RURAL WATER SUPPLIES THAT WORK, ENDURE AND REACH THE POOR: LESSONS FROM CEARA, BRAZIL

by

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ABSTRACT

The purpose of this thesis is to examine empirical evidence on factors associated with successful management of communally-held water supply infrastructure. The analysis is based on information gathered during three months of field work in rural communities of central Ceará, Northeast Brazil. In some of these communities, beneficiaries are maintaining their communally-held water sources, whereas in other communities, people do not organize for this purpose. Why do water supply facilities work well, last, and reach the poor in some rural villages, but not in other places located just a few miles away within the same region ? This is the central question of this thesis.

In this semi-arid region there is virtually no rural household with water connections. Villagers withdraw water from common-use water sources; they average 10 trips for water every day (approximately three hours). There are different water supply facilities; villagers clearly differentiate among them and assign each facility to specific purposes according to the water quality, location and reliability. Fresh water is exclusively used for drinking and cooking; and saline water for personal hygiene, house cleaning, laundry, and flushing. Collective cisterns seem to elicit more community involvement than tube wells and open wells. Locating collective cisterns, actually forces beneficiaries to come together to discuss and choose the site. Other water supply systems do not promote such involvement. Villagers also monitor the contractors' work. Staff from the agricultural extension agency taught villagers how to do it. This practice proved to be a very good device against faulty workmanship and inferior materials. In some communities, villagers have managed to link perennial and seasonal water sources. Villagers have self-organized a set of *de facto* rules and roles to withdraw water from collective cisterns, as well as to maintain the facilities. International donors insist in creating water-user associations to manage water supply facilities, however, self-organized groups, based on existing structures of authority, have successfully managed common-use water resources in some of the villages here studied. Faulty technical design can nevertheless jeopardize the good operation and maintenance of rural water supplies despite active community involvement.

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CHAPTER ONE

INTRODUCTION

Policy makers usually expect common use water supplies to deteriorate and fall into disuse a short time after construction, particularly in poor and isolated rural communities, where villagers either "don't care" or "don't understand" about infrastructure. Myriad cases support this view.[1] Yet there is empirical evidence showing that under some circumstances water projects do not fall into disuse, but instead work well and are maintained.

In Northeast Brazil, the largest cluster of rural poverty in Latin America, most of the rural population has very limited access to infrastructure and service systems. In this thesis I look specifically at the provision of water for domestic use (drinking, cooking, washing, etc.) in rural communities within a particularly water-deprived area in the state of Ceará, the fourth largest state in Northeast Brazil (148,000 km^2) (see Appendix One). The objective of my research was to learn about water management in small rural communities in semi-arid environments, and to identify ways in which the state can improve the access of the rural poor to water supply.

Part of the water supply infrastructure existing in the study area (e.g., shallow wells, artificial lakes) is the result of many and frequently uncoordinated actions from federal, state and municipal governments. Governments have intervened to make the local population less vulnerable to the effects of protracted droughts, a very common phenomenon not only in the study region, but in most of Northeast Brazil. These man-made water sources complemented the unreliable natural supplies typical of this semi-arid zone. Other water supply facilities in this area (community cisterns, dug wells, tube wells, small artificial lakes) resulted from a state-wide strategy to alleviate rural poverty

[1] See Glennie (1983); Steffes (1996) mentions Briscoe and Ferranti (1993), and World Bank (1994).

that the state government of Ceará has been carrying out since 1981 in association with the World Bank.

State government cannot cope--either financially or administratively--with the task of maintaining a large number of water supply facilities over wide areas in the countryside. By transferring the responsibility for decision-making and project implementation to municipal governments and local communities, the state government aims to improve the access of rural population to reliable systems of water supply (World Bank, 1995). In Ceará, the State Department of Hydraulic Works (SOHIDRA) is building collective water supply facilities where villagers request them through their legally constituted community associations. Community associations bear the responsibility for operating and maintaining of all of those investments.[2] What I observed during three months of field work in two municipalities of central Ceará--Mombaça and Quixeramobim--was that in some villages, beneficiaries maintain their common-use water sources, whereas in other villages, people do not organize themselves for this purpose. Why do beneficiaries maintain water supply facilities over time in some rural villages, but not in other places located just a few miles away within the same region?

The literature on collective action reveals two different ways to look at this question. The conventional wisdom in many disciplines is that resources held in common are subject to massive degradation. [3] Many theorists on property rights argue that common property resources, as opposed to those resources owned by the state or by private individuals, will be overexploited as demand rises. From this perspective, the way to avoid the "tragedy of the commons" is to have the state manage the commons, or to

[2] This condition is specified in the agreement for the release of project funds (World Bank, 1995: 22).
[3] According to Fenny *et al.* (1990), the idea that people overexploit resources that are held in common has become part of the conventional wisdom in environmental studies, policy, economics, ecology, and political science.

turn the commons into private property.[4] On the other hand, some authors provide real-world examples of successful local-level cooperation in managing common-use resources.[5] The prescription that derives from this latter approach is to recognize collective action as a viable alternative way to manage common-use resources.

In the rural communities where I did my research I found a diversity of common-use water sources: collective cisterns, open wells, tube wells, fresh water lakes, and saline water lakes. A common factor across these villages is that fresh-water projects (lakes and cisterns) seem to be in better physical shape than facilities providing saline water. Villagers use fresh water exclusively for drinking and cooking, and saline water for personal hygiene, washing clothes, cleaning the house, and flushing. Saline water sources also work as back-up sources that people can use to water animals, to cook, and in the most desperate circumstances to drink when local fresh water sources go dry. Years after construction, collective cisterns continue to supply relatively safe water to most villagers and not only to the better-off families; they constitute an example of a water supply project that does not become inoperable a short time after construction.

Some water supply facilities elicit more community participation than others. In the villages where I worked, collective cisterns are the facilities that mobilize local beneficiaries the most. Villagers are willing to maintain collective cisterns because these facilities are their main source of drinking water. Fresh water in this region is very scarce; most of the local water sources supply saline water. The collective action around community cisterns takes several forms. Users help decide where to locate these facilities, monitor contractors during the construction phase, impose rules to control the quantity of water withdrawn, and transfer water from perennial reservoirs to community cisterns.

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[4] Examples of this literature include the widely noted works of Mancur Olson (1965) and Garret Hardin (1968).

[5] See Ostrom (1990); Wade (1987); Messerschmidt (1986); McKean (1986); Arnold & Campbell (1986).

Cooperation from beneficiaries, however, is not a constant. It happens in some places, but not in others. What I found is that cooperation is more likely to occur in communities where local people have a tradition of working together as a group. Groups seem to play a key role in setting the stage for successful management of common-use resources, because they provide local people with organizational skills and support networks. Such groups include those initiated and supported by the Catholic Church (*Comunidades Eclesiales de Base*); the rural-workers trade union (*Sindicato dos Trabalhadores Rurais*); marketing cooperatives, and the State Secretariat of Agriculture Extension Agency (EMATERCE). Also, the presence of committed and capable leadership at the local level is very important if common-use facilities working are to work well over time. Very effective leadership already exists in some of the villages that I visited. Local leaders have played a very important role in organizing people not only in their own communities, but also in neighboring villages.

Finally, I found that physical design is a key factor that can facilitate or complicate the future operation and maintenance of water supply facilities. In one of the better organized and most participative communities, I found a type of collective cistern that stopped working much sooner than sponsors had expected, not because of any lack of operation and maintenance, but because of faulty design. The development literature that I reviewed frequently emphasizes institutional and financial issues, and overlooks the question of technical design.[6]

[6] See for example, World Bank (1976)

1.1. Methodology

This study is based on three months of field work in Ceará, Brazil, between June and September of 1995. During this period I visited 18 rural communities (with numbers of households ranging from 15 to 150) in the municipalities of Mombaça and Quixeramobim. I looked mainly at small-scale water supply projects (97 facilities) such as community cisterns, dug wells, and tube wells, which villagers use to satisfy household purposes (drinking, cooking, washing, etc.).

To learn about the attributes of these different small-scale supplies, and local institutional arrangements to operate and maintain them, I interviewed residents, members of community associations, local leaders, and agricultural extension agents.

In selecting locations for my research I chose to work in Mombaça and Quixeramobim because both municipalities are located in one of the most water-deprived areas within Ceará, a semi-arid region where highly variable rainfall patterns limit the availability of surface water, and where impervious soils severely constrain the availability of groundwater. I expected people in this water-poor region to have developed effective strategies to manage the scarce resource. Also I chose these municipalities because they have many government-sponsored rural water supply projects around which I expected to find collective arrangements for operation and maintenance.

The study was complemented with a review of written materials and data collection from government agencies at the state capital, Fortaleza, as well as consultation with government officials at the State Secretariat of Planning and Coordination (SEPLAN), the State Department of Hydraulic Works (SOHIDRA), the State Secretariat of Water Resources (SRH), the State Secretariat of Agriculture (*Secretaria de Agricultura*), and officials from the municipal governments of Mombaça and Quixeramobim.

CHAPTER TWO

BACKGROUND

Mombaça and Quixeramobim[7] are municipalities located in one of the most water-deprived regions within Ceará: the semi-arid and crystalline zone. In this chapter I describe natural features related to the water supply problem in this region. The study area is characterized by highly variable rainfall patterns, and high concentrations of salts in both groundwater and surface reservoirs. These features complicate self-help approaches to water provision. The federal, state, and municipal governments have intervened by building different types of water reservoirs, trying to improve the access of the rural population to water supply. However, the percentage of the population served with reliable systems of water supply in the rural areas of Mombaça and Quixeramobim lags behind state and regional averages, which are already very low. In this chapter I describe natural constraints and institutional aspects related to the region's water supply problem, as well as collective facilities that resulted from those different state interventions.

2.1. Natural Features of Water Supply in the Crystalline Zone

Most of Ceará's territory (92%) falls within the "drought polygon," a region afflicted by frequent and protracted periods of rain shortage. Records and historical evidence indicate that droughts in Ceará occur at least once every ten years, lasting from three to five years each time (Veras, 1992). Rain shortages would not affect the population so drastically if

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[7] Mombaça and Quixeramobim are among the 50 most populated municipalities in Ceará (the 34th and the 15th respectively of a total of 187), with 1990 total populations of 40,814 and 59,115. (Governo do Ceará, IPLANCE, 1994).

ground-water reservoirs provided potable water. The problem is that most aquifers in the crystalline region, which covers approximately 75% of Ceará's territory, provide saline, alkaline, and hard water, not suitable for drinking, as opposed to aquifers in other regions of the state (Cariri, for example) which yield water which is safe to drink without any form of treatment (Gov. Ceará, 1994).

