

THE UNIVERSITY OF HULL

**Water Resources Management in the Eastern Caribbean:**  
A Study of the Two Small Island Developing States, Trinidad and Tobago  
and Barbados

being a Thesis submitted for the Degree of Doctor of Philosophy

in the University of Hull

by

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January, 2003

**CONTAINS**

**PULLOUTS**



## **Abstract**

Water resource management is currently an issue of major significance at a global level both in terms of policy-making and academia. Small island states represent a special group, with Trinidad and Tobago and Barbados, even more particular cases. Development, industrialisation, tourism and resource usage continue to intensify, placing considerable pressures on freshwater supply, demand and quality. This situation is accentuated by the uncertainties surrounding changes in global climatic conditions. Furthermore, water security is not an end in itself, but a means to other ends: health, industrial and agricultural production, for example. These sectors in turn introduce a range of social, economic and environmental issues and problems. This project aims to evaluate the current freshwater management practices in Trinidad and Tobago and Barbados and propose various options for sustainable water resources management which may then improve water security. In Barbados, water resources are limited, as extractions from groundwater aquifers have reached the safe yield points. This is currently placing major constraints on a number of developmental proposals. Although in general, the water reserves in Trinidad and Tobago are abundant in relation to demand, wide regional disparities exist. Shortages are related to this uneven distribution but moreover, because of the inefficient operations of the national water authority. Through the rehabilitation and modernisation of the systems at the water authorities, coupled with the upgrading of the existing water legislation, tariff structure and the regulatory framework, water security in Trinidad and Tobago and Barbados can be greatly improved.

## **Acknowledgements**

This thesis could not have been successfully completed without the assistance of many people. First and foremost, my supervisors, Dr. David Watts, Dr. Phil Bradley and Dr. Ian Drummond to whom I would like to express my gratitude for their enthusiasm, guidance and generous advice. I would also like to extend special thanks to Mr. Philip Jackman for assisting with the organisation and execution of the Barbados fieldwork component. An even greater debt is owed to Mr. Akeel Ahmed and Dr. John Prince for the much-needed moral support and for assisting with all the little but crucial details that are required throughout a project such as this. In both Trinidad and Tobago and Barbados, several representatives at various organisations gave their time freely and contributed significantly to the empirical content of the project. Thanks must also go to the University of Hull for providing some of the financial support and having confidence in my ability to participate in this PhD programme.

# Contents

	Page
<b>Abstract</b>	<b>i</b>
<b>Acknowledgements</b>	<b>ii</b>
<b>Contents</b>	<b>iii</b>
<b>List of figures</b>	<b>vi</b>
<b>Abbreviations and Acronyms</b>	<b>x</b>
<b>Introduction</b>	<b>xii</b>
<b>Chapter 1      Global Freshwater Issues</b>	<b>1</b>
1.1 <i>Introduction</i>	1
1.2 <i>Qualifying the Challenge</i>	1
1.3 <i>The Emerging 'New Agenda'</i>	3
1.4 <i>Completing the 'Old' and starting the 'New'</i>	4
1.5 <i>Categorisation of Water Resource Problem</i>	22
1.6 <i>The Factors contributing to the Water Resource Problem</i>	26
1.7 <i>The Ingredients to developing a Sustainable Water Sector</i>	35
<b>Chapter 2      Global Climate Change</b>	<b>37</b>
2.1 <i>Introduction</i>	37
2.2 <i>The Greenhouse Effect</i>	39
2.3 <i>Climates of the Past</i>	42
2.4 <i>Putting Climate Change on the Agenda</i>	48
2.5 <i>Anthropogenic Interference with Climate Change</i>	57
2.6 <i>Impacts of Climate Change</i>	59
2.7 <i>Climate Variation, Vulnerability &amp; Impact in Eastern Caribbean</i>	66
2.8 <i>Managing under Uncertainty</i>	74
<b>Chapter 3      The Two Dimensions of Freshwater Management</b>	<b>76</b>
3.1 <i>Introduction</i>	76
3.2 <i>Basic Needs or the Supply-driven Approach to Water Management</i>	77
3.3 <i>Four Principal Failures</i>	79
3.4 <i>Demand-driven Approach to Water Management</i>	82
3.5 <i>Efficiency in Water Use</i>	88
3.6 <i>Consumer Demand Theory</i>	92
3.7 <i>Pricing Systems in the Eastern Caribbean</i>	99

		Page
Chapter 3	<b>Continued</b>	
3.8	<i>Willingness to Pay</i>	103
3.9	<i>Valuing Water as a Public Good</i>	106
3.10	<i>Summary</i>	119
Chapter 4	<b>Methodology</b>	<b>121</b>
4.1	<i>Introduction</i>	121
4.2	<i>Case Study Justification</i>	121
4.3	<i>Project Design</i>	124
4.4	<i>Limitations of the Study</i>	137
4.5	<i>Expected Outcomes of the Research</i>	138
Chapter 5	<b>The Freshwater Sector of Trinidad and Tobago</b>	<b>140</b>
5.1	<i>Introduction</i>	140
5.2	<i>Physical Features</i>	141
5.3	<i>Socio-economic Conditions</i>	152
5.4	<i>History of Freshwater Development</i>	158
5.5	<i>The Water and Sewerage Authority</i>	160
5.6	<i>The Water Supply Dimension</i>	170
5.7	<i>The Water Demand Dimension</i>	185
Chapter 6	<b>The Current Scenario in Trinidad and Tobago: Interpretation and Analysis</b>	<b>200</b>
6.1	<i>Introduction</i>	200
6.2	<i>The Danger of the Current Situation</i>	201
6.3	<i>Water Supply System Problems</i>	203
6.4	<i>WASA's Organisational Problems</i>	210
6.5	<i>Options for Reformation</i>	229
6.6	<i>Steps toward Reforming WASA</i>	249
6.7	<i>Sweating out the Dry Season</i>	263
6.8	<i>Green Issues</i>	265
Chapter 7	<b>The Barbados Freshwater Sector</b>	<b>266</b>
7.1	<i>Introduction</i>	266
7.2	<i>Physical Features</i>	266
7.3	<i>Socio-economic Conditions</i>	278
7.4	<i>History of Public Water Supply</i>	284
7.5	<i>Policies and Legislation for Groundwater Management</i>	287

		Page
Chapter 7	<b>Continued</b>	
7.6	<i>The Barbados Water Authority</i>	289
7.7	<i>The Water Supply Dimension</i>	294
7.8	<i>The Water Demand Dimension</i>	312
Chapter 8	<b>The Current Scenario in Barbados: Interpretation and Analysis</b>	<b>325</b>
8.1	<i>Introduction</i>	325
8.2	<i>The Current Threat</i>	325
8.3	<i>Water Supply System Problems</i>	326
8.4	<i>Institutional Problems</i>	328
8.5	<i>Legislative Problems</i>	330
8.6	<i>Water Scarcity – the Primary Problem</i>	334
8.7	<i>Alternatives to Groundwater</i>	339
Chapter 9	<b>Beyond the Status Quo</b>	<b>347</b>
9.1	<i>Introduction</i>	347
9.2	<i>Small Island Developing States</i>	349
9.3	<i>The Issues</i>	352
9.4	<i>Re-thinking the Approach to Water Resource Management</i>	355
9.5	<i>Barbados: A Model for Caribbean SIDS?</i>	356
9.6	<i>Trinidad and Tobago: An Agenda for Change</i>	362
9.7	<i>Managing Water Resources under Uncertain Climate Conditions</i>	376
9.8	<i>The Way Forward: IWRM</i>	378
9.9	<i>Concluding Remarks</i>	379
<b>References</b>		<b>383</b>

## List of Figures

	Page
Figure 1.1	<b>Hydrological Cycle</b> 2
Figure 1.2	<b>Degree of Cost Recovery in Infrastructure Sectors in Developing Countries</b> 18
Figure 1.3	<b>Shifting Paradigms in Water Resource Management</b> 21
Figure 2.1	<b>Variation of Global Surface Temperature from 1860-2000</b> 44
Figure 2.2	<b>The Evolution and Pathway of Climate Change Science And Politics, 1950-2002</b> 49
Figure 2.3	<b>Examples of Impacts resulting from projected changes in extreme climate events</b> 61
Figure 2.4	<b>Summary of Potential Climate Change Effects on Freshwater Resources</b> 66
Figure 2.5	<b>Total Annual Rainfall for 1959-1998 (Trinidad and Tobago)</b> 70
Figure 2.6	<b>Mean Minimum and Maximum Temperatures for 1960-1998 (Trinidad and Tobago)</b> 70
Figure 2.7	<b>Total Annual Rainfall for 1959-1999 (Barbados)</b> 72
Figure 2.8	<b>Average Minimum and Maximum Temperatures for 1960-1999 (Barbados)</b> 72
Figure 3.1	<b>Major Differences between the Two Approaches to Water Management</b> 85
Figure 3.2	<b>Optimal Expenditure on Waste (Leakage) Detection</b> 89
Figure 3.3	<b>Classification of Goods</b> 93
Figure 3.4	<b>Variation of Price/Cost with Quantity Water Used</b> 95
Figure 3.5	<b>Influences on Water Usage according to Whittington et al. Model</b> 98
Figure 3.6	<b>Pricing Policy and Capacity Extension</b> 100
Figure 3.7	<b>Willingness to Pay</b> 104
Figure 3.8	<b>Classes of Behaviour-based Methods for Valuing Public Goods</b> 108
Figure 4.1	<b>Research Approaches in Human Geography</b> 126
Figure 5.1	<b>Trinidad and Tobago – Caribbean Setting</b> 143
Figure 5.2	<b>Trinidad and Tobago – Physiography</b> 144
Figure 5.3	<b>Hydrogeological Areas of Trinidad</b> 149
Figure 5.4	<b>Geology of Tobago</b> 150
Figure 5.5	<b>Average Rainfall Variation across Trinidad and Tobago</b> 151

	Page
Figure 5.6	<b>Main Cities and Towns in Trinidad and Tobago</b> 155
Figure 5.7	<b>Gross Domestic Product (Percentage Sector Contribution)</b> 157
Figure 5.8	<b>Regulatory Structure via RIC</b> 163
Figure 5.9	<b>Structure of WASA's Financial Division</b> 164
Figure 5.10	<b>Structure of WASA's Technical Division</b> 165
Figure 5.11	<b>Historical Trends in World Oil Prices 1973-2001</b> 166
Figure 5.12	<b>GDP of Trinidad and Tobago at Constant 1985 Prices</b> 166
Figure 5.13	<b>Capital Investment in Public Utilities in Trinidad and Tobago for 1982-1992</b> 167
Figure 5.14	<b>Water Rates of WASA</b> 169
Figure 5.15	<b>Trinidad – Watersheds and Hydrometric Areas</b> 171
Figure 5.16	<b>Tobago – Watersheds and Hydrometric Areas</b> 172
Figure 5.17	<b>Trinidad and Tobago – Surface Water Systems</b> 176
Figure 5.18	<b>Trinidad – Waterworks and Intakes</b> 180
Figure 5.19	<b>Tobago – Waterworks and Intakes</b> 181
Figure 5.20	<b>Total Production by WASA from 1996-2000</b> 182
Figure 5.21	<b>Customer Accounts according to WASA's Classification System</b> 186
Figure 5.22	<b>Breakdown of Water Services provided by WASA</b> 187
Figure 5.23	<b>Percentage of Population served by each type of Supply</b> 190
Figure 5.24	<b>Levels of Service received from WASA by population percentage</b> 191
Figure 5.25	<b>Trinidad and Tobago – Surface Water Quality Assessment</b> 194
Figure 5.26	<b>Trinidad and Tobago – Major Water Systems and Potential Pollution Sources</b> 195
Figure 5.27	<b>Trinidad and Tobago – Erosion Status of Watersheds</b> 198
Figure 6.1	<b>Total Public Water Consumption</b> 204
Figure 6.2	<b>Summary of WASA's Revenue and Expenditure in TT\$M for 1988-1993</b> 211
Figure 6.3	<b>Profile of the Domestic Consumer Category based on Annual Taxable Values</b> 213
Figure 6.4	<b>Comparison of Water Rates in US\$/m<sup>3</sup> for 1993</b> 214

	Page	
Figure 6.5	<b>Comparison of Current Water Tariffs for Trinidad and Tobago and Barbados</b>	215
Figure 6.6	<b>Indicators of WASA's Collection Efforts 1988 and 1992</b>	217
Figure 6.7	<b>Operating Deficit of WASA from 1973-1998</b>	220
Figure 6.8	<b>Actors Views regarding Corporatisation</b>	230
Figure 6.9	<b>Summary of Average Existing Prices and the WTP Values for Areas surveyed in Trinidad</b>	238
Figure 6.10	<b>Percentages of Household Income spent on Water Services</b>	238
Figure 7.1	<b>Location of Barbados within the Eastern Caribbean</b>	268
Figure 7.2	<b>Physiography of Barbados</b>	269
Figure 7.3	<b>Coral Rock Regions and the Adjoining Scotland District</b>	273
Figure 7.4	<b>Geological Cross-section across the Island</b>	274
Figure 7.5	<b>Rainfall Variance across the Island</b>	277
Figure 7.6	<b>Parishes and Towns of Barbados</b>	281
Figure 7.7	<b>Organisational Chart of the Barbados Water Authority</b>	291
Figure 7.8	<b>Water Rates</b>	293
Figure 7.9	<b>Percentage of Metered and Non-metered Consumers for 1980-1999</b>	294
Figure 7.10	<b>Breakdown of Available Water Resources</b>	296
Figure 7.11	<b>Locations of Public Wells on the Island</b>	297
Figure 7.12	<b>Private Well Locations on the Island</b>	298
Figure 7.13	<b>Evaluation of Output from Public Water Wells</b>	300
Figure 7.14	<b>Locations of the Six Service Zones</b>	307
Figure 7.15	<b>Locations of the 19 Groundwater Distribution Sub-Systems</b>	308
Figure 7.16	<b>Water Balance for the Sub-systems within the Distribution Network</b>	311
Figure 7.17	<b>Water Usage in 1999</b>	313
Figure 7.18	<b>Population Distribution into Water Pressure Zones</b>	315
Figure 7.19	<b>Number of Metered and Non-metered Customers for 1980-1999</b>	316
Figure 7.20	<b>Trends in Water Production and Consumption for 1980-1999</b>	316
Figure 7.21	<b>Domestic Water Consumption by Income Level</b>	317



