Governo do Estado do Ceará
Secretaria dos Recursos Hídricos

Geoenvironmental Evaluation of Conservational Practices Implemented in Cangati River Microbasin, Canindé-CE

Volume 3

Série: Tecnologias e Práticas Hidroambientais para Convivência com o Semiárido

GEOENVIRONMENTAL EVALUATION OF CONSERVATIONAL PRACTICES IMPLEMENTED IN CANGATI RIVER MICROBASIN, CANINDÉ-CE

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Governo do Estado do Ceará

GEOENVIRONMENTAL EVALUATION OF CONSERVATIONAL PRACTICES IMPLEMENTED IN CANGATI RIVER MICROBASIN, CANINDÉ-CE

Work prepared under PRODHAM – Hydroenvironmental Development Project of Ceará Secretariat of Water Resources, a component of PROGERIRH – Integrated Water Resource Management Program for the State of Ceará, supported by the World Bank through the Loan Agreement 4531-BR/BIRD.

Fortaleza
Secretariat of Water Resources
2010

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PRESENTATION

The Government of the State of Ceará, using the proceeds of the Loan Agreement 4531-BR, partially financed by the World Bank, developed the Hydroenvironmental Development Project – PRODHAM.

PRODHAM was designed to promote sustainable water resources through actions for soil, water and vegetation conservation in hydrographic basins, where man was the focal point. To achieve such objectives, the Secretariat of Water Resources – SRH and the Superintendence of Hydraulic Works – SOHIDRA made a series of physical, economic and socioenvironmental interventions in hydrographic microbasins, and established Cangati River Microbasin, in the municipality of Canindé, as the pilot area.

Upon the implantation of the physical infrastructure and the diagnosis of geoenviromental aspects of that area, Fundação Cearense de Meteorologia e Recursos Hídricos (Ceará Meteorology and Water Resource Foundation) – Funceme, a member of the Integrated Water Resource Management System - SIGERH, performed the biophysical monitoring of that microbasin.

To give logistic support to works, services and monitoring of that microbasin, the Agreement no. 015/2007-Funceme/PROGERIRH/SRH/ Dimensão Engenharia de Projetos e Construções Ltda. was entered into.

Monitoring, including the physical structure, extended for fourteen months. Data collected on hydrological and environmental variables were sufficient to provide a scope and characterization of hydroenvironmental behavior in that microbasin and provide an important knowledge and information for the rational management, satisfaction of physical demands and risk management in semiarid region, which relate to a population as vulnerable and deprived of opportunities as that of said region, thus contributing to Ceará sustainable development.

Studies have also contributed to the generation of technical-scientific works and post-graduation researches, as well as to capacity building and training of middle-level technical staff and local community.

Eduardo Sávio Passos Rodrigues Martins
President of FUNCEME

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INTRODUCTION

Subproject for Geoenvironmental Study of Cangati River Microbasin in Canindé-CE (Pilot Area) implanted by Fundação Cearense de Meteorologia e Recursos Hídricos – Funceme, funded by the Hydroenvironmental Development Project (PRODHAM), partially financed by the World Bank, started on August 01, 2007 and ended on December 31, 2008. Its final report was completed in August 2009.

Cangati River microbasin monitoring studies address topics related to water, soil and vegetation.

The microbasin object of the study is included in the Systematic Map of the Northeast Development Superintendence (SUDENE), SB-24-V-VI – Quixadá, on 1:100.000 scale, covering a surface area of 75.65 km2, and located in the northeastern portion of the State of Ceará, limited by the following geographic coordinates: 04º34’00” south latitude and 39º26’25” west longitude, and 04º42’00” south latitude and 39º21’00” west longitude.

Field works started with the survey of the area and identification of the first data sampling points related to water resources (water bodies and wells) and ended with water collections (surface water and groundwater).

Fundação Núcleo de Tecnologia Industrial (Industrial Technology Center Foundation) – NUTEC was responsible for analyzing samples of surface water (reservoirs) and groundwater (wells), as well as suspended solids.

Monitoring activities under the subproject were performed by the technical staff of Water Resource and Environment Department (DHIMA) through Basic Studies and Support System Division (DIESB) and Geoprocessing Division (DIGEO).

SIGNIFICANCE OF SUBPROJECT

The search for adequate instruments and/or technologies to support the planning and management of environmental resources of small hydrographic basins is today a major concern of current governments. Studies and researches, in this field of knowledge, have been intensified all over the world. Evaluation of effects of degradation and/or changes of the environment is a particular basin on its eventual processes is known to be generally based on data collected locally, which are obtained from equipment and/or structures implanted therein.

In effect, monitoring the natural resources of a basin constitutes a strategic activity leading to the creation of a data and information base that, if continuedly updated and disseminated, will guide the management of such resources, and support the decision making process and the formulation of guidelines and actions. The joint, integrated analysis of diversity of generated data through the monitoring of hydroenvironmental variables will expand the knowledge on the basin dynamics, its physical aspects and their interrelationship.

In line with that opinion and looking for a better understanding of the environmental dynamics of small hydrographic basins in the semiarid region, Funceme, under the Hydroenvironmental Development Project (PRODHAM), designed and executed the Subproject for Geoenvironmental Study of Cangati River Microbasin in Canindé-CE, as detailed in this document. It should be highlighted that said microbasin, due to changes in occupation and use of soil, anthropic factors, and especially the increased agricultural activity, has been undergoing environmental impacts, what justifies the importance of collecting their related data and information, and emphasizes the significance of this survey.

This way, the subproject, which is based on the implantation of a monitoring infrastructure adequate to the region, has supported the management of microbasin natural resources to improve the local community's life quality, thus justifying the funds for its execution and stressing its importance. In fact, data generated from monitoring activities has served as input for studies on the estimate of groundwater potentialities, quantification of surface runoff, understanding of sediment transportation and accumulation in successive dams constructed in that microbasin, and changes to its water quality, among others.

From this view, it should be remembered that the subproject, through its actions and works, has contributed, among other things, to ciliary forest recovery, which was quite degraded in the past; reduction of sanding-up process in reservoirs; soil moisture increase; unirrigated agricultural productivity increase; and to population's awareness on the sustainable use and preservation of natural resources.

It is important to emphasize that the subproject, all over its implantation period, played the role of applied research aimed to generate new knowledge and technological contribution that are significant to the management and sustainability of microbasin environmental resources, with direct applications to its management.

It should also be remembered the care to incorporate and clarify the participatory aspect of the subproject. Local community's participation in the construction and implantation of monitoring infrastructure and collection of hydroenvironmental variables made a great difference and contributed substantially to its success. Actually, concerns with the qualification of human resources and transfer of applied technologies during the survey development were uninterrupted all over the subproject management and proved to be highly significant.

It is also worth emphasizing the subproject technical-scientific aspect, and the concern with the provision and dissemination of information generated in the subproject. In this sense, a partnership was strategically sought with the Federal University of Ceará, through its Department of Geology, which culminated in the development of a master course dissertation titled "Effects of microdams on subsistence agriculture – Bananeiras stream – Canindé – Ceará – Brazil".

Also, according to the strategy described in the survey, related to the production and dissemination of technical-scientific information, researchers involved in the project drafted the article "Behavior of water quality parameters in surface reservoirs in Cangati river microbasin – Ceará," to be presented in the XVIII Brazil Water Resources Symposium.

Finally, it should be pointed out that the insertion of this subproject in public policies is significant from the view of natural resource management in Northeastern semiarid region. In fact, environmental sustainability in semiarid regions is so critical that the issue has been the focus of basic policies and guidelines by the State government, which considers the rational use of soil and water a major instrument for its development. Emphasis is also given to the need of investments in the search of information, studies and technologies that would contribute to a better use of such resources.

From this standpoint, studies made under this subproject clearly meet such concerns and make it a focus of interest of such international organizations as the World Bank, which has promoted studies through its special projects, such as PRODHAM, to identify alternatives for the solution of related problems.

BACKGROUND

In the body of the policy established in the State Water Resource Plan, an integral part of the State Sustainable Development Plan, as well as in other segments, the Hydroenvironmental Development Project (PRODHAM) emerged to support the State Government's hydroenvironmental plan and complement the existing Water Resource Programs with the general objective of ensuring environmental recovery measures and actions.

That project had the following specific objectives:

- to develop an environmental model;
- to establish a conservational methodology;
- to develop soil and water retaining techniques in hydrographic microbasins;
- to promote the resurgence of several forms of vegetal and animal life;
- to ensure water availability for animal consumption;
- to educate and qualify the rural communities in areas of influence of Project;
- to promote the community organization and strengthen their self-management; and
- to show the importance of soil recovery and correction.

With the purpose of implanting the Project, a partnership between the Secretariat of Water Resources (SRH), the World Bank (financial partnership) and GTZ (technical partnership) was established. Thereafter, the terms of reference were prepared and the methodology to be followed was established to identify and select the microbasins to be contemplated.

The adopted methodology was the Fast Participatory Diagnosis (FPD), which is a research-learning process developed by means of dialogues, observations, diagram and field analyses jointly with the population.

Once the methodology was established, field visits for microbasin selection started, which included teams composed of technicians from SRH and Fundação Cearense de Meteorologia e Recursos Hídricos - Funceme, as well as consultants from Sociedade de Projetos Agropecuários (GFA-Agrar).

To select the microbasins, the teams traveled to Maciço de Baturité region, guided by previously established criteria, such as:

- production potential and natural resources, that is, natural conditions favorable to the implementation of conservational environmental practices, areas exposed to natural resource (soil, water and vegetation) degradation and change processes;
- existence and expressiveness of formal or informal organizations, such as Municipal Councils, NGOs, Labor Unions, Associations or Cooperatives joined by producers open to innovations and changes, and willing to test them in their own lands, as well as to contribute their own workforce and/or other resources;
- significant contribution of farming activities to family income; and
- access through existing vicinal ways and roads.

Therefore, to obtain a selection, several microbasins in Maciço de Baturité region were visited, three of which were selected, including Cangati River microbasin, which showed the best conditions in relation to predefined criteria.

In that microbasin, three communities were identified and analyzed – Iguaçu, São Luiz and Bom Jesus – to which the Fast Participatory Diagnosis (FPD) was applied; however, due to its higher representativeness and organization, Iguaçu community was applied a more thorough FDP.

Once Cangati River microbasin was selected, basic studies started, which consisted of a semidetailed soil survey and evaluation of land use capacity performed by Funceme pedology team.

In possession of studies performed by Funceme, SRH started the works listed in PRODHAM Technical Operational Manual, which included alternative hydroenvironmental control practices, such as:

- successive sediment retaining dams;
- underground dams;
- recovery and preservation of ciliary vegetation along water courses;
- reclamation of degraded areas; and
- adequacy of vicinal ways.

Also, alternative edaphic control practices were performed, such as:

- terracing;
- drainage channels;
- permanent vegetation buffers;
- windbreaks;
- surrounding stone barriers;
- soil decompaction;
- dead cover;
- level cultivation – dry-farming system;
- organic matter; and
- grazing management.

SUBPROJECT OBJECTIVES

The core objective of the subproject for Geoenvironmental Study of Cangati River Microbasin in Canindé-CE, designed by Fundação Cearense de Meteorologia e Recursos Hídricos – Funceme was the performance of water, soil and vegetation monitoring studies in Cangati River microbasin in the municipality of Canindé.

For that, pilot and participatory works and services were carried out for the development of articulated and sustainable actions to recover and preserve mineral resources.

In addition to focusing on the introduction of a natural resource preservation culture, studies made in that microbasin intended to show the importance of implanted hydroenvironmental and edaphic works, consolidate and develop the management instruments, and promote the participation of the benefited community, by summoning them to play a more expressive multiplying role and disseminate the knowledge and promote the teaching and learning process upon dealing with the environment when they live.

Among other objectives, the following stand out:

- maintenance of the ecological equilibrium upon the appearance of forms of vegetal and animal life;
- improvement of water quality;
- increase of soil moisture and pasture supply during dry periods;
- replacement of ciliary vegetation and maintenance of the consequent soil sustenance to prevent both its loss during rainy periods and reservoir sanding-up, as well as the maintenance of soil moisture for a longer period;
- increase of unirrigated crop yields through the maintenance of soil moisture for a longer period;

- increase of water supply for other uses;
- actions in other income-generating production activities and increase of countrymen's conservational awareness, to make them feel co-responsible for the preservation and recovery of the environment where they live; and
- higher supply of soil moisture for crops.

Characterization of Study Area 1

PART 1 – CHARACTERIZATION OF STUDY AREA

1.1- Geoenvironment Configuration

A description of the main physical and anthropic aspects of the surveyed microbasin is shown below.

1.1.1– Location and Access

Cangati River microbasin is located in the municipality of Canindé, in the northeastern portion of the State of Ceará, between South Latitude parallels 04°34'00" and 04°42'00" and meridians 39°21'00" and 39°26'25" West of Greenwich, occupying a surface area of 75.65 km² (FIGURE 2.01). From Fortaleza, access is made through BR-020 road to a distance of approximately 145 km.

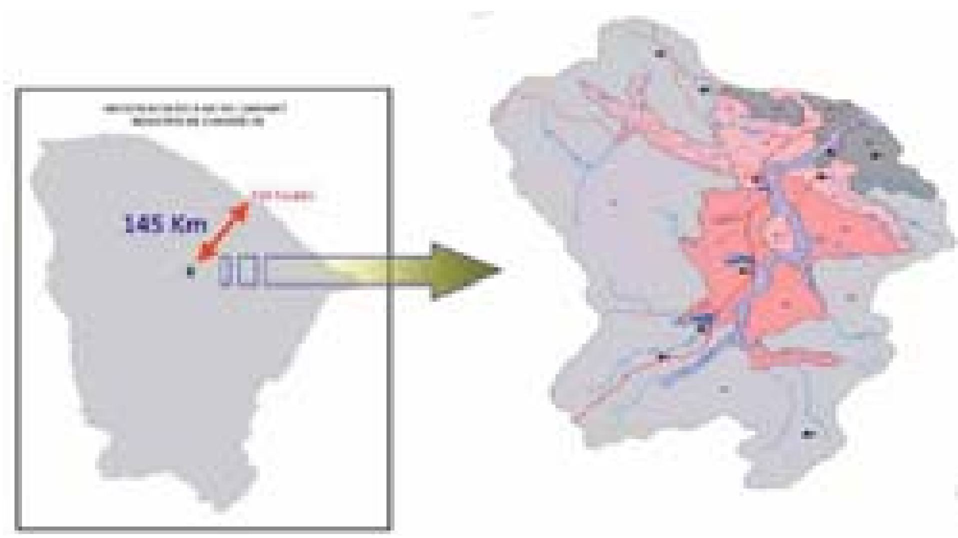

FIGURE 1.01 – Location of study area

BR-020 road crosses the microbasin and the three major municipalities in the regions, namely: São Luiz, Iguaçu and Lajes.

Internal traffic in the microbasin is through unpaved roads, most of them in poor conditions and mostly impassable during rainy periods.

1.1.2– Geological Aspects

All published works on crystalline soils in Canindé region domain have a regional scope, where defined units are inserted in a wide geological context comprising the crystalline basement (represented by Precambrian rocks) and unconsolidated surface materials (represented by (1) alluviums and colluviums existing in river channels and dissection slopes, respectively). At regional level, lithologic types defined by Brito Neves (1975 apud COSTA, 20004) and Nascimento and Gava (1977 apud COSTA, 2004) show alternate sequences of mica slates, micaceous quartzites, paragneisses, migmatites and marbles. Intrusions of dikes comprising the (2) Upper Precambrian magmatic suite (questionable opinion) predominantly confined in (3) Itatira complex rocks also occur. In Cangati River hydrographic basin, (4) migmatites and gneisses of Northeast / Lower to Middle Precambrian Complex predominate and influence the basic composition of weathering cover and morphologic compartmentalization of local relief. A description of lithologic components follows for a better understanding of dynamics of processes related to erosion, transportation and deposit of materials (COSTA, 2004).

Questionable plutonic rocks

Bodies represented here may be defined as olivine gabbros of massif aspect and medium granulation. They are generally small, subcircular and mostly show evidence of granitization. They are considered questionable due to the lack or unavailability of data, especially geo chronologic data, based on K/Ar dating (COSTA, 2004).

Northeast / Lower to Middle Precambrian Complex

This comprises homogeneous and heterogeneous migmatites, varied gneisses and granitoid nuclei, in addition to lower occurrences of quartzite, schist, calcosilicatic marbles, and more scarcely, metabasic and meta-ultrabasic rocks. Northeast Complex, together with other Precambrian areas, is positioned as a substratum of supracrustal sequences. Obtained geochronologic standard indicates the involvement of rocks of that Complex in Upper Precambrian events, and that the TransAmazon event was the most active in the formation of migmatites and gneisses, according to radiometric values (Isochronal Rb/Sr). The main representative rock of this group is a migmatitic rock belonging to crystalline basement. This rock is basically constituted of alkaline feldspar, biotite and quartz, with the occurrence of opaque minerals and pyrope grenade at different oxidation levels. Zones of intense migmatization and occurrence of feldspathic bands are common, which typically follow rock banding (COSTA, 2004).

Itatira / Upper Precambrian Complex

This includes a set of paraderived gneisses with intercalations of schists, marbles and quartzite. Gneisses show a light-gray color, medium granulation, and gneissic texture. Banding is clear and regular, where lighter quartz-feldspathic levels alternate with darker biotite-rich levels. This metasedimentary unit overlaps the Northeast Complex. Metamorphism level combined with the lithologic type also differs greatly from Northeast Complex, as a deep anatexis is noted in that unit, including the appearance of homogeneous migmatites, anatexites and granitic nuclei. Itatira Complex rocks show a deformation standard based on synform and antiform structures and holomorphic folds, which is different from their basement. Their contact with the Northeast Complex are mostly gradational and diffuse, and eventually tectonic. Locally, zones of intensive granitization to basal lithologic zones may appear. However, as a general rule, there is a progressive verticalization of layer heights toward the Northeast Complex, followed of the increased deeping intensity and gradual disappearance of layered and foliated structures (COSTA, 2004).

Tertio-quaternary Covers (Qa)

According to Macedo (1977 apud COSTA, 2004), alluvial deposits are composed of detrital material, including pebbles, bolders and angular flint-stones commonly represented by quartzites, migmatites and sandstone. They are typically misclassified and angular, what indicates rocks from sources close to the deposit. Together with detrital material, grits and even impure varied-colored argyle appear. This material originates basically from rocks composing the Northeast Complex and Itatira Complex. Fluvial transportation operates to remobilize poorly reworked, angular and predominantly coarse sediments, in spite of the occurrence of granulation of silty-argillaceous sediments directly associated with fluvial terraces and floodplains (COSTA, 2004).

Geological structures

Main structures in the region appear as faults predominantly in NE-SW direction, which represent sequences disposed according to the preferential direction of breaking efforts. Folding systems exposed both in Northeast Complex and Itatira Complex show a structural complexity generated under ductile conditions between Lower and Upper Precambrian ages. In Canindé region there is a sequence of antiform and synform folds forming a "dome" and "basin" folding standard, the axis of which shows a double sinking. In Canindé outskirts, the general direction of foliation and consequently of such structures changes toward NW-SE direction (Costa, 2004).

1.1.3– Geomorphologic Aspects

Analysis of geomorphologic aspects shows the dynamic influence of current and past geological, paleoclimatic and morphodynamic factors occurred in the area along its geoenvironmental development. Morphogenetic processes predominate, as local climate conditions combined with the surface runoff regime, topography and vegetative cover represent the main denudation agents, in prejudice to chemical processes associated with more humid climates (COSTA, 2004).

Plains and fluvial terraces

These are the most characteristic forms of fluvial accumulation, which longitudinally follow the courses of rivers and streams. These areas provide the best soil conditions and water availability, and therefore constitute geoenvironmental differentiation zones in the context of semiarid backwoods. Within the scope of backwoods surface (crystalline soils), watercourses create narrow alluvial deposits. This unit has no significant spatial representativeness. In that area, such zones are represented by floodplains of plain and softly undulated relief (COSTA, 2004).

Backwoods depression

This corresponds to a planing surface developing on crystalline rocks, where erosive work indistinctly eliminated several lithologic types. Backwoods depression morphology is marked by a plain or softly undulated topography where average altitude ranges between 130 - 150 m. At higher levels above 300 m, dissection is more evident, isolating convex watersheds, and forming hilly, tabuliform or sloped relief The surveyed region is a major characteristic sector of backwoods depression, which is defined as peripheral depression. Its most important characteristics include: (a) an accentuated lithologic diversification due to the occurrence of crystalline and sedimentary rocks of different origins and ages; (b) outstanding role in physical weathering process and waste removal by diffuse and concentrated runoff. (c) indistinct elimination of lithologies and structures by erosion, and the consequent development of pediplain surfaces; (d) widespread brushwood cover, with eventual changes of appearance and flora due to climate and soil changes; and (e) small thickness of rock alteration cover (SOUZA, 1988 apud COSTA, 2004).

Residual Massifs

The monotonous plain and softly undulated forms in backwoods depression are now and then interrupted by the strong rupture of mountain slopes and residual hills. Such forms of relief are predominantly constituted of granitic-migmatic rocks and originated from surrounding area lowering (less resistant – gneissic lithology) by differential erosion. They show themselves dissected into pointed top features forming dry mountains and in the form of inselbergs. They are represented in the area by a 500-800-m high relief and operate as a divisor for the hydrographic basin. In Cangati River microbasin, relief is undulated and contains rounded hills cut by gullies (excavations, grooves) caused by rains, which form intermittent streams. Hill tops are plain and slopes have a declivity around 4% (COSTA, 2004).

1.1.4–Soil aspects

Understanding the soils constitutes one of the main bases for territorial planning works. For that, a semidetailed survey and an evaluation of land use were made (FUNCEME 2001). With the objective of adjusting to the current Brazilian Soil Classification System (EMBRAPA, 2006), classes of soils identified have been renamed.

Heterogeneity of environmental characteristics to which Ceará is subject provides a vast soil variation. By analyzing the pedological context of the surveyed hydrographic microbasin, the prevalence of typical backwoods depression environments can be noted, which are characterized by an association of quite diversified soils that are typically shallow or moderately deep, with incidence of rock outcrops and detrital pavements layers. because of their little favorable physical characteristics, they present accentuated restrictions to mechanization, insufficient effective depth, low water retention capacity, risks of flood and salinization, in addition to water deficiency due to the prevailing semiarid climate.

Plantation on the hill slope is a current practice in Ceará agriculture and a major factor of soil degradation. This is added of other habitual practices, such as boring, fire clearance, uprooting, deforestation for planting area opening and/or timber exploration for the most diverse purposes (construction of houses and buildings, firewood, fences, stables, coal, etc.), which also substantially impair the ecosystem sustainability in microbasins and brushwoods.

General characteristics of soil classes according to Funceme (2001) are listed below, including the soil nomenclature according to EMBRAPA (1999) and the new corresponding classification, between brackets) according to EMBRAPA (2006).

NON-CALCIC RED-YELLOW/ BROWN PODZOLIC SOIL (CHROMIC LUVISOL)

This includes B-textural, non-hydromorphic, acid soils with low aluminum saturation and a high quantity of easily decomposable primary minerals, which constitute sources of plant nutrients. They have medium to high natural fertility (JACOMINE *et al*, 1973) and present, according to the same authors, well-differentiated profiles, typically sandy or medium texture in A horizon, and frequently gravely argillaceous or medium texture in B horizon. They also present a sudden textural change from A to B. They typically are well-drained soils, except for shallow soils, which have a moderate / incomplete drainage. They are moderately acid to acid, rarely neutral or even slightly alkaline. In sand and gravel fractions of those soils the predominance of quartz is noted (which decreases with depth), in addition to the occurrence of potassic and sodic feldspar, sometimes with ferruginous adherence at percentages as high as 40%, and a high content of biotite and muscovite in Bt and C horizons. In general, such soils have a medium to high agricultural potential, depending on water availability and relief conditions. In that unit. gravel, abrupt, plintic and stony phase variations occur. Erosion control should be intensive and include adequate conservational practices to maintain its production capacity. In stony areas, stones can be used for the construction of surrounding strings. Use of very light agricultural tools is recommended, preferably animal traction tools, and the adoption of direct planting system is convenient. In Cangati River microbasin area, such soils have high-activity clay, that is, capacity for cation exchange after correction to carbon above 24 cmolc/kg of clay. They have an Eutrophic Aspect (V > 50%) and are little deep soils. According to its occurrence in Cangati River microbasin, that class of soil has been grouped into the following associations: PE1, PE2, Costa (2004).

EUTROPHIC ALLUVIAL SOILS (LITHOLIC NEOSOLS)

These comprise little developed, predominantly non-hydromorphic mineral soils from recent fluvial deposits, where only the surface A horizon is differentiated and followed by a succession of stratified layers that in general do not have a pedogenetic relation with one another (JACOMINE *et al.*, 1973). According to such authors, these soils range from moderately deep to very deep and have the most diverse textures, a typically incomplete or moderate drainage and a high agricultural potential. Characteristics of such soils vary especially according to the nature of original material from recent deposits. Because of their position, risk of flood constitutes their main limitation, in addition to the extended dry season in areas where they occur. However, in light of their qualities, such as high natural fertility and depth, among others, such soils can be cultivated in the rainy period with most diverse short-cycle crops, such as herbaceous cotton, beans, maize, as well as long-cycle crops, such as fruits and sugarcane. They can also be used for different pastures for bovine, ovine and caprine food. Rice cultivation is also recommended in areas of more argillaceous texture. If irrigated, special care should be taken with salinization and drainage-related risks. According to Costa (2004), they are classified by the symbol Ae and extend along rivers of Cangati River microbasin.

EUTROPHIC LITHOLIC SOILS

According to Jacomine *at al.* (1973), these are little developed, from shallow to very shallow soils, provided with only an A horizon occurring directly on rock or related material at a more advanced weathering level, and constituting a C horizon with many primary materials and semi-weathered blocks of rock of several sizes on a coherent and hard underlying rock. They are therefore soils with A-C-R or A – R horizon sequence. Such soils may be eutrophic or distrophic and mostly present too many stones and rocks on the surface. The A horizon is normally weak or moderate, with thicknesses ranging between 15 cm and 40 cm and several shades. They have moderate to accentuated drainage and are typically susceptible to erosion because of their reduced thickness. Original material is mostly represented by gneiss saprolite, migmatites and granites, with the occurrence of soils derived from quartzite, sandstone, phyllite and schist as well. Relief ranges from plain to mountainous, where vegetation is a wood/brushwood transition and dry wood. Limitations to the use of such soils refer to their low depth, in addition to consequences from declivity and relief of areas where they occur. The low agricultural use of such soils results of strong to very strong limitations, water shortage, too many stones and rocks, and low depth. The exploration of such soils is only practicable with the use of primitive agricultural systems and manual tools. Cattle raising can be explored in some areas of such soils, provided that plain, softly undulated or even undulated sections are selected, where declivities are not steep, and there is a lower occurrence of stones and rocks. Hilly areas should be reserved for regional flora and fauna preservation. In the surveyed area, such soils display an eutrophic aspect with weak or moderate A horizon and sandy or medium texture on a mountainous, strongly undulated and undulated relief. According to Costa (2004), in Cangati River microbasin the following associations of eutrophic litholic soils were made: Re1, Re2.

1.1.5– Vegetative Cover Aspects

The state of Ceará has several types of vegetation, among which brushwood predominates. This is due to semiarid conditions, stony soil conditions, water shortage and to the fact that most of the State is has altitudes below 500 m. Variation of such factors (climate, edaphic and geomorphologic) have a great importance for facies standards and flora distribution. Seasonal caducifoliate xeromophic shrubby vegetation (brushwoods) covers most of the State semiarid territory, which is represented by caducifoliate vegetal species with morphologic and physiologic adaptations to the dry environment.

According to Duque (1980 apud COSTA, 2004), brushwood is a set of trees and/or shrubs of dense or open appearance generally low and with few branches and diverse floristic variation, which display at caducity and in small size of leaves characteristics that, together with other adaptation forms, such as spare organs, allow them to develop in semiarid environment conditions. The vegetative cover predominating in Cangati River microbasin is low brushwood (FERNANDES, 2001 apud COSTA, 2004), which corresponds to a xerophytic vegetation where species of shrubby appearance and physiology ranging between 2 and 4-m high predominate. Given the existing anthropic influence, the original landscape has been quite modified by the loss of most of its original floristic components. Anthropic action toward agricultural and livestock exploration has changed most of vegetation, even though the occurrence of remaining original areas can be noted especially in higher and more sloped areas, either previously or currently used, which have very often recovered their original aspect. Main species found in the area include: quince tree (*Croton sonderianus*), jurema preta (*Mimosa hostilis*), mastic tree (*Astronium urundeuva*), apple tree (*Aspidesperma pirifolium*), pau branco (*Auxema onconcalyx*), umburuna de espinheiro (*Bursera leptophlocos*), angico (*Anadenanthera macroarpa*), black acacia (*Mimosa hostilis*), mofumbo (*Cobretum leprosum*), oiticica (*Licania rígida*), carnauba wax palm (*Copernicia prunifera*), apple tree (*Aspidosperma pirifolium*) pitiá (*Aspidosperma ulei*), mororó (*Bauhínia forficata*), catingueira (*Caesalpinia piramidalis*), canafistula (*Cássia ferruginea*) and juazeiro (*Ziziphus joazeiro*).

1.1.6– Hydroclimatological characterization

Climate

Most of natural processes are influenced by climate. Topography, soil, vegetation, water resources, and especially the human life are adjusted to weather and climate conditions. Approximately 92% of the state of Ceará is influenced by the semiarid climate and extended drought periods when socioeconomic activities are greatly modified by production drop, rural migration, increased poverty, etc. Ceará semiarid region occupies areas corresponding to subequatorial latitude and therefore displays the following characteristics:

- high temperatures all over the year;
- high insolation all over the year;
- low precipitation rates that are generally below 800 mm per year, concentrated in short periods and have an accentuated spatial and temporal irregularity;
- high evapotranspiration rates due to the high thermal coefficient and small volume of water available for vegetation development;
- small capacity for water storage in the soil, because of prevalence of crystalline soils (some 75% of the State surface area);
- low surface water and groundwater resource potential; and
- small amount of land with favorable climate conditions, fertile soils and favorable topography (sedimentary soils).

Such unfavorable climate conditions, combined with the indiscriminate removal of native vegetative cover, accelerate the soil weathering processes and contribute to the environmental degradation of the State in further inland regions. According to Koppen's classification (BRAZIL, 1973), Cangati River microbasin may be classified in BSw'h' climate type (hot, semiarid climate), where rainy season is late in autumn and a temperature higher than 18ºC is reached in the coldest month. Gaussen's bioclimatic classification (GALVÃO, 1967 apud COSTA, 2004) is based on the determination of dry period and xerothermal index, and lists the behavior of temperatures and precipitation throughout the year and considers the States that are favorable and unfavorable to vegetation. Short duration of rainy season is a consequence of penetration of continental equatorial mass (Emc) and intertropical front downward move (FIT).

In Northeastern Brazil, atmosphere circulation includes four meteorological systems: SE trade winds from intertropical convergence (CIT), equatorial Amazon (EC) and Atlantic polar front (FPA). As the municipality of Canindé is located in the central portion of Ceará, the first rains occur in December-February (beginning of Summer) – like in the rest of the State. The intertropical convergence system (CIT) operates in that region at a lower intensity than in coast and mountain areas, where it is influenced by trade winds and relief, respectively. In the zone corresponding to backwoods depression, influence comes from the greater continent heating against the ocean, what shortens the *doldruns* range in that area. Solar radiation is high, at some 2,640 h/year. Because of its location close to Equator line, incidence of sunlight is practically uniform all over the year. Average temperature is some 27ºC, maximum temperature nears 27ºC, and minimum temperature is around 22ºC. Annual precipitation is around 756.1 mm. Driest quarter is in August-October period, and the most humid quarter is in February-April and sometimes extends to May.

Water resources

The study of hydrographic network of a particular region will lead to the identification of the occurrence and availability of its water resources, in addition to diagnosing the degradation conditions of neighboring areas in terms of production, transportation and sediment deposits (hydrosedimentological processes) in river beds and intermediate strips (slopes and watersheds). According to Souza (1988 apud COSTA, 2004), rains fall suddenly as heavy rains, which increase their eroding efficiency, and run off according to diffuse downpours, thus constituting the main agent of transportation of changes from physical rock disaggregation.

The continuity of this process leads to the concentration of laminar flow and, because of process competence, material transportation and deposit becomes selective, where coarser material remains upstream to sediments to constitute stony soils Smaller sediments are transported downstream to the bottom of valleys or small depressions to constitute floodable accumulation areas.

The drainage patter layout depends on the set of physical (rock substrate, relief, climate and soils), biological (vegetative cover) and – last but not least – socioeconomic variables, through several levels of anthropic intervention in the area. Watercourse classification, Costa (2004) provides that first-class rivers are those with no tributaries; second-class rivers only receive first-class tributaries; third-class rivers may receive one or more second-class tributaries and even first-class tributaries; fourth-class rivers receive third-class and lower tributaries, and so on. The main river is, however, classified in the same class since its springs.

The municipality of Canindé comprises Curu basin (78.4%), Metropolitan basin (19.2%), Acaraú basin (2.16%) and Banabuiú basin (0.23%). Cangati River microbasin occupies a surface area of 75,65 km^2, and extends over the right and left margins of Cangati River, which ranks second in hydrographic hierarchy of Choró River, a component of the Metropolitan Basin. Cangati River has Serra da Pintada e Serrinha, close to the district of Cachoeira, in the municipality of Canindé and on the margins of BR-020 road, as the watersheds of its springs. Among Cangati River tributaries, the following stand out: on the right margin, Imburana, Carneiro, Compasso, Felão, Camuru and Arapuá streams; on the left margin, Boqueirão, Macacos, Maíba, Boi Pombo, das Minas, Salgadinho and Preá streams.

Felling of inexistence of ciliary forest along the watercourses of this microbasin adversely affects the soil because of the transportation of organic matter and mineral nutrients that affects the water quality and causes sanding-up in watercourse beds and hydraulic basin of reservoirs, thus reducing their water storage capacity. Because of the occurrence of a crystalline lithologic substrate, drainage pattern is dendritic and overconcentrated, giving the area low groundwater storage potential.

Given the predominance of crystalline lithology, aquifers in the region have a low hydrogeological potential. On that basement there is a very thin little-permeable material that reduces water infiltration and consequently water accumulation in rock substrate fractures (COSTA, 2004).

1.1.7– Use and occupation of soil

According to the map of use and occupation of the municipality of Canindé, Figure 1.02, in the area of influence of PRODHAM in Iguaçu district agriculture and remaining forests predominate. In Cangati River hydrographic microbasin (HMB) land tenure status comprises six (06) institutional aspects: (a) family property; (b) heirs' land; (c) squatters' land; (d) tenant's land; (e) partnership land; and (f) "others". The term "others" practically means leased land. Number of landed estates amounts to 193 according to Chart 1.01.

In Chart 1.01 it is noted that Iguaçu community has a higher number of landed estates, or 31.61% of total. Cacimba de Baixo community ranks second with 24.35% of landed estates; it is followed by São Luiz community with 21.24%; Lages with 12.44%; and Barra Nova community with the lowest number of landed estates, or 10.36%.

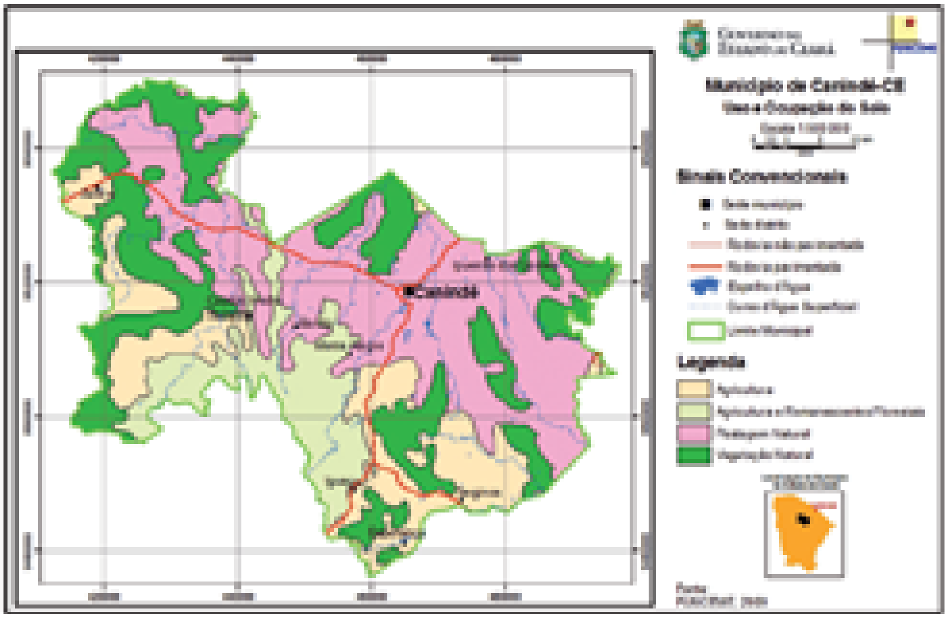

FIGURE 1.02 – Map of the Municipality of Canindé

CHART 1.01 – Landed estates per community and legal status

Community	Family Property	Heirs' Land	Squatters' Land	Tenant's Land		Partner-ship Land	Others	Total
				Partner-ship	Lease			
Barra Nova	0	4	0	4	7	3	2	20
C. de Baixo	9	12	0	9	8	4	5	47
Iguaçu	8	35	0	0	5	3	10	61
Lages	0	3	0	10	10	1	0	24
São Luiz	10	17	0	5	2	1	6	41
Total	**27**	**71**	**0**	**28**	**32**	**12**	**23**	**193**

Source: FAHMA, 2005-2008

The distribution of the number of properties per type in communities has the following concentration profile:

- **(a)** Family property – higher occurrence in São Luiz community with 37.04%, followed by Cacimba de Baixo with 33.33%, and Iguaçu with 29.63%;

- **(b)** Heirs' Land – higher occurrence in Iguaçu community (49.30%), followed by São Luiz (23.94%), Cacimba de Baixo (16.90%), Barra Nova (5.63%), and Lages (4.23%);

- **(c)** Squatter's Land – no occurrence;
- **(d)** Tenant's Land (sum of partnership and lease) – the distribution is as follows: Lages records 33.33%; Cacimba de Baixo 28.33%, Barra Nova 18.33%, São Luiz 11.67%, and Iguaçu 8.33%;
- **(e)** Partnership Land – higher concentration occurs in Cacimba de Baixo (33.33%), followed by Iguaçu and Barra Nova (25.00% each) and finally Lages and São Luiz (8.33% each; and
- **(f)** Land classified as "others " (which, according to the respective records, corresponds mostly to leased land) – distribution in communities is as follows: higher occurrence (43.48%) in Iguaçu community. It is followed by São Luiz (26.09%); Cacimba de Baixo (21.74%), and finally Barra Nova (8.70%).

The following topic refers to types of use of land in communities of Cangati River hydrographic microbasin (HMB) Number of uses amounts to three hundred and seven (307) distributed over one hundred and eighty-one (181) agricultural activities; forty-nine (49) grazing activities; sixty (60) fallow activities; and seventeen (17) forest and reforestation activities, according to Chart 1.02.

Chart 1.02 shows that Iguaçu community has the highest number of land uses, accounting for 32.57% of total uses. It is followed by Cacimba de Baixo with 25.41% of uses, São Luiz with 25.08%, Lages with 9.12%, and finally Barra Nova with 7.82%.

CHART 1.02 – Number of occurrences per type of current use of soil

Community	Agriculture	Grazing	Fallow	Forest/ Reforest.	Total
Barra Nova	18	1	5	0	24
Iguaçu	45	10	13	10	78
Cacimba de Baixo	57	15	22	6	100
Lages	22	2	4	0	28
São Luiz	39	21	16	1	77
Total	**181**	**49**	**60**	**17**	**307**

Source: FAHMA (2009)

From community standpoint, type of use has the following behavior:

- Agricultural – centralized in Iguaçu, at 31.49%; followed by Cacimba de Baixo (24.86%); São Luiz (21.55%); Lages (12.15%); and Barra Nova (9.94%);

- Grazing – centralized in São Luiz at 42.86%; followed by Iguaçu (30.61%); Cacimba de Baixo (20.41%); Lages (4.08%); and Barra Nova (2.04%);

- Fallow – higher concentration in Iguaçu at 36.67%; followed by São Luiz (26.67%); Cacimba de Baixo (21.67%); Barra Nova (8.33%); and Lages (6.67%);

- Forests and reforestation – occurring only in Cacimba de Baixo, Iguaçu and São Luiz, at 58.82%, 35.29% and 5.88%, respectively.

At distribution per type of use, considering the communities as geographic locations, it is noted that in Lages community agricultural use has a higher concentration percentage, that is, 78.57%. Out of remaining 21.43%, 14.29% are used for fallow and 7.14% for pasture. Barra Nova community has an agricultural use percentage of 75.00%. The remaining 25.00% are used for fallow (20.83%) and pasture (4.17%).

In Cacimba de Dentro community, on the other hand, agricultural use accounts for 57.69% of total use, followed by fallow (16.67%) and pasture and forest/reforestation in the remaining 25.64%. In Iguatu community, agricultural use absorbs 57.00%, fallow 22.00%, pasture 15.00% and forest/reforestation 6.00%.

Finally, São Luiz community, where land is use is more balanced, has the following distribution profile: agricultural, 50.65%; pasture, 27.27%; fallow, 20.78%; and forests and reforestation, 1.35%.

In conclusion, Chart 1.02 shows that land use is predominantly agricultural in Cangati River HMB.

1.1.7.1- Main activities related to soil use

Integrated production

According to family/producer records, agricultural production activities in Cangati River HMB are centralized in only five (5) products: (a) cotton, (b) maize, (c) beans, (d) broad beans, and (e) rice. They are mostly explored in the form of integrated crops, as shown in Chart 1.03 *et seq*.

The first study refers to total integrated production in Cangati River HMB at community level, according to parameters related to cultivated area (ha), production (kg), sale and consumption. With respect to consumption, it was estimated as the difference between total production and sale.

By analyzing the information of Chart 1.03 related to total integrated production in Cangati River HMB, it is noted that it records a total production of 149,676 kg of maize, 15,602 kg of beans, 210 kg of broad beans, 20 kg of rice, and 346 kg of cotton.

At community level, by analyzing each product separately, the following behavior is noted:

(a) Maize – the highest production of this product is centralized in Iguaçu community, which accounts for 34.93% of total, followed by the following communities in decreasing order: São Luiz (19.37%); Cacimba de Baixo (17.12%); Barra Nova (15.71%), and Lages (12.87%);

(b) Beans – the production of this leguminous product is also centralized in Iguaçu community, and accounts for 27.02% of total. It is followed by the following communities and percentages in a decreasing order: Lages (21.72%); São Luiz (19.10%); Cacimba de Baixo (18.64%); and Barra Nova (13.52%);

(c) Board beans – broad beans production is centralized in Barra Nova (71.43%) and Iguaçu (28.57%) communities. In the other communities, no production was reported;

(d) Rice – only São Luiz community recorded the production of this cereal at a percentage of 100%; and

(e) Cotton – the production of this agricultural product was recorded in three (03) communities. Barra Nova community was the major producer accounting for 43.35% of total. It is followed by São Luiz (39.31%) and Iguaçu (17.34%).

CHART 1.03 – Integrated production of maize, beans, broad beans, rice and cotton in communities

Crops – Total and per community	Surface Area (ha)	Production (kg)
HMB – Cangati River		
Maize	336.10	149,676
Beans	336.60	15,602
Board beans	13.00	210
Rice	0.50	20
Cotton	10.00	346
Total	**0.00**	**0.00**
Communities		
BARRA NOVA	**-**	**-**
Maize	38.30	23,520
Beans	37.30	2,110
Board beans	8.00	150
Rice	-	-
Cotton	1.00	150
CACIMBA DE BAIXO	**-**	**-**
Maize	82.00	25,620
Beans	84.00	2,908
Board beans	-	-
Rice	-	-
Cotton	-	-
IGUAÇU	**-**	**-**
Maize	130.80	52,280
Beans	130.80	4,216
Board beans	5.00	60
Rice	-	-
Cotton	5.00	60
LAGES	**-**	**-**
Maize	39.00	19,260
Beans	39.00	3,388
Board beans	-	-
Rice	-	-
Cotton	-	-
SÃO LUIZ	**-**	**-**
Maize	46.00	28,996
Beans	45.50	2,980
Board beans	-	-
Rice	0.50	20
Cotton	4.00	136

Source: FAHMA (2009)

Independent or non-integrated production

According to family/producer records, non-integrated agricultural production activities in Cangati River HMB are centralized in only three (3) products: (a) cotton, (b) maize, and (c) beans, as shown in Chart 1.04 below.

Analysis focuses on total independent production in that microbasin and production per community, according to parameters related to cultivated area (ha), production (kg), sale and consumption. With respect to consumption, it was estimated as the difference between total production and traded quantity.

By analyzing the information of Chart 1.04 related to total non-integrated production in the microbasin, it is noted that it records a total production of 36,600 kg of maize, 2,280 kg of beans, and 375 kg of cotton. Maize and beans crops predominate.

The cultivated area corresponds to 33.25 ha for maize, 13.75 ha for beans and 0.20 ha for total, in a total of 47.20 ha.

At community level, by analyzing each product separately, the following behavior is noted:

- (**a**) Maize – the highest production of this product is centralized in Iguaçu community, which accounts for 60,49% of total, followed by the following communities in decreasing order: São Luiz (28.52%); Cacimba de Baixo (9.34%); and Barra Nova (1.64%); In Lages community no independent production was reported;
- **(b)** Beans – the production of this leguminous product is centralized in São Luiz community, and accounts for 51.32% of total. It is followed by the following communities and percentages in a decreasing order: Iguaçu (39.04%); Barra Nova (7.89%), and Cacimba de Baixo (1.75%); and
- **(c)** Cotton – A production of this product was recorded only in Barra Nova community, reaching 375 kg in a cultivated areas of 0.20 ha.

Chart 1.05 shows the agricultural production and highlights the traded volume and price per product for both integrated and non-integrated crops, as well as the consumption by each surveyed community.

CHART 1.04 – Independent production of maize, beans, broad beans, rice and cotton in communities

Total crops and per community	Surface Area (ha)	Production (kg)
HMB – Cangati River		
Maize	336.10	149,676
Beans	336.60	15,602
Broad beans	13.00	210
Rice	0.50	20
Cotton	10.00	346
Total	**0**	**0**
Communities		
BARRA NOVA	**-**	**-**
Maize	38.30	23,520
Beans	37.30	2,110
Broad beans	8.00	150
Rice	-	-
Cotton	1.00	150
CACIMBA DE BAIXO	**-**	**-**
Maize	82.00	25,620
Beans	84.00	2,908
Broad beans	-	-
Rice	-	-
Cotton	-	-
IGUAÇU	**-**	**-**
Maize	130.80	52,280
Beans	130.80	4,216
Broad beans	5.00	60
Rice	-	-
Cotton	5.00	60
LAGES	**-**	**-**
Maize	39.00	19,260
Beans	39.00	3,388
Broad beans	-	-
Rice	-	-
Cotton	-	-
SÃO LUIZ	**-**	**-**
Maize	46.00	28,996
Beans	45.50	2,980
Broad beans	-	-
Rice	0.50	20
Cotton	4.00	136

Source: FAHMA (2009)

CHART 1.05 – Production, commercialization and consumption

HMB & Communities	Agricultural Products				
	Maize	Beans	Broad beans	Rice	Cotton
HMB					
Production (kg)	186,276	17,882	210	20	721
Commercialization (kg)	62,632	355	-	-	721
Commercialization (R$)	19,680.00	355,00	-	-	790.00
Consumption (kg)	123,644	17,527	-	-	-
Barra Nova					
Production (kg)	24,120	2,290	150	-	525
Commercialization (kg)	11,700	120	-	-	525
Commercialization (R$)	3,805.00	120.00	-	-	610.00
Consumption (kg)	12,420	2,170	-	-	-
Cacimba de Baixo					
Production (kg)	29,040	2,948	-	-	-
Commercialization (kg)	8,298	-	-	-	-
Commercialization (R$)	2,542.00	-	-	-	-
Consumption (kg)	20,742	2,948	-	-	-
Iguaçu					
Production (kg)	74,420	5,106	60	-	60
Commercialization (kg)	20,980	-	-	-	60
Commercialization (R$)	7,108.00	-	-	-	44.00
Consumption (kg)	53,440	5,106	-	-	-
Lages					
Production (kg)	19,260	3,388	-	-	-
Commercialization (kg)	9,060	120	-	-	-
Commercialization (R$)	2,958.00	120.00	-	-	-
Consumption (kg)	10,200	3,268	-	-	-
São Luiz					
Production (kg)	39,436	4,150	-	20	136
Commercialization (kg)	12,594	115	-	-	136
Commercialization (R$)	3,267.00	115,00	-	-	136.00
Consumption (kg)	26,842	4,035	-	-	-

Source: FAHMA (2009)

As shown above, maize has the most significant production in Cangati River HMB, reaching a total of 186,276 kg. Out of this total, 62,632 kg are intended for commercialization and 123,644 kg for consumption, that is, 33.62% and 66.38%, respectively. The commercialized volume amounted to R$ 19,680.00, equivalent to an average price of R$ 0.31/kg. Production at community level indicates that Iguaçu is the major producer, followed by São Luiz, Cacimba de Baixo, Barra Nova and Lages. With respect to the commercialization of this product, the major seller was also Iguaçu (33.50%), followed by São Luiz (20.11%), Barra Nova (18.68%), Lages (14.47%) and Cacimba de Baixo (13.25%). Average prices per community were: Iguaçu, R$ 0.34/kg; São Luiz, R$ 0.,26/kg; Barra Nova and Lages, R$ 0.33/kg; and Cacimba de Baixo, R$ 0.31/kg. If compared to HMB average (R$ 0.31), such prices indicate that Iguaçu community obtained the highest price, while São Luiz obtained the lowest price. In terms of consumption, Iguaçu community was also the leader, accounting for 43.22% of total, followed by São Luiz (21.71%), Cacimba de Baixo (16.78%), Barra Nova (10.04%), and Lages (8.25%).

Beans production ranks second in the microbasin, amounting to a total of 17,882 kg. Production at community level indicates that Iguaçu is the major producer, followed by São Luiz, Lages, Cacimba de Baixo, and Barra Nova. With respect to commercialization, only Barra Nova, Lages and São Luiz communities sell the product, however in minimum quantities.

Broad beans and rice production was fully used for consumption. Broad beans were produced in Barra Nova (71.43%) and Iguaçu (28.57%). Rice was produced only in São Luiz.

Cotton was produced only in Barra Nova, Iguaçu and São Luiz communities. The greatest production was in Barra Nova (72.82%), followed by São Luiz (18.86%) and Iguaçu (8.32%). It was fully allotted for commercialization and reached an average price of R$ 1.16/kg in Barra Nova, R$ 1.00/kg in São Luiz, and R$ 0.73/kg in Iguaçu (the lowest price).

Finally, the total amount of agricultural production commercialized in the microbasin reached R$ 20,825.00.

Livestock

In Cangati River HMB, livestock activity is focused on apiculture, breeding of different fowls, cattle raising (bovine, caprine, ovine, and porcine cattle), and production of eggs and milk. Such animals and other byproducts are distributed over all five (05) communities: Barra Nova, Cacimba de Baixo, Iguaçu, Lages and São Luiz, as shown in Chart 1.06.

That chart shows that Cangati River HMB most animals are fowls which amount to 2,824. Aviculture supplies fowl and eggs to the microbasin, in addition to a marketable surplus. Egg production reaches 179,760 units.

At community level, the greatest number of fowls is concentrated in Iguaçu community, which also stands up for 33.38% of egg production.

The number of bovine cattle heads in that microbasin amounts to 282, 45.39% of which are located in Iguaçu community, 30.50% in São Luiz, 16.31% in Cacimba de Baixo, 4.61% in Barra Nova, and 3.19% in Lages.

Porcine cattle include two hundred and forty-three (243) heads distributed as follows: 43.62% in Iguaçu; 32.51% in São Luiz; 16.05% in Cacimba de Baixo; 5.35% in Barra Nova; and 2.47% in Lages

Sixty-eight (68) heads of sheep are also present in the microbasin and distributed over Iguaçu, São Luiz and Barra Nova communities. Concentration percentages of those animals are: 52.94%, 36.76% and 10.29%, respectively.

Caprine cattle is also present totaling twenty-six (26) heads distributed over São Luiz (57.69%), Cacimba de Baixo (23.08%) and Iguaçu (19.23%) communities.

Only in Iguaçu and Cacimba de Baixo communities the occurrence of apiculture was noted, comprising sixty-six (66) honey-producing beehives. The greatest quantity of beehives is in Iguaçu community with 62.12%, followed by Cacimba de Baixo with 37.88%.

In terms of total number of heads, most of animals are concentrated in Iguaçu community, where there are one thousand for hundred and fifty-four (1,454) animals. It is followed by São Luiz seven hundred and eleven (711), Cacimba de Baixo with six hundred and forty-six (646), Lages with three hundred and forty-six), and finally Barra Nova with two hundred and eighty-seven (287) animals.

In general, it is noted that local livestock production is more focused on consumption of local families of producers and residents.

CHART 1.06 – Cattle raising per community

No. of beehives, animals, several fowls, eggs, and herd	Barra Nova	Cacimba de Baixo	Iguaçu	Lages	São Luiz	Total
1. Apiculture	-	25	41	-	-	66
2. Several fowls	254	554	1.179	331	506	2.824
3. Bovine cattle	13	46	128	9	86	282
4. Caprine cattle	-	6	5	-	15	26
5. Donkeys	-	1	-	-	-	1
6. Ovine cattle	7	-	36	-	25	68
7. Eggs	14,400	31,440	60,000	23,760	50,160	179,760
8. Porcine cattle	13	39	106	6	79	243

Source: FAHMA (2009)

Extractivism

Extractivism activity in Cangati River HMB is focused on the exploration of vegetal coal, spits and toothpicks obtained from quince-tree, which is a native plant in the region, and fishing for consumption (Chart 1.07).

That chart shows that extractive activity is practically fully focused on commercialization in that microbasin.

Total commercialized amount, as evidenced at the survey, reached R$ 26,063.00. By establishing a ranking for activities and percentages comprising that total, it is noted that activity related to barbecue spits accounting for 70.05% ranks first. It is followed by vegetal coal, accounting for 22.12%, and fishing, accounting for 7.83%.

By extending the study to community level, we noted that Barra Nova is the most representative community, where commercialized amount reaches R$ 13,352.00, that is, 51.23% of HMB total. With that percentage, it the most representative community in terms of commercialization of extractivism activity. Activities are focused on barbecue spits (63.68%) and coal (36.32%).

CHART 1.07 – Main silviculture and extractivism products per community.

Communities and HMB	Main products	Main Destination	
		Consum-ption	Commercializa-tion (R$)
Barra Nova	Coal	-	4,850.00
	Barbecue spit	-	8,502.00
	Quince-tree toothpick	-	-
	Fishing	100,00	-
	Total Amount		**13,352.00**
Cacimba de Baixo	Coal	-	30.00
	Barbecue spit	-	216.00
	Quince-tree toothpick	-	-
	Fishing	-	300.00
	Total Amount		**546.00**
Iguaçu	Coal	-	85.00
	Barbecue spit	-	-
	Quince-tree toothpick	-	-
	Fishing	-	1,740.00
	Total Amount		**1,825.00**
Lages	Coal	-	800.00
	Barbecue spit	-	9,540.00
	Quince-tree toothpick	-	-
	Fishing	-	-
	Total Amount		**10,340.00**
São Luiz	Coal	-	-
	Barbecue spit	-	-
	Quince-tree toothpick	-	-
	Fishing	-	-
	Total Amount		**-**
Total (HMB)	Coal	-	5,765.00
	Barbecue spit	-	18,258.00
	Quince-tree toothpick	-	-
	Fishing	-	2,040.00
	Total Amount		**26,063.00**

Source: FAHMA (2009)

The second-ranked community in terms of more significant commercialization is Lages, accounting for 39.67% of total. Related activities have the same Barra Nova profile, that is, they are focused on barbecue spits (92.26%) and coal (7.74%).

On the other hand, the third-ranked most representative community, Iguaçu, is to far from the best ranked communities above, accounting for only 7.00% of total commercialized amount. Extractive activities include fishing (95.34%) and coal (4.66%).

The fourth ranked community at HMB level is Cacimba de Baixo, accounting for only 2.09% of total commercialization, which is distributed as follows: 5.49% for coal, 39.56% for spits, and 54.95% for fishing.

São Luiz community reported no extractivism activity.

1.1.8 – Anthropic environment in area of influence of subproject

1.1.8.1– Resident population

In Cangati River HMB two hundred and thirteen (213) families are settled, the members of which comprise a population of eight hundred and seventy-one (871) inhabitants. Such families are distributed over five (5) communities: Barra Nova, Cacimba de Baixo, Iguaçu, Lages and São Luiz (Chart 1.08).

CHART 1.08 – Number of families and inhabitants per community

Community	Families	Inhabitants
Barra Nova	21	111
Cacimba de Baixo	65	258
Iguaçu	63	244
Lages	27	127
São Luiz	37	131
Total	**213**	**871**

Source: FAHMA (2009)

Chart 1.08 shows that Cacimba de Baixo community has the highest number of families (30.52%) and the highest number of inhabitants (29.62%). Iguaçu comes second with 29.58% of families and 28.01% of population, followed by São Luiz community with 17.37% of families and 15.04% of population, and Lages community with 12.67% of families and 14.58% of population. Barra Nova community has the lowest number of families (9.86%) and the lowest number of inhabitants (12.75%).

The average number of family members in Cangati River HMB is 4.09.

The community with the highest number of family members is Barra Nova, with 5.29. The others have the following average numbers, in decreasing order: Lages 4.70, Cacimba de Baixo 3.97, Iguaçu 3.87 and São Luiz 3.54.

Population in that microbasin is constituted of four hundred and forty-three (443) males and four hundred and twenty-eight (428) females (Chart 1.09).

Chart 1.09 shows an equilibrium between the male population and the female population in the microbasin, and that in absolute terms, the male population slightly exceeds the female population. This evidence is also noted in all other communities comprising the HMB, and only in São Luiz community the absolute number of females exceeds that of males.

CHART 1.09 – Population per community and gender

Community	Males	Females	Total
Barra Nova	56	55	111
Cacimba de Baixo	130	128	258
Iguaçu	127	117	244
Lages	66	61	127
São Luiz	64	67	131
Total	**443**	**428**	**871**

Source: FAHMA (2009)

Out of two hundred and thirteen (213) families living in Cangati River HMB, one hundred and eighty-four (184), or 86.38%, are headed by men, while twenty-nine (29), or 13,.2%), are headed by women (Chart 1.10).

In all communities, the highest percentage of families headed by women was found in Cacimba de Baixo (23.08%), and the lowest in Barra Nova (4.26%). In all other communities, such percentages are: Lages, 11.11%; São Luiz, 10.81%; and Iguaçu, 9.52%;

Most of female heads of families (72.41%) are widows or unmarried women with children.

They are followed by widows and unmarried women without children (13.79% of total). The percentage of women with a spouse or a partner and children, and women with spouse under temporary migration, and widows with children is 13.80%.

CHART 1.10 – Heads of family per community and gender.

Community	Males	Females	Total
Barra Nova	20	1	21
Cacimba de Baixo	50	15	65
Iguaçu	57	6	63
Lages	24	3	27
São Luiz	33	4	37
Total	**184**	**29**	**213**

Source: FAHMA (2009)

1.1.8.2- Family structure and characterization

Chart 1.11 shows the distribution of heads of family in communities per age range and gender in Cangati River HMB.

It is noted in that chart all heads of family are concentrated in the ranges of 55-59, 40-44 and 30-34 years old, all exceeding the percentage of 10.00% and accounting together for 34.75%. Heads of family with lower percent participation are concentrated in the age ranges of 10-14, 70-74 and

80 years old, at percentages of 2.35, 3.29 and 2.82%.

The lowest range of 10-14 years, the presence of heads of family at such an early age calls the attention, as that fact constitutes an exceptionality derived from early pregnancy, breadwinner status for widowhood, or other factors.

Chart 1.12 shows the population per age range and gender in that microbasin, at community level.

In HMB, as a whole, most of population is within the age range of 7-15 years old (25.72%).

CHART 1.11 – Total heads of family per community, age group and gender

Age Range (years)	Barra Nova		Cacimba de Baixo		Iguaçu		Lages		São Luiz		Total		
	F	M	F	M	F	M	F	M	F	M	F	M	M+F
10 - 14	-	-	-	5	-	-	-	-	-	-	-	5	5
20 - 24	-	3	-	3	-	2	1	-	-	1	1	9	10
25 - 29	-	1	1	5	-	-	-	-	1	1	2	16	18
30 - 34	-	1	1	5	1	8	-	3	-	3	2	20	22
35 - 39	-	3	3	2	-	3	-	4	-	6	3	18	21
40 - 44	1	4	-	3	-	5	1	3	-	7	2	22	24
45 - 49	-	1	-	4	-	4	-	1	1	2	1	12	13
50 - 54	-	1	2	5	1	3	-	3	-	2	3	14	17
55 - 59	-	4	3	1	-	11	-	6	-	3	3	25	28
60 - 64	-	2	-	4	-	2	1	1	-	1	2	10	12
65 - 69	-	-	-	5	-	3	1	-	1	4	2	12	14
70 - 74	-	-	-	3	-	4	-	-	1	-	1	7	8
75 - 79	-	-	2	5	2	1	-	2	-	1	4	9	13
80+	-	-	1	2	1	2	-	-	-	2	2	6	8
TOTAL	**1**	**20**	**13**	**52**	**6**	**57**	**4**	**23**	**4**	**33**	**28**	**185**	**213**

Source: FAHMA (2009)

CHART 1.12 – Family aggregates per community and age range.

Age range	Barra Nova	Cacimba de Baixo	Iguaçu	Lages	São Luiz	Total
0 - 6	15	31	24	13	13	96
7 - 15	46	78	46	29	25	224
16 - 21	11	23	31	26	14	105
22 - 30	7	38	44	9	16	114
31 - 40	13	18	28	18	23	100
41 - 50	9	18	20	13	12	72
51 - 65	10	31	31	16	16	104
66 - 70	-	3	8	1	7	19
71+	-	18	12	2	5	37
TOTAL	**111**	**258**	**244**	**127**	**131**	**871**

Source: FAHMA (2009)

There is an equilibrium in HMB population percentage for age ranges of 0-6, 16-21, 22-30, 31-40, and 51-65 years old, with a variation of 11-13%. The age range with the lowest proportional percentage is that of 66-70 years old (2.18%).

In Barra Nova community, population in the age range of 7-15 years old predominates (41.4%), where there are no inhabitants more than 66 years old.

In Cacimba de Baixo community, where the predominating population is also within the age range of 7-15 years old (30.23%), there is an equilibrium of 7-9% in age ranges of 16-21, 31-40, 41-50 and 71+ years old.

In Iguaçu, Lages and São Luiz communities there is no concentration of people in the age range of 7-15 years old like in Barra Nova and Cacimba de Baixo communities, what shows a greater equilibrium in the population distribution over the several age ranges surveyed.

Chart 1.13 shows the population schooling in Cangati River HMB per community.

In that HMB, pure illiterates (ANA) account for 26.64% of total population, with a higher incidence in male gender at a percentage of 29.07%

against 23.98% in female gender.

With respect to functional illiterates (ANAF), they account for 5.86% of the microbasin population, and are concentrated in the female gender (6.95%). In masculine gender, percentage is 4.85%. Literate inhabitants (ALF) account for 9.30% of total population. Women stand out in that topic by accounting for the highest number of literates (9.59% against 9.03% among males).

People that started but did not complete the basic school (FUNINC) account for 43.05% of total population, or 40.97% for the male gender and 45.32% for the female gender, which constitute the highest concentration of HMB inhabitants, and establish the education profile of the region in Cangati River HMB.

People who completed the basic school (FUMCOMP) account for 2.99% of population, of which 1.92% are females and 3.96% are males.

The expressive difference between population classified as FUMCOMP and FUNINC should be highlighted, as it shows the high number of people who start but do not complete basic school.

CHART 1.13 – Members of family aggregates per schooling and gender

Community	Gender	ANA	ANAF	ALF	FU-NINC	FUN-COMP	SE-INC	SE-COMP	TE-RINC	TER-COMP	TOTAL
Barra Nova	F	12	4	3	30	-	2	3	-	-	54
	M	14	5	1	27	5	3	2	-	-	57
C. de Baixo	F	24	8	8	74	1	4	7	-	-	126
	M	48	1	10	61	4	2	4	2	-	132
Iguaçu	F	32	3	13	46	4	7	12	1	1	119
	M	27	4	17	50	4	13	10	-	-	125
Lages	F	9	9	4	23	1	6	4	-	-	56
	M	24	8	4	24	2	1	8	-	-	71
São Luiz	F	23	5	12	16	2	2	2	-	-	62
	M	19	4	9	24	3	5	5	-	-	69
TOTAL	**F**	**100**	**29**	**40**	**189**	**8**	**21**	**28**	**1**	**1**	**417**
	M	**132**	**22**	**41**	**186**	**18**	**24**	**29**	**2**	**-**	**454**
	F+M	**232**	**51**	**81**	**375**	**26**	**45**	**57**	**3**	**1**	**871**

Source: FAHMA (2009)

Legend:

ANA - illiterate individual;
ANAL - individual who may be considered as functional illiterate, that is, attended 2 or 3 school years, but is unable to read and/or write simple things, such as notes, advertisements, short letters, instruction manuals and other typical items;
ALF - literate individual that fully or almost (3 or 4 years) completed elementary school, either through literacy courses or others; FUNINC: individual that started but did not complete basic school;
FUNCOMP - individual that completed basis school;
SEINC - individual that started but did not complete high school;
SECOMP - individual that completed high school;
TERINC - individual that started but did not complete middle school;
TERCOMP - individual that completed middle school.

With respect to those who started but did not complete high school (SEINC), we note that this group accounts for 5.17% of population, being 5.29% in the male gender and 5.04% in the female gender. People who completed high school (SECOMP) account for 6.54% of total inhabitants of that HMB.

All those who completed middle school (TERCOMP) are females, accounting for 0.11% of total HMB population. The percentage of total female population is 0.24%.

In this analysis, it is worth stressing that ANA and ANAF schooling levels together account for 32.50% on inhabitants.

By extending the analysis of Chart 1.13 to communities, results are as follows:

In Barra Nova community, illiterate people (ANA) account for 23.42% of total population, a percentage that is 3.22% below that of total HMB. Male illiterates (24.56%) exceed female illiterates (22.22%) by 2.34%.

With respect to functional illiterates (ANALF), total population percentage is 8.11%, exceeding by 2.25% that of total HMB. Male ANAF predominate at 8.77%, against 7.41% of female ANAF.

Literate people (ALF) in the community account for 3.60% of population that, if compared to total HMB, is a much lower number, that is, a difference of 5.70%.

On the other hand, inhabitants that started by did not complete basic school (FUNINC) account for more than half the population, that is, 51.35%, and exceeds the total HMB (43.05%). Most of that total refers to the female gender (55.56%) against 47.37% to the male gender.

All those who completed basic school (FUNCOMP) are males and account for 8.77% of population and 4.50% of total community population. However, that indicator exceeds that of HMB of only 2.99%.

People who started but did not complete high school (SEINC) account for 4.50% of total, being 3.70% for the female gender and 5.26% for the male gender.

People who completed high school (SECOMP) match those people who started but did not complete the course, that is, 4.50%. Female gender accounts for 5.56% of total community population, while male gender accounts for 3.51%.

In the community there was no report of individuals who started but did not complete middle school, or individuals who completed middle school.

By analyzing Cacimba de Baixo community, illiterate people account for 27.91% of total population, a percentage that exceeds total HMB by 1.27%. Male illiterates on the other hand (36.366%) exceed female illiterates (19.05%) by 17.31%.

With respect to functional illiterates, total population percentage is 3.49%, 2.37% below that of total HMB. Female illiterates (6.65%) predominate over male illiterates (0.76%).

Literate people in the community account for 6.98% of population that, if compared to total HMB, is a 2.32% below.

On the other hand, inhabitants that started by did not complete basic school account for more than half the population, that is, 52.33%, and exceeds total HMB (43.05%). Most of that total refers to the female gender (58.73%) against 46.21% to the male gender.

People who completed the basic school account for 1.94% of population, of which 3.03% are males and 0.79% is female. In relation to total HMB, the community has a percentage of people the completed basic school that is 1.05% below.

People who started but did not complete high school account for 2.33% of total, being 3.17% for the female gender and 1.52% for the male gender.

As compared to HMB percentage, the community percentage shows a better condition, that is, 2.33% against 5.17%.

Percentage of people who completed high school is lower than those who started but did not complete that course, that is, 4.26% against 2.33%, a percentage that is also lower than that of total HMB. Female gender accounts for 5.56% of total community population, while male gender accounts for 3.03%.

In the community there was a percentage of 0.78% of inhabitants that stared but did not complete middle school. Such inhabitants are males and account for 1.52 of this group of the population.

In Iguaçu community, illiterate people account for 24.18% of total population, a percentage that is 2.46% below that of total HMB. Male illiterates, on the other hand, (21.60%) are 5.29% below female illiterates (26.89%). With respect to functional illiterates, total population percentage is 2.87%, 2.99% below that of total HMB. Male illiterates (3.20%) predominate over female illiterates (2.52%).

Literate people in the community account for 12.30% of total population that, if compared to total HMB, is a 3.00% above. Male illiterates (13.60%) exceed female illiterates (10.92%) by 2.68%.

On the other hand, inhabitants that started by did not complete basic school account for 39.34% of total population, a percentage that is, 3.71% below that of HMB (43.05%). Most of that total refers to the male gender (40.00%) against 38.66% to the female gender.

People who completed basic school account for only 3.28% of population, of which 3.20% are males and 3.36% are females. In relation to total HMB, the community has a percentage 0.29% higher of people that completed basic school.

People who started but did not complete high school account for 8,20% of total, being 5,88% for the female gender and 10,40% for the male gender. As compared to HMB percentage, the community percentage shows a worse condition, that is, 8.20% against 5.17%.

Percentage of people who completed high school is lower than those who started but did not complete that course, that is, 9.02% against 8.20%, a percentage that is also above that of total HMB. Female gender accounts for 10,08% of total community population, while male gender accounts for 8,00%.

In the community there was a percentage of 0.41% of inhabitants that stared but did not complete middle school. Such inhabitants are females and account for 0.84% of this group of the population.

In Lages community, illiterate people account for 25.98% of total population. Male illiterates (33,80%) are 17.73% above female illiterates (16,07%), which a quite significant figure.

With respect to functional illiterates, total population percentage is 13.40%, exceeding by 7.54% that of total HMB. Functional female illiterates (16.10%) predominate over male illiterates (11.30%).

Literate people in the community account for 6.30% of population, a number that, if compared to total HMB, is 3.00% below. Male illiterates (5,63%) are 1.51% below female illiterates (7,14%).

On the other hand, inhabitants that started by did not complete basic school account for 37.01% of total community population, a percentage that is 6.04% below that of HMB (43.05%). Most of that total refers to the female gender (41.07%) against 33.80% to the male gender. The difference favorable to males is 7.27%.

People who completed the basic school account for only 2.36% of population, of which 2.82% are males and 1.79% is female.

People who started but did not complete high school account for 5,51% of total, being 10,71% for the female gender and 1,41% for the male gender.

Percentage of people who completed high school is higher than that of those who started but did not complete that course, that is, 9.45% against 5.51%, a percentage that is above that of total HMB. Female gender accounts for 7.14% of total community population, while male gender accounts for 11.27%. Number of males exceeds that of females by 4.13%. No higher education student was reported in the community.

In São Luiz community, the percentage of illiterates (32.06%) exceeds that of HMB illiterates (26.64%) by 5.42%. In the community, the percentage of female illiterates exceeds that of male illiterates, which are 37.10% and

27.54%, respectively. With respect to functional illiterates, total population percentage is 6.87%, exceeding by 1.01% that of total HMB.

Functional female illiterates (8.06%) predominate over male illiterates (5.80%).

Literate people in the community account for 16.03% of population, a number that, if compared to that of total HMB, is 6.73% higher. Male illiterates (13,04%) are 6,31% below female illiterates (19,35%).

Inhabitants who started but did not complete basic school account for 30.53% of community population, a percentage that is 12.52% lower than that of HMB (43.05%). Most of this total refers to male gender (34.78%), against 25.81% to female gender.

People who completed basic school account for only 3.82% of population, of which 4.35% are males and 3.23% are females. In relation to total HMB, the community has a percentage 0.83% higher of people that completed basic school.

People who started but did not complete high school account for 5,34% of total, being 3,23% for the female gender and 7,25% for the male gender.

People who completed high school account for the same percentage of people who started but did not complete that course, that is, 5.34%, and therefore there was no education progress. Female gender accounts for 3.23% of total community population, while male gender accounts for 7.25%.

No higher education students were reported in the community.

By analyzing the baseline study of Cangati River HMB from education view, the following approach refers to the population's schooling pee age range (Chart 1.14).

Chart 1.14 shows that illiterate population in HMB concentrate within the age range of 25+ years old (55.60%) and 0-6 years old (40.09%), or a total of 95.69%. That is followed by the population in the age range of 7-14 years old with 2.59%. For age ranges of 18-19 and 20-24 years old, percentage reaches 0.86%.

Population considered as functional illiterate also concentrates in the age range of 25+ years old, at 92.16%. Then, concentration occurs in the age range of 20-24 years old range (3.92%) followed by age ranges of 0-14 and 18-19 years old at a percentage of 1.96%. The other age ranges – 0-6 and 15-17 years old – report no functional illiterates.

Literate population also concentrates in age range of 25+ years old, at 96.30%. Other age ranges that report literacy include only those of 7-14 (1.23%) and 20-24 (2.47%) years old.

Still, HMB population that started but did not compete basic school concentrates in the age range of 7-14 years old at 47.47%, followed by age ranges of 25+ years old (29.07%), 15-17 (10.67%), 20-24 (7.47%), 18-19 (4.53%), and 0-6 (0.80%) years old.

CHART 1.14 – Total members of family aggregates per schooling and age range

Schooling	0 - 6	7 - 14	15 - 17	18 - 19	20 - 24	25+	Total
ALF	-	1	-	-	2	78	81
ANA	96	6	-	2	2	129	232
ANAF	-	1	-	1	2	47	51
FUNCOMP	-	3	4	5	10	4	26
FUNINC	-	184	40	17	28	109	375
SECOMP	-	-	3	6	27	18	57
SEINC	-	-	22	10	2	8	45
TERCOMP	-	-	-	-	-	1	1
TERINC	-	-	-	-	1	2	3
TOTAL	**96**	**195**	**69**	**41**	**74**	**396**	**871**

Source: FAHMA (2009) (See legend next to Chart1.13)

It should be noted that the population in the age range of 25+ years old attending basic school attend special literacy schools that usually have special working hours and are part of the government's fight against illiteracy.

HMB population that completed basic school also concentrates in the age ranges of 25+ and 20-24 years old (38.46%), followed by age ranges of 18-19 (19.23%), 15-17 (15.38%) and 7-14 (11.54%) years old.

Inhabitants who started but did not complete high school are more present in the age range of 15-17 years old with 48.89% of total. That is followed by age ranges of 18-19 (22.22%), 25+ (17.78%), 7-14 (6.67%) and finally 20-24 (4.44%) years old.

For population that completed high school, concentration occurs in the age ranges of 25+ and 20-24 years old (47.37%), followed by ages ranges of 25+ (31.58%), 18-19 (10.53%), and finally 7-14 and 15-17 (5.26%) years old.

In HMB there are people who started but did not complete middle school at the following percentages: 66.67% for the age range of 25+ years old, and 33.33% for the age range of 20-24 years old. However, the number of those people is only three (3), which accounts for only 0.34% of total HMB population. Those who completed middle school concentrate in the age range of 25+ years old and account for only 0.11% of total population.

Classification of population schooling in Cangati River HMB presents the following aspects according to a decreasing percent classification:

Individuals who started but did not complete basic school account for 43.05% of total population. Illiterates accounts for 26.64% of population, and literates account for 9.30%.

Individuals who complete high school account for 6.54% of total population. Functional illiterates (2 or 3 schooling years) account for 5.86%.

They are followed by those individuals who started but did not complete high school, which account for 5.17% of total population. Finally, those who completed basic school account for 2.99% of total population.

Individuals who started but did not complete middle school account for only 0.34% of inhabitants, while those who completed that course account for 0.11%.

The following analysis aims to identify the population member of rural associations and rural labor unions active in Cangati River HMB (Chart 1.15).

CHART 1.15 – Participation of family aggregates in rural associations and/or labor unions (STR)

Members of family aggregate	Associated entity		
	Only association	Only STR	Association / STR
	Number		
Head of family	94	21	58
Spouse	46	21	41
Son	14	-	-
Daughter	4	1	3
Stepson	2	-	-
Stepdaughter	1	-	-
Mother-in-law	-	1	-
Brother-in-law	1	-	-
Sister-in-law	-	1	-
Uncle	-	1	-
TOTAL	**162**	**46**	**102**

Source: FAHMA (2009)

Chart 1.15 shows that Cangati River HMB has one hundred and sixty-two (162) members of local associations, forty-six (46) members of rural labor unions, and one hundred and two (102) members of both types of entities concomitantly.

With respect to associations, most participants include heads of family (58.02%) followed by spouses (28.40%), sons (8.64%), daughters (2.47%, stepsons (1.23%) and stepdaughters (0.62%).

Among family members that participate in rural labor unions, heads of family and respective spouses account for 91.30% evenly distributed (45.65% for each type of member). All other family members, such as daughters, mothers-in-law, sisters-in-law and uncles account for the remaining 8.70%. For inhabitants that participate in associations and labor unions, distribution also concentrates in heads of family with 56.86%. They are followed by spouses (40.20%) and daughters (2.94%).

The focus of next analysis is on the composition of family income in Cangati River HMB (Chart 1.16).

CHART 1.16 – Total members of family aggregates per economic activity

Economic Activity	Members of Family Aggregate				Total
	Head of Family	Spouse	Children	Others	
Slaughter-House	1	0	0	0	1
Agriculture	180	58	46	7	291
Brother Assistant	1	1	0	0	2
Assistant Trucker	1	0	0	0	1
Apiculture	1	0	0	0	1
Workmanship	2	0	0	0	2
Baby sitter	1	0	1	0	2
Bar	0	1	1	0	2
Food Allowance Program	0	1	0	0	1
School Allowance Program	4	56	0	1	61
Family Allowance Program	1	13	0	0	14
Foreman	1	0	0	0	1
Coal merchant	1	0	0	0	1
Spit seller in Fortaleza	0	1	0	0	1
Merchant	4	3	0	0	7
Commerce	1	0	0	0	1

(continue)

(continuation)

Economic Activity	Members of Family Aggregate				Total
	Head of Family	Spouse	Children	Others	
Hawker	2	0	0	0	2
Ready-made clothes	0	1	1	0	2
Paid employment job	16	15	5	0	36
Extractivism	22	16	13	1	52
Blacksmith	4	0	1	0	5
Zero Starvation Program	7	59	1	0	67
Player	1	0	1	0	2
Laundress	0	1	0	0	1
Bicycle Technician	1	0	0	0	1
Other Pensions	1	0	0	1	2
Livestock	37	20	4	2	63
Mason	1	0	0	0	1
Retirement Pension	55	26	3	10	94
Fishing	4	0	1	1	6
Cloth Resale	1	0	0	0	1
Avon Resale	0	2	0	0	2
Unemployment Insurance	1	0	0	0	1
Gas Voucher Program	3	7	0	0	10
Service Provider	87	2	19	4	112
Hawker	0	0	3	0	3
Total	**441**	**283**	**100**	**27**	**851**

Source: FAHMA (2009)

To make the analysis of this segment easier, frequencies of income-generating activities were classified into three components: economic activities, governmental grants, and other sources of income (Chart 1.17).

Results show a frequency of eighty hundred and fifty-one individuals striving for income in that microbasin, distributed as follows: heads of family account for 51.82% of total frequency; spouses account for 33.25%; sons and daughters account for 11.75%; and others (mothers-in-law, stepchildren and others) account for 3.17%.

With respect to economic activities performed by farmers, cattle breeders, extractivists and others, income composition of heads of family predominate (58.89%), followed of those of spouses (23.09%), children (15.47%) and others (2.54%).

With respect to governmental grants, which are constituted of Federal Government's policies to fight hunger, such as school allowance and gas voucher programs, spouses account for 88.89%, followed by heads of family (9.80%) and children and others (0.65%, respectively).

With regard to item related to other sources of income, where income from retirement pensions, provision of services and paid employment job predominate, heads of family account for 64.53%, followed by spouses (17.74%), children (12.08%), and others (5.66%).

In total of families' frequency in search of income, family agriculture activities predominate at 67.21%, followed by livestock (14.55%) and extractivism (12.01%), which amount together to 93.77%. Difference of 6.23% is divided into apiculture and fishing, workmanship, several commercial trades, ready-made clothes, tools and mechanics.

CHART 1.17 – Total economic activities per family aggregates

Economic Activities	Head of Family	Spouse	Children	Others	Total
Economic Activities	255	100	67	11	433
Governmental Grants	15	136	1	1	153
Other sources of income	171	47	32	15	265
TOTAL	**441**	**283**	**100**	**27**	**851**

Source: FAHMA (2009)

So-called governmental grants are concentrated in item related to food (53.59%), followed by school allowance (39.87%) and gas voucher (6.54%).

With respect to such sources of income in Cangati River HMB, except for provision of services, which is mostly focused on provision of services to PRODHAM and coal production, all other activities are urban, although they are performed in rural environment.

More outstanding income-generating activities include: provision of services (43.26%), retirement pension (35.47%) and paid employment job (13.58%). The sum of such activities amount to a percentage of 92.31%. The sum of all other activities associated with hawkers, unemployment insurance, and general dealers amounts to only 7.69%).

To complement this study, Chart 1.18 shows in percentages the sources of complementary activities of HMB families. These are not activities included only in income item, such as "student" and "housewife", which are not remunerated. A complementary activity in this study means an activity performed jointly with the main activity.

Complementary activities include a total of six hundred and ninety-four (694) occurrences distributed over one hundred and ninety-two (192) heads of family, one hundred and fifty-three (153) spouses, three hundred and two (302) children, and forty-seven (47) individuals classified as others. Complementary activities of heads of family have a higher occurrence among farmers (90.63%) followed by agriculture (7.81%).

All other activities, such as housewife, retirement and watchman have a low representativeness and account together for only 1.56%. Spouses perform a complementary activity focused on agriculture (56.86%), housewife (27.45%), and farmer (12.42%), which are the most representative activities in HMB.

Student and 'retirement' activities have low significance (3.26%). With respect to family aggregates represented by children, the predominating activity is that of "student" *81.46%) followed by farmer (11.92%), which together account for 93.38%. The remaining 6.62% refer to no activities.

CHART 1.18 – Total members of family aggregates per economic activity and other complementary sources of income.

Activity	Head of family	Spouse	Children	Others	Total
None	-	-	3	-	3
Husbandman	174	19	36	8	237
Student	-	4	246	30	280
Housewife	1	42	7	3	53
Retired	1	1	-	3	5
Watchman	1	0	1	-	2
Farm woman	15	87	9	3	114
TOTAL	**192**	**153**	**302**	**47**	**694**

Source: FAHMA (2009)

In item "Others", students and farmers are the most representative complementary activities, accounting for 63.83% and 17.02%, respectively. Household, retirement and agricultural activities account for 6.38% each

1.1.8.3 - Migration experience

It was observed that definitive emigration over the last ten (10) years in Cangati River HMB included a total of seventy-two (72) individuals, whose kinship to the head of family includes daughters, sons, grandsons and nephews (Chart 1.19).

CHART 1.19 – Family members that emigrated definitively over the last 10 years

Family Aggregates	Barra Nova	Cacimba de Baixo	Iguaçu	Lages	São Luiz	Total
Daughter	4	14	4	7	9	38
Son	3	12	8	1	8	32
Grandson	-	1	-	-	-	1
Nephew	-	-	13	-	-	1
Total	**7**	**7**	**13**	**8**	**17**	**72**

Source: FAHMA (2009)

It is noted that, with respect to family aggregates, the highest number of migrants is constituted of daughters (52.78%), followed by sons (44.44%), and grandsons and nephews (1.39%).

This behavior also applies to all communities, except for Iguaçu, where the number of sons exceeds that of daughters (61.54% and 30.57% respectively). Migration of grandsons and nephews only occurred in Cacimba de Baixo and Iguaçu communities, accounting for 3.70% and 7.69% of total, respectively.

The highest numbers of migrants are concentrated in Cacimba de Baixo community (37.50%), followed by São Luiz (23.61%), Iguaçu (18.06%), Lages (11.11%), and finally Barra Nova (9.72%)

In Cangati River HMB, migrants' destination was mostly the State of Ceará, comprising forty-eight (48) inhabitants, while twenty-four (24) other migrants headed for other Brazilian States, as shown in Chart 1.20.

Chart 1.20 shows that daughters account for 52.78% of migrants, thus representing the leading group among all other relatives. Regarding destination, they mostly head for the State of Ceará (60.42%), which 37.50% prefers other Brazilian States.

In contrast, sons mostly head for other States (58.33%), and only 37.50% select the State of Ceará.

The Chart shows no migrations of other family members, such as parents, heads of family and others.

CHART 1.20 – Family members that migrated definitively over the last 10 years

Family members	Ceará	Out of Ceará	Total
Son	18	14	32
Daughter	29	9	38
Grandson	1	-	1
Nephew	-	1	1
TOTAL	**48**	**24**	**72**

Source: FAHMA (2009)

1.1.9 – Socioeconomic aspects

Cangati River hydrographic microbasin houses a population of eight hundred and seventy-one (871) individuals distributed over two hundred and thirteen (213) families. As the microbasin covers a surface area of 75.65 km^2, its demographic density is 11.51 inhabitants per km^2. This average is lower than those of the municipality of Canindé and the state of Ceará (21.81 and 51.00 inhabitants per km^2, respectively).

