

# EVALUATION OF THE EXISTING PERFORMANCE OF INFILTRATION GALLERIES IN ALLUVIAL DEPOSITS OF THE PARAPETI RIVER

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## INTRODUCTION

The Parapeti River is part of the drainage system of the Parapeti-Izozog watershed, which covers about 52,000 km<sup>2</sup> and is the sole water resource for supplying drinking water to the city of Camiri, Bolivia. The strata of the basin consist of Quaternary deposits and the permeability is good; however, precipitation is low (only 700 to 800 mm) and, as this zone is located in the watershed between the Amazons and La Plata River systems, existing groundwater quantity is very low. The aquifer depth is between 100 to 200 m in the vicinity of Camiri (yield capacity is less than 1.0 L/s). The City is located in the region of Santa Cruz, Bolivia, at an altitude of 810-m above sea level, in the southeast, and has a population of 25,000 inhabitants. The average temperature is 25-degrees Celsius, with a maximum of 38-degrees Celsius in the summer and a minimum of 11-degrees Celsius in the winter.

The City's water demand is supplied by five infiltration galleries buried below the riverbed (Figure 1), on the bedrock, at a depth of about 4 to 5 m. The galleries are interconnected through a network and linked to a collector well sited on the riverbank. From there, the collected water is pumped to a disinfection tank prior to delivery to customers.

The infiltration galleries are channels with a 1.0 x 1.0 m section or drains of 12-in covered by four layers (see Table 1) of a filter medium (Figure 2)

Table 1. Artificial Filterbed Layers. Infiltration Galleries

Bed Layers	Type/Size	Height
First Layer (Top)	Coarse Sand	1.75 m
Second Layer	Gravel, 1 to 2 in	1.0 m
Third Layer	Gravel, 2 to 3 in	1.0 m
Fourth Layer (Bottom)	Small Stone, 3 to 6 in	1.0 m

In this area of the Parapeti River, where the galleries are in operation, the riverbed consists of permeable alluvial material, sand, and gravel of about 4- to 5-m deep, which creates favorable conditions for groundwater flow through the unconfined aquifer (Huisman, L.,1978). Because in the granular material, the movement of groundwater develops small velocities, the flow is laminar (Harr, M.E., 1990) and this is the driving force for the sedimentation process in the sand and gravel layers of the river. The Parapeti is a mountain river whose water flow is subject to dramatic variations, both in quality and quantity, during the dry season (May to October) and rainy season (November to April). With a relatively steep slope (0.5 to 1 percent), intensive sediment transport rates occur in the rainy season (the maximum flow exceeds 1,000 m<sup>3</sup>/s, as compared to 5 m<sup>3</sup>/s in the dry season). Regarding water quality in the river, turbidity levels in the rainy season have been reported at about 15,000 ntu and suspended solid (SS) concentrations at 30,000 mg/L (Binnie & Partners Consultants, 1982).

In spite of Parapeti's water quality, infiltration galleries have worked continuously for more than 15 years, producing water of good quality and using disinfection as the only treatment process, with a discharge of 48 to 50 L/s. The only annual O&M consists of removing the finest particles of sand that have reached the bottom of the galleries.

