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A Water Quality Assessment of the Rio Katari River and its Principle Tributaries, Bolivia

Sara M. Chudnoff

A WATER QUALITY ASSESSMENT OF THE RIO KATARI RIVER AND ITS PRINCIPLE TRIBUTARIES, BOLIVIA

BY

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B.S. Earth and Environmental Science (Geology Option)
New Mexico Institute of Mining and Technology (May, 2006)

Professional Project

Submitted in Partial Fulfillment of the
Requirements for the Degree of

Masters in Water Resources

The University of New Mexico
Albuquerque, New Mexico

December, 2009

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ABSTRACT OF THESIS

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ABSTRACT

The Altiplano region of Bolivia located between Lake Titicaca and La Paz is one of the fastest growing regions in the world. Demands for safe drinking water, sewage treatment and cleaner industrial and agriculture methods are not being met and are adversely affecting surface and groundwater sources. Detrimental water quality often leads to water borne illnesses that can be fatal, especially in young children, the elderly and immune compromised individuals.

This paper describes a project that was conducted to determine the impact of El Alto and surrounding communities on the water quality of the Rio Katari and its principal tributaries. Water samples were collected and analyzed in January and June 2009 to determine the seasonal changes and the spatial variability in the Rio Katari, Rio Seco and Rio Pallina. Results indicate that the waters of the Rio Seco and Rio Pallina are greatly impacted by anthropogenic activities from the cities of El Alto and Viacha. The Rio Katari is impacted by agricultural uses and the discharge of the Rio Pallina. At all sampling locations during both sampling events fecal coliform exceeded Safe Drinking Water Act (SDWA) Minimum Concentration Limit (MCL). In addition to fecal coliform nitrate-N exceeded its SDWA MCL and World Health Organization (WHO) recommended limit at one location and neared the SDWA MCL and WHO recommended limit at other locations. Toluene exceeded its SDWA MCL and WHO recommended limit at

multiple locations, and sulfate exceeded its SDWA MCL at two locations.

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1.0 INTRODUCTION

1.1 Problem Statement

The Altiplano region of Bolivia, located between Lake Titicaca and La Paz (study region) (Figure 1 and 2) is one of the fastest growing regions in the world (Arbona and Kohl, 2004). As the population of this region has increased, so have the stresses on the water sources and water and wastewater systems. Currently, there are limited facilities in the area to properly collect and treat municipal wastewater prior to discharge. It is estimated that between 35% and 54% of the population of the municipality of El Alto have access to the El Alto wastewater treatment facility (WWTP). This estimation is based on a portion of El Alto, not the entire municipality, thus it is an over-estimation of coverage (Inter-American Development Bank, 1998). The remaining waste, from the population of El Alto that is not connected and from the municipality of Viacha (which lacks a wastewater treatment facility) is thought to be discharged directly to surface water or to onsite latrines (Komives, 1999). Other contributors to surface water contamination in the region include impacts from erosion, industrial discharges, and urban storm water (Field visit, 2009).

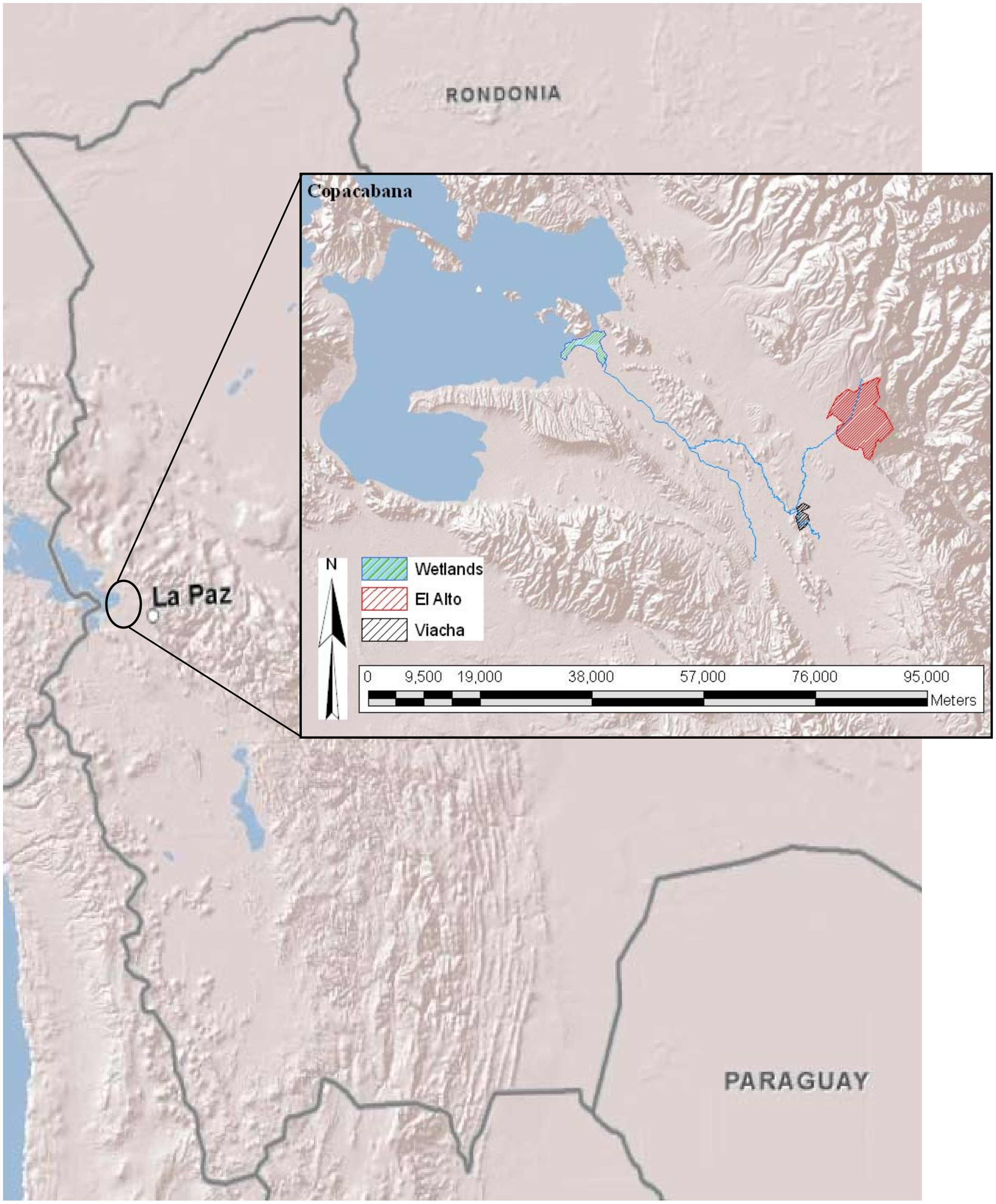

Figure 1: Location of Bolivia with study site circled and blown up.

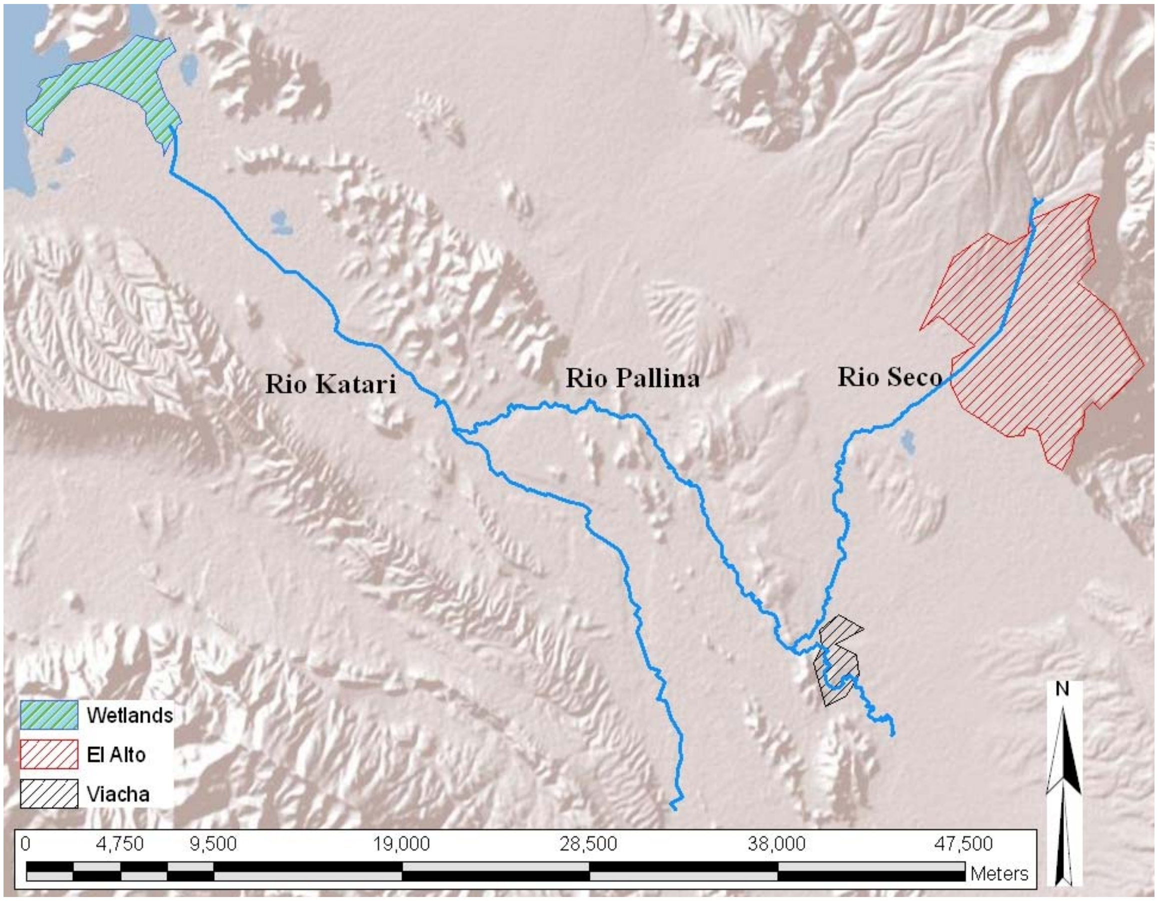

Figure 2: Study site showing the location of the Rio Katari, Rio Seco and Rio Pallina and the municipalities of El Alto and Viacha.

Three rivers flow through the study region; the Rio Katari, Rio Seco and Rio Pallina. Because of rapid growth, a lack of environmental protection, lack of facilities to properly treat wastewater, urban contaminants and other types of waste the three rivers are being adversely impacted. The Rio Seco flows through El Alto, where treated and untreated sewage and other contaminants are discharged into it. The Rio Seco discharges into the Rio Pallina approximately 20.8 km downstream of El Alto and 2 km downstream of Viacha. The Rio Pallina flows through Viacha, where untreated sewage and contaminants are discharged into it (Field visit, 2009) and flows into the Rio Katari approximately 18 km downstream of Viacha. The Rio Katari flows through rural areas and discharges into Lake Titicaca. Figure 3 provides three photos taken in the study region, showing some of the types of contamination in the region.

Figure 3. Three common types of contamination in the study region. The picture on the left is raw sewage and waste from a nearby slaughter house/tannery entering the Rio Pallina. The middle picture is an oil change business where the waste oil/fluids are being discharged into the Rio Seco. The picture on the right is the Viacha cement plant that increases sediment levels in the river and air.

In the study region there are two large municipalities; El Alto and Viacha (Figure 2). As mentioned above El Alto has a wastewater collection and treatment system servicing up to 54% of the population, while Viacha has no wastewater treatment system (WEFTA, 2008). In addition to El Alto and Viacha there are small villages and single family houses spread out in the region between the two cities and Lake Titicaca.

Human exposure to and consumption of the impaired water in the study region can result in waterborne illnesses. Waterborne illnesses cause gastro-intestinal symptoms such as diarrhea and abdominal cramps. According to the World Health Organization (WHO), 17% of the deaths in children worldwide under five are caused by diarrheal diseases (World Health Organization, October 2008). Ingesting excessive fecal coliform may lead to bloody diarrhea, diarrhea and abdominal cramps. Children under five and the elderly can also contract hemolytic uremic in which red blood cells are destroyed and the kidneys fail. Elevated nitrogen concentrations in the water may cause methemoglobinemia (blue baby syndrome) in young children and in infants. Methemoglobinemia impairs the oxygen carrying capacity of the blood. In adults elevated nitrogen may cause diuresis, an increase in starchy deposits and hemorrhaging of the spleen. Many of the volatile organic carbons found in gasoline and industrial waste are carcinogenic and may cause an increase in cancer related illnesses (Center for Disease Control and Prevention, October 2008). Consumption of impaired water in El Alto has led to the outbreak of acute Fascioliasis (Bjorland, et. Al., 1995) and Cryptosporidium (Esteban, et. Al, 1998). Figure 4 is a photo of women washing laundry in the Rio Seco, it is unknown if they also consume the water.

Figure 4. Women washing laundry in the Rio Seco, El Alto, during field work. Human consumption of the water was not observed, however water borne pathogens and contaminants can also enter the human body through open wounds and the eyes and nose.

1.2 Study Objectives

The objective of this project was to investigate the impacts of urban development on the water quality of the Rio Katari, Rio Seco and Rio Pallina. The three rivers flow through varying forms of land use so to the extent feasible, a determination as to how each of the three rivers are being impacted and what they are being impacted by was also completed.

The specific objects were to:

- Determine water quality characteristics of the three rivers during two sampling events that occurred in the dry season and wet season.
- Identify critical areas of contamination
- Make recommendations for future work

2.0 BACKGROUND

2.1 Project Site and Description

2.1.1 El Alto-City Profile

The region in the Altiplano in Bolivia located between Lake Titicaca and La Paz is one of the fastest growing regions in the world. The reason for the rapid growth of the area can be attributed to the geography of the region and natural and economic events (Arbona and Kohl, 2004). El Alto is located adjacent to the Bolivian capitol city of La Paz, which is located in a steep canyon with limited room for growth. In the early 1900's industries that needed a lot of space built their facilities in El Alto. Industries included a railroad, oil refinery and an airport (Arbona and Kohl, 2004). In the 1950's as workers in rural areas were set free from estates in which they worked they migrated to El Alto. A drought between 1982 and 1983 brought tens of thousands of farmers to El Alto. Another population boom occurred in 1985 as state mines closed, many of those who lost jobs migrated to El Alto. As a result of these events, El Alto has experienced an average growth rate of about 8.2% per year and estimates project the population to approach 1 million people by 2010 (Arbona and Kohl, 2004). In 1988 El Alto became incorporated; however the high poverty rate makes it difficult to tax citizens to support needed infrastructure (Arbona and Kohl, 2004).

2.1.2 Viacha-City Profile

Viacha is located approximately 12 kilometers southwest of El Alto. In 2001 the population of Viacha was 29,108 (Instituto Natcional de Estadistica, 2009). Viacha is a relatively wealthy city due to industry. Industry in Viacha includes a cement plant, and a bottling plant for Bolivia's largest brewery. Many textile, brick and tile factories are spread out between El Alto and Viacha along the road known as Camino de Viacha. The industries are taxed; however those who benefit financially from the different industries tend to relocate to La Paz bringing their wealth with them (Faguet, 2003).

2.1.3 Water and Wastewater System of El Alto-La Paz

In 1966 SAMAPA (Servicio Autonomo Municipal de Agua Potable y Alcantarillado) was established in La Paz to supply drinking water and sewer services to La Paz and its suburbs (Komives, 1999). When El Alto became incorporated in 1988 SAMAPA extended its service to cover both municipalities. The national government announced a plan in the 1990's to place national supervision over water and sanitation services offered by municipalities. The National Regulations for Water and Sanitation Service in Urban Areas founded in 1992 declared that the only acceptable long-term management of water and wastewater would be to offer all services in individual homes, thus public bathrooms and delivered potable water would be unacceptable. In 1997 another regulation was passed to appoint a Superintendencia de Aguas (Superintendent of Water), who would be responsible in giving permission to municipalities to extend water and wastewater services. In 1997 the Superintendent of Water gave Aguas del Illimani, a private company and subsidiary of Lyonnaise des Eaux, a 30-year contract to take over SAMAPA and supply water and wastewater services to El Alto and La Paz (Komives, 1999),

Aguas del Illimani signed a contract with specific targets for expansion of water and wastewater connections. In the contract Aguas del Illimani was obligated to bring wastewater coverage in La Paz up to 82% and in El Alto up to 41%. The contract also required Aguas del Illimani to bring water connections up to 84% in La Paz and 71% in

El Alto by 2001 (Inter-American Development Bank, 1998). Contract requirements were not met and in 2006 the contract with Aguas de Illimani was dissolved due to a popular movement that opposed privatization of water and wastewater services (Jacobs, 2007). The water and wastewater systems are now managed by a Minister of Water and strategic planning is in place to extend water and wastewater coverage (bolivia.gov, 2009).

2.1.4 Environmental Laws and Regulations Protecting the Waters of Bolivia

On April 27, 1992 the Ministry of Sustainable Development and the Environment of Bolivia published the "Reglamento de la Ley N° 1333 del Medio Ambiente, Reglamento en Materia de Contaminacion Hidrica." A copy of the law can be found in Appendix E. This environmental law was promulgated for the prevention and control of water pollution. The law is divided into sections as follows:

- Title I – Classification of the four types of water (Articles 1-7)
- Title II – Institutional Framework (Articles 8-12)
- Title III – Technical and Administrative Procedures (Articles 13-29)
- Title IV – Monitoring, Evaluation, Prevention, Protection and Conservation of Water Quality (Articles 30-70)
- Title V – Legal Violations (Article 71)
- Title VI – Transitory Disposition (Articles 72-74)

Currently the situation in the study area is such that the law is not being abided by or enforced. Title III primarily addresses wastewater effluent; it is unknown if the El Alto WWTP is following these laws, or if any industries in the area are, but based on observations it is unlikely. Title 4, Article's 41, 43, 44, 46, 50, 51, 53 and 63 are all being violated: Article 41 addresses the spills of hydrocarbons; Article 43 addresses the entry of mining water to surface waters; Article 44 addresses the entry of large volumes of untreated/treated effluent into surface waters; Article 46 addresses the discharge of effluent from leach fields; Article 50 addresses the pre-treatment of industrial effluent;

Article 51 addresses the protection of wetlands; Article 53 addresses corrective action by the ministry for impaired waters and Article 69 addresses the maintenance of international waters.

2.1.5 Environmental Management of Lake Titicaca

In 1955 Peru and Bolivia signed a formal agreement to manage and study the Lake Titicaca watershed (Rieckermann, et. Al., 2006). This agreement was formalized in 1986, and the European Union was asked to help develop a framework for the management of the Lake Titicaca watershed. Consulting and engineering firms from Europe carried out multiple studies, which resulted in a "Binational General Master Plan for the Development of the Integrated Region of Lake Titicaca." The master plan has a time-frame of 20 years and was evaluated by Rieckermann, Daebel, Ronteltap and Bernauer in a research article titled *Assessing the performance of International Water Management at Lake Titicaca*. What the article found that information is limited, management objectives are vague and the environmental problem is larger than what was anticipated. The authors also found widespread poverty impedes environmental awareness, and due to the lake straddling the border of two third-world countries, the plan is not realistic.

2.2 Climate and River Network

2.2.1 Climate

The height of the wet season in the study area is in January when the area receives about 130 mm of rainfall during the month (Table 1). Given the localized nature of the thunderstorms, one portion of the watershed may experience heavy precipitation while other areas remain dry. The height of the dry season is in June, when the region receives about 4mm of precipitation during the month (gaisma.com, 2009). During the dry season flow in the rivers is highly augmented by treated and raw domestic and industrial waste from El Alto and Viacha.

Table 1. Average Monthly Precipitation

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Precipitation (mm/month)	130	104	75	33	13	4	6	16	34	34	51	99

Data acquired from Gaisma

2.2.2 River Network

The Rio Katari flows through the Altiplano and discharges into either a wetland (when water levels in Lake Titicaca are low) or into the Cohana Bay of Lake Titicaca (when water levels are high) (Figure 1). The slope of the Rio Katari is approximately 0.07%. The river profile for the Rio Katari can be seen in Figure 32, Appendix C. The wetlands are utilized for farming and transportation. Along the Rio Katari there are scattered farms. The density of farms increases as the river nears Lake Titicaca. There are many ephemeral tributaries that flow into the Rio Katari, but only two perennial tributaries; the Rio Seco and Rio Pallina. The headwaters of the Rio Seco originate north-east of the Rio Katari, which flows through the city of El Alto and into the Rio Pallina. The Rio Seco has a slope of about 0.9%. The river profile for the Rio Seco can be seen in Figure 33, Appendix C. The headwaters of the Rio Pallina are east of the Rio Katari, and the rivers flows through the city of Viacha and into the Rio Katari. The slope of the Rio Pallina is approximately 0.03%. The river profile for the Rio Pallina can be seen in Figure 34, Appendix C.

2.3 Geology of the Site

The Project Site is located in the region of the Andes known as the Altiplano, between Lake Titicaca and La Paz. The Altiplano is an intra-arc basin located between the eastern and western cordilleras of the Andes (Smith and Landis, 1995). The basin began to form about 16.4 million years ago and contains fill of up to 10 kilometers in thickness (Smith and Landis, 1995). The basin fill consists of primarily of clastic sediments derived from streams and shallow lakes; in addition there are sandstones, mudstones and reworked volcanic material present (Allmendinger, et. al., 1997).

2.4 Previous Work

In 2002 Octavio Maquera Nina and John Wilson Loza Callisaya, two students of the Engineering Department at the Universidad Mayor de San Andres (UMSA) completed a study titled "Evaluacio de la Calidad de las Aguas del Curso de Agua "Rio Seco" de la Ciudad de El Alto" as part of their degree requirement. The general objectives of this report were to evaluate the stream quality of the portion of the Rio Seco that flows through El Alto, determine the chemical, physical and microbiological characteristics of the River and determine uses of the river and quantify contamination in the river. The specific objectives were to categorize water quality, evaluate the river's impact on the ecosystem, establish the level of impairment, evaluate the applicability of environmental law, determine possible uses for the river and provide El Alto with a study of the water quality.

The study found 13 facilities/industries located along the margins of the Rio Seco including; milk and soda factory, two tanneries, a sawmill, a PVC factory, two laundry and dry cleaning facilities, two public bathrooms, the El Alto-La Paz international airport and a mechanic. In addition to the 13 identified facilities/industries there are undocumented facilities/industries along the Rio Seco, which include slaughter houses, tanneries, car washes and sand and gravel mining activities. The documented and undocumented facilities/industries do not have treatment, and it is presumed they discharge into the Rio Seco. Downstream of El Alto livestock impacts include sheep and pigs.

The results of this study indicated that the Rio Seco is impacted by domestic sewage, garbage, discharges from documented and undocumented facilities/industries and downstream of El Alto by livestock (sheep and pigs). The study found the highest impact is from the slaughter houses and tanneries. During dry months contamination accumulates due to the lack of precipitation and runoff from glaciers. The direct impact to human health has not been quantified, but the study speculates that those who live on the margin of the Rio Seco and utilize the water may suffer from diarrhea, parasites and dysentery. Furthermore animals that consume the water may become ill and when they are consumed, those illnesses may spread outside the margins of the Rio Seco.

As documented in the study, a large part of the problem is related to the fact that El Alto has no strategic or integrated plans to help address improvements to infrastructure, manage growth or educate people about the environmental consequences associated with the quality of the river. The study recommended the implementation of programs to improve environmental awareness, especially for those who live near the Rio Seco. The recommendations include a public authority to develop/adopt environmental standards, instantiating a campaign to improve the water quality, control stormwater runoff from entering the river, improve open channels to improve oxygenation of the Rio

Seco and provide solid waste management. The study also recommends further monitoring, examination of solid waste impact on water quality and placement of new industries in a consolidated area where post treatment can occur prior to discharge to the Rio Seco. Further recommendations include the implementation of treatment for slaughter houses and tanneries and examination of appropriate technologies for treatment of waste from households. Future work the study identified includes quantification of population and population distribution, mapping topography, quantifying discharges, improving hydrologic data available and consolidating work that has been completed.

In November 2006 volunteers from the non-profit group Water Engineers for the Americas (WEFTA) visited the Lake Titicaca region of Bolivia and were alerted to water quality issues at Lake Titicaca and its tributaries (Personal Interview with Peter Fant, President of WEFTA, 2008). During various other visits to Bolivia, WEFTA volunteers photo documented additional examples of significant water contamination, such as leaking wastewater transmission lines, leachate from landfills entering surface water, agricultural waste directly discharged to surface water, and slaughter-house waste being discharged into the surface water.

Tierramerica is an online newsletter published by the United Nations Environment Program (UNEP), United Nations Development Program (UNDP) and the World Bank (Tierraamerica, 2008). The newsletter focuses on informing people of environmental and development issues. In the June 2, 2008 issue, Bernarda Claure contributed a piece titled “Titicaca Truths Revealed” highlighting the issues associated with developing surface water monitoring programs at Lake Titicaca and its affiliated tributaries. This article also highlighted the problem that although many private, public and academic institutions have investigated contamination at Lake Titicaca and its tributaries, the information collection efforts have not been standardized, sustained or continuous. What is known is that untreated sewage, industrial and agriculture discharges have a very large impact on water quality in the region. Due to the lack of consolidated data the full impact is unknown (Tierraamerica, 2009).

The compromised water quality impacts the environment, social welfare and health of the people who depend on the Rio Katari its tributaries and Lake Titicaca. Those who are most impacted are the ones who do not have access to safe drinking water, or a shallow well that is hydrologically connected to the contaminated rivers, those that are downstream of the contamination, and anyone who needs to utilize the rivers and/or Lake Titicaca. Based on this information there is a need for a continuation of the investigation of water quality impacts in the region, as well as the need for recommendations to curb the problems.

3.0 METHODOLOGY

3.1 Introduction

The objectives of this project were to analyze the quality of the Rio Katari and its principal tributaries; Rio Seco and Rio Pallina. Due to rapid growth, a lack of facilities to manage waste and no strategic planning, the Rio Katari, Rio Seco and Rio Pallina are being contaminated. Locations that would best represent water quality prior to contamination and areas that would best show where contamination was coming from were selected for sampling. Analysis was done for parameters that would help determine the chemistry of the water, as well as the types of contamination impacting the area. For this project sample analysis was performed by the Universidad Mayor de San Andres Facultad Ingenieria Carrera de Ingenieria Civil Laboratorio (UMSA Lab), and by Hall Environmental Analytical Laboratory (Hall). The UMSA Lab was selected because of its proximity to the field area and Hall was chosen for their capabilities in analyzing volatile organic carbons (VOCs).

3.2 Sample Site Selection and Sampling Frequency

The Rio Seco, Rio Katari and Rio Pallina were surveyed to determine where the location of headwaters and discharge points are located, as well as determine land use along the rivers. Sample sites were chosen in order to determine water quality upstream from development, degree of water quality degradation along the length of the river, and to determine areas of greatest impact. In addition, intermittent points along the Rio Seco and Rio Pallina were sampled to determine the impact El Alto and Viacha have on the rivers.

January and June were selected as the sampling months in order to determine seasonal water quality in the region. In January 2009 (the wet season), 13 sampling sites were selected. Five sampling sites were located on the Rio Seco, four sites on the Rio Pallina, two sites on the Rio Katari and one site in a ditch that flows between El Alto and Viacha. Additionally, one sample was inadvertently taken at a river that was thought to be the Rio Katari near Lake Titicaca, but was not. In June 2009 (the dry season) the same sites were selected, except for the incorrect river, and two additional samples from the Rio Katari were taken. Figure 5 shows the sampling locations for the January and June 2009 sampling events.

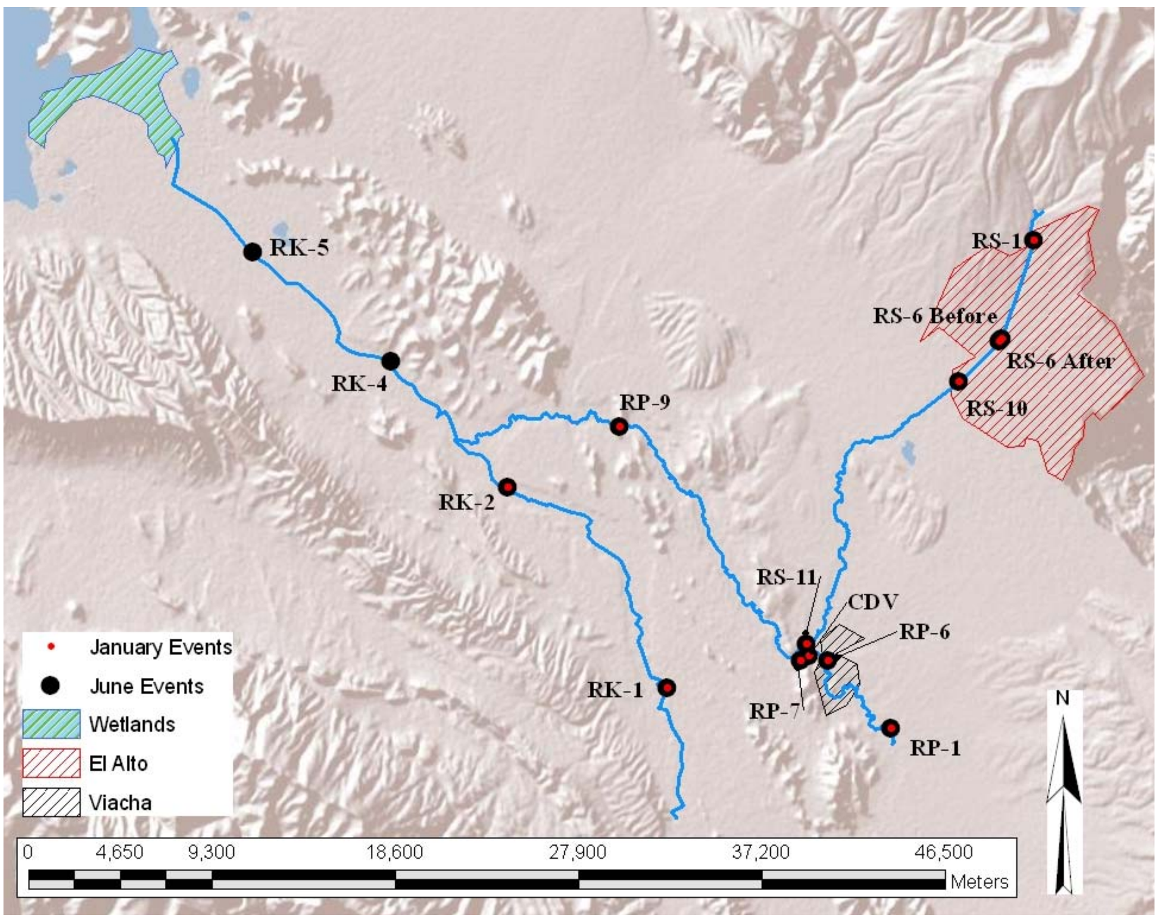

Figure 5. January and June 2009 sampling event and sample locations.

The selected sites and their description are as follows:

RS-1 is located at the headwaters of the Rio Seco, which is at the northern edge of El Alto. In January a ditch, lined with trash, from a cluster of nearby houses discharged into the river. Between the January and June sampling events the trash lined ditch was replaced with a plastic pipe. In January there was flow in the river upstream of the above mentioned discharge point. The water upstream of the discharge point was sampled, however in June there was no base flow and the water sample was collected from the discharge water that came from the nearby housing cluster. During both sampling events the water downstream of the discharge was grey and had a slight wastewater odor. During both sampling events the river was used for watering livestock, excavation of rocks and dirt, and as a dumping ground for trash. In addition during both sampling events children and adults were seen in the river. Figure 6 shows sample location RS-1 during the January and June 2009 sampling events.

Figure 6. Photo on left shows RS-1 during January 2009 when there was water in the river. The photo on the right shows RS-1 during June, when the only water in the river was from raw sewage being discharged into the river.

RS-6 wet season and dry season sampling sites are located in the Rio Seco in El Alto. In this reach the Rio Seco is confined to a cement channel with a rocky bottom. Between the two sampling points is a large ditch from the downtown portion of El Alto that enters the river (Ceja). At both sampling location the water had a slight wastewater odor and at RS-6 After the water contained blood. At these sampling points there were dead animals and trash in the water course. During both sampling events people were observed in the river utilizing the water for cleaning clothing, vehicles and recreational use (children playing in the water, adults and children walking in the water). Figure 7 is two photos of the sampling sites taken in January and June 2009.

Figure 7. RS-6 Before and RS-6 After sampling locations. The photo on the left shows the site in January 2009, during this sampling event the river was discolored because of animal slaughter waste being dumped into the river. RS-6 before was taken upstream of the canal on the right hand side of the photo, and RS-6 after was taken downstream of the canal after the two waters had mixed.

RS-10 is located in the Rio Seco. During the January 2009 sampling event this sampling point coincided with the end of development in El Alto. In January 2009 there was extensive foaming observed in the water and there was a slight wastewater odor. During June 2009 the river was dark grey and had a very strong wastewater odor. During both sampling events the river was used for livestock watering and recreational uses. In June 2009 new development at this point was observed, this consisted of installing a pipe (use uncertain) from the new houses to the river, as well as mining gravel from the river. Due to the removal of the gravel the course of the river had also shifted dramatically. Figure 8 is photos of sample site RS-10 during the January and June 2009 sampling events.

Figure 8. The photo on the left is RS-10 during the January 2009 sampling event and the photo on the right is from the June 2009 sampling event. Between the two sampling events water level in the river had decreased greatly. They were also developing more adjacent to the site and the course of the river had been moved and gravel was being excavated at the sampling site.

RS-11 is located in the Rio Seco, downstream of the WWTP and upstream of where the Rio Seco discharges into the Rio Pallina. During both events water was clear, with a slight wastewater odor and extensive foaming was observed in the water. Vegetation consisting of duckweed and algae was observed at this sampling point. Figure 9 is photos of RS-11 taken in January and June 2009.

Figure 9. The left photo is from RS- 11 during the January 2009 sampling event and the photo on the right is from the June 2009 sampling event.

RP-1 is located at the headwaters of the Rio Pallina and upstream of Viacha. The water was clear and contained no odor. Upstream of this point is a small community, it is unknown if the community discharges wastewater into the dry bed portion of the Rio Pallina. Figure 10 is photos from the January and June 2009 sampling events.

Figure 10. Photo on right is RP-1 during the January 2009 sampling event and the photo on the right is from the June 2009 sampling event. Flow was very low during both events.

RP-6 is located in the Rio Pallina, downstream of Viacha. The water was dark grey and had a very strong wastewater odor. During both events garbage and dead animals were observed in the water. During both sampling events children were seen playing in the river. Figure 11 is photos from the January and June 2009 sampling events.


Figure 11. The photo on the right is RP-6 during the January 2009 sampling event, and the photo on the left is from the June 2009 sampling event. During both events people were using the river for recreation purposes, and the sewage odor was very strong.

RP-7 is located in the Rio Pallina, upstream of the confluence with the Rio Seco. The Viacha cement plant is located adjacent to this sampling point. During both sampling events no discharge points from the cement plant were observed entering the river. The water was clear with a very slight wastewater odor. Vegetation consisting of duckweed and algae was present in the river. Along this region the air quality was compromised due to the cement plant, and suspended sediment was present in the river. Figure 12 is photos taken at RP-7 during the January and June 2009 sampling events.

Figure 12. Photo on the left is RP-7 during the January 2009 sampling event and the photo on the right is from the June 2009 sampling event. In January there was more sediment in the river.

RP-9 is the in the Rio Pallina down stream of its confluence with the Rio Seco and upstream of where it discharges into the Rio Katari. The water was slightly turbid with a slight wastewater odor. Figure 13 is photos from the January and June 2009 sampling events.

Figure 13. Photo on the left is RP-9 during the January 2009 sampling event and the photo on the right is from the June 2009 sampling event.

RK-1 is located at the headwaters of the Rio Katari. During the January 2009 sampling event the river was very turbid, in June 2009 the water was clear and some algae was growing on and around rocks. Adjacent to the sample point is agriculture fields and red windblown sands. Figure 14 is photos from the January and June 2009 sampling events.

Figure 14. The photo on the left RK-1 during the January 2009 sampling event and the photo on the right is from the June 2009 sampling event. The water level had decreased between the two events as well as the amount of suspended sediments. In June precipitates could be seen on the gravel along the bank of the river.

RK-2 is in the Rio Katari and is upstream of the confluence with the Rio Pallina. During January 2009 sampling event the river was very turbid, during the June 2009 sampling event the water was clear. Adjacent to the sampling point is agriculture fields and red windblown sands. Figure 15 is photos from the January and June 2009 sampling event.

Figure 15. The photo on the left is RK-2 during the January 2009 sampling event, and the photo on the right is from the June 2009 sampling event. The amount of flow and suspended sediment decreased between the two events. In June 2009 there was precipitates present on the bank of the river and algae in the river.

RK-4 is in the Rio Katari downstream of its confluence with the Rio Pallina. This point was only sampled during the June 2009 event. Water was clear with no odor; algae growth was observed in the river along the sides and attached to rocks and other objects in the river. Adjacent to the sampling point is an agriculture field and a single family home, no impact from the family was observed during sampling. Figure 16 is a photo from the June 2009 sampling event.

Figure 16. Photo of RK-4 during the June 2009 sampling event. The bottom of the river had lots of algae growth.

RK-5 is located in the Rio Katari, and was only sampled during the June 2009 event. The water was clear with no odor and algae was present in the water. Adjacent to the site is a foot bridge, agriculture fields, red windblown sand and an adobe wall (possibly from Tiwanaku raised bed agriculture). Figure 17 is a photo of RK-5 during the

June 2009 sampling event.

Figure 17. Photo of RK-5 during the June 2009 sampling event.

3.3 Sample Collection Procedure and Analytical Procedure

Water samples were collected with field assistance from Suma Jayma (non-profit in Bolivia), Maryknoll lay Missionaries (January 2009 event) and Engineers in Action (June 2009 sampling event). Clean sample bottles were provided by the UMSA Lab, and rinsed with sample water prior to the collection of the water sample. The water sample was collected between the bank and middle of the river, depending on the height of the river bank. Samples were then placed in a cooler and brought to the UMSA lab on a daily basis for sample preservation and analysis. Prior to sampling, photos of the site were taken, Global Positioning System (GPS) coordinates, date, time and color and odor of water were recorded in a field notebook in addition to any other site observations that were pertinent in determining the basic chemistry of the water and contaminants. Water temperature, pH and conductivity were measured in the field using a multi-meter and recorded in the field book. Prior to field work the multi-meter was calibrated with a buffer solution and rinsed with clean water between samples. During the June 2009 sampling event the multi-meter broke in the field and UMSA lab measured temperature, pH and conductivity of the samples upon delivery of the samples to the lab. Table 1 lists the constituents measured and the analytical methods used.

Samples were also collected for VOC's, preserved with HCL, placed on ice and brought back to the United States for analysis by Hall Environmental Analytical Laboratory (Hall). Table 1 is a table of the ASTM standards that the UMSA lab and Hall used for analysis of the water samples.

Table 2. Water Quality Analysis Methodology			
Type of Analysis	Method Number	Method Name	Reference
Temperature	SMWW 2550	pH and Conductivity meter	SMEWW, 2005
pH	SMWW 4500-H^+ B	pH and Conductivity meter	SMEWW, 2005
Conductivity	SMWW 2510	pH and Conductivity meter	SMEWW, 2005
Calcium	SMWW 3500-Ca B	EDTA Titrimetric Method	SMEWW, 2005
Magnesium	SMWW 3500-Mg B	Atomic Absorption Spectrometric Method	SMEWW, 2005
Sodium	SMWW 3111 B	Direct Air-Acetylene Flame Method	SMEWW, 2005
Potassium	SMWW 3111 B	Direct Air-Acetylene Flame Method	SMEWW, 2005
Alkalinity	SMWW 2320 B	Titration Method	SMEWW, 2005
Chloride	SMWW 4500-Cl^- E	Automated Ferricyanide Method	SMEWW, 2005
Sulfate	SMWW 4500-$SO4^{2-}$ E	Turbidimetric Method	SMEWW, 2005
Nitrate	SMWW 4500-$NO3^-$ E	Cadmium Reduction Method	SMEWW, 2005
TKN	4500 N_{org} C 4500-NH3 B	Micro-Semi kjeldahl Method and preliminatry Distillation	SMEWW, 2005
Total Phosphorus	SMWW 4500-P B	Digestion/Colurimetry	SMEWW, 2005
Fecal Coliforms	SMWW 9222 D	Membrante Filtration	SMEWW, 2005
Chemical Oxygen Demand	SM 5220 B	Open Reflux Method	SMEWW, 2005
Volatile Organic Carbon	EPA 8260	Gas Chromatography/ Mass Spectrometry	EPA, 2009

SMWW/SMEWW-Standard Methods for the Examination of Water and Wastewater
EPA-Environmental Protection Agency

3.4 Discharge Measurements

Estimates of flow volume were done in areas where flow could be estimated without having to contact the water, or where flow over a weir could be estimated. Flow estimates were utilized to estimate contaminant loading. During the January 2009 sampling event six sites were estimated. Five of the sites were located at a sampling site, and one measurement was taken upstream of a sampling site. In June only four estimates were taken due to sites no longer being accessible.

The velocity-area method was utilized in determining the discharge. This was done by finding a location with uniform width, with little to no flow disruptions in the stream and a constant velocity. The stream profile was measured by measuring the depth of water approximately every foot across the stream channel. Velocity along the river was then estimated by measuring a length along the river and calculating the time it took for a partially filled bottle to travel the distance, this was done multiple times to improve the estimate. Because the velocity profile varies between the surface and bottom of the stream the measured velocity is multiplied by a correction factor of 0.66 (USBR, 2001). Discharge was calculated by multiplying the cross sectional area by the corrected velocity.

Mass flow is the total amount of mass per time of a particular constituent flowing past a given location in the river. This calculation is done by multiplying the discharge (liters per second) by the concentration of the constituent of concern (mg/l), this calculation yields mg/s. Mass flows are used to determine the input of constituents in the river and their transport along the river. They are also useful in quantifying the transformations of reactive constituents such as nitrogen species and coliform bacteria.

4.0 RESULTS AND DISCUSSION

4.1 Background

Samples were collected from the Rio Katari, Rio Seco and Rio Pallina in January and June 2009. In the field, pH, temperature and conductivity were measured with a calibrated multimeter. Samples were collected in the field and analyzed for cations, anions, nitrate, Total Kjeldahl nitrogen (TKN), total phosphorus, fecal coliform and chemical oxygen demand (COD) at the UMSA lab. After evaluation of the first set of samples TKN and COD were added to the sampling list for analysis during the June 2009 sampling event. The results are compared to USEPA Safe Drinking Water Act (SDWA) Maximum Concentration Level (MCL) and World Health Organization (WHO) recommended drinking water concentrations. SDWA MCLs and WHO recommended concentrations were chosen for comparison because drinking water standards for Bolivia could not be located. Additionally the river is source of drinking water. WHO's recommended list is not as extensive as the one compiled by SDWA, thus both SDWA and WHO's recommended limits were chosen for comparison. Constituent which were detected above either the SDWA MCL or WHO level are noted in Table 5 in red and bold and Table 2, 3 and 4 in Appendix B.

4.2 Discharge Measurements

In January and June discharge measurement were taken where site conditions made it allowed. In many areas the river is channelized and access to it is limited. Other areas were deemed as too much of a health related risk to enter due to the presence of large quantities of blood, dead animals and raw sewage. Figure 18 is a bar graph of discharge measurements collected in the field area. Although no precipitation occurred in the region during the June 2009 sampling event, discharge increased at some locations relative to the January 2009 sampling event. Increase of discharge occurred downstream of the WWTP, thus the increase is probably due to an increase in effluent discharge from the WWTP.