Average number of family members is 4.09, which is lower than those of the Municipality of Canindé and the state of Ceará (4.40 and 4.21, respectively, according to IBGE (2000)).

There is slight predominance of male inhabitants (50.8%) over female inhabitants (49.14%). According to IBGE (2000), the same occurs in the municipality of Canindé (50.12% of males and 49.88% of females), but in contrast, in the state of Ceará the male population is 48.09% and female population is 51.91%.

Heads of family are predominantly men. However, there is a significant number of families headed by women (13.62%). Such heads of family are widows with or without children, unmarried mothers, women with children and partners, and married women that engage in temporary migration.

Most heads of family are in the age range of 30-59 years old. However, some are 14 years old or younger (2.35%). There are cases derived from early pregnancy, breadwinning for widowship reasons, among others. It should be stressed that in some communities there are heads of families that are 80+ years old.

Most population is in the age range of 7-15 years old (25.72%). This characteristic is outstanding in Barra Nova and Cacimba de Baixo communities. In all other communities, population is distributed more evenly over other age ranges.

26.64% of total population are illiterate. By excluding the children in the age range of 0-6 years old, this percentage falls to 15.61%. Most population, that is, 43.05%, started but did not complete basic school. In the microbasin, only 1 individual has completed middle school.

Associations have two hundred and sixty-five (265) members, 57.58% are heads of family, 32.95% are spouses, 7.95% are sons and daughters, and the remaining 1.52% includes stepsons, brother-in-law and uncle.

Over the last ten years, seventy-two (72) individuals migrated definitively from the microbasin. Migrants are daughters (52.78%), sons (44.44%), and grandsons and nephews (1.39%). Among migrants, a small predominance of female gender is noted.

Temporary migration is insignificant among the microbasin dwellers. Only five (05) individuals were reported to have stayed some period of time out of the microbasin.

Family members earn income from thirty-three (33) sources or activities. The leading activity is agriculture and livestock with three hundred and seventy-four (374) occurrences; it is followed by school allowance, food allowance, family allowance/zero starvation, and gas voucher programs with two hundred and ninety-one occurrences (291); then comes the provision of services with one hundred and twenty-eight (128) occurrences; the fourth is represented by retirement and pensions with one hundred and eleven (111) occurrences.

Most families live in “heir’ land” (32.86%), followed by “tenant’s land” (30.51%, “family land” (15.02%), “partnership land” (6.10%), and “others” (15.49%).

Main use of soil is agriculture, mentioned by 89.20% of properties; 23.00% use soil for pasture; 3.75% for forests or reforestation; and 28.17% of properties have fallow land.

Agricultural production in Cangati River HMB is focused on cotton, maize, broad beans and rice, which are mostly explored in integrated crops. Productivity is very low, due to the lack and poor distribution of rains.

Total amount of production last year, based on the average price of sold portion, was R$ 76,590.66 (seventy-six thousand, five hundred and ninety reais and sixty-six centavos). R$ 20,825.00 (27.19%) of that amount corresponds to the sold portion of production.

Livestock production in the microbasin is significant and comprises apiculture, fowls, bovine, ovine, equine and porcine animals and mules. Portion of production sold generated an income of R$ 35,874.00 (thirty-five thousand, eight hundred and seventy-four reais). Main product sold was bovine cattle, accounting for 51.20%, followed by swine (20.56%), eggs (15.65%), bee products (7.04%), fowls (5.07%), and ovine cattle (only 0.56%).

In addition to agriculture and livestock, Cangati River HMB dwellers perform extractive activities to obtain recipes. Extractive activities include coal making, manufacture of barbecue spits, and fishing. Last year, such activities generated an income of R$ 26,063.00 (twenty-six thousand and sixty-three reais).

Water use infrastructure most used by families is cistern, which amounts to ninety-eight (98) units in the microbasin. Other infrastructures identified were water hole (56 units), family pool (51) and deep well (4).

Most families dwell in masonry houses (81.43%). Other types of houses include mud house (16.67%) and improved mud house (1.90%).

In general, dwellings have more than one water supply source. Most common water sources are cisterns, water holes and wells (42.68%), reservoirs and pools (29.50%), collective CAGEGE and Municipal systems (26.61%). Other less frequent sources include desalinators, individual piping system and tank trucks.

Sewerage is quite deficient in most dwellings. In 53.62%, sewage is disposed on the surface; 51.64% have not toilet in the bathroom; and 31.92% have no bathroom.

As means of transportation, families use especially bicycle (69.01%), tamed animals (45.07%) and motorcycle (8.92%). Other means of transportation that are little used include: car, cart load or light cart, and truck.

Families have benefited of PRODHAM works and activities, as follows: leveled stone barrier and successive dams for sediment retention benefited 47.0%; terraces (27.23%); cisterns (24.41%); access roads (20.18%); underground dams (11.27%); ciliary vegetation recomposition (6.10%); agrosilvipastoral system (1.88%); and dead cover (1.88%).

Families have participated significantly in execution of PRODHAM works and activities. Five hundred and thirty-five (535) occurrences of involvement of individuals who performed 12,399.5 days of work were reported, which gave the workers a remuneration of R$ 108,128.50 (one hundred and eight thousand, one hundred and twenty-eight reais and fifty centavos).

PRODHAM offered directly or indirectly training in production systems and water and soil preservation practices and environmental preservation. In the former, forty-seven (47) individuals were trained, and in the latter, one hundred and eighty-seven (187) individuals were trained).

Likewise, disseminated environmental information reached one hundred and fifty-one (151) individuals. It was noted that one hundred and one individuals performed joint initiatives to solve environmental problems.

Domestic waste destination is still a concern, as 24.64% of families dispose waste on vegetation or on the margins of BR-020 road.

There are five (05) associations in the microbasin, one in each community. Four (4) of them are in full operation, and one (1) has already been organized but still waits for its CNPJ issuance. All of them comprise small producers. All five (05) associations have a total of two hundred and sixty-five members involving two hundred and twenty-one (221) families. As there are two hundred and thirteen (213) families in the microbasin, it means that some families have members in several associations.

Four (4) of such five (05) associations were supported by PRODHAM. Barra Nova association was not benefited because it was not legally constituted at the time.

Hydroenvironmental works involved four (4) associations and the participation of one hundred and sixty-two (162) individuals of one hundred and thirty-two (132) families. Capacity building/experimentation, environmental education and reforestation actions, sport and accounting training activities involved two (2) associations and benefited sixty-three (63) families.

Four (04) oldest associations were given an additional support by PRODHAM for the development of project of community interest in 1993-2004 period. Currently, no association is developing an additional PRODHAM subproject.

Water Resources 2

PART 2 – WATER RESOURCES

2.1 – Introduction

Water is considered an economic good because it is finite, vulnerable and critical for life and environment preservation. Its shortage retards the development of several regions. In some areas, it has become scarce and limited, what has aroused a collective awareness of its preservation and rational use.

The increased water demand combined with water quality degradation has contributed to a reduced availability of that resource, leading to critical quantities in some regions. In Northeastern semiarid region, this problem has aggravated and some conflicts may be identified.

Conflicts of interests associated with water use and represented by needs by urban supply, irrigation, industry, and tourism, among others, evidence the need of an inter-institutional articulation and the adoption of an integrated water resource management policy. In fact, to achieve the rational water resource management of a particular basin, it is indispensable not only the involvement of local community, but also a technical-scientific and political involvement to ensure water supply and support to the sustainable development of important economic activities.

It should be highlighted that one of water resource management tools is qualitative and quantitative water monitoring. In effect, monitoring the water resources of a basin constitutes a strategic activity leading to the creation of a data and information base that, if continuedly updated and disseminated, will guide the management of such resources, and support the decision making process.

In this context, emphasis should be given to Federal Law no. 9,433, of January 8, 1997, which provided for the National Water Resource management Policy and System and establishes the need of water resource use award for all projects provided with a significant river water quantity. It also establishes that water use charge. The need of implantation of a monitoring network is evident, which will generate, if efficiently and continuously operated, historical data series that will allow a better understanding of water potential in hydrographic basis and support the application of management instruments established in Law no. 9,433.

In fact, data generated from hydrological variable monitoring in a particular hydrographic basin and their application in simulation models are instruments that will allow the required actions for effective basin management to be planned. They will also allow water availability in the basin to be monitored, and the evaluation of its hydrological processes and water quality to be evaluated. The analysis of potential impacts of interventions and/or new works or any other external actions on the behavior of rivers comprising the basin will also be possible.

However, understanding a hydrographic basin will only be possible by performing topographic, geological, climatic, socioeconomic, environmental and hydrological studies. Topography, geology, vegetation, environmental and socioeconomic conditions may be understood through a physical study of the area and a future follow-up of potential changes. On the other hand, climate and hydrological regime will only be understood if we are provided with a history of a series of hydrometeorological data on the region. This cannot be achieved at once. The longer the history and the best the spatial distribution of stations and data quality, the greater the understanding of the hydrographic basin under study.

Based on that such aspects, Funceme designed and implanted the "Subproject for Geoenvironmental Study of Cangati River Microbasin in Canindé-CE", which is aimed at the implantation of an adequate monitoring infrastructure in the region and expects to support the microbasin water resource management and improve the local community's life quality.

2.2 – Surface water monitoring

All activities performed in a particular hydrographic basin directly or indirectly affect the relationships between other natural resources and water; this way, considering the hydrological in the plan of integrated use of such resources is indispensable. In fact, changes to soil use will affect infiltration capacity, hydraulic conductivity, and the soil capacity of retaining water, changing consequently the volume of water drained in the basin. Construction of dams in river beds may change downstream water quality and increase the energy available for erosion, etc.

Changes to soil occupation and use, anthropic factors and especially the intensified agricultural activity have caused environmental disturbances in Cangati River Microbasin in Ceará. In effect, some processes, such as soil erosion, sediment accumulation and transportation, and river sanding-up can be noted and represent some of impacts on its water resources. It is then evident the importance of collecting data and information on Cangati River microbasin hydrology to support the evaluation of hydrological consequences from interventions in the microbasin, such as the removal of native vegetative cover, and the construction of successive dams, among others.

Actually, hydrographic actions, such as precipitation, discharge and evaporation, among others, are critical for understanding both the hydrological behavior of a hydrographic basin, either for a specific event or for a particular period of time, and the problems associated with use, management and preservation of its water resources. This way, the continued water resource monitoring in a basin and the collection of historical series of environmental data constitute essential instruments for a better evaluation of critical hydrological phenomena occurred in that basin. Such data will also support the calibration and validation of hydrological models and, consequently, the scientific assumptions incorporated in such models.

In this context, to evaluate the effect of changes to conservational practices in Cangati River microbasin in Ceará, stream discharges and other hydrological variables were monitored. With this purpose, the microbasin was instrumentalized by structures that enabled the field collection of hydrological parameters to allow Funceme, among other things, to make studies to quantity the surface runoff and sediment transportation and accumulation in successive dams constructed in that microbasin under PRODHAM.

In effect, possession of data collected from the monitoring structures installed in the microbasin, led to the generation of information that would enable a better understanding of the dynamics of its hydrological processes, more specifically the generation of discharges and the flow of sediments to successive dams.

The survey comprised two stages: The first stage involves an intensive field activity intended to identify the reality of microbasin under study, by providing a diagnosis of current conditions of its water resources, including the indication of the location of installation of structure necessary for the study and the hydrological variables to be monitored. In the second stage, data generated by monitoring were checked, tabulated and made available to allow important hydrological processes to be modeled.

2.2.1 – Staff mobilization and training

To collect hydrological and sedimentological data provided in the scope of subproject, such as: reading of limnimetric rulers installed in successive dams built in river and stream beds, reading of data stored in Data Collection Platforms (DCP), and collection of water samples for laboratory analysis, among others, a training was held for people resident in Cangati River microbasin region. Those people were trained by Funceme technical staff, and Dimensão Engenharia provided all logistic support necessary for that training.

Priority was given to members of local community who had worked previously in other stages of PRODHAM project, had some experience in similar services and lived near the areas where monitoring structures and/or equipment were implanted, such as:

- areas where two (02) flow measuring flumes and respective data collection platforms – DCP had been constructed;
- areas close to successive dams where limnimetric rulers had been installed;
- areas where rulers for sedimentological data monitoring had been installed;
- areas where water and soil collectors had been installed to monitor sedimentological data;
- rivers, streams and reservoirs where water was collected for laboratory analysis of physical-chemical and bacteriological parameters, including suspended material.

Selection of candidates to said training also met the following criteria:

- be literate (able read and write);
- be of age;
- have basic knowledge in mathematics, that is, able make sum, subtraction, multiplication and division operations;
- be proactive and creative in day-to-day situations;
- have a leadership spirit and good insertion in the community;
- have commitment and responsibility with the work;
- have basic knowledge of general services; and
- live in the community.

This way, the team selected and trained for the performance of services included in the scope of the subproject was composed by the following persons: Antônio Napoleão de Souza Furtado, João Paulo Matias Furtado, Francisco Edson Abreu Cordeiro, Antônio Matias Furtado (known as Galberto), and Evangelista Pinto Pereira.

Before the training, a preparatory meeting was held in PRODHAM house, located in Cangati River microbasin region, to introduce and mobilize the teams involved (Photos 2.01 and 2.02), as follows: field team (local selected dwellers), Funceme and Dimensão Engenharia Ltda. Technicians.

Photo 2.01 – Team Introduction

Photo 2.02 – PRODHAM House

2.2.2 – Basin instrumentalization

2.2.2.1 – Flow measuring flumes and limnograph protection works

After the study of existing maps and visits to several streams in Cangati River microbasin, Funceme team established the position of both flow measuring flumes. Dimensão Engenharia investigated the selected sites to determine their main characteristics and made their topographic survey. This way, sites selected for the construction of measuring flumes were Salgadinho stream and Gatos stream.

a) Flume 1 – Salgadinho stream

Site characteristics

- UTM coordinates: 0458591 and 9488845;
- stream with a trapezoid geometric cross section and a longitudinal bottleneck in picket Ø region;
- stream bed axis is longitudinally straight (aligned) over a 20-m long stretch between pickets -10 and +10;
- two additional points (pickets -20 and +20) out of the alignment referred to above (after a small curve toward each of them) were considered to allow a better evaluation of bed declivity, as this stream is wider and less constant than that of Flume 2.

Survey

- negative pickets (-3, -10 and -20) were upstream to picket Ø. Therefore, positive pickets were downstream;
- three (3) cross sections were marked. in pickets -3, Ø and +3. Each one was composed of 5 levels: a level in the main riverbed longitudinally straight (aligned) between pickets -10 and +10 (as mentioned previously); two levels in left and right inflection points on the bed

base in that section; and two levels in ending points of left and right edges of that section or indicating the mark of the highest water level;

- in cross sections, point "c" is that of the axis referred to above, which corresponds to pickets -3, Ø and +3. Points "a" and "b" are located on the left of the axis in relation to the stream water flow, while points "d" and "e" are located on the right;
- the highest level (defined as 0.00) is that of point "e" of section +3;
- the schematic drawing of said sections and their longitudinal profile are shown in Figures 2.01 and 2.02 below.

b) Flume 2 – Gatos stream

Site characteristics

- UTM coordinates: 0455773 and 9486599;
- stream with a well-established and reasonably constant trapezoid geometric cross section (with few variations) in the selected 10-m long section (pickets -5 to +5);
- stream bed axis is longitudinally straight (aligned) in the aforementioned stream;
- this section is located between two successive sediment retaining dams, where the distance between its center (picket Ø) and the upstream and downstream dams is 14.30 m and 27.40 m, respectively.

Survey

- negative pickets (-3 and-10 -20) were upstream to picket Ø. Therefore, positive pickets were downstream;
- three (3) cross sections were marked. in pickets -3, Ø and +3. Each one was composed of 5 levels: a level in the main riverbed longitudinally straight (aligned) between pickets -5 and +5 (as mentioned previously); two levels in left and right inflection points on the bed base in that section; and two levels in ending points of left and right

edges of that section or indicating the mark of the highest water level;

- in cross sections, point "c" is that of the axis referred to above, which corresponds to pickets -3, Ø and +3. Points "a" and "b" are located on the left of the axis in relation to the stream water flow, while points "d" and "e" are located on the right;
- the highest level (defined as 0.00) is that of point "e" of section +3;
- the schematic drawing of said sections and their longitudinal profile are shown in Figures 2.03 and 2.04 below.

SEÇÕES TRANSVERSAIS

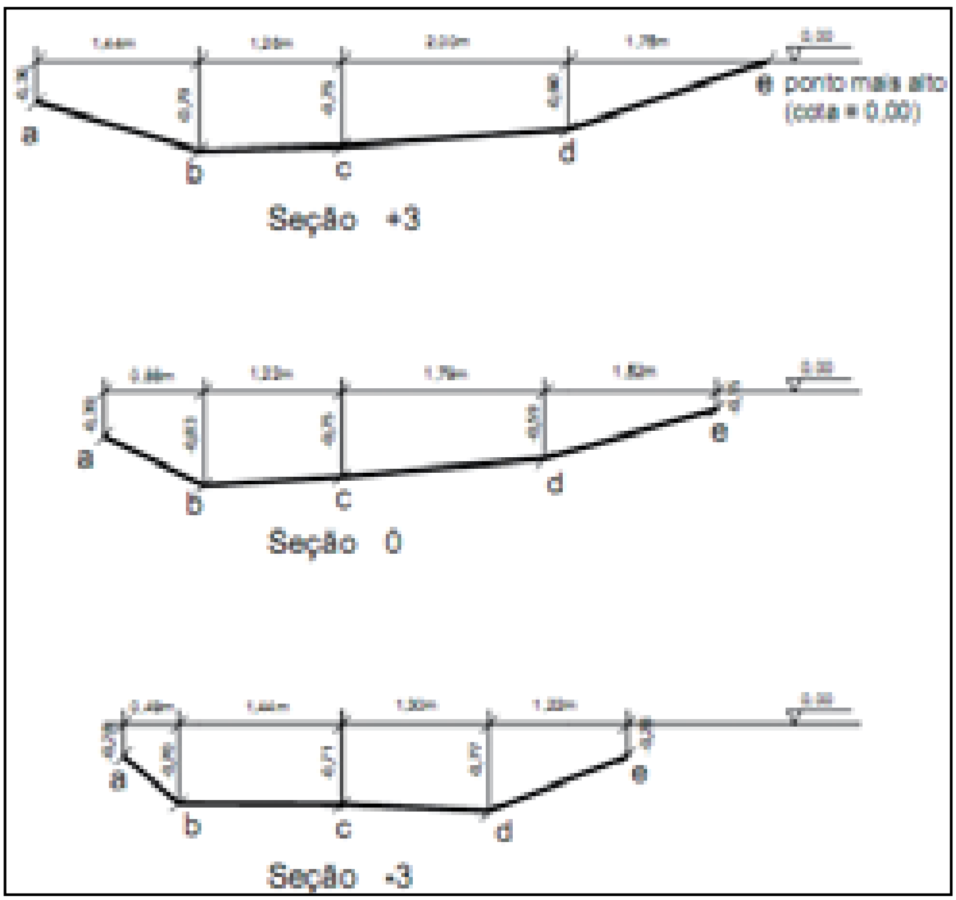

Figure 2.01 – Cross sections of flume 01

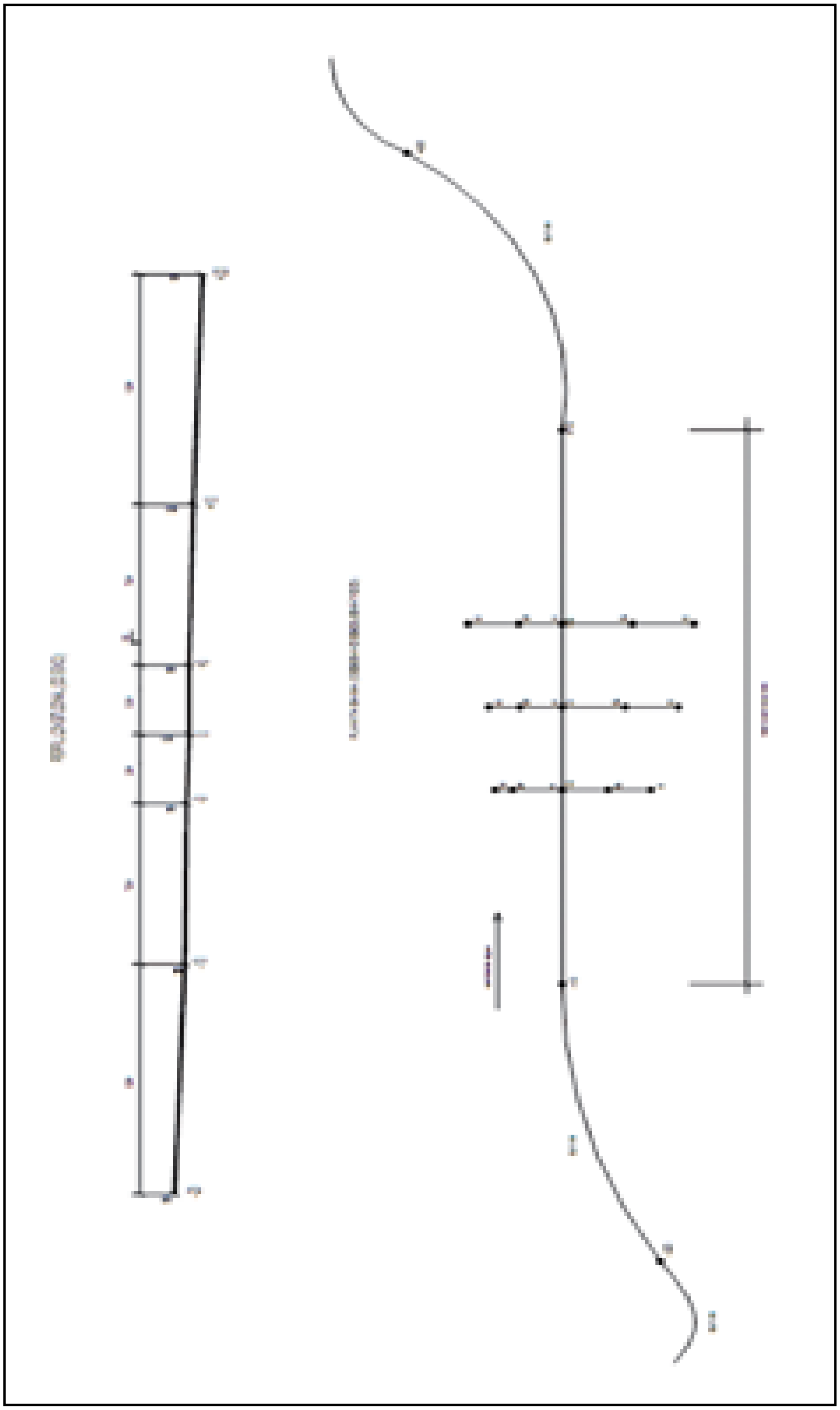

Figure 2.02 – Longitudinal section and view plan of flume 01

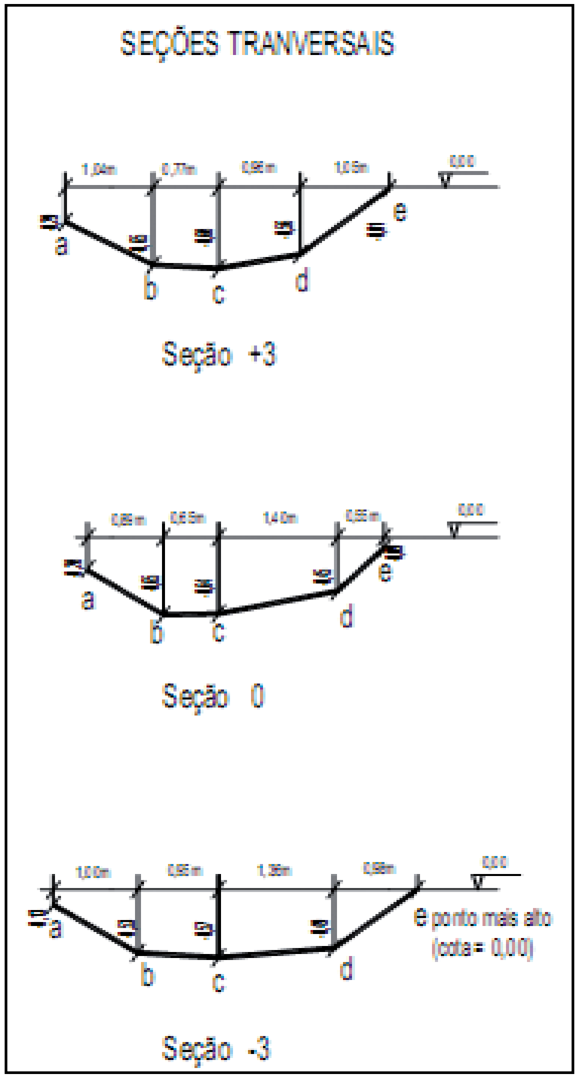

Figure 2.03 – Cross sections of flume 02

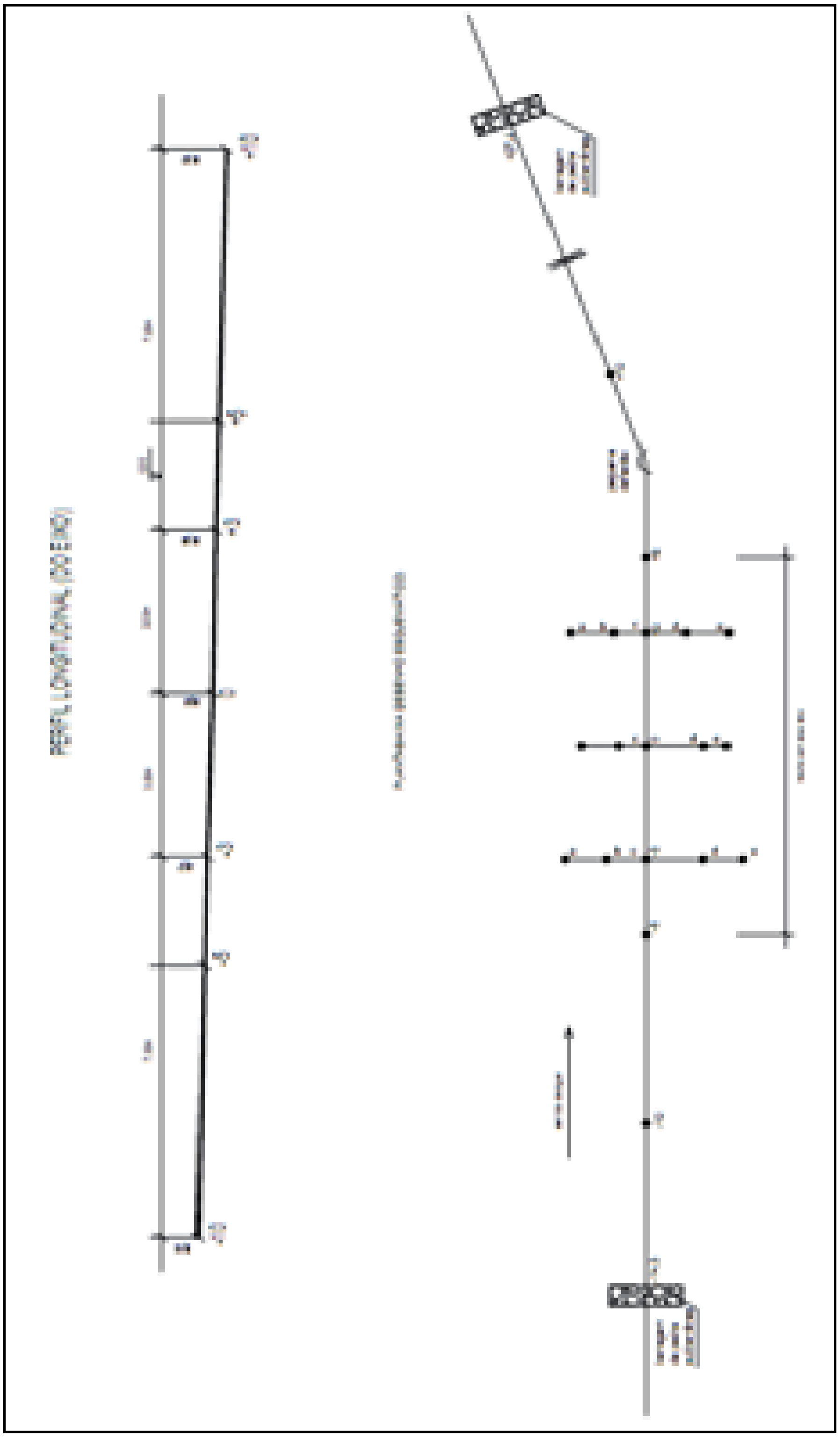

Figure 2.04 – Longitudinal section and view plan of flume 02

Bases on such characteristics of selected sites and related surveys and additional information, such as the surface area of the hydrographic basin of those flumes, and pluviometry, among others, Funceme estimated and projected the geometric form (internal surface) of each of them.

Following that stage, Dimensão Engenharia executed each of the measuring flumes according to the same construction procedure. Related technical notes are summarized as follows:

- soil excavation to allow the execution of infrastructure works and give the geometric shape established by Funceme;
- laying of two 40cm wide stone masonry foundations (1:5 trace mortar) perpendicularly to the stream and all over its cross section extension, being one at the beginning and the other at the end of the flume to the depth of stable soil;
- construction of an 08cm thick reinforced concrete slab (20 Mpa) all over the flume floor, making a 30cm deep vertical turn adjacent to both stone masonry foundations to allow slab to involve (by 30cm) part of such foundations as a protection against erosion in the junction of two components (slab and foundations);
- construction of stone masonry (1:5 trace mortar) sloping lateral walls (retaining walls), according to the selected geometry; a coarse sand layer (pad) was placed between those sloping walls and the soil to alleviate eventual transversal water pressures occurring outwards in the flume;
- installation of a Ø100-mm PVC still well to accommodate the DCP level sensor, interlinked to the approach canal by a Ø50mm PVC pipe positioned 02cm above the floor level;
- for wall and floor slab finish, a 1:5 trace mortar regularization (plaster) was applied;
- finally, at the same outflow section, a complementary flume section made of foundation stones was applied to floor and sloping wall surfaces; and

- additionally, a 3x3-m fence was implanted to protect the data collection platform - DCP, made of preformed concrete stakes, barbed wire and a painted iron gate.

Construction stages for construction of flumes 01 and 03 can be viewed in Photos 2.3 and 2.4 below.

Photo 2.03 – Construction stages of flume 01: plotting, iron structure, concrete application, finish and completion.

Photo 2.04 – Construction stages of flume 02: plotting, iron structure, concrete application,, finish and completion.

It should be highlighted that 2008 rainy season was subject to one of the strongest erosions caused by river waters, because of its high pluviometric index. However, both flumes performed correctly without undergoing any construction damage throughout their use.

2.2.2.2 – Automatic pluvial & fluvial stations

The subproject acquired two (02) data collection (level sensor and pluviometer) and transmission platforms – DCP, constituted of the following components:

- AGS9_512 Datalogger from Ag Solve;
- TR-525M precipitation sensor provided with 25-foot cable, from Campbell;
- PTX 1830 2.5-psi level sensor provided with 10-m cable, from GE Druck;
- metallic box and fittings;
- solar panel with battery;
- GSMMC35 terminal and GSMRS232 cable; and
- AG Wather PC Alone software with Flash screen.

DCPs were installed in the protection structures of that equipment, properly fenced and placed adjacent to flow measuring flumes. In each of them, the level sensor was placed inside the still well, and pluviometer was fastened to a 1.50-m high mast made of galvanized pipe with a diameter of one (1) inch. Metallic box, solar panel and antenna were fastened to a second mast also made of galvanized pipe with a diameter of 1.5 inch. Such masts have been anchored to cyclopic concrete bases measuring 0.50 x 0.50 x 0.60 m (b1 x b2 x h). Datalogger, battery and a terminal with cell phone chip were installed in the watertight, protective metallic box. Equipment was grounded.

Following equipment installation, calibration and adjustments necessary for DCP correct operation were made. The schematic drawing of DCP installation is shown in Figure 2.05.

Stage of installation of pluviometric and fluviometric data collection platforms in flumes 01 and 02 is illustrated in Photos 2.5 and 2.6.

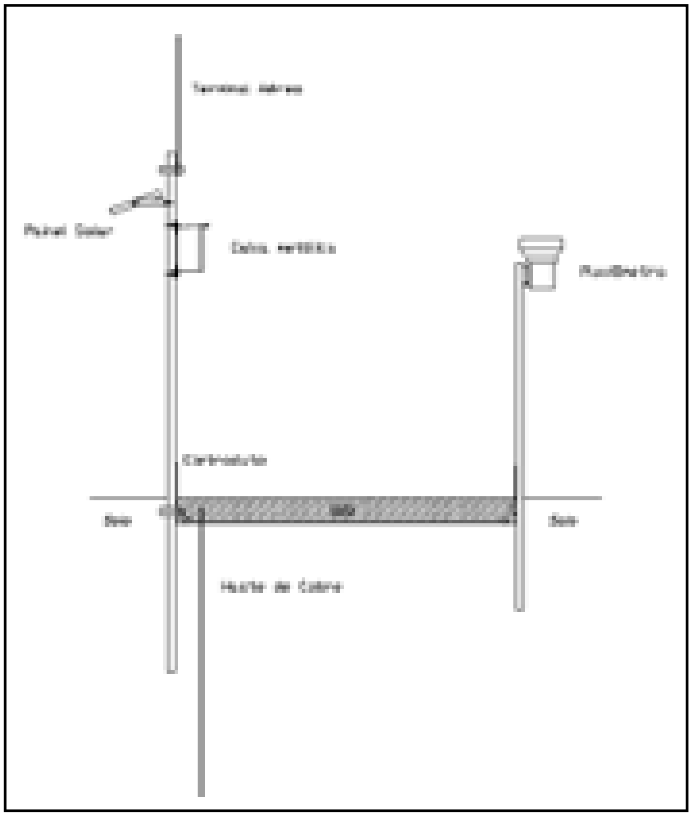

Figure 2.05 – Schematic drawing of DCPs

Photo 2.05 – DCP installation in flume 01, data collection and evaluation of equipment calibration.

Photo 2.06 – DCP installation in flume 02, data collection and evaluation of equipment calibration.

2.2.2.3 – Scales for water and sediment monitoring

Limnimetric rulers were installed in flow measuring flumes to allow accuracy of level sensor dataloger to be adjusted. Such rulers were installed in sloping walls (45^o) of approach canals of both flumes, at the same water intake point in still well.

Rulers were fastened to lateral walls by anchor bolts to make their removal difficult. Because rulers were positioned in a 45^o sloping position and measurement was made vertically (water level), an adjustment was made to the scale printout, where every 1.00 cm of vertical water level variation would correspond to 1.41 cm on the sloping scale of the ruler, to allow the correct measurement by anyone without the need of additional calculations. Photos 2.7 and 2.8 show the limnimetric ruler fastening to outflow measurement flumes.

Also, 06 limnimetric rulers were installed in two sections of Cangati River for water level reading. 1.50-m rulers were installed on three levels because of water head variation. They were arranged in such a way that 0.00 m in the second ruler corresponded to 1.00 m in the first ruler, and 0.00 m in the third ruler corresponded to 1.00 m in the second ruler, to allow measurement over the variation range of 0.00 m – 3.50 m. However, a heavy rain fell right after their installation and they were pulled out.

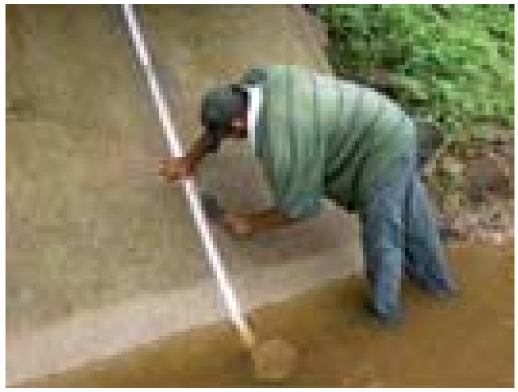

Photo 2.07 – Installation of limnimetric ruler in flume 01

Photo 2.08 – Installation of limnimetric ruler in flume 02

Funceme also selected some successive dams, four of them in Gatos stream, where two rulers were installed upstream to the flow measuring flume, and two downstream. Others rulers were installed in Guerredo and Bananeiras streams, all of them designed to monitor sediments retained in riverbeds by successive dams (Photo 2.09).

2.2.2.4 – Meteorological station

Close to Cangati River microbasin community a Campbell meteorological station was installed, constituted of a datalogger of CR23X model, a power supply system constituted of a 20-W solar panel, battery charge regulator/control, and 24-Ah gelatinous battery, satellite communication system (SCD/ARGOS), and mobile telephony, in addition to four sensors:

air temperature, atmospheric pressure, relative air humidity, wind speed and direction, pluviometric precipitation, and total solar radiation.

Photo 2.09 – Limnimetric rulers installed in successive dams monitored by subproject..

The station was assembled within an area of 100 square meters, surrounded by a barbed wire, concrete stake and access gate structure. It was installed on a metallic structure to support several sensors, constituted of a 10-m high triangular, truss-framed aluminum tower. That structure serves to hold the equipment mentioned above, excluding the pluviometer, which was assembled on an independent base. That tower also serves to hold the protection system against atmospheric discharges and surges, and is part of the grounding system.

Air temperature and relative air humidity sensors were kept in the meteorological shelter constructed according to international standards, while the atmospheric pressure sensor was kept in a metallic cabinet.

For wind direction and speed measurement, a Met One 034B sensor with a 0.4-m/sec partition threshold was installed, which combines speed and direction in a module installed at a 10-m height. For solar radiation determination, a SP-Lite radiometer with sensitivity of 10uV/(Wm^{-2}), wave length measurement range of 400-1100 nm, and a BPW-34 silicon detector was installed. A TB-4 bascule digital pluviometer provided with a 200-cm^3 rain collection area, aluminum body and filler, and 0.2-mm accuracy was installed to measure precipitation. All sensors were properly calibrated.

Data were stored by CR23X Datalogger provided with non-volatile 4-MG memory and non-subscribed data storage capacity for approximately one year, reading frequency for all sensors every hour, 8-digit display/ keypad, peripheral interfaces, 24 channels for analogue sensor reading, 3 analogue voltage output channels, 4 channels for digital sensor reading, 8 channels for logical level reading and writing or interruption, and a real-time clock.

Equipment was provided with a software constituted of data collection program and laboratory data transmission and handling program.

Map of Figure 2.06 shows the installation sites of microbasin water resource monitoring infrastructure.

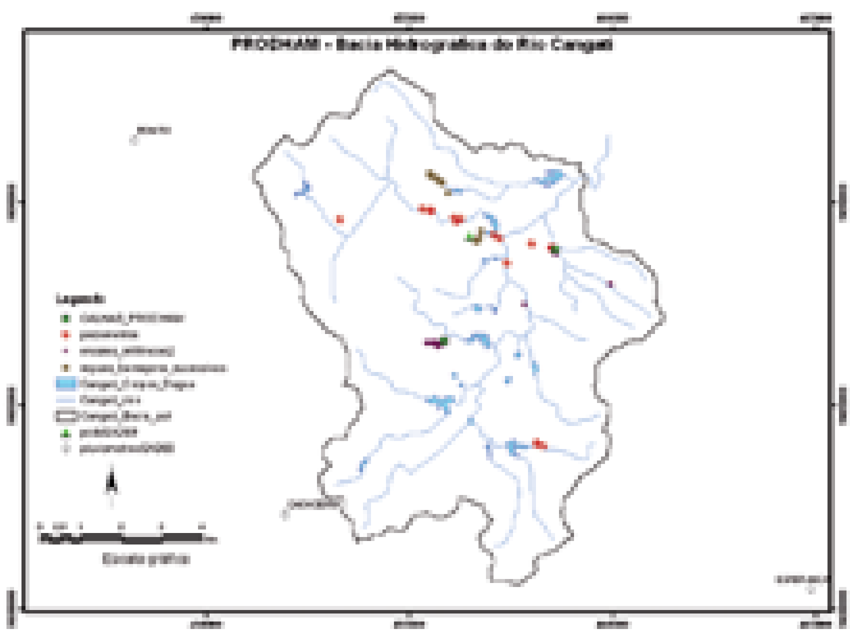

Figure 2.06 – Cangati River hydrographic microbasin and monitoring structures.

2.2.3 – Data collection

Works developed in this part of study referred to the collection of real data on physical hydrology parameters in the microbasin, especially those included in rain-discharge transformation process. Such data are extremely significant for the understanding of hydrological process dynamics in the microbasin, including the quantification of sediment influx to successive dams, one of the targets of this subproject.

Data collection campaign logistics was basically constituted of a field team composed of individuals of the same community, who performed parameter monitoring on a daily basis; and another team that traveled periodically to Fortaleza to execute and/or supervise field works.

The field team was equipped with two motorcycles to allow them to travel rapidly across the microbasin areas, and a pickup vehicle (4x4) for more difficult accesses. That team was also provided with devices, tools and instruments necessary for the performance of services, such as: level meters, photo camera, test tube, water sampler, measuring tapes, graduated ropes, filler, depth ruler, plane tables, timer, charts, 1-liter bottles, bags, labels, raincoats, among others.

The Fortaleza-based team supervised the monitoring works jointly with Funceme, and was also responsible for water quality monitoring. This way, that team traveled every month to the study area to collect water samples and field-monitored information, with the objective of recording and updating the monitoring spreadsheets.

Campaign procedure included the collection of quantitative and qualitative data in each monitoring area under study. A description of collection procedures is provided below.

2.2.3.1 – Climatologic data

During the survey period, climatologic data monitoring was supported by a meteorological station implanted by Funceme in the area, which was responsible for collection and analysis of that information.

Monitored climatologic data included: air temperature, atmospheric pressure, relative air humidity, wind speed and direction, pluviometric precipitation, and total solar radiation.

2.2.3.2 – Infiltration

Infiltration is an hydrological process of high practical importance, as its quickness will determine the water volume to be discharged across the microbasin area, thus influencing the erosion phenomenon. Understanding that parameter is critical for the calibration of rain-discharge transformation models. In fact, in case of MCV, infiltration takes on a key importance, as it separates slow runoff from fast runoff, especially when a small basin is simulated.

As such, for direct determination of water infiltration capacity, infiltration essays were made in several points of the microbasin, with the objective of obtaining the most similar conditions possible in each of them. Such essays, as previously pointed out, were made to separate low runoff from fast runoff, where that activity became more significant by taking into account that the monitored basin was small.

To make infiltration essays provided in the subproject, a 2-week intensive field campaign was held. Funceme, after analyzing the maps, established the likely locations of essays. During a field visit, pre-selected points were checked, and the exact locations were established after the necessary adjustments.

It was also decided that, in addition to the type of essay by concentric, a most adequate approach through "Beerkan" method should be made to include a greater number of tests for hydrodynamic soil characterization in terms of effective execution of works and spatial representativeness. It should be pointed out that water quantity required by that test is very small, but the method requires laboratory analyses, one for each test, to indicate granulometry, density and humidity (initial and final). As informed by researchers, that method may advantageously replace the traditional essay using concentric rings, especially in location of difficult access and restricted water collection. Infiltration tests using concentric rings were performed close to flume 1 in Salgadinho stream, while "Beerkean" method tests were spatially distributed over the monitored basin area.

Photos 2.10 and 2;11 illustrate the infiltration tests performed both by concentric ring and "Beerkan" methods.

Photo 2.10 – Infiltration essays using concentric rings

Photo 2.11 – Infiltration essays using "Beerkan" method

2.2.3.3 – Fluviometric data

Fluviometric data (level and discharge) necessary for the survey were obtained from data collection platforms (DCP) installed in the microbasin. Data recorded by those devices were compared to readings in limnimetric rulers installed in the site, which also served as level reference for flow measuring flume calibration. In such control sections, discharge curves were calibrated.

Data were collected from streams (where eight successive dams were located), from two (02) level and flow measuring flumes, and from Cangati River, and started in the rainy season. Locations were visited on a daily basis and collection was made whenever a heavy rain occurred of the water head at the deepest point exceeded 20 cm. On a daily basis, water level measurements were made in both flumes rulers, and whenever it rained, measurements of retained sediment level were made in rulers installed in successive dams.

It is important to point out that, although visits were made on a daily basis, samples were only collected when conditions were favorable.

Key curve calibration

This activity relied on the logistic support of the firm Dimensão Engenharia for field essays related to flow measurements for key curve calibration in monitoring sections (Photo 2.12). Three campaigns were carried out; however, in the last campaign, flows in selected measurement sites were insufficient to allow essays.

The location of three measurement sites established by Funceme was: in both flumes, where data collection platforms were installed, and in Cangati River, as the main river of monitored microbasin. In those same sites, the field team made water collections to analyze the concentration of suspended solids.

Photo 2.12 – Discharge measurement at key-curve calibration stage.

Water level measurement in flumes

Water level reading in both rulers installed in flow measuring flumes was made on a daily basis, by recording the measurement and its date, as shown in Tables 2.01 and 2.02 below. Photo 2.13 shows the water level measurement in flume 1 built in Salgadinho stream. On a daily basis, an inspection was made in both data collection platforms installed near the flumes to determine if everything was operating correctly.

Table 2.01 – Readouts of water levels in flume 01 – Salgadinho stream

April	Height (cm)	May	Height (cm)	June	Height (cm)	July	Height (cm)
8/4/2008	18.0	1/5/2008	12.5	1/6/2008	11.0	1/7/2008	10.0
9/4/2008	18.0	2/5/2008	12.0	2/6/2008	11.0	2/7/2008	10.0
10/4/2008	17.0	3/5/2008	11.5	3/6/2008	11.0	3/7/2008	10.0
11/4/2008	17.0	4/5/2008	11.0	4/6/2008	10.5	4/7/2008	10.0
12/4/2008	16.0	5/5/2008	11.0	5/6/2008	10.5	5/7/2008	9.5
13/4/2008	15.0	6/5/2008	13.5	6/6/2008	11.0	6/7/2008	8.0
14/4/2008	23.0	7/5/2008	13.0	7/6/2008	11.0	7/7/2008	8.0
15/4/2008	19.0	8/5/2008	12.0	8/6/2008	11.5	8/7/2008	7.5
16/4/2008	17.0	9/5/2008	11.5	9/6/2008	11.5	9/7/2008	7.5
17/4/2008	16.0	10/5/2008	18.0	10/6/2008	11.0	10/7/2008	7.5
18/4/2008	15.0	11/5/2008	18.0	11/6/2008	11.0	11/7/2008	6.5
19/4/2008	14.5	12/5/2008	17.0	12/6/2008	10.5	12/7/2008	5.5
20/4/2008	13.5	13/5/2008	19.0	13/6/2008	10.5	13/7/2008	4.5

Continue

(continuation)

April	Height (cm)	May	Height (cm)	June	Height (cm)	July	Height (cm)
21/4/2008	12.5	14/5/2008	17.5	14/6/2008	10.5	14/7/2008	4.0
22/4/2008	13.0	15/5/2008	15.5	15/6/2008	10.5	15/7/2008	3.0
23/4/2008	12.5	16/5/2008	14.0	16/6/2008	10.5	16/7/2008	2.0
24/4/2008	12.0	17/5/2008	14.5	17/6/2008	10.5	17/7/2008	1.0
25/4/2008	11.5	18/5/2008	15.5	18/6/2008	10.5	18/7/2008	0.0
26/4/2008	11.0	19/5/2008	14.5	19/6/2008	10.5	19/7/2008	0.0
27/4/2008	10.5	20/5/2008	13.5	20/6/2008	10.5	20/7/2008	0.0
28/4/2008	10.0	21/5/2008	13.0	21/6/2008	10.5	21/7/2008	0.0
29/4/2008	11.0	22/5/2008	12.5	22/6/2008	10.5	22/7/2008	0.0
30/4/2008	13.5	23/5/2008	11.5	23/6/2008	10.5	23/7/2008	0.0
-	-	24/5/2008	11.5	24/6/2008	10.5	24/7/2008	0.0
-	-	25/5/2008	11.5	25/6/2008	10.5	25/7/2008	0.0
-	-	26/5/2008	11.0	26/6/2008	10.5	26/7/2008	0.0
-	-	27/5/2008	10.5	27/6/2008	10.5	27/7/2008	0.0
-	-	28/5/2008	11.5	28/6/2008	10.5	28/7/2008	0.0
-	-	29/5/2008	11.5	29/6/2008	10.0	29/7/2008	0.0
-	-	30/5/2008	11.5	30/6/2008	10.0	30/7/2008	0.0
-	-	31/5/2008	11.0	-	-	31/7/2008	0.0

Table 2.02 – Readouts of water levels in flume 02 – Gatos stream

April	Height (cm)	May	Height (cm)	June	Height (cm)	July	Height (cm)
8/4/2008	10.0	1/5/2008	7.0	1/6/2008	6.0	1/7/2008	1.0
9/4/2008	10.0	2/5/2008	6.0	2/6/2008	6.0	2/7/2008	1.0
10/4/2008	8.0	3/5/2008	6.0	3/6/2008	6.0	3/7/2008	1.0
11/4/2008	7.0	4/5/2008	6.5	4/6/2008	6.0	4/7/2008	1.0
12/4/2008	7.0	5/5/2008	6.5	5/6/2008	6.0	5/7/2008	1.0
13/4/2008	6.0	6/5/2008	6.0	6/6/2008	6.0	6/7/2008	1.0
14/4/2008	8.0	7/5/2008	6.0	7/6/2008	6.0	7/7/2008	0.0
15/4/2008	6.0	8/5/2008	6.5	8/6/2008	6.5	8/7/2008	0.0
16/4/2008	6.0	9/5/2008	6.0	9/6/2008	6.0	9/7/2008	0.0

Continue

(continuation)

April	Height (cm)	May	Height (cm)	June	Height (cm)	July	Height (cm)
17/4/2008	6.0	10/5/2008	8.0	10/6/2008	6.0	10/7/2008	0.0
18/4/2008	6.0	11/5/2008	8.0	11/6/2008	6.0	11/7/2008	0.0
19/4/2008	6.0	12/5/2008	7.0	12/6/2008	6.0	12/7/2008	0.0
20/4/2008	6.0	13/5/2008	9.0	13/6/2008	5.5	13/7/2008	0.0
21/4/2008	6.0	14/5/2008	7.5	14/6/2008	5.5	14/7/2008	0.0
22/4/2008	6.5	15/5/2008	7.0	15/6/2008	5.5	15/7/2008	0.0
23/4/2008	6.0	16/5/2008	6.0	16/6/2008	4.5	16/7/2008	0.0
24/4/2008	6.0	17/5/2008	6.5	17/6/2008	4.5	17/7/2008	0.0
25/4/2008	6.0	18/5/2008	7.0	18/6/2008	4.5	18/7/2008	0.0
26/4/2008	6.0	19/5/2008	6.5	19/6/2008	3.5	19/7/2008	0.0
27/4/2008	6.0	20/5/2008	6.0	20/6/2008	3.5	20/7/2008	0.0
28/4/2008	6.0	21/5/2008	6.0	21/6/2008	3.5	21/7/2008	0.0
29/4/2008	6.5	22/5/2008	6.5	22/6/2008	3.5	22/7/2008	0.0
30/4/2008	8.0	23/5/2008	6.0	23/6/2008	3.0	23/7/2008	0.0
-	-	24/5/2008	6.0	24/6/2008	3.0	24/7/2008	0.0
-	-	25/5/2008	6.0	25/6/2008	3.0	25/7/2008	0.0
-	-	26/5/2008	6.0	26/6/2008	3.0	26/7/2008	0.0
-	-	27/5/2008	6.0	27/6/2008	2.0	27/7/2008	0.0
-	-	28/5/2008	6.5	28/6/2008	2.0	28/7/2008	0.0
-	-	29/5/2008	6.0	29/6/2008	2.0	29/7/2008	0.0
-	-	30/5/2008	6.5	30/6/2008	2.0	30/7/2008	0.0
-	-	31/5/2008	6.0	-	-	31/7/2008	0.0

Photo 2.13 – Measurement of water level in Salgadinho stream flume. UTM geographic coordinates: 0458591 / 9488845.

2.2.3.4 – Collection of water samples for determination of physical-chemical and bacteriological parameters

To characterize water quality in the microbasin, water samples were collected in the period of September 2007 through December 2008 for physical-chemical and bacteriological analyses. Samples were monthly collected from selected reservoirs, rivers and streams in the microbasin, in 2-day campaigns. This way, 16 water sample collection campaigns were carried out, where sampling was made on the surface of selected water bodies.

In this sense, 10 collection points were selected in reservoirs, and 6 in rivers and streams. It should be pointed out that the selection of such points took into consideration such criteria as accessibility, their representativeness in relation to anthropic actions in the region, and their representativeness in relation to the survey objectives, among others. Map of Figure 2.07 shows the selected water sample collection points.

With respect to sample collection procedure, the technique recommended by the technology company was followed (1988). Analysis methodology followed APHA recommendations (1998). Samples were processed in the laboratory of Fundação Núcleo de Tecnologia Industrial do Ceará (NUTEC).
Table 2.03 shows the surface water sampling points selected in the microbasin, and Table 2.04s indicate the months when collections were possible in each point.

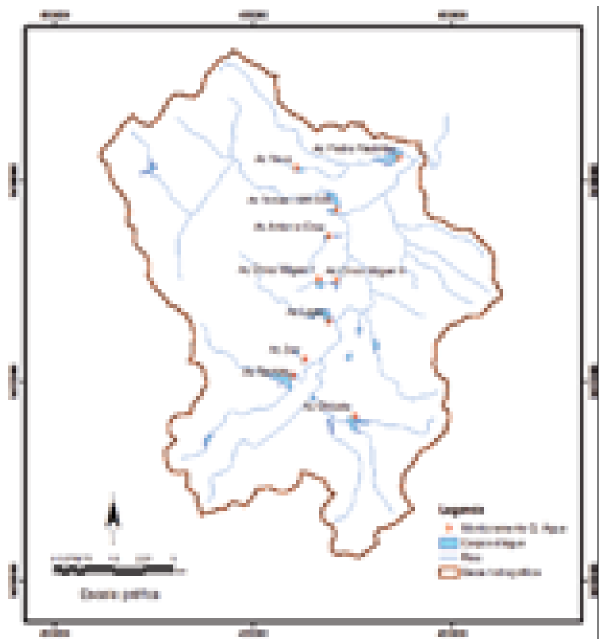

Figure 2.07 – Water sample collection points in Cangati River microbasin – CE

Table 2.03 – Surface water sample collection points

Point	Name	UTM Coordinates		Location	River / Stream
		Latitude	Longitude		
Reservoirs					
AC01	Chicote	9484161	0457539	Barra Nova	Chicote
AC02	Ramin	9485176	0455966	Barra Nova	-
AC03	"Zuir"	9485582	0456271	Barra Nova	-
AC04	Lajes	9486493	0456886	Lajes	Porta stream
AC05	Chico Miguel I	9487545	0456641	Lajes	-
AC06	Chico Miguel II	9487524	0457075	Lajes	-
AC07	Antônio Cruz	9488621	0456891	Iguaçu	-
AC08	Tobias	9489288	0457072	Iguaçu	Felão
AC09	Novo	9490338	0456073		Bananeiras
AC10	Pedro Paulino	9490600	0458650	São Luiz	-
Rivers/Streams					
RC01	Cangati I River	9489136	0457202	Fazenda Iguaçu	Cangati
RC02	Cangati II River	9488356	0457313	Cacimba de Baixo	Cangati
RF01	Felão I Stream	9489807	0455511	São Luiz	Felão
RF02	Felão II Stream	9489601	0456262	-	Felão
RG01	Gatos Stream			-	Gatos
RCH01	Chicote Stream	9484952	0456620	Barra Nova	Chicote

Table 2.04 – Months when surface water collections were made in selected points

Reservoir	Months							
	Sep/07	Oct/07	Nov/07	Dec/07	Jan/08	Feb/08	Mar/08	Apr/08
Chicote	x	x	x	x	x	x	-	-
Ramin	x	x	x	x	x	x	x	x
"Zuir"	x	x	-	-	-	-	x	x
Lajes	x	x	x	x	x	x	x	x
Chico Miguel I	x	x	x	x	x	x	x	x
Chico Miguel II	x	x	x	x	-	-	x	x
Antônio Cruz	x	x	x	-	-	-	x	x
Tobias	x	x	x	x	x	x	x	x
Novo	x	x	x	x	x	x	x	x
Pedro Paulino	x	x	x	x	x	x	x	x
Reservoir	**Months**							
	May/08	Jun/08	Jul/08	Aug/08	Sep/08	Oct/08	Nov/08	Dec/08
Chicote	-	x	x	x	x	x	x	x
Ramin	x	x	x	x	x	x	x	x
"Zuir"	x	x	x	x	x	x	x	x
Lajes	x	x	x	x	x	x	x	x
Chico Miguel I	x	x	x	x	x	x	x	x
Chico Miguel II	x	x	x	x	x	x	x	x
Antônio Cruz	x	x	x	x	x	x	x	x
Tobias	x	x	x	x	x	x	x	x
Novo	x	x	x	x	x	x	x	x
Pedro Paulino	x	x	x	x	x	x	x	x
River/Stream	**Months**							
	Sep/07	Oct/07	Nov/07	Dec/07	Jan/08	Feb/08	Mar/08	Apr/08
Cangati I River							x	x
Cangati II River							x	x
Felão I Stream							x	x
Felão II Stream							x	x
Gatos Stream							x	x
Chicote Stream							x	x
River/Stream	**Months**							
	May/08	Jun/08	Jul/08	Aug/08	Sep/08	Oct/08	Nov/08	Dec/08
Cangati I River	x	x						
Cangati II River	x	x						
Felão I Stream	x	x						
Felão II Stream	x	x						
Gatos Stream	x							
Chicote Stream								

Physical-chemical and bacteriological parameters analyzed during the survey are shown in Table 2.05 below.

Photos 2.14 and 2.15 show the surface water collection points selected in the study.

Table 2.05 – Physical-chemical and bacteriological parameters analyzed

Parameters	Unit
Physical-Chemical Parameters	
Parameters	**Unit**
pH at 25ºC	
Conductivity	(micromhos / cm)
Partial alkalinity	($mgCaCO_3/L$)
Total alkalinity	($mgCaCO_3/L$)
Total hardness	($mgCaCO_3/L$)
Organic matter	(mgO_2cons/L)
Nitrites	($mgN\text{-}NO_2^{--}/L$)
Dissolved solids	(mg/L)
Total solids	(mg/L)
Calcium	($mgCa^{++}/L$)
Magnesium	($mgMg^{++}/L$)
Sodium	($mgNa^{+}/L$)
Potassium	(mgK^{+}/L)
Total iron	(mgFe/L)
Chlorides	($mgCl^{-}/L$)
Carbonates	($mgCO_3^{--}/L$)
Bicarbonates	($mgHCO_3^{-}/L$)
Hydroxides	($mgOH^{-}/L$)
Sulfates	($mgSO_4^{-}/L$)
Nitrates	($mgN\text{-}NO_3^{-}/L$)
DO	(mgO_2/L)
Total phosphor	(mgP/L)
Turbidity	(NTU)
Bacteriological Parameters	
Total coliforms	(NMP/100mL)
Thermotolerant coliforms (Fecal)	(NMP/100mL)
Count of heterotrophic bacteria	(UFC/mL)

Photo 2.14 – Reservoirs monitored by subproject.

Photo 2.15 – Streams monitored by subproject.

2.2.3.5 – Collection of sedimentometric data

Sedimentometric data monitored during the study included: depth of sediments retained in riverbeds by successive dams, and sediments suspended in water, including the determination of their granulometry. Such parameters were critical for the study, as they allowed the dynamics of sediment accumulation in microbasin area to be evaluated.

For a better understanding of works carried out during this survey stage, and prior to describing the activities performed, it is necessary to consider the following concepts:

Sediment - sediment, as referred to in this work, is a solid material mainly originated from rock weathering. When transported, suspended or deposited by natural processes in the hydrographic basin it is referred to as “fluvial sediment”. Additionally, chemical/biochemical precipitates and decomposed organic material (humus) are also included. Their quantity, characteristics and causes of occurrences in streams are mainly due to environmental factors and soil use. Main factors are topography, soil characteristics, soil cover and intensity and total of rains.

Concentration of suspended sediments in rivers – this is the concentration of suspended sediments, weighed by river speed in sampling region (from surface to a distance of approximately 10cm from the bottom), denominated in milligrams of dry sediment per liter of water-sediment mix (mg/L). Analytic technique uses the mass of all sediments and the net weight of water-sediment mix in a sample to calculate sediment concentration.

After the considerations above, collection works started using the following equipment and basic materials:

- 10-15 numbered bottles with capacity for 1 liter each;
- 10-liter container for sample homogenization;
- depth-integrating sampler for suspended sediments;
- centimeter graduated ruler;
- portable table, pencil and card for sample data record;
- 0GPS, calculator and timer; and
- meter-by-meter graduated rope and staffs for cross section marking.

Because of speeds and depths found in the subproject, the construction of a simple depth-integrating sampler and its use in collection activities was chosen, like that shown in Figures 2.08 to 2.10.

Based on available technical literature, it was estimated that the sampler bottle should have a capacity for approximately 750ml, and even 1.000ml if necessary. Air escape should have a diameter or approximately 3mm, and the sampler nozzle should have a diameter of approximately 7mm and be made of copper of rigid plastic material, while the pipe diameter should be determined experimentally. Support should be sufficient steady to hold the bottle during its immersion in water and allow the inlet nozzle direction to be contrary to flow direction. Inlet pipe should be approximately parallel to flow lines, and bottle should be at an angle of 30 degrees with the horizontal plane.

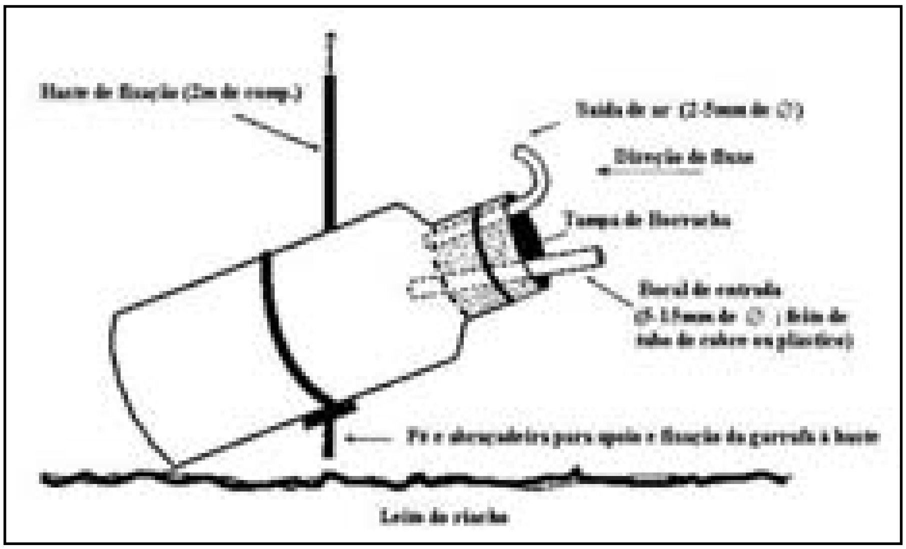

Figure 2.08 – Depth-integrating sampler produced by the subproject.

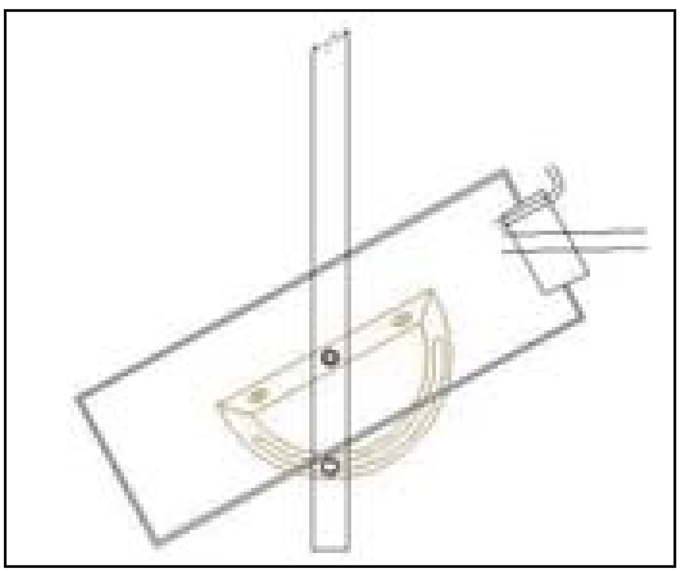

Figure 2.09 – Schematic drawing of depth-integrating sampler model produced to collect suspended samples

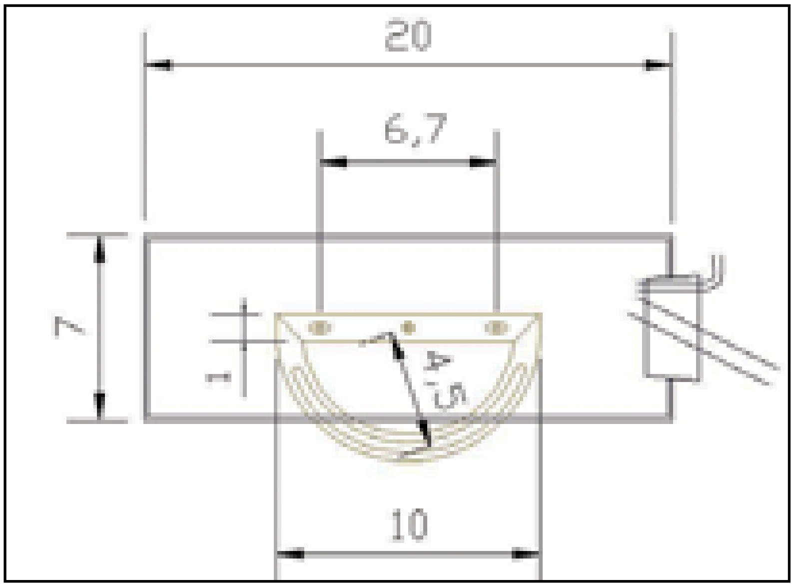

Figure 2.10 – Schematic drawing of depth-integrating sampler model produced to collect suspended samples

In practical terms, at field collection the depth-integrating sampler should be lowered to the river bottom and immediately pulled back to the surface. Care should be taken to ensure that transit times of sampler lowering and rising are equal. It should be pointed out that the objective of this procedure is to fill the sample up to 90% of its capacity. If the sampler is completely full of water at reaching the surface, this means that the apparatus failed to collect material at a particular height, and therefore the operation should be repeated by increasing the transit time.

With respect to the collection procedure adopted, it is important to point out that, in each selected point, two types of measurement were made: measurement using the incremental equidistant width technique, and punctual measurement.

a) Incremental equidistant width technique

This method is uses in small streams where it is possible to made measurement on foot, and provided accurate data on the average suspended sediment concentration passing through a particular control section. In short, collection procedure using this technique follows the methodological steps listed below:

- preparation and cleaning of a great-capacity vessel (~10 liters) for homogenization of collected sample(s);
- preparation and cleaning of several sequentially numbered 1-liter vessels to store temporarily the samples during collection;
- determination of correct sampler position on the support and whether air inlet and escape nozzles are unobstructed;
- operator's demarcation of stations evenly spaced along the river cross section, like in a flow measurement (Figure 2.11). For this study, that spacing ranged between 0.5 and 1.0m;
- determination of the deepest point in the cross section. If depth is uniform, the cross section center should be determined (record the water depth) (Figure 2.12);
- sampling test to estimate the transit time in deepest section. Care should be taken to avoid bottle overflow upon returning to the surface; it should contain 80-90% of its maximum capacity;
- storage of first sample in a clean 1-liter bottle marked with the collection station number. Example: if the central section is number 3, sample should be stored in the corresponding vessel;
- repetition of process for all other stations starting from the margin, always using the same bottle lowering and rising transit rate. It is important to maintain the same transit rate for a representative sample. At the end, the final bottle volume in other sections will be variable, depending on the river speed and depth at each station;
- when sampling is completed in all stations, and the operator is sure that no station needs to be resampled, each numbered bottle should be shaken and its content should be poured in a large vessel;
- homogenization of sample composition in 10-l vessel per shake. Two or three sub-sampling operations should be made, that is, 3 bottles

(800-1,000 ml) should be removed, identified by date, location, sample number, and then sent to the laboratory for analytic determination of suspended sediment concentration.

Photo 2.16 illustrates the sequence of a water collection using this method.

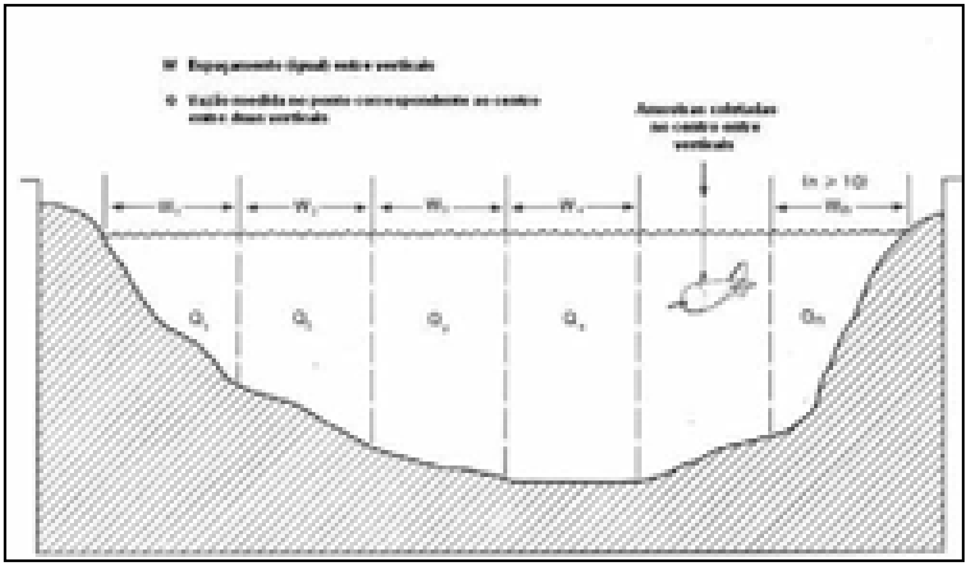

Figure 2.11 – Demarcation of stations in the stream cross section for suspended sediment sampling

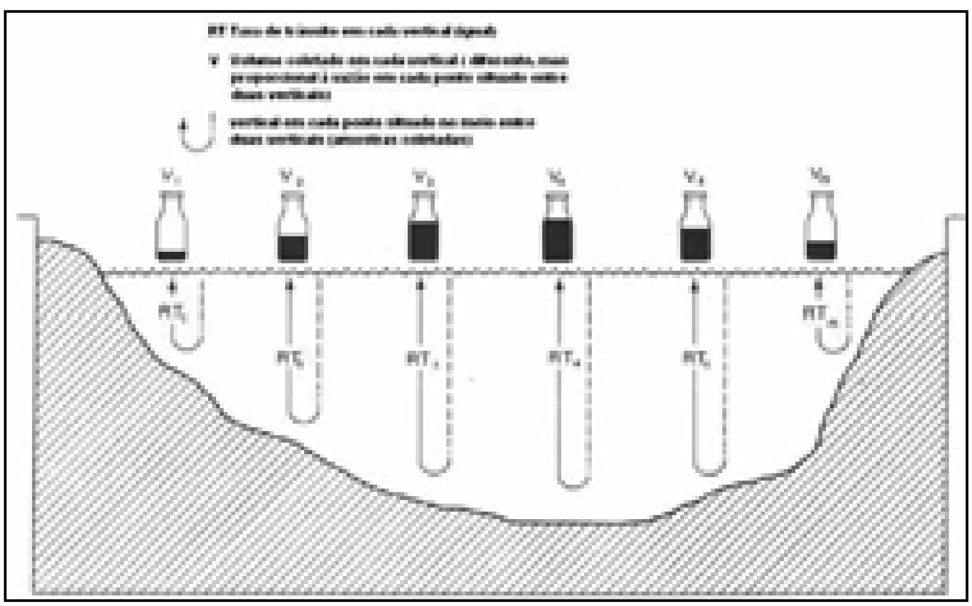

Figure 2.12 – Volumes collected proportionally to outflow in each vertical section

Photo 2.16 – Sequence of a water collection

b) Punctual measurement

At each suspended sediment collection point, punctual measurement is made to a particular depth and to a fixed distance from the margin (see Photos 2.17 and 2.18). Bottle should be identified as punctual measurement rather than full measurement. In this study, a punctual sample was collected from 50% of stream depth at its deepest section.

Punctual measurement was made by closing the sampler nozzle and lowering the sampler to the measurement depth and then opening the sampler inlet to fill it completely and closing it to being it back to the surface. Water depth at measurement time was then recorded in a spreadsheet. The objective of that sampling was to determine the possibility of relating the punctual measurement to the full section measurement to make the future routine monitoring easier.

Photo 2.17 – Station plotting along the river cross section

Photo 2.18 – Depth measurement

With respect to water collection points for suspended solid analysis, eleven (11) points were selected. This way, collection was made in eight (8) successive dams and other three (3) sites: two (02) points located in flumes constructed during the survey, being one in each flume, and the other in Cangati River. Collection was made on a fortnightly basis in all eleven (11) points and/or upon the occurrence of a heavy rain that increased the water level in monitored water bodies. The optimal result was the performance of two collections a week.

At each point, a volume of 0.5 to 1.0 liter of water was collected, followed by both sampling techniques previously described. This way:

In each flume:

- full measurement: flume width was divided into 4 parts and collection was made (as previously described) from the 3 central points;
- punctual measurement: collection was made from the central point of flume width;

In Cangati River (downstream to BR-020 road crossing):

- full measurement: river width was divided by the graduated rope into meter sections, and the collection points were determined. Collection was made (see procedure for full collection) from each of those points.
- punctual measurement: collection was made from only one point, i.e., the deepest point.

In all four selected successive dams (stone), close to flume 2:

- full measurement: collection was made from only one point, i.e., the deepest point.
- punctual measurement: collection was made from the same point referred to above.

In 4 (or more) successive dams (stone) selected in Mr. Napoleão's property:

- full measurement: collection was made from only one point, i.e., the deepest point.
- punctual measurement: collection was made from the same point referred to above.

Punctual collection was always made from a single point of each stream, river or flume. Full collection occurred only when water was as least 20-cm deep. It should be noted that one or more collection points could occur in the same location.

During collection, care was taken to avoid stirring the decanted soil, to prevent it from mixing with water and changing the sample result.

By using labels, collection date and collection point reference were recorded. As such, the following references were used for each collection point:

- flumes: CL1 and CL2, for flumes 1 and 2, respectively;
- cangati River: RC;
- successive dams close to flume 2: BC1 to BC4, where BC1 was the most upstream dam (highest), and BC4 the most downstream dam (the lowest);
- successive dam in Mr. Napoleão's land: Bananeiras stream, BB1 to BB11, where BB1 referred to the most upstream dam (the highest), and BB11 the most downstream dam (the lowest); Guerredo stream, BG1 to BG6, where BG1 referred to the most upstream dam (the highest), and BG5 the most downstream dam (the lowest);
- labels were fixed by a transparent adhesive tape surrounding the whole bottle to avoid risk of data loss.

During collections, water depths were recorded in punctual collection tables (deepest point at each location) and full collection (all points subject to collection at each location) (TABLES 2.6 and 2.7). After collections, labeled bottles were packed and prepared for transportation.

Table 2.06 – Depth measurement – punctual water collection

LOCATION	DATE			
	4/29/2008	4/30/2008	5/1/2008	5/10/2008
CL 1				0.18
CL 2				
RC		0.46	0.30	0.46
BC 1				
BC 2				
BC 3				
BC 4				
BNG 1	0.24			
BNG 2	0.20			
BNB 1				
BNB 2				

Table 2.07 – Dept measurement – full water collection

LOCATION	POINT	DATE			
		4/29/2008	4/30/2008	5/1/2008	5/10/2008
FLUME 1	**P 1**				
	P 2				
	P 3				
FLUME 2	**P 1**				
	P 2				
	P 3				
CANGATI RIVER	**P 1**		0.17	0.14	0.26
	P 2		0.32	0.24	0.22
	P 3		0.38	0.30	0.22
	P 4		0.36	0.10	0.30
	P 5		0.38		0.46
	P 6		0.46		0.18
	P 7				
	P 8				
SUCCESSIVE DAMS	**BC 1**				
	BC 2				
	BC 3				
	BC 4				
	BNG 1	0.24			
	BNG 2	0.20			
	BNB 1				
	BNB 2				

2.3 – Results and Discussion – Surface waters

2.3.1 – Characterization of water quality in microbasin

Water use in several human activities has many different consequences on the water body. Water resources maybe used for urban and industrial supply, irrigation, aquiculture, power generation, fluvial navigation, fishing, entertainment, and others.

Regarding the effects of human activities on waters, most of them are polluting: urban and industrial supply causes organic and bacteriological pollution, pours out toxic substances, and increase water temperature; irrigation carries pesticides and fertilizers; sewage disposal causes organic, physical, chemical and bacteriological pollution. Electric power generation, in turn, is not a polluting activity, but it causes changes to water regime and quality. The construction of large dams by flooding areas covered by abundant vegetation not only impairs substantially the water quality, but also may bring consequences to the whole surrounding environment.

Pollution control is directly related to health protection, assurance of an ecologically balanced environment, and therefore the improvement of human life quality, health and welfare, as well as the ecologic and aquatic equilibrium human should not be affected by water quality deterioration.

The main hydrographic characteristic of Brazilian semiarid region is the intermittent aspect of its rivers. This characteristic is directly related to precipitation in the region. Rivers and streams are irregular and surface water flow disappears during the dry period.

In such a scenario, reservoirs, artificial ecosystems, constitute the main water source for human supply in urban centers of Ceará municipalities. In addition to its most outstanding use, that of home supply, some reservoirs enable watercourse perennialization, a significant factor in the state of Ceará where tropical semiarid climate prevails. Over the last years, water quantity, which was considered as the most significant factor, has shifted to a qualitative approach with the objective of keeping the scarce water supplies adequate for multiple uses. In this context, water quality control in such environments has become a highly significant aspect of water resource management.

In fact, the study of physical-chemical and biological behavior of reservoirs is today a major aspect of water resource management system in the State. The government has a great interest in the search for instruments that would allow potential changes in aquatic environments to be forecast to ensure their preservation and consequently the satisfaction of populations' needs.

Problems related to water quality in reservoirs have also aroused the population's sensibility to adverse environmental impacts associated with their construction. Some years ago, when concerns with the environment were still incipient, deforestation of flooded area was not required. As such, decomposition of submerged vegetation consumed large volumes of dissolved oxygen, which not only affected the survival of fish and other animals, but also established an anaerobic decomposition process, leading to the production of toxic and corrosive sulphydric acid. Also as a result of vegetative matter decomposition, nitrogen and phosphor compounds appear and stimulate aquatic plants proliferation. All that process may lead to water body eutrophication and impair its use.

In general, size and depth of reservoirs make discharges exert a lower influence, leading the analyses of physical, chemical and biological phenomena to be made vertically, without a detailed regard with hydrodynamics. According to Esteves (1988), in such environments differences in temperature generate water layers of different densities, which build a physical barrier that prevent water layers from mixing together. If wind power is not sufficient to mix them, heat will not distribute evenly over the water head, thus creating a thermal stratification. Such layers are in general physically, chemically and biologically differentiated.

The importance if water quality is well characterized in the national Water Resource Policy, one of objectives of which is "to ensure to present and future generations the necessary water availability at quality standards adequate to respective uses." The National Water Resource Policy also establishes, as one of the National Water Resource Management System guidelines, "the systematic water resource management, without dissociation of quantity and quality aspects, and with integration of water resource management with environmental management" (NATIONAL AGENCY ..., 2005)

In this context, emphasis should be given to Resolution no. 357/2005 of the National Environment Council (CONAMA), which constitutes an important instrument for surface water resource management. It considers that the classification of fresh, brackish and saline waters is critical to protect their quality levels. This classification is evaluated by specific requirements and standards that take into account the priority uses and environmental quality classes required for a particular water body, to ensure the predominant water resource uses. That Resolution provides for the classification and environmental guidelines for classification of surface water bodies, in addition to establishing requirements and standards for effluent discharge.

Although the classification of water resources is a preservation instrument, Ceará has not applied it so far to its surface water sources, and therefore fresh waters are included in class 2, according to Art. 42 of CONAMA Resolution no. 357/2005.

Class 2 water may have the following destinations: human consumption supply after conventional treatment; protection of aquatic communities; primary contact recreation, such as swimming and diving (this item should comply with CONAMA Resolution no. 274/2000); irrigation of vegetables, fruit plants, and parks, gardens, sport and leisure fields, with which the public may have any direct contact; and aquiculture and fishing.

As shown above and for the diagnosis and understanding of processes affecting water quality in a particular basin, monitoring the collection and analysis of physical-chemical and bacteriological parameters of water samples is indispensable. In effect, water quality monitoring currently made in semiarid region reservoirs frequently has a monthly measurement based on the survey of physical-chemical parameters made on a vertical profile, as well as an analysis of water samples collected close to the surface in the proximities of earth dams, which includes a greater quantity of parameters. To be efficient, that sampling should take into account the relevant physical, chemical and biological processes influencing the parameter to be analyzed.

This way, it is expected that, through sample collection and evaluation of several water quality parameters, PRODHAM project will generate information and data on water quality conditions in the microbasin, to allow the establishment and/or adoption of management practices aimed to its preservation and control.

2.3.1.1 – Brief discussion of reservoirs surveyed

Information related to monitored reservoirs included in this document is the result of on-site examinations during the performance of activities under the subproject.

Most technical characteristics or reservoirs were estimated. As such, volumes were estimated by assuming V = A.h/3. Areas selection was based on satellite image. Maximum depths correspond to values measured on site this year (an approximation that considers that overflow level was reached by all reservoirs).

Chicote Reservoir

This reservoir has a hydrographic microbasin of approximately

4.14 km^2. Its maximum storage capacity is 188,457.7 m^3 and its estimated maximum depth is 7.0m. Given its characteristics, this is a reservoir that maintains its water storage capacity around 50%, even in years of normal or below-average rainy periods. It should also stressed that at the end of 2007 dry season, this reservoir stored approximately 50% of its capacity. Upon the start of 2008 rainy season, this reservoir even overflowed by reaching 70% of its storage capacity during the development of 2008 dry season (December 2008). In terms of lake size, Chicote reservoir is one of the four largest reservoirs in the microbasin with an hydraulic basin of 8,0767.6 m^2.

In the surroundings of the hydraulic basin of this reservoir there is no evidence of expressive anthropic actions, and ciliary forest and vegetation are preserved. It should be pointed out that, because of heavy rains in 2008 rainy season, the occurrence of aquatic macrophytes was detected on the margins of this water source, which had been carried by floods occurred in that season. However, downstream to that reservoir, the presence of human action has already been evidenced by deforestation and the occurrence of some coal production areas. At the time of collection made in this reservoir, the occurrence of subsistence fishing activity was frequently noted during the monitoring stage. The presence of animals or livestock activity in the area was seldom noted.

Ramin Reservoir

This reservoir is one of the four largest reservoirs in the surveyed microbasin. Its lake has a surface area of 119,304.1m^2, and a significant microbasin drainage area of 8.09 km^2, as compared to reservoir standards found in the region. Its maximum water storage capacity is 202,817.0 m^3 and its maximum depth is 5.1m. however, in less rainy years, its storage capacity falls to approximately 40% of its normal volume. Given the characteristics of its hydraulic basin and high evaporation rates, in normal or below-average precipitation years, especially consecutive years, the occurrence of overflows is hardly noted. At the end of 2007 dry season (December), this reservoir stored water to approximately 50% of its capacity and no overflow occurred that year. At the end of 2008 dry season (December), Ramin reservoir was full to some 70% of its storage capacity.

The surroundings of this reservoir are greatly damaged in terms of vegetative cover. Expressive areas of very exposed soils are noted especially in dry periods. Ciliary forest around its hydraulic basin is very damaged, sparse and containing very thin vegetation. No occurrence of macrophytes was detected on the margins of this reservoir. Its waters are used for animal consumption and cloth wash. The practice of small-scale subsistence fishing is also noted.

Zuir Reservoir

This is the smallest reservoir surveyed in the microbasin. It occupies an hydrographic microbasin surface area of 0.04 km^2 and an hydraulic basin of 4,246.2 m^2. It maximum storage capacity is around 4,200 m^3. Its marking characteristics include, without limitation: low depth (maximum depth around 3.0 meters) and the occurrence of a significant concentration of macrophytes, which may be an indicator of occurrence of an eutrophication process. Because of its dimensions, this reservoir practically uses to dry at the end of dry season, even when the rainy period is around average or below average of historical precipitation series. According to local information, this water source did not overflowed during 2007 rainy season, and at the end of dry season in the same year it was practically dry. It should be mentioned that during the rainy period, this reservoir reached its maximum storage capacity and even overflowed. At the end of 2008 dry period (December), it was at approximately 70% of its total water volume.

Ciliary forest surrounding this reservoir is quite damaged. Bare soil and rock outcrops are frequently noted. To aggravate the situation, in dry periods the presence of animals eating and depositing their excrements in its hydraulic basin is quite common. Its waters are used for animal consumption and small cultivation of fruit trees and vegetables.

Lages Reservoir

This is one of the largest reservoirs in the surveyed microbasin. It has a drainage microbasin of 4.06 km^2, and its main tributary is Porta stream. Out of all surveyed reservoirs, this is among those having a largest lake surface area (81,975.1 m^2). Its maximum storage capacity and depth are 25.8 m^3 and 9.3 m, respectively. At the end of 2007 dry season, this reservoir was full to approximately 50% of its storage capacity. In 2008 rainy season, it overflowed and reached some 70% of its storage capacity at the end of that year.