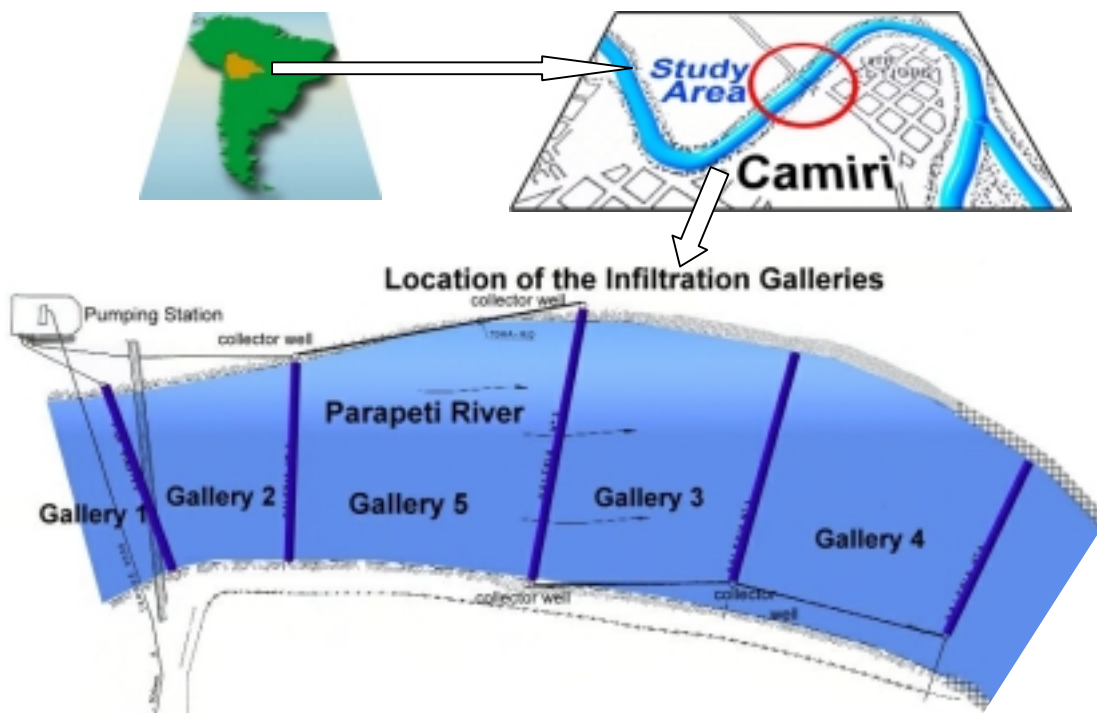


Figure 1. Location of the study areas.

## OBJECTIVES

The aim of the study was to evaluate the existing performance of infiltration galleries to improve on the water quality of surface waters. The study was oriented to answer the following question: “To what extent do infiltration galleries work to remove contaminants from surface-water supplies?”

## MATERIALS AND METHODS

A sampling program was implemented during the dry and rainy seasons. Two complete sets of water samples were collected and analyzed between 2002 and 2003 (Ray, C. et al editors, 2002, German Experience with Riverbank Filtration Systems). The first set of samples was taken in the dry season, from early October to November 2002, when SS concentrations in the river are low. The second set of samples was collected during the rainy season, from February and April, when the river carries higher SS concentrations. In both periods, water samples were taken over a period of 41 to 45 days. Grab samples were collected three times per day in the Parapeti River and in two of the five infiltration galleries (Numbers 1 and 4). Raw-water samples collected in the river were taken from a depth of 0.30-m below the surface and 100-m upstream of the galleries. At the same time, water samples were taken from the effluents of the two infiltration galleries (Numbers 1 and 4) at the inlet point of the disinfection tank.

Eight water-quality parameters were chosen: temperature, color, turbidity, SS, total dissolved solids, pH, conductivity, and fecal coliform (FC) counts. Grab samples for temperature and pH were collected in glass bottles and analyzed on site. Random samples for color, turbidity, SS, total dissolved solids, and conductivity were collected in glass bottles for analysis in a laboratory. Microbiological samples were collected in sterile 50-mL Pyrex glass for analysis in a laboratory within 24 hours. The test was conducted using a portable OXFAM-DEL AGUA water test kit (membrane filtration technique). A

duplicate was prepared from each sample. All the experimental tests were based on the “Standard Methods for the Examination of Water and Wastewater” (1975).

In addition, exploration holes were dug into different layers of the coarse material to take samples from different filter media that cover the galleries. Each layer of the filter media, from Galleries 3, 4, and 5, was washed with distilled water to perform a column-settling test. This experiment was conducted to determine the frequency distribution of settling velocities and particle diameters. Also, each sample was subject to physical analysis, such as mass density, porosity, and granular grain-size distribution.