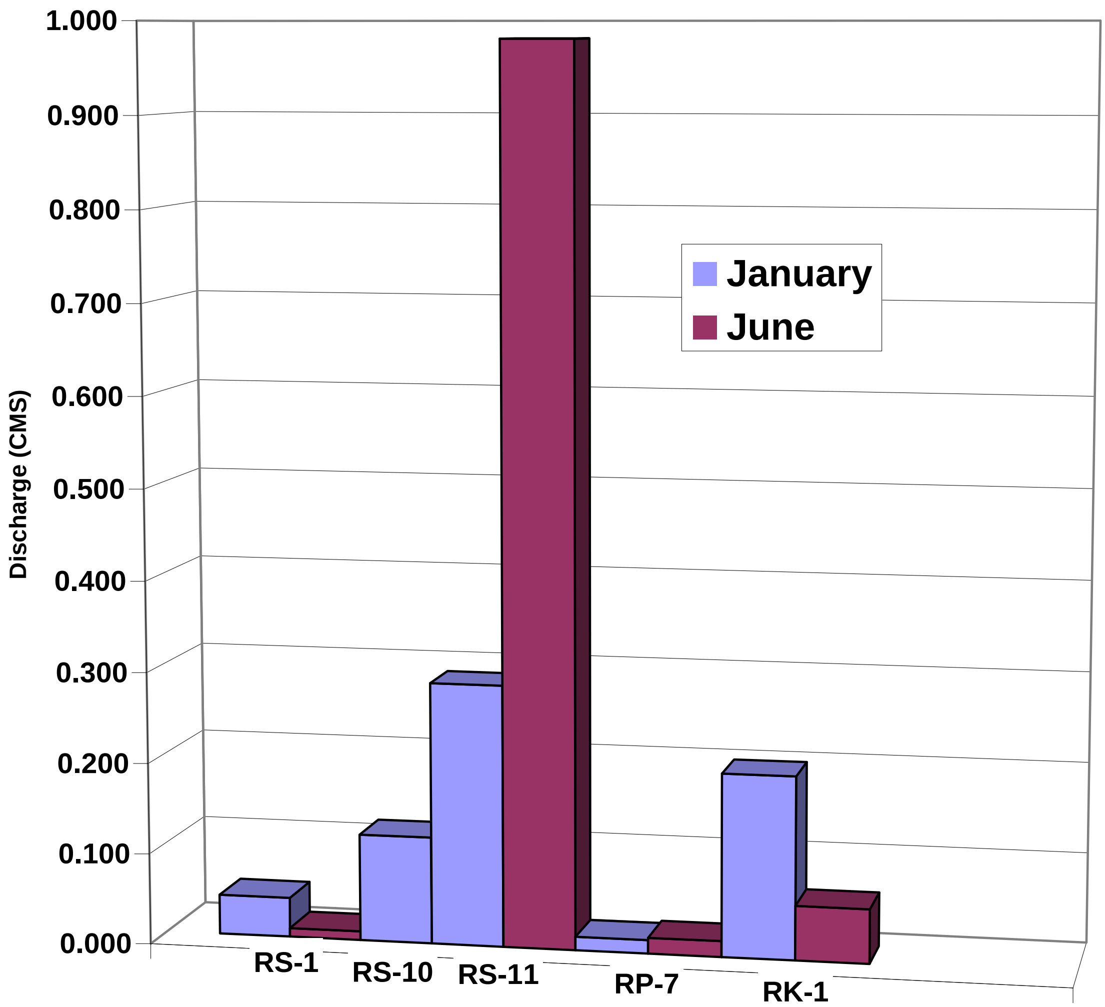

Figure 18. Bar graph of discharges calculated during the January and June 2009 sampling events. A discharge estimate was not available for RS-10 during the June sampling event

4.3 Water Chemistry

Samples were collected and analyzed for pH, temperature, conductivity, cations and anions to help determine changes in water chemistry due to anthropogenic impacts.

Table 1 in Appendix B is field measurements; Table 2 in Appendix B is the cation and anion analytical results. Figures 1-10 in Appendix C are graphs showing the spatial distribution of field measurements and cation/anion concentrations for the Rio Katari and Rio Pallina for the January and June 2009 sampling events. Figures 16-25 in Appendix C are graphs of the spatial distribution of field measurements and cation/anion concentrations for the Rio Seco and Rio Pallina for the January and June 2009 sampling events. Table 3 shows results of the ion balance completed for all sample sites for both sampling events. Full results and calculations can be seen in Appendix D. The ion balance indicates eight of the 26 samples have a difference in excess of 10%. This difference is likely associated with laboratory analytical error. Table 4 shows the ion mass loading calculations done for sites with calculated or estimated discharges.

Table 3. Table Cation/Anion Balance Results		
Sample ID	**Sample Date**	**% Balance**
RS-1	1/27/2013	1.21
RS-1	6/23/2013	18.75
RS-6 Before	1/27/2013	0.45
RS-6 Before	6/23/2013	1.65
Large open channel from Ceja region of El Alto flows into the Rio Seco between these points		
RS-6 After	1/27/2012	7.70
RS-6 After	6/23/2013	16.10
RS-10	1/27/2013	0.62
RS-10	6/23/2013	12.50
Effluent from El Alto WWTP flows into Rio Seco between these points		
RS-11	1/28/2013	16.68
RS-11	6/25/2013	14.27
CDV	1/28/2013	11.40
CDV	6/25/2013	5.13
RP-1	1/28/2013	3.64
RP-1	6/25/2013	2.60
RP-6	1/28/2013	3.23
RP-6	6/25/2013	16.25
RP-7	1/28/2013	6.20
RP-7	6/25/2013	4.43
Rio Seco and Camino de Viacha ditch flow into Rio Pallina between these points		
RP-9	1/28/2013	0.76
RP-9	6/24/2013	3.70
RK-1	1/28/2013	7.78
RK-1	6/25/2013	5.64
RK-2	1/28/2013	10.15
RK-2	6/24/2013	12.91
Rio Pallina flows into Rio Katari between these points		
RK-4	NS	
RK-4	6/24/2013	10.04
RK-5	NS	
RK-5	6/24/2013	6.69

Table 4. Cation and Anion Mass Loading									
Sample ID	Sample Date	Conductivity (µs/d)	Calcium (kg/d)	Magnesium (kg/d)	Sodium (kg/d)	Potassium (kg/d)	Alkalinity (kg/d)	Chloride (kg/d)	Sulfate (kg/d)
RS-1	1/26/2009	4.68E+08	34.54	10.94	20.23	11.99	22.48	7.53	147.58
RS-1	6/22/2009	1.17E+09	46.21	12.01	79.07	48.92	403.58	84.40	116.92
RS-10	1/26/2009	1.03E+10	508.92	98.74	1,178.33	288.49	1,970.66	1,380.68	1,043.23
RS-11	1/27/2009	3.06E+10	1,096.82	362.70	3,134.47	910.49	8,458.09	3,331.00	1,857.79
RS-11	6/24/2009	1.31E+11	4,078.16	1,442.19	10,174.21	4,408.82	40,357.68	13,773.33	4,814.94
CDV	1/27/2009	9.13E+08	15.95	65.72	84.29	22.01	304.39	59.52	74.69
RP-7	1/27/2009	7.34E+08	36.63	17.28	82.76	23.61	182.79	50.16	103.00
RP-7	6/24/2009	1.45E+09	63.41	16.48	141.64	52.74	436.98	109.21	128.77
RP-9*	1/27/2009	2.85E+10	1,195.54	364.78	2,968.21	869.70	7,693.29	2,993.57	1,986.89
RP-9*	6/23/2009	1.27E+11	4,576.29	1,488.89	11,588.02	4,222.32	38,794.55	13,637.06	5,056.85
RK-1	1/27/2009	2.07E+10	127.19	20.06	195.48	12.44	159.94	2,846.42	282.43
RK-1	6/24/2009	6.45E+09	480.27	82.43	687.32	40.70	651.15	845.98	1,123.77
RK-4*	6/24/2009	1.29E+11	4,693.44	1,548.42	11,446.47	4,226.66	38,649.01	14,107.13	6,033.17

*Flows for RP-9 and RK-4 were not measured in the field, mass loading for these two sampling sites were calculated based on mass loadings and discharge of upstream sampling points

4.2.1 Rio Katari

The region along the Rio Katari is more rural then that around the Rio Seco and Rio Pallina. Along the reach there are single family homes and land use consists of primarily agricultural practices (livestock grazing and food production fields). Figure 19 is stiff diagrams for RK-1, RK-2 and RP-9 for the January 2009 sampling event, Figure 20 is stiff diagrams for RK-1, RK-2, RK-4, RK-5 and RP-9 for the June 2009 sampling event. Figure 21 is a trilinear diagram for the Rio Katari for both sampling events, and Figure 22 is a graph showing the spatial distribution of conductivity in the Rio Katari and Rio Pallina for both sampling events. Figures 4-10 in Appendix C show the spatial distribution of cations and anions in the Rio Katari and Rio Pallina, for both sampling events.

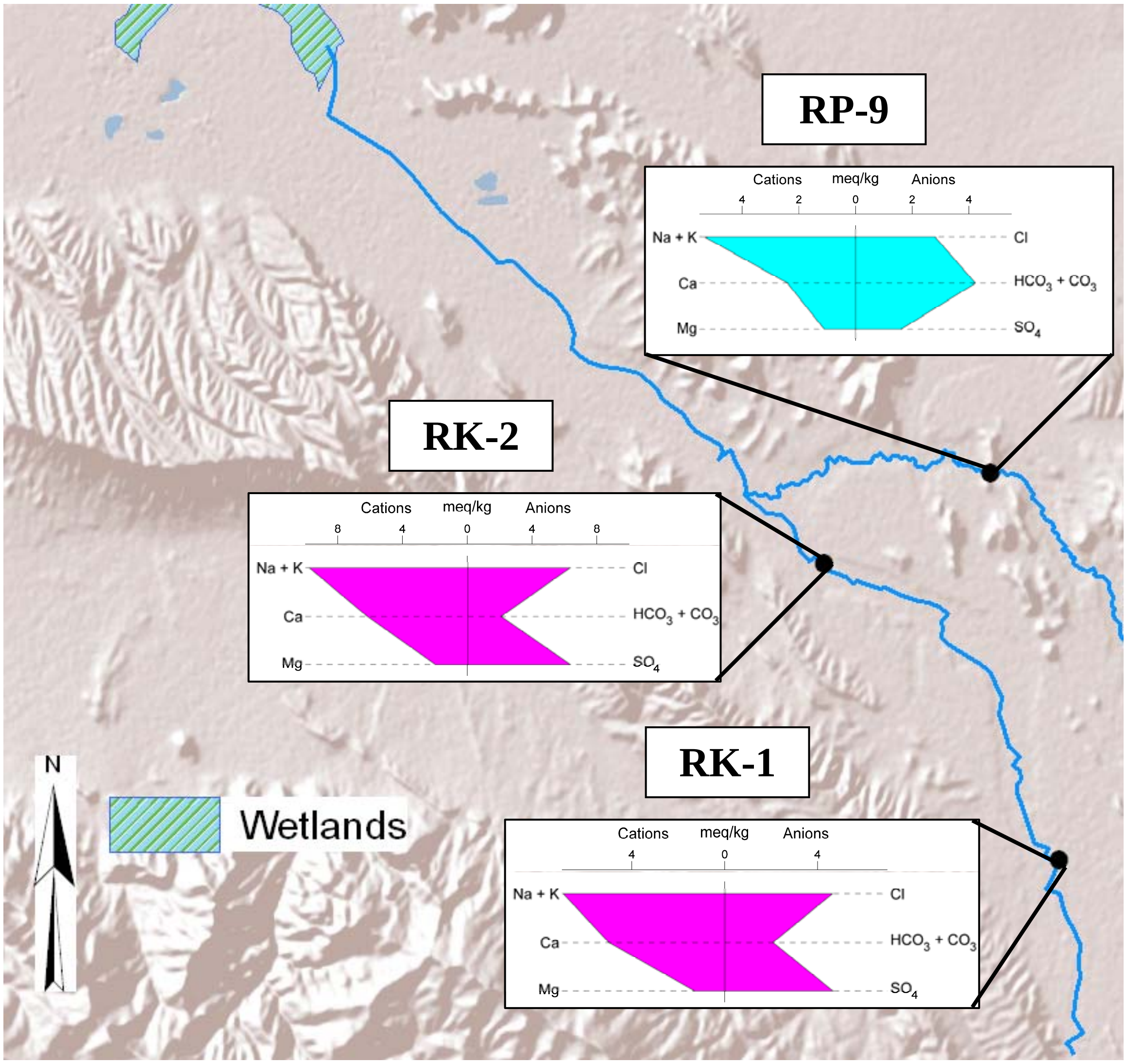

Figure 19. Stiff diagrams for the RK-1, RK-2 and RP-9 January 2009 sampling event.

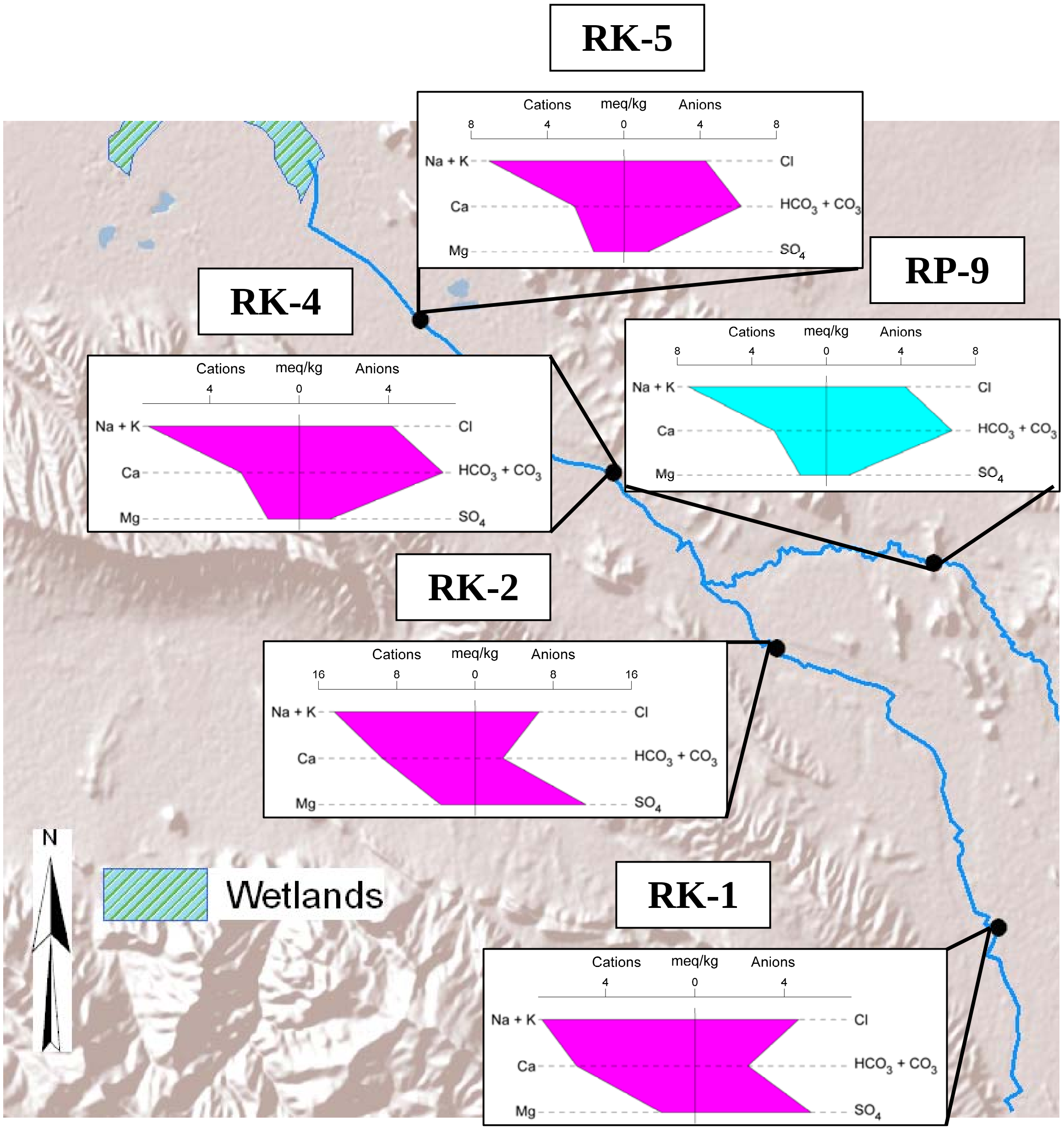

Figure 20. Stiff diagrams for the RK-1, RK-2, RK-4 and RK-5 and RP-9 June 2009 sampling event.

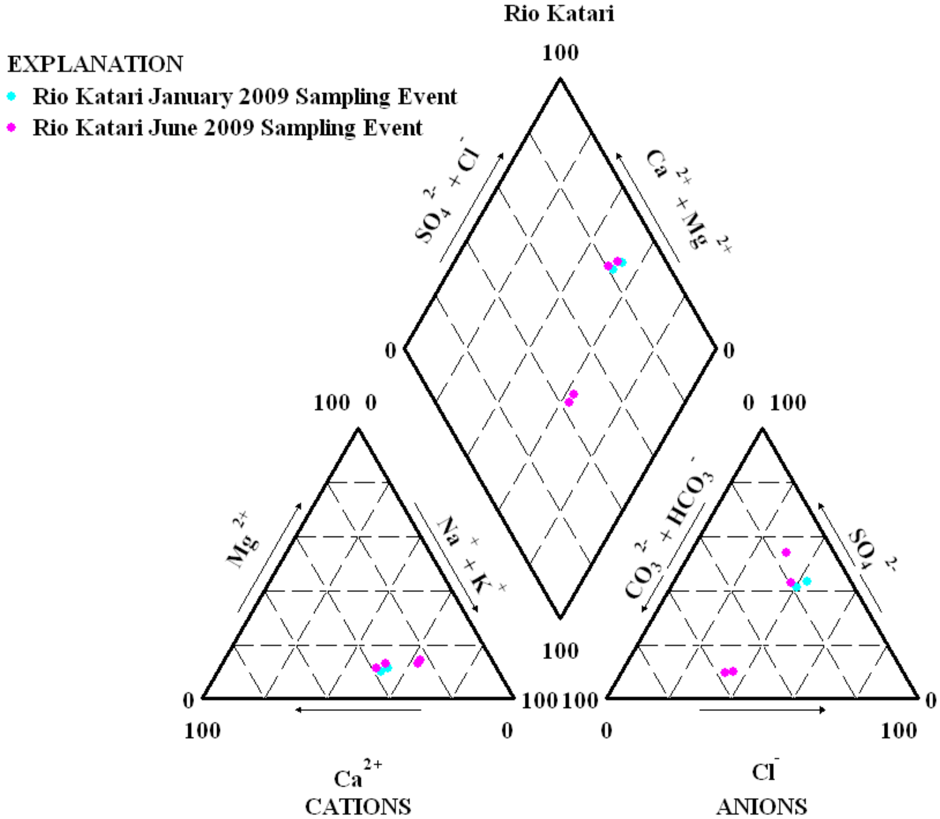

Figure 21. Rio Katari trilinear diagram

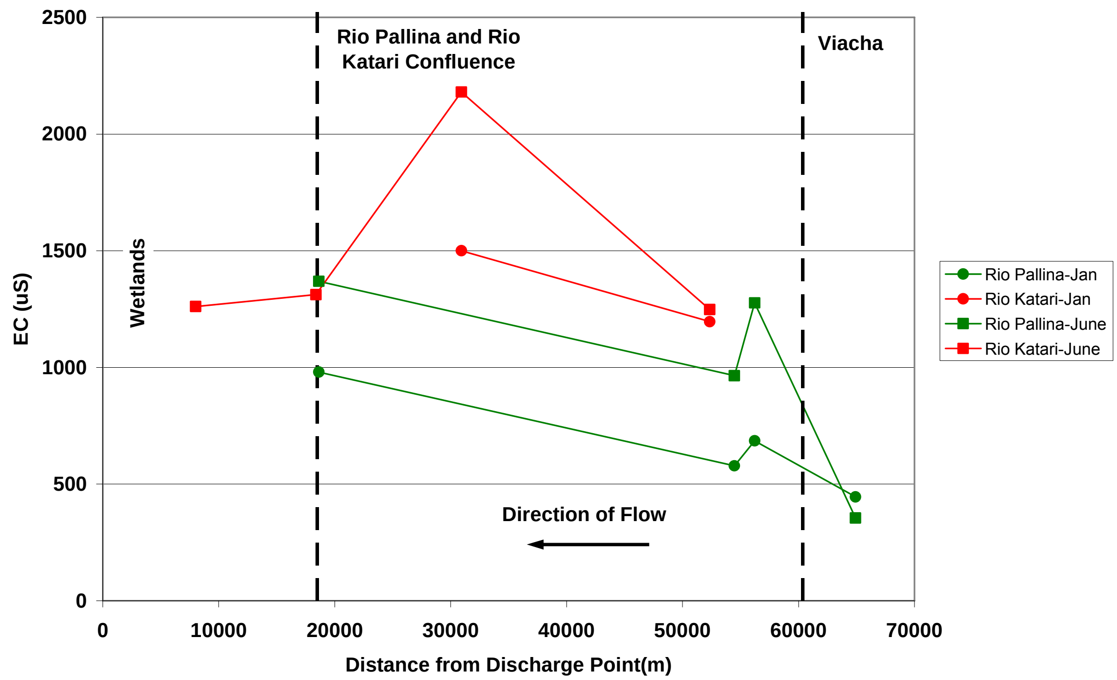

Figure 22. Spatial distribution of conductivity in the Rio Katari and Rio Pallina

In January 2009 conductivity, calcium, magnesium, sodium, potassium, alkalinity, chloride and sulfate increased between RK-1 and RK-2 (Figure 19). During the sampling event there was a lot of suspended sediment in the river, which may have resulted in the concentration increase, from surface water and sediment interactions. Groundwater might also be upwelling in the region, which also may introduce cations and anions.

In June 2009 concentrations of conductivity, calcium, magnesium, sodium, potassium, alkalinity, chloride and sulfate increased (Figure 20). During this sampling event some suspended sediment was noted in the river, but not as much as the January 2009 sampling event. The increase of cations and anions may be from surface water/sediment interactions, groundwater/sediment interactions, surface water/ground water interaction or evaporates along the water course being dissolved.

The January 2009 and June 2009 sampling events show the same trend with respect to which cations/anions increase (Figures 19, 20, 21 and 22). Sample analysis results for RK-1 during the January and June sampling events varied slightly. However during the June sampling event the following constituents increased between 19% and 79% in RK-2 relative to the January RK-2 sampling event; conductivity (45%), calcium (53%), magnesium (74%), sodium (46%), potassium (70%), alkalinity (19%) and sulfate (79%). The large variation in the RK-2 variance can be attributed to precipitation diluting the surface water in January and the small change in RK-1 can be attributed to the water source for the headwaters remaining constant between the two events.

Between RK-2 and RK-4 the Rio Pallina flows into the Rio Katari. All cations/anions approach the cation/anion concentration values present at sampling site RP-9. The change of cations/anion concentration can be attributed to the flow in the Rio Pallina being much greater then the flow in the Rio Katari (Figure 20 and 22).

Between RK-4 and RK-5 concentrations of cations and anions stay relatively constant, as there are no new discharges into the river. Mass loading was calculated for RK-1, and estimated for RK-4 and RP-9 for the June 2009 sampling event. Mass loading results indicate that the Rio Pallina discharges large quantities of cations/anions into the Rio Katari (Table 4).

4.2.2 Rio Seco

RS-1 was taken at two different locations during the January and June 2009 sampling events. In January the river had flow so the sample was taken prior to any contamination flowing into the river. In June there was no flow in the river, therefore the sample was taken immediately below a pipe that carries wastewater from nearby houses.

Because of the different sampling locations these two points can not be compared. Results of the analysis of cations/anions and field measurements at RS-1 can be seen in Table 2 in Appendix B. Figure 23 is stiff diagrams for RS-1, RS-6 Before, RS-6 After, RS-10 and RS-11 for the January 2009 sampling event, Figure 24 is stiff diagrams for RS-1, RS-6 Before, RS-6 After, RS-10 and RS-11 for the June 2009 sampling event. Figure 25 is a trilinear diagram for the Rio Seco for both sampling events, and Figure 26 is a graph showing the spatial distribution of conductivity in the Rio Seco and Rio Pallina for both sampling events. Figures 19-25 in Appendix C show the spatial distribution of cations and anions in the Rio Seco and Rio Pallina for both sampling events.

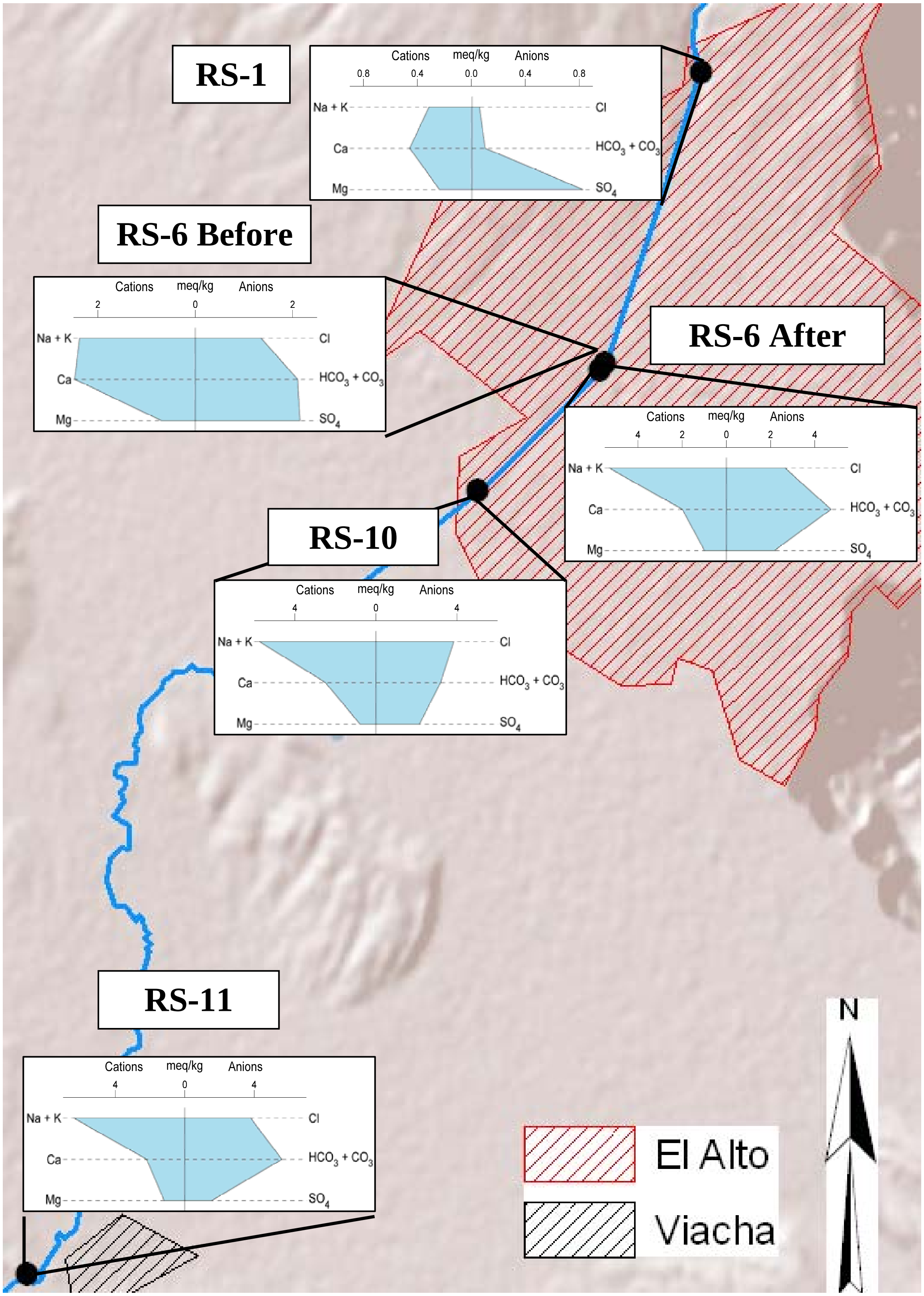

Figure 23. Stiff diagrams for the Rio Seco January 2009 sampling event.

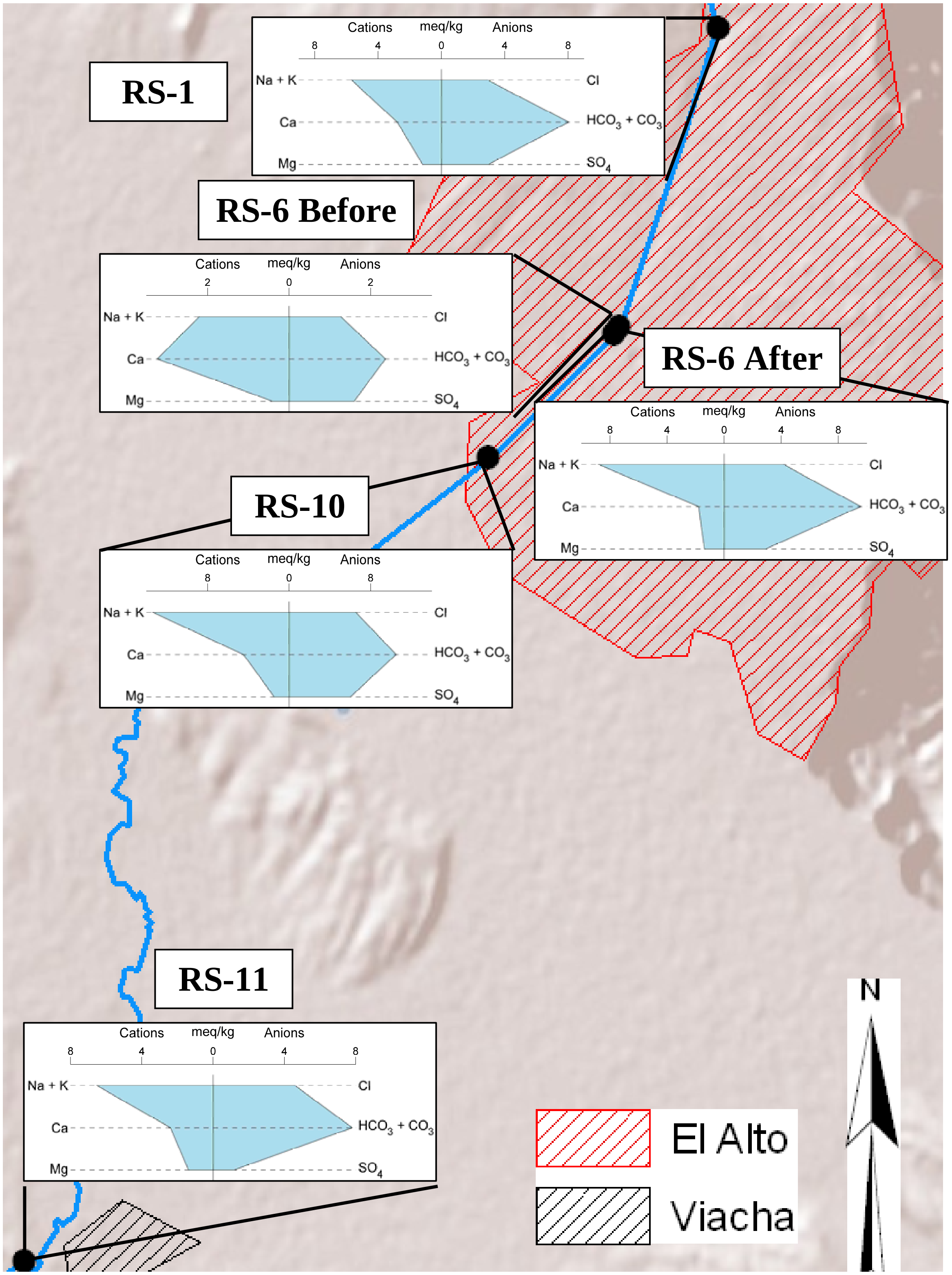

Figure 24. Stiff diagrams for the Rio Seco June 2009 sampling event.

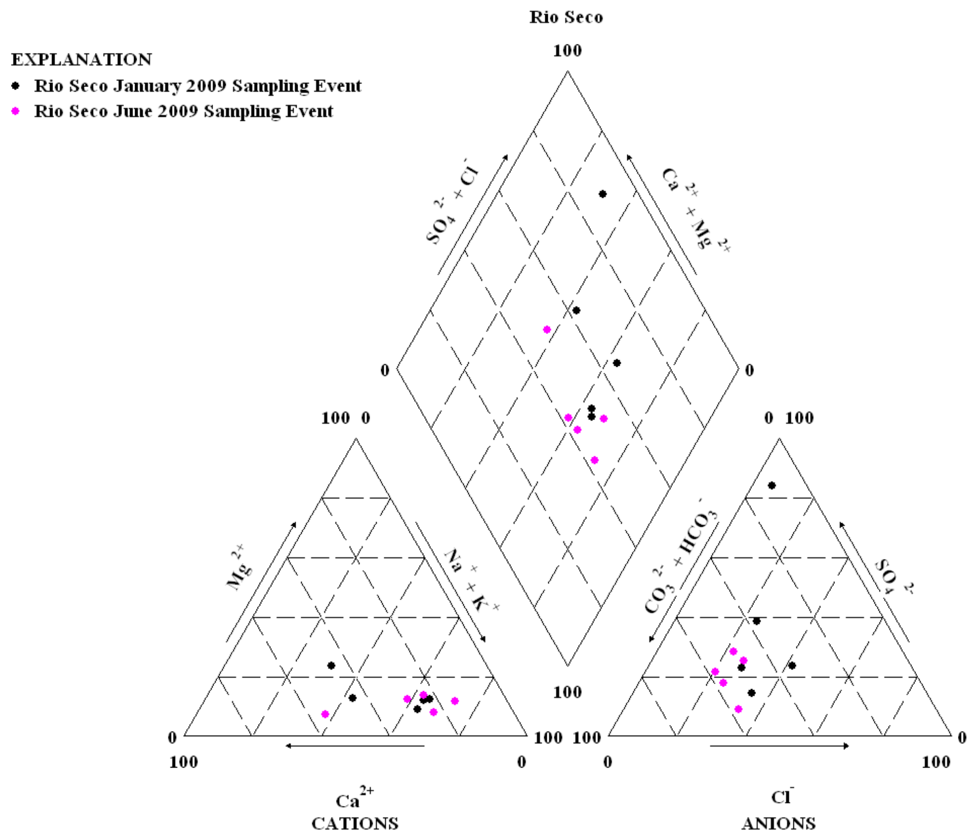

Figure 25. Rio Seco trilinear diagram

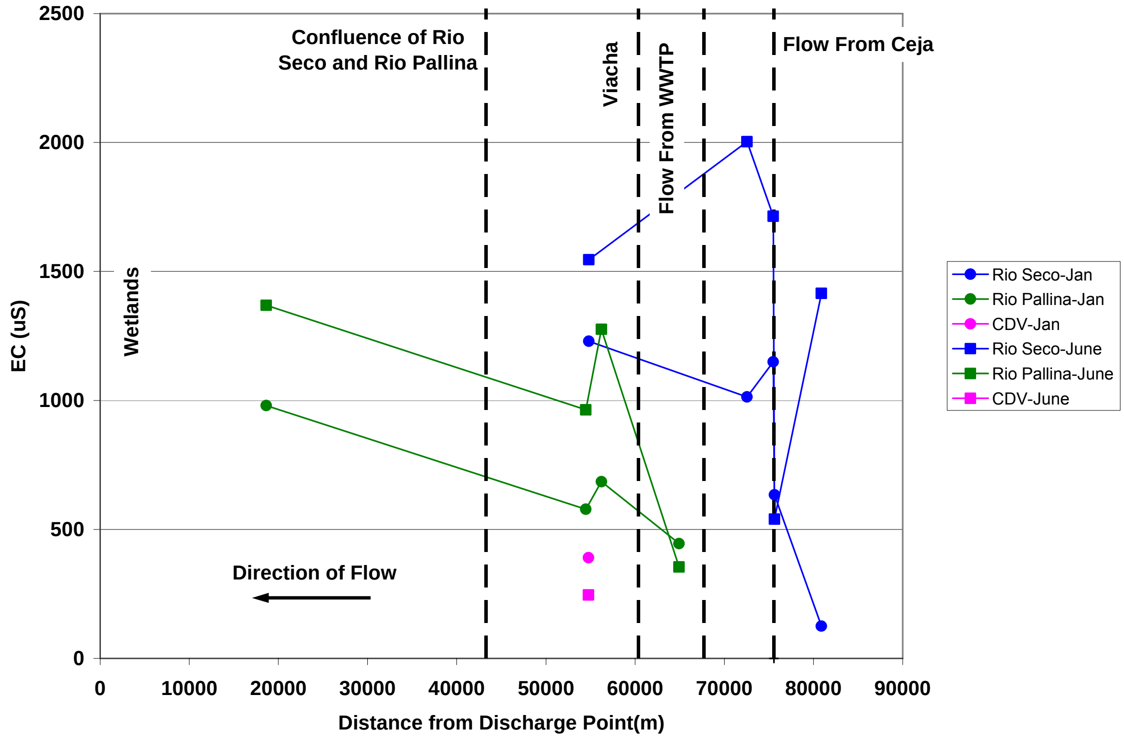

Figure 26. Spatial distribution of conductivity in the Rio Seco and Rio Pallina

<u>RS-6 Before to RS-6 After</u>

In January and June 2009 conductivity and concentrations of magnesium, potassium, sodium, alkalinity, chloride and sulfate increased. Calcium decreased during both events. The increase in most concentrations is due to a large input between the two points. In January increases in cations/anions between RS-6 Before and RS-6 After are as follows: conductivity (81%), magnesium (43%), sodium (133%), potassium (92%), alkalinity (125%), chloride (97%) and sulfate (0.3%). In June increases in cations/anions between RS-6 Before and RS-6 After are as follows: conductivity (217%), magnesium (233%), sodium (260%), potassium (527%), alkalinity (305%), chloride (229%) and sulfate (83%). The large difference in the increase of constituents between the two points is seasonally influenced, as there is no precipitation in June. Calcium concentrations probably decreased because of dilution (Figures 23, 24, 25 and 26).

RS-6 After to RS-10

In January and June 2009 concentrations of calcium, sodium and chloride increased and potassium decreased. In January 2009 magnesium, alkalinity and sulfate decreased, whereas in June 2009 they increased. These differences can be attributed to precipitation in January diluting the concentrations, whereas in June there is no precipitation, thus no dilution (Figures 23, 24, 25 and 26).

RS-10 to RS-11

In January and June 2009 concentrations of calcium, chloride and sulfate decreased. In January 2009 concentrations of magnesium, sodium, potassium and alkalinity increased, while in June 2009 these concentrations decreased. Between these two sampling points is the El Alto WWTP. Effluent from the WWTP in June dilutes concentrations in the river, whereas in January concentrations of cations/anions in the river upstream of the WWTP are below the concentrations of the effluent the effluent acts as a source (Figures 23, 24, 25 and 26). Mass loading calculated between RS-10 and RS-11 for the January 2009 sampling event show an increase of conductivity, calcium, sodium, potassium, alkalinity, chloride and sulfate loads (Table 4). This increase indicates the WWTP is a point source pollutant for cations and anions.

4.2.3 Rio Pallina

In general, waters from the Rio Pallina do not tend to vary much seasonally or spatially. Unlike the Rio Seco, the Rio Pallina has less non-point source and point source pollution. Figure 27 is stiff diagrams for RP-1, RP-6, RP-7, RP-9, RS-11 and CDV for the January 2009 sampling event, Figure 28 is stiff diagrams for RP-1, RP-6, RP-7, RP-9, RS-11 and CDV for the June 2009 sampling event. Figure 29 is a trilinear diagram for the Rio Pallina for both sampling events, and Figures 22 and 26 are graphs showing the spatial distribution of conductivity in the Rio Katari and Rio Pallina and the Rio Seco and Rio Pallina for both sampling events. Figures 4-10 in Appendix C show the spatial distribution of the Rio Katari and Rio Pallina for both sampling events and Figures 19-25 in Appendix C show the spatial distribution of the Rio Katari and Rio Pallina for both sampling events

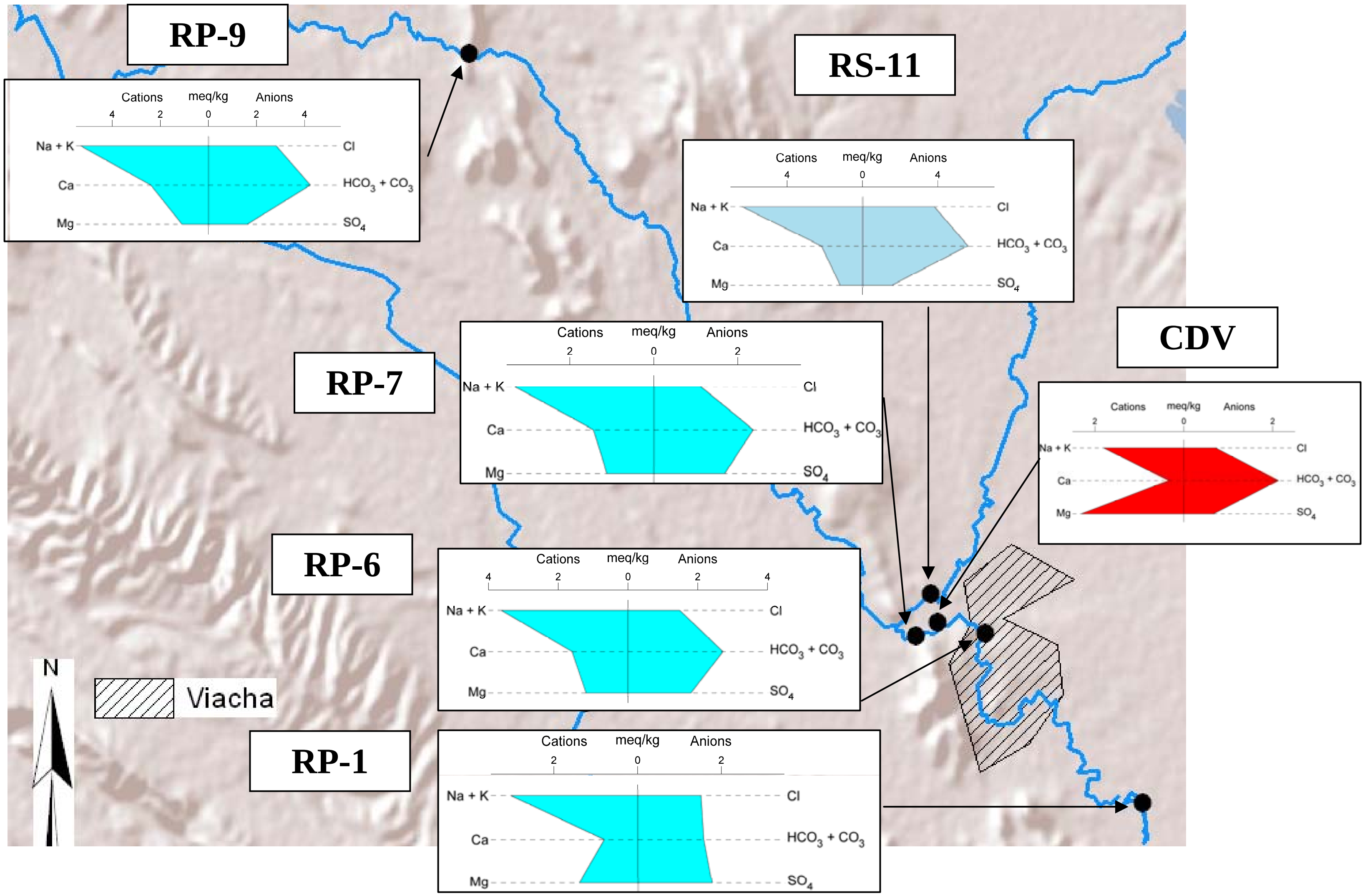

Figure 27. Stiff diagrams for the Rio Pallina, RS-11 and CDV January 2009 sampling event.

