Ideal WQ Site ID	Rationale	Description	Stream	Combined WQ Site ID
I_01	reference	headwaters of Mona above road crossing, upstream of mine influence	Mona	none
I_02	mine impact	just below confluence with Mona, above next tributary	Pijibay	SW_02
I_03	above major mining impacts	upstream of road to mine, La Esmeralda	Mico	SW_04
I_04	upstream of town and downstream of most mining impacts	downstream of Santa Fe confluence	Mico	SW_14
I_05	downstream of town impacts	downstream of bridge out of town to east	Mico	SW_17
I_06	reference	upstream of road, headwaters of Chamarro	Chamarro	none
I_07	upstream of mining impacts, shows agricultural impacts	upstream of bridge, upstream of confluence w. Chorizo	San Miguel	none
I_08	downstream of mining impacts	upstream of road	San Miguel	SW_24
I_09	dilution of mine impacts	downstream of road, downstream of confluence w San Isidro E & W	Mico	SW_31
I_10	reference, green space in headwaters	San Antonio headwaters above road	San Antonio	none
I_11	Kinuma influence	upstream of road	Kinuma	SW_32
I_12	downstream of Kinuma influence, above San Pedro de Lovago	upstream of road	Mico	none
I_13	downstream of town influence	downstream of confluence w El Lajal	Mico	SW_35
I_14	reference, green space in Los Hoyos headwaters	upstream of road	Tamarindo	none
I_15	reference, green space in Los Hoyos headwaters	400 m E of trail, 1.5 km N of hwy	Zapote/Balsamo	none

Table 4-2. "Ideal" surface water sampling sites with existing data

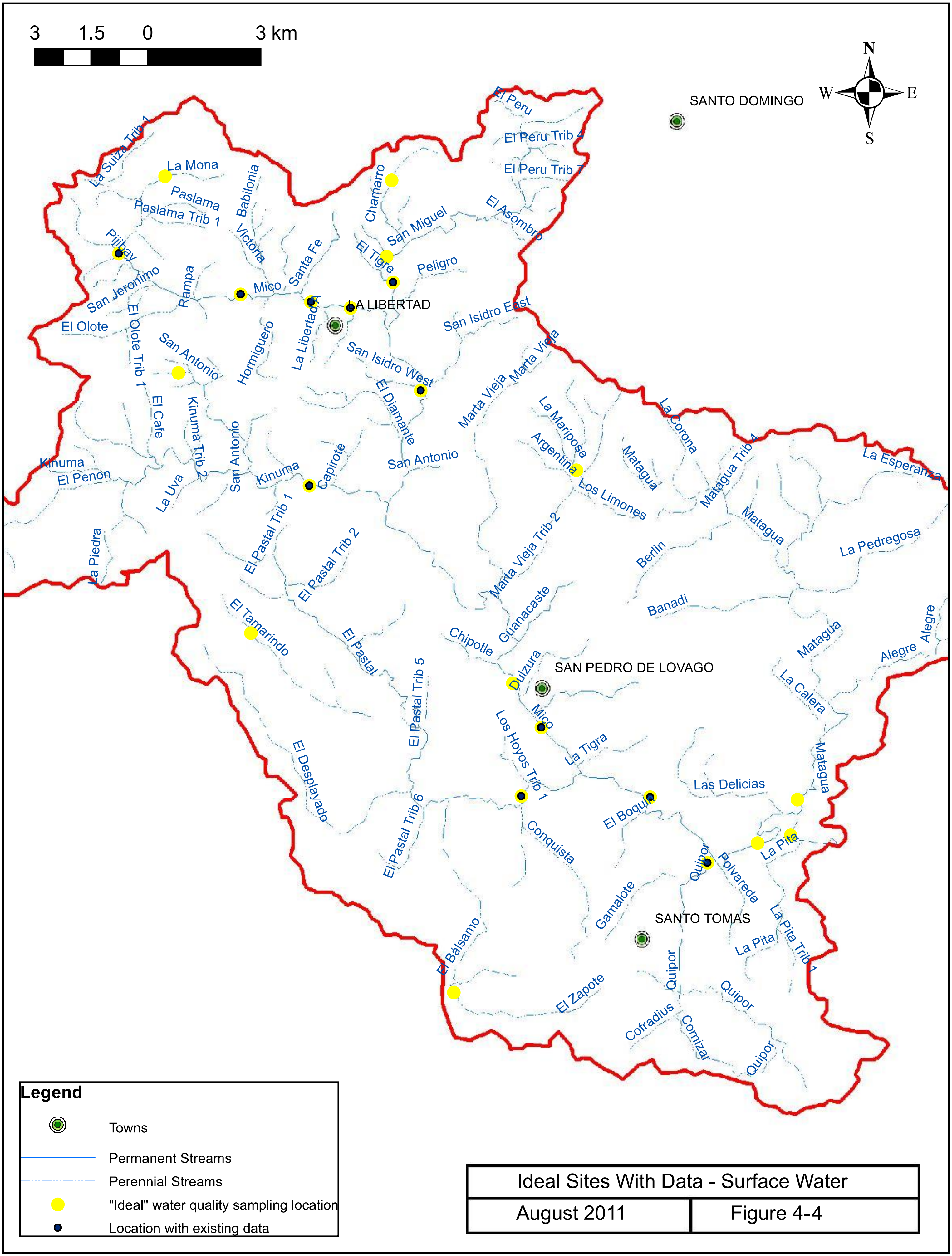
Ideal WQ Site ID	Rationale	Description	Stream	Combined WQ Site ID
I_16	Los Hoyos influence	downstream of road and Conquista confluence	Los Hoyos	SW_36
I_17	upstream of Santo Tomás	San Vicente pass	Mico	SW_28
I_18	Santo Tomás influence	upstream of confluence w Mico	Quipor	SW_15
I_19	Matagua influence	upstream of confluence w Mico	Matagua	none
I_20	above Matagua	downstream of road	Mico	none
I_21	downstream of Matagua	downstream of Matagua	Mico	none
I_22	reference, green space Matagua headwaters	northeast of Loma El Paraiso	Alegre	none
I_23	reference	green space north of El Despierto	Los Limones	none

The most notable gap in existing data is insufficient or non-existent reference information. As discussed already, pass/fail criteria have their limitations, and without a true understanding of existing background conditions one cannot adequately monitor and mitigate for industrial impacts.

Most studies have focused on heavy metals contamination, and many locations where sampling has occurred have reasonably good (i.e., $n \geq 10$) coverage over the years for these parameters. Less data exist for other contaminants of concern given agricultural or urban impacts in the area. As discussed in **Section 4.2.1**, very little attention has been given to microbiological contamination or agricultural chemicals. Poor data coverage ($n < 10$) is available for physical parameters such as dissolved oxygen, temperature, turbidity and conductivity. These parameters can be cheaply measured *in situ* with hand-held meters, and are often good proxy indicators for other parameters (e.g., conductivity for total dissolved solids).

Another concern with water quality sampling to date has been its piecemeal nature: a series of mostly unrelated studies rather than a continuous monitoring plan. The exception to this is the on-going effluent and receiving body monitoring by DESMINIC.

Figure 4-3. La Libertad bridge. Sample site SW-17/I-05 is on far (downstream) side of bridge.



Ideal Sites With Data - Surface Water

August 2011 | Figure 4-4

4.3.2 Bioassessment

Little usable data exist with regards to bioassessment. The lack of appropriate reference sites[9], absence of habitat data and inconsistency of methodologies between studies has resulted in a set of data that cannot be used in building an RCA model for the region. However, there is overlap between "ideal" sampling locations and existing data. What data are available can be used as a qualitative comparison to future results, especially if habitat data are collected from sites known to be minimally changed in morphology or vegetation cover since previous benthic invertebrate assessments. **Table 4-3** and **Figure 4-5** show "ideal" bioassessment sites where data have been collected.

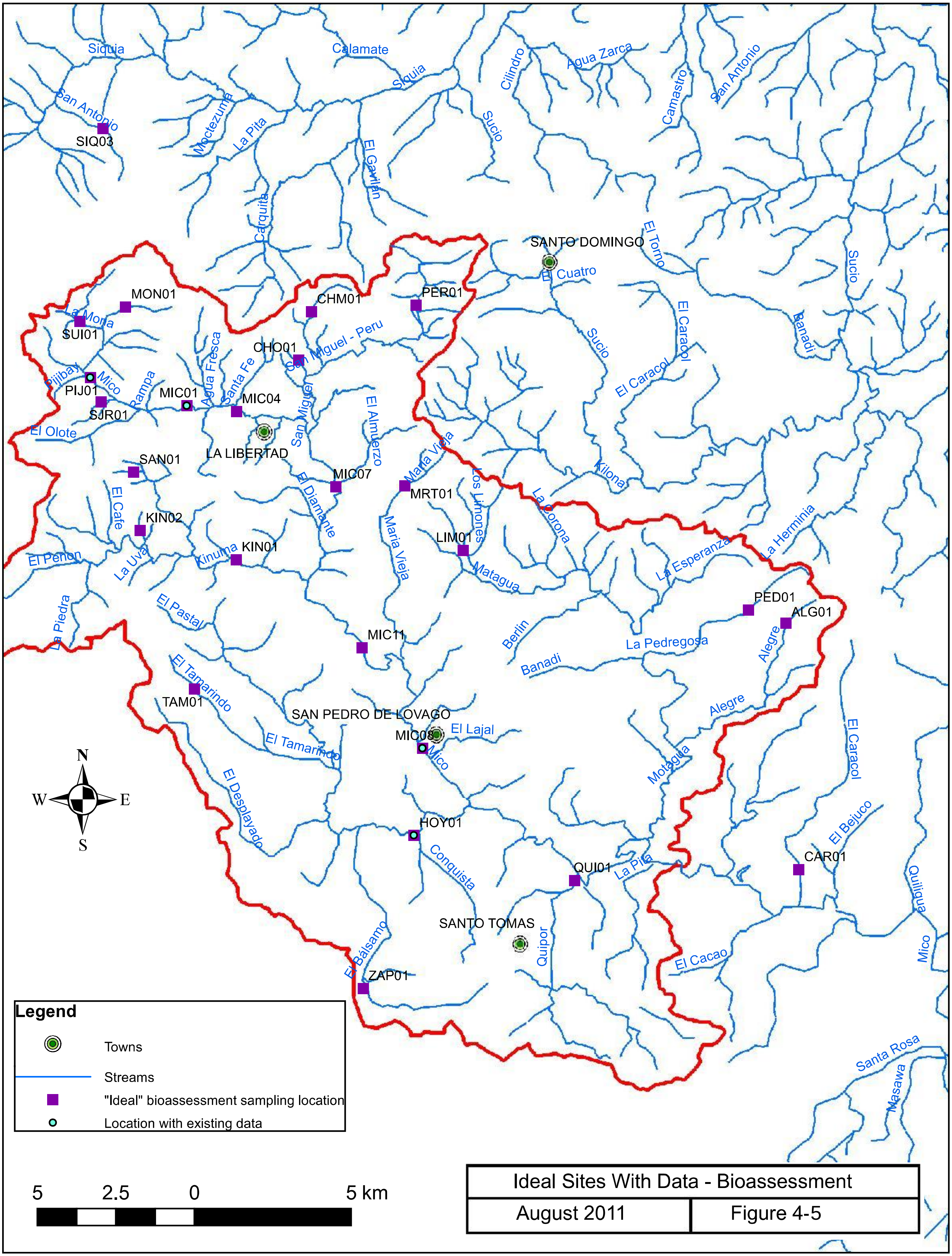
Table 4-3. "Ideal" bioassessment sites with existing data

Site ID	Rationale	Description	Stream	Existing Data
MON01	Reference	La Mona headwaters	Mona	
SUI01	Reference	La Suiza downstream of headwaters confluence	Suiza	
PIJ01	Impact	agriculture and mine impacts	Pijibay	X
MIC01	Impact	La Esmeralda	Mico	X
SJR01	Reference	forest patch on San Jeronimo	San Jeronimo	
SAN01	Reference	headwaters San Antonio	San Antonio	
MIC04	Impact	downstream of mine and upstream of town	Mico	X
CHM01	Reference	headwaters	Chamarro	
CHO01	Reference	could be impacted by small mining	Chorizo	X
PER01	Reference	reference site Peru	Peru	
MIC07	Impact	Santa Isabel	Mico	X
KIN01	Impact	Kinuma at road	Kinuma	
KIN02	Reference	Kinuma headwaters	Kinuma	
TAM01	Reference	Los Hoyos headwaters	Tamarindo	
MIC11	Impact	green space, dilution, possible semi-reference	Mico	
MRT01	Reference	Marta Vieja headwaters	Marta Vieja	

[9] The entire study area has been subject to human impacts, specifically ranching. Reference locations in this context would be sites located upstream of industrial impacts and/or communities, and within relatively intact riparian forest patches.

Table 4-3. "Ideal" bioassessment sites with existing data

Site ID	Rationale	Description	Stream	Existing Data
LIM01	Reference	green space north of El Despierto	Los Limones	
ALG01	Reference	northeast of Loma El Paraiso	Alegre	
PED01	Reference	Pedregosa headwaters	Pedregosa	
MIC08	Impact	bridge into San Pedro de Lovago	Mico	X
HOY01	Impact	upstream of road	Los Hoyos	X
QUI01	Impact	Santo Tomás impact	Quipor	
ZAP01	Reference	Los Hoyos headwaters	Zapote/Balsamo	
CAR01	Reference	downstream of study area	Caracol	
SIQ03	Reference	upstream of Betulia, Siquia headwaters	Siquia	



Ideal Sites With Data - Bioassessment

August 2011 | Figure 4-5

4.4 Personal Impressions

The individuals who provided me with the majority of my insights into local issues and politics were the environmental manager at the municipality, the environmental manager at the mine, the secretary of COOPELMICH, a local Peace Corps volunteer and the Chontales department delegate for ENACAL. Nicaragua is a place where people love talking politics, and most people were willing to share their perceptions and ideas.

Two main issues stood out as likely to impact future attempts to monitor and protect water quality in the Mico River watershed, based on the informal discussions I had with community members and other stakeholders while I was in Chontales. Lack of trust was a big one, both with regards to government and to industry. The other was frustration with repeated diagnostic studies and capacity building rather than just getting funding to do the job at hand.

Many people I spoke to were cynical about corruption and partisanship in government. Many spoke about how few people paid their taxes, leaving municipal governments with reduced revenue; however these same people were willing to contribute significant sums of money to local public projects when they could see how it was spent. I also heard frustration about turnover in experienced staff and programs being closed whenever the political party in power changed, including one story of an entire school administration being replaced midway through the school year. I also heard several people express the opinion that MARENA could be bought, or that they gave large industry an easier time than smaller operators.

Employees of the mine talked about the difficulties inherent in dealing with a deeply suspicious local population. I also heard small miners talk about contracts made with the mine being repeatedly broken and the desire to not be dependent on an outside party for the economic life of the town. Something I personally found fascinating was how the different world views of the small miners and the La Libertad Mine management shaped how they saw the same issues. My impression was that both groups were genuine in wanting a fair solution to ore access and processing issues, yet the different frameworks for viewing this problem resulted in conflicting ideas of what the problem was and how to solve it.

Finally, when talking about funding from outside agencies and donors several people expressed their impatience with endless training and capacity building workshops. This involved a great deal of productive time taken away from other activities, and high staff turnover resulted in the loss of many trained individuals. Money seldom seemed available to simply go ahead and actually do the work, or to hire qualified personnel for the job.

4.5 Results in the Context of Existing Literature

Previous studies found elevated lead and mercury concentrations associated with areas of artisanal mining (Alfaro & Ortiz 2009; SRK 1995; Vanmen & Y. Flores 2006), a result which also appears evident from the combined data. The combined data shows elevated concentrations of heavy metals throughout the study area, with isolated hot spots of high concentrations in the immediate vicinity of the mine. The 2005 and 2009 Humboldt Centre reports, the 1995 SRK report, the 1996 Knight Piesold audit and the 2006 CIRA report all reported these elevated concentrations of metals. However, the

Humboldt Centre attributes these levels to mining activities, while SRK and CIRA consider them possibly due to natural background concentrations of metals. Knight Piesold's results come from sample too turbid to be an accurate reflection of actual metals concentrations in surface water. Without reference location data, these conclusions are just speculation. I consider them well grounded speculation, as it appears likely to me that the region does have naturally elevated levels of many heavy metals, and also that some contamination is occurring due to the mine.

The combined results show that cyanide levels exceeded the effluent criteria in the past, but have dropped in more recent times (**Appendix F**). This is consistent with anecdotal evidence of livestock becoming ill from drinking water (Centro Humboldt 2005; Tolvanen 2003) and previous practices of discharging effluent directly to waterbodies (Knight Piesold 1997) reported from the 1990s. I would cautiously hope that the reduced levels of cyanide in more recent data are the result of improved tailings treatment facilities and practices; however, this is a case in point of the shortcomings of relying on water chemistry data alone. A tailings dam breach and subsequent spill could result in serious impacts to downstream aquatic life, but the cyanide itself would quickly degrade and be undetectable unless sampling was conducted immediately after any hypothetical spill. Average cyanide levels have dropped over time, but isolated exceedances of the drinking water criteria have occurred as recently as 2007.

Combined data for oils and greases were in exceedance of criteria at many locations, consistent with audit findings by Knight Piesold (1997) and MARENA (Alfaro & Ortiz 2009) regarding compliance with best management practices around storage and disposal of hydrocarbons at the La Libertad Mine. Not mentioned in these reports are other potential sources of hydrocarbon contamination, such as local practices of washing vehicles in the river (personal observation 2008).

Most studies to date have been heavily focused on potential metals contamination and mining impacts. The 2006 CIRA report has limited results intended to measure the impacts of dairies, tanneries and urban areas. Most studies did not spend much effort on measuring oils and greases, despite their elevated levels throughout the study area. Limited data available for dissolved oxygen and bacteria seems to indicate that these parameters may be impacting water quality in the region as well.

Chapter 5. Conclusions and Recommendations

5.1 Summary

The headwaters of the Mico River provide aquatic habitat for many species of fish, amphibians and other wildlife (SRK 1995). The water is used for human consumption, and for watering cattle and other livestock. Industrial uses include cheese and milk production, and mining. Potential impacts to water quality and aquatic ecosystem health in the region result from artisanal and industrial mining, cattle ranching, dairy and tannery effluent, and domestic waste. Given these uses and potential impacts, metals, cyanide, bacteria and nutrients, pesticides, sediment (i.e., TSS or turbidity), temperature and dissolved oxygen were considered the parameters of interest for this study.

With regards to water chemistry, sufficient data exist to assess metals concentrations in the areas between the mine and the town of La Libertad, and in the Mico River adjacent to the towns of San Pedro de Lovago and Santo Tomás. Cyanide, temperature, pH and TSS are also well covered in this area. Limited data are available for the other study parameters of interest. Major tributaries to the Mico River downstream of La Libertad have few sample sites and little information available for any parameter.

Existing bioassessment information is minimally useful and not statistically comparable between studies or with future results. No habitat data were recorded, and sampling methodologies were either unquantifiable, inappropriate for the substrate conditions, or both. Site assessments were done based on indices that were applied incorrectly and/or were not applicable to tropical conditions.

The highest concentrations of metals are generally found in the immediate vicinity of the La Libertad Mine, in the headwaters of the Rampa, Babilonia and Santa Fe creeks, although manganese and zinc are the only metals assessed where exceedances are only found clustered here. Exceedances of the criteria used for aluminum, silver and other metals are found throughout the study area and may be naturally present in high concentrations. No clear trends over time are visible for most metals, with the exception of mercury, lead and silver which all show a drop in concentrations over time.

Mercury contamination is present in surface water and sediment both in the immediate vicinity of mining activities and further downstream. This is unsurprising, given current and historic artisanal mining processes utilizing mercury amalgamation to process ore. Lead in surface water shows a similar pattern to mercury, although it is less present in sediment. Exceedances of these metals are found clustered in areas of artisanal mining in and around the town of La Libertad (**Figure 5-1)**, although mercury exceedances in both surface water and sediment are also found downstream in the Kinuma River, at San Pedro de Lovago and at Santo Tomás. Both of these elements are seldom found in high concentrations naturally and are likely the result of mining activities.

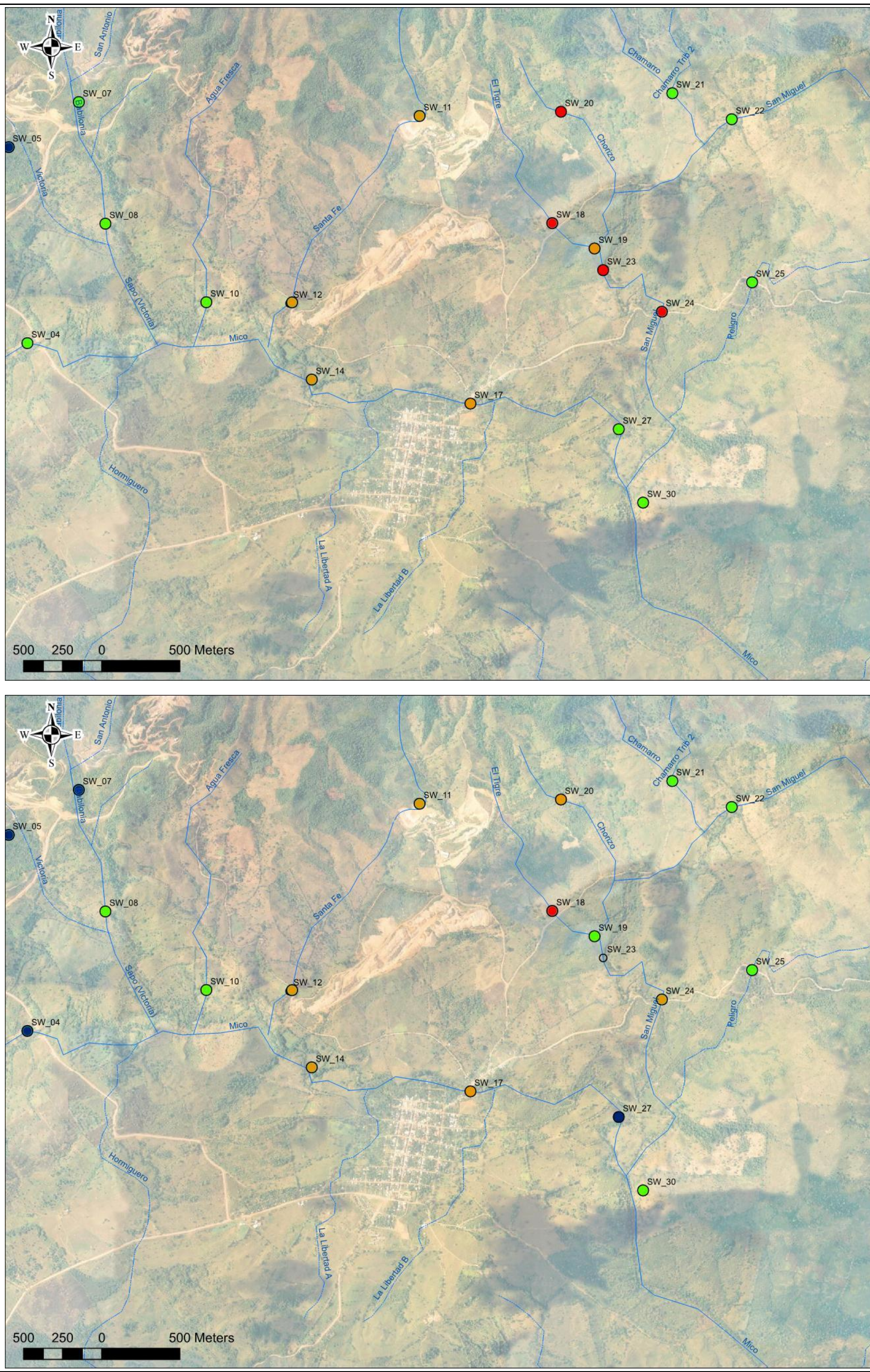


Figure 5-1. Lead (top) and mercury (bottom) exceedances in the vicinity of La Libertad (adapted from aerial photograph provided by Central Sun, 2008). Legend: red = exceeds effluent criteria, orange = exceeds drinking water criteria, blue = exceeds aquatic life criteria, green = below criteria.

Drinking water criteria for metals are met in the majority of locations, except for lead, mercury and aluminum. Aquatic life criteria are frequently failed for most metals analysed, however, as argued in **Section 2.1.1** generic criteria are not always the best indicator of actual impacts. Cyanide meets the drinking water criteria in all but two locations. Oil and grease concentrations fail the effluent criteria at many locations. Physical parameters such as temperature and pH are generally within guidelines, but dissolved oxygen was low at almost half the locations sampled during the one occasion when it was analysed. Insufficient data exist to speak to water quality with regards to pesticides and bacteria.

The most notable data gap, both for water/sediment chemistry and for bioassessment data, is the lack of reference locations. Without adequate background data it is impossible to determine what and how much impact activities in the watershed may be having on the aquatic environment. Secondly, previous studies have focused heavily on metals contamination, with insufficient focus on other contaminants such as bacteria, pesticides and effluent from dairies and urban areas. Finally, there has been a lack of coordination and consistency between studies, making comparison and development of long term trends difficult. **Section 5.3** contains recommendations to fill these gaps in information.

5.2 Limitations

5.2.1 Quantitative

The greatest limitation to the quantitative aspect of my research was the quality and reliability of existing data. Only two of the reports I looked at contained original laboratory reports. I have no way of verifying that no transcription errors occurred in the presentation of data in reports without laboratory raw data. Most of the studies I reviewed had poor or non-existent QA/QC and methodology descriptions. As discussed in **Section 4.1**, descriptions of site locations varied widely in accuracy.

My search for data sources occurred primarily over a four month period in Nicaragua, and consisted of networking with individuals in government, academia, industry and the non-profit sectors. I also conducted a desktop search of institutional websites, academic databases and other search engines online, both before and after my field work. I am reasonably confident that I located all relevant studies conducted in the ten years previous to my field work season, but it is possible that I did not, and data that could contribute to understanding of the region are missing from my gap analysis.

5.2.2 Qualitative

The two major limitations to the qualitative aspects of my research were the language barrier and my lack of connections to groups in the region. I was an outsider in the community, and my entrée into the project was through academic and government institutions. While I managed to make contact with both small miners and DESMINIC, I never spoke to any ranchers about their experience while in La Libertad, and I had only one limited conversation with the owner of a dairy. I spoke to the secretary of COOPELMICH and a couple of members, but not to any independent small miners. I spoke to the environmental manager of the La Libertad Mine and to the CEO of Central Sun, but not to any lower pay-grade workers. I often struggled with a complete understanding of conversations in Spanish, particularly when present at a meeting with more than one other person present.

In some ways, the language barrier made me more aware of other less tangible forms of communication and understanding. I found it much easier to understand and communicate with Spanish speakers with similar educational and class backgrounds to myself, and I do not think this was entirely due to rural versus city accents. For this reason I used a translator when speaking to small miners. Both the technologies they were using and the place they were speaking from were less familiar to me, and I wanted to make sure I didn't miss anything important during these conversations. However, this shared background aided me in comprehension when speaking to the mine's environmental manager about environmental mitigation and other topics in which I have professional experience.

I relied heavily on a local Peace Corps volunteer for introductions and translation. She had a good knowledge of the place and its people, having lived there for the previous two years, but was not a local. Like me she was from North America and shared my own background culturally and educationally.

All of these factors contributed to my decision to not conduct formal qualitative research, as I realized that I would not be able to do so with rigour and confidence. That being said, the impressions I formed during my time in Chontales agree with the literature on artisanal mining, on corporate social responsibility, on participatory development and on the specific history of the region. I made an effort to speak to at least one representative from the mine, from the small miners, and from the municipality about mining and water quality issues. What I learned from these interactions played an important part in informing the recommendations discussed in the next section.

5.3 Recommendations

The intent of this study is to inform development of a potential community monitoring plan in the study area. The technical information presented here consists of merely one factor determining what such a plan would ultimately look like. Questions of funding, staffing, decision-making responsibility and local politics are equally important in developing such a plan. While these factors are outside of the scope of this study, I have kept them in mind in an attempt to provide useful recommendations for the technical aspect of any future monitoring in the region.

The major gaps in existing information are:

- Insufficient baseline/ reference information;
- Insufficient information on impacts from contaminants other than metals;
- Insufficient coverage of streams not directly impacted by the La Libertad Mine
- Poor quality of data; and
- Poor coordination/ continuity between studies done to date.

Although land use and hydrology were not specifically addressed in this gap analysis, these are important pieces of data that would assist in interpretation of water quality data and target future monitoring of specific potential impacts.

It would be in the best interests of the La Libertad Mine to increase their monitoring effort to include reference locations, both upstream of mining impacts and in comparable watersheds nearby. The elevated levels of metals in the watershed have not gone unnoticed by local environmental NGOs (Alfaro & Ortiz 2009) and good data for reference locations would aid in determining whether the source of these elevated concentrations of metals was natural or anthropogenic.

If DESMINIC were to increase their monitoring effort to include reference locations, monitoring coverage with regards to metals would be adequate to determine quality of surface water in and around La Libertad. However, there are issues of trust between the mine and local stakeholders, as described in **Chapter 1**. Monitoring results are currently reported directly to MARENA, and while in theory these are public record, gaining access to them is not a simple or easy task. Distribution of monitoring results directly to local stakeholders, including original laboratory results, record of QA/QC procedures and clear maps, would show good faith and transparency on the part of the mine. Rather than duplicate effort and expense by monitoring for parameters already covered by DESMINIC's ongoing effluent and receiving water monitoring program, perhaps there is potential for community members to audit the mine's program.

In order to address gaps in data both spatially and for parameters such as pesticides, I would not recommend increased monitoring of surface water chemistry. As described in

Section 2.1.1, monitoring water chemistry alone to determine aquatic conditions is expensive, technically demanding and labour intensive. A well designed bioassessment program using benthic invertebrates should be implemented. If and where impacts are shown to be occurring, targeted surface water chemistry sampling combined with investigation into surrounding land use and potential impacts would then be appropriate.

As discussed in **Section 2.3.3**, the use of bioassessment indices developed in temperate climates is not appropriate for tropical ecosystems. Indices may allow for comparisons of sites or times where collections have been made using different sample sizes, methods or habitats. People with little biological experience can easily collect the required data and interpret indices. However, indices are not a quick fix solution. Proper application of an index may require as much or more data than building a site-specific model using RCA. The biological and statistical assumptions on which a particular index is based may not always be applicable. Finally, indices do not account for background physical limitations of the site on benthic invertebrate diversity or abundance to be considered when deciding if the site is impaired by anthropogenic influences (R. H. Norris & Georges 1993).

Any bioassessment program to be implemented should be well designed and adapted for the region, not transplanted directly from a North American or European model. If indices developed for similar regions of Costa Rica or Panama are available, they may be useable in Chontales; however an RCA based model would be preferable as it would be site specific and not hampered by a lack of available information on local invertebrate species and their pollution tolerances. Proper training of staff is vital, so that the data collected are reliable and useable. Such a program will likely not be successful if it consists of an initial training workshop and no follow-up support. Reliable funding, dedicated staff and a clear mandate are essential.

Study design of such a program will require both qualitative and quantitative methods. The specific monitoring goals, study design (site selection, schedule, reference site definition, sampling collection procedures and data analysis) should meet the standards of rigourous, defensible science and incorporate the knowledge and logistical constraints of local staff who will be implementing the program.

There may be potential to coordinate equipment and share information with DESMINIC, if their benthic monitoring program is ongoing (DESMINIC & Glencairn 2007). Efforts should be made during program design to ensure that data from these two programs are interchangeable. Furthermore, efforts should be made to coordinate with current benthic invertebrate studies occurring in similar regions of Nicaragua and Costa Rica. Developing a proper RCA model requires a large number of reference locations; data appropriate for developing the model could potentially be available elsewhere.

A more immediately achievable goal may be for community monitoring of physical parameters such as dissolved oxygen, temperature, pH, turbidity and conductivity using a hand-held meter. Such meters are relatively inexpensive and combined with observations and photos they allow for immediate and frequent assessment of stream health. Care should be taken that all users are properly trained in use and calibration of the meter, in order that readings are accurate and reliable.

Any future studies should build on existing work. Where applicable, the same sample sites should be used. Ideally, a database could be produced and maintained where different users could search for and contribute data for the region. Regardless of the form future monitoring takes, proper planning and good design are critical if the data produced are to be useful.

One of the goals of this work was to determine if the water in the Mico River was fit for human consumption, as water quality (Radio Centro 870 AM 2011) and quantity (Sequeira 2011) remain problematic in the region. I cannot help but wonder if a more appropriate response to drinking water problems would be to initially focus on groundwater before defaulting to a non-pristine surface water source. Undoubtedly water is currently being lost to leaking infrastructure, and in the long term reforestation and other efforts should be undertaken to restore aquifer recharge.

Drinking water is not the only value or use of the Mico River and its tributaries, however; and ensuring the health of the system is worth pursuing. Monitoring is a good initial step to provide information about the status of water quality and aquatic habitat in the region, but in order to protect and restore aquatic values further effort is required. These efforts include accurate mapping of land use, especially locations of *rastras* and dairies; education and incentives to implement BMPs by ranchers, small miners, DESMINIC, dairy managers and others; and enforcement of existing environmental regulations. Technical information alone will not accomplish these tasks.

References

ADB, 2011. *Nonrevenue Water: A Governance Challenge*, Asian Development Bank (ADB). Available at: http://www.adb.org/water/topics/non-revenue/default.asp.

ADB, 2001. *Special Evaluation Study on Participatory Development Processes in Selected Asian Development Bank Projects in Agriculture, Natural Resources and Social Infrastructure Sectors*, Asian Development Bank (ADB). Available at: http://www.adb.org/Documents/PERs/sst-oth-2000-07/ses-pdp.asp.

Aiyer, A., 2004. In Search of the Midas Touch: Gold, Güiriseros and Globalization in Nicaragua. *Anthropologica*, 46(2), pp.139-151.

Alfaro, A., 2010. *Reporte de Monitoreo Ambiental del Municipio de la Libertad: Enero - Junio 2010*, Managua, Nicaragua: Centro Humboldt.

Alfaro, A. & Ortiz, F., 2009. *Estado Actual de la Minería Metálica en Nicaragua e Impactos Ambientales de Algunos Proyectos Mineros Emblematicos*, Managua, Nicaragua: Centro Humboldt.

Anderson, L.E., 2008. The Authoritarian Executive? Horizontal and Vertical Accountability in Nicaragua. *Latin American Politics and Society*, 48(2), pp.141-169.

Andraka, S., 2001. Terrestrial Ecoregions -- Central American dry forests (NT0209). *World Wildlife Fund Ecoregion profile*. Available at: http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0209_full.html [Accessed July 28, 2011].

ANZECC, 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. *Australian and New Zealand Environment Conservation Council (ANZECC)*. Available at: http://www.mincos.gov.au/publications/australian_and_new_zealand_guidelines_for_fresh_and_marine_water_quality [Accessed February 25, 2011].

Ascencio, J., 2002. *Diagnostico sobre los sistemas de vigilancia y control de la calidad del agua para consumo humano en Nicaragua*, Managua: Panamerican Health Organization/ World Health Organization (PAHO/WHO).

B2Gold, 2010. B2Gold Corp - Precious Metals Exploration Company - La Libertad Mine. *B2Gold Corporation*. Available at: http://www.b2gold.com/projects/nicaragua/lalibertadmine.html [Accessed February 24, 2011].

Banks, D. *et al*., 2002. Groundwater contamination from rural pit latrines: Examples from Siberia and Kosova. *Water and Environmental Journal*, 16(2), pp.147-152.

Barbour, M.T. *et al*., 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish* Second Edition., Washington, DC: US Environmental Protection Agency (EPA). Available at: http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfm.

Baxter, J. & Eyles, J., 1997. Evaluating Qualitative Research in Social Geography: Establishing “Rigour” in Interview Analysis. *Transactions of the Institute of British Geographers*, 22(4), pp.505-525.

Beatty, J.M. *et al*., 2006. *Guidelines for Sampling Benthic Invertebrates in British Columbia Streams*, Ministry of Environment (MoE).

Belt, T., 1911. *The Naturalist in Nicaragua*, London: J.M. Dent.

Bessette, G., 2004. *Involving the community : a guide to participatory development communication*, Penang, Malaysia; Ottawa, ON: Southbound ; International Development Research Centre (IDRC).

Booth, J.A. & Richard, P.B., 2008. Revolution’s Legacy: Residual Effects on Nicaraguan Participation and Attitudes in Comparative Context. *Latin American Politics and Society*, 48(2), pp.117-140.

Bosnic, M., Buljan, J. & Daniels, R.P., 2000. *Polluntants in Tannery Effluents: Definitions and Environmental Impact/ Limits for Discharge into Water Bodies and Sewers*, United Nations Industrial Development Organization. Available at: http://www.elaw.org/system/files/L_pollutants.pdf.

Boyd, D., 2006. *The water we drink an international comparison of drinking water quality standards and guidelines : a report*, Vancouver, BC: David Suzuki Foundation.

Boyero, L. *et al*., 2009. Are tropical streams really different? *Journal of the North American Benthological Society*, 28(2), pp.397-403.

Brauman, K.A. *et al*., 2007. The Nature and Value of Ecosystem Services: An Overview Highlighting Hydrologic Services. *Annual Review of Environment and Resources*, 32(1), pp.67-98.

Brown, E. & Cloke, J., 2005. Neoliberal reform, governance and corruption in Central America: Exploring the Nicaraguan case. *Political Geography*, 24(5), pp.601-630.

Calderón, F., 2008. A historic turning point. Political change and the socio-institutionalsituation in Latin America. *CEPAL Review*, 96, pp.123-136.

Canada, 2006. *Corporate social responsibility an implementation guide for Canadian business.*, Ottawa, ON: Industry Canada.

Canada, 2002. *Metal Mining Effluent Regulations*, Available at: http://laws.justice.gc.ca/eng/SOR-2002-222/index.html [Accessed February 11, 2011].

CAPRE, 1994. *Normas de Calidad del Agua para Consumo Humano*, San Jose, Costa Rica: Comité Coordinator Regional de Instituciones de Agua Potable y Saneamiento de Centroamérica, Panama y República Dominicana (CAPRE). Available at: http://biblioteca.enacal.com.ni/bibliotec/Libros/pdf/CAPRE_Normas_Regional.pdf.

Castelletti, A. & Soncini-Sessa, R., 2006. A procedural approach to strengthening integration and participation in water resource planning. *Environmental Modelling & Software*, 21(10), pp.1455-1470.

Castro, C. de, 2008. *Global Integrity Report*, Global Integrity: Information on Anti-Corruption. Available at: http://report.globalintegrity.org/Nicaragua/2008/notebook [Accessed February 22, 2011].

Cavanagh, N. *et al*., 1998. *Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia: Field Test Edition*, Resources Inventory Committee (RIC) for BC Ministry of Environment, Lands and Parks (MELP). Available at: http://ilmbwww.gov.bc.ca/risc/pubs/aquatic/design/index.htm.

CCAD, 2005. *Actores, Agendas y Procesos en la gestión de los Recursos Hídricos de Centroamerica*, San Salvador, El Salvador: Comisión Centroamericana de Ambiente y Desarollo (CCAD). Available at: http://www.sica.int/busqueda/Centro%20de%20Documentaci%C3%B3n.aspx?IDItem=9054&IdCat=35&IdEnt=2&Idm=1&IdmStyle=1.

CCME, 2011a. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Available at: http://ceqg-rcqe.ccme.ca/ [Accessed March 8, 2011].

CCME, 2011b. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Available at: http://ceqg-rcqe.ccme.ca/ [Accessed March 8, 2011].

Central Sun, 2008. Central Sun Operations Update: Orosi Mill Project Advancing Well and Recovery Improves at Limon Mine. *Marketwire*. Available at: http://www.marketwire.com/press-release/Central-Sun-Mining-Inc-TSX-CSM-897303.html [Accessed September 20, 2008].

Central Sun & DESMINIC, 2006. *Estudio de Impact Ambiental: Determinación de Areas para Exploración Minera en los Municipios de La Libertad y Santo Domingo. 2ªRevision. DRAFT*, Managua, Nicaragua: Central Sun Mining Inc. (Central Sun).

Centro Humboldt, 2005. *Resultados del monitoreo in situ de la actividad minera en los departamentos de Chontales, Boaco, Matagalpa y municipios de Chinandega Norte*, Managua, Nicaragua: Centro Humboldt.

CEPREDENAC, 2006. Atlas Regional de Amenazas Naturales para América Central. Available at: http://atlas.snet.gob.sv/new/referencia.phtml [Accessed October 2, 2010].

Cermeño, A., 2001. Tilapias: proyecto desastroso. *El Nuevo Diario*. Available at: http://archivo.elnuevodiario.com.ni/2001/diciembre/13-diciembre-2001/nacional/nacional23.html [Accessed March 7, 2011].

Clark, T., 2003. CERLAC Colloquia Paper. In Canadian Mining Companies in Latin America: Community Rights and Corporate Responsibility. North York, ON: Centre for Research on Latin America and the Caribbean, York University.

Davidson, T. & Gulka, S., 2007. *Livestock Watering Systems in Saskatchewan: Producer Experiences*, Ducks Unlimited Canada. Available at: http://yourland.ducks.ca/manage/pdf/sk-watering-systems.pdf [Accessed February 26, 2011].

Denzin, N. & Lincoln, Y., 1998. *Collecting and interpreting qualitative materials*, Thousand Oaks, CA: Sage Publications.

DESMINIC & Glencairn, 2005. *Estudio Hidrobiológico del Sistema Acuático circundante al Proyecto "Ampliación Cerro Mojón": 077-2004. Informe de Cumplimiento Ambiental No. 1*, La Libertad, Nicaragua: DESMINIC; Glencairn Gold Corporation.

DESMINIC & Glencairn, 2006. *Estudio Hidrobiológico del Sistema Acuático circundante al Proyecto "Ampliación Cerro Mojón": 077-2004. Informe de Cumplimiento Ambiental No. 2*, La Libertad, Nicaragua: DESMINIC; Glencairn Gold Corporation.

DESMINIC & Glencairn, 2007. *Estudio Hidrobiológico del Sistema Acuático circundante al Proyecto "Ampliación Cerro Mojón": 077-2004. Informe de Cumplimiento Ambiental No. 3*, La Libertad, Nicaragua: DESMINIC; Glencairn Gold Corporation.

DFO & EC, 1997. Module 4: Stream Invertebrate Survey. In *The Streamkeepers Handbook: A Practical Guide to Stream and Wetland Care*. North Vancouver, BC: Fisheries and Oceans Canada (DFO) and Environment Canada (EC) for Pacific Streamkeepers Federation. Available at: http://www.pskf.ca/publications/handbook.html.

Dinerstein, E., 1995. *A conservation assessment of the terrestrial ecoregions of Latin America and the Caribbean*, Washington, DC: World Bank.

Dolores, J., 2008. personal communication with municipal Environmental Coordinator re: La Libertad social and environmental issues.

Earthworks & Oxfam America, 2007. *Golden Rules: Making the case for sustainable mining*, No Dirty Gold. Available at: http://www.nodirtygold.org/pubs/GoldenRules_FINAL.pdf.

EC, 2010. Canadian Aquatic Biomonitoring Network (CABIN). *Environment Canada - Water*. Available at: http://www.ec.gc.ca/rcba-cabin/ [Accessed March 1, 2011].