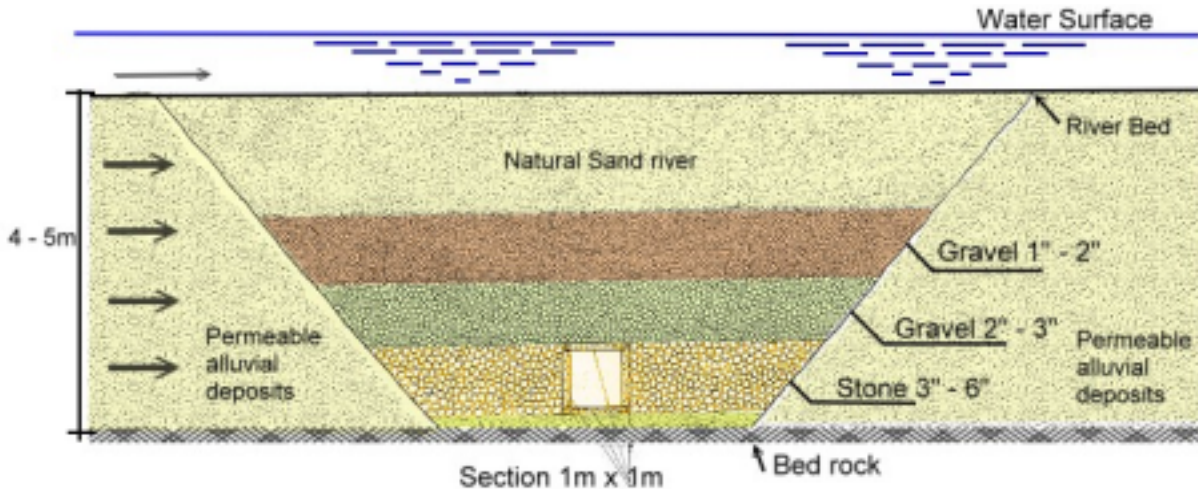


Figure 2. Infiltration gallery system.

## RESULTS AND DISCUSSION

Figures 3 to 5 illustrate seasonal variations in water quality in the Parapetí River and infiltration galleries. For the purposes of this paper, only two indicators of water quality were chosen: SS and FC.

During the rainy season, raw water in the Parapetí River had SS levels ranging from 45 to 4,850 mg/L, with a mean value of 618 mg/L. These figures differ substantially in comparison to the dry season, where the average value was 72 mg/L and the maximum was 410 mg/L. In the rainy season, because the river's flow is high (from 5 to 1,000 m<sup>3</sup>/s, with a mean value of 30 m<sup>3</sup>/s), the elevated SS concentration is caused by erosion that occurs on the steep slopes of watershed highlands. As shown in Figures 3 to 8, the infiltration galleries that were evaluated during the same period had very low levels. The values were ranged from 0 to 7 mg/L, with average of 2 mg/L far below the common standards. From this evidence, it has been demonstrated that the performance of the infiltration galleries reached a removal ratio of more than 90 percent. Turbidity of 5 ntu or less in 98 percent of the daily samples was reported in the effluents (see Figure 5).

Microbiological water-quality parameters in the Parapetí River show poor quality with a wide range of 160 to 60,000 FC counts/100 mL, with an average value of 9,000 FC counts/100 mL. The infiltration gallery data illustrate that in one gallery (Gallery 1), the mean value was zero FC counts/100 mL, with a maximum of 20 FC counts/100 mL achieving a removal ratio of more than 90 percent. Three FC counts /100 mL or less in 98 percent of the samples was found. In the other gallery (Gallery 4), the mean value was a concentration of 32 FC counts/100 mL, with a maximum of 169 FC/100 mL representing a removal ratio of more than 90 percent. In this gallery, a 120 FC counts/100 mL or less in 98 percent of the daily samples was found. These differences may be attributed to variations in the O&M of the galleries.

## CONCLUSIONS

Infiltration galleries built in the permeable alluvial deposits of the rivers can be suitable systems for improving water quality from surface waters. Removal ratios of more than 90 percent for turbidity, SS, and FC have been recorded (during this research project). Infiltration galleries produce high-quality and stable volumes of water independent of seasonal variations in the quality and quantity of raw surface stream, minimizing environmental effects.

It seems that there is a natural and self-cleaning filtration process at work here. The permeable deposits of the Parapeti River form a highly efficient system for the pretreatment of water that contains high concentrations of solids.