Surface reservoirs, such as lakes and shallow ponds, are not a reliable source of drinking water in the semi-arid and crystalline zone of Ceará either: their high indexes of evaporation guarantee that they dry out fast. In this region's sunny climate approximately 2,000 millimeters evaporate from water surfaces every year.[8]

The poor natural resource base of the semi-arid zone is one factor correlated with rural poverty in Ceará and the Northeast in general. Agro-climatic conditions and skewed land distribution are two other factors that contribute to making Northeast Brazil the single largest pocket of rural poverty in Latin America (World Bank, 1995). One of the characteristics that defines rural poverty is the limited access to infrastructure and service systems. The lack of access to sources of clean water has been well documented in terms of its consequences for health and productivity.[9] In the study region, where prolonged droughts are one of the major threats to life, improving the access of rural population to reliable systems of water supply has long been one of the state government's major concerns.

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[8] When I visited this region, right after the rainy season, I saw lakes and streams near most of the communities. Most of those water bodies dry out a few months after the rainy season. Annual evaporation accounts for the disappearance of lakes less than 2 meters deep.

[9] See for example the work of Feachem (1984).

2.2. Access of The Rural Population to Water Supply

In the communities studied here, levels of water supply service range from one or more water points (lakes, wells) with no distribution system, to simple distribution systems where a single source (well, lake) supplies water to a public fountain. More elaborate distribution systems serving public hydrants and house connections are uncommon in this region. Only in three villages, all located in Quixeramobim (São Miguel, Oiticica, and Santa Isabel), are there water supply systems with house connections.

Fully-piped networks exist only in the capitals of the municipalities, called *sedes*, and a few of the larger villages.[10] The piped-water service provided by public companies reaches only a small portion of the population. In the municipality of Mombaça, only 20% of the population living in the city in 1990 was served with piped water (Governo do Ceará, 1994). There is no piped water in the rural areas of this municipality (see Table 1). In the Northeast region, the percentage of the rural population served with piped water is 6%, and in all of rural Brazil, 27%.

Table 1
Population served with Piped Water
Municipality of Mombaça, Ceará (1990)

	Population	Served (%)	Not Served (%)
Urban	13,608	19	81
Rural	27,206	0	100
Total	40,814	6	94

Source: Governo do Estado do Ceará (1994). Qualidade e Conservação da Agua com com vistas ao Desenvolvimento Sustentável do Ceará. ÁRIDAS. SEPLAN, Fortaleza.

[10]The piped-water service is provided by public companies: the State Company of Water and Sanitation (*Companhia de Agua e Esgoto do Ceará,* CAGECE); the National Foundation of Health (*Fundaçao Nacional de Saude*); and municipal governments or *Prefeituras*. This service is not yet available in all the municipalities in Ceará. In 1990 there were still 27 municipalities with no water supply infrastructure. (Gov. do Ceará, ARIDAS, 1994)

In some households not yet being served with piped water, there are tanks made of concrete, called cisterns, where people store rainwater collected on roofs.[11] The capacity of the private tanks that I saw in the communities ranged from 10,000 to 20,000 liters. When people run out of rainwater stored in private cisterns, they turn to either of two options: they buy water from private vendors,[12] or fetch water from common-use water sources outside their homes. The poor also store rainwater for household purposes, but in metallic barrels with a capacity of approximately 5,000 liters. According to local informants, the rural poor cannot afford to buy water from water vendors. Local informants told me that 20 liters of water delivered to a home costs the equivalent of US $0.05. The price is fair, they say, but they cannot afford it.

People in rural communities traditionally consumed water from streams, seasonal lakes, and shallow wells. The problem with these sources is that they are often polluted, inconveniently located, or exist only during the rainy season. The government has provided water sources to complement these seasonal and unreliable supplies.

2.3. <u>Government Provision of Rural Water Supplies</u>

Numerous agencies are normally responsible for the rural water supply, including various national and state ministries, national and regional water authorities, and rural development agencies. In Ceará, several institutions are involved in providing water in rural areas. According to the World Bank (1976) the overlapping of responsibilities among several government agencies is an institutional weakness that commonly affects rural water supply programs.

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[11] For a detailed description of how cisterns work, see Chapter Five.

[12] In the municipality of Mombaça, for example, the mayor's son owns a few water trucks, and sells water to private households and small businesses.

Early in this century the federal government started to intervene through several agencies which later became the National Department of Public Works Against Droughts (DNOCS). This agency has been in charge of building large infrastructure projects (dams, tube wells, roads) to reduce the vulnerability to drought of the population settled in dispersed and isolated rural communities. Between 1945 and 1991 DNOCS built 536 dams and drilled 1153 wells throughout Ceará. DNOCS worked most of the time in cooperation with landowners, and built 85% of the water reservoirs on private property (Veras, 1992). These water stocks, however, were intended to supply drinking water to all the people living in the area.

The state government also built artificial lakes, but usually smaller than those built by DNOCS, and drilled tube wells. Up until 1987, when the State Secretariat of Water Resources (SRH) was created and assumed these responsibilities, the Government of Ceará took care of the water supply problem in the rural areas through the State Secretariat of Agriculture (SAA), the State Secretariat of Public Works (SOEC); and the Agricultural Extension Agency (EMATERCE). The latter has played a key role in times of drought emergency by building a large number of shallow wells (dug wells) and collective cisterns in rural communities within the study region. Municipal governments also intervened by contracting out to build small dams, drill wells, and build cisterns in public spaces (e.g., schools).

Part of the water supply infrastructure in the rural areas of Mombaça and Quixeramobim resulted from the many frequently uncoordinated government projects implemented during times of drought emergency, including, for example, the many dug wells throughout the region, and a few perennial artificial lakes (For more detail see Table 2). Other water supply facilities (community cisterns, new dug wells, tube wells, and small artificial lakes) are part of a strategy to alleviate rural poverty that the state government of Ceará has been carrying in association with the World Bank. In Brazil, the federal and state governments have been involved since the early 1970s in financing schemes to alleviate rural poverty in the Northeast. Within this framework, the government of Ceará implemented the first statewide rural development project, POLONORDESTE, during 1981-1986. This was revised in 1987 and became the Program of Assistance to the Small Farmer, PAPP. In 1993, it was transformed into a community-based development program where rural communities participate in identifying, financing, and implementing of subprojects that meet their most pressing needs. PAPP aims to increase the access of the rural poor to basic social and economic infrastructure by financing rural water supply projects, local road improvements, small bridges, fords, rural electrification, day care centers, etc. PAPP also intends to create employment and income-generating opportunities in the rural areas by financing small-scale agro-processing projects (rice, manioc mills), minor irrigation schemes, sugar refineries, tractors for communal use, apiaries, etc. (World Bank, 1995).

The State Secretariat of Planning and Coordination (SEPLAN) has overseen the implementation of PAPP in Ceará and has overall responsibility for coordinating the program. The State Department of Hydraulic Works (SOHIDRA), set up in 1987, is in charge of implementing water supply projects under the PAPP program. Between 1987 and 1995, under the PAPP program, the Government of Ceará built 976 rural water supply systems (shallow wells, tube wells, collective cisterns, small artificial lakes). These facilities are described in more detail in Table 3.

Table 2
Sources of Water Supply for Human Consumption
Selected Communities in Mombaça and Quixeramobim, Ceará.

Type of Facility	Location	**Characteristics** How Done	Description	Quality	**Assessment** Quantity	Accessibility	Reliable
Hand Dug Wells	Determined by natural conditions	Self-help	Holes excavated by hand in the bottoms of valleys towards which ground water flows	–	–	–	–
Dug Wells	Determined by natural conditions	Self-help technical assistance from the agriculture extension agency EMATERCE	Wells excavated using hand tools. Diameter 2 or 3 meters; depth 5 to 10 meters. Sides cased with stone or brick. Many were built in times of drought emergency	–	+ / -	+ / -	+ / -
Artificial Lakes	Determined by natural conditions	Federal Gov. DNOCS State Gov. SOHIDRA	Surface reservoirs that store run-off water from surrounding slopes	+	+	–	+ / -
Streams	Determined by natural conditions	N/A		–	–	–	–
Cisterns	Flexible	Local stone mason. Technical Assistance from EMATERCE	Tanks for storing rainwater collected on roofs	+	–	+	+

Source: Field Work, Summer 1995.

(+) Good in Most Cases; (-) Bad in Most Cases ; (+/-) Mixed Evidence

Table 3
Water Supply Projects in Program of Assistance to the Small Farmer (PAPP), Mombaça and Quixeramobim, Ceará

Type of Facility	Characteristics: Location	Characteristics: How Done	Characteristics: Description	Assessment: Quality	Assessment: Quantity	Assessment: Accessibility	Assessment: Reliable
Dug Wells	Determined by natural conditions	Self-help with Technical assistance from SOHIDRA and EMATERCE	Well excavated using hand tools. Diameter 2 or 3 meters; depth 5 to 10 meters. Sides cased with stone or brick. AVERAGE COST: US $2,000	–	+/-	–	+/-
Tube Wells	Determined by studies of geophysical prospecting	SOHIDRA	Well excavated using pneumatic drills. Mean Depth: 50 meters AVERAGE COST: US $10, 600 (Treatment Plant: additional US $3,000)	–	+/-	–	+
Public Fountains	Depends on distance and slope from wells/ lakes that supply them and source of energy	SOHIDRA	Concrete tanks for storing water pumped from nearby wells or lakes AVERAGE COST: US $9,700	–	+/-	+	+/-
Artificial Lakes	Determined by local conditions	SOHIDRA	Surface reservoirs to store run-off from surrounding slopes AVERAGE COST: US $25,400	+	+	–	+
Cisterns	Flexible	Local stone mason with technical assistance from EMATERCE	Reservoirs to store rain-water collected on roofs. Made of poured concrete. Capacity 30 to 60 m3. AVERAGE COST: US $4,600	+	–	+	+

Source: Field Work, Summer 1995. Information about costs: World Bank office in Recife, Brazil. (+) Good in Most Cases; (-) Bad in Most Case ; (+/-) Mixed Evidence

CHAPTER THREE

MANAGEMENT OF RURAL WATER SUPPLIES IN THE CRYSTALLINE REGION

In each of the communities in this study there is a diversity of common-use water projects: community cisterns, open wells, tube wells, fresh-water lakes, and saline-water lakes. A common factor across these villages is that fresh-water projects (lakes and cisterns) seem to be in better physical shape than saline water projects, even though the latter play an important role in communities which are not served with piped water and are located in areas afflicted by recurrent and protracted droughts.

In this chapter I want to draw attention to the diversity of water supply projects existing at the local level in order to highlight two things. First, water supply facilities do not stand alone, but are related as components of local water supply strategies. It is essential to understand the role that different sources play in local systems of water provision in order to identify intervention paths that can improve the year-round access to safe water among the rural poor. Secondly, collective cisterns seem to be performing well, in contrast to tube wells. These factors--the diversity of water supply projects, the conscious strategy of relying on various sources as a system, and the relatively good performance of collective cisterns--receive little attention in the PAPP program literature that I reviewed, and did not emerge in my interviews with public officials in Ceará. By not acknowledging the diversity of small-scale water supply projects in the communities, and focusing only on the performance of tube wells, analysts of PAPP water supply systems have failed to recognize the good performance and endurance of other rural water supply facilities, particularly collective cisterns.