This reservoir is located in an area that is characterized by a softly undulated relief, a typical thin brushwood vegetation, and exposed soil areas especially in dry periods. The ciliary forest surrounding its hydraulic basin is poorly preserved. The occurrence of houses and restaurant is also noted on the margins of this reservoir. The occurrence of maize and grass plantations is also noted. During the monitoring period, there was no evidence of presence of macrophytes in that water body. According to local information, its waters are predominantly used for animal consumption, small-scale subsistence fishing, and cloth washing. Its bathing use by customers of the existing restaurant was also identified.

Chico Miguel I Reservoir

This reservoir has a drainage basin of approximately 0.38 km^2. It has an hydraulic basin of 23,766.4 m^2 and a maximum water storage capacity of 33,273.0 m^3. It maximum depth was estimated in 4.2m. In years of normal or above-average pluviometry, especially consecutive years, this reservoir is quite likely to overflow. According to local information, in 2007 rainy season, that is, before PRODHAM monitoring activities, this reservoir did not overflow. At the end of that year (2007 dry season), it reached a level lower than 50% of its capacity. But in the next rainy period (2008), given the goods rains occurred, the reservoir had a good recharge and even overflowed. At the end of that year (dry season), it was at some 60% of its storage capacity.

Ciliary forest surrounding this reservoir is relatively preserved. The region where it is inserted is characterized by a softly undulated relief, sparse small and medium vegetation typical of brushwood, and some exposed soil areas, especially in dry period. No signs of significant anthropic actions were identified, but in occasions when the subproject team visited the region, the presence of animals on the reservoir margins was common. It should be emphasized that in rainy period, macrophytes and other materials were carried into its hydrographic basin and concentrated close to spillway. Its waters are mainly used for animal consumption, cloth wash and bathing.

Chico Miguel II Reservoir

Drainage microbasin of this reservoir is limited (0.65 km2), and therefore a rainy season with above-average precipitation is necessary to prevent this reservoir from drying. It has a hydraulic basin surface area of 11,805.7 m2, maximum storage capacity of 17,315.0 m3, and depth around 4.4 m. At the end of 2007, it dried up and caused the death of fish and other animals, and the exhalation of bad smell in its hydraulic basin area. In 2008 rainy season, it obtained a considerable water recharge and reached some 90% of its storage capacity. Upon the start and development of 2008 dry season, because of its evaporation rates, the volume of water observed in this reservoir at the end of the year reached approximately 60% of its total capacity.

Ciliary forest surrounding this reservoir is relatively preserved in one of its margins. In the other margin, the occurrence of medium arboreal brushwood vegetation is noted. There are no significant signs of anthropic action, but the presence of animals grazing in the area is common. Its waters are mainly used for animal consumption.

Antonio Cruz Reservoir

Antônio Cruz reservoir is considered one of the smallest reservoirs in the surveyed microbasin. Its drainage microbasin is limited and covers some 1.07 km2. It has an hydraulic basin of 10,267.6 m2, depth and maximum storage capacity of 5.2 m and 17,797.3 m3, respectively. At the end of 2007, this reservoir dried up. However, in 2008 rainy season, it gained a good water recharge and reached at the end of that season some 90% of its storage capacity. At the end of 2008 dry period it reached approximately 60% of its total water volume.

In the surroundings of this reservoir, the ciliary forest is quite damaged. In the proximities of its hydraulic basin, the occurrence of a thin vegetation and visibly exposed soil, especially in dry periods, is noted. This is a reservoir with a strong occurrence of aquatic macrophytes. The presence of animals grazing on its margins is common. Main water uses are: animal consumption, cloth wash and bathing.

Tobias Reservoir

This reservoir has a maximum storage capacity of 114,496.1m^3 and an hydraulic basin covering approximately 70,822.3 m^2. It has a drainage microbasin of 16.73 km^2 that, for the microbasin standards, is quite significant, taking into account that its main tributary, Felão stream, is one of the largest streams in the region. However, because it is a relatively shallow reservoir (maximum depth of 4.9m) and given the high evaporation rate in the region (above 2,000 mm/year), in the second semester of the year (dry season) most of its hydraulic basin becomes rapidly exposed. In effect, in spite of the reasonable size of its lake and the fact that it is fed by one of the main streams in the microbasin, Tobias reservoir, in years of normal or below-average rainy period, has approximately 50% of its hydraulic basin exposed and fails to overflow.

According to information obtained locally, this reservoir did not overflow in 2007 rainy period, and at the end of dry season that year (December 2007) it reached only 20% of its storage capacity. Upon the start of the next rainy season (2008), Tobias reservoir recovered the total volume of water stored in its hydraulic basin and even overflowed. Upon the start and development of 2008 dry season, this reservoir reached only approximately 60% of its total storage capacity.

Regarding the environmental conditions in the surroundings if this reservoir, the ciliary forest is poorly preserved and the occurrence of thin vegetation (brushwood type) is noted in dry period and a little denser vegetation in rainy period. This reservoir is dammed by BR-020 road. Most frequently, the presence of animals (bovine, caprine and porcine animals and chicken, among others) is noted in its surroundings or even inside its hydraulic basin, especially in dry periods. There is no evidence of significant anthropic activities. Waters of this reservoir are not used for human consumption, but only for animal consumption and cloth wash. Local population performs small-scale fishing for their own consumption.

Novo Reservoir

Novo reservoir, one of the smallest reservoirs in the region, has a drainage microbasin of 0.52 km2. It has a lake surface area of approximately 18,575.9 m2, and a maximum storage capacity of 17,337.5 m3. In normal or above-average rainy seasons, this reservoir overflows. In 2007 rainy season, there was no overflow, as it was in December 2007 at approximately 40% of its storage capacity, given the high evaporation rates in the region. The reservoir overflowed in 2008 rainy season and reached 70% of its storage capacity at the end of that year.

Ciliary forest surrounding this reservoir is relatively preserved in only one of its margins. In the other margin, the occurrence of a thin vegetation is noted, where most of soil becomes exposed. Close to the hydraulic basin, there are no signs of anthropic action, but the presence of animals is commonly noted. Its waters are basically used for animal consumption, cultivation of small vegetables and subsistence fishing.

Pedro Paulino Reservoir

Pedro Paulino reservoir is among the largest reservoirs monitored in the surveyed microbasin. It has one of the most significant drainage microbasins in the region, which extends across a surface area of 6.63 km^2. Its storage capacity is 169,271.5 m^2 and has an hydrographic basin of 110,394.4 m^2. At the end of 2007 dry season, in volumetric terms this reservoir reached some 50% of its storage capacity. It gained a significant water recharge in 2008 rainy season, and at the end of that year (dry season) it had reached 70% of its storage capacity.

There is no evidence of anthropic actions in its surrounding area, and its ciliary forest is reasonably preserved. According to local information, its waters are free of aquatic macrophytes, and apparently, in terms of salinity, are considered among the best waters in the region. Its waters are mainly used for subsistence pisciculture and animal consumption.

2.3.1.2 – Consistency of laboratory data through ionic balance

In general, activities performed during this stage involved data tabulation and storage in electronic spreadsheets; sorting, determination and consistency of laboratory data; performance of basic statistical analyses, among others.

All measurements are known to be followed by a certain experimental error, and the estimate of its magnitude is important for result validation. This way, results of laboratory analyses to determine ions present in collected samples were submitted to a consistency analysis by ion balance.

In water analyses, any error in analytic process may be estimated by ion balance, based on the fact that in a full chemical analysis the total concentration of cations, expressed in meq/L, should be similar to that of anions. The difference expressed in percentage if defined as analysis error. In fact, it is noted that, in practice, there is a difference between such two sums because of errors accumulated in any of determinations, and the fact that some smallest ionic contributions are not considered. Great differences may imply the existence of abnormal quantities of secondary ions or a serious analysis error.

Feitosa and Manoel Filho (2000) agree that an ionic balance error cannot exceed 10 to allow the analysis to be analytically correct. The main causes of error may be associated to mistakes in the analytical procedure, extended sample storage time, non-quantification of other ions present in substantial water quantities, among others. Small differences can be significant in percentage terms when compared to total anions and cations.

Results of laboratory analyses to determine the ions present in samples collected under PRODHAM project were submitted to a consistency analysis by ionic balance, using the program for water quality data treatment, QUALIGRAF, available in Funceme website. Methodology adopted for this program considers the following formulas:

- **Ionic Balance No. 1** – Based on practical error (Ep) defined by CUSTÓDIO AND LHAMAS (1983), where:

$$Ep(\%) = \left| \frac{r\sum \text{anions} - r\sum \text{cations}}{r\sum \text{anions} + r\sum \text{cations}} \right| x200$$

Theoretical errors are the maximum P.E. permissible considering the electric conductivity (E.C.) as shown below:

Electric Cond. (mS/cm)	50	200	500	2.000	>2.000
Permissible error (%)	30	10	8	4	<4

- **Ionic Balance No. 2** – Based on practical error (Ep) defined by Logann (1965), where:

$$Ep(\%) = \left| \frac{r\sum anions - r\sum cations}{r\sum anions + r\sum cations} \right| x100$$

Theoretical errors are the maximum P.E. permissible considering the ion values shown below.

Σ cations or Σ anions	<1	1	2	6	10	30	>30
Permissible error (%)	15	10	6	4	3	2	1

Results of ionic balances related to surface water samples collected during campaigns carried out in Cangati River microbasin are shown in Tables 2.8 to 2.22 below. Dates that were disregarded in discussions includes in the body of this work are highlighted.

Table 2.08 – Result of analysis of ionic data consistency (meq/l) in Chicote reservoir – AC01.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
10/16/2007	1.68	1.17	1.71	2.11	2.37	0.09	553	4.57	4.57	0.01	0	OK
11/20/2007	1	1.83	2.99	2.61	3.08	0.11	629	5.81	5.81	0.05	0.02	OK
12/18/2007	2.92	1.18	1.45	2.76	2.63	0.21	654.6	5.55	5.6	0.98	0.49	OK
1/15/2008	2.11	1.5	1.88	2.6	2.82	0.09	661	5.49	5.51	0.39	0.19	OK
2/19/2008	8.52	1.27	1.64	3.18	2.54	0.53	944	11.44	6.24	58.75	29.37	IB #1 & 2
6/17/2008	0.8	0.5	0.32	0.57	0.95	0.15	210.03	1.62	1.67	2.99	1.5	OK
7/15/2008	0.66	0.57	0.75	0.61	1.23	0.13	247.7	1.98	1.97	0.41	0.21	OK
8/12/2008	0.74	0.69	0.43	0.48	1.26	0.12	241.2	1.86	1.86	0.12	0.06	OK
9/16/2008	0.89	0.56	0.6	0.58	1.34	0.15	265.7	2.05	2.07	0.77	0.39	OK
10/14/2008	1.02	0.68	0.42	0.67	1.32	0.13	272.9	2.12	2.12	0.08	0.04	OK
11/19/2008	0.69	0.67	0.67	0.66	1.25	0.13	340.6	2.03	2.04	0.26	0.13	OK
12/16/2008	0.87	0.85	0.58	0.71	1.46	0.12	390.38	2.3	2.3	0.08	0.04	OK

Table 2.09 – Result of analysis of ionic data consistency (meq/l) in Ramin Reservoir - AC02.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
09/13/07	5.6	1.63	2.83	6.98	2.74	0.34	1125	10.06	10.06	0.05	0.02	OK
10/16/07	5.76	1.67	3.66	7.76	3.36	0.11	1227.3	11.09	11.24	1.33	0.66	OK
11/20/07	5.27	2.79	4.14	10.22	0.81	1.25	1237	12.2	12.28	0.63	0.31	OK
12/18/07	5.73	2.1	6.97	11.19	3.52	0.17	1550.6	14.81	14.89	0.58	0.29	OK
01/15/08	6.06	2.47	5.66	2.58	1.04	0.41	777.4	14.19	4.03	111.59	55.79	**IB #1 & 2**
02/19/08	6.67	0.79	0.86	2.63	4.39	1.24	1059	8.31	8.26	0.65	0.32	OK
03/26/08	1.91	0.32	0.78	1.11	1.03	0.94	389	3.01	3.08	2.19	1.1	OK
04/15/08	1.14	0.48	0.63	0.97	1.1	0.21	248	2.26	2.27	0.7	0.35	OK
05/08/13	1.56	0.58	0.63	1.05	1.12	0.6	343	2.77	2.77	0.05	0.02	OK
06/17/08	1.18	0.62	0.6	0.63	0.95	2.14	314.56	2.4	3.71	42.98	21.49	**IB #1 & 2**
07/15/08	2.38	1	1.06	1.79	1.62	0.15	423.8	4.44	3.57	21.7	10.85	**IB #1 & 2**
08/12/08	1.74	1.2	0.91	1.81	1.8	0.23	464.7	3.85	3.85	0.11	0.05	OK
09/16/08	1.88	1.16	1.14	2.11	1.81	0.28	498.5	4.19	4.2	0.33	0.17	OK
10/14/08	2.12	1.24	1.37	2.43	2.01	0.29	544.5	4.72	4.72	0.11	0.05	OK
11/19/08	2.04	1.33	1.6	2.67	2.1	0.23	777.75	4.97	5	0.56	0.28	OK
12/16/08	2.53	1.55	1.7	2.99	2.5	0.32	883.32	5.78	5.81	0.5	0.25	OK

Table 2.10 – Result of analysis of ionic data consistency (meq/l) in Zuir Reservoir - AC03.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
09/13/07	0.62	1.5	2	0.4	3.7	0.04	915	4.12	4.13	0.25	0.13	OK
10/16/07	3.28	1	4.01	1.85	6.42	0.07	1079.6	8.28	8.35	0.82	0.41	OK
03/26/08	2.39	0.42	0.46	0.27	1.05	0.9	339	3.27	2.22	38.4	19.2	**IB #1 & 2**
04/15/08	0.56	0.52	0.75	0.43	1.17	0.27	237	1.83	1.86	1.65	0.83	OK
05/08/13	1.07	0.44	0.66	0.23	1.54	0.42	285	2.17	2.19	1.1	0.55	OK
06/17/08	0.7	0.36	0.2	0.14	1.05	0.09	177.9	1.25	1.28	1.77	0.89	OK
07/15/08	0.09	0.51	0.47	0.14	0.92	0.08	145.6	1.06	1.14	6.68	3.34	OK
08/12/08	0.21	0.49	0.3	0.04	0.85	0.11	137.3	1.01	1	0.6	0.3	OK
09/16/08	1.19	0.26	0.41	0.08	0.94	0.09	183.5	1.86	1.11	50.07	25.04	**IB #1 & 2**
10/14/08	0.37	0.36	0.42	0.08	0.99	0.07	158.2	1.15	1.14	0.6	0.3	OK
11/19/08	1.15	0.37	0.59	0.03	2.02	0.1	407.75	2.12	2.15	1.49	0.74	OK
12/16/08	0.3	0.47	0.67	0.07	1.32	0.09	266.55	1.45	1.48	1.99	0.99	OK

Table 2.11 – Result of analysis of ionic data consistency (meq/l) in Lages Reservoir - AC04.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
09/13/07	3.65	1.52	2.38	4.59	2.77	0.2	879	7.56	7.56	0.03	0.01	OK
10/16/07	3.64	1.67	2.62	4.49	3.43	0.07	931.1	7.93	7.98	0.66	0.33	OK
11/20/07	2.4	2.5	2.99	5.6	0.85	1.49	819	7.89	7.93	0.53	0.27	OK
12/18/07	4.92	2.1	2.89	6.27	3.61	0.12	1142.1	9.91	9.99	0.78	0.39	OK
01/15/08	2.16	2.5	2.95	1.34	0.87	0.1	432.6	7.62	2.31	106.87	53.43	**IB nº1 e 2**
02/19/08	6.08	1.99	3.36	6.76	4	0.68	1298	11.43	11.45	0.14	0.07	OK
03/26/08	1.71	0.26	0.74	7.42	1.09	1.01	349	2.71	9.52	111.36	55.68	**IB nº1 e 2**
04/15/08	0.34	0.8	0.8	0.38	0.64	0.92	219	1.93	1.93	0.15	0.08	OK
05/08/13	1.26	0.46	0.58	0.58	1.36	0.38	303	2.3	2.32	0.89	0.44	OK
06/17/08	1.08	0.7	0.62	0.87	1.28	0.13	288.64	2.39	2.29	4.44	2.22	OK
07/15/08	0.89	0.88	0.84	0.9	1.52	0.2	325.4	2.6	2.61	0.41	0.2	OK
08/12/08	0.62	0.91	1.06	0.83	1.62	0.14	321.2	2.6	2.59	0.38	0.19	OK
09/16/08	0.89	0.78	1	1.15	1.69	0.24	364.4	2.67	3.09	14.69	7.34	**IB nº1 e 2**
10/14/08	1.34	1	0.82	1.09	1.82	0.24	397.3	3.16	3.15	0.4	0.2	OK
11/19/08	1.11	0.99	1.13	1.19	1.82	0.25	533.39	3.23	3.25	0.57	0.29	OK
12/16/08	0.49	0.91	0.52	0.18	1.56	0.18	348.31	1.92	1.93	0.53	0.26	OK

Table 2.12 – Result of analysis of ionic data consistency (meq/l) in Chico Miguel I Reservoir - AC05.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
09/13/07	0.39	0.46	1.33	0.18	1.85	0.16	320	2.19	2.19	0.09	0.05	OK
10/16/07	1.8	0.58	1.25	0.83	2.68	0.15	479.8	3.63	3.66	0.77	0.39	OK
11/20/07	1.38	1.06	1.92	2.46	0.71	1.21	465	4.36	4.38	0.39	0.2	OK
12/18/07	3.32	0.69	1.5	2.24	3.13	0.19	674.9	5.52	5.56	0.65	0.32	OK
01/15/08	0.32	1.02	1.46	0.34	0.83	0.32	220.6	2.81	1.48	61.72	30.86	**IB #1 & 2**
02/19/08	5.04	1.02	1.68	1.91	4.62	0.87	943	7.73	7.4	4.43	2.21	OK
03/26/08	1.49	0.2	0.24	0.54	0.94	0.43	251	1.92	1.92	0.36	0.18	OK
04/15/08	0.69	0.48	0.33	0.39	0.99	0.12	259	1.5	1.5	0.16	0.08	OK
05/08/13	2.36	0.3	0.34	1.76	1.01	0.24	361	3	3.01	0.45	0.22	OK
06/17/08	0.32	0.22	0.5	0.12	0.8	0.11	136.38	1.04	1.03	0.26	0.13	OK
07/15/08	0.39	0.53	0.72	0.16	1.1	0.13	192.4	1.64	1.39	16.57	8.28	OK
08/12/08	0.36	0.51	0.49	0.07	1.13	0.14	183.6	1.35	1.35	0.43	0.22	OK
09/16/08	1.61	0.46	0.5	0.13	1.28	0.19	257.5	2.57	1.6	46.8	23.4	**IB #1 & 2**
10/14/08	0.56	0.64	0.42	0.17	1.3	0.15	218.2	1.61	1.61	0.38	0.19	OK
11/19/08	0.22	0.63	0.63	0.13	1.21	0.16	265.76	1.49	1.5	0.96	0.48	OK
12/16/08	1.38	1.11	1.21	1.3	2.13	0.28	584.51	3.7	3.71	0.47	0.23	OK

Table 2.13 – Result of analysis of ionic data consistency (meq/l) in Chico Miguel II Reservoir - AC06.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
09/13/07	3.02	0.33	1.55	0.67	3.49	0.78	900	4.91	4.94	0.78	0.39	OK
10/16/07	7.4	0.5	1.81	4.74	4.88	0.18	1146.1	9.7	9.81	1.08	0.54	OK
11/20/07	7.87	0.86	2.7	7.61	1.41	2.52	1248	11.43	11.54	0.96	0.48	OK
12/18/07	21.49	0.89	2.61	14.4	9.14	1.71	3046.1	24.98	25.25	1.06	0.53	OK
03/26/08	1.23	0.14	0.36	0.3	0.96	0.54	268	1.73	1.8	3.86	1.93	OK
04/15/08	0.97	0.72	0.3	0.52	1.36	0	269	2	1.89	5.71	2.86	OK
05/08/13	0.66	0.34	0.63	0.36	1.38	0.23	248	1.63	1.98	19.57	9.78	IB #1 & 2
06/17/08	1.28	0.7	0.9	1.47	1.26	0.15	340.61	2.88	2.88	0.15	0.08	OK
07/15/08	1.07	0.62	1.12	0.68	2	0.13	362.2	2.81	2.82	0.07	0.03	OK
08/12/08	1.2	0.73	0.77	0.67	1.9	0.11	315.6	2.71	2.69	0.56	0.28	OK
09/16/08	2.73	0.84	0.9	0.81	2.25	0.14	471.2	4.47	3.21	32.83	16.41	IB #1 & 2
10/17/08	1.82	0.9	1	1.02	2.57	0.12	464.7	3.72	3.71	0.26	0.13	OK
11/19/08	1.53	0.89	1.39	1.06	2.6	0.16	639.91	3.81	3.82	0.31	0.15	OK
12/16/08	2.32	1.11	1.39	1.27	3.39	0.16	809.12	4.82	4.82	0.03	0.01	OK

Table 2.14 – Result of analysis of ionic data consistency (meq/l) in Antônio Cruz Reservoir - AC07.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
09/13/07	2.88	1.29	2.5	1.29	3.17	2.24	1300	6.67	6.7	0.45	0.22	OK
10/16/07	7.88	1.54	3.77	8.9	4.34	0.06	1507.6	13.19	13.31	0.86	0.43	OK
11/21/07	8.44	2.12	5.87	15	1.33	0.24	1665	16.43	16.56	0.8	0.4	OK
03/26/08	1.65	0.28	0.52	0.45	1.09	0.98	306	2.44	2.52	3.09	1.55	OK
04/15/08	0.93	0.59	0.68	0.65	1.34	0.23	224	2.2	2.21	0.51	0.26	OK
05/08/13	1.48	0.68	0.78	0.71	1.85	0.4	388	2.94	2.96	0.58	0.29	OK
06/17/08	1.41	0.9	1.1	1.1	2.21	0.1	432.43	3.41	3.41	0.07	0.04	OK
07/15/08	1.55	1.39	1.29	1.4	2.73	0.11	535.4	4.23	4.23	0.04	0.02	OK
08/12/08	1.85	1.42	1.32	1.62	2.87	0.09	577.3	4.59	4.59	0.1	0.05	OK
09/16/08	2.61	1.65	1.53	1.9	3.51	0.16	715.2	5.78	5.57	3.82	1.91	OK
10/14/08	2.68	1.18	2.25	2.21	3.75	0.13	757.9	6.11	6.08	0.35	0.18	OK
11/19/08	2.52	2.04	2.06	2.47	4	0.16	1100.87	6.62	6.63	0.17	0.08	OK
12/16/08	3.22	1.82	2.78	3.02	4.61	0.2	1251.13	7.82	7.82	0.02	0.01	OK

Table 2.15 – Result of analysis of ionic data consistency (meq/l) in Tobias Reservoir- AC08.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
09/13/07	2.53	1.7	2.72	1.03	3.11	2.85	1100	6.96	6.99	0.39	0.2	OK
10/17/07	5.01	1.77	2.68	5.97	3.39	0.19	1093	9.47	9.54	0.78	0.39	OK
11/21/07	4.19	2.41	1.83	7.46	0.81	0.22	875	8.42	8.5	0.87	0.44	OK
12/19/07	13.58	0.42	1.12	11.42	3.5	0.4	1749	15.12	15.32	1.3	0.65	OK
01/15/08	8.73	2.45	3.26	2.72	0.75	0.24	801	14.44	3.7	118.34	59.17	IB #1 & 2
02/19/08	5.28	0.54	0.77	2.8	2.42	1.43	799	6.59	6.65	0.94	0.47	OK
03/25/08	1.52	0.84	1.2	1.56	1.7	0.31	383	3.56	3.57	0.34	0.17	OK
04/15/08	1.44	0.7	0.78	1.04	1.76	0.16	324	2.92	2.95	1.11	0.56	OK
05/08/13	1.78	0.92	1.37	1.56	2.11	0.4	505	4.06	4.07	0.2	0.1	OK
06/17/08	3	1.24	1.98	2.92	2.63	0.19	697.9	6.22	5.73	8.2	4.1	OK
08/07/15	3.16	2.04	1.92	3.38	3.12	0.2	814.6	7.11	6.7	5.96	2.98	OK
08/12/08	3.05	2.24	1.85	3.56	3.42	0.15	805.9	7.13	7.13	0.05	0.02	OK
09/16/08	5.67	2.17	2.59	3.93	4.09	0.34	1071	10.43	8.36	22.05	11.02	IB #1 & 2
10/17/08	4.19	1.64	3.11	4.61	3.99	0.35	1019	8.94	8.95	0.01	0.01	OK
11/19/08	4.12	1.57	3.81	5.25	3.92	0.4	1472	9.5	9.57	0.79	0.4	OK
12/16/08	5.34	1.86	3.53	6.29	4.16	0.32	1607	10.73	10.77	0.36	0.18	OK

Table 2.16 – Result of analysis of ionic data consistency (meq/l) in Pedro Paulino Reservoir - AC10.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
09/13/07	3.25	1.42	1.3	0.51	2.89	2.62	610	5.97	6.01	0.7	0.35	OK
10/17/07	2.27	1.39	1.69	2.36	2.97	0.05	657.9	5.35	5.39	0.68	0.34	OK
11/21/07	3.25	1.64	2.7	2.84	4.57	0.18	912	7.59	7.58	0.06	0.03	OK
12/19/07	7	0.29	0.79	5.07	3.03	0.07	978.4	8.08	8.18	1.16	0.58	OK
01/15/08	2.89	1.39	2.12	3.22	3.17	0.06	765.4	6.4	6.45	0.88	0.44	OK
02/19/08	3.18	1.43	2.05	3.79	2.75	0.11	747	6.66	6.65	0.06	0.03	OK
03/26/08	2.54	0.94	1.16	2.16	2.28	0.23	576	4.64	4.67	0.66	0.33	OK
04/16/08	1.26	0.56	0.54	0.56	1.49	0.32	313	2.37	2.38	0.52	0.26	OK
05/08/13	1.34	0.42	0.98	0.66	1.76	0.32	355	2.73	2.73	0	0	OK
06/18/08	1.02	0.72	0.64	0.76	1.41	0.2	300.38	2.38	2.37	0.3	0.15	OK
07/16/08	1.04	0.72	0.69	0.84	1.47	0.14	357	2.46	2.45	0.28	0.14	OK
08/12/08	0.92	0.85	0.61	0.79	1.5	0.09	310.9	2.38	2.38	0.25	0.13	OK
09/17/08	1.12	0.76	0.81	0.81	1.78	0.1	344.5	2.69	2.69	0.12	0.06	OK
10/14/08	1.41	0.92	0.76	1	1.82	0.16	282.5	3.09	2.99	3.4	1.7	OK
11/19/08	0.99	0.89	0.95	0.95	1.82	0.06	474.76	2.84	2.83	0.1	0.05	OK
12/16/08	1.16	1.17	0.9	1	2.11	0.1	523.07	3.22	3.22	0.05	0.02	OK

Table 2.17 – Result of analysis of ionic data consistency (meq/l) in Cangati I River - RC01.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
03/25/08	1.53	0.82	1.32	1.33	1.61	0.72	449	3.67	3.66	0.08	0.04	OK
04/16/08	4.49	1.14	1.12	1.48	2.48	0.29	645	6.75	4.26	45.28	22.64	IB #1 & 2
05/14/08	1.72	0.76	0.94	1.16	1.89	0.37	432	3.41	3.42	0.32	0.16	OK
06/18/08	3.93	1.14	4.01	4.47	4.15	0.48	1090.19	9.08	9.1	0.21	0.1	OK

Table 2.18 – Result of analysis of ionic data consistency (meq/l) in Cangati II River - RC02.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
3/26/08	1.34	0.4	0.58	0.84	1.26	0.19	297	2.32	2.29	1.54	0.77	OK
4/15/08	1.29	0.98	0.81	1.29	1.63	0.16	344	3.09	3.07	0.44	0.22	OK
5/14/08	1.31	0.6	0.08	0.89	1.25	0.6	328	1.99	2.74	31.95	15.97	IB #1 & 2
6/18/08	7.49	0.86	4.04	4.23	4.13	0.43	1180.01	12.39	8.79	34.01	17	IB #1 & 2

Table 2.19 – Result of analysis of ionic data consistency (meq/l) in Felão I Stream - RF01.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
3/25/08	2.02	1	1.14	1.86	1.95	0.35	509	4.17	4.15	0.31	0.16	OK
4/16/08	1.58	0.98	1.3	1.84	1.89	0.12	467	3.86	3.86	0.02	0.01	OK
5/14/08	2.1	0.8	1.14	1.56	2.07	0.42	502	4.04	4.04	0.18	0.09	OK
6/18/08	4.94	2.12	2.89	5.64	3.31	0.22	1078.42	9.95	9.17	8.18	4.09	IB #1 & 2

TABLE 2.20 – Result of analysis of ionic data consistency (meq/l) in Felão II Stream - RF02.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
3/25/08	1.64	0.96	1.56	1.94	1.88	0.32	440	4.16	4.14	0.32	0.16	OK
4/16/08	0.86	1	1.37	1.84	2.42	0.33	517	3.23	4.59	34.76	17.38	IB #1 & 2
5/14/08	2.16	0.8	0.98	1.52	2.07	0.35	496	3.93	3.94	0.14	0.07	OK
6/18/08	3.95	1.96	3	5.49	3.43	0.2	1022.1	8.91	9.12	2.31	1.16	OK

Table 2.21 – Result of analysis of ionic data consistency (meq/l) in Gatos Stream - RG01.

Date	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
3/26/08	1.23	0.16	0.38	0.53	0.79	0.41	282	1.77	1.74	1.66	0.83	OK
4/16/08	0.92	0.52	0.5	0.61	1.1	0.26	253	1.94	1.96	1.05	0.53	OK
5/14/08	1.42	0.18	0.22	0.3	0.64	0.92	244	1.82	1.85	1.67	0.84	OK

Table 2.22 – Result of analysis of ionic data consistency (meq/l) in Chicote Stream - RCH01.

Data	NaK	Ca	Mg	Cl	CO3 + HCO	SO	CE	Total Cat.	Total Ani.	I.B. #1	I.B. #2	Status
3/26/08	1.66	0.52	0.7	0.94	1.19	0.77	367	2.88	2.9	0.79	0.39	OK
4/15/08	1.3	1.18	1.34	2.1	1.56	0.16	446	3.82	3.82	0.11	0.06	OK

2.3.1.3 – Hydrochemistry of surface water in microbasin

Hydrochemical classification by Piper diagrams

With the objective of mitigate the adverse climate effects on Northeast population, more specifically with respect to water supply, since the last century the government has developed public policies focused on, among other things, the intensification of damming program in that region. Even though the reservoirs contribute significantly to water supply, concerns related to the quantity of stored water have arisen: in reservoirs, waters are subject to high evaporation rates and become saline, reaching in some cases such high concentrations that make their use inappropriate for human consumption and agriculture.

In effect, waters stored in some reservoirs in Northeastern Brazil have high saline concentration rates that make them inappropriate for consumption and leave saline residues visibly deposited in the hydraulic basin soil.

Factors that contribute to the production of saline water and the origin of that salt are diverse and have been object of studies worldwide. Based on information on the salt origin and salinization processes it will be possible, in many cases, to indicate a form of management that would stop the natural salinization process.

A work performed by Santiago (1984) in two Ceará reservoirs showed the contribution of salt leaching processes in the hydrographic basin at the arrival of first rains, which increase both the mass of salts and evaporation, and increase salt concentration in reservoirs. That work also showed the need of an adequate management in dry period to allow incoming water during rainy periods to dilute stored salts and leave water at satisfactory salinity levels.

In a study performed to evaluate reservoir salinization in Brazilian semiarid region, Santos, Oliveira and Massaro (2000) concluded that reservoirs constructed without an adequate planning, with the only purpose of storing water, have constituted factors for water resource deterioration, because of concentration of elements present in the solution caused by evaporation.

A research performed by Funceme (2002) to study water salinization in small hydrographic basins stresses that processes that have increased salt concentration in water are several, among which evaporation stands out, which concentrates the salts by keeping the cation/anion ratios. It occurs greatly in surface waters and is stronger in regions of arid and semiarid climates. Rock weathering by hydrolysis is also a source of salt, which is likely to change the predominance of cations or anions. Another important process responsible for salts dissolved in water refers to eventual exchanges between cations dissolved in water and cations associated with argyles.

As shown above, water samples were collected from reservoirs and streams existing in the microbasin for ionic analysis to identify the main components of salts present in water, determine the water hydro chemical standards, and track their variations during both dry and rainy seasons.

This way, results of analyses of collected analyses were positioned on

PIPER triangular diagrams shown in Figures 2.13 and 2.14. This information is highly important, as it allows inferences on possible chemical reactions likely to occur in microbasin waters.

The analysis of such diagrams shows that mixed bicarbonated waters predominate, and indicates the ingress of new waters from rains in the water body. It should be noted that reservoirs evaluated in the microbasin are mostly small, where annually most of their waters are renewed. In dry periods there is a great reduction of stored volumes, which in some cases dry up. A similar result was obtained by Pereira et al. (2006), in a study to evaluate water salinity in Gameleira basin in the municipality of Aiuaba-Ce, when they concurrently made the analysis of waters of small reservoirs.

Exceptions were observed in Ramin, Lages and Tobias reservoirs. In fact, mixed waters predominate in Ramin reservoir, while mixed chlorinated waters predominate in Tobias reservoir. In Lages reservoir, stored waters changed from mixed chlorinated to mixed bicarbonated water.

By evaluating the seasonality effect on the behavior of such reservoirs, it is noted that waters stored in Chicote reservoir at the end of 2007 dry season (November and December) showed a tendency of equilibrium between chlorides and bicarbonates. Upon the start of 2008 rainy season, waters were enriched by bicarbonates, thus changing the previous equilibrium. It was also noted that the predominance of that anion continued for the whole 2008 dry season.

With respect to cations, it should be noted that throughout the evaluation period, waters were classified as mixed, and the predominance of any of such elements was identified.

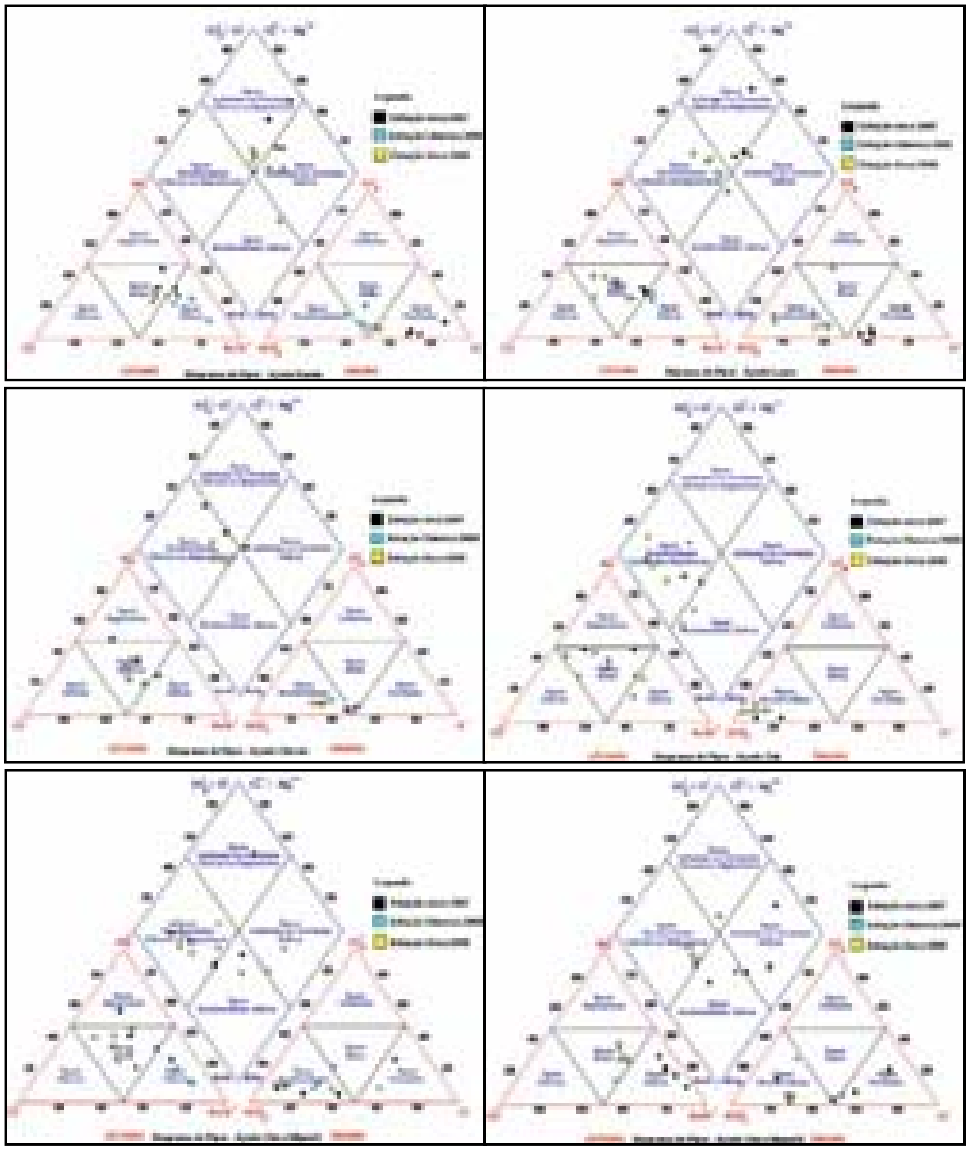

Figure 2.13 – Piper Diagrams related to Chicote, Ramin, Zuir, Lages, Chico Miguel I and Chico Miguel II Reservoirs

In Ramin reservoir, during 2007 dry season, when reservoir levels were lower and therefore the evaporation effect was more perceptible, an increased proportion of chlorides in waters was noted. Upon the start of rains and water runoff to the reservoir, there was a dilution process that reduced the chlorides and caused an equilibrium between that ion and bicarbonates present in waters. With respect to cations, it was noted that during 2008 rainy season probably was a transportation of sodium to that reservoir waters.

In Zuir reservoir, with respect to anion concentration, influence of seasonality on the behavior of that reservoir was not identified, and bicarbonate remained as the predominant element all over the evaluation period. With regard to cations, it was noted that concentrations of those elements in waters of that reservoir were quite balanced. Exceptions were noted at the end of 2008 rainy season (May and June), when a small increase in sodium concentration was detected.

With respect to Lages reservoir, it was noted that in 2007 dry season, when the reservoir stored a smaller volume of water associated with high evaporation rates, chlorides appeared in higher concentrations. Upon the arrival of 2008 rainy season and the great ingress of water in the reservoir, which even overflowed, a process of chloride dilution and water enrichment by bicarbonates was evidenced, probably due to ingress of new rain waters. That pattern persisted during 2008 dry season when the reservoir water levels were comparably higher than those recorded in 2007 dry season. With respect to cations, it was noted that at the end of 2007 dry season and start of 2008 rainy season, waters in that reservoir were enriched by sodium, probably due to a leaching process.

Throughout the monitoring activity, bicarbonate was the predominant ion in Chico Miguel I reservoir. With respect to cations, it was noted that their concentrations were well balanced in most part of evaluated period. Exceptions were noted at the end of 2007 dry season and start of 2008 rainy season, when a small increase of sodium content in water was detected.

Notwithstanding the predominance of bicarbonates among anions present in samples evaluated in Chico Miguel II reservoir, it was noted that in 2007 dry season water was enriched by chlorides. However, it was noted that concentrations of those two elements tended to be balanced at the end of that period. This fact was probably due to low reservoir levels associated with high evaporation rates. With respect to cations, it should be pointed out that concentrations of those elements were balanced, but in 2007 dry station a water enrichment by sodium was noted.

In Tobias reservoir, it noted that upon the start of 2008 rainy season and the ingress of new rain waters in that water body, there was a dilution process that led to a balanced proportion of chlorides and bicarbonates present in waters.

Finally, in Pedro Paulino reservoir it was noted that at the end of 2007 dry period and arrival of first rains in 2008, there was water enrichment by chlorides. As such, in that period bicarbonates and chlorides tended to equilibrium. However, upon the development of 2008 rainy season and 2008 dry season, a predominance of bicarbonates was evidenced.

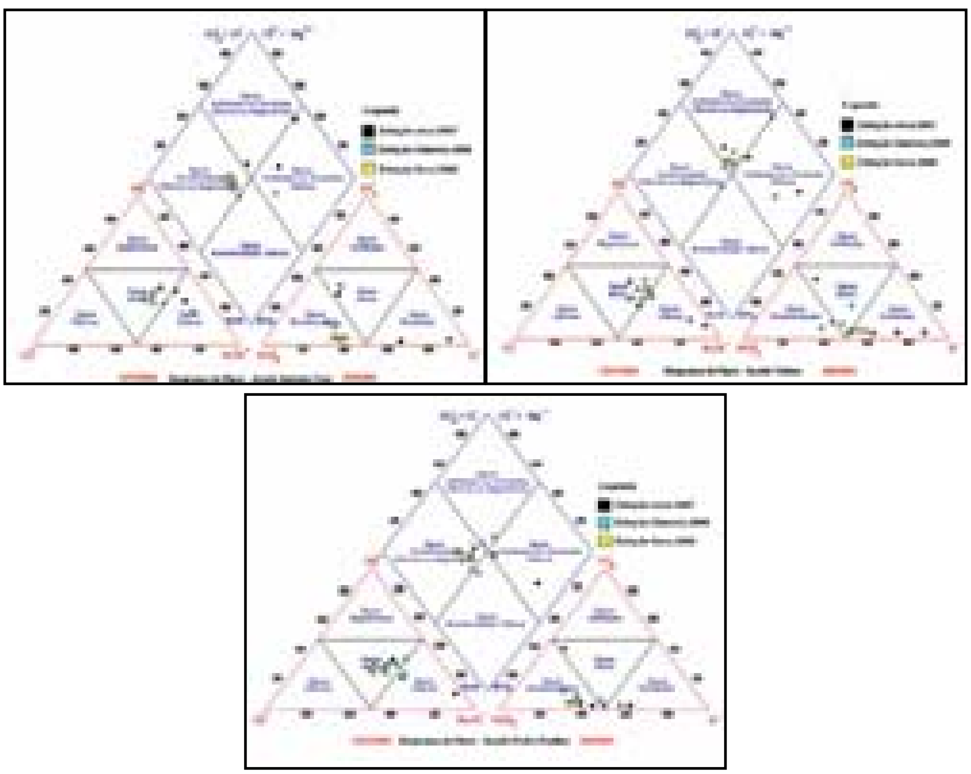

Figure 2.14 – Piper diagrams related to Antônio Cruz, Tobias and Pedro Paulino reservoirs

Predominating ions

Ion concentrations (mg/l), as measured in water of reservoirs evaluated in the microbasin, are shown in Figures 2.15 and 2.16. Bases on the analysis of such graphs, it is noted that in general the predominating ions are bicarbonates, followed by chlorides. Potassium, carbonate and sulfate concentrations were generally inexpressive. It should be pointed out that in most of evaluation period, chloride concentrations remained below 250 mg/l, a limit established by CONAMA Resolution no. 357/05 for class-2 fresh waters, and therefore had no restrictions to human consumption.

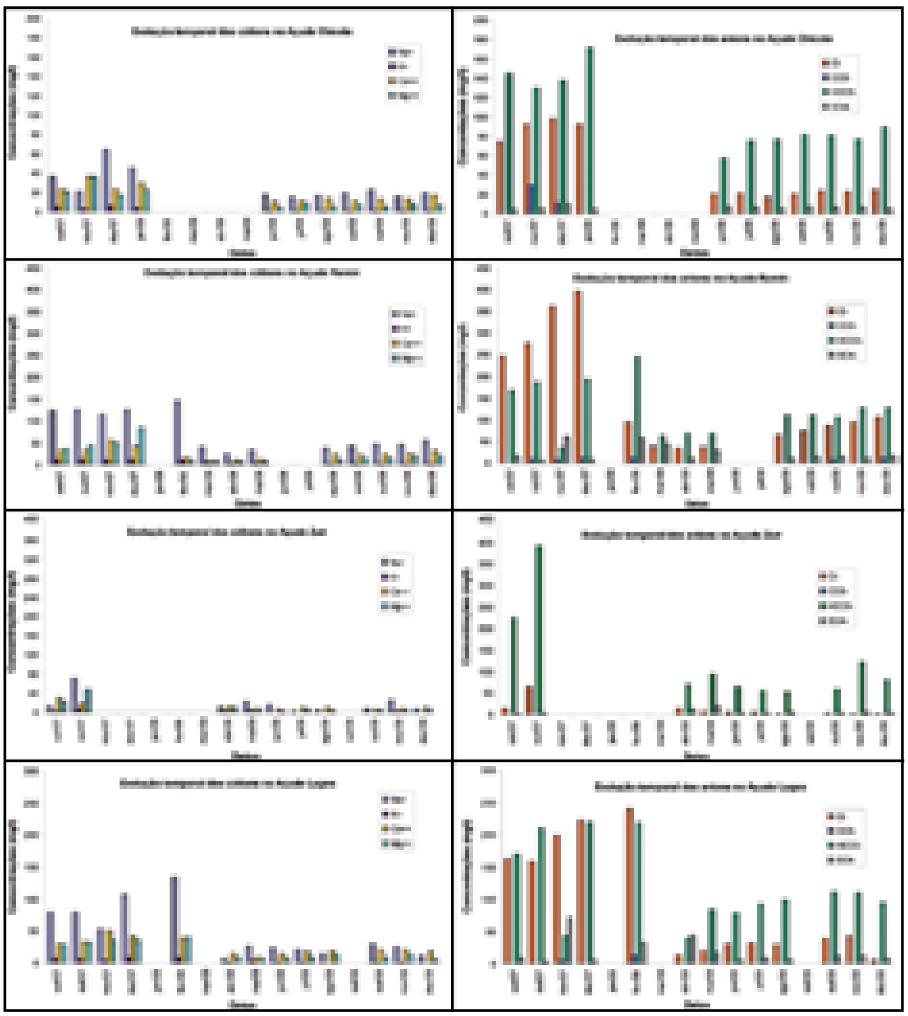

Figure 2.15 – Temporal evolution of ion concentrations in Chicote, Ramin, Zuir and Lages reservoirs in Cangati River microbasin–CE.

It was also noted that, in 2007 dry season, sodium content was higher, but in general at concentrations below 200 mg/l, a limit established by Directive no. 518/04 of the Ministry of Health, which provided for control and surveillance of human consumption water.

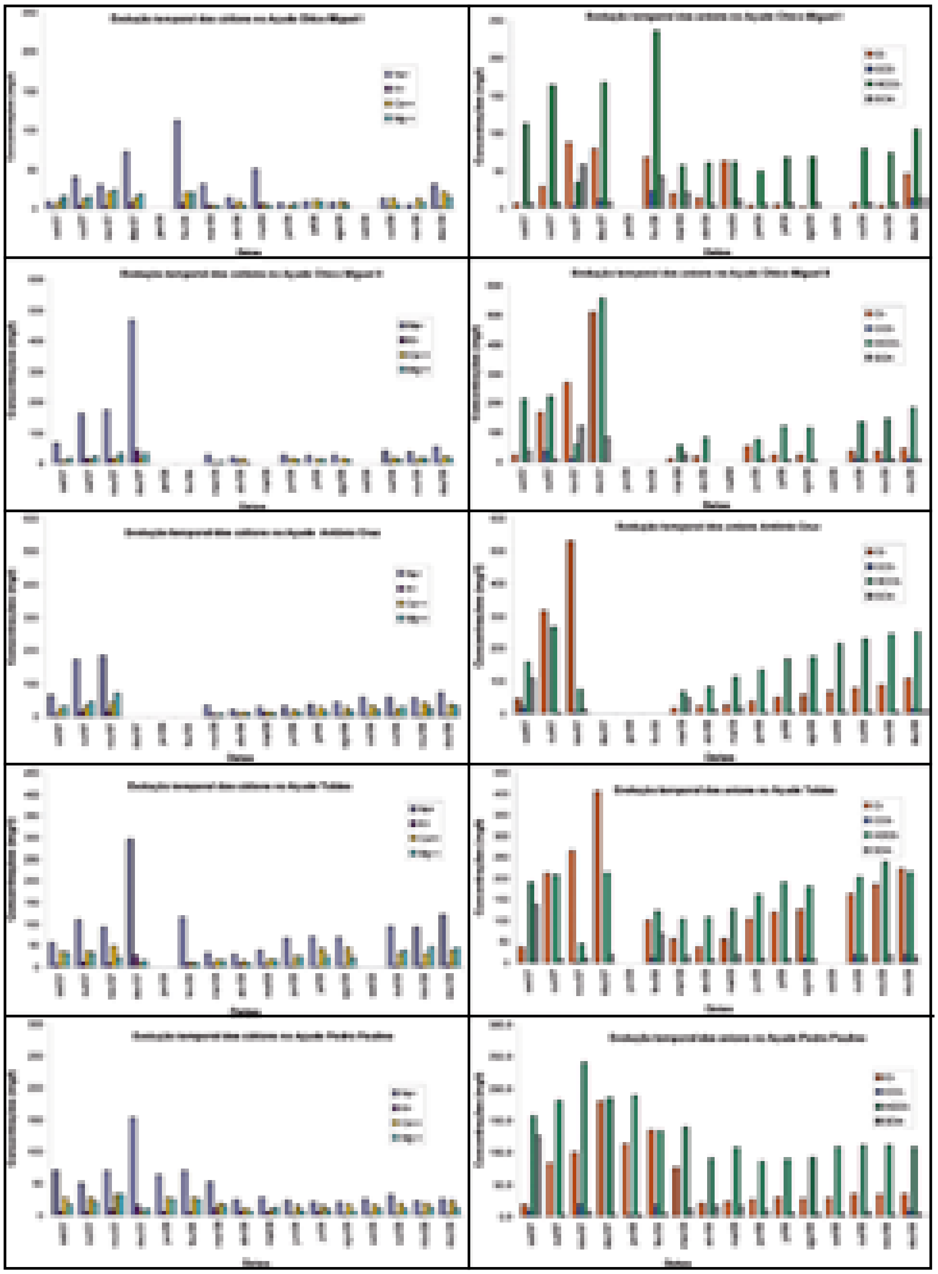

Figure 2.16 – Temporal evolution of ion concentrations in Chico Miguel I e II, Antônio Cruz, Tobias and Pedro Paulino reservoirs (Cangati River - Ce).

Also with respect to potability and considering the standards recommended by the World Health Organization, it us emphasized that in most of collected samples, chloride and sodium content comply with the standards recommended by that organization, and therefore do not affect the organoleptic quality of waters.

Exceptions were noted in Ramin, Chico Miguel II, Antônio Cruz and Tobias reservoirs where, in certain months, chloride and/or sodium concentrations in water of those reservoirs exceed the limits recommended by law.

In effect, in Ramin reservoir, where bicarbonates and chlorides predominate, chloride content remained above 259mg/L in all 2007 dry season campaigns, showing therefore restrictions to human consumption, according to standards established by CONAMA Resolution no. 357/05. In 2007, there was some increase in chloride concentrations, probably due to evaporation process. However, upon the arrival of the first rains in 2008, water enrichment by bicarbonate was noted. During the development of that season, the concentrations of those two elements became balanced.

In Chico Miguel II reservoir, highest ion concentrations are those of bicarbonates and chlorides. In 2007 dry season, such elements occurred at concentrations very close to or hither than those noted in 2008 dry season. It is also noted that, upon the start of 2008 rainy season, bicarbonate content, although lower than those found in 2007 dry season, predominated over that of chlorides. Chloride concentration in that reservoir waters in December 2007 was as high as 510.6 mg/L, that is, well above the limits recommended by CONAMA Resolution no. 357/05 for human consumption. At that same time, sodium content reached 468.0 mg/L, in deviation of standards established by Directive no. 518/04 of the Ministry of Health. It should be pointed out that in that period the reservoir reached its lowest level close to drying up.

In Antônio Cruz reservoir, even though bicarbonates predominate in its waters, higher chloride levels were noted in October and November 2007 (dry season), which even exceeded those of bicarbonates. In that period, chloride concentration was as high as 531.7 mg/L, exceeding the limits recommended by CONAMA Resolution no. 357/05.

In 2007 dry season, the highest chloride concentrations were found in Tobias reservoir waters, which reached 404.8 mg/L in December 2007, and therefore above the limits recommended by CONAMA Resolution no. 357/05. At that time, sodium peaked 295.8 mg/l, exceeding the limit established by Directive no. 518/04 of the Ministry of Health.

It should be highlighted that 2007 dry season, for most reservoirs included in the study, was the period where generally a strong concentrations of ions dissolved in water occurred. This fact may be explained by the increased evaporation rates, followed by precipitation shortage in the region during the evaluation period. A similar behavior was noted by Laraque (1989), upon performing salinization studies in Northeast reservoirs. On the other hand, it was noted that in 2008 rainy season, which coincides with precipitation, there was a reduction in parameters figures, thus emphasizing the power of rain dilution that caused a reduction in ion concentrations.

2.3.1.4 – Classification of surface waters according to total dissolved solids (TDS)

Total dissolved solids (TDS) corresponds to the total weight of mineral elements present in water per volume unit, that is, it represents the concentration of the all volatile or non-volatile material dissolved in water. Electric conductivity (EC) keeps a close relationship with TDS.

Typically, most or all content of solids dissolved in water samples is constituted of inorganic material. One of the simplest procedures used to evaluate the dissolved solid content is that of electric conductivity. Under that procedure, the organic content is not determined; only ions can be measured. EC measurement is influenced by temperature and nature of soils contained in water.

Water electric conductivity is the water capacity to transmit electric current, which is determined by the presence of dissolved substances dissociated into anions and cations. Electric conductivity variation may provide information on important processes likely to occur in aquatic ecosystems, such as primary production (reduced values) and decomposition (increased values).

In general, EC keeps a direct relationship with TDS. Usually, the fixed portion of dissolved solids is regarded as salinity. Thus, excess TDS in water may cause changes to taste, corrosion and soil salinization problems. According to CONAMA Resolution no. 357/05, of 03/17/2005, for human supply water (fresh water, class 2), a maximum TDS value of 500 mg/L is allowed.

Class 2 waters may have the following destinations: human consumption supply after conventional treatment; protection of aquatic communities; primary contact recreation, such as swimming and diving (this item should comply with CONAMA Resolution no. 274/2000); irrigation of vegetables, fruit plants, and parks, gardens, sport and leisure fields, with which the public may have any direct contact; and aquiculture and fishing.

According to APHA (1995), electric conductivity measurement devices allow the direct measurement of total dissolved solids. In general, TDS concentration ranges between 50 and 90% of conductivity, and is expressed in μS/cm.

Electric conductivity indicates the quantity of salts existing in water head, thus representing an indirect measurement of pollutant concentration. In general, levels higher than 100 μS/cm indicate impacted environments (CETESB, 2006). By this parameter, it is possible to evaluate the content of total dissolved solids, as in general the electric conductivity: total dissolved solid ratio is 1.5:1.0.

Santos (Apud FEITOSA and MANOEL FILHO, 2000) highlights that in most natural groundwater, water EC multiplied by a factor ranging between 0.55 and 0.75, will generate a good TDS estimate. For saline waters, that factor is usually above 0.75, and for acid waters, it is below 0.55.

QUALIGRAF software, used to generate the graphs indicated in the body of this report, adopts an average value of 0.65 that is considered reasonable, especially for Northeastern region where climate is hot.

This way, based on estimated TDS, the following classification is made:

TABLE 2.23 – Classification of waters according to concentrations of total dissolved solids

Type of waters	TDS (mg/L)
Fresh	0 – 500
Brackish	500 – 1500
Salty	> 1500

Note: waters with TDS higher than 35,000 mg/L are considered brines (Ex.: Sea waters).

Figures 2.17 and 2.18 show graphs related to water classification in microbasin reservoirs, according to total dissolved solids (TDS) values in evaluation period. It is noted that in most of evaluated reservoirs, fresh water predominates at TDS values below 500 mg/L. An exception occurs in Ramin and Tobias reservoirs, where lower-quality brackish waters predominate at TDS values above 500 mg/L, which present, therefore, restrictions to use, according to CONAMA Resolution no. 357/2005 for class-2 fresh waters.

With respect to river/streams monitored by the subproject (Figure 2.19), given its intermittent nature where runoff occurs only in rainy periods, it is noted that collected water, in terms of total dissolved solids, are classified as fresh waters, what indicates that no significant quantities of mineral components dissolved in collected samples were found. However, as there were only a few water collection campaigns focused on those water bodies, it is suggested that campaigns be intensified in that period and monitoring is continued through campaigns in successive years, for a better evaluation of interannual variation and dynamics of that process.

By analyzing the season variation of TDS concentrations, it is noted that in most of evaluated reservoirs brackish waters predominate in dry

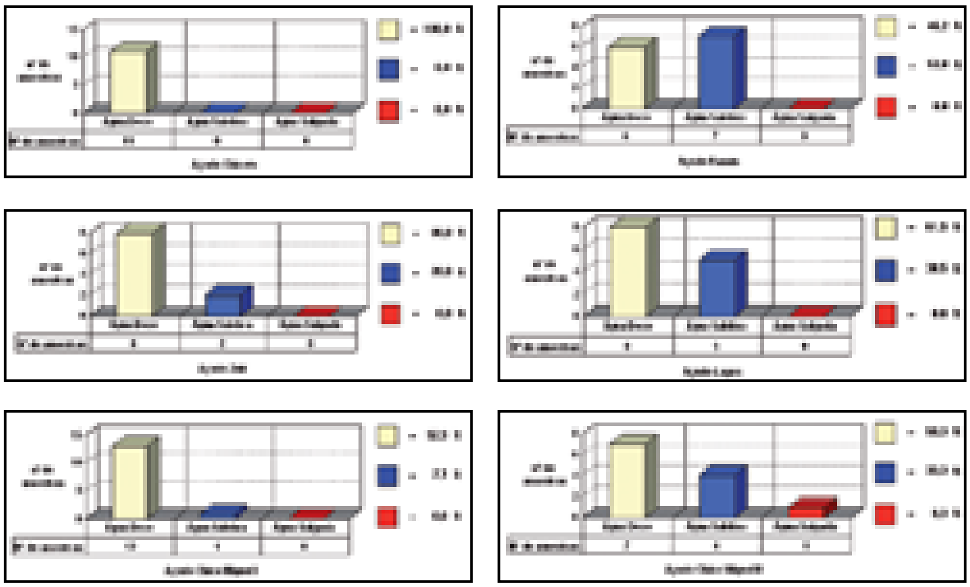

Figure 2.17 – Water classification according to TDS in Chicote, Ramin, Zuir, Lages, Ramin, Zuir, Lages, Chico Miguel I e Chico Miguel II reservoirs.

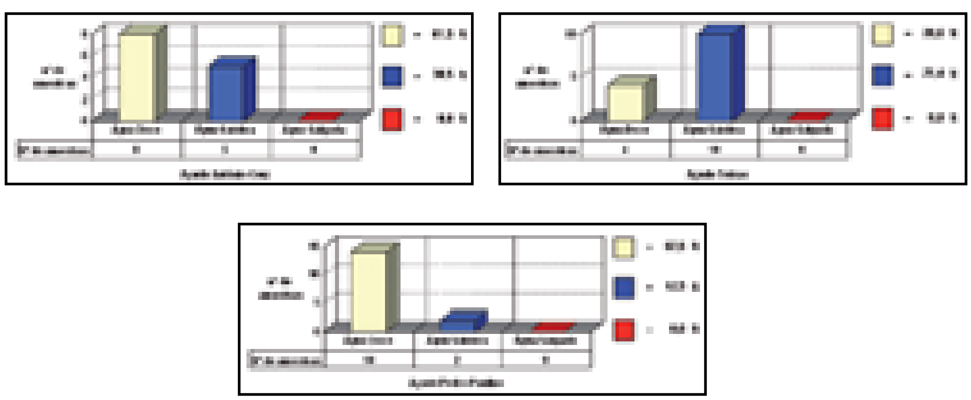

Figure 2.18 – Water classification according to TDS in Antônio Cruz, Tobias and Pedro Paulino reservoirs.

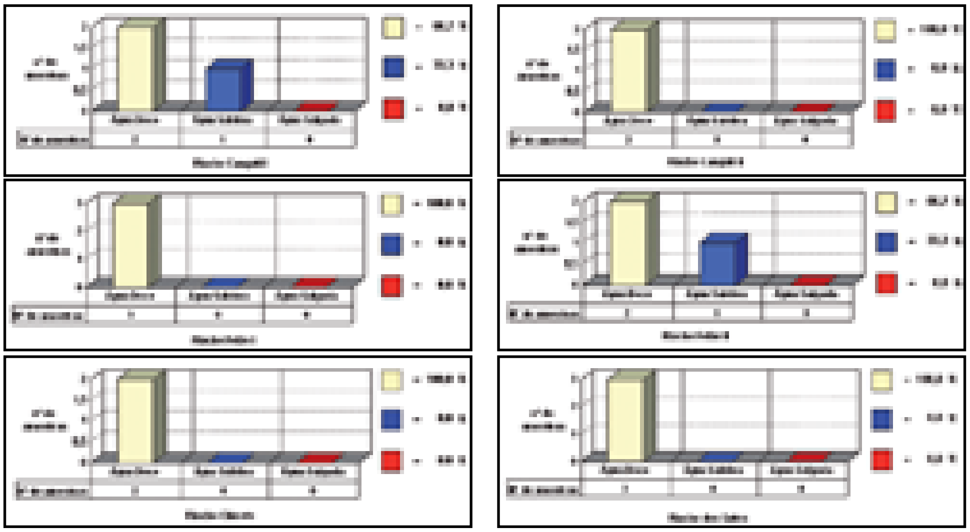

Figure 2.19 – Water classification according to TDS in river/streams in Cangati River microbasin – Ce.

periods, and fresh water predominate in rainy periods (Table 2.24). This can be explained by 2009 rainy season, which was too significant to the point of causing the dilution of salts and other elements present in analyzed samples, and accordingly, the change of their class.

It is also noted that, in general, in 2007 dry season, stored water had TDS values exceeding those observed in 2008 dry season. This behavior may be attributed to volumes stored in reservoirs in the beginning of monitoring activity (2007 dry season), which were lower than those observed in the following dry season (2008), since, because the significant water discharge in reservoirs during the rainy season, they had higher water levels.

It should be pointed out that in Chicote reservoir, stored waters remained in fresh class all over the evaluation period. In this sense, it is important to highlight that this reservoir is located in the highest point of the microbasin, in a region where significant anthropic actions were not observed, and where ciliary forest was very well preserved, what can explain TDS values within the limits established by CONAMA Resolution no. 357/2005. A similar behavior was noted in Chico Miguel I reservoir.

In Pedro Paulino reservoir, it was noted that in the beginning of 2007 dry season (September and October 2007) stored waters were classified as fresh waters. It should be pointed out that this reservoir has a greater storage capacity, and therefore the evaporation rates observed in that period were not sufficient to increase the concentration of solids dissolved in water or change its class. However, upon the development of 2007 dry season, evaporation effect became more perceptible, making TDS values increase and the classification of waters stored in that reservoir change to brackish, presenting, therefore, restrictions to human supply.

It should also be highlighted that, among all evaluated reservoirs, Chico Miguel II reservoir presented at the end of 2007 dry season the most critical TDS levels (1980 mg/L), and therefore its waters were classified as salty at the campaign of December 2007. In effect, this is a very small reservoir and during 2007 dry season it came close to drying up, where only a very small percentage of its full capacity was filled with water.

Table 2.24 – Classification of waters in reservoirs of Cangati River microbasin– CE, according to total dissolved solid values.

RESERVOIR	DATE	CE (μS/cm)	TDS (mg/L)	CLASSIFICATION
Chicote	10/16/07	553.0	359.5	Fresh water
	11/20/07	629.0	408.9	Fresh water
	12/18/07	654.6	425.5	Fresh water
	01/15/08	661.0	429.7	Fresh water
	06/17/08	210.03	136.5	Fresh water
	07/15/08	247.7	161.0	Fresh water
	08/12/08	241.2	156.8	Fresh water
	09/16/08	265.7	172.7	Fresh water
	10/14/08	272.9	177.4	Fresh water
	11/19/08	340.6	221.4	Fresh water
	12/16/08	390.38	253.7	Fresh water
	09/13/07	1125.0	731.3	Brackish water
	10/16/07	1227.3	797.7	Brackish water
	11/20/07	1237.0	804.1	Brackish water
	12/18/07	1550.6	1007.9	Brackish water
	02/19/08	1059.0	688.4	Brackish water
	03/26/08	389.0	252.9	Fresh water
	04/15/08	248.0	161.2	Fresh water

(continue)

(continuation)

RESERVOIR	DATE	CE (μS/cm)	TDS (mg/L)	CLASSIFICATION
Ramin	05/08/13	343.0	223.0	Fresh water
	08/12/08	464.7	302.1	Fresh water
	09/16/08	498.5	324.0	Fresh water
	10/14/08	544.5	353.9	Fresh water
	11/19/08	777.75	505.5	Brackish water
	12/16/08	883.32	574.2	Brackish water
Zuir	09/13/07	915.0	594.8	Brackish water
	10/16/07	1079.6	701.7	Brackish water
	04/15/08	237.0	154.1	Fresh water
	05/08/13	285.0	185.3	Fresh water
	17/06/08	177.9	115.6	Fresh water
	07/15/08	145.6	94.6	Fresh water
	12/08/08	137.3	89.2	Fresh water
	14/10/08	158.2	102.8	Fresh water
	19/11/08	407.8	265.0	Fresh water
	16/12/08	266.6	173.3	Fresh water
Lages	09/13/07	879.0	571.4	Brackish water
	16/10/07	931.1	605.2	Brackish water
	11/20/07	819.0	532.4	Brackish water
	18/12/07	1142.1	742.4	Brackish water
	19/02/08	1298.0	843.7	Brackish water
	15/04/08	219.0	142.4	Fresh water
	13/05/08	303.0	197.0	Fresh water
	17/06/08	288.6	187.6	Fresh water
	07/15/08	325.4	211.5	Fresh water
	12/08/08	321.2	208.8	Fresh water
	14/10/08	397.3	258.2	Fresh water
	19/11/08	533.4	346.7	Fresh water
	16/12/08	348.3	226.4	Fresh water
Chico Miguel I	09/13/07	320.0	208.0	Fresh water
	16/10/07	479.8	311.9	Fresh water
	11/20/07	465.0	302.3	Fresh water
	18/12/07	674.9	438.7	Fresh water
	19/02/08	943.0	613.0	Brackish water
	26/03/08	251.0	163.2	Fresh water
	15/04/08	259,0	168,4	Fresh water
	13/05/08	361,0	234,7	Fresh water
	17/06/08	136,4	88,6	Fresh water
	07/15/08	192,4	125,1	Fresh water
	12/08/08	183,6	119,3	Fresh water
	14/10/08	218,2	141,8	Fresh water
	19/11/08	265,8	172,7	Fresh water
	16/12/08	584,5	379,9	Fresh water

(continue)

(continuation)

RESERVOIR	DATE	CE (µS/cm)	TDS (mg/L)	CLASSIFICATION
Chico Miguel II	09/13/07	900,0	585,0	Brackish water
	16/10/07	1146,1	745,0	Brackish water
	11/20/07	1248,0	811,2	Brackish water
	18/12/07	3046,1	1980,0	Salt water
	26/03/08	268,0	174,2	Fresh water
	15/04/08	269,0	174,9	Fresh water
	17/06/08	340,6	221,4	Fresh water
	07/15/08	362,2	235,4	Fresh water
	12/08/08	315,6	205,1	Fresh water
	10/17/08	464,7	302,1	Fresh water
	19/11/08	639,9	415,9	Fresh water
	16/12/08	809,1	525,9	Brackish water
Antônio Cruz	09/13/07	1300,0	845,0	Brackish water
	10/16/07	1507,6	979,9	Brackish water
	11/21/07	1665,0	1082,3	Brackish water
	03/26/08	306,0	198,9	Fresh water
	04/15/08	224,0	145,6	Fresh water
	05/08/13	388,0	252,2	Fresh water
	06/17/08	432,4	281,1	Fresh water
	07/15/08	535,4	348,0	Fresh water
	08/12/08	577,3	375,2	Fresh water
	09/16/08	715,2	464,9	Fresh water
	10/14/08	757,9	492,6	Fresh water
	11/19/08	1100,9	715,6	Brackish water
	12/16/08	1251,1	813,2	Brackish water
Tobias	09/13/07	1100,0	715,0	Brackish water
	10/17/07	1092,9	710,4	Brackish water
	11/21/07	875,0	568,8	Brackish water
	12/19/07	1749,4	1137,1	Brackish water
	02/19/08	799,0	519,4	Brackish water
	03/25/08	383,0	249,0	Fresh water
	04/15/08	324,0	210,6	Fresh water
	05/08/13	505,0	328,3	Fresh water
	06/17/08	697,9	453,7	Fresh water
	07/15/08	814.6	529.5	Brackish water
	08/12/08	805.9	523.8	Brackish water
	10/17/08	1019.0	662.4	Brackish water
	11/19/08	1471.8	956.7	Brackish water
	12/16/08	1607.2	1044.7	Brackish water
	09/13/07	610.0	396.5	Fresh water
	10/17/07	657.9	427.6	Fresh water
	11/21/07	912.0	592.8	Brackish water
	12/19/07	978.4	636.0	Brackish water

(continue)

(continuation)

RESERVOIR	DATE	CE (µS/cm)	TDS (mg/L)	CLASSIFICATION
Pedro Paulino	01/15/08	765.4	497.5	Fresh water
	02/19/08	747.0	485.6	Fresh water
	03/26/08	576.0	374.4	Fresh water
	04/16/08	313.0	203.5	Fresh water
	05/08/13	355.0	230.8	Fresh water
	06/18/08	300.4	195.2	Fresh water
	07/16/08	357.0	232.1	Fresh water
	08/12/08	310.9	202.1	Fresh water
	09/17/08	344.5	223.9	Fresh water
	10/14/08	282.5	183.6	Fresh water
	11/19/08	474.8	308.6	Fresh water
	12/16/08	523.1	340.0	Fresh water

Table 2.25 – Classification of waters in river/streams in Cangati River microbasin -CE, according to total dissolved solid values.

RIVER/STREAM	DATE	CE (µS/cm)	TDS (mg/L)	CLASSIFICATION
R. Cangati I	03/25/08	4490	2919	Fresh water
	05/14/08	4320	2808	Fresh water
	06/18/08	10902	7086	Brackish water
R. Cangati II	03/26/08	2970	1931	Fresh water
	04/15/08	3440	2236	Fresh water
R. Felão I	03/25/08	5090	3309	Fresh water
	04/16/08	4670	3036	Fresh water
	05/14/08	5020	3263	Fresh water
R. Felão II	03/25/08	4400	2860	Fresh water
	05/14/08	4960	3224	Fresh water
	06/18/08	10221	6644	Brackish water
R. Chicote	03/26/08	3670	2386	Fresh water
	04/15/08	4460	2899	Fresh water
R. Gatos	03/26/08	2820	1833	Fresh water
	04/16/08	2530	1645	Fresh water
	05/14/08	2440	1586	Fresh water

2.3.1.5 – Classification of irrigation waters

Classification of irrigation waters is determined by the concentration of some ions, such as sodium, chloride, sulfate, and such parameters as dissolved salts, electric conductivity and total concentration of cations, which influence in a differentiated manner the development of each vegetal species.

To evaluate the quality of irrigation water, a special emphasis was given to the possibility of occurrence of salinity and infiltration problems derived from its use. In fact, most common problems related to waters for irrigation include salinity, soil infiltration speed, toxicity, excess of nutrients, and corrosion of irrigation equipment. Waters rich in sodium or very poor in calcium and magnesium tend to reduce soil permeability, increase puddle formation, and make vegetation feeding difficult. Waters that are not chemically hazardous, when applied to poorly permeable soils, may cause salinization, which is a frequent danger in Northeastern region.

In this sense, an attempt was made to determine the level of restriction to the use of such waters, by classifying them for irrigation, according to the U.S. Salinity Laboratory. In effect, among the criteria for classification of irrigation waters, one of the most widely accepted is the classification proposed by the "United States Salinity Laboratory" (USSL). This classification is based on sodium absorption ratio (RAS) and on electric conductivity of water.

Salinity effect is osmotic and can affect directly the crop yields, which behave differently as to tolerance to salts in water. Sodicity, on the other hand, refer to the relative effect of sodium on irrigation water, which tends to increase the exchangeable sodium percentage (ESP) in soil, causing damages to its physical-chemical properties and infiltration problems. High ESP in the soil, especially under low salinity conditions, will cause particle dispersion and the reduction of hydraulic soil conductivity.

Interchangeable cations of soil colloids are in equilibrium with soil solution ions. By increasing the proportions of sodium in irrigation waters, alkalinity will tend to increase.

Sodium danger cannot be estimated by measuring separately its percentage in irrigation areas, bur rather through the correlation between sodium, on one side, and calcium and magnesium on the other. According to U.S. Salinity Laboratory, the relative sodium proportion to other salts may be expressed in terms of sodium absorption ration (RAS), which can be calculated by the following formula:

$$RAS = \frac{rNa}{\sqrt{\frac{r(Ca+Mg)}{2}}}$$

Where concentrations of Na^{+}, Ca^{++} and Mg^{++} are expressed in meq/L (milliequivalent per liter).

Sodium absorption ratio – RAS is used together with electric conductivity in classification of irrigation waters. The higher the RSA, the least appropriate the water for irrigation. RAS is a ratio that indicates the percentage of sodium content in water, which can be absorbed by the soil.

Table 2.26 shows the classes of risks of soil salinization and alkalinization by irrigation waters, as proposed by the United States Salinity Laboratory.

Table 2.26 – Classification of salinity and alkalinity risks of irrigation waters by the U.S. Salinity Laboratory

Classes	Salinity Risk	E.C. at 25ºC (mS/cm)	Dissolved Salts (mg/L)
C0	No restriction	<100	<64
C1	Low	100-250	64-160
C2	Medium	250-750	160-480
C3	High	750-2,250	480-1,440
C4	Very high	2,250-5,000	1,440-3,400
C5	Exceptionally high	>5,000	>3,400
Classes	**Alkalinity Risk**	**RAS**	
S1	Low	<10	-
S2	Medium	10-18	-
S3	Strong	18-26	-
S4	Very strong	>26	-

Based on concepts above, classification of irrigation water was made in reservoirs and streams of Cangati River microbasin - Ce. Results are plotted in graphs of Figures 2.20 to 2.22. By evaluating the monitored period as a whole, it is noted that C2S1 waters predominate. C2 waters are considered of medium salinity risk. They should be used with care, and can be used in silty-sandy, silty or sandy-argillaceous soils when there is a moderate soil leaching. Vegetables with low saline tolerance may also be cultivated in most cases. Regarding the soil alkalinization aspect, S1 waters are considered weekly sodic and can be used in nearly all soils with a low risk of creating harmful contents of sodium susceptible to exchange. They can be used for the cultivation of almost all vegetables.

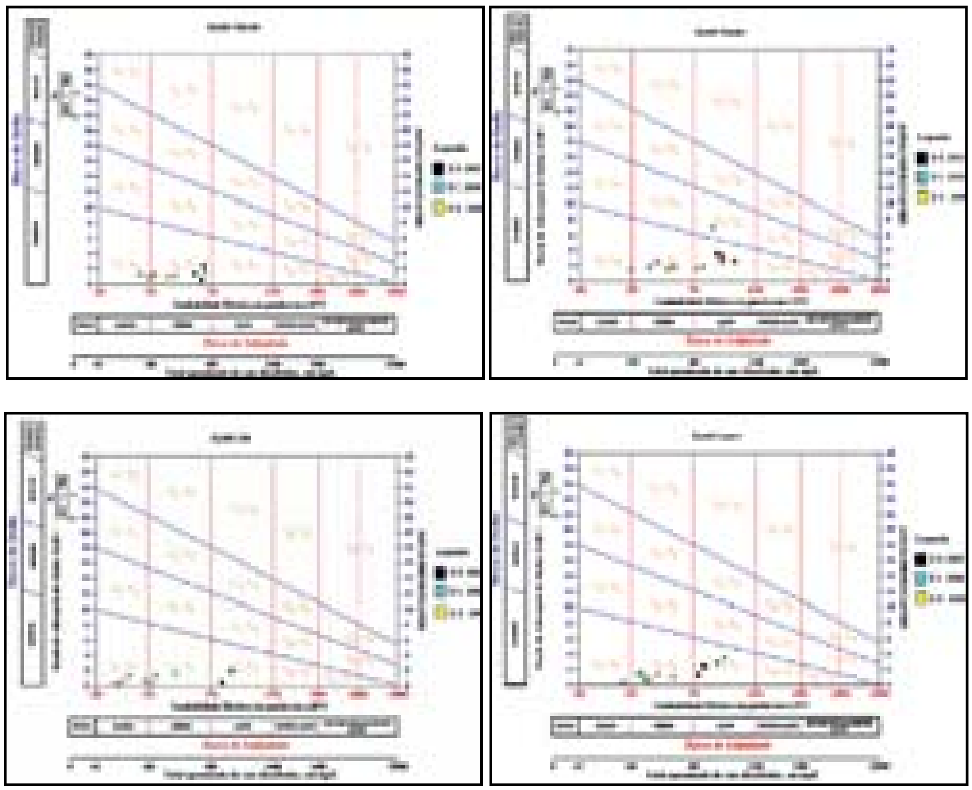

Figure 2.20 – Classification of waters of Chicote, Ramin, Zuir and Lages reservoirs according to the U.S. Salinity Laboratory

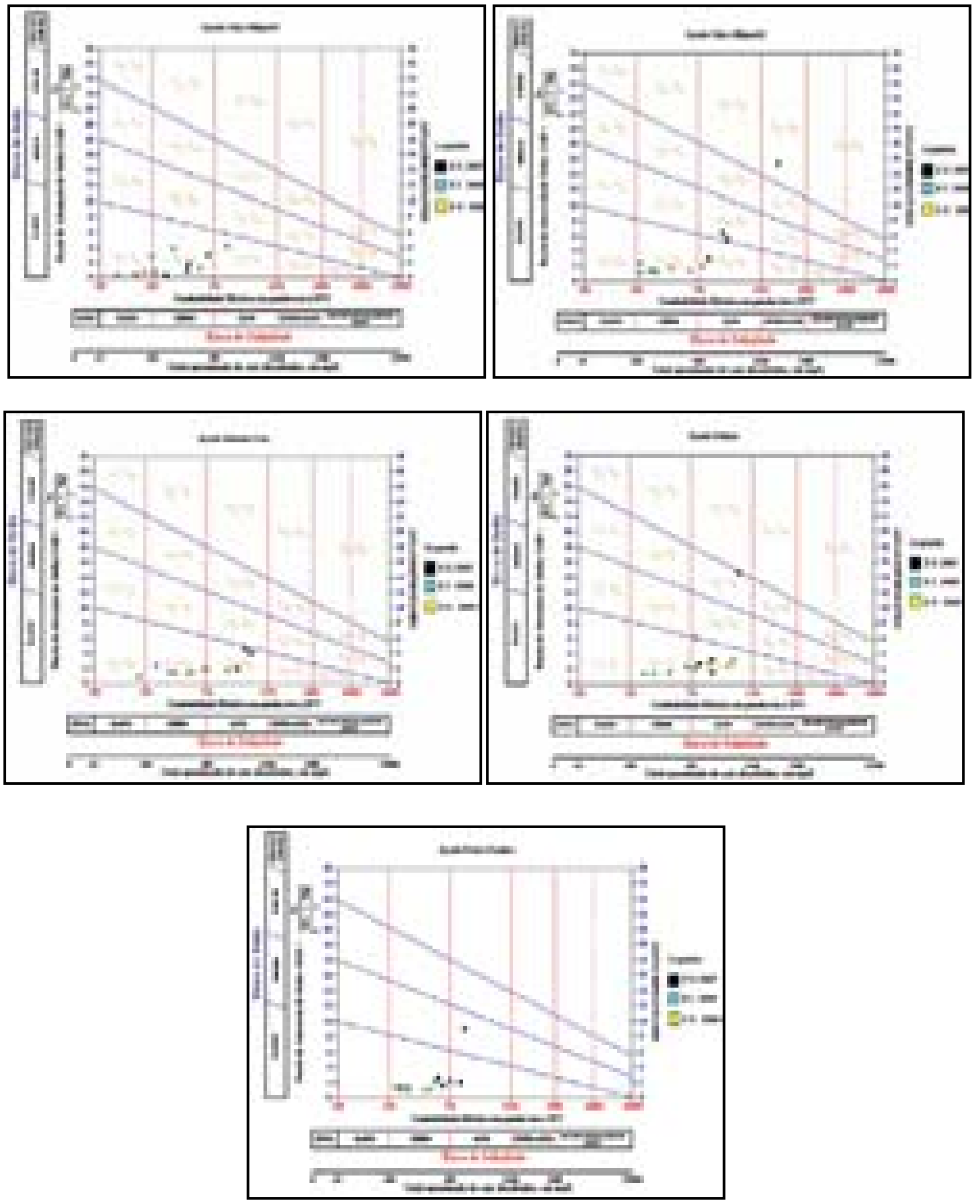

Figure 2.21 – Classification of waters of Chico Miguel I, Chico Miguel II, Antônio Cruz,Tobias and Pedro Paulino reservoirs according to the U.S. Salinity Laboratory

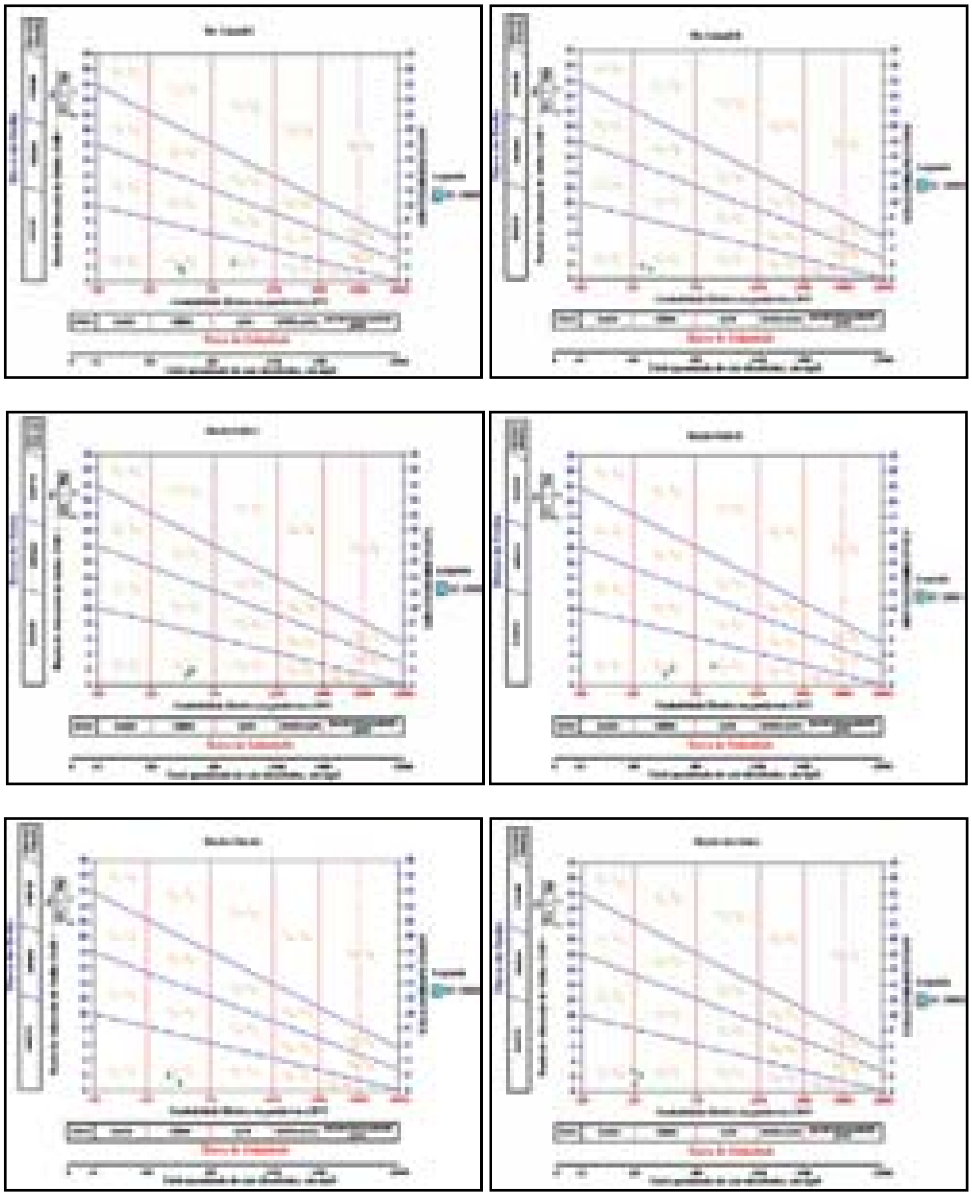

Figure 2.22 – Classification of waters of river/streams of Cangati River microbasin according to the U.S. Salinity Laboratory.

However, it is noted that in 2007 dry season, in most of evaluated reservoirs, irrigation waters had a very poor quality and C3S1 waters predominated. It should be pointed out that C3 waters are considered of high salinity. They should only used in well drained soils. Even in well cared for soils, special precautions should be taken to prevent salinization, and only high saline tolerance vegetables should be cultivated. Exceptions occur in Chicote, Chico Miguel I and Pedro Paulino reservoirs, where C2S1 waters were observed in that season. It was also noted that in Chico Miguel II reservoir waters ranged between C3S2 and C4S4 (December 2007). S2 waters are moderately sodic, represent a risk of salinization for thin texture soils, and have a strong cation exchange capacity. They may be used in coarse texture soils or soils rich in organic matter having a good permeability. C4S4 waters, on the other hand, are inadequate for irrigation. It is worth emphasizing that Chico Miguel II is one of the smallest reservoirs in the microbasin, and that in 2007 dry season, water volumes stored in its basin were very low, and it practically dried up in December 2007.