Moreover, the filtration qualities of the deposits are constantly maintained by the action of the river itself: during periods of flooding, the top layer of filtration material – the coarse sand – is stirred-up and cleaned by the sheer force of water flow. As flooding subsides, the clean, loose sand re-settles on the riverbed, thus preventing the natural process of clogging and hardening, which would otherwise impair its efficacy as a filter. It is, therefore, possible that the natural composition of the river deposits, assisted by the cycle of the river itself, are acting as an effective and self-cleaning filter of the solids contained in the river.

With proper studies and depending on local conditions and the characteristics of raw-water quality, infiltration galleries are a suitable alternative for supplying drinking water to small and medium communities, with minimum capital costs and lower O&M costs. The system in Camiri has been running since the early 1980s, and no critical O&M problems have been observed (particularly clogging). It is essential that galleries must have easy access to facilitate the periodic cleaning of sediments from conduits (the minimum channel section should be 1.0 x 1.0 m or more for manual cleaning). The infiltration gallery system in Camiri has shown that the amount of maintenance required on the galleries is very small indeed. For this reason, as well as the benefits of improved or maintained water quality, infiltration galleries have a significant advantage over other conventional systems.

Further research is still needed to form a complete understanding of the whole process and the mechanisms that are involved in removing contaminants at higher concentrations.

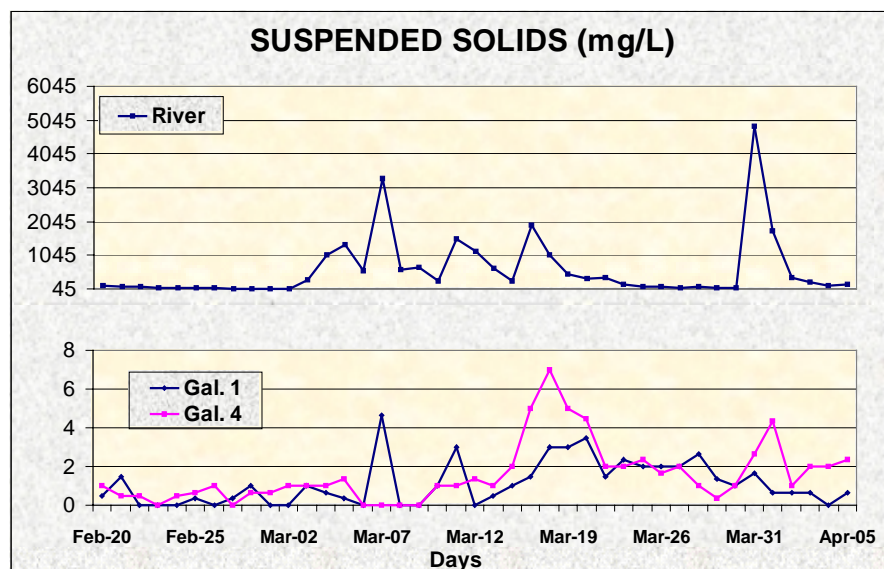


Figure 3. Raw water and infiltration gallery water quality.

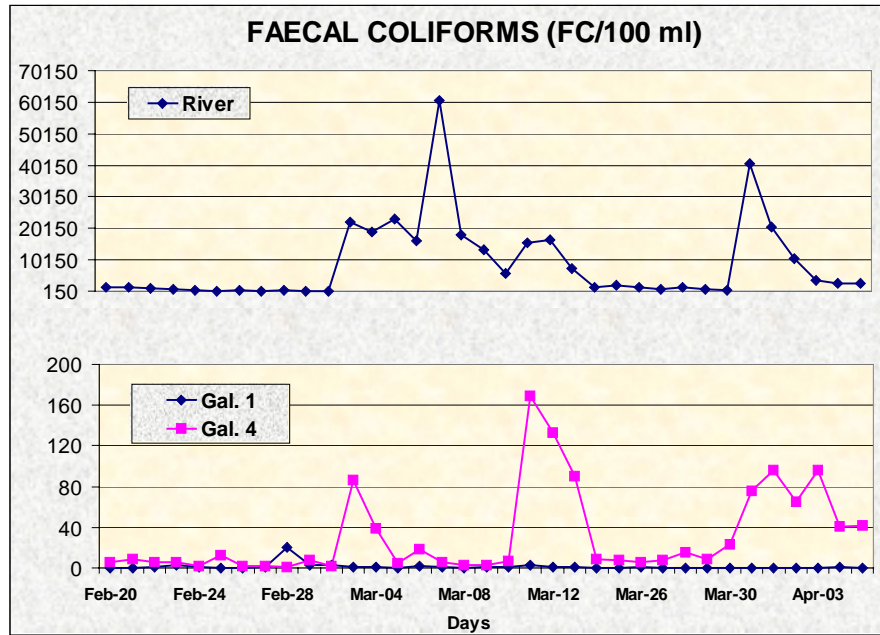


Figure 4. Raw water and infiltration gallery water quality.