EPA, 2008. Ecological Toxicity Information | Region 5 Superfund | US EPA. Available at: http://www.epa.gov/region5superfund/ecology/html/toxprofiles.htm [Accessed September 11, 2011].

EPA, 1996a. *Guidance for data quality assessment : practical methods for data analysis EPA QA/G-9, QA96 version*, Washington, DC: US Environmental Protection Agency (EPA). Available at: http://cfpub.epa.gov/ols/catalog/catalog_display.cfm?&FIELD1=SUBJECT&INPUT1=Hazardous%20materials%20sampling&TYPE1=EXACT&item_count=5 [Accessed November 6, 2011].

EPA, 2010. Impaired Waters and Total Maximum Daily Loads. *Total Maximum Daily Loads (303d)*. Available at: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/index.cfm [Accessed March 8, 2011].

EPA, 1996b. *The Metals Translator: Guidance For Calculating A Total Recoverable Permit Limit From A Dissolved Criterion. Report No. EPA 823-B-96-007*, Washington, DC: United States Environmental Protection Agency (EPA). Available at: http://www.dep.wv.gov/WWE/permit/individual/Documents/365_dissmetals.pdf.

EPA, 1997. *Volunteer Stream Monitoring: A Methods Manual. Report No. 841-B-97-003*, Washington, DC: United States Environmental Protection Agency (EPA). Available at: http://water.epa.gov/type/rsl/monitoring/upload/2002_08_13_volunteer_stream_stream.pdf.

EPA & OW, 2002. *Consolidated Assessment and Listing Methodology–Toward a Compendium of Best Practices* First Edition., US Environmental Protection Agency (EPA) and Office of Wetlands, Oceans, and Watersheds (OW). Available at: http://water.epa.gov/type/watersheds/monitoring/calm.cfm [Accessed November 6, 2011].

EPA, O., 2011. National Recommended Water Quality Criteria. Available at: http://water.epa.gov/scitech/swguidance/standards/current/index.cfm [Accessed September 8, 2011].

Esquivel, M.J. *et al*., 2007. Effects of pasture management on the natural regeneration of neotropical trees. *Journal of Applied Ecology*, 45(1), pp.371-380.

EU, 2000. *Water Framework Directive*, Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:en:HTML [Accessed September 9, 2011].

European Commission, 2007. *Nicaragua Country Strategy Paper: 2007-2013. Report No. E/2007/479*, European Commission. Available at: http://www.eeas.europa.eu/nicaragua/csp/07_13_en.pdf.

Farrington, J., Turton, C. & James, A.J., 2000. *Participatory Watershed Development: Challenges for the Twenty-First Century*, Delhi; Oxford: Oxford University Press.

FishBase, 2010. Carcharhinus leucas, Bull shark : fisheries, gamefish. *FishBase*. Available at: http://www.fishbase.org/Country/CountrySpeciesSummary.php?c_code=558&id=873 [Accessed March 6, 2011].

Flores, F., 2008. personal communication with Juigalpa ENACAL re: potential research in La Libertad.

Fore, L.S., Paulsen, K. & O'Laughlin, K., 2001. Assessing the performance of volunteers in monitoring streams. *Freshwater Biology*, 46(1), pp.109-123.

Friedrichs, J., 1975. *Participant observation : theory and practice*, Farnborough Hants.; Lexington Mass.: Saxon House; Lexington Books.

Gaffney, M., 2008. Participatory Action Research: An Overview--What Makes It Tick? *Kairaranga*, 9, p.15.

Galatowitsch, M., 2006. Monitoreo de los Macroinvertebrados en las Partes Altas del Río Mico en La Libertad, Chontales, Nicaragua.

Galatowitsch, M., 2008. personal communication with Peace Corps volunteer re: his research in La Libertad.

Gibson, B., 1996. The environmental consequences of stagnation in Nicaragua. *World Development*, 24(2), pp.325-339.

Gillespie, T.W., Grijalva, A. & Farris, C.N., 2000. Diversity, composition, and structure of tropical dry forests in Central America. *Plant Ecology*, 147(1), pp.37-47.

Gonsalves, J.F., 2005. *Understanding participatory research and development*, International Development Research Centre (IDRC).

Grey, M. & Stewart, E., 2011. Module 4. Study design and the statistics of model building. In *Online CABIN training program*. University of New Brunswick: Canadian Aquatic Biomonitoring Network (CABIN), Environment Canada (EC). Available at: http://www.unb.ca/research/institutes/cri/training/courses/cabin-rcba/cabin.html [Accessed July 28, 2011].

Hart, B.T. *et al*., 2001. Application of the Australian river bioassessment system (AUSRIVAS) in the Brantas River, East Java, Indonesia. *Journal of Environmental Management*, 62(1), pp.93-100.

Hassan, R., Scholes, R. & Ash, N. eds., 2005. *Ecosystems and Human Well-being: Current States and Trends*, Washington, DC: Island Press. Available at: http://www.maweb.org/en/Condition.aspx#download [Accessed January 12, 2011].

Hassanein, A. *et al*., 2006. *Corporate Social Responsibility & the Canadian International Extractive Sector: A Survey*, Revelstoke, BC: The Canadian Centre for the Study of Resource Conflict. Available at: http://www.resourceconflict.org/resources.html.

Hentschel, T., Hruschka, F. & Priester, M., 2003. *Artisanal and small-scale mining : challenges and opportunities*, London: International Institute for Environment and Development (IIED).

Hilsenhoff, W.L., 1988. Rapid Field Assessment of Organic Pollution with a Family-Level Biotic Index. *Journal of the North American Benthological Society*, 7(1), pp.65-68.

Hinton, J., Veiga, M. & Veiga, A.T., 2003. Clean artisanal gold mining: a utopian approach? *Journal of Cleaner Production*, 11(2), pp.99-115.

Hruschka, F. & Echavarria, C., 2011. *Rock-solid chances for responsible artisanal mining*, Medellin, Columbia: Association for Responsible Mining. Available at: http://communitymining.org/attachments/059_RSC_FINAL_web_low.pdf.

IMF, 2010. Report for Selected Countries and Subjects. Available at: http://www.imf.org/external/pubs/ft/weo/2010/02/weodata/index.aspx [Accessed February 2, 2011].

INEC, 1995. *República de NicaraguaInstituto Nacional de Estadística y Censos: Censos Nacionales 1995*, Managua, Nicaragua: Instituto Nacional de Estadisticas y Censos (INEC). Available at: http://www.inide.gob.ni/censo95/censo95.htm [Accessed March 8, 2011].

INETER, 2004. *Caso urbano de la ciudad de Juigalpa, Municipio de Juigalpa, Departmento de Chontales. Evaluacion de las Amenazas Geologicas e Hidrometeorologicas para Sitios de Urbanizacion. Informe No. 5*, Managua: El Instituto Nicaragüense de Estudios Territoriale (INETER).

INETER, 2010. República de Nicaragua: Mapa de la División Política Administrativa. Available at: http://www.ineter.gob.ni/.

Jiron, R., 2008. personal communication with COOPELMICH secretary re: artisanal mining in La Libertad.

Karadima, C. *et al*., 2010. Ecological risk assessment of cheese whey effluents along a medium-sized river in southwest Greece. *Journal of Environmental Science and Health. Part A, Toxic/Hazardous Substances & Environmental Engineering*, 45(6), pp.775-781.

Kerr, J., 2002. Mainstreaming Participatory Watershed Development. *Economic and Political Weekly*, 37(3), pp.225-242.

Khanlou, N., 2010. Participatory health research. *Nursing inquiry*, 17(4), p.281.

Kingdom, B., Liemberger, R. & Marin, P., 2006. *The Challenge of Reducing Non-Revenue Water (NRW) in Developing Countries. How the Private Sector Can Help: A Look at Performance-Based Service Contracting*, Washington, DC: World Bank. Available at: http://siteresources.worldbank.org/INTWSS/Resources/WSS8fin4.pdf.

Knight Piesold, 1997. *Greenstone Resources Canada Ltd., Environmental Audit: Cerro Mojon*, Denver, Colorado: Knight Piesold and Co. (Knight Piesold) for Greenstone Resources Canada Ltd. (Greenstone).

Kralik, D. & Koch, T., 2006. *Participatory action research in health care*, Blackwell Pub.

Kumah, A., 2006. Sustainability and gold mining in the developing world. *Journal of Cleaner Production*, 14(3-4), pp.315-323.

Land & Water Australia, 2011. AUSRIVAS Home. *Australian River Assessment System*. Available at: http://ausrivas.canberra.edu.au/ [Accessed March 1, 2011].

Larson, A.M., 2002. Natural Resources and Decentralization in Nicaragua: Are Local Governments Up to the Job? *World Development*, 30(1), pp.17-31.

Lazo, O.J., 2005. *El Mineral: Historia de La Libertad, Chontales* Segunda Edición., Juigalpa, Chontales, Nicaragua: Gráfica Editores.

Lofland, J., 2006. *Analyzing social settings : a guide to qualitative observation and analysis* 4th ed., Belmont CA: Wadsworth/Thomson Learning.

Lopez, A., 2008. We Have to Learn to Stop Taking Water for Granted. *Revista Envío Digital*, 321.

MAC, 2000. *Developing an operation, maintenance and surveillance manual for tailings and water management facilities*, Ottawa, ON: Mining Association of Canada (MAC).

Manuel, J., 2007. Estudio geofísico para microlocalización de pozo en el sitio Monasterio Santa María de La Paz.

May, T.W. *et al*., 2001. Influence of mining-related activities on concentrations of metals in water and sediment from streams of the Black Hills, South Dakota. *Archives of Environmental Contamination and Toxicology*, 40(1), pp.1-9.

McKay, S., Crowe, J. & Ramsden, V.R., 2010. The pursuit of excellence: engaging the community in participatory health research. *Global health promotion*, 17(4), pp.32-42.

Mendoza, A., 2008. personal communication re: his research in Chontales.

Mitchell, K., 2008. personal communication with Peace Corps volunteer re: history and social situation in La Libertad.

Mol, J.H. & Ouboter, P.E., 2004. Downstream Effects of Erosion from Small-Scale Gold Mining on the Instream Habitat and Fish Community of a Small Neotropical Rainforest Stream. *Conservation Biology*, 18(1), pp.201-214.

Montambault, J., 2004. *Sustainable Forest Management in Rural Nicaragua: Self-Reported Household Behavior and Stated Management Preferences in Santo Tomás, Chontales*. MSc. University of Florida.

Montenegro, S., 1997. *Diagnostic Study of the San Juan River Basin and Guidelines for an Action Plan*, PROCUENCA. Available at: http://www.oas.org/sanjuan/english/documents/diagnostic.html.

Montenegro, S., 2006. *Lake Cocibolca/ Nicaragua: Experience and Lessons Learned Brief*, CIRA/UNAN. Available at: http://www.worldlakes.org/uploads/09_Lake_Cocibolca_27February2006.pdf [Accessed October 9, 2007].

Montenegro, S., Engi, D. & Vammen, K., 1999. *Managing Nicaraguan Water Resources: Definition and Relative Importance of Information Needs*, Sandia National Laboratories.

Muraleedharan, K., 2006. *Participatory Development: Issues and Lessons*, New Delhi: Serials Publications.

Nicaragua, 1995. *Disposiciones para el Control de la Contaminación Provenientes de las Descargas de Aguas Residuales Domesticas, Industriales y Agropecuarias*, Available at: http://legislacion.asamblea.gob.ni/Indice.nsf/344673776869a7cf0625701400553938/a9fe211ed95fc0f10625700d004e3bdc?OpenDocument [Accessed February 26, 2011].

Nicaragua, 2001. *Ley Especial sobre Exploración y Explotación de Minas*,

Nicaragua, 2008. *Ley General de Aguas Nacionales y su Reglamento*,

Nietschmann, B., 1990. Conservation by Conflict in Nicaragua. *Natural History*, 99(11), p.42.

Norris, R.H. & Georges, A., 1993. Chapter 8: Analysis and interpretation of benthic surveys. In *Freshwater Biomonitoring and Benthic Invertebrates*. Canberra, Australia: Chapman and Hall, pp. 234-286.

Novo, P. & Garrido, A., 2005. *The new Nicaraguan water law in context: institutions and challenges for water management and governance*, International Food Policy Research Institute (IFPRI). Available at: http://www.ifpri.org/publication/new-nicaraguan-water-law-context [Accessed February 25, 2011].

Nunan, F. *et al*., 2002. *Poverty and the Environment: Measuring the Links*, UK Department for International Development (DFID). Available at: http://www.unpei.org/PDF/PEMonitoring/ug-Pov-Env-Measuring-Links-study-PE-Indicators.pdf.

Ocón, M. & Martínez, M., 2001. Tilapia en el Cocibolca "agita la marea." *La Prensa*. Available at: http://archivo.laprensa.com.ni/archivo/2001/noviembre/19/economia/economia-20011119-05.html [Accessed March 6, 2011].

OECD, 1995. *Participatory Development: From Advocacy to Action*, Paris; Washington, DC: Organisation for Economic Co-operation and Development (OECD).

Ongley, E.D., 1997. Matching water quality programs to management needs in developing countries: the challenge of program modernization. *European Water Pollution Control*, 7(4), pp.43-48.

Perez, A., 2001. *Informe Sobre Lineas de Base de Biodiversidad*, Managua: Ministerio del Ambiente y los Recursos Naturales (MARENA). Available at: http://www.bio-nica.info/biblioteca/Perez2001InformeBiodiversidadNicaragua.pdf.

Pound, B. *et al*. eds., 2003. *Managing Natural Resources for Sustainable Livelihoods: Uniting Science and Participation.*, London, UK: Earthscan; International Development Research Centre (IDRC). Available at: http://web.idrc.ca/en/ev-34000-201-1-DO_TOPIC.html.

Pringle, C.M. & Ramirez, A., 1998. Use of both benthic and drift sampling techniques to assess tropical stream invertebrate communities along an altitudinal gradient, Costa Rica. *Freshwater Biology*, 39(2), pp.359-373.

Radio Centro 870 AM, 2011. *Liberteños demandan agua de calidad.*, Juigalpa, Chontales, Nicaragua. Available at: http://www.radiocentro870am.com/index.php?option=com_content&view=article&id=2208:-libertenos-demandan-agua-de-calidad&catid=81:noticias-nacionales&Itemid=458 [Accessed September 12, 2011].

Ramírez, A., Wantzen, K.M. & Winemiller, K.O., 2006. New vistas in Neotropical stream ecology—Preface. *Journal of the North American Benthological Society*, 25(1), pp.61-65.

Ravnborg, H.M., 2003. Poverty and environmental degradation in the Nicaraguan hillsides. *World Development*, 31(11), pp.1933-1946.

Resh, V.H., 2007. Multinational, Freshwater Biomonitoring Programs in the Developing World: Lessons Learned from African and Southeast Asian River Surveys. *Environmental Management*, 39(5), pp.737-748.

Reynoldson, T.B. *et al*., 2001. *Invertebrate Field and Laboratory Manual for running water habitats*, Canadian Aquatic Biomonitoring Network (CABIN), Environment Canada (EC). Available at: http://www.ec.gc.ca/rcba-cabin/.

Reynoldson, T.B. *et al*., 2000. The reference condition: problems and solutions. In *Assessing the biological quality of fresh waters: RIVPACS and other techniques. Proceedings of an International Workshop held in Oxford, UK, on 16-18 September 1997.* pp. 293–309.

Rhoads, Wilson & Urban, 1999. Interaction Between Scientists and Nonscientists in Community-Based Watershed Management: Emergence of the Concept of Stream Naturalization. *Environmental Management*, 24(3), pp.297-308.

RISC, 1998. *Guidelines for Interpreting Water Quality Data: Version 1.0*, Resources Information Standards Committee (RISC): Ministry of Environment, Lands and Parks (MELP), LandData BC, Geographic Data BC for the Land Use Task Force, Resources Inventory Committee (RIC). Available at: http://archive.ilmb.gov.bc.ca/risc/pubs/aquatic/interp/index.htm [Accessed August 28, 2011].

Salas, H. & Martino, P., 2001. *Metodologías Simplificadas para la Evaluación de Eutroficación en Lagos Cálidos Tropicales*, Centro Panamerico de Ingeniería Sanitaria y Ciencias del Ambiente (CEPIS).

Sequeira, M., 2011. Santo Tomás también padece crisis de agua. *El Nuevo Diario*. Available at: http://www.elnuevodiario.com.ni/departamentales/92722 [Accessed September 12, 2011].

Shannon, C., 1948. A mathematical theory of communication. *Bell System Technical Journal*, 27(10), pp.623–656.

Sherzer, J., 1987. Discourse-Centered Approach to Language and Culture, A. *American Anthropologist*, 89, p.295.

Smith, H.M., 1893. Sharks in Lake Nicaragua. *Science*, 22(555), pp.166-167.

Smith-Spark, L., 2006. Nicaragua canal: just a pipe dream? *BBC*. Available at: http://news.bbc.co.uk/2/hi/americas/6069022.stm [Accessed March 6, 2011].

Soares, L.C.R. *et al*., 2002. Inequities in access to and use of drinking water services in Latin America and the Caribbean. *Revista Panamericana De Salud Pública = Pan American Journal of Public Health*, 11(5-6), pp.386-396.

Soldner, M. *et al*., 2004. Relationship between macroinvertebrate fauna and environmental variables in small streams of the Dominican Republic. *Water Research*, 38(4), pp.863-874.

Speirs, G., 2008. personal communication with Central Sun CEO re: Orosi Mine and community relations.

Spiegel, S.J. & Veiga, M., 2010. International guidelines on mercury management in small-scale gold mining. *Journal of Cleaner Production*, 18(4), pp.375-385.

SRK, 1995. *Baseline Study: La Libertad Project, Nicaragua*, Lakewood, CO: Steffen, Robertson and Kirsten Inc. (SRK) for Greenstone Resources Canada Inc. (Greenstone).

SRK, 1996. *Estudio de Impacto Ambiantal: La Libertad, project no. 72601.4*, Lakewood, CO: Steffen, Robertson and Kirsten Inc. (SRK) for Greenstone Resources Canada Inc. (Greenstone).

Stauffer, J.R. *et al*., 1995. African Tilapia in Lake Nicaragua: Ecosystem in Transition. *Bioscience*, 45(6), pp.406-411.

Tarras-Wahlberg, N.H. *et al*., 2001. Environmental impacts and metal exposure of aquatic ecosystems in rivers contaminated by small scale gold mining: the Puyango River basin, southern Ecuador. *The Science of The Total Environment*, 278(1-3), pp.239-261.

Tolvanen, A., 2003. "We Cannot Just Speak About Things That Are Pretty": The Legacy of Greenstone Resources in Nicaragua. *MiningWatch Canada*. Available at: http://www.miningwatch.ca/en/legacy-greenstone-resources-nicaragua [Accessed February 19, 2008].

Transparency International, 2010. Corruptions Perceptions Index 2010. *Transparency International - the global coalition against corruption*. Available at: http://www.transparency.org/policy_research/surveys_indices/cpi/2010/results [Accessed February 21, 2011].

UN, 2002. *Berlin II: Guidelines for Mining and Sustainable Development*, United Nations (UN). Available at: http://commdev.org/content/document/detail/903/.

UN, 2010. *The Millennium Development Goals Report 2010*, New York: United Nations (UN). Available at: http://www.un.org/millenniumgoals/pdf/MDG%20Report%202010%20En%20r15%20-low%20res%2020100615%20-.pdf#page=60.

UN, 2006. *Water : a shared responsibility* 2nd ed., Paris; New York: United Nations Educational Scientific and Cultural Organization (UNESCO); Berghahn Books. Available at: http://www.unesco.org/water/wwap/wwdr/wwdr2/.

UN, 2009. *Water in a changing world* 3rd ed., Paris; London: United Nations Educational Scientific and Cultural Organization (UNESCO); Earthscan. Available at: http://www.unesco.org/water/wwap/wwdr/wwdr3/.

UN GEMS, 2006. *Water Quality for Ecosystem and Human Health*, Burlington, ON: UN GEMS, Water Programme Office. Available at: http://www.gemswater.org/.

UNDP, 1997. *Capacity Development. Technical Advisory Paper 2*, New York: United Nations Development Programme (UNDP).

UNEP & WHO, 1996. *Water quality monitoring : a practical guide to the design and implementation of freshwater quality studies and monitoring programmes* 1st ed. J. Bartram & J. Ballance, eds., London; New York: E & FN Spon. Available at: http://www.bvsde.paho.org/bvsacd/who/monito.pdf.

UNESCO, 2006. Pit Latrines. *UNEP Wastewater Training*. Available at: http://www.training.gpa.unep.org/content.html?id=207&ln=6. [Accessed October 2, 2008].

Vanmen, K. & Flores, Y., 2006. *Diagnóstico Ambiental: La Subcuenca Alta de los Ríos Siquia y Mico*, Managua, Nicaragua: CIRA/UNAN & MARENA.

Veiga, M., 1997. Mercury in Artisanal Gold Mining in Latin America: Facts, Fantasies and Solutions. In UNIDO - Expert Group Meeting - Introducing new technologies for abatement of global mercury pollution deriving from artisanal gold mining. Vienna. Available at: http://www.facome.uqam.ca/facome/pdf/veiga_02.pdf.

Veiga, M. *et al*., 2009. Mill leaching: a viable substitute for mercury amalgamation in the artisanal gold mining sector? *Journal of Cleaner Production*, 17(15), pp.1373-1381.

Velasco, P., 2001. *The Mineral Industries of Central America: Belize, Costa Rica, El Salvador, Honduras, Nicaragua, and Panama*, US Geological Survey. Available at: http://minerals.usgs.gov/minerals/pubs/country/2001/camermyb01r.pdf.

Velásquez, G., 1994. *Diagnostic study of environmental contamination due to mining activity in the Sucio, Mico and Sinecapa Rivers, Nicaragua*. Geosciences. Belém: Federal University.

Vidal, J., 2006. $20bn and 10 years to build - a giant rival for Panama canal | Environment | The Guardian. *the Guardian*. Available at: http://www.guardian.co.uk/environment/2006/oct/04/water.conservationandendangeredspecies [Accessed March 6, 2011].

Vidich, A.J. & Shapiro, G., 1955. A Comparison of Participant Observation and Survey Data. *American Sociological Review*, 20(1), pp.28-33.

Wadsworth, Y., 1998. *What is Participatory Action Research?*, Action Research International. Available at: http://www.scu.edu.au/schools/gcm/ar/ari/p-ywadsworth98.html.

Washington, H.G., 1984. Diversity, biotic and similarity indices: A review with special relevance to aquatic ecosystems. *Water Research*, 18(6), pp.653-694.

Webster, T., Waite, L. & Markley, B., 2001. *Water Resources Assessment of Nicaragua*, US Army Corps of Engineers (USACE).

WHO, 2011. *Guidelines for drinking-water quality* 4th ed., World Health Organization. Available at: http://www.who.int/water_sanitation_health/monitoring/en/.

Williams, W.D., 2002. Community participation in conserving and managing inland waters. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 12(3), pp.315-326.

Wisner, B., Stea, D. & Kruks, S., 1991. Participatory and Action Research Methods. In *Advances in Environment, Behaviour, and Design*. New York & London: Plenum Press.

Wood, R., 2010. *Nicaragua* 4th ed., Berkeley, CA: Avalon Travel; distributed by Publishers Group West.

Yamamoto, W., Dewi, I.A. & Ibrahim, M., 2007. Effects of silvopastoral areas on milk production at dual-purpose cattle farms at the semi-humid old agricultural frontier in central Nicaragua. *Agricultural Systems*, 94(2), pp.368-375.

Appendix A
Source Material and Raw Data

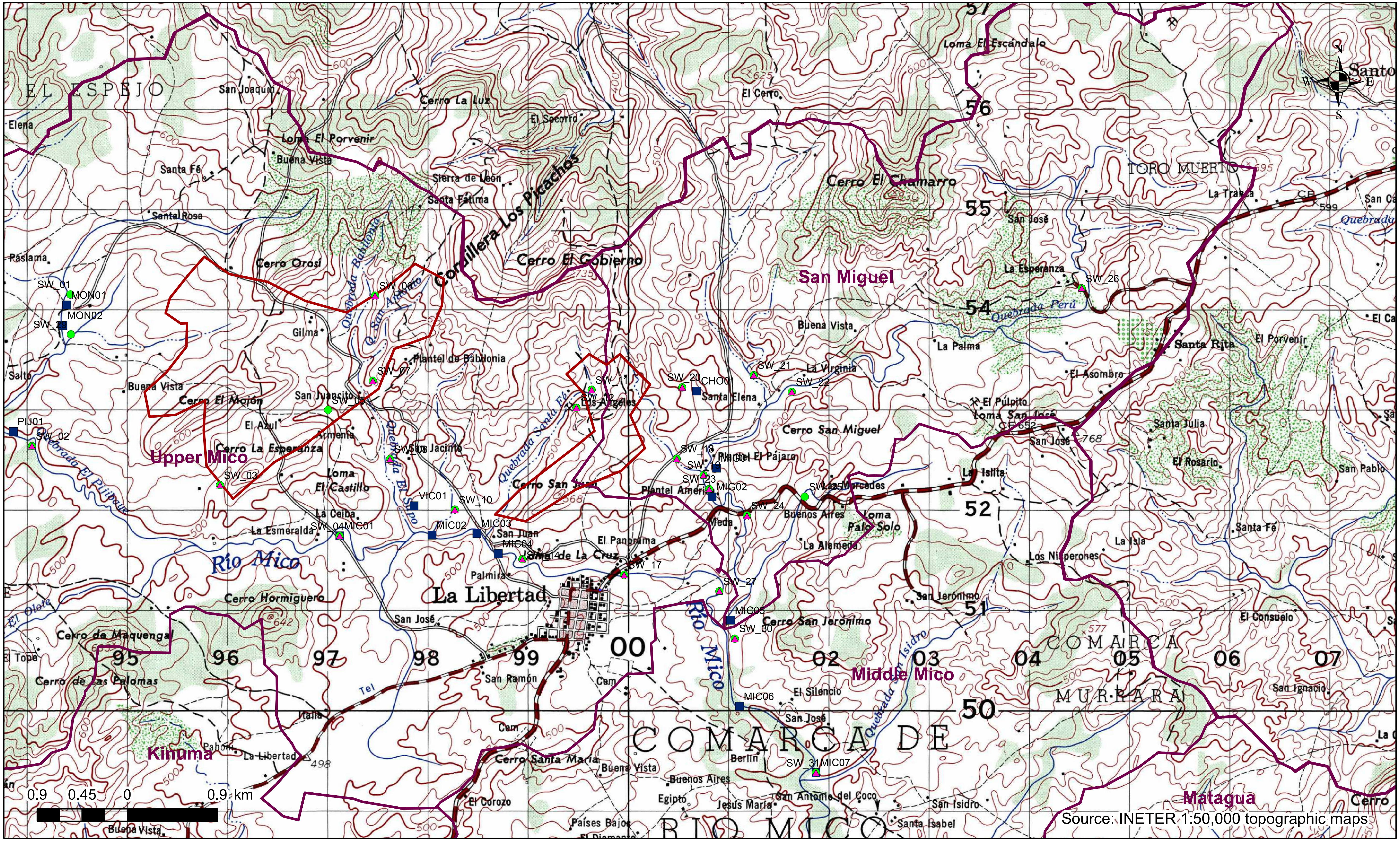
Contact Kathy Chambers at kchambers@hemmera.com or the University of Victoria Geography Department at geoginfo@uvic.ca for Access database, ArcGIS shapefiles and pdfs of original source studies (where in public domain)

Appendix B
Location Errata

Table B-1. Location Errata

Study ID	Original ID	Original Northing	Original Easting	Description	Rationale	Correction	Corrected Northing	Corrected Easting	Datum
DES01a	P1a	135488	695168.96	Quebrada Paslama 1a above dam	Northing appears to be missing a digit	Added zero to Northing	1354880.03	695168.96	NAD27
DES02	P2	1353829	694358.25	Quebrada Pijibay	Possible GPS error, location is within 10 m of P1 and not on Pijibay	Moved to Pijibay near likely access point (unpaved road)	1352638	694046	NAD27
DES03	P3	1352022	697874.91	Rio Mico	Possible GPS error, location is within 10 m of P4 and not on Victoria	Assumed same location as GAL17	1351750	698037	NAD27
GAL01	Los Chiles	1339642	579758	Puente El Chile	Possible transcription error, coordinates are for Managua	Used description to locate	1375333	725437	NAD27
GAL03	above Alegre/ above Estrella	unknown	unknown	above Estrella	1. Field notes list this as above Quebrada Alegre, tabulated data lists location as above Estrella. 2. No corresponding CIRA site for "above Estrella"	1. Assumed Estrella correct as there is a small mining operation located here and described in many previous points as a pollution source. 2. Chose location upstream of Estrella near likely access point.	1354643	709074	NAD27
GAL04	Alegre/ Estrella	unknown	unknown	Estrella	Field notes list this as Quebrada Alegre, tabulated data lists location as Estrella.	Assumed Estrella correct as there is a small mining operation located here and described in many previous points as a pollution source.	1357238	709539	NAD27
GAL16	Victoria	unknown	unknown	Victoria before confluence with Mico	No corresponding CIRA site.	Assume same as DESMINIC. Discussion indicates this site and Mico site are 20 m apart from each other so may actually be closer to confluence with Mico than DESMINIC site.	1352043.74	697860.05	NAD27
GAL17	Mico	unknown	unknown	Mico after confluence with Victoria	No corresponding CIRA site.	Assumed just downstream of confluence. Discussion indicates this site and Victoria are 20 m apart from each other so may actually be closer than shown on map.	1351750	698037	NAD27
GAL18	Pijibay	unknown	unknown	Pijibay	No corresponding CIRA site.	Assumed Pijibay near closest access point below confluence with Mona	1352638	694046	NAD27
SRK06 through SRK15	2 through 12	unknown	unknown	various	No UTM coordinates provided	Used descriptions to locate on map	various	various	NAD27
B_9 through B_23	M-09 through M-23	unknown	unknown	none given	No coordinates provided	Used site maps in report to locate general area and watercourse; placed near likely access points	various	various	NAD27
CR_01 through CR_17	I through XVII	various	various	various	Coordinates provided to nearest 50 m	Used description to provide more accurate locations	various	various	NAD27
D_01 through D_24	various	various	various	various	No coordinates provided	Used descriptions to locate on map; assumed identical to SRK sites where applicable. Generally good descriptions, and detailed site plans and aerial photos available for mine area provided good confidence in these locations	various	various	NAD27
S_01 through S_24	various	various	various	various	Coordinates provided to nearest 100 m	Used description to provide more accurate locations	various	various	NAD27
ENACAL	various	various	various	various	Coordinates not provided for all sites	Used descriptions where possible to locate on map	various	various	NAD27

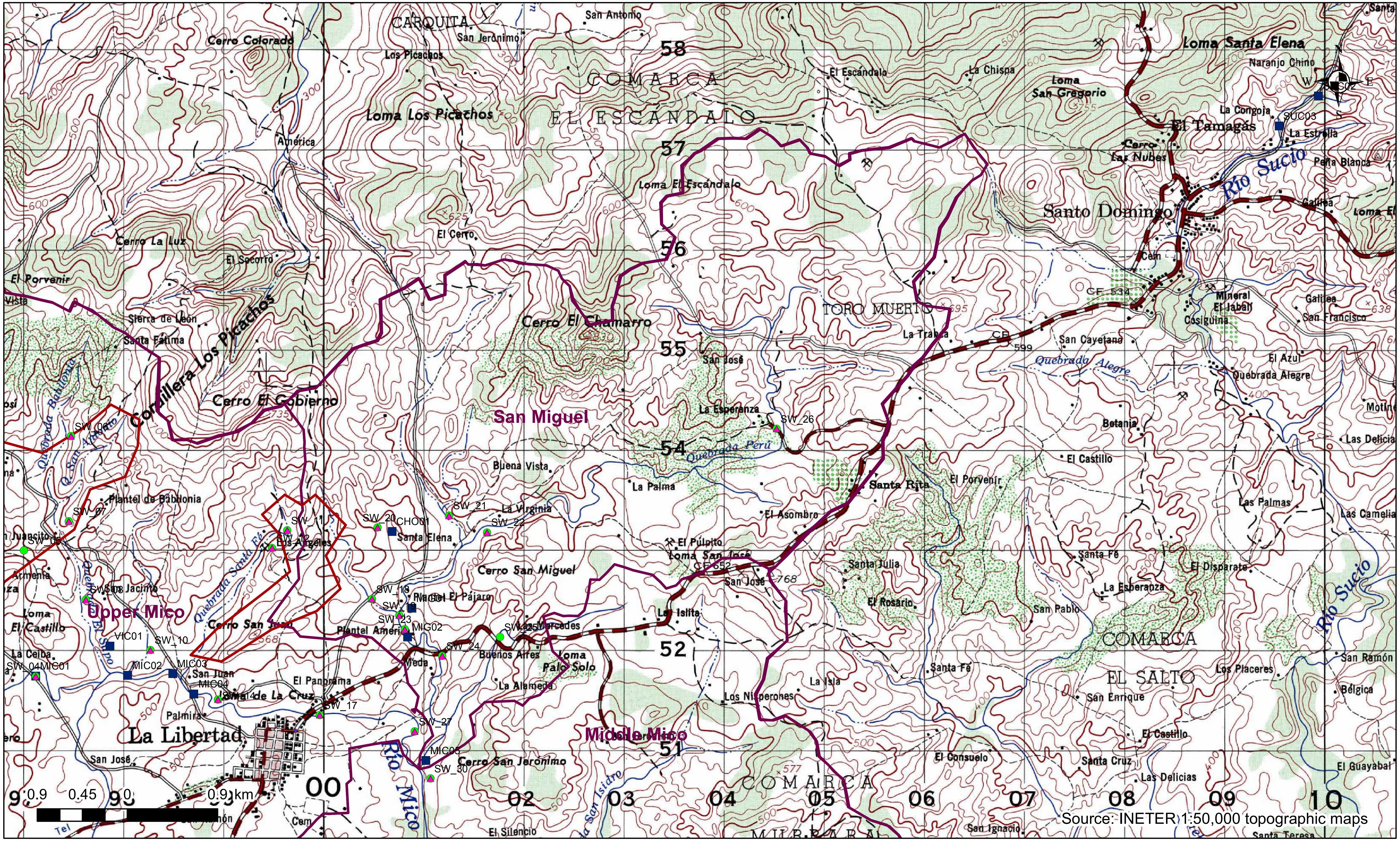
Appendix C
Combined Sample Locations by Watershed



Legend

- Watershed Boundary
- La Libertad Mine
- Combined Sediment Sites
- Combined Surface Water Sites
- Combined Bioassessment Sites

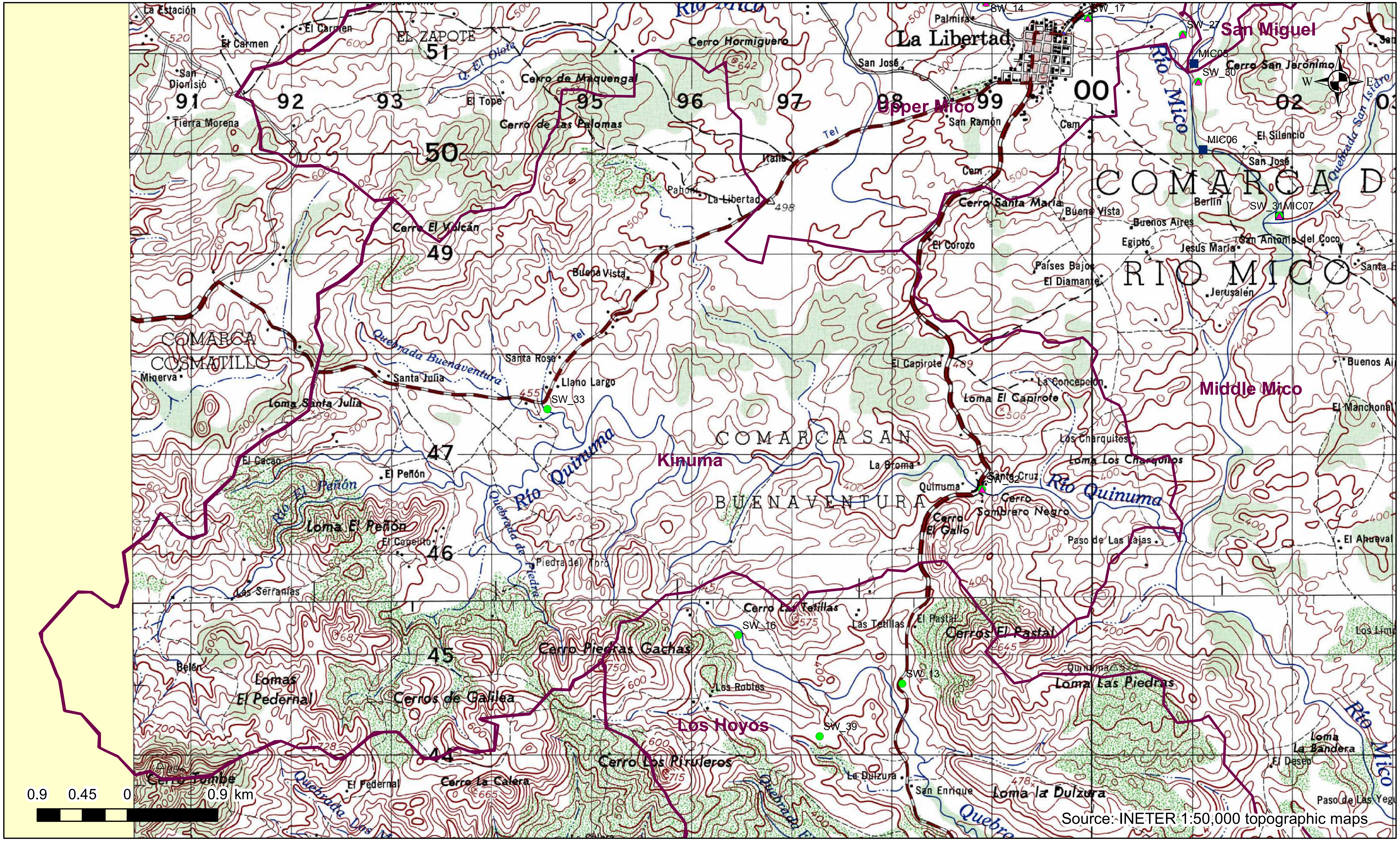
Combined Data Locations - Upper Mico	
December 2011	Figure C-1



Legend

- Watershed Boundary
- La Libertad Mine
- Combined Sediment Sites
- Combined Surface Water Sites
- Combined Bioassessment Sites

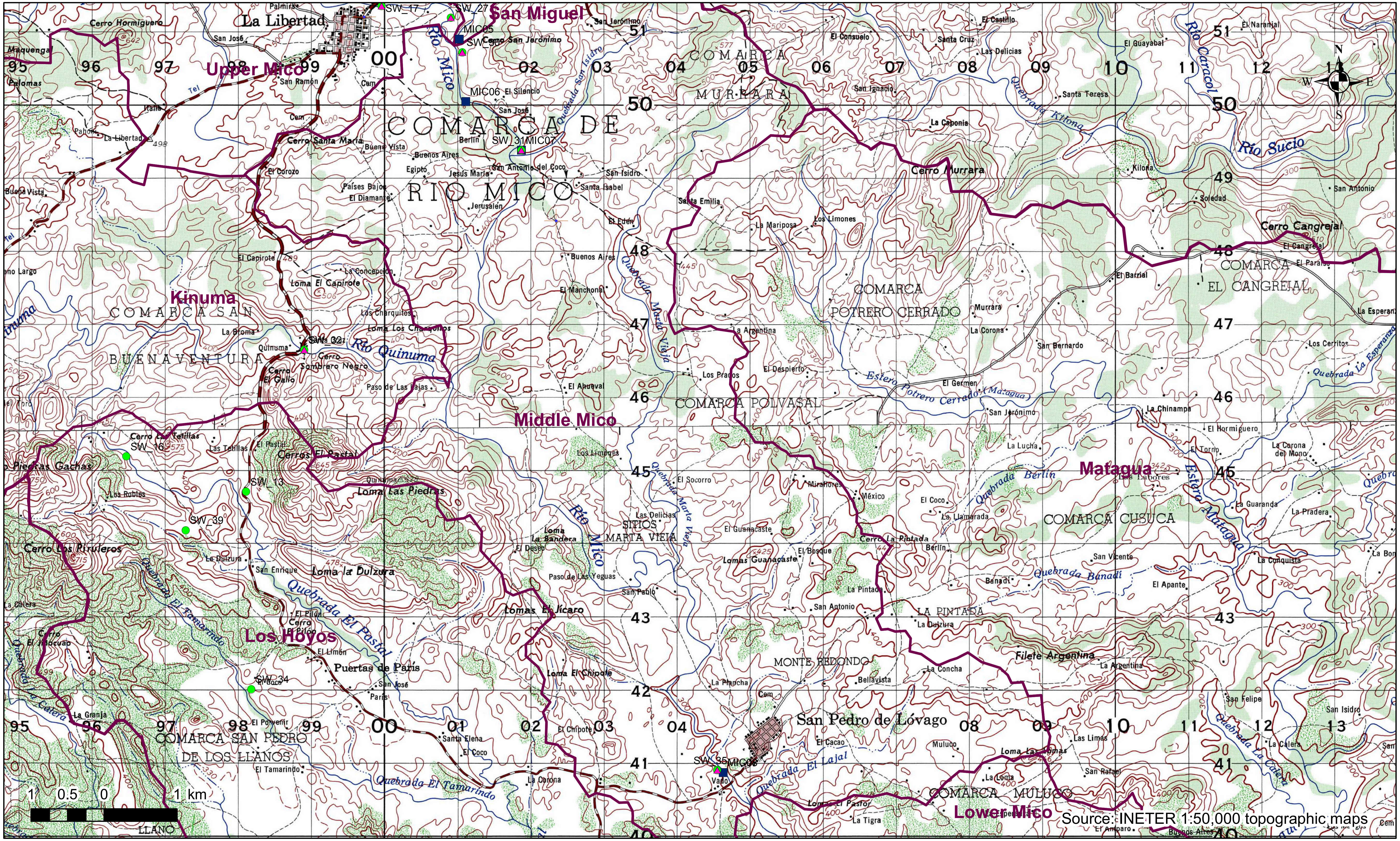
Combined Data Locations - San Miguel	
December 2011	Figure C-2



Legend

- Watershed Boundary
- La Libertad Mine
- Combined Sediment Sites
- Combined Surface Water Sites
- Combined Bioassessment Sites