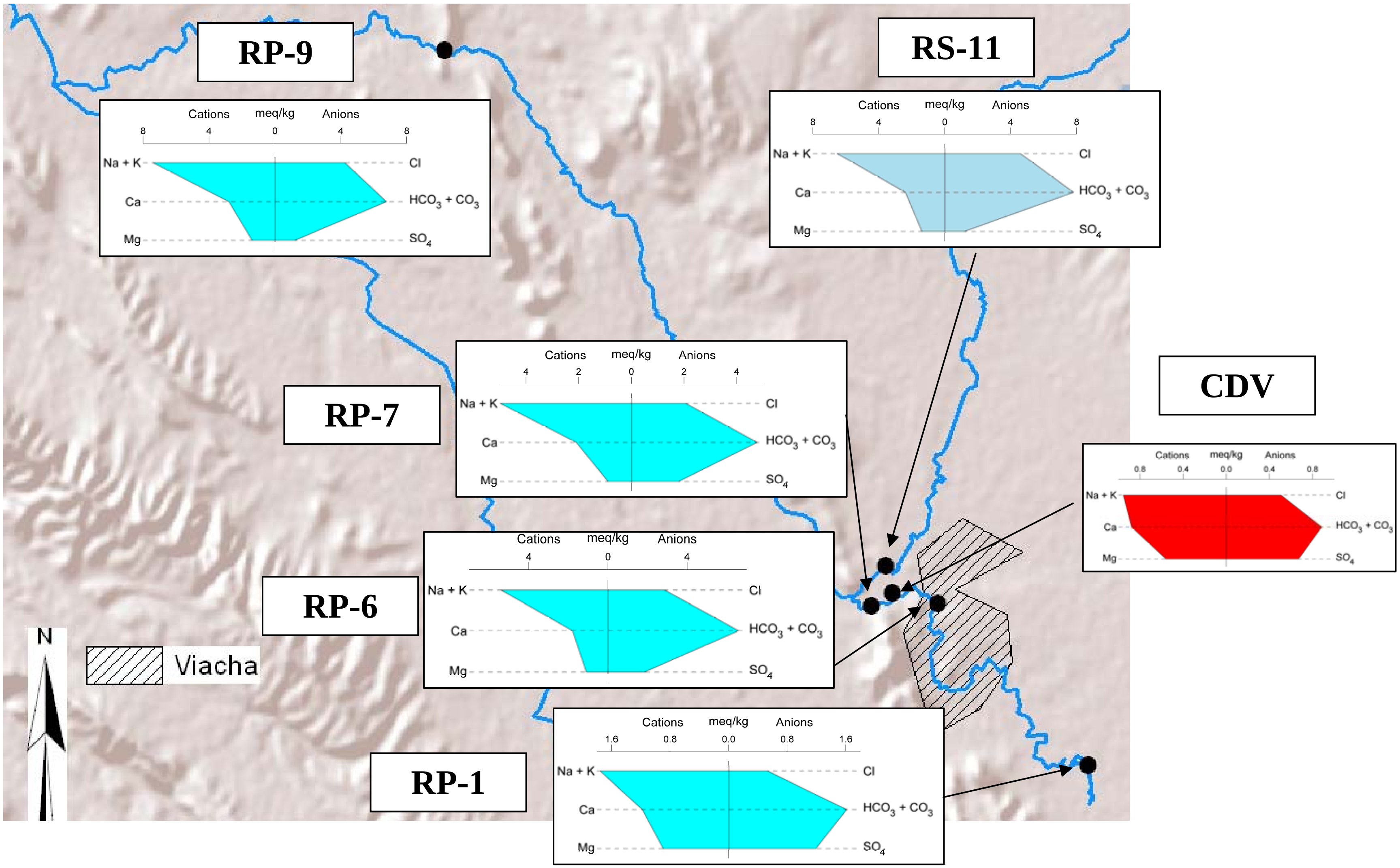

Figure 28. Stiff diagrams for the Rio Pallina, RS-11 and CDV June 2009 sampling event.

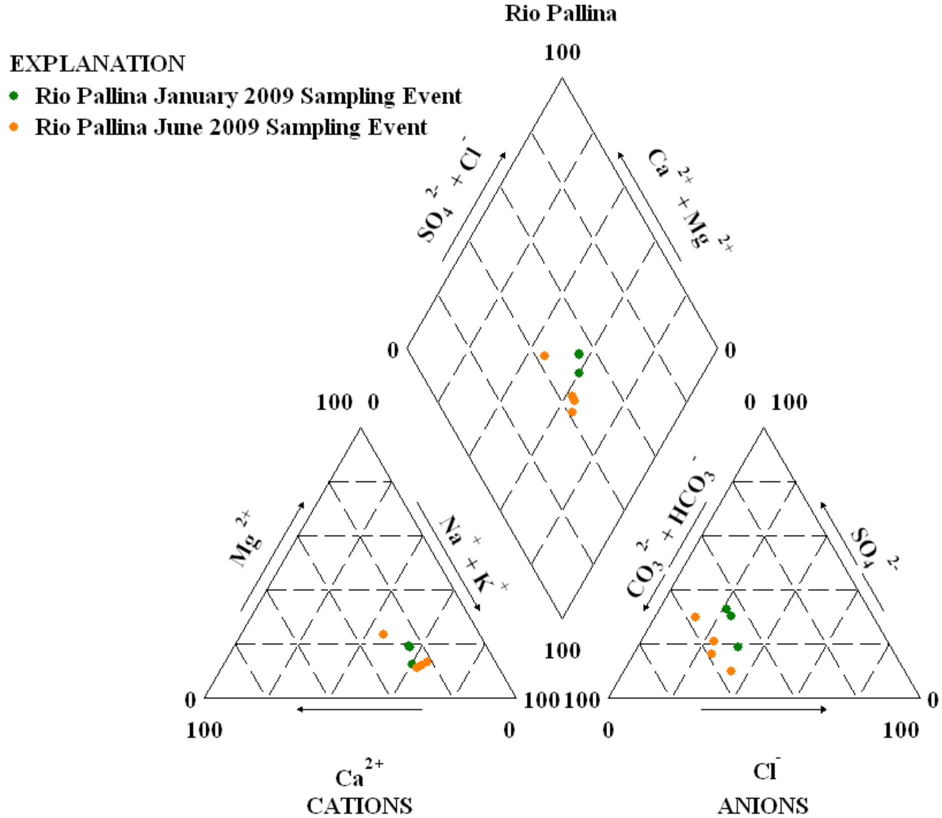

Figure 29. Trilinear diagram of the Rio Pallina

RP-1 to RP-6

January and June 2009 concentrations of calcium, potassium, sodium, alkalinity, chloride and sulfate increased between RP-1 and RP-6. In January and June 2009 magnesium decreased (Figures 22, 26, 27, 28 and 29). The increase can be attributed to land practices between the two points. Between these two points is Viacha, which lacks any wastewater collection or treatment system and discharges many pollutants into the river. Viacha also utilizes groundwater, which may contain dissolved concentrations of the cations/anions, thus increase the amount in the surface water. In January constituents increased between RP-1 and RP-6 by the following: calcium (100%), sodium (20.3%), potassium (17.6%), alkalinity (72.9%), and sulfate (2%). In June constituents increased between RP-1 and RP-6 by the following: calcium (52.6%), sodium (191%), potassium (282%), alkalinity (310%), and sulfate (54%). The variability of the increase of constituents during the two sampling events can be attributed to seasonal changes and changes in discharges.

RP-6 to RP-7

In January and June 2009 with the exception of calcium in June 2009 all concentrations of cations/anions decreased. In January the decrease can be attributed to dilution from precipitation. In June the decrease of cations and anions may be from unseen irrigation practices (Figures 22, 26, 27, 28 and 29). The percent change between the cations and anions at the two sampling points during the two events does not vary much.

RP-7 to RP-9

In January and June 2009 concentrations of calcium, potassium, sodium, alkalinity and chloride increased. In January 2009 concentrations of magnesium and sulfate decreased, whereas in June 2009 they increased. Between these two points the Rio Seco flows into the Rio Pallina, during both sampling events the concentrations of cations/anions in the Rio Pallina approach those in the last sampling point of the Rio Seco. During field work the flow in the Rio Seco was greater than the Rio Pallina, therefore the concentration trends of the Rio Seco tends to dominate the ion composition (Figures 22, 26, 27, 28 and 29). This can also be seen in mass loading (Table 4) in which the loads of conductivity, cations and anions increase.

4.4 Water Contamination

Samples were collected and analyzed for nitrates, fecal coliform, total phosphorus, TKN, COD and VOC's to determine the anthropogenic impact. Table 5 is the sampling results for nitrates, fecal coliform, total phosphorus, TKN and COD at all sampling locations during both sampling events and Table 6 is mass loading results for the above mentioned constituents, calculated where flows were measured. Table 4 in Appendix B is the VOC sampling results. Figures 11-15 in Appendix C are graphs showing the spatial distribution of nitrate-N, fecal coliform, total phosphorus, TKN and COD concentrations in the Rio Katari and Rio Pallina for the January and June 2009 sampling events. Figures 26-30 in Appendix C are graphs showing the spatial distribution of nitrate-N, fecal coliform, total phosphorus, TKN and COD concentrations in the Rio Seco and Rio Pallina for the January and June 2009 sampling events. Where applicable on the spatial distribution graphs exceedances of the MCL was noted. Table 7 is a table of TKN and COD ratios from a literature review for raw effluent from hog slaughter house waste and high concentrate wastewater compared to the June 2009 sampling results from the site. Figure 31 in Appendix C is TKN vs. COD for the Rio Katari, Rio Seco and Rio Pallina.

Table 5. Contaminant Concentration Results

Sample ID	Sample Date	Nitrate (mg/l)	Nitrate-N (mg/l)	TKN (mg/l)	Total Phosphorus (mg/l)	Fecal Coliform (CFU/l)	Chemical Oxygen Demand
RS-1	1/26/2009	1.09	0.25	NA	ND	**2.00E+03**	NA
RS-1	6/22/2009	17.9	4.05	119	11.6	**5.00E+06**	782
RS-6 Before	1/26/2009	1.16	0.26	NA	0.53	**1.50E+04**	NA
RS-6 Before	6/22/2009	3.15	0.71	10.5	1.47	**4.20E+03**	46.0
Large open channel from Ceja region of El Alto flows into the Rio Seco between these points							
RS-6 After	1/26/2008	11.8	2.66	NA	11.9	**3.00E+07**	NA
RS-6 After	6/22/2009	43.2	9.77	204	36.1	**2.70E+07**	2,600
RS-10	1/26/2009	2.02	0.46	NA	2.26	**1.10E+06**	NA
RS-10	6/22/2009	55.8	**12.6**	214	21.2	**1.20E+06**	1,920
Effluent from El Alto WWTP flows into Rio Seco between these points							
RS-11	1/27/2009	2.83	0.64	NA	ND	**5.00E+03**	NA
RS-11	6/24/2009	14.1	3.18	83.3	14.8	**2.10E+04**	204
CDV	1/27/2009	2.07	0.47	NA	ND	**4.00E+03**	NA
CDV	6/24/2009	5.95	1.34	4.20	1.29	**2.00E+03**	ND
RP-1	1/27/2009	1.02	0.23	NA	ND	**6.10E+01**	NA
RP-1	6/24/2009	2.86	0.65	0.70	ND	**5.00E+02**	ND
RP-6	1/27/2009	1.48	0.33	NA	0.08	**5.30E+06**	NA
RP-6	6/24/2009	14.3	3.22	37.8	20.6	**3.10E+06**	562
RP-7	1/27/2009	1.31	0.30	NA	ND	**9.80E+04**	NA
RP-7	6/24/2009	9.08	2.05	45.5	10.1	**6.60E+05**	98.0
Rio Seco and Camino de Viacha ditch flow into Rio Pallina between these points							
RP-9	1/27/2009	2.12	0.48	NA	3.82	**4.60E+03**	NA
RP-9	6/23/2009	10.6	2.39	64.4	11.8	**4.30E+04**	102
RK-1	1/27/2009	0.58	0.13	NA	ND	**1.20E+03**	NA
RK-1	6/24/2009	1.97	0.45	2.10	1.47	**9.90E+01**	ND
RK-2	1/27/2009	1.07	0.24	NA	ND	**7.00E+02**	NA
RK-2	6/23/2009	3.30	0.75	10.5	1.31	**4.00E+02**	ND
Rio Pallina flows into Rio Katari between these points							
RK-4	NS	NS	NS	NS	NS	NS	NS
RK-4	6/23/2009	7.66	1.73	53.9	10.59	**5.60E+01**	148
RK-5	NS	NS	NS	NS	NS	NS	NS
RK-5	6/23/2009	7.84	1.77	49.0	11.8	**8.50E+03**	70.0
SDWA MCL (mg/l)		None	10	None	None	Presence/ absence	None
WHO (mg/l)		None	11.3	None	None	None	None

ND-Non Detect
NS-Not Sampled
NA-Not Analyzed
Red and bold indicates the sample is above SDWA MCLs and/or WHO values

Table 5. Contaminant Mass Loading							
Sample ID	Sample Date	Nitrate (kg/d)	Nitrate-N (kg/d)	TKN (kg/d)	Total Phosphorus (kg/d)	Total Coliforms (CFU/d)	Chemical Oxygen Demand (kg/d)
RS-1	1/26/2009	4.08	0.92			7.49E+09	
RS-1	6/22/2009	14.77	3.34	98.01	9.55	4.12E+12	644.08
RS-10	1/26/2009	20.52	4.64		22.96	1.12E+13	
RS-11	1/27/2009	70.40	15.91			1.24E+11	
RS-11	6/24/2009	1194.62	269.98	7062.59	1250.58	1.78E+12	17296.15
CDV	1/27/2009	4.85	1.10			9365.76	
RP-7	1/27/2009	1.66	0.38			1.24E+11	
RP-7	6/24/2009	13.68	3.09	68.56	15.17	9.94E+05	1709.12
RP-9*	1/27/2009	63.75	14.41		99.88	1.20E+05	
RP-9*	6/23/2009	1076.59	243.31	6441.26	1158.45	3.84E+06	105431.78
RK-1	1/27/2009	10.06	2.27			2.08E+10	
RK-1	6/24/2009	10.18	2.30	10.85	7.60	5.12E+07	
RK-4*	6/24/2009	959.53	216.85	6035.84	1120.95	5.12E+03	15416.09

*Flows for RP-9 and RK-4 were not measured in the field, mass loading for these two sampling sites were calculated based on mass loadings and discharge of upstream sampling points

Table 7. TKN:COD				
Sample Name	COD (mg/l)	TKN (mg/l)	COD:TKN	Source
1	2941	174	16.90	Masse, 2000
2	3589	271	13.24	Masse, 2000
3	4976	372	13.38	Masse, 2000
4	2333	90	25.92	Masse, 2000
6	3417	158	21.63	Masse, 2000
High Strength Wastewater	800	70	11.43	Metcalf & Eddy 2003
RS-1	782	119	6.57	Analysis from June 2009 sampling
RS-6 Before	46	10.5	4.38	Analysis from June 2009 sampling
RS-6 After	2600	204	12.75	Analysis from June 2009 sampling
RS-10	1920	214	8.97	Analysis from June 2009 sampling
RS-11	204	83.3	2.45	Analysis from June 2009 sampling
RP-6	562	37.8	14.87	Analysis from June 2009 sampling
RP-7	98	45.5	2.15	Analysis from June 2009 sampling
RP-9	102	64.4	1.58	Analysis from June 2009 sampling
RK-4	148	53.9	2.75	Analysis from June 2009 sampling
RK-5	70	49	1.43	Analysis from June 2009 sampling

4.3.1 Rio Katari

In January and June 2009 fecal coliform is present in all samples. Upstream of the Rio Katari's confluence with the Rio Pallina the source of fecal coliform in the river is probably from a mixture of agriculture and households (Figure 30). RK-4, the sample taken downstream of the confluence with the Rio Pallina has increased concentrations of TKN (Figure 31), nitrate-N (Figure 32), total phosphorus (Figure 13 Appendix C) and COD (Figure 33), however fecal coliform decreases. Between RK-4 and RK-5 nitrate-N, TKN and total phosphorus changes slightly and COD decreases by 50%. The decrease then increase in fecal coliform may be from the limited of amounts of nutrients available for the fecal coliform, thus the dying of colonies. The increase of fecal coliform is probably from a new source of contamination that was unseen during field work

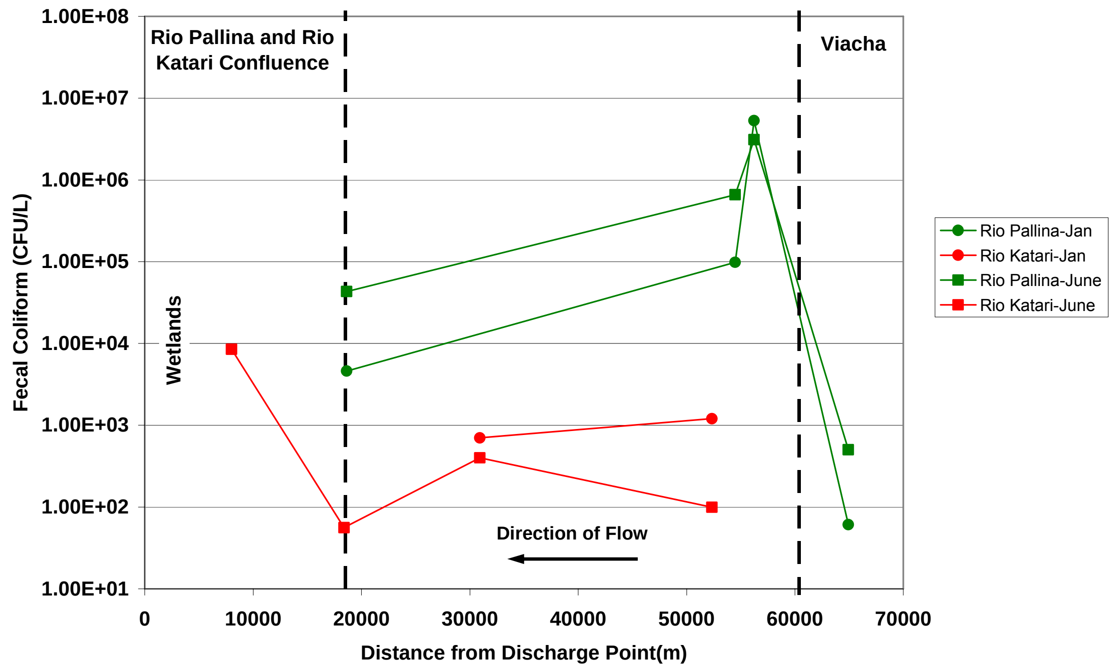

Figure 30. Spatial distribution of fecal coliform concentrations in the Rio Katari and Rio Pallina.

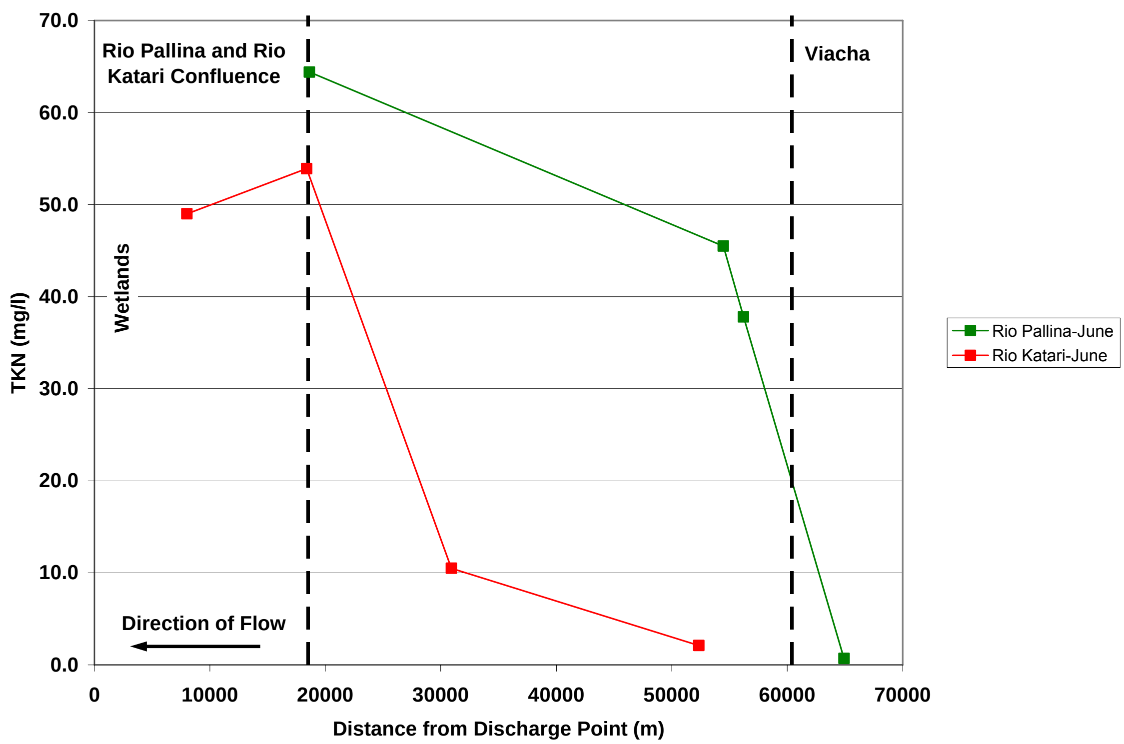

Figure 31. Spatial distribution of TKN concentrations in the Rio Katari and Rio Pallina.

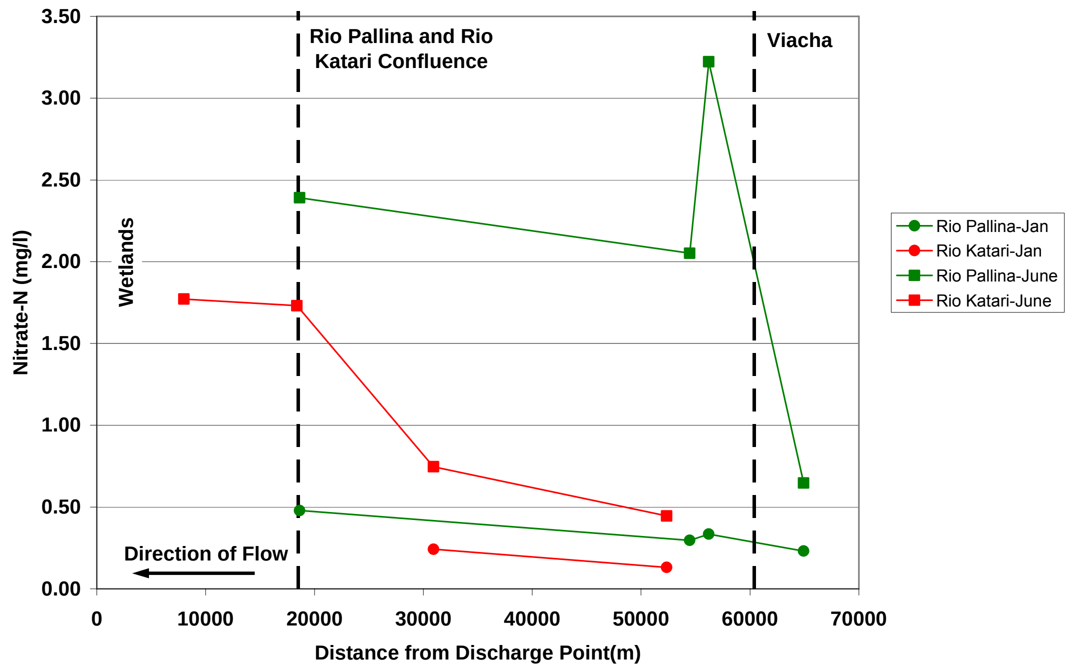

Figure 32. Spatial distribution of nitrate-N concentrations in the Rio Katari and Rio Pallina.

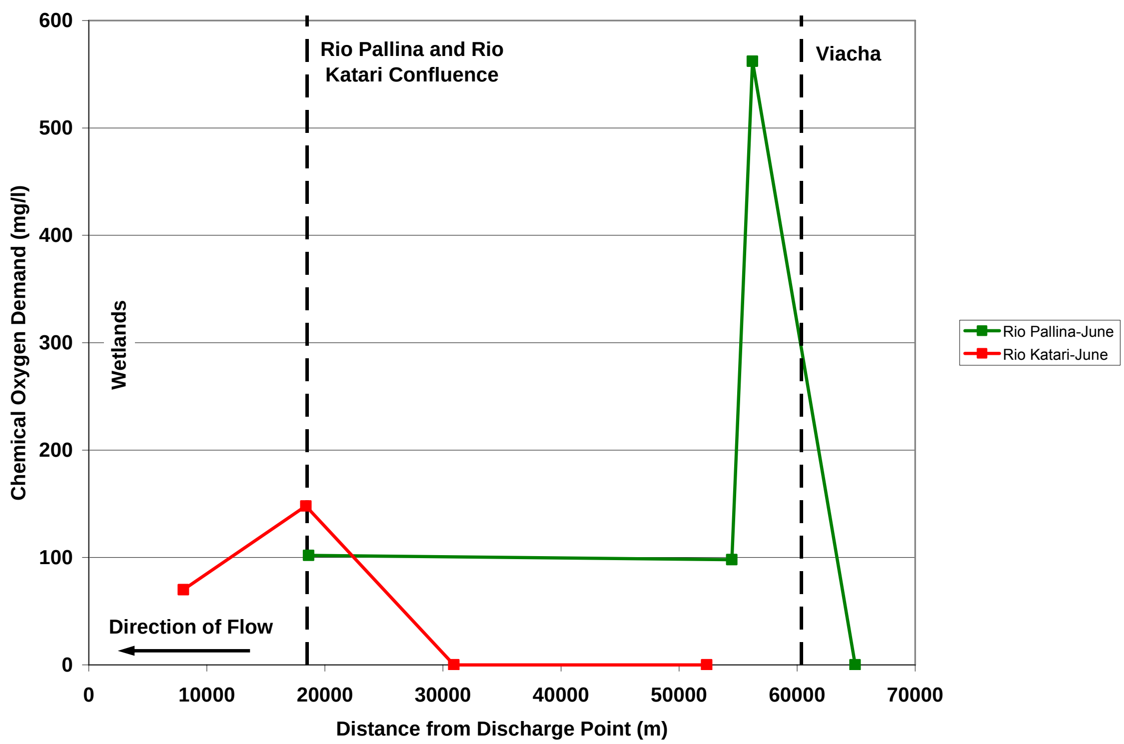

Figure 33. Spatial distribution of COD concentrations in the Rio Katari and Rio Pallina.

4.3.2 Rio Seco

The largest source of municipal contaminants enters the Rio Seco between RS-6 Before and RS-6 After. The pollution comes from an arroyo that flows through the Ceja and discharges into the Rio Seco. The pollution in the arroyo is from residences, slaughter houses, tanneries, textile factories, laundry facilities, dry cleaning facilities, public bathrooms and automotive repair shops that discharge into the arroyo. Between these two points during both events concentrations of fecal coliform (Figure 34), TKN (Figure 35), nitrate-N (Figure 36), COD (Figure 37) and total phosphorus (Figure 28 Appendix C) increased. The high concentration of TKN and COD relative to the low concentration of nitrate-N indicates anoxic conditions, which is suppressing nitrification of TKN. In order to determine the cause of the anoxic conditions COD and TKN were plotted on a graph (Figure 31 Appendix C). Results of the graph and R^2 calculated values indicate a positive relationship between COD and TKN. However, because so much dilution is happening in the system nitrification is not seen.

To determine the source of TKN, TKN and COD concentrations from untreated hog slaughter house effluent (Masse, 2000) and high concentration wastewater effluent (Metcalf and Eddy, 2003) values were compared to the Rio Seco concentrations (Table 7). COD:TKN ratio in the slaughter house waste ranged between 13 and 25, and the COD: TKN ratio in the high concentration wastewater effluent was 11.43. The COD:TKN ratio in RS-6 After was 12.75 and in RS-10 it was 8.97, indicating the source could be either. However given the nature of the site it is most likely a combination of wastewater effluent and slaughter house effluent.

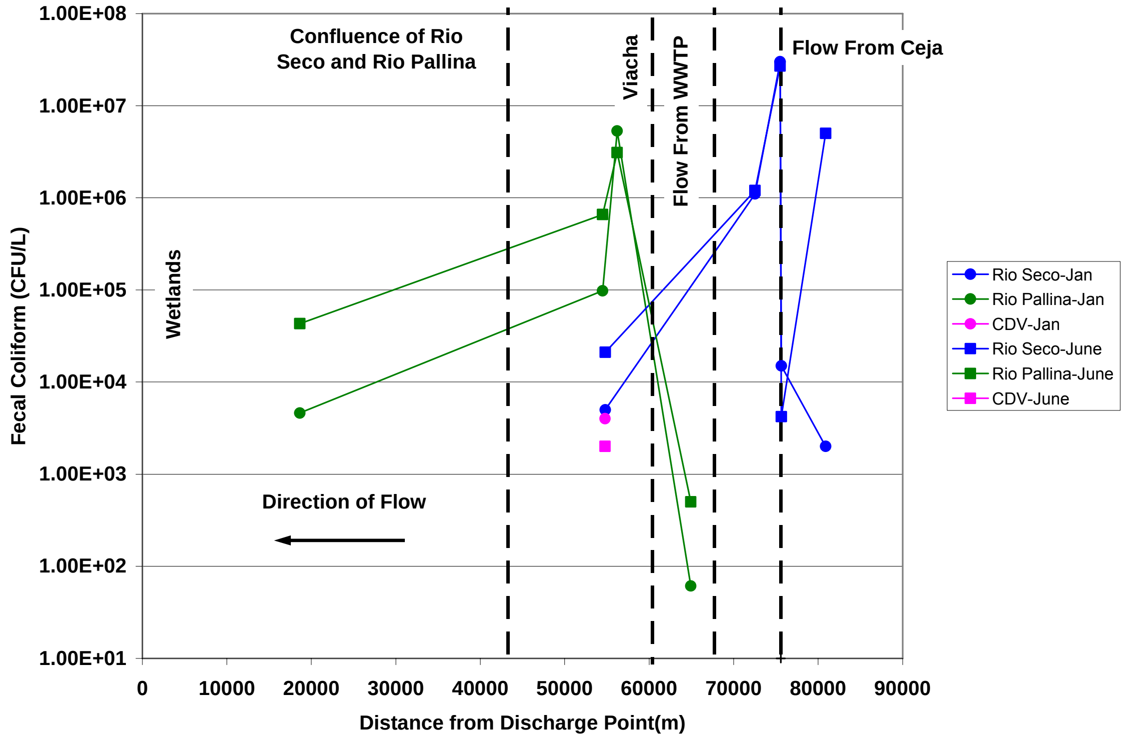

Figure 34. Spatial distribution of fecal coliform concentrations in the Rio Seco and Rio Pallina.

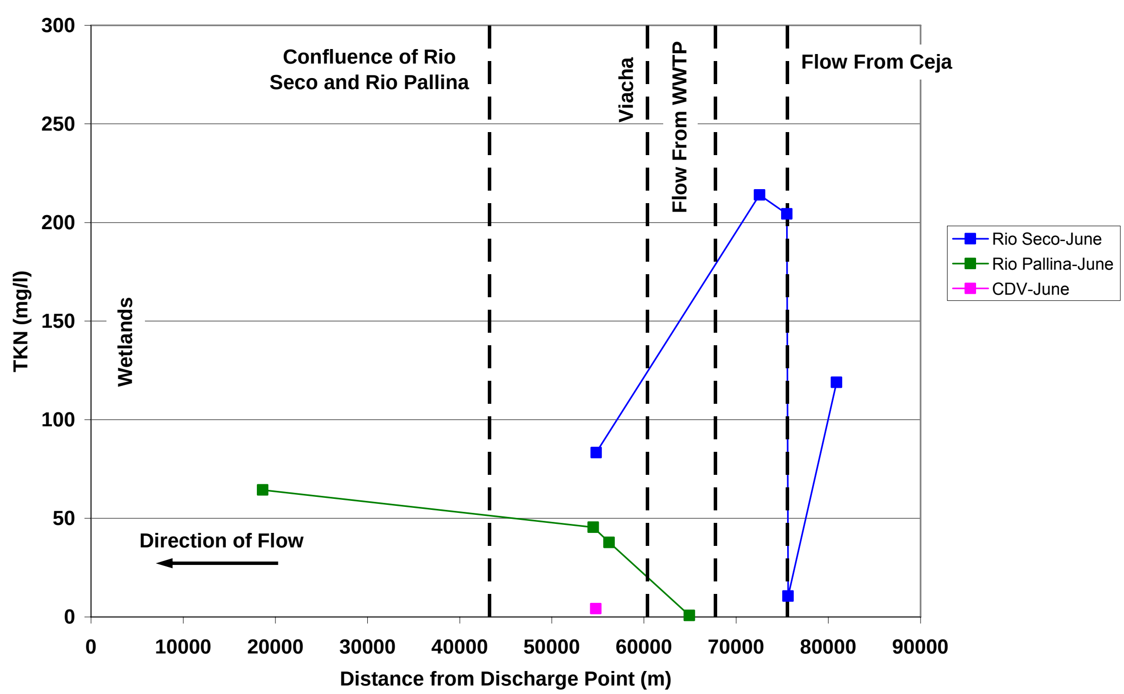

Figure 35. Spatial distribution of TKN concentrations in the Rio Seco and Rio Pallina.

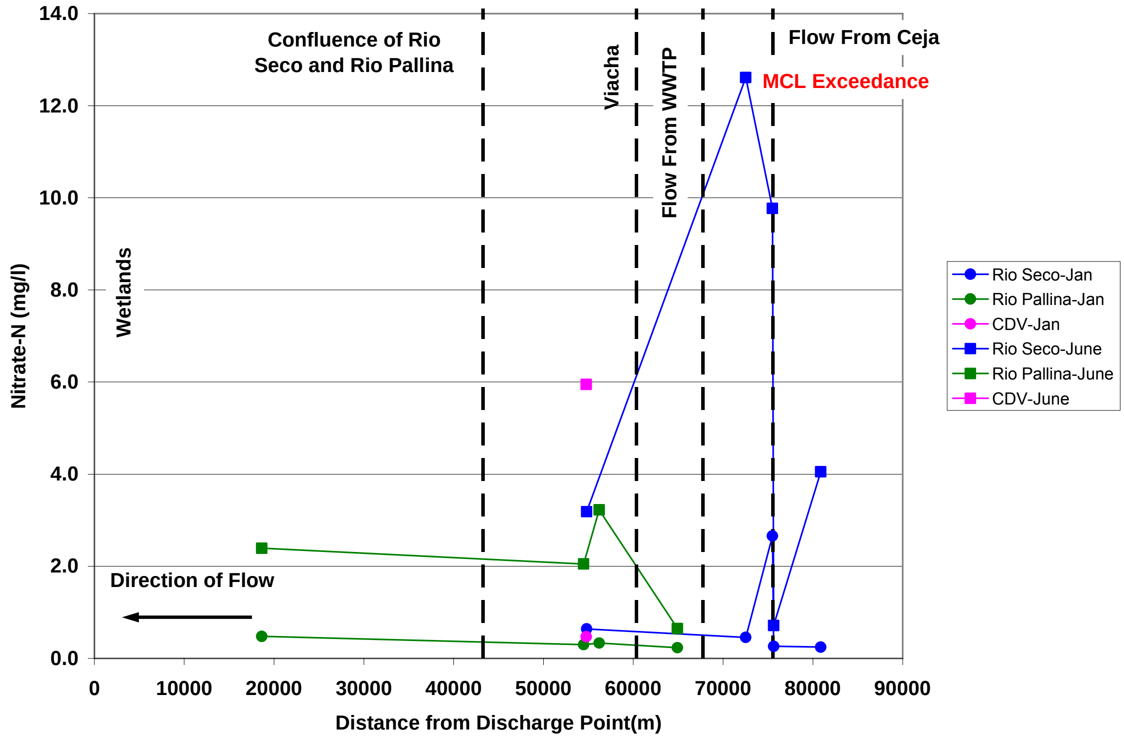

Figure 36. Spatial distribution of nitrate-N concentrations in the Rio Seco and Rio Pallina.

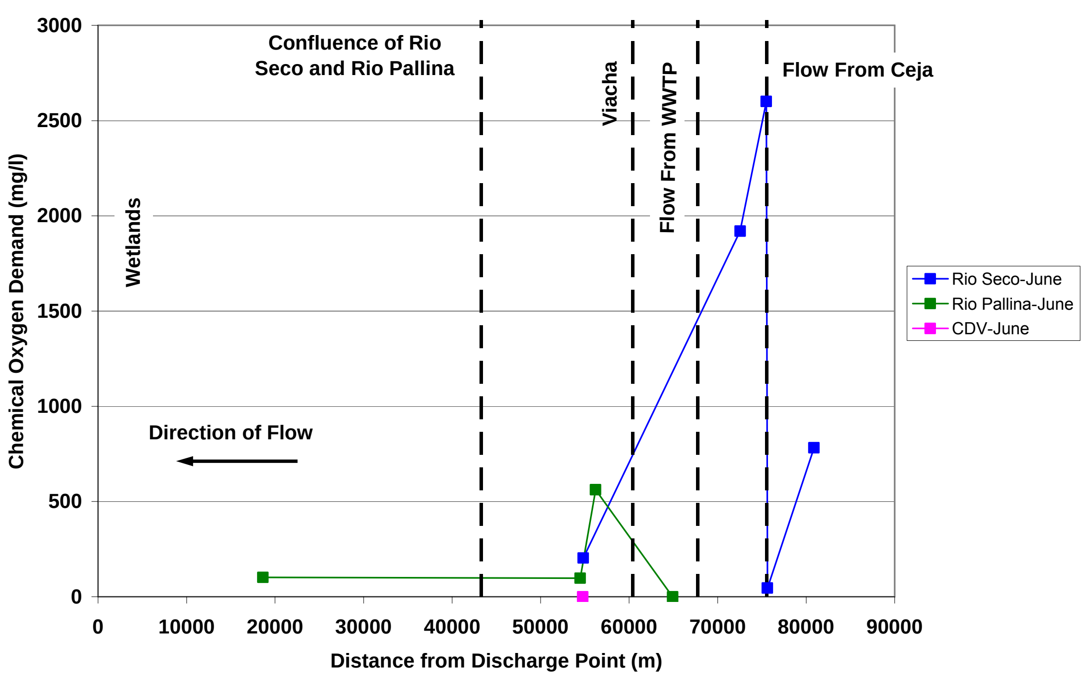

Figure 37. Spatial distribution of COD concentrations in the Rio Seco and Rio Pallina.

In January 2009 between RS-10 and RS-11 concentrations of fecal coliform and nitrate-N decreased. In June 2009 between RS-10 and RS-11 concentrations of fecal coliforms, TKN, nitrate-N and COD decreased. The decrease of TKN, nitrate-N and COD indicates dilution of all three constituents is occurring from the WWTP effluent. However, mass loading calculations (Table 5 Appendix B) shows an increase in the nitrate load between RS-10 and RS-11. The increase of nitrate is probably from a combination of WWTP loading and the nitrification of TKN.

4.3.3 Rio Pallina

In the Rio Pallina the main sources of pollution come from Viacha and the Rio Seco. Fecal coliform concentrations increase at the sampling point just downstream of Viacha during both sampling events, and then decrease (Figures 30 and 34). TKN (Figures 31 and 35), nitrate-N (Figures 32 and 36) and COD (Figure 33 and 37) all increase at the sampling point adjacent to Viacha, then decrease. However upon the confluence with the Rio Seco the concentrations of fecal coliform, TKN, nitrate-N and COD all approach the concentrations of the RS-11 sampling site.

COD:TKN rations at RP-6 immediately downstream of Viacha was 14.87, which falls in the range of COD:TKN ratios of slaughter house effluent. Although the ratio was high there is a large amount of untreated wastewater in the Rio Pallina, so the source of TKN is probably from a combination of untreated wastewater and slaughter house waste. COD and TKN values were plotted (Figure 31 Appendix C), however the R^2 value is very small, showing no relationship between the two, indicating another source may also be responsible for anoxic conditions.

4.3.4 Volatile Organic Carbon

Toluene, acetone, 2-butenon, carbon disulfide and 4-isopropyltoluene were detected at various points in all three rivers (Table 4 Appendix B). Possible sources for these constituents are laundry facilities, dry cleaning facilities, plastic manufacturing factory and mechanical workshops. Toluene has a SDWA MCL of 0.001 micrograms per liter (μg/l) and a WHO recommendation of 0.0007 μg/l. In January 2009 the SDWA MCL and WHO recommendation was exceeded at RS-10, RS-11, RP-6, RP-7 and RP-9. In June 2009 the SDWA MCL and WHO recommendation was exceeded at RS-1, RS-6 After, RS-10, RS-11, RP-6, RP-7 and RP-9. None of the other VOC detected have a SDWA MCL or WHO recommendation; however studies have shown many of the above mentioned constituents may have adverse health effects.

5.0 CONCLUSTIONS AND SUGGESTIONS FOR FUTURE WORK

The water quality of the Rio Katari, Rio Seco and Rio Pallina has been impacted by human use and negligence. Prior to its confluence with the Rio Pallina fecal coliform is present in the Rio Katari. During field work few houses were seen along the Rio Katari, however there are animals that graze along the river. A possible source of the fecal coliform in the Rio Katari may be a combination of the few households in the region and the animals that graze along the river. In the Rio Seco and Rio Pallina land use and water quality analysis indicates the impacts to the water quality are anthropogenic in nature. Mass flow calculations done for the January 2009 sampling event show an increase of loading of cations and anions between a factor of 1.7 and 4 and an increase of nitrate-N by a factor of 3.4 as a result of the WWTP effluent. The largest input of cations, anions and contaminant load to the Rio Pallina is the Rio Seco, and as a result the largest input of cations/anions and contamination to the Rio Katari is the Rio Pallina

In El Alto contamination comes from factories (bottling plant, milk factory and plastics), slaughter houses, leather tanneries, laundry and dry cleaning facilities, mechanical workshops, car repair and maintenance waste and public and private bathrooms. The effect is decreased levels of oxygen and increased levels of cations/anions, sulfate, nitrate-N, total phosphorus, TKN, total coliform, toluene, acetone, carbon disulfide and 4-isopropyltoluene all of which are detected in the water. Rainfall and effluent from the El Alto WWTP dilutes some of the constituents, but this is a seasonal and a temporary reduction. Downstream these constituents can accumulate in soils and vegetation, and through vegetative consumption and leaching may be reintroduced into the system.

The city of Viacha lacks a wastewater collection system and treatment plant, and during both field visits various types of discharges were observed entering the river. Discharges that were identified included raw domestic wastewater and discharge from a slaughter house and leather tannery. Total phosphorus, toluene, acetone, carbon disulfide and 4-isopropyltoluene detected in the Rio Pallina indicate that laundry/dry cleaning facilities and mechanical workshops are also present.

Land use along the Rio Katari is comprised of sparse single family houses, and agricultural practices (livestock and food production). The dominant indicator of contamination is fecal coliform, which is most likely from livestock. Downstream of the Rio Katari's confluence with the Rio Pallina anthropogenic contaminant concentrations increase.

Although direct consumption of the river water was not observed by people, animals were observed consuming the water, and through living in close proximity and consuming animal derived products people can become ill. Concentrations of fecal coliform were detected above SDWA MCL's at all sampling sites during January and June 2009. Nitrate-N exceeded its SDWA MCL and WHO recommendation in RS-10 in June and neared these levels at other sites. Toluene was detected at many of the sample sites above SDWA MCL's and WHO recommended standards. Sulfate exceeded SDWA MCL's at two locations. The consumption of fecal coliform, nitrate-N, toluene and sulfate may have adverse health affects and the consumption of these constituents may lead to death.

This study occurred during two different seasons and only one sample at each location was taken during each event. Because of this the analysis only provides a snapshot that represents that moment of time. Samples were taken during Monday, Tuesday and Wednesday during the day, so effects from households might be dampened as people are at work during these times. On weekends discharge from industrial areas might decrease because they're shut down during weekends, and flow from the wastewater treatment plant may increase. However the data collected does provide a general idea of the water quality in the three rivers as well as land use practices.