3.1. Differentiation of Rural Water Supply Projects

Each of the communities in this study has several water supply sources. Table 4 shows the different combinations of sources in each of the villages. Planners outside from the communities do not always recognize such diversity, or the role that different sources play in local strategies of water provision. Appraisal reports aggregate information under the category of "water supply projects," rather than differentiate among the various types funded under the PAPP program.[13] Villagers clearly differentiate among these water supply facilities, and assign each one to specific purposes according to the water quality, location, and reliability.

Table 4
Inventory of Common-Use Water Sources
Selected Communities in Mombaça and Quixeramobim, Ceará

Municipality / Community	Cisterns	Dug Wells (*)	Tube Wells	Fresh Water Lake	Saline Water Lake	Seasonal River
Mombaça:						
Morada N.	2	1	-	1	2	-
Umari	3	1	-	1	2	1
Massape	2	-	1	1	4	
São Bento	4	7	-	1	2	1
Os Matos	3	-	-		1	
Zorra	2	1	-	1	2	1
Cangati	1	-	1	1	2	1
São Pedro	2	1	-	-	1	
Catole	-	3	-	1	-	1
Travesao	1	2	-	-	2	1
Boa Vista	3	3	1	-	5	1
Sto. Andre	3	3	-	1	3	1
Bom Jesus	1	1	-	-	1	
Carnauba	-	1	1	1		1
Quixeramobim:						
Oiticica	3	3	3	2	1	1
São Miguel	8	-	-	1	2	
São Bento	9	7	-	1	1	1
Santa Isabel	9	-	-	1	1	1
Total	56	34	7	14	32	N/A

Source: Field Work, Summer 1995.

[13] World Bank (1995); and Miranda (1990) in his evaluation of PAPP projects uses broad categories such as "projects of water supply", "collective equipment."

Open wells (dug wells) are by far the most numerous facility in this region. Table 4 does not reflect this fact because it includes only water facilities that are common property, that is, facilities owned by the community association. Most dug wells are located on private property; they become collective facilities in times of drought emergency.

3.2. Local Strategies of Rural Water Supply

To ensure a reliable supply of water for household purposes over time, villagers in this region have a strategy of combining fresh and saline water sources, and shifting water sources when some water points go dry.

- **Combining Fresh and Saline Water Sources**

  Villagers in these communities consume both fresh and saline water. Under normal circumstances they use fresh water exclusively for drinking and cooking, and saline water for personal hygiene, house cleaning, laundry, and flushing (see Table 5). SOHIDRA built tube wells knowing that most aquifers in this region provide saline water. Several considerations justify the construction of wells in zones where the groundwater is saline. First, in non-drought times, people can use saline water for household purposes. This reduces the need to use ponds and streams for household purposes, freeing villagers from longer walks to fetch water, and exposure to parasitic and other infections.[14] Second, in times of drought emergency, saline wells become backup sources to water livestock, to cook, and in the most desperate circumstances,

[14] Such as schistosomiasis (bilharzia) and dracontiasis (guinea worm). (World Bank, 1976). Feachem (1984) also mentions skin, eye, and louse-borne infections (typhus).

to drink. SOHIDRA also built these wells with a view towards installing desalinization plants in the future.[15]

Table 5
Water Consumption in a Sample Household
Community of Morada Nova, Mombaça, Ceará.

Type of Use	Type of Water	Type of Source	Quantity 1 can = 20 liters
Drinking	Fresh	Collective Cisterns Fresh-Water Lakes	2 to 3 cans per week (40 - 60 liters/week)
Cooking	Fresh and Saline	Collective Cisterns Saline Water Tank supplied by Well	4 to 6 cans per week (80 - 120 liters/ week)
Bathing	Saline	Saline Water Tank supplied by Well Saline-Water Lakes	7 cans per week (per person) 140 liters/person /week N/A.
House cleaning (including dishes)	Saline	Saline Water Tank supplied by Well	14 cans per week
Laundry	Saline	Saline-Water Lake	N/A
Flushing	Saline	Saline-Water Tank supplied by Well	14 cans per week

These consumption figures are calculated for a household of four people.
Source: Field Work, Summer 1995.

[15] The government of Ceará is presently studying a project to install desalinization plants, and has already initiated contacts with possible contractors.

- **Shifting Water Sources**

  Community cisterns and fresh-water lakes supply drinking water, but at different times of the year. The seasonal water-use pattern can be seen in the form of increased reliance on cisterns in the first part of the dry season (August-October) as shallow surface reservoirs dry up, and increased reliance on perennial fresh-water lakes during the second part of the dry season (October-December), as communities run out of water stored in collective cisterns. Provided there is some rain, the cisterns collect and store rainfall during the first six months of the year. During those months people fetch water from surface reservoirs. In all cases, the amount of rainwater stored in collective cisterns is not enough to supply villagers during the entire dry season. At some stage (usually around October) cisterns have to be refilled with water from fresh-water lakes.[16]

3.3. The Good Performance of Collective Cisterns

When evaluating water supply projects, analysts of the PAPP Program have primarily looked at tube wells,[17] perhaps because these were the most common water supply facility in areas where they conducted research. In the region where I did field work, such wells are not very common. Table 6 shows that tube wells comprised only 7% of the 97 water facilities in the 18 communities that I visited.

While in the communities, I evaluated water supply projects using the following criteria: whether the facilities stood or had collapsed, and if standing, whether they had water, had water and some leaks, or were empty. The results are summarized in Table 6.

[16] In this sense, the good performance of collective cisterns should be, at least in part, attributed to previous investments in large infrastructure projects, such as roads and perennial lakes.

[17] Tendler (1993); Silverman (1994) mentions that in the municipalities within the State of Paraiba where she did her work about 70% of the water supply facilities were tube wells.

Table 6
Typology of Rural Water Supplies and Performance Record
Selected Communities in Mombaça and Quixeramobim, Ceará

	Com. Cisterns	Dug Wells	Tube Wells	Total
Type of System	58% (56)	35% (34)	5% (7)	100% (97)
Systems Working	71% (39.5)*	65% (22)	43% (3)	66% (64.5)*

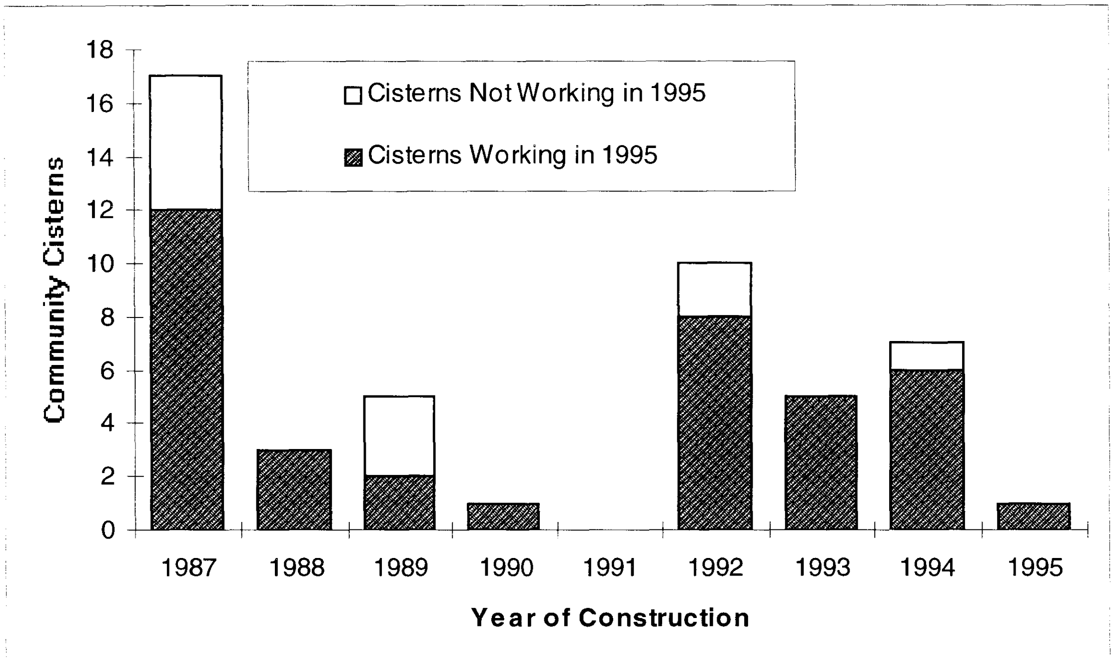
Source: Field Work, Summer 1995. (*) Community cisterns that were not working at full capacity because of leaks were counted as 0.5.

In interviews, government officials at the state secretariats of planning, and water resources, expressed the view that beneficiaries waste water and fail to maintain water facilities. People in the communities, officials said, are encouraged by the harsh natural conditions typical of drought-hit environments to consume as much water as they can before other people do, leaving no water at the jointly-used water sources; villagers act without considering the implications that their consumption will have on other people.

According to Steffes (1996), such a lack of will within communities to maintain water systems is the reason government officials from water works agencies cited most frequently for the poor performance of water systems. In the development literature, I found similar claims: "the community," says Glenny (1983), "is unlikely on its own initiative to carry out all the routine preventive maintenance tasks that are necessary for the continued reliability and long life of the supply." Glennie argues that people in rural areas lack the financial capacity to pay the cost of spare parts, and the technical capacity to carry out anything but minor repairs. Their main resource is labor, and possibly the ability to raise minimal sums of money, but this, he says, is not enough.

In many cases, water supply facilities fall into disuse a short time after construction, but my research indicates that other facilities have been working since they were built several years ago. Community cisterns, in particular, have served villagers for a number of years, as shown in Figure 1. These observations contrast with reports evaluating PAPP-funded infrastructure projects, where analysts indicate that public equipment funded by PAPP works well only for short periods of time (Miranda, 1990).

Figure 1
Longevity of Community Cisterns
Selected Communities in Mombaça and Quixeramobim, Ceará



Source: Field Work, Summer 1995. (*) The reasons why collective cisterns built in 1989 were less sustainable are explained in detail in Chapter Five.

By not acknowledging the diversity of small-scale water supply projects existing in the communities, and focusing only on the performance of tube wells, analysts of PAPP water supply systems have failed to recognize the good performance and endurance of other rural water supply facilities, particularly collective cisterns. As discussed in the following chapter, an array of collective action around community cisterns contributes to their relatively good performance.

CHAPTER FOUR

COLLECTIVE ACTION AROUND COMMUNITY CISTERNS

In many of the communities in this study I found collective action organized around water supply facilities, particularly for fresh-water sources (lakes and community cisterns). This chapter focuses on the collective action around community cisterns. The importance that villagers attribute to collective cisterns is explained by the fact that these facilities supply the best quality water available locally; they are also more accessible than fresh-water lakes, the alternative source of drinking water in the region.

4.1. <u>Reasons for Collective Action</u>

In rural communities in the developing world, Runge (1986) says, several interrelated features spawn collective action. First, because relative poverty imposes budget constraints on many forms of individual action, many activities are possible only through joint action. Secondly, the productivity of the resource base is low and varies spatially and over time. In the municipalities where I did my research, this is precisely the case: on the one hand, in this region, as in the rest of Northeast Brazil, the majority of the rural population live below the absolute poverty line with annual per capita incomes under US $214, which is less than one tenth of the national average (World Bank, 1995). In the municipality of Mombaça the annual per capita income is US $139, 60% of the already low average for the Northeast. Quixeramobim's annual per capita income is US $223.