Combined Data Locations - Kinuma	
December 2011	Figure C-3



Legend

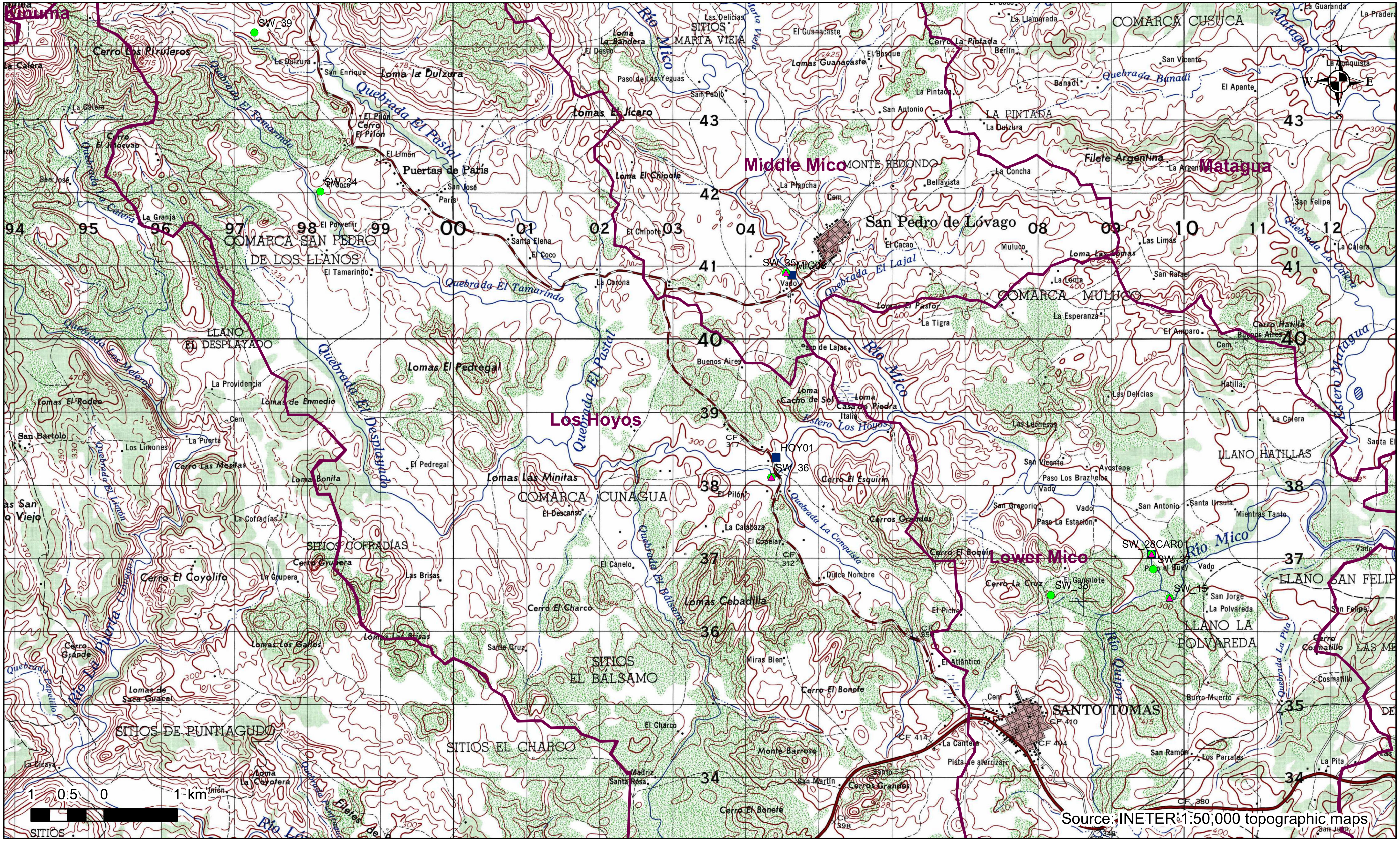
- Watershed Boundary
- La Libertad Mine
- Combined Sediment Sites
- Combined Surface Water Sites
- Combined Bioassessment Sites

Combined Data Locations - Middle Mico	
December 2011	Figure C-4

Legend

- Watershed Boundary
- La Libertad Mine
- Combined Sediment Sites
- Combined Surface Water Sites
- Combined Bioassessment Sites

Combined Data Locations - Matagua	
December 2011	Figure C-5



Legend

- Watershed Boundary
- La Libertad Mine
- Combined Sediment Sites
- Combined Surface Water Sites
- Combined Bioassessment Sites

Combined Data Locations - Los Hoyos	
December 2011	Figure C-6

Legend

- Watershed Boundary
- La Libertad Mine
- Combined Sediment Sites
- Combined Surface Water Sites
- Combined Bioassessment Sites

Combined Data Locations - Lower Mico	
December 2011	Figure C-7

Appendix D
Descriptive Statistics for Surface Water and Sediment Results

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_01					SW_02										SW_03									
						Season:	wet					dry					wet					dry					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	**Unit**	**Decreto 33-95 [3]**	**MMER Max Grab [4]**	***CAPRE DW [5]***	***WHO DW [6,7]***	**CCME FAL SW [8]**																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	13.25	13.25	13.25	-	1	-	-	-	-	0	-	-	-	-	0	25	25	25	-	1	-	-	-	-	0
Colour	TCU	-	-	15	-	-	***25***	***25***	***25***	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	48.20	48.2	48.2	-	1	***429***	***429***	***429***	-	1	134	134	134	-	1	71	71	71	-	1	-	-	-	-	0
Dissolved Oxygen	mg/L	-	-	-	-	5.5	**5.40**	**5.4**	**5.4**	-	1	8.16	8.16	8.16	-	1	7.96	7.96	7.96	-	1	-	-	-	-	0	-	-	-	-	0
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	9.84	9.84	9.84	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	6.62	6.62	6.62	-	1	7.05	***6.3***	7.5	0.66	3	7.15	6.5	8	0.73	4	7.34	6.9	7.8	0.33	6	6.69	***4.2***	7.66	1.41	5
Temperature	ºC	40	-	18-30	-	-	24.10	24.1	24.1	-	1	26.90	26.9	26.9	-	1	27.10	27.1	27.1	-	1	26.08	24.7	28	1.20	5	26.70	26	27.4	0.63	5
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	37.90	37.9	37.9	-	1	65	60	70	7.07	2	40	10	60	26.46	3	42.20	5	190	56.80	10	634.41	7	***4239***	1461.71	8
Total Suspended Solids	mg/L	50	30	-	-	-	-	-	-	-	0	ld	ld	ld	0	2	47.33	10	**108**	53	3	9.46	ld	**86**	25.95	11	6.85	ld	50	17.52	8
Turbidity	NTU	-	-	-	-	-	31.90	31.9	31.9	-	1	150	150	150	-	1	650	650	650	-	1	-	-	-	-	0	-	-	-	-	0
Inorganics																															
Chloride	mg/L	-	-	-	-	-	3.62	3.62	3.62	-	1	-	-	-	-	0	-	-	-	-	0	5	5	5	-	1	-	-	-	-	0
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	ld	ld	ld	-	1	0.01	ld	0.02	0.01	3	0.03	ld	***0.06***	0.03	4	0	ld	0.046	0.01	10	ld	ld	ld	0	9
Fluoride	mg/L	-	-	0.7	1.5	0.12	0.08	0.08	0.08	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	0.11	0.11	0.11	-	1	-	-	-	-	0
Nitrate and Nitrite	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0.11	0.11	0.11	-	1	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	0	03	03	-	1	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Ammonia	mg/L	-	-	0.5	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	0.11	0.113	0.113	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	ld	07	0	2	3.71	ld	11.13	6.43	3
Sulfate	mg/L	-	-	250	-	-	1.03	1.03	1.03	-	1	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Oils and greases	mg/L	5	-	-	-	-	-	-	-	-	0	-	-	-	-	0	**20**	ld	**40**	28.28	2	**25.74**	4.2	**45.6**	16.71	10	**17.74**	ld	**44.5**	16.94	9
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_04										SW_05										SW_06				
						Season:	dry					wet					dry					wet					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	CAPRE DW [5]	WHO DW [6,7]	CCME FAL SW [8]																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	16	16	16	-	1	29.20	29.2	29.2	-	1	15.33	ld	26	13.61	3	-	-	-	-	0	-	-	-	-	0
Colour	TCU	-	-	15	-	-	-	-	-	-	0	50	50	50	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	56	56	56	-	1	112.90	112.9	112.9	-	1	85.67	63	129	37.54	3	-	-	-	-	0	364	364	364	-	1
Dissolved Oxygen	mg/L	-	-	-	-	5.5	-	-	-	-	0	5.10	5.1	5.1	-	1	-	-	-	-	0	-	-	-	-	0	7.80	7.8	7.8	-	1
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	16	16	16	-	1	26.55	26.55	26.55	-	1	26	26	26	-	1	-	-	-	-	0	-	-	-	-	0
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	7.23	6	8.71	0.59	67	7.36	6	8.75	0.58	117	7.18	3.9	8.57	0.67	68	7.25	5	8.75	0.51	101	7.42	7.42	7.42	-	1
Temperature	ºC	40	-	18-30	-	-	25.18	22.6	28.5	1.97	6	25.80	23.3	27.5	1.59	6	25.82	24.5	29	1.84	5	26.84	26	27.8	0.65	5	30	30	30	-	1
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	61.78	ld	224	54.82	15	52.13	7	102	30.63	13	142.87	12	1350	335.14	15	7478.73	ld	51669	17119.82	11	-	-	-	-	0
Total Suspended Solids	mg/L	50	30	-	-	-	5.88	ld	64	16.64	16	3.24	ld	14	5.77	12	19.01	ld	122	33.46	16	13453.20	ld	174000	48238.42	13	-	-	-	-	0
Turbidity	NTU	-	-	-	-	-	6	6	6	-	1	1025	1025	1025	-	1	-	-	-	-	0	-	-	-	-	0	0.68	0.68	0.68	-	1
Inorganics																															
Chloride	mg/L	-	-	-	-	-	5	5	5	-	1	5.77	5.77	5.77	-	1	4.67	4	5	0.58	3	-	-	-	-	0	-	-	-	-	0
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	0	ld	0.043	0.01	15	0.01	ld	0.13	0.04	14	0.01	ld	0.062	0.02	14	0.01	ld	0.07	0.02	13	-	-	-	-	0
Fluoride	mg/L	-	-	0.7	1.5	0.12	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	0.28	0.12	0.44	0.23	2	1.18	1.18	1.18	-	1	0.16	0.13	0.18	0.03	3	-	-	-	-	0	-	-	-	-	0
Nitrate and Nitrite	mg/L	-	-	-	-	-	0.12	0.12	0.12	-	1	-	-	-	-	0	0.16	0.13	0.18	0.03	3	-	-	-	-	0	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	ld	ld	ld	-	1	0.04	0.039	0.039	-	1	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0
Ammonia	mg/L	-	-	0.5	-	-	0.05	0.05	0.05	-	1	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	-	-	-	-	0	0.19	0.188	0.188	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/L	-	-	-	-	-	ld	ld	ld	0	2	18.87	ld	56.6	32.68	3	ld	ld	ld	0	3	ld	ld	ld	0	3	-	-	-	-	0
Sulfate	mg/L	-	-	250	-	-	ld	ld	ld	-	1	11.79	11.79	11.79	-	1	6.67	ld	20	11.55	3	-	-	-	-	0	-	-	-	-	0
Oils and greases	mg/L	5	-	-	-	-	16.09	ld	48.4	16.88	14	9.67	ld	28	11.09	13	18.94	ld	45	18.26	13	10.29	ld	44.5	12.86	12	-	-	-	-	0
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_06					SW_07										SW_08									
						Season:	dry					wet					dry					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	**Unit**	**Decreto 33-95** [3]	**MMER Max Grab** [4]	***CAPRE DW*** [5]	***WHO DW*** [6,7]	**CCME FAL SW** [8]																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	-	-	-	-	0	20	20	20	-	1	-	-	-	-	0	26	26	26	-	1	-	-	-	-	0
Colour	TCU	-	-	15	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	103	103	103	-	1	197.50	65	330	187.38	2	71	71	71	-	1	63	63	63	-	1	-	-	-	-	0
Dissolved Oxygen	mg/L	-	-	-	-	5.5	7.33	7.33	7.33	-	1	7.40	7.4	7.4	-	1	7.33	7.33	7.33	-	1	-	-	-	-	0	-	-	-	-	0
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	-	-	-	-	0	20	20	20	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	7.11	7.11	7.11	-	1	6.99	***6.3***	7.8	0.42	12	6.94	***6***	7.52	0.46	12	7.02	***6.31***	7.9	0.63	5	7.45	7.06	7.7	0.28	4
Temperature	ºC	40	-	18-30	-	-	30	30	30	-	1	26.53	24.5	29.8	2.20	6	26.95	25	30	1.65	6	26.48	25.4	29	1.70	4	27.18	26	28	0.99	4
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	-	-	-	-	0	44.94	ld	174	43.02	16	64.49	ld	304.6	79.82	13	40.65	5	79	36.82	4	38.67	ld	106	58.53	3
Total Suspended Solids	mg/L	50	30	-	-	-	-	-	-	-	0	7.32	ld	84	20.16	17	58.58	ld	378	136.21	13	ld	ld	ld	0	4	ld	ld	ld	0	3
Turbidity	NTU	-	-	-	-	-	90	90	90	-	1	95	95	95	-	1	92	92	92	-	1	-	-	-	-	0	-	-	-	-	0
Inorganics																															
Chloride	mg/L	-	-	-	-	-	-	-	-	-	0	5	5	5	-	1	-	-	-	-	0	5	5	5	-	1	-	-	-	-	0
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	-	-	-	-	0	0	ld	***0.051***	0.01	15	0	ld	0.02	0.01	14	ld	ld	ld	0	4	ld	ld	ld	0	4
Fluoride	mg/L	-	-	0.7	1.5	0.12	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	-	-	-	-	0	0.18	0.18	0.18	-	1	-	-	-	-	0	0.17	0.17	0.17	-	1	-	-	-	-	0
Nitrate and Nitrite	mg/L	-	-	-	-	-	-	-	-	-	0	0.18	0.18	0.18	-	1	-	-	-	-	0	0.17	0.17	0.17	-	1	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Ammonia	mg/L	-	-	0.5	-	-	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/L	-	-	-	-	-	-	-	-	-	0	ld	ld	ld	0	2	ld	ld	ld	0	3	ld	ld	ld	-	1	ld	ld	ld	0	2
Sulfate	mg/L	-	-	250	-	-	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Oils and greases	mg/L	5	-	-	-	-	-	-	-	-	0	22.42	ld	96	27.12	13	11.28	ld	37.5	14.35	13	18.70	1.2	44	20.53	4	14.85	6	26.8	8.87	4
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_09										SW_10					SW_11									
						Season:	dry					wet					dry					dry					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	**Unit**	**Decreto 33-95** [3]	**MMER Max Grab** [4]	***CAPRE DW*** [5]	***WHO DW*** [6,7]	**CCME FAL SW** [8]																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	16	16	16	-	1	10	10	10	0	2	-	-	-	-	0
Colour	TCU	-	-	15	-	-	-	-	-	-	0	***50***	***50***	***50***	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	-	-	-	-	0	124.30	124.3	124.3	-	1	56	56	56	-	1	49	49	49	0	2	-	-	-	-	0
Dissolved Oxygen	mg/L	-	-	-	-	5.5	-	-	-	-	0	5.70	5.7	5.7	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	-	-	-	-	0	37.62	37.62	37.62	-	1	-	-	-	-	0	10	10	10	-	1	-	-	-	-	0
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	***9***	***9***	***9***	-	1	7.35	7.35	7.35	-	1	6.60	6.6	6.6	-	1	6.78	***6.3***	7.5	0.42	12	6.66	***6.1***	7.7	0.56	9
Temperature	ºC	40	-	18-30	-	-	24	24	24	-	1	22.50	22.5	22.5	-	1	-	-	-	-	0	26.62	24	29.5	2.12	5	26.46	25.5	28	0.96	5
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	-	-	-	-	0	90.39	90.39	90.39	-	1	-	-	-	-	0	44.20	ld	202	53.13	15	47.55	ld	128	38.74	12
Total Suspended Solids	mg/L	50	30	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	5.62	ld	42	12.73	15	0.51	ld	6	1.73	12
Turbidity	NTU	-	-	-	-	-	7	7	7	-	1	79.60	79.6	79.6	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Inorganics																															
Chloride	mg/L	-	-	-	-	-	-	-	-	-	0	5.88	5.88	5.88	-	1	5	5	5	-	1	4	4	4	0	2	-	-	-	-	0
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	ld	ld	ld	-	1	ld	ld	ld	-	1	-	-	-	-	0	0	ld	0.041	0.01	15	0	ld	0.02	0.01	13
Fluoride	mg/L	-	-	0.7	1.5	0.12	-	-	-	-	0	0.04	0.04	0.04	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	7.08	7.08	7.08	-	1	0.83	0.83	0.83	-	1	0.12	0.12	0.12	-	1	0.76	0.76	0.76	0	2	-	-	-	-	0
Nitrate and Nitrite	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	0.12	0.12	0.12	-	1	0.76	0.76	0.76	0	2	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	-	-	-	-	0	0.01	0.01	0.01	-	1	ld	ld	ld	-	1	ld	ld	ld	0	2	-	-	-	-	0
Ammonia	mg/L	-	-	0.5	-	-	-	-	-	-	0	-	-	-	-	0	0.05	0.05	0.05	-	1	ld	ld	ld	0	2	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	-	-	-	-	0	0.06	0.058	0.058	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3	ld	ld	ld	0	3
Sulfate	mg/L	-	-	250	-	-	-	-	-	-	0	2.85	2.85	2.85	-	1	ld	ld	ld	-	1	ld	ld	ld	0	2	-	-	-	-	0
Oils and greases	mg/L	5	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	**29.14**	ld	**184**	50.07	13	**19.65**	ld	**66**	20.29	11
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	2.75	2.75	2.75	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	21.43	21.43	21.43	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_12										SW_13					SW_14									
						Season:	dry					wet					dry					dry					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95[3]	MMER Max Grab[4]	*CAPRE DW*[5]	*WHO DW*[6,7]	CCME FAL SW[8]																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	28	20	36	11.31	2	22.90	22.9	22.9	-	1	-	-	-	-	0	31	31	31	0	2	-	-	-	-	0
Colour	TCU	-	-	15	-	-	-	-	-	-	0	***20***	***20***	***20***	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	245.75	79	***408***	164.37	4	75.87	62	84	12.07	3	***510***	***510***	***510***	-	1	215.50	81	368	156	4	74.40	64	83	9.63	3
Dissolved Oxygen	mg/L	-	-	-	-	5.5	7.60	7.6	7.6	0	2	6.67	**4.5**	7.76	1.88	3	-	-	-	-	0	7.45	7.4	7.5	0.07	2	7.86	7.76	7.96	0.14	2
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	-	-	-	-	0	21.15	21.15	21.15	-	1	-	-	-	-	0	31	31	31	-	1	-	-	-	-	0
pH[9]	pH	6-9		6.5-8.5	-	6.5-9	6.82	***6.3***	7.25	0.41	4	7.28	6.79	7.55	0.43	3	7.53	7.53	7.53	-	1	7.15	6.3	7.82	0.46	14	6.97	6.3	7.86	0.44	14
Temperature	ºC	40	-	18-30	-	-	28.35	27	29.7	1.91	2	25.53	24.1	27	1.45	3	25.60	25.6	25.6	-	1	25.91	24	28.1	2.05	7	26.54	25	27.7	1.05	8
Total Dissolved Solids	mg/L	1[10]	-	1000	-	-	-	-	-	-	0	52.99	52.99	52.99	-	1	-	-	-	-	0	54.63	ld	256	62.54	16	634.61	14	7948	2105.53	14
Total Suspended Solids	mg/L	50	30	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	7.68	ld	88	21.51	17	95.61	ld	598	213.54	14
Turbidity	NTU	-	-	-	-	-	65.38	0.75	130	91.39	2	50.09	0.76	130	69.84	3	-	-	-	-	0	91	72	110	26.87	2	130	90	170	56.57	2
Inorganics																															
Chloride	mg/L	-	-	-	-	-	7	6	8	1.41	2	5.21	5.21	5.21	-	1	-	-	-	-	0	6	6	6	0	2	-	-	-	-	0
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	***0.36***	***0.11***	***0.96***	0.41	4	***0.16***	0.03	***0.28***	0.18	2	-	-	-	-	0	0.02	ld	***0.09***	0.03	17	0.01	ld	***0.15***	0.04	18
Fluoride	mg/L	-	-	0.7	1.5	0.12	-	-	-	-	0	0.12	0.12	0.12	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	0.36	0.13	0.59	0.33	2	0.70	0.7	0.7	-	1	-	-	-	-	0	0.10	0.1	0.1	0	2	-	-	-	-	0
Nitrate and Nitrite	mg/L	-	-	-	-	-	0.38	0.13	0.63	0.35	2	-	-	-	-	0	-	-	-	-	0	0.10	0.1	0.1	0	2	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	0.02	ld	0.04	0.03	2	0.03	0.03	0.03	-	1	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0
Ammonia	mg/L	-	-	0.5	-	-	0.09	0.06	0.12	0.04	2	-	-	-	-	0	-	-	-	-	0	0.06	0.06	0.06	0	2	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	-	-	-	-	0	0.05	0.046	0.046	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/L	-	-	-	-	-	0.17	0.029	0.301	0.19	2	-	-	-	-	0	-	-	-	-	0	0.01	ld	0.01	0.01	3	ld	ld	ld	0	3
Sulfate	mg/L	-	-	250	-	-	10	ld	20	14.14	2	3.75	3.75	3.75	-	1	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0
Oils and greases	mg/L	5	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	28.59	ld	215.6	55.34	14	10.85	ld	30.8	11.06	13
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_15										SW_16					SW_17									
						Season:	dry					wet					dry					dry					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	31	31	31	-	1	-	-	-	-	0
Colour	TCU	-	-	15	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	-	-	-	-	0	-	-	-	-	0	382	382	382	-	1	83	83	83	-	1	98.95	75	122.9	33.87	2
Dissolved Oxygen	mg/L	-	-	-	-	5.5	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	7.60	7.6	7.6	-	1	7.76	7.76	7.76	-	1
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	-	-	-	-	0	-	-	-	-	0	7.11	7.11	7.11	-	1	7.31	6	8.45	0.63	58	7.44	6.09	9.12	0.54	94
Temperature	ºC	40	-	18-30	-	-	-	-	-	-	0	-	-	-	-	0	28.20	28.2	28.2	-	1	27.50	27.5	27.5	-	1	26.85	25.8	27.9	1.48	2
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Total Suspended Solids	mg/L	50	30	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Turbidity	NTU	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	150	150	150	-	1
Inorganics																															
Chloride	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	6	6	6	-	1	-	-	-	-	0
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	***0.09***	***0.09***	***0.09***	-	1	0.02	0	0.05	0.03	3
Fluoride	mg/L	-	-	0.7	1.5	0.12	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0.09	0.09	0.09	-	1	-	-	-	-	0
Nitrate and Nitrite	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0.09	0.09	0.09	-	1	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	0	0	-	1	-	-	-	-	0
Ammonia	mg/L	-	-	0.5	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	0	0	-	1	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0.02	0.018	0.018	-	1	-	-	-	-	0
Sulfate	mg/L	-	-	250	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	0	0	-	1	-	-	-	-	0
Oils and greases	mg/L	5	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_18										SW_19										SW_20				
						Season:	dry					wet					dry					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95[3]	MMER Max Grab[4]	*CAPRE DW*[5]	*WHO DW*[6,7]	CCME FAL SW[8]																										
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	57	57	57	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Colour	TCU	-	-	15	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	176.67	105	320	124.13	3	158	158	158	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Dissolved Oxygen	mg/L	-	-	-	-	5.5	7.27	7.27	7.27	-	1	7.33	7.33	7.33	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	57	57	57	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
pH[9]	pH	6-9		6.5-8.5	-	6.5-9	7.20	***6***	8.1	0.48	64	7.36	*5.98*	***8.62***	0.50	98	-	-	-	-	0	-	-	-	-	0	7.20	7.2	7.2	-	1
Temperature	ºC	40	-	18-30	-	-	***30.30***	***30.3***	***30.3***	-	1	28	28	28	-	1	-	-	-	-	0	-	-	-	-	0	25.40	25.4	25.4	-	1
Total Dissolved Solids	mg/L	1[10]	-	1000	-	-	75	60	100	13.78	6	72	40	140	39.62	5	-	-	-	-	0	-	-	-	-	0	61	61	61	-	1
Total Suspended Solids	mg/L	50	30	-	-	-	43.33	ld	230	92.23	6	428	ld	1880	815.93	5	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Turbidity	NTU	-	-	-	-	-	83	83	83	-	1	300	300	300	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Inorganics																															
Chloride	mg/L	-	-	-	-	-	7	7	7	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	0	ld	0.01	0	6	0.01	ld	0.03	0.01	5	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Fluoride	mg/L	-	-	0.7	1.5	0.12	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	0.06	0.06	0.06	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrate and Nitrite	mg/L	-	-	-	-	-	0.06	0.06	0.06	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	ld	ld	ld	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Ammonia	mg/L	-	-	0.5	-	-	ld	ld	ld	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/L	-	-	-	-	-	0.01	06	06	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Sulfate	mg/L	-	-	250	-	-	ld	ld	ld	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Oils and greases	mg/L	5	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	33.60	33.6	33.6	-	1
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_21										SW_22										SW_23				
						Season:	dry					wet					dry					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	<u>CCME FAL SW</u> [8]																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	20	20	20	0	2	-	-	-	-	0	30	30	30	0	2	-	-	-	-	0	-	-	-	-	0
Colour	TCU	-	-	15	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	66	66	66	0	2	-	-	-	-	0	71	71	71	0	2	-	-	-	-	0	-	-	-	-	0
Dissolved Oxygen	mg/L	-	-	-	-	5.5	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	20	20	20	-	1	-	-	-	-	0	30	30	30	-	1	-	-	-	-	0	-	-	-	-	0
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	6.84	6.6	7.2	0.19	7	***<u>6.45</u>***	***<u>6</u>***	6.9	0.37	4	6.97	6.7	7.2	0.17	7	6.56	***<u>6.2</u>***	7	0.36	5	-	-	-	-	0
Temperature	ºC	40	-	18-30	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	48.33	40	60	7.53	6	82.50	40	190	71.82	4	43.33	20	70	17.51	6	48	40	60	8.37	5	-	-	-	-	0
Total Suspended Solids	mg/L	50	30	-	-	-	5	ld	22	8.92	6	4.50	ld	18	9	4	5	ld	12	5.62	6	1.20	ld	6	2.68	5	-	-	-	-	0
Turbidity	NTU	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Inorganics																															
Chloride	mg/L	-	-	-	-	-	5	5	5	0	2	-	-	-	-	0	5	5	5	0	2	-	-	-	-	0	-	-	-	-	0
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	0	ld	0.01	0	5	0.01	ld	0.03	0.02	4	0	ld	0.01	0	5	0	ld	0.02	0.01	5	-	-	-	-	0
Fluoride	mg/L	-	-	0.7	1.5	0.12	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	0.12	0.12	0.12	0	2	-	-	-	-	0	0.06	0.06	0.06	0	2	-	-	-	-	0	-	-	-	-	0
Nitrate and Nitrite	mg/L	-	-	-	-	-	0.12	0.12	0.12	0	2	-	-	-	-	0	0.06	0.06	0.06	0	2	-	-	-	-	0	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	ld	ld	ld	0	2	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0	-	-	-	-	0
Ammonia	mg/L	-	-	0.5	-	-	0.05	0.05	0.05	0	2	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/L	-	-	-	-	-	0.01	0.012	0.012	0	2	-	-	-	-	0	0.02	0.016	0.016	0	2	-	-	-	-	0	-	-	-	-	0
Sulfate	mg/L	-	-	250	-	-	10	10	10	0	2	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0	-	-	-	-	0
Oils and greases	mg/L	5	-	-	-	-	5.75	ld	15	7.23	4	ld	ld	ld	0	2	4.67	ld	14	8.08	3	ld	ld	ld	0	3	-	-	-	-	0
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_23					SW_24										SW_25									
						Season:	wet					dry					wet					dry					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	**Unit**	**Decreto 33-95** [3]	**MMER Max Grab** [4]	***CAPRE DW*** [5]	***WHO DW*** [6,7]	**CCME FAL SW** [8]																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	15.10	15.1	15.1	-	1	26	26	26	0	2	-	-	-	-	0	31	31	31	-	1	-	-	-	-	0
Colour	TCU	-	-	15	-	-	***25***	***25***	***25***	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	51	51	51	-	1	204.33	69	***475***	234.40	3	82	82	82	-	1	83	83	83	-	1	-	-	-	-	0
Dissolved Oxygen	mg/L	-	-	-	-	5.5	6.20	6.2	6.2	-	1	7.72	7.47	7.96	0.35	2	7.33	7.33	7.33	-	1	-	-	-	-	0	-	-	-	-	0
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	13.75	13.75	13.75	-	1	26	26	26	-	1	-	-	-	-	0	31	31	31	-	1	-	-	-	-	0
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	6.89	6.89	6.89	-	1	7.23	***6***	8.38	0.59	65	7.49	***6.1***	*9.24*	0.62	98	7.14	6.8	7.6	0.34	5	6.73	***6.1***	7.1	0.37	6
Temperature	ºC	40	-	18-30	-	-	23.60	23.6	23.6	-	1	27.03	24.7	29.2	2.25	3	30	30	30	-	1	-	-	-	-	0	-	-	-	-	0
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	41.76	41.76	41.76	-	1	58	50	68	6.93	6	52	40	70	13.04	5	66	60	70	5.48	5	76.67	60	120	24.22	6
Total Suspended Solids	mg/L	50	30	-	-	-	-	-	-	-	0	1	ld	6	2.45	6	41.60	ld	172	73.46	5	34.20	ld	160	70.38	5	15	ld	40	17.33	6
Turbidity	NTU	-	-	-	-	-	22.80	22.8	22.8	-	1	200	200	200	-	1	500	500	500	-	1	-	-	-	-	0	-	-	-	-	0
Inorganics																															
Chloride	mg/L	-	-	-	-	-	3.82	3.82	3.82	-	1	5	5	5	0	2	-	-	-	-	0	6	6	6	-	1	-	-	-	-	0
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	-	-	-	-	0	0.01	ld	0.02	0.01	6	0	ld	0.02	0.01	5	0	ld	0.01	0.01	4	0	ld	0.02	0.01	6
Fluoride	mg/L	-	-	0.7	1.5	0.12	0.06	0.06	0.06	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	ld	ld	ld	-	1	0.04	0.04	0.04	0	2	-	-	-	-	0	0.09	0.09	0.09	-	1	-	-	-	-	0
Nitrate and Nitrite	mg/L	-	-	-	-	-	-	-	-	-	0	0.04	0.04	0.04	0	2	-	-	-	-	0	0.09	0.09	0.09	-	1	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	ld	ld	ld	-	1	ld	ld	ld	0	2	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Ammonia	mg/L	-	-	0.5	-	-	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	0.01	0.012	0.012	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/L	-	-	-	-	-	-	-	-	-	0	0.01	06	06	0	2	-	-	-	-	0	0.02	0.018	0.018	-	1	-	-	-	-	0
Sulfate	mg/L	-	-	250	-	-	2.74	2.74	2.74	-	1	ld	ld	ld	0	2	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Oils and greases	mg/L	5	-	-	-	-	-	-	-	-	0	9.90	ld	31.6	14.95	4	1.33	ld	4	2.31	3	3.33	ld	10	5.77	3	ld	ld	ld	0	4
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_26										SW_27										SW_28				
						Season:	dry					wet					dry					wet					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	39	39	39	-	1
Colour	TCU	-	-	15	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	10	10	10	-	1
Conductivity	uS/cm	-	-	400	-	-	-	-	-	-	0	176	176	176	-	1	***446***	***446***	***446***	-	1	90.50	89	92	2.12	2	109	109	109	-	1
Dissolved Oxygen	mg/L	-	-	-	-	5.5	7.90	7.9	7.9	-	1	7.52	7.52	7.52	-	1	7.96	7.96	7.96	-	1	7.86	7.76	7.96	0.14	2	**5.10**	**5.1**	**5.1**	-	1
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	42.57	42.57	42.57	-	1
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	7.40	7.4	7.4	-	1	7.35	7.35	7.35	-	1	7.37	7.37	7.37	-	1	7.71	7.69	7.72	0.02	2	7.54	7.54	7.54	-	1
Temperature	ºC	40	-	18-30	-	-	28.60	28.6	28.6	-	1	30	30	30	-	1	27.10	27.1	27.1	-	1	27.90	27.8	28	0.14	2	21.60	21.6	21.6	-	1
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	65.48	65.48	65.48	-	1
Total Suspended Solids	mg/L	50	30	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Turbidity	NTU	-	-	-	-	-	-	-	-	-	0	940	940	940	-	1	250	250	250	-	1	175	160	190	21.21	2	3	3	3	-	1
Inorganics																															
Chloride	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	4.65	4.65	4.65	-	1
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	-	-	-	-	0	-	-	-	-	0	0.02	0.02	0.02	-	1	0.03	ld	0.05	0.04	2	-	-	-	-	0
Fluoride	mg/L	-	-	0.7	1.5	0.12	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0.06	0.06	0.06	-	1
Nitrate	mg/L	-	-	50	50	13	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0.39	0.39	0.39	-	1
Nitrate and Nitrite	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	03	03	-	1
Ammonia	mg/L	-	-	0.5	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0.05	0.048	0.048	-	1
Phosphorus	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Sulfate	mg/L	-	-	250	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	1.21	1.21	1.21	-	1
Oils and greases	mg/L	5	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_29										SW_30										SW_31				
						Season:	dry					wet					dry					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	**Unit**	**Decreto 33-95** [3]	**MMER Max Grab** [4]	***CAPRE DW*** [5]	***WHO DW*** [6,7]	**CCME FAL SW** [8]																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	25	25	25	-	1	-	-	-	-	0	25	25	25	-	1
Colour	TCU	-	-	15	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	-	-	-	-	0	-	-	-	-	0	121	79	163	59.40	2	79	79	79	-	1	79	79	79	-	1
Dissolved Oxygen	mg/L	-	-	-	-	5.5	-	-	-	-	0	-	-	-	-	0	7.96	7.96	7.96	-	1	7.96	7.96	7.96	-	1	-	-	-	-	0
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	25	25	25	-	1
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	7.23	***6***	8.5	0.61	133	7.54	***6***	*12.23*	0.70	370	7.33	7	7.65	0.46	2	7.64	7.64	7.64	-	1	7.12	6.78	8.18	0.42	10
Temperature	ºC	40	-	18-30	-	-	25.41	22.7	28	2.11	15	26.56	25.2	28.4	0.96	13	27.10	27.1	27.1	-	1	27.90	27.9	27.9	-	1	24.93	23.5	27.5	1.79	4
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	50.37	ld	128	42.50	19	39.54	ld	87	27.47	14	-	-	-	-	0	-	-	-	-	0	52.20	ld	189	48.95	15
Total Suspended Solids	mg/L	50	30	-	-	-	5.10	ld	78	17.84	20	0.04	ld	0.4	0.11	14	-	-	-	-	0	-	-	-	-	0	7.26	ld	100	24.83	16
Turbidity	NTU	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	750	750	750	-	1	290	290	290	-	1	-	-	-	-	0
Inorganics																															
Chloride	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	5	5	5	-	1	-	-	-	-	0	5	5	5	-	1
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	0.01	ld	***0.098***	0.02	19	0.01	ld	***0.07***	0.02	17	ld	ld	ld	0	2	***0.14***	***0.14***	***0.14***	-	1	0	ld	***0.054***	0.01	15
Fluoride	mg/L	-	-	0.7	1.5	0.12	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	-	-	-	-	0	-	-	-	-	0	0.03	0.03	0.03	-	1	-	-	-	-	0	0.03	0.03	0.03	-	1
Nitrate and Nitrite	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	0.03	0.03	0.03	-	1	-	-	-	-	0	0.03	0.03	0.03	-	1
Nitrite	mg/L	-	-	0.1	3	0.06	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	-	1
Ammonia	mg/L	-	-	0.5	-	-	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	-	1
Ammonium	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	-	1
Phosphorus	mg/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	7	0.01	0.011	0.011	-	1	-	-	-	-	0	0.01	ld	0.011	0.01	2
Sulfate	mg/L	-	-	250	-	-	-	-	-	-	0	-	-	-	-	0	10	10	10	-	1	-	-	-	-	0	10	10	10	-	1
Oils and greases	mg/L	5	-	-	-	-	22.08	2.4	44	14.79	19	18.39	ld	49	13.07	16	-	-	-	-	0	-	-	-	-	0	16.97	ld	46.8	19.46	12
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_31					SW_32										SW_33					SW_34				
						Season:	wet					dry					wet					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	**Unit**	**Decreto 33-95** [3]	**MMER Max Grab** [4]	***CAPRE DW*** [5]	***WHO DW*** [6,7]	**CCME FAL SW** [8]																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	26.50	26.5	26.5	-	1	-	-	-	-	0	-	-	-	-	0	45.90	45.9	45.9	-	1	-	-	-	-	0
Colour	TCU	-	-	15	-	-	***40***	***40***	***40***	-	1	-	-	-	-	0	-	-	-	-	0	***70***	***70***	***70***	-	1	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	88.50	88.5	88.5	-	1	-	-	-	-	0	-	-	-	-	0	122.10	122.1	122.1	-	1	-	-	-	-	0
Dissolved Oxygen	mg/L	-	-	-	-	5.5	**4.60**	**4.6**	**4.6**	-	1	-	-	-	-	0	-	-	-	-	0	6.60	6.6	6.6	-	1	-	-	-	-	0
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	24.60	24.6	24.6	-	1	-	-	-	-	0	-	-	-	-	0	37.38	37.38	37.38	-	1	-	-	-	-	0
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	7.05	6.5	8.16	0.46	11	7.44	7.2	7.7	0.21	5	7.03	6.7	7.2	0.22	4	7.33	7.33	7.33	-	1	-	-	-	-	0
Temperature	ºC	40	-	18-30	-	-	25.47	23.8	27.2	1.31	6	-	-	-	-	0	-	-	-	-	0	23.30	23.3	23.3	-	1	-	-	-	-	0
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	60.23	ld	248.5	60.74	14	136	130	160	13.42	5	112.50	100	120	9.57	4	90.60	90.6	90.6	-	1	-	-	-	-	0
Total Suspended Solids	mg/L	50	30	-	-	-	15.57	ld	106	32.78	13	4.40	ld	16	6.99	5	2.50	ld	10	5	4	-	-	-	-	0	-	-	-	-	0
Turbidity	NTU	-	-	-	-	-	161	161	161	-	1	-	-	-	-	0	-	-	-	-	0	45.40	45.4	45.4	-	1	-	-	-	-	0
Inorganics																															
Chloride	mg/L	-	-	-	-	-	4.79	4.79	4.79	-	1	-	-	-	-	0	-	-	-	-	0	6.23	6.23	6.23	-	1	-	-	-	-	0
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	0	ld	0.02	0.01	15	ld	ld	ld	0	5	*0.20*	ld	*0.8*	0.40	4	-	-	-	-	0	-	-	-	-	0
Fluoride	mg/L	-	-	0.7	1.5	0.12	0.07	0.07	0.07	-	1	-	-	-	-	0	-	-	-	-	0	**0.13**	**0.13**	**0.13**	-	1	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	0.64	0.64	0.64	-	1	-	-	-	-	0	-	-	-	-	0	0.39	0.39	0.39	-	1	-	-	-	-	0
Nitrate and Nitrite	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	0.01	0.01	0.01	-	1	-	-	-	-	0	-	-	-	-	0	0.01	0.01	0.01	-	1	-	-	-	-	0
Ammonia	mg/L	-	-	0.5	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	0.02	0.019	0.019	-	1	-	-	-	-	0	-	-	-	-	0	0.05	0.05	0.05	-	1	-	-	-	-	0
Phosphorus	mg/L	-	-	-	-	-	0.18	ld	0.53	0.31	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Sulfate	mg/L	-	-	250	-	-	3.58	3.58	3.58	-	1	-	-	-	-	0	-	-	-	-	0	1.88	1.88	1.88	-	1	-	-	-	-	0
Oils and greases	mg/L	5	-	-	-	-	20.69	1.6	64	20.22	9	0.75	ld	3	1.50	4	2	ld	4	2.83	2	-	-	-	-	0	-	-	-	-	0
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_35										SW_36										SW_37				
						Season:	dry					wet					dry					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Physical Tests																															
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	62	62	62	0	2	35	35	35	-	1	-	-	-	-	0	56	56	56	-	1	-	-	-	-	ld
Colour	TCU	-	-	15	-	-	-	-	-	-	0	40	40	40	-	1	-	-	-	-	0	***100***	***100***	***100***	-	1	-	-	-	-	ld
Conductivity	uS/cm	-	-	400	-	-	108	108	108	0	2	122.70	99.2	158	31.13	3	-	-	-	-	0	142.10	142.1	142.1	-	1	-	-	-	-	ld
Dissolved Oxygen	mg/L	-	-	-	-	5.5	-	-	-	-	0	**5.30**	**5.3**	**5.3**	-	1	-	-	-	-	0	**4.80**	**4.8**	**4.8**	-	1	-	-	-	-	ld
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	62	62	62	-	1	29.95	29.95	29.95	-	1	-	-	-	-	0	43.90	43.9	43.9	-	1	-	-	-	-	ld
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	7.30	6.8	8	0.39	8	6.92	6.79	7.3	0.21	7	-	-	-	-	0	7.16	7.16	7.16	-	1	7.23	6.9	7.5	0.28	4
Temperature	ºC	40	-	18-30	-	-	28	28	28	-	1	25.40	22.8	26.9	2.26	3	-	-	-	-	0	23	23	23	-	1	-	-	-	-	ld
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	75	60	90	10.49	6	77.46	70	90	8.29	5	-	-	-	-	0	101.50	101.5	101.5	-	1	95	90	100	5.77	4
Total Suspended Solids	mg/L	50	30	-	-	-	4	0	16	6.69	6	16.50	0	38	15.78	4	-	-	-	-	0	-	-	-	-	0	11	ld	36	17.09	4
Turbidity	NTU	-	-	-	-	-	5	5	5	-	1	371	371	371	-	1	-	-	-	-	0	47.20	47.2	47.2	-	1	-	-	-	-	ld
Inorganics																															
Chloride	mg/L	-	-	-	-	-	7	7	7	0	2	5.85	5.85	5.85	-	1	-	-	-	-	0	5.51	5.51	5.51	-	1	-	-	-	-	ld
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	0	0	0.01	0	6	0	0	0.02	0.01	8	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	ld	4
Fluoride	mg/L	-	-	0.7	1.5	0.12	-	-	-	-	0	0.10	0.1	0.1	-	1	-	-	-	-	0	**0.24**	**0.24**	**0.24**	-	1	-	-	-	-	ld
Nitrate	mg/L	-	-	50	50	13	0.29	0	0.88	0.51	3	0.53	0.53	0.53	-	1	-	-	-	-	0	0.25	0.25	0.25	-	1	-	-	-	-	ld
Nitrate and Nitrite	mg/L	-	-	-	-	-	0	0	0	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Nitrite	mg/L	-	-	0.1	3	0.06	0	0	0	0	2	0.02	0.016	0.016	-	1	-	-	-	-	0	0.02	0.02	0.02	-	1	-	-	-	-	ld
Ammonia	mg/L	-	-	0.5	-	-	0	0	0	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Ammonium	mg/L	-	-	-	-	-	-	-	-	-	0	0.06	0.057	0.057	-	1	-	-	-	-	0	0.02	0.022	0.022	-	1	-	-	-	-	ld
Phosphorus	mg/L	-	-	-	-	-	0.08	0.077	0.077	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Sulfate	mg/L	-	-	250	-	-	0	0	0	0	2	3.82	3.82	3.82	-	1	-	-	-	-	0	0.38	0.38	0.38	-	1	-	-	-	-	ld
Oils and greases	mg/L	5	-	-	-	-	1	0	4	2	4	1.25	0	5	2.50	4	-	-	-	-	0	-	-	-	-	0	2.25	ld	5	2.63	4
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	1.25	1.25	1.25	-	1	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	27.07	27.07	27.07	-	1	-	-	-	-	0