With respect to 2008 rainy period, it is noted that C1S1 waters predominated in Chicote and Zuir reservoirs, which have an excellent quality for irrigation, indicating that rains occurred in the region were sufficient to dilute salts and consequently reduce the electric conductivity values. In addition, Chicote reservoir is one of the largest reservoirs in the microbasin, its surrounding ciliary forest is very well preserved and, even in drier years, it stores a considerable volume of water.

Finally, it should be highlighted that waters stored in reservoirs in 2008 dry season showed a better quality for irrigation than those observed in 2007 dry season.

Regarding the streams monitored by PRODHAM, C2S1 waters predominate, and therefore there are no restrictions to their use for irrigation. Gatos stream showed the best quality.

2.3.1.6 – Temporal variability of physical-chemical parameters

According to the study performed, pH behavior in evaluated reservoirs and streams is shown in Figures 2.23 to 2.25.

Only Lajes, Chico Miguel II and Tobias reservoirs exceeded the maximum pH limits established for class 2 by CONAMA Resolution no. 357/2005. Most pH increases occurred in those three reservoirs in months considered of low precipitation (October and November) In general, it can be noted that lower pH values occurred in the period of higher rain intensity (February-May), what may have contributed to water renewal and dilution of chemical components responsible for pH increase.

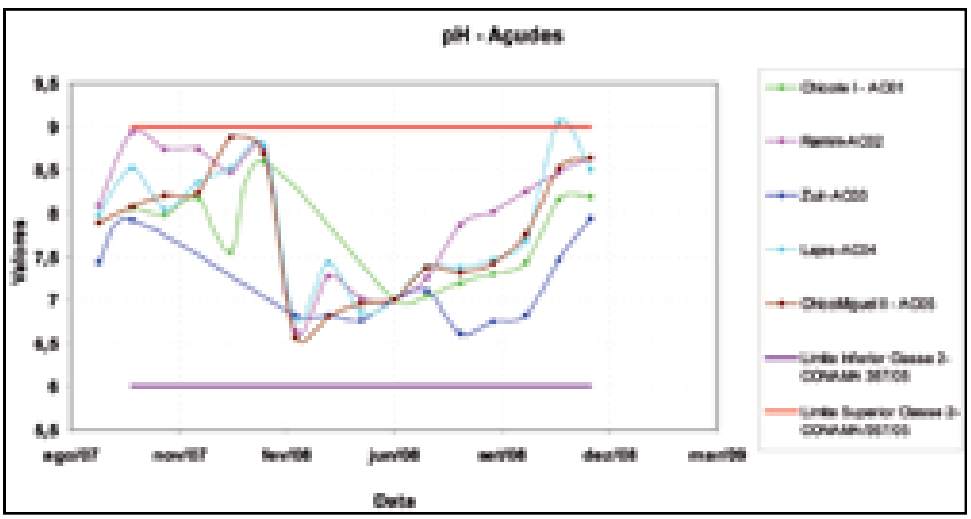

Figure 2.23 – pH behavior in Chicote, Ramin, Zuir, Lages and Chico Miguel (reservoirs

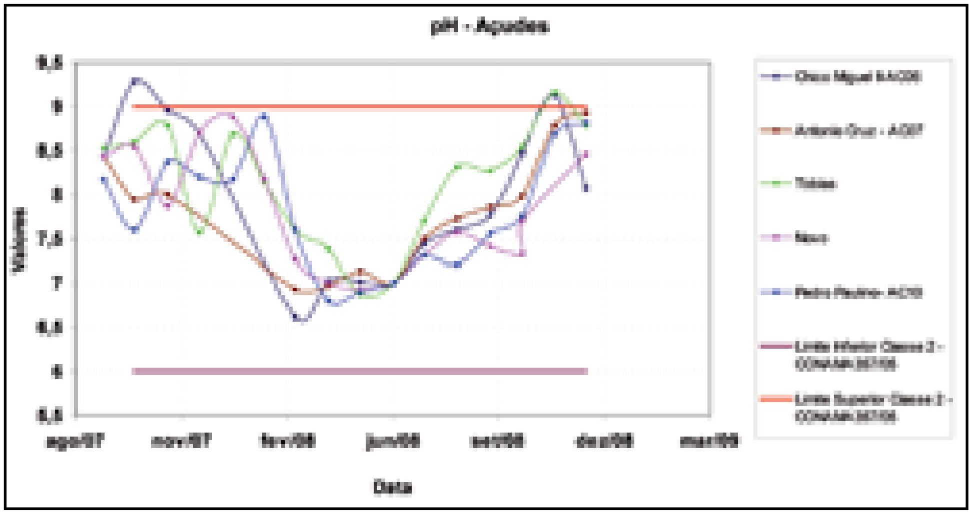

Figure 2.24 – pH behavior in Chico Miguel II, Antônio Cruz, Tobias, Novo and Pedro Paulino reservoirs.

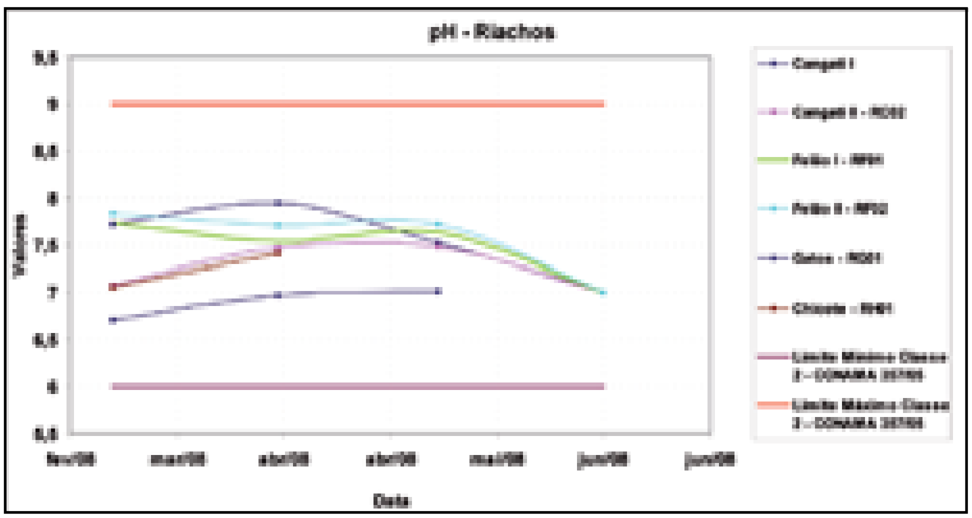

Figure 2.25 – pH behavior in Cangati I, Cangati II, Felão I, Felão II, Gatos and Chicote river/ streams.

Only Lajes, Chico Miguel II and Tobias reservoirs exceeded the maximum pH limits established for class 2 by CONAMA Resolution no. 357/2005. Most pH increases occurred in those three reservoirs in months considered of low precipitation (October and November). In general, it can be noted that lower pH values occurred in the period of higher rain intensity (February-May), what may have contributed to water renewal and dilution of chemical components responsible for pH increase.

All evaluated streams were in conformity with CONAMA Resolution no. 357/2005.

Phosphor behavior in evaluated reservoirs and streams is shown in Figures 2.26 to 2.28.

All reservoirs exceeded the maximum limit established for total phosphor in lentic environments for class-2 fresh water according to CONAMA Resolution no. 357/2005. Highest values found referred to Novo and Lages reservoirs.

Phosphates present in aquatic ecosystems may be from natural sources, originated from rocks in the drainage basin and from artificial sources, from residential and industrial sewage, and industrial particulate material present in the atmosphere (ESTEVES, 1998).

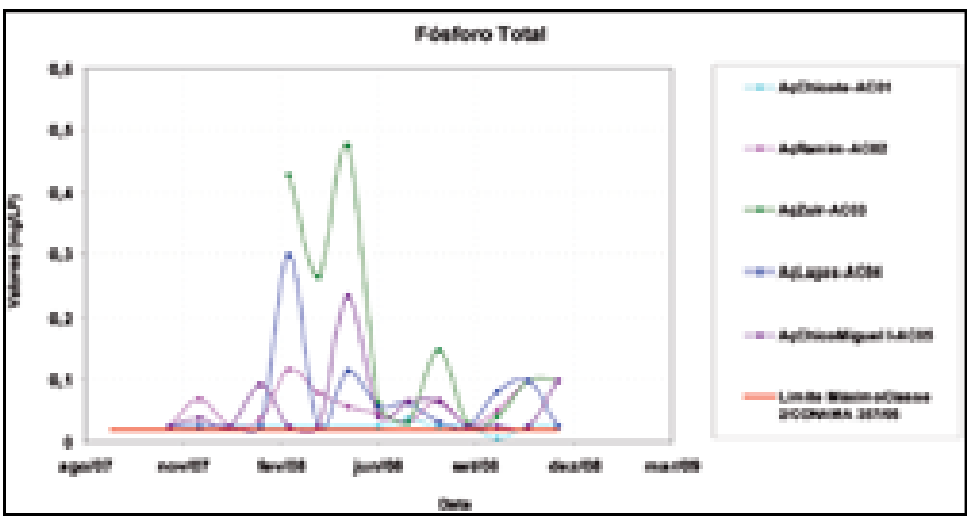

Figure 2.26 – Phosphor behavior in Chicote, Ramin, Zuir, Lages and Chico Miguel I reservoirs

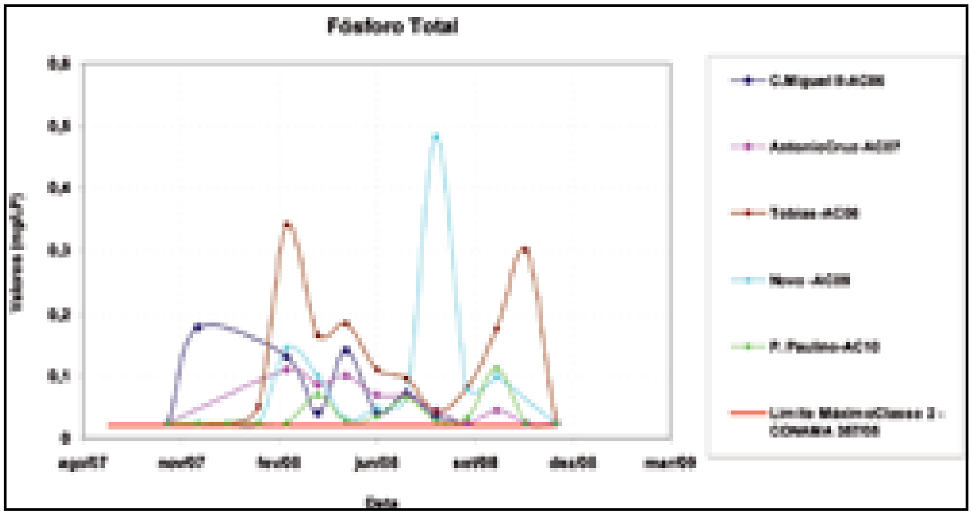

FIGURE 2.27 – Phosphor behavior in Chico Miguel II, Antonio Cruz, Tobias, Novo and Pedro Paulino reservoirs

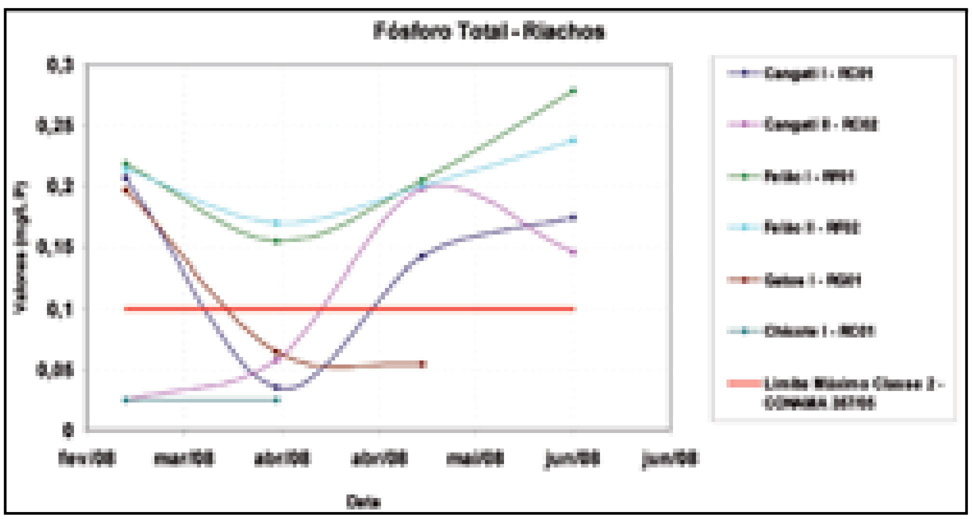

Figure 2.28 – Phosphor behavior in Cangati I, Cangati II, Felão I, Felão II, Gatos and Chicote rivers/streams

Rains are a significant source of phosphor and nitrogen in lakes and reservoirs, what suggests the possibility of evaluated reservoirs receiving a constant significant afflux of phosphor from diffuse sources, regardless of being carried by storms, according to Esteves (1998).

Streams have failed to conform to the maximum limit for total phosphor in lotic environments for class-2 fresh waters established by CONAMA Resolution no. 357/2005.

Evaluation of dissolved oxygen (OD) in reservoirs and streams is shown in Figures 2.29 to 2.31.

All reservoirs, in different months of the study period, showed OD concentration results below the minimum limit established by CONAMA Resolution no. 357/2005 for class-2 fresh waters. Lowest OD values were found in Zuir (1.4 mg/LO_2) and Novo (1.6 mg/LO_2) reservoirs in the rainy period.

Reductions in OD concentrations in water bodies are mainly caused by disposal of organic matter according to Derísio (1992). In rainy period, there is an increased concentration of dissolved and particulate organic matter, which contributes to increase water deoxygenation in tropical lakes, and may have contributed to a greater OD fall in Novo reservoir in the rainy period (ESTEVES, 1998).

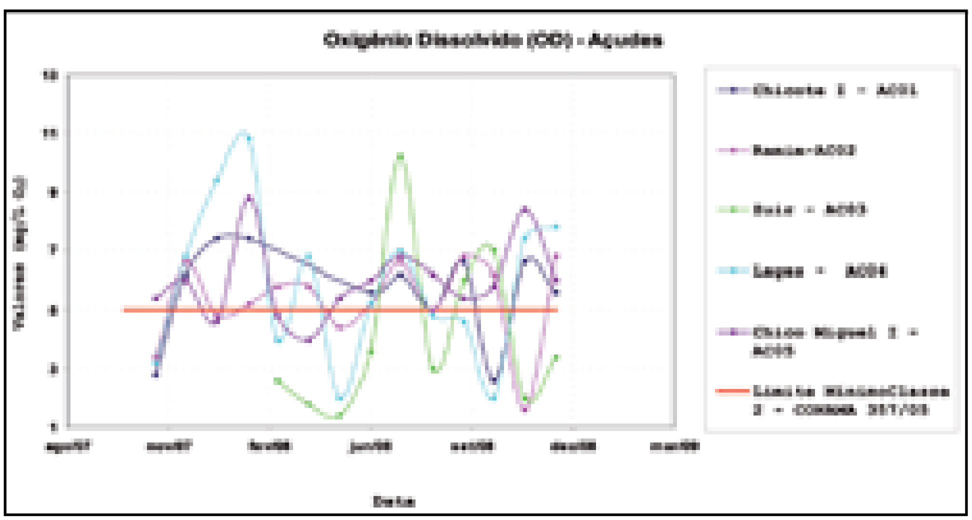

Figure 2.29 – OD behavior in Chicote, Ramin, Zuir, Lages and Chico Miguel I reservoirs

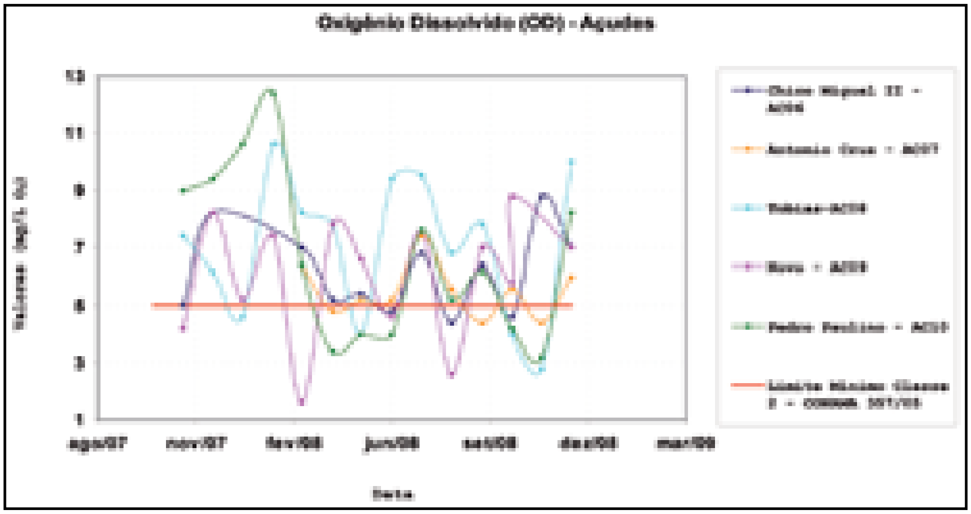

Figure 2.30 – DO behavior in Chico Miguel II, Antonio Cruz, Tobias, Novo and Pedro Paulino reservoirs

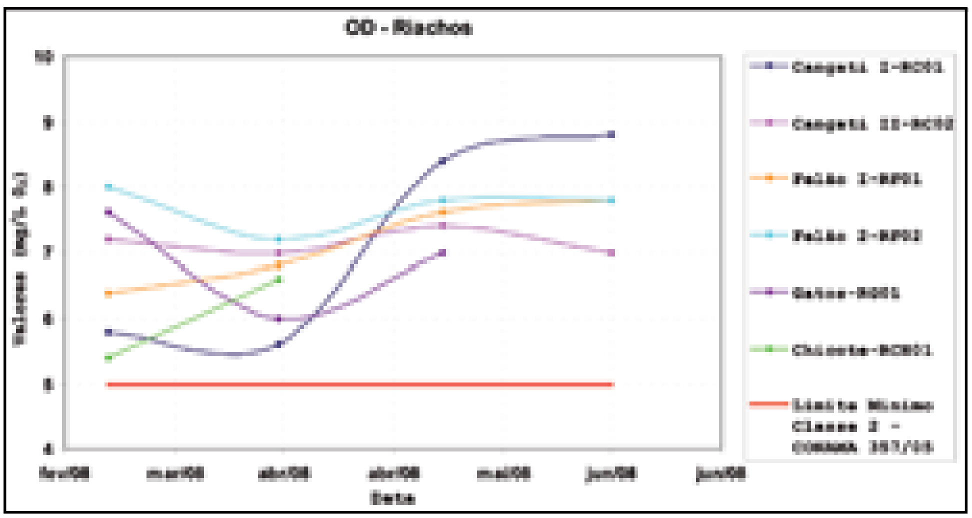

Figure 2.31 – DO behavior in Cangati I, Cangati II, Felão I, Felão II, Gatos and Chicote rivers/streams.

With respect to streams, all of them were in conformity with the maximum limit for dissolved oxygen (DO) for class-2 fresh waters established by CONAMA Resolution no. 357/2005.

Nitrate behavior in reservoirs and streams is shown in Figures 2.32 to 2.34.

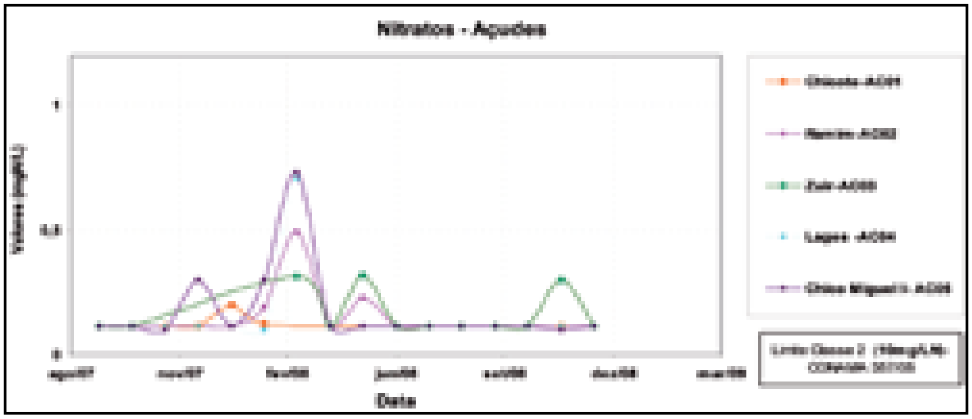

Figure 2.32 – Nitrate behavior in Chicote, Ramin, Zuir, Lages and Chico Miguel I reservoirs

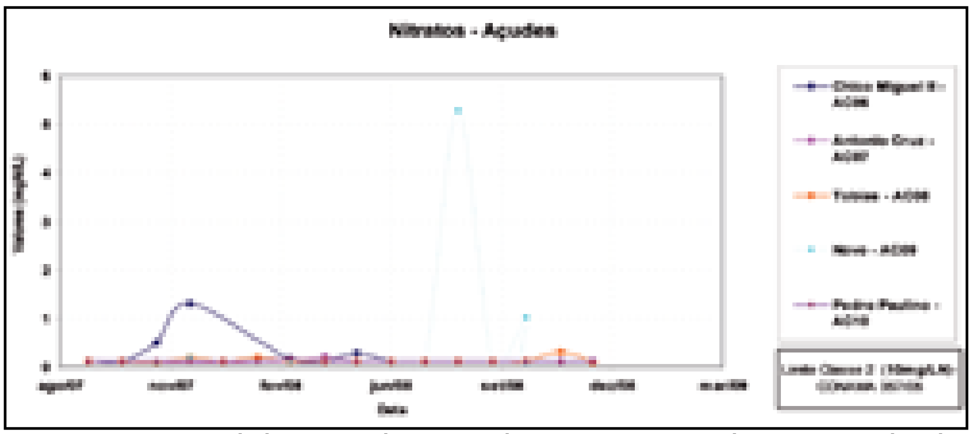

Figure 2.33 – Nitrate behavior in Chico Miguel II, Antonio Cruz, Tobias, Novo and Pedro Paulino reservoirs

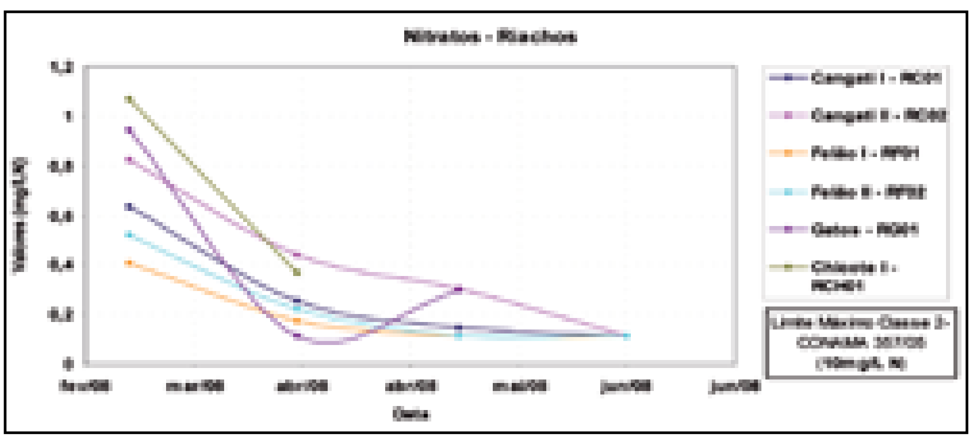

Figure 2.34 – Nitrate behavior in Cangati I, Cangati II, Felão I, Felão II, Gatos and Chicote rivers/streams

All reservoirs and streams were within the limits established for nitrates in lentic and lotic class-2 fresh water environments by CONAMA Resolution no. 357/2005. Nitrate is one of ions that are most found in natural waters, and generally occurs at low content in surface waters, nevertheless it can reach high concentrations in deep waters (AMERICAN PUBLIC ..., 1998).

Nitrite behavior in reservoirs and streams is shown in Figures 2.35 to 2.37.

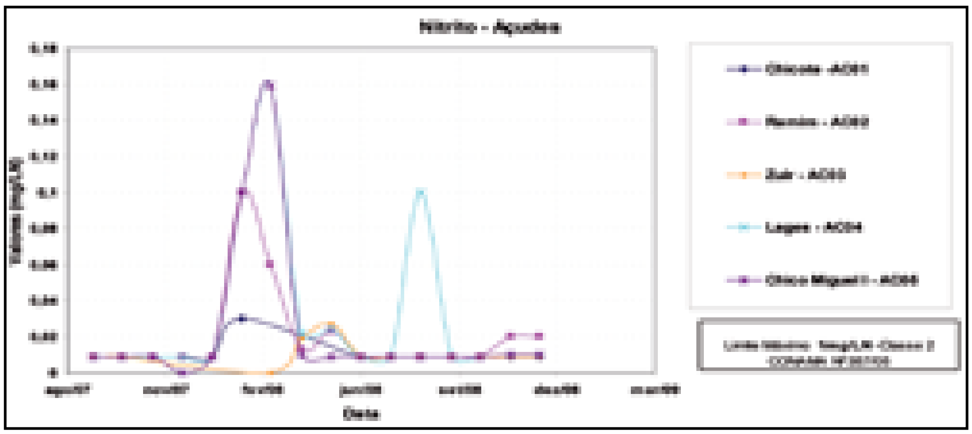

Figure 2.35 – Nitrite behavior in Chicote, Ramin, Zuir, Lages and Chico Miguel I reservoirs

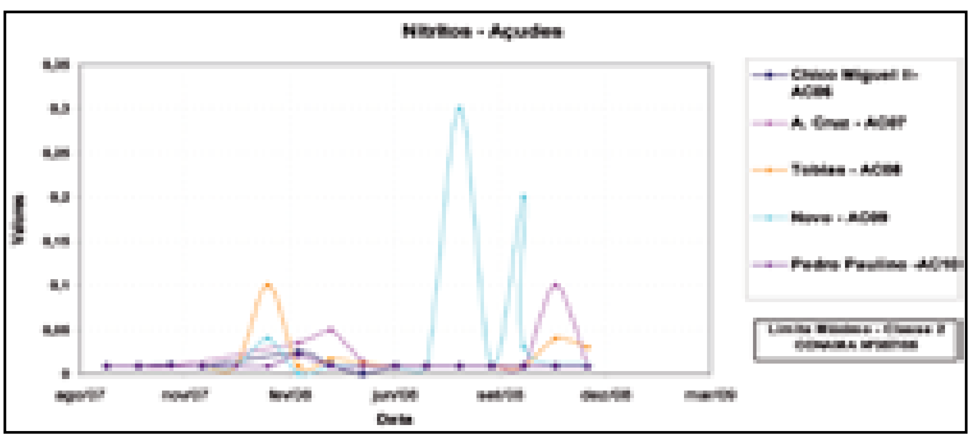

Figure 2.36 – Nitrite behavior in Chico Miguel II, Antonio Cruz, Tobias, Novo and Pedro Paulino reservoirs

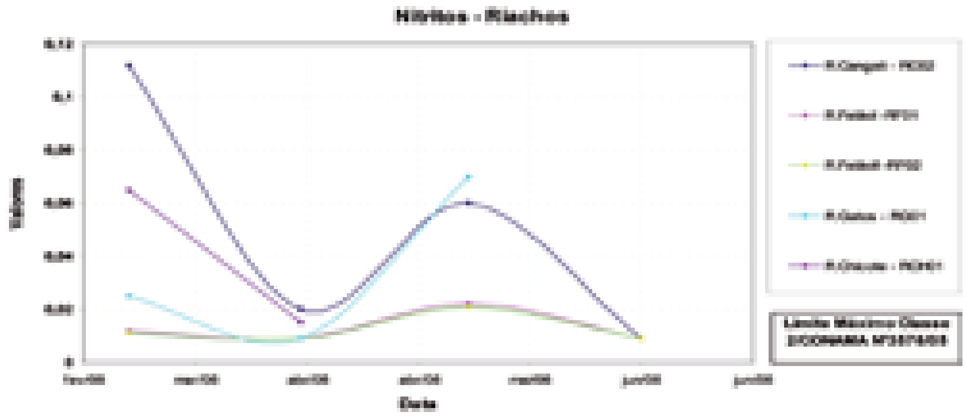

Figure 2.37 – Nitrite behavior in Cangati I, Cangati II, Felão I, Felão II, Gatos and Chicote rivers/streams

All water bodies covered by the study were within the limits established for nitrites in lentic and lotic class-3 water environments by CONAMA Resolution no. 357/2005. Nitrite is an intermediary oxidation state of nitrogen, both in ammonia oxidation to nitrate and its reduction to nitrate. That oxidation and reduction may occur in natural waters, residual waters from water treatment stations and distribution systems. Nitrite may also enter a water supply system through its use to inhibit corrosion in industrial process water (AMERICAN PUBLIC…, 1998).

In lakes, nitrite concentration is low as compared to ammoniacal nitrogen and nitrate content. Only in polluted lakes nitrite concentration may reach significant values (ESTEVES, 1998).

Turbidity behavior in reservoirs and streams is shown in Figures 2.38 to 2.40.

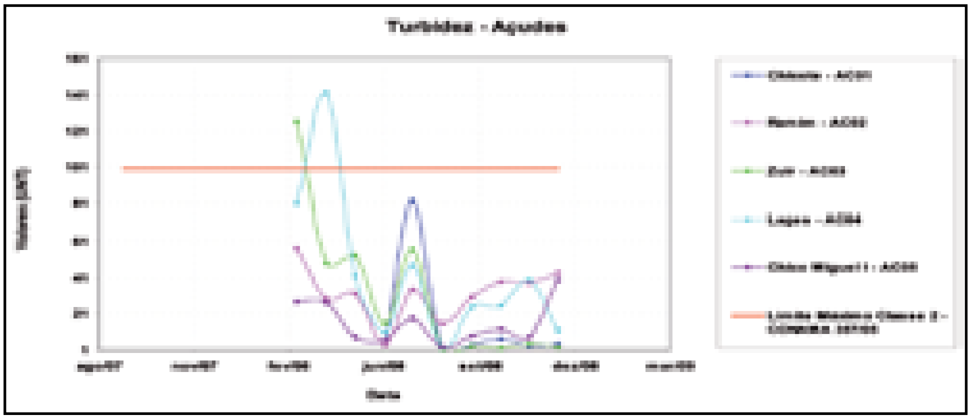

Figure 2.38 – Turbidity behavior in Chicote, Ramin, Zuir, Lages and Chico Miguel I reservoirs

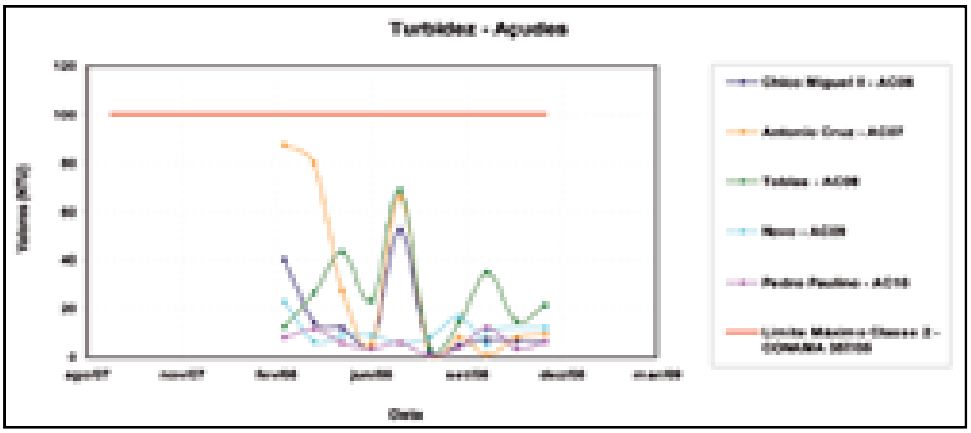

Figure 2.39 – Turbidity behavior in Chico Miguel II, Antonio Cruz, Tobias, Novo and Pedro Paulino reservoirs.

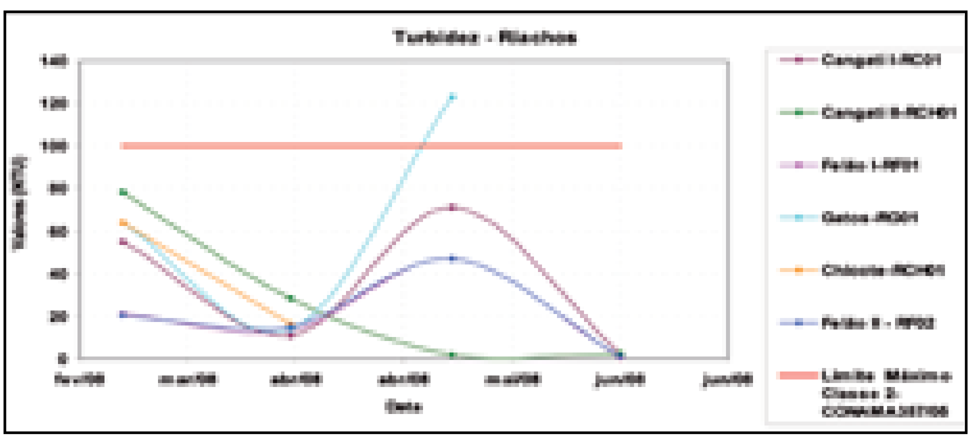

Figure 2.40 – Turbidity behavior in Cangati I, Cangati II, Felão I, Felão II, Gatos and Chicote rivers/streams.

Only Zuir and Lages reservoirs and Gatos stream exceeded the maximum limit for class-2 fresh water turbidity established by CONAMA Resolution no. 357/2005. Turbidity represents an optic property that measures how water disperses light, provided that this dispersion increases with the quantity of suspended particulate material; as such, turbidity increases with the suspended sediment load (TEIXEIRA; SENHORELO, 2000). Water turbidity is caused by suspended and colloidal matter, such as clay, silt, thinly divided matter, organic and inorganic matter, plankton and other microscopic organisms (AMERICAM PUBLIC..., 1998). According to Derísio (1992), turbidity may occur naturally from erosion process, and artificially, from residential and industrial waste disposal.

Highest turbidity values in analyzed samples were found in rainy period, where water-borne sediments increase the values of suspended solids and consequently turbidity values.

Thermotolerant coliform behavior in reservoirs and streams is shown in Figures 2.41 to 2.43.

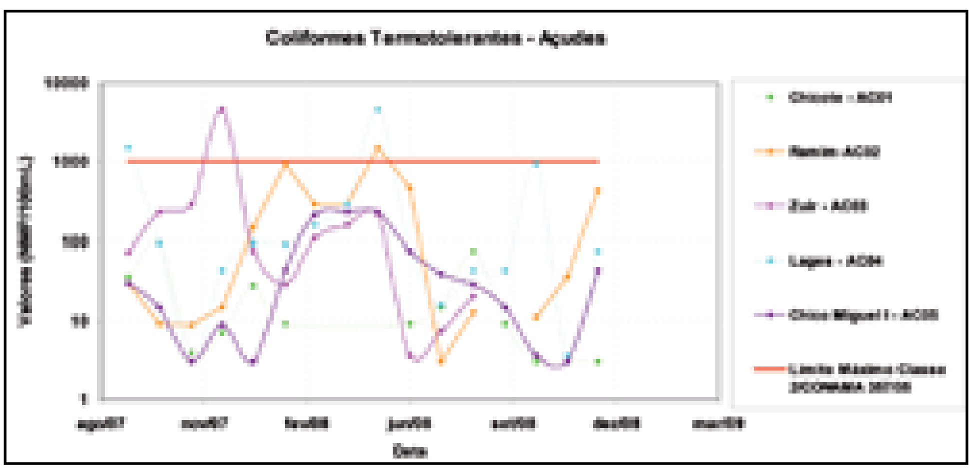

Figure 2.41 – Thermotolerant coliform behavior in Chicote, Ramin, Zuir, Lages, and Chico Miguel I reservoirs

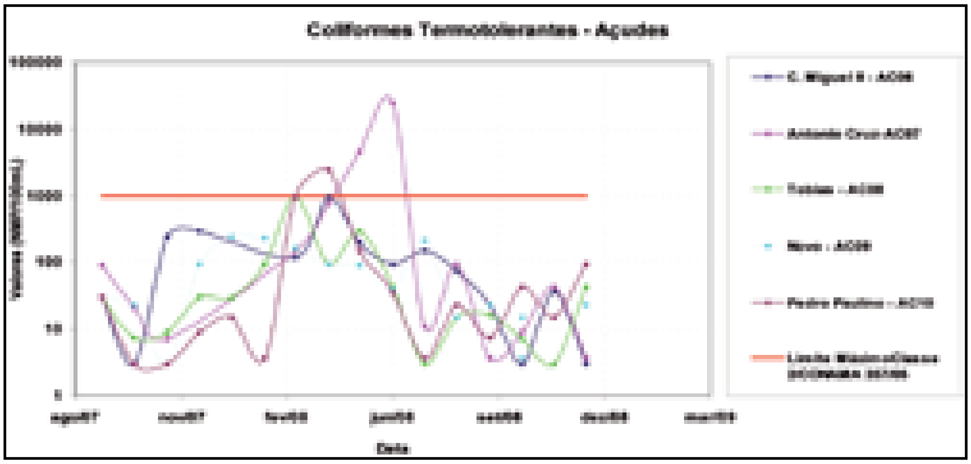

Figure 2.42 – Thermotolerant coliform behavior in Chico Miguel II, Antonio Cruz, Tobias, Novo and Pedro Paulino reservoirs.

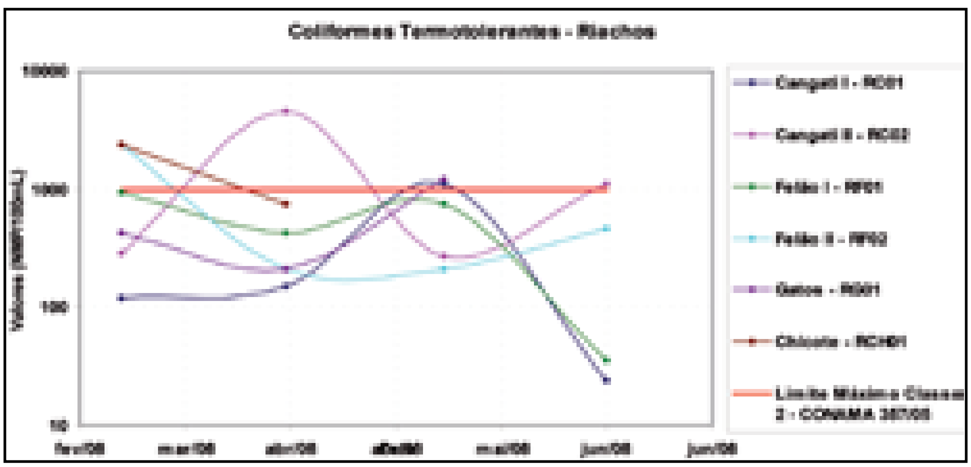

Figure 2.43 – Thermotolerant coliform behavior in Cangati I, Cangati II, Felão I, Felão II, Gatos and Chicote rivers/streams.

Only Novo and Tobias reservoirs and Felão I stream failed to exceed the maximum limit established for class-2 waters by CONAMA Resolution no. 357/2005. Thermotolerant coliforms, in addition to being present in human and homeothermic animals. Occur in soils, plants or other environmental matrices that have not been contaminated by fecal material (CONAMA Resolution no. 357 – BRAZIL, 2005).

2.4 – Groundwater monitoring

Cangati River microbasin is located, as mentioned previously, in the domain of Undivided Precambrian crystalline rock area (see item 2.1.1). From hydrogeology standpoint, this environment has no favorable conditions for groundwater reservation and availability. Aquifer constituted by such rocks (fractured aquifer) is typically discontinuous and form restricted water storage and circulation domains, and eventual water supplies frequently present salt content above the limit tolerated by man and animals. Thus, notwithstanding it does not constitute a worthless water source, groundwater exploration in Cangati River microbasin almost exclusively tales place in alluvial aquifers.

Alluvial deposits are constituted of sedimentary sandy-argillaceous deposits of fluvial origin disposed along drainage areas. Alluvial deposits typically offer good groundwater recharge (infiltration), storage and flow conditions, thus characterizing as aquifers of good hydrogeological potential. In semiarid region, several techniques have been adopted, among which the construction of underground dams stands out, which increase water availability in that environment.

Many projects aimed to expand water availability in the State in regions where crystalline rocks predominate, either for public supply or economic projects (agricultural or industrial), consider alluvial groundwater supplies in their projections. Among them, Poços do Sertão and Caminhos de Israel projects stand out, which are developed by the Secretariats of Rural Development (SDR) and Agriculture and Livestock (SEAGRI) of the State of Ceará. Poços do Sertão project is focused on the construction of more than 5,000 wells in alluvial zones in 101 municipalities. Caminhos de Israel Project helps small farmers in the implementation of agricultural projects.

Nevertheless, there are still few studies specifically focused on alluviums in crystalline areas. The Water Resource Plan of the State of Ceará

– Base II Studies (SRH-CE, 1992) addresses the matter quite superficially, and practically provides no data on alluviums in the municipality of Canindé. Funceme, through its Department of Water Resources and Environment (DRJIMA) has been developing studies on that matter since 1996. Studies of hydraulic characteristics of an alluvium section in Mundaú River stands out, among others: Project for "Integrated Study of Mundaú Hydrographic Basin - Ceará", published by Funceme in 1998; project for evaluation of water potential in an alluvial section of Palhano River in Ibicuitinga/CE; project for "Integrated Alluvial Surface and Underground Water Resource Management", published by Funceme and Federal University of Ceará (UFC) in 1999, and the papers: " Geometric modeling of an alluvial section in Palhano River in Chile community, on the border of the municipalities of Morada Nova and Ibicuitinga-CE" by Leite *et al*. (2000) and "Hydrogeological underground dam potential estimate: a case study", by de Möbus; Andrade and Leite (2001); river-aquifer interaction: projects for "Ongoing Water Loss in Perennialized Rivers in Semiarid Region", by Funceme (2002), performed in Juazeiro river sections in Coreaú-CE, and mapping and evaluation of hydrogeological potential at regional level, such as Projects for "Mapping and Evaluation of Groundwater Potential in Semiarid Zone Alluviums Using Remote Sensing and GIS Techniques", Funceme (2007), and "Use of MDT and Satellite Images for Mapping and Evaluation of the Hydrological Potential of Small Alluvial Aquifers at Regional level," which is underway.

Bases on that experience, a specific approach plan was formulated for the study of alluvial aquifers in the microbasin, which places emphasis on underground dams constructed under the subproject. At a first stage, water intervention works (wells and underground dams) existing in the microbasin were surveyed. Bases on that information, areas to be focused by the studies were selected. Dimensional and hydraulic characterizations were performed in those areas. At a second stage, potentiometric levels in those aquifers were monitored for a year, and water samples were periodically collected for physical-chemical analyses. In possession of such data, the aquifer system was modeled in the underground dam domain, with the objective to estimate water supplies in that environment. Activities performed, treatment of resulting data, and results of respective analyses are detailed below:

2.4.1 – Staff mobilization and training

As mentioned in item 2.2.1, a training was provided to members of microbasin residents. In hydrogeology area, trained individuals performed the systematic water level monitoring (potentiometry) in selected alluviums, by means of electric probe reading in piezometers and observation wells.

2.4.2 – Preliminary works

Four alluvium sections were selected to be studied, all of them associated with underground dams existing at the time in the microbasin. Figure 2.44 shows the spatial distribution of such underground dams.

Underground dam in Chicote River is located in a region close to the springs of that river, which is the alluvial section of lowest anthropic intervention. The investigated alluvial section is less than 1-km long. According to local dwellers, dam well waters had not been used yet for irrigation, because water levels were usually low.

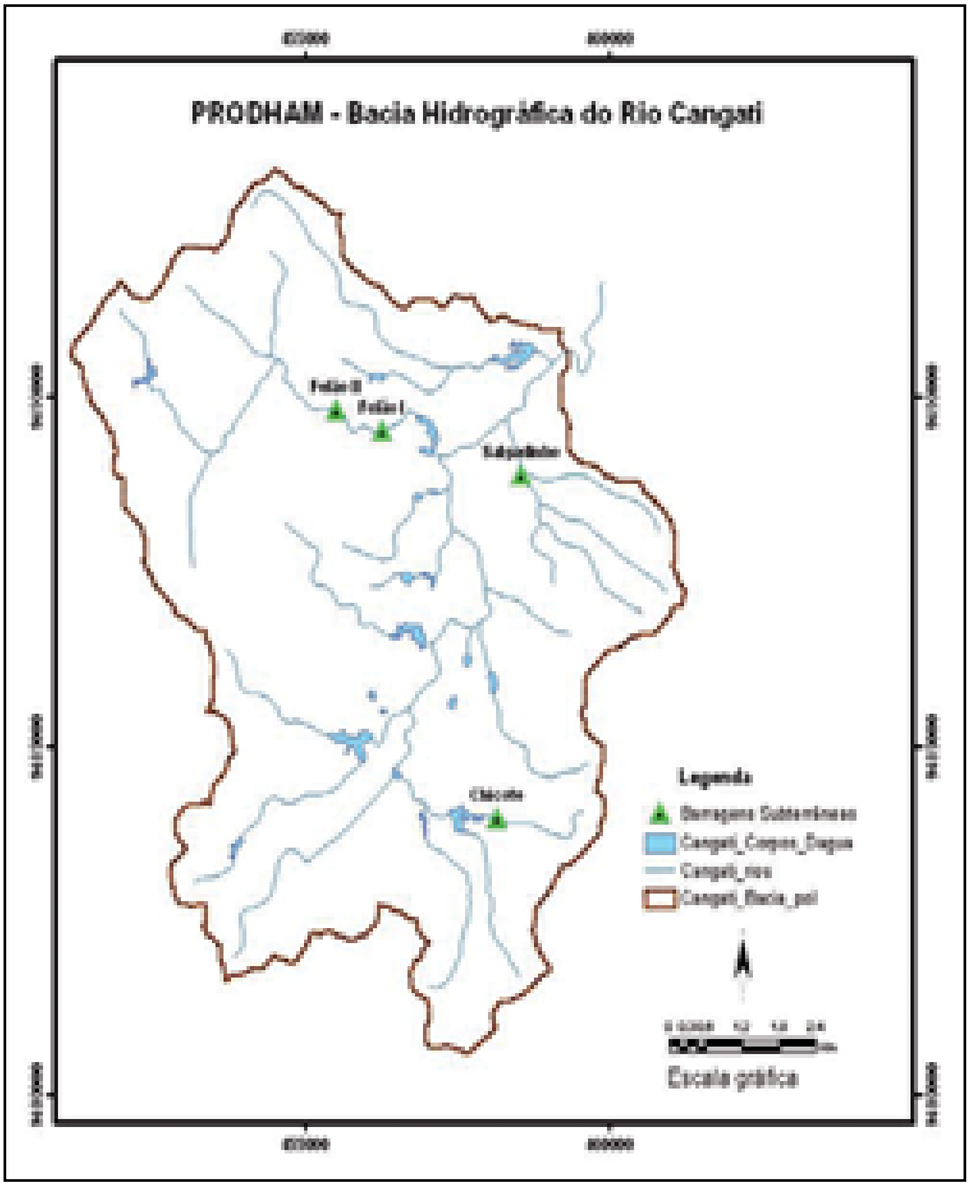

Figure 2.44 – Underground dams in Cangati River microbasin

The dam associated with Salgadinho stream has already a significant upstream alluvial extension, including significant plantation zones. Drillings were made over an extension of 1.8 km. Two branches were discarded, as they had no significant alluviums from hydrogeological standpoint, but which must be considered in terms of main drainage feeding. At the half of the first semester of 2008, a second underground dam was constructed 300 m upstream to the existing dam.

In Felão stream, on the other hand, two successive underground dams were constructed. Felão I underground dam was constructed first, and according to oral information, it had a water leakage since its construction, as it used to dry up after every rainy season. Felão II dam constructed less than 1 km from Felão I dam contains the more robust alluvium and displays the strongest anthropic intervention (agriculture). Between those two works, there is a rock outcrop in the largest riverbed.

Geometric and hydraulic characteristics of alluvium sections upstream to all underground dams were surveyed for characterization of hydrogeological potential of the alluvial aquifer associated with each dam. Activities performed and results obtained at that survey stage are described below.

2.4.2.1 – Geometric parameterization of alluvial sections surveyed

Geometric parameterization of alluvial sections consisted of establishing the outline of such formations with the help of DGPS, and making drillings along alluvial bodies until the point where alluvium thickness allowed such deposits to be characterized as an aquifer. The main geometric aspects surveyed included the thickness of sedimentary alluvial package and the width of alluvium cross sections. Width was measured directly by a measuring tape. Auger drillings were made to determine thickness.

a) Determination of alluvium outlines

Outlines of alluvial bodies upstream to each of the four underground dams were established. Surveys extended to the point where alluvial deposits displayed aspects, such as width and thickness, that characterized them as aquifer units and their respective groundwater flow were influenced by the respective underground dams.

Survey was supported by a DGPS Promark 3, which had a millimetric precision at walking mode. In places of considerable vegetative cover to the point of impairing satellite reception, a local station was used (Leica TC605-L)). That was the case of most of Salgadinho stream alluvium survey.

Figure 2.45 shows the schematic drawing of alluvium outlines in all four dams, including contour lines generated by that same survey.

b) Alluvium thicknesses and lithologic facies estimate

In each one of the four selected alluviums, subsoil investigations were made by auger drillings to determine the thicknesses and characterize the sediments the predominantly compose the deposits.

The lithologic profile of each auger drilling bore was described. Material extracted from bores was orderly deposited on the soil for analysis and description, and the following characteristics were considered: depth, granulometry, occurrence of fines or coarser material, color, moisture content and, whenever possible, likely composition and alteration material. Photo 2.19 shows some of stages involved in each drilling. Fir drillings, augers especially made to operate in sandy soils were used (Photo 2.20).

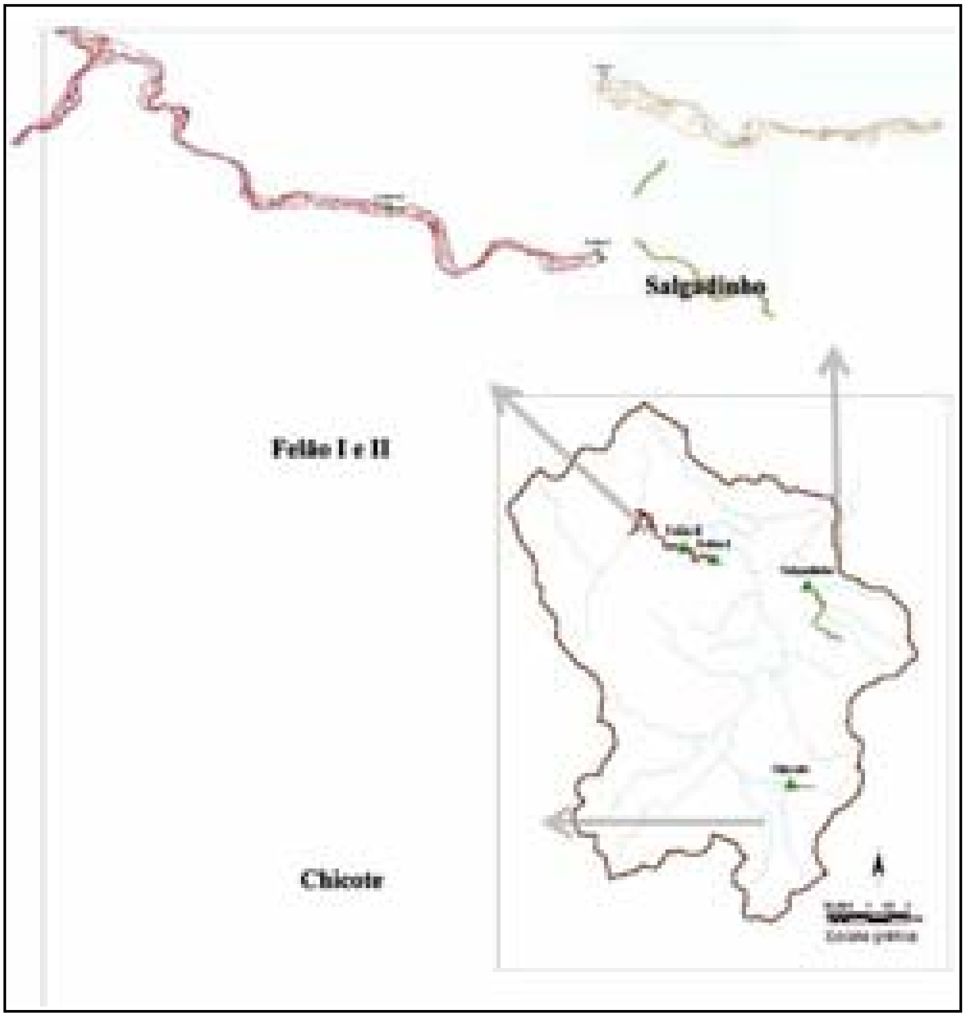

Figure 2.45 – Outline of alluviums associated with underground dams in Cangati River microbasin.

Photo 2.19 – Auger drilling stages during field works.

Photo 2.20 – Equipment used for alluvium drilling: (a) stone collector; (b) dry sand glass; (c) buster; and (d) argillaceous material glass.

Figures 2.46 to 2.48 show drilling distribution in each of the sections. The objective of latest drillings performed in Salgadinho stream alluvium (Figure 2.4.6) was only to determine the geometric characteristics of that alluvium, even out of underground dam domain, for a possible consideration of a future underground dam. The same occurred in Felão and Salgadinho streams.

Tables 2.27 to 2.29 show the absolute depth values obtained from each drilling for each section surveyed. Those tables, in addition to bore coordinates, show the predominating lithology and the relative height of the point, both at the base and at the top. Figures 2.49 to 2.51 shows, in addition to simplified profiles, the thicknesses estimated by drillings in alluvial bodies in each of sections surveyed.

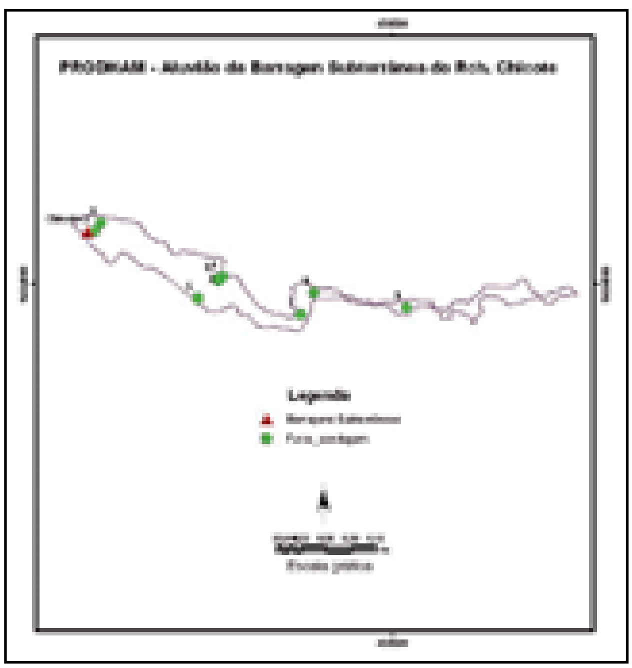

Figure 2.46 – Location of auger drillings in alluvium of Chicote stream U.D.

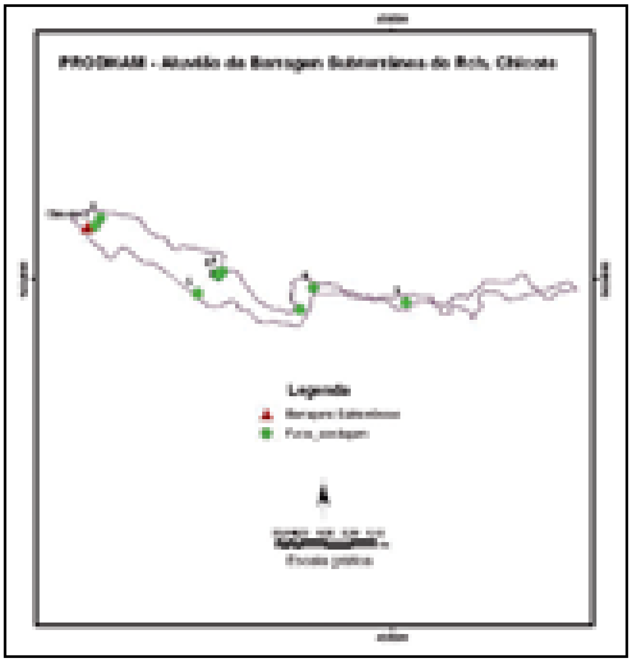

Figure 2.47 – Location of auger drilling in alluvium of Felão stream U.D.

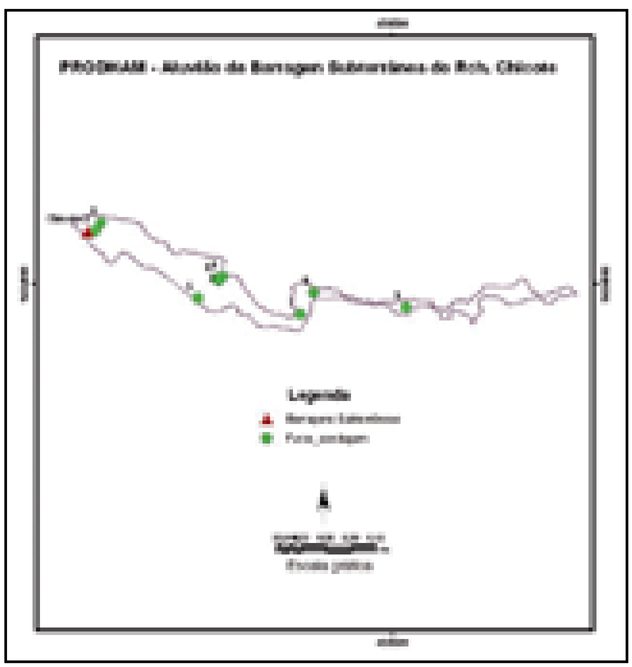

Figure 2.48 – Location of auger drilling in alluvium of Salgadinho stream U.D.

Table 2.27 – Auger drilling data – Chicote stream

Drilling Bores – Underground Dam in Chicote Stream							
Drilling Number*	Coordinates		Soil Height (m)	Depth (m)	Bottom height (m)	Width (m)	Predominating lithologic type
	N	L					
1 (1)	458151	9484074	284.09	4.4	279.69	39.60	Medium to coarse sand
2 (2)	458144	9484065	284.33	3.9	280.43	39.60	Medium to coarse sand
3 (3)	458293	9484005	289.64	3.27	286.37	57.14	Medium to coarse sand
4 (4)	458297	9484009	289.26	4.07	285.19	57.14	Coarse sand
5 (3.2)	458267	9483983	289.26	2.03	285.99	57.14	Fine sand
6 (PZ)	458290	9484007	288.76	3.76	284.79	57.14	Medium to coarse sand
7 (5)	458390	9483963	295.6	3.27	292.33	17.92	Coarse sand
8 (6)	458406	9484002	301.97	2.73	299.24	12.15	Medium to coarse sand
9 (7)	458517	9483972	291.18	2.17	289.01	14.56	Coarse sand

* - Between brackets: numbers corresponding to field cards.

TABLE 2.28 – Auger drilling data – Felão Stream

Drilling Bores – Underground Dam in Felão Stream							
Drilling Number*	Coordinates		Soil Height (m)	Depth (m)	Bottom height (m)	Width (m)	Predominating lithologic type
	N	L					
				Felão I			
10 (PZ)	456280	9489595	241.64	4.61	237.03	25.20	Medium sand
11 (1)	456094	9489636	242.89	5.19	237.7	51.95	Fine sand
12 (2)	456264	9489581	241.91	3.90	238.01	51.95	Coarse sand
13 (3)	456150	9489577	243.84	3.90	239.94	79.70	Coarse sand
14 (PZ)	456137	9489544	247.43	4.40	243.03	79.70	Medium to coarse sand
15 (5)	455838	9489567	245.72	3.65	242.07	15.33	Medium to coarse sand
16 (6)	455714	9489602	248.46	3.47	244.99	20.46	Fine sand
17 (7)	455652	9489772	251.57	3.46	248.11	38.65	Fine sand
				Felão II			
18 (1)	455500	9489822	250.37	3.69	246.68	42.49	Medium to coarse sand
19 (PZ)	455536	9489816	249.43	2.10	247.33	19.51	Coarse sand
20 (2)	455482	9489814	249.47	2.10	247.37	42.49	Coarse sand
21 (PZ)	455355	9489845	250.52	3.28	247.24	43.94	Coarse sand
22 (3)	455346	9489855	251.59	2.65	248.94	43.94	Coarse sand
23 (5)	455039	9489863	253.64	3.82	249.82	28.95	Medium to coarse sand
24 (7)	455111	9489837	254.49	1.25	253.24	24.75	Fine sand
25 (6)	455086	9489851	251.11	1.78	249.33	28.95	Coarse sand

(continued)

(continuation)

Drilling Bores – Underground Dam in Felão Stream							
Drilling Number*	Coordinates		Soil Height (m)	Depth (m)	Bottom height (m)	Width (m)	Predominating lithologic type
	N	L					
26 (8)	455000	9489911	253,78	2,51	251,27	37,56	Medium to coarse sand
27 (9)	454973	9490004	252.84	2.87	249.97	25.57	Coarse sand
28 (10)	454816	9490104	253.94	2.91	251.03	18.23	Coarse sand
29 (11)	454734	9490253	255.11	2.87	252.24	24.13	Coarse sand
30 (12)	454654	9490314	256.5	3.15	253.35	19.00	Medium to coarse sand
31 (13)	454669	9490467	256.07	3.15	252.92	25.62	Medium to coarse sand
32 (14)	454458	9490568	257.72	2.70	255.02	21.20	Coarse sand
33 (15)	454450	9490586	258.27	3.20	255.07	21.20	Medium to coarse sand
34 (16)	454301	9490284	260.37	2.45	257.92	28.55	Medium to coarse sand
35 (17)	454152	9490173	262.91	2.37	260.54	22.45	Coarse sand

* - Between brackets: numbers corresponding to field cards.

Table 2.29 – Auger drilling data – Salgadinho Stream

Drilling Bores – Underground Dam in Felão Stream							
Drilling Number*	Coordinates		Soil Height (m)	Depth (m)	Bottom height (m)	Width (m)	Predominating lithologic type
	N	L					
36 (PZ)	458529,9	9488863,6	234.5	2.1	232.4	22.75	Fine sand
37 (1)	458525,9	9488843,9	234.75	2.11	232.64	18.45	Fine sand
38 (3)	458699,4	9488744,6	235.82	2.55	233.27	25.50	Medium to coarse sand
39 (2)	458676,9	9488738	235.6	2.17	233.43	25.50	Fine sand
40 (4)	458750,3	9488664,2	236.39	2.91	233.48	19.53	Fine sand
41 (5)	458809,3	9488521,5	237.97	1.98	235.99	15.70	Coarse sand
42 (6)	458821,2	9488503,3	238.19	1.98	236.21	31.77	Medium to coarse sand
43 (7)	458936,7	9488441,8	239.87	2.69	237.18	22.01	Fine sand
44 (8)	458887,5	9488418,8	240.28	2.1	238.18	22.24	Medium to coarse sand
45 (9)	458866,9	9488253,6	241.79	1.69	240.1	18.25	Fine sand
46 (10)	459055,4	9487706,4	255.89	1.9	253.99	12.75	Medium sand
47 (11)	459094,1	9487637,3	257.6	1.71	255.89	14.53	Medium sand
48 (12)	459314,4	9487579	264.27	1.8	262.47	17.47	Fine sand
49 (13)	459331,2	9487528,8	263.37	1.45	261.92	9.87	Fine sand

* - Between brackets: numbers corresponding to field cards.

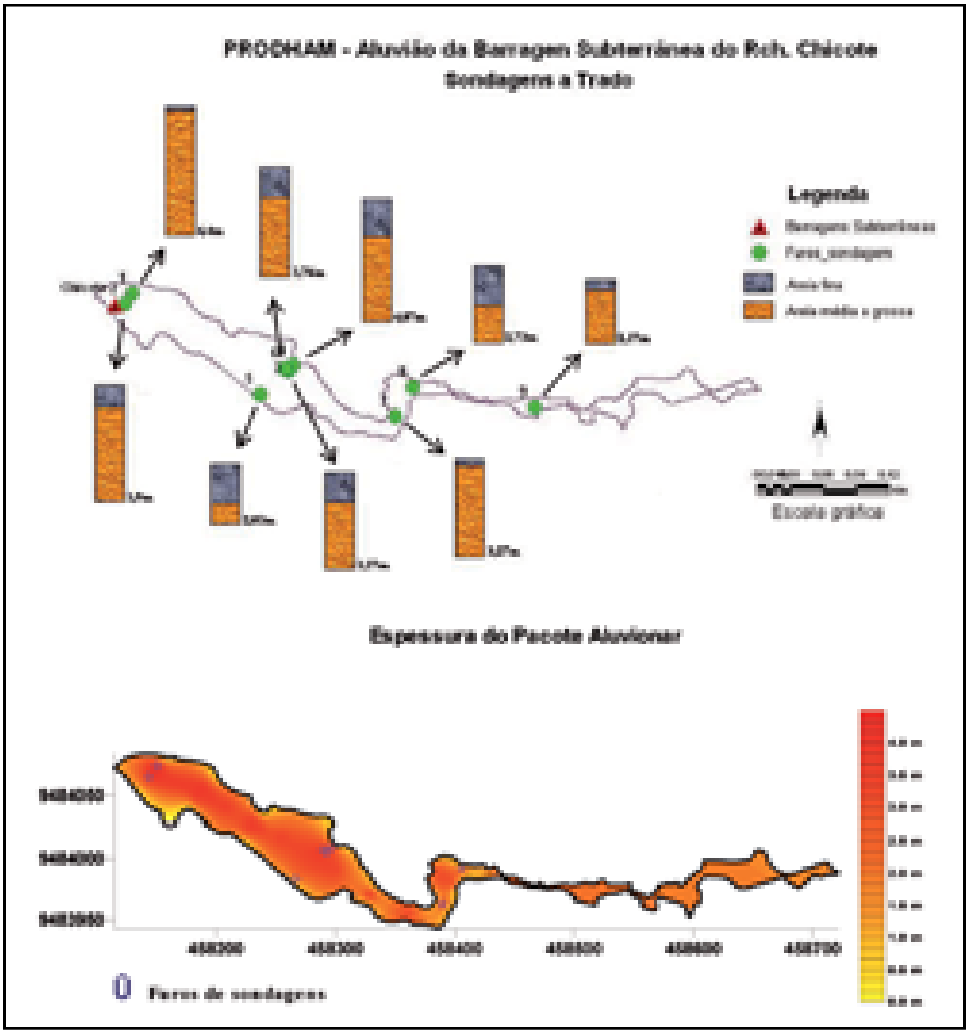

Figure 2.49 – Auger drilling and estimated thickness of Chicote stream U.D. alluvium

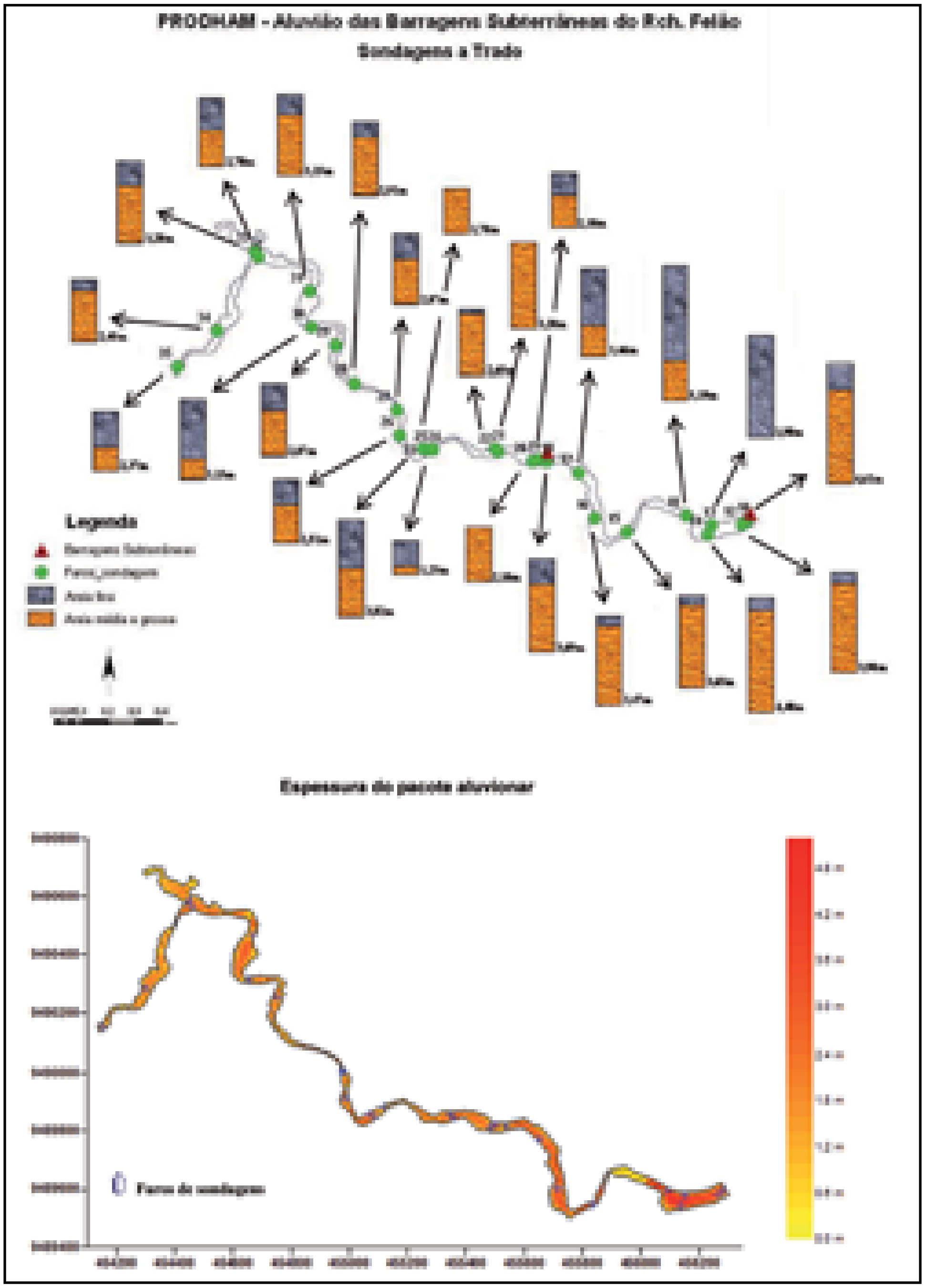

Figure 2.50 – Auger drilling and estimated thickness of Felão stream U.D. alluvium.

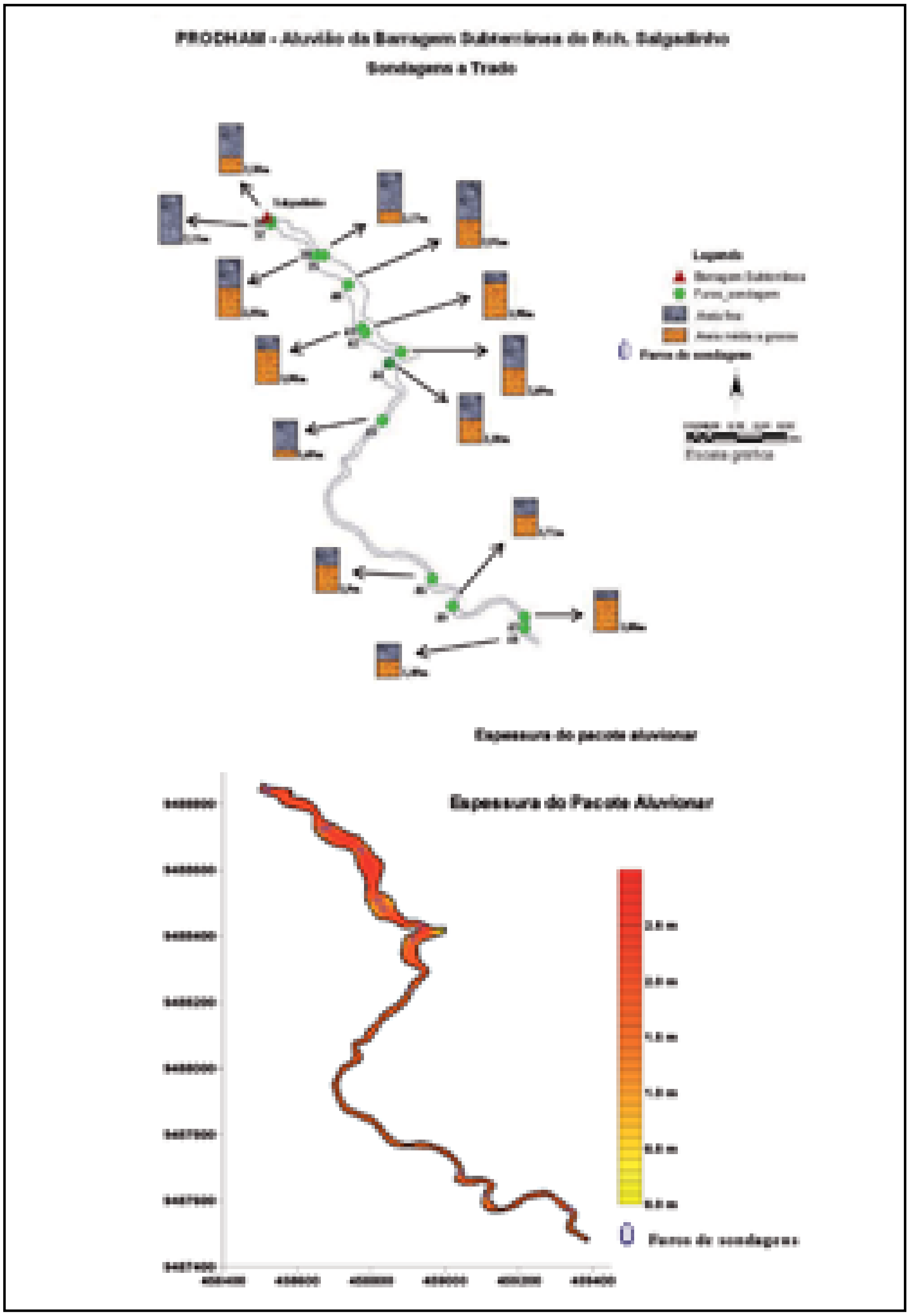

Figure 2.51 – Auger drilling and estimated thickness of Salgadinho stream U.D. alluvium

2.4.2.2 – Hydraulic parameterization of alluvial sections surveyed

Concomitantly with works for geometric characterization of alluvial sections, field essays were performed for hydraulic parameterization of such alluviums. To perform such essays, the following material was used:

- timer & GPS;
- well water level measuring device; and
- water containers.

In sections where auger drillings were made, essays to estimate the hydraulic conductivity of alluvial environment were also performed. As there more or less permeable levels along the vertical profile of an alluvium and drillings explored alluvium packages of different thicknesses, it was decided that essays would be performed always to the same depth (1 m) to allow sampling standardization.

Pourche method, also known as "inverted well method" was adopted, which is used for soils without water table. The technique consists of making a bore by auger and, after saturating the thickness to be analyzed, measuring the time x lowering ratio after filling the bore with water. Essay should be repeated at least three times. The metering device (Figure 2.52) was made according to recommendations provided in Manual for Laboratory and Field Irrigation and Drainage Essays (CAUDURO; DORFMAN, 1988).

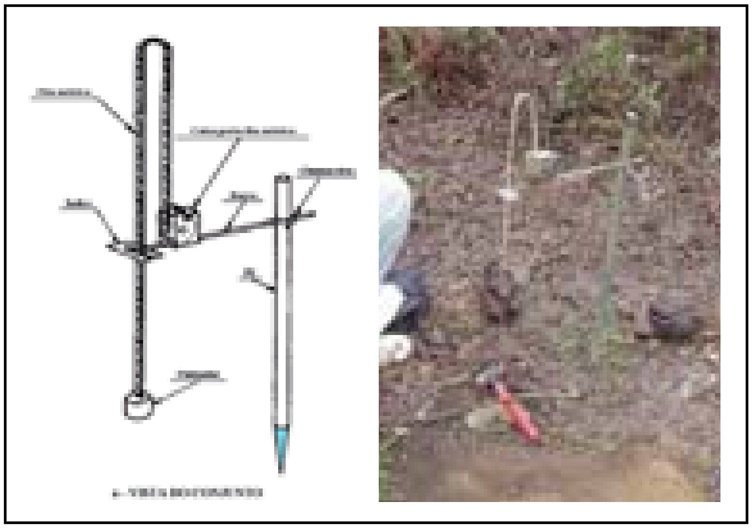

Figure 2.52 – Schematic drawing and photo of water level meter

Data collected from essays should be plotted into a monolog graph (hi + r/2) x t. A. Figure 2.53 shows all related variables.

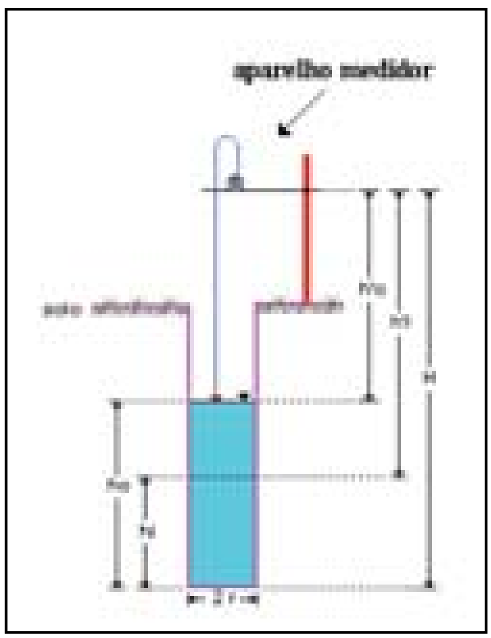

Figure 2.53 – Variables involved in permeability estimate

Thus, hydraulic conductivity may be obtained by the following equation:

$$K = 1{,}15r\,\frac{\log(hi(1) + r/2) - \log(hi(2) + r/2)}{ti(2) - ti(1)}$$

where:

K	= electric conductivity (m/day);
R	= well radius (cm);
hi(1) + r/2	= height corresponding to a specific point of interpolating straight line (cm);
hi(2) + r/2	= height corresponding to a second point of interpolating straight line (cm);
ti(1) e ti(2)	= times corresponding to frist and second level readouts on the straight line (cm).

Tables 2.30 to 2.32 show the characteristics values of hydraulic conductivity (K), estimated in field essays in respective alluvial sections surveyed. As intervals of hydraulic conductivity values those suggested by *U.S. Bureau of Plant Industry and Agricultural Engineering* (CAUDURO; DORFMAN, 1988) were used (Table 2.33).

TABLE 2.30 – Hydraulic Conductivity (K) in Chicote stream alluvium

Characteristic Hydraulic Conductivity (K) Values – Chicote stream					
Essay / Drilling	Coordinates		Depth (m)	K (cm/h)	Class
	N-S	E-W			
01/01	458144	9484065	0.97	3,38	Moderate
02/04	458290	9484007	1.05	2,42	Moderate
04/08	458407	9484003	0.80	2,28	Moderate
Average value				2,69	Moderate

TABLE 2.31 – Hydraulic Conductivity (K) in Felão stream alluvium

Characteristic Hydraulic Conductivity (K) Values – Felão Stream					
Essay / Drilling	Coordinates		Depth (m)	K (cm/h)	Class
	N-S	E-W			
FELÃO I					
01/11	456256	9489609	0.94	2.15	Moderate
02/15	455838	9489567	0.96	7.47	Moderately fast
FELÃO II					
01/18	455500	9489822	0.99	4.34	Moderate
02/20	455337	9489861	1.07	3.08	Moderate
03/22	455069	9489861	0.73	10.58	Moderately fast
04/26	454997	9489916	0.80	8.09	Moderately fast
05/23	454962	9490004	1.05	11.07	Moderately fast
06/28	454816	9490107	0.98	15.13	Fast
07/35	454152	9490173	1.00	6.76	Moderately fast
08/33	454450	9490586	1.03	3.91	Moderate
Average value				6,87	Moderately fast

Table 2.32 – Hydraulic Conductivity (K) in Salgadinho stream alluvium

Characteristic Hydraulic Conductivity (K) Values – Salgadinho Stream					
Essay / Drilling	Coordinates		Depth (m)	K (cm/h)	Class
	N-S	E-W			
01/47	459087	94877628	0.87	6,76	Moderately fast
02/46	459054	9487701	0.92	5,24	Moderate
03/48	459320	9487572	0.95	3,97	Moderate
04/49	459336	9487537	0.94	3,56	Moderate
05/44	458890	9488415	0.99	10,61	Moderately fast
06/43	458935	9488442	0.93	8,78	Moderately fast
07/41	458804	9488529	0.84	6,38	Moderately fast
08/40	458749	9488668	0.96	2,7	Moderate
09/39	458680	9488744	0.99	6,84	Moderately fast
10/45	458862	9488238	0.95	11,01	Moderately fast
Average value				6,58	Moderately fast

Table 2.33 – Hydraulic conductivity (K) classes (U.S. Bureau of Plant Industry and Agricultural Engineering).

CLASSES	ACRONYM	HYDRAULIC CONDUCTIVITY - K (cm/h)
1 – Very low	MLL	< 0,13
2 – Low	L	0.13 a 0.51
3 – Moderately low	ML	0.51 a 2.00
4 – Moderate	M	2.00 a 6.30
5 – Moderately fast	MR	6.30 a 12.70
6 – Fast	R	12.70 a 25.40
7 – Very fast	MRR	> 25.40

Hydraulic conductivity (K) values in Chicote stream alluvium showed uniform and relatively low for this type of deposit. K values in Felão stream alluvium, on the other hand, ranged from Moderate to Moderately Fast, which are consistent with the type of material predominating in surface layers (up to 1 m) of most drillings. In Salgadinho stream, hydraulic conductivity also showed relatively high values consistent with the type of essayed material (sand), as well as a clear positive increase in that hydraulic parameter as it drillings the underground dams.

2.4.3 – Groundwater monitoring (systematic data collection)

With respect to groundwater in Cangati River microbasin, potentiometric levels were monitored and water samples were collected from observation wells in alluvium sections associated with underground dams, and groundwater samples were collected from wells existing in Cangati River alluvium not associated with underground dams. Data obtained from that monitoring, including their analysis and remarks on the set of data are provided below.

2.4.3.1 – Potentiometric level monitoring

Groundwater monitoring in selected alluvial sections took place in February-November 2008, when field activities of subproject came to an end. Before that, it was not possible to made water level reading in piezometers and wells, as they were dry.

Monitoring was supported by an electronic level meter and measuring tape. Selected monitoring points in each alluvium section were determined according to their position in relation to underground dams. This way, in each section one point upstream to the dam (upstream piezometer), one point downstream to the dam (downstream piezometer) and one point in the dam itself (water hole) were selected. Table 2.34 shows the coordinates of selected points in each section, as well as the water levels, from depth and hydraulic load views, observed in the monitoring period.

Figures 2.54 to 2.57 provide the same information (a – hydraulic load; b – level depth) in a graph format. It is noted that water level behavior (standard) in all dams, both upstream and downstream, were similar. Only the amplitude of such oscillations had some variation. It can be clearly noted that levels will rise more expressively in the portion upstream to the dam (upstream well and piezometer) than in downstream portion, what shows the efficiency of damming works (underground dams) for groundwater storage, without compromising significantly the natural flow of that resource.