Additionally, the erratic rainfall patterns typical of this region are a major source of uncertainty which further discourages villagers from acting on their own. The needs of the poor and of small-scale users in harsh environments like those considered here, are therefore best to met within common-property regimes.

4.2. Why Collective Action Around Community Cisterns?

Two main factors explain why villagers have a vested interest in maintaining the community cisterns: quality and convenience.

- **The Quality Factor**

The sustainability of small, simple systems is assured as long as they serve the basic needs of their users (Schubeler, 1991). Community cisterns serve the basic need for potable water in this crystalline region where most water sources are saline. In the municipalities of Mombaça and Quixeramobim, 70% of the groundwater reserves are saline.[18] Some of the surface reservoirs, such as lakes and ponds, are also saline.[19] To remove salts from water requires treatment plants which are not yet available in the communities.

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[18] Mombaça has 1,347,790 m^3/year of exploitable reserves of ground-water; 943,453 (70%) are saline. The reserves in Quixeramobim are 1,503,070 m^3/year; of this total 1,052,149 (70%) have quality problems (Gov. Ceará, IPLANCE, 1994).

[19] Large quantities of salts are usually washed into surface reservoirs by irrigation return flows and wastewater; in the dry season, the salts dissolved in water concentrate even further due to high evaporation indexes (Dunne, 1987).

Cisterns provide fresh water, but this water may be contaminated with bacteria. During storage, the rainwater collected from roofs may deteriorate as organic material in the water putrefies, or as bacteria and other micro-organisms grow (Hofkes, 1983). This does not, however, represent a serious inconvenience because there are already local mechanisms in place to solve this problem. To clean the water in collective cisterns is easy and economic; it only requires adding chlorine to water. Chlorine is already available locally from the State Department of Health. Apparently, villagers dislike the taste of water with chlorine and do not use chlorine in the water stored at home; however, community health agents routinely apply chlorine to water stored in collective cisterns. Collective cisterns are, in this sense, a very effective public-health device.

- **The Distance Factor**

Collective cisterns seem to be a "user friendly" system for supplying water in the sense that they are located closer to most households. Cisterns can be built almost anywhere, as long as there is a large roof to act as a collection area for rainfall. Artificial lakes and dams, on the other hand, cannot be built where the population is settled, but only where topographic conditions are favorable for accumulating runoff water. Using the formula shown in Appendix Two, we can calculate the mean distance that people need to travel to reach one of the water reservoirs that exist in this particular area. In the best case scenario, the mean distance that people need to travel to reach a lake in Mombaça is 1.2 kilometers, and 1.4 km in Quixeramobim.[20] Most people get to water reservoirs by foot,

[20] This would be in the best case scenario where sources of water and rural populations are evenly distributed in the territory, and assuming that all surface reservoirs in these municipalities are perennial, which unfortunately is not the case. Water reservoirs are distributed unevenly, and a significant number of

and carry the water containers themselves. Women and children usually carry the water. Several women in the study villages told me that they average 10 trips for water every day, starting early in the morning (5 or 6 a.m.). Each trip takes them on average 20 minutes. Besides time (they invest approximately three hours every day in fetching water), the energy requirements used on this task are very high. White and Bradley and White (1962), in their study of rural settlements in East Africa, estimated that over one-quarter of one person's daily energy requirements were used in fetching water; for individual households, this figure could be as high as 80 %.[21] "The income of the household", Steffes (1996) says, "is negatively affected when the water source is located far from the house. Women spend time fetching water at the expense of other activities such as child care, education, and wage labor".

4.3. Collective Action in Motion

Besides fitting better into pre-existing environments, collective cisterns have the advantage of mobilizing community participation. In the villages of this study I found that community cisterns elicit more community participation than wells. Beneficiaries select sites, work on construction, and in operation and maintenance. Their acceptance

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them exist only during years when it rains. According to Pontes (1983), lakes with capacities of 300,000m^3 or less do not survive two or more consecutive years of rain shortage; 70% of the lakes in Mombaça have a capacity of less than 300,000 m^3, and are therefore the type of reservoir that dries out frequently.

[21] White, Bradley, and White (1962), *Drawers of Water: Domestic Water Use in East Africa*. The University of Chicago Press.

and cooperation promotes the proper use and maintenance of facilities, and minimizes conflicts and delays. These tasks are described below.

. Selection of Sites

The involvement of the community in selecting sites to drill tube wells is minimal. Geological constraints and technical requirements do not leave much room for beneficiaries' opinions. Aquifers in the crystalline zone exist only where the rock strata are fractured; its only where rocks are fractured that rainfall can percolate into the earth to create groundwater reservoirs. Finding aquifers in the crystalline region requires geophysical prospecting analysis conducted by specialized technicians whose service is usually not available at the municipal level. Additionally, aquifers in the crystalline zone are deeper than aquifers in alluvial zones. The low number of tube wells in Mombaça and Quixeramobim demonstrates how difficult it is to find and drill wells in this area. According to statistics provided by the government of Ceará, in the whole municipality of Mombaça there are only 31 tube wells, and in Quixeramobim, 12 (Governo do Ceará, IPLANCE, 1994).[22]

In the decision about where to locate collective cisterns, on the other hand, there is room for beneficiaries' opinions. Locating collective cisterns actually forces beneficiaries to come together to discuss and choose the site where they want to have the water supply

[22] Tube wells therefore provide saline water and are less accessible. Both problems could be solved: de-salinization plants could be installed, and public hydrants more conveniently located. However, such additions would substantially increase the cost of the water supply system. Under the PAPP program, each community can apply for funding twice a year, and each project cannot exceed US $50,000. From what I saw in the communities, villagers prefer to request funding for income-generation projects. Cisterns can be built with construction materials and money left over from other projects, whereas more complex water supply projects (e.g., wells with distribution facilities) cannot.

facility. Collective cisterns can exist in a variety of locations. These choices include the roofs of private houses; common property buildings (sugar and manioc flour mills, clothes factories, community centers, etc.); and public buildings (schools and health centers). Participating in the decision about location is one of the first steps into developing a sense of ownership over water supply facilities. When beneficiaries think of water facilities as state property, they expect the government to take care of them; but when they own the facilities, they know that operation and maintenance tasks are their responsibility.

Various elements need to be weighed in the decision about where to locate a collective cistern. First, villagers consider the dimensions of the roof. The larger the roof, the more rainfall it collects.[23] People are inclined to choose the bigger, more solid roofs within the village; these are often on the houses of the better-off families, or on commonly-owned buildings. Villagers also consider distance and accessibility of sites during both the dry and the rainy seasons, since they and their children will need to reach the source and carry water containers all the way back to their houses. Another very important factor is whether the site is conflict-free. Rival groups may interfere and block access to water sources. Sometimes the problem is not that someone may block access, but that users would hesitate to drawing water from sources controlled by individuals or groups with whom they do not have good relationships. Local people know what group alliances exist within their own village and sometimes manage to allocate water facilities

[23] The quantity of rainwater that can be collected through roof catchment will be largely determined by the effective areas of the roof and the local annual rainfall. One millimeter of rainfall on $1m^2$ of roof will yield about 0.8 liters of water. For a roof measuring 5m x 8m and assuming an average annual rainfall of 750 mm, the amount of rainwater which can be collected in a year may be estimated as 5 x 8 x 750 x 0.8 = 24,000 liters / year (Hofkes,1983).

so internal divisions minimally affect the distribution of drinking water among villagers. Collective cisterns located at different spots within the community could better satisfy the demand for drinking water of different factions or groups, rather than having only one source which would potentially concentrate the benefits on one group within the community.

As can be seen in Table 7 the largest number of collective cisterns are located next to private houses. Those people whose house roofs become the collection area for the community cistern are compensated by the convenience of having a source of fresh water next to their homes, which means that members of that household will not need to fetch drinking water from distant sources as the rest of the villagers do. Besides, having the source of fresh water at home, may allow people to consume a little more water than the rest of the villagers. People living in those houses do not have to bear all the operation and maintenance duties that collective cisterns require. The community association helps them by organizing groups of volunteers to take care of heavier tasks such as clearing vegetation from the surroundings and path to the source, and building or restoring fences to keep animals away from the facility.

Table 7
Location of Common-Use Cisterns

	Quantity
Public Space	
School	9
Plaza	1
Street	3
Community Space	
Sugar Mill	2
Manioc Flour Mill	3
CommunityCenter	1
Clothing Factory	1
Private Space	
President's House	7
Member's House	17
Other House	6
TOTAL	50

Source: Field Work. Summer 1995.

The way villagers decide where to locate the collective cisterns varies from one community to another. I came across two different types of situations. Sometimes leaders, or elite groups, decide the location without consulting with other people in the community; in other cases leaders assemble local people to discuss the issue and choose locations that benefit most families in the community.

One example of non-participatory local decision making occurred in Umari, Mombaça, where the president of the community association decided on the location of the community cisterns. He decided to have one built right next to his house, and the other at the other side of the village. People living in that area thought of this cistern as "his," and expected him to look after it. He took good care of the cistern built next to his house, but not so much of the other one. While the first cistern has survived and is in pretty good shape, the latter collapsed. Apparently the problem was that neighbors did not make sure that some water was left in the tank. The empty tank cracked, and after some time, one wall collapsed.

Another non-participatory case occurred in Santo André, Mombaça, where the president of the community association decided to install PAPP cisterns, one next to his house, and the other next to his brother's house. Some members of the community did not approve of his decision, or of his family's discretionary use of the water. The collective cisterns have become a source of conflict and division in this community. The disgruntled families stopped taking water from these sources and went back to the traditional, and poorer quality, streams and wells. In São Pedro, Mombaça, there is a similar situation: discontented families went back to using water from a lake that receives wastewater from nearby households. In São Miguel, Quixeramobim, the community association decided to build a collective cistern in the school yard. Neighbors assumed that the school staff would be responsible for its operation and maintenance. The school staff did not take responsibility for the collective cistern as part of their duties. No one ever made sure that the cistern was completed. Years after its construction it still lacks a gutter to convey water from the roof. The gutter is sitting in the schools' store room.

In other cases, local people participated in deciding on the location. In the communities of São Bento, and Santa Isabel, Quixeramobim, the community associations allocated the PAPP cisterns after meeting with local residents. At these meetings villagers also discussed who was to provide the land for the cisterns. As a result of these meetings, members of the community not only agreed on sites for collective cisterns, but they also assigned a fixed number of families to each cistern. Therefore, each cistern has a well-defined group of users, usually those who live close to it. Each group of users is responsible for the water facility assigned to it. Those households who benefit most from the cisterns contribute money and labor to repair the cistern when necessary, and they are responsible for routine maintenance tasks.