In order to quantify the water quality seasonally and daily much work needs to be done. A higher sampling frequency during both seasonal events and throughout the week could better help quantify what water quality looks like through out the day as well as the week. The effects of isolated precipitation events and stormwater runoff could be better quantified by an increased sampling frequency. Gauging discharge in the river would provide a tool to calculate contaminant loading volumes. Samples from the drinking water systems in El Alto and Viacha, as well as a sample from the El Alto WWTP would help determine what portion of the constituents are anthropogenic.

A land use survey needs to be done to determine the location and nature of industries as well as what they are manufacturing, how much they are manufacturing, what is being discharged and concentrations of discharge. Upon the survey a sampling list that is designed for the region to determine the effect of contamination would better help determine effects. Due to financial constraints this study did not look at metals.

Nina and Callisaya (2002) made recommendations in order to better quantify the quality of the water in the Rio Seco and to control pollution. They recommend quantifying population distribution, discharge, hydrological data and compiling data, these recommendations should also apply to the Rio Katari and Rio Pallina. In addition to better monitoring, El Alto needs to connect 100% of the population to the El Alto WWTP, restrict growth, require industrial pre-treatment and stop dumping and discharges into the Rio Seco, Viacha needs to build a wastewater treatment facility as well as restrict dumping and discharging into the Rio Pallina. The responsible parties for carrying out these tasks are uncertain. Currently monitoring work is done by non-profits and UMSA. There is no compilation of data and studies become redundant. Non-profits don't have the means nor the financial resources to build wastewater treatment facilities and wastewater collection systems for tens of thousands of people. The government of Bolivia needs to enforce and implement environmental laws, monitoring plans and build and expand treatment facilities to help improve the water quality of the Rio Katari and its tributaries.

Appendix A

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Appendix B

Tables

Table 1. Field Measurments

Sample ID	Sample Date	Lat	Long	+/-	Temp (°C)	pH	Conductivity (uS at 25°C)
RS-1	1/26/2009	-16.466800	-68.193780	3m	11.5	6.30	125
RS-1	6/22/2009	-16.466800	-68.193780	3m	14.3	8.00	1415
RS-6 Before	1/26/2009	-16.509020	-68.212510	3m	23.5	7.30	634
RS-6 Before	6/22/2009	-16.509020	-68.212510	3m	16.3	**9.04**	540
Large open channel from Ceja region of El Alto flows into the Rio Seco between these points							
RS-6 After	1/26/2008	-16.509960	-68.213270	3m	17.9	7.96	1150
RS-6 After	6/22/2009	-16.509960	-68.213270	3m	12.6	8.11	1714
RS-10	1/26/2009	-16.526770	-68.234920	4m	16.7	7.52	1014
RS-10	6/22/2009	-16.526770	-68.234920	4m	15.6	**8.66**	2003
Effluent from El Alto WWTP flows into Rio Seco between these points							
RS-11	1/27/2009	-16.638840	-68.317380	4m	14.4	7.98	1230
RS-11	6/24/2009	-16.638840	-68.317380	4m	4.00	8.12	1546
CDV	1/27/2009	-16.643800	-68.316460	3m	15.9	7.53	390
CDV	6/24/2009	-16.643800	-68.316460	3m	3.00	7.78	246
RP-1	1/27/2009	-16.677710	-68.277430	3m	14.0	7.58	445
RP-1	6/24/2009	-16.677710	-68.277430	3m	5.00	**9.43**	354
RP-6	1/27/2009	-16.646280	-68.307180	3m	15.2	7.46	685
RP-6	6/24/2009	-16.646280	-68.307180	3m	11.0	8.35	1276
RP-7	1/27/2009	-16.645930	-68.320920	3m	15.2	7.33	578
RP-7	6/24/2009	-16.645930	-68.320920	3m	6.00	7.77	964
Rio Seco and Camino de Viacha ditch flow into Rio Pallina between these points							
RP-9	1/27/2009	-16.538540	-68.403720	4m	16.7	7.90	980
RP-9	6/23/2009	-16.538540	-68.403720	4m	12.6	8.29	1369
RK-1	1/27/2009	-16.654480	-68.387600	3m	16.4	8.18	1196
RK-1	6/24/2009	-16.654480	-68.387600	3m	6.00	8.26	1248
RK-2	1/27/2009	-16.562580	-68.461050	3m	21.2	8.20	1500
RK-2	6/23/2009	-16.562580	-68.461050	3m	12.8	8.38	2180
Rio Pallina flows into Rio Katari between these points							
RK-4	NS	NS	NS	NS	NS	NS	NS
RK-4	6/23/2009	-16.504260	-68.515460	3.6	13.2	8.38	1312
RK-5	NS	NS	NS	NS	NS	NS	NS
RK-5	6/23/2009	-16.452940	-68.580760	3.3	12.7	**8.86**	1261
SDWA MCL (mg/l)		None	None	None	None	6.5-8.5	None
WHO (mg/l)		None	None	None	None	None	None

ND-Non Detect
NS-Not Sampled

Table 2. Cation and Anion Analysis Results

Sample ID	Sample Date	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Alkalinity (mg/l)	Carbonate (mg/l)	Bicarbonate (mg/l)	Chloride (mg/l)	Sulfate (mg/l)
RS-1	1/26/2009	9.22	2.92	5.40	3.20	6.00	ND	6.00	2.01	39.4
RS-1	6/22/2009	56.1	14.6	96.0	59.4	490	ND	490	102	142
RS-6 Before	1/26/2009	49.7	8.51	42.0	21.6	128	ND	128	47.6	103
RS-6 Before	6/22/2009	64.9	5.10	42.8	13.4	144	24.0	120	44.7	76.5
Large open channel from Ceja region of El Alto flows into the Rio Seco between these points										
RS-6 After	1/26/2008	40.1	12.2	98.0	41.4	288	ND	288	93.6	104
RS-6 After	6/22/2009	36.1	17.0	154	84.0	584	ND	584	147	140
RS-10	1/26/2009	50.1	9.72	116	28.4	194	ND	194	136	103
RS-10	6/22/2009	90.2	18.2	266	72.0	640	60.0	580	231	**289**
Effluent from El Alto WWTP flows into Rio Seco between these points										
RS-11	1/27/2009	44.1	14.6	126	36.6	340	ND	340	134	74.7
RS-11	6/24/2009	48.1	17.0	120	52.0	476	ND	476	162	56.8
CDV	1/27/2009	6.81	28.1	36.0	9.40	130	ND	130	25.4	31.9
CDV	6/24/2009	17.6	6.80	18.2	6.40	54.0	ND	54.0	18.0	32.2
RP-1	1/27/2009	16.0	17.0	59.0	18.2	96.0	ND	96.0	53.4	84.9
RP-1	6/24/2009	23.7	10.9	33.0	12.6	98.0	40.0	58.0	18.7	56.9
RP-6	1/27/2009	32.1	14.6	71.0	21.4	166	ND	166	52.6	86.6
RP-6	6/24/2009	36.1	13.4	96.0	48.2	402	2.00	400	101	87.6
RP-7	1/27/2009	28.9	13.6	65.2	18.6	144	ND	144	39.5	81.1
RP-7	6/24/2009	42.1	10.9	94.0	35.0	290	ND	290	72.5	85.5
Rio Seco and Camino de Viacha ditch flow into Rio Pallina between these points										
RP-9	1/27/2009	48.1	13.4	104	30.8	258	ND	258	99.7	77.0
RP-9	6/23/2009	56.1	17.0	144	44.6	412	8.00	404	150	57.9
RK-1	1/27/2009	100	15.8	154	9.80	126	ND	126	164	223
RK-1	6/24/2009	106	18.2	152	9.00	144	ND	144	164	249
RK-2	1/27/2009	124	24.3	218	10.8	124	ND	124	223	303
RK-2	6/23/2009	190	42.5	320	18.4	172	24.0	148	231	**544**
Rio Pallina flows into Rio Katari between these points										
RK-4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
RK-4	6/23/2009	52.1	17.0	130	43.2	392	64.0	328	147	65.6
RK-5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
RK-5	6/23/2009	52.1	19.4	138	42.0	372	72.0	300	150	58.6
SDWA MCL (mg/l)		None	None	None	None	None	None	None	250	250
WHO (mg/l)		None	None	None	None	None	None	None	None	None

ND-Non Detect
NS-Not Sampled
Red and bold indicates the sample is above SDWA MCLs and/or WHO values

Table 3. Nutrient Analysis Results							
Sample ID	Sample Date	Nitrate (mg/l)	Nitrate-N (mg/l)	TKN (mg/l)	Total Phosphorus (mg/l)	Fecal Coliform (CFU/l)	Chemical Oxygen Demand
RS-1	1/26/2009	1.09	0.25	NA	ND	**2.00E+03**	NA
RS-1	6/22/2009	17.9	4.05	119	11.6	**5.00E+06**	782
RS-6 Before	1/26/2009	1.16	0.26	NA	0.53	**1.50E+04**	NA
RS-6 Before	6/22/2009	3.15	0.71	10.5	1.47	**4.20E+03**	46.0
Large open channel from Ceja region of El Alto flows into the Rio Seco between these points							
RS-6 After	1/26/2008	11.8	2.66	NA	11.9	**3.00E+07**	NA
RS-6 After	6/22/2009	43.2	9.77	204	36.1	**2.70E+07**	2,600
RS-10	1/26/2009	2.02	0.46	NA	2.26	**1.10E+06**	NA
RS-10	6/22/2009	55.8	**12.6**	214	21.2	**1.20E+06**	1,920
Effluent from El Alto WWTP flows into Rio Seco between these points							
RS-11	1/27/2009	2.83	0.64	NA	ND	**5.00E+03**	NA
RS-11	6/24/2009	14.1	3.18	83.3	14.8	**2.10E+04**	204
CDV	1/27/2009	2.07	0.47	NA	ND	**4.00E+03**	NA
CDV	6/24/2009	5.95	1.34	4.20	1.29	**2.00E+03**	ND
RP-1	1/27/2009	1.02	0.23	NA	ND	**6.10E+01**	NA
RP-1	6/24/2009	2.86	0.65	0.70	ND	**5.00E+02**	ND
RP-6	1/27/2009	1.48	0.33	NA	0.08	**5.30E+06**	NA
RP-6	6/24/2009	14.3	3.22	37.8	20.6	**3.10E+06**	562
RP-7	1/27/2009	1.31	0.30	NA	ND	**9.80E+04**	NA
RP-7	6/24/2009	9.08	2.05	45.5	10.1	**6.60E+05**	98.0
Rio Seco and Camino de Viacha ditch flow into Rio Pallina between these points							
RP-9	1/27/2009	2.12	0.48	NA	3.82	**4.60E+03**	NA
RP-9	6/23/2009	10.6	2.39	64.4	11.8	**4.30E+04**	102
RK-1	1/27/2009	0.58	0.13	NA	ND	**1.20E+03**	NA
RK-1	6/24/2009	1.97	0.45	2.10	1.47	**9.90E+01**	ND
RK-2	1/27/2009	1.07	0.24	NA	ND	**7.00E+02**	NA
RK-2	6/23/2009	3.30	0.75	10.5	1.31	**4.00E+02**	ND
Rio Pallina flows into Rio Katari between these points							
RK-4	NS	NS	NS	NS	NS	NS	NS
RK-4	6/23/2009	7.66	1.73	53.9	10.59	**5.60E+01**	148
RK-5	NS	NS	NS	NS	NS	NS	NS
RK-5	6/23/2009	7.84	1.77	49.0	11.8	**8.50E+03**	70.0
SDWA MCL (mg/l)		None	10	None	None	Presence/ absence	None
WHO (mg/l)		None	11.3	None	None	None	None

ND-Non Detect
NS-Not Sampled
NA-Not Analyzed
Red and bold indicates the sample is above SDWA MCLs and/or WHO values

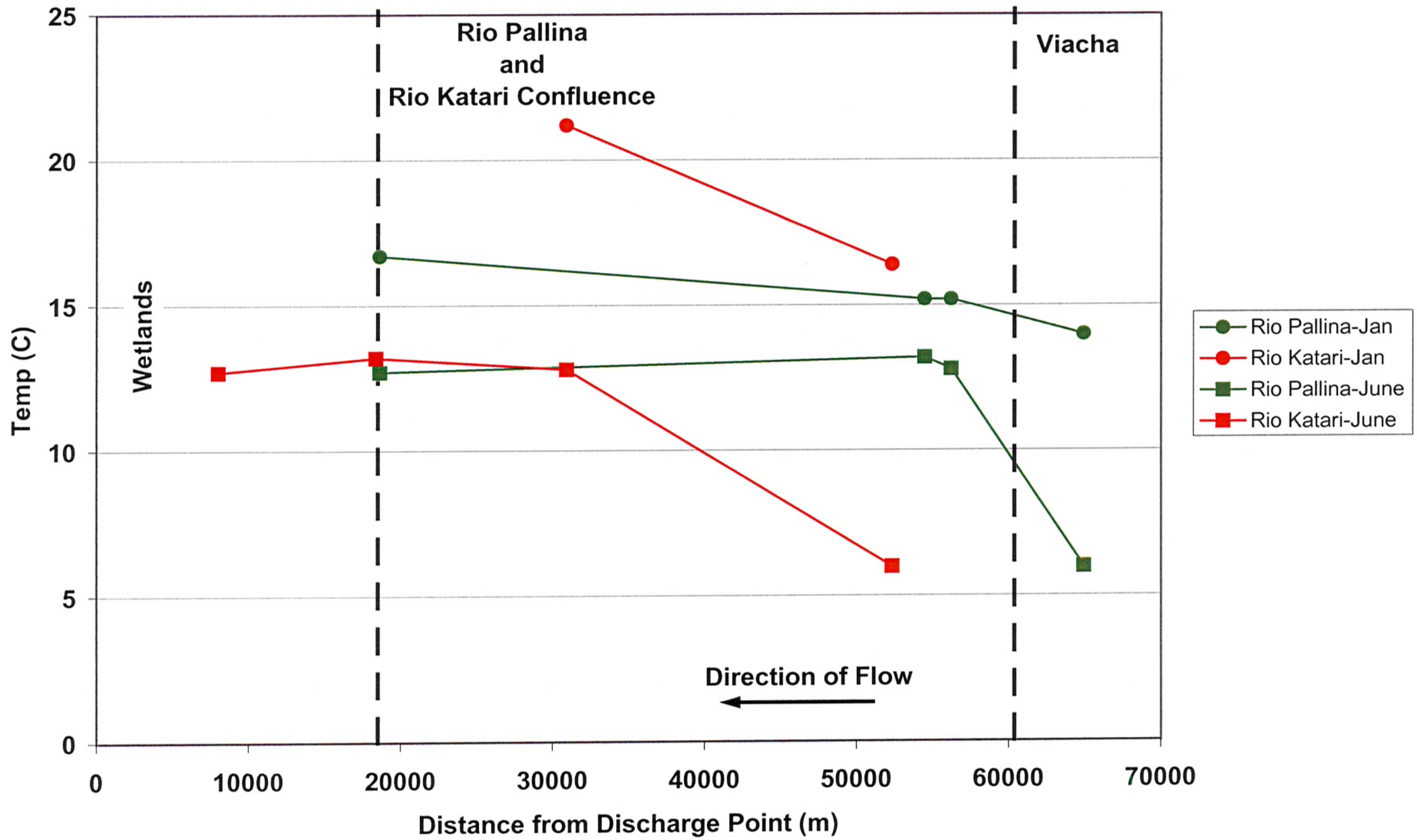
Table 4. VOC Analysis Results						
Sample ID	Sample Date	Toluene (µg/l)	Acetone (µg/l)	2-Butenone (µg/l)	Carbon Disulfide (µg/l)	4-Isopropyltoluene (µg/l)
RS-1	1/26/2009	ND	ND	ND	ND	ND
RS-1	6/22/2009	**37**	24	3.3	ND	1.6
RS-6 Before	1/26/2009	0.37	160	1.4	ND	ND
RS-6 Before	6/22/2009	ND	33	4.9	ND	0.38
Large open channel from Ceja region of El Alto flows into the Rio Seco between these points						
RS-6 After	1/26/2008	0.78	89	3	ND	ND
RS-6 After	6/22/2009	**6.5**	63	6.4	0.7	0.44
RS-10	1/26/2009	**1.3**	15	2.3	2.4	ND
RS-10	6/22/2009	**10**	34	13	710	1.6
Effluent from El Alto WWTP flows into Rio Seco between these points						
RS-11	1/27/2009	**1.0**	7.1	1.3	ND	ND
RS-11	6/24/2009	**3.2**	18	3.8	ND	0.35
CDV	1/27/2009	0.21	ND	0.98	ND	ND
CDV	6/24/2009	0.44	ND	ND	ND	ND
RP-1	1/27/2009	0.26	ND	ND	ND	ND
RP-1	6/24/2009	ND	ND	ND	ND	ND
RP-6	1/27/2009	**17**	11	1.1	ND	ND
RP-6	6/24/2009	**150**	83	4.1	1.0	2.3
RP-7	1/27/2009	**20**	ND	0.84	ND	0.23
RP-7	6/24/2009	**63**	33	3.4	1.9	1.5
Rio Seco and Camino de Viacha ditch flow into Rio Pallina between these points						
RP-9	1/27/2009	**1.6**	ND	ND	ND	ND
RP-9	6/23/2009	**5.2**	13	2.0	ND	0.35
RK-1	1/27/2009	ND	ND	ND	ND	ND
RK-1	6/24/2009	ND	ND	ND	ND	ND
RK-2	1/27/2009	ND	ND	ND	ND	ND
RK-2	6/23/2009	ND	ND	ND	ND	ND
Rio Pallina flows into Rio Katari between these points						
RK-4	NS	NS	NS	NS	NS	NS
RK-4	6/23/2009	0.39	12	1.1	0.50	0.29
RK-5	NS	NS	NS	NS	NS	NS
RK-5	6/23/2009	ND	ND	0.71	ND	0.28
SDWA MCL (µg/l)		0.001	None	None	None	None
WHO (µg/l)		0.0007	None	None	None	None

ND-Non Detect
NS-Not Sampled
NA-Not Analyzed
Blue Indicates the sample was detected below laboratory PQL
Red and bold indicates the sample is above SDWA MCLs and/or WHO values

Appendix C

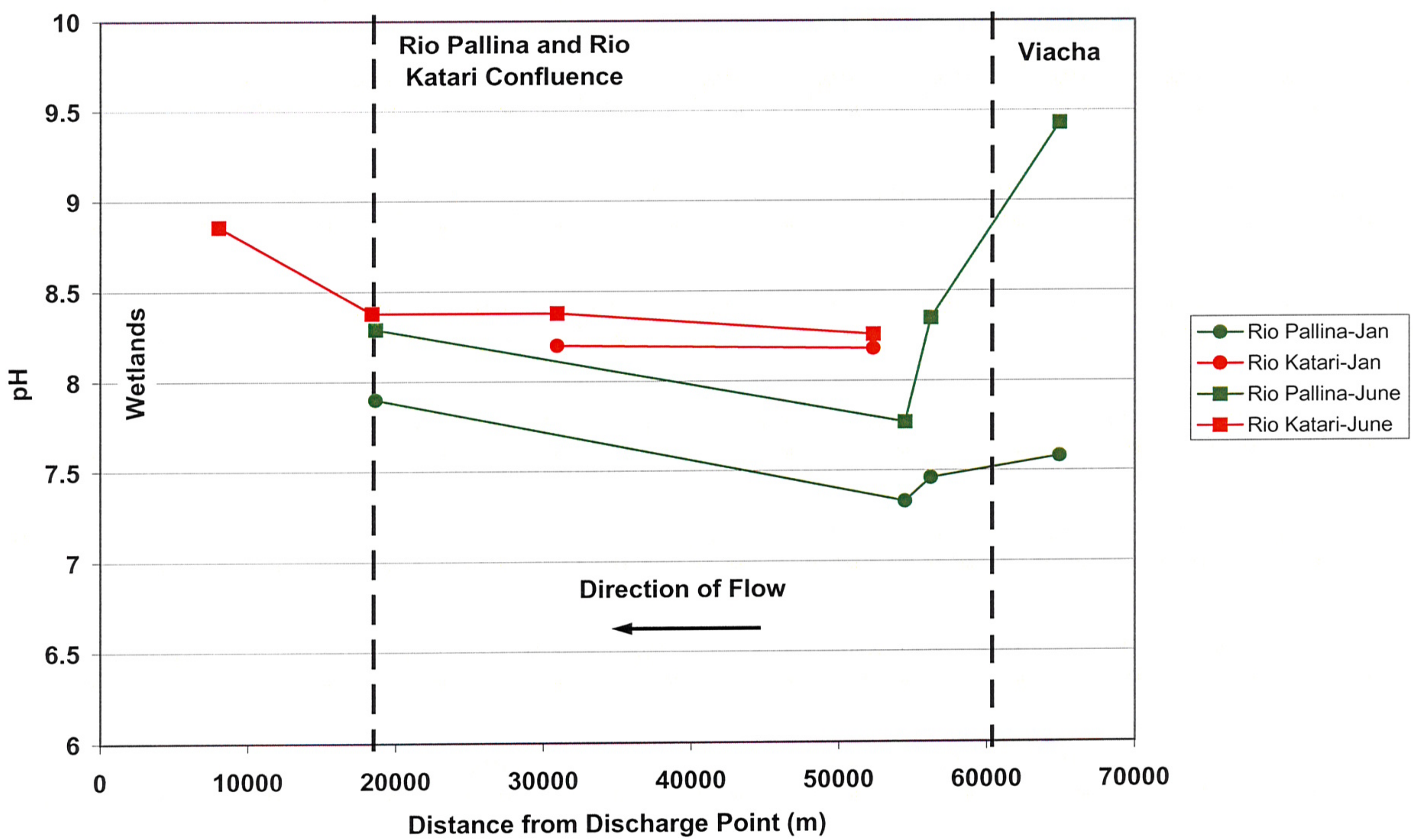
Graphs

Figure 1



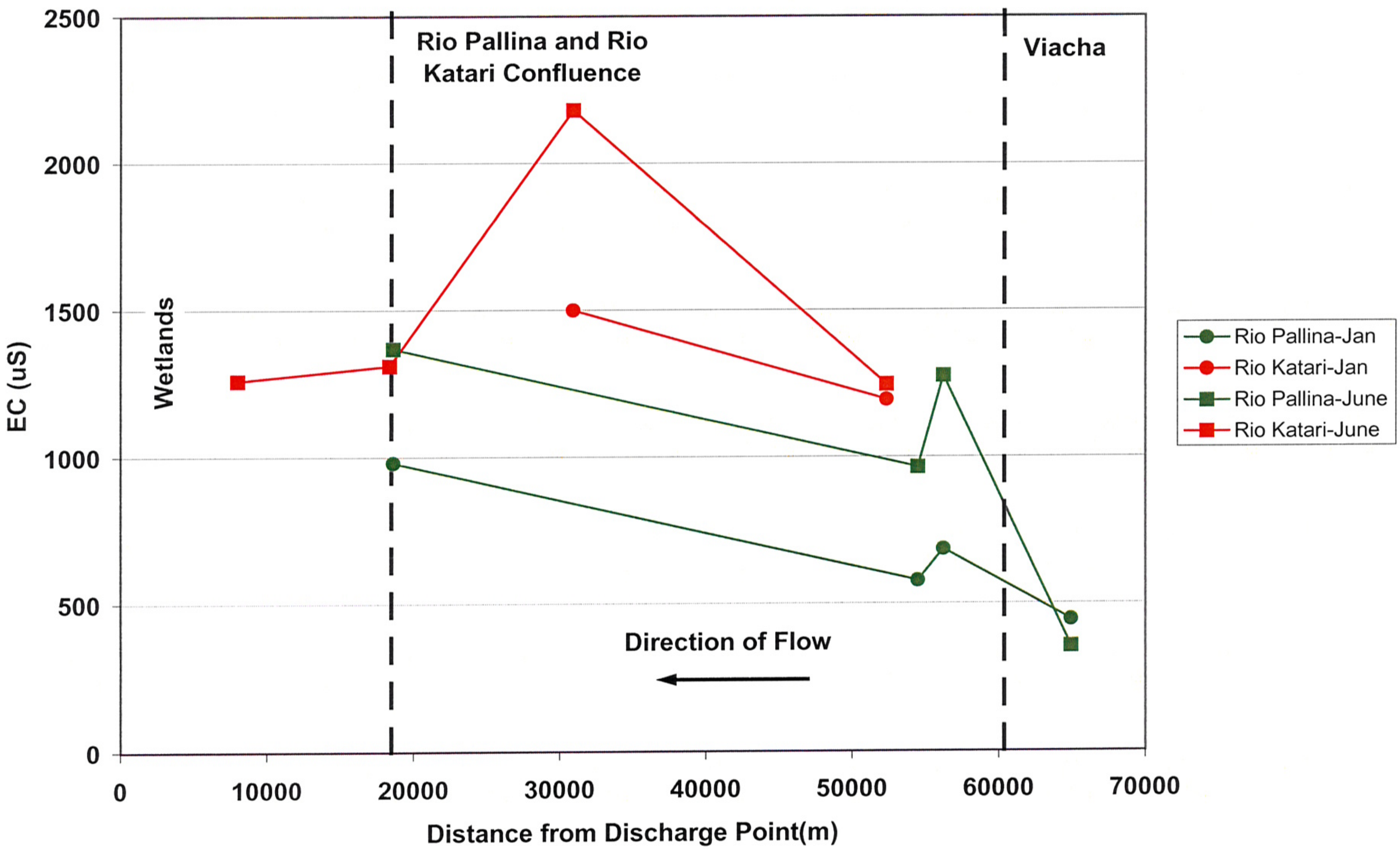
Rio Pallina
and
Rio Katari Confluence
Viacha
Wetlands
Direction of Flow
Temp (C)
25
20
15
10
5
0
0
10000
20000
30000
40000
50000
60000
70000
Distance from Discharge Point (m)
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 2



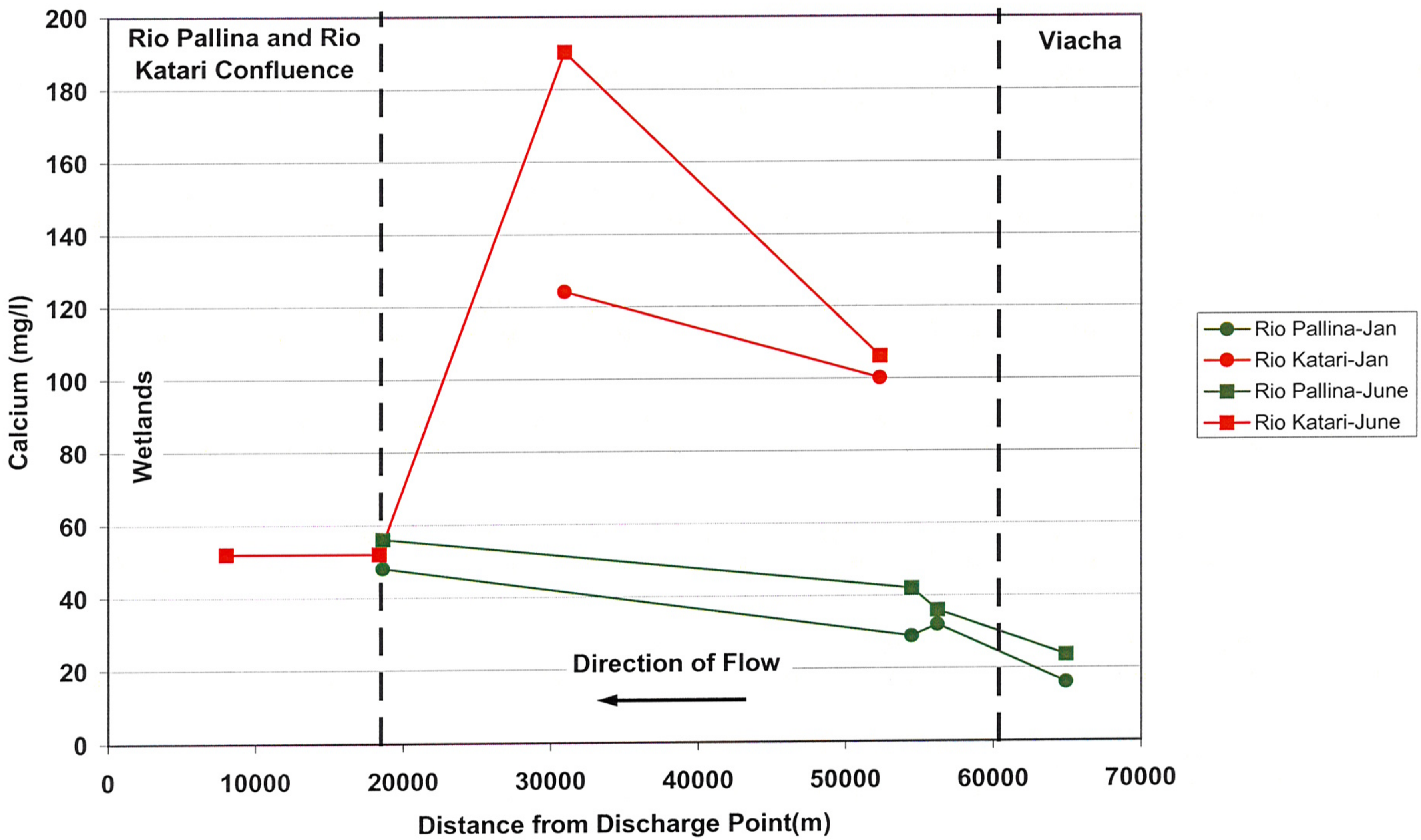
pH
10
9.5
9
8.5
8
7.5
7
6.5
6
0
10000
20000
30000
40000
50000
60000
70000
Distance from Discharge Point (m)
Rio Pallina and Rio
Katari Confluence
Viacha
Wetlands
Direction of Flow
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 3



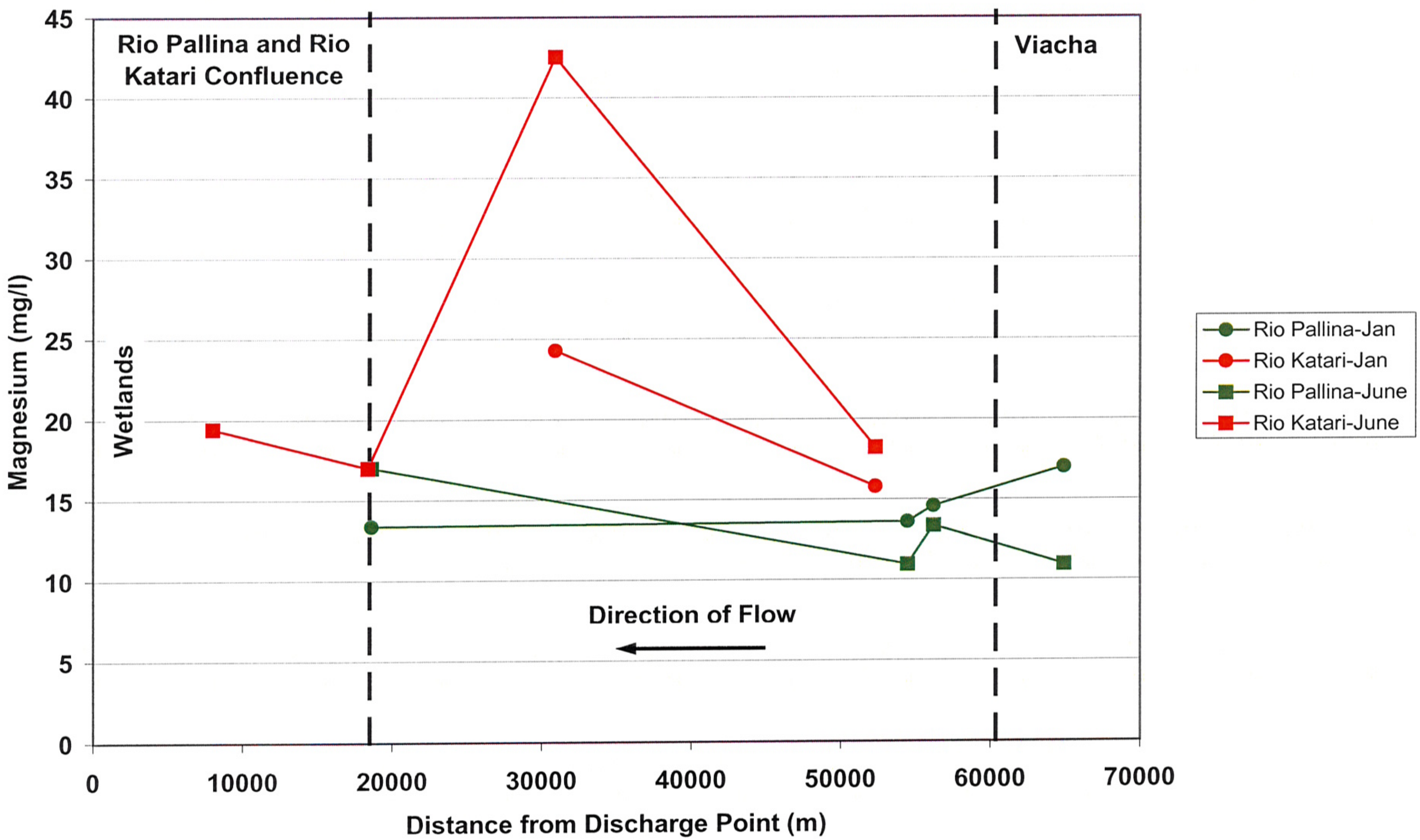
2500
2000
1500
1000
500
0
EC (uS)
Wetlands
Rio Pallina and Rio
Katari Confluence
Viacha
Direction of Flow
0
10000
20000
30000
40000
50000
60000
70000
Distance from Discharge Point(m)
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 4



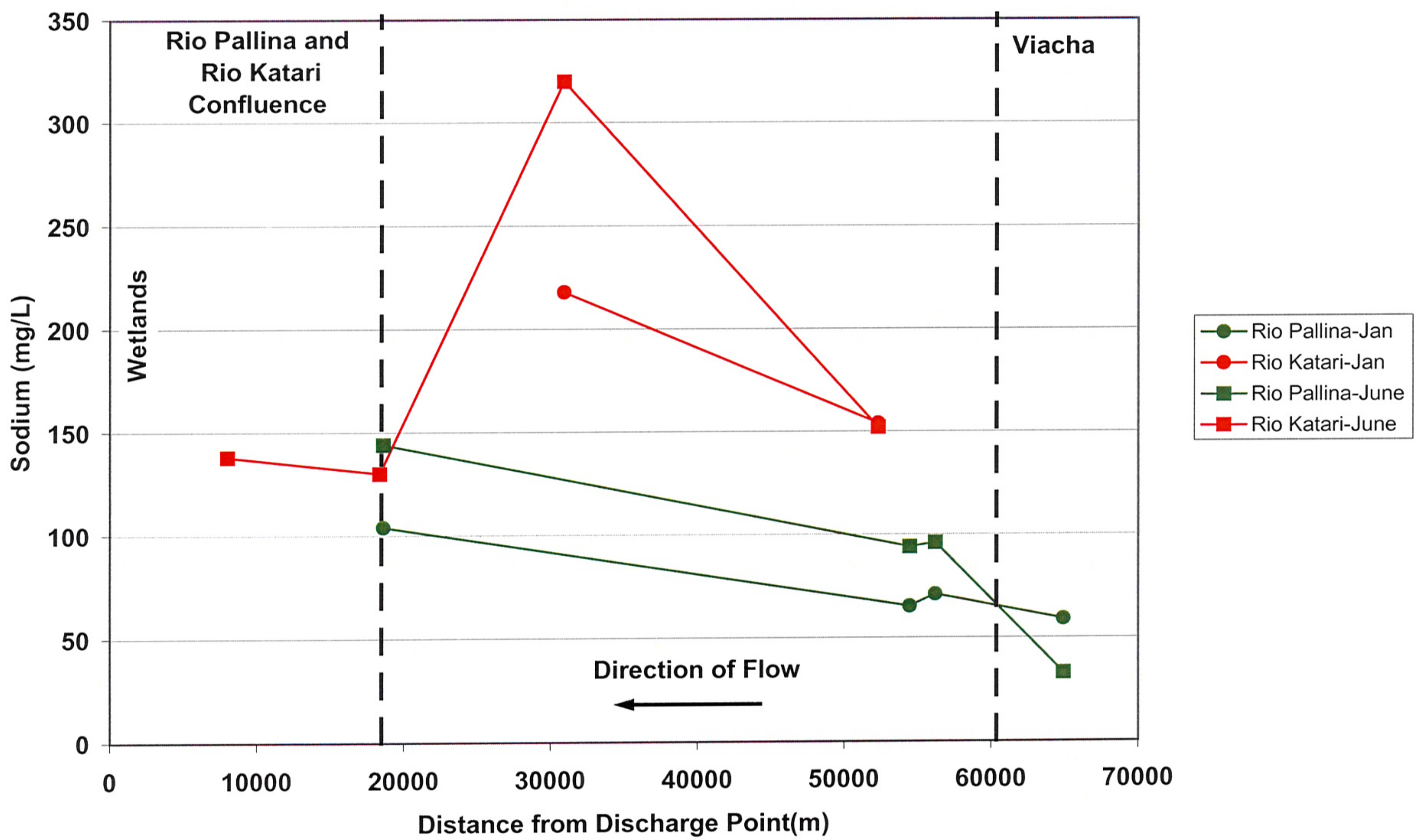
Rio Pallina and Rio Katari Confluence
Viacha
Wetlands
Direction of Flow
Calcium (mg/l)
Distance from Discharge Point(m)
200
180
160
140
120
100
80
60
40
20
0
0
10000
20000
30000
40000
50000
60000
70000
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 5



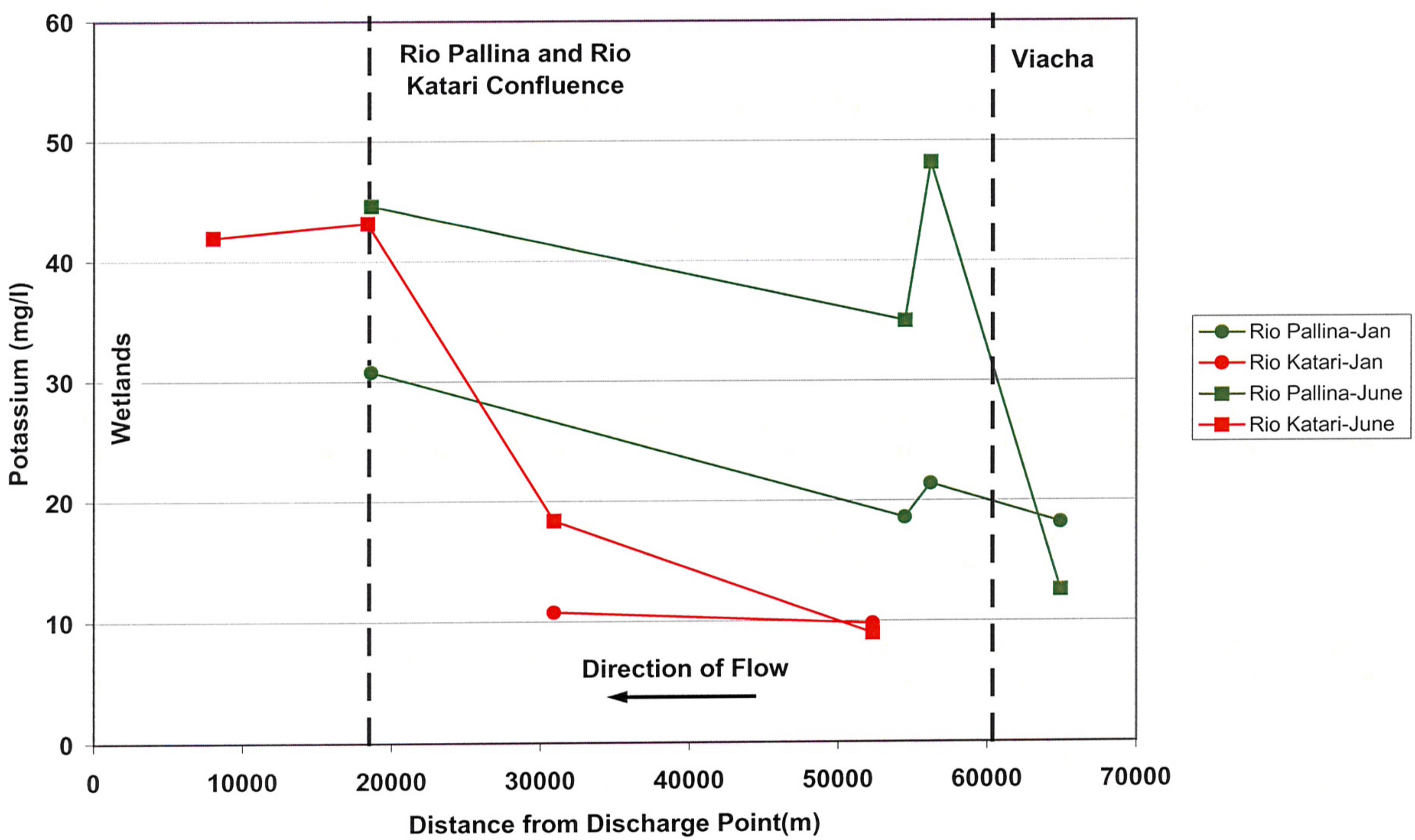
Rio Pallina and Rio Katari Confluence
Viacha
Wetlands
Direction of Flow
Magnesium (mg/l)
Distance from Discharge Point (m)
0
5
10
15
20
25
30
35
40
45
0
10000
20000
30000
40000
50000
60000
70000
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 6



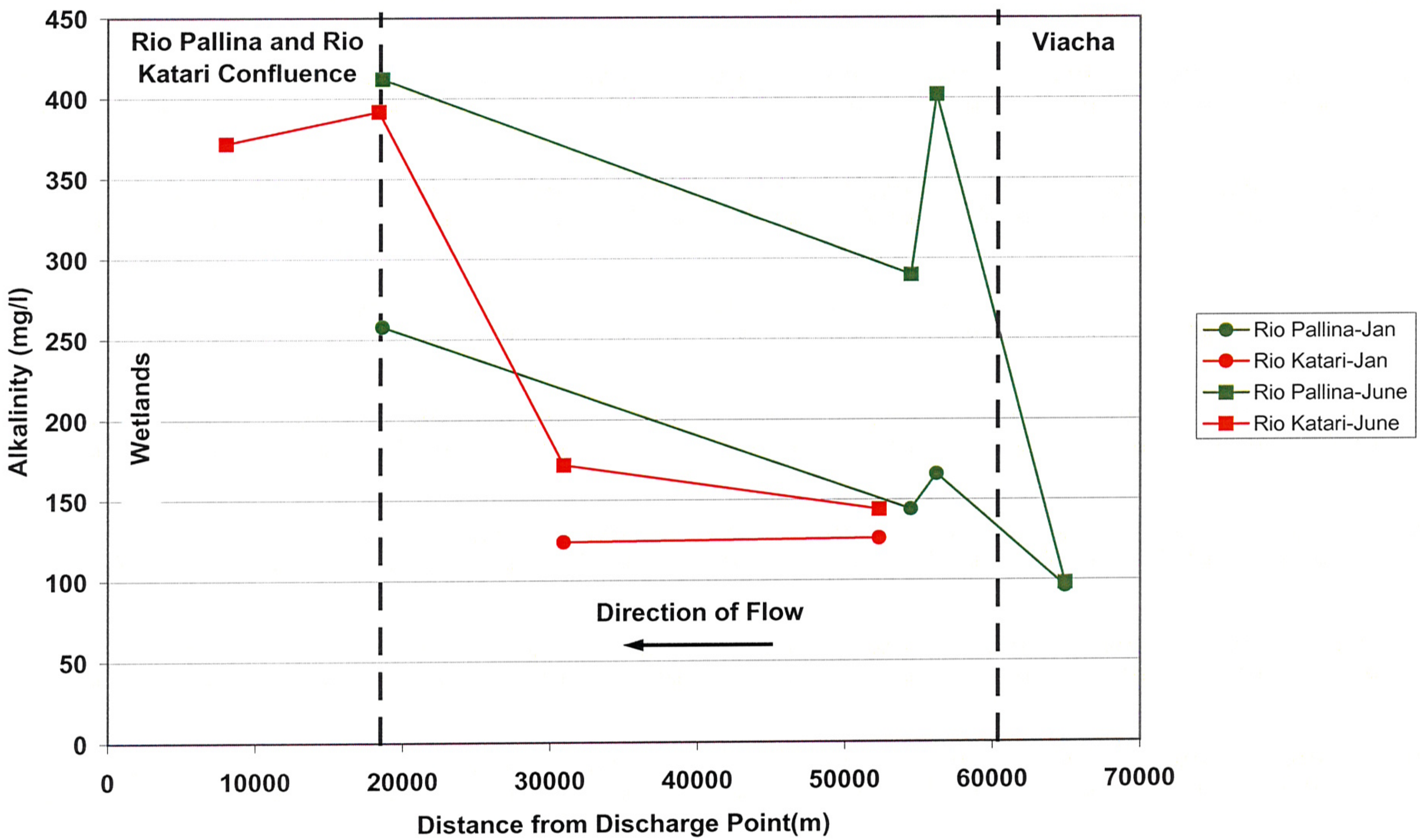
Rio Pallina and
Rio Katari
Confluence
Viacha
Wetlands
Direction of Flow
Sodium (mg/L)
Distance from Discharge Point(m)
0
50
100
150
200
250
300
350
0
10000
20000
30000
40000
50000
60000
70000
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 7