Table D-1-1. Surface Water Results: Physical Tests and Inorganics

						Sample ID:	SW_37					SW_38					SW_39				
						Season:	wet					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	**Unit**	**Decreto 33-95** [3]	**MMER Max Grab** [4]	***CAPRE DW*** [5]	***WHO DW*** [6,7]	**CCME FAL SW** [8]															
Physical Tests																					
Alkalinity, Total (CaCO3)	mg/L	-	-	-	-	-	89	89	89	-	1	86	86	86	-	1	-	-	-	-	0
Colour	TCU	-	-	15	-	-	50	50	50	-	1	***25***	***25***	***25***	-	1	-	-	-	-	0
Conductivity	uS/cm	-	-	400	-	-	158.17	93.5	213	60.35	3	270	270	270	-	1	***471***	***471***	***471***	-	1
Dissolved Oxygen	mg/L	-	-	-	-	5.5	**5**	**5**	**5**	-	1	**1.86**	**1.86**	**1.86**	-	1	-	-	-	-	0
Hardness, Total (CaCO3)	mg/L	-	-	400	-	-	81.18	81.18	81.18	-	1	65.65	65.65	65.65	-	1	-	-	-	-	0
pH [9]	pH	6-9		6.5-8.5	-	6.5-9	6.99	6.6	7.59	0.32	7	7.53	7.53	7.53	-	1	7.62	7.62	7.62	-	1
Temperature	ºC	40	-	18-30	-	-	24.27	21.1	26.1	2.75	3	23.10	23.1	23.1	-	1	27.30	27.3	27.3	-	1
Total Dissolved Solids	mg/L	1 [10]	-	1000	-	-	118.30	100	151.48	19.85	5	160.60	160.6	160.6	-	1	-	-	-	-	0
Total Suspended Solids	mg/L	50	30	-	-	-	30	ld	54	27.18	4	-	-	-	-	0	-	-	-	-	0
Turbidity	NTU	-	-	-	-	-	22.30	22.3	22.3	-	1	17.40	17.4	17.4	-	1	-	-	-	-	0
Inorganics																					
Chloride	mg/L	-	-	-	-	-	9.74	9.74	9.74	-	1	18.64	18.64	18.64	-	1	-	-	-	-	0
Cyanide + Thiocyanate	mg/L	0.1	-	0.05	-	-	0	ld	0.03	0.01	7	-	-	-	-	0	-	-	-	-	0
Fluoride	mg/L	-	-	0.7	1.5	0.12	0.04	0.04	0.04	-	1	0.09	0.09	0.09	-	1	-	-	-	-	0
Nitrate	mg/L	-	-	50	50	13	1.34	1.34	1.34	-	1	2.82	2.82	2.82	-	1	-	-	-	-	0
Nitrate and Nitrite	mg/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Nitrite	mg/L	-	-	0.1	3	0.06	0.01	0.01	0.01	-	1	0.01	07	07	-	1	-	-	-	-	0
Ammonia	mg/L	-	-	0.5	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Ammonium	mg/L	-	-	-	-	-	0.08	0.079	0.079	-	1	0.05	0.047	0.047	-	1	-	-	-	-	0
Phosphorus	mg/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Sulfate	mg/L	-	-	250	-	-	3.17	3.17	3.17	-	1	5.73	5.73	5.73	-	1	-	-	-	-	0
Oils and greases	mg/L	5	-	-	-	-	22.25	ld	89	44.50	4	-	-	-	-	0	-	-	-	-	0
BOD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
COD	mg/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_01					SW_02										SW_03									
						Season:	wet					dry					wet					dry					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	CAPRE DW [5]	WHO DW [6,7]	CCME FAL SW [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]	***1481.70***	***368.4***	***2595***	1574.44	2	**163.33**	ld	**250**	141.54	3	***3252.50***	80	***8510***	3753.04	4	23.64	ld	**260**	78.39	11	***4777.78***	ld	***19600***	6360.75	9
Antimony	ug/L	-	-	-	20	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Arsenic	ug/L	-	1000	-	10	5	0.97	ld	1.94	1.37	2	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	2	ld	ld	ld	0	3
Barium	ug/L	2000	-	-	700	-	-	-	-	-	0	29.50	28	31	2.12	2	37.90	26	44.6	8.65	4	7.64	ld	50	17.36	11	34.22	ld	120	52.49	9
Beryllium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Bismuth	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Boron	ug/L	-	-	-	2400	1500	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	**3**	**3**	**3**	-	1	ld	ld	ld	0	2	**1.78**	ld	**5**	2.37	4	ld	ld	ld	0	11	ld	ld	ld	0	9
Calcium	mg/L	-	-	100	-	-	1.97	1.97	1.97	-	1	-	-	-	-	0	-	-	-	-	0	6.45	4.4	8.5	2.90	2	19.75	13.6	27.25	6.93	3
Chromium	ug/L	1000	-	-	50	1	ld	ld	ld	-	1	ld	ld	ld	0	4	**33.07**	ld	**230**	86.84	7	ld	ld	ld	0	20	ld	ld	ld	0	17
Cobalt	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	2	36.67	ld	100	55.08	3
Copper	ug/L	500	600	2000	2000	2-4 [10]	10.18	10.18	10.18	-	1	ld	ld	ld	0	2	5	ld	10	5.77	4	ld	ld	ld	0	11	192.22	ld	600	226.92	9
Iron	ug/L	-	-	300	-	300	1.45	1.45	1.45	-	1	-	-	-	-	0	-	-	-	-	0	0.50	0.14	0.86	0.51	2	1.88	ld	3.75	2.65	2
Lead	ug/L	2000	400	-	10	1-7 [13]	ld	ld	ld	0	2	**16.67**	ld	**50**	28.87	3	0.31	ld	1.23	0.61	4	ld	ld	ld	0	11	ld	ld	ld	0	9
Lithium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Magnesium	mg/L	-	-	50	-	-	1.19	1.19	1.19	-	1	-	-	-	-	0	-	-	-	-	0	3.15	2.7	3.6	0.64	2	14.91	3.91	31.22	14.41	3
Manganese	ug/L	2000	-	500	-	-	69.03	45.05	93	33.91	2	138.50	93	184	64.35	2	304	ld	648	232.37	5	2531.36	ld	9110	3278.85	11	6865.56	ld	16860	6000.43	9
Mercury	ug/L	2	-	-	6	0.026	ld	ld	ld	0	2	0.01	ld	0.02	0.01	3	ld	ld	ld	0	4	ld	ld	ld	0	7	ld	ld	ld	0	5
Molybdenum	ug/L	-	-	-	-	73	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Nickel	ug/L	1000	1000	-	70	25-150 [14]	10.89	10.89	10.89	-	1	ld	ld	ld	0	2	5.15	ld	20.6	10.30	4	ld	ld	ld	0	11	44.44	ld	200	88.19	9
Potassium	mg/L	-	-	10	-	-	0.98	0.98	0.98	-	1	-	-	-	-	0	-	-	-	-	0	0.50	ld	1	0.71	2	0.21	ld	0.63	0.36	3
Selenium	ug/L	-	-	-	40	1	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	2	ld	ld	ld	0	3
Silicon	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	14400	14400	14400	-	1	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	-	-	-	-	0	ld	ld	ld	0	2	**14.33**	ld	**43**	24.83	3	ld	ld	ld	0	11	***713.33***	ld	***6420***	2140	9
Sodium	mg/L	-	-	200	-	-	4.01	4.01	4.01	-	1	-	-	-	-	0	-	-	-	-	0	6.75	5.5	8	1.77	2	9.91	9.49	10.32	0.59	2
Strontium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	54	54	54	-	1	93.67	71	120	24.70	3
Thallium	ug/L	-	-	-	-	0.8	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Tin	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Titanium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	17.33	ld	52	30.02	3
Uranium	ug/L	-	-	-	30	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	3
Vanadium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Zinc	ug/L	1000	1000	3000	-	30	**116.18**	**116.18**	**116.18**	-	1	5	ld	10	7.07	2	20	ld	30	17.32	3	10	ld	**60**	18.44	11	**226.91**	ld	**870**	341.85	9
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	2

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_04										SW_05										SW_06				
						Season:	dry					wet					dry					wet					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]	42.50	ld	***470***	117.56	16	***969.26***	ld	*4430*	1318.89	16	***667.06***	ld	*4000*	1153.52	17	*162686*	ld	*2390000*	616196	15	-	-	-	-	0
Antimony	ug/L	-	-	-	20	-	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0
Arsenic	ug/L	-	1000	-	10	5	ld	ld	ld	0	2	0.71	ld	3.57	1.60	5	ld	ld	ld	0	3	0.25	ld	1	0.50	4	-	-	-	-	0
Barium	ug/L	2000	-	-	700	-	12.40	ld	48	17.49	15	16.13	ld	58	19.33	15	41.44	ld	340	80.23	18	***1208.27***	ld	*17300*	4452.04	15	-	-	-	-	0
Beryllium	ug/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0
Bismuth	ug/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0
Boron	ug/L	-	-	-	2400	1500	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	ld	ld	ld	0	15	ld	ld	ld	0	13	ld	ld	ld	0	16	**43.63**	ld	600	160.15	14	-	-	-	-	0
Calcium	mg/L	-	-	100	-	-	5	3.7	6.3	1.84	2	8.79	3.35	11.54	3.71	4	4.13	4.1	4.2	0.06	3	11.01	9.63	12.03	1.24	3	-	-	-	-	0
Chromium	ug/L	1000	-	-	50	1	ld	ld	ld	0	29	**1.08**	ld	**27**	5.40	25	0.34	ld	**10**	1.86	29	**37.73**	ld	**1000**	192.34	27	-	-	-	-	0
Cobalt	ug/L	-	-	-	-	-	ld	ld	ld	0	2	2.47	ld	7.4	4.27	3	ld	ld	ld	0	3	ld	ld	ld	0	3	-	-	-	-	0
Copper	ug/L	500	600	2000	2000	2-4 [10]	ld	ld	ld	0	15	ld	ld	ld	0	13	0.63	ld	10	2.50	16	422.63	ld	5000	1328.70	14	-	-	-	-	0
Iron	ug/L	-	-	300	-	300	0.26	002	0.41	0.23	3	5.16	ld	14.89	8.43	3	0.99	0.16	1.6	0.74	3	0.67	ld	1.33	0.94	2	-	-	-	-	0
Lead	ug/L	2000	400	-	10	1-7 [13]	ld	ld	ld	0	16	0.37	ld	**5.22**	1.40	14	**2.50**	ld	**40**	10	16	**3.08**	ld	**40**	11.09	13	0.69	0.69	0.69	-	1
Lithium	ug/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0
Magnesium	mg/L	-	-	50	-	-	2.30	1.9	2.7	0.57	2	3.55	3.08	4.42	0.60	4	2.50	2.1	3.2	0.61	3	5.63	4.74	6.08	0.77	3	-	-	-	-	0
Manganese	ug/L	2000	-	500	-	-	52.73	ld	171	54.63	15	91.06	ld	260	69.38	16	882.71	159	3950	880.72	17	11123	460	115000	29980	15	-	-	-	-	0
Mercury	ug/L	2	-	-	6	0.026	ld	ld	ld	0	12	0.06	ld	0.62	0.19	11	ld	ld	ld	0	12	0.37	ld	3.3	1.10	9	0.43	0.43	0.43	-	1
Molybdenum	ug/L	-	-	-	-	73	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0
Nickel	ug/L	1000	1000	-	70	25-150 [14]	ld	ld	ld	0	15	ld	ld	ld	0	13	0.63	ld	10	2.50	16	86.97	ld	1000	268.10	14	-	-	-	-	0
Potassium	mg/L	-	-	10	-	-	0.50	ld	1	0.71	2	2.53	ld	5.41	2.29	4	0.87	0.5	1.1	0.32	3	1.13	ld	3.39	1.96	3	-	-	-	-	0
Selenium	ug/L	-	-	-	40	1	ld	ld	ld	0	2	ld	ld	ld	0	3	ld	ld	ld	0	3	ld	ld	ld	0	3	-	-	-	-	0
Silicon	ug/L	-	-	-	-	-	13100	13100	13100	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	**0.38**	ld	**6**	1.50	16	ld	ld	ld	0	13	**0.63**	ld	**10**	2.50	16	**76.92**	ld	1000	277.35	13	-	-	-	-	0
Sodium	mg/L	-	-	200	-	-	5.95	4.9	7	1.48	2	14.89	8.99	26.47	10.03	3	4.37	3.2	5	1.01	3	8.36	8.24	8.47	0.16	2	-	-	-	-	0
Strontium	ug/L	-	-	-	-	-	43	43	43	-	1	35	ld	53	30.32	3	-	-	-	-	0	53.33	50	57	3.51	3	-	-	-	-	0
Thallium	ug/L	-	-	-	-	0.8	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0
Tin	ug/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0
Titanium	ug/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0
Uranium	ug/L	-	-	-	30	-	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0
Vanadium	ug/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0
Zinc	ug/L	1000	1000	3000	-	30	6.88	ld	**40**	10.78	16	24.32	ld	**110**	34.70	13	20.63	ld	**80**	27.68	16	**89.76**	ld	**630**	205.29	13	-	-	-	-	0
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_06					SW_07										SW_08									
						Season:	dry					wet					dry					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]	-	-	-	-	0	69.38	ld	**410**	134.58	16	**2328.13**	ld	**8830**	3259.18	16	60	ld	300	134.16	5	ld	ld	ld	0	4
Antimony	ug/L	-	-	-	20	-	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	2
Arsenic	ug/L	-	1000	-	10	5	-	-	-	-	0	ld	ld	ld	0	2	ld	ld	ld	0	4	ld	ld	ld	-	1	ld	ld	ld	0	2
Barium	ug/L	2000	-	-	700	-	-	-	-	-	0	34.19	ld	340	83.30	16	41.19	ld	120	40.48	16	7	ld	35	15.65	5	14.50	ld	58	29	4
Beryllium	ug/L	-	-	-	-	-	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	2
Bismuth	ug/L	-	-	-	-	-	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	2
Boron	ug/L	-	-	-	2400	1500	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	-	-	-	-	0	ld	ld	ld	0	16	**0.80**	ld	**6**	2.11	15	ld	ld	ld	0	5	ld	ld	ld	0	4
Calcium	mg/L	-	-	100	-	-	-	-	-	-	0	6.55	4.2	8.9	3.32	2	11.64	10.4	13.13	1.38	3	4.10	4.1	4.1	-	1	10.99	9.33	12.65	2.35	2
Chromium	ug/L	1000	-	-	50	1	-	-	-	-	0	ld	ld	ld	0	30	**1.15**	ld	**13**	3.37	27	ld	ld	ld	0	9	ld	ld	ld	0	7
Cobalt	ug/L	-	-	-	-	-	-	-	-	-	0	10	ld	20	14.14	2	ld	ld	ld	0	3	ld	ld	ld	-	1	ld	ld	ld	0	2
Copper	ug/L	500	600	2000	2000	2-4 [10]	-	-	-	-	0	ld	ld	ld	0	16	5.33	ld	40	14.07	15	ld	ld	ld	0	5	ld	ld	ld	0	4
Iron	ug/L	-	-	300	-	300	-	-	-	-	0	5.08	1.6	8.56	4.92	2	0.44	ld	0.88	0.62	2	1.20	1.2	1.2	-	1	0.28	ld	0.56	0.40	2
Lead	ug/L	2000	400	-	10	1-7 [13]	ld	ld	ld	-	1	0.07	ld	**1.26**	0.31	17	ld	ld	ld	0	15	ld	ld	ld	0	5	ld	ld	ld	0	4
Lithium	ug/L	-	-	-	-	-	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	2
Magnesium	mg/L	-	-	50	-	-	-	-	-	-	0	3.10	2.2	4	1.27	2	3.32	3.11	3.68	0.31	3	2.10	2.1	2.1	-	1	3.93	3.23	4.62	0.98	2
Manganese	ug/L	2000	-	500	-	-	-	-	-	-	0	528.31	20	4800	1152.34	16	388.19	ld	1010	275.62	16	132	ld	280	132.93	5	178.50	94	390	141.88	4
Mercury	ug/L	2	-	-	6	0.026	0.14	0.14	0.14	-	1	0.02	ld	0.21	0.06	13	0.05	ld	0.52	0.16	11	ld	ld	ld	-	1	ld	ld	ld	-	1
Molybdenum	ug/L	-	-	-	-	73	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	2
Nickel	ug/L	1000	1000	-	70	25-150 [14]	-	-	-	-	0	0.63	ld	10	2.50	16	ld	ld	ld	0	14	ld	ld	ld	0	5	ld	ld	ld	0	4
Potassium	mg/L	-	-	10	-	-	-	-	-	-	0	0.55	ld	1.1	0.78	2	1.98	ld	5.08	2.72	3	1	1	1	-	1	1.06	ld	2.11	1.49	2
Selenium	ug/L	-	-	-	40	1	-	-	-	-	0	ld	ld	ld	0	2	ld	ld	ld	0	3	ld	ld	ld	-	1	ld	ld	ld	0	2
Silicon	ug/L	-	-	-	-	-	-	-	-	-	0	6730	6730	6730	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	-	-	-	-	0	**160.88**	ld	**2560**	639.78	16	ld	ld	ld	0	14	ld	ld	ld	0	5	ld	ld	ld	0	4
Sodium	mg/L	-	-	200	-	-	-	-	-	-	0	6.50	5	8	2.12	2	6.71	6.46	6.95	0.35	2	4.90	4.9	4.9	-	1	6.35	6.35	6.35	-	1
Strontium	ug/L	-	-	-	-	-	-	-	-	-	0	66	66	66	-	1	34.67	ld	53	30.04	3	-	-	-	-	0	**76**	**53**	99	32.53	2
Thallium	ug/L	-	-	-	-	0.8	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	2
Tin	ug/L	-	-	-	-	-	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	2
Titanium	ug/L	-	-	-	-	-	-	-	-	-	0	ld	ld	ld	-	1	20	ld	60	34.64	3	-	-	-	-	0	ld	ld	ld	0	2
Uranium	ug/L	-	-	-	30	-	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	2
Vanadium	ug/L	-	-	-	-	-	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3	-	-	-	-	0	ld	ld	ld	0	2
Zinc	ug/L	1000	1000	3000	-	30	-	-	-	-	0	**30.63**	ld	**310**	76.46	16	20.94	ld	**80**	30.04	14	4	ld	20	8.94	5	18.50	ld	64	30.70	4
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0	ld	ld	ld	-	1

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_09										SW_10					SW_11									
						Season:	dry					wet					dry					dry					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]	ld	ld	ld	-	1	**508.20**	**508.2**	**508.2**	-	1	60	60	60	-	1	45.29	ld	**330**	94.08	17	**349.38**	ld	**2770**	815.51	16
Antimony	ug/L	-	-	-	20	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Arsenic	ug/L	-	1000	-	10	5	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	-	1	ld	ld	ld	0	3	ld	ld	ld	0	4
Barium	ug/L	2000	-	-	700	-	-	-	-	-	0	-	-	-	-	0	10	10	10	-	1	5.41	ld	22	7.41	17	33.32	ld	197	52.48	16
Beryllium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Bismuth	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Boron	ug/L	-	-	-	2400	1500	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	**0.24**	ld	**4**	0.97	17	ld	ld	ld	0	13
Calcium	mg/L	-	-	100	-	-	-	-	-	-	0	9.92	9.92	9.92	-	1	3.70	3.7	3.7	-	1	2.45	2.3	2.74	0.25	3	7.68	3.5	10.21	3.65	3
Chromium	ug/L	1000	-	-	50	1	ld	ld	ld	-	1	ld	ld	ld	-	1	ld	ld	ld	-	1	ld	ld	ld	0	31	0.08	ld	**2**	0.39	26
Cobalt	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3	ld	ld	ld	0	3
Copper	ug/L	500	600	2000	2000	2-4 [10]	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	2.94	ld	50	12.13	17	1.43	ld	20	5.35	14
Iron	ug/L	-	-	300	-	300	ld	ld	ld	-	1	2.90	2.9	2.9	-	1	0.41	0.41	0.41	-	1	0.59	0.45	0.87	0.24	3	0.57	ld	1.13	0.80	2
Lead	ug/L	2000	400	-	10	1-7 [13]	ld	ld	ld	-	1	ld	ld	ld	-	1	ld	ld	ld	-	1	**510.56**	ld	**9170**	2161.12	18	**6114.29**	ld	**85600**	22878	14
Lithium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Magnesium	mg/L	-	-	50	-	-	-	-	-	-	0	3.13	3.13	3.13	-	1	1.90	1.9	1.9	-	1	1.60	1.5	1.8	0.17	3	2.67	2.42	2.97	0.28	3
Manganese	ug/L	2000	-	500	-	-	-	-	-	-	0	351	351	351	-	1	110	110	110	-	1	156.59	ld	1100	276.32	17	182.69	ld	1030	259.91	16
Mercury	ug/L	2	-	-	6	0.026	ld	ld	ld	-	1	ld	ld	ld	0	2	ld	ld	ld	-	1	ld	ld	ld	0	14	34.55	ld	290	88.92	11
Molybdenum	ug/L	-	-	-	-	73	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Nickel	ug/L	1000	1000	-	70	25-150 [14]	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	0.59	ld	10	2.43	17	4.47	ld	50	13.34	15
Potassium	mg/L	-	-	10	-	-	-	-	-	-	0	1.68	1.68	1.68	-	1	1	1	1	-	1	0.27	ld	0.4	0.23	3	0.41	ld	1.22	0.70	3
Selenium	ug/L	-	-	-	40	1	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3	ld	ld	ld	0	3
Silicon	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	5320	5320	5320	-	1	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	ld	ld	ld	-	1	-	-	-	-	0	**6**	**6**	**6**	-	1	**98.82**	ld	**1680**	407.46	17	**4.77**	ld	**62**	17.20	13
Sodium	mg/L	-	-	200	-	-	-	-	-	-	0	9.01	9.01	9.01	-	1	4.90	4.9	4.9	-	1	4.33	4	4.5	0.29	3	7.41	6.97	7.85	0.62	2
Strontium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	16	16	16	-	1	7.67	ld	23	13.28	3
Thallium	ug/L	-	-	-	-	0.8	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Tin	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Titanium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Uranium	ug/L	-	-	-	30	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	3
Vanadium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Zinc	ug/L	1000	1000	3000	-	30	ld	ld	ld	-	1	-	-	-	-	0	10	10	10	-	1	22.94	ld	**230**	55.09	17	18.77	ld	**120**	35.26	13
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	2

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_12										SW_13					SW_14									
						Season:	dry					wet					dry					dry					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]	**35250**	**1500**	**69000**	47730	2	-	-	-	-	0	-	-	-	-	0	123.53	ld	1300	314.50	17	2458.75	ld	17600	4699.77	16
Antimony	ug/L	-	-	-	20	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Arsenic	ug/L	-	1000	-	10	5	**13**	2	**24**	15.56	2	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	0	3	ld	ld	ld	0	5
Barium	ug/L	2000	-	-	700	-	393	96	690	420	2	-	-	-	-	0	-	-	-	-	0	16.47	ld	48	18.47	17	46.73	ld	290	70.46	17
Beryllium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Bismuth	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Boron	ug/L	-	-	-	2400	1500	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	**3.50**	ld	**7**	4.95	2	-	-	-	-	0	-	-	-	-	0	**0.24**	ld	**4**	0.97	17	ld	ld	ld	0	15
Calcium	mg/L	-	-	100	-	-	7.30	5.2	9.4	2.97	2	3.94	3.94	3.94	-	1	-	-	-	-	0	5.87	5.4	6.81	0.81	3	11.59	10.69	12.46	0.89	3
Chromium	ug/L	1000	-	-	50	1	**20**	ld	**40**	28.28	2	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	31	0.76	ld	**8**	2.28	29
Cobalt	ug/L	-	-	-	-	-	30	ld	60	42.43	2	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	3	1.70	ld	5.1	2.94	3
Copper	ug/L	500	600	2000	2000	2-4 [10]	315	10	620	431.34	2	-	-	-	-	0	-	-	-	-	0	0.59	ld	10	2.43	17	30.07	ld	330	85.05	15
Iron	ug/L	-	-	300	-	300	51.35	2.7	100	68.80	2	0.93	0.93	0.93	-	1	-	-	-	-	0	0.57	0.4	0.66	0.15	3	0.26	ld	0.51	0.36	2
Lead	ug/L	2000	400	-	10	1-7 [13]	**564.37**	ld	**2470**	1074	5	**346496**	ld	**1968000**	794871	6	-	-	-	-	0	**191.68**	ld	**3740**	835.27	20	**150131**	ld	**2986000**	667505	20
Lithium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Magnesium	mg/L	-	-	50	-	-	2.30	2.1	2.5	0.28	2	2.75	2.75	2.75	-	1	-	-	-	-	0	2.70	2.6	2.9	0.17	3	3.68	3.29	4.37	0.60	3
Manganese	ug/L	2000	-	500	-	-	2090	680	3500	1994	2	-	-	-	-	0	-	-	-	-	0	66.71	ld	200	49.64	17	1008.93	ld	12470	3175	15
Mercury	ug/L	2	-	-	6	0.026	0.12	ld	0.6	0.27	5	96	ld	280	115.24	5	-	-	-	-	0	0.06	ld	0.36	0.12	16	76.30	ld	1000	252.36	16
Molybdenum	ug/L	-	-	-	-	73	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Nickel	ug/L	1000	1000	-	70	25-150 [14]	10	ld	20	14.14	2	-	-	-	-	0	-	-	-	-	0	0.59	ld	10	2.43	17	1.16	ld	18.6	4.65	16
Potassium	mg/L	-	-	10	-	-	5.05	1.2	8.9	5.44	2	0.88	0.88	0.88	-	1	-	-	-	-	0	0.93	ld	1.4	0.81	3	0.96	ld	2.87	1.66	3
Selenium	ug/L	-	-	-	40	1	2	1	3	1.41	2	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	3	ld	ld	ld	0	3
Silicon	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	11800	11800	11800	-	1	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	**25**	ld	**50**	35.36	2	-	-	-	-	0	-	-	-	-	0	112.65	ld	1910	463.17	17	6.07	ld	91	23.50	15
Sodium	mg/L	-	-	200	-	-	8.30	5.6	11	3.82	2	6.24	6.24	6.24	-	1	-	-	-	-	0	6.47	6.2	7	0.46	3	14.42	8.26	20.58	8.71	2
Strontium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	43	43	43	-	1	36	ld	55	31.19	3
Thallium	ug/L	-	-	-	-	0.8	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Tin	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Titanium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Uranium	ug/L	-	-	-	30	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	3
Vanadium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	ld	ld	ld	0	3
Zinc	ug/L	1000	1000	3000	-	30	**230**	30	**430**	282.84	2	-	-	-	-	0	-	-	-	-	0	27.65	ld	270	65.34	17	58	ld	280	90.02	15
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	2

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_15										SW_16					SW_17									
						Season:	dry					wet					dry					dry					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	250	250	250	-	1	-	-	-	-	0
Antimony	ug/L	-	-	-	20	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Arsenic	ug/L	-	1000	-	10	5	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	0	0	-	1	-	-	-	-	0
Barium	ug/L	2000	-	-	700	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	35	35	35	-	1	-	-	-	-	0
Beryllium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Bismuth	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Boron	ug/L	-	-	-	2400	1500	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	0	0	-	1	-	-	-	-	0
Calcium	mg/L	-	-	100	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	5.80	5.8	5.8	-	1	-	-	-	-	0
Chromium	ug/L	1000	-	-	50	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	0	0	-	1	-	-	-	-	0
Cobalt	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	0	0	-	1	-	-	-	-	0
Copper	ug/L	500	600	2000	2000	2-4 [10]	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	0	0	-	1	-	-	-	-	0
Iron	ug/L	-	-	300	-	300	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0.82	0.82	0.82	-	1	-	-	-	-	0
Lead	ug/L	2000	400	-	10	1-7 [13]	ld	ld	ld	-	1	ld	ld	ld	-	1	-	-	-	-	0	**1201.72**	0	**3600**	2076.97	3	**362739**	0	**1808000**	807929	5
Lithium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Magnesium	mg/L	-	-	50	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	2.70	2.7	2.7	-	1	-	-	-	-	0
Manganese	ug/L	2000	-	500	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	82	82	82	-	1	-	-	-	-	0
Mercury	ug/L	2	-	-	6	0.026	ld	ld	ld	-	1	ld	ld	ld	-	1	-	-	-	-	0	0.10	0	0.29	0.17	3	77.62	0.01	240	113.14	4
Molybdenum	ug/L	-	-	-	-	73	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nickel	ug/L	1000	1000	-	70	25-150 [14]	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	0	0	-	1	-	-	-	-	0
Potassium	mg/L	-	-	10	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	1.30	1.3	1.3	-	1	-	-	-	-	0
Selenium	ug/L	-	-	-	40	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	0	0	-	1	-	-	-	-	0
Silicon	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0	0	0	-	1	-	-	-	-	0
Sodium	mg/L	-	-	200	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	6.20	6.2	6.2	-	1	-	-	-	-	0
Strontium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Thallium	ug/L	-	-	-	-	0.8	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tin	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Titanium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Uranium	ug/L	-	-	-	30	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Zinc	ug/L	1000	1000	3000	-	30	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	10	10	10	-	1	-	-	-	-	0
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_18										SW_19										SW_20				
						Season:	dry					wet					dry					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]	**821.43**	50	**5010**	1848.01	7	**11975**	**410**	**52300**	20038.24	6	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Antimony	ug/L	-	-	-	20	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Arsenic	ug/L	-	1000	-	10	5	ld	ld	ld	0	2	1	1	1	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Barium	ug/L	2000	-	-	700	-	115.29	16	335	113.13	7	123.19	18	266	78.29	7	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Beryllium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Bismuth	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Boron	ug/L	-	-	-	2400	1500	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	ld	ld	ld	0	7	**1.40**	ld	**8**	3.24	6	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Calcium	mg/L	-	-	100	-	-	7.40	7.4	7.4	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Chromium	ug/L	1000	-	-	50	1	0.83	ld	**10**	2.89	12	**29.33**	ld	**240**	79.10	9	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	0	2
Cobalt	ug/L	-	-	-	-	-	ld	ld	ld	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Copper	ug/L	500	600	2000	2000	2-4 [10]	7.14	ld	50	18.90	7	48	ld	180	75.30	5	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Iron	ug/L	-	-	300	-	300	0.87	0.87	0.87	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Lead	ug/L	2000	400	-	10	1-7 [13]	**1561.11**	ld	**13920**	4634.78	9	**355.71**	ld	**2400**	901.74	7	**2190**	**2190**	**2190**	-	1	**9180**	**9180**	**9180**	-	1	**345**	ld	**690**	487.90	2
Lithium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Magnesium	mg/L	-	-	50	-	-	3.30	3.3	3.3	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Manganese	ug/L	2000	-	500	-	-	1183.57	174	3850	1408.87	7	1087.14	476	1970	501.39	7	-	-	-	-	0	-	-	-	-	0	80	80	80	-	1
Mercury	ug/L	2	-	-	6	0.026	0.46	ld	3.8	1.26	9	9.34	ld	60	22.36	7	ld	ld	ld	-	1	-	-	-	-	0	160	160	160	-	1
Molybdenum	ug/L	-	-	-	-	73	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nickel	ug/L	1000	1000	-	70	25-150 [14]	1.43	ld	10	3.78	7	3.10	ld	18.6	7.59	6	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Potassium	mg/L	-	-	10	-	-	1.40	1.4	1.4	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Selenium	ug/L	-	-	-	40	1	ld	ld	ld	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Silicon	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	**247.14**	ld	**1730**	653.88	7	ld	ld	ld	0	5	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Sodium	mg/L	-	-	200	-	-	8.90	8.9	8.9	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Strontium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Thallium	ug/L	-	-	-	-	0.8	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tin	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Titanium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Uranium	ug/L	-	-	-	30	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Zinc	ug/L	1000	1000	3000	-	30	**50**	ld	**280**	102.47	7	**32**	ld	**70**	25.88	5	-	-	-	-	0	-	-	-	-	0	10	10	10	-	1
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_21										SW_22										SW_23				
						Season:	dry					wet					dry					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	**Unit**	**Decreto 33-95** [3]	**MMER Max Grab** [4]	***CAPRE DW*** [5]	***WHO DW*** [6,7]	**CCME FAL SW** [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]	***476.25***	ld	***1720***	769.95	8	***438.33***	**140**	***1340***	450.48	6	***590***	ld	***1670***	682.72	7	***416.67***	60	***1750***	664.19	6	-	-	-	-	0
Antimony	ug/L	-	-	-	20	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Arsenic	ug/L	-	1000	-	10	5	ld	ld	ld	0	2	ld	ld	ld	-	1	ld	ld	ld	0	2	ld	ld	ld	-	1	-	-	-	-	0
Barium	ug/L	2000	-	-	700	-	56.88	14	335	112.46	8	83	17	266	98.36	7	19.43	14	34	6.92	7	15.50	13	18	1.87	6	-	-	-	-	0
Beryllium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Bismuth	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Boron	ug/L	-	-	-	2400	1500	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	ld	ld	ld	0	7	ld	ld	ld	0	4	ld	ld	ld	0	7	ld	ld	ld	0	5	-	-	-	-	0
Calcium	mg/L	-	-	100	-	-	4.20	4.2	4.2	0	2	-	-	-	-	0	4.60	4.6	4.6	0	2	-	-	-	-	0	-	-	-	-	0
Chromium	ug/L	1000	-	-	50	1	ld	ld	ld	0	12	**3.22**	ld	**14**	5.33	9	ld	ld	ld	0	12	0.67	ld	**6**	2	9	-	-	-	-	0
Cobalt	ug/L	-	-	-	-	-	ld	ld	ld	0	2	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0	-	-	-	-	0
Copper	ug/L	500	600	2000	2000	2-4 [10]	ld	ld	ld	0	7	ld	ld	ld	0	4	1.43	ld	10	3.78	7	ld	ld	ld	0	5	-	-	-	-	0
Iron	ug/L	-	-	300	-	300	0.32	ld	0.64	0.45	2	-	-	-	-	0	3.30	3.3	3.3	0	2	-	-	-	-	0	-	-	-	-	0
Lead	ug/L	2000	400	-	10	1-7 [13]	ld	ld	ld	0	7	ld	ld	ld	0	4	ld	ld	ld	0	7	ld	ld	ld	0	5	ld	ld	ld	-	1
Lithium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Magnesium	mg/L	-	-	50	-	-	2.30	2.3	2.3	0	2	-	-	-	-	0	2.60	2.6	2.6	0	2	-	-	-	-	0	-	-	-	-	0
Manganese	ug/L	2000	-	500	-	-	73	40	122	32.30	8	136	93	232	49.28	6	148	47	370	152.28	7	67.50	46	105	21.73	6	-	-	-	-	0
Mercury	ug/L	2	-	-	6	0.026	ld	ld	ld	0	7	ld	ld	ld	0	4	ld	ld	ld	0	7	ld	ld	ld	0	5	-	-	-	-	0
Molybdenum	ug/L	-	-	-	-	73	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nickel	ug/L	1000	1000	-	70	25-150 [14]	ld	ld	ld	0	7	ld	ld	ld	0	4	2.86	ld	10	4.88	7	ld	ld	ld	0	5	-	-	-	-	0
Potassium	mg/L	-	-	10	-	-	0.60	0.6	0.6	0	2	-	-	-	-	0	0.80	0.8	0.8	0	2	-	-	-	-	0	-	-	-	-	0
Selenium	ug/L	-	-	-	40	1	ld	ld	ld	0	2	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0	-	-	-	-	0
Silicon	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	**168.57**	ld	**1180**	446	7	**2**	ld	**8**	4	4	**124.86**	ld	**874**	330.34	7	ld	ld	ld	0	5	-	-	-	-	0
Sodium	mg/L	-	-	200	-	-	5.20	5.2	5.2	0	2	-	-	-	-	0	5.20	5.2	5.2	0	2	-	-	-	-	0	-	-	-	-	0
Strontium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Thallium	ug/L	-	-	-	-	0.8	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tin	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Titanium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Uranium	ug/L	-	-	-	30	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Zinc	ug/L	1000	1000	3000	-	30	**32.86**	ld	**110**	37.29	7	12.50	ld	20	9.57	4	25.71	ld	**90**	32.59	7	16	ld	30	11.40	5	-	-	-	-	0
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_23					SW_24										SW_25									
						Season:	wet					dry					wet					dry					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95[3]	MMER Max Grab[4]	*CAPRE DW*[5]	*WHO DW*[6,7]	CCME FAL SW[8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100[11]	-	-	-	-	0	54	ld	**120**	41.95	10	***1620***	**170**	*3900*	1401.99	10	***732***	50	*3080*	1314.96	5	*2016.25*	**150**	*4630*	1558.45	8
Antimony	ug/L	-	-	-	20	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Arsenic	ug/L	-	1000	-	10	5	ld	ld	ld	-	1	ld	ld	ld	0	2	ld	ld	ld	-	1	ld	ld	ld	-	1	1	1	1	-	1
Barium	ug/L	2000	-	-	700	-	-	-	-	-	0	20.63	ld	40	11.51	8	28.86	19	50	11.02	7	40.60	33	64	13.16	5	38.43	17	51.4	10.43	8
Beryllium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Bismuth	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Boron	ug/L	-	-	-	2400	1500	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017[12]	-	-	-	-	0	ld	ld	ld	0	7	ld	ld	ld	0	4	ld	ld	ld	0	6	**0.06**	ld	**0.4**	0.15	7
Calcium	mg/L	-	-	100	-	-	2.76	2.76	2.76	-	1	4.60	4.6	4.6	0	2	ld	ld	ld	-	1	5.80	5.8	5.8	-	1	-	-	-	-	0
Chromium	ug/L	1000	-	-	50	1	-	-	-	-	0	ld	ld	ld	0	12	**9.89**	ld	**83**	27.49	9	**1.11**	ld	**10**	3.33	9	**6.68**	ld	**60**	17.23	12
Cobalt	ug/L	-	-	-	-	-	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Copper	ug/L	500	600	2000	2000	2-4[10]	-	-	-	-	0	ld	ld	ld	0	7	2	ld	10	4.47	5	2.50	ld	10	5	4	3.33	ld	10	5.16	6
Iron	ug/L	-	-	300	-	300	1.22	1.22	1.22	-	1	0.57	0.57	0.57	0	2	-	-	-	-	0	0.82	0.82	0.82	-	1	-	-	-	-	0
Lead	ug/L	2000	400	-	10	1-7[13]	2305	ld	4610	3259.76	2	**370**	ld	3700	1170.04	10	**278.57**	ld	**1950**	737.03	7	ld	ld	ld	0	5	ld	ld	ld	0	6
Lithium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Magnesium	mg/L	-	-	50	-	-	1.67	1.67	1.67	-	1	2.40	2.4	2.4	0	2	-	-	-	-	0	2.70	2.7	2.7	-	1	-	-	-	-	0
Manganese	ug/L	2000	-	500	-	-	-	-	-	-	0	53.78	ld	158	42.34	9	113.14	49	235	63.01	7	108.40	54	249	79.57	5	102.25	35	198	59.24	8
Mercury	ug/L	2	-	-	6	0.026	-	-	-	-	0	55.59	ld	500	166.65	9	5.73	ld	40	15.11	7	ld	ld	ld	0	5	ld	ld	ld	0	6
Molybdenum	ug/L	-	-	-	-	73	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nickel	ug/L	1000	1000	-	70	25-150[14]	-	-	-	-	0	ld	ld	ld	0	7	ld	ld	ld	0	5	ld	ld	ld	0	5	2.76	ld	19.3	7.29	7
Potassium	mg/L	-	-	10	-	-	0.78	0.78	0.78	-	1	0.60	0.6	0.6	0	2	-	-	-	-	0	1.30	1.3	1.3	-	1	-	-	-	-	0
Selenium	ug/L	-	-	-	40	1	-	-	-	-	0	ld	ld	ld	0	2	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Silicon	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	-	-	-	-	0	ld	ld	ld	0	7	ld	ld	ld	0	5	263.80	ld	1310	584.86	5	ld	ld	ld	0	6
Sodium	mg/L	-	-	200	-	-	4.53	4.53	4.53	-	1	5.40	5.4	5.4	0	2	-	-	-	-	0	6.20	6.2	6.2	-	1	-	-	-	-	0
Strontium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Thallium	ug/L	-	-	-	-	0.8	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tin	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Titanium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Uranium	ug/L	-	-	-	30	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Zinc	ug/L	1000	1000	3000	-	30	-	-	-	-	0	11.43	ld	**60**	22.68	7	18	ld	**40**	14.83	5	**46**	ld	**160**	66.56	5	28.33	10	**50**	14.72	6
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_26										SW_27										SW_28				
						Season:	dry					wet					dry					wet					wet				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Antimony	ug/L	-	-	-	20	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Arsenic	ug/L	-	1000	-	10	5	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Barium	ug/L	2000	-	-	700	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Beryllium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Bismuth	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Boron	ug/L	-	-	-	2400	1500	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Calcium	mg/L	-	-	100	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	9.92	9.92	9.92	-	1
Chromium	ug/L	1000	-	-	50	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cobalt	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Copper	ug/L	500	600	2000	2000	2-4 [10]	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Iron	ug/L	-	-	300	-	300	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0.12	0.12	0.12	-	1
Lead	ug/L	2000	400	-	10	1-7 [13]	ld	ld	ld	-	1	ld	ld	ld	-	1	0.57	0.57	0.57	-	1	0.93	0.72	1.14	0.30	2	-	-	-	-	0
Lithium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Magnesium	mg/L	-	-	50	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	4.33	4.33	4.33	-	1
Manganese	ug/L	2000	-	500	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Mercury	ug/L	2	-	-	6	0.026	0.15	0.15	0.15	-	1	0.23	0.23	0.23	-	1	0.06	0.06	0.06	-	1	ld	ld	ld	-	1	ld	ld	ld	-	1
Molybdenum	ug/L	-	-	-	-	73	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nickel	ug/L	1000	1000	-	70	25-150 [14]	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Potassium	mg/L	-	-	10	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	0.68	0.68	0.68	-	1
Selenium	ug/L	-	-	-	40	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Silicon	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Sodium	mg/L	-	-	200	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	3.30	3.3	3.3	-	1
Strontium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Thallium	ug/L	-	-	-	-	0.8	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tin	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Titanium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Uranium	ug/L	-	-	-	30	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Zinc	ug/L	1000	1000	3000	-	30	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_29										SW_30										SW_31				
						Season:	dry					wet					dry					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	**CCME FAL SW** [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]	**126.32**	ld	***700***	264.24	19	**120.59**	ld	***1070***	340.78	17	**170**	**170**	**170**	-	1	-	-	-	-	0	**198.75**	ld	***2400***	591	16
Antimony	ug/L	-	-	-	20	-	ld	ld	ld	-	1	ld	ld	ld	0	7	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Arsenic	ug/L	-	1000	-	10	5	ld	ld	ld	-	1	**10.86**	ld	**76**	28.73	7	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	0	2
Barium	ug/L	2000	-	-	700	-	16.67	ld	300	70.71	18	29.41	ld	150	50.67	17	27	27	27	-	1	-	-	-	-	0	13.81	ld	52	17.22	16
Beryllium	ug/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	7	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Bismuth	ug/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	7	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Boron	ug/L	-	-	-	2400	1500	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	ld	ld	ld	0	19	ld	ld	ld	0	17	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	0	15
Calcium	mg/L	-	-	100	-	-	-	-	-	-	0	12.36	7.43	17.71	4.09	7	5.60	5.6	5.6	-	1	-	-	-	-	0	6.31	5.6	7.01	1	2
Chromium	ug/L	1000	-	-	50	1	ld	ld	ld	0	37	ld	ld	ld	0	31	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	0	28
Cobalt	ug/L	-	-	-	-	-	ld	ld	ld	-	1	3	ld	11	5.13	7	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	0	2
Copper	ug/L	500	600	2000	2000	2-4 [10]	ld	ld	ld	0	19	15.88	ld	270	65.48	17	ld	ld	ld	-	1	-	-	-	-	0	0.71	ld	10	2.67	14
Iron	ug/L	-	-	300	-	300	-	-	-	-	0	2.04	ld	6.98	2.83	6	0.65	0.65	0.65	-	1	-	-	-	-	0	0.47	0.28	0.65	0.26	2
Lead	ug/L	2000	400	-	10	1-7 [13]	ld	ld	ld	0	19	0.35	ld	**6**	1.46	17	ld	ld	ld	0	2	1.86	1.86	1.86	-	1	ld	ld	ld	0	15
Lithium	ug/L	-	-	-	-	-	ld	ld	ld	-	1	7.14	ld	50	18.90	7	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Magnesium	mg/L	-	-	50	-	-	-	-	-	-	0	3.42	2.43	3.95	0.69	7	2.70	2.7	2.7	-	1	-	-	-	-	0	2.85	2.7	3	0.21	2
Manganese	ug/L	2000	-	500	-	-	1291.11	ld	5090	1917.72	18	802.24	ld	4860	1352.83	17	50	50	50	-	1	-	-	-	-	0	49.31	ld	216	55.33	16
Mercury	ug/L	2	-	-	6	0.026	ld	ld	ld	0	5	ld	ld	ld	0	7	0.03	ld	0.06	0.04	2	ld	ld	ld	-	1	ld	ld	ld	0	12
Molybdenum	ug/L	-	-	-	-	73	ld	ld	ld	-	1	7.29	ld	51	19.28	7	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Nickel	ug/L	1000	1000	-	70	25-150 [14]	ld	ld	ld	0	19	ld	ld	ld	0	17	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	0	15
Potassium	mg/L	-	-	10	-	-	ld	ld	ld	-	1	0.33	ld	1.66	0.63	7	1.10	1.1	1.1	-	1	-	-	-	-	0	0.55	ld	1.1	0.78	2
Selenium	ug/L	-	-	-	40	1	ld	ld	ld	-	1	ld	ld	ld	0	7	ld	ld	ld	-	1	-	-	-	-	0	ld	ld	ld	0	2
Silicon	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	10300	10300	10300	-	1
Silver	ug/L	200	-	-	-	0.1	**1.58**	ld	**30**	6.88	19	**2.94**	ld	**50**	12.13	17	ld	ld	ld	-	1	-	-	-	-	0	**94.40**	ld	**1410**	363.95	15
Sodium	mg/L	-	-	200	-	-	-	-	-	-	0	11.62	6.32	16.79	5.86	4	6.20	6.2	6.2	-	1	-	-	-	-	0	6.60	6.2	7	0.57	2
Strontium	ug/L	-	-	-	-	-	-	-	-	-	0	50.14	ld	76	34.91	7	-	-	-	-	0	-	-	-	-	0	43	43	43	-	1
Thallium	ug/L	-	-	-	-	0.8	ld	ld	ld	-	1	ld	ld	ld	0	7	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Tin	ug/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	7	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Titanium	ug/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	7	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Uranium	ug/L	-	-	-	30	-	-	-	-	-	0	ld	ld	ld	0	7	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/L	-	-	-	-	-	ld	ld	ld	-	1	ld	ld	ld	0	7	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Zinc	ug/L	1000	1000	3000	-	30	0.53	ld	10	2.29	19	**54.60**	ld	**700**	167.66	17	10	10	10	-	1	-	-	-	-	0	16.67	ld	**130**	34.16	15
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	0	ld	ld	ld	0	4	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_31					SW_32										SW_33					SW_34				
						Season:	wet					dry					wet					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]	**980.63**	ld	*3620*	1108.29	16	44	30	60	11.40	5	**1588**	**630**	*2690*	745.73	5	-	-	-	-	0	-	-	-	-	0
Antimony	ug/L	-	-	-	20	-	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Arsenic	ug/L	-	1000	-	10	5	ld	ld	ld	0	5	-	-	-	-	0	1	1	1	-	1	-	-	-	-	0	1.70	1.7	1.7	-	1
Barium	ug/L	2000	-	-	700	-	19.44	ld	71	22.06	16	52.40	46	66	8.38	5	40.20	36	44	3.56	5	-	-	-	-	0	-	-	-	-	0
Beryllium	ug/L	-	-	-	-	-	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Bismuth	ug/L	-	-	-	-	-	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Boron	ug/L	-	-	-	2400	1500	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	ld	ld	ld	0	14	**2.40**	ld	**6**	3.29	5	**1**	ld	**4**	2	4	-	-	-	-	0	-	-	-	-	0
Calcium	mg/L	-	-	100	-	-	9.80	5.13	12.81	3.28	4	-	-	-	-	0	-	-	-	-	0	7.29	7.29	7.29	-	1	-	-	-	-	0
Chromium	ug/L	1000	-	-	50	1	**3.01**	ld	**81**	15.59	27	**2**	ld	**10**	4.22	10	**1.71**	ld	**12**	4.54	7	-	-	-	-	0	-	-	-	-	0
Cobalt	ug/L	-	-	-	-	-	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Copper	ug/L	500	600	2000	2000	2-4 [10]	12.56	ld	160	42.54	14	2	ld	10	4.47	5	2.50	ld	10	5	4	-	-	-	-	0	-	-	-	-	0
Iron	ug/L	-	-	300	-	300	2.35	ld	6.39	3.52	3	-	-	-	-	0	-	-	-	-	0	2.71	2.71	2.71	-	1	-	-	-	-	0
Lead	ug/L	2000	400	-	10	1-7 [13]	0.33	ld	**5**	1.29	15	**3.33**	ld	**20**	8.16	6	**618**	ld	**3090**	1381.89	5	-	-	-	-	0	-	-	-	-	0
Lithium	ug/L	-	-	-	-	-	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Magnesium	mg/L	-	-	50	-	-	3.55	2.87	4.79	0.85	4	-	-	-	-	0	-	-	-	-	0	4.66	4.66	4.66	-	1	-	-	-	-	0
Manganese	ug/L	2000	-	500	-	-	86.47	ld	190	65.21	16	20.60	10	40	11.48	5	52.60	25	80	24.72	5	-	-	-	-	0	-	-	-	-	0
Mercury	ug/L	2	-	-	6	0.026	ld	ld	ld	0	11	ld	ld	ld	0	6	34	ld	170	76.03	5	-	-	-	-	0	-	-	-	-	0
Molybdenum	ug/L	-	-	-	-	73	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nickel	ug/L	1000	1000	-	70	25-150 [14]	1.17	ld	17.6	4.54	15	ld	ld	ld	0	5	ld	ld	ld	0	4	-	-	-	-	0	-	-	-	-	0
Potassium	mg/L	-	-	10	-	-	1.01	ld	2.66	1.28	4	-	-	-	-	0	-	-	-	-	0	2.68	2.68	2.68	-	1	-	-	-	-	0
Selenium	ug/L	-	-	-	40	1	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Silicon	ug/L	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	**0.50**	ld	**7**	1.87	14	**224**	ld	**1120**	500.88	5	**46.50**	ld	**181**	89.70	4	-	-	-	-	0	-	-	-	-	0
Sodium	mg/L	-	-	200	-	-	9.25	6.24	14.11	4.25	3	-	-	-	-	0	-	-	-	-	0	8.04	8.04	8.04	-	1	-	-	-	-	0
Strontium	ug/L	-	-	-	-	-	38.67	ld	65	34.21	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Thallium	ug/L	-	-	-	-	0.8	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tin	ug/L	-	-	-	-	-	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Titanium	ug/L	-	-	-	-	-	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Uranium	ug/L	-	-	-	30	-	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/L	-	-	-	-	-	ld	ld	ld	0	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Zinc	ug/L	1000	1000	3000	-	30	**84.71**	ld	**520**	153.91	14	**42**	ld	**140**	58.05	5	20	ld	**40**	18.26	4	-	-	-	-	0	-	-	-	-	0
Zirconium	ug/L	-	-	-	-	-	ld	ld	ld	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_35										SW_36										SW_37				
						Season:	dry					wet					dry					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]																									
Total Metals																															
Aluminum	ug/L	2000	-	200	-	5-100 [11]		137.50	0	400	172.11	8	1559.59	390	3390	1018.81	8	-	-	-	-	0	-	-	-	-	0	62.50	30	80	23.63	4
Antimony	ug/L	-	-	-	20	-		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Arsenic	ug/L	-	1000	-	10	5		0	0	0	0	2	1.42	0	3.26	1.67	3	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Barium	ug/L	2000	-	-	700	-		31.14	28	40	4.22	7	182.63	34	1040	378.12	7	-	-	-	-	0	-	-	-	-	0	32	28	36	3.37	4
Beryllium	ug/L	-	-	-	-	-		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Bismuth	ug/L	-	-	-	-	-		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Boron	ug/L	-	-	-	2400	1500		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Cadmium	ug/L	100	-	-	3	006-0.017 [12]		**1.14**	0	**8**	3.02	7	**0.06**	0	**0.3**	0.13	5	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	ld	4
Calcium	mg/L	-	-	100	-	-		8.10	8.1	8.1	0	2	7.62	7.62	7.62	-	1	-	-	-	-	0	12.02	12.02	12.02	-	1	-	-	-	-	ld
Chromium	ug/L	1000	-	-	50	1		**1.54**	0	**10**	3.76	13	**10.85**	0	**70**	22.79	10	-	-	-	-	0	**1.36**	**1.36**	**1.36**	-	1	**2.50**	ld	**10**	4.63	8
Cobalt	ug/L	-	-	-	-	-		0	0	0	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Copper	ug/L	500	600	2000	2000	2-4 [10]		0	0	0	0	7	2.50	0	10	5	4	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	ld	4
Iron	ug/L	-	-	300	-	300		0.47	0	0.7	0.40	3	9.71	9.71	9.71	-	1	-	-	-	-	0	2.10	2.1	2.1	-	1	-	-	-	-	ld
Lead	ug/L	2000	400	-	10	1-7 [13]		**3.33**	0	**30**	10	9	**658.88**	0	**5160**	1819.10	8	ld	ld	ld	-	1	**3120**	**3120**	**3120**	-	1	ld	ld	ld	ld	4
Lithium	ug/L	-	-	-	-	-		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Magnesium	mg/L	-	-	50	-	-		3.40	3.4	3.4	0	2	2.66	2.66	2.66	-	1	-	-	-	-	0	3.38	3.38	3.38	-	1	-	-	-	-	ld
Manganese	ug/L	2000	-	500	-	-		34.86	19	61	13.81	7	83.94	27.5	186	47.44	8	-	-	-	-	0	-	-	-	-	0	48.75	31	75	18.98	4
Mercury	ug/L	2	-	-	6	0.026		0.13	0	0.6	0.26	9	23.36	0	210	69.99	9	ld	ld	ld	-	1	130	130	130	-	1	ld	ld	ld	ld	4
Molybdenum	ug/L	-	-	-	-	73		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Nickel	ug/L	1000	1000	-	70	25-150 [14]		1.43	0	10	3.78	7	3.36	0	16.8	7.51	5	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	ld	4
Potassium	mg/L	-	-	10	-	-		1.60	1.6	1.6	0	2	1.58	1.58	1.58	-	1	-	-	-	-	0	1.78	1.78	1.78	-	1	-	-	-	-	ld
Selenium	ug/L	-	-	-	40	1		0	0	0	0	2	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Silicon	ug/L	-	-	-	-	-		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Silver	ug/L	200	-	-	-	0.1		162.50	0	1300	459.62	8	37.50	0	150	75	4	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	ld	4
Sodium	mg/L	-	-	200	-	-		8.40	8.4	8.4	0	2	8.38	8.38	8.38	-	1	-	-	-	-	0	9.56	9.56	9.56	-	1	-	-	-	-	ld
Strontium	ug/L	-	-	-	-	-		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Thallium	ug/L	-	-	-	-	0.8		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Tin	ug/L	-	-	-	-	-		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Titanium	ug/L	-	-	-	-	-		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Uranium	ug/L	-	-	-	30	-		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Vanadium	ug/L	-	-	-	-	-		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld
Zinc	ug/L	1000	1000	3000	-	30		32.50	0	180	60.89	8	15	0	30	12.91	4	-	-	-	-	0	-	-	-	-	0	10	ld	30	14.14	4
Zirconium	ug/L	-	-	-	-	-		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld

Table D-1-2. Surface Water Results: Metals

						Sample ID:	SW_37					SW_38					SW_39				
						Season:	wet					wet					dry				
						Descriptive Statistics	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	Unit	Decreto 33-95 [3]	MMER Max Grab [4]	*CAPRE DW* [5]	*WHO DW* [6,7]	CCME FAL SW [8]															
Total Metals																					
Aluminum	ug/L	2000	-	200	-	5-100 [11]	2306.67	750	6030	1952.05	6	-	-	-	-	0	-	-	-	-	0
Antimony	ug/L	-	-	-	20	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Arsenic	ug/L	-	1000	-	10	5	0.67	ld	2	1.15	3	-	-	-	-	0	-	-	-	-	0
Barium	ug/L	2000	-	-	700	-	49.49	17	66.4	18.09	7	-	-	-	-	0	-	-	-	-	0
Beryllium	ug/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Bismuth	ug/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Boron	ug/L	-	-	-	2400	1500	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/L	100	-	-	3	006-0.017 [12]	**0.75**	ld	**3**	1.50	4	-	-	-	-	0	-	-	-	-	0
Calcium	mg/L	-	-	100	-	-	19.05	19.05	19.05	-	1	19.44	19.44	19.44	-	1	-	-	-	-	0
Chromium	ug/L	1000	-	-	50	1	**10.59**	ld	**87**	27.22	10	-	-	-	-	0	-	-	-	-	0
Cobalt	ug/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Copper	ug/L	500	600	2000	2000	2-4 [10]	5	ld	10	5.77	4	-	-	-	-	0	-	-	-	-	0
Iron	ug/L	-	-	300	-	300	1.10	1.1	1.1	-	1	0.93	0.93	0.93	-	1	-	-	-	-	0
Lead	ug/L	2000	400	-	10	1-7 [13]	0.66	ld	**5.25**	1.86	8	-	-	-	-	0	-	-	-	-	0
Lithium	ug/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Magnesium	mg/L	-	-	50	-	-	8.18	8.18	8.18	-	1	4.17	4.17	4.17	-	1	-	-	-	-	0
Manganese	ug/L	2000	-	500	-	-	74.88	33.3	113	29.29	6	-	-	-	-	0	-	-	-	-	0
Mercury	ug/L	2	-	-	6	0.026	ld	ld	ld	ld	7	-	-	-	-	0	-	-	-	-	0
Molybdenum	ug/L	-	-	-	-	73	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Nickel	ug/L	1000	1000	-	70	25-150 [14]	3.40	ld	17	7.60	5	-	-	-	-	0	-	-	-	-	0
Potassium	mg/L	-	-	10	-	-	2.08	2.08	2.08	-	1	4.24	4.24	4.24	-	1	-	-	-	-	0
Selenium	ug/L	-	-	-	40	1	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Silicon	ug/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Silver	ug/L	200	-	-	-	0.1	45	ld	180	90	4	-	-	-	-	0	-	-	-	-	0
Sodium	mg/L	-	-	200	-	-	14.10	14.1	14.1	-	1	23.60	23.6	23.6	-	1	-	-	-	-	0
Strontium	ug/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Thallium	ug/L	-	-	-	-	0.8	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Tin	ug/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Titanium	ug/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Uranium	ug/L	-	-	-	30	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0
Zinc	ug/L	1000	1000	3000	-	30	22.50	10	40	12.58	4	-	-	-	-	0	-	-	-	-	0
Zirconium	ug/L	-	-	-	-	-	-	-	-	-	ld	-	-	-	-	0	-	-	-	-	0

Table D-2. Sediment Results

			SW_02					SW_03					SW_04					SW_06					SW_07					SW_08				
Parameter	Unit	CCME FAL sed[16]	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Physical Tests																																
pH	pH		-	-	-	-	0	5.3	5.3	5.3	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	7.1	7.1	7.1	-	1
Inorganics																																
Cyanide + Thiocyanate	mg/kg		-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/kg		-	-	-	-	0	0.04	0.04	0.04	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Metals																																
Aluminum	ug/kg		-	-	-	-	0	4100000	4100000	4100000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	6000000	6000000	6000000	-	1
Antimony	ug/kg		-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Arsenic	ug/kg	5900	-	-	-	-	0	**11200**	**11200**	**11200**	-	1	1.345	1.345	1.345	-	1	-	-	-	-	0	-	-	-	-	0	**9600**	**9600**	**9600**	-	1
Barium	ug/kg		-	-	-	-	0	82000	82000	82000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	110000	110000	110000	-	1
Beryllium	ug/kg		-	-	-	-	0	300	300	300	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Bismuth	ug/kg		-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Boron	ug/kg		-	-	-	-	0	2000	2000	2000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/kg	600	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	**800**	**800**	**800**	-	1
Calcium	mg/kg		-	-	-	-	0	160	160	160	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	1000	1000	1000	-	1
Chromium	ug/kg	37300	-	-	-	-	0	4000	4000	4000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	10000	10000	10000	-	1
Cobalt	ug/kg		-	-	-	-	0	22000	22000	22000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Copper	ug/kg	35700	-	-	-	-	0	88000	88000	88000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	39000	39000	39000	-	1
Iron	ug/kg		-	-	-	-	0	31000	31000	31000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	32000	32000	32000	-	1
Lead	ug/kg	35000	27.83	14.27	39.54	12.74	3	14000	14000	14000	-	1	10.66	10.66	10.66	-	1	72.195	4.62	139.77	95.57	2	59.18	34.96	83.39	34.25	2	8000	8000	8000	-	1
Lithium	ug/kg		-	-	-	-	0	6000	6000	6000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Magnesium	mg/kg		-	-	-	-	0	130	130	130	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	870	870	870	-	1
Manganese	ug/kg		-	-	-	-	0	1000000	1000000	1000000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	1400000	1400000	1400000	-	1
Mercury	ug/kg	170	0.13	ld	0.393	0.23	3	30	30	30	-	1	0.281	0.281	0.281	-	1	2.902	1.473	4.331	2.02	2	1.80	0.974	2.617	1.16	2	**980**	**980**	**980**	-	1
Molybdenum	ug/kg		-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nickel	ug/kg		-	-	-	-	0	7000	7000	7000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	5000	5000	5000	-	1
Potassium	mg/kg		-	-	-	-	0	430	430	430	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	370	370	370	-	1
Selenium	ug/kg		-	-	-	-	0	300	300	300	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	600	600	600	-	1
Silver	ug/kg		-	-	-	-	0	2400	2400	2400	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	1900	1900	1900	-	1
Sodium	mg/kg		-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1
Strontium	ug/kg		-	-	-	-	0	2000	2000	2000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Thallium	ug/kg		-	-	-	-	0	300	300	300	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tin	ug/kg		-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Titanium	ug/kg		-	-	-	-	0	1000	1000	1000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tungsten	ug/kg		-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/kg		-	-	-	-	0	52000	52000	52000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Zinc	ug/kg	123000	-	-	-	-	0	49000	49000	49000	-	1	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	42000	42000	42000	-	1

Table D-2. Sediment Results

Parameter	Unit	CCME FAL sed [16]	SW_09					SW_10					SW_11					SW_12					SW_14				
			Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Physical Tests																											
pH	pH		-	-	-	-	0	6.1	6.1	6.1	-	1	5.20	5.2	5.2	-	1	-	-	-	-	0	7.3	7.3	7.3	-	1
Inorganics																											
Cyanide + Thiocyanate	mg/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Metals																											
Aluminum	ug/kg		-	-	-	-	0	11000000	11000000	11000000	-	1	1200000	12000000	12000000	-	1	5300000	5300000	5300000	-	1	1700000	1700000	1700000	-	1
Antimony	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Arsenic	ug/kg	5900	0.087	0.087	0.087	-	1	3000	3000	3000	-	1	**6100**	**6100**	**6100**	-	1	**6700**	**6700**	**6700**	-	1	5100	5100	5100	-	1
Barium	ug/kg		-	-	-	-	0	72000	72000	72000	-	1	46000	46000	46000	-	1	240000	240000	240000	-	1	46000	46000	46000	-	1
Beryllium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Bismuth	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Boron	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	2000	2000	2000	-	1	-	-	-	-	0
Cadmium	ug/kg	600	-	-	-	-	0	ld	ld	ld	-	1	0	0	0	-	1	**700**	**700**	**700**	-	1	ld	ld	ld	-	1
Calcium	mg/kg		-	-	-	-	0	2200	2200	2200	-	1	750	750	750	-	1	680	680	680	-	1	280	280	280	-	1
Chromium	ug/kg	37300	11.544	11.544	11.544	-	1	3000	3000	3000	-	1	6000	6000	6000	-	1	7000	7000	7000	-	1	2000	2000	2000	-	1
Cobalt	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	41000	41000	41000	-	1	-	-	-	-	0
Copper	ug/kg	35700	-	-	-	-	0	39000	39000	39000	-	1	62000	62000	62000	-	1	100000	100000	100000	-	1	25000	25000	25000	-	1
Iron	ug/kg		-	-	-	-	0	32000	32000	32000	-	1	38000	38000	38000	-	1	36000	36000	36000	-	1	10000	10000	10000	-	1
Lead	ug/kg	35000	8.247	8.247	8.247	-	1	ld	ld	ld	-	1	20386.67	0	**55160**	30263.65	3	**42214.68**	36.48	**103260**	45341.79	8	27858.18	42.59	**93750**	36737.02	8
Lithium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	10000	10000	10000	-	1	-	-	-	-	0
Magnesium	mg/kg		-	-	-	-	0	1900	1900	1900	-	1	720	720	720	-	1	620	620	620	-	1	120	120	120	-	1
Manganese	ug/kg		-	-	-	-	0	620000	620000	620000	-	1	450000	450000	450000	-	1	100000	100000	100000	-	1	410000	410000	410000	-	1
Mercury	ug/kg	170	0.328	0.328	0.328	-	1	30	30	30	-	1	**215.00**	60	**310**	113.87	4	**526.45**	0	**2460**	870.53	8	**512.87**	0.569	**2100**	801.89	8
Molybdenum	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Nickel	ug/kg		-	-	-	-	0	2000	2000	2000	-	1	4000	4000	4000	-	1	9000	9000	9000	-	1	2000	2000	2000	-	1
Potassium	mg/kg		-	-	-	-	0	650	650	650	-	1	460	460	460	-	1	170	170	170	-	1	60	60	60	-	1
Selenium	ug/kg		-	-	-	-	0	800	800	800	-	1	2000	2000	2000	-	1	600	600	600	-	1	400	400	400	-	1
Silver	ug/kg		-	-	-	-	0	ld	ld	ld	-	1	0	0	0	-	1	7000	7000	7000	-	1	3300	3300	3300	-	1
Sodium	mg/kg		-	-	-	-	0	100	100	100	-	1	0	0	0	-	1	ld	ld	ld	-	1	ld	ld	ld	-	1
Strontium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	7000	7000	7000	-	1	-	-	-	-	0
Thallium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Tin	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Titanium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	33000	33000	33000	-	1	-	-	-	-	0
Tungsten	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0
Vanadium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	70000	70000	70000	-	1	-	-	-	-	0
Zinc	ug/kg	123000	-	-	-	-	0	47000	47000	47000	-	1	43000	43000	43000	-	1	91000	91000	91000	-	1	24000	24000	24000	-	1

Table D-2. Sediment Results

Parameter	Unit	CCME FAL sed [16]	SW_15					SW_17					SW_18					SW_19					SW_20				
			Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Physical Tests																											
pH	pH		-	-	-	-	0	7	7	7	-	1	6.3	6.3	6.3	-	1	-	-	-	-	ld	-	-	-	-	0
Inorganics																											
Cyanide + Thiocyanate	mg/kg		-	-	-	-	0	-	-	-	-	0	1.02	1.02	1.02	-	1	-	-	-	-	ld	-	-	-	-	0
Phosphorus	mg/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Metals																											
Aluminum	ug/kg		-	-	-	-	0	7900000	7900000	7900000	-	1	13000000	13000000	13000000	-	1	-	-	-	-	ld	-	-	-	-	0
Antimony	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Arsenic	ug/kg	5900	-	-	-	-	0	**7600**	**7600**	**7600**	-	1	5900	5900	5900	-	1	-	-	-	-	ld	-	-	-	-	0
Barium	ug/kg		-	-	-	-	0	170000	170000	170000	-	1	130000	130000	130000	-	1	-	-	-	-	ld	-	-	-	-	0
Beryllium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Bismuth	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Boron	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Cadmium	ug/kg	600	-	-	-	-	0	600	600	600	-	1	ld	ld	ld	-	1	-	-	-	-	ld	-	-	-	-	0
Calcium	mg/kg		-	-	-	-	0	1400	1400	1400	-	1	1300	1300	1300	-	1	-	-	-	-	ld	-	-	-	-	0
Chromium	ug/kg	37300	-	-	-	-	0	8000	8000	8000	-	1	63000	63000	63000	-	1	-	-	-	-	ld	-	-	-	-	0
Cobalt	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Copper	ug/kg	35700	-	-	-	-	0	78000	78000	78000	-	1	64000	64000	64000	-	1	-	-	-	-	ld	-	-	-	-	0
Iron	ug/kg		-	-	-	-	0	35000	35000	35000	-	1	49000	49000	49000	-	1	-	-	-	-	ld	-	-	-	-	0
Lead	ug/kg	35000	28660	15260	**42060**	18950.46	2	30633.888	29.94	**62080**	29479.53	5	16612.77	30.18	**37010**	18938.42	5	**57925**	**57680**	**58170**	346.48	2	31350	31350	31350	-	1
Lithium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Magnesium	mg/kg		-	-	-	-	0	970	970	970	-	1	1100	1100	1100	-	1	-	-	-	-	ld	-	-	-	-	0
Manganese	ug/kg		-	-	-	-	0	1600000	1600000	1600000	-	1	1400000	1400000	1400000	-	1	-	-	-	-	ld	-	-	-	-	0
Mercury	ug/kg	170	155	90	**220**	91.92	2	**846.56**	0.452	**1780**	805.85	5	**249.04**	0.523	**700**	312.46	5	**380**	**380**	**380**	-	1	**390**	**230**	**550**	226.27	2
Molybdenum	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Nickel	ug/kg		-	-	-	-	0	8000	8000	8000	-	1	11000	11000	11000	-	1	-	-	-	-	ld	-	-	-	-	0
Potassium	mg/kg		-	-	-	-	0	360	360	360	-	1	720	720	720	-	1	-	-	-	-	ld	-	-	-	-	0
Selenium	ug/kg		-	-	-	-	0	600	600	600	-	1	800	800	800	-	1	-	-	-	-	ld	-	-	-	-	0
Silver	ug/kg		-	-	-	-	0	4700	4700	4700	-	1	ld	ld	ld	-	1	-	-	-	-	ld	-	-	-	-	0
Sodium	mg/kg		-	-	-	-	0	60	60	60	-	1	90	90	90	-	1	-	-	-	-	ld	-	-	-	-	0
Strontium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Thallium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Tin	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Titanium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Tungsten	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Vanadium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	ld	-	-	-	-	0
Zinc	ug/kg	123000	-	-	-	-	0	82000	82000	82000	-	1	46000	46000	46000	-	1	-	-	-	-	ld	-	-	-	-	0

Table D-2. Sediment Results

			SW_21					SW_22					SW_23					SW_24					SW_26				
			Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Parameter	**Unit**	**CCME FAL sed** [16]																									
Physical Tests																											
pH	pH		6.7	6.7	6.7	-	1	6.8	6.8	6.8	-	1	-	-	-	-	0	7.9	7.9	7.9	-	1	-	-	-	-	0
Inorganics																											
Cyanide + Thiocyanate	mg/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Phosphorus	mg/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Metals																											
Aluminum	ug/kg		13000000	13000000	13000000	-	1	18000000	18000000	18000000	-	1	-	-	-	-	0	9000000	9000000	9000000	-	1	-	-	-	-	0
Antimony	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Arsenic	ug/kg	5900	3700	3700	3700	-	1	2300	2300	2300	-	1	-	-	-	-	0	4300	4300	4300	-	1	-	-	-	-	0
Barium	ug/kg		200000	200000	200000	-	1	140000	140000	140000	-	1	-	-	-	-	0	83000	83000	83000	-	1	-	-	-	-	0
Beryllium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Bismuth	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Boron	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/kg	600	**800**	**800**	**800**	-	1	**700**	**700**	**700**	-	1	-	-	-	-	0	500	500	500	-	1	-	-	-	-	0
Calcium	mg/kg		1400	1400	1400	-	1	1600	1600	1600	-	1	-	-	-	-	0	2500	2500	2500	-	1	-	-	-	-	0
Chromium	ug/kg	37300	25000	25000	25000	-	1	9000	9000	9000	-	1	-	-	-	-	0	9000	9000	9000	-	1	-	-	-	-	0
Cobalt	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Copper	ug/kg	35700	60000	60000	60000	-	1	56000	56000	56000	-	1	-	-	-	-	0	49000	49000	49000	-	1	-	-	-	-	0
Iron	ug/kg		49000	49000	49000	-	1	55000	55000	55000	-	1	-	-	-	-	0	30000	30000	30000	-	1	-	-	-	-	0
Lead	ug/kg	35000	9000	9000	9000	-	1	5000	5000	5000	-	1	28175	25370	30980	3967	2	18754.01	36.58	**59560**	27380.52	7	16.62	0.99	32.24	22.10	2
Lithium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Magnesium	mg/kg		2400	2400	2400	-	1	2000	2000	2000	-	1	-	-	-	-	0	2800	2800	2800	-	1	-	-	-	-	0
Manganese	ug/kg		2000000	2000000	2000000	-	1	2000000	2000000	2000000	-	1	-	-	-	-	0	960000	960000	960000	-	1	-	-	-	-	0
Mercury	ug/kg	170	50	50	50	-	1	40	40	40	-	1	-	-	-	-	0	138.99	0	**590**	218.66	7	0.51	0.263	0.753	0.35	2
Molybdenum	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nickel	ug/kg		7000	7000	7000	-	1	4000	4000	4000	-	1	-	-	-	-	0	6000	6000	6000	-	1	-	-	-	-	0
Potassium	mg/kg		940	940	940	-	1	380	380	380	-	1	-	-	-	-	0	460	460	460	-	1	-	-	-	-	0
Selenium	ug/kg		600	600	600	-	1	900	900	900	-	1	-	-	-	-	0	500	500	500	-	1	-	-	-	-	0
Silver	ug/kg		ld	ld	ld	-	1	ld	ld	ld	-	1	-	-	-	-	0	1600	1600	1600	-	1	-	-	-	-	0
Sodium	mg/kg		90	90	90	-	1	70	70	70	-	1	-	-	-	-	0	110	110	110	-	1	-	-	-	-	0
Strontium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Thallium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tin	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Titanium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tungsten	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Zinc	ug/kg	123000	52000	52000	52000	-	1	56000	56000	56000	-	1	-	-	-	-	0	52000	52000	52000	-	1	-	-	-	-	0

Table D-2. Sediment Results

			SW_27					SW_28					SW_30					SW_31					SW_32				
Parameter	Unit	CCME FAL sed [16]	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Physical Tests																											
pH	pH		-	-	-	-	0	-	-	-	-	0	7.7	7.7	7.7	-	1	-	-	-	-	0	-	-	-	-	0
Inorganics																											
Cyanide + Thiocyanate	mg/kg		-	-	-	-	0	-	-	-	-	0	0.68	0.68	0.68	-	1	ld	ld	ld	-	1	-	-	-	-	0
Phosphorus	mg/kg		-	-	-	-	0	-	-	-	-	0	0.02	0.02	0.02	-	1	-	-	-	-	0	-	-	-	-	0
Metals																											
Aluminum	ug/kg		-	-	-	-	0	-	-	-	-	0	7400000	7400000	7400000	-	1	-	-	-	-	0	-	-	-	-	0
Antimony	ug/kg		-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0
Arsenic	ug/kg	5900	-	-	-	-	0	-	-	-	-	0	6100	6100	6100	-	1	0.927	0.927	0.927	-	1	-	-	-	-	0
Barium	ug/kg		-	-	-	-	0	-	-	-	-	0	150000	150000	150000	-	1	-	-	-	-	0	-	-	-	-	0
Beryllium	ug/kg		-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0
Bismuth	ug/kg		-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0
Boron	ug/kg		-	-	-	-	0	-	-	-	-	0	2000	2000	2000	-	1	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/kg	600	-	-	-	-	0	-	-	-	-	0	500	500	500	-	1	-	-	-	-	0	-	-	-	-	0
Calcium	mg/kg		-	-	-	-	0	-	-	-	-	0	1700	1700	1700	-	1	-	-	-	-	0	-	-	-	-	0
Chromium	ug/kg	37300	-	-	-	-	0	-	-	-	-	0	10000	10000	10000	-	1	-	-	-	-	0	-	-	-	-	0
Cobalt	ug/kg		-	-	-	-	0	-	-	-	-	0	25000	25000	25000	-	1	-	-	-	-	0	-	-	-	-	0
Copper	ug/kg	35700	-	-	-	-	0	-	-	-	-	0	56000	56000	56000	-	1	-	-	-	-	0	-	-	-	-	0
Iron	ug/kg		-	-	-	-	0	-	-	-	-	0	34000	34000	34000	-	1	-	-	-	-	0	-	-	-	-	0
Lead	ug/kg	35000	35.63	26.65	44.6	12.69	2	-	-	-	-	0	8036.05	32.32	24000	13825.20	3	10.33	10.33	10.33	-	1	16240	7070	25410	12968.34	2
Lithium	ug/kg		-	-	-	-	0	-	-	-	-	0	6000	6000	6000	-	1	-	-	-	-	0	-	-	-	-	0
Magnesium	mg/kg		-	-	-	-	0	-	-	-	-	0	1400	1400	1400	-	1	-	-	-	-	0	-	-	-	-	0
Manganese	ug/kg		-	-	-	-	0	-	-	-	-	0	1800000	1800000	1800000	-	1	-	-	-	-	0	-	-	-	-	0
Mercury	ug/kg	170	0.30	0.102	0.497	0.28	2	0.094	0.094	0.094	-	1	107.023	0	320	184.44	3	0.732	0.732	0.732	-	1	285	20	550	374.77	2
Molybdenum	ug/kg		-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0
Nickel	ug/kg		-	-	-	-	0	-	-	-	-	0	6000	6000	6000	-	1	-	-	-	-	0	-	-	-	-	0
Potassium	mg/kg		-	-	-	-	0	-	-	-	-	0	270	270	270	-	1	-	-	-	-	0	-	-	-	-	0
Selenium	ug/kg		-	-	-	-	0	-	-	-	-	0	500	500	500	-	1	-	-	-	-	0	-	-	-	-	0
Silver	ug/kg		-	-	-	-	0	-	-	-	-	0	2800	2800	2800	-	1	-	-	-	-	0	-	-	-	-	0
Sodium	mg/kg		-	-	-	-	0	-	-	-	-	0	50	50	50	-	1	-	-	-	-	0	-	-	-	-	0
Strontium	ug/kg		-	-	-	-	0	-	-	-	-	0	11000	11000	11000	-	1	-	-	-	-	0	-	-	-	-	0
Thallium	ug/kg		-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0
Tin	ug/kg		-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0
Titanium	ug/kg		-	-	-	-	0	-	-	-	-	0	59000	59000	59000	-	1	-	-	-	-	0	-	-	-	-	0
Tungsten	ug/kg		-	-	-	-	0	-	-	-	-	0	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/kg		-	-	-	-	0	-	-	-	-	0	52000	52000	52000	-	1	-	-	-	-	0	-	-	-	-	0
Zinc	ug/kg	123000	-	-	-	-	0	-	-	-	-	0	67000	67000	67000	-	1	-	-	-	-	0	-	-	-	-	0

Table D-2. Sediment Results

Parameter	Unit	CCME FAL sed [16]	SW_35					SW_36					SW_37				
			Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N	Mean	Min	Max	Std Dev	N
Physical Tests																	
pH	pH		8.1	8.1	8.1	-	1	-	-	-	-	0	-	-	-	-	0
Inorganics																	
Cyanide + Thiocyanate	mg/kg		0.213333333	0	0.64	0.37	3	-	-	-	-	0	0	0	0	0	2
Phosphorus	mg/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Metals																	
Aluminum	ug/kg		10000000	10000000	10000000	-	1	-	-	-	-	0	-	-	-	-	0
Antimony	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Arsenic	ug/kg	5900	2050.40	0.804	4100	2898.57	2	-	-	-	-	0	2274	2274	2274	-	1
Barium	ug/kg		180000	180000	180000	-	1	-	-	-	-	0	-	-	-	-	0
Beryllium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Bismuth	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Boron	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Cadmium	ug/kg	600	ld	ld	ld	-	1	-	-	-	-	0	-	-	-	-	0
Calcium	mg/kg		6200	6200	6200	-	1	-	-	-	-	0	-	-	-	-	0
Chromium	ug/kg	37300	2505.822	11.644	5000	3527.30	2	5.76	5.76	5.76	-	1	-	-	-	-	0
Cobalt	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Copper	ug/kg	35700	20000	20000	20000	-	1	-	-	-	-	0	-	-	-	-	0
Iron	ug/kg		23000	23000	23000	-	1	-	-	-	-	0	-	-	-	-	0
Lead	ug/kg	35000	18919.11	16.43	**42300**	18838.70	4	31400	16660	**46140**	20845.51	2	29659	29659	29659	-	1
Lithium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Magnesium	mg/kg		2600	2600	2600	-	1	-	-	-	-	0	-	-	-	-	0
Manganese	ug/kg		650000	650000	650000	-	1	-	-	-	-	0	-	-	-	-	0
Mercury	ug/kg	170	**322.60**	0.38	**780**	360.85	4	**500**	**370**	**630**	183.85	2	152	152	152	-	1
Molybdenum	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Nickel	ug/kg		3000	3000	3000	-	1	-	-	-	-	0	-	-	-	-	0
Potassium	mg/kg		630	630	630	-	1	-	-	-	-	0	-	-	-	-	0
Selenium	ug/kg		200	200	200	-	1	-	-	-	-	0	-	-	-	-	0
Silver	ug/kg		700	700	700	-	1	-	-	-	-	0	-	-	-	-	0
Sodium	mg/kg		270	270	270	-	1	-	-	-	-	0	-	-	-	-	0
Strontium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Thallium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tin	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Titanium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Tungsten	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Vanadium	ug/kg		-	-	-	-	0	-	-	-	-	0	-	-	-	-	0
Zinc	ug/kg	123000	41000	41000	41000	-	1	-	-	-	-	0	-	-	-	-	0

Notes

(1) - = No standard or not analysed
(2) ld = Less than detection limit
(3) Decreto 33-95 = Nicaragua Executive Decree 33-95, June 26, 1995
(4) MMER Max Grab = Fisheries Act (R.S., 1985, c. F-14), Metal Mining Effluent Regulations (SOR/2002-222), Schedule 4: Authorized Limits of Deleterious Substances (SOR/2006-239, s.25), Column 4: Maximum Authorized Concentration in a Grab Sample
(5) Default to Decreto 33-95 where differ in value
(6) CAPRE DW = Comité Coordinator Regional de Instituciones de Agua Potable y Saneamiento de Centroamérica, Panama y República Dominicana, Water Quality Norms for Human Consumption, 1993, updated to March 1994
(7) WHO DW = World Health Organization, Guidelines for Drinking Water Quality
(8) Default to CAPRE where differ in value
(9) CCME FAL SW = Canadian Council of Ministers of the Environment, Chapter 4, Canadian Water Quality Guidelines for the Protection of Aquatic Life, Freshwater, updated to June 28, 2011
(10) pH X-Y indicates pH not < X and not > Y
(11) This appears to be a typo, as 1 mg/L as a TDS limit for effluent is: a) unrealistic and b) far more stringent than the drinking water standard, which intuitively should be the reverse. Assume standard of 1000 as per CAPRE
(12) Aluminum varies with Hardness, Ca2+ in mg/L as follows for CCME FAL:

5	if	Ca2+<4
100	if	Ca2+>=4

Aluminum varies with Dissolved Organic Carbon in mg/L as follows for CCME FAL FAL:

5	if	DOC<2
100	if	DOC>=2

Aluminum varies with pH as follows for CCME FAL:

5	if	pH<6.5
100	if	pH>=6.5

(13) Cadmium varies with Hardness in mg/L as follows for CCME FAL: 10^{0.86[log(hardness)] - 3.2}; the following calculated criteria have been applied conservatively: 0.0006 µg/L if H < 46 mg/L, 0.017 µg/L if H >= 46 mg/L
(14) Copper varies with Hardness in mg/L as follows for CCME FAL:

2	if	H<120
3	if	H>=120 and H<180
4	if	H>=180

Lead varies with Hardness in mg/L as follows for CCME FAL:

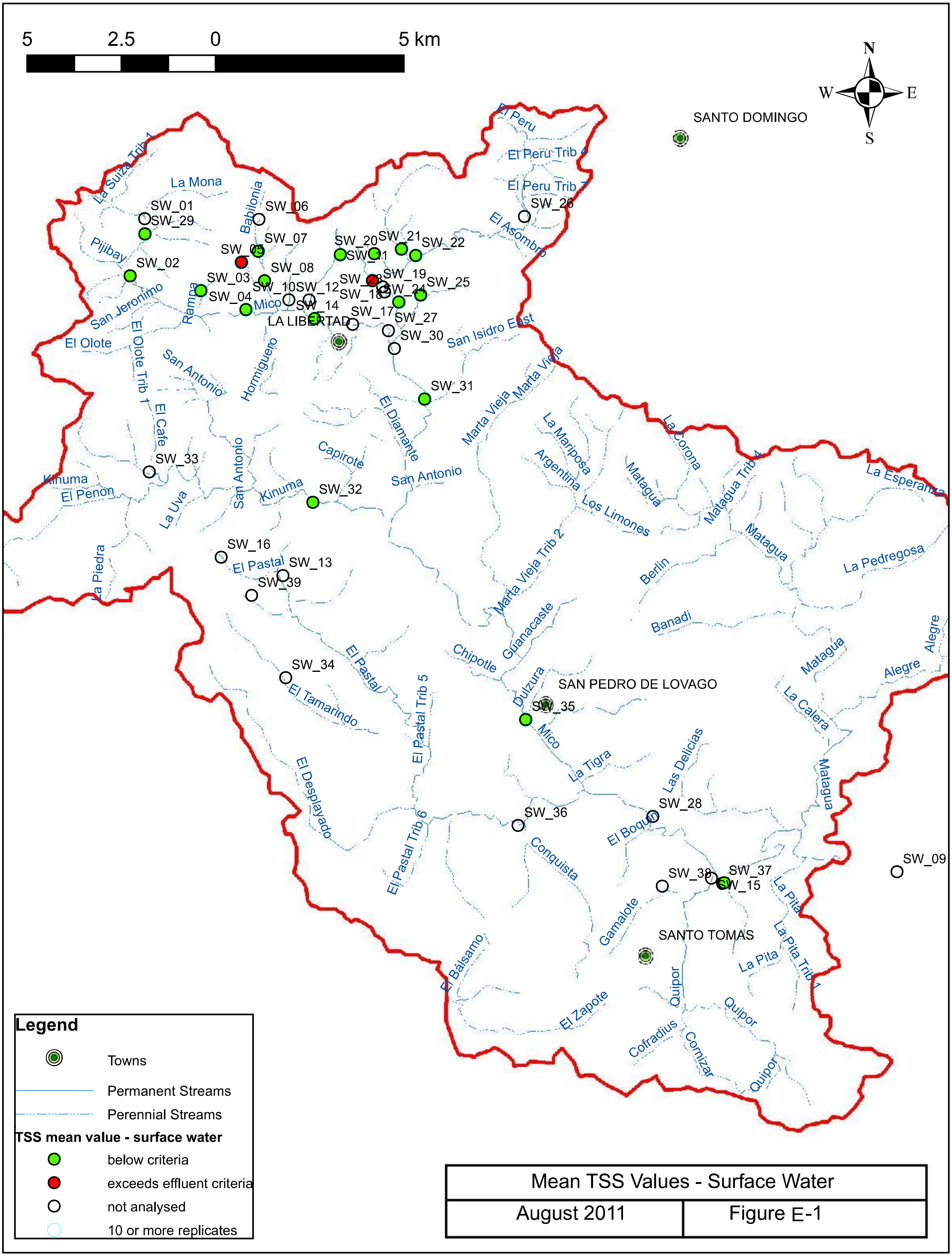
1	if	H<60
2	if	H>=60 and H<120
4	if	H>=120 and H<180
7	if	H>=180

(15) Nickel varies with Hardness in mg/L as follows for CCME FAL:

25	if	H<60
65	if	H>=60 and H<120
110	if	H>=120 and H<180
150	if	H>=180

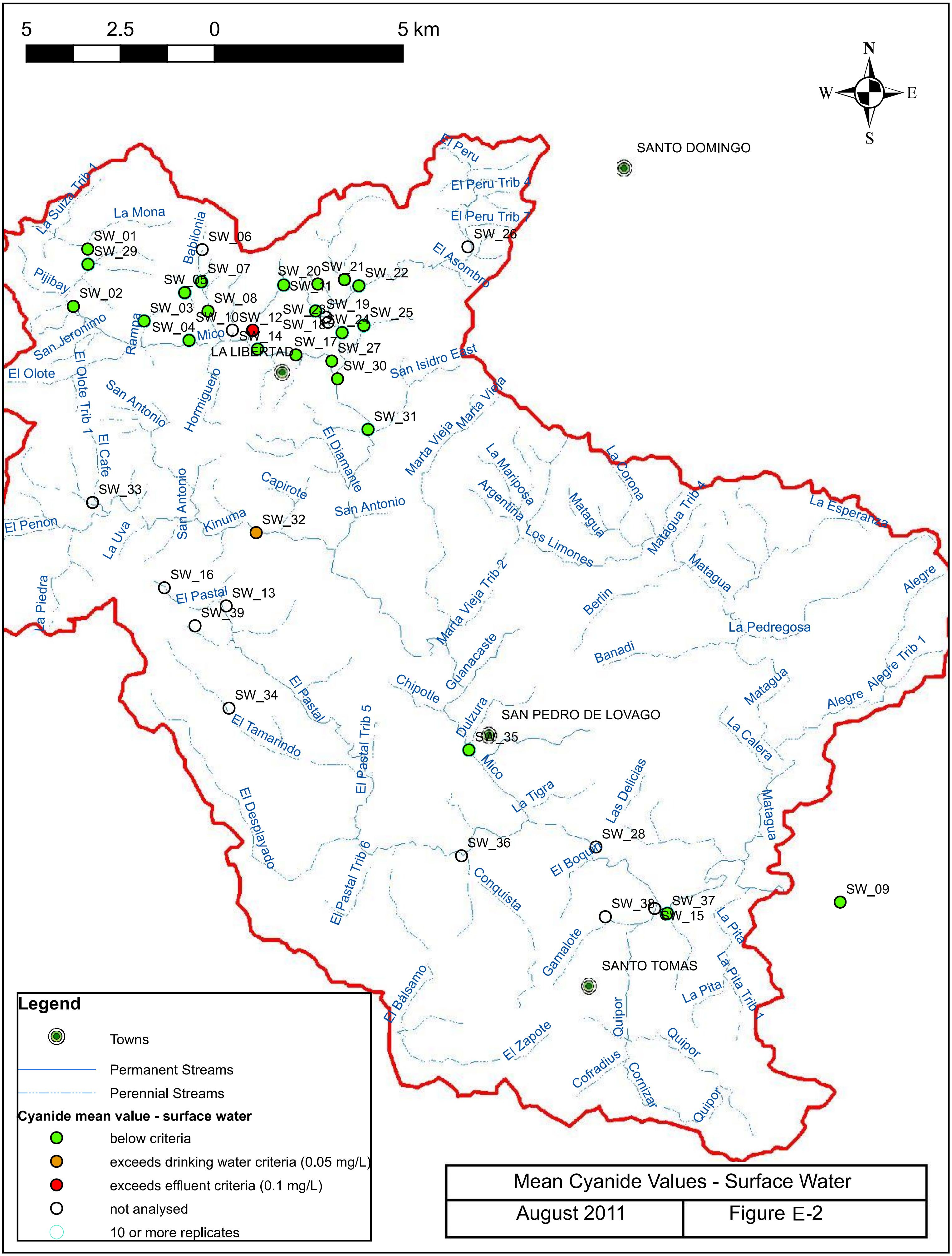
(16) CCME FAL sed = Canadian Council of Ministers of the Environment, Chapter 4, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater, updated to June 28, 2011