	Page
Figure 7.22 <b>Occupied Dwelling Units by Parish and Type of Water Supply Received</b>	318
Figure 7.23 <b>Principal Features of Development Control Zones</b>	322
Figure 7.24 <b>Location of Groundwater Protection Control Zones</b>	323
Figure 8.1 <b>Supply Breakdown by Source Percentages</b>	335
Figure 8.2 <b>Average Minimum and Maximum Temperatures for 1980-1999</b>	336
Figure 8.3 <b>Annual Seasonal Rainfall for 1980-1999</b>	337
Figure 8.4 <b>Unit Production Costs for Supply Augmentation Schemes</b>	340
Figure 8.5 <b>Applications for Wastewater Reuse and corresponding CEHI Treatment Requirements</b>	346
Figure 9.1 <b>Outline of Proposed Barbados Groundwater Protection Policy</b>	362
Figure 9.2 <b>Water Saving Devices vs. Conventional Devices</b>	366
Figure 9.3 <b>Summary of Recommendations for WASA</b>	375

## Abbreviations and Acronyms

millimetre	mm
centimetre	cm
metre	m
kilometre	km
square kilometre	km <sup>2</sup>
cubic metre	m <sup>3</sup>
cubic metres per day	m <sup>3</sup> /day
litres per capita per day	lpcd
gallon per minute	gpm
million gallons per day	mgd
parts per million	ppm
pounds per square inch	psi
hectare	h
degree (Centigrade)	°C

annual taxable value	ATV
biochemical oxygen demand	BOD
build, own, operate & transfer	BOOT
chlorofluorocarbons	CFCs
contingent ranking	CR
contingent valuation	CV
contingent valuation method	CVM
general circulation models	GCMs
gross domestic product	GDP
interim operating agreement	IOA
long-term agreement	LTA
million cubic metres	MCM
polyvinylchloride	PVC
rate of return	ROR
small island developing states	SIDS
sea level rise	SLR
total suspended solids	TSS
Trinidad and Tobago	TT
Barbados	BDS
unaccounted for water	UFW
willingness to pay	WTP

BLP	Barbados Labour Party
BPOA	Barbados Programme of Action
BWA	Barbados Water Authority
CARIRI	Caribbean Industrial Research Institute
CEHI	Caribbean Environment Health Institute
CIDA	Canadian International Development Agency
CPACC	Caribbean Planning for Adaptation to Global Climate Change
CSO	Central Statistical Office
COP	Conference of Parties
CWDA	Central Water Distribution Agency

DLP	Democratic Labour Party
DOE	Department of Environment
EED	Environmental Engineering Division
EMA	Environmental Management Authority
FAO	Food and Agriculture Organisation of the United Nations
GEF	Global Environment Facility
IADB	Inter-American Development Bank
IMA	Institute of Marine Affairs
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climatic Changes
ITCZ	Inter-Tropical Convergence Zone
IWRM	Integrated Water Resource Management
JICA	Japan International Co-operation Agency
MMC	Monopolies and Mergers Commission
MPTC	Ministry of Power, Transportation, Communication and Works
NAR	National Alliance for Reconstruction
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
PAHO	Pan American Health Organisation
PFC	Private Firms Commission
PLIPDECO	Point Lisas Port Development Company
PNM	Peoples' National Movement
PSA	Public Services Association
PUC	Public Utilities Commission
RIC	Regulatory Industries Commission
SEDU	Sustainable Economic Development Unit
TIDCO	Tourism and Industrial Development Company
UFW	Unaccounted-for-Water
UNC	United National Congress
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNFCCC	UN Framework Convention on Climate Change
USEPA	United States Environment Protection Agency
UWI	University of the West Indies
WASA	Water and Sewerage Authority
WHO	World Health Organisation
WMO	World Meteorological Organisation
WRA	Water Resources Agency

#### Currency Equivalents as January 10, 2003

US\$ 1 = TT\$ 6.015, UK £1 = TT\$ 9.3329

US\$ 1 = BD\$ 2.00, UK £1 = BD\$ 3.1008

## **Introduction**

Many small island states presently have development trajectories which have brought about the need for informed and effective water resource management strategies. Rapid and large-scale industrial development, transformation of traditional agricultural systems and tourism development have placed considerable pressures on the water resource base. This problem is accentuated by the uncertainties surrounding global climate change. Moreover, problems with water resource management are themselves linked to a range of other economic, social and environmental issues and problems.

This project is concerned with evaluating the current water supply arrangements in terms of the theoretical alternatives by relating these approaches to the conditions pertaining to Trinidad & Tobago and Barbados respectively, and then proposing options for greater water security. In order to address the primary research question, the study involves:

- documenting the current water supply and regulatory arrangements in Trinidad & Tobago and Barbados,
- identifying the impacts of the various socio-economic development trajectories in Trinidad & Tobago and Barbados and their effects on the water resource base,
- identifying a) the social, economic and environmental impacts of the supply arrangements as well as b) the developmental implications of these arrangements, and
- evaluating the current and future provision of water a) technically and b) in terms of the social and political context to form options for policy and development.

The issue of water security is one of major significance at a global level both in terms of policy-making and academia. Small island states represent an even more particular case, involving both general and specific policy and management issues. The project will present a clear picture of the current water supply scenario in Trinidad and Tobago and Barbados. It aims to contextualise water resource management in light of the various developmental pressures, the natural environment, the social and political circumstances of the islands, the increasing globalisation of economies as well the further uncertainty which global climate change introduces.

In theory (see for example, Rees, 1990), there are a range of approaches which might be used to promote more sustainable patterns of water use. These include both supply-side and demand-side measures. Both sides will be investigated and analysed since methods to rationalise water usage would not only have direct economic benefit for the demand sector, but for the supplier as well. Environmental benefits include the conservation of limited water reserves and perhaps some aquatic life. Other benefits to be derived from more effective water resource management in Trinidad and Tobago and Barbados include a higher level of customer service, less water shortages and consequently better living conditions including health aspects.

Any government's ability to develop effective resource management policies is constrained by the need to balance several, possibly incompatible goals at the same time. Until recently, water resource managers in many small island states were concerned primarily with economic and political objectives, such as maintaining or rewarding the party in power, curbing inflation, providing employment or avoiding deficits. Now, with increased emphasis being placed on sustainability issues, it is by no means unusual for governments simultaneously to want companies to operate in a manner consistent with the above objectives whilst introducing a whole host of new factors such as efficiency, security, equity, growth and environmental quality, irrespective of the tensions which exist between these objectives. According to Rees (1990), in these circumstances, public policy is frequently reduced to a series of ad hoc measures taken against a shifting

background of social attitudes, political pressures, economic realities and the distribution of effective power within society. This project aims to provide a fuller understanding of how more integrative resource management policies can be developed and implemented.

The report begins by identifying the global issues surrounding freshwater, including changes in water management philosophy and practices in Chapter 1. A discussion of global climate change and its effects is presented in Chapter 2. Chapter 3 gives an evaluation of the two dimensions of water resource management, namely the supply and demand measures. Chapter 4 explains the methodology undertaken for this study. A review of the water sector in Trinidad and Tobago is presented in Chapter 5 followed by an analysis of the current problems in Chapter 6. Similarly, Chapter 7 describes the freshwater picture in Barbados and the analysis of this case study is carried out in Chapter 8. Brief historical accounts of the development of the water management systems, current supply capacities and demand projections are given in chapters 5 and 7. On the supply side, the sources of supply and regulatory systems in place to collect and distribute freshwater are noted. On the demand side, data pertaining to population growth and service, other water service sectors (industrial, agricultural) and the effects of usage on the environment are described. The problems associated with both sides are also discussed. The major conclusions of the study are then brought together in Chapter 9 and recommendations for improving water security in Trinidad and Tobago and Barbados are presented before closing with some final remarks.

## **1.0 Global Freshwater Issues**

### **1.1 Introduction**

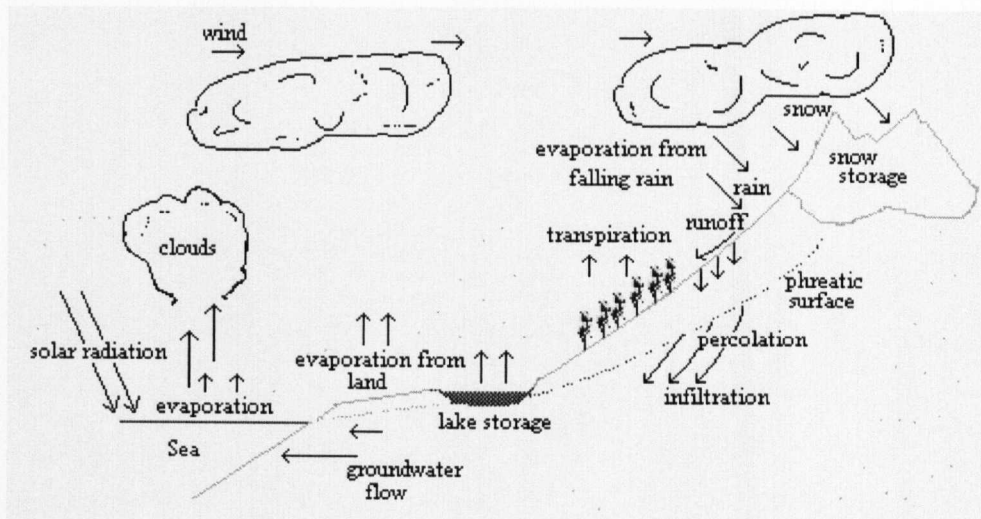
Freshwater is a fundamental resource, integral to all natural and societal processes and as we enter the 21st century, we must now acknowledge that water security is a critical issue and that many of our efforts to manage the earth's water resources have been inadequate or misdirected.

Several challenges in water resources management are now coming to the fore. Foremost among them is how to satisfy the food, drinking water, sanitation and health needs of future generations when current management practices are failing to do so at present. Water will also be required for economic development – new industrial and tourism development, new energy projects, expanded agricultural efforts, including irrigation and the like. Adding to this difficulty however is a problem of uncertain but potentially enormous magnitude: the alteration of the earth's atmosphere, especially global climate change.

### **1.2 Qualifying the Challenge**

Every day, over 1,000 cubic kilometres of water evaporates from the land and sea. The water vapour condenses into tiny droplets of liquid that make up clouds, and eventually it falls back to the earth as rain, hail or snow. Every year, the turnover of water on Earth involves approximately 577,000 cubic kilometres of water. It is called the hydrological cycle (see figure 1.1) and all life on the planet depends on its proper management.

**Figure 1.1: Hydrological Cycle**



Source: EMA (1998)

Water resources management involves the interplay of: a) water quantity and quality demanded, b) water quantity and quality supplied, c) water pollution and d) water recycling and reuse; as well as the impact of public policy measures on all these interacting components (Spulber and Sabbaghi, 1994, pp. 3-4).

Financing such management in a responsible and sustainable way is a challenge that must be met successfully. The challenge is however two-fold. First, there is the 'old agenda' of providing all the people of the world with an adequate water supply. Second, there is the challenge of the 'new agenda', which requires that much greater attention be paid to ensuring that our use of water resources is sustainable, in terms of both quantity and quality.

Evaluating the current situation as a half-filled glass of water, two perspectives can be seen. Considering the glass as half-full, much progress has already been made. Worldwide, over the last twenty-five years, an additional 1.6 billion people were provided access to water of reasonable quality and the number of urban people with access to an adequate supply of water increased by about 80 per cent. Now, viewing the glass as half-



empty demonstrates the enormous challenge that remains: over 1 billion people still lack access to an adequate water supply. (World Bank, 2002)

### **1.3 The Emerging 'New Agenda'**

While the old agenda with its focus on household services still poses large financial, technical and institutional challenges, a new agenda that emphasises environmentally sustainable development has emerged forcefully – and appropriately – in recent years. This concern extends to both the quantity and quality of surface water and groundwater.

The quality of the aquatic environment is a global concern, but the situation in developing countries is especially acute. Even in most of the middle-income countries, sewerage is rarely treated. Buenos Aires, for instance, treats only 2 per cent of its sewerage – a figure typical for middle-income countries of Latin America. Furthermore, while environmental quality in industrial countries improved over the 1980s, it did not improve in middle-income countries, and declined sharply in low-income countries, (Lee, 1991).

Considering services and environmental issues together, it is instructive to note the sequence in which people demand water supply and sanitation services. Consider for instance, a family that migrates to a shanty-town. Usually, their first 'environmental' priority is to secure an adequate water supply at reasonable cost. This is normally followed by the need to secure a private, convenient and sanitary place for defecation. Families show a high willingness to pay for these household or private services, in part because of the health implications and also because the alternatives are so unsatisfactory or so costly. Generally, they put substantial pressure on local and national governments to provide such services and it is therefore only natural, that the bulk of external assistance to developing countries in

the early stages of development goes to meeting this strong demand. However, satisfaction of these primary demands induces secondary demands, in particular, removal of wastewater from the household and then from the neighbourhood. The multiplier effect continues, as meeting the secondary demands usually gives rise to problems of protecting the environment from the degrading effects of large amounts of water-borne waste.

A number of implications emanate from this situation. The historical experience of industrial countries and the contemporary experience of developing countries demonstrate clearly that only when the first challenge – the provision of services – has been substantially met, do households and the wider society pay attention to the ‘higher order’ challenges of environmental protection. Thus, it is not surprising, and probably not inappropriate, that the portfolios of external assistance agencies have to date concentrated on the provision of adequate water supplies. For example, of World Bank lending for water and sanitation for the period 1962-1992, only about 15 per cent have been for sanitation and sewerage. (See World Bank 1993b, pp. 95 ff.).

#### **1.4 Completing the ‘Old’ and starting the ‘New’**

In most developing countries, planning and service development was initially concerned with economic growth. Concomitant attention was not given to physical and social infrastructure development that was necessary to propel and sustain growth. Consequently, development in post-colonial countries was constrained by this as well as low rates of economic growth thus deepening the problem of poverty. However, reform in planning philosophy, supported by policies of international agencies and local factors have resulted in significant shifts in the approach and scope of development.