Table 2.34 – Monitoring data on potentiometric loads in selected alluvial sections

Potentiometric Data												
Coordinates		Observation Point	Height (m)	External Column Height (m)	02/27/08		03/17/08		04/01/08		04/09/08	
x	y				Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)
458290	9484007	Chicote – Piez. Montante	288,76	0,64	4,56	284,84	3,07	286,33	1,13	288,27	1,19	288,21
458139	9484067	Chicote – Poço Barragem	284,33	0,78	4,42	280,7	1,91	283,2	0,92	284,2	0,99	284,13
458121	9484068	Chicote – Piez. Jusante	284,09	0,64	2,56	282,17	2,19	282,54	1,21	283,52	1,32	283,41
455352	9489851	Felão I – Piez. Montante	250,52	0,72	3,22	248,02	1,51	249,73	1,47	249,77	1,6	249,64
456262	9489601	Felão I – Poço Barragem	241,87	0,29	2,9	239,26	0,71	241,45	0,54	241,62	0,6	241,56
455536	9489816	Felão I – Piez. Jusante	249,43	0,58	2,55	247,46	1,14	248,87	1,07	248,94	1,09	248,92
456094	9489636	Felão II – Piez. Montante	242,89	0,60					1	242,49	1,09	242,4
455511	9489807	Felão II – Poço Barragem	250,37	0,74	4,31	246,8	0,97	250,14	0,74	250,37	0,89	250,22
456280	9489595	Felão II – Piez. Jusante	241,87	0,64	5,2	237,31	0,99	241,52	0,84	241,67	0,89	241,62
458527	9488866	Salgadinho – Piez. Mont.	234,5	0,67	2,73	232,44	0,99	234,18	1,55	233,62	1,71	233,46
458648	9488767	Salgadinho – Poço (B.Nova)	235,49	1,12	4,58	232,03	2,35	234,27	0,92	235,7	1,29	235,33
458487	9488895	Salgadinho – Piez. Jus.	234,71	0,68	2,68	232,72	1,64	233,76	2,03	233,37	2,17	233,23
458530	9488886	Salgadinho – Poço (B. Velha)	233,88	0,69	3,11	231,46	3,25	231,33	1,27	233,31	0,89	233,69
458290	9484007	Chicote – Piez. Montante	288,76	0,64	1,19	288,21	1,22	288,18	1,15	288,25	1,24	288,16
458139	9484067	Chicote – Poço Barragem	284,33	0,78	1,05	284,07	1,1	284,02	0,89	284,23	1,11	284,01
458121	9484068	Chicote – Piez. Jusante	284,09	0,64	1,29	283,44	1,39	283,34	1,14	283,59	1,16	283,57
455352	9489851	Felão I – Piez. Montante	250,52	0,72	1,5	249,74	1,58	249,66	1,51	249,73	1,59	249,65
456262	9489601	Felão I – Poço Barragem	241,87	0,29	0,6	241,56	0,66	241,5	1,61	240,55	0,72	241,44
455536	9489816	Felão I – Piez. Jusante	249,43	0,58	1,09	248,92	1,16	248,85	1,1	248,91	1,2	248,81
456094	9489636	Felão II – Piez. Montante	242,89	0,60	1,06	242,44	1,18	242,32	1,07	242,42	1,23	242,27

(continued)

(continuation)

Potentiometric Data												
Coordinates		Observation Point	Height (m)	External Column Height (m)	02/27/08		03/17/08		04/01/08		04/09/08	
x	y				Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)
455511	9489807	Felão II – Poço Barragem	250,37	0,74	0,79	250,32	0,99	250,12	0,82	250,29	1	250,11
456280	9489595	Felão II – Piez. Jusante	241,87	0,64	0,9	241,61	0,97	241,54	0,89	241,62	0,99	241,52
458527	9488866	Salgadinho – Piez. Mont.	234,5	0,67	1,6	233,57	1,76	233,41	1,86	233,31	1,94	233,23
458648	9488767	Salgadinho – Poço (B.Nova)	235,49	1,12	1,29	235,33	1,34	235,28	1,35	235,27	1,39	235,23
458487	9488895	Salgadinho – Piez. Jus.	234,71	0,68	2,08	233,32	2,2	233,2	2,23	233,17	2,27	233,13
458530	9488886	Salgadinho – Poço (B. Velha)	233,88	0,69	0,84	233,74	0,98	233,6	1,06	233,52	1,15	233,43
458290	9484007	Chicote – Piez. Montante	288,76	0,64	1,07	288,33	1,25	288,15	1,28	288,12	1,29	288,11
458139	9484067	Chicote – Poço Barragem	284,33	0,78	1,32	283,8	1,09	284,03	1,13	283,99	1,14	283,98
458121	9484068	Chicote – Piez. Jusante	284,09	0,64	1,22	283,51	1,35	283,38	1,42	283,31	1,44	283,29
455352	9489851	Felão I – Piez. Montante	250,52	0,72	1,52	249,72	1,57	249,67	1,58	249,66	1,59	249,65
456262	9489601	Felão I – Poço Barragem	241,87	0,29	0,62	241,54	0,69	241,47	0,69	241,47	0,69	241,47
455536	9489816	Felão I – Piez. Jusante	249,43	0,58	1,12	248,89	1,17	248,84	1,19	248,82	1,17	248,84
456094	9489636	Felão II – Piez. Montante	242,89	0,60	1,11	242,39	1,19	242,31	1,19	242,3	1,19	242,31
455511	9489807	Felão II – Poço Barragem	250,37	0,74	0,86	250,25	1	250,11	0,99	250,12	0,99	250,12
456280	9489595	Felão II – Piez. Jusante	241,87	0,64	0,89	241,62	1,35	241,16	0,98	241,53	0,96	241,55
458527	9488866	Salgadinho – Piez. Mont.	234,5	0,67	1,87	233,3	1,92	233,25	1,99	233,18	2,03	233,14
458648	9488767	Salgadinho – Poço (B.Nova)	235,49	1,12	1,33	235,29	1,37	235,25	1,49	235,12	1,42	235,2
458487	9488895	Salgadinho – Piez. Jus.	234,71	0,68	2,23	233,17	2,28	233,12	2,29	233,11	2,29	233,1
458530	9488886	Salgadinho – Poço (B. Velha)	233,88	0,69	1,05	233,53	1,11	233,47	1,15	233,43	1,18	233,4
458290	9484007	Chicote – Piez. Montante	288,76	0,64	1,33	288,07	1,48	287,92	1,59	287,81	1,7	287,7

(continuation)

Potentiometric Data												
Coordinates		Observation Point	Height (m)	External Column Height (m)	02/27/08		03/17/08		04/01/08		04/09/08	
x	y				Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)
458139	9484067	Chicote – Poço Barragem	284,33	0,78	1,17	283,95	1,24	283,87	1,3	283,81	1,39	283,73
458121	9484068	Chicote – Piez. Jusante	284,09	0,64	1,46	283,27	1,55	283,18	1,62	283,11	1,72	283,01
455352	9489851	Felão I – Piez. Montante	250,52	0,72	1,6	249,64	1,61	249,63	1,72	249,52	1,8	249,44
456262	9489601	Felão I – Poço Barragem	241,87	0,29	0,77	241,39	0,72	241,44	0,73	241,43	0,73	241,43
455536	9489816	Felão I – Piez. Jusante	249,43	0,58	1,19	248,82	1,2	248,81	1,21	248,8	1,22	248,79
456094	9489636	Felão II – Piez. Montante	242,89	0,60	1,21	242,29	1,23	242,27	1,26	242,24	1,3	242,19
455511	9489807	Felão II – Poço Barragem	250,37	0,74	1,03	250,08	1,04	250,07	1,07	250,04	1,11	250
456280	9489595	Felão II – Piez. Jusante	241,87	0,64	1	241,51	0,99	241,52	1,03	241,48	1,07	241,44
458527	9488866	Salgadinho – Piez. Mont.	234,5	0,67	2,04	233,13	2,05	233,12	2,07	233,1	2,13	233,04
458648	9488767	Salgadinho – Poço (B.Nova)	235,49	1,12	1,56	235,06	1,7	234,92	1,76	234,86	1,82	234,8
458487	9488895	Salgadinho – Piez. Jus.	234,71	0,68	2,31	233,09	2,32	233,08	2,33	233,07	2,34	233,06
458530	9488886	Salgadinho – Poço (B. Velha)	233,88	0,69	1,19	233,39	1,2	233,38	1,2	233,37	1,23	233,35
458290	9484007	Chicote – Piez. Montante	288,76	0,64	1,96	287,44	2,06	287,34	2,17	287,23	2,22	287,18
458139	9484067	Chicote – Poço Barragem	284,33	0,78	1,6	283,52	1,71	283,41	1,88	283,24	1,96	283,16
458121	9484068	Chicote – Piez. Jusante	284,09	0,64	1,93	282,8	2,02	282,71	2,13	282,6	2,19	282,54
455352	9489851	Felão I – Piez. Montante	250,52	0,72	2,13	249,11	2,22	249,02	2,34	248,9	2,41	248,83
456262	9489601	Felão I – Poço Barragem	241,87	0,29	0,74	241,42	0,74	241,42	0,76	241,4	0,77	241,39
455536	9489816	Felão I – Piez. Jusante	249,43	0,58	1,23	248,78	1,23	248,78	1,32	248,69	1,32	248,69
456094	9489636	Felão II – Piez. Montante	242,89	0,60	1,49	242,01	1,59	241,91	1,75	241,75	1,84	241,66
455511	9489807	Felão II – Poço Barragem	250,37	0,74	1,26	249,85	1,38	249,73	1,56	249,55	1,61	249,5

(continuation)

Potentiometric Data												
Coordinates		Observation Point	Height (m)	External Column Height (m)	02/27/08		03/17/08		04/01/08		04/09/08	
x	y				Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)
456280	9489595	Felão II – Piez. Jusante	241,87	0,64	1,24	241,27	1,35	241,16	1,51	241	1,59	240,92
458527	9488866	Salgadinho – Piez. Mont.	234,5	0,67	2,18	232,99	2,22	232,95	1,26	233,91	2,27	232,9
458648	9488767	Salgadinho – Poço (B.Nova)	235,49	1,12	1,92	234,7	1,97	234,65	2,05	234,57	2,11	234,51
458487	9488895	Salgadinho – Piez. Jus.	234,71	0,68	2,4	233	2,47	232,93	2,52	232,88	2,56	232,84
458530	9488886	Salgadinho – Poço (B. Velha)	233,88	0,69	1,25	233,33	1,26	233,32	1,29	233,29	1,29	233,29
458290	9484007	Chicote – Piez. Montante	288,76	0,64	2,26	287,14	2,32	287,08	2,35	287,05	2,4	287
458139	9484067	Chicote – Poço Barragem	284,33	0,78	2,03	283,09	2,15	282,97	2,22	282,9	2,34	282,78
458121	9484068	Chicote – Piez. Jusante	284,09	0,64	2,23	282,5	2,35	282,38	2,4	282,33	2,49	282,24
455352	9489851	Felão I – Piez. Montante	250,52	0,72	2,5	248,74	2,53	248,71	2,55	248,69	2,62	248,62
456262	9489601	Felão I – Poço Barragem	241,87	0,29	0,79	241,37	0,84	241,32	0,87	241,29	0,93	241,23
455536	9489816	Felão I – Piez. Jusante	249,43	0,58	1,4	248,61	1,48	248,53	1,53	248,48	1,62	248,39
456094	9489636	Felão II – Piez. Montante	242,89	0,60	1,9	241,6	2,05	241,45	2,13	241,37	2,24	241,26
455511	9489807	Felão II – Poço Barragem	250,37	0,74	1,68	249,43	1,83	249,28	1,91	249,2	2,02	249,09
456280	9489595	Felão II – Piez. Jusante	241,87	0,64	1,65	240,86	1,77	240,74	1,89	240,62	2	240,51
458527	9488866	Salgadinho – Piez. Mont.	234,5	0,67	2,3	232,87	2,35	232,82	2,4	232,77	2,48	232,69
458648	9488767	Salgadinho – Poço (B.Nova)	235,49	1,12	2,16	234,46	2,25	234,36	2,31	234,31	2,42	234,2
458487	9488895	Salgadinho – Piez. Jus.	234,71	0,68	2,58	232,82	2,64	232,76	2,67	232,73	2,67	232,73
458530	9488886	Salgadinho – Poço (B. Velha)	233,88	0,69	1,3	233,27	1,36	233,22	1,39	233,18	1,46	233,12
458290	9484007	Chicote – Piez. Montante	288,76	0,64	2,45	286,95	2,47	286,93	2,5	286,9	2,54	286,86
458139	9484067	Chicote – Poço Barragem	284,33	0,78	2,42	282,69	2,52	282,59	2,62	282,49	2,76	282,36
458121	9484068	Chicote – Piez. Jusante	284,09	0,64	2,53	282,2	2,54	282,19	2,54	282,19	2,53	282,2

(continuation)

Potentiometric Data													
Coordinates		Observation Point	Height (m)	External Column Height (m)	02/27/08		03/17/08		04/01/08		04/09/08	
x	y				Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)
455352	9489851	Felão I – Piez. Montante	250,52	0,72	2,67	248,57	2,69	248,55	2,76	248,48	2,84	248,4
456262	9489601	Felão I – Poço Barragem	241,87	0,29	0,96	241,2	1,02	241,14	1,05	241,11	1,07	241,09
455536	9489816	Felão I – Piez. Jusante	249,43	0,58	1,66	248,35	1,71	248,3	1,74	248,27	1,8	248,21
456094	9489636	Felão II – Piez. Montante	242,89	0,60	2,34	241,16	2,43	241,07	2,5	240,99	2,67	240,83
455511	9489807	Felão II – Poço Barragem	250,37	0,74	2,12	248,99	2,23	248,88	2,3	248,81	2,45	248,66
456280	9489595	Felão II – Piez. Jusante	241,87	0,64	2,07	240,44	2,17	240,34	2,27	240,24	2,43	240,08
458527	9488866	Salgadinho – Piez. Mont.	234,5	0,67	2,6	232,57	2,69	232,48	2,7	232,47	2,73	232,44
458648	9488767	Salgadinho – Poço (B.Nova)	235,49	1,12	2,5	234,11	2,59	234,02	2,67	233,95	2,76	233,86
458487	9488895	Salgadinho – Piez. Jus.	234,71	0,68	2,67	232,73	2,67	232,73	2,67	232,73	2,67	232,73
458530	9488886	Salgadinho – Poço (B. Velha)	233,88	0,69	1,5	233,07	1,64	232,93	1,64	232,93	1,64	232,93
458290	9484007	Chicote – Piez. Montante	288,76	0,64	2,58	286,82	2,64	286,76	2,70	286,70	2,76	286,64
458139	9484067	Chicote – Poço Barragem	284,33	0,78	2,85	282,26	2,97	282,15	3,06	282,06	3,16	281,96
458121	9484068	Chicote – Piez. Jusante	284,09	0,64	2,53	282,2	2,55	282,18	2,55	282,18	2,55	282,18
455352	9489851	Felão I – Piez. Montante	250,52	0,72	2,91	248,33	2,96	248,28	3,03	248,21	3,06	248,18
456262	9489601	Felão I – Poço Barragem	241,87	0,29	1,21	240,95	1,25	240,91	1,33	240,83	1,44	240,72
455536	9489816	Felão I – Piez. Jusante	249,43	0,58	1,84	248,17	1,88	248,13	1,93	248,08	1,96	248,05
456094	9489636	Felão II – Piez. Montante	242,89	0,60	2,78	240,72	2,89	240,60	3,00	240,50	3,10	248,18
455511	9489807	Felão II – Poço Barragem	250,37	0,74	2,55	248,56	2,67	248,44	2,76	248,35	2,87	240,72
456280	9489595	Felão II – Piez. Jusante	241,87	0,64	2,52	239,99	2,62	239,89	2,72	239,79	2,82	248,05
458527	9488866	Salgadinho – Piez. Mont.	234,5	0,67	2,73	232,44	2,73	232,44	2,73	232,44	2,73	232,44

(continuation)

Potentiometric Data												
Coordinates		Observation Point	Height (m)	External Column Height (m)	02/27/08		03/17/08		04/01/08		04/09/08	
x	y				Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)	Depth (m)	Hydr. Load (m)
458648	9488767	Salgadinho – Poço (B.Nova)	235,49	1,12	2,8	233,81	2,85	233,76	2,95	233,66	3,04	233,57
458487	9488895	Salgadinho – Piez. Jus.	234,71	0,68	2,67	232,73	2,67	232,73	2,67	232,73	2,67	232,73
458530	9488886	Salgadinho – Poço (B. Velha)	233,88	0,69	1,64	232,93	1,64	232,93	1,64	232,93	1,64	232,93

Potentiometric Data						
Coordinates		Observation Point	Height (m)	External Column Height (m)	Date	
					11/10/08	
X	Y				Depth (m)	Hydr. Load (m)
458290	9484007	Chicote – Piez. Montante	288,76	0,64	2,80	286,60
458139	9484067	Chicote – Poço Barragem	284,33	0,78	3,24	281,87
458121	9484068	Chicote – Piez. Jusante	284,09	0,64	2,55	282,18
455352	9489851	Felão I – Piez. Montante	250,52	0,72	3,10	248,14
456262	9489601	Felão I – Poço Barragem	241,87	0,29	1,49	240,67
455536	9489816	Felão I – Piez. Jusante	249,43	0,58	2,00	248,01
456094	9489636	Felão II – Piez. Montante	242,89	0,60	3,19	240,30
455511	9489807	Felão II – Poço Barragem	250,37	0,74	2,97	248,14
456280	9489595	Felão II – Piez. Jusante	241,87	0,64	2,92	239,59
458527	9488866	Salgadinho – Piez. Mont.	234,5	0,67	2,73	232,44
458648	9488767	Salgadinho – Poço (B.Nova)	235,49	1,12	3,08	233,54
458487	9488895	Salgadinho – Piez. Jus.	234,71	0,68	2,67	232,73
458530	9488886	Salgadinho – Poço (B. Velha)	233,88	0,69	1,64	232,93

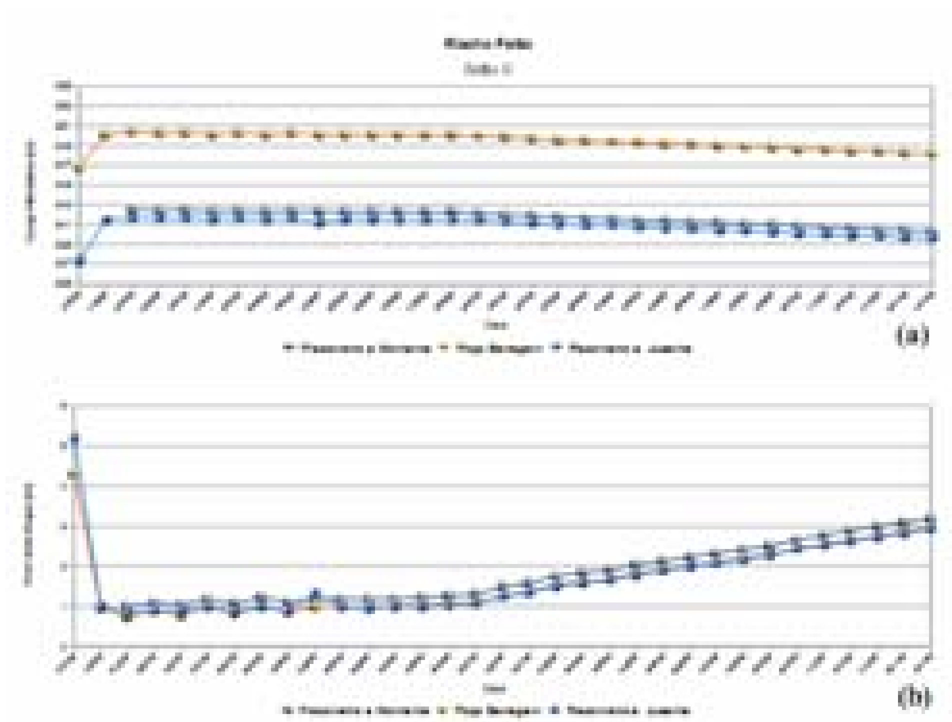

Figure 2.54 – Behavior of water levels in monitoring points in Chicote stream alluvium

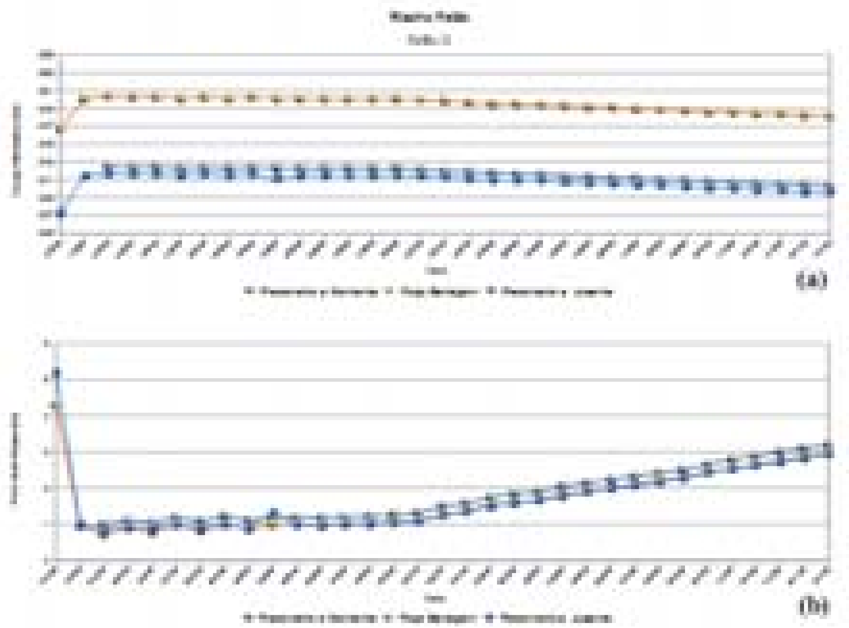

Figure 2.55 – Behavior of water levels in monitoring points in Felão stream alluvium - Felão II U.D.

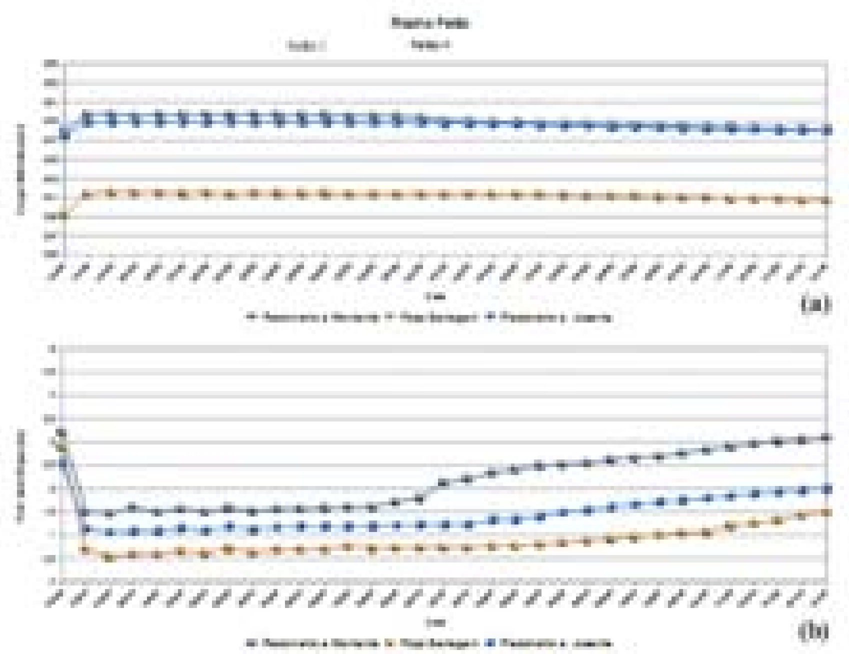

Figure 2.56 – Behavior of water levels in monitoring points in Felão stream alluvium – Felão I U.D.

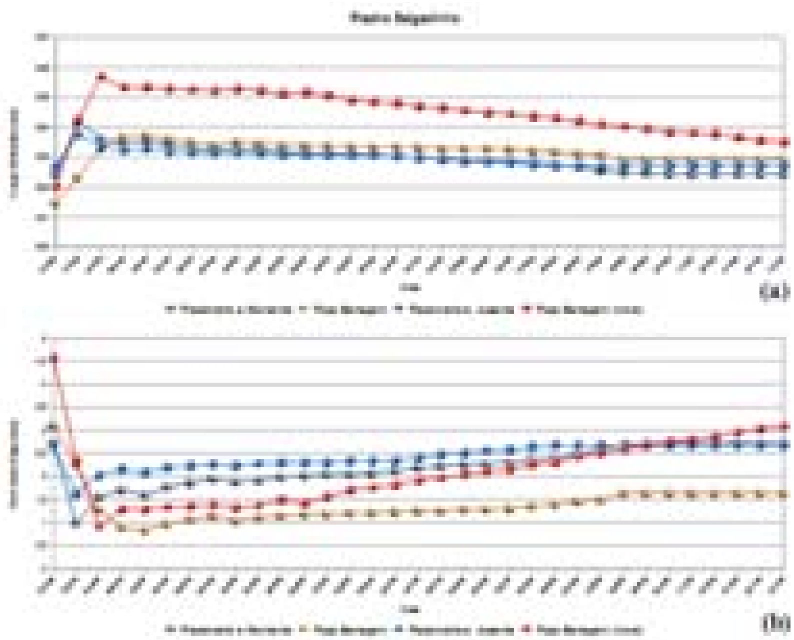

Figure 2.57 – Behavior of water levels in monitoring points in Salgadinho stream alluvium

2.4.3.2 – Monitoring of groundwater physical-chemical characteristics

To characterize groundwater quality in the microbasin, water samples were collected in the period of September 2007 through December 2008 for physical-chemical and bacteriological analyses. Samples were collected from wells selected in alluvial bodies. Sixteen water sample collection campaigns were carried out, where sampling was made with the help of a collector and then stored in a plastic container.

In alluvial sections associated with underground dams, wells in Felão stream and Salgadinho stream dams were monitored. Collections in Chicote stream dam were interrupted in February 2008 because of difficult access to the site. In addition, three wells were monitored in other alluviums (Cangati River) of the microbasin to evaluate the condition of non-hydraulic interference of dams with hydrochemical characteristics of groundwater in alluvial aquifers. Map of Figure 2.58 shows the selected water sample collection points.

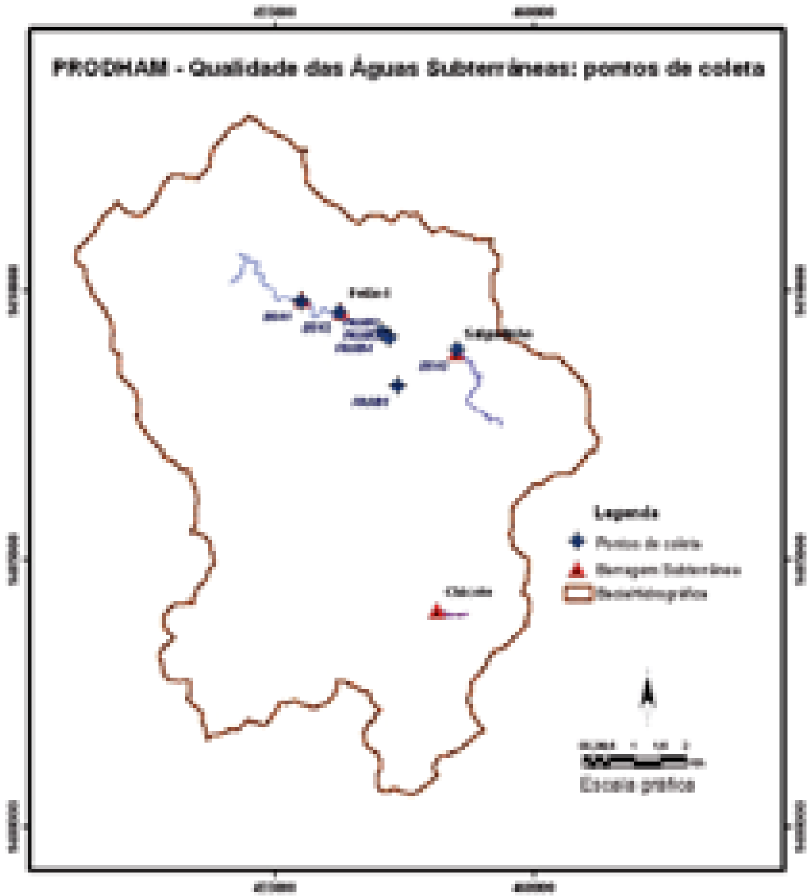

Figure 2.58 – Water sample collection points in Cangati River microbasin

Like in campaigns for reservoir and river water sampling, electric conductivity (μS/cm), dissolved solids (mg/L), air temperature (°C), and water temperature (°C) values were measured on-site using a portable conductivity meter. Values and other relevant information obtained were recorded in the field card. Sample collection followed the technique recommended by the Technology Company… (1988). Analysis methodology followed the recommendations of American Public... (1988). Samples were processed in the laboratory of Fundação Núcleo de Tecnologia Industrial do Ceará (NUTEC).

Table 2.35 shows the reference elements of groundwater sampling points in the microbasin. Table 2.36 shows the months when collections were possible in each point. Physical-chemical and bacteriological parameters analyzed were those applied to surface water samples (see Table 2.5).

Table 2.35 – Groundwater sample collection points

Point	Structure	UTM Coordinates		Location	River/ Stream
		Latitude	Longitude		
BS01	Well in Felão Stream U.D. (I)	9489807	455511	São Luís	Felão
BS02	Well in Felão Stream U.D. (II)	9489601	456262	São Luís	Felão
BS03	Well in Salgadinho Stream U.D.	9488886	458530	Boqueirão	Salgadinho
PAM01	Piezometric well	9488216	457387	Cacimba de Baixo	Cangati
PAM02	Piezometric well	9489136	457202	Fazenda Iguaçu	Cangati
PAM03	Piezometric well	9489128	457220	Fazenda Iguaçu	Cangati
PAM04	Piezometric well	9489222	457069	Fazenda Iguaçu	Cangati

Table 2.36 – Months when groundwater collections were made.

POINT	MONTHS							
	Sep/07	Oct/07	Nov/07	Dec/07	Jan/08	Feb/08	Mar/08	Apr/08
BS01	x	x	x	x	-	-	X	x
BS02	x	x	x	-	-	-	X	-
BS03	-	-	-	-	-	-	-	-
PAM01	-	X	x	x	x	x	-	-
PAM02	-	-	x	x	x	x	-	-
PAM03	-	-	x	x	x	x	-	-
PAM04	-	-	x	x	x	x	X	x

POINT	MONTHS							
	May/08	Jun/08	Jul/08	Aug/08	Sep/08	Oct/08	Nov/08	Dec/08
BS01	x	X	x	x	x	x	X	x
BS02	x	X	x	x	x	x	X	x
BS03	-	X	x	x	-	-	-	-
PAM01	-	-	-	-	-	-	-	-
PAM02	-	-	-	-	-	-	-	-
PAM03	-	-	x	x	x	x	X	x
PAM04	x	X	x	x	x	x	X	x

2.5 – Results and Discussion – Groundwater

2.5.1. – Characterization of groundwater quality in microbasin

2.5.1.1 – Consistency of laboratory data through ionic balance

As mentioned in item 2.3.1.2, all laboratory analysis results to determine the ions present in samples collected under PRODHAM project were submitted to a consistency analysis by ionic balance.

In general, activities performed during this stage involved data tabulation and storage in electronic spreadsheets; sorting, determination and consistency of laboratory data; performance of basic statistical analyses; and sample classification, among others.

Results of ionic balances related to groundwater samples are shown in Tables 2.37 to 2.43 below. Dates when values slightly above those permissible for their ranges were recorded in ionic balance analysis are highlighted. As such values are not considered a threat, such samples were not disregarded at discussions made in the body of this document, given the rather reduced set of samples.

Table 2.37 – Result of ionic data consistency analysis in well of 1st U.D. in Cangati stream (Felão I)

Well in Underground Dam 01 – Felão Stream (BS01)												
Data in mg/L							EC	Total Cat.	Total Ani.	I.B. 1	I.B. 2	Status
Date	Na + K	Ca	Mg	Cl	CO3 + HCO	SO						
09/13/07	5.25	2.2	1.92	4.59	3.4	1.38	1127	9.37	9.37	0.05	0.02	OK
10/16/07	3.95	2.48	2.83	5.22	4.05	0.05	1089.9	9.26	9.32	0.7	0.35	OK
11/20/07	1.23	2.79	3.66	6.49	0.91	0.31	760	7.68	7.71	0.32	0.16	OK
12/18/07	6.15	2.93	1.97	5.9	5.14	0.1	1290.5	11.05	11.13	0.76	0.38	OK
03/25/08	2.92	1.38	1.32	2.12	2.68	0.25	656	5.63	5.06	10.69	5.34	OK
04/16/08	1.52	0.84	0.34	0.71	1.45	0.5	328	2.7	2.67	1.08	0.54	OK
05/14/08	2.05	1.28	0.78	1.33	2.22	0.58	526	4.12	4.13	0.31	0.16	OK
06/18/08	2.42	1.96	1.14	2.67	2.65	0.21	670.08	5.52	5.53	0.06	0.03	OK
07/16/08	2.23	2.27	1.63	3.11	2.9	0.05	659	6.13	6.06	1.07	0.53	OK
08/08/13	0.56	0.42	1.1	0.2	0.98	0.11	195.8	2.08	1.29	46.92	23.46	IB 1 & 2
08/17/08	3.42	2.85	2.2	4.66	3.49	0.07	975.8	8.47	8.22	3.02	1.51	OK
10/15/08	6.54	2.4	4.8	6.91	5.99	0.84	1618.8	13.74	13.74	0.01	0.01	OK
11/20/08	0.56	4.84	2.74	0.46	7.55	0.15	1492.81	8.14	8.17	0.36	0.18	OK
12/17/08	6.44	3.9	4.28	9.87	4.51	0.27	2177.52	14.62	14.65	0.16	0.08	OK

Table 2.38 – Result of ionic data consistency analysis in well of 2nd U.D. in Felão Stream (Felão II)

Well in Underground Dam 02 – Felão Stream (BS02)												
Data in mg/L							EC	Total Cat.	Total Ani.	I.B. 1	I.B. 2	Status
Data	Na + K	Ca	Mg	Cl	CO3 + HCO	SO						
09/14/07	4.55	3.88	4.85	4.45	6.45	2.36	1628.0	13.29	13.26	0.23	0.11	OK
10/17/07	12.96	3.15	7.13	9.38	12.32	1.72	2889.9	23.24	23.42	0.8	0.4	OK
11/21/07	0.41	6.25	3.66	7.99	2.06	0.3	1027.0	10.32	10.34	0.17	0.09	OK
03/25/08	0.66	1.86	1.44	0.78	2.85	0.35	503.0	3.96	3.97	0.47	0.23	OK
04/16/08	0.65	2.64	1.41	2.56	1.93	0.21	544.0	4.7	4.7	0.03	0.01	OK
05/14/08	2.63	3.96	2.08	0.3	8.15	0.23	1224.0	8.67	8.68	0.08	0.04	OK
06/18/08	1.06	2.75	4.19	0.39	7.39	0.24	1079.41	8.01	8.02	0.07	0.04	OK
07/16/08	2.12	4.76	2.72	0.71	7.96	0.12	1242.0	9.59	8.79	8.79	4.39	**IB 1 & 2**
08/08/13	2.61	2.56	2.07	3.68	3.18	0.07	931.0	7.24	6.93	4.29	2.15	OK
09/17/08	3.76	1.57	3.15	0.53	7.8	0.16	1178.0	8.48	8.49	0.08	0.04	OK
10/15/08	3.74	3.48	5.09	4.18	7.92	0.21	1529.8	12.31	12.3	0.07	0.03	OK
11/20/08	5.49	2.63	5	8.89	3.88	0.36	1922.93	13.12	13.13	0.1	0.05	OK

Table 2.39 – Result of ionic data consistency analysis in well of Salgadinho Stream U.D.

Well in Underground Dam – Salgadinho Stream (BS03)												
Data in mg/L							EC	Total Cat.	Total Ani.	I.B. 1	I.B. 2	Status
Date	Na+K	Ca	Mg	Cl	CO3 + HCO	SO						
06/18/08	7.28	1.04	4.12	3.53	7.23	0.63	1553.44	12.44	11.39	8.79	4.4	**IB 1 & 2**
07/16/08	4.63	4.27	4.06	4.83	7.87	0.07	1604.0	12.96	12.77	1.48	0.74	OK
08/08/13	0.39	4.76	2.55	0.41	7.16	0.13	1059.2	7.69	7.7	0.07	0.03	OK

Table 2.40 – Result of ionic data consistency analysis in piezometric well 01 in Cangati Stream

Piezometric Well – Cangati Stream (PAM 01)												
Data in mg/L							EC	Total Cat.	Total Ani.	I.B. 1	I.B. 2	Status
Date	Na+K	Ca	Mg	Cl	CO3 + HCO	SO						
10/17/07	5.9	2.71	4.01	5.67	6.27	0.77	1536.6	12.62	12.71	0.7	0.35	OK
11/21/07	0.16	3.27	4.05	5.75	1.45	0.29	743.0	7.47	7.49	0.17	0.09	OK
12/19/07	11.5	0.79	1.04	7.17	6.22	0.1	1671.8	13.33	13.48	1.07	0.53	OK
01/17/08	27.26	3.22	3.78	28.48	6.05	0.18	3814.9	34.26	34.71	1.32	0.66	OK
02/20/08	6.81	1.47	4.98	6.13	7	0.12	1.607.0	13.26	13.26	0.01	0.00	OK

Table 2.41 – Result of ionic data consistency analysis in piezometric well 02 in Cangati River

Piezometric Well 02 – Cangati Stream(PAM 02)												
	Data in mg/L						EC	Total Cat.	Total Ani.	I.B. 1	I.B. 2	Status
Date	Na+K	Ca	Mg	Cl	CO3 + HCO	SO						
11/21/07	4.64	3.37	7.61	6.49	8.93	0	1.847.0	15.61	15.43	1.19	0.6	OK
12/19/07	13.76	0.79	1.29	8.14	7.83	0.06	2.006.6	15.84	16.03	1.2	0.6	OK
01/17/08	29.95	3.72	5.93	32.27	7.73	0.05	4.406.2	39.6	40.05	1.11	0.55	OK
02/20/08	6.41	2.74	5.52	6.43	8.12	0.13	1.789.0	14.67	14.68	0.08	0.04	OK

Table 2.42 – Result of ionic data consistency analysis in piezometric well 03 in Cangati River

Piezometric Well 03 – Cangati River (PAM 03)												
	Data in mg/L						EC	Total Cat.	Total Ani.	I.B. 1	I.B. 2	Status
Date	Na+K	Ca	Mg	Cl	CO3 + HCO	SO						
11/21/07	0.6	4.04	6.64	9.18	1.93	0.2	1111.0	11.29	11.31	0.17	0.08	OK
12/19/07	16.3	0.83	1.33	9.85	8.76	0.07	2325.9	18.46	18.68	1.21	0.61	OK
01/17/08	37.11	3.37	5.17	38.02	8.14	0.04	5087.2	45.66	46.2	1.19	0.59	OK
02/20/08	9.59	1.54	5.37	7.58	8.81	0.11	2020.0	16.5	16.49	0.03	0.02	OK
06/18/08	4.12	1.24	4.08	4.71	4.38	0.34	1105.29	9.44	9.44	0	0	OK
07/15/08	6.8	3.27	4.25	7.71	5.62	1	1672.7	14.32	14.33	0.07	0.03	OK
08/08/13	5.49	3.07	4.74	6.99	6.09	0.22	1599.8	13.3	13.3	0.01	0	OK
09/17/08	7.04	2.43	4	6.8	5.88	0.79	1599.6	13.46	13.47	0.05	0.02	OK
10/15/08	5.2	3.36	3.5	7.47	4.17	0.35	1364.4	12.07	12	0.6	0.3	OK
11/20/08	6.84	1.19	6.03	7.7	5.41	0.97	2149.48	14.06	14.08	0.16	0.08	OK
12/17/08	6.88	3.13	4.78	8.2	6.11	0.5	2297.45	14.79	14.81	0.18	0.09	OK

Table 2.43– Result of ionic data consistency analysis in piezometric well 04 in Cangati River

Piezometric Well 04 – Cangati River (PAM 04)												
	Data in mg/L						EC	Total Cat.	Total Ani.	I.B. 1	I.B. 2	Status
Date	Na+K	Ca	Mg	Cl	CO3+HCO	SO						
11/21/07	2.71	3.75	8.18	5.15	9.35	0.15	1733.0	14.64	14.65	0.02	0.01	OK
12/19/07	11.99	0.87	1.85	6.64	8.16	0.07	1889.3	14.71	14.87	1.1	0.55	OK
01/17/08	21.8	3.32	7.15	25.03	7.5	0.04	3591.1	32.27	32.57	0.94	0.47	OK
02/20/08	4.76	2.08	6.76	5.1	8.39	0.11	1665.0	13.6	13.6	0	0	OK
03/25/08	1.31	4.76	10.76	6.92	9.74	0.17	1912.0	16.83	16.83	0.01	0.01	OK
04/16/08	5.86	5.04	6.69	6.54	10.72	0.33	2179.0	17.6	17.6	0.02	0.01	OK
05/14/08	5.57	2.74	8.5	5.68	10.72	0.4	1978.0	16.81	16.8	0.02	0.01	OK
06/18/08	4.52	0.88	8.91	4.96	9.01	0.35	1731.6	14.31	14.32	0.09	0.05	OK
07/15/08	4.18	4.78	5.57	5.14	9.06	0.31	1797.8	14.52	14.52	0.06	0.03	OK
08/08/13	2.87	3.6	6.75	4.72	8.38	0.12	1609.8	13.22	13.21	0.03	0.02	OK
09/17/08	3.53	2.31	5.92	4.05	7.38	0.31	1439.7	11.75	11.74	0.15	0.08	OK
10/15/08	1.17	0.58	0.42	0.32	1.19	0.26	253.2	2.17	1.78	19.6	9.8	**IB 1 & 2**
11/20/08	3.27	2.2	6.21	4.12	7.21	0.36	1895.96	11.68	11.69	0.1	0.05	OK
12/17/08	3.62	3.63	4.42	3.97	7.51	0.2	1943.09	11.67	11.67	0.01	0	OK

2.5.1.2 – Hydrochemistry of groundwater in microbasin

To identify the presence of components of salts occurring in waters, highest concentrations of cations and anions were determined: calcium, magnesium, sodium, potassium, chloride, sulfate, bicarbonate and carbonate, expressed in mg/L water. Based on those elements, some widely recognized analysis and classification techniques were applied.

a) Hydrochemical classification of waters according to Piper Diagram

Piper Diagram was used to classify waters in terms of predominant salts (Figures 2.5.59 to 2.5.65). That analysis aimed to evaluate especially the temporal groundwater behavior for a further analysis using the recharge standard of alluvial aquifers.

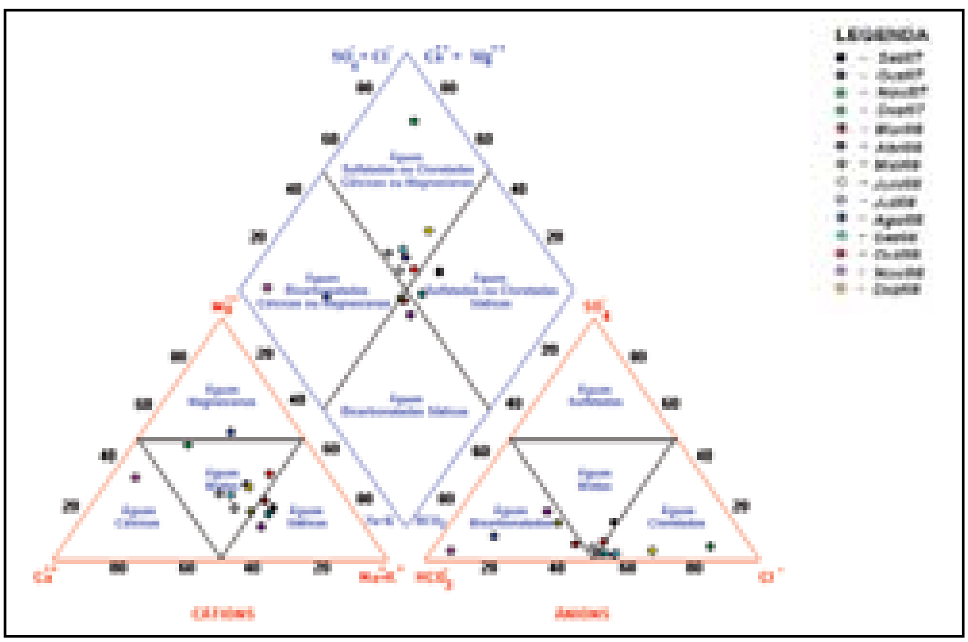

Figure 2.59 – Piper Diagrams of Felão I U.D. – Felão stream

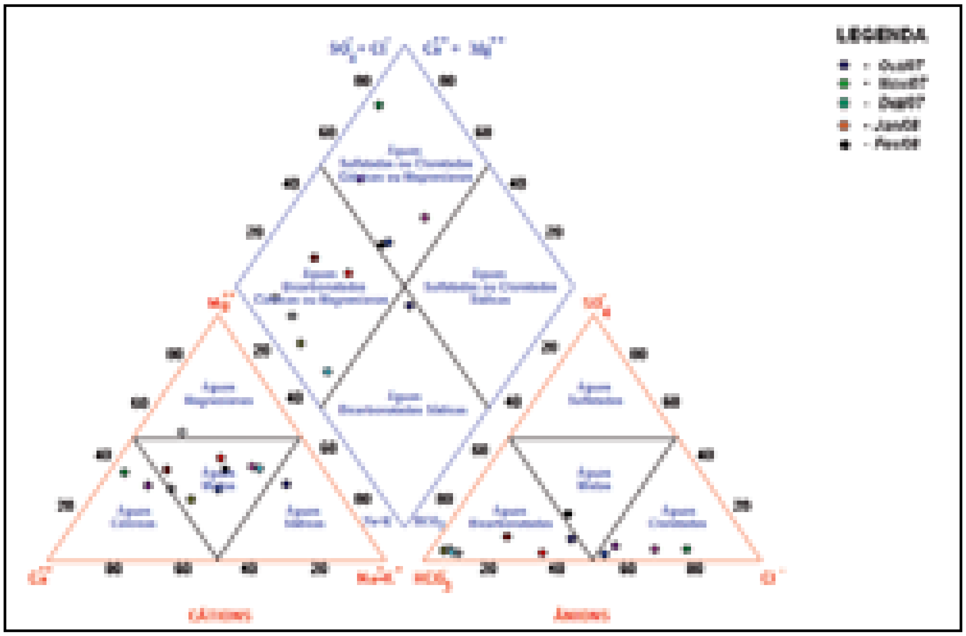

Figure 2.60 – Piper Diagrams of Felão II U.D. – Felão Stream

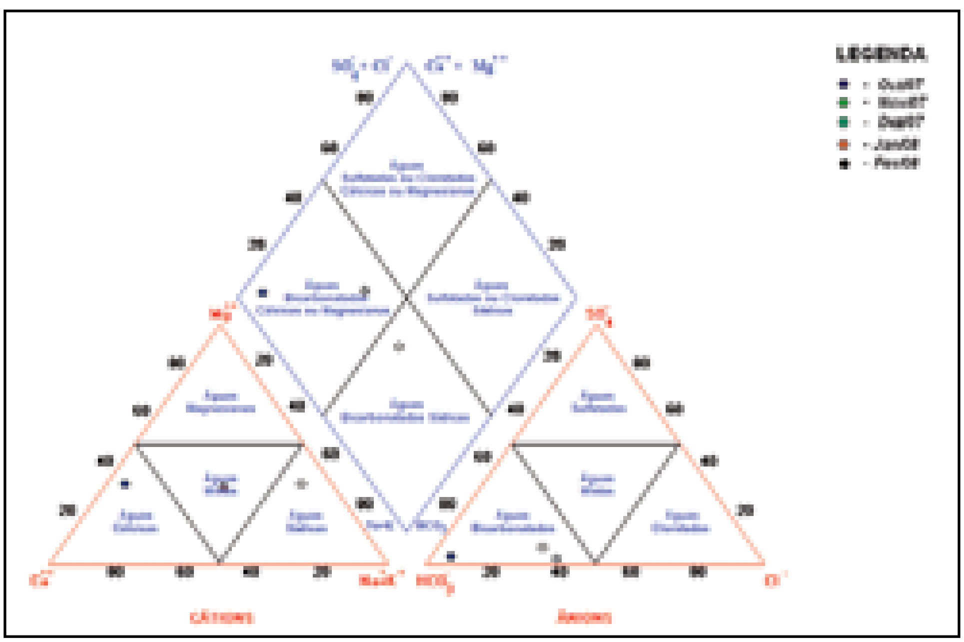

Figure 2.61 – Piper Diagrams of U.D. waters in Salgadinho stream

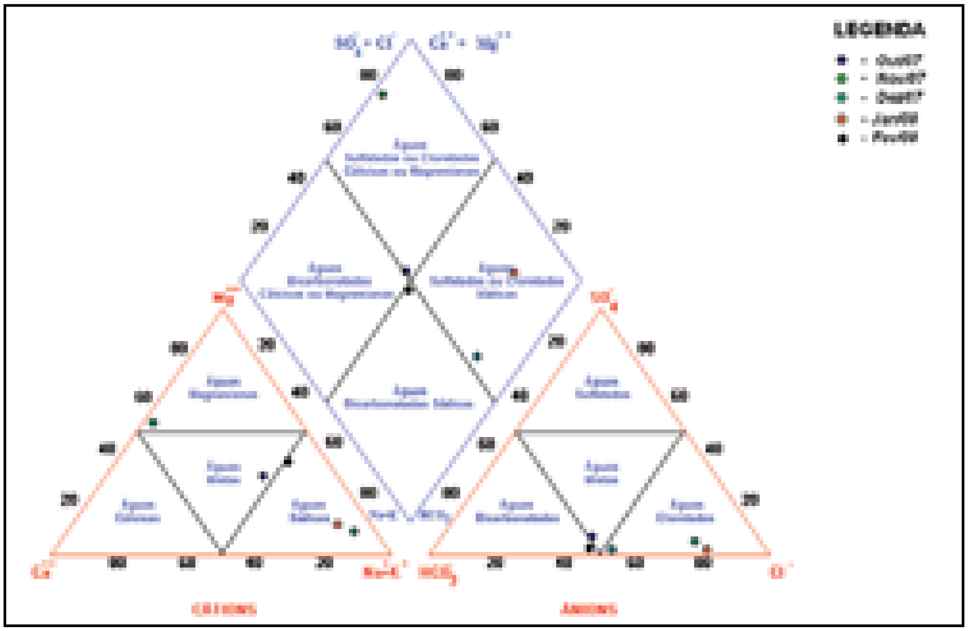

Figure 2.62 – Piper Diagram of Piezometric Well 01 waters (PAM 01)

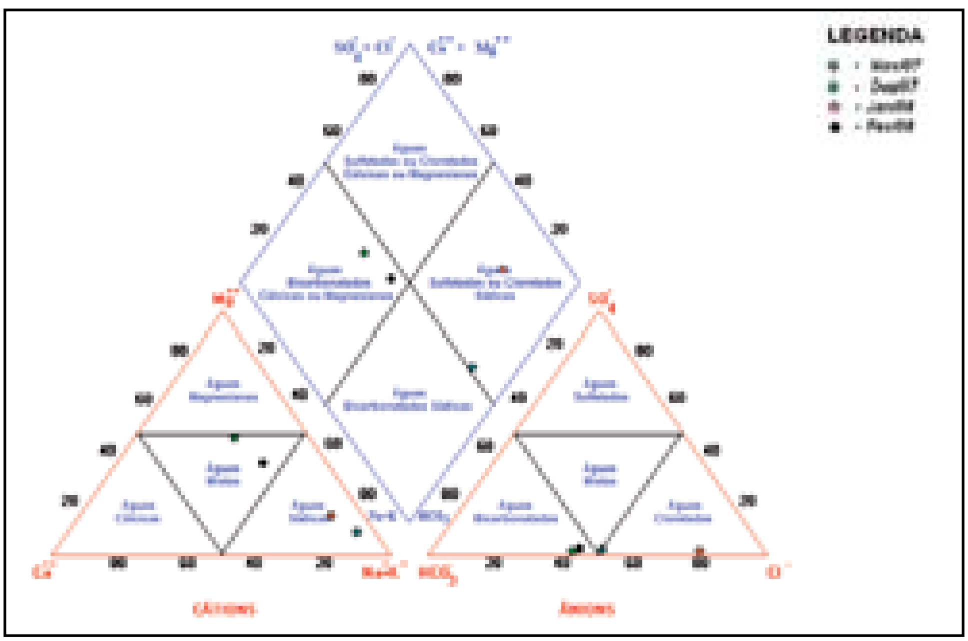

Figure 2.63 – Piper Diagram of Piezometric Well 02 waters (PAM 02)

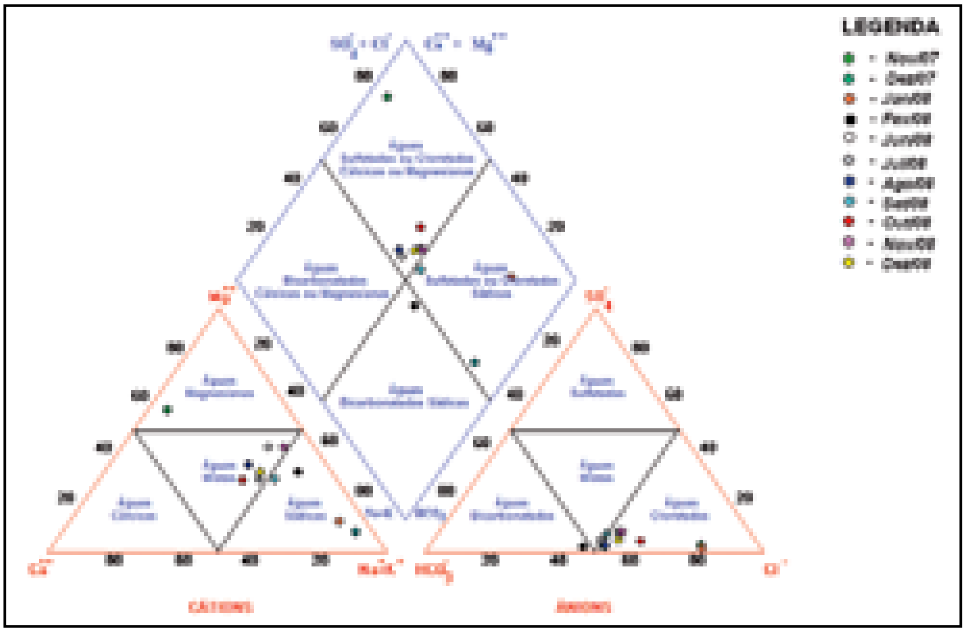

Figure 2.64 – Piper Diagram of Piezometric Well 03 waters (PAM 03)

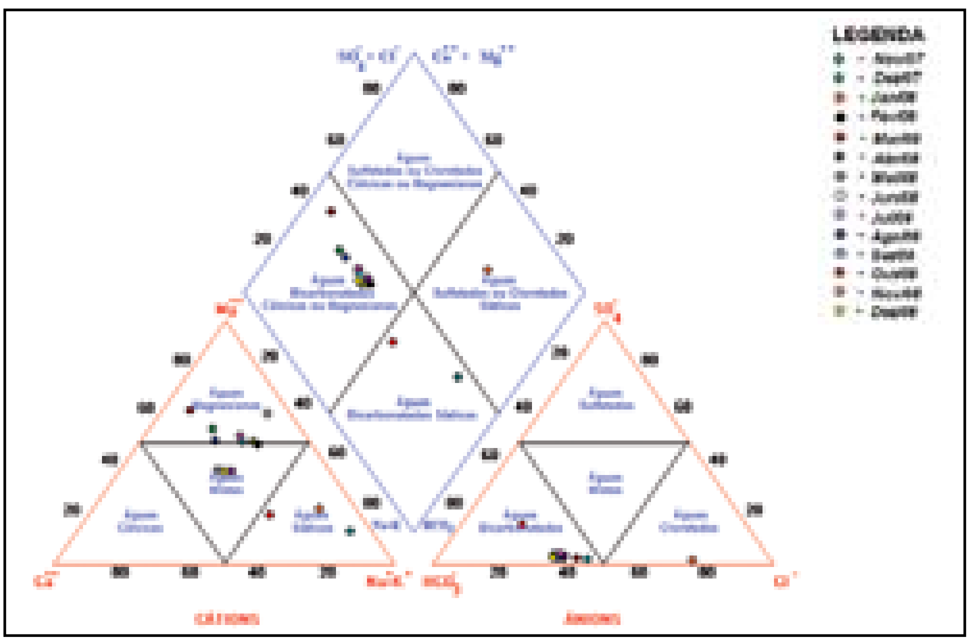

Figure 2.65 – Piper Diagram of Piezometric Well 04 waters (PAM 04)

By analyzing Figure 2.59, it is noted that waters associated with Felão I underground dam have some predominance of chloride and bicarbonates among anions. Among cations, on the other hand, there is no predominant ion. They are predominantly classified as mixed chlorinated waters. Samples representative of rainy period (Jan/2008 – Jul/2008) show a sodium and bicarbonate enrichment normally associated with quick aquifer recharge by surface runoff, which is typically observed in this period in the flow along stream channels.

Waters associated with Felão II underground dam are classified as mixed chloratinated and bicarbonated waters. Most outstanding ion is bicarbonate, but strangely the samples collected in the rainy period showed no accentuated predominance of that ion.

There is little to say about the characteristics of waters of Salgadinho stream underground dam because of the reduced number of samples, but the behavior of all three samples collected at the end of rainy season is typical of a recent water influx to the system.

Water hole waters samples along Cangati stream made ionic classification range from chlorinated to bicarbonated waters, and from magnesian to mixed waters. PAM-04 point showed a magnesium content above the standard observed in the region. It is interesting to note the similarity of water sample composition in all wells in January, where ionic ratio is unique in relation to all other samples.

b) Hydrochemical behavior of waters according to Stiff Diagram

Stiff diagram is a powerful graphic tool for identification of changes in standards of groundwater ionic ratios; This diagram is obtained from the representation of main ion and cation concentrations on parallel lines. By connecting the points, a geometric figure is obtained, which is characteristic for a sample analyzed at a certain time. Figures 2.66 to 2.72 show the respective diagrams of each point sampled throughout the collection period.

Apparently no standard (or tendency) was noted in the evolution of anion and cation arrangement over the time. Groundwater associated with Felão stream alluvium clearly shows bicarbonate ion enrichment during the aquifer recharge period. A similar behavior was only noted in piezometric well PAM 04. The anomalous layout standard at the final stages of dry season (November-December) called the attention, especially in waters associated with Felão I and Felão II underground dams. No conclusive factor for that behavior was identified. Unique ionic ratio in water samples from Cangati Stream water holes collected in January is again evidenced by the differentiated layout in respective figures.

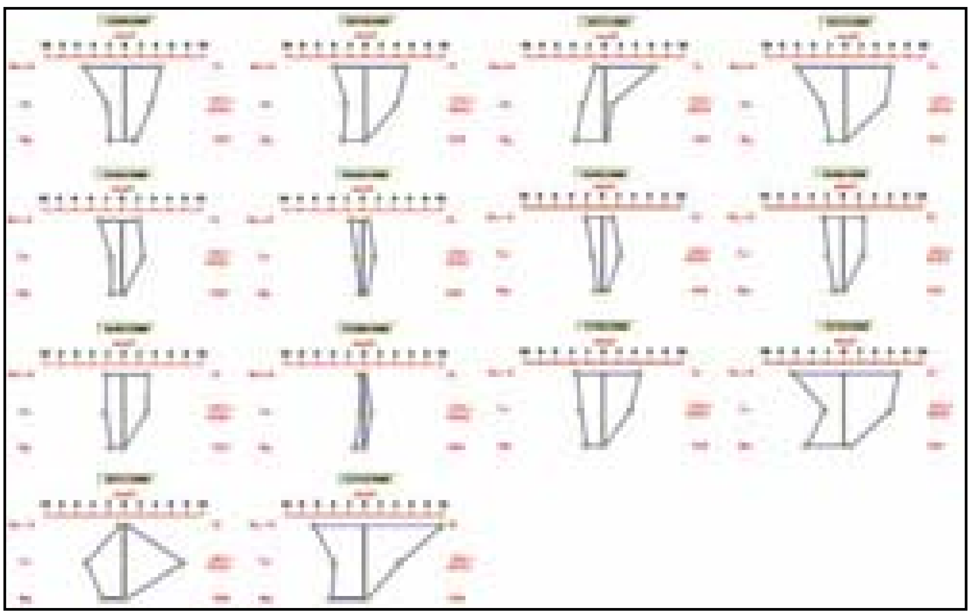

Figure 2.66 – Stiff Diagram of Felão I U.D. – Felão stream

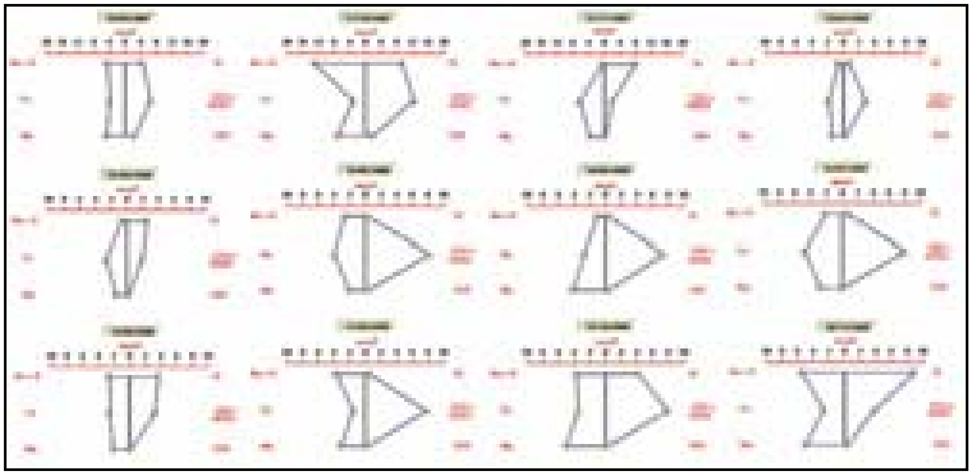

Figure 2.67 – Stiff Diagram of Felão II U.D. – Felão Stream

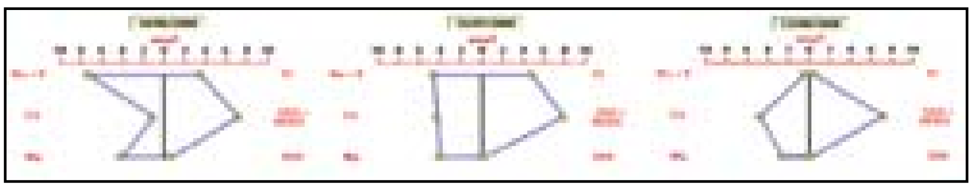

Figure 2.68 – Stiff Diagrams of U.D. waters in Salgadinho stream

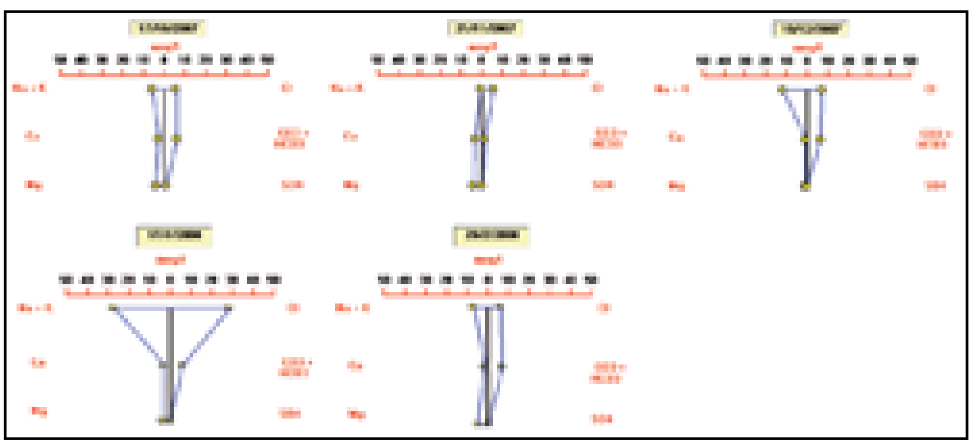

Figure 2.69 – Stiff Diagram of piezometric well waters (PAM 01) – Cangati River

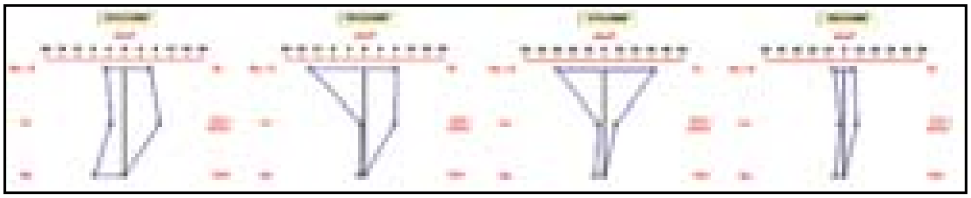

Figure 2.70 – Stiff Diagram of piezometric well waters (PAM 02) – Cangati River

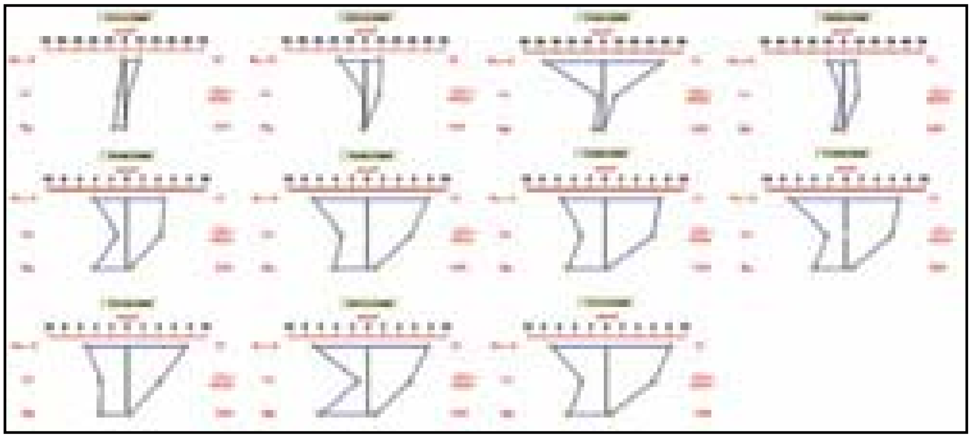

Figure 2.71 – Stiff Diagram of piezometric well waters (PAM 03) – Cangati River

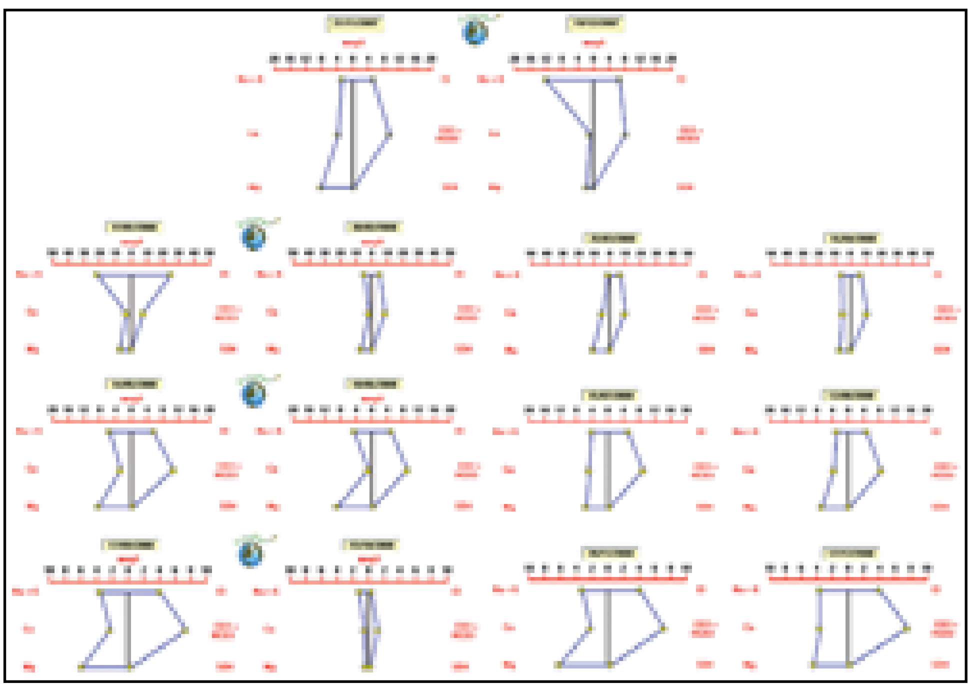

Figure 2.72 – Stiff Diagram of piezometric well waters (PAM 04) – Cangati River

c) Classification according to total dissolved solids (TDS)

Based on TDS estimated on electric conductivity, groundwater was classified for salinity (Table 2.44), according to the values shown in Table 2.23 (water classification according to TDS concentrations).

Table 2.44 – Classification of microbasin groundwater based on estimated TDS

Collection point	Date	CE	TDS (mg/L)	Classification
BS01 – Felão I	09/13/07	1127.0	733	Brackish water
	10/16/07	1089.9	708	Brackish water
	11/20/07	760.0	494	Fresh water
	12/18/07	1290.5	839	Brackish water
	03/25/08	656.0	426	Fresh water
	04/16/08	328.0	213	Fresh water
	05/14/08	526.0	342	Fresh water
	06/18/08	670.1	436	Fresh water
	07/16/08	659.0	428	Fresh water
	08/08/13	195.8	127	Fresh water
	09/17/08	975.8	634	Brackish water
	10/15/08	1618.8	1052	Brackish water
	11/20/08	1492.8	970	Brackish water
	12/17/08	2177.5	1415	Brackish water
BS02 – Felão II	09/14/07	1628.0	1058	Brackish water
	10/17/07	2889.9	1878	Salt water
	11/21/07	1027.0	668	Brackish water
	03/25/08	503.0	327	Fresh water
	04/16/08	544.0	354	Fresh water
	05/14/08	1224.0	796	Brackish water
	06/18/08	1079.4	702	Brackish water
	07/16/08	1242.0	807	Brackish water
	08/08/13	931.0	605	Brackish water
	09/17/08	1178.0	766	Brackish water
	10/15/08	1529.8	994	Brackish water
	11/20/08	1922.9	1250	Brackish water
BS03 – Salgadinho	06/18/08	1553.4	1010	Brackish water
	07/16/08	1604.0	1043	Brackish water
	08/13/08	1059.2	688	Brackish water
PAM 01	10/17/07	1536.6	999	Brackish water
	11/21/07	743.0	483	Fresh water
	12/19/07	1671.8	1087	Brackish water
	01/17/08	3814.9	2480	Salt water
	02/20/08	1607.0	1045	Brackish water
PAM 02	11/21/07	1847.0	1201	Brackish water
	12/19/07	2006.6	1304	Brackish water
	01/17/08	4406.2	2864	Salt water
	02/20/08	1789.0	1163	Brackish water

(continued)

(continuation)

Collection point	Date	CE	TDS (mg/L)	Classification
PAM 03	11/21/07	1111.0	722	Brackish water
	12/19/07	2325.9	1512	Salt water
	01/17/08	5087.2	3307	Salt water
	02/20/08	2020.0	1313	Brackish water
	06/18/08	1105.3	718	Brackish water
	07/15/08	1672.7	1087	Brackish water
	08/13/08	1599.8	1040	Brackish water
	09/17/08	1599.6	1040	Brackish water
	10/15/08	1364.4	887	Brackish water
	11/20/08	2149.5	1397	Brackish water
	12/17/08	2297.5	1493	Brackish water
PAM 04	11/21/07	1733.0	1126	Brackish water
	12/19/07	1889.3	1228	Brackish water
	01/17/08	3591.1	2334	Salt water
	02/20/08	1665.0	1082	Brackish water
	03/25/08	1912.0	1243	Brackish water
	04/16/08	2179.0	1416	Brackish water
	05/14/08	1978.0	1286	Brackish water
	06/18/08	1731.6	1126	Brackish water
	07/15/08	1797.8	1169	Brackish water
	08/13/08	1609.8	1046	Brackish water
	09/17/08	1439.7	936	Brackish water
	10/15/08	253.2	165	Fresh water
	11/20/08	1896.0	1232	Brackish water
	12/17/08	1943.1	1263	Brackish water

Based on Table 2.5.25, it can be concluded that in the microbasin, in general, groundwater associated with alluvial aquifers shows significant salt content, and their waters are classified as brackish (TDS: 500 - 1500 mg/L) in most of time. Only in two locations associated with underground dams (Felão I and II), there was an improved water quality under this criterion (fresh waters: < 500 mg/L), during recharge period (rainy season).

d) Classification of irrigation waters

As mentioned above in the equivalent topic in section about surface waters, this subproject tried to evaluate the water potential for creating soil conditions likely to restrict its use and its effect on crop yields. In this sense, an attempt was made to determine the level of restriction to the use of such waters, by classifying them for irrigation, according to USSL (U.S. Salinity Laboratory). This classification is based on sodium absorption ration (RAS) as an indicator of risk of soil alkalinization or sodification, as well as on water Electric Conductivity (EC), as in indicator of risk of soil salinization. Some classification diagrams based on such criteria are shown below (Figures 2.73 to 2.79).

It is interesting to note that, except for groundwater associated with underground dams, all others tend to present higher risks to irrigation after the rainy season, and reach their hazard peak in January. Underground dams apparently minimize their trend to increase concentrations in dry periods.

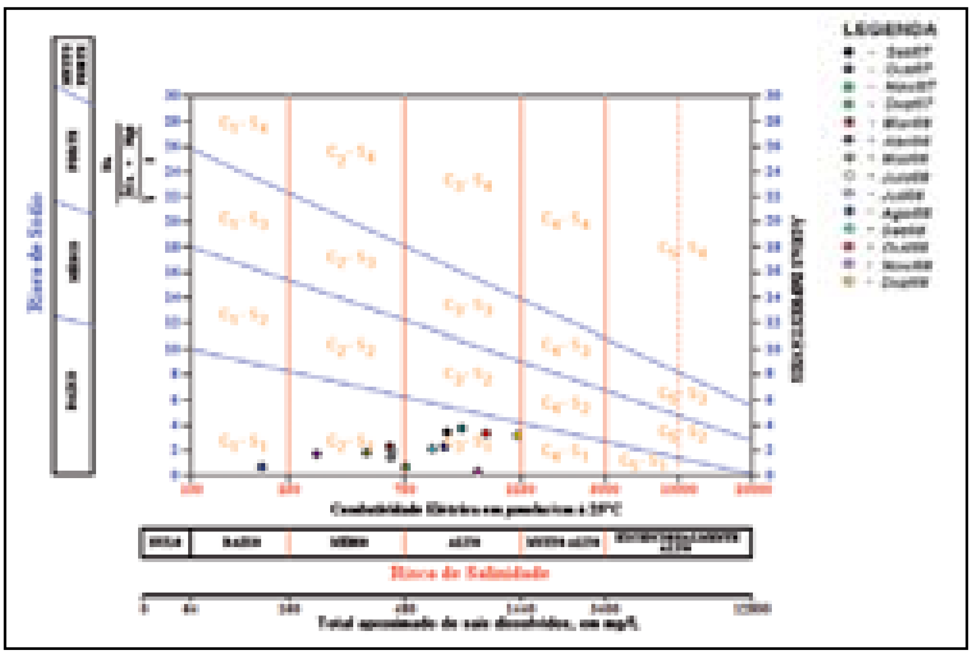

Figure 2.73 – Classification of Felão I U.D. waters for irrigation – Felão Stream.

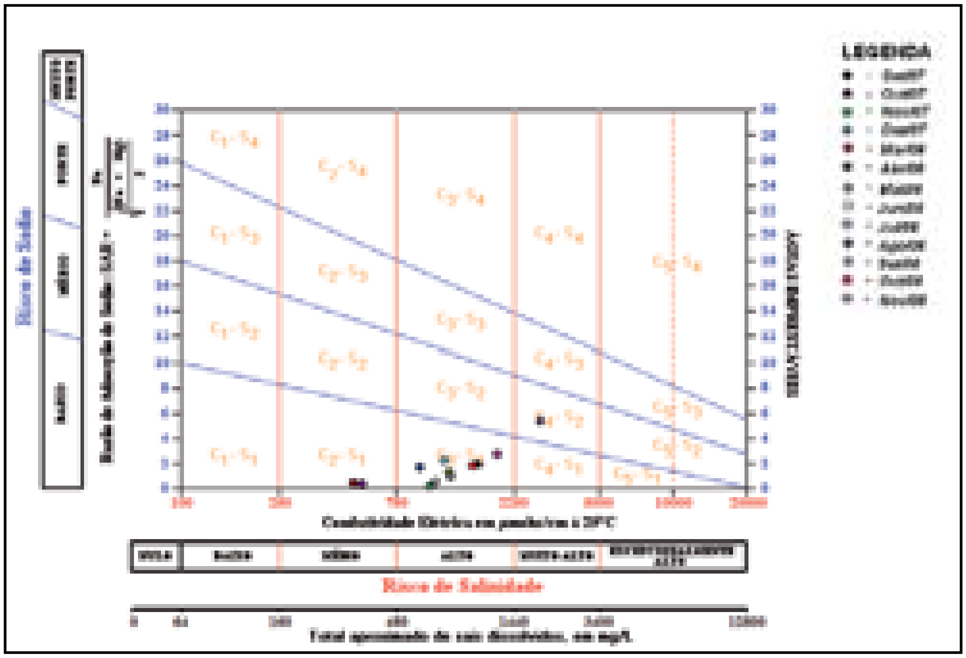

Figure 2.74 – Classification of Felão II U.D. waters for irrigation – Felão Stream.

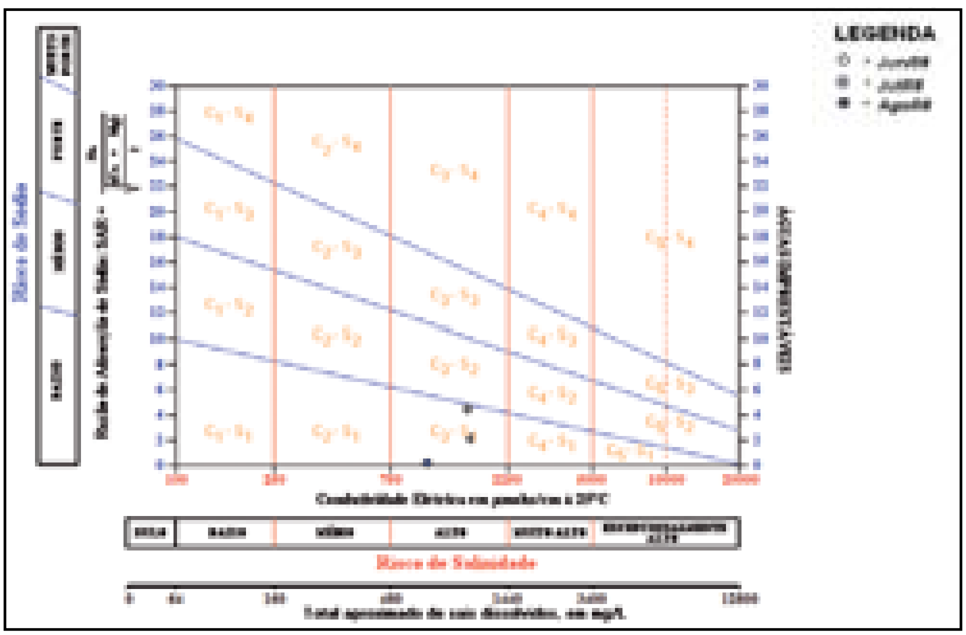

Figure 2.75 – Classification of waters of Salgadinho stream U.D. for irrigation

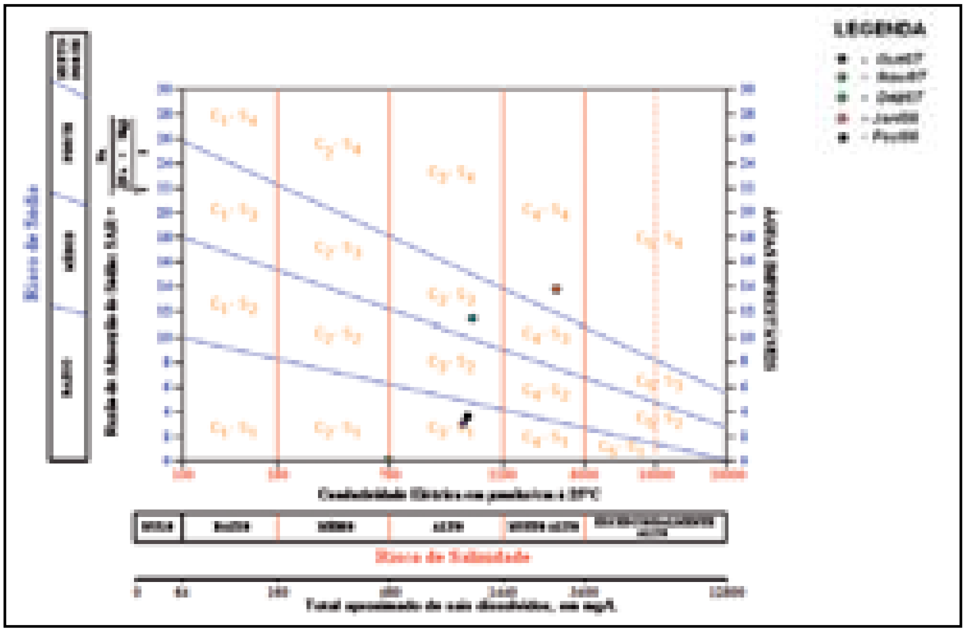

Figure 2.76 – Classification of piezometric well 01 (PAM 01) waters for irrigation - Cangati River

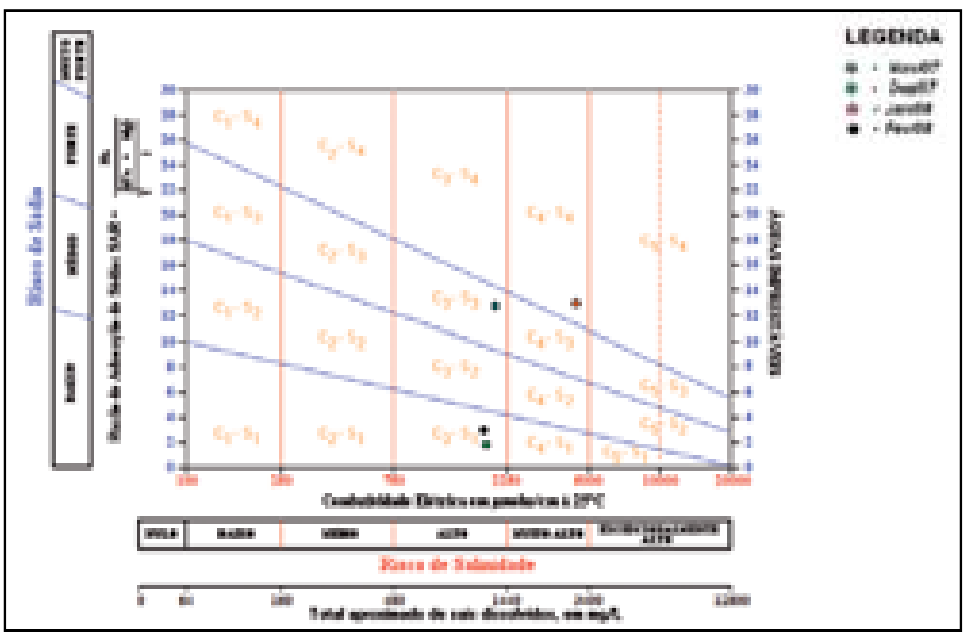

Figure 2.77 – Classification of piezometric well 02 (PAM 02) waters for irrigation - Cangati River

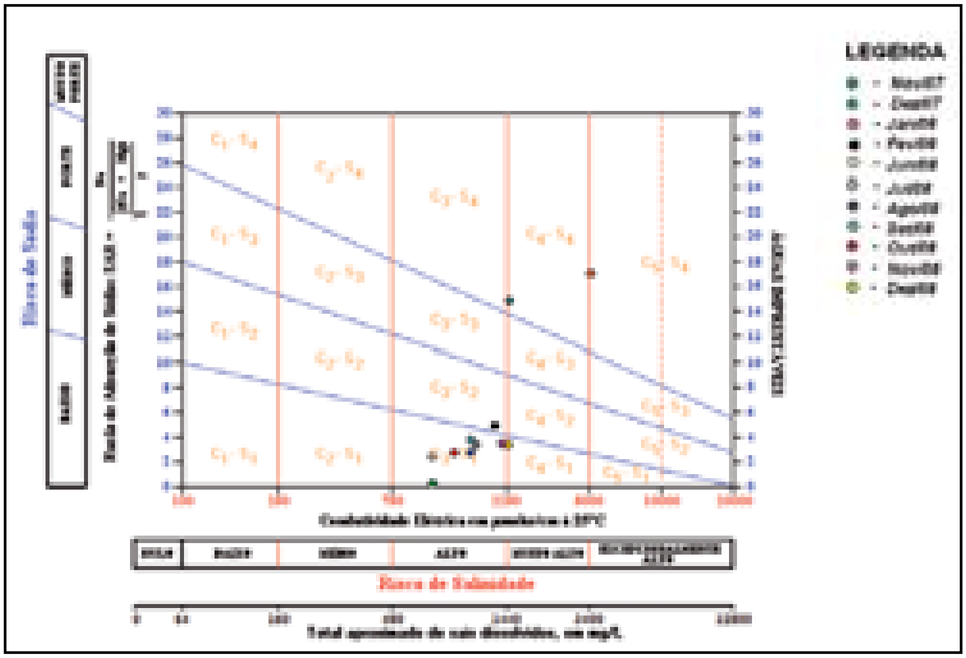

Figure 2.78 – Classification of piezometric well 03 (PAM 03) waters for irrigation - Cangati River

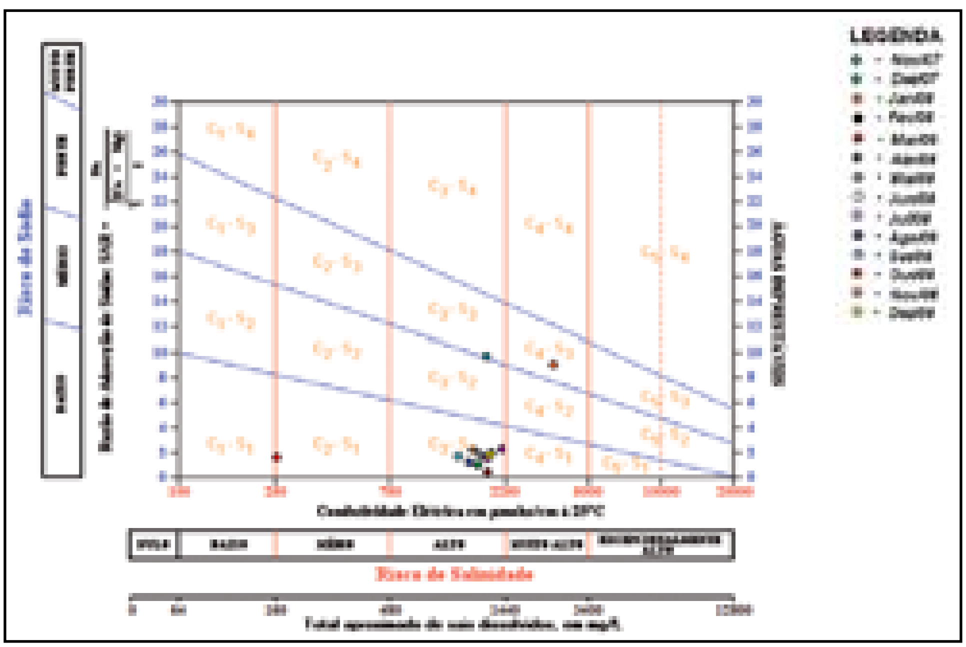

Figure 2.79 – Classification of piezometric well 04 (PAM 04) waters for irrigation - Cangati River

Classification of groundwater associated with dams, both in Felão stream (Figures 2.73 and 2.74) and Salgadinho stream (Figure 2.75), is predominantly C3-S1. Notwithstanding such waters display no harmful sodium content susceptible to exchanges, they show a high salinity and high total solid content typically above 480 mg/L, what causes restriction to their use for irrigation of many crops. Even though the soil (alluvium) has a very good natural drainage, the use of such waters is restricted only to vegetables of high saline tolerance, such as cotton, barley, spinach, etc. It is interesting to note that, during the rainy period, in Felão I underground dam (Figure 2.73 – March-June 2008 samples) there was a significant content dilution in such a way that all water samples collected in that period were classified as C2-S1, thus reducing the risk of salinization and increasing the range of vegetables in conditions to absorb such waters.