Appendix E
Spatial Distribution of Exceedances –
Selected Parameters



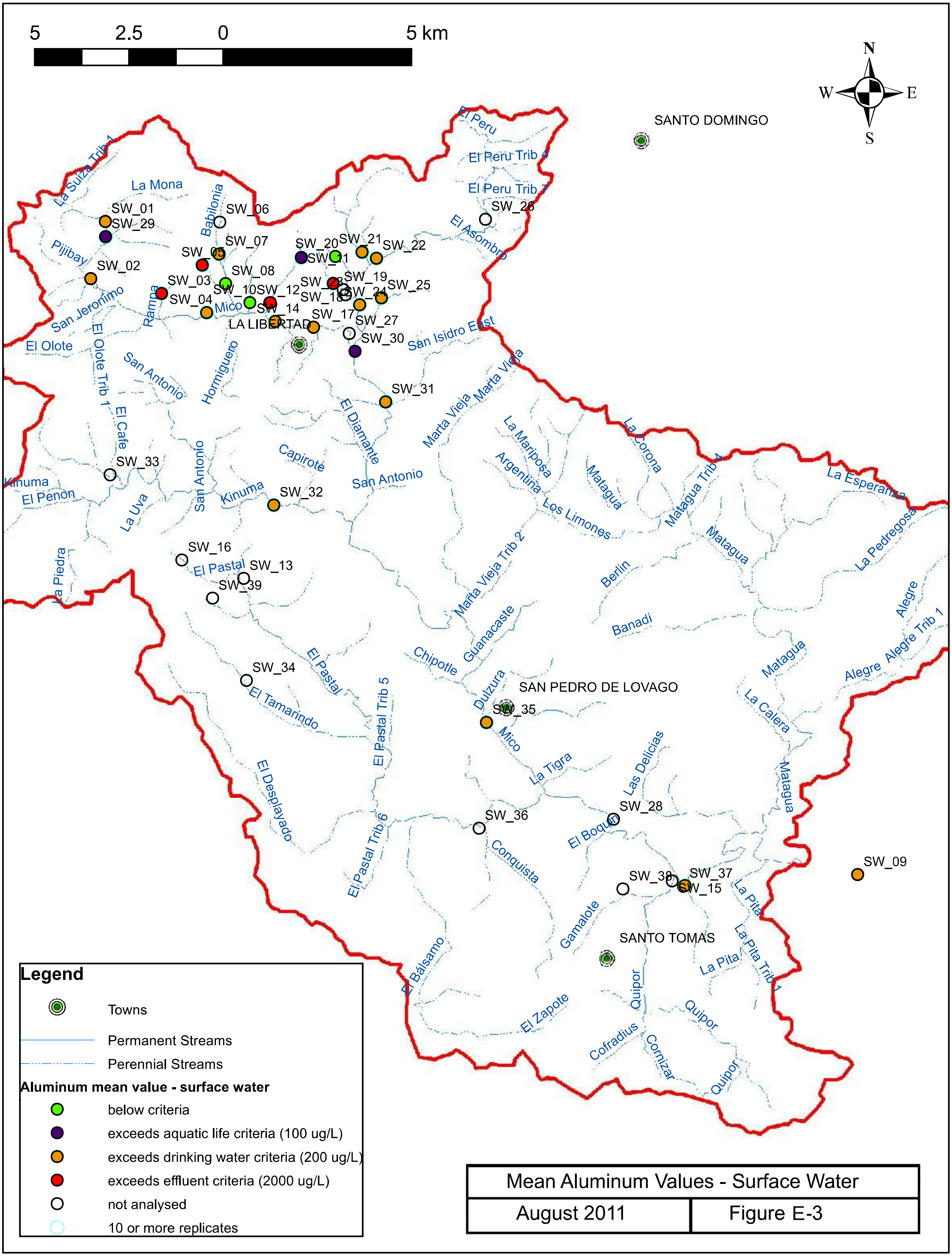
Mean TSS Values - Surface Water

August 2011 | Figure E-1

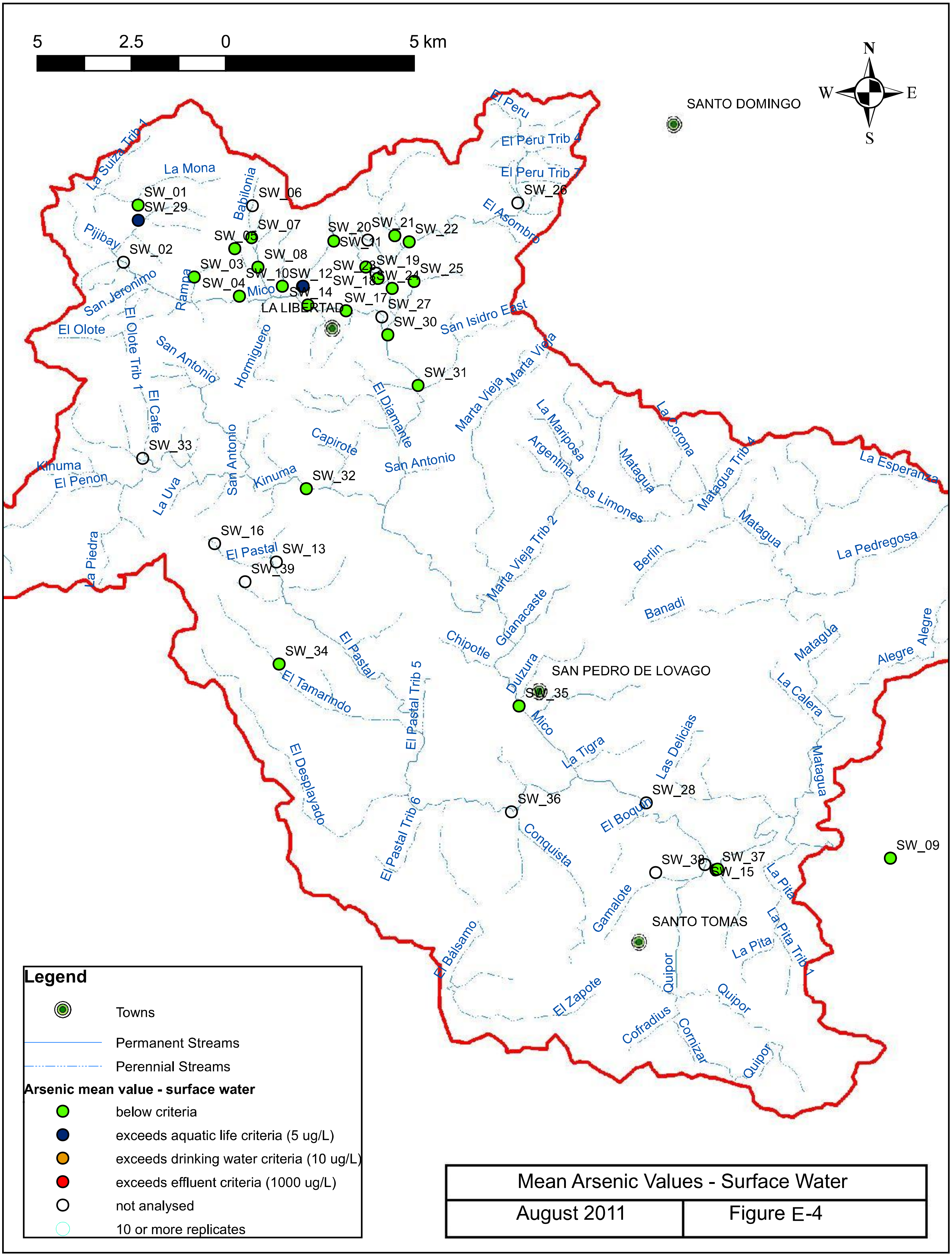


Mean Cyanide Values - Surface Water

August 2011 | Figure E-2

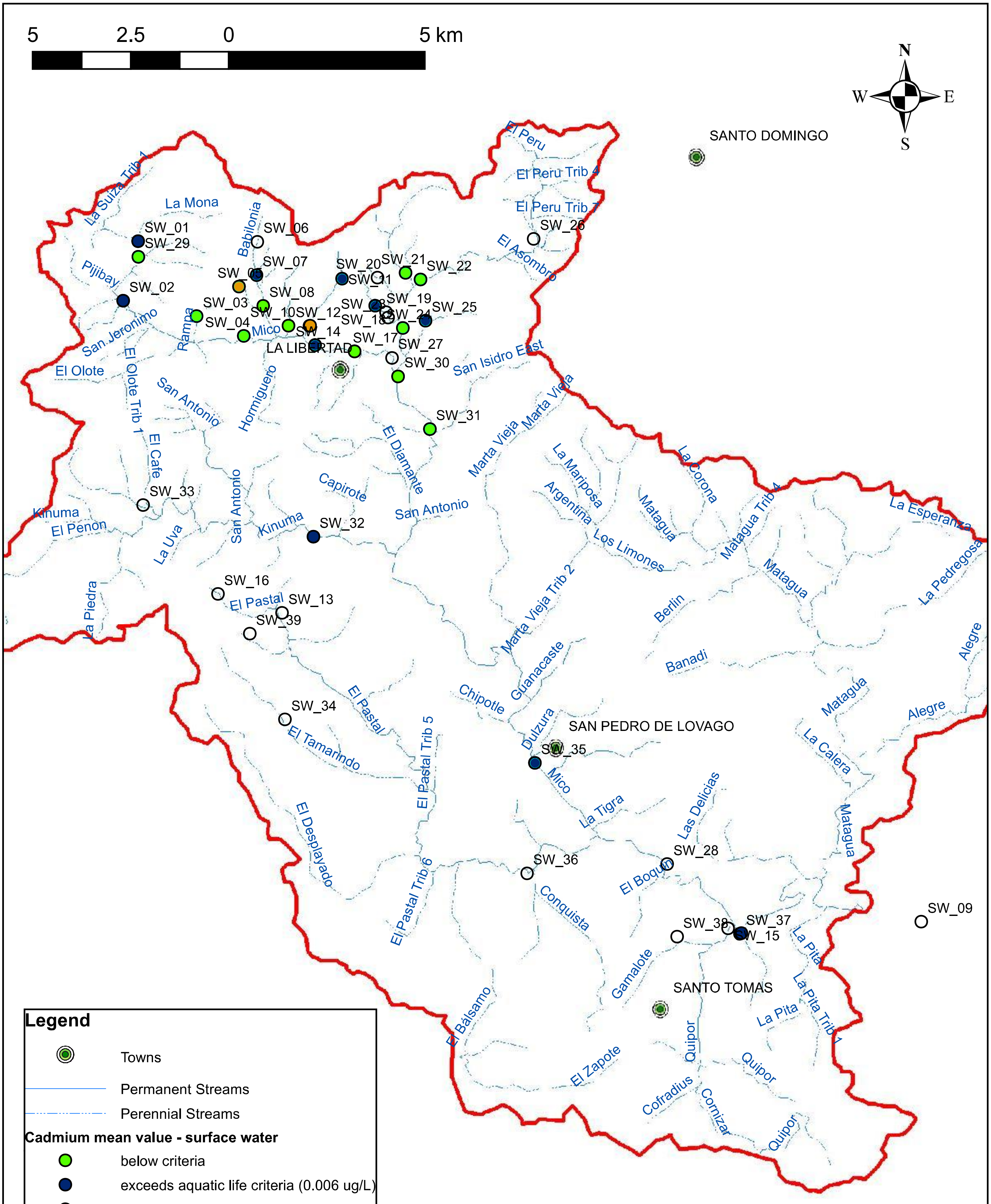


Mean Aluminum Values - Surface Water	
August 2011	Figure E-3

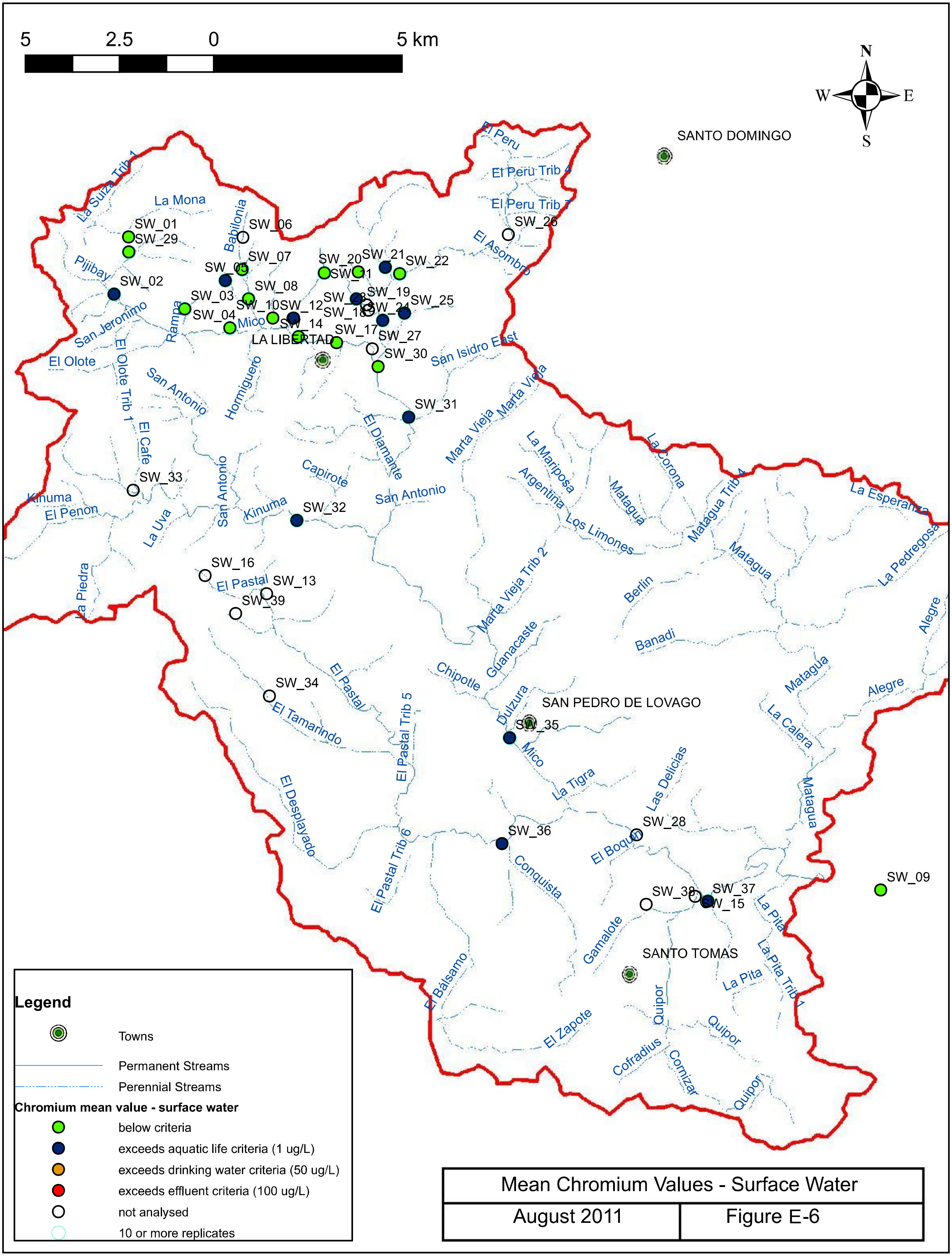


Mean Arsenic Values - Surface Water

August 2011 | Figure E-4

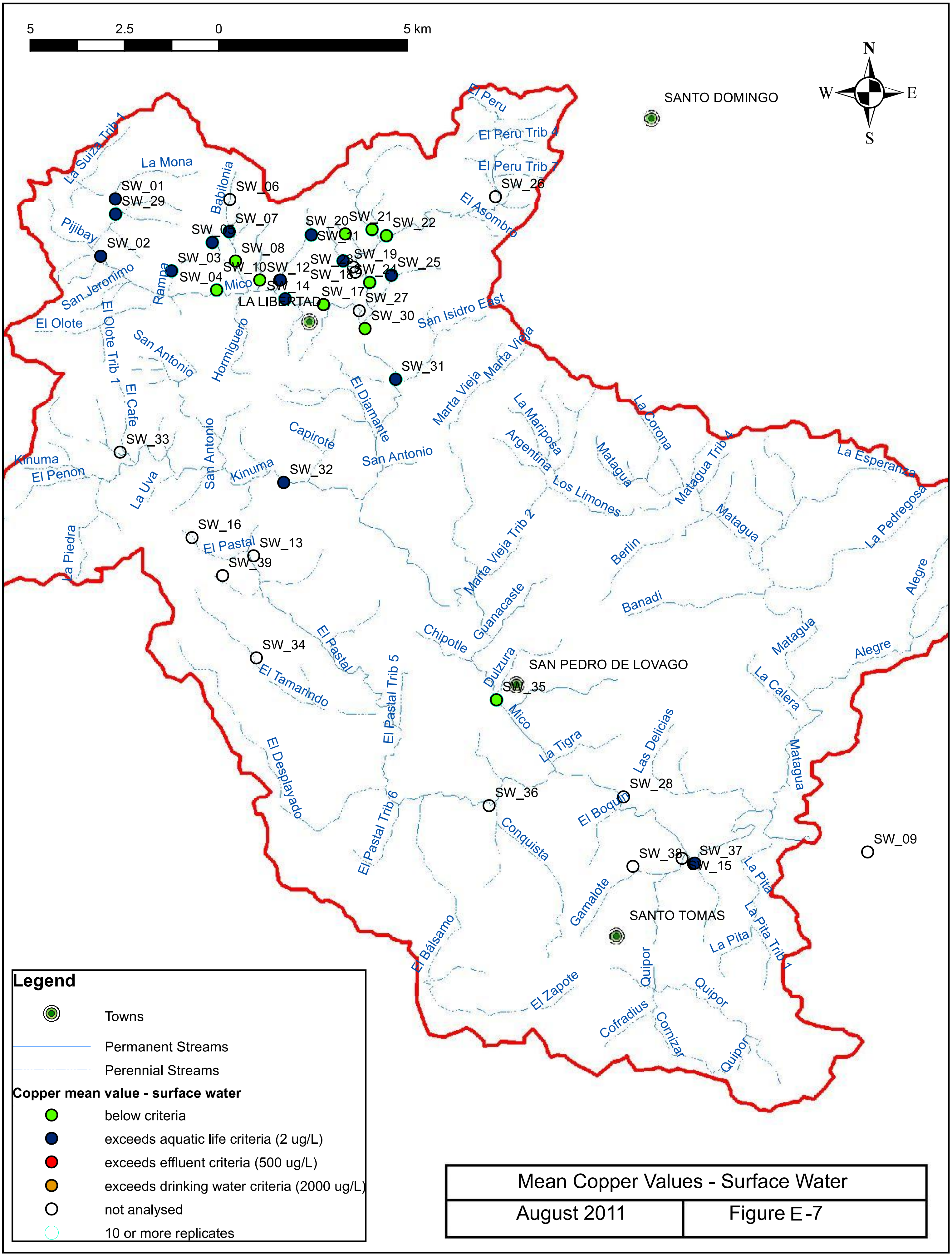


Mean Cadmium Values - Surface Water	
August 2011	Figure E-5

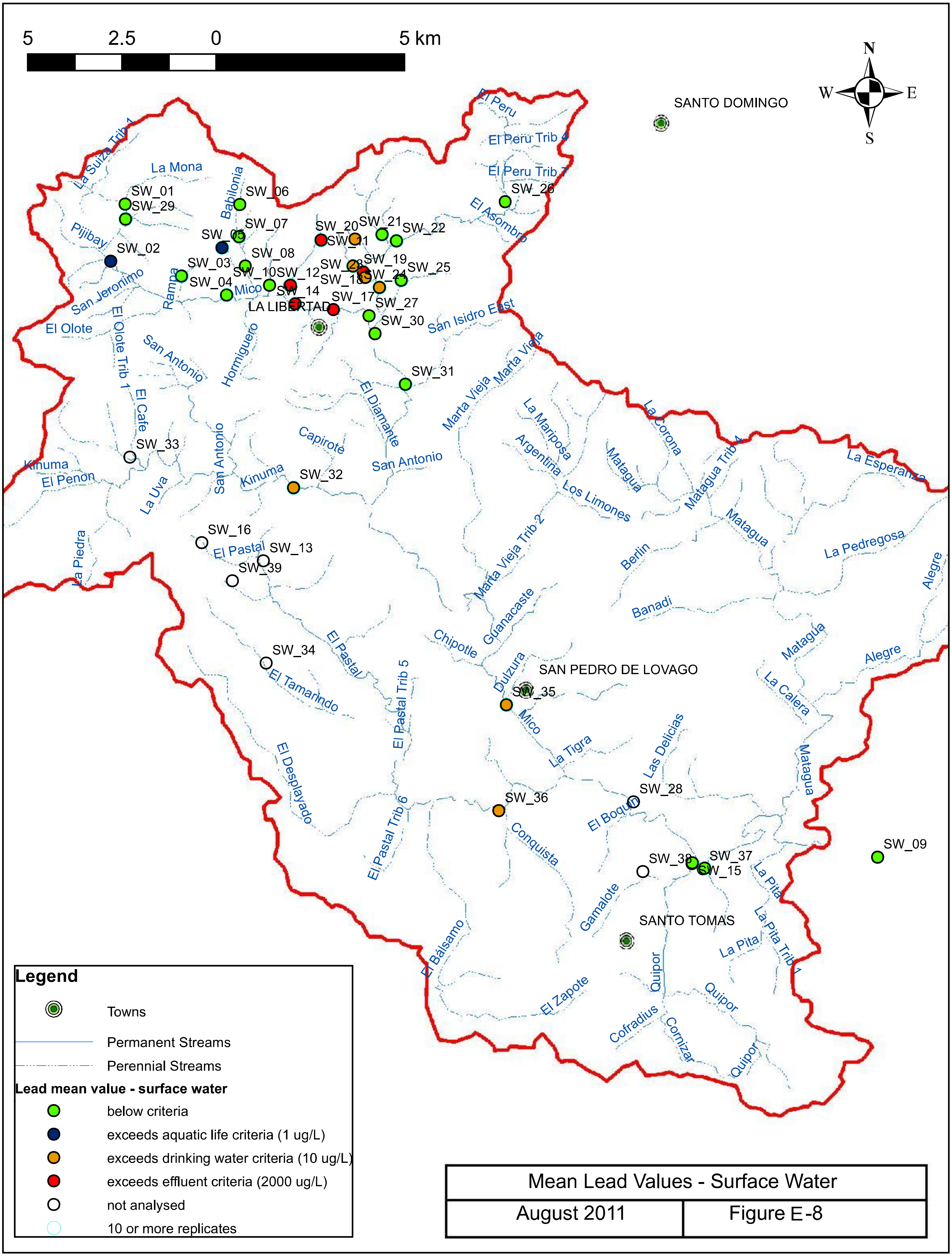


Mean Chromium Values - Surface Water

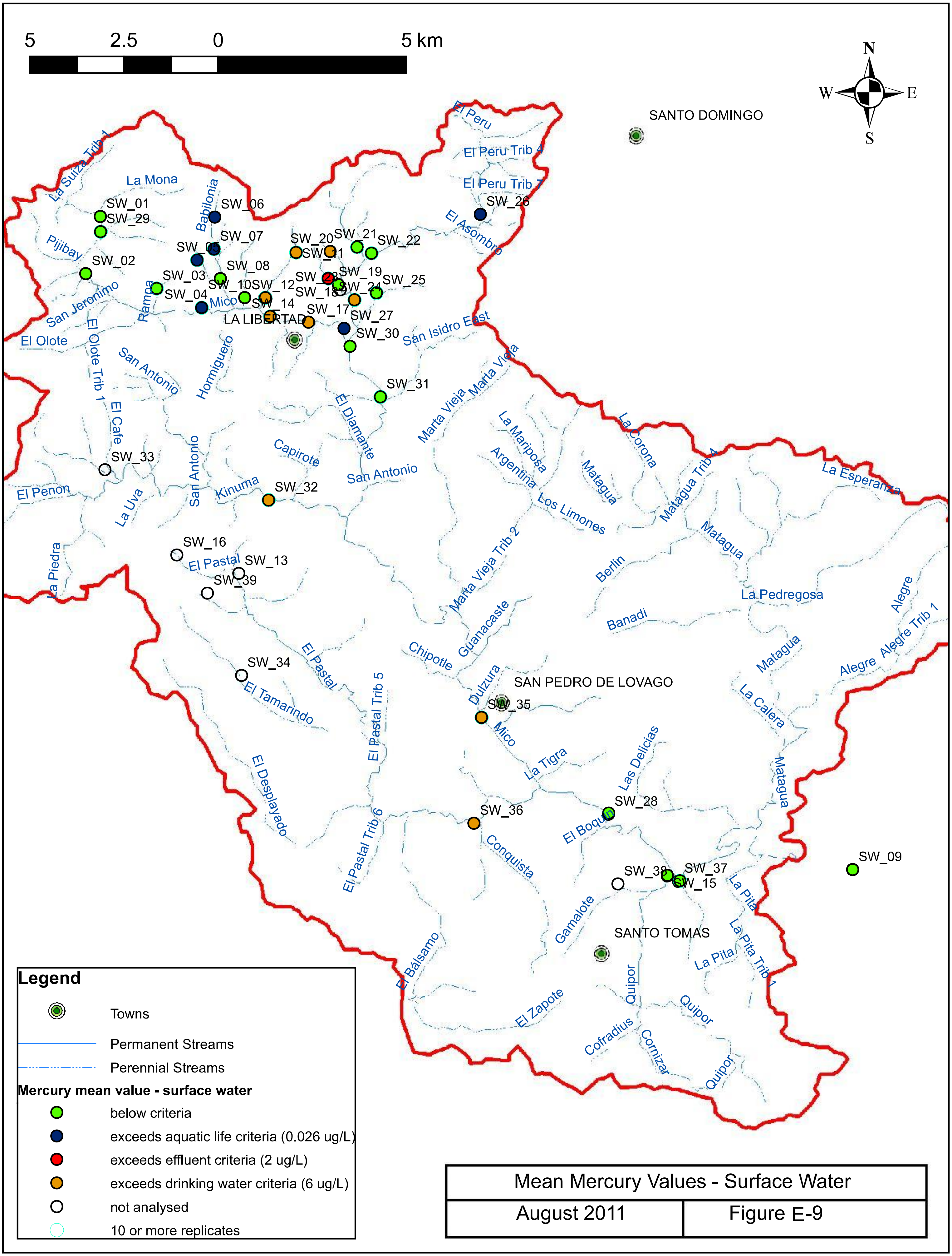
August 2011 | Figure E-6



Mean Copper Values - Surface Water	
August 2011	Figure E-7

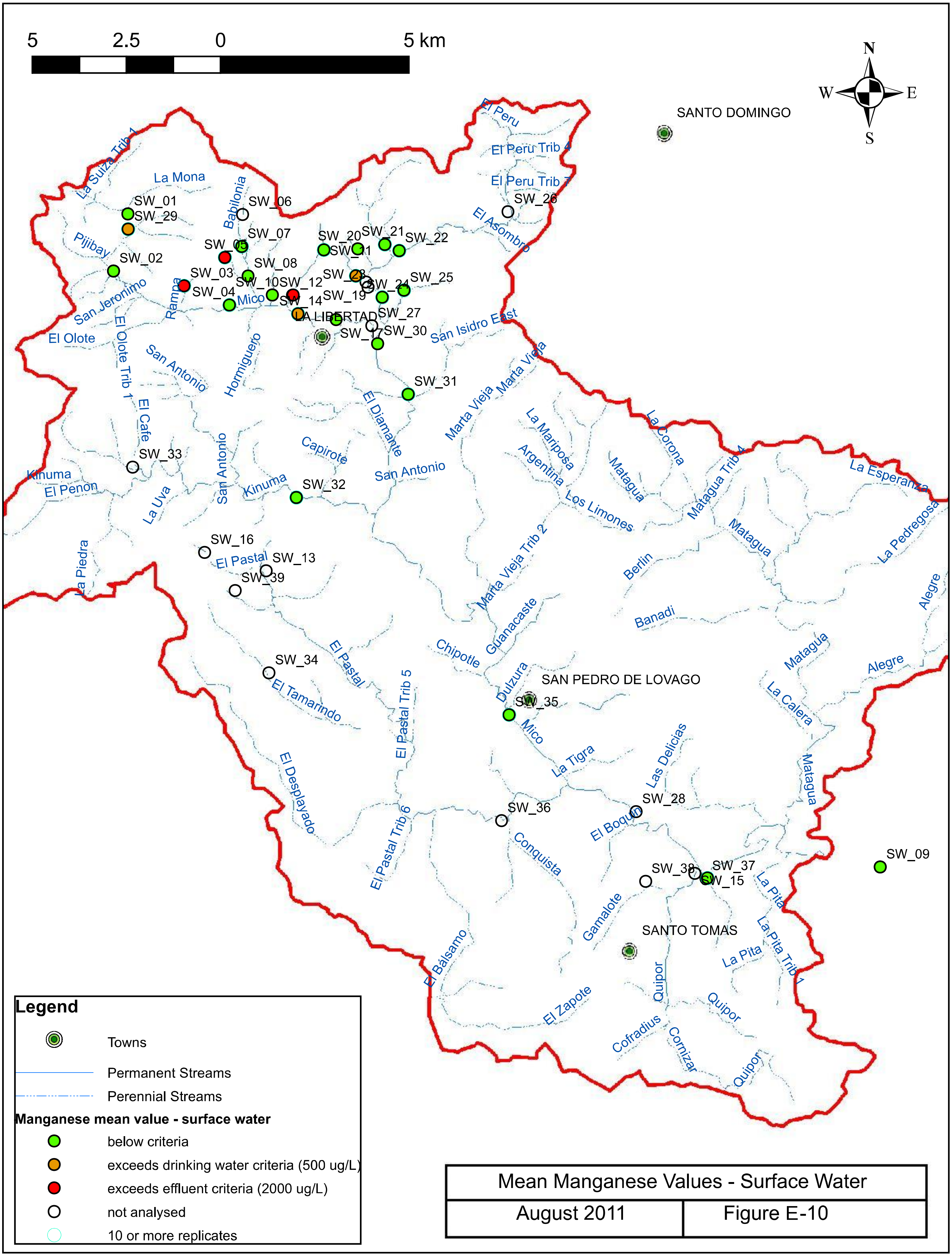


Mean Lead Values - Surface Water	
August 2011	Figure E-8



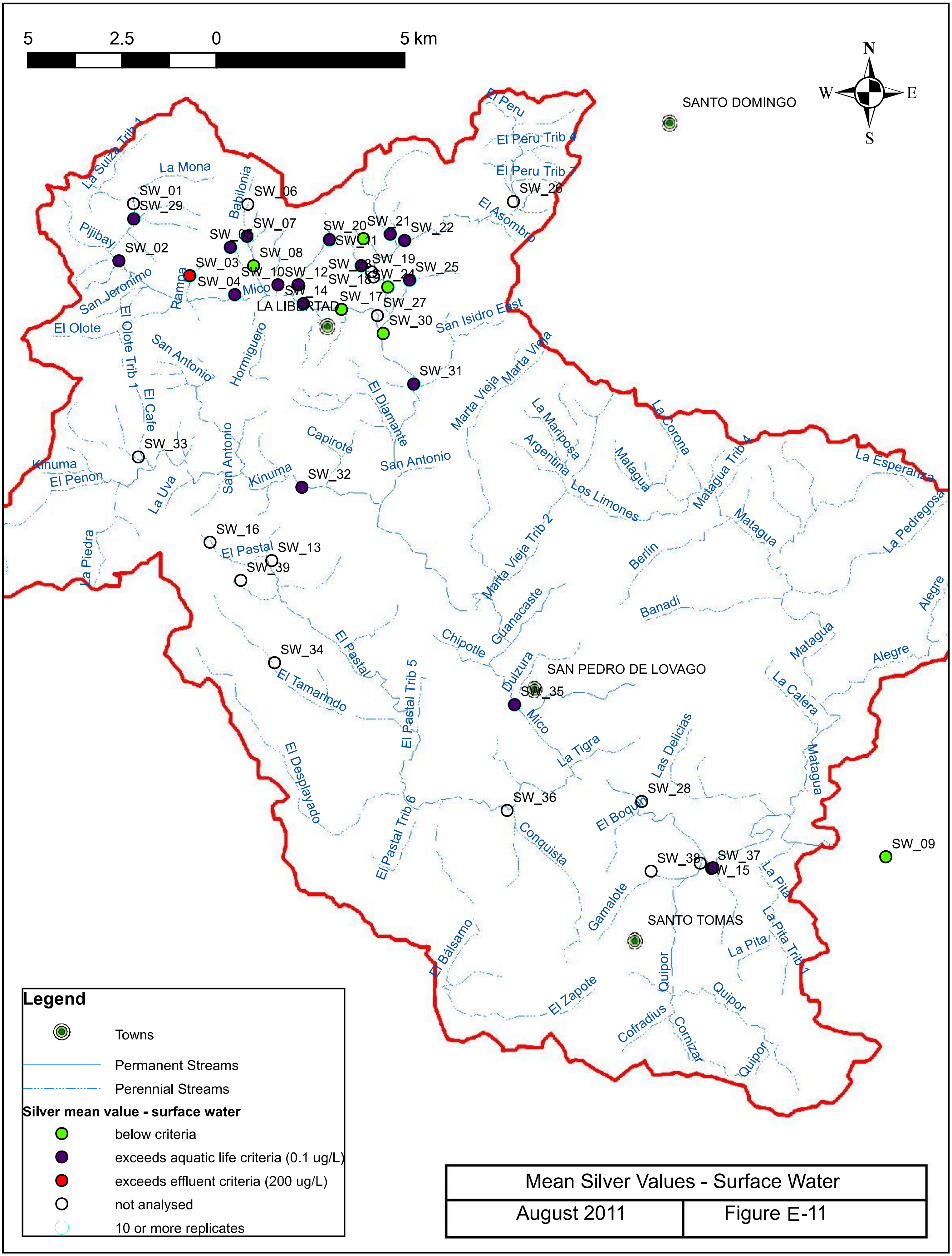
Mean Mercury Values - Surface Water

August 2011 | Figure E-9



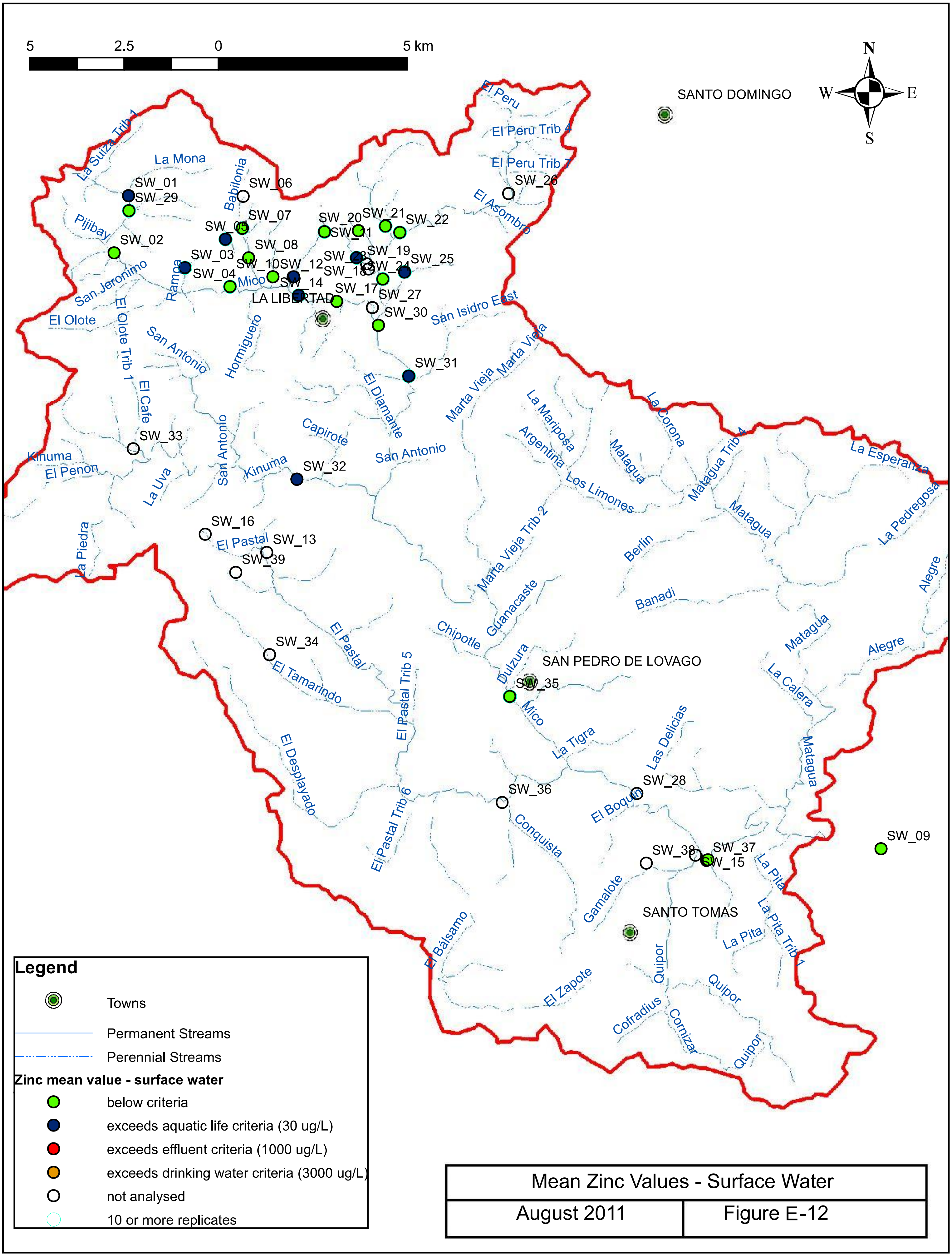
Mean Manganese Values - Surface Water

August 2011 | Figure E-10

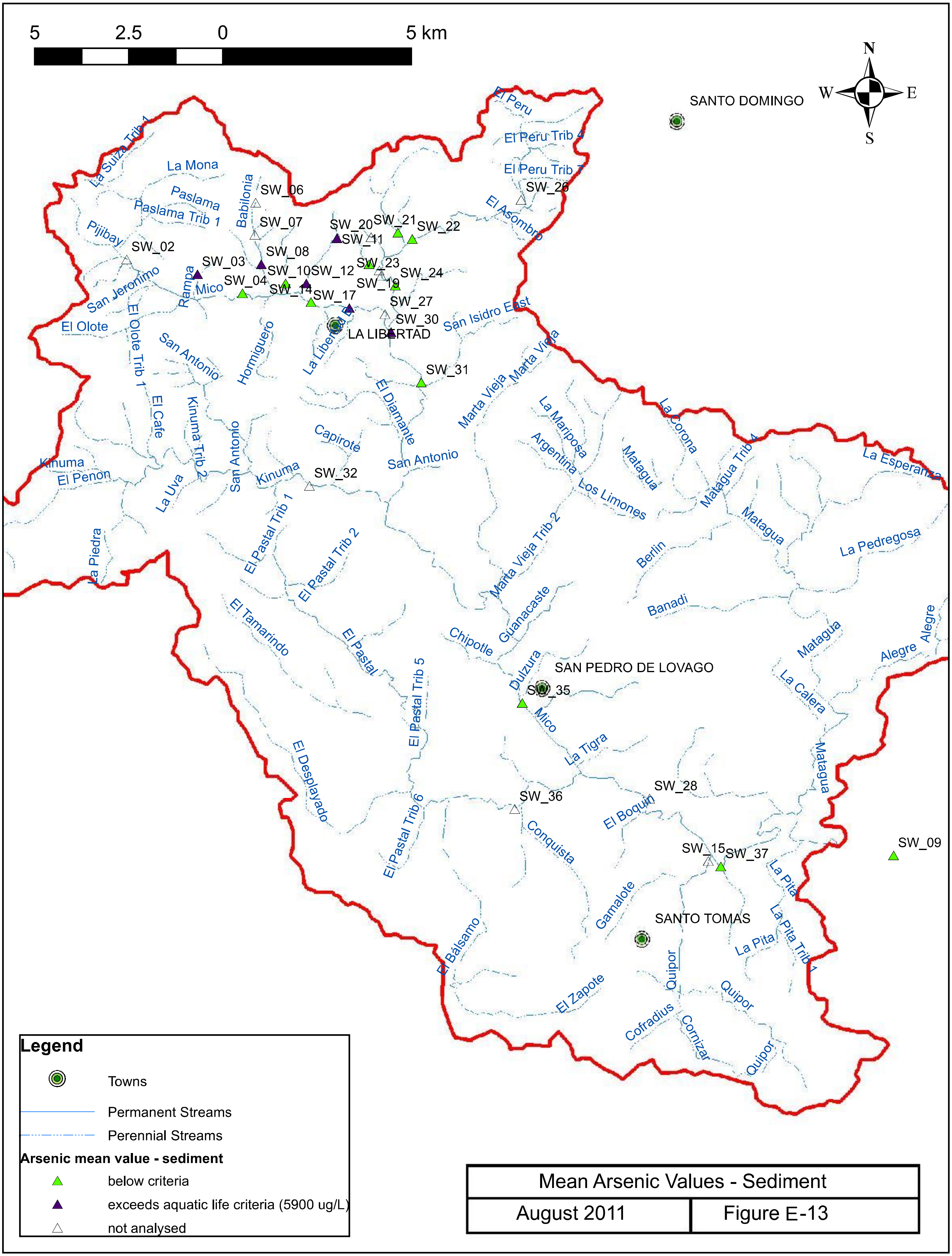


Mean Silver Values - Surface Water

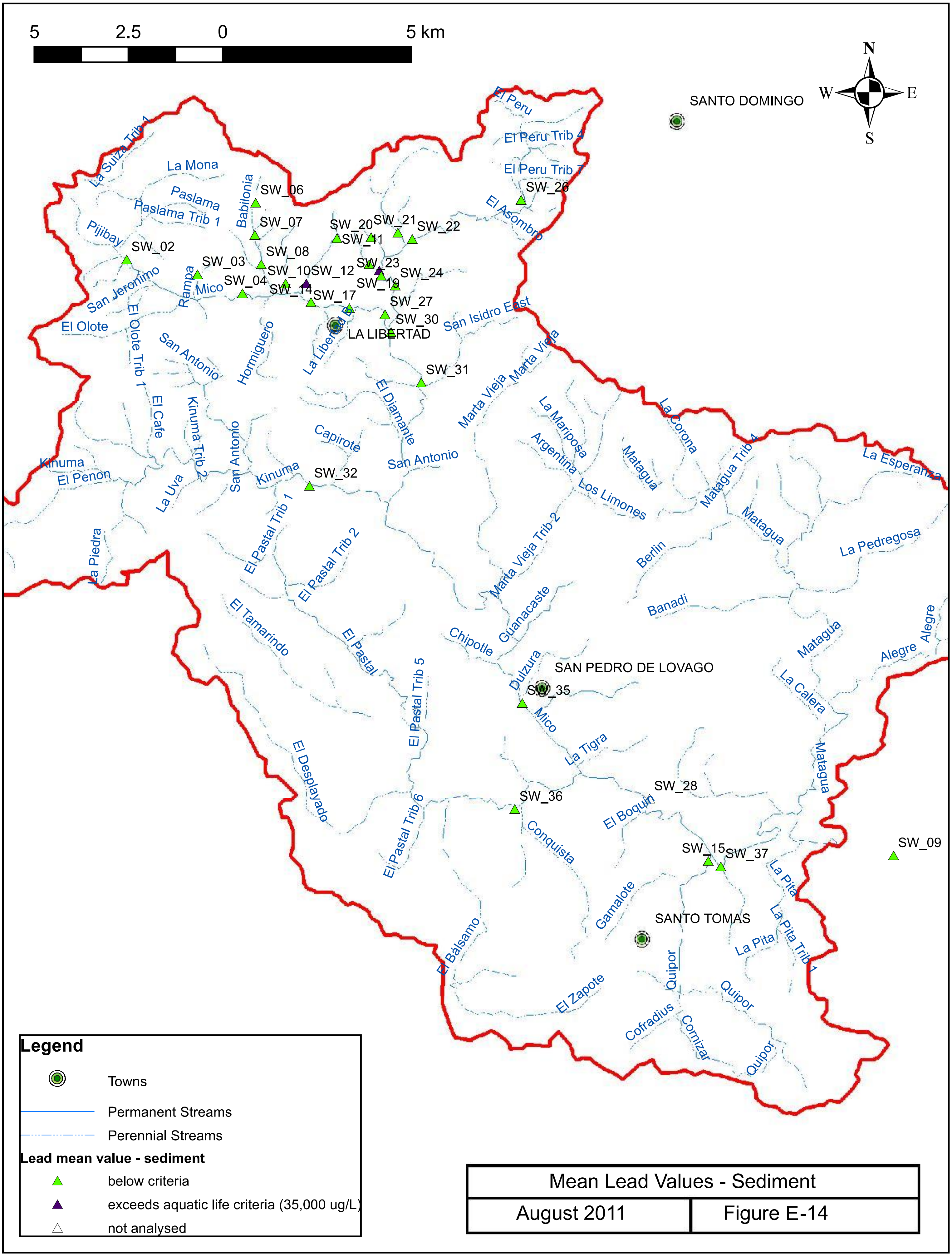
August 2011 | Figure E-11



Mean Zinc Values - Surface Water	
August 2011	Figure E-12

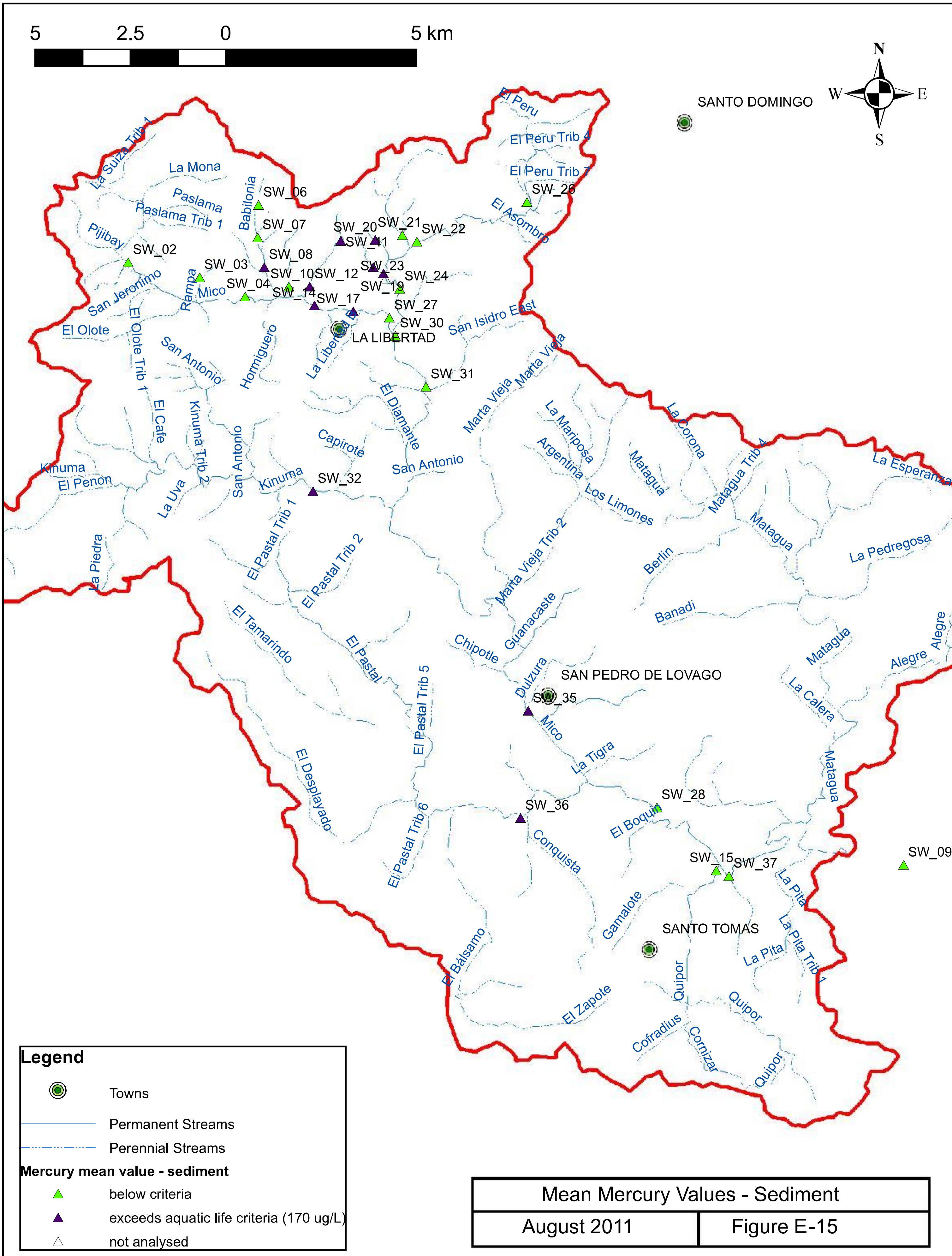


Mean Arsenic Values - Sediment	
August 2011	Figure E-13



Mean Lead Values - Sediment

August 2011 | Figure E-14

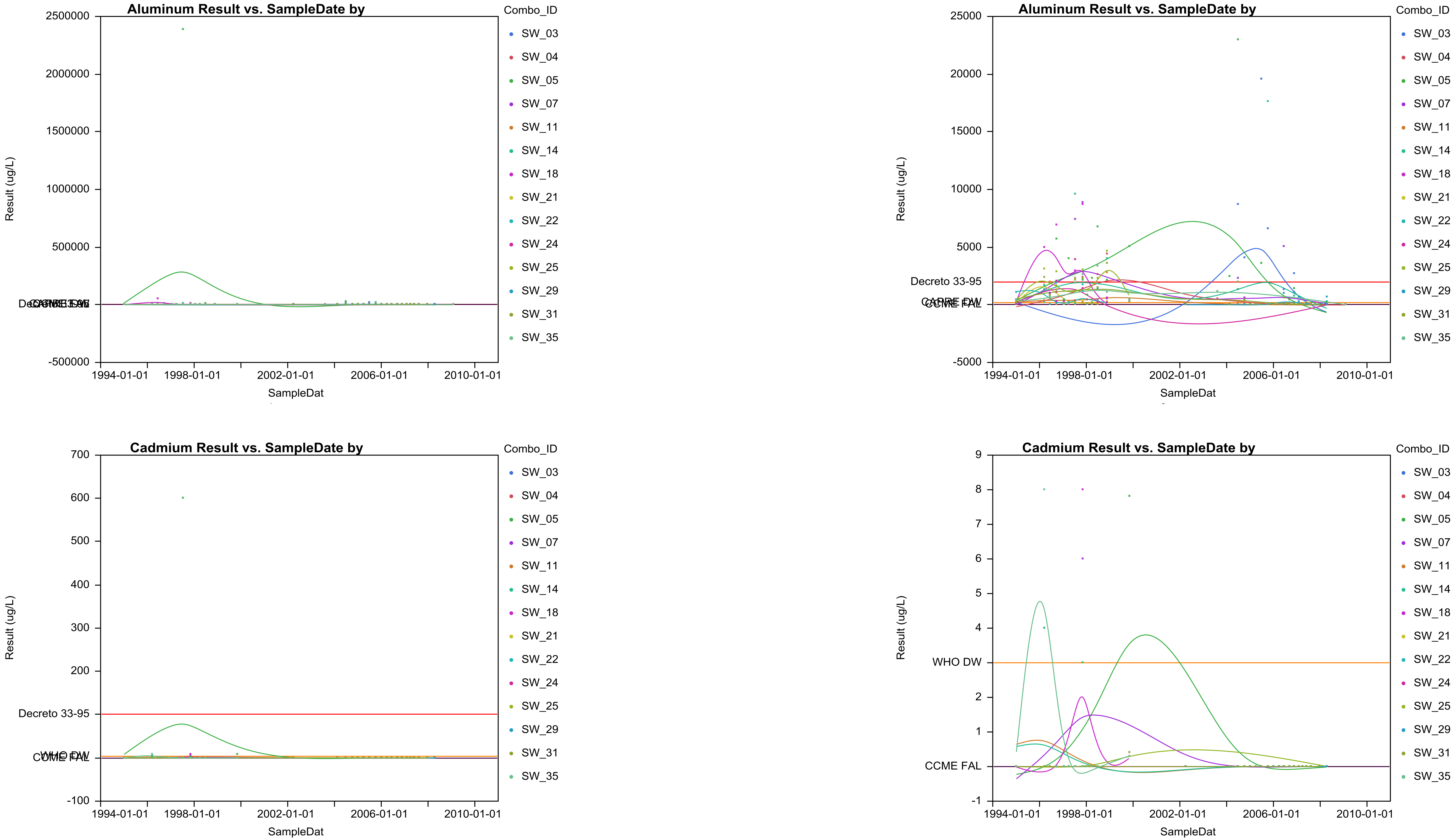


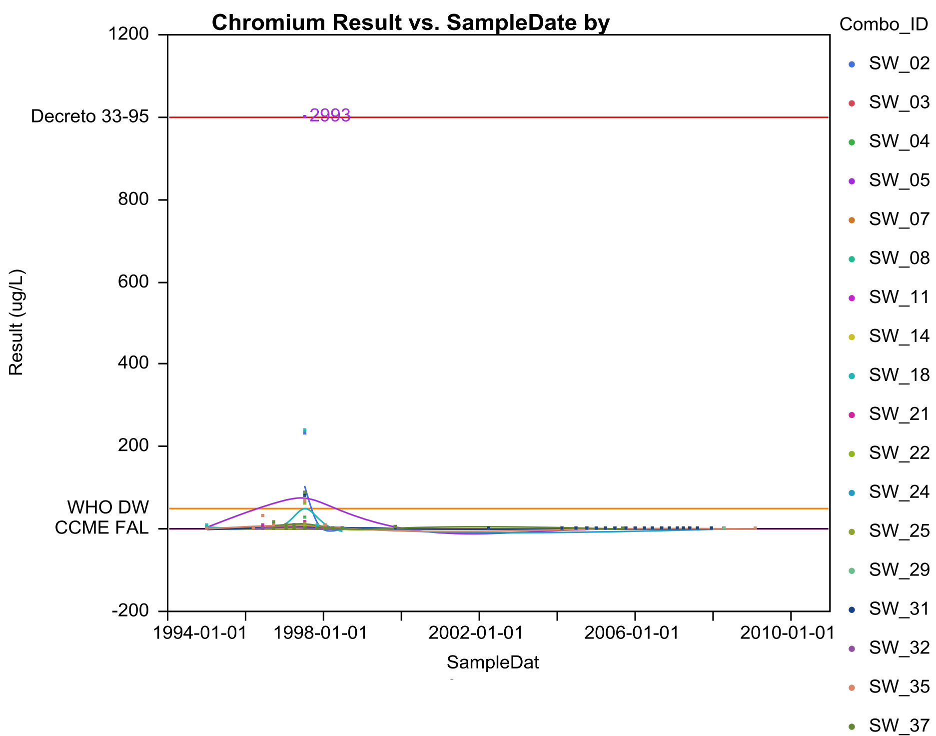
Mean Mercury Values - Sediment	
August 2011	Figure E-15

Appendix F
Surface Water Mean Results (n≥10) over Time

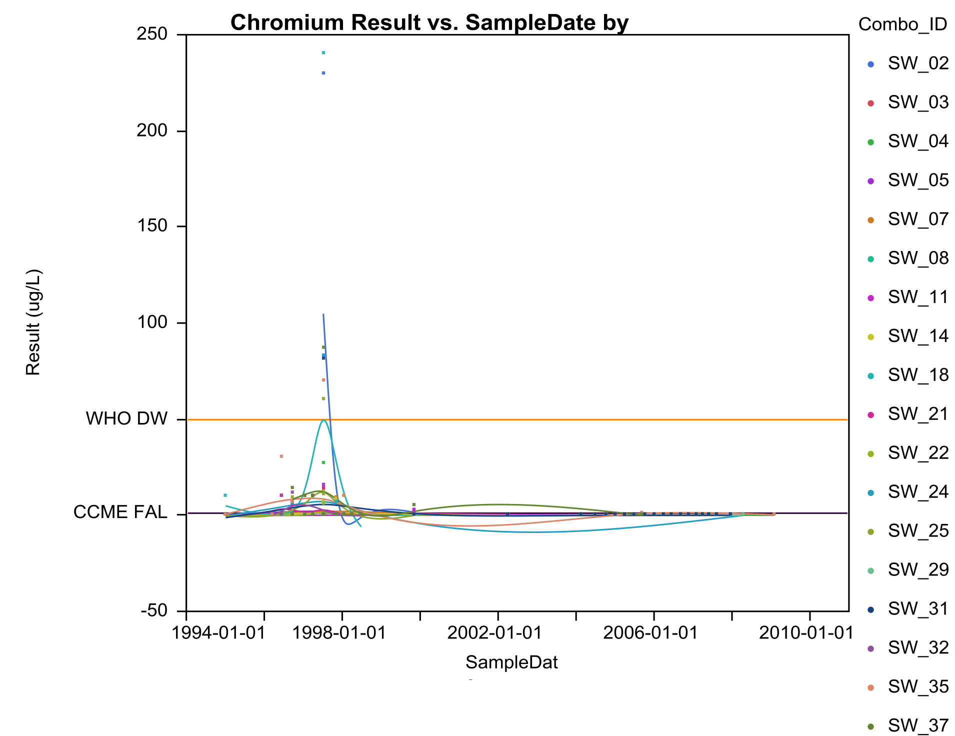
Figure F-1. Surface Water Mean Results (n≥10) vs Time

Note: Repeated figures to the right of the page show results with one or two greatest outliers removed in order to see trends more clearly.

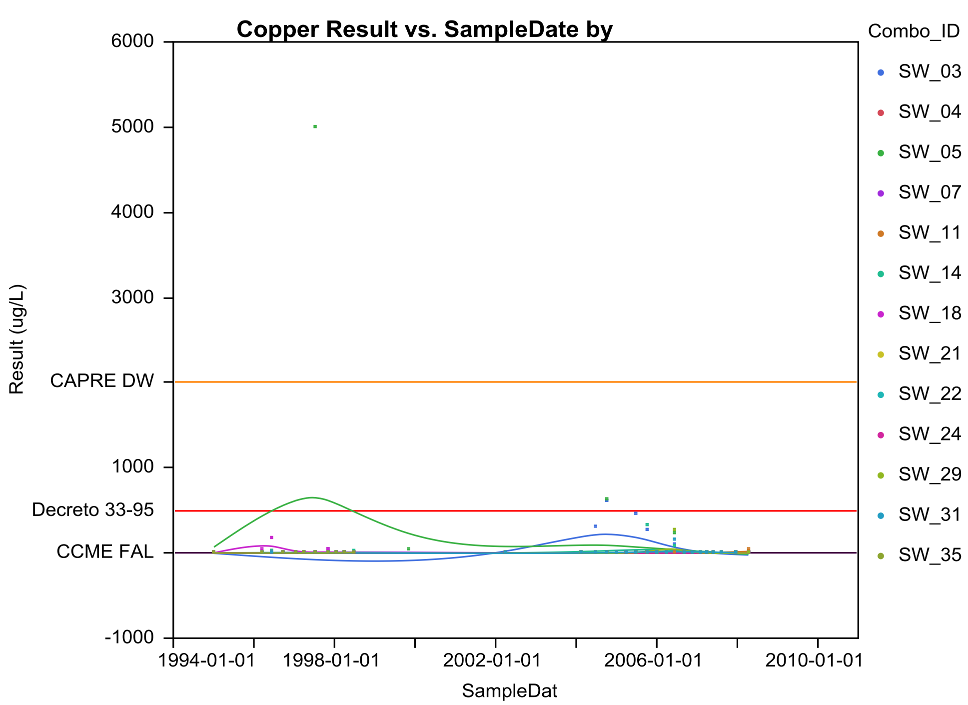




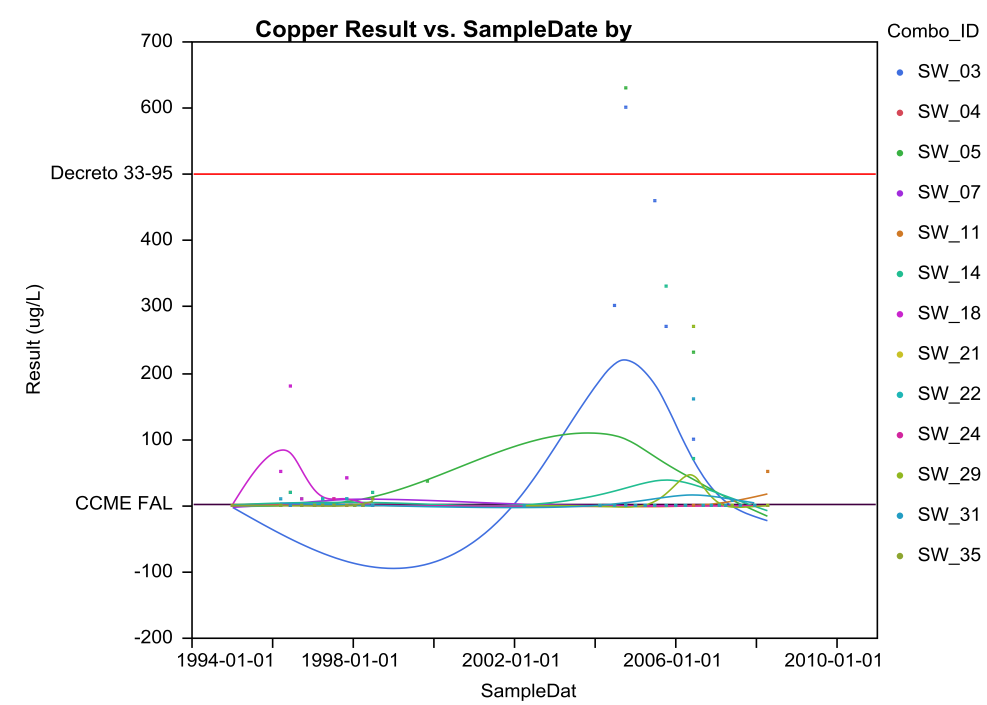
Chromium Result vs. SampleDate by
Combo_ID
SW_02
SW_03
SW_04
SW_05
SW_07
SW_08
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_32
SW_35
SW_37
1200
Decreto 33-95
2993
800
600
400
200
WHO DW
CCME FAL
-200
Result (ug/L)
1994-01-01
1998-01-01
2002-01-01
2006-01-01
2010-01-01
SampleDat



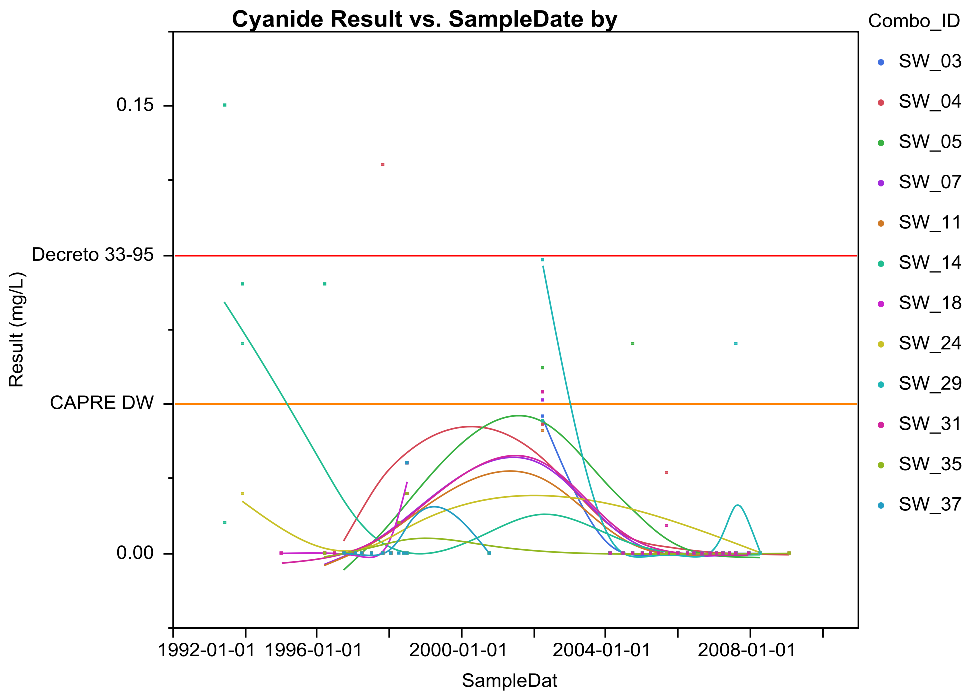
Chromium Result vs. SampleDate by
Combo_ID
SW_02
SW_03
SW_04
SW_05
SW_07
SW_08
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_32
SW_35
SW_37
250
200
150
100
WHO DW
CCME FAL
-50
Result (ug/L)
1994-01-01
1998-01-01
2002-01-01
2006-01-01
2010-01-01
SampleDat

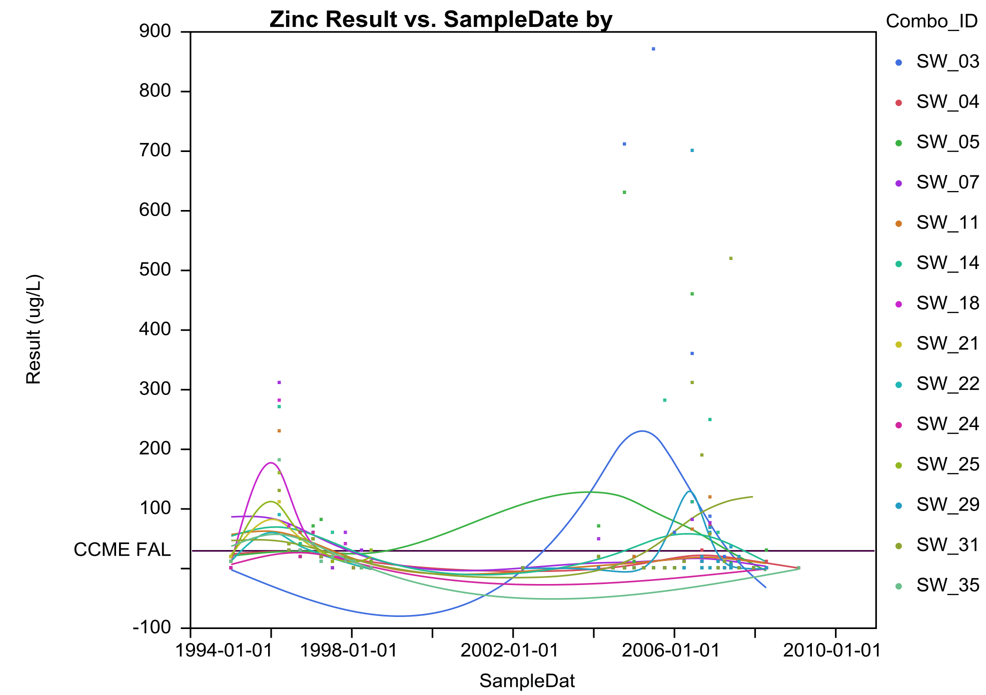


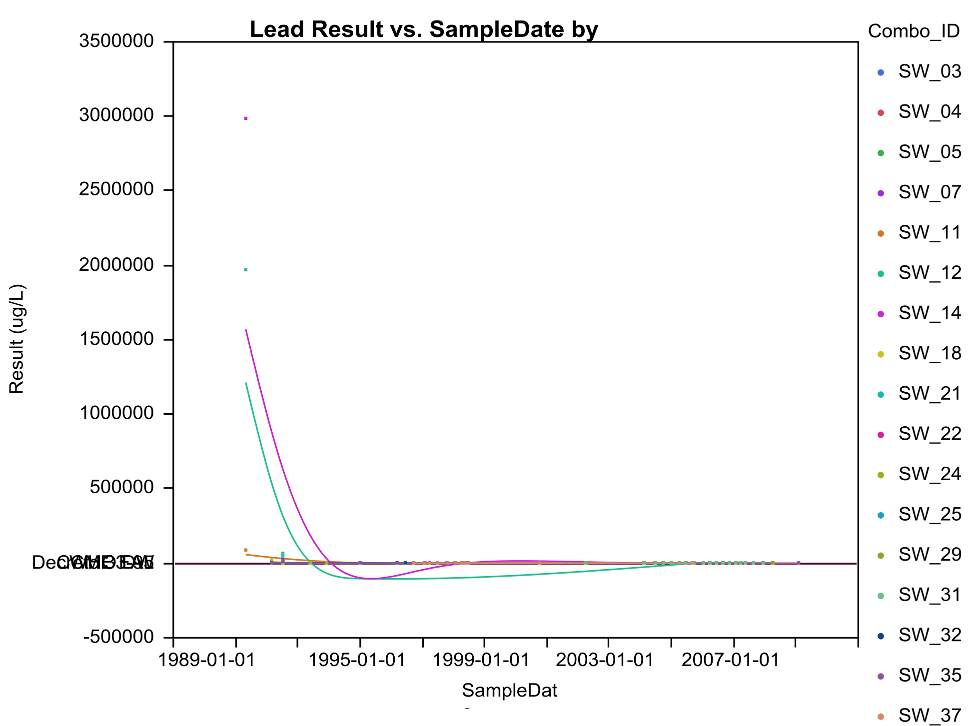
Copper Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_29
SW_31
SW_35
6000
5000
4000
3000
CAPRE DW
1000
Decreto 33-95
CCME FAL
-1000
Result (ug/L)
1994-01-01
1998-01-01
2002-01-01
2006-01-01
2010-01-01
SampleDat

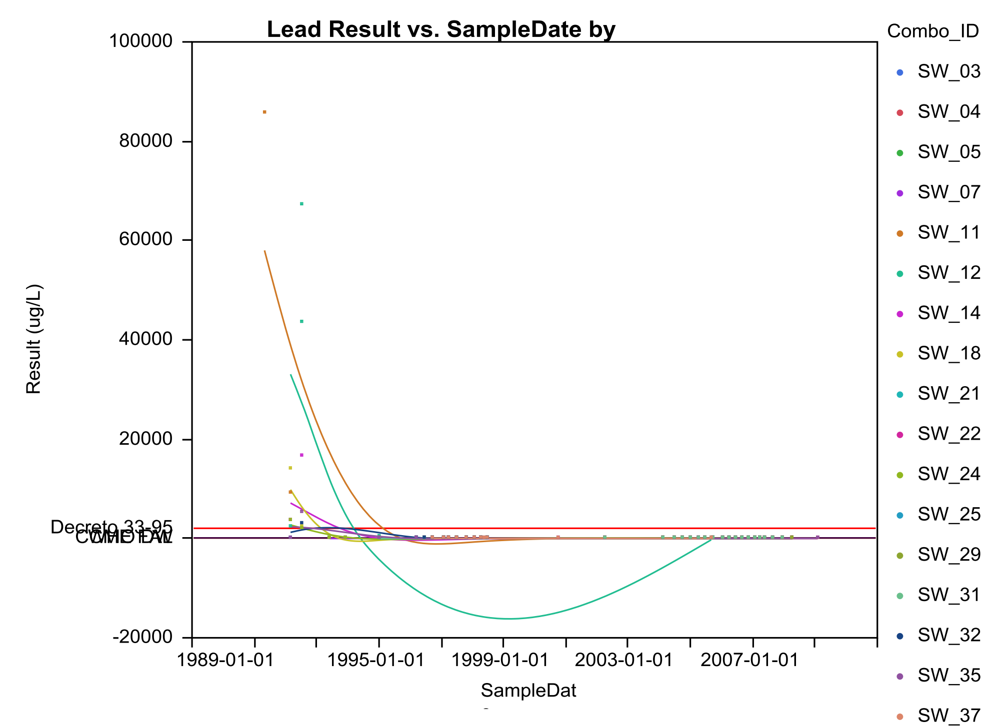


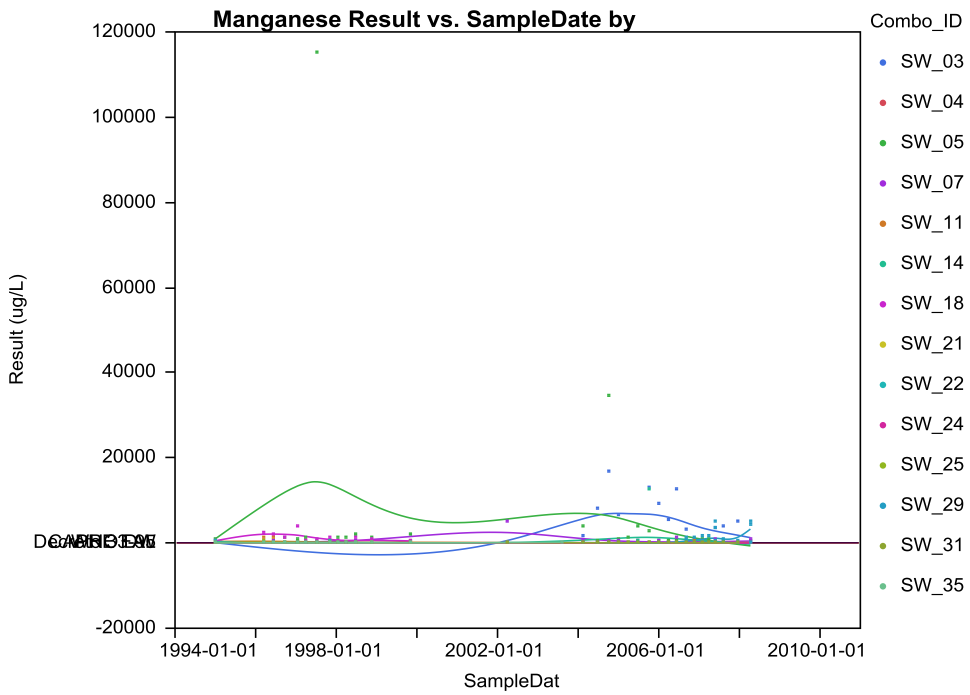
Copper Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_29
SW_31
SW_35
700
600
Decreto 33-95
400
300
200
100
CCME FAL
-100
-200
Result (ug/L)
1994-01-01
1998-01-01
2002-01-01
2006-01-01
2010-01-01
SampleDat

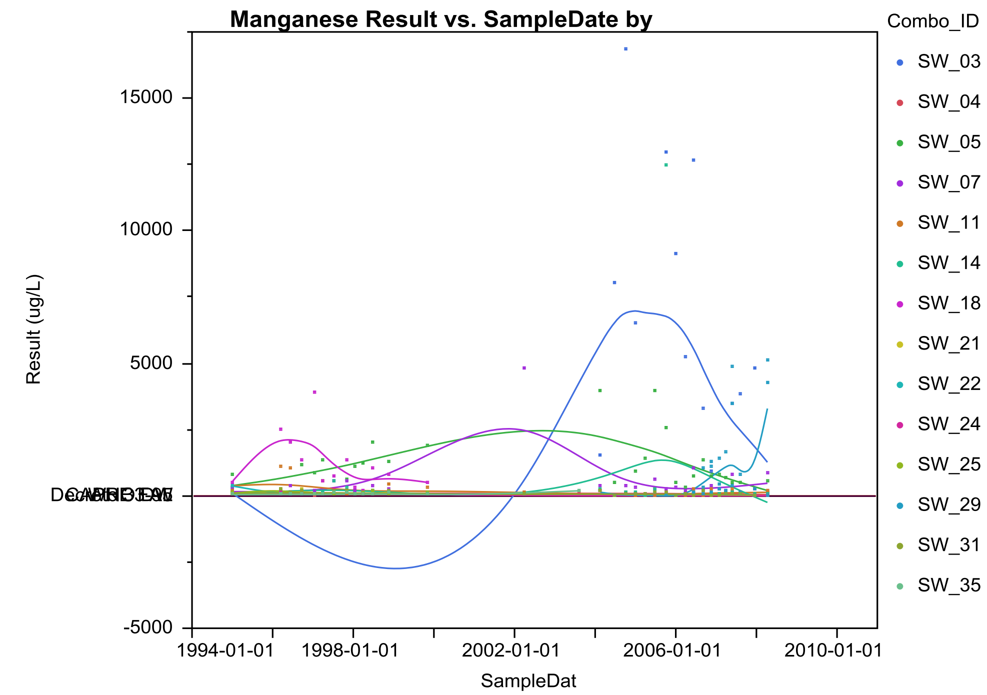

Cyanide Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_24
SW_29
SW_31
SW_35
SW_37
Result (mg/L)
0.15
Decreto 33-95
CAPRE DW
0.00
1992-01-01
1996-01-01
2000-01-01
2004-01-01
2008-01-01
SampleDat

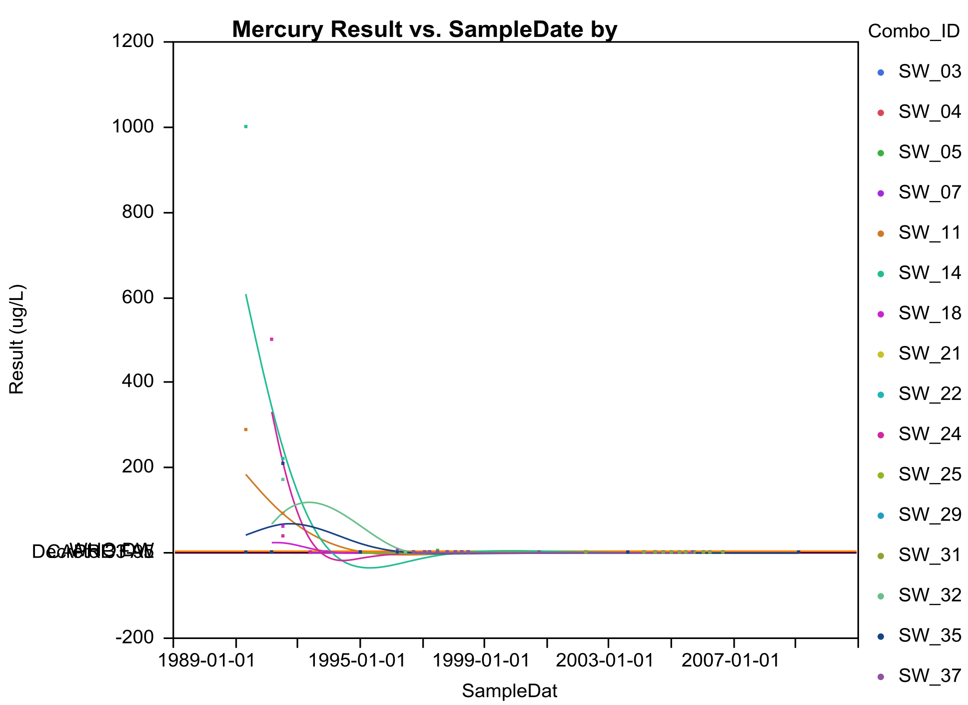

Zinc Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_35
Result (ug/L)
900
800
700
600
500
400
300
200
100
CCME FAL
-100
1994-01-01
1998-01-01
2002-01-01
2006-01-01
2010-01-01
SampleDat