Indications are that trends in water provision commencing from the mid-nineteenth century have been influenced by five periods of paradigm shifts in public policy and development. Predicated on the ideology of water as a public good, public policy has evolved by moving through: economic growth, modernisation and state capitalism in the 1950s to 1960s; redistribution with growth till the mid 1970s; the basic needs approach in the late 1970s; the free market approach in the 1980s; and privatisation in the 1990s. Although these five periods identify the point at which ‘new’ concepts surfaced, there has been significant carry-over from one era to the next, as developing countries struggled with the changes. As such, developing countries face the formidable double-barrelled challenge of completing the old agenda and making progress on the new agenda.

#### 1.4.1 Economic Growth, Modernisation and State Capitalism

In the 1950s and 1960s, economists tended to dominate the development debates and essentially determined their scope. The concern with economic objectives was manifested in a preoccupation with increasing the rate of growth or production capacity. Urban-based industrialisation and the modernisation of infrastructure were equated with economic growth (Moser, 1993). These trends were also reflected in Trinidad and Tobago as can be observed by the Budget Speech of the 1961, which read:

*“There may, conceivably in the future, be found another road to continuous growth and higher living standards. In the present state of human knowledge, however, there is no alternative to industrialisation” (Budget Speech, 1961:255).*

The view of the ‘big push’ by the state was embraced by the governments of Trinidad and Tobago and Barbados. In fact soon after independence from Britain in 1962, Dr. Eric Williams, the Prime Minister of Trinidad and Tobago, adopted the West Indian development model advanced by W. A.

Lewis (also a West Indian) which promoted “industrialisation by invitation” (Lewis, 1959). The governments noted that social overhead investment was essential to address the inadequate physical and social infrastructure set up during colonisation as well as increase the rate of economic growth. In their opinion, the stock of infrastructure – electricity, transportation, health, water and other services – was seriously lacking and so a policy of heavy initial public sector investment was warranted.

In the first development plans after gaining independence from Britain, the role of the state was enunciated as simply to provide basic subsidised infrastructure such as water, roads, and electricity and the fiscal arrangements within which context, the private sector (foreign and domestic) would create economic growth.

Growing concern among international agencies regarding the scale of urban water supply problems was another feature of the 1950s and 1960s (Lee, 1969). The root of this concern was the serious health hazards attributable to deficiencies in urban water supply. Hence in 1959, a special programme was established by the World Health Organisation (WHO) to improve the provision of piped water supplies at the community level in urban areas. The distinction was made between urban and rural on the basis that the provision of water in urban areas was more relevant to economic development and improvements in public health. The goals and standards of the programme were based on the findings of a survey of existing conditions in seventy-five developing countries. The ultimate goals of the programme were as follows:

1. Piped water supply should be provided to all premises;
2. Adequate service should be maintained at all times;
3. Water for drinking, household and other purposes should be provided in adequate volume;
4. Standards for drinking water quality should be adopted and enforced that would be no less rigid than those set by the WHO;

5. Water sources should be protected against pollution;
6. Water schemes should be administered independently from Central Governments and according to sound management practices and;
7. Regular revenues should be established to cover operation, maintenance, capital charges and depreciation.

Another major agency disturbed by the growing water supply problems was the United States Agency for International Development (USAID). The major points of the USAID programme were (Lee, 1969):

1. Water supply systems should be considered as a public utility in the same way as electricity, gas or telephone systems, and users or beneficiaries should pay the full cost of supplying water;
2. Community water supply development and management should be the responsibility of a single agency, preferably at the municipal or metropolitan level. In less developed countries, it argued this was not always feasible and the responsibility for water supply should lie in the hands of an autonomous national or regional agency and;
3. The national or state public health agency should be the primary agent of government for the promotion of community water supplies since the lack of water in most under-developed countries constituted a major health hazard. The control of public water supplies should not lie with the water resource agencies.

Strong arguments for government direction and centralised planning were made by decision-makers because the market price system was unable to give proper 'signals' to the private sector in developing countries. Accordingly, the failure of the market meant Government would have to produce goods such as water that were warranted and in the 'public interest' (World Bank, 1988).

But, by the end of the 1960s, the euphoria about economic growth had died. None of the assumptions underlying the justifications for rapid economic

growth turned out to be universally true. Except for a few countries, there was no automatic tendency for income to be widely spread, nor did governments take radical corrective action to reduce poverty. The gap between the few rich and the many poor widened and the 'trickle down' effect did not materialise as new opportunities went to those who were better qualified (Nagamine, 1981). And, still less than half of the population of many countries of the 'South' (including Africa, South America, Latin America and the Caribbean) had access to adequate basic services such as potable water.

#### 1.4.2 Redistribution with Growth

*"Our policy has always been to pursue economic development within the framework of social justice. Economic development without social justice would be meaningless in any country, even more so in our country, with its peculiar history of colonialism, slavery, indentureship and exploitation" (Trinidad and Tobago Budget Speech, 1969: 459).*

The new emphasis in the 1970s shifted to redistribution with growth, (Higgins, 1981). The objective was to achieve a greater distribution of wealth, as this was seen as a pre-requisite to generate mass markets which could then exploit economies of scale. In addition, unemployment and under-employment were seen to be the cause of inequality. Hence, redistribution of productive assets was considered as a path to reduce inequality.

The poor income distribution in Trinidad and Tobago led to deep social and ethnic cleavages which were precipitated by the Black Power Riots in 1970. Unemployment which had increased in absolute terms after independence, was most severe among the lower income groups and especially among the urban black. This sub-group developed an acute sense of being denied the benefits of economic growth. On the other hand,

the traditional local elite or 'gatekeepers' (strategically placed individuals, groups and institutions with the ability to control access to society's rewards and resources) - who were invariably of white or French Creole ancestry - were able to take advantage of the fiscal incentives for industry, along with the foreign private sector. Carrington (1971) has shown the employment generated by the new enterprises started by the local elite did not justify the incentives provided by Government for that purpose. The Black Power riots of 1970 were therefore in some ways, the tangible reaction to a perceived failure of equal income distribution and increased inequality.

The 1970 riots surely unnerved the Government of the day which had derived most of its political support from the predominantly black urban population and forced the Government into a redistributive stance. This was made possible by the global oil boom (Yelvington, 1993). From 1970 – 1973, the government expanded social services, including public health and education and provided heavily subsidised low-cost housing, water supplies, electricity and public transport facilities. With regard to water improvements, the government applied to the Inter-American Development Bank to fund the building of the country's largest dam. It also undertook several water supply expansion projects, provided large subsidies to the water authority and did not adjust water tariffs in keeping with increasing inflation rates.

Ironically the low tariffs enjoyed by many households only had a limited redistributive effect spatially, since there was no water transmission to some parts of the country or an unreliable service in other areas.

World-wide, the golden age of growth with greater equality ushered in after a period of growing inequality began to move into a distant future, no sooner had it arrived as it was discovered that reductions in inequality did not reduce poverty (Higgins, 1981).

### 1.4.3 Basic Needs Approach

In the late 1970s, the development objective was narrowed down to meeting basic human needs (Higgins, 1981). A number of studies in the early 1970s had illustrated the continuing deplorable living conditions of the urban poor and although income redistribution was attempted, taxation favoured privileged groups such that income redistribution was not apparent.

As a consequence of the growing problems of mass poverty, despite substantial economic growth, the United Nations announced the failure of growth-oriented development planning and placed prime consideration on the fulfilment of basic human needs. This strategy shifted thinking from the highly aggregated magnitudes like 'national income' and 'growth rates' to increasingly disaggregated objectives such as safe water, adequate shelter, cheap transport and preventive medical services. Thus the late 1970s witnessed the dethronement of GNP and heralded the concept of primary needs to the centre stage, marking the beginning of a new act in the continuing drama of world development (Higgins, 1981).

The experiences of Trinidad and Tobago and Barbados in the context of basic needs were notably different from that of other developing countries in Latin America, Asia, Africa and the Middle East. One dynamic socio-economic force in their history that helped shape strategies for the fulfilment of primary needs was the experience of slavery (and indentureship in T&T) and the peculiar nature of the colonial plantation economy. The resulting concomitant disparate ethnic and economic groups in society required a development strategy at the earliest stage of nationhood which addressed their fundamental needs. Prior to independence and in the immediate post-independence era, these groups did not have equal access to shelter, education, jobs and other services. Further, in the special case of Trinidad and Tobago, while the importance of meeting basic needs largely remained development rhetoric in some



countries, the global oil crisis in 1973 led to boom times and provided the Government with the actual financial means to embark on major social development projects. The socio-economic indicators for the period 1970 to 1990 indeed showed that household access to piped water in dwelling units improved from 36 per cent to 55 per cent (CSO, 1990). The Government of Trinidad and Tobago defended its subventions on the grounds that such benevolent interventions addressed the equity issue. Similarly in Barbados, the Waterworks Department and the Barbados Water Authority were heavily subsidised and controlled by the Government up to the mid-1980s.

In hindsight, according to Todaro (1985) and other academics, the 1970s were marked by excessive government intervention. Their suggestion is that limited finances and skilled manpower meant that government intervention was necessary to modify resource constraints, by choosing and co-ordinating investment projects which channelled scarce resources into meeting basic needs (Todaro, 1985). For Trinidad and Tobago, although the mid to late 1970s was marked by tremendous oil revenue, the limited indigenous entrepreneurship and an embryonic private sector still required significant government involvement (Rampersad, 1988).

#### 1.4.4 Free Market Economics

The global recession of the 1980s and general disenchantment with central planning influenced a number of Western economists, as well as the heads of major international development organisations and even some finance ministers in developing countries into advocating increased usage of market mechanisms as key instruments for promoting greater efficiency and more rapid growth (Todaro, 1985). The decade of the 1980s came to be known as the era of Reaganomics and Thatcherism which emphasised “rolling back the frontiers of the state”. While the 1970s may be described as a period of increased public sector activity in pursuit of more equitable

development, the early eighties witnessed a re-emergence of free market economics, as efficiency became the new 'buzz' word.

Among the international agencies preaching the virtues of the free market were the International Monetary Fund and the World Bank. The World Bank began scrutinising its state-lending policies to ensure that proposed projects could not otherwise be undertaken by the private sector. Much of the new emphasis was due to the rising burden of public spending. Further, given the poor maintenance of public projects, many of the 'free marketers' argued that with private enterprise playing a greater role in undertaking projects, this could lead to more efficient utilisation of resources.

The intensification of the problems of growing population and worsening water quality in the late 1970s led the United Nations to declare the 1981-1990 period 'The International Drinking Water Supply and Sanitation Decade'. As Brookshire and Whittington (1993) observed, both governments and opposition parties responded to grassroots demand for improved water services by re-asserting that access to water was a basic human right. Further, it was the government's responsibility to ensure that systems (public or private) were in place so that all citizens were supplied with clean, adequate water.

By the early 1980s, Trinidad and Tobago – after being spoilt by oil money like Venezuela, Mexico and Nigeria – entered into a debt crisis as oil prices tumbled from US \$45 in 1973 to US \$15 per barrel in 1981. Even after the 'boom-bust', Government continued to maintain all its welfare programmes and high levels of public sector subvention and employment in agencies such as the Water and Sewerage Authority (Barsotti, 1988).

The Governments of Trinidad and Tobago and Barbados maintained the philosophy of the 1950s and 1960s that water was a public good and state intervention could not be reduced to allow free market forces to operate.

While cautioning that it was necessary to cease the almost total reliance of the public utilities on the Exchequer, these small-island states contended that state involvement in the provision of essential services such as water was important to cushion the effects of economic adjustment on the populace, particularly the more disadvantaged members of society. The Finance Minister of Trinidad and Tobago in 1984 stated that:

*“The Government, as prime mover in the economy, unhesitantly accepts the responsibility for giving the lead in the process of adjustment. In the face of less buoyant revenues, public expenditure must be contained. However, the imperative of providing public goods and satisfying legitimate aspirations for basic amenities must continue.” (Budget Speech, 1984: 20)*

So, largely it was ‘business as usual’.

A World Bank mission to Trinidad and Tobago in 1987 reported however that many of the subsidy programmes were badly structured and administered, in that the intended beneficiaries received little benefit, while others who did not need assistance got it. It was also noted that public utilities and state enterprises received subventions as a matter of course, without serious insistence on their adopting policies to improve efficiency and reduce costs. The World Bank concluded: “however desirable it might be from a social point of view, the government cannot afford to provide the present level of welfare and heavily state-subsidised services without adopting tax measures that could affect the recovery of the economy...” (World Bank, 1988: 11)

In 1987, with a change in government, the philosophy embraced by the newly elected party, the National Alliance for Reconstruction (NAR) was one of making the utilities less dependent on the Treasury. In adopting the World Bank’s recommendations for a programme of policy reform and renewed growth, measures of fiscal discipline were introduced to ensure

that the adjustment plans were consistent with new objectives of economic restructuring. The government argued that:

*“Trinidad and Tobago has come to the end of one era, and stands at the threshold of another. For a long time certain unhealthy and dangerous notions have been propagated in our society. They included the notion that the State should somehow be a tireless mother, forever providing, a guarantor of welfare, and a haven of security, while making no demands for effort and energy on our part. There was also the propaganda that hard work bore no necessary relation to our survival and success, and that providing quality service to our customers and clients was either an unreasonable expectation on their part or, at best a favour to be occasionally dispensed. Now all of this must change. To escape from this crisis and to transform this society once and for all, requires a veritable revolution in how we as a people think and perceive...” (Budget Speech, 1989: 39)*

#### 1.4.5 Privatisation

Although development policy since the mid-1980s consisted largely of macro-economic reform for structural adjustment designed to assist bankrupted economies on the road to recovery, one of the most visible manifestations of the global crisis was the continued poor delivery and maintenance of essential services such as water provision.

In the wake of this growing infrastructure crisis and a repeated appeal for less central planning, the 1990s saw the concepts of 1) water as an economic resource; 2) cost recovery; 3) self-financing and autonomous institutions; 4) deregulation and 5) privatisation gaining currency among policy-makers and practitioners.