- **Monitoring Contractors**

State water engineers or private contractors do not require that beneficiaries participate in installing tube wells. There is no way for beneficiaries to tell whether state engineers or contractors are following the right procedure or using the appropriate materials in excavating deep wells, and in placing casings, screens and fittings. Villagers usually have no one to turn to for advice. Local technicians do not know much about this more sophisticated technology. SOHIDRA and a few private contractors are the only ones in the state familiar with the procedure and machinery required to drill deep wells. Tube wells end up being like "black boxes" which beneficiaries do not fully understand. The drilling of a tube well usually takes a few weeks and during the short period that contractors work in the area, there is little chance for beneficiaries to get to know the facility in detail. However, once the well is built and the pump is installed, beneficiaries become responsible for operation and maintenance.

The technology used to build cisterns, on the other hand, is so simple and common that beneficiaries can actually judge whether the contractors are doing a good job or not. Community associations contract with stone masons to build the collective cisterns. In some villages, beneficiaries help excavate the site, collect sand and foundation stone, carry materials, and clear an access road to the new water source. The stone masons are in charge of building the walls of the tank (which should resist friction from both the terrain and the water), the roof (which should be strong enough for people to walk on), and the manhole (for buckets to draw water). They are also responsible for mixing the concrete, installing reinforcing bars, and pouring the concrete slab.

In some communities the collective cisterns were constructed very well as demonstrated by their years of endurance. According to local informants, the good construction resulted largely from having beneficiaries monitor the contractors very closely. Competent supervision is very important because shortcomings in construction are usually very difficult to rectify (Glennie, 1983). Having beneficiaries supervising contractors proved to be a very good way to prevent faulty workmanship and poor-quality building materials.

How can illiterate people monitor contractors when they cannot read the construction plans? In some villages, beneficiaries learned from the agricultural extension agents what they should watch for if they wanted to "monitor" the contractor's work. In São Bento, Quixeramobim, for example, the community leader met with agricultural extension agents to learn details of how concrete tanks should be built; he asked the extension agents for a copy of the building specifications to take with him to the village where he explained them to other members of the community. Unskilled villagers could monitor contractors because they understood what had to be done. Apparently, they had no difficulty remembering the stages of construction and the principal dimensions. The extension agents had told them to make sure that the contractors used 1 sack of cement per 8 sacks of sand in the concrete mix. The beneficiaries reported back to the president of the community association when they observed contractors scrimping on cement and replacing it with sand. The community leader, who had a copy of the project specifications with him, demanded that the contractor abide by the specifications. The construction of collective cisterns proceeded under the direct supervision of beneficiaries with sporadic visits from the EMATERCE staff.

Under the PAPP programs the design of common and non-sophisticated facilities is standard. Beneficiaries submit proposals for project investments based on their priority needs; they receive standard documentation to prepare their project proposal. These standard forms aim to facilitate the preparation of project proposals and the screening process. The project operation manual contains standardized technical designs, including cost parameters (e.g., cost per physical unit).[24] Beneficiary associations may solicit technical assistance for sophisticated or less common project types. However, for simple projects standard designs are already available (World Bank, 1995: 20). In the municipalities where I worked, the Secretariat of Agricultural Extension Agency (EMATERCE) adapted the existing designs for simple water projects (such as collective cisterns) and made them available to beneficiary associations.

To reduce the risk of collapse, facilities are commonly over designed; villagers are well aware of this. By supervising contractors very closely, they ensured that contractors

[24] Standardizing tank construction (thickness of floors, walls, and roofs; heights of walls and central roof support pillars) reduces the need for special technical supervision and thus lowers project costs (Glennie, 1983).

did not waste resources. Villagers used extra resources to increase the size or number of projects. For example, the villagers in São Bento, Quixeramobim made a tank of 42,000 liters instead of one of 30,000 liters (40% increase). In Umari, beneficiaries stretched the funding for a cistern of 50,000 liters and built one of 68,000 liters (37% increase). In São Bento, Quixeramobim using funding for 19 collective cisterns, villagers managed to build 21 cisterns, benefiting people from neighboring villages. In São Bento, Mombaça, they built a community cistern plus a tank of 20,000 liters with the same funding. In Morada Nova, villagers administered the funding for a clothing factory so that they could build a collective cistern of 25,000 liters in addition. Finally, villagers have used extra resources to improve the physical design of tanks: elevated tanks are much more expensive than those built on the ground, but villagers with good administrative skills not only managed to build these more expensive tanks, but also to provide them with additions, such as stairs, to facilitate users access to the manholes.

- **Conveying Water from Perennial Sources to Distribution Points**

In order to improve the provision of safe water to rural areas, particularly during the dry season, the government has to develop mechanisms to convey water from perennial or "strategic reservoirs" to water tanks (private and collective) in the communities. Traditionally, water trucks have done this work. Under normal circumstances, municipal government provide this service. In drought emergencies, the state government supplements the supply with its own water trucks.[25] This is not a popular solution because water distributed by public trucks is usually poor in terms of quality, and expensive (for

[25] State Department of Roads (*Departamento de Estradas e Rodoviarias*).

the government). Also because delivery is at the discretion of truck drivers, which has apparently led to corrupt practices. In the end, it is not the villages that need water very badly who receive it, but those who pay drivers to stop in their communities.

The state government has, inadvertently, taken a first step into developing more efficient ways to convey water in the rural areas by providing communities with tractors and motorized pumps. Tractors are one of the items funded under the PAPP program. In some communities I found that villagers were using the collective tractor to pull a water wagon. When necessary, the person responsible for the community tractor drives to a nearby fresh-water lake, and uses a motorized pump, also the property of the community association, to fill a mobile water tank. Back in the community, they refill the collective cisterns and also supply private cisterns. The latter service is charged and community associations use the fee to pay for the diesel fuel used by both the community tractor and the motorized pump.[26]

- **Administering Water Withdrawal**

In the joint use of collective cisterns, the quantity of water that one individual withdraws can adversely affect the amount left to other people. In order to deal with this problem,[27] in some villages beneficiaries have self-imposed a set of *de facto* rules to govern common-use water sources. I do not know how these rules originated. Probably, as Ostrom (1990) suggests, they started from a process of trial and error. In some communities people told me they learned rules from other communities with similar

[26] For a discussion of community tractors in Ceará and benefits they report, see Hesse (1996).
[27] In the common-use resources literature this is known as the "subtractability problem" (Fenny *et al.* 1990)

problems. Villagers discussed rules in community meetings, which are conflict-resolution forums for drinking-water disputes.

The use of fresh-water facilities is more regulated than the use of saline-water sources.[28] Apparently no one is interested in controlling the number of containers that an individual fills with water from open wells, deep wells, or saline-water lakes because there is no lack of salty water from wells and lakes, and polluted water from streams. The rules governing the quantity, timing, and location to withdraw fresh-water from collective cisterns are very similar across the communities in this study.

Quantity [29]

In the sites that I studied villagers rationed water from collective cisterns by limiting the number of liters per family per day, and by queuing. Each household, regardless of its number of members, has the right to withdraw from collective cisterns two containers per day (approximately 40 liters). Villagers use this water for drinking and cooking. In a few localities the rule was two containers every third day. Apparently, a daily allowance of 40 liters was enough to satisfy drinking and cooking needs in most households. [30]

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[28] In most villages, there are de facto rules restricting the use of fresh water lakes for bathing, washing clothes, and watering animals. These rules aim to prevent clean water reservoirs from becoming polluted. Villagers keep the pond shores clear and control the growth of weeds and vegetation which could decompose and affect the quality of water. There is no limit on the number of containers that villagers can withdraw from fresh-water lakes. In this case, distance seems to be the rationing mechanism: most of these lakes are dispersed and frequently distant from people's houses. Villagers obviously restrict consumption because they have to carry the water themselves over long distances.

[29] The quantity of water required depends on the level of service to be provided; this varies from country to country depending on climatic and cultural factors. A survey conducted by the World Health Organization reported daily consumption figures ranged from 20 to 40 liters/capita/day (see World Bank, 1976).

[30] According to Hofkes (1983) 40 liters/day is the basic drinking and domestic water requirement of a family of 6 people. The World Bank (1976) says that for households without water connections 40 liters per day is a common consumption figure. Households connected to the piped system increase daily consumption to 100 liters per day.

According to Wade (1987) two factors explain why demand is adjusted at a relatively high level of aggregation, rather than at the level of individual needs. First, most people managing common-use resources have only a limited capacity to process information. It is easier for community associations to establish a fixed quantity of water containers for everyone in the village, than to assign a different amount to each individual household. Second, high margins of discretionary control over water allocation may lead to corruption. It is in the best interests of the community association to avoid corruption. If villagers distrust the system, they may no longer cooperate with labor and money and this may make it harder for the community associations to manage the water supply projects.

Queuing seems to be an effective way to discourage those better-off individuals from consuming water from the common-use cisterns.[31] Those people who have private cisterns at home do not use the common-use water sources, except in times of acute need (when rainfall was not enough to refill their private tanks, and water trucks have not come to the village).

Timing

The collective cisterns located in public spaces (schools, sugar cane mills, community centers, etc.) are open two hours per day, early in the morning (in most communities from 6 to 8 a.m.). Normally, the community association appoints someone to come every morning to the collective cistern, unlock it, and control the number of containers that

[31] Queuing acts as a side-mechanism that helps to make this rationing process more effective. Baden (1977) sees different rationing systems: rationing by reservation, by random selection, by queuing, and by pricing.

beneficiaries withdraw. After two hours, the cistern is locked until the next day. If people from one household fail to take the allotted amount one day, they cannot take more water the following day. Collective cisterns also have a calendar: in most cases, cisterns only supply water during part of the dry season, and once other water alternatives have dried out, this usually happens in late July or August.

Location

In communities with several collective cisterns there is a distribution of users per source. In the community of Santo Andre, the collective cisterns had a list of users posted on the wall, to ensure that only the families stipulated on the list withdrew from the source.

Standard Containers

Each family withdraws water from collective cisterns using the same type of container: a metallic can with a capacity of 20 liters. If someone tries to use a larger container they would be easily detected.

Monitoring

The families who live closest to the reservoirs are usually the ones who monitor villagers' compliance to rules governing their use. Their proximity to the collective cisterns facilitates their job as caretakers. These people are not remunerated, but they carry out this job anyway; by keeping the source in good shape they are released from the inconvenience of fetching water from other reservoirs. When they see someone infringing the rules, they report it to the community association, or to community leaders, who "visit" the violators, and ask them to restrain from such behavior. Continued non-compliance is likely to bring a loss of reputation and the application of informal sanctions (Ostrom,1990).

Enforcing

According to McKean (1986), no rules are self-enforcing. Even in villages with strong community identity, where people are concerned about social reputation and bonds with the group and have internalized as a vital goal the preservation of the commons, people are still tempted to bend, evade, and violate the rules. Thus there has to be a scheme of penalties and these have to be enforced.