Rio Pallina and Rio
Katari Confluence
Viacha
Wetlands
Direction of Flow
Potassium (mg/l)
0
10
20
30
40
50
60
0
10000
20000
30000
40000
50000
60000
70000
Distance from Discharge Point(m)
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 8



Rio Pallina and Rio Katari Confluence
Viacha
Wetlands
Direction of Flow
Alkalinity (mg/l)
Distance from Discharge Point(m)
450
400
350
300
250
200
150
100
50
0
0
10000
20000
30000
40000
50000
60000
70000
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 9

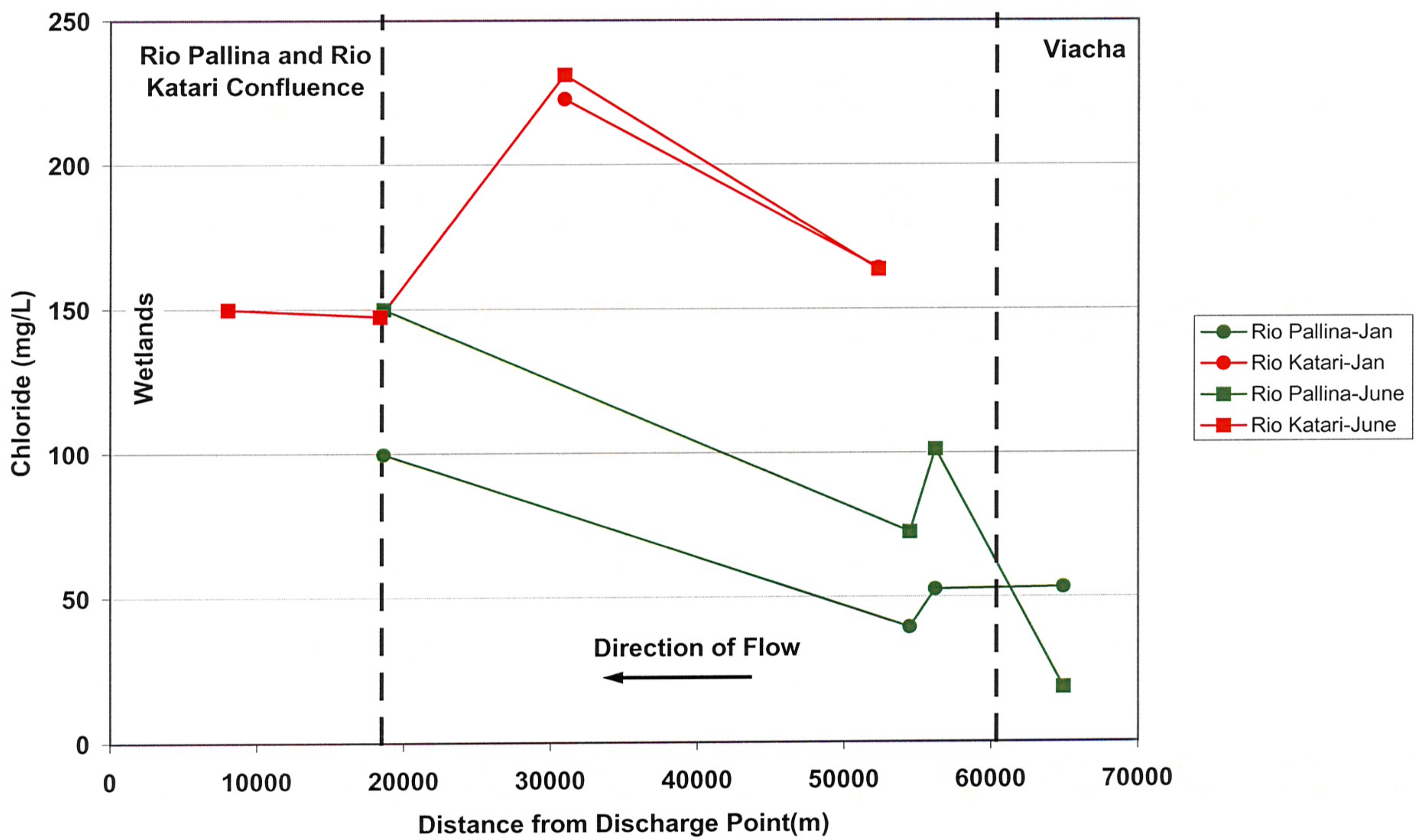
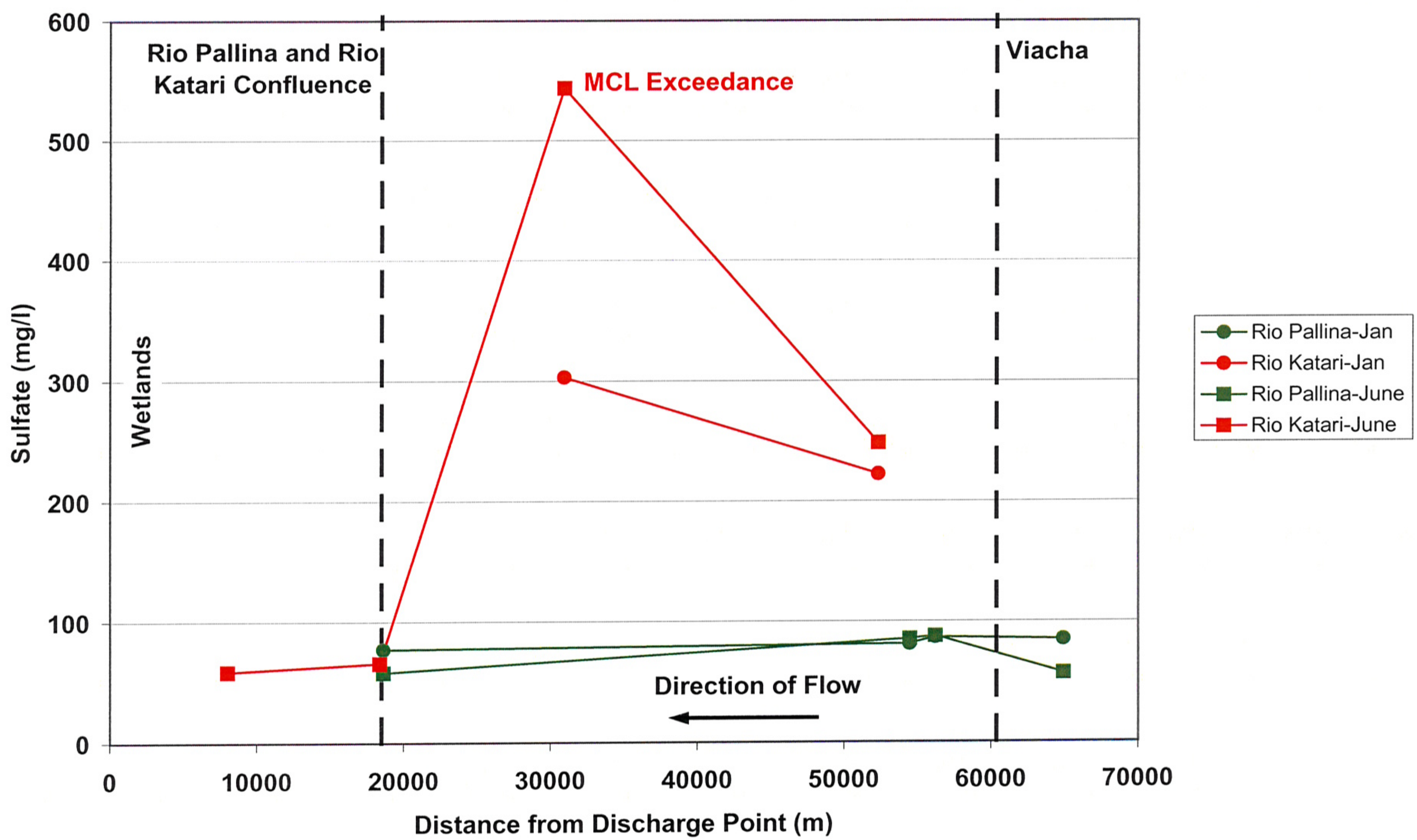
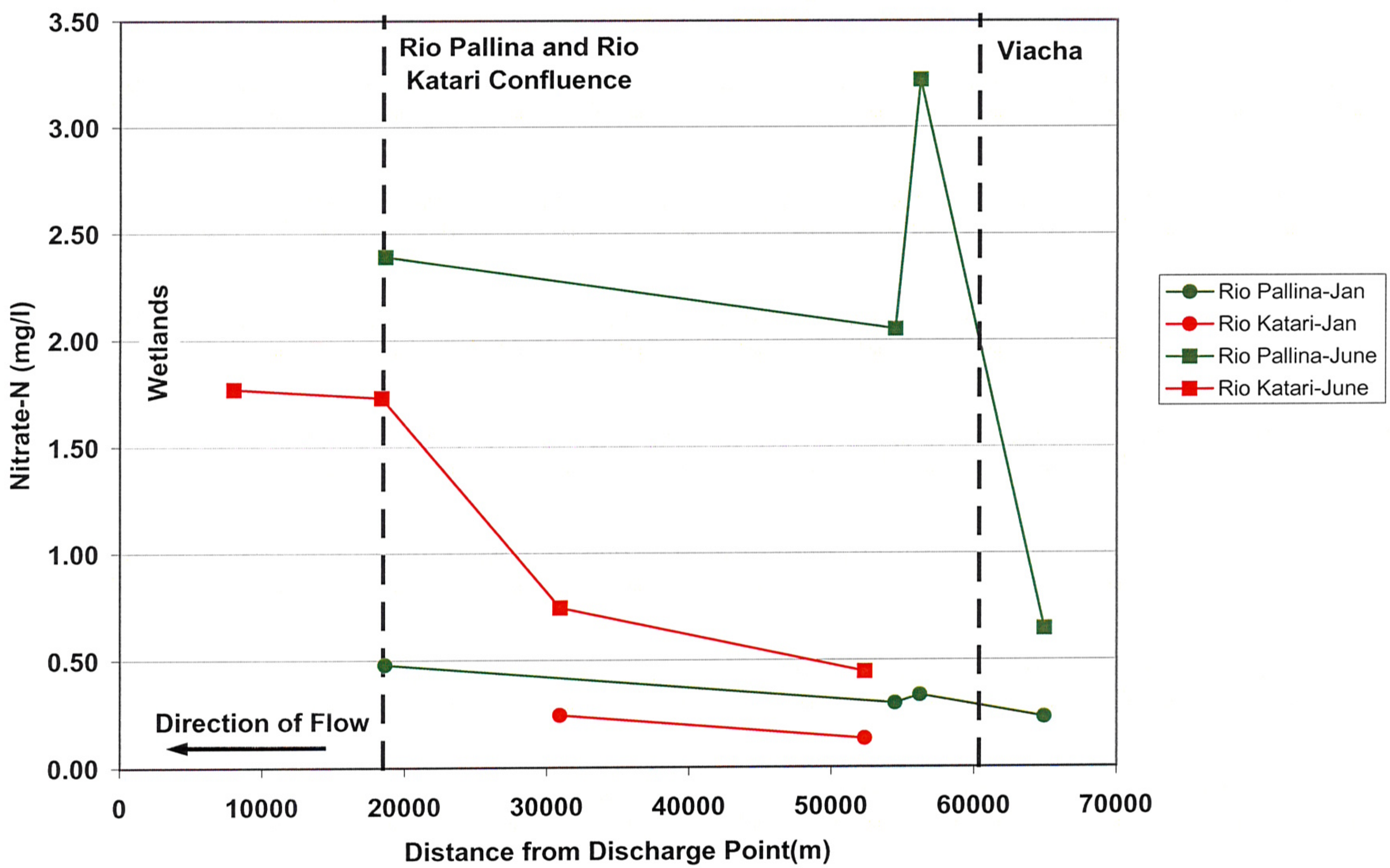

Rio Pallina and Rio Katari Confluence
Viacha
Wetlands
Direction of Flow
Chloride (mg/L)
Distance from Discharge Point(m)
250
200
150
100
50
0
10000
20000
30000
40000
50000
60000
70000
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 10



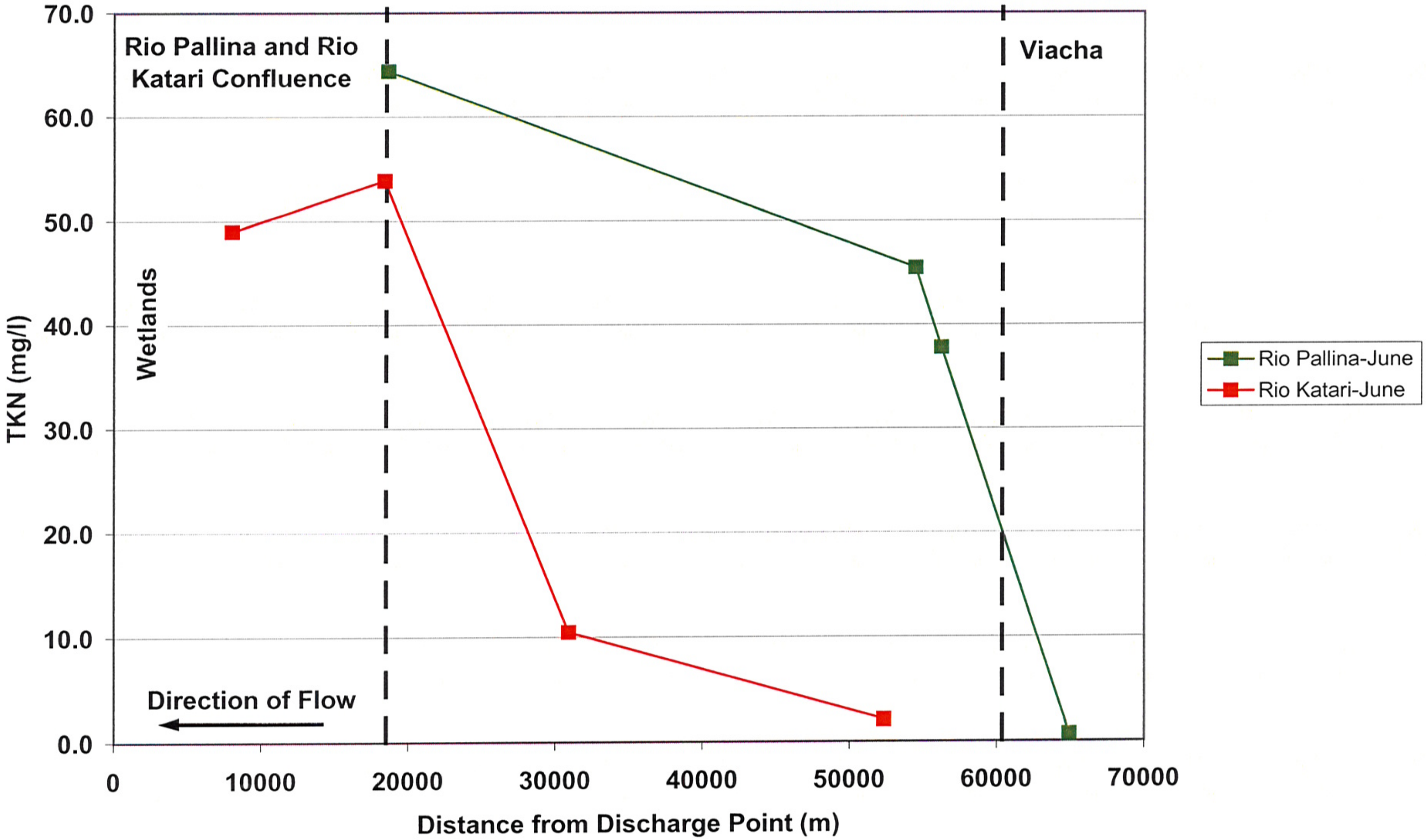
600
500
400
300
200
100
0
Sulfate (mg/l)
Wetlands
Rio Pallina and Rio
Katari Confluence
MCL Exceedance
Viacha
Direction of Flow
0
10000
20000
30000
40000
50000
60000
70000
Distance from Discharge Point (m)
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 11



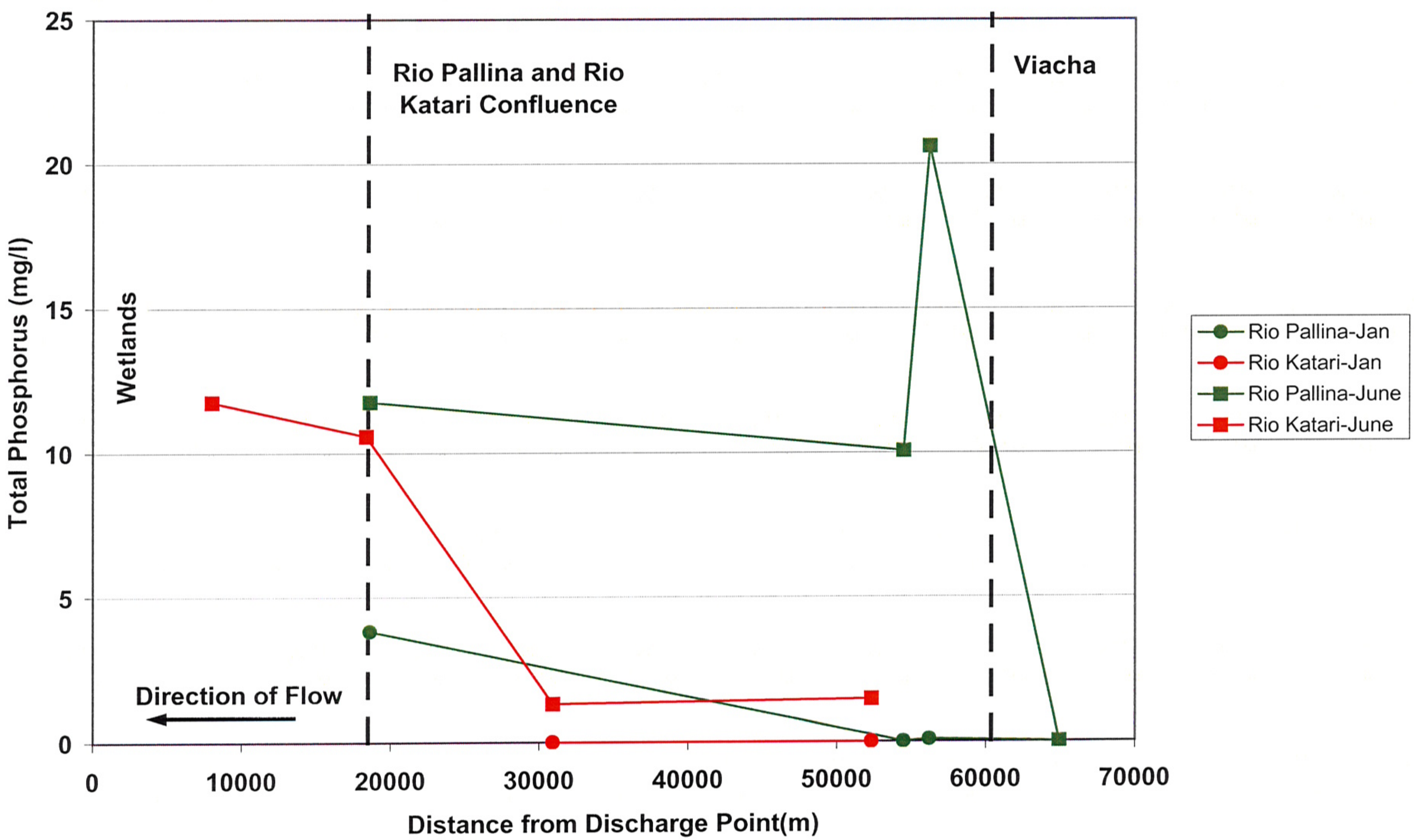
Nitrate-N (mg/l)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Wetlands
Rio Pallina and Rio Katari Confluence
Viacha
Direction of Flow
0
10000
20000
30000
40000
50000
60000
70000
Distance from Discharge Point(m)
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 12



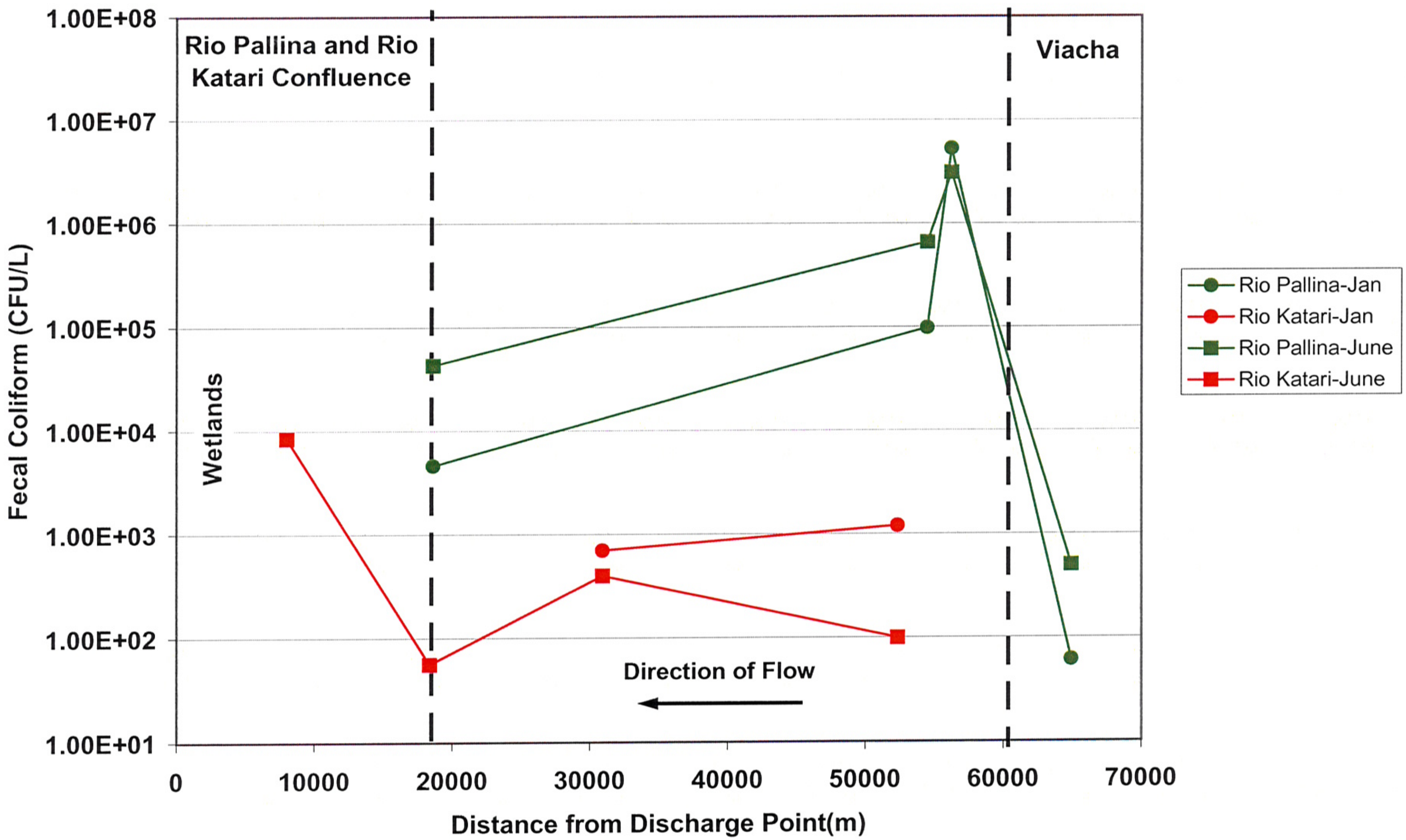
Rio Pallina and Rio Katari Confluence
Viacha
Wetlands
Direction of Flow
TKN (mg/l)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
10000
20000
30000
40000
50000
60000
70000
Distance from Discharge Point (m)
Rio Pallina-June
Rio Katari-June

Figure 13



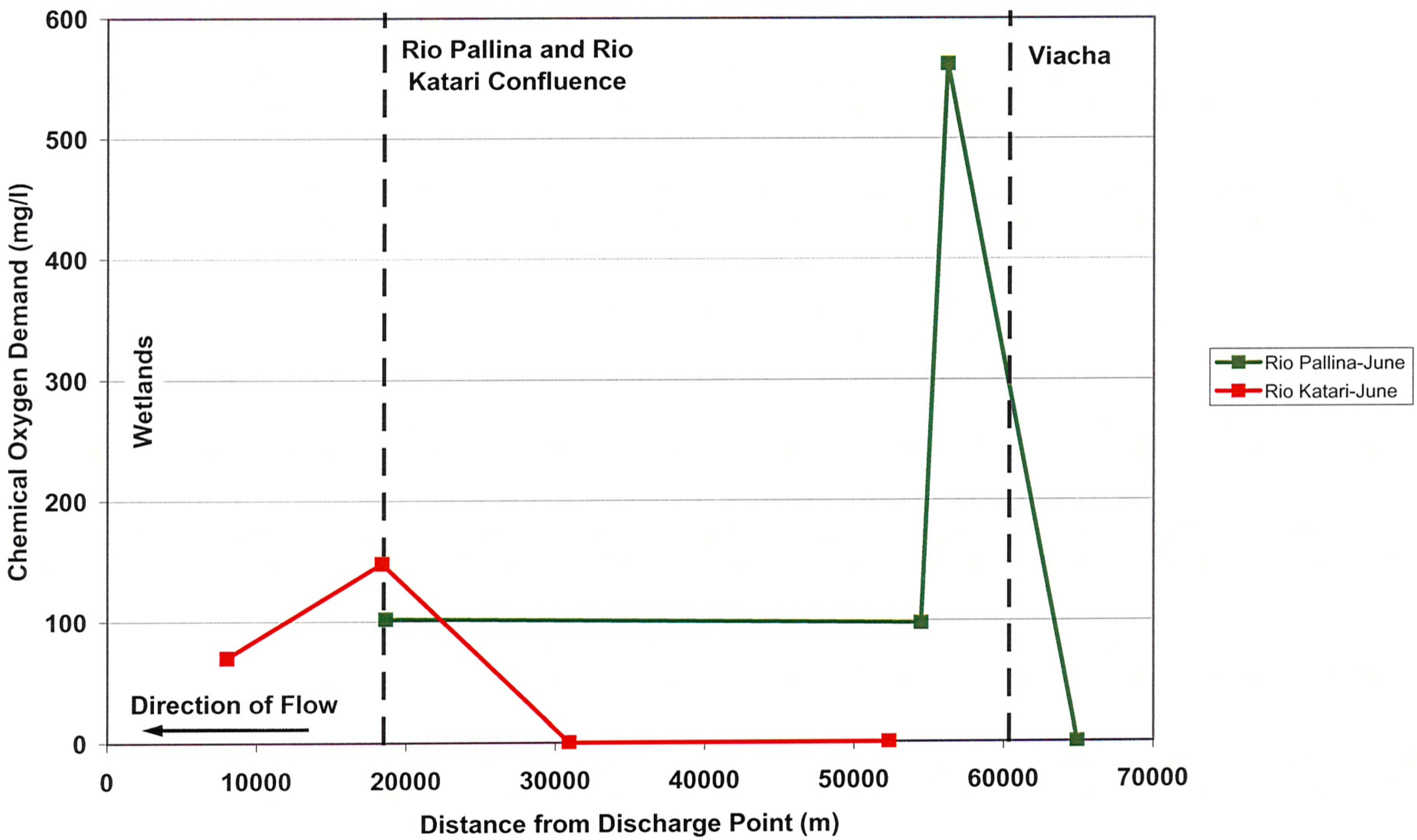
Total Phosphorus (mg/l)
25
20
15
10
5
0
Wetlands
Rio Pallina and Rio Katari Confluence
Viacha
Direction of Flow
0
10000
20000
30000
40000
50000
60000
70000
Distance from Discharge Point(m)
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 14



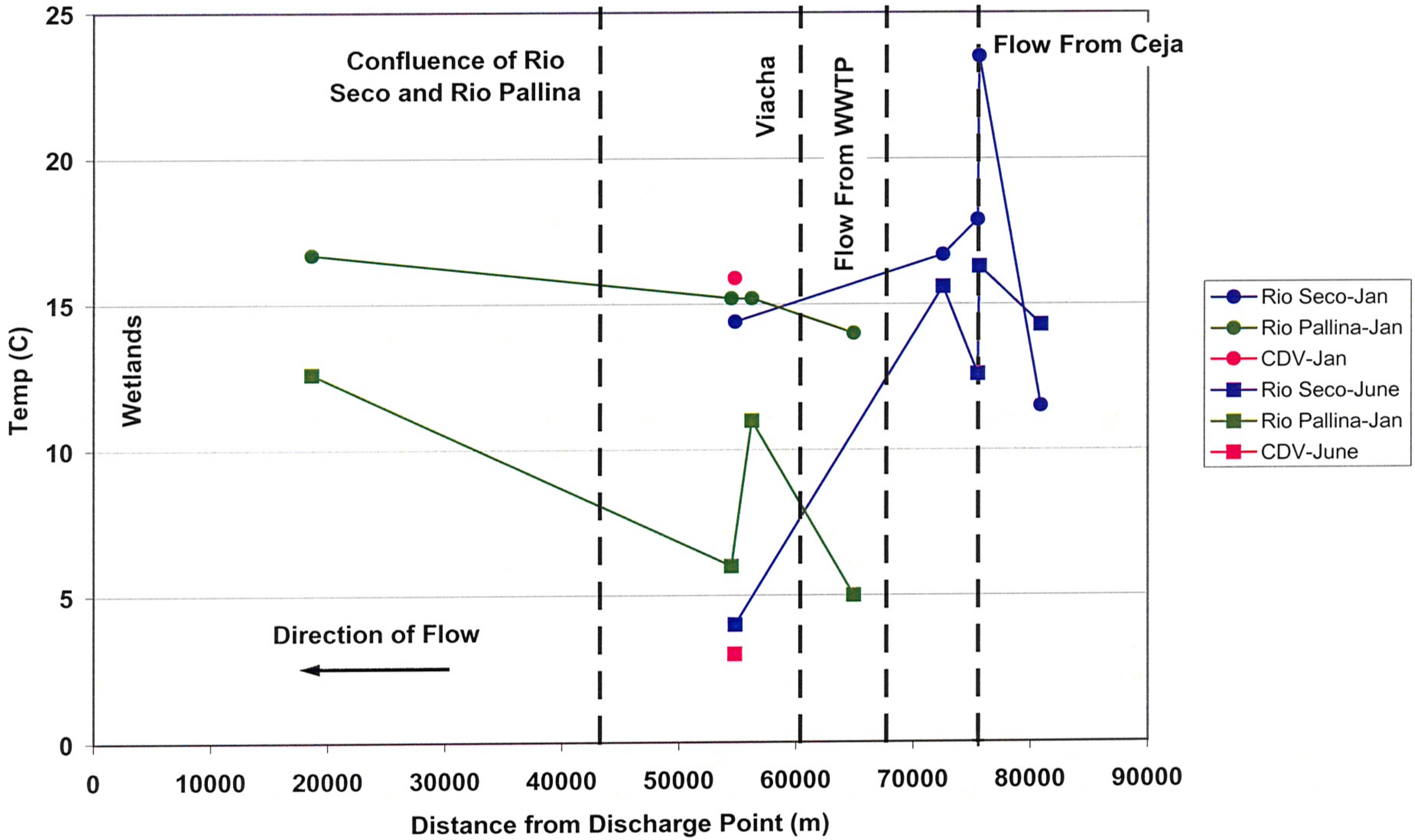
Fecal Coliform (CFU/L)
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
0
10000
20000
30000
40000
50000
60000
70000
Distance from Discharge Point(m)
Rio Pallina and Rio Katari Confluence
Viacha
Wetlands
Direction of Flow
Rio Pallina-Jan
Rio Katari-Jan
Rio Pallina-June
Rio Katari-June

Figure 15



Chemical Oxygen Demand (mg/l)
600
500
400
300
200
100
0
0
10000
20000
30000
40000
50000
60000
70000
Distance from Discharge Point (m)
Rio Pallina and Rio Katari Confluence
Viacha
Wetlands
Direction of Flow
Rio Pallina-June
Rio Katari-June

Figure 16



Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Wetlands
Direction of Flow
Temp (C)
Distance from Discharge Point (m)
25
20
15
10
5
0
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-Jan
CDV-June

Figure 17

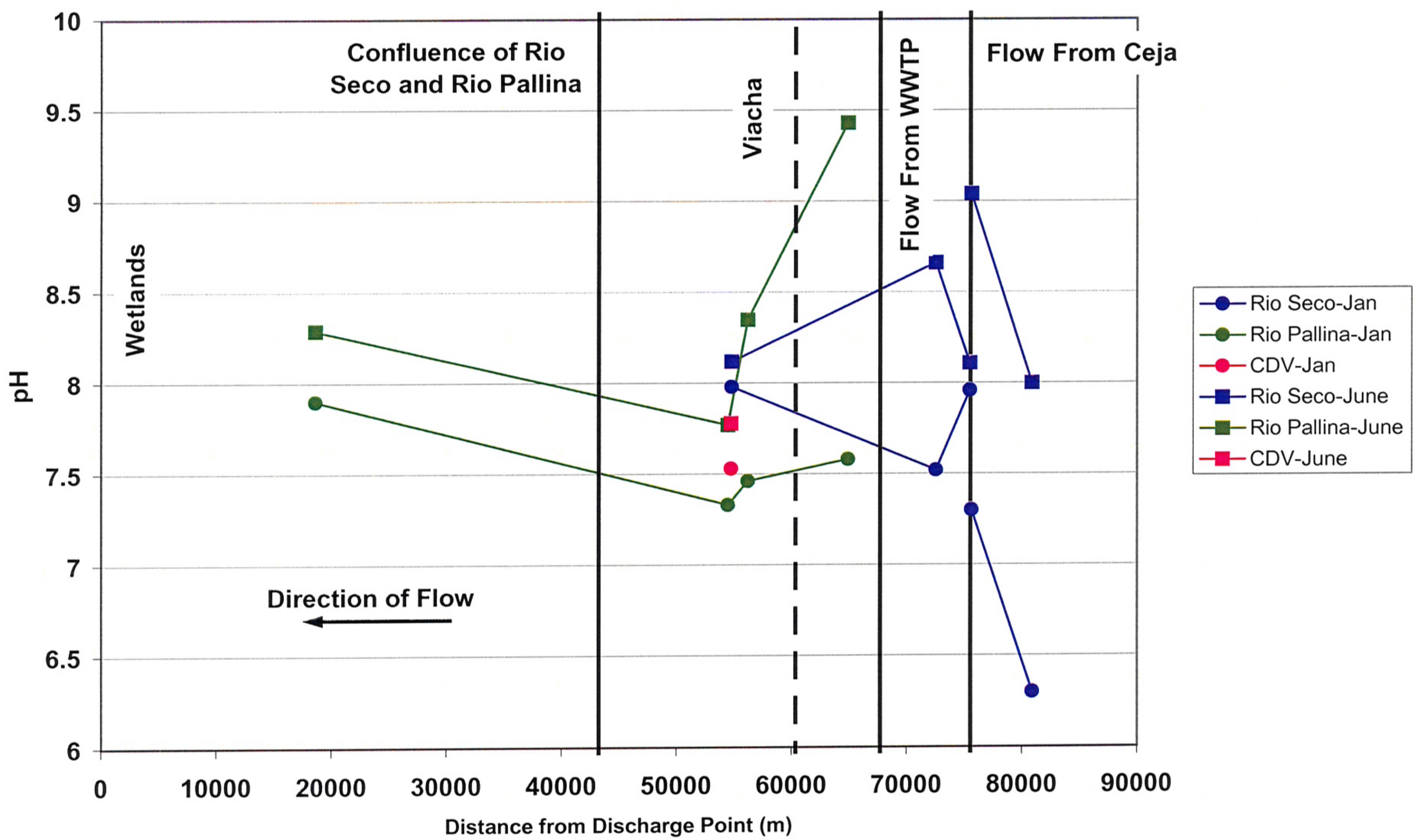
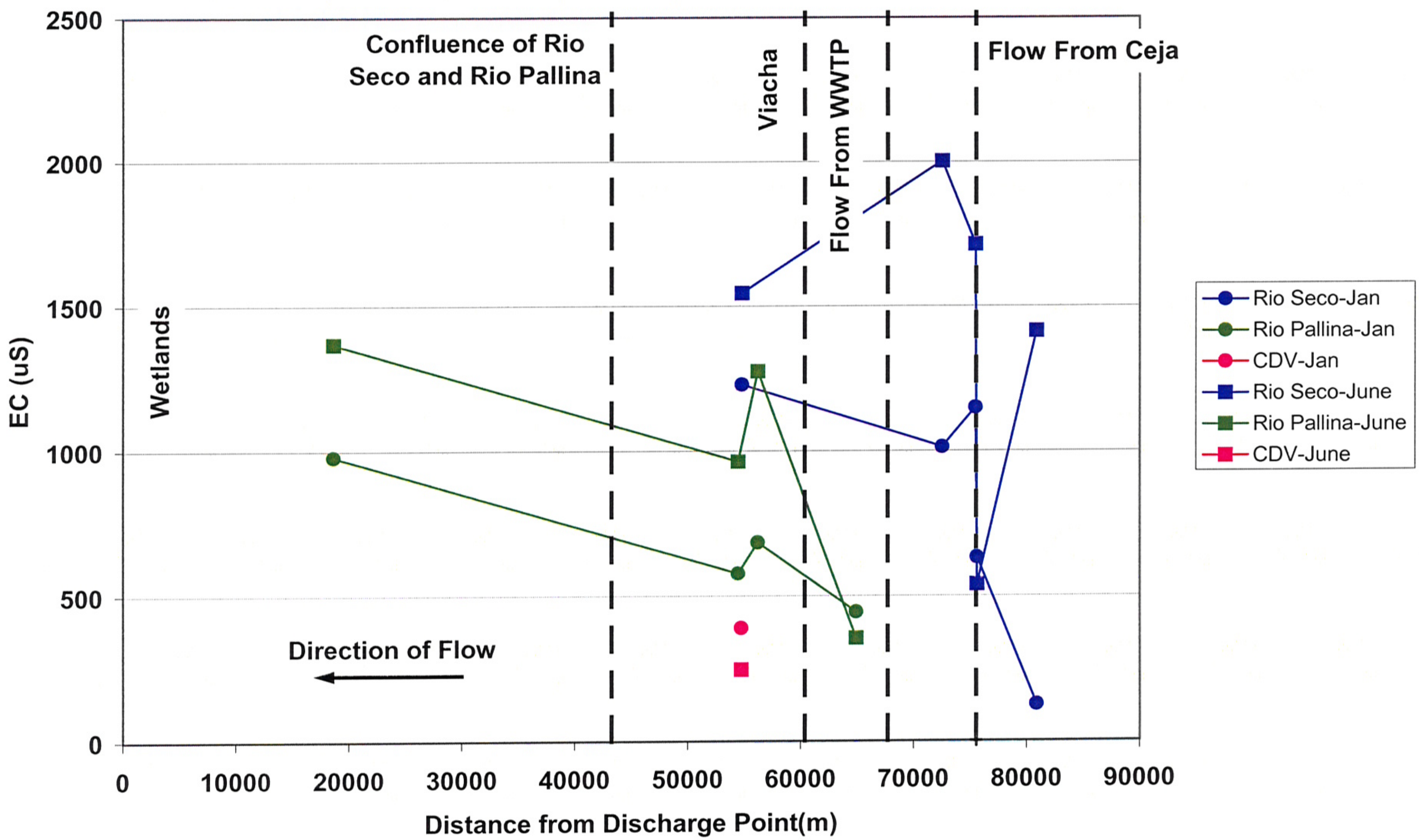

pH
Distance from Discharge Point (m)
Wetlands
Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Direction of Flow
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 18



EC (uS)
2500
2000
1500
1000
500
0
Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Wetlands
Direction of Flow
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Distance from Discharge Point(m)
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 19