Relating to the water sector, a global consultation began in 1990 in New Delhi to examine the achievements of the International Drinking Water Supply and Sanitation Decade (1981-1990). The main statement issued was that there should be “some (water) for all rather than more for some,” (UNDP, 1990: 8). This meeting was followed by the Earth Summit in 1992 in Rio de Janeiro along with other international consultations in Dublin and Brussels. From these sessions, the principles for a comprehensive framework emerged such that:

- *water must be managed as an economic good which would lead to proper pricing for water services and greater efficiency, as well as generate funds to extend services to the poor;*
- *sector institutions must be more responsive to consumer demand;*
- *participation gives people the opportunity to make choices and contributions to their ownership of new facilities and;*
- *government should be a promoter rather than a provider of services (UNDP and World Bank, 1994).*

Another main statement which emanated from the International Conference on Water and the Environment held in Dublin in 1992 and endorsed by international agencies such as the World Bank and the United Nations was that water has an economic value in all its competing uses and should be recognised as an economic good, so much so that past failure to recognise this has led to wasteful and environmentally damaging use of the resource (World Bank, 1993:24).

After three and a half decades (1950s to mid-1980s) of high levels of public sector spending on water infrastructure, low water tariffs and subsidies to the water utility, coupled with reduced oil revenues and debt crisis, the governments of Trinidad and Tobago and Barbados began to investigate ways of liberating aspects of the public utilities so as to improve efficiency and access new technology.

The wave of privatisation that swept across many countries in the 1990s has reached the shores of these small-island states and the respective governments are currently debating its pros and cons.

#### 1.4.6 What do services cost, and how are the costs changing?

The real costs of water supply and sanitation services are increasing for several reasons. First, there are demographic and economic factors. As the population becomes more urbanised, per capita costs rise. In 2000, twenty-two countries had renewable water resources of less than 1,000 m<sup>3</sup> per capita (including Barbados) – a level commonly taken to indicate water scarcity – and an additional eighteen countries had less than 2,000 m<sup>3</sup> per capita (WHO, 2000). Elsewhere, as in Trinidad and Tobago for example, water scarcity is less of a problem at the national level, but is nevertheless severe in certain regions, at certain times of the year and during periods of drought. The effects of these ‘natural’ factors are further exacerbated by the widespread mismanagement of water resources, especially where there is provision of large quantities of water at minimal or no cost for low-value agricultural and commercial use.

Another influencing factor on costs is that cities normally first seek water where it is easiest and cheapest to obtain, and as they grow, the ‘population shadows’ around them often badly foul existing water intakes, necessitating expensive relocation of source-points.

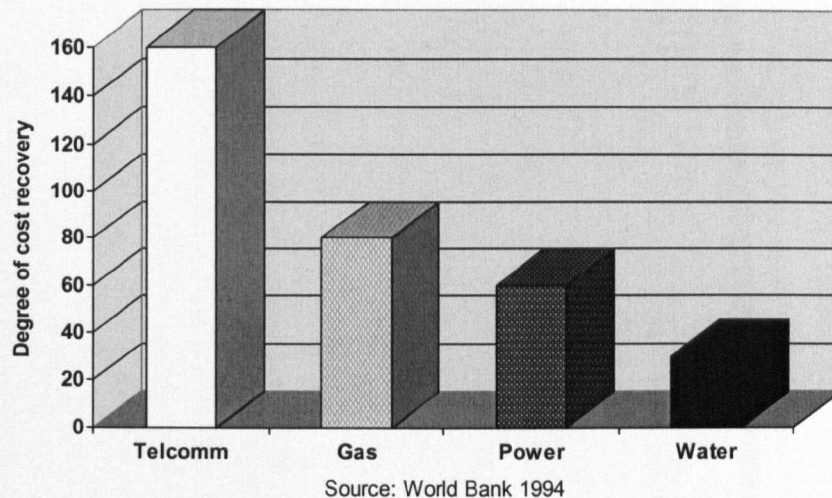
Widespread inefficiency in supplying water and sanitation is also a major factor in the high cost of water sector services, as is documented in a recent World Bank study (World Bank, 1994). Two examples illustrate how serious the situation still is:

- *In Trinidad and Tobago, an estimated 4 per cent of connections are not registered, while in Caracas and Mexico City, this figure is closer to 30 per cent.*

- *Unaccounted for water is 8 per cent of total water supply in Singapore, but 58 per cent in Manila, 60 per cent in Barbados, between 45-50 per cent in Trinidad and Tobago and about 40 per cent in most Latin American cities.*

The financial performance of water and sewerage agencies is often very poor and, as shown in figure 1.2, much worse than for other infrastructure sectors. A World Bank review (World Bank, 1994) showed that public utilities in developing countries seldom recovered all of their costs from users. The shortfalls have to be met by large injections of public money. In Brazil, between the mid-1970s and the mid-1980s, about \$1 billion US dollars of public cash was invested in the water sector annually. The federal subsidy for water and sewerage services to Mexico City amounts to more than \$1 billion US dollars a year, 0.6 per cent of gross domestic product (GDP). Similarly in Trinidad and Tobago, government subsidies to this utility were as high as \$90 million US dollars in 1985. This figure steadily decreased over the subsequent decade as the country faced a period of recession. Prior to 1985, the Barbados water utility was also heavily subsidised. The average annual government subvention over the period 1958 to 1979 was approximately BD \$0.5 million (US \$0.25 million). By agreement with the Inter-American Development Bank from which the Barbados Government was procuring a loan to improve water services, from 1980 onwards, water rates were gradually increased in an attempt to achieve viability by 1985. Clear indications are that most public utilities in developing countries are high cost, low efficiency producers of services, especially the water and sewerage utilities.

**Figure 1.2: Degree of Cost Recovery in Infrastructure Sectors in Developing Countries**



The performance of most rural water supply systems has also been generally poor. A common approach has been for governments to limit services in these areas by restricting the level of supply and by supporting only low-cost technologies (such as improved pit latrines and hand pumps). While the development of low-cost, robust technologies of this sort are vital, some World Bank experts argue that a key mistake made in many such programmes has been to restrict the choices available to people. This approach adopted by governments has proved highly counter-productive. From an economist's perspective, the fundamental reason is that the services offered have not corresponded to those which people, including the poor, want and are 'willing to pay for'. In many instances, this has led to a 'low-level equilibrium trap' in which people become unwilling to pay for what they see as unsatisfactory service. The result is that resources for the operation and maintenance of the service are not generated, and the quality of the service then declines further (Serageldin, 1994).

The lessons to be learnt here are evident. From a demand perspective, people must be trusted to choose from a menu of service levels: those services they want and are willing to pay for. From the supply-side, the



message is that rigorous attention must be paid to providing households with the level of service required at the lowest possible cost.

#### 1.4.7 More public funds for the Water Sector or not?

Two assessments by the World Bank provide a clear overview of public financing for the water and sanitation sector in developing countries (World Bank, 1993a and b). On average, the portion of GDP invested in water supply and sanitation rose from about 0.25 per cent in the 1960s to about 0.45 per cent in the 1980s. Furthermore, although it was widely believed that the allocation to the sector fell during the difficult years of the late 1980s, a 1991 World Bank analysis of information from public investment reviews in twenty-nine countries showed a different picture. Overall, public investment did indeed decline, from 10.9 per cent of GDP in 1985 to 8.7 per cent in 1988, but over this same period, investment in water and sanitation held virtually constant at about 0.45 per cent of GDP.

Moreover, in many cases where formal institutions – in this case, water authorities – have performed inadequately, a large, informal, private industry has arisen to meet those needs that are not sufficiently served by the formal institutions. So, in cities throughout the developing world, households tend to cope with the unreliability of the formal water supply service by installing in-house water storage tanks, booster pumps and sinking wells or by purchasing water from vendors at exorbitant prices. The size of this informal and often hidden economy varies between countries but, it at times dwarfs the size of the formal economy. For example, in Pakistan, more than 3 million families have wells fitted with pumps, many of which are motorised. The wells are paid for in full by the families and all equipment is provided and serviced by a profitable local private industry.

The existence of the informal economy has important implications for service provision. First, there is a high demand for services that has not been met successfully by the formal sector. Second, although some services are provided efficiently by the informal sector, in other cases, such as water vending in the urban periphery, the costs of service are exorbitant. This is in large part attributable to the inability of informal providers to take advantage of the large economies of scale involved in transmitting water by pipe rather than by person or vehicle. Finally, the responsibility for ensuring a secure water supply – a public good – has largely been abandoned by the state and passed on to the consumer.

#### **1.4.8 Summary of Shifting Paradigms in Water Resource Management**

Figure 1.3 summarises the evolution of water provisioning policies as discussed above. Although these ideologies and management practices have been discussed in the period in which they were first introduced, in Trinidad and Tobago and Barbados, some of these issues rolled over and continued to be significant in subsequent years, thereby compounding the water resource management problem.

**Figure 1.3: Shifting Paradigms in Water Resource Management**

Period	Paradigm
1950s – 1960s	<p><b>Economic Growth, Modernisation and State Capitalism:</b></p> <ul style="list-style-type: none"> <li>• Accelerated economic growth model adopted;</li> <li>• High government involvement in infrastructure provision to achieve rapid economic growth;</li> <li>• Industrialisation and meet public needs.</li> </ul>
1960s – mid 1970s	<p><b>Redistribution with Growth:</b></p> <ul style="list-style-type: none"> <li>• Failure of economic growth model</li> <li>• Increasing inequalities, unemployment and poverty;</li> <li>• Limited income redistribution;</li> <li>• Subsidisation of public utilities for social equity reasons.</li> </ul>
Mid 1970s – 1980	<p><b>Basic Needs Approach:</b></p> <ul style="list-style-type: none"> <li>• Failure of redistribution with growth approach;</li> <li>• UN introduces focus on fulfilment of basic needs i.e. safe water, shelter, health.</li> </ul>
1980s	<p><b>Free Market Economics:</b></p> <ul style="list-style-type: none"> <li>• Global recession;</li> <li>• ‘Thatcherism and Reaganomics’;</li> <li>• Rising burden of public sector financing leading to cuts in expenditure on public utilities;</li> <li>• International Drinking Water Supply and Sanitation Decade.</li> </ul>
1990s	<p><b>Privatisation:</b></p> <ul style="list-style-type: none"> <li>• Visible deterioration of infrastructure and quality of essential services;</li> <li>• Introduction of private sector participation in public utilities;</li> <li>• International conferences on water and the environment held.</li> </ul>

## **1.5 Categorisation of the Water Resource Problem**

As J. Ahmed (1976) has pointed out,

*“The pressing priorities of the developing world constitute a very different set of environmental problems from those encountered in the developed countries... In general – and at the cost of some oversimplification – it may be said that developed country environmental problems are caused by an overindulgent and wasteful pattern of consumption (and production) without considering environmental spill-over, while developing country environmental problems are the result of poverty and under-development.” (Ahmed, 1976, pp. 226-7)*

This same point is made by Hardoy and Satterthwaite (1984, p.308), who argue that in the Third World, the concerns are not so much with “what are conventionally understood in the West as ‘environmental’ problems”, but with “the problem of poverty... and the refusal (or inability) of... governments to tackle poverty’s underlying causes”. The problems caused by what Mabogunje (1984) so graphically calls the ‘pollution of poverty’ are unlikely to require the same means of correction as those arising from the ‘pollution of affluence’. Although still a gross generalisation and simplification, especially in the cases of Trinidad and Tobago and Barbados, stemming from this, it is useful conceptually to distinguish three major classes of problem: resource depletion, uncertainty and welfare distribution. None of these is a discrete entity and the concerns regarding water resources encompass all three types of problems.

### **1.5.1 Scarcity**

The first problem is resource depletion. Rees (1985) argues that from an anthropocentric viewpoint, scarcity and depletion are not necessarily identical since scarcity is a cultural concept and implies the need for

specific goods and services; whilst if alternatives exist, depletion, or even the total exhaustion of a renewable resource need not mean scarcity. For example, the exhaustion of natural gas stocks need not matter if alternative energy sources are readily available. So too, the exhaustion of tuna stocks need not be significant if adequate alternative food supplies are assured. Hence Rees (1985) treats resource depletion and scarcity as two separate problem categories. However since in the case of freshwater, depletion does lead to crucial supply shortages, depletion and scarcity have been amalgamated into one problem category.

Scarcity first refers here to the situation where essential water supplies are insufficient to enable human beings to survive at baseline standards of living. It is important to note that baseline levels of supply are culturally determined. Defined in this restricted sense, scarcity is at present primarily a developing world problem, although conceivably a breakdown in water supply systems anywhere in the world would make it applicable. As previously mentioned, there can be no doubt that severe shortages of freshwater are already affecting the basic existence of millions of people. Soil erosion and desertification are now widespread phenomena resulting in problems, for e.g., aquifer regeneration and water quality.

Endemic water shortages affect nearly 50 per cent of the world's population, and not only act directly to reduce human health and welfare standards, but also exacerbate the problems relating to agricultural productivity.

To the economist, scarcity arises when the quantity demanded is higher than that being supplied 'at the going price'. Theoretically they believe that if the price is increased, the quantity demanded will decline and the quantity supplied will rise until equilibrium is gained and no economic shortages occur. In a sense, the water scarcities in much of the developing world are economic since the price the people can and do pay is insufficient to provide an incentive to maintain supplies. But, increasingly the tariffs in

such countries will only remove the appearance of scarcity within the market, leaving untouched – in fact exacerbating – the fundamental problem of the gap between supply and baseline needs.

A 1976 regulation had held US gas prices below the level required to achieve a demand – supply equilibrium and economic scarcities resulted which became more marked over time as the incentive to invest in new supply sources was reduced. This form of scarcity also occurs widely for public water supplies, particularly to the domestic and agricultural (irrigation) sectors. When supply authorities maintain unit prices well below the long-run cost of supply, shortages tend to arise unless physical rationing devices are introduced or massive capacity extensions undertaken, subsidised either by other water users or by tax-payers (Hirschleifer et al., 1960; Rees, 1976, 1982, 1985).

Any supply shortages, which arise can be tackled either by increasing supply or controlling demand (or a combination of both) and price rises are one possible method of control. Price changes can only satisfactorily resolve the problem of allocating supplies between competing users if it is accepted that ability to pay is the correct distributive criterion.

### 1.5.2 Uncertainty

The second problem, uncertainty is of a different nature. It is critically entwined with lack of knowledge, with largely unquantifiable risks and with mankind's highly imperfect institutional and economic mechanisms for dealing with risk.