"Local common-property management", Lawry (1989) says, "will not emerge simply by giving greater official rein to local action. Policy initiatives will have little impact unless an important array of incentives supportive of common-property management are operating at the local level." In the communities where I did my research villagers calculate that if they do not cooperate with the community association, it may deny them access to other community projects, which are an important source of income in these villages. Residents in some villages comply with the rules because they want to be on good terms with the local elite, who lead community associations in several communities (e.g., Morada Nova, Umari, São Bento-Mombaça, São Bento-Quixeramobim, Santa Isabel). Being on good terms with the community association becomes a strategy to gain access to credit (in various cases presidents of community associations are the owners of local shops); jobs (the local elite own land, which may represent job opportunities, especially for landless villagers); food baskets (community associations sometimes have access to food baskets distributed by local churches),. and transportation (people in these isolated communities express deep concern about being unable to reach a hospital in case of emergency. Being on good terms with the community association may provide them with transportation in times of trouble (if those who lead the community association do not own a car themselves, they may get someone to provide transportation). Also in some communities, the association manages the day care center (*creche*); by participating in activities organized by the community association, villagers may increase their chance to have their children accepted in these centers. *Creches* provide not only education, but meals.

4.4. The Process of Building Institutional Capital

"International donors and policy makers proclaim participation as a goal and assume that once proclaimed it will happen by fiat. When little participation actually happens, projects fail lamentably" (Cernea, 1992). Participatory episodes, as I described in the previous section, happen more frequently in some settings than in others. In this section I will provide evidence drawn from my on-site research about what those settings are. The idea is to explain why some of these villages succeed in their attempts to self-govern their common-use resources. Such factors can be grouped into two broad categories: organizational expertise and elite leadership.

One common factor shared by the most successful cases from my sample, is the existence of organizational expertise at the local level. It appears that the spirit of participation does not come to a village overnight. Peasants in the localities where I found the best-managed common-use water facilities had been working together for years before they tackled community projects such as PAPP. It seems to me that the most successful community associations draw upon traditional forms of community life and cooperation, and from groups which preceded them, such as those I will now describe.

There is a wide spread tradition of voluntary self-help called *mutirao* (mutual aid)[32] by which kinship groups and other local people worked together to take care of common duties, such as maintaining country roads, and building fences around water reservoirs to keep livestock away. A traditional *mutirao* is helping each other in times of harvest, and working together in collective vegetable gardens. In some villages, women collect food and prepare meals to offer to participants during the day of the *mutirao*. In the community of São Bento, Quixeramobim instead of punishing those who did not collaborate, organizers of the *mutirao* sent them food, to motivate them to join the group the next time.

Besides kinship groups and the *mutirao* brigades, there were other groups in these villages which ensured and gradually institutionalized participation at the local level. In most cases, these other groups were initiated and supported by the Catholic Church

[32] These also seems to be a common practice elsewhere in Brazil. See for example the work of Ferguson (1992) in the state of Parana.

(*Comunidades Eclesiales de Base*), the rural workers trade union, marketing cooperatives (the *Cooperativa de Senador Pompeu*), and the agricultural extension agency (EMATERCE).

Local people drew a number of organizational skills and knowledge from working together on different activities, and from participating in the groups mentioned above. Seven skills seem particularly important in the current management of community projects, and seem to be missing in those villages with less organizational tradition: it is crucial to be able to get local people to come regularly to community meetings; discuss community problems; give space to different opinions; motivate local residents to contribute labor and/or money to group projects; negotiate/mediate among people with different priorities in the group; manage conflict (but not suppress it or avoid it); and establish contacts with associations from other villages and government entities.

CHAPTER FIVE

TECHNICAL DESIGN AND THE SUSTENANCE OF COLLECTIVE CISTERNS

So far I have remarked on the good performance and advantages of collective cisterns. However, not all of the collective cisterns perform well. In the communities that I visited I found different types of collective cisterns, some doing better than others. This observation brings into the discussion the importance of technical design as a key factor that can facilitate or complicate the future operation and maintenance of water supply infrastructure. The development literature emphasizes institutional and financial issues, and overlooks the design question. In the Northeast, no one is building canvas cisterns anymore; however I consider it relevant to compare traditional cisterns and canvas cisterns because it draws attention to the technical design issue, and illustrates points from which to derive lessons for improving the performance of decentralized water supply facilities.

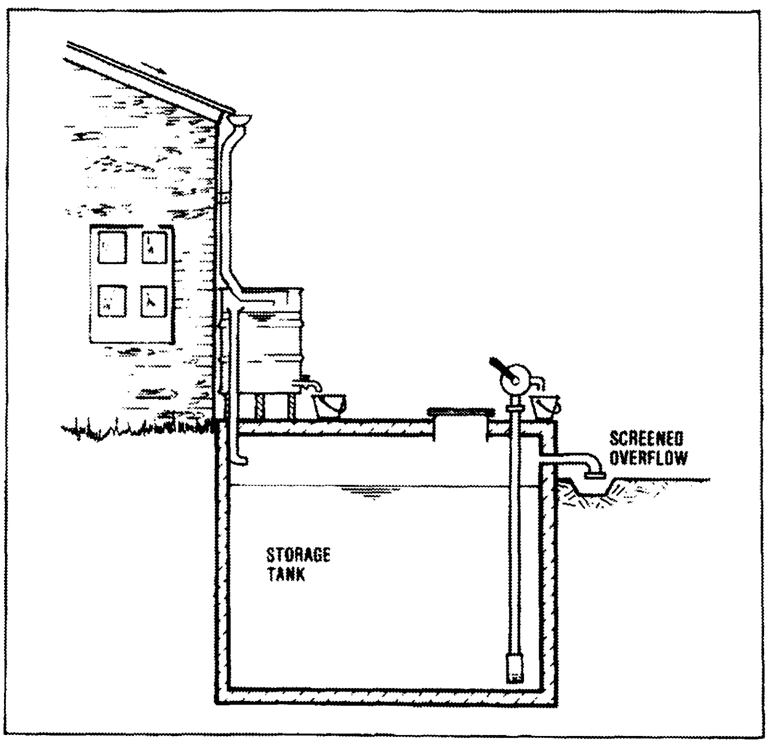
5.1. Typology of Collective Cisterns

In the rural communities where I conducted my research, I found two different types of collective cisterns: those that I will here call "traditional," and the "*Padre Cicero*" cisterns. In the 18 communities I found a total of was 51 traditional cisterns. The PAPP program sponsored 51% of them; 25% were built under the Emergency Program against the Drought; 15% were built by municipal governments; and 2% under the sponsorship of the Inter-American Development Bank. The Padre Cicero cisterns, a total of 5, were sponsored by the Ministry of the Interior (federal government).

- **Traditional Model Cisterns**

The traditional cistern consists of a roof, an even roof overhang, collection troughs, and a storage tank. The storage tanks are circular or rectangular reinforced concrete structures with a fixed roof. Their capacity ranges from 10,000 to 60,000 liters. Tanks store rain-water that falls on roofs. The rainwater is led to an even roof overhang (a semicircular gutter made of sheet-metal, plastic, or clay) by means of a slope in the roof surface. The gutter conveys rainwater first to a downspout and then to the storage tank. To strain out suspended matter, there are sand filters at the entrance of the storage tanks (Merritt,1994).

Figure 2
Traditional Cisterns



Source: E.H.Hofkes (1983:62)

- ***Padre Cicero* Cisterns**

These cisterns consisted of a hole dug in the ground covered with a layer of canvas, and then with a slab of concrete. In this system, rainwater falls over a smooth impervious surface on the ground, runs by means of a slope in the concrete slab to an opening slot, and then passes through a sand filter on its way into the canvas tank. These cisterns measure approximately 22 meters long, 4 meters wide and 1.5 meters deep.

The canvas model of collective cisterns has several advantages over the traditional model. First, these cisterns have three or four times the capacity of the traditional cisterns. Their capacity is 100,000 liters, compared to 25,000 to 30,000 liters for most of the traditional cisterns. Second, the quality of the collected rainwater is better than in traditional cisterns. Rain falls on a flat and clean platform instead of on roofs. Most house roofs in these areas are made of tiles. To clean roofs thoroughly people would need to remove the tiles, clean the surface and the tiles, and reinstall the tiles on the roof. Dust, dead leaves, and bird droppings accumulate on roofs during the dry periods.[33] Rather than removing the tiles, people let the first new rains wash off the roofs. The new rains, however, may not be strong enough to wash roofs where rats and other animals live. On the other hand, to clean the catchment area in *P.Cicero* cisterns people only need to sweep. If there is anything on the plain ground surface it would be very visible, whereas people cannot see what is under the roof tiles. Third, *P.Cicero* cisterns have below-ground storage facilities, so they are cooler, and suffer practically no loss of water through evaporation (Hofkes, 1983).

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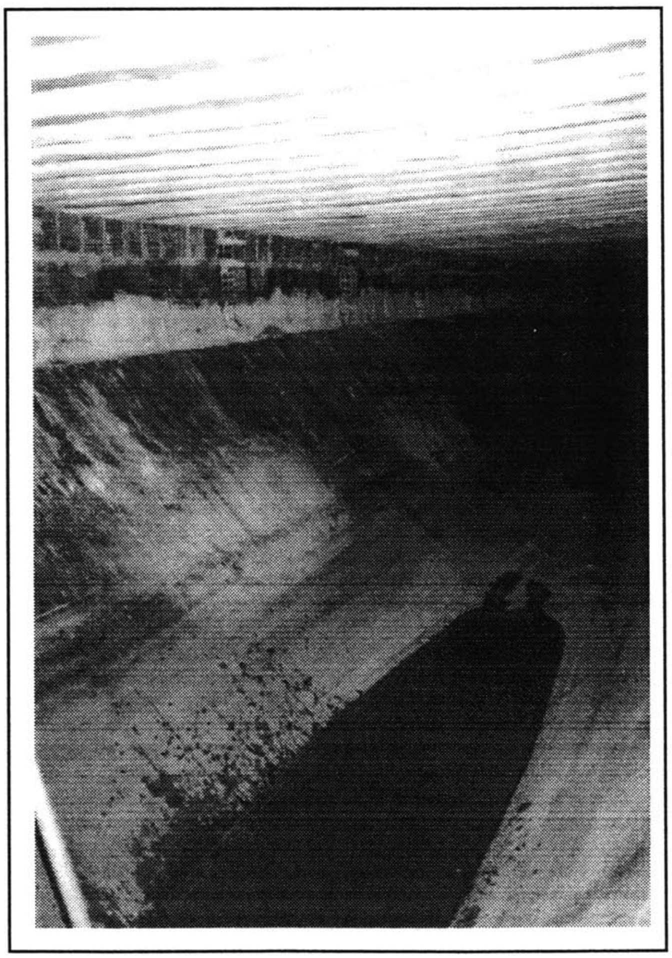
[33] Bird droppings can cause health hazards, such as salmonellosis (Hofkes,1983).

In the traditional cisterns, rainwater is filtered through a wire mesh, whereas in the *P.Cicero* cisterns water passes through a thick sand filter which is much more effective than wires. People in the community of São Bento think that *P.Cicero* cisterns are better than traditional cisterns because they collect better water in greater quantity. Therefore, they have tried to maintain these facilities. However, several problems, which that I will now describe, made their efforts futile.