Waters from Cangati River water holes (Figures 2.76 to 2.79) also showed high salinity waters, what greatly restricted their use for irrigation. At the end of 2007 dry period (December 2007 and January 2008), samples showed salt concentration peaks, where sodium content likely to cause soil salinization was also extremely high.

2.5.1.3 – Temporal variability of physical-chemical parameters

In Brazil, like in the rest of the world, groundwater has been given an increasing importance as a source of residential, agricultural and industrial supply. Use of that resource has increased over the last decades, in part because of its advantages in connection with surface storage, and in part because of the increasing understanding of its occurrence and recharge and flow mechanisms. Another significant factor is the volume of fresh water accumulated in the subsoil, which accounts for some 97% of water resources available in the Earth (SILVA *et al,* 1955).

Although groundwater is naturally more protected against contaminating agents than surface waters, the considerable expansion of anthropic activities in both urban and rural areas has caused the pollution of aquifer systems, especially from landfills, industrial landfills, inadequate storage, handling and disposal of chemicals, effluents and waste, including the indiscriminate use of pesticides and fertilizers (TECHNOLOGICAL COMPANY..., 1997).

Resolution 396/2008 issued by the National Environmental Council (CONAMA), providing for the classification and environmental guidelines for classification, prevention and control of groundwater pollution, establishes parameters to be selected to support the proposed classification, which should be selected on the basis of predominant uses, hydrogeological and hydrochemical characteristics of pollution sources, and other technical criteria established by the relevant authority. Among the selected parameters, at least total dissolved solids, nitrate and thermotolerant coliforms should be considered.

Behavior of total dissolved soils in surveyed groundwater is shown in Figures 2.80 and 2.81. Except for Salgadinho dam – UD03, all aquifers included in the study exceed the maximum dissolved solid limit established by CONAMA Resolution no. 396/08 for groundwater. In some groundwater sources, a reduced concentration of dissolved solids in rainy period can be noted, probably due to aquifer recharge.

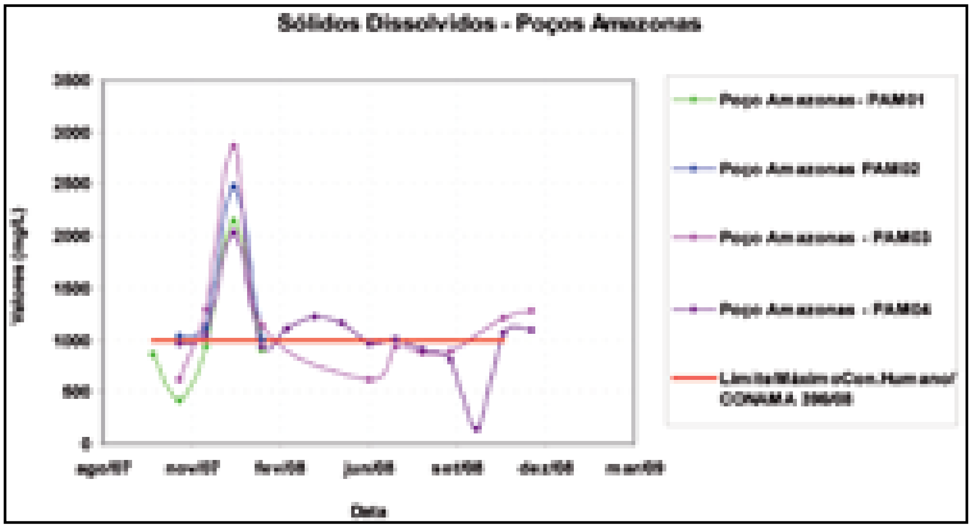

Figure 2.80 – Behavior of dissolved solids in piezometric wells

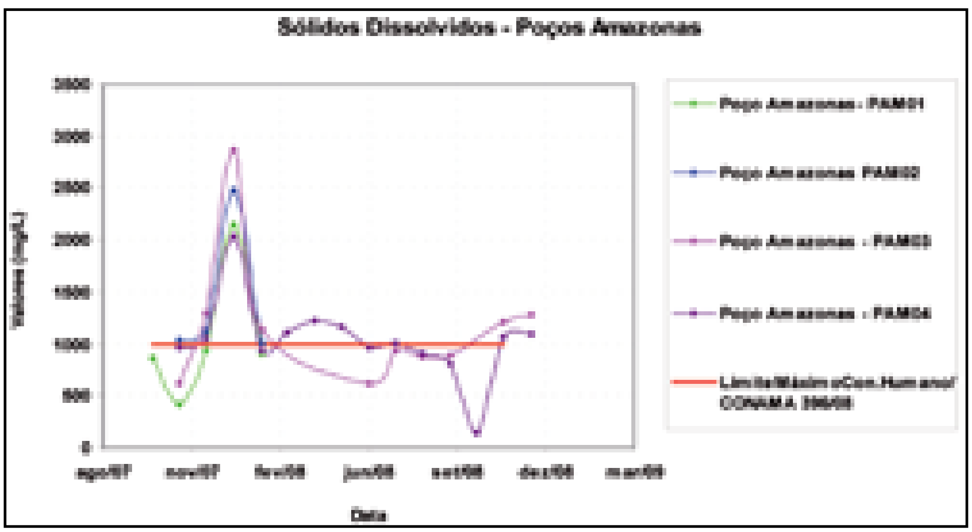

Figure 2.81 – Behavior of dissolved solids in underground dams

High dissolved solid concentrations may adversely affect water quality in several ways, both causing a bad taste or an unfavorable physiological reaction to the consumer (AMERICAN PUBLIC…, 1998). Nevertheless the American Public… (1998) establishes 500 mg/L as the desirable limit for human consumption, CONAMA Resolution no. 396/08 recommends a value up to 1000 mg/L.. When highly mineralized, waters are not either adequate for many industrial applications, according to the American Public… (1998).

Nitrate behavior in groundwater is shown in Figures 2.82 and 2.83. All samples analyzed are in conformity with human and animal consumption limits established by CONAMA Resolution no. 396/08 for groundwater.

Nitrates are highly soluble in water and have a great mobility in soils. In groundwater, nitrates generally occur at contents below 6 mg/L. Content exceeding that limit in groundwater is an indicative of pollution, as the result of direct surface water penetration or infiltration of polluted human activity waters in aquifers.

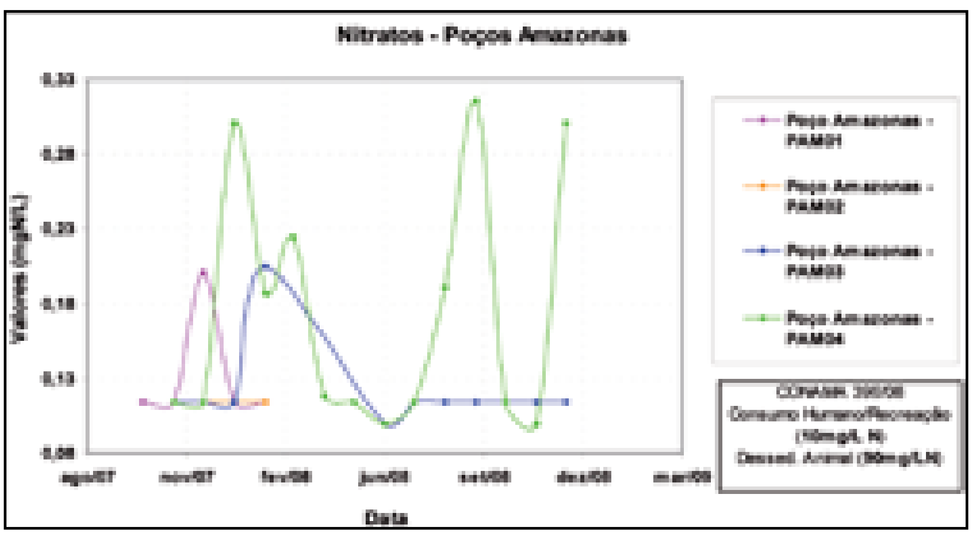

Figure 2.82 – Behavior of nitrate in piezometric wells

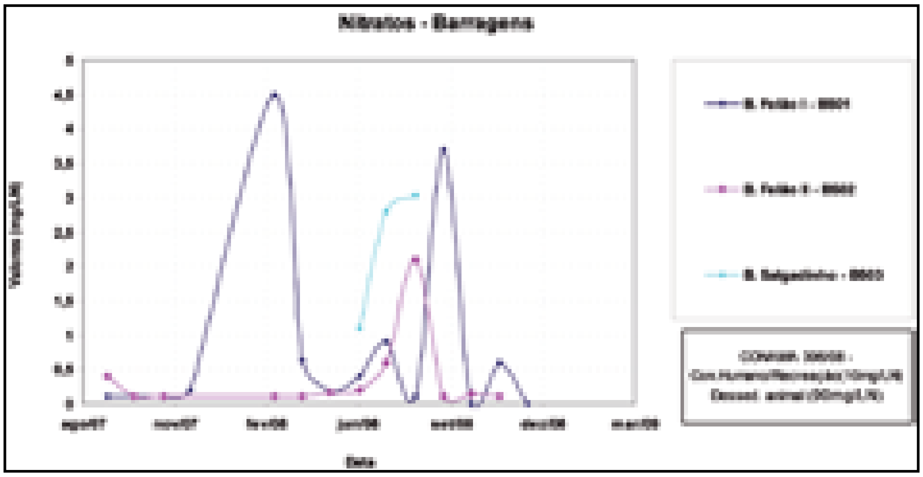

Figure 2.83 – Behavior of nitrate in underground dams

Because of its molecular stability, nitrate extraction is difficult, being therefore subtracted by reverse osmosis – what requires much energy and is impracticable in great quantities. By accepting contents above those permitted by law, nitrate becomes extremely harmful to human health and generates the "Blue Baby Syndrome (metahemoglobinemia) in babies up to three months old, according to Rodrigues and Pereira (2008).

Nitrite behavior in groundwater is shown in Figures 2.84 and 2.85.

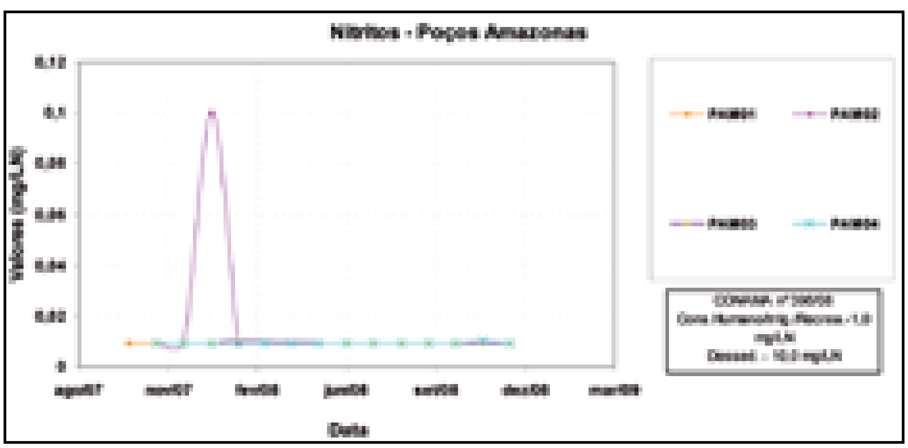

Figure 2.84 – Nitrite behavior piezometric wells

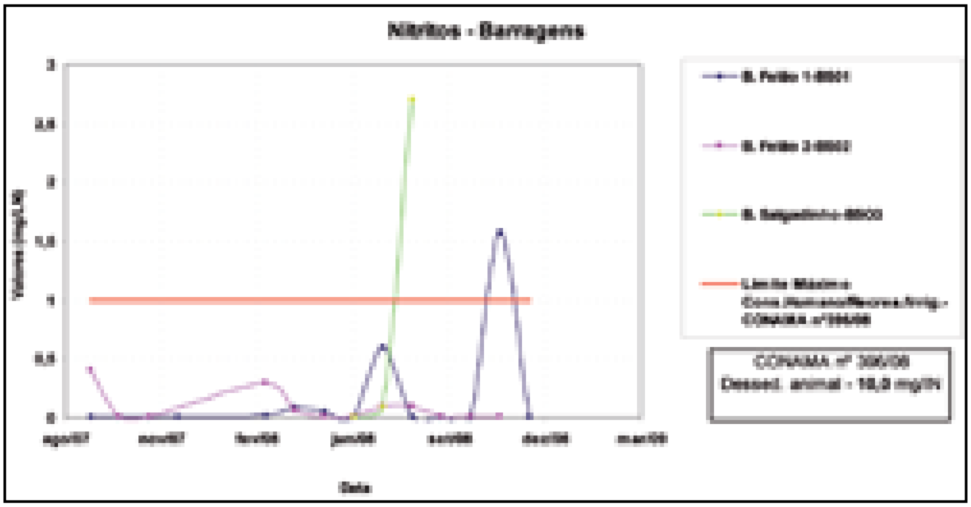

Figure 2.85 – Nitrite behavior in underground dams

Only Salgadinho dam – BS03 (2.5 mg/LN) exceeded the maximum nitrite value established by CONAMA Resolution no. 396/08 for human consumption, entertainment and irrigation, and was only below maximum values for animal consumption (10.0 mg/LN). All other aquifers showed nitrite contents well below the maximum limit for all uses established by the same Resolution.

Presence of nitrogen compounds at its different oxidation stages is an indicator of aquifer contamination and possible unsatisfactory hygienic-sanitary conditions. In addition to induction to methahemoglobinemia, another effect on health caused high nitrite and nitrate concentrations is associated with the potential formation of carcinogenic nitrosamines and nitrosamides, according to Alaburda and Nisihara (2010).

Behavior or thermotolerant coliforms in groundwater is shown in Figures 2.86 and 2.87. All collected samples failed to comply with human consumption standards (absence of thermotolerant coliforms) established by CONAMA Resolution no. 396/98 for groundwater. Felão I-BS01 and Felão II-BS02 dams exceeded the upper limits for entertainment and consumption, probably due to water renewal in rainy periods, which also causes the ingress of pollutants, even having the soil as a barrier against the ingress of microbial contamination.

Soil plays an important role in retention of microorganisms through physical and chemical environmental factors that affect infiltration and transportation of microorganisms to the water table (MARTINS *et al.*, 1991).

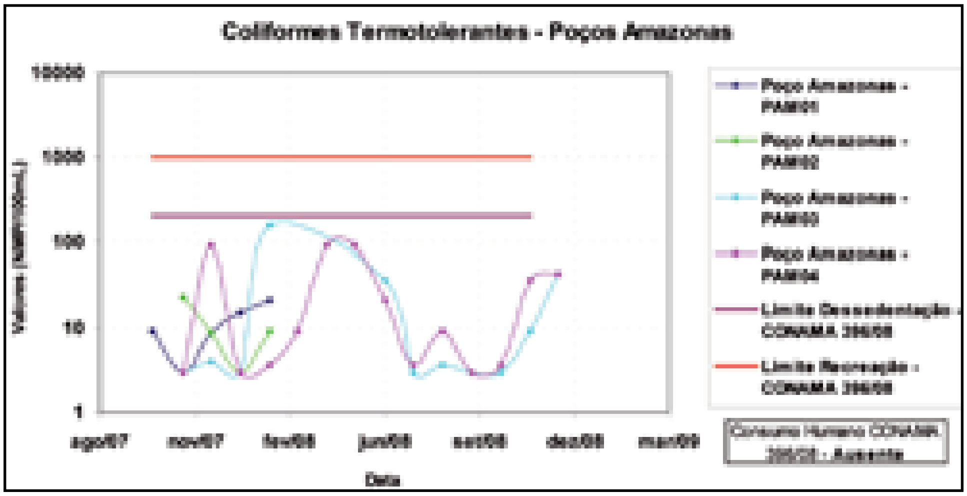

Figure 2.86 – Behavior or thermotolerant coliforms in piezometric wells.

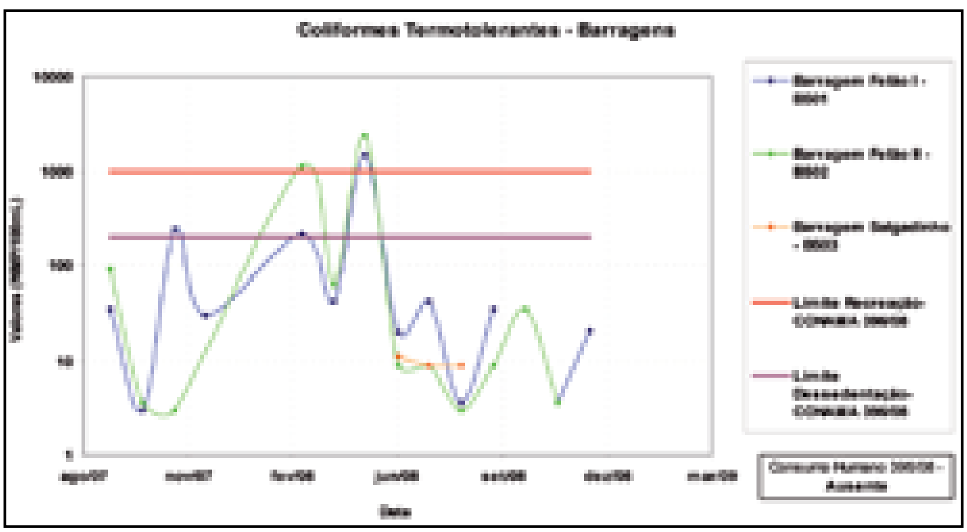

Figure 2.87 – Behavior or thermotolerant coliforms in underground dams

Several factors likely to endanger groundwater quality. Final residential and industrial sewage destination in cesspools and septic tanks, the inadequate disposal of urban and industrial solid waste, gas stations and car washes, and the agricultural modernization constitute sources of groundwater contamination by bacteria and pathogens, parasites, and organic and inorganic substances (SILVA, ARAUJO, 2010).

According to OPS (2000), cited by Silva and Araujo (2010), some 20% of emerging countries' population is provided with septic tanks or other on-site treatment to protect their house's healthfulness. Such techniques, however, could enable the release of pathogens that infiltrate and may reach groundwater, thus endangering the health of neighbors who consume water from that source.

2.5.2 – Evaluation of water behavior in underground dams

Period of potentiometric level analysis was too short for a more conclusive evaluation of groundwater behavior in alluvial aquifers, and therefore all remarks made in this document are subject to reevaluation in light of new data on such aquifers.

First, water behavior in alluvial aquifers was evaluated for feeding from rains, diffuse surface infiltration, especially along the respective stream channels (surface runoff). For that, precipitation data generated by Thiessen's polygons for three stations close to microbasin were used, namely: Bonito, Cachoeira and Esperança stations (Figure 2.88). Precipitation data collected from pluviometers in fluviometric stations (Salgadinho and Gatos streams) were also used, notwithstanding the short sampling period. Precipitation values (mm) organized in the same observation period of potentiometric levels of wells are shown in Table 2.45, and as monthly totals in Figure 2.89. Figures 2.90 to 2.93 shows water levels observed and rain distribution at each reading period.

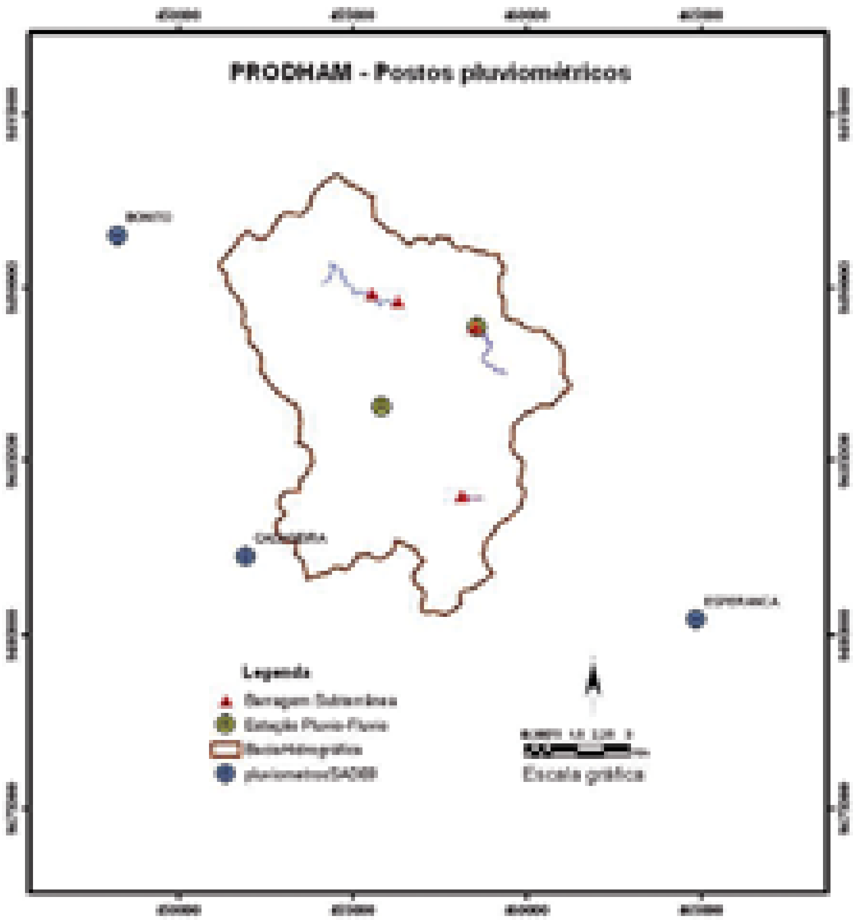

Figure 2.88 – Location of pluviometric stations in surveyed region.

Table 2.45 – Precipitation data related to Cangati River hydrographic microbasin.

Month	Monthly Precipitation (mm)	Reading Date	Precipitation in the period (mm)
January	57.02	01/01/08	0
		01/17/08	0
February	52.23	02/07/08	65.47
		02/27/08	31.27
March	341.03	03/17/08	109.71
April	187.83	04/01/08	243.83
		04/09/08	114.52
		04/15/08	21.16
		04/22/08	20.64
		04/30/08	13.09

(continued)

(continuation)

Month	Monthly Precipitation (mm)	Reading Date	Precipitation in the period (mm)
May	133.79	05/08/08	41.54
		05/16/08	55.28
		05/23/08	31.69
		05/30/08	16.4
June	17.18	06/06/08	7.29
		06/13/08	13.86
		06/22/08	3.32
		06/28/08	0
July	0	07/04/08	0
		07/16/08	0
		07/23/08	0
August	5.74	08/02/08	0
		08/08/08	0
		08/15/08	5.74
		08/22/08	0
		08/29/08	0
September	0	09/06/08	0
		09/12/08	0
		09/19/08	0
		09/28/08	0
October	0	10/05/08	0
		10/11/08	0
		10/20/08	0
		10/27/08	0
November	0	11/10/08	0
		11/30/08	0
December	1.28	12/31/08	1.28
Total – 2008			**796.09**

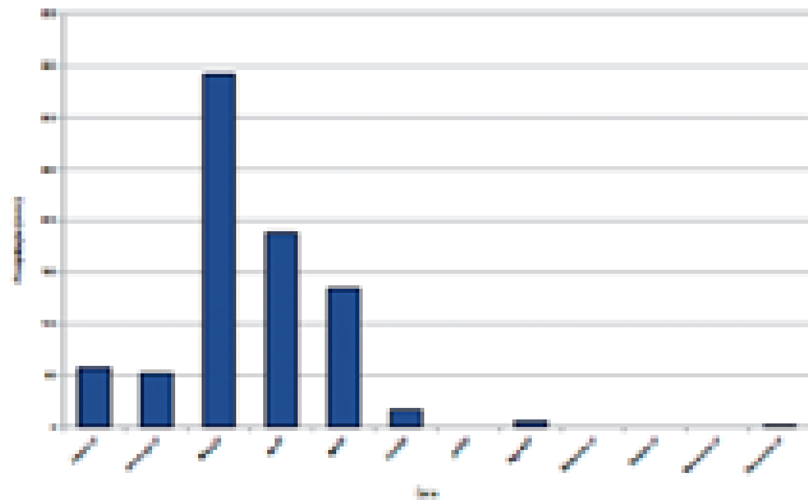

Figure 2.89 – Precipitation in Cangati River microbasin – 2008 (generated).

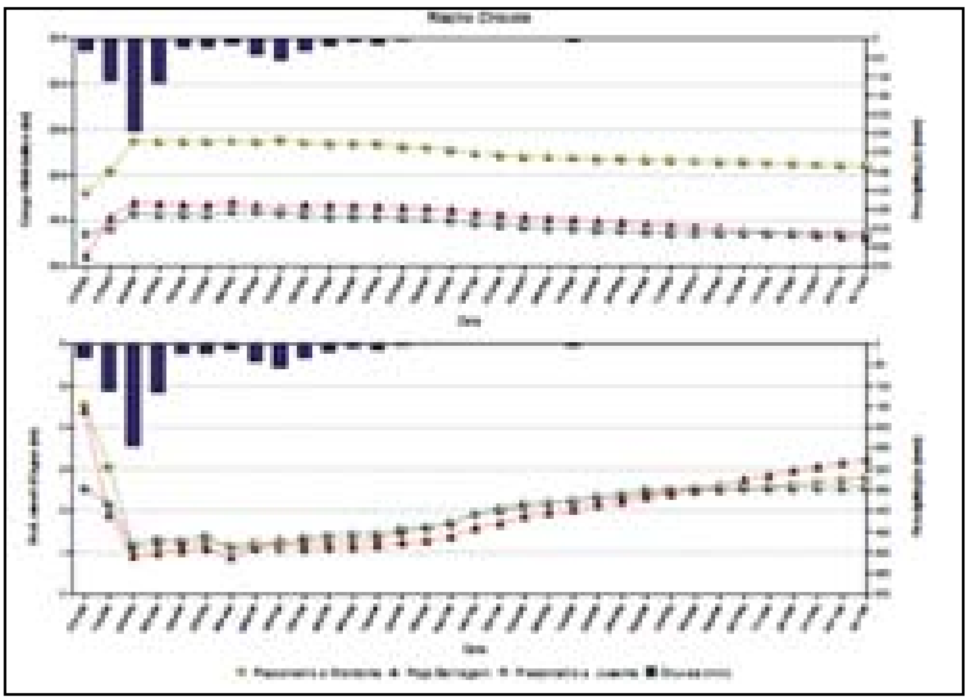

Figure 2.90 – Water Levels & Precipitation: U.D. in Chicote stream

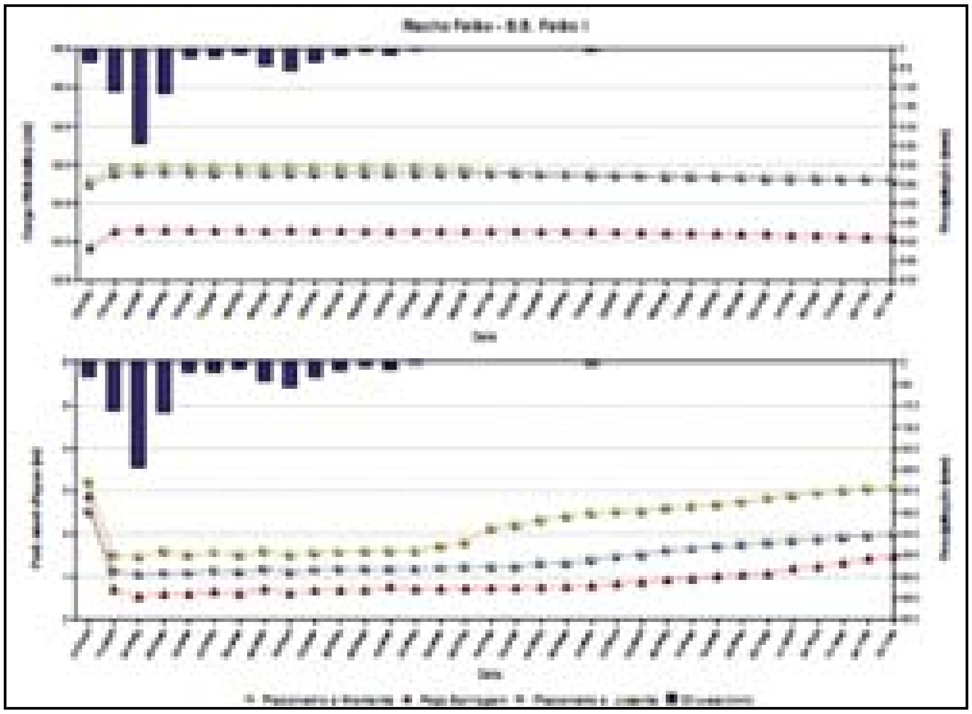

Figure 2.91 – Water Levels & Precipitation: Felão I U.D. - Felão stream

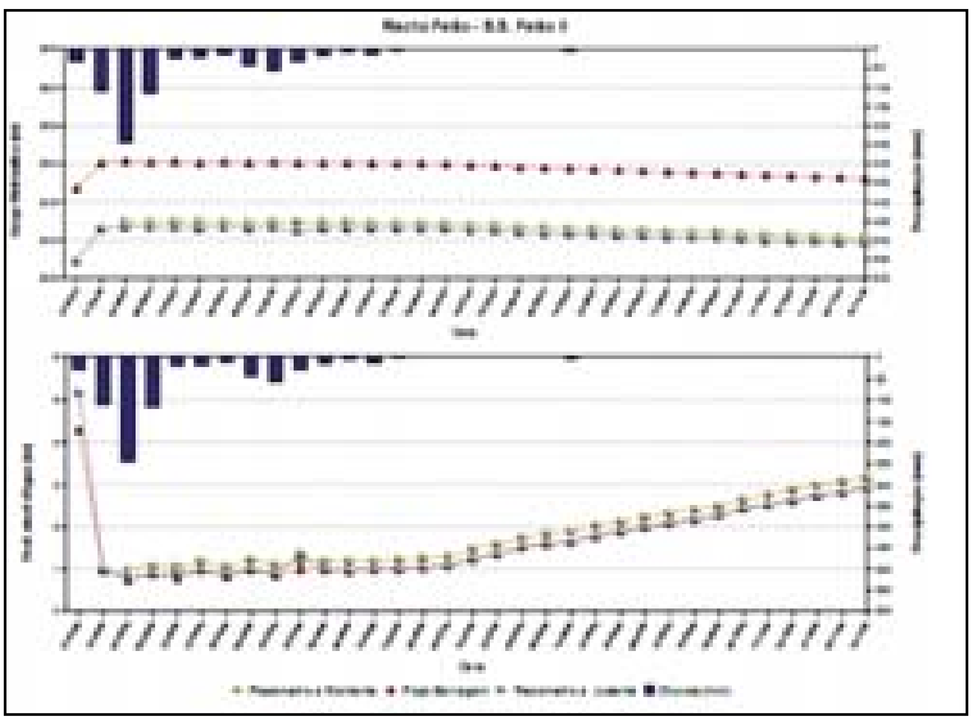

Figure 2.92 – Water Levels & Precipitation: Felão II U.D. - Felão stream

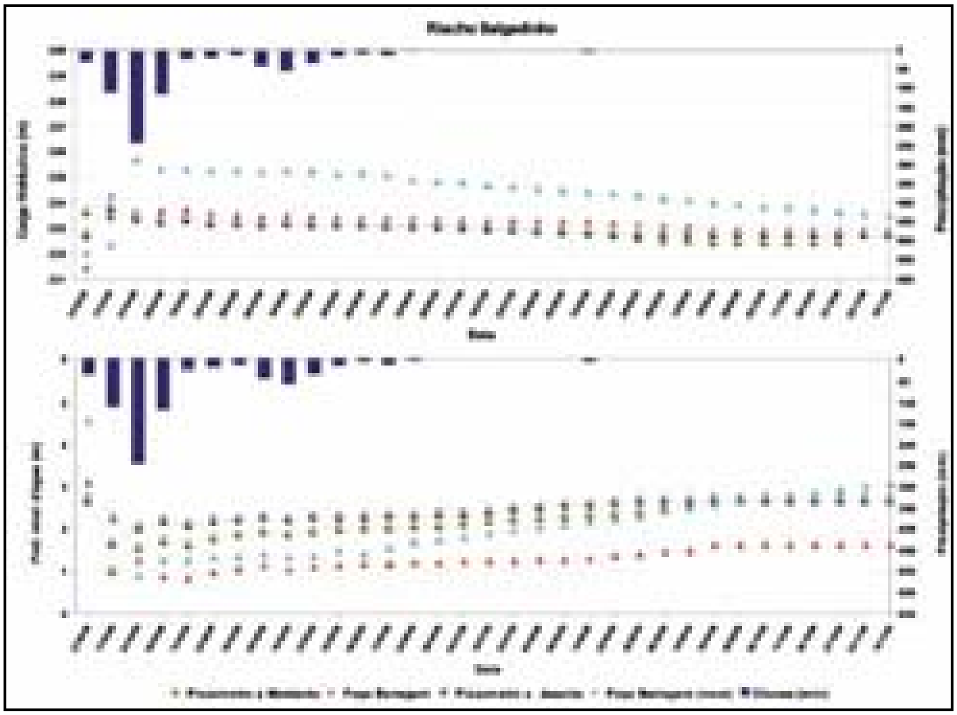

Figure 2.93 – Water Levels & Precipitation: Salgadinho stream U.D.

Based on data provided above, significant level variations in monitored wells were noted during the short monitoring period. Table 2.46 shows extreme values (maximum and minimum) measured in each observation point.

Table 2.46 – Extreme depth values measured in observation points

Observation Point	Maximum Depth (m)	Date	Minimum Depth (m)	Date	Variation (m)
Chicote – Upst. Piezometer	4,555	02/27/08	1.065	05/16/08	3.490
Chicote – Dam Well	4,415	02/27/08	0.885	04/30/08	**3.530**
Chicote – Downst. Piezometer	2,555	02/27/08	1.135	04/30/08	1.420
Felão I – Upst. Piezometer	3,215	02/27/08	1.465	04/01/08	1.750
Felão I – Dam Well	2,895	02/27/08	0.535	04/01/08	**2.360**
Felão I – Downst. Piezometer	2,545	02/27/08	1.065	04/01/08	1.480

(continued)

(continuation)

Observation Point	Maximum Depth (m)	Date	Minimum Depth (m)	Date	Variation (m)
Felão II – Upst. Piezometer	3,190*1	11/10/08	1.000	04/01/08	2.190
Felão II – Dam Well	4,305	02/27/08	0.735	04/01/08	**3.570**
Felão II – Downst. Piezometer	5,195	02/27/08	0.835	04/01/08	4.360
Salgadinho – Upst. Piezometer	2,725*2	02/27/08	0.985	03/17/08	1.740
Salgadinho – New dam well	3,58*4	02/27/08	0.915	04/01/08	**2.67**
Salgadinho – Downst. Piezometer.	2,675*3	02/27/08	1.635	03/17/08	1.040
Salgadinho – Old dam well	3,110*5	02/27/08	0.835	04/15/08	**2.275**

*1, *2 , *3, *4, *5 – See paragraph below

Values in bold in Table 2.46 show oscillations noted in groundwater wells. It should be pointed out that level variation in piezometer upstream to Felão II U.D. (*1) possibly was higher, as data for the period immediately before 2008 rainy period are missing. Salgadinho stream U.D. aquifer was the only to present, at the end of monitoring period, in both upstream (*2) and downstream (*3) piezometers, a return to level conditions recorded at monitoring start, what appear to indicate the low efficiency of such underground dams as water storage works. It should be stressed that this area underwent significant changes caused by the construction of the new underground dam. During 2008 rainy period (February-June), because to the great water flow in Salgadinho stream channel, associated with heavy rains, there was a significant increase of sedimentary package in dam region, which disguised water level depth in subsequent periods (*4 and *5) (change to reference plan).

In general, in underground dams water level oscillations almost always were higher upstream, but behavior over the time was quite similar for all monitored structures (both upstream and downstream to dams). Table 2.47 shows the percentage of such oscillations in alluvial package thickness in the respective underground dam region.

Table 2.47 – Water head (variation) x alluvium thickness in underground dams. Period: February – November 2008

Well Observation	Water level variation (m)	Estimated local alluvium thickness (m)	Percentage(%)
Chicote stream	3.5	4.5	78%
Felão stream – Felão I	2.4	4.6	55%
Felão stream – Felão II	3.5	3.7	95%
Salgadinho stream – New U.D.	2.6	2.7	96%
Salgadinho stream – Old U.D.	2.2	2.3	96%

It is noted that, except for Felão I, all others U.D. showed a saturation above 80% of sedimentary package. According to information, Felão I underground dam always had leakage problems that did not allow groundwater storage for extended dry periods.

During groundwater monitoring associated with underground dams, well (water holes) were also monitored in other alluvial aquifers. Such wells are the same where water samples were collected for qualitative groundwater monitoring. Monitoring of four (4) wells started, but for technical reasons it was completed in only two (2) wells. Such wells correspond to PAM-02 and PAM-04 points (Figure 2.58). Activities to record water levels in those wells started in march 2008 and ended in October of the same year. Figure 2.94 shows groundwater behavior levels and precipitation during the same observation periods of graphs previously shown.

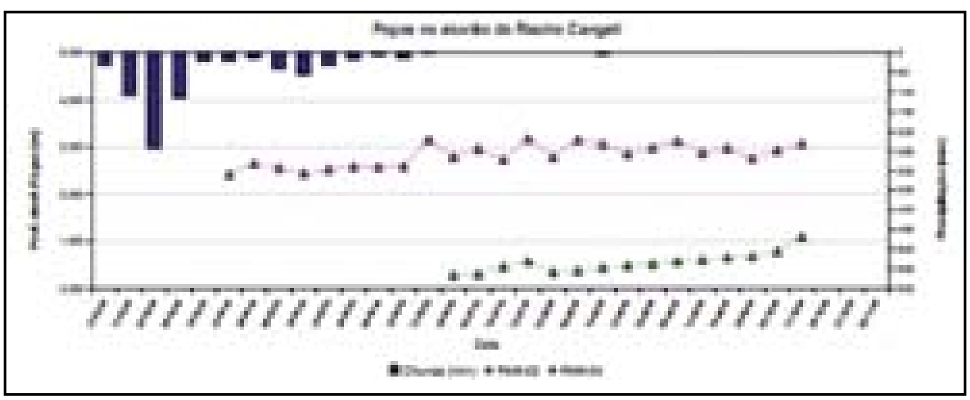

Figure 2.94 – Water Levels & Precipitation in PAM-02 and PAM-04 wells: Cangati River.

It is noted that water level fluctuations, especially in PAM-04 well, are more accentuated that those noted in underground dam wells. As there were no rains in most accentuated peak period, and there are no regulating reservoirs upstream, it appears that it was due to irrigation water pumping. Table 2.48 shows the maximum variations observed in such two wells, and the maximum oscillations observed in wells associated with underground dams in that same period. Except for Felão I underground dam (as mentioned above) and the old Salgadinho underground dam, all other dams showed a higher water level lowering rate in that period. The storage capacity of underground dam in Salgadinho stream, herein referred to as old dam, was seriously affected by the construction of another underground dam 400 m upstream in April 2008.

Table 2.48 – Water head variations in wells. Period: April-October 2008.

Observation well	Water level variation
PAM-02	0.81
PAM-04	0.76
Chicote stream	2.36
Felão stream – Felão I	0.89
Felão stream – Felão II	2.16
Salgadinho stream – New U.D.	1.75
Salgadinho stream – Old U.D.	0.67

2.5.3 – Evaluation of underground dams and associated alluvial aquifers.

Based on information obtained from drilling works (item 2.4.2.1), it was possible to estimate a 3D model for each of alluvial sections associated with the four underground dams (Figures 2.95 to 2.97).

3-D models (block diagrams) of alluvial bodies allowed sediment volumes in each block diagram to be estimated. Table 2.49 shows those volumes. It is noted that, notwithstanding the alluvial package associated with the underground dam in Salgadinho stream is almost three times the alluvial area of Chicote stream underground dam, stored volume in the latter is proportionally higher. In this aspect, Chicote and Felão stream alluviums show characteristics that are more favorable to groundwater storage.

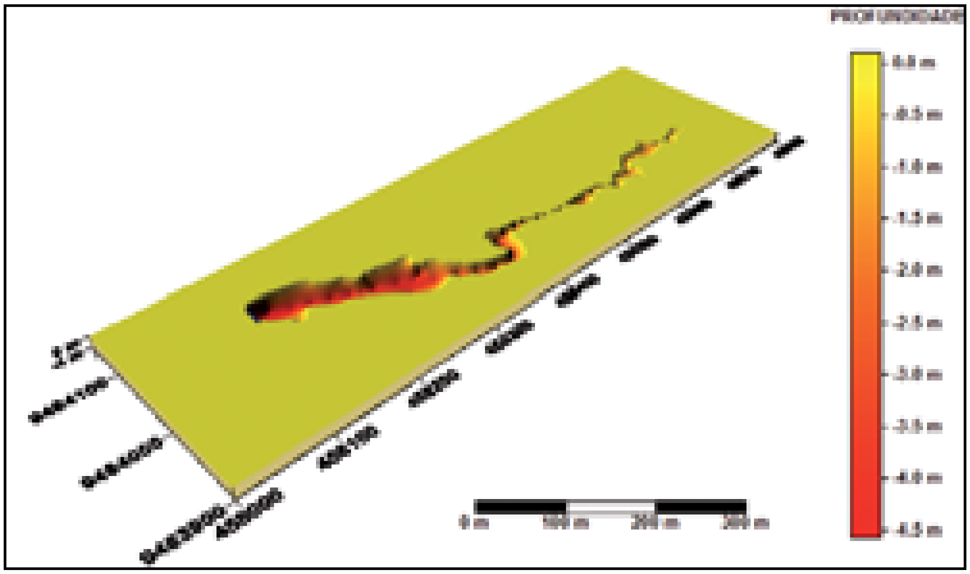

Figure 2.95 – Block diagram of alluvium associated with underground dam in Chicote stream.

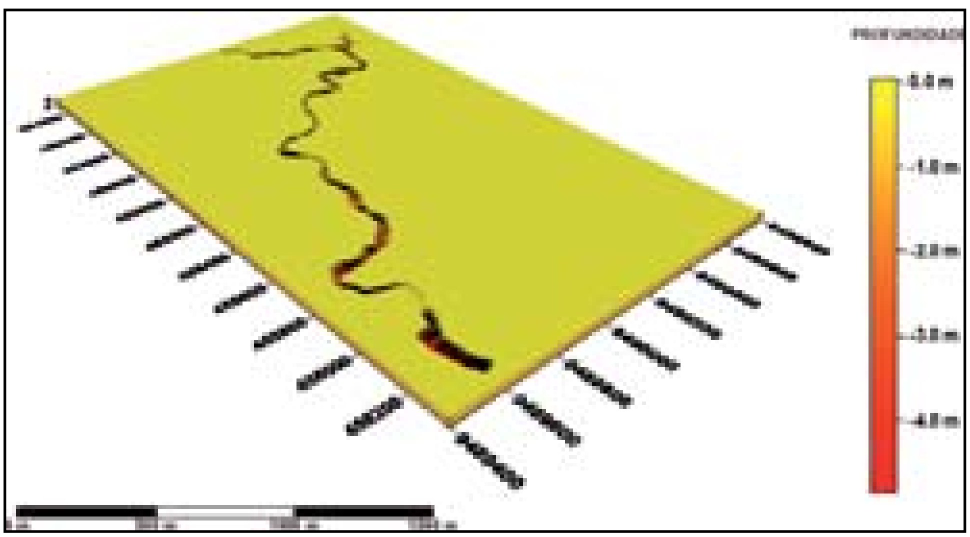

Figure 2.96 – Block diagram of alluvium associated with underground dams in Felão stream.

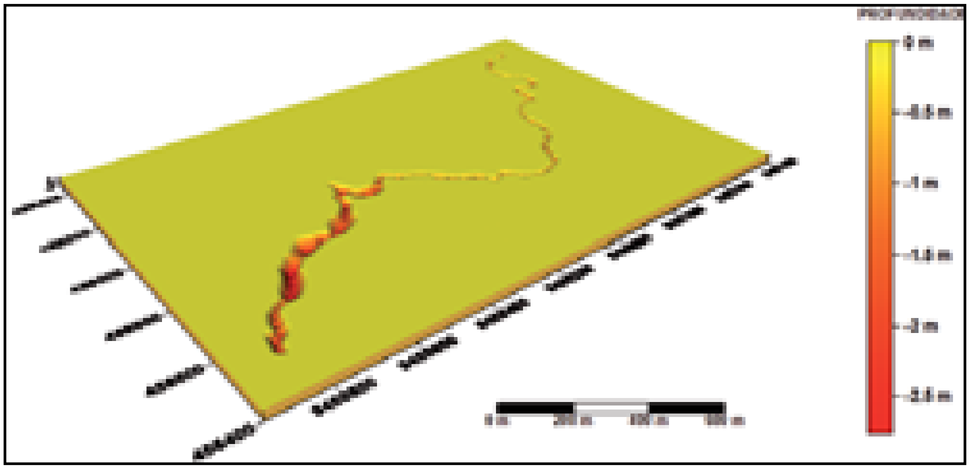

Figure 2.97 – Block diagram of alluvium associated with underground dam in Salgadinho stream.

Table 2.49 – Area x Volume of sediments associated with alluvial packages in underground dams.

Alluvium	(A) Area -m²	(V) Sediment Volume - m³	(V)/(A)
Chicote stream	13,231.59	27.494.10	2.07
Felão stream	75,836.44	162,826.25	2.15
Salgadinho stream	39,250.67	47,307.87	1.21

Based on altimetry data, it was possible to obtain, in addition to surface plan (top heights), the heights of drilling bases. Such data allowed the package declivity gradient to be evaluated, and therefore the lake surface area of underground dams to be estimated at their top heights.

Figure 2.98 (a) shows the behavior of water levels exclusively in relation to Chicote stream underground dam, the height of which (depth) was estimated in 4.5m. Saturated area is relatively small, showing a reduced storage capacity. This is due to the accentuated soil declivity in this region, as highlighted in Figure 2.98 (b). It should be remembered, however, that lithology predominated in this portion is medium to coarse sand, what ensures an excellent effective porosity.

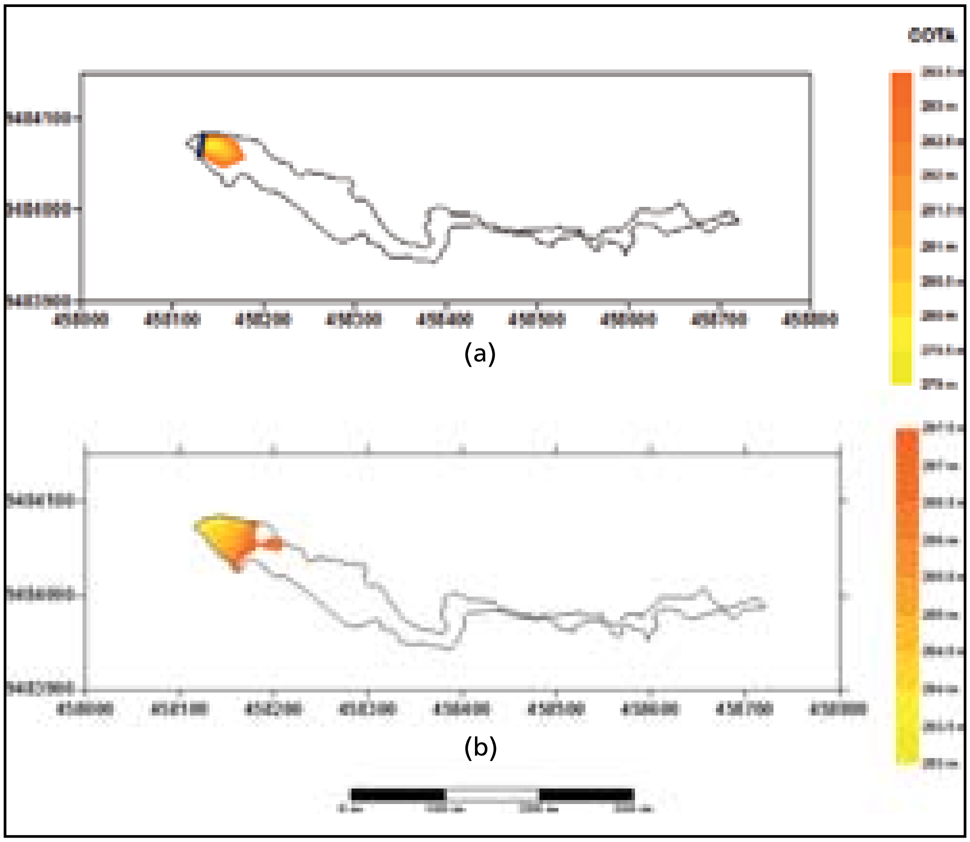

Figure 2.98 – Lake (a) and soil heights (b) in the location of underground dam in Chicote stream

Based on that approach, it is possible to estimate the water volume that could be stored exclusively in terms of underground dam. For that, a permeability of some 10% was estimated, which is considered representative for alluvial sediments, but excessively conservative for the situation under analysis as already mentioned for the predominating lithologic type in this alluvium section. Data are shown in Table 2.50. Such values evidence the small storage capacity of the underground dam at issue.

Table 2.50 – Estimated volumes of sediments associated with the underground dam in Chicote stream (H=4.5 m).

Target	Surface Area – m²	Sediment Volume – m³	Estimated effective porosity (%)	Storage capacity (m³)
Alluvium – whole section	13,231.59	27,494.10		-
Alluvium – hydraulic basin	1,409.18	2,482.38	10%	248.23

Figure 2.96 clearly shows that there is a hydraulic independence between both underground dams in Felão stream (Felão I and II), in spite of their proximity to ach other. Figure 2.00 shows the water level behavior exclusively in relation to both underground dams. To estimate the hydraulic basin of Felão I and Felão II underground dams, dam heights of 4.5 m and 3.5, respectively were considered.

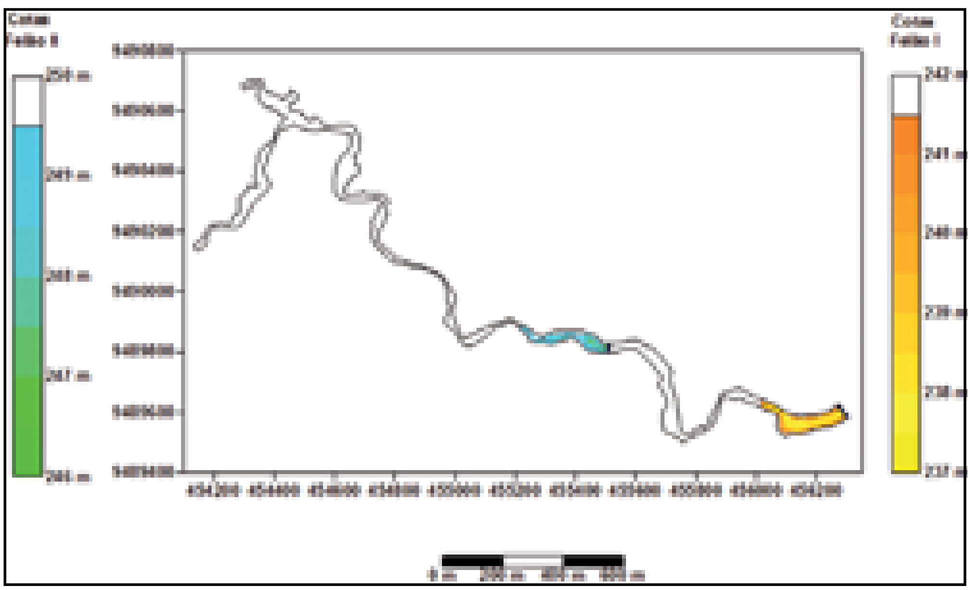

Figure 2.99 – Lake (hydraulic basin) of underground dams (Felão I and Felão II) in Felão stream.

Resulting maps allowed volumes of sediments involved in each of dams to be estimated. Such data are provided in Table 2.51 and show that, notwithstanding the proximity between the works, Felão II dam is located in an area where the topographic gradient is more accentuated that the downstream dam area, which results in a less thick sedimentary package and a smaller lake. This is also reflected in the smaller storage capacity of Felão II dam, as compared to Felão I dam.

Table 2.51 – Estimated volumes of sediments associated with the underground dam in Felão stream ($H_{FELÃO\ I}$ = 4.5 m; $H_{FELÃO\ II}$ = 3.55 m)

Target	Surface Area – m^2	Sediment Volume – m^3	Estimated effective porosity (%)	Storage capacity (m^3)
Alluvium – whole section	75,836.44	162,827,43		-
Hydraulic basin – Felão I	11,557.22	24,804,74	10%	2,480.04
Hydraulic basin – Felão II	7,306.58	8,693.04	10%	869.30

In Salgadinho stream underground dam, the behavior of water levels in both dams (old and new dams) was simulated. Figure 2.100 shows the result of those assumptions. It can be noted in that Figure that the newest dam apparently is out of the domain (hydraulic basin) of the older dam.

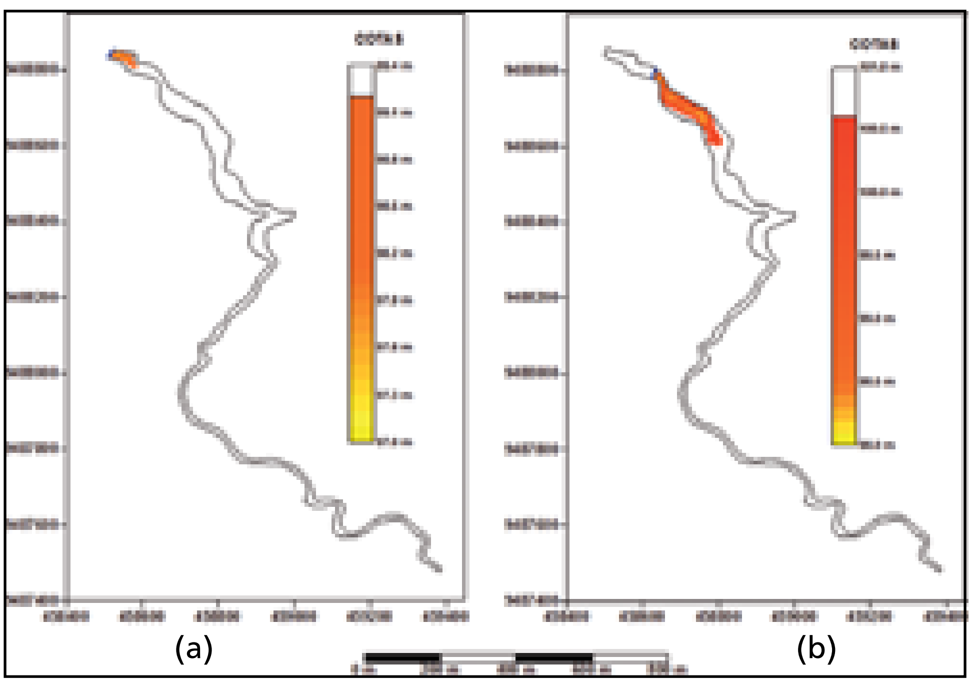

Figure 2.100 – Lake (hydraulic basin) of old (a) and new (b) underground dams in Salgadinho stream

Table 2.52 shows the volumes of sediments associated with both underground dams and, consequently, provides an estimate of volume possible to stored in each of such dams. The older dam is 2.2-m high, while the new dam is 2.5-m high. It is noted that the volume associated with the new dam is almost ten times greater than that of the old dam.

Table 2.52 – Estimated volume of sediments associated with underground dams in Salgadinho Stream (H_{OLD} = 2. 2m; H_{NEW} = 2.5 m).

Target	Surface Area – m^2	Sediment Volume – m^3	Estimated effective porosity (%)	Storage capacity (m^3)
Alluvium – whole section	39,250.67	47,307.87		-
Hydraulic basin – Old U.D.	1,296.38	794.72	10%	79.47
Hydraulic basin – New U.D.	7,876.29	7,619.67	10%	761.96

2.6 – Hydrogeological Modeling

2.6.1 – Surface Hydrology Modeling

The role of hydrologic modeling tools in this study is to support the subproject multidisciplinary team with respect to specific aspects of interpretation of hydrological and water quality data obtained during biophysical monitoring.

2.6.1.1 – Objectives and scope

The main objective of mathematic modeling activity related to surface hydrology is to reconstitute liquid and solid flows in control sections of interest of hydrographic sub-basins.

The adopted strategy was the intensive monitoring of two (02) microbasins using the flow measuring flumes designed and constructed in representative sub-basins, eventual campaigns for flow measurement in streams, and the integration of such data with the help of deterministic rain-discharge transformation models.

The scope of this activity is restricted to numeric simulation tools used to estimate surface runoff, water balance in reservoirs, as well as the indirect quantification of mass flows kin selected microbasins. Whenever possible, estimates obtained from models were compared to available data. Where no observation data were available in a specific control section, the magnitude of numeric values resulting from any simulation was always estimated by the previous experience of participating hydrologists and the scientific literature available.

2.6.1.2 - Climatology

Cangati River microbasin presents the climate type BSw'h' of Köppen's classification (1918). That is a region that is part of dry semiarid climate group, with a small humid season that allows the development of underbrush and shrubby vegetation, and where the driest period occurs in winter and the highest precipitation occurs in Autumn. Annual average temperature and the coldest month temperature are equal of above 20.0°C (Table 2.53). According to Thornthwaite's classification (1948), the microbasin is located in a region where the climate type is DdA'a'. This is characterized by a semiarid, megathermal climate with small or no excess water, where the concentration of three summer months accounts for 29.0% of potential normal evaporation.

Table 2.53 – Normal climatology in Cangati River microbasin

Month	Temperature (°C)			Relative Humidity (%)	Wind speed (m/sec)	Precipitation .(mm)	Nebulos. (0-10)	Insolation (h/month)
	Maximum	Minimum	Average					
Jan	33.7	23.1	27.5	73	2,8	50,5	5,3	205,1
Feb	32.6	22.8	26.8	79	2,6	100,0	5,8	167,4
Mar	31.7	22.8	26.5	84	2,3	167,8	6,5	150,5
Apr	31.4	22.6	26.3	85	1,7	155,4	6,3	166,3
May	31.7	22.2	26.4	83	1,7	96,0	4,9	204,6
Jun	32.2	21.6	26.3	78	2,0	46,8	4,2	218,9
Jul	32.9	21.5	26.5	72	2,5	26,9	4,0	246,4
Aug	34.3	21.9	27.2	66	2,7	7,6	3,1	271,9

(continued)

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Month	Temperature (°C)			Relative Humidity (%)	Wind speed (m/sec)	Precipitation .(mm)	Nebulos. (0-10)	Insolation (h/month)
	Maximum	Minimum	Average					
Sep	34.8	22.3	27.4	65	3,7	3,7	3,2	262,8
Oct	35.3	22.6	27.8	66	3,3	6,4	3,2	271,1
Nov	35.0	22.8	27.9	66	2,8	10,9	3,5	269,6
Dec	35.0	23.1	28.2	69	2,8	23,1	4,2	247,3
Annual						**695.0**		**2,681.9**

Cangati River microbasin has a high incidence of solar radiation, a daytime temperature variation of some 10ºC, annual average relative air humidity close to 68%, extremely variable precipitation, and high evaporation rate. Maximum historic average temperature is 35.3°C, which occurs in October (Figure 2.101). Annual average precipitation is 695 mm, with a variation ratio of 0.42 for normal annual historic series in 1961-1990 period. On the other hand, 74.6% of total precipitation concentrates in the four-month period of February-March-April-May.

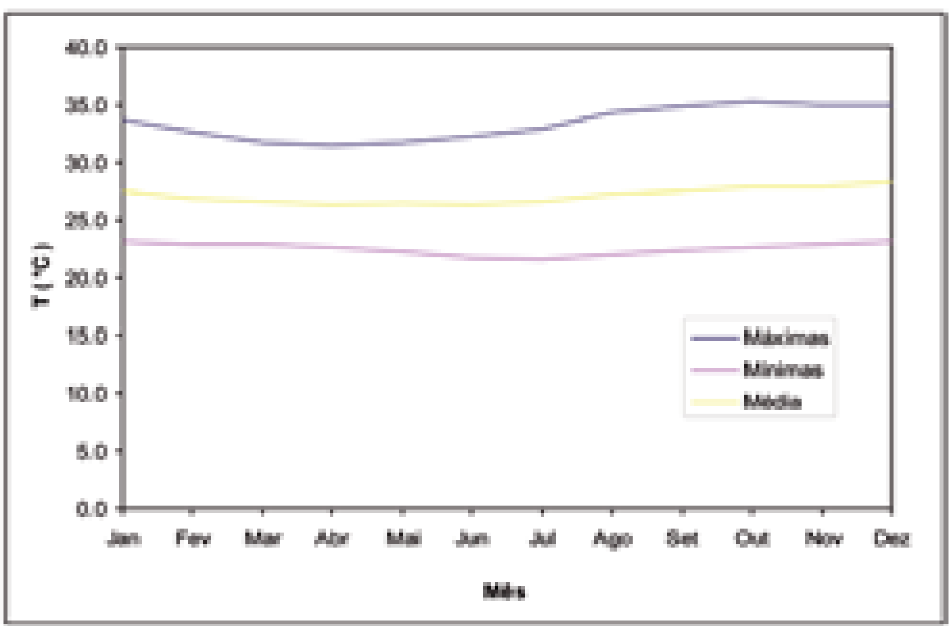

Figure 2.101 – Maximum, average and minimum temperatures in Quixeramobim meteorological station (IMET national network)

Climatologic water balance (Table 2.54 and Figure 2.102) was based on monthly average pluviometry in São José da Cacaoca station, and the potential reference evapotranspiration estimated according to document FAO56, which uses Penman-Monteith's formulas, according to data from Quixeramobim meteorological station. To determine the climate classification according to Thornthwaite (1948) and obtained from that balance, the following indexes were calculated:

- Im (%) = -40 (water index or effective humidity index);
- Ia (%) = 66 (dryness index);
- Iu (%) = 0 (humidity index);
- CV (%) = 29 (Summer months concentration index).

Table 2.54 - Climate water balance based on Penman-Monteith evapotranspiration - FAO56 (1998), using Thornthwaite & Mather (1955) method, for 125-mm soil storage capacity.

Month	P	ETo	P-ETo	NEG ACUM	ARM	ALT	ER	EXC	DEF
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Jan	50.5	189.5	-138.9	-1,478.7	0.0	0.0	50.5	0.0	138.9
Fen	100.0	158.3	-58.3	-1,537.1	0.0	0.0	100.0	0.0	58.3
Mar	167.8	147.9	19.9	-229.9	19.9	19.9	147.9	0.0	0.0
Apr	155.4	123.8	31.6	-110.9	51.5	31.6	123.8	0.0	0.0
May	96.0	126.9	-30.9	-141.8	40.2	-11.3	107.3	0.0	19.6
Jun	46.8	127.8	-81.0	-222.9	21.0	-19.2	65.9	0.0	61.8
Jul	26.9	159.5	-132.6	-355.5	7.3	-13.7	40.6	0.0	118.9
Aug	7.6	191.7	-184.1	-539.6	1.7	-5.6	13.2	0.0	178.5
Sep	3.7	220.0	-216.3	-755.9	0.3	-1.4	5.1	0.0	214.9
Oct	6.4	221.0	-214.6	-970.5	0.1	-0.2	6.6	0.0	214.4
Nov	10.9	203.8	-192.8	-1,163.3	0.0	0.0	11.0	0.0	192.8
Dec	23.1	199.6	-176.5	-1,339.8	0.0	0.0	23.1	0.0	176.5
YEAR	**695.0**	**2,069.7**	**-1,374.7**	**-**	**141.9**	**0.1**	**695.0**	**0.0**	**1,374.7**

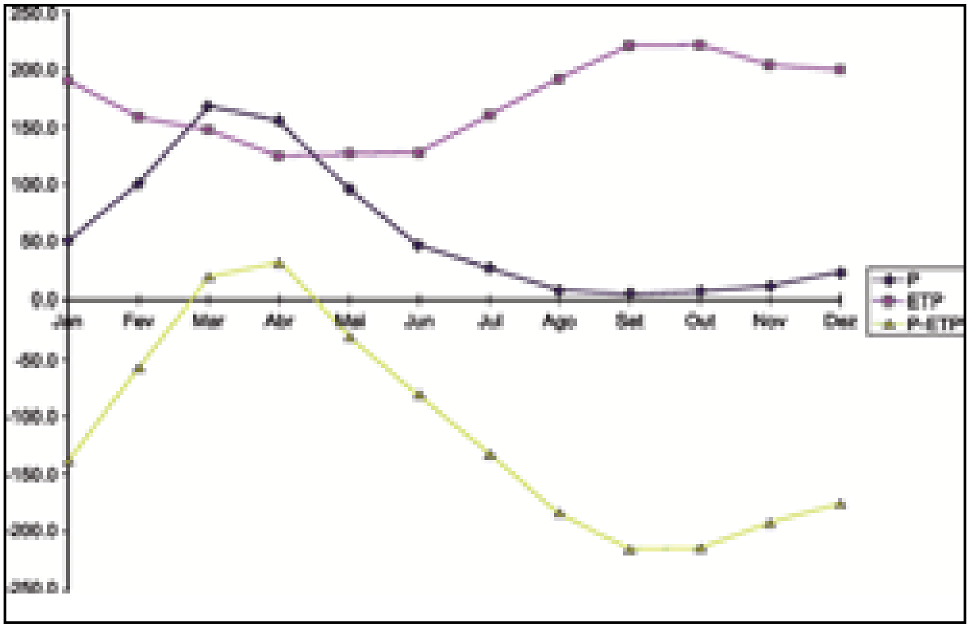

Figure 2.102 – Climate water balance

2.6.1.3 – Spatial domain and physical characteristics of sub-basins

Microbasin hydrology is related to all monitored variables, from water quality in reservoirs to sediment production and accumulation in successive dams. The whole region included in Cangati River hydrographic microbasin was considered as our area of study. The use of geoprocessing techniques and a geographic information system were critical to enable data integration with the respective monitoring locations (Figure 2.104). The list of field-measured physical characteristics and mapping of respective areas or drainage area fractions allowed assumptions for the hydrological operation of monitored microbasins to be formulated. Translating the mapped topics into mathematical model parameters is the most stable part of the interactive mass balance quantification process. Geographic contextualization also can eventually justify scientifically the extrapolations resulting from biophysical monitoring in the form of any derived empiric model.

Evaluation of physical parameters at sub-basin level was based on data obtained from detailed hydrography mapping through the interpretation of CBETS satellite image and the use of topographic data derived from the numeric land model in the area, at a final 30-m interpolated resolution (Figure 2.104).

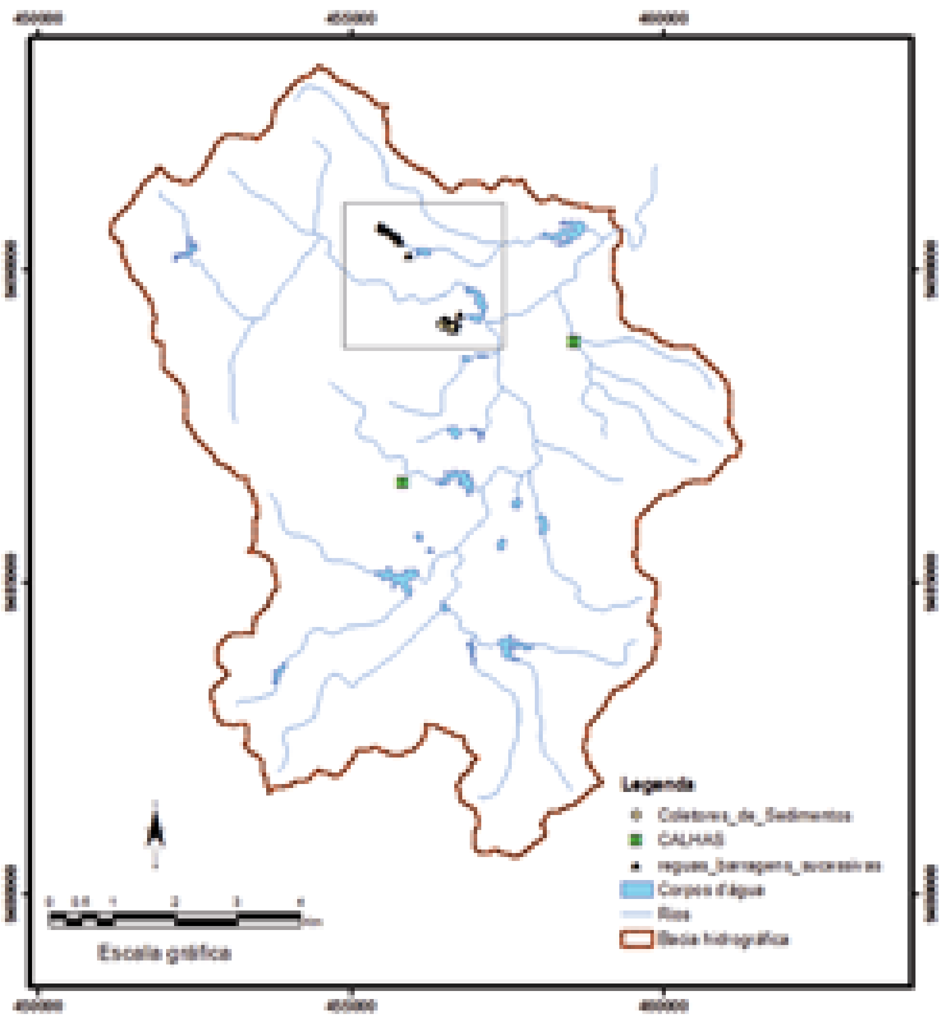

Figure 2.103 – Monitoring points

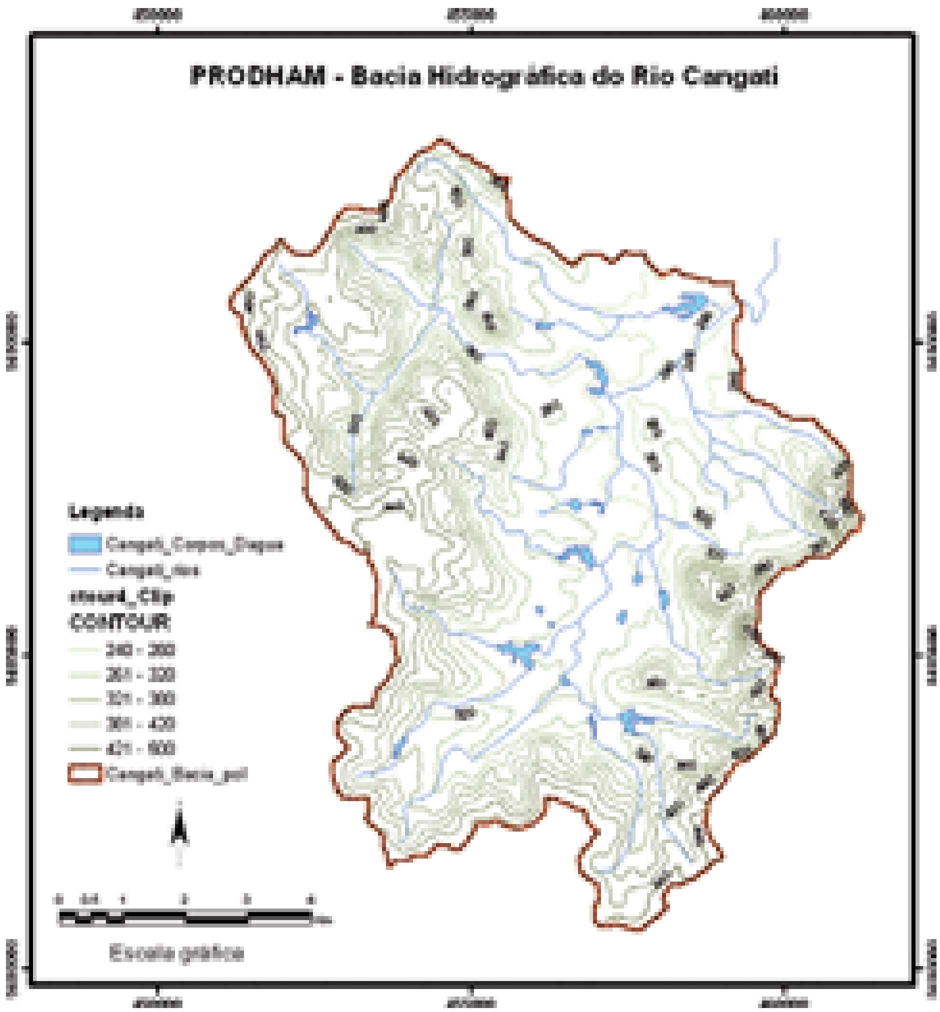

Figure 2.104 – Relief of hydrographic microbasin

Possible combinations of surface parameters are countless, as the profiles depend on the location of control points related to at least ten (10) reservoirs, three (03) underground dams, two (02) flow measurement flumes, and two (02) successive dam areas to retain sediments. Organizing systematically the data in a GIS was the approach adopted to perform the task of describing the surrounding conditions of mathematical surface runoff model. It was decided to include as much information as possible in the geographic information system so that, after the consistency and integration with other teams' activities, the georeferenced database could be naturally incorporated to the subproject workflow.

During the application of simulation programs and interpretation of physical variables observed on site, a list was established to contain important physical characteristics of some sub-basins identified under the following three groups: sub-basins of flow measuring flumes, sub-basins of main reservoirs, and sub-basins of sediment accumulation dams (Figure 2.105; Tables 2.55 to 2.63).

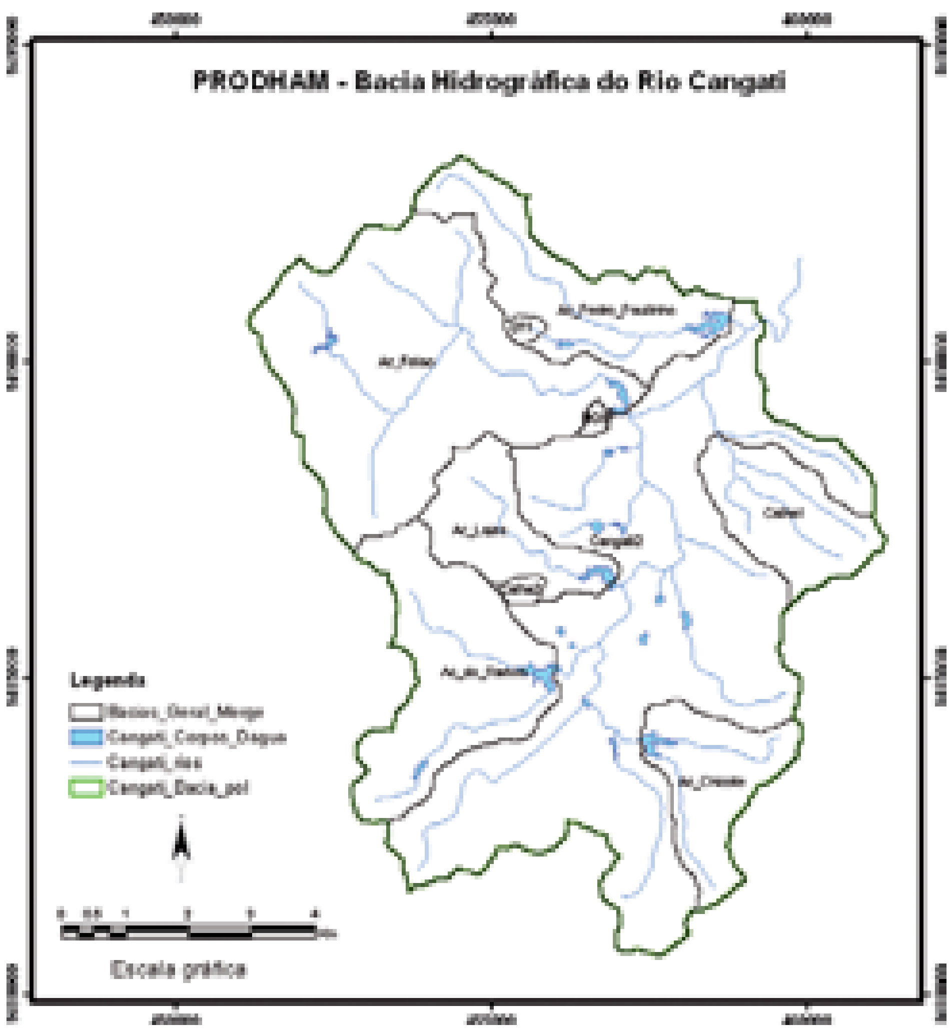

Figure 2.105 – Outline of sub-basins

Determinations of sub-basin surface characteristics, which restrict surface runoff included relief, types of soil and the conditions of vegetative cover (Figures 2.104, 2.106 and 2.107). Some quantitative analysis results are summarized in Tables 2.55 and 2.56.

Table 2.55 – Quantification of spatial scope of soil types

Type of soil	Surface area (km²)	Area (%)
Ae – Alluvium	2.57	3.56
PE1 – Eutrophic Podzolic 1	8.19	11.34
PE2 – Eutrophic Podzolic 2	10.76	14.88
Re1 – Litholic 1	47.77	66.13
Re2 - Litholic 2	2.95	4.09
Total	**72.24**	**100.00**

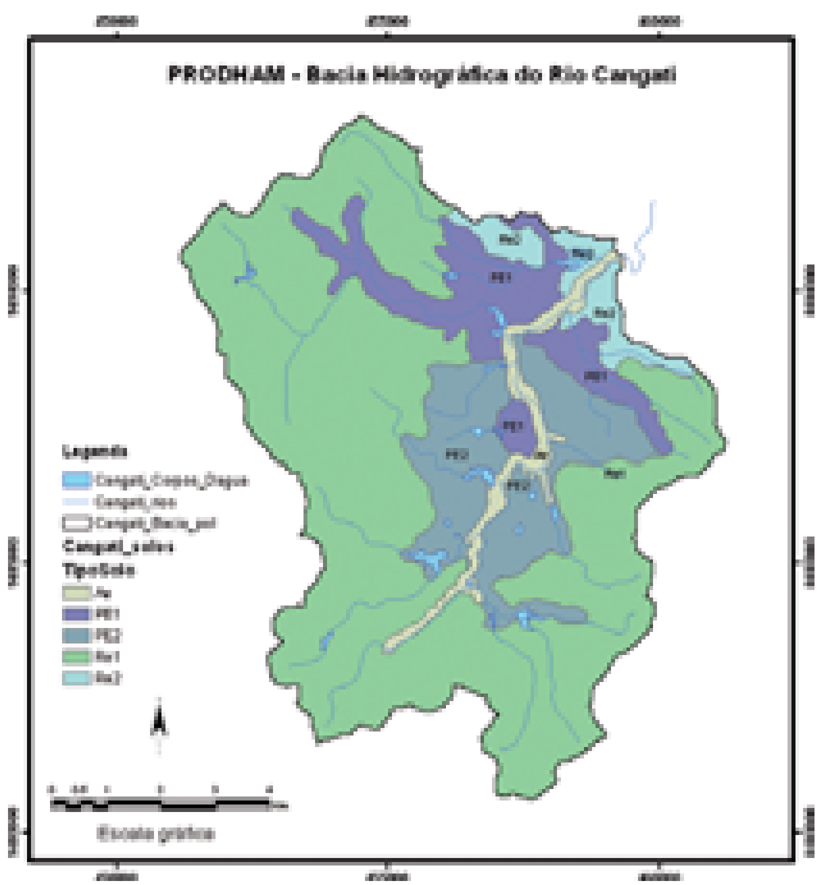

Figure 2.106 – Simplified pedologic map

Table 2.56 – Vegetation status (digital interpretation of a SPOT5 image)

Class	Surface Area (km²)	Area (%)
Conserved	39.48	54.65
Degraded	12.75	17.64
Strongly degraded	4.05	5.63
Partially degraded	14.44	19.99
Exposed soil	1.51	2.09
Non classified		
Total	**72.24**	**100.00**

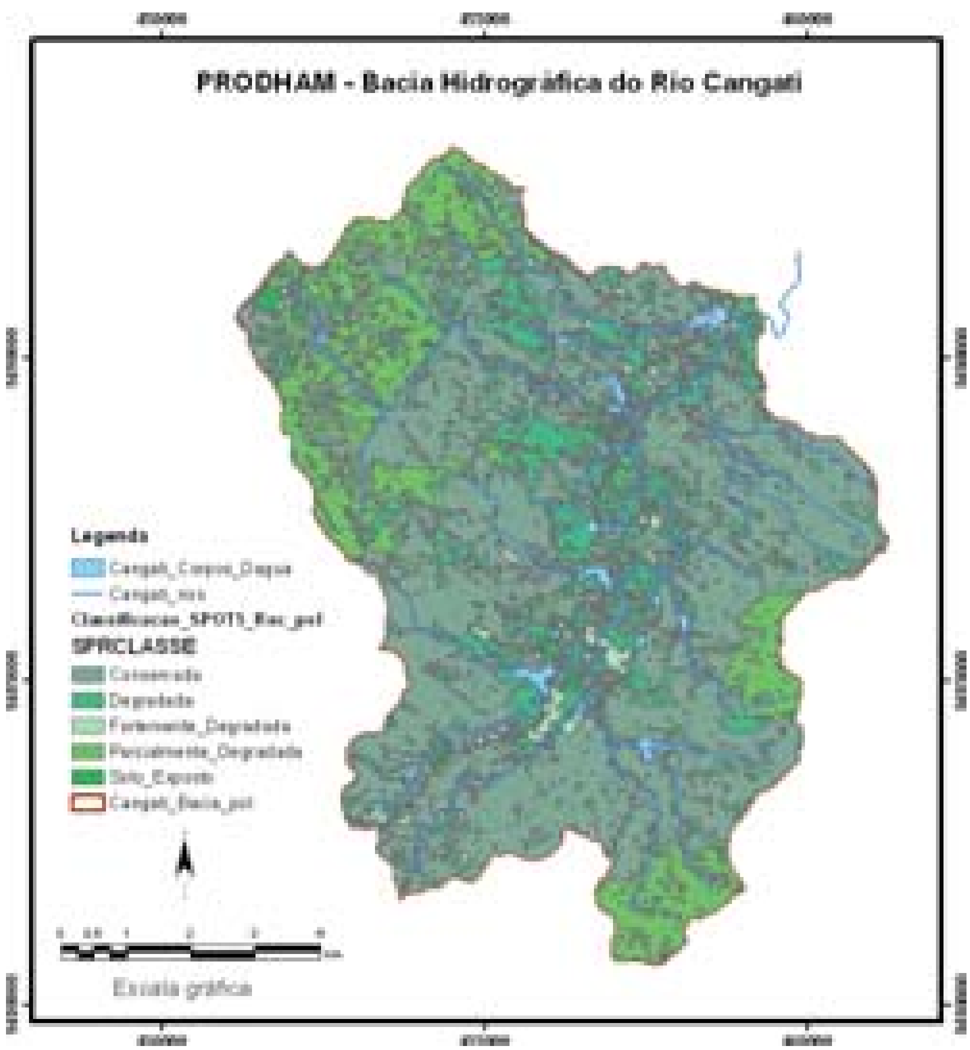

Figure 2.107 – Vegetative cover map

Table 2.57 – Sub-basin characteristics

Name	Surface Area (km^2)	Perimeter (km)	Average Declivity (%)	Watercourse Declivity (m/m)	Watercourse length (km)
Cangati	72.24	55.86	9.68	0.0128	14.47
Ramin	8.10	19.20	9.58	0.0220	4.89
Chicote	4.15	13.14	13.93	0.0474	3.45
P. Paulino	6.63	19.62	7.92	0.0220	7.08
Lajes	4.06	12.54	11.48	0.0299	4.31
Tobias (Felão)	16.73	26.04	13.66	0.0225	9.72

Table 2.58 – Characteristics of sub-basins of measuring flumes

Name	Surface Area (km^2)	Perimeter (km)	Average Declivity (%)	Watercourse Declivity (m/m)	Watercourse length (km)
Salgadinho (Flume 1)	4.13	11.76	11.34	0.0312	3.81
Gatos (Flume 2)	0.27	2.17	9.80	0.0976	0.82

Table 2.59 – Characteristics of sub-basins o successive dams

Name	Surface Area (km^2)	Perimeter (km)	Average Declivity (%)	Watercourse Declivity (m/m)	Watercourse length (km)
B11	0.24	1.88	25.40	0.08261	0.46
G5	0.17	2.40	4.54	0.03143	0.35

Table 2.60 – Vegetation status in monitored microbasins

Class	Salgadinho (%)	Gatos (%)	B11 (%)	G5 (%)
Conserved	81.13	85.76	14.10	34.00
Degraded	12.00	5.60	63.71	41.11
Strongly degraded	2.60	5.92	8.12	13.20
Partially degraded	3.40	0.38	13.59	5.45
Exposed soil	0.85	2.35	0.49	6.24
Non classified	0.02	0.00	0.00	0.00
Total	**100.00**	**100.00**	**100.00**	**100.00**

Table 2.61 – Percentage of each type of soil in reservoir sub-basins

Type of soil	Sub-basin (% of area)				
	Ramin	Chicote	P. Paulino	Lajes	Tobias
Ae	-	-	-	0.26	0.10
PE1	-	-	-	-	18.60
PE2	94.69	9.68	20.70	28.82	0.00
Re1	5.31	90.32	55.27	70.92	81.30

(continued)

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Type of soil	Sub-basin (% of area)				
	Ramin	Chicote	P. Paulino	Lajes	Tobias
Re2	0.00	0.00	24.03	0.00	0.00
Total (%)	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Total (km^2)	**8.10**	**4.15**	**6.63**	**4.06**	**16.73**

Table 2.62 – Percentage of each type of soil in flume sub-basins

Type of Soil	Sub-basin (% of area)	
	Flume 1 (Salgadinho Stream)	Flume 2 (Gatos Stream)
PE1	25.20	-
PE2	29.56	15.23
Re1	44.50	84.77
Total (%)	**100.00**	**100.00**

Table 2.63 – Percentage of each type of soil in successive dam sub-basins

Type of Soil	Sub-basin (% of area)	
	B11	G5
PE1	-	92.73
Re1	100.00	7.27
Total (%)	**100.00**	**100.00**

2.6.1.4 – Hydrological data observed

Data from Funceme conventional pluviometers on a daily basis, which were the most complete data in 2008, mostly originated from Esperança station, code 372, and are stored in a text file [“372.txt”]. Other stations that were also used included São João de Macaoca, Bonito and Targinos. Data from the meteorological station of data collection platform-type (DCP) in Mr. Napoleão’s property in the center of the hydrographic microbasin provided important data for the calculation of potential evapotranspiration. Due to a battery defect, data were missing until May 21, 2008. Date related to solar radiation, temperature, relative humidity and wind speed obtained from Ibaretama station were used to fill that gap in the beginning of the year.