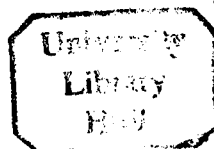
At the height of the 1970s environmental movement, pseudo-scientific predictions of the imminent collapse of life support systems were commonplace, often based on extremely dubious extrapolations and guesswork about natural regulatory or adjustment mechanisms.

Scientists have for many years argued that human activity has reduced biological diversity and changed the global energy budget and the critical bio-geochemical cycles. But, natural systems alter markedly on their own over time, quite independently of human activity. Kellogg and Schwere (1981, 1982), for example, have demonstrated that the 'natural' climate has an ever-changing character. Only 18,000 years ago much of Canada and north-western Europe was covered by ice-sheets. Such glacial episodes and the kind of inter-glacial period the earth is now experiencing have alternated at approximately 100,000 year intervals for at least the last two million years (Berger et al., 1982). These natural changes in global heat and water balances dwarf any changes as yet induced by humans, who had minimal impact until about 150 years ago.

Today most scientists view the global system as rather more robust although potentially harmful disequilibria could be induced. Few doubt that man-induced environmental change could have profound socio-economic implications. As a case in point, while increasing levels of atmospheric carbon dioxide could act to improve plant productivity at least in the short-term, more importantly, they could so alter the global energy and water budgets that major shifts in world climate patterns and sea levels occurred.

A popular hypothesis suggests that large areas of the Middle East, Africa, India and China might cease to be water-deficient areas, whereas much drier conditions could occur over much of North America and Russia (New Scientist, Jan. 1980). It is ironic to think that such inadvertent alterations to regional water balances could actually serve to reduce international spatial inequalities, a measure which the political and economic systems have been unable to achieve.

These changes however, remain largely speculative. Global climate change and the scientific certainties and uncertainties will be discussed in more detail in Section 2. What is relevant here is that solutions to this category



of problem will depend on how they are perceived in relation to the group of other – usually more immediate – economic, political and social ‘crises’ facing countries, and on the political will to intervene.

### 1.5.3 Welfare Distribution

Although freshwater quality and pollution will not be discussed in detail in this document, it is important to note that the degradation of water resources clearly imposes economic and welfare losses. These primarily include damage to human health; the reduction of agricultural yields; and increased water treatment costs. Conversely, damage avoidance or abatement are rarely costless procedures. Ultimately then, the basic question is how are these various costs and losses to be distributed spatially and temporally between different groups within society? In other words, the underlying concern is with the effective allocation of income, wealth and welfare (Rees, 1985).

## 1.6 The Factors contributing to the Water Resource Problem

Various fundamental problem causes were identified by academics working from different analytical perspectives in the 1960s and 1970s, of which five were particularly popular: population pressure, technological change, economic growth, market failure and ethical beliefs.

### 1.6.1 Population

Population pressure was viewed as the basic issue by many writers and so they called for ‘zero population growth’ or even more harshly ‘the one-child family’ (Ehrlich and Ehrlich, 1970). Birth control and liberalisation of abortion were therefore seen as the obvious answers. Apart from the fact that these may not be politically or morally acceptable as solutions, it is



clear that population numbers are only one dimension in the level of demand for water services. A static or even declining population will not prevent depletion and environmental degradation if those remaining experience an increase in their material prosperity. If households merely increase their per capita water consumption to take up the services effectively released by the forgone child, then there will be no change in the resource use position. Moreover, it is highly possible that with increased material wealth, people may start to demand services which place even more strain on water systems. For example, a change in service from a standpipe serving a street to individual house pipe connections would result in a need for increased supply to that area. While writers such as Simon (1981) doubt that population growth has serious ill-effects; most agree that it is a contributing factor and few would deny that population control programmes may be necessary to help solve scarcity problems, especially in the lower developing countries such as Peru and India. Still such programmes are no more than an adjunct to other social and economic policies.

### 1.6.2 Technological Change

It is frequently argued that new techniques of production are inherently more disruptive and polluting than the technologies that they displace (Commoner, 1972a, 1972b). Rees (1985) opines that there is little doubt that mass-production techniques, increased levels of packaging, the production of more complex processed goods, energy intensive techniques and the development of synthetic substances have all added to the demands placed on the natural system. But, it must be remembered that traditional production techniques also cause depletion and pollution. Soil erosion, desertification, water scarcity and deforestation need not necessarily occur as a result of sophisticated production methods, just the most basic traditional techniques applied at a scale incompatible with natural regenerative cycles.

All forms of production involve some use of environmental resources, whether depletion and damage result will depend on how intensively they are used. On the one hand, it is claimed that new technologies involve greater risk and uncertainty than those used in the past. On the other, there are also technologies which are unmistakably less damaging than the ones they replace. For example, health risks and water pollution are clearly reduced when sewerage and sewage treatment displace the direct discharge of wastes into streams.

In the end, the net effect of technological change on renewable resources is not decisive. Indications are that technological change exacerbates some renewable resource problems but it will continue to also offer solutions.

### 1.6.3 Economic Growth

Technology cannot be viewed as an independent cause separate from the economic growth which powers it and is in turn, powered by it. Growth and new investment stimulate technological change, which in turn produces new market opportunities which then fuel the growth process (Rosenburg, 1976; Layton, 1977). The pace of economic growth and its measurement in materialistic terms, therefore is the third popular factor contributing to renewable resource problems.

Rees (1985) explains the three strands of this cause. First, it is argued that economic growth is incompatible with the essentially closed and limited physical system of the earth. However the implied 'no growth' solution has little practical relevance or moral justification when applied to countries in the developing world. In the first instance, some growth would have to occur to allow those living at bare subsistence levels to continue to live at all; unless, population growth was also cut to zero. No growth would simply consign millions of people to levels of material existence, which few would seriously consider acceptable. Further, it can do nothing to

solve the problems which already exist when present use intensities exceed the natural regenerative capacity of the environment.

Neo-Malthusian writers working from the assumption that 'spaceship earth' cannot support on a sustained basis even the current population at present levels of consumption have argued that attempts to produce growth in developing countries should be halted. This argument is based on a highly romantic notion of what conditions are actually like in these societies and ignores the fact that the people concerned may have quite a different view of their own fate.

The arguments of Mishan (1967), Hodson (1972), Daly (1973), Schumacher (1973) and many others who see growth mania, material acquisitiveness and glaring consumption as indicators of misplaced moral values have more appeal when applied to affluent developed societies. It is easier to dismiss the need for growth when it results in the production of computer games, animal beauty parlors and elaborate restaurant meals. But, regardless of where it is applied in the world, unless no growth policies are accompanied by a total redistribution of wealth, it seems inevitable that most people will demand the chance to enjoy the affluence experienced by the wealthy. Why should everyone not enjoy the 'luxury' of pipe-borne water into their homes and indoor toilets? Needs are a relative, not absolute concept.

It can hardly be denied that greater levels of service and consumption will inevitably place increased pressures on the water resource base. In other words, while most people would accept that growth is one factor contributing to current resource depletion and degradation, such recognition is far removed from the acceptance of no growth as a morally, politically or economically feasible policy option.

Second, there is the short-run economic growth with which politicians and economists are preoccupied. This view distorts the whole process of

production towards maximising the net present value of physical output as defined by the current tastes and income levels, to the detriment of spatial and temporal distributive equity. Not only are the requirements of future generations ignored, but present-day consumers are denied non-marketable goods or services. In the longer term, she argues that the continued pursuit of material growth will serve to reduce, not increase real social welfare (Rees, 1985, pp. 257-258).

The third strand in the economic growth argument concerns the use of GNP as a measure of economic welfare. Gross national product is the market value of all goods and services produced in an economy; any non-market products and services are all excluded.

Growth as GNP cannot be equated as growth in human welfare for several reasons. First, all goods and services including non-benefits (pollution, crime and so on) must be priced and included within the market exchange system which does not hold. Second, the consumer is not sovereign in determining the value of goods free from manipulation by producers. Finally, there is no direct relationship between the physical output produced by an individual, his wealth and the use value of things to him.

An enormous amount of literature now exists on the deficiencies of GNP and related market price measures of economic welfare. Attempts have also been made to devise more meaningful 'real' welfare indicators, but, these have had negligible impact on how GNP growth is calculated in practice. Further, GNP continues to play a central role as a policy objective. The difficulty here is that it is much easier to show that market values are inappropriate than to devise a system for appropriately measuring welfare.

#### 1.6.4 Market Failure

There is little doubt that the failure of conventional economics to incorporate all the social costs involved in resource use has contributed to the depletion and degradation of the resource base.

Externalities (or external costs and benefits) are the uncompensated side-effects of any economic or social activity which are not considered when making policy decisions. Traditionally, only those goods and services which were directly used in production and consumption were priced and incorporated into the market. The reverse flow of unwanted products back to the environment was systematically ignored. Neither was any value placed on the limited capacity of the environment to assimilate waste products.

It was thanks to Boulding (1966) who argued that consumption was not the 'final act' of the economic system that the importance of reverse waste flows was recognised. By ensuring that all products and services, including the earth's assimilative capacity are priced and incorporated into the market system of exchange, all resources would be allocated to maximise their net value in use. But this theoretically simple task of correcting market failure belies several crucial political, social, practical and ethical limitations and complexities.

#### 1.6.5 Ethical Beliefs

There are many different dimensions to the argument concerning ethical beliefs and how they impact renewable resources, but basically two major points are made. First, as Tuan (1974) and Cotgrove (1982) explain, the dominant religious and political philosophies in 'advanced' societies envisage mankind as separate from and above nature. This does not occur in many of the less developed societies where nature, man and God are

interdependent and neither is man separate from nature nor nature discrete from God.

Second, and perhaps more relevant to this study, human beings are inherently myopic, with an in-built preference for the known present over the uncertain future (Ramsey, 1928; Pigou, 1932). This means that social, political and economic decisions are inevitably biased towards the needs of the present generation with the consequent disregard for the potential requirements of future generations.

In both cases, the attitudes are essentially man-centred to facilitate the survival of the human species. It is difficult to pursue these arguments very far since they are products of moral judgement and reasoning. Still, differences in ethical beliefs cannot go unmentioned as they are another important factor affecting the management of renewable resources, particularly freshwater.

#### 1.6.6 The Tragedy of the Commons

The discussion above yields some insight into the problems. One thing is clear - there is no one simple cause or any universal panacea. Still, to further complicate an already complex issue, many analysts claim that these factors produce particularly acute difficulties because of the common property aspects of water resources.

Common property refers to the traditional regard for the water resource base as being inexhaustible and freely available for use by all. Individuals have minimal incentive to take conservation or pollution reduction actions, and technological changes have taken place which assume their continued free availability. The evidence suggests however, that unless some usage controls are imposed, resources tend to be exploited in the short-term and in the longer-term, the total flow could be seriously depleted.

This is the sort of problem that Hardin (1968) refers to in his well-known essay on the 'Tragedy of the Commons'. The focus of this article was population growth within a finite world. To demonstrate that 'our present policy of laissez-faire in reproduction' will lead to disaster, the analogy of the use of common land by herdsmen is employed:

*"Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. As a rational being, each herdsman seeks to maximise his gain."*

Even when the carrying capacity of the common land is exceeded, each herdsman will continue to add stock because he receives all the gains from the sale of additional animals but only shares a fraction of the costs of the resulting overgrazing:

*"Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit – in a world that is limited... Freedom in a commons brings ruin to all." (Hardin, 1968, p.1244)*

There can be no dispute that Hardin's notion that uncontrolled free access to a resource in finite supply is likely to result in overuse and degradation. But there are certain limitations in his analysis of the commons issue: the assertion that a herdsman would be compelled to increase his herd without limit is questionable. For instance, if a number of companies and farmers are pumping the same aquifer at a rate which exceeds natural replenishment, every extra litre pumped will increase everyone's pumping costs. However, individuals will only control usage when it costs them personally more to pump than the extra water is worth. In the same way, as Dasgupta (1982, p.14) has pointed out:

*“Animals are not costless, even to the herdsman who own them. And such private costs set limits on the number of animals each herdsman finds most profitable to introduce.”*

In addition, Hardin’s assumption that common land was open to all is misleading. It was in fact open only to those within specific communities, governed by strict rules of social conduct and collective responsibility. As early as 1938, Ciriacy-Wantrup was stressing the historic importance of social controls over common property resource use:

*“Common property of natural resources in itself is no more a tragedy in terms of environmental depletion than private property. It all depends on what social institutions... are guiding resource use.”*  
*(quoted in Clawson, 1974, p.61)*

As Stillman (1982) argues, Hardin in fact artificially creates a set of conditions which makes the destruction of the commons inevitable. In practice, social institutions are adaptable and have tended to change once the effects of depletion become evident. Common and over-extracted aquifers frequently have either become subject to some form of government regulation or been taken over by private ownership.

While there can be no question that common resources tend to be misused and depleted, these problems cannot simply be solved by taking the resources into single ownership, be it public or private. This disregards all other problem causes and trivialises the efficient and equitable allocation of water resources.



## **1.7 The Ingredients to developing a Sustainable Water Sector**

Recalling the ‘old view’ which accompanied the ‘old agenda’ until the late 1980s, it assumes that government has the primary responsibility for financing, managing and operating services. Within this perspective, it is government’s task to define the services to be provided, to subsidise these services (especially for the poor) and to develop infrastructure for service delivery.

But, remarkably the consensus – the ‘new view’ – that has been emerging in recent years is for managing water resources on an efficient, equitable and sustainable basis. At the heart of this consensus are two closely related guiding principles enunciated at the 1992 Dublin International Conference on Water and the Environment, which preceded the United Nations Conference on Environment and Development (UNCED 1992 - the ‘Earth Summit’) the same year:

- *Water is a limited resource and has an economic value in all its competing uses and should be recognised as an economic good.*
- *Water development and management should be based on a participatory approach involving users, planners and policy-makers at all levels, with decisions taken at the lowest appropriate level.*

These principles are being widely adopted – for instance, in the World Bank’s policy paper on water resources management and by the Development Assistance Committee of the Organisation for Economic Co-operation and Development (OECD).

The great challenges now facing the sector are articulation of the details implicit in these general principles and the translation of the Dublin principles into practice. One central tenet is that both efficiency and equity

require proper management of the two dimensions of the water sector – the supply-side and the demand-side.