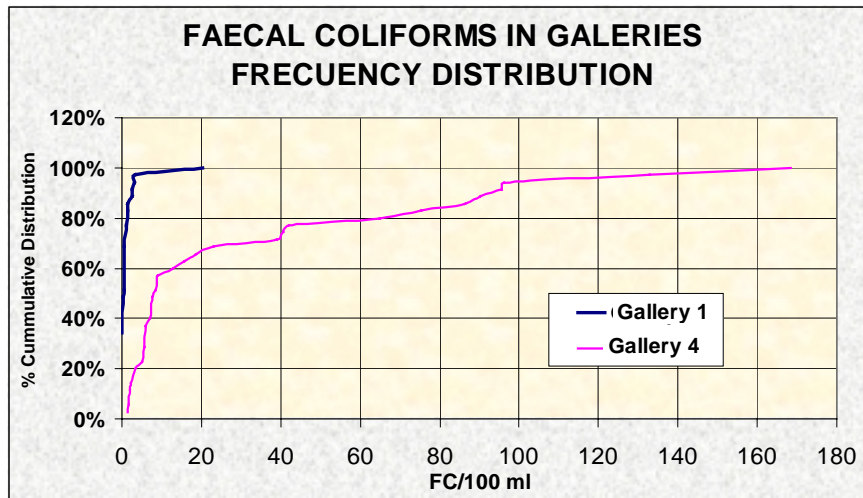


Figure 5. Quality of water produced in the infiltration galleries.

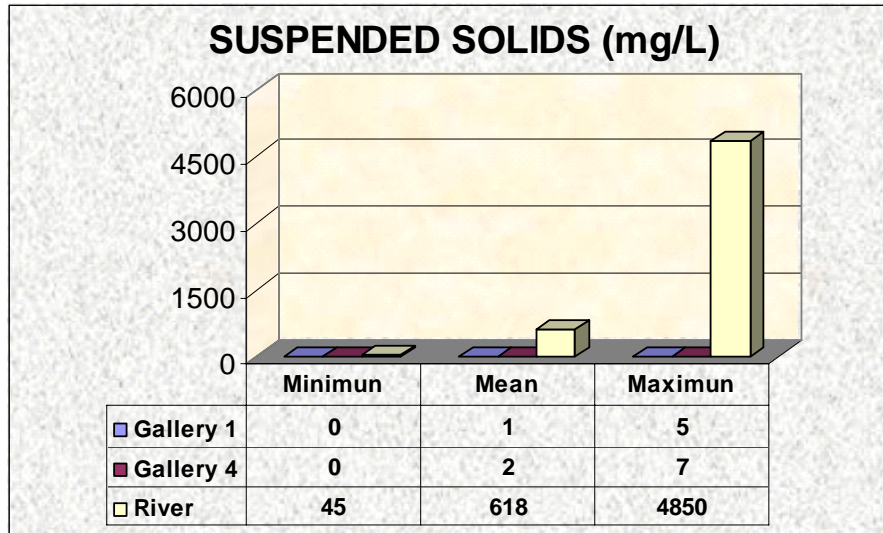


Figure 6. A comparison of raw water and water produced by the galleries.