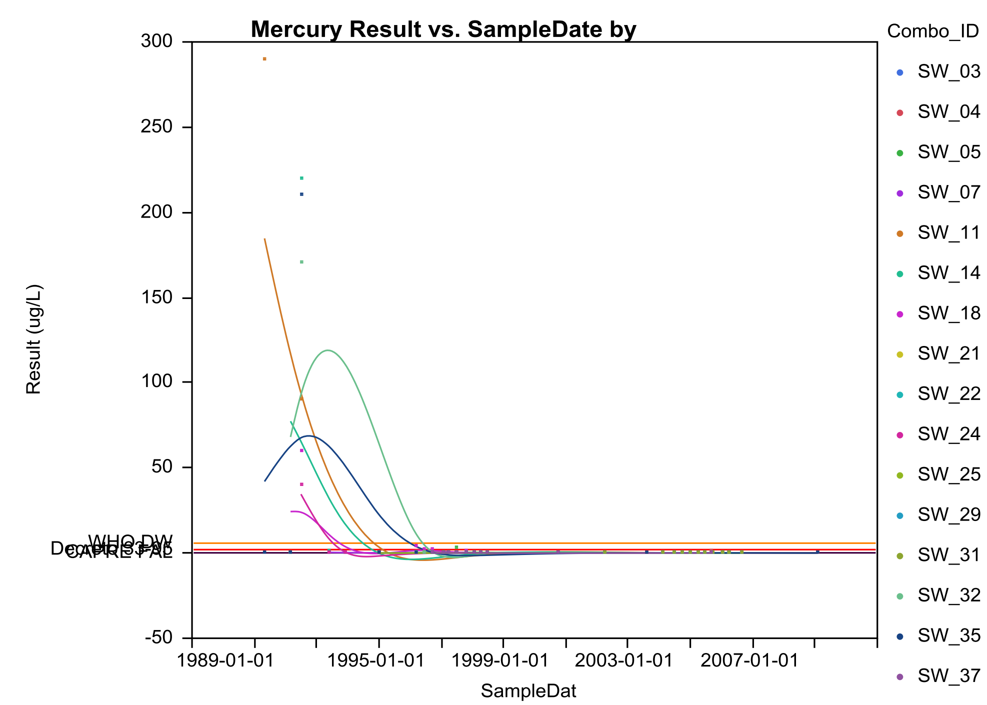

Lead Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_12
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_32
SW_35
SW_37
Result (ug/L)
3500000
3000000
2500000
2000000
1500000
1000000
500000
-500000
1989-01-01
1995-01-01
1999-01-01
2003-01-01
2007-01-01
SampleDat

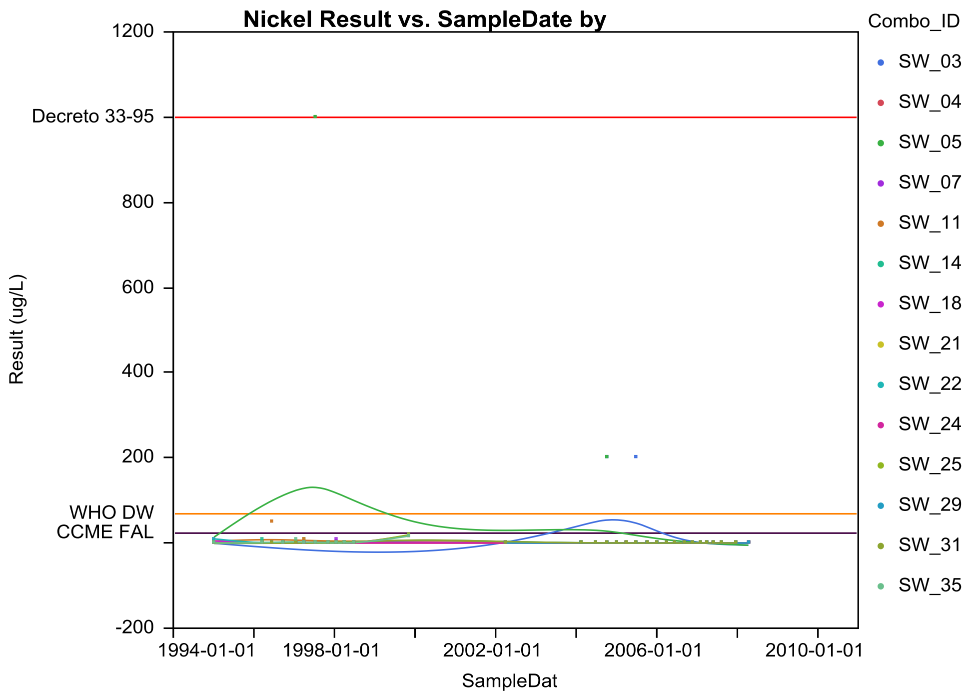

Lead Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_12
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_32
SW_35
SW_37
Result (ug/L)
100000
80000
60000
40000
20000
-20000
1989-01-01
1995-01-01
1999-01-01
2003-01-01
2007-01-01
SampleDat

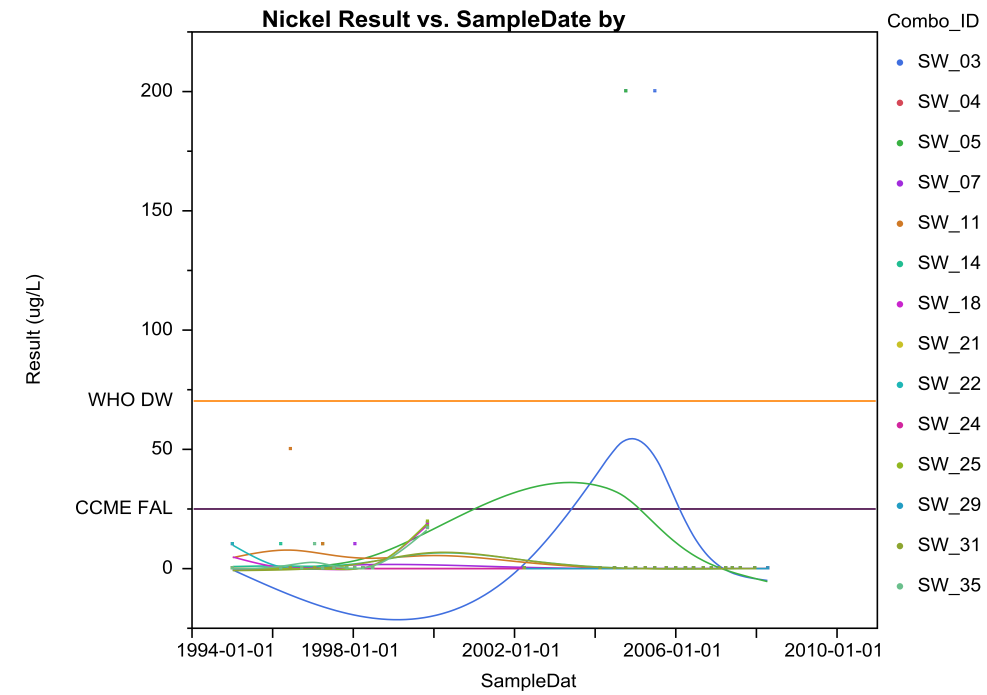

Manganese Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_35
Result (ug/L)
SampleDat
120000
100000
80000
60000
40000
20000
-20000
1994-01-01
1998-01-01
2002-01-01
2006-01-01
2010-01-01

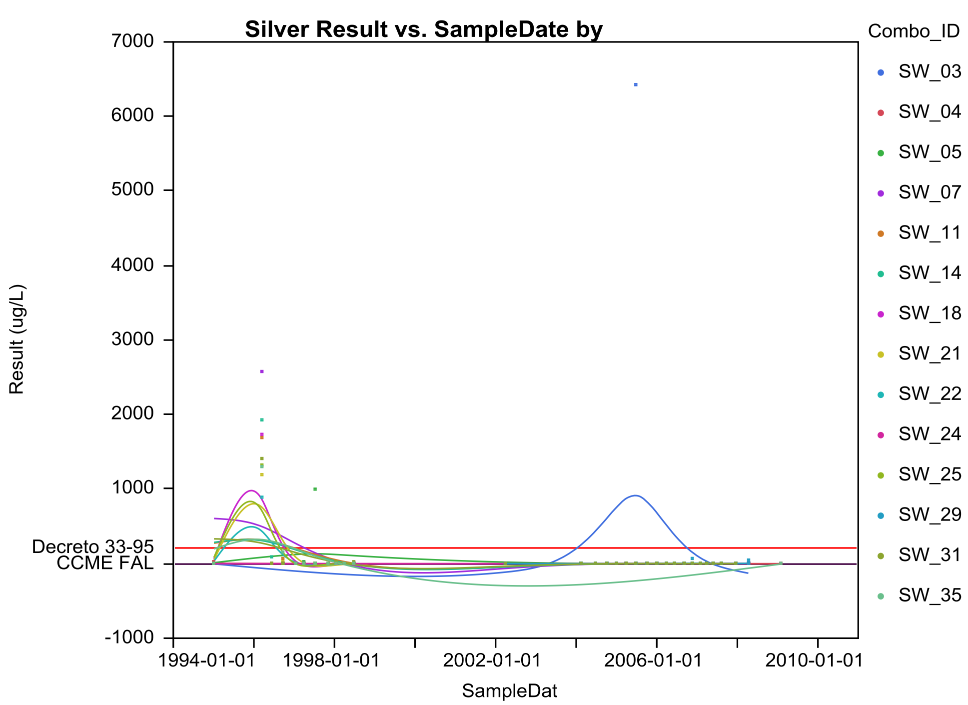

Manganese Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_35
Result (ug/L)
SampleDat
15000
10000
5000
-5000
1994-01-01
1998-01-01
2002-01-01
2006-01-01
2010-01-01

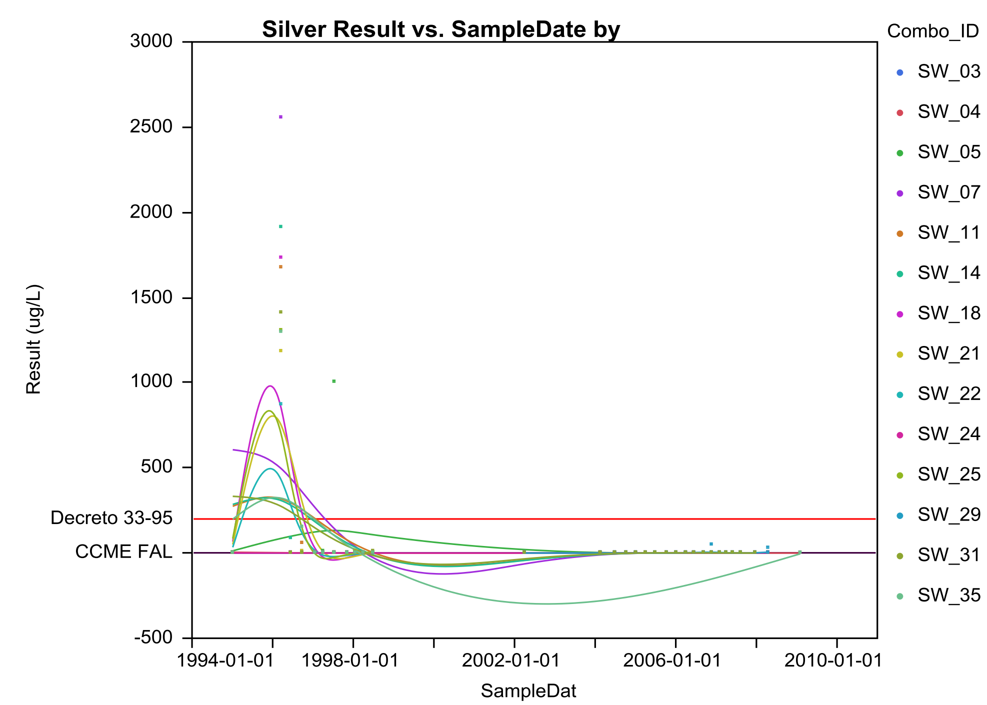

Mercury Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_32
SW_35
SW_37
Result (ug/L)
SampleDat
1200
1000
800
600
400
200
-200
1989-01-01
1995-01-01
1999-01-01
2003-01-01
2007-01-01


Mercury Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_32
SW_35
SW_37
Result (ug/L)
SampleDat
300
250
200
150
100
50
-50
WHO DW
CAPRE PAL
1989-01-01
1995-01-01
1999-01-01
2003-01-01
2007-01-01


Nickel Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_35
Result (ug/L)
1200
Decreto 33-95
800
600
400
200
WHO DW
CCME FAL
-200
1994-01-01
1998-01-01
2002-01-01
2006-01-01
2010-01-01
SampleDat


Nickel Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_35
Result (ug/L)
200
150
100
WHO DW
50
CCME FAL
0
1994-01-01
1998-01-01
2002-01-01
2006-01-01
2010-01-01
SampleDat


Silver Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_35
Result (ug/L)
7000
6000
5000
4000
3000
2000
1000
Decreto 33-95
CCME FAL
-1000
1994-01-01
1998-01-01
2002-01-01
2006-01-01
2010-01-01
SampleDat


Silver Result vs. SampleDate by
Combo_ID
SW_03
SW_04
SW_05
SW_07
SW_11
SW_14
SW_18
SW_21
SW_22
SW_24
SW_25
SW_29
SW_31
SW_35
Result (ug/L)
3000
2500
2000
1500
1000
500
Decreto 33-95
CCME FAL
-500
1994-01-01
1998-01-01
2002-01-01
2006-01-01
2010-01-01
SampleDat

Appendix G
Benthic Invertebrate Results

Table G-1. Benthic Invertebrate Results by Family

Site Code				CAL01	CAR01	HOY01	MIC01					MIC02		MIC07		MIC08			MIC09	
Sampling Method				kick net	kick net	kick net	Eckman	kick net		Van Veen		Van Veen		Eckman	kick net	Eckman	kick net	Van Veen	Eckman	kick net
Sample Date				07/02/06	09/02/06	05/02/06	30/04/07	07/02/06	29/09/06	25/06/95	05/05/06	31/10/05	05/05/06	01/09/06	08/02/07	01/09/06	06/02/06	25/06/95	01/09/06	09/02/06
Phylum	**Class**	**Order**	**Family**	count	count	count	count/m^2	count	count	count/m^2	count/m^2	count/m^2	count/m^2	count/m^2	count	count/m^2	count	count/m^2	count/m^2	count
Annelida	Branchiobdellida	Branchiobdellida	Branchiobdellida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Clitellata	Haplotaxida	Naididae	-	-	-	-	-	-	22	-	-	-	-	-	-	-	-	-	-
			Tubificidae	-	-	-	65	-	-	131	-	-	-	-	-	164	-	44	-	-
		Rhynchobdellida	Glossiphoniidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Suborder Hirudinea	Hirudinea	-	8	-	-	-	-	-	-	-	-	-	4	-	-	-	-	2
	Oligochaeta	Oligochaeta	Oligochaeta	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-
Arthropoda	Arachnida	Trombidiformes	Hydracarina group	-	-	-	-	-	-	-	-	-	-	11	-	-	-	-	-	-
	Arthropoda	Arthropoda	Arthropoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Insecta	Coleoptera	Coleoptera	5	5	2	-	-	-	-	-	-	-	-	3	-	-	-	-	-
			Elmidae	8	2	1	11	2	-	-	-	-	11	-	1	-	-	-	-	-
			Muscidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Psephenidae	2	3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
		Diptera	Ceratoppogonidae	-	-	-	-	-	-	33	-	-	174	-	-	-	-	22	-	-
			Chironomidae	-	1	-	1657	-	-	469	-	22	512	-	1	22	3	1515	4	27
			Diptera	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-	4	-
			Ephydridae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Nymphomiidae	-	-	-	-	-	-	44	-	-	-	-	-	-	-	87	-	-
			Simuliidae	63	5	6	-	-	4	-	-	-	-	-	1	-	4	-	7	40
		Ephemeroptera	Baetidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-
			Leptoplebiidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Tricorythidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-
		Hemiptera	Hemiptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Megaloptera	Corydalidae	8	1	7	-	7	-	-	-	-	-	-	4	-	2	-	-	4
			Megaloptera	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-
		Microsepta grp	Microsepta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Odonata	Aeshnidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Caenagrionidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Gomphidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	-	-
			Suborder Anisoptera	2	-	-	-	1	5	-	-	-	-	-	4	-	-	-	-	-
			Suborder Zygoptera	16	3	17	-	1	-	-	-	-	-	-	1	-	-	-	-	4
		Plecoptera	Perlidae	2	1	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-
			Plecoptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Subclass Ostracoda	Ostracoda	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-	-	-
		Trichoptera	Hidropsychidae	-	4	1	-	1	-	-	-	-	-	-	1	-	-	-	-	2
			Trichoptera	19	8	52	-	24	44	-	-	-	-	-	8	-	29	-	4	33
Mollusca	Gastropoda	Gastropoda	Gastropoda	1	2	-	-	-	-	-	-	-	-	11	32	-	-	-	-	-
	Pelecypoda	Pelecypoda	Pelecypoda	-	-	-	-	-	-	-	131	-	44	-	-	-	-	-	-	-
Nematoda	Nematoda	Nematoda	Nematoda	-	-	-	-	-	-	-	-	-	11	11	-	11	-	-	-	-
Total Count of Individuals				***126***	***43***	***86***	***1733***	***38***	***66***	***699***	***131***	***22***	***752***	***33***	***62***	***219***	***38***	***1701***	***33***	***112***
Total Count of Families				***10***	***12***	***7***	***3***	***8***	***5***	***5***	***1***	***1***	***5***	***3***	***13***	***5***	***4***	***5***	***6***	***7***

Table G-1. Benthic Invertebrate Results by Family

Site Code				MIC10		MIG01	MON01			MON02	MUH01	PIJ01		SIQ01		SIQ02	SUC01		SUC02	SUC03
Sampling Method				Eckman	kick net	kick net	Eckman	kick net	Van Veen	Van Veen	kick net	Eckman	Van Veen	kick net	Van Veen	Van Veen	kick net	Van Veen	kick net	kick net
Sample Date				01/09/06	25/11/05	07/02/06	30/04/07	07/02/06	05/05/06	31/10/05	25/11/05	30/04/07	05/05/06	21/11/05	25/06/95	25/06/95	21/11/05	25/06/95	08/02/06	08/02/06
Phylum	**Class**	**Order**	**Family**	count/m^2	count	count	count/m^2	count	count/m^2	count/m^2	count	count/m^2	count/m^2	count	count/m^2	count/m^2	count	count/m^2	count/m^2	count
Annelida	Branchiobdellida	Branchiobdellida	Branchiobdellida	-	-	-	-	-	-	-	-	-	-	-	44	-	-	-	-	-
	Clitellata	Haplotaxida	Naididae	-	-	-	-	-	-	-	-	-	-	-	174	22	-	87	-	-
			Tubificidae	4	-	-	-	-	-	-	-	11	22	-	185	44	-	-	-	-
		Rhynchobdellida	Glossiphoniidae	-	-	-	-	-	22	-	-	-	-	-	88	44	-	-	-	-
		Suborder Hirudinea	Hirudinea	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	6	3
	Oligochaeta	Oligochaeta	Oligochaeta	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Arthropoda	Arachnida	Trombidiformes	Hydracarina group	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Arthropoda	Arthropoda	Arthropoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Insecta	Coleoptera	Coleoptera	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
			Elmidae	4	1	1	-	-	-	-	2	-	-	4	-	-	-	-	6	1
			Muscidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Psephenidae	-	-	2	-	-	-	-	1	-	-	4	-	-	-	-	2	1
		Diptera	Ceratoppogonidae	-	-	-	-	-	-	-	-	-	-	-	22	44	-	109	-	-
			Chironomidae	14	-	-	11	6	-	110	3	-	-	-	283	3411	1	3477	-	1
			Diptera	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Ephydridae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	44	-	-
			Nymphomiidae	-	-	-	-	-	-	-	-	-	-	-	316	599	-	98	-	-
			Simuliidae	-	-	3	-	6	-	-	5	-	-	5	-	-	2	-	5	1
		Ephemeroptera	Baetidae	43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Leptoplebiidae	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Tricorythidae	229	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Hemiptera	Hemiptera	39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Megaloptera	Corydalidae	-	-	1	-	5	-	-	4	-	-	-	-	-	-	-	1	-
			Megaloptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Microsepta grp	Microsepta	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-
		Odonata	Aeshnidae	-	-	-	-	-	-	-	-	-	-	-	-	11	-	185	-	-
			Caenagrionidae	-	-	-	-	-	-	-	-	-	-	-	-	44	-	-	-	-
			Gomphidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Suborder Anisoptera	-	1	1	-	-	-	-	1	-	-	1	-	-	-	-	-	2
			Suborder Zygoptera	-	6	1	-	1	-	-	2	-	-	7	-	-	1	-	1	2
		Plecoptera	Perlidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	6
			Plecoptera	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Subclass Ostracoda	Ostracoda	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-
		Trichoptera	Hidropsychidae	43	2	1	-	2	-	-	-	-	-	-	-	-	-	-	1	-
			Trichoptera	54	12	67	-	35	-	-	17	-	-	3	-	-	1	-	14	9
Mollusca	Gastropoda	Gastropoda	Gastropoda	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pelecypoda	Pelecypoda	Pelecypoda	-	-	-	-	-	-	-	-	-	33	-	-	-	-	-	-	-
Nematoda	Nematoda	Nematoda	Nematoda	4	-	-	-	-	-	65	-	-	-	-	-	-	-	-	-	-
Total Count of Individuals				***554***	***24***	***80***	***11***	***55***	***22***	***197***	***36***	***11***	***55***	***24***	***1112***	***4219***	***5***	***4000***	***45***	***26***
Total Count of Families				***14***	***7***	***9***	***1***	***6***	***1***	***4***	***9***	***1***	***2***	***6***	***7***	***8***	***4***	***6***	***10***	***9***

Table G-1. Benthic Invertebrate Results by Family

Site Code				VIC01		
Sampling Method				**Eckman**	**Van Veen**	
Sample Date				**30/04/07**	**31/10/05**	**05/05/06**
Phylum	**Class**	**Order**	**Family**	**count/m²**	**count/m²**	**count/m²**
Annelida	Branchiobdellida	Branchiobdellida	Branchiobdellida	-	-	-
	Clitellata	Haplotaxida	Naididae	-	-	-
			Tubificidae	-	-	-
		Rhynchobdellida	Glossiphoniidae	-	-	-
		Suborder Hirudinea	Hirudinea	-	-	-
	Oligochaeta	Oligochaeta	Oligochaeta	-	-	-
Arthropoda	Arachnida	Trombidiformes	Hydracarina group	-	-	-
	Arthropoda	Arthropoda	Arthropoda	-	11	-
	Insecta	Coleoptera	Coleoptera	-	-	-
			Elmidae	-	-	11
			Muscidae	44	-	-
			Psephenidae	-	-	-
		Diptera	Ceratoppogonidae	-	-	-
			Chironomidae	11	44	-
			Diptera	-	-	-
			Ephydridae	-	-	-
			Nymphomiidae	-	-	-
			Simuliidae	-	-	-
		Ephemeroptera	Baetidae	-	-	-
			Leptoplebiidae	-	-	-
			Tricorythidae	-	-	-
		Hemiptera	Hemiptera	-	-	-
		Megaloptera	Corydalidae	-	-	-
			Megaloptera	-	-	-
		Microsepta grp	Microsepta	-	-	-
		Odonata	Aeshnidae	-	-	-
			Caenagrionidae	-	-	-
			Gomphidae	-	-	-
			Suborder Anisoptera	-	-	-
			Suborder Zygoptera	-	-	-
		Plecoptera	Perlidae	-	-	-
			Plecoptera	-	-	-
		Subclass Ostracoda	Ostracoda	-	-	-
		Trichoptera	Hidropsychidae	-	-	-
			Trichoptera	-	-	-
Mollusca	Gastropoda	Gastropoda	Gastropoda	-	-	-
	Pelecypoda	Pelecypoda	Pelecypoda	-	-	11
Nematoda	Nematoda	Nematoda	Nematoda	-	11	-
Total Count of Individuals				***55***	***66***	***22***
Total Count of Families				***2***	***3***	***2***

Table G-2. Benthic Invertebrate Results by Species

				Site Code	CAL01	CAR01	HOY01	MIC01					MIC02		MIC07		MIC08		
				Sampling Method	**kick net**	**kick net**	**kick net**	**Eckman**	**kick net**		**Van Veen**		**Van Veen**		**Eckman**	**kick net**	**Eckman**	**kick net**	**Van Veen**
				Sample Date	**07/02/06**	**09/02/06**	**05/02/06**	**30/04/07**	**07/02/06**	**29/09/06**	**25/06/95**	**05/05/06**	**31/10/05**	**05/05/06**	**01/09/06**	**08/02/07**	**01/09/06**	**06/02/06**	**25/06/95**
Phylum	**Class**	**Order**	**Family**	**Species**	**count**	**count**	**count**	**count/m^2**	**count**	**count**	**count/m^2**	**count/m^2**	**count/m^2**	**count/m^2**	**count/m^2**	**count**	**count/m^2**	**count**	**count/m^2**
Annelida	Branchiobdellida	Branchiobdellida	Branchiobdellida	Branchiobdellida sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Clitellata	Haplotaxida	Naididae	Nais communis	-	-	-	-	-	-	22	-	-	-	-	-	-	-	-
			Tubificidae	Limnodrilus sp	-	-	-	65	-	-	131	-	-	-	-	-	164	-	44
		Rhynchobdellida	Glossiphoniidae	Placobdella parasitica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Placobdella sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Suborder Hirudinea	Hirudinea	Hirudinea sp	-	8	-	-	-	-	-	-	-	-	-	4	-	-	-
	Oligochaeta	Oligochaeta	Oligochaeta	Oligochaeta sp	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-
Arthropoda	Arachnida	Trombidiformes	Hydracarina group	Hydracarina sp	-	-	-	-	-	-	-	-	-	-	11	-	-	-	-
	Arthropoda	Arthropoda	Arthropoda	Arthropoda sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Insecta	Coleoptera	Coleoptera	Coleoptera sp	5	5	2	-	-	-	-	-	-	-	-	3	-	-	-
			Elmidae	Elmidae sp	8	2	1	11	2	-	-	-	-	11	-	1	-	-	-
				Lara sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Muscidae	Limnophora sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Psephenidae	Psephenidae sp	2	3	-	-	1	-	-	-	-	-	-	-	-	-	-
		Diptera	Ceratoppogonidae	Bezzia sp.	-	-	-	-	-	-	33	-	-	-	-	-	-	-	22
				Culicoides sp	-	-	-	-	-	-	-	-	-	174	-	-	-	-	-
			Chironomidae	Chironomidae sp	-	1	-	1657	-	-	-	-	22	512	-	1	-	3	-
				Chironomus sp	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-
				Coelotanypus concinnus	-	-	-	-	-	-	33	-	-	-	-	-	-	-	240
				Coelotanypus sp	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-
				Cricotopus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Cryptochironomus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Dicrotenidipes sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Glyptontenidpes sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Lenziella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	65
				Ortocladius sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Paracladopelma sp	-	-	-	-	-	-	33	-	-	-	-	-	-	-	-
				Polypedilum sp	-	-	-	-	-	-	174	-	-	-	-	-	-	-	698
				Procladius sp	-	-	-	-	-	-	185	-	-	-	-	-	-	-	360
				Rheotanytarsus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Stictochironoms sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Tanytarsus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Xenochironomus xenolabis	-	-	-	-	-	-	44	-	-	-	-	-	-	-	152
			Diptera	Diptera sp	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-

Site Code					CAL01	CAR01	HOY01	MIC01					MIC02		MIC07		MIC08		
Sampling Method					kick net	kick net	kick net	Eckman	kick net		Van Veen		Van Veen		Eckman	kick net	Eckman	kick net	Van Veen
Sample Date					07/02/06	09/02/06	05/02/06	30/04/07	07/02/06	29/09/06	25/06/95	05/05/06	31/10/05	05/05/06	01/09/06	08/02/07	01/09/06	06/02/06	25/06/95
Phylum	**Class**	**Order**	**Family**	**Species**	count	count	count	count/m^2	count	count	count/m^2	count/m^2	count/m^2	count/m^2	count/m^2	count	count/m^2	count	count/m^2
			Ephydridae	Notophilia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Nymphomiidae	Palaeopdipteron walkeri	-	-	-	-	-	-	44	-	-	-	-	-	-	-	87
			Simuliidae	Simuliidae sp	63	5	6	-	-	4	-	-	-	-	-	1	-	4	-
				Simulium sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Ephemeroptera	Baetidae	Baetodes sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Dactilobaetis sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Leptoplebiidae	Paraleptophlebia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Traverella sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Tricorythidae	Tricorythodes sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Hemiptera	Hemiptera	Hemiptera sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Megaloptera	Corydalidae	Corydalidae sp	8	1	7	-	7	-	-	-	-	-	-	4	-	2	-
			Megaloptera	Megaloptera sp	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-
		Microsepta Group	Microsepta	Microsepta sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Odonata	Aeshnidae	Aeshna marchali	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Anax amazili	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Caenagrionidae	Argia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Gomphidae	Phyllogomphoides sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33
			Suborder Anisoptera	Anisoptera sp	2	-	-	-	1	5	-	-	-	-	-	4	-	-	-
			Suborder Zygoptera	Zygoptera sp	16	3	17	-	1	-	-	-	-	-	-	1	-	-	-
		Plecoptera	Perlidae	Perlidae sp	2	1	-	-	1	-	-	-	-	-	-	1	-	-	-
			Plecoptera	Plecoptera sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Subclass Ostracoda	Ostracoda	Ostracoda sp	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-
		Trichoptera	Hidropsychidae	Hidropsyche sp	-	4	1	-	1	-	-	-	-	-	-	1	-	-	-
			Trichoptera	Trichoptera sp	19	8	52	-	24	44	-	-	-	-	-	8	-	29	-
Mollusca	Gastropoda	Gastropoda	Gastropoda	Gastropoda sp	1	2	-	-	-	-	-	-	-	-	11	32	-	-	-
	Pelecypoda	Pelecypoda	Pelecypoda	Pelecypoda sp	-	-	-	-	-	-	-	131	-	44	-	-	-	-	-
Nematoda	Nematoda	Nematoda	Nematoda	Nematoda sp	-	-	-	-	-	-	-	-	-	11	11	-	11	-	-
Total Count of Individuals					126	43	86	1733	38	66	699	131	22	752	33	62	219	38	1701
Total Count of Species					10	12	7	3	8	5	9	1	1	5	3	13	6	4	9

Table G-2. Benthic Invertebrate Results by Species

				Site Code	**MIC09**		**MIC10**		**MIG01**	**MON01**			**MON02**	**MUH01**	**PIJ01**		**SIQ01**	
				Sampling Method	**Eckman**	**kick net**	**Eckman**	**kick net**	**kick net**	**Eckman**	**kick net**	**Van Veen**	**Van Veen**	**kick net**	**Eckman**	**Van Veen**	**kick net**	**Van Veen**
				Sample Date	**01/09/06**	**09/02/06**	**01/09/06**	**25/11/05**	**07/02/06**	**30/04/07**	**07/02/06**	**05/05/06**	**31/10/05**	**25/11/05**	**30/04/07**	**05/05/06**	**21/11/05**	**25/06/95**
Phylum	**Class**	**Order**	**Family**	**Species**	**count/m^2**	**count**	**count/m^2**	**count**	**count**	**count/m^2**	**count**	**count/m^2**	**count/m^2**	**count**	**count/m^2**	**count/m^2**	**count**	**count/m^2**
Annelida	Branchiobdellida	Branchiobdellida	Branchiobdellida	Branchiobdellida sp	-	-	-	-	-	-	-	-	-	-	-	-	-	44
	Clitellata	Haplotaxida	Naididae	Nais communis	-	-	-	-	-	-	-	-	-	-	-	-	-	174
			Tubificidae	Limnodrilus sp	-	-	4	-	-	-	-	-	-	-	11	22	-	185
		Rhynchobdellida	Glossiphoniidae	Placobdella parasitica	-	-	-	-	-	-	-	-	-	-	-	-	-	44
				Placobdella sp	-	-	-	-	-	-	-	22	-	-	-	-	-	44
		Suborder Hirudinea	Hirudinea	Hirudinea sp	-	2	-	-	3	-	-	-	-	-	-	-	-	-
	Oligochaeta	Oligochaeta	Oligochaeta	Oligochaeta sp	-	-	-	1	-	-	-	-	-	1	-	-	-	-
Arthropoda	Arachnida	Trombidiformes	Hydracarina group	Hydracarina sp	-	-	4	-	-	-	-	-	-	-	-	-	-	-
	Arthropoda	Arthropoda	Arthropoda	Arthropoda sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Insecta	Coleoptera	Coleoptera	Coleoptera sp	-	-	-	1	-	-	-	-	-	-	-	-	-	-
			Elmidae	Elmidae sp	-	-	4	1	1	-	-	-	-	2	-	-	4	-
				Lara sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Muscidae	Limnophora sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Psephenidae	Psephenidae sp	-	-	-	-	2	-	-	-	-	1	-	-	4	-
		Diptera	Ceratoppogonidae	Bezzia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	22
				Culicoides sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Chironomidae	Chironomidae sp	-	27	-	-	-	11	6	-	-	3	-	-	-	-
				Chironomus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Coelotanypus concinnus	-	-	-	-	-	-	-	-	-	-	-	-	-	33
				Coelotanypus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Cricotopus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Cryptochironomus sp	-	-	7	-	-	-	-	-	-	-	-	-	-	-
				Dicrotenidipes sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Glyptontenidpes sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Lenziella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Ortocladius sp	-	-	-	-	-	-	-	-	33	-	-	-	-	-
				Paracladopelma sp	-	-	-	-	-	-	-	-	-	-	-	-	-	11
				Polypedilum sp	-	-	-	-	-	-	-	-	-	-	-	-	-	109
				Procladius sp	-	-	-	-	-	-	-	-	-	-	-	-	-	65
				Rheotanytarsus sp	-	-	7	-	-	-	-	-	44	-	-	-	-	-
				Stictochironoms sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Tanytarsus sp	4	-	-	-	-	-	-	-	33	-	-	-	-	-
				Xenochironomus xenolabis	-	-	-	-	-	-	-	-	-	-	-	-	-	65
			Diptera	Diptera sp	4	-	18	-	-	-	-	-	-	-	-	-	-	-

				Site Code	MIC09		MIC10		MIG01	MON01			MON02	MUH01	PIJ01		SIQ01	
				Sampling Method	**Eckman**	**kick net**	**Eckman**	**kick net**	**kick net**	**Eckman**	**kick net**	**Van Veen**	**Van Veen**	**kick net**	**Eckman**	**Van Veen**	**kick net**	**Van Veen**
				Sample Date	**01/09/06**	**09/02/06**	**01/09/06**	**25/11/05**	**07/02/06**	**30/04/07**	**07/02/06**	**05/05/06**	**31/10/05**	**25/11/05**	**30/04/07**	**05/05/06**	**21/11/05**	**25/06/95**
Phylum	**Class**	**Order**	**Family**	**Species**	**count/m^2**	**count**	**count/m^2**	**count**	**count**	**count/m^2**	**count**	**count/m^2**	**count/m^2**	**count**	**count/m^2**	**count/m^2**	**count**	**count/m^2**
			Ephydridae	Notophilia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Nymphomiidae	Palaeopdipteron walkeri	-	-	-	-	-	-	-	-	-	-	-	-	-	316
			Simuliidae	Simuliidae sp	-	40	-	-	3	-	6	-	-	5	-	-	5	-
				Simulium sp	7	-	-	-	-	-	-	-	-	-	-	-	-	-
		Ephemeroptera	Baetidae	Baetodes sp	7	-	14	-	-	-	-	-	-	-	-	-	-	-
				Dactilobaetis sp	-	-	29	-	-	-	-	-	-	-	-	-	-	-
			Leptoplebiidae	Paraleptophlebia sp	-	-	61	-	-	-	-	-	-	-	-	-	-	-
				Traverella sp	-	-	29	-	-	-	-	-	-	-	-	-	-	-
			Tricorythidae	Tricorythodes sp	7	-	229	-	-	-	-	-	-	-	-	-	-	-
		Hemiptera	Hemiptera	Hemiptera sp	-	-	39	-	-	-	-	-	-	-	-	-	-	-
		Megaloptera	Corydalidae	Corydalidae sp	-	4	-	-	1	-	5	-	-	4	-	-	-	-
			Megaloptera	Megaloptera sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Microsepta Group	Microsepta	Microsepta sp	-	-	-	-	-	-	-	-	11	-	-	-	-	-
		Odonata	Aeshnidae	Aeshna marchali	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Anax amazili	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Caenagrionidae	Argia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Gomphidae	Phyllogomphoides sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Suborder Anisoptera	Anisoptera sp	-	-	-	1	1	-	-	-	-	1	-	-	1	-
			Suborder Zygoptera	Zygoptera sp	-	4	-	6	1	-	1	-	-	2	-	-	7	-
		Plecoptera	Perlidae	Perlidae sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Plecoptera	Plecoptera sp	-	-	4	-	-	-	-	-	-	-	-	-	-	-
		Subclass Ostracoda	Ostracoda	Ostracoda sp	-	-	-	-	-	-	-	-	11	-	-	-	-	-
		Trichoptera	Hidropsychidae	Hidropsyche sp	-	2	43	2	1	-	2	-	-	-	-	-	-	-
			Trichoptera	Trichoptera sp	4	33	54	12	67	-	35	-	-	17	-	-	3	-
Mollusca	Gastropoda	Gastropoda	Gastropoda	Gastropoda sp	-	-	4	-	-	-	-	-	-	-	-	-	-	-
	Pelecypoda	Pelecypoda	Pelecypoda	Pelecypoda sp	-	-	-	-	-	-	-	-	-	-	-	33	-	-
Nematoda	Nematoda	Nematoda	Nematoda	Nematoda sp	-	-	4	-	-	-	-	-	65	-	-	-	-	-
Total Count of Individuals					33	112	554	24	80	11	55	22	197	36	11	55	24	1112
Total Count of Species					6	7	17	7	9	1	6	1	6	9	1	2	6	12

Table G-2. Benthic Invertebrate Results by Species

				Site Code	SIQ02	SUC01		SUC02	SUC03	VIC01		
				Sampling Method	Van Veen	kick net	Van Veen	kick net	kick net	Eckman	Van Veen	
				Sample Date	25/06/95	21/11/05	25/06/95	08/02/06	08/02/06	30/04/07	31/10/05	05/05/06
Phylum	Class	Order	Family	Species	count/m^2	count	count/m^2	count/m^2	count	count/m^2	count/m^2	count/m^2
Annelida	Branchiobdellida	Branchiobdellida	Branchiobdellida	Branchiobdellida sp	-	-	-	-	-	-	-	-
	Clitellata	Haplotaxida	Naididae	Nais communis	22	-	87	-	-	-	-	-
			Tubificidae	Limnodrilus sp	44	-	-	-	-	-	-	-
		Rhynchobdellida	Glossiphoniidae	Placobdella parasitica	-	-	-	-	-	-	-	-
				Placobdella sp	44	-	-	-	-	-	-	-
		Suborder Hirudinea	Hirudinea	Hirudinea sp	-	-	-	6	3	-	-	-
	Oligochaeta	Oligochaeta	Oligochaeta	Oligochaeta sp	-	-	-	-	-	-	-	-
Arthropoda	Arachnida	Trombidiformes	Hydracarina group	Hydracarina sp	-	-	-	-	-	-	-	-
	Arthropoda	Arthropoda	Arthropoda	Arthropoda sp	-	-	-	-	-	-	11	-
	Insecta	Coleoptera	Coleoptera	Coleoptera sp	-	-	-	1	-	-	-	-
			Elmidae	Elmidae sp	-	-	-	6	1	-	-	-
				Lara sp	-	-	-	-	-	-	-	11
			Muscidae	Limnophora sp	-	-	-	-	-	44	-	-
			Psephenidae	Psephenidae sp	-	-	-	2	1	-	-	-
		Diptera	Ceratoppogonidae	Bezzia sp.	44	-	109	-	-	-	-	-
				Culicoides sp	-	-	-	-	-	-	-	-
			Chironomidae	Chironomidae sp	-	1	-	-	1	11	-	-
				Chironomus sp	-	-	-	-	-	-	-	-
				Coelotanypus concinnus	-	-	-	-	-	-	-	-
				Coelotanypus sp	-	-	-	-	-	-	-	-
				Cricotopus sp	-	-	-	-	-	-	44	-
				Cryptochironomus sp	-	-	316	-	-	-	-	-
				Dicrotenidipes sp	272	-	480	-	-	-	-	-
				Glyptontenidpes sp	-	-	534	-	-	-	-	-
				Lenziella sp.	-	-	240	-	-	-	-	-
				Ortocladius sp	-	-	-	-	-	-	-	-
				Paracladopelma sp	-	-	-	-	-	-	-	-
				Polypedilum sp	2463	-	1221	-	-	-	-	-
				Procladius sp	523	-	523	-	-	-	-	-
				Rheotanytarsus sp	-	-	-	-	-	-	-	-
				Stictochironoms sp	44	-	-	-	-	-	-	-
				Tanytarsus sp	-	-	-	-	-	-	-	-
				Xenochironomus xenolabis	109	-	163	-	-	-	-	-
			Diptera	Diptera sp	-	-	-	-	-	-	-	-

				Site Code	SIQ02	SUC01		SUC02	SUC03	VIC01		
				Sampling Method	Van Veen	kick net	Van Veen	kick net	kick net	Eckman	Van Veen	
				Sample Date	25/06/95	21/11/05	25/06/95	08/02/06	08/02/06	30/04/07	31/10/05	05/05/06
Phylum	**Class**	**Order**	**Family**	**Species**	**count/m^2**	**count**	**count/m^2**	**count/m^2**	**count**	**count/m^2**	**count/m^2**	**count/m^2**
			Ephydridae	Notophilia sp	-	-	44	-	-	-	-	-
			Nymphomiidae	Palaeopdipteron walkeri	599	-	98	-	-	-	-	-
			Simuliidae	Simuliidae sp	-	2	-	5	1	-	-	-
				Simulium sp	-	-	-	-	-	-	-	-
		Ephemeroptera	Baetidae	Baetodes sp	-	-	-	-	-	-	-	-
				Dactilobaetis sp	-	-	-	-	-	-	-	-
			Leptoplebiidae	Paraleptophlebia sp	-	-	-	-	-	-	-	-
				Traverella sp	-	-	-	-	-	-	-	-
			Tricorythidae	Tricorythodes sp	-	-	-	-	-	-	-	-
		Hemiptera	Hemiptera	Hemiptera sp	-	-	-	-	-	-	-	-
		Megaloptera	Corydalidae	Corydalidae sp	-	-	-	1	-	-	-	-
			Megaloptera	Megaloptera sp	-	-	-	-	-	-	-	-
		Microsepta Group	Microsepta	Microsepta sp	-	-	-	-	-	-	-	-
		Odonata	Aeshnidae	Aeshna marchali	-	-	185	-	-	-	-	-
				Anax amazili	11	-	-	-	-	-	-	-
			Caenagrionidae	Argia sp.	44	-	-	-	-	-	-	-
			Gomphidae	Phyllogomphoides sp	-	-	-	-	-	-	-	-
			Suborder Anisoptera	Anisoptera sp	-	-	-	-	2	-	-	-
			Suborder Zygoptera	Zygoptera sp	-	1	-	1	2	-	-	-
		Plecoptera	Perlidae	Perlidae sp	-	-	-	8	6	-	-	-
			Plecoptera	Plecoptera sp	-	-	-	-	-	-	-	-
		Subclass Ostracoda	Ostracoda	Ostracoda sp	-	-	-	-	-	-	-	-
		Trichoptera	Hidropsychidae	Hidropsyche sp	-	-	-	1	-	-	-	-
			Trichoptera	Trichoptera sp	-	1	-	14	9	-	-	-
Mollusca	Gastropoda	Gastropoda	Gastropoda	Gastropoda sp	-	-	-	-	-	-	-	-
	Pelecypoda	Pelecypoda	Pelecypoda	Pelecypoda sp	-	-	-	-	-	-	-	11
Nematoda	Nematoda	Nematoda	Nematoda	Nematoda sp	-	-	-	-	-	-	11	-
Total Count of Individuals					4219	5	4000	45	26	55	66	22
Total Count of Species					12	4	12	10	9	2	3	2