## **2.0 Global Climate Change**

### **2.1 Introduction**

There is concern that human activities may be inadvertently changing the climate of the globe through the *enhanced greenhouse effect* as claimed by The Intergovernmental Panel on Climate Change (IPCC). Their predictions regarding future climate change and its consequences for human welfare and the natural environment have encouraged the introduction of far-reaching political measures with a view to reducing emissions of carbon dioxide and other greenhouse gases. The most recent expression of this concern was the Conference of Parties (COP) for the UN Framework Convention on Climate Change (UNFCCC), held in October 2002. Prior to this, a similar COP was held in November 2001. These meetings were follow-up sessions relating to the major conference held in Kyoto, Japan in December 1997 where the Kyoto Protocol to the UNFCCC was declared.

It is highly probable that climate change will lead to changes in the global hydrological cycle, which in turn will affect the availability and distribution of regional water resources. Climate change is also expected to influence a higher incidence of tropical cyclones (also higher intensities). Increased flooding and more severe droughts pose potentially major problems, which will require special adaptation measures.

In addition, often the limited financial, technical and management resources in small-island developing states are unable to adapt efficiently to climate-imposed stresses in the hydrological sector due to the disproportionate burden that is imposed on small economies.

The debate on global climate change is however by no means concluded. On the contrary, it continues to intensify as steps are taken to translate the verbal commitments made at Kyoto into practical politics by means of

ratification and ensuing legislation in each signatory country. The USA, under the new Bush administration, has decided not to follow through with ratification. Mr. Bush opposes the Kyoto agreement, partly because he thinks it unfairly burdens the USA, as they will have to bear some of the highest costs in terms of investing in cleaner fuels. It remains to be seen if the Protocol will ever become a binding treaty now that the USA have withdrawn. Generally, the debate has been shifting from issues related to climatology, meteorology and science to the political, economic and social consequences of changes in energy policy that seek to limit and ultimately reduce the use of fossil fuels.

Be it the meteorologists or the politicians, climate change and global warming are high up on the current agendas. As Houghton (1994, pp.14) states:

*“There are urgent questions everyone is asking: are human activities altering the climate? Is global warming a reality? How big are the changes likely to be? Will there be more serious disasters, will they be more frequent? Can we adapt to climate change or can we change the way we do things so that we can slow down the change or even prevent it from occurring?”*

The earth's climate system is highly complex and because human behaviour and reaction to change, are even more intricate, providing answers to these questions is an enormous challenge to the scientists. It follows that the biological and water resources of any country would be sensitive to climate because of their clear dependence on climate circumstances: temperature, rainfall, humidity, wind speed, and sunshine. But, as with many scientific problems, only partial answers are available and for a number of reasons, the threat to the global environment posed by global warming may be exaggerated. Anticipated climate change is expected to vary greatly from region to region and from season to season. Further, local climate changes can vary substantially from the global

averages, and the impacts of climate change in any given region depend on the specific climatic changes that occur in that region. The best tools currently available to predict climate change are three-dimensional mathematical models of the climate system – atmosphere, ocean, ice, land – known as general circulation models (GCMs). However, in their current state of development, the analyses of some of the processes involved in climate determination are relatively crude, and as such, considerable uncertainty is attached to the predictions of climate change. In light of all of the above, the specific regional consequences for water availability and quality cannot yet be predicted with complete certainty.

If on the other hand, the threat of projected future climate change is real and serious, the various economic and political structures in place for handling finite water reserves will have to be made more resilient than they are at present.

## **2.2 The Greenhouse Effect**

### **2.2.1 History and Evolution**

Baron Jean Baptiste Joseph Fourier is generally recognised to have been the first person to have made an argument about the greenhouse-like properties of the atmosphere in 1827, and to suggest that the atmosphere was important in determining the temperature of the earth's surface. The next step was taken by a British scientist, John Tyndall, who, in 1863, measured the absorption of infrared radiation by carbon dioxide and water vapour. He estimated that water vapour holds about 16,000 times as much heat as do oxygen and nitrogen, the main constituents of the atmosphere. Both Kellogg (1987) and Gribbin (1990) have cited Tyndall as the first person to suggest that ice ages were caused by a decline in atmospheric carbon dioxide concentrations.

At the end of the nineteenth century, the next development in greenhouse science occurred. Swedish chemist, Svante Arrhenius, in 1896, calculated the effect of an increase in the concentration of greenhouse gases. He estimated that doubling the concentration of carbon dioxide would increase the global average temperature by 5 to 6°C. Nearly 50 years later, around 1940, G.S. Callendar was the first to postulate the warming of the atmosphere due to the increasing carbon dioxide from the burning of fossil fuels. In a presentation to the Royal Society, England, in 1938, he compared the measured growth of atmospheric carbon dioxide and the temperature records from 200 meteorological stations, and argued that this evidence supported Arrhenius's thesis about the relationship between carbon dioxide and temperature. Prior to 1957, the prevailing view was that the oceans absorbed any excess carbon dioxide emitted by human activities. Consequently, there appeared to be no reason to worry about emissions from fossil fuel burning, thus Callendar's views were largely rejected.

In an article in *Tellus* in 1957, Roger Revelle and Hans Suess supported Callendar's hypothesis (Revelle and Suess, 1957). They suggested that about half the carbon dioxide emitted would remain in the atmosphere, and that humanity was thus conducting a "large-scale geophysical experiment" (Revelle and Suess, 1957, pp.19; Pearce, 1989, pp.97). Thereafter, concern about the climate changes which might be brought about by increasing greenhouse gases began to take root. In the same year, routine measurements of carbon dioxide were started from the observatory on Mauna Kea in Hawaii.

Since then, greenhouse science has progressed to the stage where sufficient information has been gathered to make reasonable assessments of the scale of the climate and potential climate changes. That progress coupled with the continuing use of fossil fuels together with growing interest in the environment, has led to the topic of global warming moving up the political agenda through the 1980s to the Climate Change Convention signed in 1992 and then to the commitments of the Kyoto Protocol in 1997.

### 2.2.2 The Science

The greenhouse effect is a natural phenomenon whereby certain gases in the atmosphere keep the earth's temperature significantly higher than it would be otherwise. The gases, nitrogen (78 per cent) and oxygen (21 per cent) which make up the bulk of the atmosphere neither absorb nor emit thermal radiation. As previously mentioned, it is primarily the water vapour and carbon dioxide which absorb some of the thermal radiation leaving the earth's surface and act as a partial blanket for this radiation. These gases do not have much, if any, influence on the incoming, short wave radiation which passes through the earth's atmosphere. This radiation is absorbed at the earth's surface and is again radiated away, but as long wave infrared radiation. The carbon dioxide and water vapour in the atmosphere absorb and reradiate this long wave radiation. This blanketing is known as the *natural greenhouse effect*. It is called 'natural' because all the atmospheric gases responsible for the greenhouse effect occur naturally. These greenhouse gases keep the earth's surface and the lower atmosphere about 33°C warmer than it would be without them. Without this natural greenhouse effect, the surface of the earth would be inhospitable.

The greenhouse gases that have given rise to concern include carbon dioxide, water vapour, methane, nitrous oxide and chlorofluorocarbons (CFCs). All of these gases except CFCs are natural constituents of the atmosphere. The *enhanced greenhouse effect* is due to increases of the concentrations of these greenhouse gases in the atmosphere as a result of human activity.

Observations have shown that concentrations have been increasing since the industrial revolution or perhaps even longer. According to O'Riordan and Jager (1996), the level of carbon dioxide in the atmosphere increased from about 280 ppmv (parts per million by volume) in the pre-industrial period to about 355 ppmv in 1992. The methane concentration increased from 700 ppbv (parts per billion by volume) to 1714 ppbv over the same

time span. Studies carried out by Houghton et al. (1990) and other scientists confirmed that human activities such as the combustion of fossil fuels, deforestation, desertification and certain modes of agriculture add greenhouse gases to the atmosphere.

The greenhouse gases do not contribute equally to increased radiative blanketing or forcing. Estimates made by the IPCC in 1994 indicated that approximately 55 per cent of the increased radiative forcing was from carbon dioxide. Subsequent work has revised these figures slightly, but did not change the finding that carbon dioxide has made the largest individual contribution to the enhanced greenhouse effect, while methane and CFCs have contributed roughly equal but smaller amounts.

Although there are good reasons for supposing that some of this warming of the atmosphere is due to human activity, because of the size of the natural climate variability, it cannot yet be attributed unequivocally to that cause. This then begs the question: has evidence of a similar greenhouse effect/global warming been recorded in the past?

### **2.3 Climates of the Past**

The global temperature has in fact increased during the last century. In order to determine if this change is unique, as is often claimed, and if so, to what extent it may be due to the release of greenhouse gases by mankind, it is helpful to look at some of the climate changes which have occurred in the past.

The network of weather-observing stations that has provided the measurements that go into the global-average surface temperature record has built up gradually from its inception some 140 years ago. This was preceded by a period of widely scattered temperature measurements. For



still earlier times, temperature has had to be inferred from other data so that any global-average surface temperature records before about 140 years ago are only crude estimations.

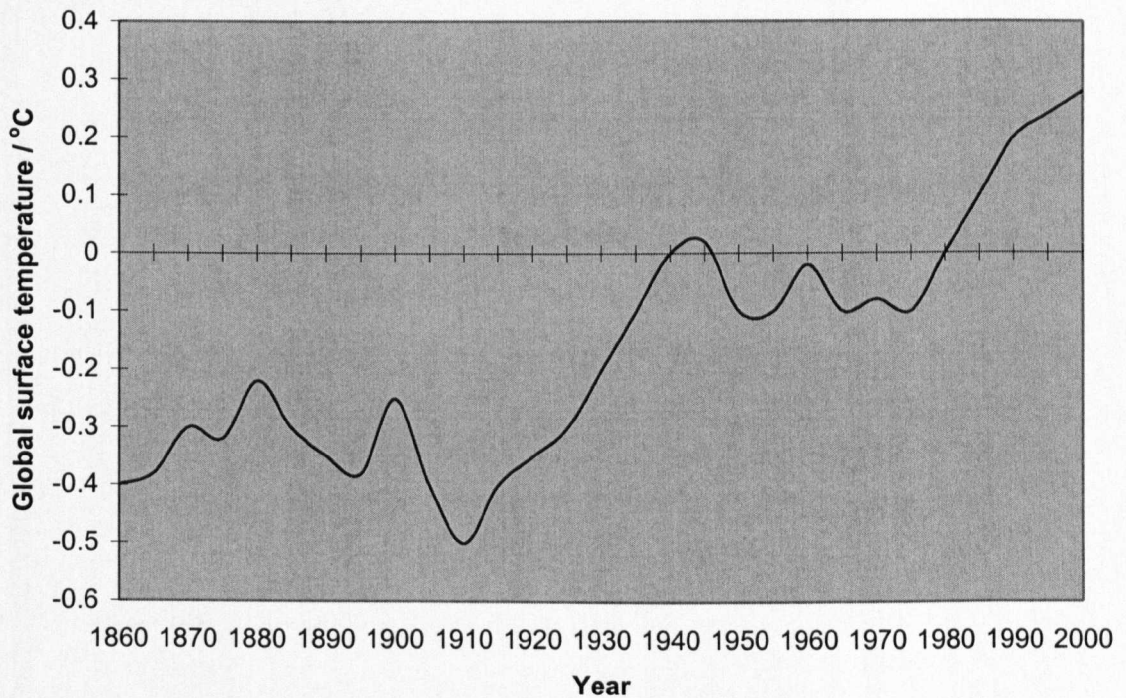
Particularly cold periods have been recorded. These are glacial episodes, more commonly referred to as ice ages, in which a significant fraction of the land area poleward of 50°N was covered by ice. The intervening warmer periods are interglacial episodes in which this polar ice cap of the Northern Hemisphere retreated. The ice ages occur at irregular intervals, but usually spaced about 100,000 years apart. The last ice age began around 120,000 years ago and was preceded by one of the warmest interglacial periods of the past million years. This interglacial period is called the Eemian interglacial. The last ice age reached its peak about 18,000 years ago and ended abruptly 12,000 years ago. The earth has been in an interglacial period, referred to as the Holocene, for the last 10,000 years.

### 2.3.1 The Last Hundred Years

The increase in global temperature during the last century has been determined on the basis of data supplied by climate stations located throughout the world. Although the extent of this global warming is open to discussion, its existence cannot be called into question. This temperature increase is frequently called unique, but palaeoclimatologists point out that similar changes have occurred repeatedly. What is indeed unique is that eight of the nine warmest years during the past century occurred during the 1980s and early 1990s (Houghton, 1997). The data mapped at Figure 2.1 show that over the period 1860 to 1990, the global average temperature has increased by between 0.3°C and 0.6°C. Sceptics such as Karlen (1999) question how a diagram like Figure 2.1 can be prepared and whether any reliance can be placed on it. Only if it can be proven that changes in climate have occurred at a large number of localities simultaneously, is it

possible to prove that a change in the radiation balance of the planet has taken place. So, to estimate the changes on land, several weather stations were chosen by Houghton (1997) and the IPCC (1996, 2001) where consistent observations have been taken from the same location over a substantial portion of the whole 140-year period (1860-2000). Changes in sea surface temperature have been estimated by processing over 60 million observations from ships – mostly merchant ships – over the same period.

**Figure 2.1: Variation of Global Surface Temperature from 1860-2000**



Adapted from Houghton (1997) and IPCC (2001)

In addition to changes in temperature, it is also interesting to note if there have been changes in other weather parameters. Measurements of precipitation tend to be much more unreliable and inconsistent than those of temperature; precipitation can also be extremely variable. Nevertheless, it has been found that over the last hundred years, sea level has risen by between 10 and 20 cm (IPCC, 2001). This increase is attributed in the main to thermal expansion of ocean water due to higher global average

temperatures and water from glaciers that have generally been retreating over the last century.