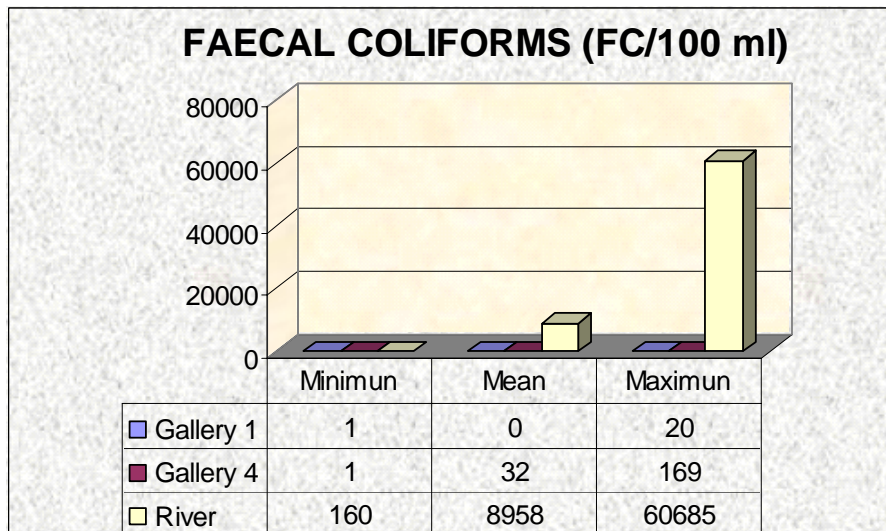


Figure 7. A comparison of raw water and water produced by the galleries.

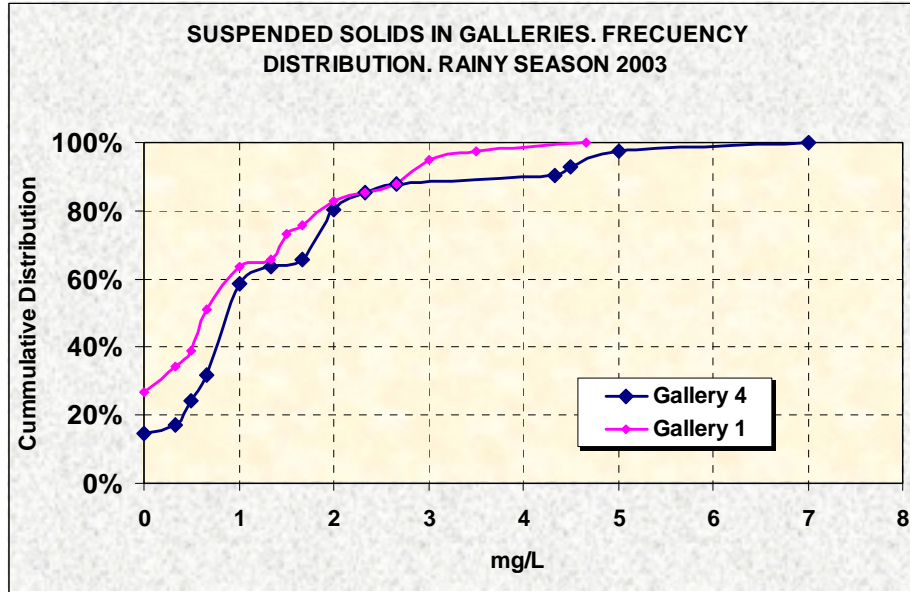


Figure 8. Quality of water produced by the galleries.

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Since 2002, Alvaro Camacho has been a consultant engineer for the water and sanitation sectors, including the Bolivian Association of Sanitary Engineers. Prior, he was the Director General of Water Supply and Sanitation for the Ministry of Housing Services of the Republic of Bolivia, a Project Leader in the Water and Sanitation Program for rural areas in Bolivia for the World Bank, and Guest Lecturer of Sanitary Engineering at the Universidad Mayor de San Andrés in Bolivia. He is also the author of several reports on topics such as water treatment plants designed within the multi-stage filtration concept, developing the water and sanitation sector in Bolivia, technical standards for the design of unconventional sewer systems in Bolivia, and guidelines for the design of water treatment plants in small and medium communities. Camacho received a degree in Civil Engineering from the Universidad Mayor de San Andrés in Bolivia and a Dipl.-Engineer in Sanitary Engineering from International Institute for Hydraulics and Environmental Engineering, in conjunction with the Technical University of Delft, The Netherlands. He is a M.S. researcher at the Universidad del Valle in Cali, Columbia, where he is conducting a field study on infiltration galleries for water supply.

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