Figure 2.108 below shows an example containing some raw data collected from the meteorological DCP installed in Cangati River microbasin. Figure 2.109, on the other hand, provided the complete series for 2008, including data refined and totalized on a daily basis.

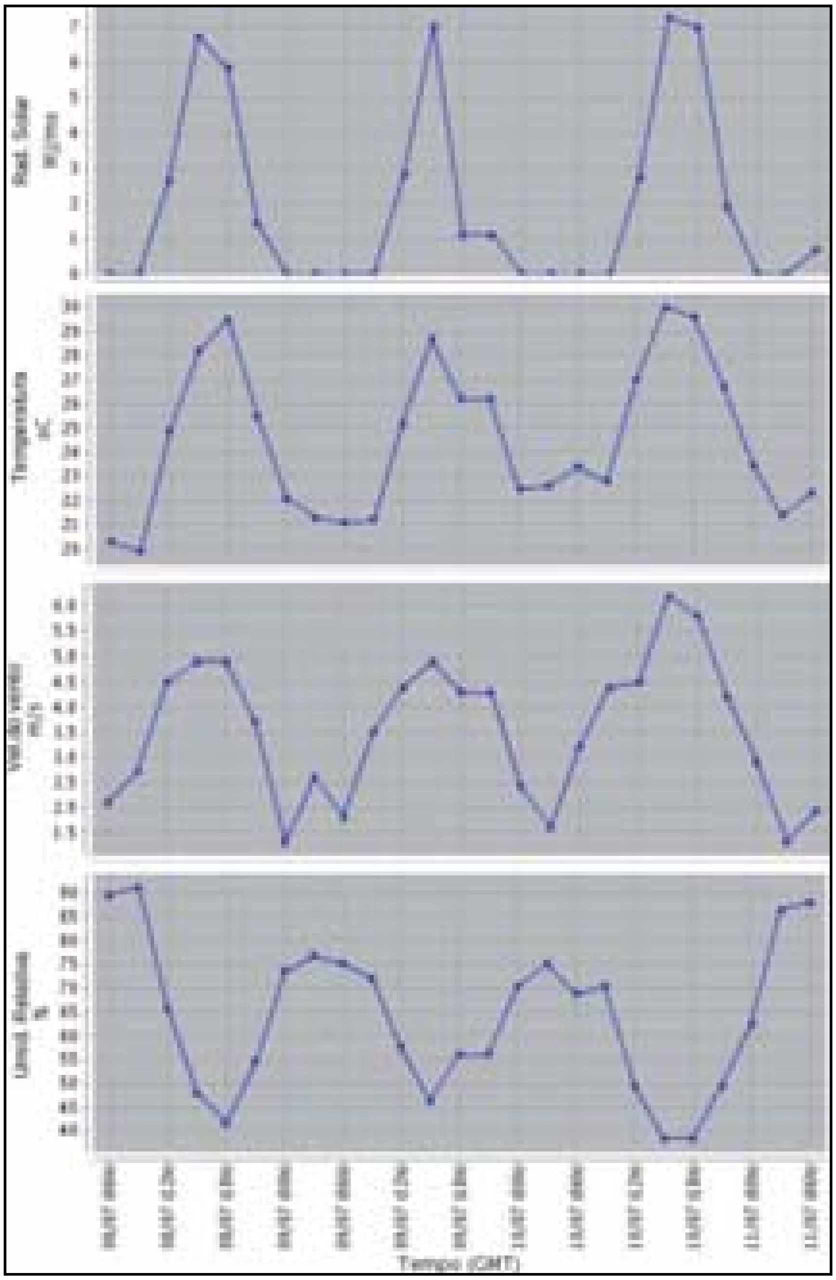

Figure 2.108 – Raw data of meteorological variables in Canindé DCP - PRODHAM

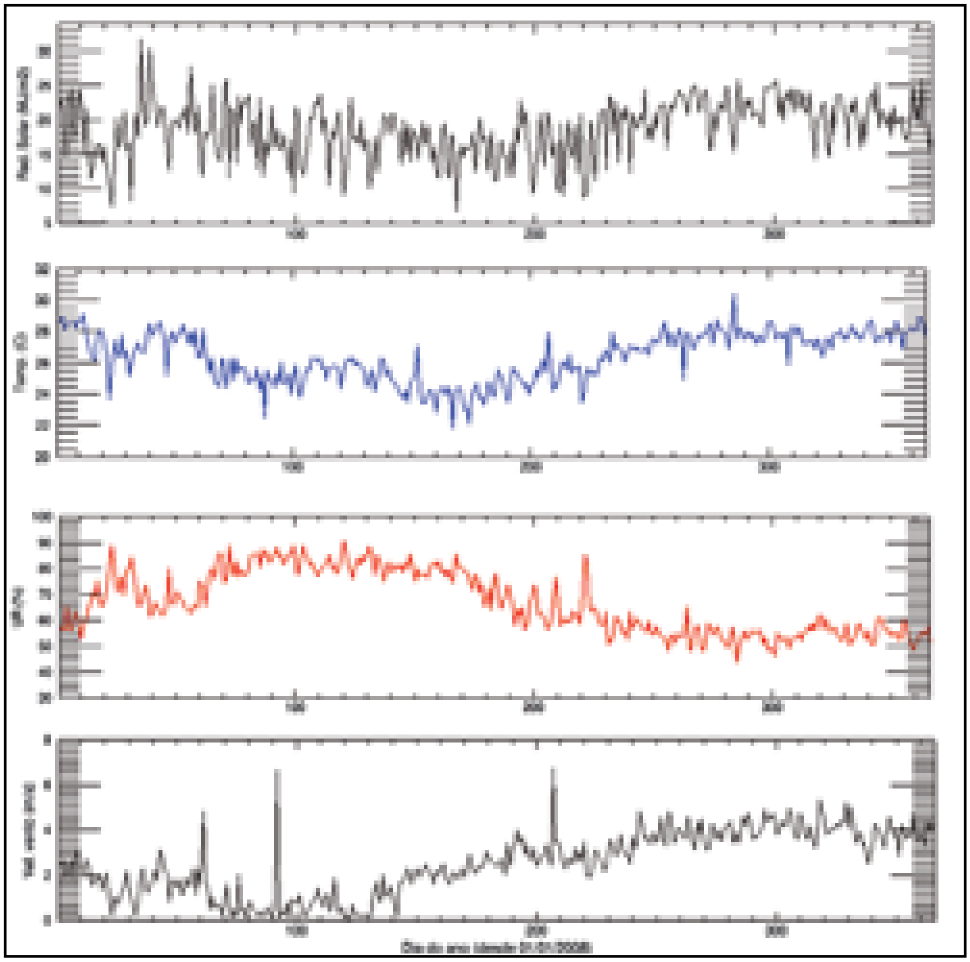

Figure 2.109 – Daily refined meteorological information used to estimate potential evapotranspiration throughout 2008.

Two flow measurement sections were established in streams located in Cangati River hydrographic microbasin under PRODHAM. It was decided to design discharge flumes with a specific drawing for each location, according to hydraulic criteria and constructed to produce the minimum interference with the flow of sediments from monitored streams. A still well is part of flume structure, where an electronic water level meter was installed. A small tower with a solar power supply panel is also part of the system, in addition to a datalloger and a pluviometer able to make measurements at 0.2mm increments.

Hydraulic specifications of flumes (Figures 2.110 and 2.111) allowed the installation of two control sections with continuous flow data in intermittent Salgadinho (Flume 1) and Gatos (Flume 2) streams. More detailed constructive aspects have already been previously documented in this work. Flumes are at full operation and have generated level data at every 10 minutes since May 2008. Examples of respective limnigrams measured and respective flows are shown as an evidence of the successful microbasin instrumentation (Figures 2.112 and 2.113).

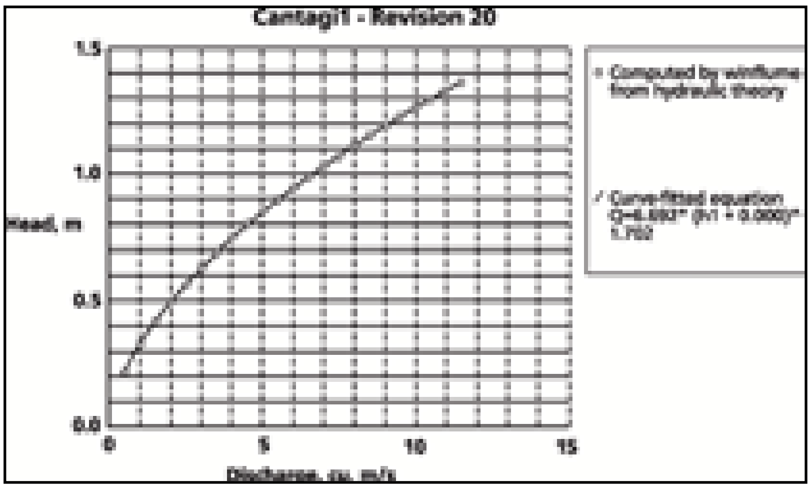

Figure 2.110 – Theoretical key curve of flume 1 (Salgadinho stream)

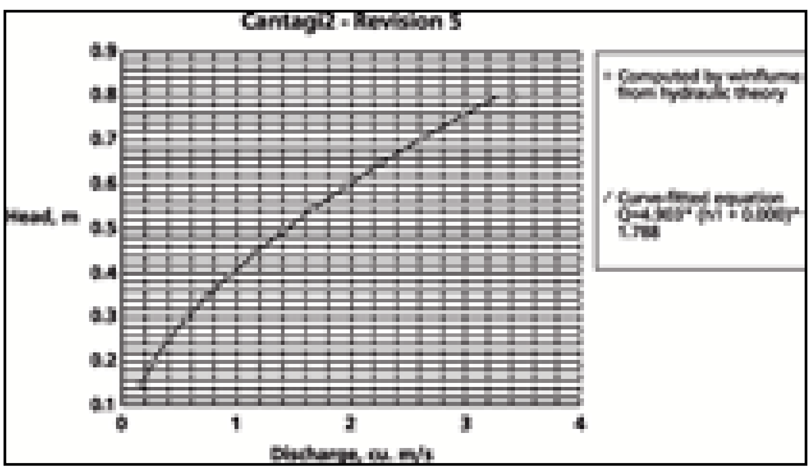

Figure 2.111 – Theoretical key curve of flume 2 (Gatos stream)

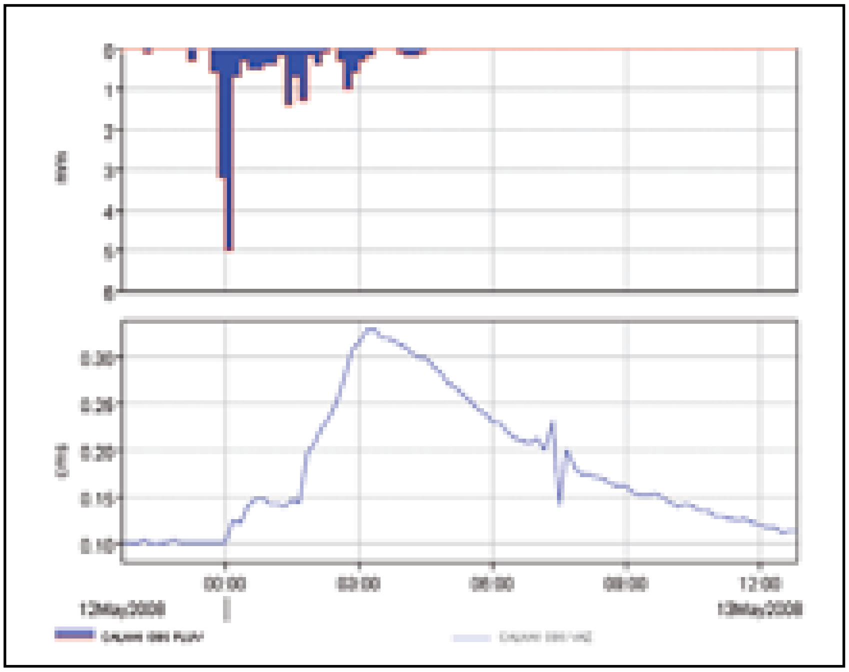

Figure 2.112 – Hydrogram seen in 05/12/2008 event in Salgadinho stream

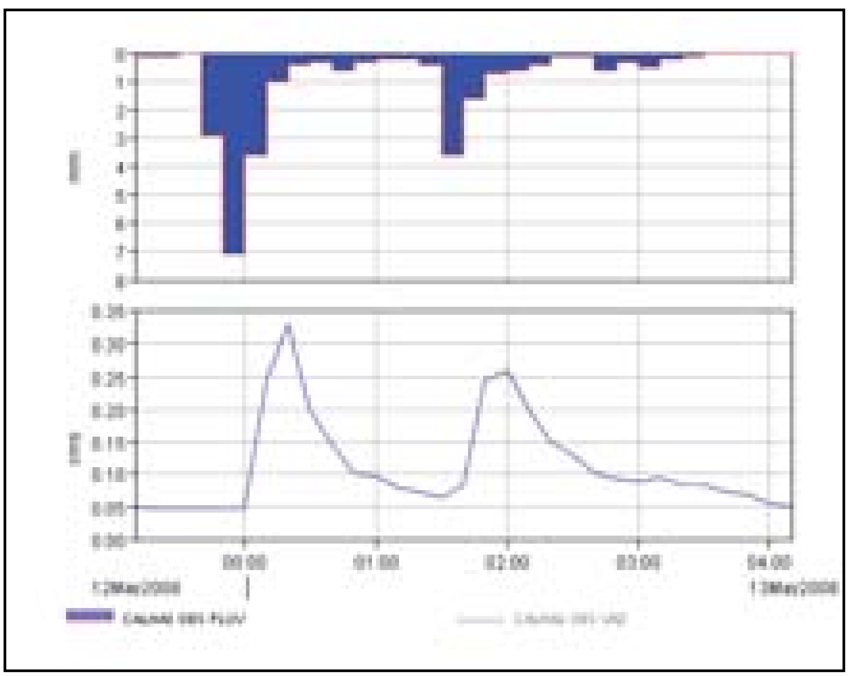

Figure 2.113 – Hydrogram seen in 05/12/2008 event in Gatos stream

Sediment accumulation in successive dams (Figure 2.114), located transversally to small microbasin streams, was monitored throughout 2008. Volume of data obtained from a single rainy season monitoring is not abundant. Even so, a summary of measurements in Guerreiro stream (G1-G5) and Bananeiras stream (B1-B11) dams is shown to provide an approximate quantitative view of sediment mass retained in each small successive sediment retaining dam. This information will be compared to results of a hydrosedimentological model, with the objective of better understanding the factors that influence the efficiency of such structures to retain sediments eroded in microbasins and transported through natural channels. Table 2.64 shows the results of estimated volume and mass deposited in successive dams during 2008 rainy season. Location detail and geometric plan of successive dams can be seen in Figure 2.114, as a result of overlapping the sediment measurement locations on georeferenced satellite image.

Figure 2.114 – Plan to estimate the surface area of sediment accumulation in B11 dam

Table 2.64 – Estimated variation of volume and mass deposited in successive dams

Ruler	Observed Values					Calculated Volumes		Mass Variation (1000 kg)
	H1 (cm)	H2 (cm)	ΔH (cm)	A (m²)	V2 (m³)	V1 (m³)	ΔV (m³)	
B1	18	31	13	50.03	5.170	1.012	4.16	5.84
B2	20	43	23	48.86	7.003	0.705	6.3	9.06
B3	13	80	67	53.95	14.386	0.062	14.32	17.76
B4	27	76	49	32.70	8.283	0.37	7.91	10.16
B5	16	38	22	29.18	3.697	0.276	3.42	4.96
B7	60	90	30	52.53	15.759	4.669	11.09	16.29
B10	23	39	16	39.40	5.122	1.051	4.07	5.5
B11	8	39	31	58.05	7.546	0.065	7.48	913
G1	22	67	45	59.32	13.249	0.469	12.78	12.65
G2	20	84	64	60.96	17.070	0.230	16.84	20.54
G3	85	109	24	35.95	13.061	6.194	6.87	8.88
G5	59	73	14	129.77	31.578	16.671	14.91	21.45

ΔV – volume variation in 2008
ΔH – height variation measured on ruler in 2008

2.6.1.5 - Application of hydrological models to selected microbasins

a) Evapotranspiration

Physical basis

Concrete approach for evapotranspiration quantification will depend on a great number of parameters, namely: type of surface (water, cultivated area, natural vegetation and tree tops in forests, mass of heterogeneous land), water availability (limited or not); use of stored energy (large-volume reservoirs), use of advected energy (e.g., a river of different temperature discharging into a lake); advected energy from the air (horizontal flow of air masses modify the local energetic balance). Other criteria for selection and application of physical-mathematical models based on meteorological studies refer to three basic aspects: (1) purpose of study (irrigation project, hydrological modeling, reservoir projects, etc.); (2) availability of data in place of region of interest; and (3) time scale (hourly, daily, monthly, annual, normal climate average).

Physically, evaporation is a diffuse process that follows Fick's law that, in finite differences, may be expressed as follows:

$$E = K_E \cdot v_a \cdot (e_s - e_a),$$

where E is the evaporation rate , e_s and e_a are steam pressures in evaporating surface and surrounding air, respectively, and v_a is the wind speed. Coefficient K_E measures the efficiency of vertical steam transportation due to wind turbulence. Thos coefficient depends on air stability conditions, as well as the surface rugosity that ultimately will determine the intensity of turbulent flow close to the surface.

Free evaporation

Dingman (1994) thoroughly discussed theoretical and practical aspects of approaches currently adopted to estimate free evaporation and evaporation from lake and artificial reservoir surfaces. Several techniques can be mentioned: water balance of water body; mass transfer to atmosphere; energy balance and Bowen's Ratio; Penman-Combination method and use of Class-A tank.

Penman's equation results from the combination of principles or mass transfer between surface and atmosphere under energy balance approach, thus eliminating theoretically the need of evaporating surface temperature measurements. This approach constitutes one of the most consistent physical theories on evaporation estimate based on meteorological data, according to the following mathematical equation:

$$E = \frac{\Delta \cdot (K + L) + \gamma \cdot K_E \cdot \rho_w \cdot \lambda_v \cdot v_a \cdot e_{sat} \cdot (1 - W_a)}{\rho_w \cdot \lambda_v \cdot \Delta + \gamma}$$

where E is the estimated evaporation for free water surface, $\boldsymbol{\Delta}$ is the declivity of steam pressure saturation curve at air temperature, $\boldsymbol{T_a}$, $\boldsymbol{K}$ is the net short wave radiation; L is the net long wave radiation, $\boldsymbol{Y}$ is the psychometric constant, $\boldsymbol{W_a}$ is the relative air humidity, $\boldsymbol{K_E}$ is a coefficient that depends on wind speed and surface rugosity and gradient ($\boldsymbol{e_{sat}}$ - $\boldsymbol{e_a}$) of steam pressure between the surface and the surrounding air layer. For $\boldsymbol{K}$ calculation, free natural water surface albedo was estimated (clean water reservoir) at approximately 0.05.

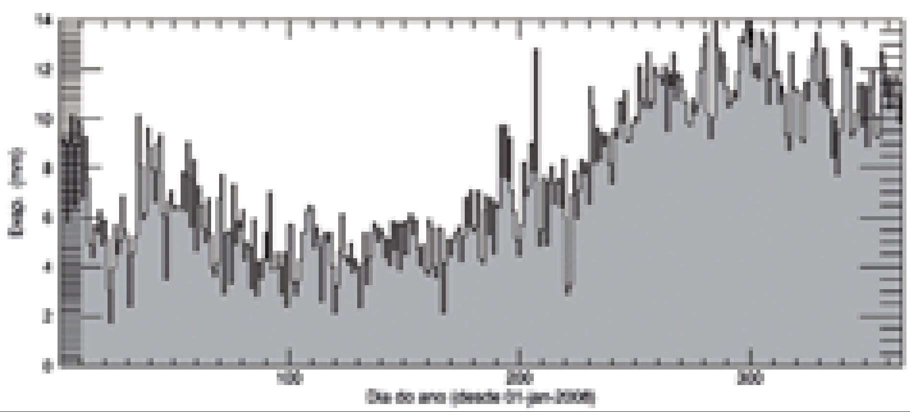

Figure 2.115 – Free evaporation in 2008

Potential evapotranspiration

Monteith showed how original Penman's equation can be modified to indicate the evapotranspiration rate on a vegetated surface, by incorporating for that purpose the term denominated surface conductance $\boldsymbol{C_{can}}$. This way, after $\boldsymbol{C_{at}}$ (atmospheric conductance) determination and an electrical analogy plan to mould the physical process, Penman-Monteith (MONTEITH, 1965) model appeared:

$$E = \frac{\Delta \cdot (K + L) + \gamma \cdot \rho_a \cdot c_a \cdot C_{at} \cdot e_{sat} \cdot (1 - W_a)}{\rho_w \cdot \lambda_v \cdot \left[\Delta + \gamma \left(1 + \frac{C_{at}}{C_{can}}\right)\right]}$$

In out case, average potential evapotranspiration was calculate for the whole year of 2008, by using data from DCP located in Cangati River hydrographic basin. A computer-based program was implemented with Penman-Monteith's equation, using the climatologic parameters synthesized and refined on a daily basis and organized into a database as a text file. Actual values of albedo (0.25) and surface rugosity parameters were used to estimate adequately atmosphere and heterogeneous surface conductance in the hydrographic basin.

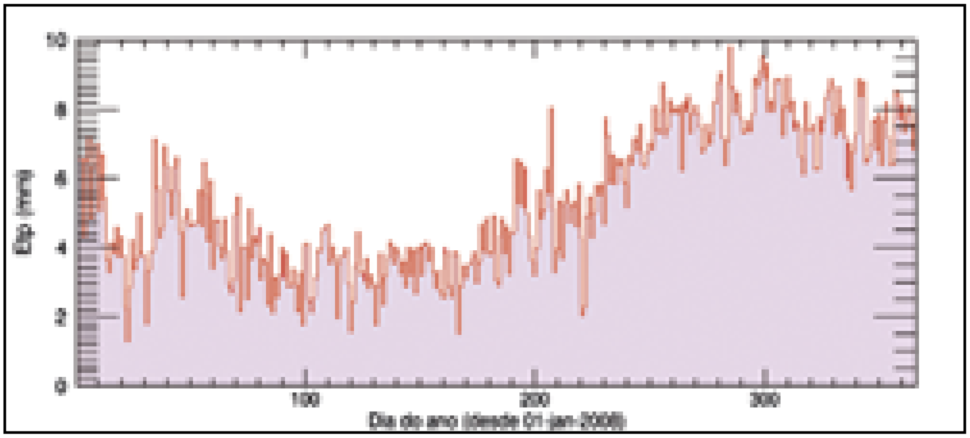

Figure 2.116 – Potential evapotranspiration in 2008.

b) Soil humidity and continuous flows naturalized by SMAPd

*Soil Moisture Accounting Procedure (SMAP) r*ain-flow model is a deterministic model with a relatively simple mathematical structure (LOPES *et al.*, 1982). The adopted version is the original version of daily simulation step, SMAPd, which is constituted of four linear reservoirs designed like conceptual hydrographic basin compartments. Simulated flows include: Ess (subsurface runoff), Ed (direct runoff) and Eb (basic runoff). At each simulation interval, soil reservoir conditions are estimated, which evaluate the saturation level of surface layers of basin soil. The relation between hypothetical model reservoirs can be seen in Figure 2.117. That Figure shows the potential evaporation (Ep), Es2 portion of surface evaporation that feeds the subsurface reservoir (Rssp), and finally Q, the flow discharged into basin outfall.

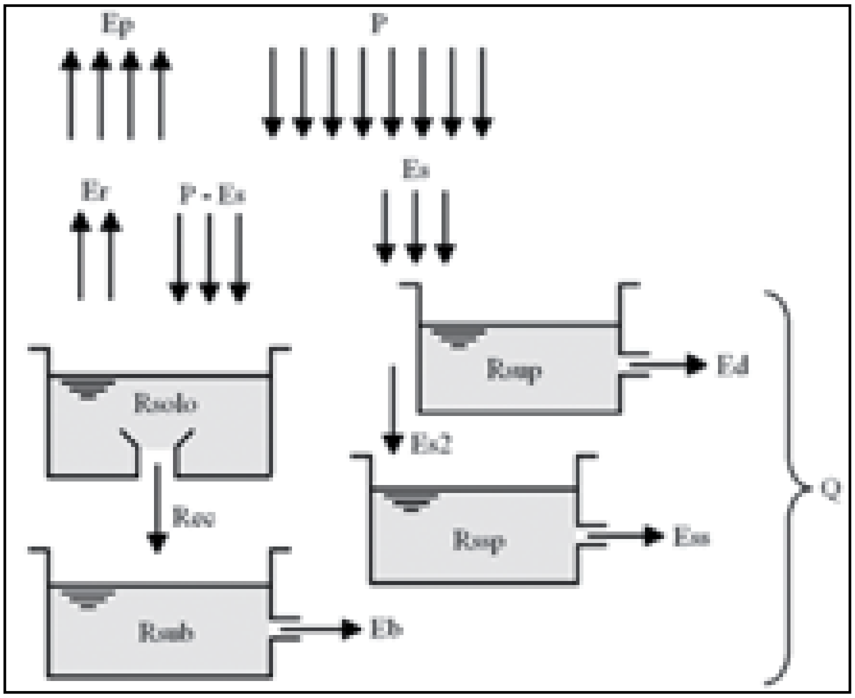

Figure 2.117 – Conceptual design of SMAPd Model
Source: Lopes et al., (1982)

In this model, the number of parameters depending on calibration is reduced when compared to the complexity of other similar conceptual models. The objective if to make calibration easier by using a limited number of flow data, and obtain a reasonable indication of outflow behavior in the hydrographic basin as a whole. For calibration, SMAP uses daily precipitation (P) in mm; potential daily evapotranspiration (EP) in mm; hydrographic basin surface area in km2, and a series of average daily flows daily as basic entry data. As the main initial requirement we have the initial soil moisture content (Tuin). Model parameters that can be adjusted include: depletion rate (K), which generates the base runoff; k2 and kkt, coefficients of surface and underground reservoir transfer; ai – initial abstraction; sat – related to the maximum saturation level of surface soil layer; capc – parameters to control soil water drainage; crec – recharge coefficient, a parameter related to the maximum infiltration rate for non-saturated soil zone. Calibration and simulation results are shown by Figures 2.118 and 2.119, respectively.

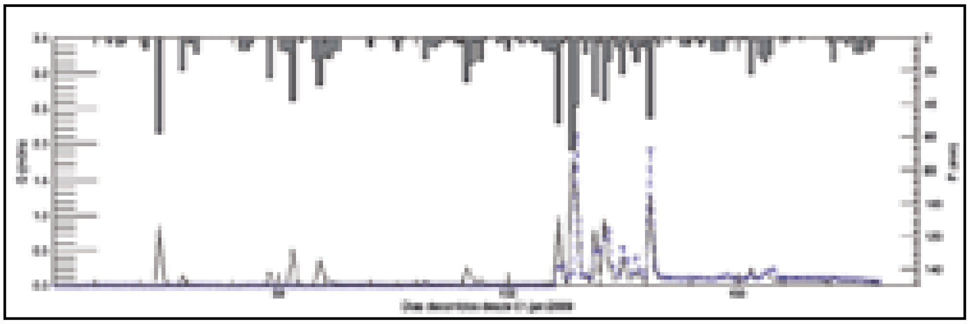

Figure 2.118 – Manual model calibration using data of first semester of 2009.

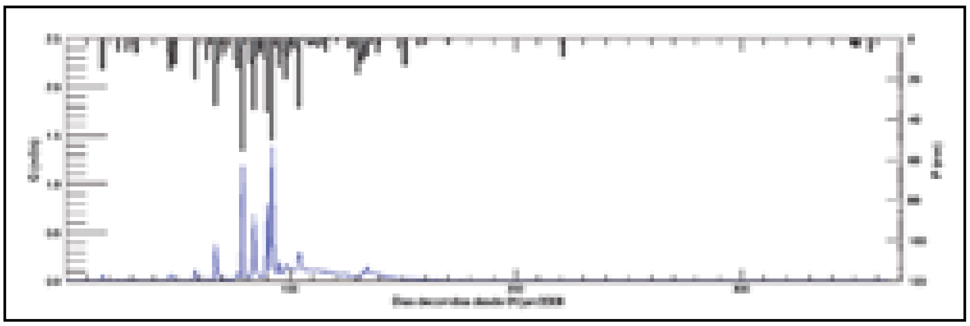

Figure 2.119 – Daily average of flows simulated in 2008 in Salgadinho stream microbasin (Flume 1)

c) Simulation of hydrological behavior of small reservoirs.

Water balance

Continuity equation is the base for reservoir water balance simulation.. Reservoir volume variation is equal to affluent volume less effluent volume, less losses at any fixed time interval. Generically, this equation may be expressed as follows:

$$\Delta V = I - O - L$$

where:

V: volume stored in reservoir; *I*:. affluent volume to reservoir; *O:* effluent volume from reservoir (controlled and non-controlled volumes); *L:* losses (net evaporation, loss from infiltration, etc.).

Equation for a reservoir water balance, as detailed in the form used for solution in a computer program, was written as follows:

$$V_{t+1} = V_t + I_t + Q_t + \frac{A_{t+1} + A_t}{2}(P - E) - R - S_t$$

with:

$$S_t = \max(B - K; 0)$$
$$B = V_t + I_t + Q_t + \frac{A_{t+1} + A_t}{2}(P - E) - R$$

where:

V_t = volume stored at the beginning of year t;

*I*t = volume affluent to reservoir during year t;

Qt: volume conveyed to reservoir;

A_t = lake surface area at the beginning of year t;

E = evaporated layer during month t, considered constant over the years;

P = precipitation on the lake during the month

K= reservoir capacity;

S_t= volume lost from discharge during month t;

R_t= total extractions, depending on required demands and volume available at time t.

V = f(h) A= f(h)By representing the hydraulic basin by ***V = f(h)*** e ***A= f(h)*** , where h = water head, that is nothing more than height-surface area-volume Table.

It is noted that the term where precipitation and evaporation ion the lake surface appear will depend on the surface area of lake at times ***t*** and ***t - 1***, what requires the use of an interactive process to determine the status variable at time ***t***. Simulation program takes that fact into account at its implementation, by solving the problem in a way to maintain continuously the mass balance.

Previous studies show that evaporation from free reservoir surfaces differs from values observed in evaporimetric tanks or estimates that do not consider the size effect or oasis effect. To consider such effects, an equation proposed by Molle (1994) was used, where free evaporation is corrected by coefficient *Ka(S)* according to the following formulation:

$$Ka(S) = 0{,}9 - 0{,}165 \cdot \operatorname{arctg} \frac{2 \cdot S}{30}$$

where S is the numeric value of lake surface area in hectares at any time.

The water balance of two reservoirs in the microbasin, Tobias and Chicote, is shown as an example (Figures 2.120 and 2.121). Main data on microbasin reservoirs are provided by Table 2.65. Estimated initial volumes derived from the calculation of the lake surface area viewed on a panchromatic CBERS2B satellite image at a 2.5-m resolution, acquired on 02/14/2008, together with field measured data during a quick survey of geometric characteristics of microbasin reservoirs.

Volumes shown in 1,000 m3 are average 5-day volumes.

Table 2.65 – Characteristics of hydrographic microbasin reservoirs

Point	Reservoir	Maximum capacity (m^3)	Hydraulic basin surface area (m^2)	Maximum depth (m)	Hydrographic basin surface area (km^2)
AC01	Chicote reservoir	188,457.7	80,767.6	7.0	4.14
AC02	Ramin reservoir	20,2817.0	119,304.1	5.1	8.09
AC03	Zuir reservoir	4,246.2	4,246.2	3..0	0.04
AC04	Lages reservoir	254,122.8	81,975.1	9.3	4.06
AC05	Chico Miguel I reservoir	33,273.0	23,766.4	4.2	0.38
AC06	Chico Miguel II reservoir	17,315.0	11,805.7	4.4	0.65
AC07	Antônio Cruz reservoir	17,797.3	10,267.6	5.2	1.97
AC08	Tobias reservoir (BR020)	114,496.1	70,822.3	4.9	16.73
AC09	Novo reservoir	17,337.5	18,575.9	2.8	0.52
AC10	Pedro Paulino reservoir	169,271.5	110,394.4	4.6	6.63

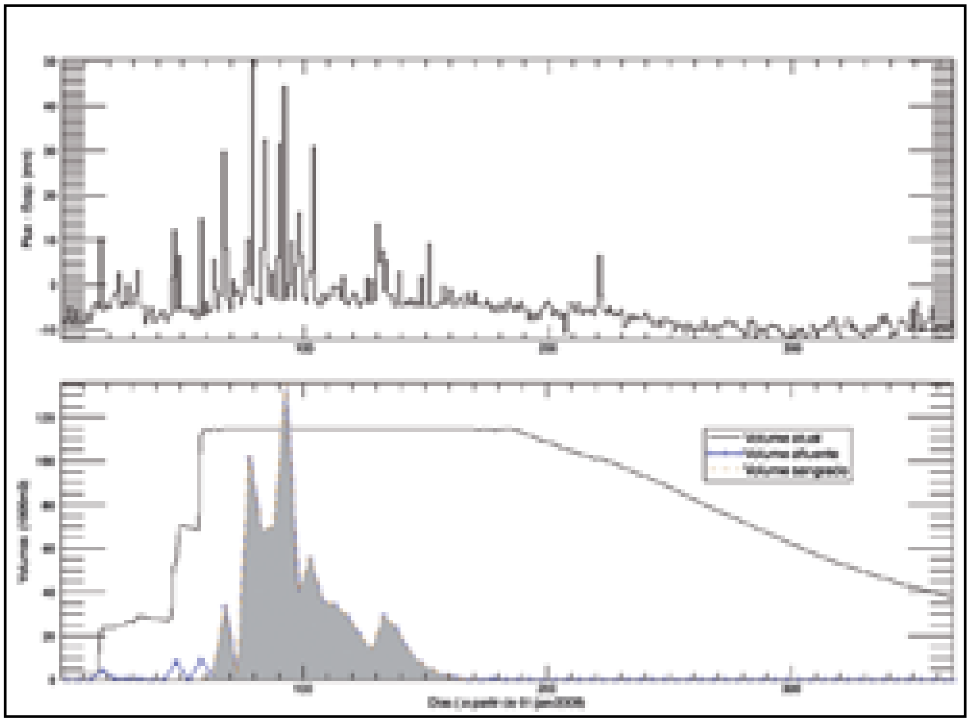

Figure 2.120 – Water balance of Tobias reservoir, downstream to Felão stream

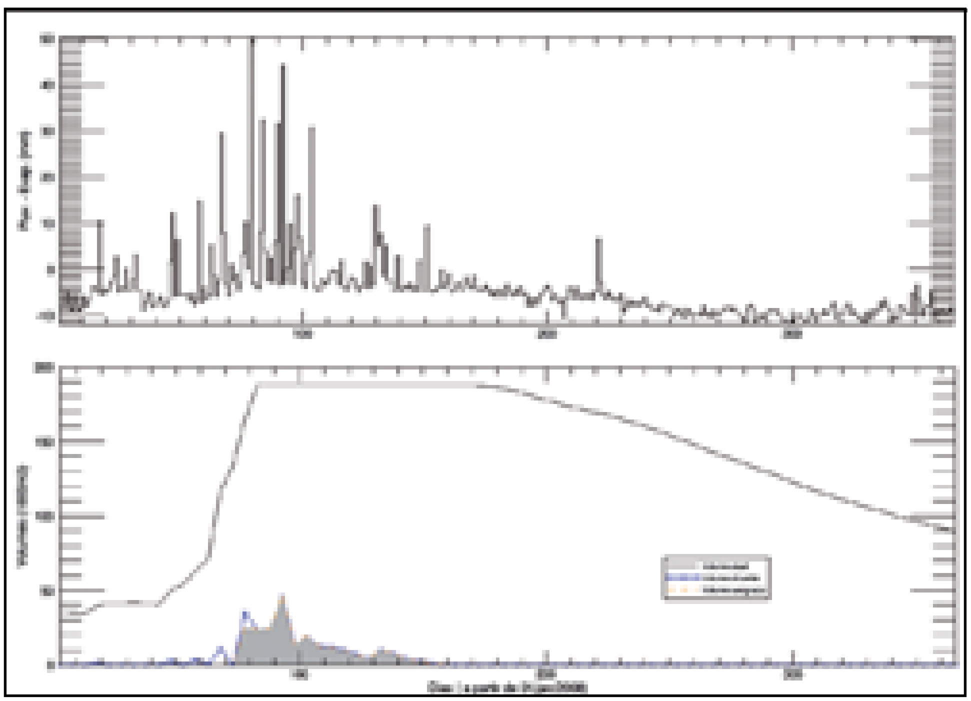

Figure 2.121 – Water balance of Chicote reservoir

Salt balance

Activities of collection and analysis of consistency of collected water quality samples required the use of tools that could relate microbasin hydrology to the amounts of salt concentration in small reservoirs surveyed. So, a solute balance was developed specifically to study the influence of natural hydrographic basin geochemistry on microbasin reservoir salinization, based on water quality data obtained during biophysical monitoring under PRODHAM.

Salt balance in small reservoirs was simulated according to the following equation:

$$\frac{dm}{dt} = m_i - m_o - m_d$$

where:

m_i = mass of incoming salts;

m_o = mass discharged by spillway or gallery;

m_d = mass deposited (precipitated) or consumed inside the reservoir.

The complete mix assumption may be used to estimate average values, by considered the actual reservoir as a simple control volume. Those are called zero-dimensional models, as they do not consider the spatial variation of salt concentration inside the lake. By making an algebraic operation using the equation above, and simplifying and replacing the terms to use monitored concentrations, we have:

$$\frac{d(V\bar{C})}{dt} = Q_i C_i - Q_o \bar{C} - K_d \bar{C}$$

Note that concentration at spillway discharge was assumed to be equal to average concentration inside the reservoir, what in most cases is an acceptable simplification. Discharged volumes and current volumes of reservoir are obtained from the water balance. Q_i Q_oAffluent and discharged

flows, Q_i and Q_o, were estimated using data observed in the microbasin, with the help of the continuous soil moisture model, SMAP, and the reservoir water balance model. K_d Coefficient K_d can be estimated by calibration or, independently, from a chemical balance model. $r_d K_d = r_d A_t$ In our case, an average deposition rate was assumed, r_d (m/day), which was multiplied by the reservoir surface area at each simulation step, $K_d = r_d A_t$.
C_i C, Affluent concentration C_i was not monitored so frequently as the average concentration C, in the water body. $C_i = aQ_i^b$ Few data obtained were used to derive a relation of $C_i = aQ_i^b$ type, so that we could have a continuous record of affluent total dissolved solid load as a function of daily average stream flow. Coefficients *a* and *b* were calibrated only for Felão stream, as this was the only stream provided with sufficient data (a = 267.7; b = -0.17; Figure 2.122).

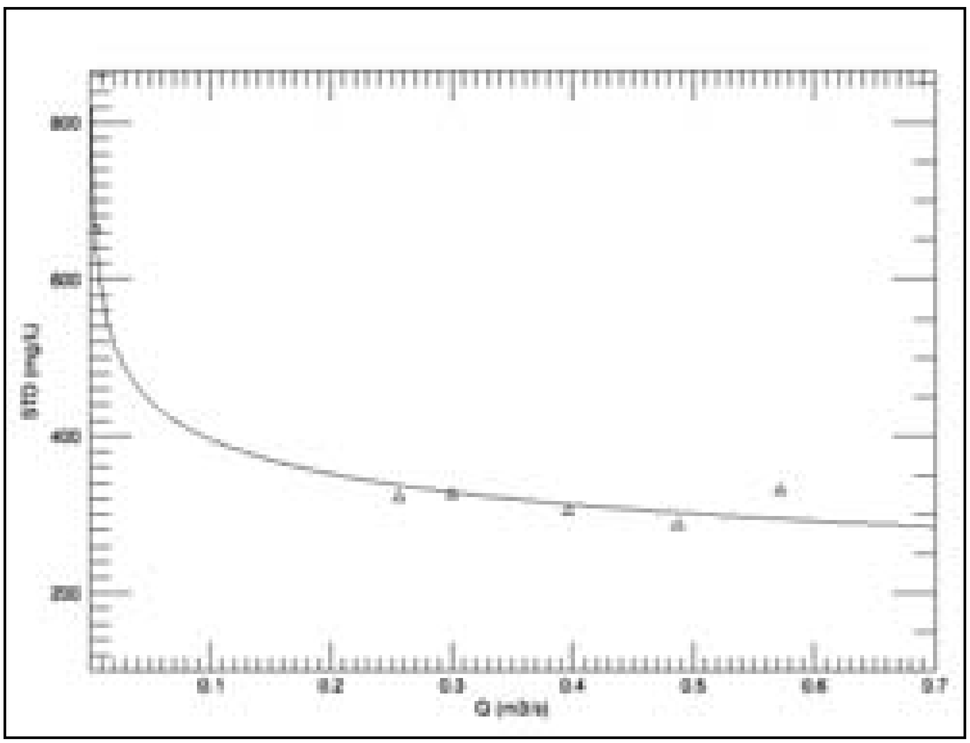

Figure 2.122 – Curve of dissolved solid load to Felão stream

To apply that equation to Chicote reservoir by using a few TDS values monitored in that site, a correction factor *fc=0.54* was estimated in relation to concentrations determined for Felão stream. In effect, salt balance coupled to the water balance of Chicote reservoir showed that such estimates were reasonable, otherwise there would be a considerable over-estimation of affluent salt load. In spite of uncertainties related to hydrologic data used and mathematic simplifications, mass balance proved quite accurate as compared to concentration data observed on site during 2008 (Figures 2.123 and 2;124).

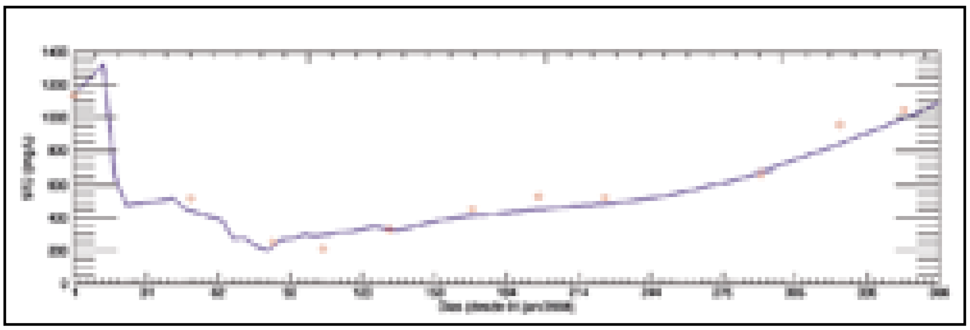

Figure 2.123 – Salt balance in Tobias reservoir downstream to Felão stream

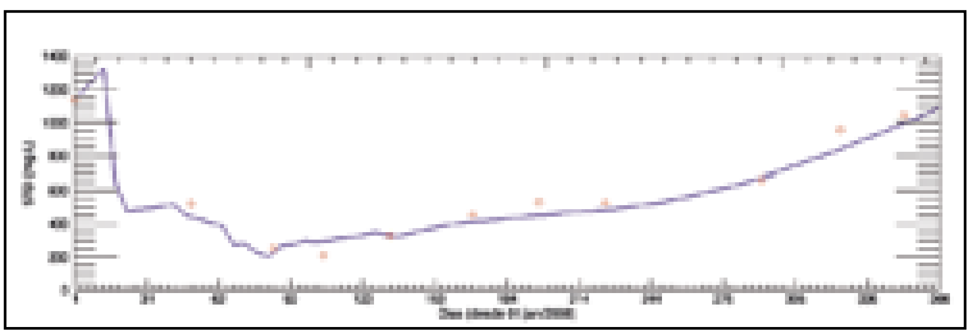

Figure 2.124 – Salt balance in Chicote reservoir

2.6.1.6 – Flood events and production of sediments

HEC-HMS Model

Hydrologic Modeling System (HEC-HMS) was developed to simulate precipitation-runoff processes in dendritic hydrographic basins, and is able to simulate hydrograms at different time and space scales, from hydrology of large rivers to runoff in small metropolitan basins. Hydrographs produced by the program may be exported and used directly in combination with other hydrologic techniques for water availability, urban drainage, quantification of damages from floods, and other studies. It is a free closed package, that is, only executable programs are available, as a development of traditional HEC1. Robustness, versatility and easy use are the most attractive characteristics of this model. Latest version is 3.3, which is available for Windows, Sun and Linux 32-bit platforms. Simulations were made at distribution both for Linux and Windows.

Main HEC-MHS use in this study was to determine the adequacy of kinematic wave model to simulate flood wave in sub-basins, by using collected rain and flow data. HEC-HMS is provided with a quite sophisticated graphic interface that allows generic models to be assembled with networked functional components. In addition, like in all mathematic models, application and interpretation of results, especially in basins provided with few data, requires the hydrologist's experience for correct discretization of physical domain and parameterization, as well as for the selection of algorithms that are most adequate to each problem.

The good result of HEC-HMS preliminary calibration confirmed the good representation of kinematic wave model coupled to Green-Ampt infiltration model as a physical-conceptual prototype representative of surface runoff generation process in surveyed sub-basins (Table 2.66; Figures 2.125 and 2.126). Thereafter, it was possible to use another model – KINEROS2 – which bases its runoff generation algorithm upon a similar assumption, and additionally calculates the production of sediments in sub-basins.

Table 2.66 – Parameters of HEC-HMS model

Parameter	Ranges of values adopted
Initial loss (mm)	1.0 - 2.5
Moisture deficit	0.12 – 0.3
Matricial soil suction potential (mm)	447
Saturated hydraulic conductivity (mm/h)	3.5 – 4.8
Recession ratio p/ peak flow	0.08 – 0.12
Rugosity N of runoff levels (slopes)	0.100 – 0.160
Manning coefficient n for runoff in channels	0.038 – 0.043

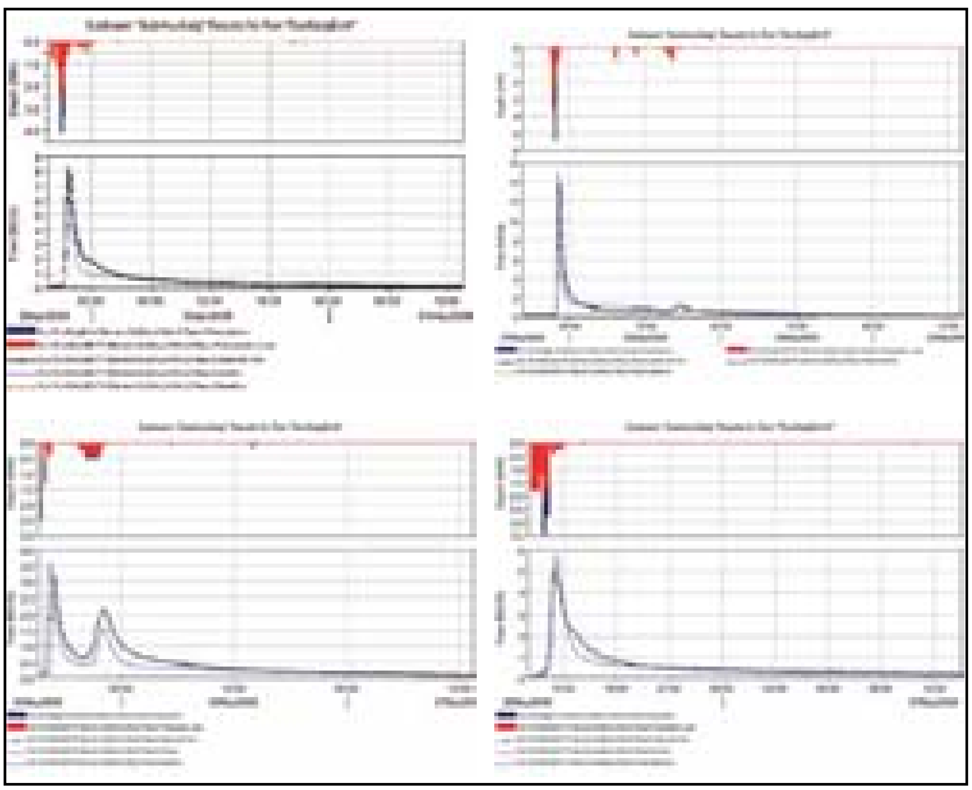

Figure 2.125 – Adjustment to parameters of HEC-HMS models for flood events observed in 2009

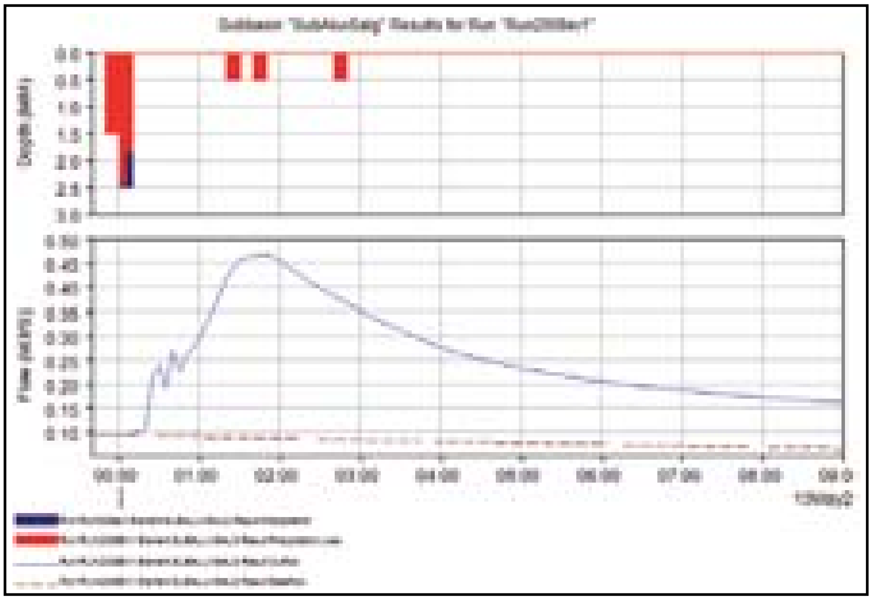

Figure 2.126 – Simulation of a flood event in 2008 (Salgadinho stream)

KINEROS2 model

Kinematic runoff and erosion model (KINEROS2) is a model focused on physical base events, which describes processes of rain interception, infiltration, surface runoff, and erosion of small rural and urban basins. The basin is represented by a cascade of rectangular planes and canals, where differential equations describing runoff, erosion and sediment transportation are solved by finite difference techniques. Spatial rain, infiltration and runoff variations, and erosion parameters may be properly accommodated in the model.

KINEROS2 (1990) source code is distributed in FORTRAN 77 and compiled versions for PC 32-bit platforms using in/out files in command line to make simulations. Interactivity and easy use are not the strength of this software, but as its source code is available, audit of possible algorithm implementation errors is complete. The program was compiled for Linux 64-bit platform, and all simulations were made in that environment.

Model selection was due to its physical base, coupled water erosion simulation, and the possibility of using the experience gained in this subproject to apply it in the future to other semiarid regions with similar problems. Surface runoff simulated by this model is Hortonian and based on kinematic wave. Infiltration is attached and distributed over the space, dynamically integrated with an infiltration algorithm implemented according to Smith e Parlange (1978) methodology.

Water erosion and sediment transportation are calculated by solving the mass continuity equation in each plane or channel. Description of erosion by raindrop detachment, laminar erosion, and transportation and deposit of sediments in basin is possible, based on formulas that take into account the transportation capacity of surface runoff at all times. More details on the theory and original concepts adopted for the implementation of such models can be found in Woolhiser et al. (1990), Govers (1990),and available at: <http://www.tucson.ars.ag.gov/kineros/>.

A critical data for application of KINEROS2 model is the temporal distribution of precipitation intensity on the hydrographic basin object of analysis. During the year of 2008, part of events of medium and great magnitude was not recorded due to problems with the datalogger in the flow measuring flume. This required the use of histograms, as observed in 2009, to produce a rule for transformation of total daily rains into smaller periods. A three-parameter logistic curve adjusted well to the typical format or rain events observed, in addition to the great variability among such events. What is important here is that an information measured at the microbasin site was incorporated, instead of using ratios from the literature, which had been mostly based on data from regions of pluviometric regime completely different from ours. Main parameters adopted can be seen in Table 2.67, and examples of surface runoff and sediment production simulations are shown in Figures 2.126 and 2.127.

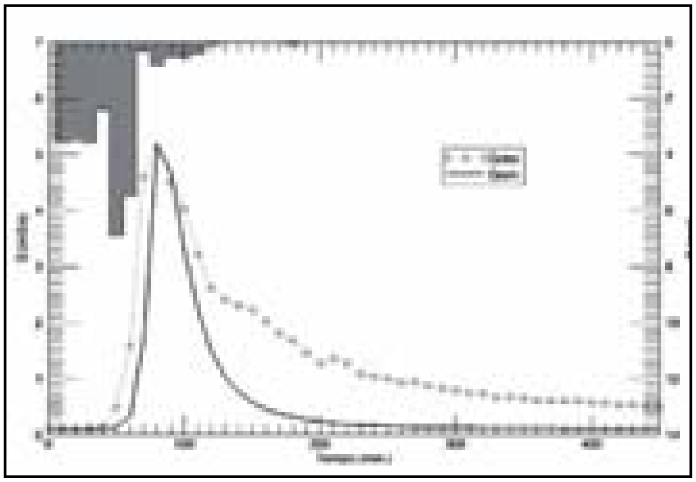

Figure 2.126 – Test for surface runoff simulation under KINEROS2

Tables 2.68 and 2.69 show the summary of potential sediment production estimated for 2008 if no retention work had been constructed. Resulting values are compared for microbasins B11 and G5. Results refer to several simulations by KINEROS2 model, subject to several uncertainties; however, exclusively based on such values, it was possible to clearly identify a susceptibility to erosion in Bananeiras stream microbasin, which was much greater than that of Guerreiro stream. Successive dams in Bananeiras stream contained approximately 16% of sediments transported during 2008, while successive dams in Guerredo stream showed a relative soil retention efficiency of 69%.

Table 2.67 – Parameters of KINEROS2 model

Parameter	Identification in Program	Range of Values Adopted
Saturated hydraulic conductivity (mm)	KSAT	3.5 – 4.8 mm/h
Average soil capillarity	G	230 – 290 mm
Volumetric rock fraction	ROCK	0.05 – 0.15
Soil porosity	POROSITY	0.38 – 0.41
Distribution coefficient	DIST	0.4
KSAT variation coefficient	CV	0.4 – 0.7
Maximum interception	INTER	2.5 mm
Vegetative cover fraction	CANOPY	0.65 – 0.85
Microtopography	RELIEF SPACING	2.0 – 4.0 0.2 – 0;4

(continued)

(continuation)

Parameter	Identification in Program	Range of Values Adopted
Soil granulometry	FRACT	DIAMS = 0.005; 0.05; 0.25 mm FRACT = 0.18; 0.32; 0.50
Raindrop impact damping coefficient	SPLASH	40 – 70
Soil cohesion	COH	0.5

Table 2.68 – Estimated total sediment production in microbasin B11 (Bananeiras stream) in 2008 based on events simulated by KINEROS2 model

Class of total rain per event (mm)	Number of events	Average depth per event (kg/ha)	Gross erosion per event (kg)	Total production (kg)
1 – 5	21	-	-	-
5 – 10	22	-	-	-
10 – 20	13	-	0.4	5.0
20 – 30	4	1,337.2	23,227.0	92,908.2
30 – 40	4	5.720.5	99,365.0	397,460.1
			Total in the year (kg) =	490,373.2
			Yield in 2008 (ton/ha/year) =	20.33
			Retention in successive sediment retaining dams (kg) =	78,704.0
			Retention efficiency (%) =	16,1

Table 2.69 – Estimated total sediment production in microbasin G5 (Guerreiro stream) in 2008 based on events simulated by KINEROS2 model

Class of total rain per event (mm)	Number of events	Average depth per event (kg/ha)	Gross erosion per event (kg)	Total production (kg)
1 – 5	21	-	-	-
5 – 10	22	-	-	-
10 – 20	13	-	-	0.3
20 – 30	4	126.9	2,204.5	8,817.8
30 – 40	4	1,198.4	20,815.7	83,262.7
			Total in the year (kg) =	92,080.8
			Yield in 2008 (ton/ha/year) =	5.30
			Retention in successive sediment retaining dams (kg) =	63,533.0
			Retention efficiency (%) =	69.0

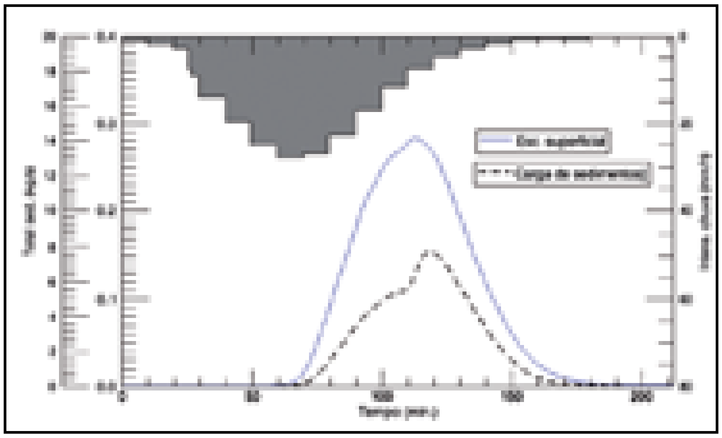

Figure 2.127 – Hydrogram and sedimentogram for a typical event

2.6.2 – Numeric modeling of groundwater runoff in Chicote, Felão and Salgadinho streams

To make works feasible in terms of analysis of aquifer scenarios in surveyed alluviums, a numeric groundwater runoff model was developed. For that, Processing Modflow – PMWIN 5.3.0 was used. This software, in addition to being a graphic case assembly tool for computer simulation, is also a front-end for MODFLOW and several packages developed for that software.

MODFLOW is a software that represents the state-of-art simulation of aquifer runoff. Il models both saturated and unsaturated regions and is provided with several packages developed by third parties to simulate specific physical conditions (e.g., precipitation, evapotranspiration, recharge at river and/or reservoir level, among others). Mathematically, MODFLOW uses a implicit finite difference system to determine runoff, what gives it stability and convergence. It operates only for rectangular hexahedral networks, what brings no problems for large physical systems. However, because of its scope, MODFLOW requires the entry of many parameters, what is an arduous and often complex task for real problems.

For each of the three surveyed alluviums, a model was assembled in PMWIN. As mentioned previously, many data are required to be entered to each model: network dimensions (length and cell size), number of layers, hydraulic conductivity (K), determination of hydraulic cell status (if the load is constant or variable), height of layer top and base, effective porosity, etc. Characteristics of entry of such data will be detailed below.

a) Generated network

As mentioned above, MODFLOW uses a rectangular hexahedral network to represent the domain of problem resolution. That network should be specified right at the beginning of simulation model assembly. This way, three networks were specified, one of each surveyed alluvium. Network characteristics were determined by the consulting firm based on its experience and dimensional characteristics of aquifers surveyed. Such characteristics are shown in Table 2.70.

Table 2.70 – Network characteristics for each aquifer surveyed

NAME	LINES	D_C_V*	COLUMNS	D_C_H**
Chicote	30	5	124	10
Felão	260	5	220	10
Salgadinho	140	10	200	5

* D_C_V (Vertical cell dimension); ** D_C_H (Horizontal cell dimension)

MODFLOW allows the use of several layers to represent different aquifer levels. As aquifers under study are essentially two-dimensional (surface area larger than depth), two layers were used, the first to represent the non-confined area, and the second to represent the crystalline basement.

To make data entry, outline conditions, etc. easier, PMWIN allows an aquifer image to be inserted. This way, a scanned image was used (the same used for topographic survey), which was transformed into a bitmap file and inserted in the program. Data related to each alluvium are shown in Table 2.71.

Table 2.71 – Position data related to each aquifer surveyed

NAME	Georeference coordinates		Boundary coordinates	
	Upper left	Lower right	Lower left	Upper right
Chicote	458116 / 9484072	458722 / 9483988	458113 / 9483824	458731 / 9484168
Felão	454133 / 9490154	456299 / 9489579	454074 / 9489447	456349 / 9490726
Salgadinho	458477 / 9488910	459358 / 9487533	456940 / 9487215	460440 / 9489485

Once georeference was concluded, networks were moved to the study area, and this phase ended by showing the situation shown in Figures 2.128 to 2.130.

Figure 2.128 – Georeferenced domain of Chicote stream

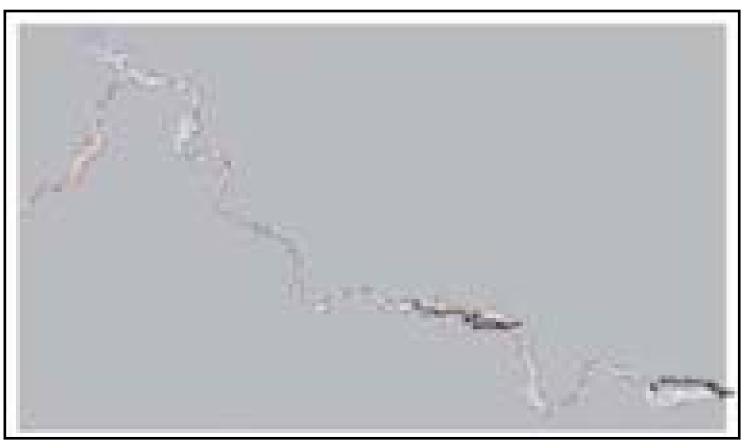

Figure 2.129 – Georeferenced domain of Felão stream

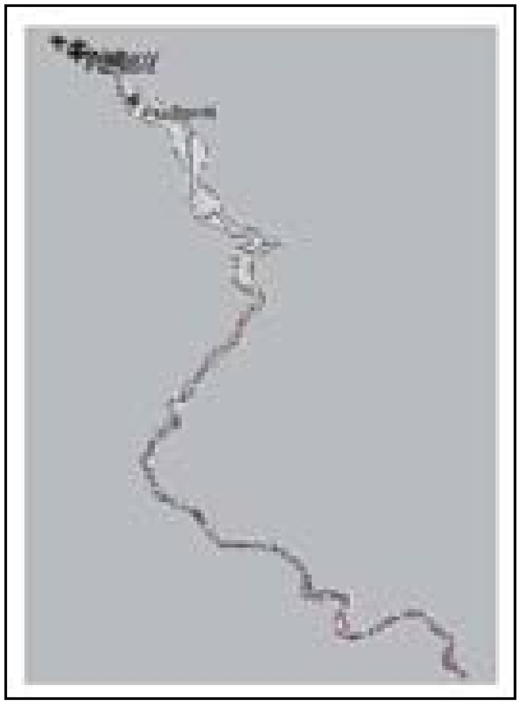

Figure 2.130 – Georeferenced domain of Salgadinho stream

b) Interpolation of hydraulic conductivity

Calculation of horizontal hydraulic conductivity (K_H) was based on field inverted well tests. PMWIN tool "Digitizer" was used to enter the values and generate a '.xyz file.' This file allowed interpolation for the whole domain, using the PMWIN tool *Field Interpolator* to interpolate values and generate a ".dat file."

The generated field was disposed in two layers. Similarly, vertical hydraulic conductivity was interpolated, the values of which were divided by 10 in relation to horizontal conductivity values.

c) Application of Outline Conditions

For the first layer, the non-flow condition around the aquifer was considered as non-confined (grey colored in Figures 2.2.56 to 2.2.58). Inside the aquifer, the active cell status was inserted (calculates the hydraulic load).

For the second layer, the non-flow condition was fully considered as non-confined (basement).

d) Height interpolation (top and base of layers)

Using the scanned map (topography), a table of monitoring point heights was obtained. This table was then inserted in 'File of heights and depths for simulation'). From that file, data were extracted to create the file 'cotas_elevacao.xyz'. *Field Interpolator* tool was used again to interpolate values and generate a .dat file, and the generated field was placed on the first layer.

The procedure was similar to that for drilling spreadsheets, from which a table of monitoring point depths was obtained. This table was then inserted in 'File of heights and depths for simulation' and corrected for local data. The file 'cotas_fundo.xyz' was extracted and *Field Interpolator* was used to interpolate values and generate the .dat file. Then the generated field was placed on the first layer. For the second layer, zero value (data origin) was used.

e) Effective porosity / specific drainage (Specific Yield) / specific storage

For such parameters, at a first moment, standard program values were used (0.25 / 0.25 / 0.0001). Future investigations may correct such values to values more representative of local physical reality.

f) Initial hydraulic loads

Field measured values of 02/27/2008 were used and inserted in 'cargas_hidr_iniciais.xyz' file. Then, *Field Interpolator* was used to interpolate values and generate the .dat file. The generated field was placed on the first l*ayer*. For the second layer (no runoff), values were simply repeated.

g) Time parameters

Twenty-eight (28) time periods were established, each one similar to the period between field sampling. Transient regime was used, and the number of steps in each period was ten times greater than the period size.

h) Precipitation and evapotranspiration data

To evaluate the behavior of generated models, packages were inserted in MODFLOW. Data from the file "Canindé precipitation and evapotranspiration data" were used, which refer to monthly averages. Average difference between precipitation and evapotranspiration in the period was entered (after converted from mm/month to m/sec into "Recharge" package. Values were evenly entered for the whole aquifer.

i) Performance of First Simulation Rounds

Once the physical model was fully inserted in PMWIN/MODFLOW, in addition to 'Recharge' package (precipitation – evapotranspiration), the first simulations could then be performed. For Chicote stream, the result is graphically depicted in Figure 2.131 for the end of the second sampling period. As it can be noted, the aquifer has already 'dried up'. This can be deducted from the fact that the model used the potential evapotranspiration, which is higher than that actually observed. Adjustments to those parameters may be easily made for future scenario analyses.

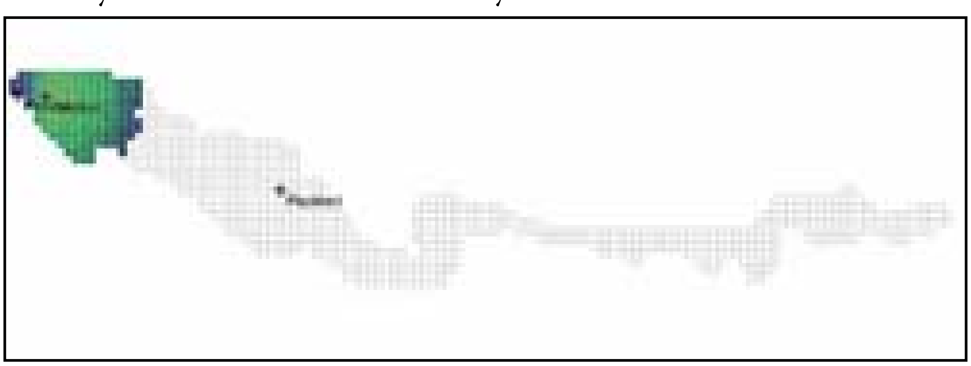

Figure 2.131 – Hydraulic load profile after simulation in Chicote stream for the second sampling period (stress period)

It can be deducted that physical models (parameters) of all three aquifers surveyed have already been fully inserted in the simulation environment. For that, field measurement was greatly used, from topography to inverted well tests (to estimate hydraulic conductivity) and geological drilling profiles. As such, environments for simulation of related scenarios, in addition to field data for model validation are provided. For that task, relevant MODFLOW packages should be inserted, and the results should be evaluated under data feedback regime.

Soils 3

PART 3 – SOILS

3.1 – Operating monitoring aspects

To understand behavior of erosion processes and sediment displacement in surveyed area, effects from rainy season on two different soils were monitored. A piece of land was cultivated with annual crops, where standard edaphic practices are used, such as: surrounding stone barriers, dead cover and organic manuring, in addition to successive dams made of stone of inverted Roman arch. The other piece of land had a brushwood vegetation and native pasture, and was used for bovine cattle raising, where successive dams were constructed.

3.1.1 - Area with annual crops

Surrounding barriers

Surrounding barriers were made of stone according to the contour line established on the soil surface, the objective of which is to retain soil removed by erosion processes and reduce the losses of macro and micro nutrients and organic matter. Such processes are known to be directly influenced by rain characteristics, soil declivity, soil infiltration capacity, as well as by vegetative cover density.

During the monitoring of this area, collectors were installed to retain water and soil, according to a model developed by professor Anor Fiorini de Carvalho from the Soil Department of Viçosa Federal University.

Collectors (Photo 3.01) consist of a 20cm wide table coupled to a mobile duct holding a plastic bag measuring 25 x 35 x 0.2cm.

Twenty-eight (28) collectors soil collectors were installed, and a similar number of water collectors. Photos 3.2, 3.3 and 3.4 illustrate the soil collector installation and arrangement. For water collector, plastic bags were laser microperforated to retain only solid particles.

Photo 3.01 – Soil and water collector

Photo 3.02 – Soil collector installation

Photo 3.03 – Front view of a soil collector

Photo 3.04 – View from above of a collector installed with a fixed bag

Collectors were disposed in pairs, 10-m spaced from each other, leveled and upstream to stone barriers (Figure 3.1 and Photo 3.05}.

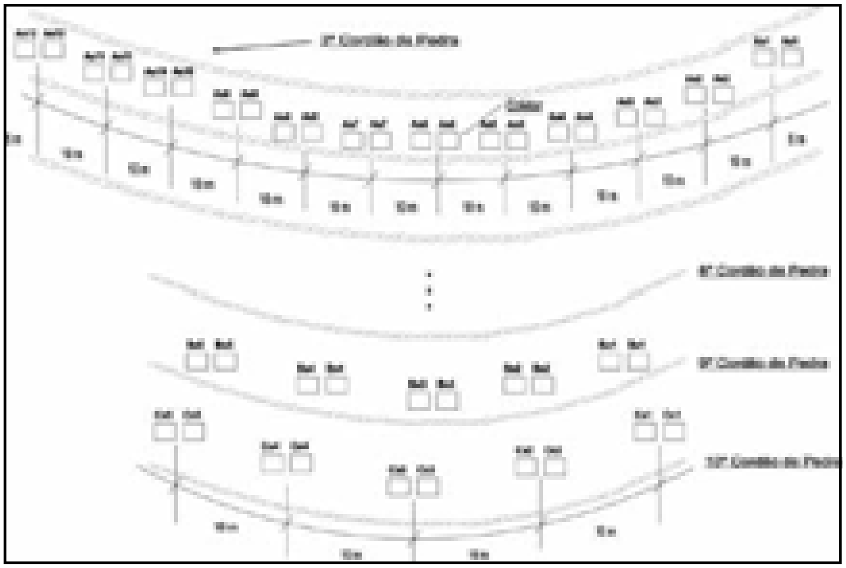

Figure 3.01 – Location plan of soil and water collectors

Photo 3.05 – View of a soil and water collector assembly

Soil dragged by a surface runoff after a rainy event and retained in collector was collected and stored in a plastic bad (some 500 g) provided with a label to indicate the collector reference, date of storage in plastic container and date of collection. Solid material was sent to soil and water laboratory where physical analyses were performed (granulometry, flocculation level, density, moisture and electrical conductivity) in addition to chemical analyses (Ca, Mg, K, Na, P, C, N, MO and pH).

The same procedure was adopted fir water samples after the rainy event, that is, accumulated water was stored in a homogenized plastic bag (Photos 3.6 and 3.7) and poured to a beaker for volume measurement. Then, it was placed in a closed and labeled bottle (some 600 ml) indicating the date of placement in the collector, date of removal from plastic bag, stored volume and collector reference number. Then, it was sent to the laboratory, where water analysis was made considering turbidity, macronutrients, suspended solids and electrical conductivity.

Tables 3.01, 3.02 and 3.03 shows data of soil and water collector installation, related to:

- position between stone barriers;
- geographic coordinates;
- type of sample (water or soil);
- distance between them;
- ramp length;
- declivity;
- soil cover;
- soil use;
- soil type; and
- position in slope.

Photo 3.06 – Turbidity difference observed in collector

Photo 3.07 – Turbidity difference noted in beakers at volume measurement

It should be noted that collectors starting with letter **A** were installed between the third and fourth stone barrier. Those starting with letter **B** were located between the eighth and ninth barrier. Those starting with letter **C** were positioned between the ninth and tenth barrier, and finally those started with **D**, after the tenth stone barrier.

Table 3.01 – Soil and water collectors 1 – installation data

Collector	GPS position of the first in the row	Row	Type	Distance between them (m)	Ramp length (m)	Declivity %	Soil cover %	Soil use	Type of soil	Position of slope
As1	0456521 / 9489174	A	soil	10	6.45	12.09	80.00	no use	Podsol - PE	NW - SE
Aa1		A	water	10	6.45	12.09	80.00	no use	Podsol - PE	NW - SE
As2		A	soil	10	7.45	11.07	65.00	no use	Podsol - PE	NW - SE
Aa2		A	water	10	7.45	11.07	65.00	no use	Podsol - PE	NW - SE
As3		A	soil	10	10.25	10.54	67.50	no use	Podsol - PE	NW - SE
Aa3		A	water	10	10.25	10.54	67.50	no use	Podsol - PE	NW - SE
As4		A	soil	10	11.60	8.62	100.00	no use	Podsol - PE	NW - SE
Aa4		A	water	10	11.60	8.62	100.00	no use	Podsol - PE	NW - SE
As5		A	soil	10	13.45	7.06	90.00	no use	Podsol - PE	NW - SE
Aa5		A	water	10	13.45	7.06	90.00	no use	Podsol - PE	NW - SE
As6		A	soil	10	15.00	7.87	95.00	no use	Podsol - PE	NNW - SSE
Aa6		A	water	10	15.00	7.87	95.00	no use	Podsol - PE	NNW - SSE
As7		A	soil	10	14.25	6.81	86.25	no use	Podsol - PE	N - S
Aa7		A	water	10	14.25	6.81	86.25	no use	Podsol - PE	N - S
As8		A	soil	10	10.65	10.80	97.50	no use	Podsol - PE	N - S
Aa8		A	water	10	10.65	10.80	97.50	no use	Podsol - PE	N - S
As9		A	soil	10	7.75	10.45	92.50	no use	Podsol - PE	NNE - SSW
Aa9		A	water	10	7.75	10.45	92.50	no use	Podsol - PE	NNE - SSW
As10		A	soil	10	7.65	10.98	87.50	no use	Podsol - PE	NNE - SSW
Aa10		A	water	10	7.65	10.98	87.50	no use	Podsol - PE	NNE - SSW
As11		A	soil	10	5.85	16.58	80.00	no use	Podsol - PE	NNE - SSW
Aa11		A	water	10	5.85	16.58	80.00	no use	Podsol - PE	NNE - SSW
As12		A	soil	10	6.15	11.87	62.50	no use	Podsol - PE	N - S
Aa12	0456454 / 9489119	A	water	10	6.15	11.87	62.50	no use	Podsol - PE	N - S

Table 3.02 – Soil and water collectors 2 – Installation data

Collector	GPS position of the first in the row	Row	Type	Distance between them (m)	Ramp length (m)	Declivity %	Soil cover %	Soil use	Type of soil	Position of slope
Bs1	0456604 / 9489113	B	soil	10	24.75	11.47	82.50	maize/ beans	Podsol - PE	NNW - SSE
Ba1		B	water	10	24.75	11.47	82.50	maize/ beans	Podsol – PE	NNW - SSE
Bs2		B	soil	10	25.35	11.56	62.50	maize/ beans	Podsol – PE	NNW - SSE
Ba2		B	water	10	25.35	11.56	62.50	maize/ beans	Podsol – PE	NNW - SSE
Bs3		B	soil	10	25.55	10.68	47.50	maize/ beans	Podsol – PE	NNW - SSE
Ba3		B	water	10	25.55	10.68	47.50	maize/ beans	Podsol – PE	NNW - SSE
Bs4		B	soil	10	25.75	10.37	10.00	maize/ beans	Podsol – PE	NNW - SSE
Ba4	0456589 / 9489084	B	water	10	25.75	10.37	10.00	maize/ beans	Podsol – PE	NNW - SSE
Bs5		B	soil	10	22.05	11.97	28.75	maize/ beans	Podsol – PE	NNW - SSE
Ba5		B	water	10	22.05	11.97	28.75	maize/ beans	Podsol – PE	NNW - SSE
Cs1	0456624 / 9489094	C	soil	10	24.25	10.06	32.50	maize/ beans	Podsol – PE	NNW - SSE
Ca1		C	water	10	24.25	10.06	32.50	maize/ beans	Podsol – PE	NNW - SSE
Cs2		C	soil	10	23.55	10.79	21.25	maize/ beans	Podsol – PE	NNW - SSE
Ca2		C	water	10	23.55	10.79	21.25	maize/ beans	Podsol – PE	NNW - SSE
Cs3		C	soil	10	21.25	13.32	33.75	maize/ beans	Podsol - PE	NNW - SSE
Ca3		C	water	10	21.25	13.32	33.75	maize/ beans	Podsol – PE	NNW - SSE
Cs4		C	soil	10	19.85	13.55	2.50	maize/ beans	Podsol – PE	NNW - SSE
Ca4	0456607 / 9489072	C	water	10	19.85	13.55	2.50	maize/ beans	Podsol – PE	NNW - SSE
Cs5		C	soil	10	18.00	13.61	28.75	maize/ beans	Podsol – PE	NNW - SSE
Ca5		C	water	10	18.00	13.61	28.75	maize/ beans	Podsol – PE	NNW - SSE

Table 3.03 – Soil and water collectors 3 – Installation data

Collector	GPS position of the first in the row	Row	Type	Distance between them (m)	Ramp length (m)	Declivity %	Soil cover %	Soil use	Type of soil	Position of slope
Ds1	0456450 / 9489220	D	soil	5	8.45	30.18	18.75	maize/beans	Podsol - PE	?
Da1		D	water	5	8.45	30.18	18.75	maize/beans	Podsol - PE	?
Ds2		D	soil	5	8.40	29.29	6.75	maize/beans	Podsol – PE	?
Da2		D	water	5	8.40	29.29	6.75	maize/beans	Podsol – PE	?
Ds3		D	soil	5	9.80	25.20	6.25	maize/beans	Podsol – PE	?
Da3		D	water	5	9.80	25.20	6.25	maize/beans	Podsol – PE	?
Ds4		D	soil	5	9.25	24.00	15.00	maize/beans	Podsol – PE	?
Da4		D	water	5	9.25	24.00	15.00	maize/beans	Podsol – PE	?
Ds5		D	soil	5	9.55	23.35	18.75	maize/beans	Podsol – PE	?
Da5		D	water	5	9.55	23.35	18.75	maize/beans	Podsol – PE	?
Ds6	0456430 / 9489238	D	soil	9	8.95	24.69	25.00	maize/beans	Podsol – PE	?
Da6		D	water	9	8.95	24.69	25.00	maize/beans	Podsol – PE	?

Successive Dams

This area is crossed by Guerreiro stream, where five (5) Roman-arch successive dams were constructed. For monitoring purposes, 150-cm graduated rulers were affixed downstream and adjacent to dams on massaranduba joists by slotted cross-head screws on the ends and another similar normal slotted head screw on the middle crossing the joist and depressed on their ends to made vandalism acts difficult (Photos 3.8 and 3.9).

Photo 3.08 – Trench for ruler installation in successive dam

Photo 3.09 – Installation of ruler

After the rainy season, a measurement of final height it sediments was made in each of rulers, and the sediment area was calculated (Figures 3.2, 3.3, 3.4, 3.5 and 3.6). For that, using a measuring tape, the visually perceived surface was measured, the edges of which were measure straightly (corners) until forming a closed polygon. All vertices were internally interlinked (marked) and measured in such a way that all internal geometric figures in the area were triangles, thus allowing the perfect reading of the area.

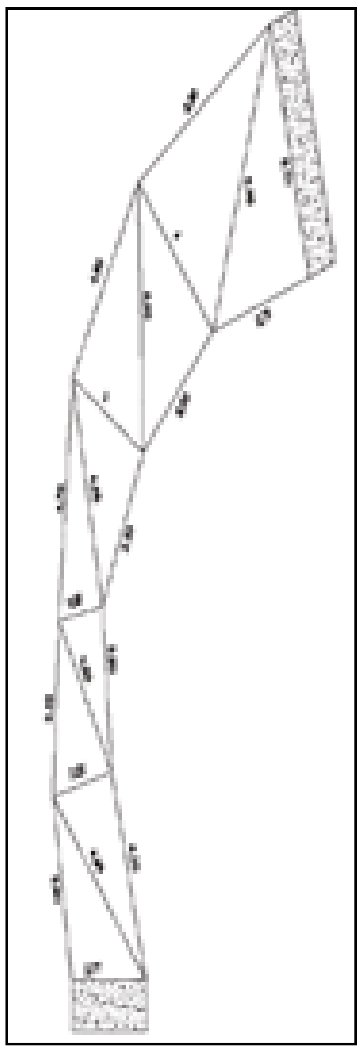

Figure 3.02 – Schematic drawing of G1 dam area

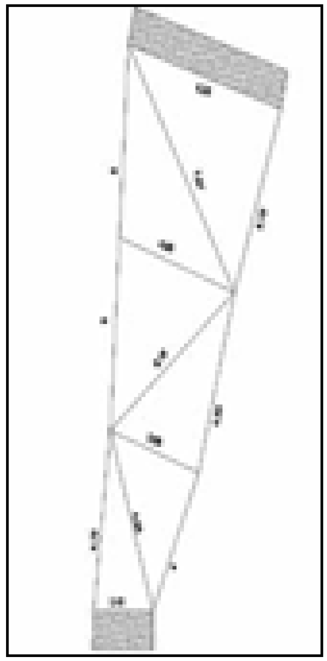

Figure 3.03 – Schematic drawing of G2 dam area

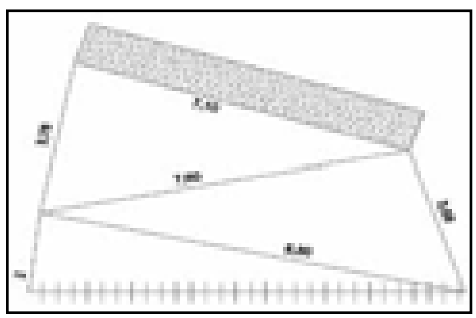

Figure 3.04 – Schematic drawing of G3 dam area

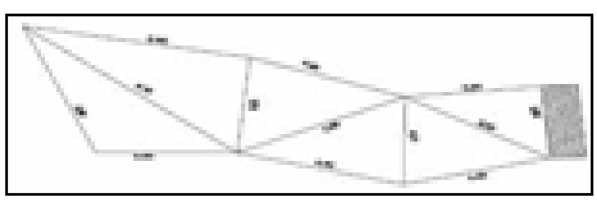

Figure 3.05 – Schematic drawing of G4 dam area

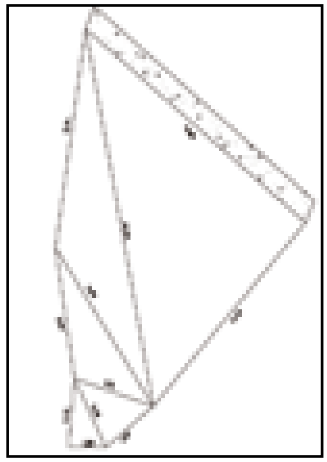

Figure 3.06 – Schematic drawing of G5 dam area

At ruler placement, 1-m long, 0.5-m wide and 0.5-m deep trenches were opened (Photo 3.10), which varied according to the height of sediments transported since the dam construction.

Photo 3.10 – Trench opening

In this profile (inverted), layers (extracts) were identified and separated, and the existing material was collected. This material was stored in plastic bags (Photo 3.11), labeled and sent to the soil laboratory for physical and chemical determinations.

Photo 3.11 – Soil samples

3.1.2. Area of natural vegetation and native pasture

Successive dams

In area delimited for monitoring, Bananeiras stream was selected, where eleven (11) graduated rulers were affixed starting in the stream springs.

This procedure was similar to that adopted for crops, that is, after the rainy season measurement was made on eight (8) rulers because one of them was damaged and two (2) of them were dragged by the flood, and the sediment accumulation area was calculated (Figures 3.7, 3.8, 3.9, 3.10, 3.11, 3.12, 3.13 and 3.14). After the identification and separation of soil layers, existing material was collected and sent to UFC/Funceme soil and water laboratory for physical-chemical analyses.