As clearly illustrated at figure 2.1, there has been considerable variability, not just from year to year, but from decade to decade. Moreover, the warming during the 20<sup>th</sup> century has not been uniformly distributed over the globe. The largest increases in temperature over the period 1976-1999 have occurred over the mid and high latitudes of the continents in the Northern Hemisphere. There have also been areas of cooling, for instance, over the period 1946 to 1975, in the North Atlantic Ocean, as well as much of the Northern Hemisphere. Year-round cooling is still evident in the north-western North Atlantic and the central North Pacific Oceans but the North Atlantic cooling trend has reversed since 1976 (IPCC, 2001 and Houghton, 1997).

In contrast, the last 10,000 years – the Holocene period – has often been considered a period of basically stable climate. However, it is now known that the climate has fluctuated even during the Holocene and thus, the timing of these fluctuations has become a question of central importance for understanding the processes that determine climate (Holmgren et al., 1999; Branchi and McCave, 1999; Bond et al., 1997; Alley et al., 1997).

### 2.3.2 The Holocene

As discussed above, the detailed systematic record for the last 100 years of weather parameters such as temperature, rainfall, cloudiness and the like covering a good proportion of the globe is not available for earlier periods. Further back, records have become much more sparse and doubt arises over the consistency of the instruments used for observation. However, many diarists and writers kept records at different times. Indirect sources such as provided by ice cores, tree rings and records of lake levels, of glacier advance and retreat of pollen distribution in the past can also yield

information to assist in building up the whole climate story of the past. Roughly 4,000 to 6,000 years ago, the earth-atmosphere climate system was characterised by warmer conditions than those at the present time (Horel and Geisler, 1997). This period is called the Holocene maximum, and it represents one of the warmest periods to date during the present interglacial.

It was when O'Brien et al. (1995) found sizeable variations in the content of soluble salts in ice cores from Greenland that the concept of major, possibly global changes in the atmospheric circulation first gained acceptance (Bond et al., 1997). These variations are of the same duration as the well-known, large amplitude variations during the last glaciation, but the amplitude of the Holocene variations is much smaller (Bond et al., 1997). Extensive studies of major climatic changes that occurred at the end of the last Ice Age lend support to the view that large climatic fluctuations have taken place at the same time over large areas (Alley et al., 1997; Broecker, 1997; Fischer et al., 1997).

Dendrochronological studies from the northern hemisphere show that major climatic changes occurred at approximately the same time in several places. Studies from northern Sweden and from the Rocky Mountains indicate particularly warm events around AD 1100, 1160, 1320, 1430, 1760 and 1940. The warming that has taken place during the last century is pronounced but not more distinct than the events that took place during the 1300s, the early 1400s and in the late 1700s (Luckman et al., 1997).

As mentioned before, the number of well-dated temperature series covering an extended period is limited. However, there are three independent data sets: one collected over land and two over the oceans, that show at least major changes in the climate took place at approximately the same time in localities situated far apart from one another (WMO, 1990).

### 2.3.3 The Past Million Years

In terms of pre-recorded human history, scientists have to rely on indirect methods to unravel much of the story of the past climate. A particularly valuable source of information is the record stored in the ice caps in Greenland and the Antarctic continent. Analysis of the ice at different levels has provided information about the conditions prevailing at different times in the past. Analysis of a Russian Vostok core in east Antarctica shows the last major ice age which began about 120,000 years ago and began to come to an end about 20,000 years ago (Houghton, 1997).

Data from ice cores can give climate information as far back as 200,000 years or so. To go further back, over the past millions years, investigation of the composition of ocean sediments has yielded useful information. For instance, from oxygen isotopes obtained from plankton fossils along with other data, it has been deduced that the sea level at the last glacial maximum, 20,000 years ago was about 120 metres lower than today (Houghton, 1997).

Further, from the variety of palaeoclimate data, variations in the volume of ice in the ice caps can be reconstructed over the greater part of the last million years. Six or seven major ice ages have thus far been identified with warmer periods in between. The period between these major ice ages was found to be approximately 100,000 years (Houghton, 1997).

As first proposed by Milankovitch, the sun's radiation is the means for establishing the cause of regular cycles in climate. Indications are the output of the sun itself has not changed to any significant extent over the last million years or so. But, because of variations in the Earth's orbit, the distribution of solar radiation has varied in a regular way, more or less during the last millennium. Careful study of the relationship between the ice ages and the Earth's orbital variations shows that the size of the climate changes is larger than expected and radiation changes alone appear to be

the forcing mechanism responsible. This therefore implies that the rapid climate changes that have occurred in the past need to be taken into account when proposing the possibilities of current and future human-induced climate changes.

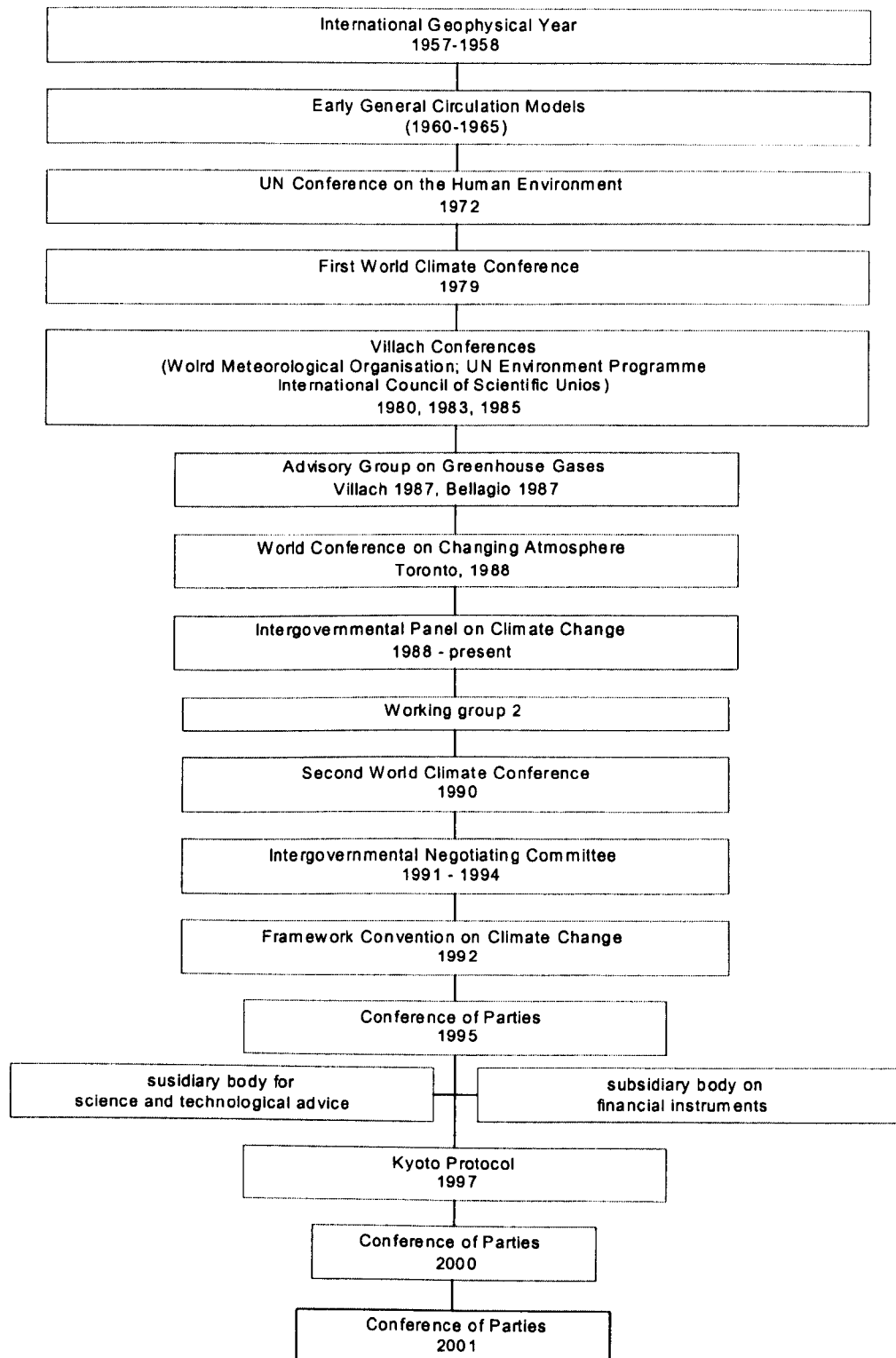
## **2.4 Putting Climate Change on the Agenda**

Since the beginning of the 1970s, scientific concerns that human activities could change the global climate have been receiving increasing attention at national and international institutions. Lanchberry and Victor (1995) provide a thorough description of the main scientific developments from the 1970s to the mid 1990s. Figure 2.2 summarises the evolution of climate change science and politics to date.

In 1988, the biggest drought in the US since the 1930s was experienced as well as other freak weather patterns across the world. These events and the realisation that the six hottest years on record were in the 1980s pushed global warming forward as a significant political issue.

The events of 1988 stimulated a flurry of international conferences and scientific assessments of the state of knowledge about global warming. The IPCC, an intergovernmental panel was also founded in 1988 by the United Nations Environmental Programme (UNEP) and the World Meteorological Organisation (WMO). The IPCC was established in order to make the fullest assessment of scientific knowledge and potential impacts of climate change and to examine potential response options (IPCC, 1988).

**Figure 2.2: The Evolution and Pathway of Climate Change Science and Politics, 1958-2002**



Adapted from O'Riordan and Jager (1996)

As the momentum was sustained, climate politics evolved, with formal negotiations to an international treaty launched in February 1991. These led to the signing of the 'Framework Convention on Climate Change' at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, in June 1992 (UN, 1992). At the same time, many industrialised states, including Germany, Canada and Norway, adopted unilateral targets to limit their own emissions of the gases believed to cause global warming.

Meanwhile, the IPCC embarked on an update of specific aspects of the science and emission scenarios, published in 1992. The second assessment report (SAR) published in June 1996 marked a crucial stage in the process of global action to combat climate change. The report's main conclusions were that:

- Greenhouse gas concentrations have continued to increase as a result of human activities possibly causing changes to the climate; and
- Global average temperature (and sea level) have risen, and recent years have been among the warmest since 1860.

Other observations and extensive scientific analysis supported these headline findings. It is perhaps this second report, more than any other that set the context for the negotiation of the Kyoto Protocol. The Third Assessment Report (TAR) of Working Group I of the IPCC was approved by member governments in January 2001. It builds upon past assessments and incorporates new results from research on climate change since 1996. It is now the most authoritative summary of the issues of climate change.

Based on additional data from new studies of current and palaeo- climates, and improved analysis of information, the main findings of the TAR were:

- The earth's climate system has demonstrably changed since the pre-industrial era, with some of these changes attributable to human activities.



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- The global average surface temperature has increased over the 20<sup>th</sup> century by approximately  $0.6^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$ . This value is about  $0.15^{\circ}\text{C}$  larger than that estimated by the SAR for the period up to 1994, due to the relatively high temperatures of 1995 to 2000.
- It is likely that globally the 1990s were the warmest decade and 1998 was the warmest year in the instrumental record since 1861.

#### 2.4.1 The Climate Change Convention

The United Nations Framework Convention on Climate Change (UNFCCC) signed by over 160 countries at the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992 came into force on March 21, 1994. The UNFCCC represents a ‘delicate balancing’ of many different political and economic interests and many complex scientific issues. The political and economic interests reflect the differences amongst the various Parties with respect to levels of development; the relative priority attached to environmental and developmental concerns; the anticipated impacts of climate change; and the equitable apportionment of responsibility for the costs and causes of climate change (O’Riordan and Jager, 1996). The scientific issues include the relationship between greenhouse gas accumulation and the climate system; the inter-relationship between atmospheric gases; and the nature, degree and location of anticipated climate impacts.

Article 2 defines the ‘ultimate’ objective of the UNFCCC and it is this Article which also identifies what the final outcome adherence to the UNFCCC should achieve. The Article states that:

*“The ultimate objective of this Convention and any related legal instruments that the Conference of Parties may adopt is to achieve in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at*

*a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.” (UN FCCC, 1992, 31 ILM 851)*

The UN FCCC recognises *inter alia*: the need to reduce anthropogenic greenhouse gas emissions; that developed countries should take the lead; that development considerations of developing countries are legitimate and allowances for these considerations need to be made; that certain countries are particularly vulnerable to the impacts of climate change; that some countries rely heavily on the income from fossil fuel production and/or consumption; that the measures to address the causes and effects of climate change should be cost effective; and that the precautionary principle should be applied (UN FCCC, *Supra*, notes, Preambles, Articles 3 and 4).

Owing to the diversity of interests which needed to be balanced, precise wording or expression of concepts was not generally possible in the UN FCCC. Some interpretative guidance has emanated from the Conference of Parties but the interpretation itself has largely been the result of negotiated agreement and hence, continues to reflect the political and economic interests of the Parties, as they evolve over time.

#### 2.4.2 The Kyoto Protocol

The Kyoto Protocol to the UN FCCC was agreed unanimously on December 11, 1997, at the Third Conference of Parties (COP 3) held at the International Conference Centre in Kyoto. In many respects, the Kyoto Protocol is without precedent in international affairs. For example, specific legal commitments capping emissions of such gases by each industrialized country constitute a new achievement that many political sceptics had

dismissed as impossible. Yet, these commitments are hedged with such a complex of flexibilities that make their exact meaning opaque and thus open to dispute.

In its central provisions, the Kyoto Protocol defines allowable greenhouse gas emissions for each industrialised country in terms of assigned amounts for the commitment period 2008-2012. The commitments apply to the industrialized countries in Annex I of the UN FCCC, and the numerical commitments are listed in Annex B of the Protocol. Specifically, the latter covers those Annex 1 countries that had ratified the Convention by the time of Kyoto, plus those whose application to Annex I was accepted during the Kyoto Conference. The commitments add up to a reduction of 5.2 per cent below 1990 levels. The 15 countries of the EU are each listed with an 8 per cent reduction from 1990 levels. The USA and Japan have committed themselves to 7 and 6 per cent respectively. Developing countries on the other hand are still permitted to increase their emissions of greenhouse gases until 2010. The base year is generally 1990, which is in most respects taken as the base year for the international climate change negotiations. A different base year is allowed for some of the transition economies of central Europe and for industrial trace gases. As Grubb (1999) explains,

*“...the numbers can only be understood as the outcome of a highly political process arising from the clash between competing numerical aims, structural visions, and root conceptions of political imperative – all combined with the personal and political dynamics of the final days at Kyoto.”*

The commitments for 2008-2012 serve as the engine for almost everything else in the Protocol. There is no earlier commitment period, though Article 3.2 states that “each Party shall by 2005, have made demonstrable progress in achieving its commitments under this Protocol.”