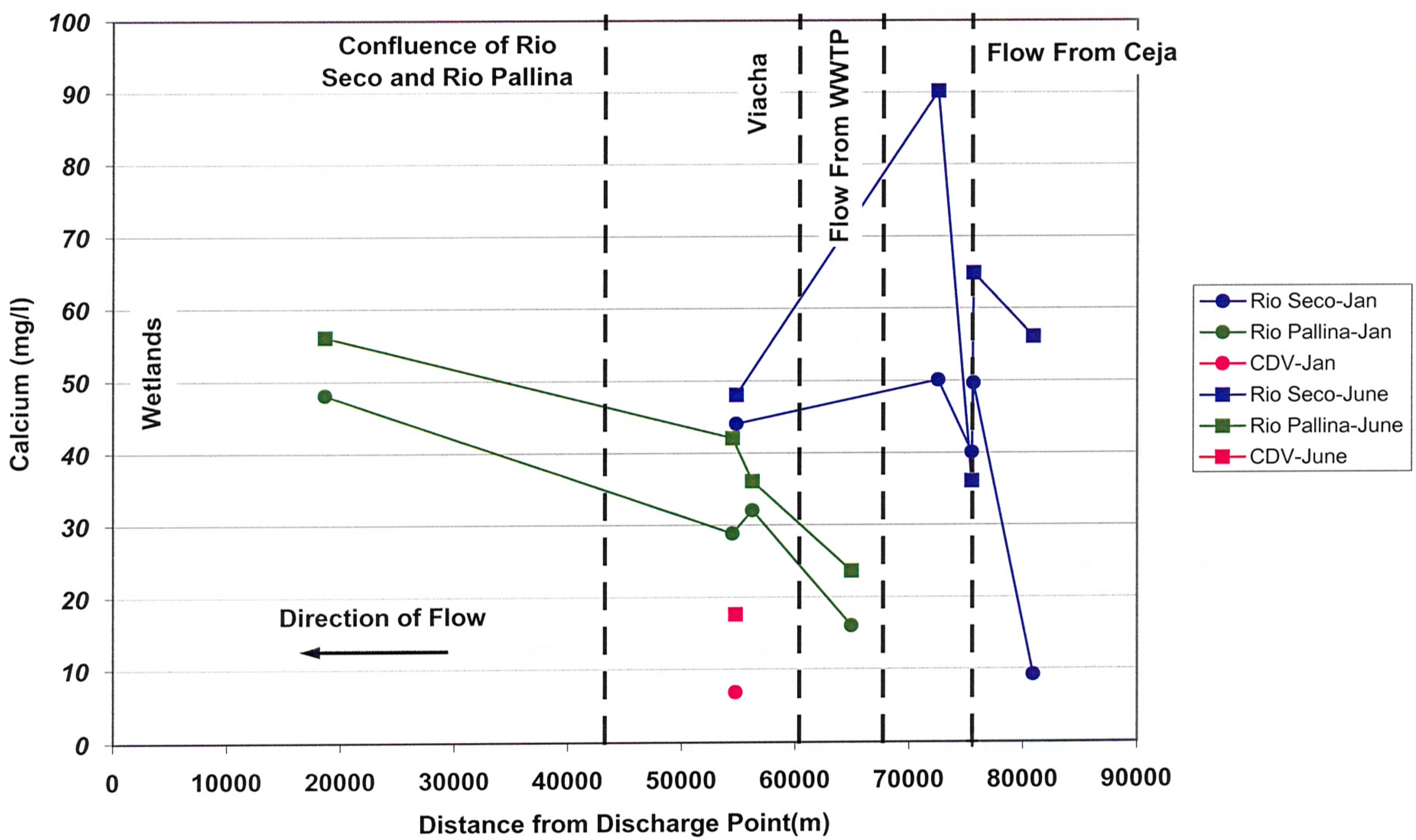
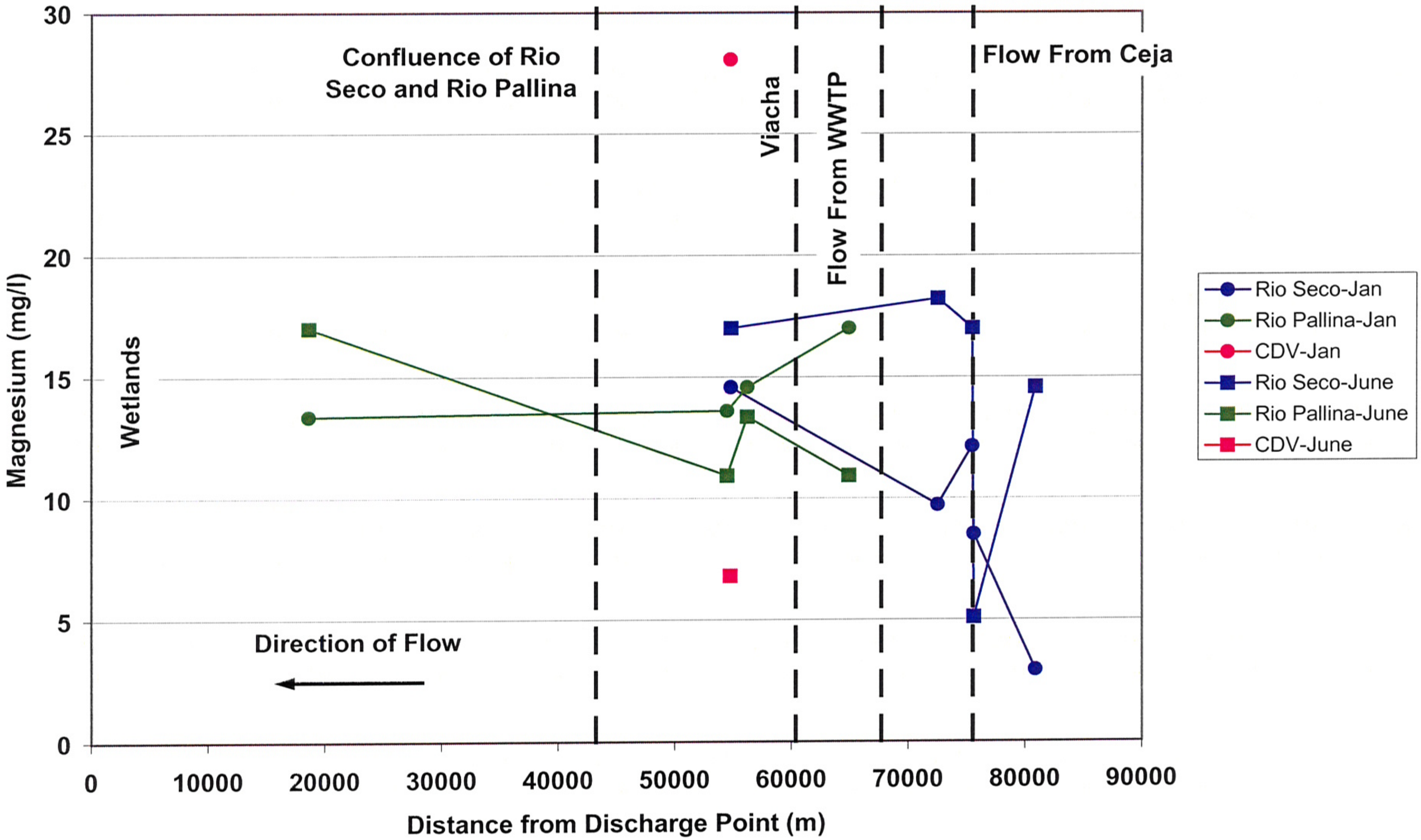
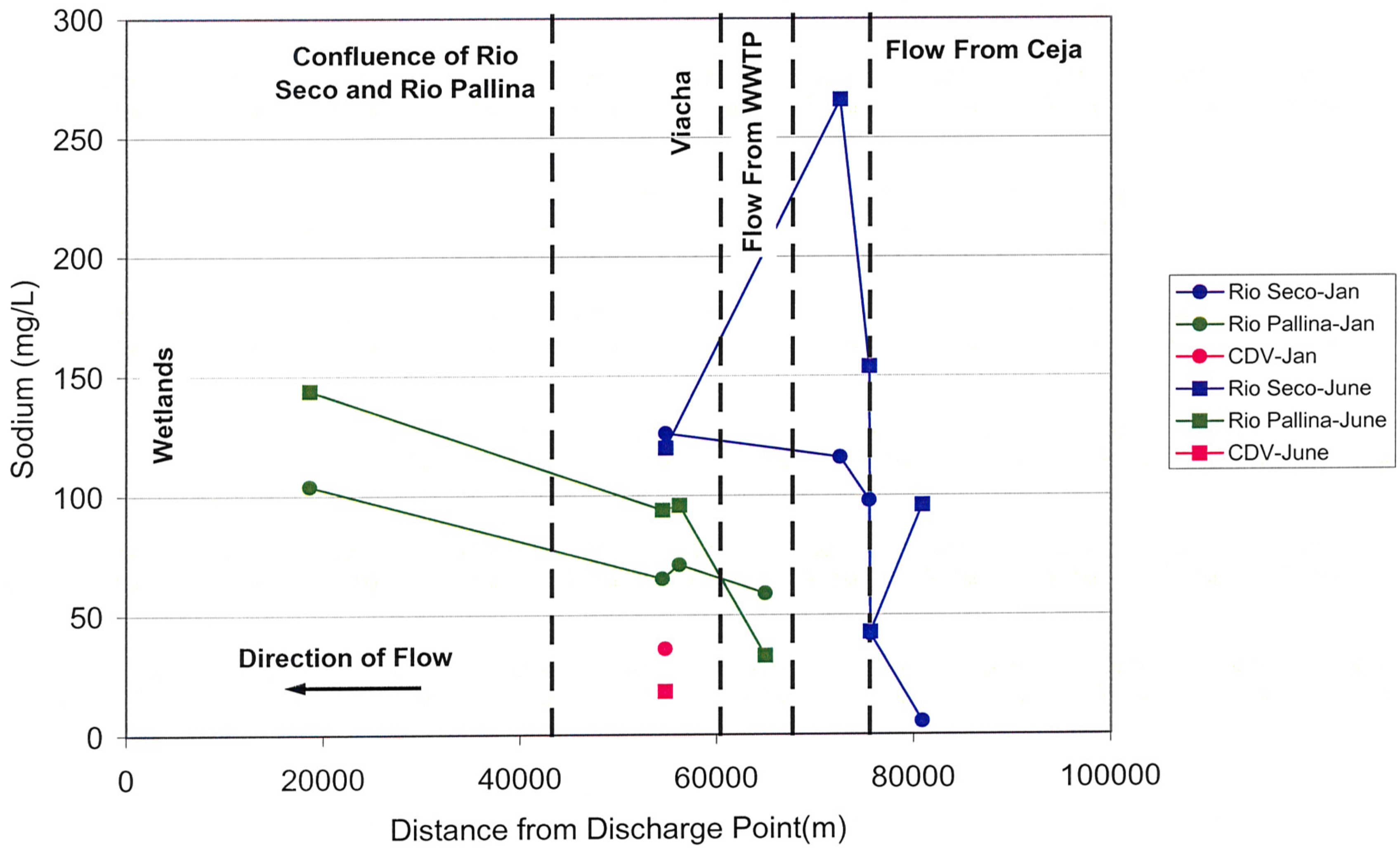

Calcium (mg/l)
100
90
80
70
60
50
40
30
20
10
0
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Distance from Discharge Point(m)
Confluence of Rio Seco and Rio Pallina
Wetlands
Viacha
Flow From WWTP
Flow From Ceja
Direction of Flow
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 20



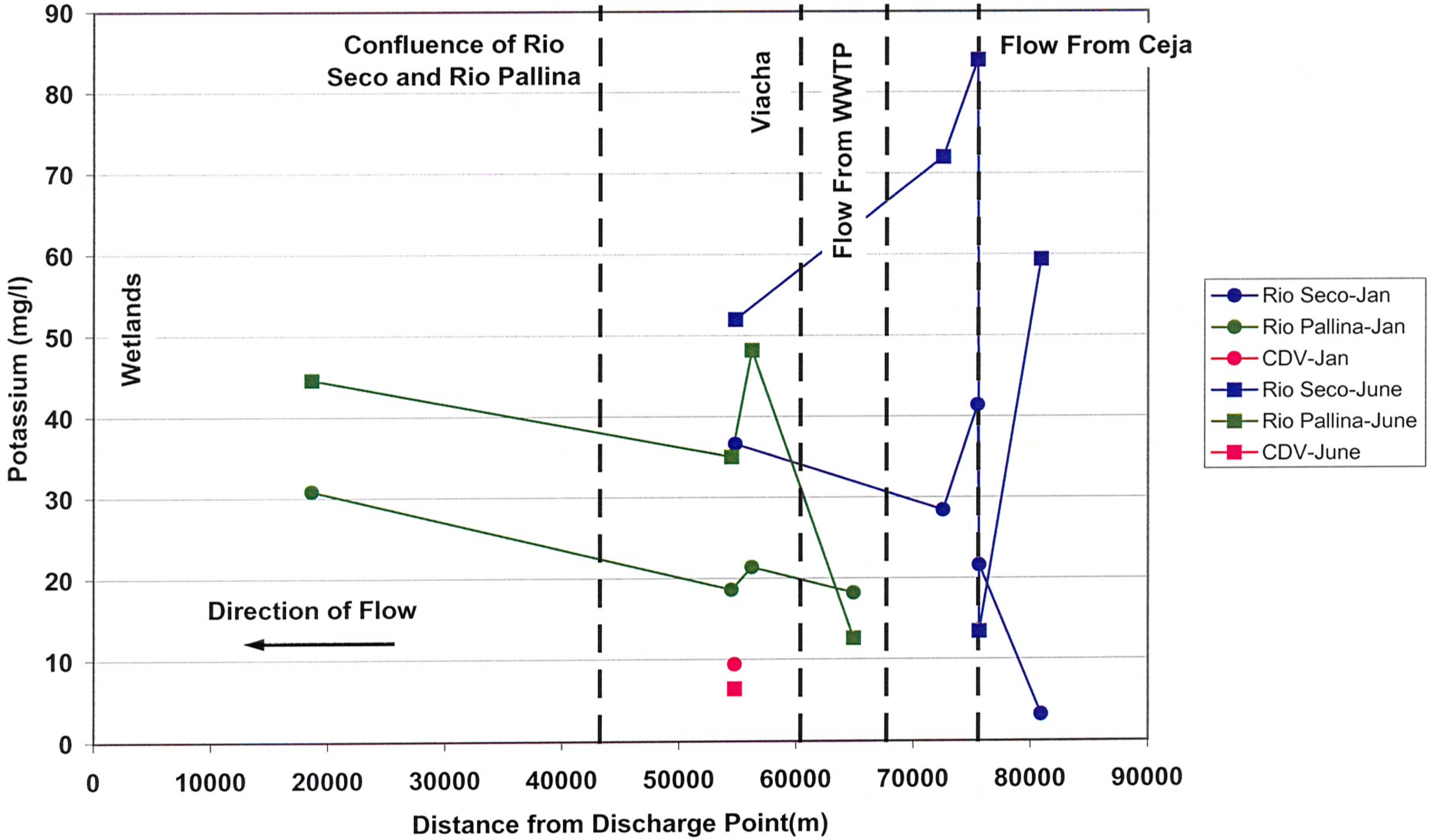
Magnesium (mg/l)
30
25
20
15
10
5
0
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Distance from Discharge Point (m)
Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Wetlands
Direction of Flow
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 21



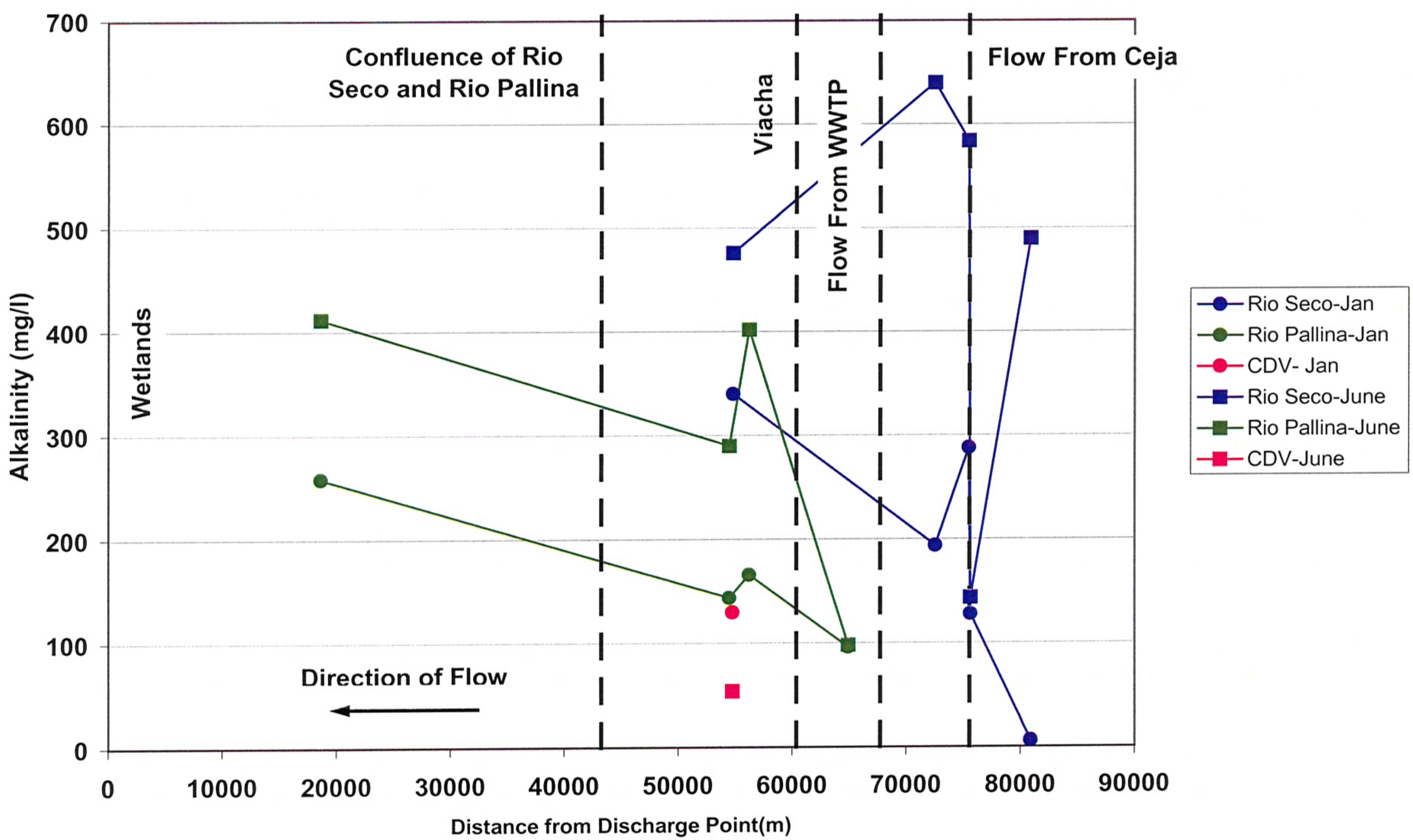
Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Wetlands
Direction of Flow
Sodium (mg/L)
Distance from Discharge Point(m)
300
250
200
150
100
50
0
20000
40000
60000
80000
100000
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 22



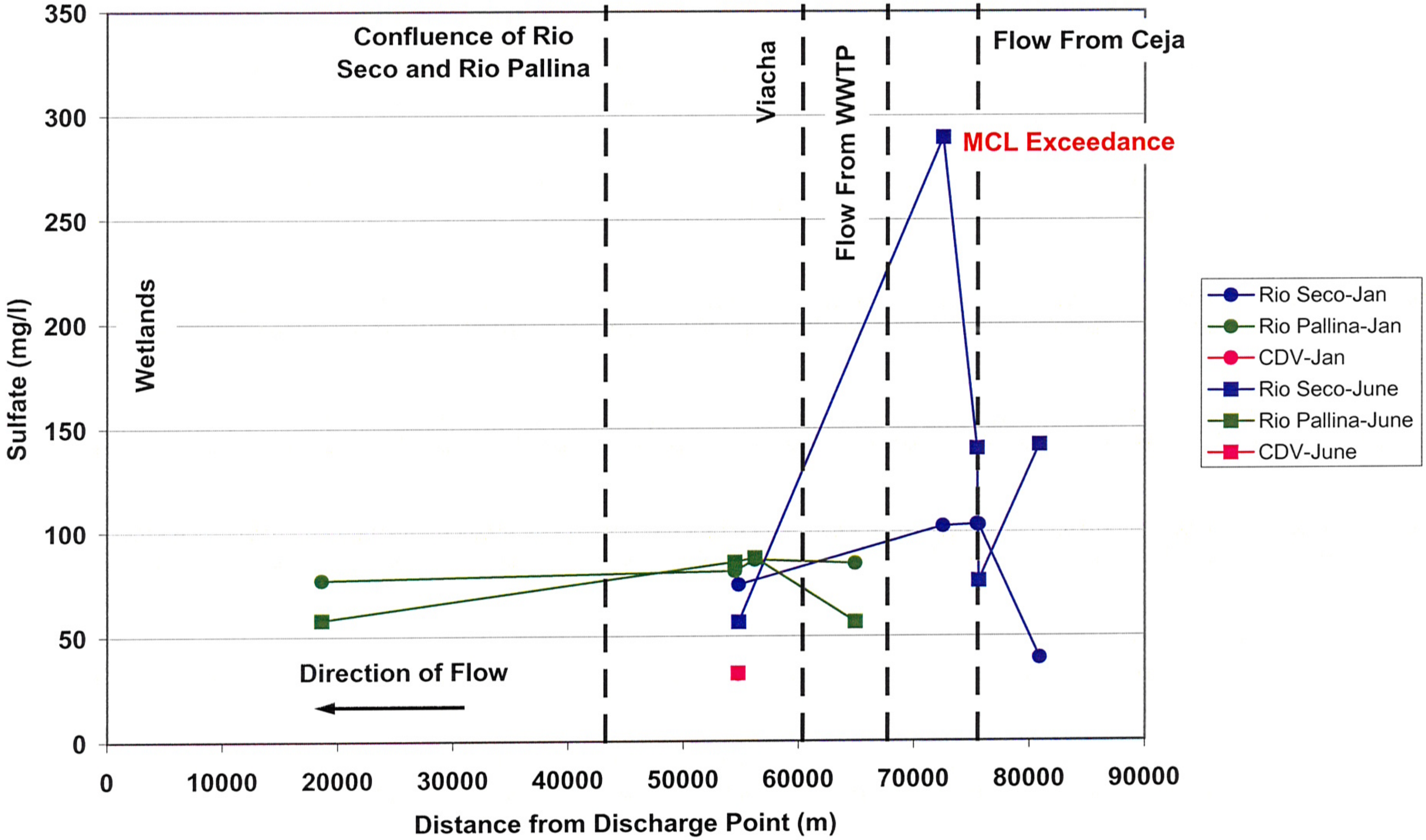
Potassium (mg/l)
90
80
70
60
50
40
30
20
10
0
Wetlands
Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Direction of Flow
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Distance from Discharge Point(m)
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 23



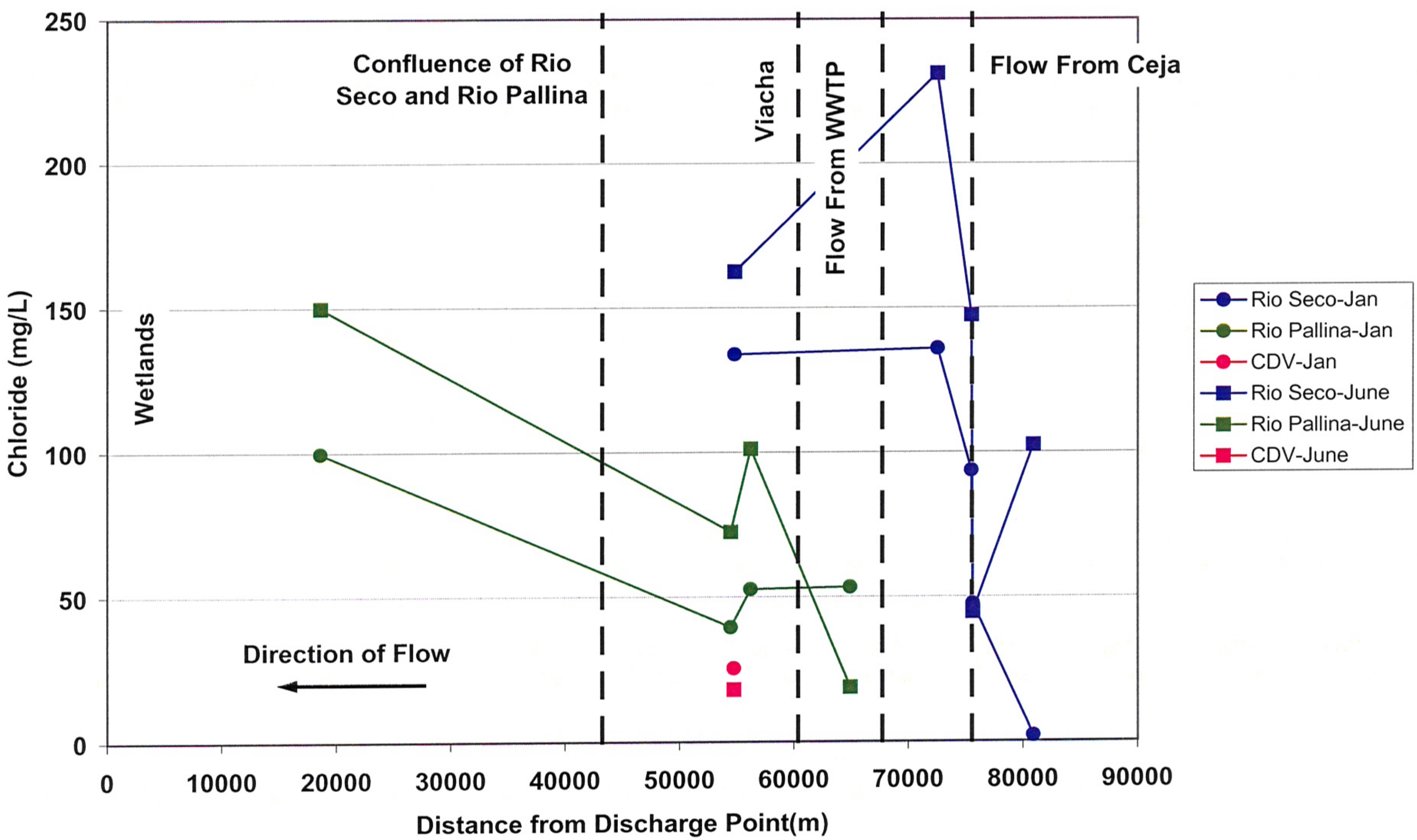
Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Wetlands
Direction of Flow
Alkalinity (mg/l)
Distance from Discharge Point(m)
0
100
200
300
400
500
600
700
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Rio Seco-Jan
Rio Pallina-Jan
CDV- Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 24



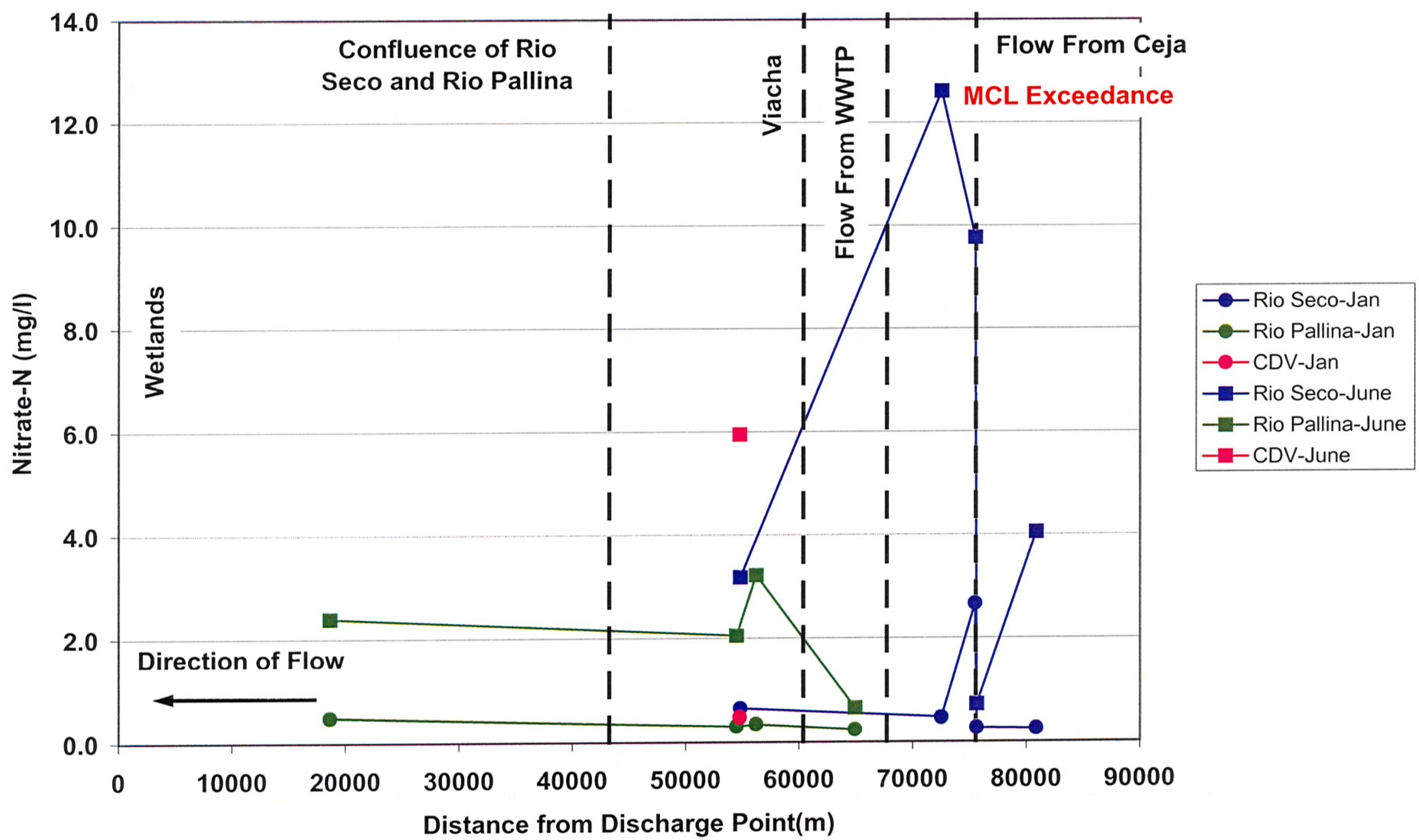
Sulfate (mg/l)
350
300
250
200
150
100
50
0
Distance from Discharge Point (m)
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Wetlands
Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
MCL Exceedance
Direction of Flow
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 25



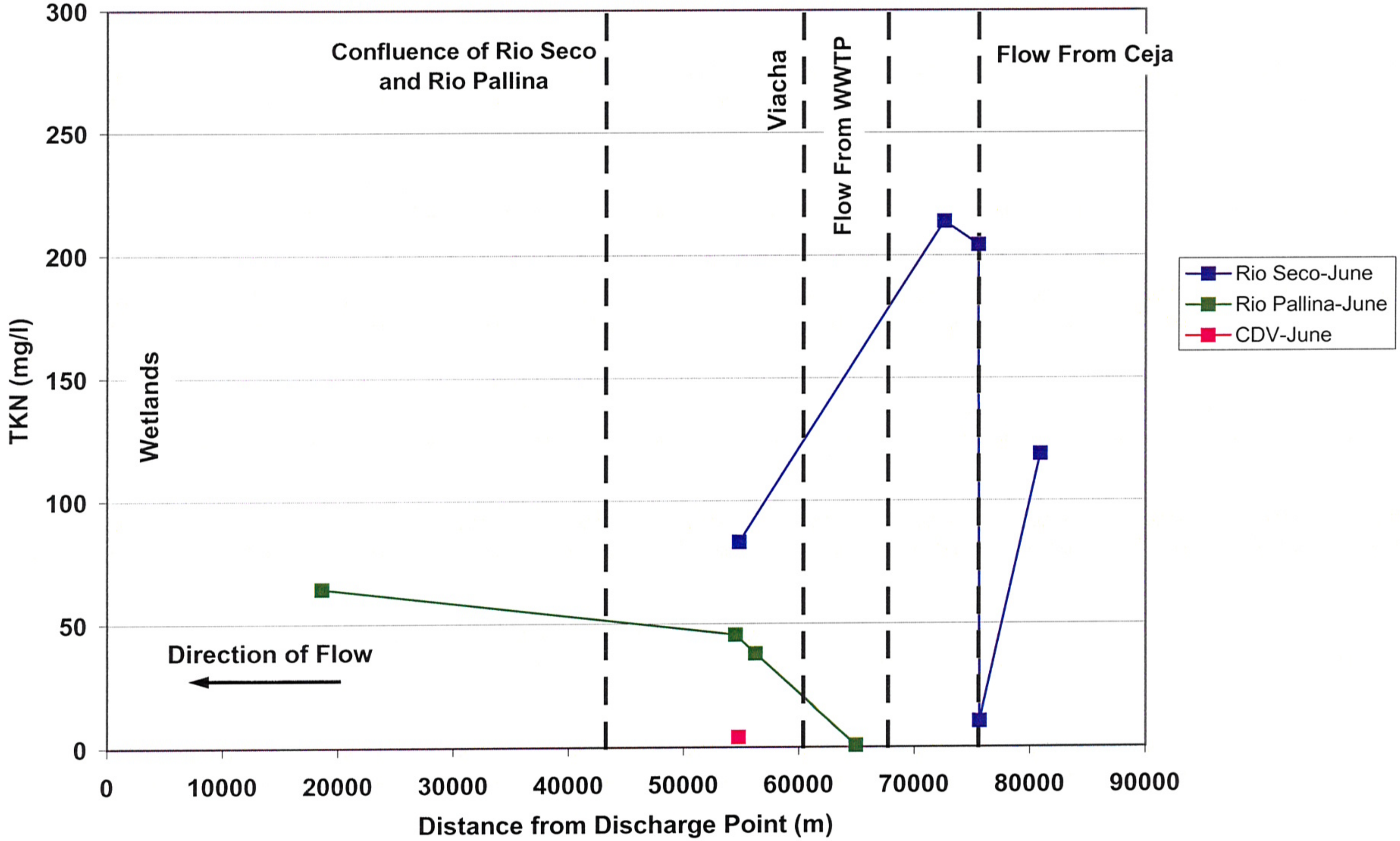
Chloride (mg/L)
250
200
150
100
50
0
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Distance from Discharge Point(m)
Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Wetlands
Direction of Flow
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 26



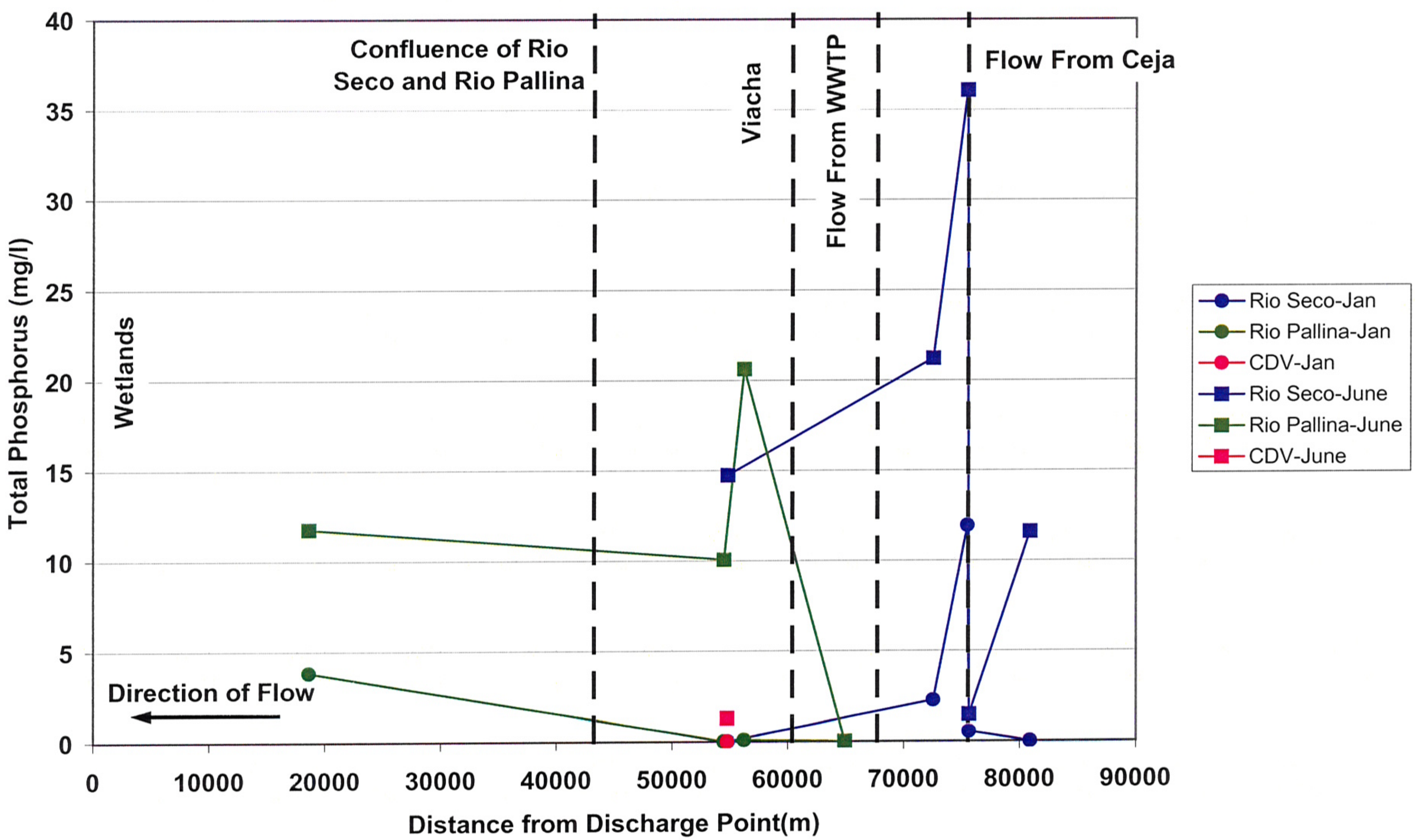
Confluence of Rio
Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
MCL Exceedance
Wetlands
Direction of Flow
Nitrate-N (mg/l)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Distance from Discharge Point(m)
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 27



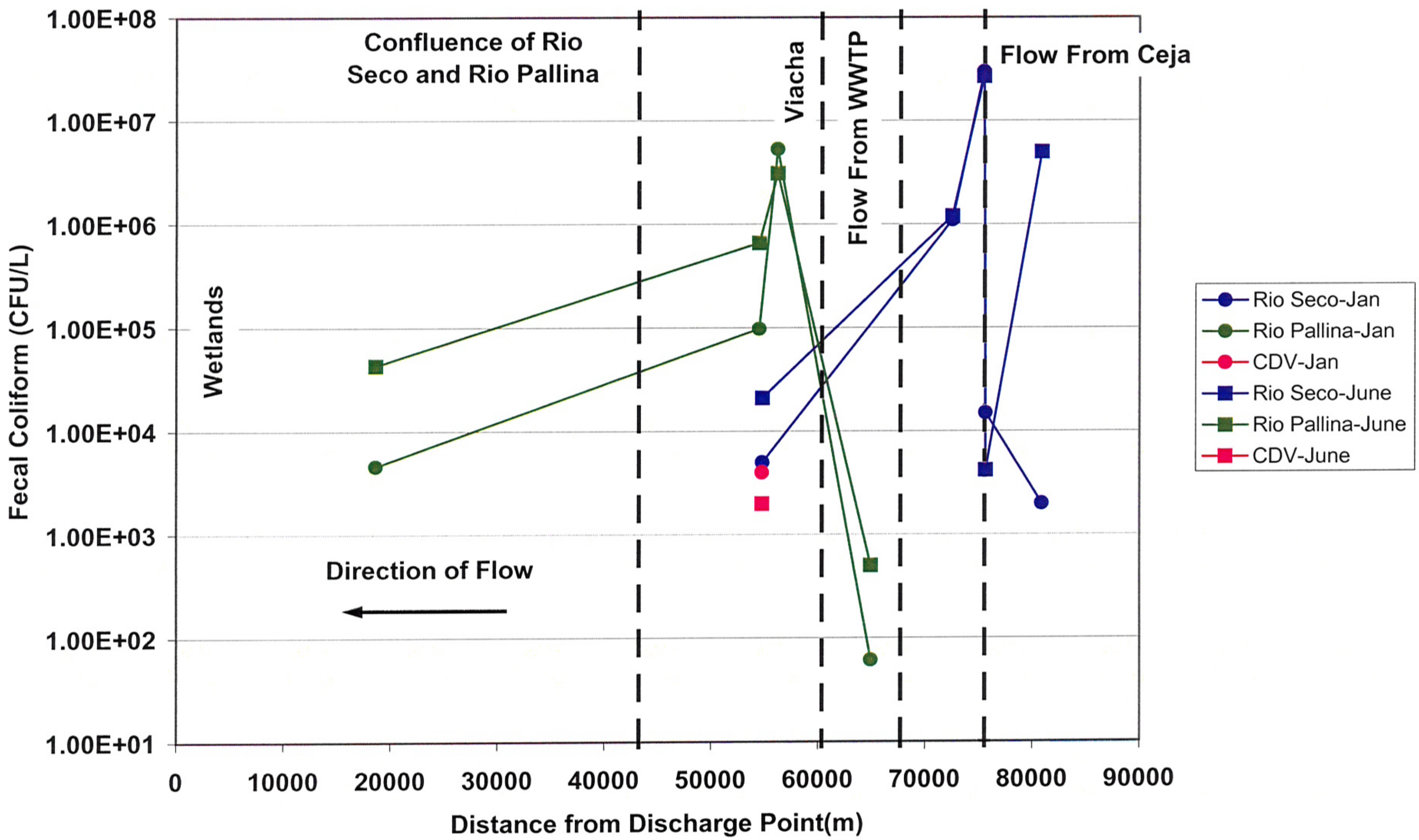
TKN (mg/l)
300
250
200
150
100
50
0
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Distance from Discharge Point (m)
Wetlands
Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Direction of Flow
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 28



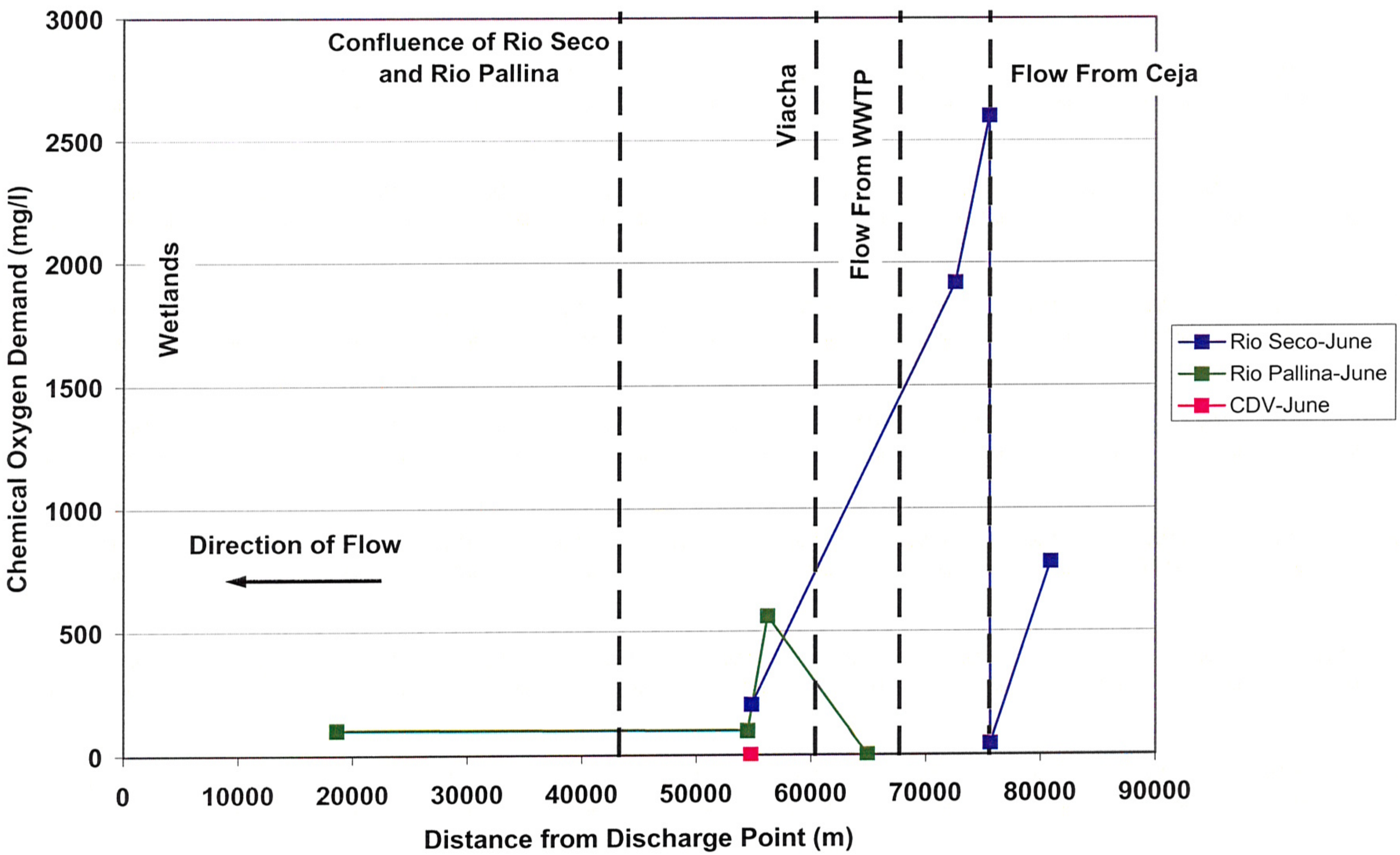
Total Phosphorus (mg/l)
40
35
30
25
20
15
10
5
0
Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Wetlands
Direction of Flow
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Distance from Discharge Point(m)
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 29



Confluence of Rio Seco and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Wetlands
Direction of Flow
Fecal Coliform (CFU/L)
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Distance from Discharge Point(m)
Rio Seco-Jan
Rio Pallina-Jan
CDV-Jan
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 30



Chemical Oxygen Demand (mg/l)
3000
2500
2000
1500
1000
500
0
Distance from Discharge Point (m)
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Confluence of Rio Seco
and Rio Pallina
Viacha
Flow From WWTP
Flow From Ceja
Wetlands
Direction of Flow
Rio Seco-June
Rio Pallina-June
CDV-June