Figure 3
Padre Cicero Cisterns



Source: Field Work, Summer 1995. Community of São Bento, Quixeramobim.

In order to evaluate whether traditional cisterns were performing better than *Padre Cicero* cisterns I used the same criteria I had used to compared collective cisterns in general to other water supply facilities (open wells and tube wells). I looked at cisterns and checked whether the facilities were still standing or had collapsed, and whether they currently could supply water, could supply water with problems (i.e. leaks), or were standing but empty. As shown in Table 8, the traditional cisterns worked in 75% of the cases in the study area, which is a better performance record than others have observed in other areas within the Northeast region.[34] Of the *Padre Cicero* cisterns, on the other hand, only 30% worked. Some of the traditional cisterns have functioned since they were built in 1987, while most *Padre Cicero* cisterns lasted 5 years or less. The *Padre Cicero* sponsors expected their cisterns to work for about 20 years. The 5 cisterns constructed in the region, only one was functioning at near-full capacity, and one at 30% capacity. The reasons that explain the different performances are summarized in Table 9.

Table 8
Type of Collective Cisterns and Performance Records
Selected Communities in Mombaça and Quixeramobim, Ceará

	Traditional Cisterns	Padre Cicero Cisterns	Total
Type of System	91% (51)	9% (5)	100% (56)
Systems Working	75% (38)	30% (1.5)*	71% (39.5)*

(*) Community cisterns that were not working at full capacity because of leaks are counted as 0.5
Source: Field Work, Summer 1995.

The World Bank (1976) provides a list of design suggestions to improve the operation and maintenance of rural water supply infrastructure. It is interesting to note

[34] According to Tendler, generally 50% or 60% of this type of water facilities work.

that while the traditional model satisfies all of those requirements, the *Padre Cicero* model fails to meet most of them. Traditional cisterns seem to be well tailored to rural environments where technical know-how, information, and financial resources are severely limited.

Table 9
Design Principles for Proper Operation and Maintenance
of Rural Water Supply Infrastructure.

Design Principles	Traditional Cisterns	Padre Cicero Cisterns
Rugged Equipment for hard use	+	–
Trouble-free Operation	+	+
Maintained by Local Technicians	+	–
Replacement Parts Locally Available	+	–
Economic to Operate and Maintain	+	–

Source: Based on The World Bank (1976).
(+) Good in Most Cases; (-) Bad in Most Cases

The water tanks in traditional cisterns are solid facilities that resist hard use, whereas the tanks in *Padre Cicero* cisterns were made of canvas, a material that rips. Concrete tanks require little maintenance work apart from routine cleaning. Concrete tanks develop slight leaks, but these are not major problems, as long as they are maintained. Minor repairs to concrete work can be done by stone masons, who are usually available locally, or can be found in neighboring villages. Some of the materials required to solve this problem (sand, stone) are also available locally, and cement can be bought in the *sede*, or capital of the municipality. Transporting a few sacks of cement to the village does not represent a problem.

P.Cicero cisterns, on the other hand, presented problems that were more difficult to solve. The friction against the rocks on the ground over which the canvas tank sits, together with the weight of stored water, caused the canvas to tear. Resting to the ground surface, the canvas was easily damaged by sharp stones and plant roots, and repairs were difficult to make. At the beginning beneficiaries covered the holes with rubber. New holes showed up, and old ones got bigger, letting the stored water out. Once the canvas rips off, the fixed concrete slab cannot be removed, so the torn canvas cannot be replaced. Additionally, the canvas used in these cisterns was imported; villagers could not find it in local markets. Beneficiaries in the communities, although they were organized and interested in keeping the cisterns in good shape, could not solve the problems caused by torn canvas.

This fact leads to an important point: that the success of water supply projects in rural areas is not only a matter of proper operation and maintenance, as the literature often emphasizes. The World Bank (1976) claims that "if institutional and financial problems be resolved, technological problems would largely disappear". The example of the *Padre Cicero* cisterns illustrates that a faulty design can jeopardize the good operation of projects, despite the existence of organized and responsible communities. In fact it was in one of the most successful communities, that these cisterns collapsed: Sao Bento, Quixeramobim, a community with an excellent record of project management where these cisterns collapsed. Clearly, the *Padre Cicero* cisterns were poorly tailored to local conditions, and so did not survive. This failure potentially undermines community participation. Those big cisterns sit on land that local people once made available for community purposes. Instead of vegetable gardens, a barn, or something else, those people now have a long useless slab of concrete next to their houses. Can we blame them if they refuse to collaborate and grant more land for collective projects, when they have a constant reminder of the poor use their previous grant had?

5.2. Stumbling at the Same Spot Over and Over

The points raised in this chapter seem to be quite obvious, however, these communities experienced other cases of water supply failures, which repeat the same type of errors as the *P. Cicero* cisterns. A very common system of water supply in these communities is to use dug wells to supply water to community tanks (*chafariz*) by means of windmills. It is true that windmills are low-cost, simple devices; they can take hard use, and are very economical, as opposed to other types of pumps that require diesel fuel or electricity. The problem with windmills is that villagers do not know much about them; neither do the local technicians (agricultural extension agents and private technicians who work in the municipal capitals). Whether contractors are assembling and installing windmills properly is a mystery to the beneficiaries. When windmills stop working neither villagers nor local technicians can determine what exactly is causing the problem and what should be done to get the windmill fixed. Spare parts are also a problem. In some communities (São Bento, Quixeramobim., São Bento, Mombaça), villagers claim that contractors did a poor job of installing windmills. In some cases the windmills were improperly installed on a slope. This caused the water pump to tilt, leading to premature aging and failures of the pump and pipes. In other cases, contractors did not join pipes properly; as a result, the pumped water leaked and did not reach the storage tank. Villagers say they should go to with problems with windmills. In one case, they called the company that installed the windmill and the company sent a technician to look at the problem. The technician charged a fee for his visit, but never came back or sent anyone else to solve the problem.

CHAPTER SIX

CONCLUSIONS

Rural villages of the semi-arid region in Ceará are largely dependent on common property water supply facilities. In some places, these facilities no longer work; in fact, in some cases they never worked at all. However, in other places government-sponsored water supply projects are still "alive" and serve very poor households as well as the better-off families. Before these facilities existed, the rural poor spent several hours every day walking to reservoirs located several kilometers from their homes; they consumed only as much water as they could carry back to their houses. In some communities, government-sponsored water supply facilities (e.g., community cisterns, shallow wells, tube wells, small artificial lakes, etc.) have improved the living conditions of rural families by giving them access to reliable and more conveniently located sources of water.[35]

In each of the communities I found a diversity of water supply projects. Villagers have developed management strategies to take advantage of their local water resources: they use fresh-water sources only for drinking and cooking, and saline-water sources for all other household needs. During the dry season they consume water they stored in collective cisterns during the rainy season, and when they run out of water stored in collective cisterns, they turn to fresh-water reservoirs usually located on the outskirts of their communities. Villagers carry out specific practices to preserve not only the physical facilities, but also the water quality of both cisterns[36] and back-up water sources.[37] In

[35] This obviously has had positive effects on public health. Some authors esteem that water supply projects also have positive effects on village economies. The time and effort that villagers invest in fetching water from distant reservoirs could be invested instead on income-generating activities. I suspect this is true, but I do not have empirical evidence to support this claim.

[36] In some communities, local health agents routinely apply chlorine to water stored in collective cisterns.

[37] For example, fencing fresh-water lakes to keep livestock from contaminating the reservoirs; preventing people from bathing or washing clothes in drinking-water sources by having villagers who live close to the water sources watch after them; organizing groups of volunteers to maintain the surrounding of lakes and access paths by cutting down vegetation that could decompose and lower the water quality.

some communities villagers have even organized mechanisms to convey water from fresh-water lakes to collective cisterns.[38] The diversity of water supplies, the different roles that sources play at the local level, and the local strategies to manage water resources are issues that receive little attention in the PAPP Program literature that I reviewed, and did not emerge in my interviews with public officials in Ceará.

Previous analysts of government-sponsored water supply systems have not differentiated among small-scale rural water supply projects and focused on the performance of tube wells. As a result they have failed to recognize the good performance over time of other water supplies, particularly community cisterns. In most of the villages I visited, community cisterns have functioned since they were first installed several years ago, and deliver potable water at locations that are easy to reach for most families. These findings seem to contradict the over-exploitation and abandonment of common-use facilities that some people in academia and government, particularly at state water departments, predict.

It is indeed true that in some cases beneficiaries do not maintain the water supply projects; however, in the region where I did my research, the opposite was also true. I looked at several successful cases trying to identify factors that explain why villagers take care of common-use facilities in some places but not in others. What I found was that villagers mobilize more around some facilities than others. For several reasons, community cisterns elicit more public participation than dug wells and drilled wells for several reason. First, collective cisterns are sources of drinking water, a very scarce resource in a region where most sources provide water very high in mineral salts. Second, cisterns supply drinking water without imposing long journeys, as fresh-water lakes require. In addition, collective cisterns have technical attributes that elicit public participation, as opposed to other facilities (e.g., tube wells) which seem to hinder the direct intervention of beneficiaries. Collective cisterns can be located in many alternative

[38] In some communities villagers use the community tractor to pull a water wagon.

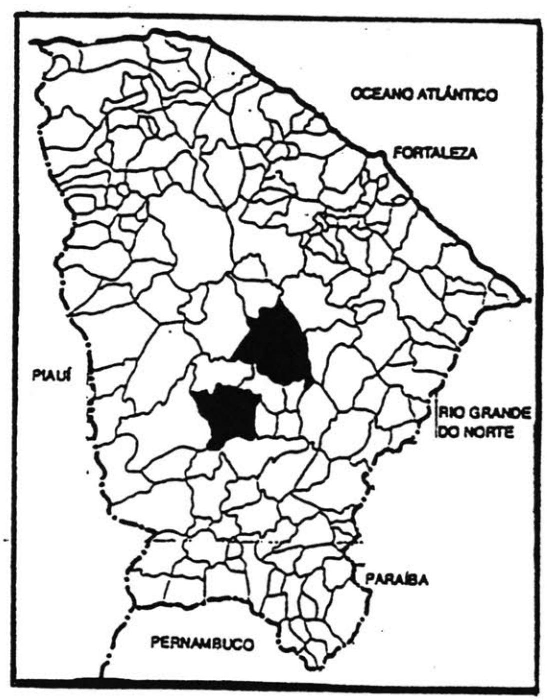
locations, a fact that forces local people to come together and decide. By comparison for other types of water supply projects (tube wells) geological conditions impose the location. Participating in the decision of where to locate a common-use facility is an important step in developing a sense of ownership over the project. When beneficiaries "own" the project, they assume maintenance responsibilities. When they perceive that projects are owned by the government, they expect the government to provide the necessary resources to maintain the facilities. In some of the communities that I visited, villagers reported that they monitored contractors as they build the collective cisterns. This practice has been successful where staff from the Agricultural Extension Agency (EMATERCE) previously explained to villagers what they had to watch for if they wanted to supervise the contractors' work. [39] Also, people refrain from using the cisterns during the rainy season and follow rules, for example, no household can withdraw more than an stipulated amount of water from the collective cisterns (in most cases, 2 containers, each of 20 liters). They also help maintaining collective cisterns, by cleaning and disinfecting the insides of tanks and gutters several times a year; clearing the area surrounding the water source, and contributing money for repairs when the concrete tanks develop leaks and require extra materials. One lesson to be drawn from these observations is that as a development strategy state governments should give credibility to local systems of common-use resource management.