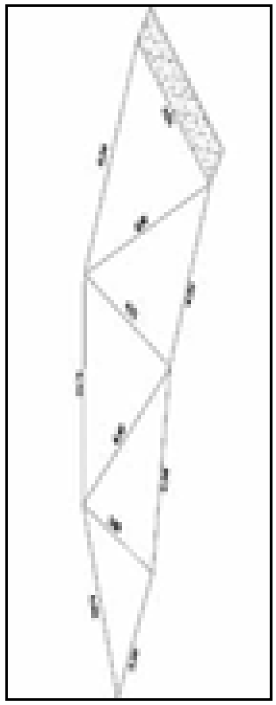

Figure 3.07 – Schematic drawing of B1 dam area

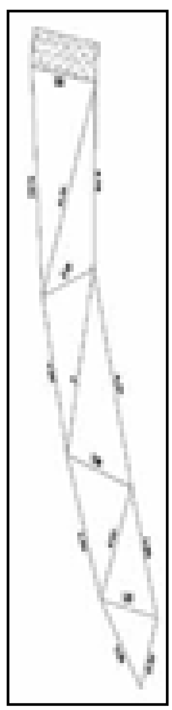

Figure 3.08 – Schematic drawing of B2 dam area

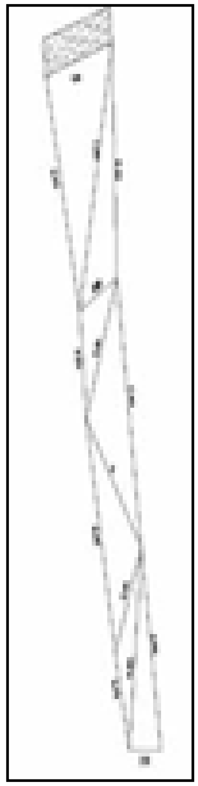

Figure 3.09 – Schematic drawing of B3 dam area

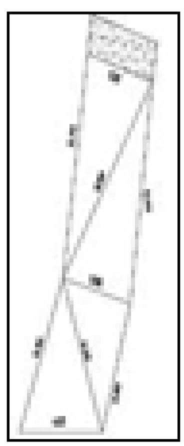

Figure 3.10 – Schematic drawing of B4 dam area

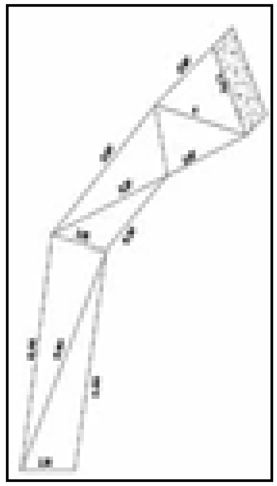

Figure 3.11 – Schematic drawing of B5 dam area

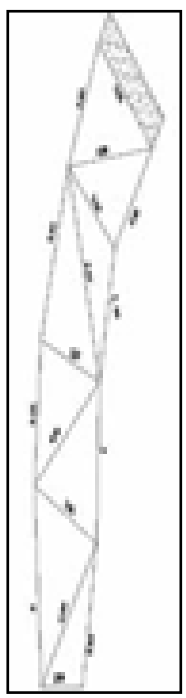

Figure 3.12 – Schematic drawing of B7 dam area

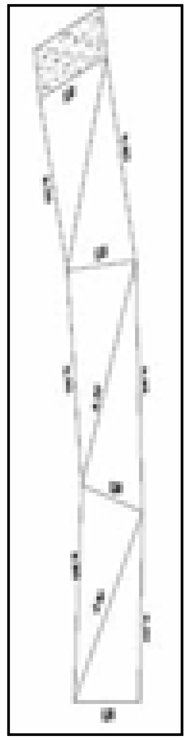

Figure 3.13 – Schematic drawing of B10 dam area

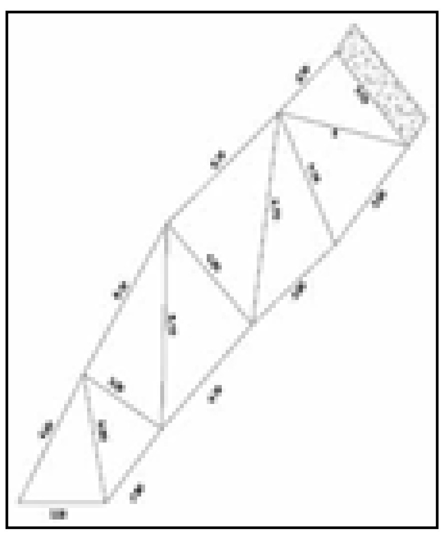

Figure 3.14 – Schematic drawing of B11 dam area

3.2 – Results and discussions

For surveyed area monitoring, erosion process follow-up, sediment displacement and soil and water conditions after the rainy season, data were collected from both pieces of land initially determined, one located in Guerreiro stream and the other located in Bananeiras stream. Results of measurement of accumulates sediment volume are shown in Chart 3.01.

Chart 3.01 – Data of sediment volume accumulated in successive dams

	MEASUREMENTS				CALCULATED MEASUREMENTS		
Ruler	Height before rainy season (cm)	Height after rainy season (cm)	Height evolution in rainy season (cm)	Final sediment area (m^2)	Volume of final accumulated sediment (m^3)	Volume of initial accumulated sediment (m^3)	Variation of accumulated sediment volume (m^3)
B1	18	31	13	50.03	5.17	1.01	4.16
B2	20	43	23	48.86	7.00	0.70	6.30
B3	13	80	67	53.95	14.39	0.06	14.32
B4	27	76	49	32.70	8.28	0.37	7.91
B5	16	38	22	29.18	3.70	0.28	3.42
B7	60	90	30	52.53	15.76	4.67	11.09
B10	23	39	16	39.40	5.12	1.05	4.07
B11	8	39	31	58.05	7.55	0.07	7.48
G1	22	67	45	59.32	13.25	0.47	12.78
G2	20	84	64	60.96	17.07	0.23	16.84
G3	85	109	24	35.95	13.06	6.19	6.87
G5	59	73	14	129.77	31.58	16.67	14.91

Legend: B = Successive dams in Bananeiras stream; and G = Successive dams in Guerreiro stream.

Information contained in Chart 3.01 shows the height, surface area and volume of accumulated sediments after rainy season in monitored successive dams, as indicated by codes B1, B2, B3, B4, B5, B7, B10 and B11 corresponding to rulers installed in Bananeiras stream, and codes G1, G2, G3 and G5 corresponding to rulers installed in Guerreiro stream. In all points, an accumulation of sediments was noted. By analyzing the evolution of sediment height in successive dam rulers, we can note a similar situation in both streams (Figure 3.15). There is an increasing initial sediment accumulation (B1 at com 13 cm, B2 at 23 cm and B3 as high as 67 cm; G1 at 45 cm, G1 at 45 cm and G2 at 64 cm.

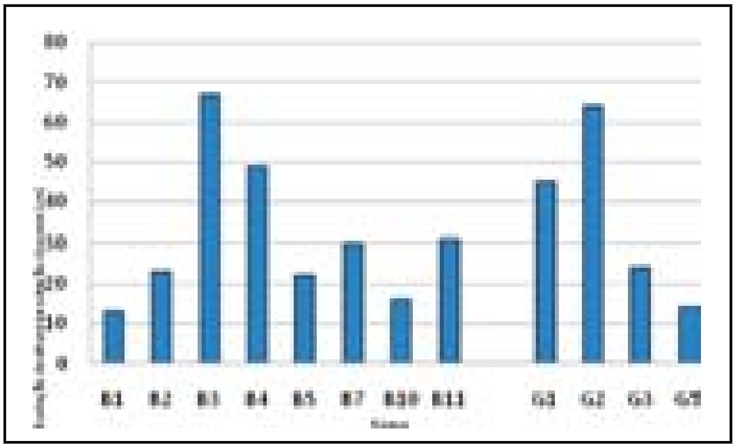

Figure 3.15 – Evolution of accumulated sediment height per successive dam

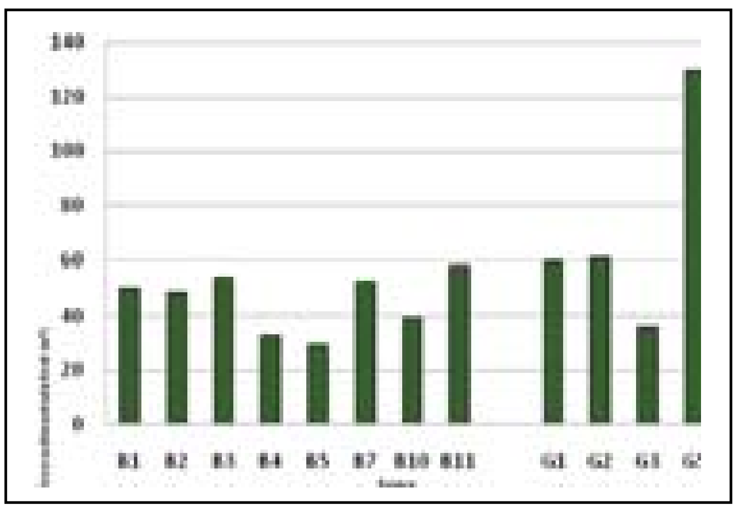

Figure 3.16 – Sediment area per successive dam

By comparing the sediment area of Bananeiras stream dam, an equilibrium of values is noted (Figure 3.16). In Guerreiro stream, first dams have similar surface areas (G1=59.32 m^2 and G2=60.96$m^{2)}$,

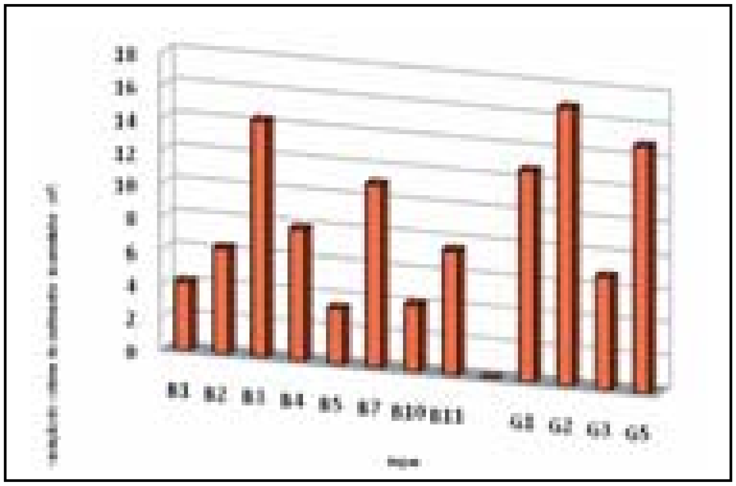

Figure 3.17 – Volume variation of accumulated sediments per successive dams

In general, it is noted that after the rainy season there was an accumulation of sediments in all successive dams in both streams, what minimized the impacts of erosion processes and promoted soil and vegetation recomposition in worked areas.

3.2.1 – Evaluation of water retained in collectors in successive dams

At water and soil monitoring, analyses of samples collected after the rainy season from installed retaining collectors were evaluate.

In water samples, cations (Ca, Mg, K, Na), anions (Cl^-, SO_4^{2-}, HCO_3, CO_3^{2-}), electrical conductivity (CE), sodium absorption ratio (RAS), pH, dissolved solids, turbidity and suspended solids were analyzed. Water was classified according to such parameters. Based on respective results, samples were classified as **C1S1**. –C1 salinity category indicates that water has low salinity, can be used for irrigation of most crops, and has little salinity risk. -S1 sodium category means that water has low sodium content and may irrigate almost all types of soils, except for the possibility of affecting certain crops that are highly sensitive to sodium. This way, it is concluded that analyzed water is of good quality. With respect to sodium absorption ratio (RAS), all analyses showed values not exceeding 0.70 meq/L, therefore quite lower than the maximum values considered adequate to irrigation, that is, 3 meq/L. That confirmed that there was no direct risk of soil salinity problems. Risk of salinity problems in the study area is indirect and unlikely to occur; their eventual occurrence would be the result of incorrect irrigation management.

3.2.2 – Evaluation of soil in collectors installed in successive dams

Soil samples related to sediments were sent to the Soil laboratory of UFC/Funceme for physical and chemical characterization. In laboratory, samples were filed, registered by a field identification number and prepared for analytical determinations. It should be emphasized that analytical data are critical for pedological surveys and mapping of soil classes, as they allow the real understanding of soil and may determine actions aimed to indicate its adequate use, management and preservation, as well as its agricultural aptitude, in addition to other technical indications essential to agricultural research and production. Therefore, it is necessary to obtain such results in this work.

Profiles of soils collected in study area showed the domain of sandy, loamy sand, loamy and sandy loam texture. Argillaceous textured soils (clay, sandy argillaceous and silty argillaceous soils) were not found. Identification of soil texture by granulometric analysis allows some general remarks related to implications of soil management and fertility. The solid mineral fraction of profiles classified as sand and loamy sand show a quartz constitution with contents of clay and silt lower than 15%. Flocculation level (indicates the stability level of soil aggregates) is below 50%, which is considered a very low index. Capacity of available water is below 0.10 $m^3.m^{-3}$. With related to soil characteristics explicitly related to sorting complex, a likely susceptibility to erosion is likely too occur because of the texture itself, with low capacity of cation exchange (CTC). However, organic matter contents are high, showing that the organic fraction is partly responsible for CTC in those soils. Organic matter is the main energetic and nutritive support of soil microorganisms; Its influence on soil capacity to withstand pH variation (buffering power) makes the organic matter indispensable for the interpretation of analytical results of soil samples, especially acid soils. It is important to point out that in some profiles exchangeable aluminum is slightly toxic for most crops, and require the application of correctives to mitigate the problem of this element in plant nutrition.

There are no problems of exchangeable sodium, as the content of this nutrient is low. However, because of their sandy texture, the tendency of such soils is that of an excessive drainage standard, with nutrient leaching problems, especially in nitrates. Soils showed low moisture retention, both at field capacity (CC) and at permanent wilt condition (PMP). Global density shows values close to 1.4 g/cm^3. In general, it can be said that the higher the global soil density, the greater its compaction, the less its organization, the less its total porosity, and consequently, the greater the restrictions to vegetation growth and development. In case of need of application of potassic acid, it should be divided into small portions when this nutrient is recommended at higher doses. Herbicides should be used cautiously, at low doses, because of the lower absorption by colloids.

In profiles evidencing a medium texture (loamy, sandy loamy), soils displayed clay + silt content above 15% and clay < 35%, showing medium/ low moisture retention values indicating a low or moderate susceptibility to erosion. Flocculation level may be considered moderate (50-75%). There is a tendency for accumulation of organic matter in such soils, thus evidencing the importance of this colloid for a higher CTC, as compared to CTC of sandy textured soils.

Vegetation 4

PART 4 – VEGETATION

4.1 – General vegetation aspects

Between April and September 2008, a floristic and phytosociological survey was made in two 800-m^2 plots, including the collection of flora specimens and vegetation data (phytosociology, vegetative structure, soil cover and biomass). The study included two 20m x 40-m plots previously delimited by PRODHAM in the district of Iguaçu (Canindé). “Plot 1” was located in a successive dam area close to a small stream, and “Plot 2” in a reforestation area on the margins of Cangati River.

Inclusion criterion adopted for phytosociological data collection and count of tree species was that of diameter at soil level (DSL) > 3 cm, which has been traditionally used for phytosociological studies in Brushwood region (RODAL; SAMPAIO; FIGUEIREDO, 1992). This way, all over the length of plots, species data were collected, including diameter, fustic and height of all individuals of DSL > 3 cm, comprising a sampled area of 1,600 m^2 (800 m^2 in each plot) including three hundred and fifty-eight (358) trees.

Vegetation predominating in the Cangati River microbasin is brushwood – a typical vegetation predominating in the whole Brazilian Northeast. (RODAL; SAMPAIO: FIGUEIREDO, 1992). Brushwood is a xerophilous vegetation of varied aspect and floristic and mainly characterized by total caducifolia of most its components due to an annual water shortage of at least six (months) (RODAL; SAMPAIO; FIGUEIREDO, 1992; VELOSO; RANGEL FILHO; LIMA, *1991*).

During the study, floristic records were made in several points around the Plots and other successive dams not included in the plots. Listed species (Table 4.01) are mostly typical or brushwood, such as *angico, pau-ferro, jurema, marmeleiro, sabiá, pinhão, mofumbo, catingueira, juazeiro, trapiá, pau-branco,* and *mandacaru*, among others, even though other exotic species (such as hydrangea) and even invasive species (such as *leucena* and '*viuvinha alegre*') were identified, indicating the human presence and environmental degradation.

The construction of successive dams along streams in the region has caused a strong sediment retention. Because of the small size of streams and dams, area affected by sediment accumulation is not vast (Figure 4.01). In such areas, the occurrence of herbaceous plants, such as *Alternanthera tenella*, *Senna obtusifolia* (*Leguminosae*, mata-pasto), *Ludwigia spp*. and *Spermacoce verticillata* was recorded, in addition to herbaceous plants of *Poaceae* and *Cyperaceae* families. Also, some pioneer ligneous species, such as *Jatropha mollissima* (*Euphorbiaceae*, *pinhão*), *Croton blanchetianus* (*Euphorbiaceae*, marmeleiro), *Mimosa caesalpiniifolia* (*Leguminosae*, sabiá) and *Combretum leprosum* (*Combretaceae*, mofumbo) were also found no sediments

Table 4.01 – List of native species found in study area region

Scientific name	Family	Popular name	Aspect
Alternanthera brasiliana	Amaranthaceae	Cabeça-branca	Herbaceous
Alternanthera tenella	Amaranthaceae	Cabeça-branca	Herbaceous
Amaranthus sp.	Amaranthaceae	Caruru	Herbaceous
Anadenanthera colubrina	Fabaceae-Mimosoideae	Angico	Tree
Anacardiaceae sp1	Anacardiaceae	Aroeira**	Tree
Auxemma oncocalix	Boraginaceae	Pau-branco	Tree
Bauhinia cheilantha	Fabaceae-Cercideae	Mororó	Tree
Bidens sp.	Asteraceae	Carrapicho-agulha	Herbaceous
Caesalpinia bracteosa	Fabaceae-Caesalpinioideae	Catingueira	Tree
Caesalpinia férrea	Fabaceae-Caesalpinioideae	Jucá	Tree
Capparis cynophallophora	Capparaceae	Beans-brabo	Tree
Cardiospermum coridum	Sapindaceae	-	Herbaceous creeper
*Calotropis procera**	Apocynaceae	Ciúme; Cotton-de-seda	Shrub
Cereus jamacaru	Cactaceae	Mandacarú	Cactus
Cissus albida	Vitaceae	-	Creeper
Cnidoscolus urens	Euphorbiaceae	Cansansão	Shrub
Combretum leprosum	Combretaceae	Mofumbo	Shrub
Commiphora leptophloeos	Burseraceae	Imburana	Tree
Crateva tapia	Capparaceae	Trapiá	Tree
Croton blanchetianus	Euphorbiaceae	Marmeleiro	Tree/Shrub
*Cryptostegia grandiflora**	Apocynaceae	Viuvinha-alegre	Shrub
Delilia biflora	Asteraceae	-	Herbaceous
Hyptis suaveolens	Lamiaceae	Bamburral	Herbaceous

(continue)

(continuation)

Scientific name	Family	Popular name	Aspect
Ipomoea nil	Convolvulaceae	Jitirana	Herbaceous creeper
Ipomoea sericophylla	Convolvulaceae	Jitirana	Herbaceous creeper
Jatropha mollissima	Euphorbiaceae	Pinhão	Tree
Lantana camara	Verbenaceae	Chumbinho	Shrub
Laportea aestuans	Urticaceae	Urtiga	Herbaceous
*Leucaena leucocephala**	Fabaceae-Mimosoideae	Leucena	Tree
Licania rígida	Chrysobalanaceae	Oiticica	Tree
Ludwigia sp1	Onagraceae	-	Herbaceous
Ludwigia sp2	Onagraceae	-	Herbaceous
Merremia aegyptia	Convolvulaceae	Jitirana-cabeluda	Herbaceous creeper
Mimosa cf. acutistipula	Fabaceae-Mimosoideae	Vaca-velha	Tree/Shrub
Mimosa caesalpiniifolia	Fabaceae-Mimosoideae	Sabiá	Tree
Mimosa tenuiflora	Fabaceae-Mimosoideae	Jurema-preta	Tree/Shrub
*Momordica charantia**	Cucurbitaceae	Melão-de-são-caetano	Herbaceous creeper
*Moringa oleifera**	Moringaceae	Moringa	Tree
Pilosocereus gounellei	Cactaceae	Faxeiro	Cactus
Poaceae SP	Poaceae	Capim	Herbaceous
Polygala martiana	Polygalaceae	-	Herbaceous
Pseudabutilon spicatum	Malvaceae	Malva	Herbaceous
Senna obtusifolia[?]	Fabaceae-Caesalpinioideae	Mata-pasto-liso	Herbaceous
Senna occidentalis[?]	Fabaceae-Caesalpinioideae	Manjerioba; mata-pasto	Herbaceous
Senna uniflora	Fabaceae-Caesalpinioideae	Mata-pasto-peludo	Herbaceous
Spermacoce capitata	Rubiaceae	Vassourinha	Herbaceous
Spermacoce verticillata	Rubiaceae	Vassourinha	Herbaceous
Spondias cf. mombin	Anacardiaceae	Cajá	Tree
Tabebuia sp.	Bignoniaceae	Pau-darco	Tree
Vitex gardneriana	Verbenacea	Jaramataia	Tree/Shrub
Ximenia americana	Olacaceae	Ameixa	Shrub
Ziziphus joazeiro	Rhamnaceae	Joazeiro	Tree

* Exotic species

? Species of doubtful origin

** Species without a confirmed name

It was not possible to confirm whether the plant called by residents as mastic tree (*aroeira*) is actually *Myracrodruon urundeuva* (*Anacardiaceae*), as only young species were found in vegetative state. As the area where species were found was a reforestation areas, mostly using exotic species, it is likely to be a kind of *Spondias* (*Anacardiaceae*) species planted for fruit growing purposes.

Herbaceous pants listed above are annual small-size plants (not more than 1.5-m high) that develop during the rainy season and fade at the start of dry season leaving only buds, or die leaving only seeds for next rainy period. Such plants pioneered the secondary succession by developing well in place of strong solar radiation (such as clearings, deforested areas and edges of forest fragments). Some of them, such as *Senna obtusifolia*, are weeds – dispersed by bovine cattle.

Photo 4.01 – Area close to successive dam – prevalence of annual herbaceous plants

Ligneous species (arboreous) found on sediments are also pioneer species typical of secondary succession, which are indicative of initial phases of (re)colonization or environmental recovery processes. Such trees are sometimes as high as 2 or 3 meters, indicating that the colonization process started some years ago. Because of the lack of phytosociological and floristic records at the start of PRODHAM action implementation, it was possible to estimate the growth speed of trees occurring in those sediment accumulation areas.

4.2 – Description of plots surveyed

Studies were made in plots previously delimited by PRODHAM.

Gross data related to diameter, fustic, and height collected in successive dam and reforestation plots on Cangati River margins are shown in Tables 4.02 and 4.03, respectively. Table 4.04 provides some general data on the plots and the vegetation description, environmental conditions and preservation state of each of them.

Table 4.02 – Phytosociological data locally collected in Plot 1 (Successive Dam)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
1	*Mimosa tenuiflora*	Leguminosae (Mimosoideae)	Jurema	4.10	0.20	3.50
2	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	3.30	2.00	2.00
3	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	5.70	0.90	0.90
4	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	6.70	1.15	0.10
5	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	6.70	0.56	0.30
6	*Croton blanchetianus*	Euphorbiaceae	Marmeleiro	11.10	0.10	0.58
7	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	4.10	0.00	2.00
8	*Croton blanchetianus*	Euphorbiaceae	Marmeleiro	8.90	0.06	1.60
9	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	9.60	0.04	2.50
10	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	7.00	0.07	2.50
11	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	3.50	1.80	3.00
12	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	3.20	1.00	2.50
13	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	7.60	0.03	3.00
14	*Mimosa caesapiniifolia*	Leguminosae (Mimosoideae)	Sabiá	3.00	0.10	2.00
15	*Combretum leprosum*	Combretaceae	Mufumbo	3.80	0.50	2.50
16	*Combretum leprosum*	Combretaceae	Mufumbo	4.90	0.00	2.50
17	*Combretum leprosum*	Combretaceae	Mufumbo	3.50	0.00	2.50
18	*Combretum leprosum*	Combretaceae	Mufumbo	9.90	0.02	3.00
19	*Mimosa acutistipula*	Leguminosae (Mimosoideae)	Vaca-velha	2.90	0.50	3.00
20	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	3.80	0.10	3.50
21	*Mimosa caesapiniifolia*	Leguminosae (Mimosoideae)	Sabiá	15.60	1.70	4.00

(continue)

(continuation)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
22	*Bauhinia cheilantha*	Leguminosae (Caesalpinoideae)	mororó	15.60	1.10	4.50
23	*Mimosa acutistipula*	Leguminosae (Mimosoideae)	Vaca-velha	17.20	23.00	4.50
24	*Polygonum sp.*	Polygonaceae	-	35.70	0.08	4.00
25	*Combretum leprosum*	Combretaceae	Mufumbo	8.00	0.40	2.00
26	*Combretum leprosum*	Combretaceae	Mufumbo	5.40	-	2.00
27	*Combretum leprosum*	Combretaceae	Mufumbo	4.00	-	2.00
28	*Combretum leprosum*	Combretaceae	Mufumbo	3.80	-	2.50
29	*Combretum leprosum*	Combretaceae	Mufumbo	6.40	-	2.00
30	*Combretum leprosum*	Combretaceae	Mufumbo	4.80	0.75	3.00
31	*Combretum leprosum*	Combretaceae	Mufumbo	3.80	0.73	3.00
32	*Combretum leprosum*	Combretaceae	Mufumbo	9.90	0.05	4.00
33	*Combretum leprosum*	Combretaceae	Mufumbo	5.40	0.72	3.00
34	*Combretum leprosum*	Combretaceae	Mufumbo	5.60	0.56	3.00
35	*Combretum leprosum*	Combretaceae	Mufumbo	5.70	1.30	3.00
36	*Combretum leprosum*	Combretaceae	Mufumbo	4.80	0.80	3.00
37	*Combretum leprosum*	Combretaceae	Mufumbo	16.90	0.05	1.80
38	*Combretum leprosum*	Combretaceae	Mufumbo	5.40	0.13	1.50
39	*Combretum leprosum*	Combretaceae	Mufumbo	10.80	0.05	1.50
40	*Combretum leprosum*	Combretaceae	Mufumbo	16.20	0.12	3.50
41	*Mimosa acutistipula*	Leguminosae (Mimosoideae)	Vaca-velha	3.30	0.13	3.00
42	*Mimosa acutistipula*	Leguminosae (Mimosoideae)	Vaca-velha	3.00	1.20	2.50
43	*Mimosa acutistipula*	Leguminosae (Mimosoideae)	Vaca-velha	4.00	0.20	2.50
44	*Combretum leprosum*	Combretaceae	Mufumbo	3.70	0.80	2.20
45	*Combretum leprosum*	Combretaceae	Mufumbo	4.30	0.15	2.50
46	*Mimosa acutistipula*	Leguminosae (Mimosoideae)	Vaca-velha	3.50	0.20	2.50
47	*Combretum leprosum*	Combretaceae	Mufumbo	7.30	0.11	2.50
48	*Anadenanthera colubrina*	Leguminosae (Mimosoideae)	Angico	14.30	0.60	5.00
49	*Croton blanchetianus*	Euphorbiaceae	Marmeleiro	4.10	0.88	3.00
50	*Anadenanthera colubrina*	Leguminosae (Mimosoideae)	Angico	6.80	1.65	5.00
51	*Anadenanthera colubrina*	Leguminosae (Mimosoideae)	Angico	13.10	0.36	5.00
52	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	2.90	0.64	1.80
53	*Combretum leprosum*	Combretaceae	Mufumbo	3.80	1.03	2.50

(continue)

(continuation)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
54	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	3.20	0.04	1.50
55	*Mimosa tenuiflora*	Leguminosae (Mimosoideae)	Jurema	4.00	0.90	3.00
56	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	3.50	0.50	2.00
57	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	6.10	0.07	2.50
58	*Mimosa acutistipula*	Leguminosae (Mimosoideae)	Vaca-velha	9.60	0.05	2.50
59	*Mimosa acutistipula*	Leguminosae (Mimosoideae)	Vaca-velha	11.10	0.03	2.50
60	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	3.80	0.03	1.40
61	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	15.90	0.05	3.50
62	*Auxemma oncocalyx*	Boraginaceae	Pau branco	30.60	0.02	4.00
63	*Combretum leprosum*	Combretaceae	Mufumbo	5.70	0.06	3.00
64	*Combretum leprosum*	Combretaceae	Mufumbo	3.50	0.33	3.00
65	*Combretum leprosum*	Combretaceae	Mufumbo	5.10	0.06	2.50
66	*Combretum leprosum*	Combretaceae	Mufumbo	6.40	0.45	2.50
67	*Combretum leprosum*	Combretaceae	Mufumbo	5.40	0.07	2.50
68	*Calotropis procera*	Apocynaceae	Hydrangea	9.60	0.08	2.30
69	*Calotropis procera*	Apocynaceae	Hydrangea	3.50	1.50	2.50
70	*Calotropis procera*	Apocynaceae	Hydrangea	5.40	0.00	2.50
71	*Calotropis procera*	Apocynaceae	Hydrangea	16.60	0.02	2.50
72	*Croton blanchetianus*	Euphorbiaceae	Marmeleiro	8.60	0.02	3.00
73	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	3.50	0.36	2.00
74	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	4.30	0.05	2.00
75	*Mimosa tenuiflora*	Leguminosae (Mimosoideae)	Jurema	3.50	0.98	2.50
76	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	4.50	0.06	2.00
77	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	4.10	0.08	2.00
78	*Cryptostegia grandiflora*	Apocynaceae	Viúva alegre	4.10	0.05	1.00
79	*Combretum leprosum*	Combretaceae	Mufumbo	14.30	0.10	2.00
80	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	Leucena	15.30	0.14	3.00
81	*Combretum leprosum*	Combretaceae	Mufumbo	6.70	0.19	2.50
82	*Combretum leprosum*	Combretaceae	Mufumbo	5.40	0.4	2.50
83	*Combretum leprosum*	Combretaceae	Mufumbo	5.60	0.15	2.00
84	*Combretum leprosum*	Combretaceae	Mufumbo	7.80	0.05	2.00
85	*Combretum leprosum*	Combretaceae	Mufumbo	3.70	-	15.00

(continue)

(continuation)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
86	*Combretum leprosum*	Combretaceae	Mufumbo	4.90	0.9	2.00
87	*Combretum leprosum*	Combretaceae	Mufumbo	14.60	0.05	2.00
88	*Combretum leprosum*	Combretaceae	Mufumbo	5.70	0.52	2.50
89	*Combretum leprosum*	Combretaceae	Mufumbo	2.90	0.27	0.50
90	*Mimosa tenuiflora*	Leguminosae (Mimosoideae)	Jurema	47.80	0.05	1.80
91	*Combretum leprosum*	Combretaceae	Mufumbo	4.60	0.03	2.50
92	*Combretum leprosum*	Combretaceae	Mufumbo	3.80	0.3	2.50
93	*Combretum leprosum*	Combretaceae	Mufumbo	11.10	0.1	2.50
94	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	Leucena	12.40	0.1	4.00
95	*Croton blanchetianus*	Euphorbiaceae	Marmeleiro	3.30	0.3	1.50
96	*Croton blanchetianus*	Euphorbiaceae	Marmeleiro	6.70	0.2	2.50
97	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	10.20	0.05	1.10
98	*Croton blanchetianus*	Euphorbiaceae	Marmeleiro	15.30	0.05	1.30
99	*Mimosa caesapiniifolia*	Leguminosae (Mimosoideae)	Sabiá	3.50	1.2	2.50
100	*Calotropis procera*	Apocynaceae	Hydrangea	3.80	1.3	1.80
101	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	6.10	0.36	2.00
102	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	5.40	0.39	2.00
103	*Mimosa tenuiflora*	Leguminosae (Mimosoideae)	Jurema	3.80	0.19	2.00
104	*Combretum leprosum*	Combretaceae	Mufumbo	4.80	0.05	2.50
105	*Combretum leprosum*	Combretaceae	Mufumbo	6.20	0.12	2.50
106	*Combretum leprosum*	Combretaceae	Mufumbo	5.40	0.85	2.50
107	*Combretum leprosum*	Combretaceae	Mufumbo	15.00	0.05	2.50
108	*Combretum leprosum*	Combretaceae	Mufumbo	3.50	0.29	2.50
109	*Combretum leprosum*	Combretaceae	Mufumbo	5.10	0.31	2.50
110	*Combretum leprosum*	Combretaceae	Mufumbo	3.80	0.36	2.50
111	*Combretum leprosum*	Combretaceae	Mufumbo	5.10	0.25	2.50
112	*Combretum leprosum*	Combretaceae	Mufumbo	3.20	0.24	2.50
113	*Combretum leprosum*	Combretaceae	Mufumbo	7.30	0.07	2.50

(continuation)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
114	*Combretum leprosum*	Combretaceae	Mufumbo	4.50	0.25	2.50
115	*Combretum leprosum*	Combretaceae	Mufumbo	8.90	0.05	2.50
116	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	Leucena	11.90	0.05	1.50
117	*Calotropis procera*	Apocynaceae	Hortência	4.10	0.19	1.50
118	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	3.80	0.99	2.50
119	*Caesalpinia gardneriana*	Leguminosae (Caesalpinoideae)	Catingueira	3.30	0.24	2.50

TABLE 4.03 – Phytosociological data locally collected in Plot 2 (reforestation on Cangati River margins).

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
501	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	1.10	4.50	7.00
502	*Jatropha mollissima*	Euphorbiaceae	pinhão	2.90	-	1.50
503	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	16.90	1.16	7.00
504	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	12.40	0.19	6.00
505	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.00	3.00	7.00
506	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.10	5.50	6.00
507	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.20	6.00	7.00
508	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	11.00	1.80	7.00
509	*Vitex cf. gardneriana*	Verbenaceae	-	27.10	0.10	5.00
510	*Jatropha mollissima*	Euphorbiaceae	pinhão	13.10	2.00	7.00
511	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.80	3.50	8.00
512	*Auxemma oncocalyx*	Boraginaceae	pau branco	8.60	0.34	6.00
513	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.70	6.00	8.00
514	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.50	-	4.50
515	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.50	1.50	5.00
516	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.30	4.00	7.00
517	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.20	-	7.00
518	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.10	-	6.00
519	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	14.60	0.95	8.00
520	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.10	5.00	8.00
521	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	11.60	0.08	8.00
522	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.20	-	8.00

(continue)

(continuation)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
523	*Tabebuia sp.*	Bignoniaceae	pau d'árco	4.10	0.90	2.50
524	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.70	-	3.00
525	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	10.20	-	7.00
526	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.20	1.60	6.50
527	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.70	0.60	6.50
528	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.10	-	5.50
529	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.40	-	5.00
530	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.30	3.00	6.00
531	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.40	3.50	6.50
532	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.60	3.50	7.00
533	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.70	6.00	7.00
534	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.30	-	7.00
535	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.30	-	6.00
536	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.50	-	2.00
537	*Spondias sp.1**	Anacardiaceae	aroeira	3.70	-	4.00
538	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.60	4.00	5.00
539	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	10.50	1.00	5.00
540	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.90	6.00	8.50
541	*Licania rigida*	Chrysobalanaceae	oiticica	41.40	0.01	6.00
542	*Licania rigida*	Chrysobalanaceae	oiticica	38.20	0.01	6.00
543	*Licania rigida*	Chrysobalanaceae	oiticica	40.10	0.01	6.00
544	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.60	4.50	7.00
545	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	10.20	-	6.50
546	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.80	3.50	7.50
547	*Ximenia americana*	Olacaceae	plum	6.10	1.30	3.30
548	*Ximenia americana*	Olacaceae	plum	3.50	-	3.50
549	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.10	-	6.50
550	*Ximenia americana*	Olacaceae	plum	3.80	-	4.00
551	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	16.60	1.00	7.50
552	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.90	2.50	8.00
553	*Tabebuia sp.*	Bignoniaceae	pau d'árco	3.50	0.50	2.50
554	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	26.80	0.20	8.00

(continue)

(continuation)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
555	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.30	3.00	5.00
556	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.10	-	5.00
557	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.00	-	6.00
558	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.70	-	5.50
559	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	13.10	0.12	6.00
560	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.50	2.50	4.00
561	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.90	1.40	6.00
562	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.30	-	4.00
563	*Jatropha mollissima*	Euphorbiaceae	pinhão	2.90	-	1.50
564	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.70	-	6.50
565	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	10.80	0.40	7.00
566	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.50	-	6.00
567	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.60	2.00	6.50
568	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.10	2.50	7.00
569	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.60	2.50	6.50
570	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.60	2.50	7.00
571	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.40	2.00	7.00
572	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.10	3.00	5.50
573	*Spondias sp.1* *	Anacardiaceae	aroeira	5.90	3.00	5.50
574	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.20	2.50	7.00
575	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.10	2.00	5.50
576	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.90	5.00	6.50
577	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.30	4.50	7.00
578	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	11.80	0.40	7.50
579	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.10	5.50	6.00
580	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.50	3.00	5.50
581	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.60	5.50	7.00
582	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	12.10	0.33	7.00
583	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.30	1.85	7.50
584	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.60	4.50	7.00
585	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.20	0.86	6.50
586	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.50	-	6.00

(continue)

(continuation)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
587	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	12.10	0.05	5.00
588	*Crateva tapia*	Leguminosae (Mimosoideae)	trapiá	0.50	0.01	5.00
589	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.70	1.40	5.00
590	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.00	1.60	6.00
591	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.30	5.00	7.00
592	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.10	-	6.00
593	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.20	-	3.00
594	*Spondias sp.1**	Anacardiaceae	aroeira	4.80	-	4.00
595	*Mimosa caesalpiniifolia*	Leguminosae (Mimosoideae)	sabiá	11.50	0.08	6.00
596	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.00	0.80	6.00
597	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.10	-	6.00
598	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	11.50	0.11	5.50
599	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.30	2.00	6.00
600	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.70	-	5.50
601	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.90	1.25	6.00
602	*Jatropha mollissima*	Euphorbiaceae	pinhão	2.90	-	1.20
603	*Jatropha mollissima*	Euphorbiaceae	pinhão	2.90	-	1.70
604	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.30	1.10	6.00
605	*Tabebuia sp.*	Bignoniaceae	pau d'árco	2.90	-	3.00
606	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.00	-	4.00
607	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.80	-	6.00
608	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.30	4.00	6.50
609	*Spondias sp.1**	Anacardiaceae	aroeira	9.20	2.50	6.50
610	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.60	5.00	7.00
611	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.60	-	6.00
612	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.20	3.50	5.50
613	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.10	4.00	6.00
614	*Jatropha mollissima*	Euphorbiaceae	pinhão	3.20	-	1.80
615	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.30	0.50	6.00
616	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	2.90	-	3.00
617	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.90	4.50	6.50
618	-	-	(morta)	0.40	-	5.00

(continue)

(continuation)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
619	*Capparis cynophallophora*	Capparaceae	feijão-brabo	2.90	1.30	3.00
620	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.70	3.50	5.50
621	*Jatropha mollissima*	Euphorbiaceae	pinhão	5.70	-	5.00
622	*Jatropha mollissima*	Euphorbiaceae	pinhão	4.80	-	5.00
623	*Jatropha mollissima*	Euphorbiaceae	pinhão	6.10	3.00	5.50
624	*Spondias sp.1* *	Anacardiaceae	aroeira	3.80	-	3.50
625	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.10	-	3.00
626	*Jatropha mollissima*	Euphorbiaceae	pinhão	3.80	-	2.50
627	*Jatropha mollissima*	Euphorbiaceae	pinhão	3.50	-	3.00
628	*Jatropha mollissima*	Euphorbiaceae	pinhão	3.80	-	2.50
629	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.80	-	5.00
630	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.90	1.80	5.50
631	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.20	-	2.00
632	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.20	-	4.00
633	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.10	-	4.00
634	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.10	-	5.00
635	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.90	2.00	7.50
636	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.50	2.50	4.00
637	*Auxemma oncocalyx*	Bignoniaceae	pau branco	4.80	-	3.00
638	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.60	6.00	6.50
639	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	2.90	-	2.00
640	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	13.10	1.00	7.00
641	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.30	-	6.50
642	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.10	-	6.50
643	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	11.80	1.10	7.00
644	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.90	-	7.00
645	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	12.70	1.40	6.50
646	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.80	-	3.50
647	*Moringa oleifera*	Moringaceae	muringa	7.60	1.20	3.00
648	*Moringa oleifera*	Moringaceae	muringa	9.20	0.40	4.00
649	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	15.30	80.00	7.50
650	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.60	0.95	5.50

(continue)

(continuation)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
651	*Spondias sp.1**	Anacardiaceae	aroeira	4.90	0.80	3.00
652	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	2.90	-	1.30
653	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	14.60	3.00	8.00
654	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.60	-	7.50
655	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.00	2.80	7.00
656	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.50	3.50	7.00
657	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.20	0.68	3.00
658	*Tabebuia sp.*	Bignoniaceae	pau d'arco	3.00	-	1.80
659	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.70	2.50	6.00
660	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.00	4.00	6.50
661	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.70	-	6.50
662	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	13.70	0.60	6.00
663	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.80	-	5.00
664	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.10	-	5.00
665	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.20	1.00	6.50
666	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	10.80	1.20	6.00
667	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.60	-	6.00
668	*Spondias sp.2*	Anacardiaceae	cajá	4.10	-	4.00
669	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.60	1.10	6.00
670	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.10	-	6.50
671	*Jatropha mollissima*	Euphorbiaceae	pinhão	2.90	-	1.60
672	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.70	1.00	5.00
673	*Mimosa caesalpiniifolia*	Leguminosae (Mimosoideae)	sabiá	8.00	0.30	5.00
674	*Jatropha mollissima*	Euphorbiaceae	pinhão	3.50	-	2.50
675	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.50	-	4.00
676	*Mimosa caesalpiniifolia*	Leguminosae (Mimosoideae)	sabiá	5.10	-	4.50
677	*Jatropha mollissima*	Euphorbiaceae	pinhão	2.90	-	1.10
678	*Mimosa caesalpiniifolia*	Leguminosae (Mimosoideae)	sabiá	7.30	0.60	5.00
679	*Spondias sp.2*	Anacardiaceae	cajá	7.30	4.00	5.50
680	*Tabebuia sp.*	Bignoniaceae	pau d'arco	4.10	0.70	3.50
681	*Jatropha mollissima*	Euphorbiaceae	pinhão	2.90	-	3.00
682	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.30	0.23	5.00

(continue)

(continuation)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
683	*Caesalpinia ferrea*	Leguminosae (Caesalpinoideae)	jucá	3.80	1.20	3.00
684	*Caesalpinia ferrea*	Leguminosae (Caesalpinoideae)	jucá	3.80	1.85	3.00
685	*Anadenanthera colubrina*	Leguminosae (Mimosoideae)	angico	16.20	3.00	9.00
686	*Caesalpinia ferrea*	Leguminosae (Caesalpinoideae)	jucá	4.50	3.00	4.00
687	*Caesalpinia ferrea*	Leguminosae (Caesalpinoideae)	jucá	10.80	2.00	5.50
688	*Caesalpinia ferrea*	Leguminosae (Caesalpinoideae)	jucá	29.00	0.03	6.00
689	*Caesalpinia ferrea*	Leguminosae (Caesalpinoideae)	jucá	5.10	3.50	5.00
690	*Tabebuia sp.*	Bignoniaceae	pau d'arco	3.80	2.00	3.50
691	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.40	2.50	5.00
692	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.60	2.50	6.50
693	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.70	4.5	6.00
694	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.70	2	5.50
695	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.40	4	7.00
696	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.00	1.5	7.00
697	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.60	2.8	6.00
698	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.40	2	7.00
699	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.00	3.2	6.50
700	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.90	1.63	7.50
701	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.50	-	7.00
702	*Tabebuia sp.*	Bignoniaceae	pau d'arco	4.10	0.6	3.00
703	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	14.80	1.7	7.00
704	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.00	-	6.00
705	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.60	1.5	6.50
706	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.30	-	5.50
707	*Spondias sp.1**	Anacardiaceae	aroeira	3.00	-	3.00
708	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.50	2	4.50
709	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.40	-	5.00
710	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.30	-	5.50
711	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	2.90	-	4.00
712	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.30	4	7.00
713	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.60	1.3	7.00
714	*Auxemma oncocalyx*	Boraginaceae	pau branco	5.40	-	5.00

(continue)

(continuation)

Plate	Scientific Name	Family	Popular name	Diameter (cm)	Fustic (m)	Height (m)
715	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.30	4.5	6.50
716	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.30	4.5	7.50
717	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	9.70	5	8.50
718	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.60	3.3	7.00
719	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.50	-	5.00
720	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.30	3	5.00
721	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	3.20	0.02	2.50
722	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.80	0.07	5.50
723	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	4.80	1.7	5.00
724	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	6.40	2.1	5.50
725	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.30	2.5	5.50
726	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	13.40	0.4	6.00
727	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.50	2.5	6.50
728	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	5.10	-	2.00
729	*Spondias sp.1**	Anacardiaceae	aroeira	3.20	-	2.50
730	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	11.00	0.67	5.50
731	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.30	2.75	6.00
732	*Tabebuia sp.*	Bignoniaceae	pau d'arco	3.80	0.9	3.00
733	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	7.00	2.2	6.00
734	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.60	2	7.00
735	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	8.00	4	7.00
736	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	leucena	10.80	2.5	7.00
737	*Auxemma oncocalyx*	Boraginaceae	pau branco	3.80	-	2.50
738	*Licania rigida*	Chrysobalanaceae	oiticica	1.00	0.01	8.00
739	*Licania rigida*	Chrysobalanaceae	oiticica	1.30	0.01	8.00

4.2.1 - Plot 1 (successive dams)

Geographic coordinates: 4° 37' 19.9" S / 39° 23' 25.8" W.

The first surveyed plot was in a successive dam area covering the surroundings of a successive dam and a longer downstream area. Because it was in an uneven relief region, the Plot declivity is as high a 25%, which drained water to a small stream bordering the Northwestern margin of the plot.

In this plot, vegetation appearance is that of a "steppe-like wooded savannah" (further details in item 4.4), including small, low-density trees (Table 4.4). The plot is surrounded by cleared areas (Photo 4.2) and its aspect appears to be associated with past deforestation – as sprouting felled trees and old burnt trunks are common – thus displaying a state of secondary succession (recovery).

Table 4.04 – General vegetation aspect in plots analyzed (Plot 1 = Successive Dams; Plot 2 = Reforestation – Cangati River).

Plot	Tree No.	Species No.	Family No.	Total density (ind/ha)	Total basal area (m^2)	Green weight (kg)	Dry weight (kg)	Piled volume (stereo)
1	119	13	6	1,487.5	0.9016	3,348.54	2,211.04	10.59
2	239	15	10	2,987.5	1.5767	13,037.43	8,608.61	41.22

Photo 4.02 – Successive dam of Plot 1 with sediments accumulated on the left

4.2.2 - Plot 2 (Reforestation of ciliary forest in Cangati River)

Geographic coordinates: 4° 37' 20.7" S / 39° 23' 23.6" W.

The second surveyed plot included a reforestation area on the South margin of Cangati River (Photo 4.03). That is a plain area fully enclosed in a floodplain and subject to floods in heavy precipitation periods. Reforestation was carried out at PRODHAM initial stage – as reported by local dwellers, around the year of 2000.

Reforestation disregarded some basic reforestation principles, by planting exotic and fruit trees without considering the composition and original proportion of species in the native forest of the area. The vegetation aspect in that Plot shows relatively dense and regularly spaced (reforestation) trees with an average height of 5-6 meters, similar to a 'steppe-like wooded savannah' (Arboreous Brushwood), even though the trees are ordinate and its floristic constitution is completely distinct.

Photo 4.03 – Reforestation area on Cangati River margins (location – Iguaçu)

4.3 – Results and Discussions

4.3.1 – Composition of communities

Species identified (Table 4.05) and physociological parameters of each surveyed Plot (Tables 4.6 and 4.7) showed conspicuous differences. In Plot 1, less species were found as compared to Plot 2 (Table 4.04), what is explained by the artificial composition of the latter's community (reforestation, where composition is directly and artificially determined). In addition, the phytosociological standard of both plots showed also too different.

Plot 1 showed a relatively balanced composition. More expressive species included *Combretum leprosum* (mofumbo) and *Mimosa tenuiflora* (jurema-preta), which account respectively for 25.09% and 20.39% of the basal plot area. All other eleven (11) species are less expressive, accounting for 0.15% to 11.08%.

Table 4.05 – Occurrence of species inventoried in each study plot (Plot 1= Successive Dams; Plot 2= Reforestation in Cangati River).

Cientific name	Family	Popular name	Succession group	Plot	
				1	2
Spondias sp.1	Anacardiaceae	Aroeira	-		X
Spondias sp.2		Cajá	-		X
Calotropis cf. procera	Apocynaceae	Hortência	Exotic	X	
Cryptostegia grandiflora		Viuvinha	Exotic (invasive)	X	
Tabebuia sp.	Bignoniaceae	Pau d'arco	-		X
Auxemma oncocalyx	Boraginaceae	Pau-branco	Intermediate / climax	X	X
Capparis cynophallophora	Capparaceae	Beans-brabo	Pioneer / intermediate		X
Crateva tapia		Trapiá	Climax		X
Licania rigida	Chrysobalanaceae	Oiticica	-		X
Combretum leprosum	Combretaceae	Mofumbo	Pioneer	X	
Croton blanchetianus	Euphorbiaceae	Marmeleiro	Pioneer	X	
Jatropha mollissima		Pinhão	-		X

(continue)

(continuation)

Cientific name	Family	Popular name	Succession group	Plot	
				1	2
Anadenanthera colubrina	Leguminosae	Angico	Climax	X	X
Bauhinia cheilantha		Mororó	-	X	
Caesalpinia ferrea		Pau-ferro	Climax		X
Caesalpinia gardneriana		Catingueira	-	X	
Leucaena leucocephala		Leucena	Exotic (invasive)	X	X
Mimosa acutistipula		Vaca-velha	-	X	
Mimosa caesalpiniifolia		Sabiá	Pioneer	X	X
Mimosa tenuiflora		Jurema-preta	Pioneer	X	
Moringa oleifera	Moringaceae	Moringa	Exotic		X
Ximenia americana	Olacaceae	Ameixa	-		X
Polygonum sp.	Polygonaceae	-	-	X	
Vitex gardneriana	Verbenaceae	Jaramataia	-		X

Plot 2, reforestation on Cangati River margins, showed a little equitable composition strongly dominated by exotic, invasive species *Leucaena leucocephala* (Leguminosae), which accounted for almost 3/5 (59.04%) of the basal Plot area. Approximately ¼ of basal area (23.84%) refers to species *Licania rígida* (Chrysobalanaceae, Oiticica), a native species typical of Northeast ciliary forests. All other thirteen (13) species are little expressive, accounting for 0.01% to 5.14% of basal area.

Table 4.06 – Phytosociological data of Plot 1 (successive dam). Dab = Absolute density; Drel = Relative density; AB = Basal Area; AB (%) = Basal area in percentage

Name	No. of individuals	Dab (ind/ha)	Drel (%)	AB (cm^2)	AB (%)
Anadenanthera colubrina	3	37.50	2.52	331.87	3.68
Caesalpinia gardneriana	26	325.00	21.85	773.39	8.58
Polygonum sp.	1	12.50	0.84	998.73	11.08
Calotropis cf. procera	6	75.00	5.04	344.51	3.82
Mimosa tenuiflora	5	62.50	4.20	1,838.40	20.39
Leucaena leucocephala	3	37.50	2.52	416.50	4.62
Croton blanchetianus	7	87.50	5.88	458.78	5.09
Bauhinia cheilantha	1	12.50	0.84	191.16	2.12
Combretum leprosum	54	675.00	45.38	2,262.00	25.09
Auxemma oncocalyx	1	12.50	0.84	733.76	8.14
Mimosa caesalpiniifolia	3	37.50	2.52	207.98	2.31
Mimosa acutistipula	8	100.00	6.72	445.84	4.94
Cryptostegia grandiflora	1	12.50	0.84	13.46	0.15
TOTAL	**119**	**1,487.50**	**100.00**	**9,016.36**	**100.00**

Invasive species, such as *Leucaena leucocephala*, are today recognized as one of the main causes of biodiversity loss and species extinction in the planet (Brazil, 2006; MCKINNEY; LOCKWOOD, 1999; VITOUSEK *et al*., 1997). Researches show that this plant has an allopathic effect on other plants (SCHERER *et al*., 2005; INSTITUTO HÓRUS, 2008), that is, it has substances that inhibit or impair other tree growth, and may also endanger the reforestation of Cangati River ciliary forest.

The Biological Diversity Convention (BRAZIL, 2000) is an UNO international treaty for diversity preservation signed during ECO'02. This treaty provides that the member countries should avoid the introduction of exotic species and, should any introduced species become invasive, the Country should control or even eradicate that species.

Table 4.07 – Phytosociological data of Plot 2 (Reforestation on Cangati River margins). Dab = Absolute density; Drel = Relative density; AB = Basal Area; AB (%) = Basal area in percentage.

Name	No. of individuals	Dab (ind/ha)	Drel (%)	AB (cm^2)	AB (%)
Ximenia americana	3	37.50	1.26	49.84	0.32
Anadenanthera colubrina	1	12.50	0.42	207.09	1.31
*Spondias sp.1**	8	100.00	3.36	168.39	1.07
Spondias sp.2	2	25.00	0.84	55.57	0.35
Caesalpinia ferrea	6	75.00	2.52	810.27	5.14
Leucaena leucocephala	176	2,200.00	73.95	9,309.24	59.04
Capparis cynophallophora	1	12.50	0.42	6.45	0.04
Moringa oleifera	2	25.00	0.84	112.82	0.72
Licania rigida	5	62.50	2.10	3,758.23	23.84
Auxemma oncocalyx	4	50.00	1.68	110.43	0.70
Tabebuia sp.	8	100.00	3.36	86.56	0.55
Jatropha mollissima	16	200.00	6.72	301.59	1.91
Mimosa caesalpiniifolia	4	50.00	1.68	215.45	1.37
Crateva tapia	1	12.50	0.42	0.17	0.00
Vitex cf. gardneriana	1	12.50	0.42	575.24	3.65
TOTAL	**238**	**2,975.00**	**100.00**	**15,767.34**	**100.00**

Brazil, as one of signatories of Biological Diversity Convention is implementing the National Communication of Invasive Exotic Species in partnership with Hórus Institute and The Nature Conservancy, in addition to the Exotic Plant Project in partnership with the Center of Teaching and Applied Research (NEPA) and Hórus Institute and The Nature Conservancy.

Taking into account that *Leucaena leucocephala* is an invasive species and its predominance in Brushwood flora is not natural and may cause serious damages to local biodiversity, it is suggested that a control plan is established for that species all over the reforestation and adjacent areas, under the supervision of biologists of forest engineers, with the objective of putting PRODHAM actions in line with the Biological Diversity Convention.

4.3.1.1 - Phytosociology

Estimated total density of Plots 1 and 2 were respectively 1,488 and 2,975 individuals/ha, which is a result lower than that found in brushwood areas, which have in general a density of 3,000 – 4,000 individuals/ha (SAMPAIO, 1996). Estimated basal area for Plots 1 and 2 was 11.30 and 20.00 m^2/ha, respectively. Although such values are low, they meet the general standard for brushwood, which ranges between 4.00 and 52.00 m^2/ha (SAMPAIO, 1996).

4.3.1.2 - Diversity

Diversity rates are a simplified form of evaluating a particular community or sample. They refer to abundance of species, that is, the number of species occurring in a particular sample (n) and the proportion of individuals of each species. Most usually adopted diversity rate, Shannon-Wiener (H') indicates a higher value for samples with a greater abundance and without predominance, and has a maximum value varying according to value "n" of the respective sample, thus making unfeasible the rate comparison between two samples with different "n". Equability rate, on the other hand, is an adaptation of H' for a common base, always ranging between 0.00 and 1.0, and therefore making possible the rate comparison between two samples with different "n".

Table 08 shows the values of H' and J' rates in each surveyed plot. A lower value for equability rate (J') means that the proportion between individuals of different species is not equal, as there is a predominance of 1 or more species. In case of surveyed plots, this may be evidenced by phytosociological data (Tables 4.6 and 4.7) where mufumbo (*Combretum leprosum*) predominance in Plot 1, and leucena (*Leucaena leucocephala*) in Plot 2 can be noted.

Table 4.08 – Diversity rate of species in each Plot surveyed

Area	Number of individuals	Number of species	Diversity rates	
			Shannon-Wiener (H')	Equability (J')
1 (Dam)	119	13	0.7476	0.6712
2 (Ciliary forest)	239	15	0.5088	0.4326

According to data shown in Table 4.08, in addition to having a greater quantity of individuals and species, Plot 2 (reforestation) has a smaller equability I(‘) than plot 1. This can be due to the fact that Plot 1 community developed under natural environmental recovery conditions (as the species have established without direct human intervention), while Plot 2 community was composed artificially (reforestation), where *Leucaena leucocephala* seedlings predominate.

4.3.2 – Vegetation architecture (facies)

To estimate the facies of surveyed vegetation, the following parameters were analyzed: diametric structure (Figures 4.01 and 4.02), vertical structure (Figures 4.03 and 4.04) and tree density (Table 4.40), in addition to on-site observations.

Diametric structure of Plot 1 (Figure 4.01) showed a great predominance of thin-trunk trees: 84% of individuals have a diameter smaller than 12cm and the maximum diameter of 47.8cm. This configuration reflects the succession state of Plot community: an area at full recovery stage (secondary succession) – with many young individuals and few adult individuals.

Diametric structure of Plot 2 (Figure 4.02) showed a quire similar standard. Although the frequency of diameter classes is somewhat better distributed, there is also a great predominance of thin-trunk trees: 91% of individuals have a diameter smaller than 12cm and the maximum diameter of 41.4cm.

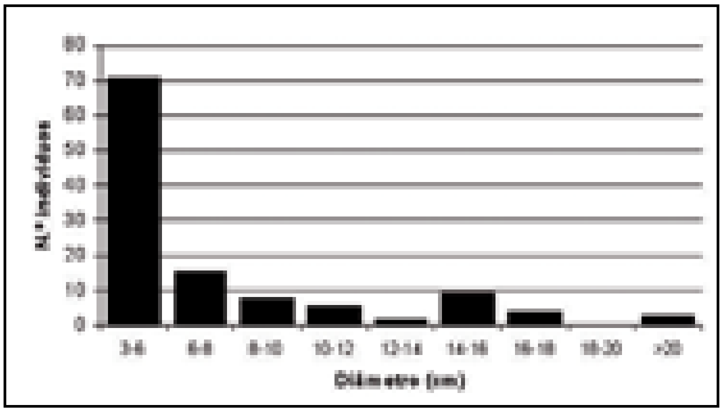

Figure 4.01 – Diametric structure of vegetal community in Plot 1 (successive dams)

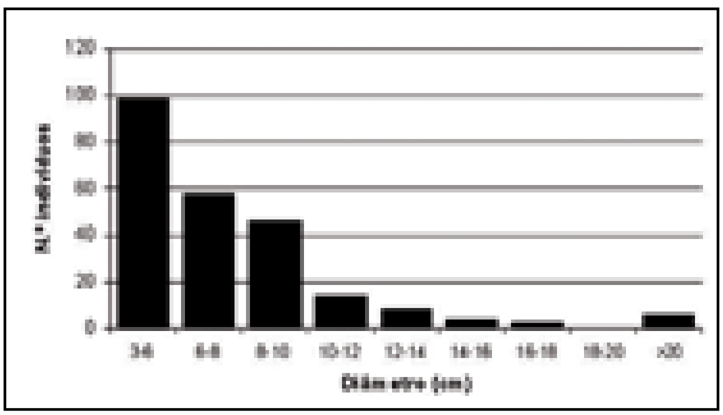

Figure 4.02 – Diametric structure of vegetal community in Part 2 (Reforestation)

In both plots, there is a gap of individuals with diameters ranging between 18 and 26cm. This shows that there are two components in vegetation of both plots: an older component of old trees that were not felled, with a diameter above 26cm, and a new component emerged less than a decade ago (after PRODHAM actions started), comprised of young thin-trunk trees with a maximum diameter of 17.2cm.

Vertical structure of Plot 1 (Figure 4.03) shows that most individuals (83%) are between 1 and 3m high. Few individuals more than 3m high do not exceed 5m.

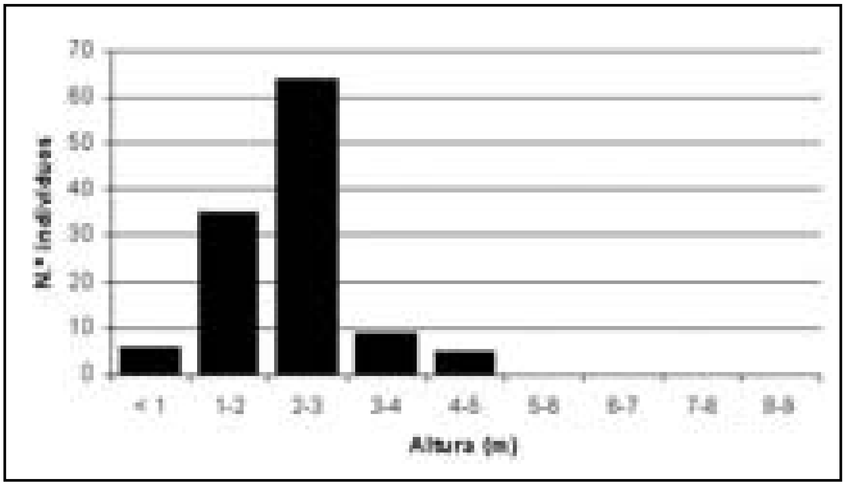

Figure 4.03 – Vertical structure of vegetal community in Plot 1 (successive dams).

Vertical structure of Plot 2 (Figure 4.04) shows a different configuration including trees expressively higher and better distributed among the different classes of sizes. Nevertheless most individuals (53%) are between 5 and 7-m high, there may of them (~37%) less than 5-m high and some 10% of individuals more than 7-m high.

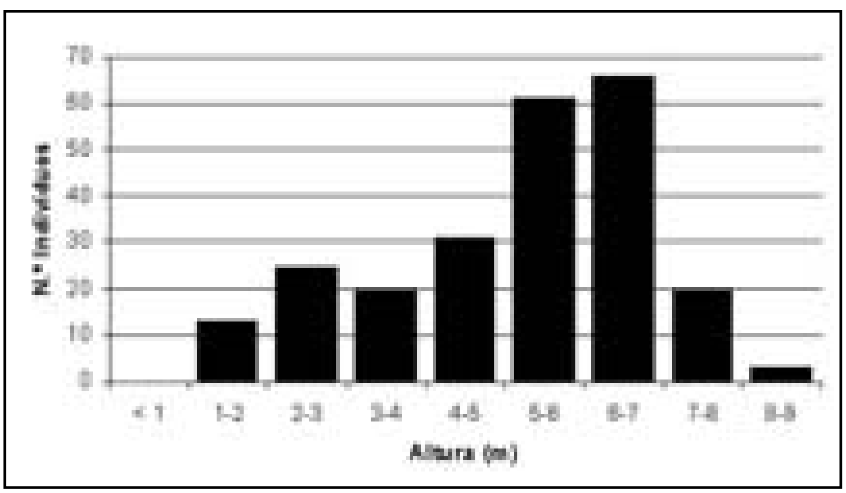

Figure 4.04 – Vertical structure of vegetal community in Plot 2 (Reforestation)

The appearance of Plot 1 vegetation (Successive Dams) was classified, according to Veloso; Rangel-Filho; Liam (1991) system, as Steppe-like Wooded Savannah, which is a formation composed of micro and nanopharenophytes in general less than 5m high, little dense (separated by clearings where herbaceous plants predominate), with a conspicuous annual seasonality and a water shortage period. The predominance of thin-trunk individuals (young) and the analysis of sub-shrubby layer (see next topic – natural succession) suggest that plot 1 is at regeneration stage and is expected to display in the future an appearance of Steppe-like Wooden Savannah.

The appearance of Plot 2 vegetation (reforestation), although artificially produced, is similar to a Steppe-like Wooded Savannah *sensu* (VELOSO; RANGEL-FILHO; LIMA, 1991); a formation similar to the previous one, although higher, with an average height of 5-6 m, sometimes exceeding 7m, with less dense thicker-trunk individuals.

4.3.3 – Natural succession

Because of the delayed start of vegetation monitoring and the short period allowed for performance of study, it was not possible to analyze any demographic aspects of surveyed communities – studies that would require a period of at least two (02) years to provide preliminary results. In a period of months, it was not possible to identify any significant development. However, delimitation of two monitoring plots in this study, record and identification of all trees and respective plots by numbered plates allow a further development of natural succession stage in surveyed plots to be evidenced at a future vegetation monitoring.

At an immediate analysis, the observation of sub-shrubby components (plantules and young trees) will allow us to understand how young individual recruitment is occurring and which species are settling in the plots. In Plot 1, twelve (12) individuals with DNS < 3cm were found in a sampled area of $40m^2$. Bases on that date, a population of two hundred and forty (240) plantules is estimated in the plot (density of 3,000 plantules/ha), and in Plot 2 (where eight (8) individuals were found in the same samples area), a population of one hundred and sixty (160) plantules is estimated in the entire Plot (density of 2,000 plantules/ha).

Such estimates suggest that there is a greater recruitment of young trees in Plot 1 (Successive Dams), as expected, vegetation in that Plot is at a less advanced natural succession stage than Reforestation (where human intervention accelerates the community succession).

Among individuals of sub-shrubby component inventoried in Plot 1 (Successive Dams), 50% belong to *Caesalpinia gardneriana* species (Leguminosae, catingueira), 41% belong to *Leucaena leucocephala* species (Leguminosae), and only one (01) individual belong to *Combretum leprosum* species (Combretaceae, mofumbo). In Plot 2 (Reforestation), 50% of individuals belong to *Leucaena leucocephala* species (leguminosae), 25% belong to the creeper *Dalechampia spp* species (Euphorbiaceae), 12.5% to *Tabebuia* species (Bignoniaceae, ipê), and 12.5% to non-identified species.

Regarding the composition of sub-shrubby layer, such estimates show that in both plots there is a strong participation of *Leucaena leucocephala* species (Leguminosae). This result was foreseen and expected for Plot 2 (Reforestation), where leucena trees predominate (Table 4.7). However, in Plot 1, where that species is present, even though it is not a native component of Ceará Brushwood, its strong participation in sub-shrubby layer shows that it is spreading out and settling autonomously, without human control, and may characterized as an invasive exotic species.

This biological invasion phenomenon is likely to cause serious impacts to Brushwood vegetal communities. The invader, *Leucaena leucocephala*, may be competing with native species and changing the composition and natural equability of such communities, and is likely to cause damages to local biodiversity.

4.3.4 – Soil Cover

Percentage of soil covered by herbaceous plants was estimated with the help of a 1 x 1 grid (Photo 4.04) divided into one hundred (100) 0.1 x 0.1-m squares by nylon threads. Whenever any part of an herbaceous plant touched one of squares of sampled Plot, it was considered that 1% of area was covered. As the vegetative cover is not constant all over the Plot, cover was estimated on the basis of the average vegetative cover of ten (10) samples for each plot.

Charts 4.01 and 4.02 show the values of each sample and the average cover for Plots 1 and 2, respectively.

Photo 4.04 – Quadrant (1 m x 1m) used to estimate soil cover by herbaceous plants

Chart 4.01 – Percentage of soil cover by herbaceous plants in Plot 1 (successive dams)

Period	Sample										Average
	1	2	3	4	5	6	7	8	9	10	
Mar/Apr	100%	40%	95%	89%	93%	81%	80%	86%	100%	100%	**86%**
Jun/Jul	71%	75%	22%	91%	64%	58%	26%	48%	48%	75%	**58%**

Chart 4.02 – Percentage of soil cover by herbaceous plants in Plot 2 (reforestation of Cangati River margins).

Period	Sample										Average
	1	2	3	4	5	6	7	8	9	10	
Mar/Apr	26%	83%	79%	75%	26%	36%	46%	66%	48%	94%	**58%**
Jun/Jul	93%	53%	73%	70%	52%	14%	92%	98%	99%	89%	**73%**

Successive Dam area showed a larger herbaceous plant cover than Reforestation area (Charts 4.1 and 4.2, respectively) – which was an expected result, as an herbaceous layer develops more strongly under extreme solar radiation. As Plot 1 (Successive Dams) has a lower tree density (Table 4.04) and smaller trees (Photo 4.03), there was a greater solar radiation on the soil to allow herbaceous plants to cover as much as 86% of soil in March and April 2008 (Chart 4.01). Although the amount of cover decreased in June and July 2008, the herbaceous layer continued to develop. That reduction in cover rate was due to the strong development of sizable annual herbaceous plants, such as 'bamburral' (*Hyptus sp.. Lamiaceae*), which were more than 2-m high and shaded the sun, thus preventing the development of smaller herbaceous plants.

Plot 2 (Reforestation, Chart 4.02) showed a relatively low cover rate (as compared to Plot 1) in March and April 2008. The lower development of herbaceous layer in that Plot was due to its higher tree density (Table 4.04) and greater size of its trees (Figure 4.01), which took on a forest appearance with a greater sun shading. There was no strong proliferation of large annual herbaceous plants (such as *Hyptis* sp. and *Bidens* sp.) in Plot 2, after the rainy season a greater proliferation of smaller herbaceous plants occurred, which increased the cover rate to as high as 73% in June and July. Due to its (shaded) forest formation, even at its peak cover by herbaceous plants, cover rate in Plot 2 (73%) failed to match that of Plot 1 (86%) – where vegetation is more open and there is, therefore, more insolation.

Because of the delay in vegetative cover monitoring in surveyed plots and the unavailability of such data before the implementation of PRODHAM actions, it was not possible to deduce any effect of such actions (Successive Dams and Reforestation) on any increase or reduction of vegetative cover in both plots.

4.3.5 - Phenology

For phenologic studies, ten (10) arboreous individuals were selected in each Plot to provide data about the presence or absence of flowers, fruits and leaves (percentage) during the study period.

By extrapolating phenologic data sampled in Plot 1 (Successive Dams, TABLE 4.09), it is noted that trees in that Plot seem to have retained all their leaves (100%) until April, and leaves started to fall in May and June, when they lost as much as 40% of their leaves (although 50% of trees did not lose any leaves).

Like observed in the Plot 1, trees I Plot 2 kept their leaves until April (Table 4.10), although they have shown a greater leave loss in June. Plot 2 trees seem to have started cadufolia soon, in May, as in June no tree maintained all (100%) its leaves, and the loss of leaves at the time was greater than in Plot 1, ranging from 10% to 100%.

Notwithstanding trees in Plot 1 (Successive Dams) have apparently retained their leaver for a longer period (showing a higher percentage of leaves in June), that different cannot be attributed to successive dam implantation, as both Plots have different vegetation species and have completely different pedological and geomorphologic conditions. Any conclusion could only be made if both vegetation and environmental conditions were similar (control group).

Phenologic standards (blooming, fructification and deciduousness periods) are characteristic of and inherent to species, which react differently to environmental variations. Blooming and fructification events observed in this study (in both Plots) do not allow the identification of a specific standard for selected species, as in some cases there was only one individual of a particular species, or in other cases, individuals of the same species behaved differently, thus making any conclusion difficult.

Like in some previous parameters, the delayed vegetation monitoring start, the unavailability of phenologic data before PRODHAM action implementation, the small number of samples, and the lack of a control group for each Plot analyzed did not allow any deduction to be made on a possible influence of Successive Dams on any phenologic aspect of communities affected by such actions.

Table 4.09 – Individuals selected in Plot 1 (successive dams) for phenologic studies according the methodology suggested by PRODHAM

Plate No.	Scientific Name	Family	Popular Name	April			June		
				Leaves	Flowers	Fruits	Leaves (%)	Flowers	Fruits
18	*Combretum leprosum*	Combretaceae	Mofumbo	100	A	A	100	A	**P**
48	*Anadenanthera colubrina*	Leguminosae (Mimosoideae)	Angico	100	A	A	90	A	A
55	*Mimosa tenuiflora*	Leguminosae (Mimosoideae)	Jurema	100	A	A	80	A	A
59	*Mimosa cf. acutistipula*	Leguminosae (Mimosoideae)	Vaca velha	100	A	A	60	A	**P**
62	*Auxemma oncocalix*	Boraginaceae	Pau branco	100	**P**	A	100	A	**P**
63	*Combretum leprosum*	Combretaceae	Mufumbo	100	A	A	100	**P**	A
72	*Croton blanchetianus*	Euphorbiaceae	Marmeleiro	100	**P**	**P**	90	A	A
80	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	Leucena	100	**P**	**P**	100	A	**P**
101	*Caesalpinia bracteosa*	Leguminosae (Caesalpinoideae)	Catingueira	100	**P**	A	85	A	A
110	*Combretum leprosum*	Combretaceae	Mufumbo	100	A	A	100	A	**P**

Table 4.10 – Individuals selected in Plot 2 (reforestation) for phenologic studies according the methodology suggested by PRODHAM.

Plate No.	Scientific Name	Family	Popular Name	April			June		
				Leaves (%)	Flowers	Fruits	Leaves (%)	Flowers	Fruits
510	*Jatropha mollissima*	Euphorbiaceae	Pinhão	100	A	**P**	80	A	**P**
530	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	Leucena	100	**P**	**P**	60	A	**P**
588	*Crateva tapia*	Capparaceae	Trapiá	100	**P**	**P**	0	A	A
595	*Mimosa caesalpiniifolia*	Leguminosae (Mimosoideae)	Sabiá	100	A	A	85	A	A
604	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	Leucena	100	**P**	**P**	60	A	**P**
630	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	Leucena	100	**P**	**P**	30	A	**P**
654	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	Leucena	100	**P**	**P**	50	A	**P**
685	*Anadenanthera colubrina*	Leguminosae (Mimosoideae)	Angico	100	A	A	90	A	A
725	*Leucaena leucocephala*	Leguminosae (Mimosoideae)	Leucena	100	**P**	**P**	40	A	**P**
738	*Licania rigida*	Chrysobalanaceae	Oiticica	100	A	A	90	A	A

Conclusions and Recommendations 5

PART 5 – CONCLUSIONS AND RECOMMENDATIONS

It is concluded that PRODHAM project, through the biophysical monitoring of Cangati River microbasin in Ceará, has contributed effectively to improve the geoenvironmental conditions in the surveyed region, as by providing data and information on physical microbasin parameters, it also supported the planning and sustainable management of its natural resources. Geoenvironmental conditions include not only the physical aspect, as the whole infrastructure implanted in the microbasin allowed a better control and understanding of related physical processes, but also and especially the human aspect. In effect, local community's participation in the construction and implantation of monitoring infrastructure and collection of hydroenvironmental variables made a great difference and contributed substantially to the subproject success.

From this view, the need of continuing the monitoring actions started in Cangati River microbasin-CE is evidenced, and it is recommended that "Biophysical Microbasin Monitoring" should be replicated in all areas of any endangered environment. Indeed, to evaluate accurately the interference of anthropic actions with the environment of small hydrographic basins and determine whether such actions are responsible for changes to physical parameter behavior, making continued, systematic studies of the topic is indispensable. We would like to emphasize, however, that because of bureaucratic reasons the monitoring period was short, as at least two years would be required to allow a greater number of data to better reflect the reality of such interventions, and consequently give a better support to related conclusions.

It is also emphasized by this subproject the importance of integration with other research institutions, not only to perform studies aimed to understanding and/or answering questions and problems associated with local reality, but also to allow the exchange of information and diffusion and availability of results obtained. In this sense, partnership with the

Federal University of Ceará, through its Department of Geology should be highlighted, which culminated in the development of a master course dissertation titled "Effects of microdams on subsistence agriculture – Bananeiras stream – Canindé – Ceará – Brazil".

In this context, it is essential to record in this document the contributions given by several studies carried out in the microbasin. Thereby, conclusions made in each knowledge area covered by the subproject and related recommendations are listed below.

On the quality of surface waters:

- although local information indicate that main uses of waters stored in small microbasin reservoirs include small-scale subsistence fishing, animal consumption and small subsistence crops, the quality of such waters indicate that, after conventional treatment, they can be used for human consumption;

- by evaluating the hydrochemical standard of waters, it was concluded that mixed bicarbonated waters predominate in most reservoirs monitored by PRODHAM;

- according to values of total dissolved solids, waters stored in most of surveyed reservoirs showed no use restrictions, as they were classified as class-2 fresh water, according to CONAMA Resolution no. 357/2005;

- ions mostly predominating in waters stored in such reservoirs are bicarbonates, followed by chlorides. Potassium, carbonate and sulfate concentrations were generally inexpressive. It should be pointed out that in most of evaluation period, chloride concentrations remained below 250 mg/l, a limit established by CONAMA Resolution no. 357/05 for class-2 fresh waters, and therefore had no restrictions to human consumption;

- with regard to quality of irrigation water, taking into account the monitoring period as a whole, C2S1 water predominate, which present a medium soil salinization risk and no danger of soil alkalinization;

- by analyzing the seasonal behavior of surveyed reservoirs, it was concluded that there is a strong variation in concentrations of analyzed parameters, according to the respective season. In fact, 2007 dry season was the period when the highest ion concentrations were found in waters, upon the arrival of 2009 rainy season, there was a fall in contents of such elements, thus indicating the diluting effect or rains;

- in the study performed, only nitrate and nitrite remained within the limits established by CONAMA Resolution no. 357/2005 for all reservoirs and streams. With respect to other parameters analyzed, most of them deviated from the law, among which phosphor showed the greatest change in waters of all reservoirs surveyed;

- in general, it could be said that seasonality had some influence on phosphor, dissolved oxygen (DO) and turbidity variations, when a significant variation occurred in most surveyed reservoirs in the period of highest precipitation;

- a thorough study of drainage basins of selected reservoirs is recommended to identify the main sources of excessive afflux of phosphor.

On underground dams:

- as reservoirs, in the short term, underground dams proved efficient, as groundwater levels in the area of influence of dams (upstream) recorded the greater oscillations among all monitored points during the rainy period (recharge), by reaching almost 100% of sedimentary package thickness;

- in the long term, the groundwater behavior (levels) were similar both upstream and downstream to underground dams, showing no significant interference with works with respect to natural groundwater runoff;

- studies of underground dams in Cangati River microbasin showed the high importance of preliminary drilling works (auger drilling or geophysical survey) and topographic survey to determine the construction site of damming works, because, as explained for underground dams in Salgadinho stream, a good location may imply a substantial increase in dam storage (hydraulic basin);

- underground dam in Chicote stream, in addition to its significant sedimentary package thickness, is very close to microbasin head and has a significant topographic gradient, the reason why its groundwater storage potential was estimated as low;

- Felão I underground dam (Felão stream), in spite of its good location (significant thickness and small soil gradient), has a storage capacity limited by the occurrence of rock outcrops. Even so, among the surveyed dams, it had the highest groundwater storage capacity (2,480.04 m^3);

- also in Felão stream, Felão II underground dam, notwithstanding close to Felão I dam, showed a much smaller sediment volume, but a good storage capacity (869.30 m^3);

- in Salgadinho stream, it was noted how criteria for dam location may be decisive for its efficiency. The old dam ranked low in item storage capacity (79.47 m^3). The new underground dam, in contrast, constructed some 20 m upstream, had a water storage capacity ten times greater (761.96 m^3).

On the quality of groundwater:

- both constructed in Felão stream, Felão II underground dam, notwithstanding close to Felão I dam, showed a much smaller sediment volume, but a good storage capacity (869.30 m^3);

- all collected groundwater samples failed to comply with human consumption standards established by CONAMA Resolution no. 396/98 for groundwater (absence of thermotolerant coliforms);

- notwithstanding local information indicated that the primary use of groundwater in the microbasin is irrigation, it was noted that such waters have a great restriction to that use;

- by evaluating the hydrochemical standard of waters, it was concluded that bicarbonated to mixed chlorinated waters predominate in most well monitored by PRODHAM;

- most groundwater samples showed restrictions to use for their content of total dissolved solids (TDS), as they were classified as brackish, where TDS values range between 500 and 1,500 mg/l. Only groundwater directly associated with underground dams improved their conditions in relation to that item (TDS content < 500 mg/l): fresh waters), in rainy period (recharge);

- anions mostly predominating in groundwater in monitored points are bicarbonates, followed by chlorides. Among cations, however, there was an equilibrium between sodium, calcium and magnesium. Potassium, carbonate and sulfate concentrations were generally inexpressive;

- with regard to quality of irrigation water, taking into account the monitoring period as a whole, C3S1 water predominate, which present some risk of soil salinization (high salinity), but no danger of soil alkalinization;

- dry season influenced the increase of dissolved solid concentrations in most groundwater sources analyzed, which was most accentuated in piezometric wells, where total dissolved solid values were higher;

- samples analyzed for nitrate and nitrite remained within the limits established for several uses by CONAMA Resolution no. 296/08, what lead us to assume that, in those sources, there was no influence of anthropic actions, such as the use of fertilizers, on nitrate and nitrite contents in the study period. Exception is made only for Salgadinho dam, which achieved a nitrate peak after the rainy season, probably as a result of aquifer recharge;

- highest thermotolerant coliform values were found in underground dams, probably due to their location close to bovine cattle breeding areas, provided that thermotolerant coliforms may be present in both human and homeothermic animal excrements.

On hydrological modeling:

- surface hydrology modeling activity generated important information, such as: continuous precipitation, evaporation and flow records in place of interest of hydrographic microbasin;

- precipitation, flow and daily modeled evapotranspiration allowed the rain-flow model parameters (SMADPd) to be adjusted. Under this model, humidity balance in sub-basins provided information sufficient to estimate daily flows in several streams of the microbasin for which no data were available;

- integrated chemicals transportation and dilution simulation model used in this study reproduced accurately all TDS values observed during the reservoir monitoring campaigns;

- the design of a georeferenced database made the analysis of monitoring data easier. In addition, it was used to establish the layout conditions to estimate the parameters of flood event simulation models HEC-HMS and KINEROS2;

- the use of KINEROS2 model in this study only enabled the evaluation of sediment production potential in sub-basins during 2008. It should be pointed out that data obtained in a single rainy season were insufficient to allow sediment mass distribution process to be simulated in each of successive dams. In this sense, the continuity of hydrologic and sedimentologic survey in this microbasin is recommended, to enhance the understanding of sediment transportation and deposition dynamics along the water bodies.

On the soil:

- sediment accumulation in successive dams constructed in Bananeiras and Guerrido streams after the rainy season mitigated the impacts or erosion processes and promoted soil and vegetation recomposition in worked areas;

- with respect to quality of water retained in collectors installed in successive dams, this study has concluded that they do not represent a direct risk of soil salinity problems. Risk of salinity problems in the study area is indirect and unlikely to occur; their eventual occurrence would be the result of incorrect irrigation management;

- according to analyses performed, it was concluded that sediment accumulation, in addition to mitigating the adverse effects of erosion processes, improved the chemical and physical characteristics of soils and provided a greater availability of water of low electrical conductivity, what results in the occurrence of non-saline soils and the development of conditions favorable to the cultivation of several types of crops. Under such conditions, natural vegetation repopulation was recorded along the stream margins, in addition to an increased soil layers with great fertility potential, resulting from accumulation of sediments rich in organic matter.

On the Vegetation:

- notwithstanding the floristic records made during the study indicate that most of listed species are typical of Brushwood, such as: angico, pau-ferro, jurema, marmeleiro, sabiá, pinhão and mandacaru, among others, the occurrence of exotic species (such as hydrangea) and even invasive species (such as leucena and 'viuvinha alegre') indicates the anthropic action and environmental degradation in the microbasin;

- the construction of successive dams along the streams of the region has caused a high accumulation of sediments and the creation of an area favorable to the development of several herbaceous plans and some pioneer ligneous species on sediments;

- based on species identified on sediments during the study, it can be concluded that an environmental recovery process is underway in the microbasin region. In effect, herbaceous and ligneous species (arboreous) found on sediments are also pioneer species typical of secondary succession, which are indicative of (re)colonization or environmental recovery processes;

- according to data related to vegetation diversity, it is concluded that human intervention in Plot 2, by recomposing artificially the vegetation by means of reforestation, resulted in a lower equability where the proportion between individuals of different species was not equalitarian, with the predominance of 1 or more species, such as *Leucaena leucocephala*. It should be pointed out that more equalitarian communities in Plot 1 (Successive Dams) have formed under natural environmental recovery conditions, where species established without any direct human intervention;

- Taking into account that Reforestation on the south margin of Cangati River (Plot 2) showed a rather equitable composition strongly dominated by the exotic, invasive *Leucaena leucocephala* (Leguminosae), it is suggested that a control plan is formulated for that species all over the Reforestation and adjacent areas. It should be noted that such a plan should be implemented under the supervision of biologists or forest engineers, with the objective of putting PRODHAM actions in line with the Biologic Diversity Convention;

- with respect to the vegetation aspect in Plot 1, notwithstanding it has been classified as steppe-like wooded savannah, the predominance of thin-trunk individuals (young) and the analysis of sub-shrubby layer suggest that Plot 1 is at regeneration stage and is expected to display in the future an appearance of Steppe-like Wooden Savannah;

- with respect to phenologic studies performed, it is concluded that, notwithstanding the trees in Plot 1 have apparently retained their leaver for a longer period, that different cannot be attributed to successive dam implantation, as both Plots surveyed have different vegetation species and have completely different pedological and geomorphologic conditions. Any conclusion could only be made if both vegetation and environmental conditions were similar (control group);

- blooming and fructification events observed in this study (in both Plots) do not allow a standard for selected species to be identified. In some cases there was only one individual of a particular species, and in other cases, individuals of the same species behaved differently, thus making any conclusion difficult;

- because of the delayed start of vegetation monitoring and the short period allowed for performance of study, it was not possible to analyze any demographic aspects of surveyed communities. From this view, the continuity of monitoring activities started in both plots is suggested to confirm the further evolution of the natural vegetation succession stage in Plots analyzed;

- the delayed start of vegetation monitoring, the unavailability of phenological and vegetation data before PRODHAM action implementation, and the lack of a control group for each Plot analyzed have not allowed conclusions to be made on possible effects of such actions on any phenologic aspects of affected communities or any increase or reduction of vegetative cover in such plots.

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