Figure 31
TKN vs. COD

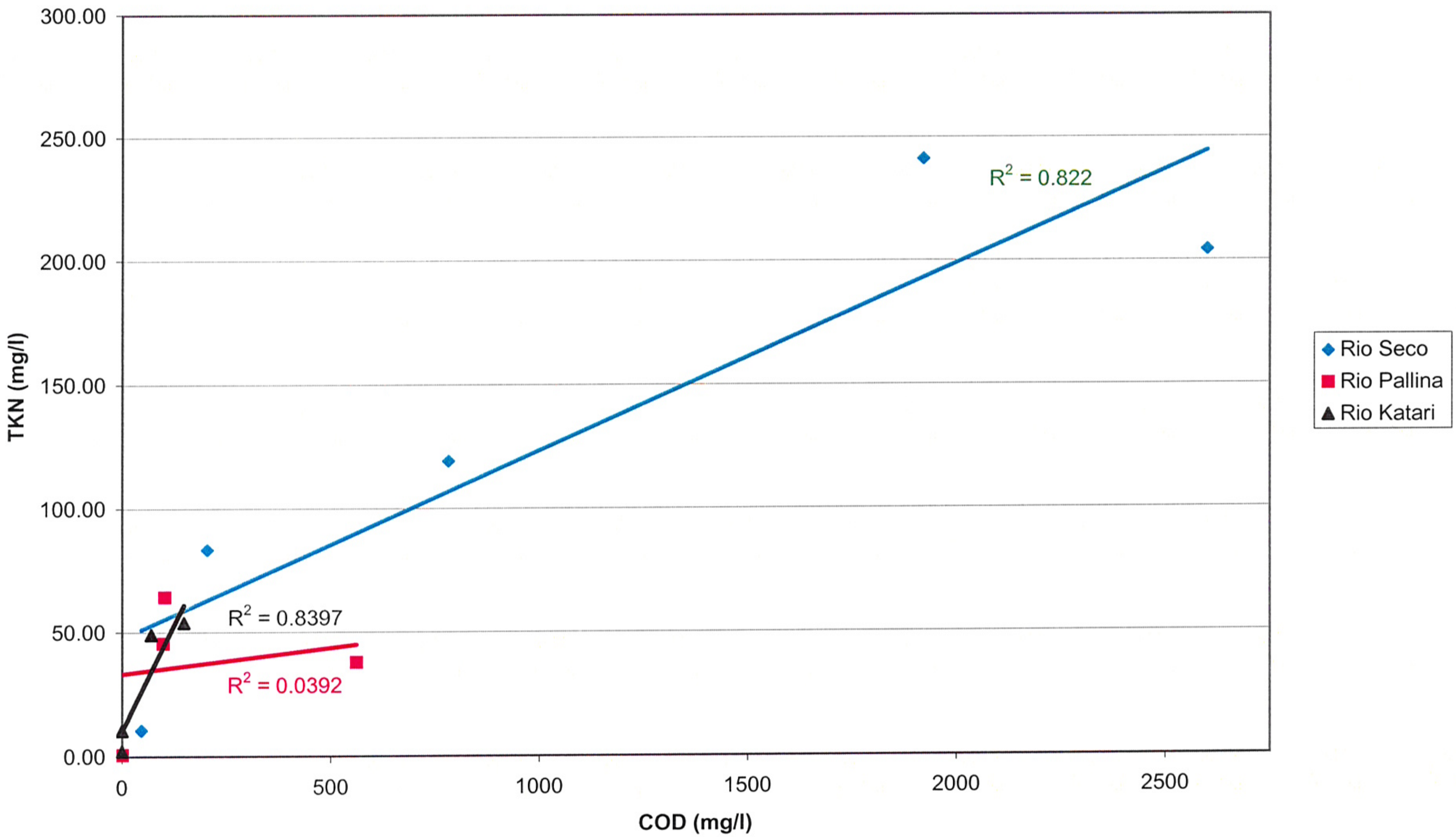


Figure 32
Rio Katari River Profile

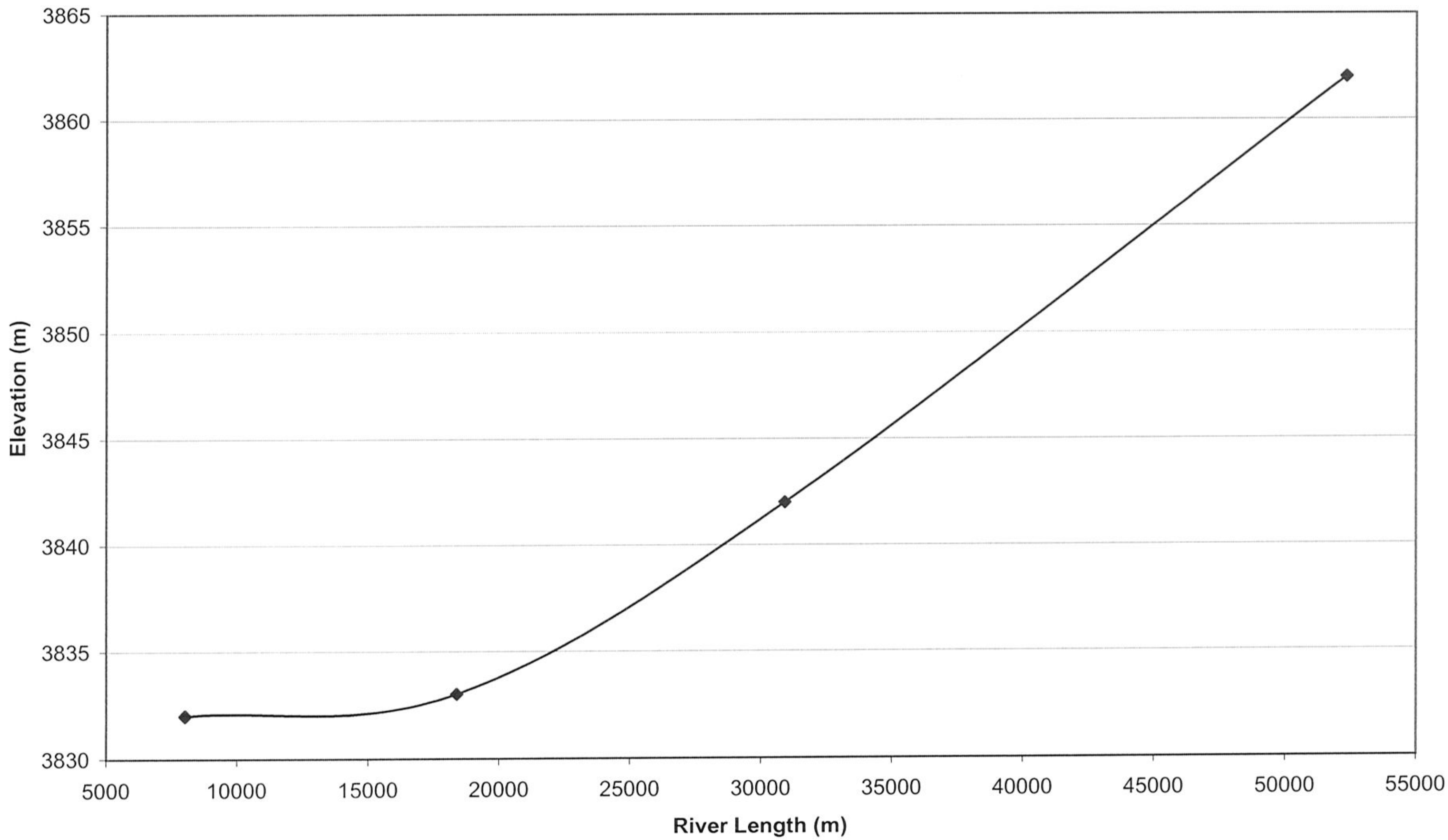


Figure 33
Rio Seco River Profile

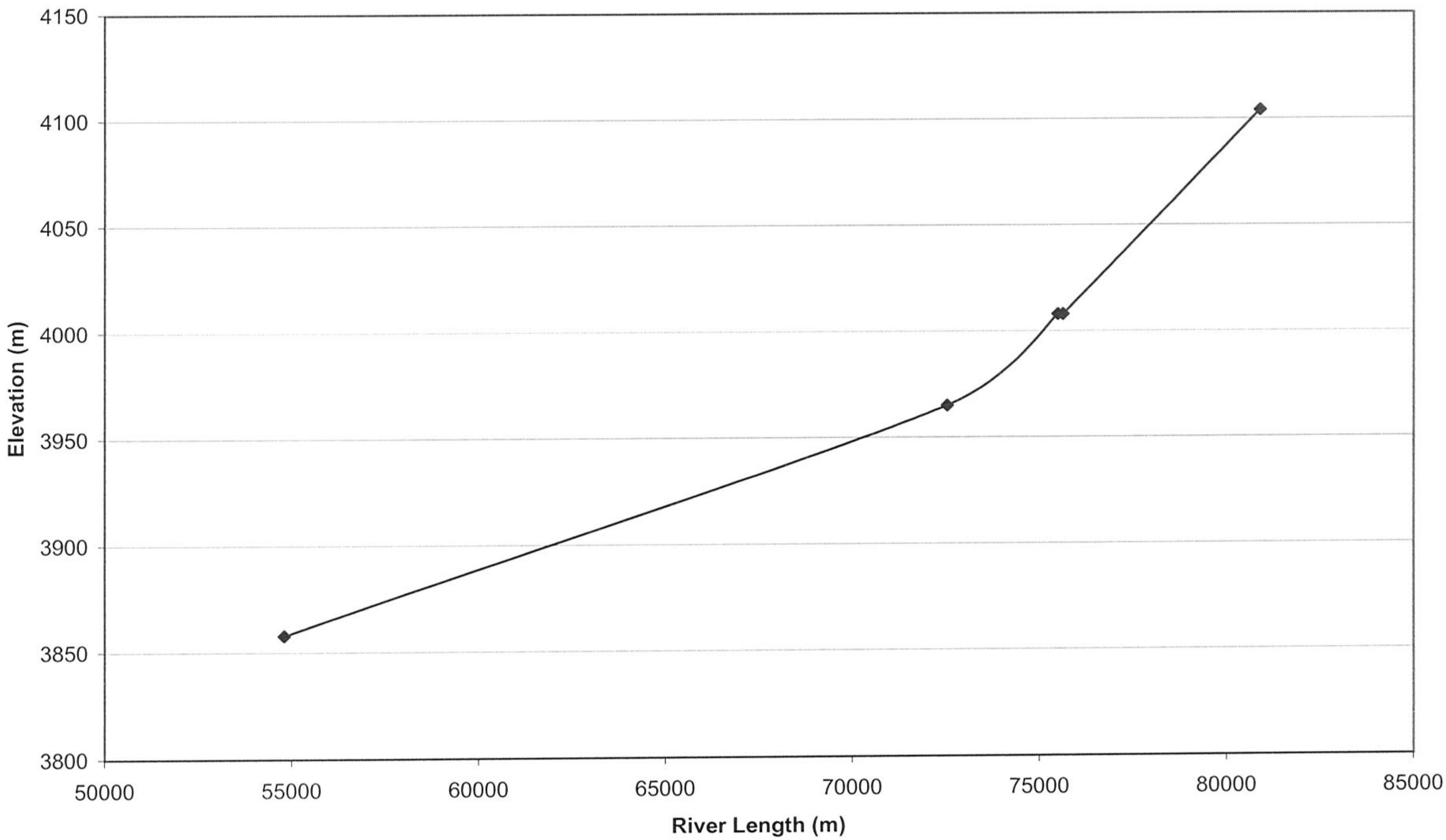
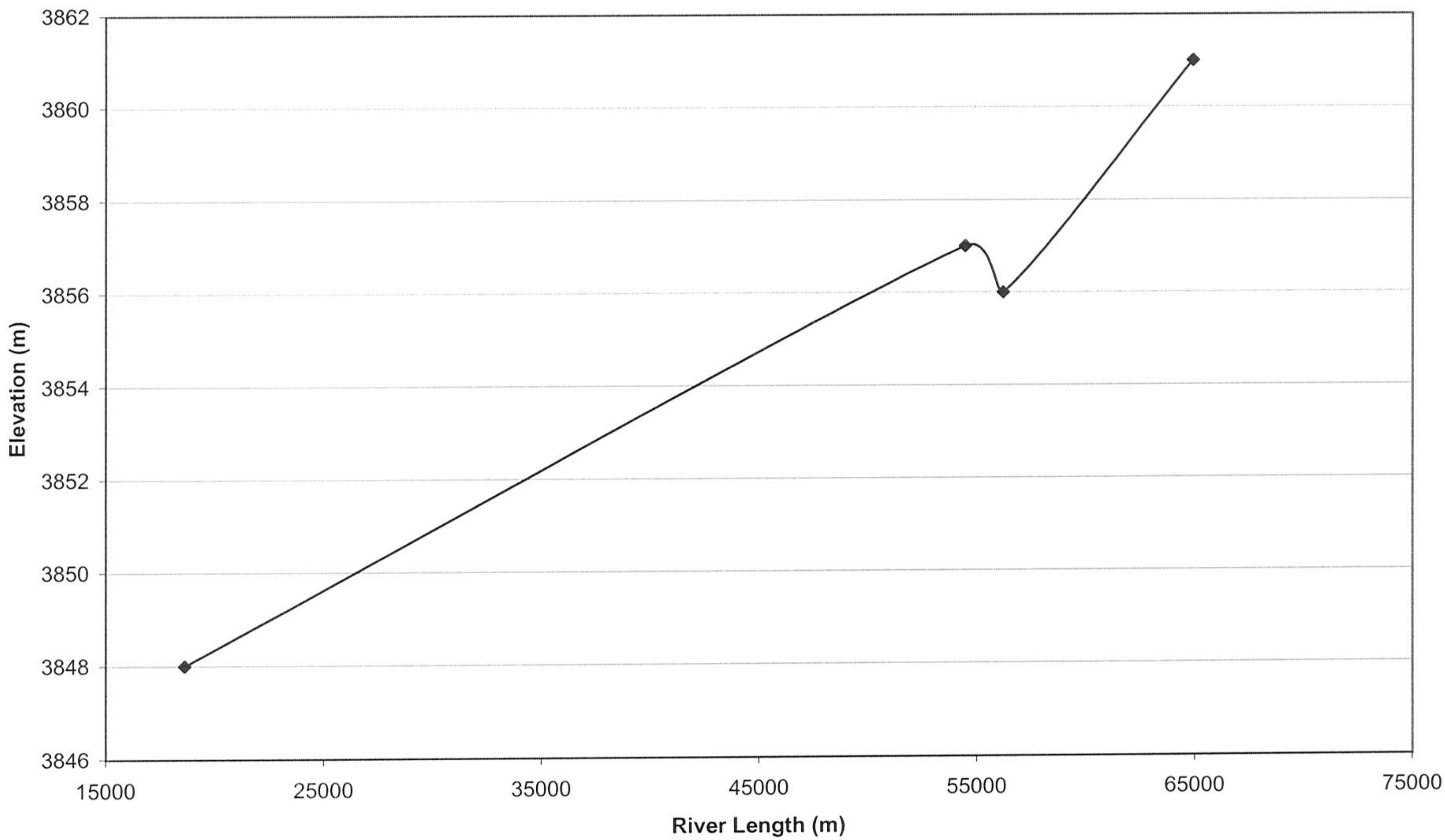


Figure 34
Rio Pallina River Profile



Appendix D

Ion Balance Tables

RK-1-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	100.2	2.500E-03	2.500	5.000	
Mg	24.31	2	15.8	6.499E-04	0.650	1.300	
Na	22.99	1	154	6.699E-03	6.699	6.699	
K	39.1	1	9.8	2.506E-04	0.251	0.251	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	126	2.066E-03	2.066	2.066	
Cl	35.45	1	164.11	4.629E-03	4.629	4.629	
SO_4	96.06	2	222.5	2.316E-03	2.316	4.633	
NO_3	62.01	1	0.58	9.353E-06	0.009	0.009	
Cations-Anions	-	-	-	-	-	-	1.91
Cations+Anions	-	-	-	-	-	-	24.59
% Balance	-	-	-	-	-	-	7.78
Ionic Strength	-	-	-	-	-	-	0.03

RK-2-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	124.24	3.100E-03	3.100	6.200	
Mg	24.31	2	24.3	9.996E-04	1.000	1.999	
Na	22.99	1	218	9.482E-03	9.482	9.482	
K	39.1	1	10.8	2.762E-04	0.276	0.276	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	124	2.033E-03	2.033	2.033	
Cl	35.45	1	222.75	6.283E-03	6.283	6.283	
SO_4	96.06	2	303.33	3.158E-03	3.158	6.315	
NO_3	62.01	1	1.07	1.726E-05	0.017	0.017	
Cations-Anions	-	-	-	-	-	-	3.31
Cations+Anions	-	-	-	-	-	-	32.61
% Balance	-	-	-	-	-	-	10.15
Ionic Strength	-	-	-	-	-	-	0.05

RK-1-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	106.21	2.650E-03	2.650	5.300	
Mg	24.31	2	18.23	7.499E-04	0.750	1.500	
Na	22.99	1	152	6.612E-03	6.612	6.612	
K	39.1	1	9	2.302E-04	0.230	0.230	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	144	2.361E-03	2.361	2.361	
Cl	35.45	1	163.7	4.618E-03	4.618	4.618	
SO_4	96.06	2	248.52	2.587E-03	2.587	5.174	
NO_3	62.01	1	1.97	3.177E-05	0.032	0.032	
Cations-Anions	-	-	-	-	-	-	1.46
Cations+Anions	-	-	-	-	-	-	25.83
% Balance	-	-	-	-	-	-	5.64
Ionic Strength	-	-	-	-	-	-	0.03

RK-2-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	190.38	4.750E-03	4.750	9.500	
Mg	24.31	2	42.53	1.749E-03	1.749	3.499	
Na	22.99	1	320	1.392E-02	13.919	13.919	
K	39.1	1	18.4	4.706E-04	0.471	0.471	
CO_3	60	2	24	4.000E-04	0.400	0.800	
HCO_3	61	1	148	2.426E-03	2.426	2.426	
Cl	35.45	1	231.18	6.521E-03	6.521	6.521	
SO_4	96.06	2	543.84	5.661E-03	5.661	11.323	
NO_3	62.01	1	3.3	5.322E-05	0.053	0.053	
Cations-Anions	-	-	-	-	-	-	6.26
Cations+Anions	-	-	-	-	-	-	48.51
% Balance	-	-	-	-	-	-	12.91
Ionic Strength	-	-	-	-	-	-	0.11

RK-4-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	52.1	1.300E-03	1.300	2.600	
Mg	24.31	2	17.01	6.997E-04	0.700	1.399	
Na	22.99	1	130	5.655E-03	5.655	5.655	
K	39.1	1	43.2	1.105E-03	1.105	1.105	
CO_3	60	2	64	1.067E-03	1.067	2.133	
HCO_3	61	1	328	5.377E-03	5.377	5.377	
Cl	35.45	1	147.45	4.159E-03	4.159	4.159	
SO_4	96.06	2	65.59	6.828E-04	0.683	1.366	
NO_3	62.01	1	7.66	1.235E-04	0.124	0.124	
Cations-Anions	-	-	-	-	-	-	-2.40
Cations+Anions	-	-	-	-	-	-	23.92
% Balance	-	-	-	-	-	-	10.04
Ionic Strength	-	-	-	-	-	-	0.03

RK-5-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	52.1	1.300E-03	1.300	2.600	
Mg	24.31	2	19.44	7.997E-04	0.800	1.599	
Na	22.99	1	138	6.003E-03	6.003	6.003	
K	39.1	1	42	1.074E-03	1.074	1.074	
CO_3	60	2	72	1.200E-03	1.200	2.400	
HCO_3	61	1	300	4.918E-03	4.918	4.918	
Cl	35.45	1	149.95	4.230E-03	4.230	4.230	
SO_4	96.06	2	58.57	6.097E-04	0.610	1.219	
NO_3	62.01	1	7.84	1.264E-04	0.126	0.126	
Cations-Anions	-	-	-	-	-	-	-1.62
Cations+Anions	-	-	-	-	-	-	24.17
% Balance	-	-	-	-	-	-	6.69
Ionic Strength	-	-	-	-	-	-	0.03

RS-1-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	9.22	2.300E-04	0.230	0.460	
Mg	24.31	2	2.92	1.201E-04	0.120	0.240	
Na	22.99	1	5.4	2.349E-04	0.235	0.235	
K	39.1	1	3.2	8.184E-05	0.082	0.082	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	6	9.836E-05	0.098	0.098	
Cl	35.45	1	2.01	5.670E-05	0.057	0.057	
SO_4	96.06	2	39.39	4.101E-04	0.410	0.820	
NO_3	62.01	1	1.09	1.758E-05	0.018	0.018	
Cations-Anions	-	-	-	-	-	-	0.02
Cations+Anions	-	-	-	-	-	-	2.01
% Balance	-	-	-	-	-	-	1.21
Ionic Strength	-	-	-	-	-	-	0.00

RS-6 Before-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	49.7	1.240E-03	1.240	2.480	
Mg	24.31	2	8.51	3.501E-04	0.350	0.700	
Na	22.99	1	42	1.827E-03	1.827	1.827	
K	39.1	1	21.6	5.524E-04	0.552	0.552	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	128	2.098E-03	2.098	2.098	
Cl	35.45	1	47.57	1.342E-03	1.342	1.342	
SO_4	96.06	2	103.32	1.076E-03	1.076	2.151	
NO_3	62.01	1	1.16	1.871E-05	0.019	0.019	
Cations-Anions	-	-	-	-	-	-	-0.05
Cations+Anions	-	-	-	-	-	-	11.17
% Balance	-	-	-	-	-	-	0.45
Ionic Strength	-	-	-	-	-	-	0.01

RS-6 After-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	40.08	1.000E-03	1.000	2.000	
Mg	24.31	2	12.15	4.998E-04	0.500	1.000	
Na	22.99	1	98	4.263E-03	4.263	4.263	
K	39.1	1	41.4	1.059E-03	1.059	1.059	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	288	4.721E-03	4.721	4.721	
Cl	35.45	1	93.63	2.641E-03	2.641	2.641	
SO_4	96.06	2	103.63	1.079E-03	1.079	2.158	
NO_3	62.01	1	11.77	1.898E-04	0.190	0.190	
Cations-Anions	-	-	-	-	-	-	-1.39
Cations+Anions	-	-	-	-	-	-	18.03
% Balance	-	-	-	-	-	-	7.70
Ionic Strength	-	-	-	-	-	-	0.02

RS-10-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	50.1	1.250E-03	1.250	2.500	
Mg	24.31	2	9.72	3.998E-04	0.400	0.800	
Na	22.99	1	116	5.046E-03	5.046	5.046	
K	39.1	1	28.4	7.263E-04	0.726	0.726	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	194	3.180E-03	3.180	3.180	
Cl	35.45	1	135.92	3.834E-03	3.834	3.834	
SO_4	96.06	2	102.7	1.069E-03	1.069	2.138	
NO_3	62.01	1	2.02	3.258E-05	0.033	0.033	
Cations-Anions	-	-	-	-	-	-	-0.11
Cations+Anions	-	-	-	-	-	-	18.26
% Balance	-	-	-	-	-	-	0.62
Ionic Strength	-	-	-	-	-	-	0.02

RS-11-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	4.09	1.020E-04	0.102	0.204	
Mg	24.31	2	14.58	5.998E-04	0.600	1.200	
Na	22.99	1	126	5.481E-03	5.481	5.481	
K	39.1	1	36.6	9.361E-04	0.936	0.936	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	340	5.574E-03	5.574	5.574	
Cl	35.45	1	133.9	3.777E-03	3.777	3.777	
SO_4	96.06	2	74.68	7.774E-04	0.777	1.555	
NO_3	62.01	1	2.83	4.564E-05	0.046	0.046	
Cations-Anions	-	-	-	-	-	-	-3.13
Cations+Anions	-	-	-	-	-	-	18.77
% Balance	-	-	-	-	-	-	16.68
Ionic Strength	-	-	-	-	-	-	0.03

RS-1-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	56.11	1.400E-03	1.400	2.800	
Mg	24.31	2	14.58	5.998E-04	0.600	1.200	
Na	22.99	1	96	4.176E-03	4.176	4.176	
K	39.1	1	59.4	1.519E-03	1.519	1.519	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	490	8.033E-03	8.033	8.033	
Cl	35.45	1	102.47	2.891E-03	2.891	2.891	
SO_4	96.06	2	141.96	1.478E-03	1.478	2.956	
NO_3	62.01	1	17.93	2.891E-04	0.289	0.289	
Cations-Anions	-	-	-	-	-	-	-4.47
Cations+Anions	-	-	-	-	-	-	23.86
% Balance	-	-	-	-	-	-	18.75
Ionic Strength	-	-	-	-	-	-	0.04

RS-6 Before-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	64.93	1.620E-03	1.620	3.240	
Mg	24.31	2	5.1	2.098E-04	0.210	0.420	
Na	22.99	1	42.8	1.862E-03	1.862	1.862	
K	39.1	1	13.4	3.427E-04	0.343	0.343	
CO_3	60	2	24	4.000E-04	0.400	0.800	
HCO_3	61	1	120	1.967E-03	1.967	1.967	
Cl	35.45	1	44.74	1.262E-03	1.262	1.262	
SO_4	96.06	2	76.53	7.967E-04	0.797	1.593	
NO_3	62.01	1	3.15	5.080E-05	0.051	0.051	
Cations-Anions	-	-	-	-	-	-	0.19
Cations+Anions	-	-	-	-	-	-	11.54
% Balance	-	-	-	-	-	-	1.65
Ionic Strength	-	-	-	-	-	-	0.01

RS-6 After-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	36.07	9.000E-04	0.900	1.800	
Mg	24.31	2	17.01	6.997E-04	0.700	1.399	
Na	22.99	1	154	6.699E-03	6.699	6.699	
K	39.1	1	84	2.148E-03	2.148	2.148	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	584	9.574E-03	9.574	9.574	
Cl	35.45	1	147.45	4.159E-03	4.159	4.159	
SO_4	96.06	2	140.27	1.460E-03	1.460	2.920	
NO_3	62.01	1	1	1.613E-05	0.016	0.016	
Cations-Anions	-	-	-	-	-	-	-4.62
Cations+Anions	-	-	-	-	-	-	28.72
% Balance	-	-	-	-	-	-	16.10
Ionic Strength	-	-	-	-	-	-	0.06

RS-10-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	90.18	2.250E-03	2.250	4.500	
Mg	24.31	2	18.23	7.499E-04	0.750	1.500	
Na	22.99	1	266	1.157E-02	11.570	11.570	
K	39.1	1	72	1.841E-03	1.841	1.841	
CO_3	60	2	60	1.000E-03	1.000	2.000	
HCO_3	61	1	580	9.508E-03	9.508	9.508	
Cl	35.45	1	231.18	6.521E-03	6.521	6.521	
SO_4	96.06	2	289.47	3.013E-03	3.013	6.027	
NO_3	62.01	1	55.8	8.999E-04	0.900	0.900	
Cations-Anions	-	-	-	-	-	-	-5.54
Cations+Anions	-	-	-	-	-	-	44.37
% Balance	-	-	-	-	-	-	12.50
Ionic Strength	-	-	-	-	-	-	0.12

RS-11-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	48.1	1.200E-03	1.200	2.400	
Mg	24.31	2	17.01	6.997E-04	0.700	1.399	
Na	22.99	1	120	5.220E-03	5.220	5.220	
K	39.1	1	52	1.330E-03	1.330	1.330	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	476	7.803E-03	7.803	7.803	
Cl	35.45	1	162.45	4.583E-03	4.583	4.583	
SO_4	96.06	2	56.79	5.912E-04	0.591	1.182	
NO_3	62.01	1	14.09	2.272E-04	0.227	0.227	
Cations-Anions	-	-	-	-	-	-	-3.45
Cations+Anions	-	-	-	-	-	-	24.14
% Balance	-	-	-	-	-	-	14.27
Ionic Strength	-	-	-	-	-	-	0.04

RP-1-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	16.03	4.000E-04	0.400	0.800	
Mg	24.31	2	17.01	6.997E-04	0.700	1.399	
Na	22.99	1	59	2.566E-03	2.566	2.566	
K	39.1	1	18.2	4.655E-04	0.465	0.465	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	96	1.574E-03	1.574	1.574	
Cl	35.45	1	53.36	1.505E-03	1.505	1.505	
SO_4	96.06	2	84.93	8.841E-04	0.884	1.768	
NO_3	62.01	1	1.02	1.645E-05	0.016	0.016	
Cations-Anions	-	-	-	-	-	-	0.37
Cations+Anions	-	-	-	-	-	-	10.09
% Balance	-	-	-	-	-	-	3.64
Ionic Strength	-	-	-	-	-	-	0.01

RP-6-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	32.06	7.999E-04	0.800	1.600	
Mg	24.31	2	14.58	5.998E-04	0.600	1.200	
Na	22.99	1	71	3.088E-03	3.088	3.088	
K	39.1	1	21.4	5.473E-04	0.547	0.547	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	166	2.721E-03	2.721	2.721	
Cl	35.45	1	52.61	1.484E-03	1.484	1.484	
SO_4	96.06	2	86.6	9.015E-04	0.902	1.803	
NO_3	62.01	1	1.48	2.387E-05	0.024	0.024	
Cations-Anions	-	-	-	-	-	-	0.40
Cations+Anions	-	-	-	-	-	-	12.47
% Balance	-	-	-	-	-	-	3.23
Ionic Strength	-	-	-	-	-	-	0.01

RP-7-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	28.86	7.201E-04	0.720	1.440	
Mg	24.31	2	13.61	5.599E-04	0.560	1.120	
Na	22.99	1	65.2	2.836E-03	2.836	2.836	
K	39.1	1	18.6	4.757E-04	0.476	0.476	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	144	2.361E-03	2.361	2.361	
Cl	35.45	1	39.52	1.115E-03	1.115	1.115	
SO_4	96.06	2	81.14	8.447E-04	0.845	1.689	
NO_3	62.01	1	1.31	2.113E-05	0.021	0.021	
Cations-Anions	-	-	-	-	-	-	0.69
Cations+Anions	-	-	-	-	-	-	11.06
% Balance	-	-	-	-	-	-	6.20
Ionic Strength	-	-	-	-	-	-	0.01

RP-9-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	48.1	1.200E-03	1.200	2.400	
Mg	24.31	2	13.37	5.500E-04	0.550	1.100	
Na	22.99	1	104	4.524E-03	4.524	4.524	
K	39.1	1	30.8	7.877E-04	0.788	0.788	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	258	4.230E-03	4.230	4.230	
Cl	35.45	1	99.67	2.812E-03	2.812	2.812	
SO_4	96.06	2	76.99	8.015E-04	0.801	1.603	
NO_3	62.01	1	2.12	3.419E-05	0.034	0.034	
Cations-Anions	-	-	-	-	-	-	0.13
Cations+Anions	-	-	-	-	-	-	17.49
% Balance	-	-	-	-	-	-	0.76
Ionic Strength	-	-	-	-	-	-	0.02

RP-1-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	23.65	5.901E-04	0.590	1.180	
Mg	24.31	2	10.94	4.500E-04	0.450	0.900	
Na	22.99	1	33	1.435E-03	1.435	1.435	
K	39.1	1	12.6	3.223E-04	0.322	0.322	
CO_3	60	2	40	6.667E-04	0.667	1.333	
HCO_3	61	1	58	9.508E-04	0.951	0.951	
Cl	35.45	1	18.74	5.286E-04	0.529	0.529	
SO_4	96.06	2	56.85	5.918E-04	0.592	1.184	
NO_3	62.01	1	2.86	4.612E-05	0.046	0.046	
Cations-Anions	-	-	-	-	-	-	-0.20
Cations+Anions	-	-	-	-	-	-	7.88
% Balance	-	-	-	-	-	-	2.60
Ionic Strength	-	-	-	-	-	-	0.00

RP-6-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	36.09	9.004E-04	0.900	1.801	
Mg	24.31	2	13.37	5.500E-04	0.550	1.100	
Na	22.99	1	96	4.176E-03	4.176	4.176	
K	39.1	1	48.2	1.233E-03	1.233	1.233	
CO_3	60	2	2	3.333E-05	0.033	0.067	
HCO_3	61	1	400	6.557E-03	6.557	6.557	
Cl	35.45	1	101.22	2.855E-03	2.855	2.855	
SO_4	96.06	2	87.64	9.123E-04	0.912	1.825	
NO_3	62.01	1	14.26	2.300E-04	0.230	0.230	
Cations-Anions	-	-	-	-	-	-	-3.22
Cations+Anions	-	-	-	-	-	-	19.84
% Balance	-	-	-	-	-	-	16.25
Ionic Strength	-	-	-	-	-	-	0.03

RP-7-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	42.08	1.050E-03	1.050	2.100	
Mg	24.31	2	10.94	4.500E-04	0.450	0.900	
Na	22.99	1	94	4.089E-03	4.089	4.089	
K	39.1	1	35	8.951E-04	0.895	0.895	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	290	4.754E-03	4.754	4.754	
Cl	35.45	1	72.48	2.045E-03	2.045	2.045	
SO_4	96.06	2	85.46	8.897E-04	0.890	1.779	
NO_3	62.01	1	9.08	1.464E-04	0.146	0.146	
Cations-Anions	-	-	-	-	-	-	-0.74
Cations+Anions	-	-	-	-	-	-	16.71
% Balance	-	-	-	-	-	-	4.43
Ionic Strength	-	-	-	-	-	-	0.02

RP-9-June 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	56.11	1.400E-03	1.400	2.800	
Mg	24.31	2	17.01	6.997E-04	0.700	1.399	
Na	22.99	1	144	6.264E-03	6.264	6.264	
K	39.1	1	44.6	1.141E-03	1.141	1.141	
CO_3	60	2	8	1.333E-04	0.133	0.267	
HCO_3	61	1	404	6.623E-03	6.623	6.623	
Cl	35.45	1	149.95	4.230E-03	4.230	4.230	
SO_4	96.06	2	57.89	6.026E-04	0.603	1.205	
NO_3	62.01	1	10.58	1.706E-04	0.171	0.171	
Cations-Anions	-	-	-	-	-	-	-0.89
Cations+Anions	-	-	-	-	-	-	24.10
% Balance	-	-	-	-	-	-	3.70
Ionic Strength	-	-	-	-	-	-	0.04

CDV-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	6.81	1.699E-04	0.170	0.340	
Mg	24.31	2	28.1	1.156E-03	1.156	2.312	
Na	22.99	1	36	1.566E-03	1.566	1.566	
K	39.1	1	9.4	2.404E-04	0.240	0.240	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	130	2.131E-03	2.131	2.131	
Cl	35.45	1	25.4	7.165E-04	0.717	0.717	
SO_4	96.06	2	31.9	3.321E-04	0.332	0.664	
NO_3	62.01	1	2.07	3.338E-05	0.033	0.033	
Cations-Anions	-	-	-	-	-	-	0.91
Cations+Anions	-	-	-	-	-	-	8.00
% Balance	-	-	-	-	-	-	11.40
Ionic Strength	-	-	-	-	-	-	0.00

CDV-January 2009							
	FW	Charge	mg/L	mol/L	mmol/L	meq/L	
Ca	40.08	2	17.6	4.391E-04	0.439	0.878	
Mg	24.31	2	6.8	2.797E-04	0.280	0.559	
Na	22.99	1	18.2	7.916E-04	0.792	0.792	
K	39.1	1	6.4	1.637E-04	0.164	0.164	
CO_3	60	2	0	0.000E+00	0.000	0.000	
HCO_3	61	1	54	8.852E-04	0.885	0.885	
Cl	35.45	1	18	5.078E-04	0.508	0.508	
SO_4	96.06	2	32.2	3.352E-04	0.335	0.670	
NO_3	62.01	1	5.95	9.595E-05	0.096	0.096	
Cations-Anions	-	-	-	-	-	-	0.23
Cations+Anions	-	-	-	-	-	-	4.55
% Balance	-	-	-	-	-	-	5.13
Ionic Strength	-	-	-	-	-	-	0.00

Appendix E

Environmental Law 1333

REGLAMENTACION DE LA LEY Nº 1333
DEL MEDIO AMBIENTE
Reglamento en Materia de Contaminación Hídrica

TITULO I
DISPOSICIONES GENERALES

CAPITULO I
DEL OBJETO Y AMBITO DE APLICACION

ARTICULO 1º La presente disposición legal reglamenta la Ley del Medio Ambiente Nº 1333 del 27 de abril de 1992 en lo referente a la prevención y control de la contaminación hídrica, en el marco del desarrollo sostenible.

ARTICULO 2º El presente reglamento se aplicará a toda persona natural o colectiva, pública o privada, cuyas actividades industriales, comerciales, agropecuarias, domésticas, recreativas y otras, puedan causar contaminación de cualquier recurso hídrico.

CAPITULO II
DE LAS SIGLAS Y DEFINICIONES

ARTICULO 3º Para efectos de este reglamento, se adopta las siguientes siglas y definiciones:

a. Siglas:

LEY:	Ley del Medio Ambiente 1333, del 27 de abril de 1992.
MDSMA:	Ministerio de Desarrollo Sostenible y Medio Ambiente.
SNRNMA:	Secretaría Nacional de Recursos Naturales y Medio Ambiente.
SSMA:	Subsecretaría de Medio Ambiente.
DBO5:	Demanda Bioquímica de Oxigeno.
DCCA:	Dirección de Control de Calidad Ambiental.
DEIA:	Dirección de Evaluación de Impacto Ambiental.
DIA:	Declaratoria de Impacto Ambiental.
DQO:	Demanda Química de Oxigeno.
EEIA:	Estudio de Evaluación de Impacto Ambiental.
EIA:	Evaluación de Impacto Ambiental.
mg/I:	miligramos por litro.
OPS/OMS:	Organización Panamericana de la Salud/Organización Mundial de la Salud.
DAA:	Declaratoria de Adecuación Ambiental.
MA:	Manifiesto Ambiental.

b. Definiciones

ACUIFERO: Estructura geológica estratigráfica sedimentaria, cuyo volumen de poros está ocupado por agua en movimiento o estática.

AGUAS NATURALES: Aquéllas cuyas propiedades originales no han sido modificadas por la actividad humana; y se clasifican en:

a) superficiales, como aguas de lagos, lagunas, pantanos, arroyos con aguas permanentes y/o intermitentes, ríos y sus afluentes, nevados y glaciares;
b) subterráneas, en estado líquido o gaseoso que afloren de forma natural o por efecto de métodos artificiales;
c) meteóricas o atmosféricas, que provienen de lluvias de precipitación natural o artificial.

Las aguas naturales según su salinidad se clasifican como sigue:

TIPO DE AGUA	Sólidos Disueltos Totales en mg/l
Dulce	menor a 1.500
Salobre	desde 1.500 hasta 10.000
Salina	desde 10.000 hasta 34.000
Marina	desde 34.000 hasta 36.000
Hiperhalina	desde 36.000 hasta 70.000

AGUAS RESIDUALES CRUDAS: Aguas procedentes de usos domésticos, comerciales, agropecuarios y de procesos industriales, o una combinación de ellas, sin tratamiento posterior a su uso.

AGUAS RESIDUALES TRATADAS: Aguas procesadas en plantas de tratamiento para satisfacer los requisitos de calidad en relación a la clase de cuerpo receptor a que serán descargadas.

AUTORIDAD AMBIENTAL COMPETENTE: Ministerio de Desarrollo Sostenible y Medio Ambiente, MDSMA, a nivel nacional, y la Prefectura a nivel departamental.

AREA DE DESCARGA: Area de influencia directa de la descarga de aguas residuales crudas o tratadas a un cuerpo receptor que incluye a los puntos de descarga y de dilución o al sistema de drenaje o alcantarillado.

CICLO HIDROLOGICO: Sucesión de estados físicos de las aguas naturales: evaporación, condensación, precipitación pluvial, escorrentía superficial, infiltración subterránea, depósito en cuerpos superficiales y nuevamente evaporación.

CLASIFICACION: Establecimiento del nivel de calidad existente o el nivel a ser alcanzado y/o mantenido en un cuerpo de agua.

CONDICION: Calificación del nivel de calidad presentado por un cuerpo de agua, en un determinado momento, en términos de su aptitud de uso en correspondencia a su clase.

CONTAMINACION DE AGUAS: Alteración de las propiedades físico-químicas y/o biológicas del agua por sustancias ajenas, por encima o debajo de los límites máximos o mínimos permisibles, según corresponda, de modo que produzcan daños a la salud del hombre deteriorando su bienestar o su medio ambiente.

CUENCA: Zona geográfica que contribuye con la escorrentía de las aguas pluviales hacia un cauce natural.

CUENCAS DE CURSO SUCESIVO: Cuencas que nacen en un país, cruzan su territorio y continúan su curso a través de uno o más países.

CUERPO DE AGUA: Arroyos, ríos, lagos y acuíferos, que conforman el sistema hidrográfico de una zona geográfica.

CUERPO RECEPTOR: Medio donde se descargan aguas residuales crudas o tratadas.

DBO5: Demanda Bioquímica de Oxigeno (en mg/I). Es la cantidad de oxígeno necesaria para descomponer biológicamente la materia orgánica carbonácea. Se determina en laboratorio a una temperatura de 20º C y en 5 días.

DESCARGA: Vertido de aguas residuales crudas o tratadas en un cuerpo receptor.

DQO: Demanda Química de Oxígeno (en mg/I). Cantidad de oxigeno necesario para descomponer químicamente la materia orgánica e inorgánica. Se determina en laboratorio por un proceso de digestión en un lapso de 3 horas.

EFLUENTE CONTAMINADO: Toda descarga líquida que contenga cualquier forma de materia inorgánica y/u orgánica o energía, que no cumpla los límites establecidos en el presente reglamento.

EFLUENTE INDUSTRIAL: Aguas residuales crudas o tratadas provenientes de procesos industriales.

EFLUENTES HOSPITALARIOS: Descargas de aguas residuales crudas o tratadas procedentes de hospitales, clínicas o morgues.

EFLUENTE SANITARIO: Aguas residuales crudas o tratadas provenientes del uso doméstico.

EMERGENCIA HIDRICA: Aquélla que sobreviene a consecuencia de una situación extraordinaria en la condición de un cuerpo de agua.

FANGOS O LODOS: Parte sólida que se produce, decanta o sedimenta durante el tratamiento de aguas.

INFORME DE CARACTERIZACION: Informe de un laboratorio de servicio autorizado sobre los resultados de los análisis de una muestra de agua.

LABORATORIO AUTORIZADO: Laboratorio que ha obtenido la acreditación del MDSMA para efectuar análisis físico-químicos y biológicos de las aguas naturales, aguas residuales, cuerpos receptores y otros necesarios para el control de la calidad del agua.

LIMITE PERMISIBLE: Concentración máxima o mínima permitida, según corresponda, de un elemento, compuesto o microorganismo en el agua, para preservar la salud y el bienestar humanos y el equilibrio ecológico, en concordancia con las clases establecidas.

LIXIVIADOS: Liquido resultante del proceso de disolución de los metales, por efecto de la lluvia y agentes químicos y/o biológicos.

MEDIDORES INDIRECTOS DE CAUDAL: Escalas con las que se mide el tirante del agua en el canal de sección triangular, trapezoidal o rectangular, permitiendo definir por cálculo, mediante una fórmula hidráulica previamente establecida, el caudal correspondiente.

MONITOREO: Evaluación sistemática cualitativa y cuantitativa de la calidad del agua.

NAPA FREATICA: Acuífero más cercano a la superficie del suelo.

NIVEL PIEZOMETRICO: Profundidad a la que se encuentra el nivel del agua en un pozo.

ORGANISMOS SECTORIALES COMPETENTES: Ministerios vinculados con el medio ambiente que representan a sectores de la actividad nacional.

POZO PROFUNDO: Pozo excavado mecánicamente y luego entubado, del que se extrae agua en forma mecánica desde cualquier profundidad.