[39] Beneficiaries learned simple things such as the proportion of cement needed in the concrete mix to build the water tanks, and made sure that contractors did not skimp on cement.

APPENDIX ONE

Figure Four
Brazil, the Northeast Region, and the State of Ceará

Figure 5
Municipalities of Mombaça and Quixeramobim



APPENDIX TWO [1]

To calculate the mean travel distance to a lake in Mombaça and Quixeramobim we have proceeded on the following way:

First we have calculated the mean area per lake by dividing the total area of each municipality by the number of lakes [2] that it has:

2,457 km^2 / 262 lakes = 9.38 km^2 / lake in Mombaça
3,579 km^2 / 264 lakes = 13.56 km^2 / lake in Quixeramobim

Then assuming that each lake is located in the center of a square of that area, we have calculated the mean distance that people need to travel to get to the lake. Assuming that the population (No. people / km^2) density is constant, this distance is:

$$\text{Mean Distance} = \frac{1}{a^2} \int_{-a/2}^{a/2} \int_{-a/2}^{a/2} \sqrt{x^2 + y^2}\, dx\, dy$$

(where a is the side of the square, 3.06 km for Mombaça and 3.68 km for Quixeramobim).

This calculation gives a result of 1.2 km for Mombaça and 1.4 km for Quixeramobim.

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[1] Calculations done by José L. Jimenez Palacios, Ph.D. Candidate, Mechanical Engineering, MIT.
[2] As appears in Gov. do Ceará (1994 b).

REFERENCES

Arnold, J.E., Campbell, G. (1986). "Collective Management of Hill Forests in Nepal: The Community Forestry Development Project". In Proceedings of the Conference on Common Property Resource Management 1986, Washington, D.C.: National Academy Press.

Baden, John (1977). "Neospartan Hedonists, Adult Toy Aficionados, and the Rationing of Public Lands". In Hardin and Baden (Eds.) Managing the Commons, San Francisco: W.W. Freeman.

Bardhan, Pranab (1993). "Analytics of the Institutions of Informal Cooperation in Rural Development." *World Development* Vol 21 No 4. Great Britain: Pergamon.

Beckhard, Richard and Reuben T. Harris (1987). Organizational Transitions, Reading, MA: Addison Wesley. Second Edition.

Bird, Richard (1994). "Decentralizing Infrastructure. For Good or for Ill?". Policy Research Working Paper, No. 1258. Washington, D.C.: The World Bank.

Blomquist, William (1992). Dividing the Waters: Governing Groundwater in Southern California, Institute for Contemporary Studies, San Francisco: ICS Press.

Cernea, Michael (1992). "The Building Blocks of Participation: Testing Bottom-Up Planning." World Bank Discussion Papers, 166. Washington, D.C.: The World Bank.

Chauhan, Sumi Krishna (1983). Who Puts the Water in the Taps? Community Participation in Third World Drinking Water, Sanitation and Health. London: International Institute for Environment and Development.

Cunha, D. Judge da (1988). "Survey of Innovative APCR Projects (A Probe in Pernambuco)." November.

Dales, J.H. (1977). "Land, Water and Ownership" in Robert and Nancy Dorfman (Eds.) Economics of the Environment: Selected Readings, New York: W.W.Norton.

Donnelly R. Paula (1984). "Women and Water" . In P.G.Bourne (Ed.,) Water and Sanitation: Economic and Sociologic Perspectives. Orlando: Academic Press.

Dunne, Thomas and Luna B. Leopold (1978). Water in Environmental Planning. New York: W.H. Freeman and Company.

Feachem, Richard (1984). "Infections Related to Water and Excreta: The Health Dimension of the Decade". In P.G.Bourne (Ed.,) Water and Sanitation: Economic and Sociologic Perspectives. Orlando: Academic Press.

Feeny, D., Berkes, McCay and Acheson (1990). "The Tragedy of the Commons: twenty-two Years Later". Human Ecology, Vol. 18. No.1.

Ferguson, Bruce (1992). "Inducing Local Growth. Two Intermediate Sized Cities in the State of Parana, Brazil." Washington D.C.: The Urban Institute.

Fortmann, Louise and Roe, Emery (1986). "Common Property Management of Water in Botswana," in Proceedings of the Conference on Common Property Resource Management. Washington D.C.: National Academy Press.

Glennie, Colin (1983). Village Water Supply in the Decade. Lessons from Field Experience. New York: J.Wiley.

Governo do Estado de Ceará (1984). Programa de Abastecimento D'Agua Simplificado para Pequenas Comunidades No Estado Do Ceará. Secretaria de Planejamento e Coordenação. Mimeo. January.

Governo do Estado do Ceará (1994 a). Uma Estrategia de Desenvolvimento Sustentavel para o Ceará. Projeto ARIDAS. GT II Recursos Hídricos. Secretaria do Planejamento e Coordenação SEPLAN. Fortaleza. December.

Governo do Estado do Ceará (1994 b). Informações Básicas Municipais: Mombaça IPLANCE. Fortaleza.

Governo do Estado do Ceará (1994 c). Informações Básicas Municipais: Quixeramobim IPLANCE. Fortaleza.

Governo do Estado do Ceará (1994 d). Legislação Sobre Sistema Integrado Dos Recursos Hídricos Do Estado Do Ceará. Secretaria dos Recursos Hídricos. Fortaleza.

Governo do Estado do Ceará (1994 e). Apresentação de Projetos para Pequenos Barramentos: Roteiro de Procedimentos. Secretaria dos Recursos Hídricos. Fortaleza.

Governo do Estado do Ceará (1995a). Uma Estrategia de Desenvolvimento Sustentavel para o Ceará. Projeto ARIDAS. GT II Recursos Hídricos. Secretaria do Planejamento e Coordenação SEPLAN. Fortaleza. March.

Governo do Estado do Ceará (1995b). "Aguas de Ceará. Programa de Agua Subterranea e Investigacao do Subsolo de Estado do Ceará PROASIS." Secretaria Dos Recursos Hídricos. Fortaleza.

Hardin, G. (1968). "The Tragedy of the Commons."Science 162: 1243-1248.

Hesse, Fernando (1996). Against All Odds: Successful Cases of Collective Use of Tractors in Rural Ceará, Brazil. Masters Thesis. Cambridge, Mass.: Massachusetts Institute of Technology.

Hirschman, Albert (1967). Development Projects Observed. Washington, DC: The Brooking Institution.

Hofkes, E.H. (Ed.) (1983). Small Community Water Supplies: Technology of Small Water Supply Systems in Developing Countries. Chichester: Wiley.

Lawry, Steven W. (1989). "Tenure Policy Toward Common Property Natural Resources." Madison:University of Wisconsin. July.

McKean, M.A. (1986). "Management of Traditional Common Lands (*Iriaichi*) in Japan." In Proceedings of the Conference on Common Property Resource Management 1986, Washington, D.C.: National Academy Press.

Marc, Alexandre (1993). "Social Funds: Issues and Prospects." Economic Development Institute (EDI) of the World Bank. Regional Seminar on Public Expenditure Management and Social Policy. Cairo.

Messerschmidt, Donald (1986). "People and Resources in Nepal: Customary Resource Management Systems of the Upper Kali Gandaki." In Proceedings of the Conference on Common Property Resource Management 1986, Washington, D.C.: National Academy Press.

Miranda, Ricardo N. (1990). "Avaliação do Projeto Nordeste e Programa de Apoio ao Pequeno Produtor". Mimeo. Fortaleza. March.

Olson, M. (1965). The Logic of Collective Action. Public Goods and the Theory of Groups. Cambridge, Mass.: Harvard University Press.

Ostrom, Elinor (1987). "Institutional Arrangements for Resolving the Commons Dilemma: Some Contending Approaches". In McCay and Acheson (Eds.) The Question of the Commons: The Culture and Ecology of Communal Resources, Tucson: University of Arizona Press.

Ostrom Elinor (1990). Governing the Commons. The Evolution of Institutions for Collective Action. New York: Cambridge University Press.

Ostrom, Elinor, Larry Schroeder and Susan Wynne (1990). Institutional Incentives and Rural Infrastructure Sustainability. Washington, D.C.: U.S. Agency for International Development.

Pontes, Jose (1983). "O Papel de DNOCS no Semi-Arido Nordestino." Ministerio do Interior. Mimeo. Fortaleza. March.

Schubeler, Peter (1991). Community Participation in Infrastructure Provision, Operation and Maintenance. Discussion Paper. UNCHS (Habitat) and Swiss Development Cooperation (SDC). Workshop for Architecture and Planning, Zurich.

Silverman, Andrea (1994). "Review of Experience of Municipal Fund in Northeast Brazil." Washington, D.C.: The World Bank. July.

Steffes, Ann (1996). Rural Water Systems: Conditions for Good Service. Ph.D. Research Proposal. Cambridge,Mass.: Massachusetts Institute of Technology.

Tendler, Judith (1993). New Lessons from Old Projects: The Workings of Rural Development in Northeast Brazil. Report No. 10183 . Washington, D.C.: The World Bank.

Therkildsen, Ole (1991). "The Desirable and the Possible: Participation in a Water Supply Project in the United Republic of Tanzania" in P. Oakley (et.al) Projects with People: The Practice of Participation in Rural Development. Geneva: International Labour Office.

Uphoff, Norman (1985). "People's Participation in Water Management: Gal Oya, Sri Lanka" in Jean-Claude Garcia-Zamor (Ed.) . Public Participation in Development Planning and Management. Colorado: Westview Press.

Veras, Beni (1992). "Uma Proposta de Acao Permanente de Combate as Secas no Nordeste." Congresso Nacional. Brasilia. Comissão de Combate As Secas. Mimeo. July.

Wade, Robert (1986). "The Management of Common Property Resources: Collective Action as an Alternative to Privatization or State Regulation". Agricultural Research Unit Discussion Paper 54. The World Bank. Washington, D.C.

Wade, Robert (1987). "The Management of Common Property Resources: Finding a Cooperative Solution". Washington, D.C.: The World Bank

Wagner, Edmund (1959). Water Supply for Rural Areas and Small Communities. World Health Organization. Monograph Series No.42. Geneva: WHO.

White, Gilbert, David Bradley, and Anne White (1962). Drawers of Water: Domestic Water Use in East Africa. The University of Chicago Press. April.

World Bank (1976). Village Water Supply. Washington, D.C.: World Bank

World Bank (1994). "World Development Report 1994: Infrastructure for Development." Oxford: University Press.

World Bank (1995). Staff Appraisal Report. Northeast Rural Poverty Alleviation Program, Rural Poverty Alleviation Project, Ceará. Washington, D.C.