POZO SOMERO: Pozo de agua generalmente excavado a mano, que sirve para obtener agua del nivel freático, principalmente para usos domésticos.

PREFECTO: El Ejecutivo a nivel departamental.

PUNTO SIN IMPACTO: Punto fuera del área de descarga en un curso de agua, aguas arriba, donde no existe impacto de la descarga de aguas residuales crudas o tratadas.

RECURSO HIDRICO: Cuerpo de agua que cumple con los límites establecidos para cualesquiera de las clases A, B, C o D.

REPRESENTANTE LEGAL: Persona natural o colectiva, pública o privada, que solicita una autorización relativa a un proyecto, obra o actividad, respecto a todas sus fases, en materia ambiental.

PREVENCION: Disposiciones y medidas anticipadas para evitar el deterioro de la calidad del agua.

REUSO: Utilización de aguas residuales tratadas que cumplan la calidad requerida por el presente Reglamento.

SISTEMA DE ALCANTARILLADO SEPARADO: Sistema de redes en que las aguas residuales son colectadas separadamente de las aguas pluviales.

SISTEMA DE ALCANTARILLADO UNITARIO: Aquél en el que las aguas residuales son colectadas juntamente con las aguas pluviales.

SOLIDOS SEDIMENTABLES: Volumen que ocupan las partículas sólidas contenidas en un volumen definido de agua, decantadas en dos horas; su valor se mide en mililitros por litro (ml/l).

SOLIDOS SUSPENDIDOS TOTALES: Peso de las partículas sólidas suspendidas en un volumen de agua, retenidas en papel filtro Nº 42.

TRATAMIENTO: Proceso físico, químico y/o biológico que modifica alguna propiedad física, química y/o biológica del agua residual cruda.

CAPITULO III
DE LA CLASIFICACION DE CUERPOS DE AGUAS

ARTICULO 4º La clasificación de los cuerpos de agua, según las clases señaladas en el Cuadro Nº 1 - Anexo A del presente reglamento, basada en su aptitud de uso y de acuerdo con las políticas ambientales del país en el marco del desarrollo sostenible, será determinada por el MDSMA. Para ello, las instancias ambientales dependientes del prefecto deberán proponer una clasificación, adjuntando la documentación suficiente para comprobar la pertinencia de dicha clasificación. Esta documentación contendrá como mínimo: Análisis de aguas del curso receptor a ser clasificado, que incluya al menos los parámetros básicos, fotografías que documenten el uso actual del cuerpo receptor, investigación de las condiciones de contaminación natural y actual por aguas residuales crudas o tratadas, condiciones biológicas, estudio de las fuentes contaminantes actuales y la probable evolución en el futuro en cuanto a la cantidad y calidad de las descargas.

Esta clasificación general de cuerpos de agua; en relación con su aptitud de uso, obedece a los siguientes lineamientos:

CLASE "A" Aguas naturales de máxima calidad, que las habilita como agua potable para consumo humano sin ningún tratamiento previo, o con simple desinfección bacteriológica en los casos necesarios verificados por laboratorio.

CLASE "B" Aguas de utilidad general, que para consumo humano requieren tratamiento físico y desinfección bacteriológica.

CLASE "C" Aguas de utilidad general, que para ser habilitadas para consumo humano requieren tratamiento físico-químico completo y desinfección bacteriológica.

CLASE "D" Aguas de calidad mínima, que para consumo humano, en los casos extremos de necesidad pública, requieren un proceso inicial de presedimentación, pues pueden tener una elevada turbiedad por elevado contenido de sólidos en suspensión, y luego tratamiento físico-químico completo y desinfección bacteriológica especial contra huevos y parásitos intestinales.

En caso de que la clasificación de un cuerpo de agua afecte la viabilidad económica de un establecimiento, el Representante Legal de éste podrá apelar dicha clasificación ante la autoridad ambiental competente, previa presentación del respectivo análisis costo - beneficio.

ARTICULO 5º Los límites máximos de parámetros permitidos en cuerpos de agua que so pueda utilizar como cuerpos receptores, son los indicados en el Cuadro Nº A-I del Anexo A de este Reglamento.

ARTICULO 6º Se considera como PARAMETROS BASICOS, los siguientes: DBO5; DQO; Colifecales NMP; Oxígeno Disuelto; Arsénico Total; Cadmio; Cianuros; Cromo Hexavalente; Fosfato Total; Mercurio; Plomo; Aldrín; Clordano; Dieldrín; DDT; Endrín; Malatión; Paratión.

ARTICULO 7º En la clasificación de los cuerpos de agua se permitirá que hasta veinte de los parámetros especificados en el Cuadro Nº A-1 superen los valores máximos admisibles indicados para la clase de agua que corresponda asignar al cuerpo, con las siguientes limitaciones:

lº Ninguno de los veinte parámetros puede pertenecer a los PARAMETROS BASICOS del Art. 6º.
2º El exceso no debe superar el 50% del valor máximo admisible del parámetro.

TITULO II
DEL MARCO INSTITUCIONAL

CAPITULO I
DEL MINISTERIO DE DESARROLLO SOSTENIBLE Y MEDIO AMBIENTE

ARTICULO 8º Las atribuciones y competencias del MDSMA corresponden a lo dispuesto por la Ley 1493, el D.S. 23630, el Reglamento General de Gestión Ambiental y otras disposiciones legales vigentes.

ARTICULO 9º Para efectos del presente reglamento, el MDSMA tendrá las siguientes funciones, atribuciones y competencias:

a) definir la política nacional para la prevención y control de la calidad hídrica;

b) coordinar con los Organismos Sectoriales Competentes, las Prefecturas, los gobiernos municipales y las instituciones involucradas en la temática ambiental, las acciones de prevención de la contaminación de los cuerpos de agua, saneamiento y control de la calidad de los recursos hídricos, así como las actividades técnicas ambientales;
c) emitir normas técnicas para la prevención y control de la contaminación hídrica, en coordinación con los Organismos Sectoriales y las Prefecturas;

d) velar por la aplicación de las normas técnicas para la prevención y control de la contaminación hídrica, en coordinación con los Organismos Sectoriales Competentes, Prefecturas y Gobiernos Municipales;

e) aprobar la clasificación de los cuerpos de agua a partir de su aptitud de uso propuesta por la Instancia Ambiental Dependiente de la Prefectura;

f) gestionar financiamiento para la aplicación de políticas de prevención y control de la contaminación hídrica;

g) revisar cada 5 años los límites máximos permisibles de los parámetros indicados en el Anexo A del presente reglamento, en coordinación con los Organismos Sectoriales Competentes; cualquier modificación se basará en la comprobación de la eficiencia de las acciones y tratamientos encontrados y propuestos en la práctica nacional y/o en tecnologías disponibles, guías de la OPS/OMS y normas sobre procesos y productos;

h) recibir información sobre el otorgamiento de permisos de descarga de aguas residuales crudas o tratadas;

i) autorizar y cancelar las licencias de los laboratorios para los fines de este Reglamento conforme a regulaciones específicas;

j) levantar y mantener un inventario de los recursos hídricos referido a la cantidad y calidad de todos los cuerpos de agua a nivel nacional a fin de determinar su estado natural y actual;

k) promover la investigación de métodos de tratamiento para la eliminación o reducción de contaminantes químicos y biológicos.

CAPITULO II
DE LA AUTORIDAD A NIVEL DEPARTAMENTAL

ARTICULO 10º Para efectos del presente Reglamento y a nivel departamental, el Prefecto tendrá las siguientes atribuciones y funciones:

a) ejecutar las acciones de prevención de la contaminación de los cuerpos de agua, saneamiento y control de la calidad de los recursos hídricos, así como las actividades técnicas ambientales en coordinación con los Organismos Sectoriales Competentes y los Gobiernos Municipales;
b) establecer objetivos en materia de calidad del recurso hídrico;
c) identificar las principales fuentes de contaminación, tales como las descargas de aguas residuales, los rellenos sanitarios activos e inactivos, las escorias y desmontes mineros, los escurrimientos de áreas agrícolas, las áreas geográficas de intensa erosión de los suelos y las de inundación masiva;
d) proponer al MDSMA la clasificación de los cuerpos de agua en función de su aptitud de uso;
e) otorgar los permisos de descarga de aguas residuales crudas o tratadas;
f) aprobar el reuso, por el mismo usuario, de aguas residuales crudas o tratadas, descargadas al cuerpo receptor;
g) levantar y mantener un inventario de los recursos hídricos referido a la cantidad y calidad de todos los cuerpos de agua a nivel departamental, a fin de determinar sus estados natural y actual;
h) dar aviso al MDSMA y coordinar con Defensa Civil en casos.que ameriten una declaratoria de emergencia hídrica a nivel departamental por deterioro de la calidad hídrica.

CAPITULO III
DE LOS GOBIERNOS MUNICIPALES

ARTICULO 11º Los Gobiernos Municipales, para el ejercicio de las atribuciones y competencias que les reconoce la ley en la presente materia, deberán, dentro del ámbito de su jurisdicción territorial:

a) realizar acciones de prevención y control de la contaminación hídrica, en el marco de los lineamentos, políticas y normas nacionales;
b) identificar las fuentes de contaminación, tales como las descargas residuales, los rellenos sanitarios activos e inactivos, escorias metalúrgicas, colas y desmontes mineros, escurrimientos de áreas agrícolas, áreas geográficas de intensa erosión de suelos y/o de inundación masiva, informando al respecto al Prefecto;
c) proponer al Prefecto la clasificación de los cuerpos de agua en función a su aptitud de uso;
d) controlar las descargas de aguas residuales crudas o tratadas a los cuerpos receptores;
e) dar aviso al Prefecto y coordinar con Defensa Civil en casos que ameriten una emergencia hídrica, a nivel local por deterioro de la calidad hídrica.

CAPITULO IV
DE LOS ORGANISMOS SECTORIALES COMPENTES

ARTICULO 12º Los Organismos Sectoriales Competentes, en coordinación con el MDSMA y el Prefecto, participarán en la prevención y control de la calidad hídrica mediante propuestas relacionadas con:

a) normas técnicas sobre límites permisibles en la materia de su competencia;
b) políticas ambientales para el sector en materia de contaminación hídrica, las mismas que formarán parte de la política general del sector y de la política ambiental nacional;
c) planes sectoriales y multisectoriales considerando la prevención y el control de la calidad hídrica.

TITULO III
DE LOS PROCEDIMIENTOS TECNICO ADMINISTRATIVOS

CAPITULO I
DE LA INSPECCION Y VIGILANCIA

ARTICULO 13º La Autoridad Ambiental Competente realizará inspecciones sistemáticas de acuerdo con el Reglamento de Prevención y Control Ambiental.

Las inspecciones incluirán monitoreo de las descargas de aguas residuales crudas o tratadas para verificar si los informes de caracterización a los que hace referencia el presente Reglamento son representativos de la calidad de las descargas.

CAPITULO II
DE LOS SERVICIOS MUNICIPALES Y COOPERATIVAS DE ABASTECIMIENTO DE AGUA POTABLE Y ALCANTARILLADO

ARTICULO 14º Los Servicios de Abastecimiento de Agua Potable y Alcantarillado que existen actualmente como servicios municipales o cooperativas, o los que se crearán en el futuro, y las administraciones de parques industriales de jurisdicción municipal:

a) elaborarán procedimientos técnicos y administrativos dentro del primer año de vigencia del presente Reglamento, para establecer convenios con las industrias, instituciones y empresas de servicio que descarguen sus aguas residuales crudas y/o tratadas en los colectores sanitarios de su propiedad o que estén bajo su control;

b) por tales convenios técnicos y administrativos, los servicios de abastecimiento de agua potable y alcantarillado asumen la responsabilidad del tratamiento de las aguas residuales bajo las condiciones que consideren necesarias, tomando en cuenta el tipo de su planta de tratamiento y las características del cuerpo receptor donde se descarga;

c) los acuerdos incluirán, sin perjuicio de la legislación sobre agua potable y alcantarillado y este Reglamento, los siguientes aspectos:

- identificación de los puntos de descarga de efluentes, volúmenes, composición, concentración y frecuencia;

- pretratamiento a aplicar antes de la descarga;

- estructura de tarifas y costos a pagar por el usuario;

- el sistema de monitoreo, incluyendo registros, medidores e inspecciones.

ARTICULO 15º Los procedimientos técnico-administrativos referidos en el anterior artículo deberán definir los métodos de cálculo de las tasas y tarifas por descargas de aguas residuales de las industrias e instituciones, tomando en cuenta lo establecido en el Reglamento Nacional de Prestación de Servicios de Agua Potable y Alcantarillado para Centros Urbanos.

CAPITULO III
DE LA DESCARGA DE EFLUENTES EN CUERPOS DE AGUA

ARTICULO 16º La autorización para descargar efluentes en cuerpos de agua, estará incluida en la DIA, en la DAA y en el Certificado de Dispensación establecidos en el Reglamento de Prevención y Control Ambiental.

ARTICULO 17º La DIA, la DAA y el Certificado de Dispensación incluirán la obligación del REPRESENTANTE LEGAL de presentar semestralmente a la Autoridad Ambiental Competente un informe de caracterización de aguas residuales crudas o tratadas emitido por un laboratorio autorizado, y de enviar al mismo tiempo una copia de dicho informe al Organismo Sectorial Competente. El informe deberá caracterizar aquellos parámetros para los que fija límites permisibles el Anexo A del presente Reglamento y que están directamente relacionados con la actividad y definidos por el Organismo Sectorial Competente en coordinación con el MDSMA.

ARTICULO 18º La revisión y aprobación del MA se efectuará de acuerdo con lo establecido en el Reglamento de Prevención y Control Ambiental.

CAPITULO IV
DE LAS DESCARGAS DE AGUAS RESIDUALES A LOS SISTEMAS DE ALCANTARILLADO

ARTICULO 19º Las obras, proyectos y actividades que estén descargando o planeen descargar aguas residuales a los colectores del alcantarillado sanitario de los Servicios de Abastecimiento de Agua Potable y Alcantarillado o de parques industriales, no requerirán permiso de descarga ni la presentación del informe de caracterización, en las siguientes situaciones:

a) las obras, proyectos o actividades en proceso de operación o implementación deberán incluir, en el MA fotocopia legalizada del contrato de descarga a los colectores sanitarios suscrito con los Servicios de Abastecimiento de Agua Potable y Alcantarillado o administraciones de parques industriales correspondientes;

b) las obras, proyectos o actividades que planeen descargar sus aguas residuales en el alcantarillado sanitario de un Servicio de Abastecimiento de Agua Potable y Alcantarillado o parque industrial, deberán cumplir en su EEIA, en lo que fuese aplicable la reglamentación de descarga vigente en la ciudad donde estarán ubicados.

ARTICULO 20º La presentación de medidas de mitigación en el MA y la caracterización de las descargas de aguas residuales crudas o tratadas, no serán exigidas a las industrias que hayan firmado contratos para descargar a los colectores de los Servicios de Abastecimiento de Agua Potable y Alcantarillado o de las administraciones de parques industriales, respectivamente.

ARTICULO 21º Las obras o proyectos que planeen descargar sus aguas residuales crudas o tratadas a los colectores de alcantarilíado sanitario de los Servicios de Abastecimiento de Agua Potable y Alcantarillado, o de parques industriales, deberán cumplir en su EEIA con las previsiones de pretratamiento vigentes en la ciudad correspondiente.

ARTICULO 22º Los Servicios de Abastecimiento de Agua Potable y Alcantarillado o las administraciones de parques industriales deben presentar anualmente al Prefecto, listas en forma de planillas de las industrias que descargan a sus colectores, con la siguiente información:

a) nombre o razón social de la industria;
b) fecha del contrato de la descarga de agua residual;
c) ubicación;
d) número de obreros y turnos de trabajo;
e) materia prima usada;
f) productos fabricados;
g) pretratamiento usado de las aguas residuales antes de su descarga. h)
h) sistema de medición del efluente;
i) volumen promedio mensual descargado;
j) kilogramos de DBO descargados como promedio mensual;
k) kilogramos de sólidos suspendidos totales descargados como promedio mensual;
1) kilogramos de DQO descargados como promedio mensual;
m) cantidad mensual de agentes conservativos descargados.

ARTICULO 23º Las descargas de aguas residuales crudas o tratadas a los colectores de alcantarillado sanitario serán aceptables si a juicio del correspondiente Servicio de Abastecimiento de Agua Potable y Alcantarillado o la administración del parque industrial no interfieren los procesos de tratamiento de la planta ni perjudican a los colectores sanitarios; con los criterios a aplicar en cuanto a los límites de calidad de las descargas serán los siguientes:

a) en caso de parques industriales con plantas de tratamiento en operación, los límites de calidad de las descargas industriales a los colectores del parque serán fijados por su administración, velando por que no interfieran con los procesos de tratamiento ni perjudiquen a los colectores sanitarios;

b) para los casos de parques industriales sin plantas de tratamiento, que descargan a los colectores del alcantarillado sanitario, los limites de calidad serán fijados por la Administración del Servicio de Abastecimiento de Agua y Alcantarillado, propietaria de los colectores.

ARTICULO 24º Se prohíbe toda conexión cruzada, por lo que:

a) en sistemas de alcantarillado separados queda prohibida toda descarga de aguas residuales, crudas o tratadas, en forma directa o indirecta a los colectores del alcantarillado pluvial, y

b) en sistemas de alcantarillado separados, no se permite ninguna descarga de aguas pluviales provenientes de techos y/o patios, en forma directa o indirecta, a los colectores del alcantarillado sanitario.

ARTICULO 25º   En caso de que existan descargas de aguas pluviales a los colectores sanitarios o de aguas residuales a los colectores pluviales, los infractores, deberán corregir esta anomalía dentro del plazo de un año.

ARTICULO 26º Los Servicios de Abastecimiento de Agua Potable y Alcantarillado y las administraciones de los parques industriales, luego de cumplido el plazo de un año, podrán inspeccionar y verificar la existencia de las conexiones a que se refiere el Art. 25º en edificios públicos, privados e industriales.

ARTICULO 27º Comprobada la existencia de las conexiones ilegales a que se refiere el Art. 25º, el propietario tendrá 60 días de plazo perentorio para corregirlas, pasado el cual se le impondrá una sanción conforme a lo establecido en el Título V del presente Reglamento.

ARTICULO 28º   Quedan prohibidas las descargas de materiales radioactivos procedentes de uso médico o industrial a los colectores de alcantarillados o a los cuerpos de agua, por encima de los límites permisibles dispuestos en este Reglamento.

Las contravenciones serán sancionadas conforme al Art. 71 del presente Reglamento, sin perjuicio de las responsabilidades civiles y penales que correspondan.

ARTICULO 29º Las tasas y tarifas por descarga de las aguas residuales crudas o tratadas a los colectores serán calculadas por los Servicios de Abastecimiento de Agua Potable y Alcantarillado y las administraciones de parques industriales, en relación al volumen de agua, la DBO5 y los sólidos suspendidos totales, tomando en cuenta las siguientes condiciones:

a) las aguas residuales tienen, como promedio, una DBO5 de 250 mg/l y los sólidos suspendidos totales una concentración de 200 mg/l. Las descargas de agua residual con concentraciones mayores a estas cifras, estarán sujetas a una tarifa adicional en relación a las cargas en toneladas por mes, tanto de DBO5 como de sólidos suspendidos totales. Dichas tarifas serán calculadas por los Servicios de Abastecimiento de Agua Potable y Alcantarillado correspondientes;

b) teniendo en cuenta que ciertos metales pueden degradar los fangos o lodos haciéndolos no aptos para el uso agrícola, los Servicios de Abastecimiento de Agua Potable y Alcantarillado y las administraciones de parques industriales podrán imponer tasas adicionales o limitar las descargas de los siguientes elementos: arsénico, cadmio, cromo +6 y cromo +3, cobre, plomo, mercurio, níquel y zinc. Las condiciones indicadas en los incisos precedentes, serán definidas en los procedimientos administrativos de los Servicios de Abastecimiento de Agua Potable y Alcantarillado o las administraciones de parques industriales, y estipuladas en los contratos con las empresas.

TITULO IV
DEL MONITOREO, EVALUACION, PREVENCION, PROTECCION Y CONSERVACION DE LA CALIDAD HíDRICA

CAPITULO I
DEL MONITOREO Y EVALUACION DE LA CALIDAD HIDRICA

ARTICULO 30º El MDSMA y el Prefecto, con el personal de los laboratorios autorizados, efectuarán semestralmente el monitoreo de los cuerpos receptores y de las descargas de aguas residuales crudas o tratadas, tomando muestras compuestas de acuerdo con lo estipulado en el Reglamento de Prevención y Control Ambiental, en relación al caudal y durante las horas de máxima producción. Los resultados de los análisis serán presentados al REPRESENTANTE LEGAL.

En caso de que uno o más parámetros excedan los límites establecidos en el presente reglamento, se procederá a la toma de una segunda muestra en similares condiciones y con la intervención del REPRESENTANTE LEGAL o delegado de éste, según los resultados del análisis se tomará una de las siguientes decisiones:

a) si los resultados dan valores que no exceden los límites establecidos, se dará por terminada la investigación;

b) en caso de que los resultados reiteren lo encontrado en el primer análisis, el Prefecto con jurisdicción sobre la cuenca correspondiente fijará día y hora para inspeccionar la planta de tratamiento a fin de definir la posible causa de tales resultados; la inspección se realizará de acuerdo a los prncedimientos establecidos en el Reglamento de Prevención y Control.

ARTICULO 31º Para realizar la inspección indicada en el articulo anterior, el REPRESENTANTE LEGAL deberá permitir el acceso al representante de la Prefectura con el fin de que verifique si:

a) existen cambios en la estructura de la planta de tratamiento;

b) existen cambios en los métodos de operación y mantenimiento, o

c) existen otras condiciones de cambio, sea por reemplazo de materia prima o equipos.

En estos casos, la industria está en la obligación de corregir las diferencias existentes en un plazo adecuado, fijado por la Autoridad Ambiental Competente.

ARTICULO 32º Los muestreos y análisis concernientes a las aguas residuales crudas o tratadas y a los subproductos que se generen durante el tratamiento de las mismas, deberán ser realizados por laboratorios autorizados.

ARTICULO 33º La información resultante de las actividades de revisión y aprobación de proyectos, construcción y operación de plantas de tratamiento de aguas residuales, así como de análisis, mediciones y registro de las descargas y evaluaciones que se practiquen, ingresará en una base de datos integrada y computarizada.

CAPITULO II
DE LA PREVENCION Y CONTROL DE LA CONTAMINACION Y CONSERVACION DE LA CALIDAD HIDRICA

ARTICULO 34º A los fines del Art. 33 de la LEY, la descarga de aguas residuales a la intemperie o a cuerpos de agua estará sujeta a autorización temporal o excepcional del Prefecto previo el estudio correspondiente, y será controlada minuciosamente en si es que:

a) contienen gases tóxicos y olores fuertes de procedencia ajena a las aguas residuales o sustancias capaces de producirlos;
b) contienen sustancias inflamables (gasolina, aceites, etc);
c) contienen residuos sólidos o fangos provenientes de plantas de tratamiento y otros;
d) contienen substancias que por su composición interfieran los procesos y operación propios de las plantas de tratamiento;
e) contienen plaguicidas, fertilizantes o sustancias radioactivas.

ARTICULO 35º Los valores máximos establecidos en la clasificación de aguas de los cuerpos receptores del Cuadro Nº A-1 no podrán ser excedidos en ningún caso con las descargas de aguas residuales crudas o tratadas una vez diluidas en las aguas del cuerpo receptor, con excepción de aquellos parámetros que durante la clasificación hayan excedido los valores del Cuadro Nº A-1, según especifica el Art. 7.

ARTICULO 36º - En caso de que un cuerpo de agua o sección de un cauce receptor tenga uno o más parámetros con valores mayores a los establecidos según su clase, la Instancia Ambiental Dependiente del Prefecto deberá investigar y determinar los factores que originan esta elevación, para la adopción de las acciones que mejor convengan, con ajuste a lo establecido en el Reglamento de Prevención y Control Ambiental.

ARTICULO 37º En los casos en que un cuerpo de agua tenga varias aptitudes de uso, los valores de los límites máximos permisibles para los parámetros indicados en el Anexo A se fijarán de acuerdo con la aptitud de uso más restrictiva del cuerpo de agua.

ARTICULO 38º Una vez que el MDSMA haya fijado la Clase de un determinado cuerpo de agua, en función de su aptitud de uso, ésta se mantendrá por un mínimo de cinco años.

ARTICULO 39º En caso de que se compruebe que los valores de uno o más parámetros de un cuerpo de agua son superiores a los determinados en la clase D, por causas naturales, o debido a la contaminación acumulada, ocasionada por actividades realizadas antes de la promulgación del presente reglamento (stocks de contaminación), las descargas se determinarán en base a estos valores y no a los indicados en el Anexo A.

ARTICULO 40º A efecto de controlar los escurrimientos de áreas agrícolas y la contaminación de los cuerpos receptores, los REPRESENTANTES LEGALES deberán informar al Prefecto los siguientes aspectos:

a) cantidad, tipos y clases de fertilizantes y herbicidas utilizados, así como los calendarios de los ciclos de producción y la periodicidad del uso de fertilizantes y plaguicidas;
b) los sistemas de riego y de drenaje utilizados;
c) efectos de los escurrimientos sobre los cuerpos receptores.

ARTICULO 41º Los responsables de la prevención de derrames de hidrocarburos o de cualesquiera de sus derivados están obligados a subsanar los efectos que puedan ocasionar tales derrames en los cuerpos receptores y a revisar sus planes de contingencias. Las Prefecturas tomarán acciones conducentes de acuerdo a los planes de contingencias.

ARTICULO 42º En caso de contaminación de cuerpos receptores o infiltración en el subsuelo por lixiviados provenientes del manejo de residuos sólidos o confinamiento de sustancias peligrosas, provenientes de la actividad, obra o proyecto, la Instancia Ambiental Dependiente de la Prefectura determinará que el REPRESENTANTE LEGAL implemente las medidas correctivas o de mitigación que resulten de la aplicación de los reglamentos ambientales correspondientes.

ARTICULO 43º Se prohíbe totalmente la descarga de aguas residuales provenientes de los procesos metalúrgicos de cianuración de minerales de oro y plata, lixiviación de minerales de oro y plata y de metales, a cuerpos superficiales de agua y a cuerpos subterráneos. En caso de que la precipitación sea mayor que la evaporación, y como consecuencia de ello se deban realizar descargas, éstas deberan cumplir los límites establecidos en el presente reglamento.

ARTICULO 44º En ningún caso se permitirá descargas instantáneas de gran volumen de aguas residuales crudas o tratadas, a ríos. Estas deberán estar reguladas de manera tal que su caudal máximo, en todo momento, será menor o igual a 1/3 (un tercio) del caudal del río o cuerpo receptor.

ARTICULO 45º Las descargas de aguas residuales crudas o tratadas que excedieren el 20% del caudal mínimo de un río, podrán excepcionalmente y previo estudio justificado ser autorizadas por el Prefecto, siempre que:

a) no causen problemas de erosión, perjuicios al curso del cuerpo receptor y/o daños a terceros;

b) el cuerpo receptor, luego de la descarga y un razonable proceso de mezcla, mantenga los parámetros que su clase establece.

ARTICULO 46º Todas las descargas a lagos de aguas residuales crudas o tratadas procedentes de usos domésticos, industriales, agrícolas, ganaderos o cualquier otra actividad que contamine eI agua, deberán ser tratadas previamente a su descarga hasta satisfacer la calidad establecida del cuerpo receptor.

ARTICULO 47º Todas las descargas de aguas residuales crudas o tratadas a ríos arroyos, procedentes de usos domésticos, industriales, agrícolas, ganaderos o de cualquier otra actividad que contamine el agua, deberán ser tratadas previamente a su descarga, si corresponde, para controlar la posibilidad de contaminación de los acuíferos por infiltración, teniendo en cuenta la posibilidad de que esos ríos y arroyos sirvan para usos recreacionales eventuales y otros que se pudieran dar a estas aguas. Para el efecto se deberá cumplir con lo siguiente:

a) en caso de arroyos, dichas aguas residuales crudas o tratadas deberán satisfacer los límites permisibles establecidos en el presente reglamento para el cuerpo receptor respectivo.

b) toda descarga de aguas residuales a ríos, cuyas características no satisfagan los límites de calidad definidos para su clase, deberá ser tratada de tal forma que, una vez diluida, satisfaga lo indicado en el Cuadro Nº 1 del presente reglamento;

c) cuando varias industrias situadas a menos de 100 metros de distancia una de la otra descarguen sus aguas residuales a un mismo tramo de río, la capacidad de dilución será distribuida proporcionalmente al caudal de descarga individual, considerando el caudal mínimo del río y como está descrito en el Art. 45 del presente Reglamento.

ARTICULO 48º El caudal de captación de agua y el caudal de descarga de aguas residuales crudas o tratadas deberán ser, como promedio diario, menores al 20% del caudal mínimo diario del río, con un periodo de retorno de 5 años.

ARTICULO 49º Los Servicios de Abastecimiento de Agua Potable y Alcantarillado desarrollarán programas permanentes de control, reparación y rehabilitación de las redes de agua y desague, a fin de eliminar el riesgo de conexiones cruzadas entre agua potable y alcantarillado, y de colapso de instalaciones en mal estado o antiguas, eligiendo materiales de tuberías con una vida útil de por lo menos 50 años, o bien utilizar materiales de la mejor calidad compatibilizados con la agresividad química del suelo y del agua.

ARTICULO 50º Las aguas residuales provenientes de centros urbanos requieren de tratamiento antes de su descarga en los cursos de agua o infiltración en los suelos, a cuyo efecto las empresas de Servicios de Abastecimiento de Agua Potable y Alcantarillado, cooperativas de servicio, comités de agua y administraciones de parques industriales con o sin plantas de tratamiento, deberán presentar el MA en un. plazo no mayor a un año, a partir de la entrada en vigencia del presente Reglamento, los estudios correspondientes. Estos estudios incluirán los sistemas de tratamiento y el reuso de aguas residuales, tendiendo a la conservación de su entorno ambiental.

ARTICULO 51º El MDSMA establecerá un régimen especial de protección para las zonas pantanosas o bofedales con el objeto de garantizar su conservación y funciones ecológicas y/o paisajísticas.

ARTICULO 52º Todos los pozos someros y profundos no utilizados, deberán ser cegados y taponados por sus propietarios antes de ser abandonados a fin de evitar accidentes y riesgo de contaminación de las aguas subterráneas.

ARTICULO 53º En caso de que las condiciones fisicas y/o químicas.de un cuerpo de agua se alteren en forma tal que amenacen la vida humana o las condiciones del medio ambiente, el Prefecto informará al MDSMA a objeto de que éste, conjuntamente las autoridades de Defensa Civil, disponga con carácter de urgencia las medidas correspondientes de corrección o mitigación.

CAPITULO III
DE LOS SISTEMAS bE TRATAMIENTO

ARTICULO 54º Todo sistema de tratamiento de aguas residuales estará bajo la total responsabilidad y vigilancia de su REPRESENTANTE LEGAL.

ARTICULO 55º   Si la Instancia Ambiental Dependiente de la Prefectura detecta que en el funcionamiento de un sistema o planta de tratamiento se están incumpliendo las condiciones inicialmente aceptadas para dicho funcionamiento, conminará al REPRESENTANTE LEGAL a modificar, ampliar y/o tomar cualquier medida, sea en la estructura de la planta de tratamiento o en los procedimientos de operación y mantenimiento, para subsanar las deficiencias.

ARTICULO 56º   Las ampliaciones en más del treinta y tres por ciento de la capacidad instalada de una planta de tratamiento de aguas residuales que hubiera sido aprobada, y que impliquen impactos negativos significativos al medio ambiente, deberán contar nuevamente con su correspondiente Ficha Ambiental y el correspondiente proceso de EIA.

ARTICULO 57º   Para evitar el riesgo de contaminación, queda prohibido el acceso de personas no autorizadas a las instalaciones de las plantas de tratamiento debiéndose también tomar las medidas que el caso aconseje a fin de evitar que animales pueda llegar hasta dichas instalaciones.

ARTICULO 58º   Los REPRESENTANTES LEGALES de distintos establecimientos podrán construir y/o utilizar obras externas y/o sistemas de tratamiento de forma individual y/o colectiva cuando las necesidades así lo requieran. Cada REPRESENTANTE LEGAL será responsable por sus instalaciones en particular, y proporcionalmente, con sus otros asociados, en lo que respecta a sus obligaciones y derechos en plantas de tratamiento colectivas sujetas a contrato entre partes.

ARTICULO 59º   Las aguas residuales tratadas descargadas a un cuerpo receptor, estarán obligatoriamente sujetas -como parte del sistema o planta de tratamiento- a medición mediante medidores indirectos de caudal, silos caudales promedios diarios son menores a 5 litros por segundo y con medidores de caudal instantáneo y registradores de los volúmenes acumulados de descarga, si el caudal promedio supera la cifra señalada.

ARTICULO 60º En caso de que se interrumpa temporalmente la operación total o parcial del sistema o planta de tratamiento, se deberá dar aviso inmediato a la correspondiente Prefectura, especificando las causas y solicitando autorización para descargar el agua residual cruda o parcialmente tratada, por un tiempo definido. Además, se deberá presentar un cronograma de reparaciones o cambios para que la planta vuelva a su funcionamiento normal en el plazo más breve posible.

ARTICULO 61º   Para efectos del articulo precedente, en lo referente a aguas parcialmente tratadas, el Prefecto autorizará el funcionamiento condicionado del Sistema o Planta siempre y cuando se garantice que la descarga, una vez diluida, no exceda los limites máximos permisibles correspondientes a la clase del cuerpo receptor o no interfiera con los procesos de tratamiento cuando se descargue a un colector sanitario.

Con este fin, se establece:

a) en forma previa a la autorización del MDSMA, el tiempo de duración de la descarga será revisado por la Instancia Ambiental Dependiente de la Prefectura, el Servicio de Abastecimiento de Agua Potable y Alcantarillado o la administración del parque industrial, según corresponda, luego de inspeccionar la planta de tratamiento y los procesos que producen las condiciones anormales así como el cronograma propuesto;

b) si al exceder los límites máximos permisibles existe peligro inminente para la salud pública y el medio ambiente el Prefecto rechazará la solicitud de descarga y ordenará de inmediato las medidas de seguridad que correspondan.

ARTICULO 62º   La desinfección de las aguas residuales crudas o tratadas es imprescindible cuando la calidad bacteriológica de esas aguas rebasa los límites establecidos y constituye riesgo de daño a la salud humana o contaminación ambiental.

CAPITULO IV
DE LA CONSERVACION DE LAS AGUAS SUBTERRANEAS

ARTICULO 63º   La extracción y recarga de aguas subterráneas con calidad para el consumo humano -Clase A- por medio de pozos profundos, requerirá de la DIA o DAA en los siguientes casos:

a) la realización de proyectos u obras nuevas que signifiquen la descarga de residuos sólidos, líquidos o gaseosos que puedan contaminar por infiltración las aguas subterráneas, o que se descarguen directamente a los acuíferos;

b) las inyecciones de efluentes tratados en el subsuelo, que pudieran sobrepasar la recarga natural del acuífero poniendo en peligro su calidad físico-química o su subsistencia;

c) la realización de proyectos de riego que signifiquen regulación y aporte de aguas cuya infiltración en el suelo pueda afectar el nivel piezométrico de la napa freática, produciendo empantanamiento o salinización de los suelos;

d) la perforación de pozos y explotación de aguas subterráneas en zonas donde exista contacto con aguas salinas que puedan contaminar los acuíferos para consumo humano o que puedan provocar su fuga a estratos permeables;

e) cualquier otra actividad que el MDSMA identifique como peligrosa a los fines de la protección de la calidad de las aguas subterráneas para consumo humano.

ARTICULO 64º   Para la recarga directa o inyección de aguas residuales crudas o tratadas en acuíferos, estas aguas deben cumplir con los límites máximos permisibles establecidos para la clase del acuífero. En los acuíferos en los que en forma natural uno o más parámetros excedan en más del 50% los límites máximos permisibles, la calidad del agua residual, cruda o tratada, deberá en lo referente a los parámetros excedidos ser inferior a la del acuífero.

ARTICULO 65º Los pozos someros para uso doméstico familiar no están sujetos al control establecido en el presente Reglamento, siendo el control de calidad del agua para consumo humano responsabilidad de las autoridades de salud correspondientes.

ARTICULO 66º La recarga de aguas subterráneas de clase A por infiltración de aguas residuales crudas o tratadas, debe cumplir con los límites máximos permisibles establecidos para esta clase, a menos que se demuestre que la descarga de agua de una clase inferior no afecte la calidad de las aguas subterráneas.

CAPITULO V
DEL REUSO DE AGUAS

ARTICULO 67º El reuso de aguas residuales crudas o tratadas por terceros, será autorizado por el Prefecto cuando el interesado demuestre que estas aguas satisfacen las condiciones de calidad establecidas en el cuadro Nº 1 -Anexo A- del presente Reglamento.

ARTICULO 68º Los fangos o lodos producidos en las plantas de tratamiento de aguas residuales que hayan sido secados en lagunas de evaporación, lechos de secado o por medios mecánicos, serán analizados y en caso de que satisfagan lo establecido para uso agrícola, deberán ser estabilizados antes de su uso o disposición final, todo bajo control de la Prefectura.

CAPITULO VI
DE LA CONTAMINACION DE CUENCAS DE CURSO SUCESIVO

ARTICULO 69º Las Autoridades Ambientales Competentes o la Instancia Ambiental Dependiente de la Prefectura, deberán respetar el régimen particular de internacionalización relativo a cuencas de curso sucesivo, establecido entre los paises vecinos, para lograr y/o mantener el aprovechamiento sostenible respectivo.

ARTICULO 70º En ausencia de tratados de cooperación sobre aprovechamiento de cuencas, se deberá mantener el principio de comunidad para el aprovechamiento de los ríos de curso sucesivo o contiguos, siempre que las descargas de aguas residuales no produzcan deterioro en la calidad de las aguas de dichos cauces.

TITULO V
DE LAS INFRACCIONES Y SANCIONES ADMINISTRATIVAS

CAPITULO UNICO

ARTICULO 71º Según lo dispuesto por el Art. 99 de la LEY y el Título IX, Capítulo I, del Reglamento General de Gestión Ambiental, se establecen las siguientes infracciones administrativas:

a) alterar o modificar, temporal o permanentemente, las plantas de tratamiento, al no cumplir lo dispuesto por los Arts. 56 y 57, según corresponda;

b) sobrepasar los valores máximos admisibles establecidos en el Cuadro Nº A-1 del ANEXO A de este Reglamento, por efecto de descargas de aguas residuales crudas o tratadas, una vez diluidas en el cuerpo receptor y transcurrido el plazo de adecuación, si corresponde;

c) descargar sustancias radioactivas a los colectores sanitarios y/o cuerpos de agua;

d) no dar aviso a la autoridad ambiental competente de fallas que interrumpan parcial o totalmente la operación de las plantas de tratamiento;

e) descargar aguas residuales, crudas o tratadas, sin obtener el Permiso de Descarga correspondiente;

f) descargar aguas residuales, crudas o tratadas, al margen de las condiciones establecidas en el Permiso de Descarga;

g) descargar masiva e instantáneamente de aguas residuales, crudas o tratadas, a los ríos;

h) descargar de aguas de lluvia a los colectores sanitarios, o aguas residuales, crudas o tratadas, a los colectores pluviales;

i) no cegar los pozos que no sean utilizados, según lo dispuesto en el Art. 52;
j) contaminar cuerpos de agua por derrame de hidrocarburos;
k) presentar el informe de caracterización de las aguas residuales, crudas o tratadas, con datos falsos;
1) presentar el informe de caracterización de las aguas residuales, crudas o tratadas, fuera de los plazos previstos.

TITULO VI
DISPOSICIONES TRANSITORIAS

CAPITULO UNICO

ARTICULO 72º En tanto sean definidas las Clases de los cuerpos receptores a las que hacen referencia los Art. 4, 5, 6 y 7 del presente reglamento, regirán los parámetros y sus respectivos valores limite, incluidos en el Anexo A-2. Una vez determinada la Clase de un determinado cuerpo de agua, se aplicará los criterios de evaluación de impacto ambiental y adecuación ambiental , en base a los límites establecidos en el Cuadro A-1 - Anexo A del presente reglamento.

Para ello se debe distinguir entre actividades existentes a la fecha de promulgación del presente reglamento y aquellas nuevas, de la siguiente forma:

I. ACTIVIDADES OBRAS Y PROYECTOS EXISTENTES A LA FECHA DE PROMULGACION DEL PRESENTE REGLAMENTO

a) Las actividades obras y proyectos existentes a la fecha de promulgación del presente reglamento, en tanto no se cuente con la Clase del respectivo cuerpo de agua y una vez presentado el MA y emitida la DAA, se regirán por los parámetros y sus respectivos valores límite incluidos en el Anexo A-2, durante 5 años a partir de la fecha de emisión de la DAA.

b) Cumplido el plazo señalado y una vez se cuente con la Clase del respectivo cuerpo de agua, deberá presentar un nuevo MA, específico para el componente agua, en el que establecerá los mecanismos para alcanzar las metas de calidad ambiental, definidas por la Clase del cuerpo de aguas al que se realiza, las descargas. Como consecuencia de este nuevo MA, la autoridad ambiental competente emitirá una DAA renovada, con ajuste a los procedimientos establecidos en el Reglamento de Prevención y Control Ambiental para la evaluación y aprobación de MAs. Esta segunda adecuación ambiental deberá ser efectivizada en el plazo máximo de cinco años a partir de la fecha de emisión de la DAA renovada.

c) Opcionalmente, el Representante Legal de la actividad, obra o proyecto, que, una vez establecida la Clase del respectivo cuerpo receptor, desee adecuarse a los criterios de calidad Ambiental, antes de los cinco años citados en el inciso a) podrá hacerlo y será beneficiado con los programas de incentivos que desarrollará el MDSMA en coordinación con la Secretaria Nacional de Hacienda.

II. ACTIVIDADES OBRAS Y PROYECTOS QUE SE INICIARAN CON POSTERIORIDAD A LA FECHA DE PROMULGACION DEL PRESENTE REGLAMENTO

a) Las actividades obras y proyectos que se iniciaran con posterioridad a la fecha de promulgación del presente reglamento, en tanto no se cuente con la Clase del respectivo cuerpo de agua y una vez emitido el CDD o la DIA, se regirán por los parámetros y sus respectivos valores límite incluidos en el Anexo A-2, durante 5 años a partir de la fecha de emisión de las citadas licencias ambientales.

b) Cumplido el plazo señalado y una vez se cuente con la Clase del respectivo cuerpo de agua, deberá presentar un MA, específico para el componente agua, en el que establecerá los mecanismos para alcanzar las metas de calidad ambiental, definidas por la Clase del cuerpo de aguas al que se realiza las descargas. Como consecuencia de este MA, la autoridad ambiental competente emitirá una DAA, con ajuste a los procedimientos establecidos en el Reglamento de Prevención y Control Ambiental para la evaluación y aprobación de MAs. La adecuación ambiental respectiva deberá ser efectivizada en el plazo máximo de cinco años a partir de la fecha de emisión de la DAA.

Opcionalmente, el Representante Legal de la actividad, obra o proyecto, que, una vez establecida la Clase del respectivo cuerpo receptor, desee adecuarse a los criterios de calidad Ambiental, antes de los cinco años citados en los incisos Ia) y Iia) podrá hacerlo y será beneficiado con los programas de incentivos que desarrollará el MDSMA en coordinación con la Secretaria Nacional de Hacienda.

ARTICULO 73º Mientras se nomine los laboratorios autorizados, los informes de caracterización de aguas residuales, referidos en este Reglamento, deberán ser elaborados por laboratorios registrados en la Subsecretaría de Medio Ambiente.

ARTICULO 74º Por el lapso perentorio de cinco (5) años, que señala el Art. 720, los responsables de las descargas líquidas deberán presentar a la Autoridad Ambiental Competente, informes de calidad de sus efluentes semestrales, incluyendo análisis de laboratorios reconocidos, que se encuentren autorizados por el MDSMA.