The Protocol makes reference to a second commitment period to succeed the first and stipulated that negotiations to define such commitments shall start no later than 2005. Article 3.1 allows emission reductions obtained over and above commitments in the first period to be 'banked' against commitments in the second period.

Critical to the commitments is the inclusion of various mechanisms for international transfer. These mechanisms are the most novel and complex aspects of the Protocol and many issues remain unresolved concerning their operation, implementation and implications. Requirements in attempting to minimize the adverse impacts both of climate change and of the response measures adopted under the Protocol could also open difficult new ground in international relations.

Grubb (1999) opined that the Protocol is weaker in areas not directly linked to the specific quantified commitments but does provide ground to build on. On the other hand, the Protocol slightly strengthens the Convention's 'soft law' commitments involving developing countries, and associated issues of finance and technology transfer.

The full implications of the Protocol are only now becoming apparent and to an important degree, the subsequent negotiations have been trying to establish how to implement the agreement and indeed whether and when it will be ratified by sufficient Parties to enter into force. The operational details, which the Kyoto Protocol left unresolved, were referred to the Conference of Parties (COP) and subsidiary bodies for further negotiation. At COP 4 (Buenos Aires, November 1998), Parties adopted the so-called "*Buenos Aires Plan of Action*", setting out a programme of work both to advance the implementation of the Convention and to flesh out the operational details of the Kyoto Protocol. This programme of work was conducted in the subsidiary bodies and at COP 5 (Bonn, October/November 1999), with a deadline of COP 6 (The Hague, November 2000). However, Parties were unable to reach agreement on a package of decisions on all

issues under the Buenos Aires Plan of Action at that session. Nevertheless, they decided to meet again in a resumed session of COP 6 to try once more to resolve their differences. At COP 6 part II, in Bonn, July 2001, Parties finally succeeded in adopting the “*Bonn Agreements on the Implementation of the Buenos Aires Plan of Action*”, registering political agreement on key issues under the Buenos Aires Plan of Action. Parties also completed their work on a set of detailed decisions based on the Bonn Agreements, which were forwarded to COP 7, held in Marrakesh for formal adoption. COP 8 recently held in New Delhi in October 2002, is the most recent of such negotiations.

This gathering of world governments was a last ditch effort to get nations to finally agree to the commitments of the Kyoto Protocol. Parties were expected to formally adopt the detailed decisions completed at COP 6 part II and COP 7, and also to finalise outstanding matters, which would pave the way for Annex I Parties to ratify the Protocol and thus bring it into force. Some member governments had expressed a wish for the Protocol to enter into force in 2002, coinciding with the tenth anniversary of the adoption of the UNFCCC and the “*Rio+10*” World Summit for Sustainable Development (Johannesburg, September 2002). This has not happened but the discussions at COP 8 have moved onto the next stage – the mechanisms provided under the Protocol to help ratifying countries meet their targets – because of the confidence that the Protocol will come into force early in 2003 when Russia and Canada are expected to ratify it. It remains to be seen if the Kyoto Protocol will be ratified and until then, the debate on global warming and climate change continues.

In the circumstances, the discussion below is concurrent with selected material from the IPCC Second and Third Assessment Reports, relevant to interpreting Article 2 of the UN FCCC to provide the context for treating with the principal issues relating to climate change.

## **2.5 Anthropogenic Interference with the Climate System**

An appreciation of current atmospheric concentrations and trends of greenhouse gases, and their consequences (both present and projected) to the climate system is necessary in order to understand what constitutes concentrations of greenhouse gases that could cause dangerous interference with the climate system.

The atmospheric concentrations of the greenhouse gases, among them, carbon dioxide, methane and nitrous oxide have increased significantly since pre-industrial times (about 1750 AD). IPCC (2001a) recorded values for carbon dioxide up from about 280 ppmv in 1750 to almost 368 ppmv in 2000, and increases for methane from 700 to 1745 ppbv, and nitrous oxide from about 270 to 316 ppbv, over the same time frame.

The IPCC claims that these trends can be attributed largely to human activities, mainly fossil-fuel use, land-use change and agriculture. Concentrations of other anthropogenic greenhouse gases have also increased.

According to the IPCC (2001a), global mean surface temperature has increased by about  $0.6^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$  since the late 19<sup>th</sup> century, a change that is unlikely to be entirely natural in origin. It is also very likely that the 1990s were the warmest decade and 1998, the warmest year on record since 1861. Most of the increase in global temperature over the 20<sup>th</sup> century has taken place in 2 periods: 1910 to 1945 and 1976 to the present. The rate of increase for both periods is approximately  $0.15^{\circ}\text{C}/\text{decade}$ . Recent warming has been greater over land compared to oceans – the increase in sea surface temperature over the period 1950 to 1993 is about half that of mean land-surface air temperature. Based on data from tide gauges, the sea level has also risen by between 10 and 20 cm over the past 100 years, and the 1997 to 1998 El Niño occurrence stands out as an extreme high global

temperature event. Changes have also been noted in other important aspects of climate, such as precipitation, snow and ice coverage.

Under all IPCC (2001a) emission scenarios, carbon dioxide concentrations, globally averaged surface temperature and sea level are projected to increase during the 21<sup>st</sup> century. By 2100, the projected concentration of CO<sub>2</sub> ranges from 540 to 970 ppm. The globally averaged surface temperature is projected to increase by 1.4 to 5.8°C over the period 1990 to 2100. Temperature increases are now projected to be greater than those stated in the SAR which were about 1.0 to 3.5°C, due primarily to lower projected sulphur dioxide emissions. Globally averaged annual precipitation is projected to increase during the 21<sup>st</sup> century, though at regional scales, both increases and decreases are forecasted, of about 5 to 20 per cent. Between 1990 and 2100, global mean sea level is projected to rise 0.09 to 0.88m, but with significant regional variations. Glaciers are also expected to continue their retreat and extreme events (e.g. storms, hurricanes, monsoons) likely to be more intense and more frequent.

There are however still uncertainties in some key factors, including the magnitude and patterns of long-term natural variability. The IPCC admits to an imperfect knowledge of:

- future rates of man-made emissions;
- the quantification of climate change at the global, regional and local levels;
- the exact response of climate and adaptation to changed concentrations of man-made emissions.

The IPCC emission scenarios do not include climate initiatives, such as the implementation of the UNFCCC or the emissions targets of the Kyoto Protocol. Uncertainties also result from model imperfections. The largest of these are humidity and cloud feedback (those factors affecting the cloud amount and distribution as well as the interaction of clouds with solar and terrestrial radiation). Others arise from the transfer of energy between the



atmosphere and ocean; the atmosphere and land surfaces; and between the upper and deep layers of the ocean. Nevertheless, according to the Third Scientific Report of the IPCC, models have significantly evolved since 1996, and they provide credible simulations of climate, at least down to sub-continental scales and over temporal scales from seasonal to decadal. On regional scales, there is some evidence of changes in some extremes and climate variability indicators. Some of these changes however, have been toward lower variability.

## **2.6 Impacts of Climate Change**

Scientists agree that the character of climate change and its effects are likely to vary a great deal from place to place. For instance, in some regions, precipitation will increase; in other regions, it will decrease. According to Houghton (1997), not only is there a large amount of variability in the character of the likely change, there is also variability in the degree to which systems respond to climate change. This is customarily referred to as variable sensitivity.

Among the expected changes in the earth's climate are higher global and regional temperatures, changes in the regional patterns of rainfall, snowfall and snowmelt, variations in the intensity, severity and timing of storm patterns and a wide range of other geophysical effects. These changes will have many secondary impacts on freshwater resources, altering both the demand and supply of water as well as changing its quality (Gleick, 1992).

Based on studies carried out by the IPCC (2001), changes in physical and biological systems have been observed in many aquatic, terrestrial and marine environments. These include: shrinkage of glaciers and ice-sheets, thawing of permafrost, lengthening of mid- to high-latitude growing

seasons, declines of some plant and animal populations and earlier flowering of trees and emergence of insects.

Warmer temperatures will also lead to a more vigorous hydrological cycle; this translates into prospects for more severe droughts and/or floods in some places and less severe droughts and/or floods in other places. Several models indicate an increase in precipitation intensity, suggesting a possibility for more extreme rainfall events. Figure 2.3 illustrates some examples of impacts due to projected changes in extreme climate events.

**Figure 2.3: Examples of impacts resulting from projected changes in extreme climate events.**

(Adapted from: Climate Change 2001: Impacts, Adaptation, and Vulnerability)

<b>Projected Changes during the 21st Century in Extreme Climate Phenomena and their Likelihood<sup>a</sup></b>	<b>Representative Examples of Projected Impacts<sup>b</sup> (all high confidence of occurrence in some areas<sup>c</sup>)</b>
<b>Simple Extremes</b>	
Higher maximum temperatures; more hot days and heat waves <sup>d</sup> over nearly all land areas ( <i>very likely</i> <sup>a</sup> )	<ul style="list-style-type: none"> <li>• Increased incidence of death and serious illness in older age groups and urban poor</li> <li>• Increased heat stress in livestock and wildlife</li> <li>• Shift in tourist destinations</li> <li>• Increased risk of damage to a number of crops</li> <li>• Increased electric cooling demand and reduced energy supply reliability</li> </ul>
Higher (increasing) minimum temperatures; fewer cold days, frost days, and cold waves <sup>d</sup> over nearly all land areas ( <i>very likely</i> <sup>a</sup> )	<ul style="list-style-type: none"> <li>• Decreased cold-related human morbidity and mortality</li> <li>• Decreased risk of damage to a number of crops, and increased risk to others</li> <li>• Extended range and activity of some pest and disease vectors</li> <li>• Reduced heating energy demand</li> </ul>
More intense precipitation events ( <i>very likely</i> <sup>a</sup> over many areas)	<ul style="list-style-type: none"> <li>• Increased flood, landslide, avalanche, and mudslide damage</li> <li>• Increased soil erosion</li> <li>• Increased flood runoff could increase recharge of some floodplain aquifers</li> <li>• Increased pressure on government and private flood insurance systems and disaster relief</li> </ul>
<b>Complex Extremes</b>	
Increased summer drying over most mid-latitude continental interiors and associated risk of drought ( <i>likely</i> <sup>a</sup> )	<ul style="list-style-type: none"> <li>• Decreased crop yields</li> <li>• Increased damage to building foundations caused by ground shrinkage</li> <li>• Decreased water resource quantity and quality</li> <li>• Increased risk of forest fire</li> </ul>
Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities ( <i>likely</i> <sup>a</sup> over some areas) <sup>e</sup>	<ul style="list-style-type: none"> <li>• Increased risks to human life, risk of infectious disease epidemics, and many other risks</li> <li>• Increased coastal erosion and damage to coastal buildings and infrastructure</li> <li>• Increased damage to coastal ecosystems such as coral reefs and mangroves</li> </ul>
Intensified droughts and floods associated with El Niño events in many different regions ( <i>likely</i> <sup>a</sup> ) (see also under droughts and intense precipitation events)	<ul style="list-style-type: none"> <li>• Decreased agricultural and rangeland productivity in drought- and flood-prone regions</li> <li>• Decreased hydro-power potential in drought-prone regions</li> </ul>
Increased Asian summer monsoon precipitation variability ( <i>likely</i> <sup>a</sup> )	<ul style="list-style-type: none"> <li>• Increased flood and drought magnitude and damages in temperate and tropical Asia</li> </ul>
Increased intensity of mid-latitude storms (little agreement between current models) <sup>d</sup>	<ul style="list-style-type: none"> <li>• Increased risks to human life and health</li> <li>• Increased property and infrastructure losses</li> <li>• Increased damage to coastal ecosystems</li> </ul>

<sup>a</sup> Likelihood refers to judgmental estimates of confidence used by TAR WGI: *very likely* (90-99 chance); *likely* (66-90 chance). Unless otherwise stated, information on climate phenomena is taken from the Summary for Policymakers, TAR WGI.

<sup>b</sup> These impacts can be lessened by appropriate response measures.

<sup>c</sup> High confidence refers to probabilities between 67 and 95%.

<sup>d</sup> Information from TAR WGI, Technical Summary, Section F.5.

<sup>e</sup> Changes in regional distribution of tropical cyclones are possible but have not been established.

The assessment of the impacts of global warming is made even more complex because global warming is not the only human induced environmental problem occurring. The loss of soil and its impoverishment, the over-extraction of groundwater, deforestation and the damage due to acid rain are examples of environmental degradation on local and regional scales that are already having substantial impacts. Many areas in the Mediterranean, for example regions in Greece and France are now severely eroded. In the Caribbean, accelerated soil erosion and its impacts are increasingly becoming a major problem. St. Vincent experiences very rapid sheet and gully erosion, aided by heavy rainfall whilst, in Antigua, erosion is common on both the limestone and volcanic hills. In Barbados, within the last twenty years, recurrent soil loss has been high on the steeper slopes of the Scotland District (see figure 7.3 for location). According to fieldwork conducted by the Barbados Soil Conservation Unit (1986), very high rates of soil loss, approximately 319.6 and 26.1 tons of soil/ha/year occurred from clay substrates, on bare and vegetated plots respectively. Deforestation is believed to contribute as much as 25 per cent of the increased carbon dioxide content in the atmosphere (Mannion and Bowlby, 1992). Estimates made in the early 1990s by FAO for tropical forests suggest that at least 0.6 per cent of these forests are lost annually. If these activities are not arrested, the negative impacts that are likely to arise due to global warming may be exacerbated.

Many uncertainties remain about the timing, direction and extent of climate change, and about their biological and physical impacts, as well as social implications. These uncertainties greatly complicate rational water resource planning for the future and have also contributed to the continuing intense political debate over how to respond to the problem of climate change.

## 2.6.1 Hydrology and Water Resources

The IPCC claim there are apparent increasing and decreasing trends in streamflow volumes in several regions. However, confidence that these trends are as a result of climate change is low because of factors such as the variability of hydrological behaviour over time and the response of river flows to stimuli other than climate change. In contrast, models project with high confidence that widespread accelerated glacier retreat will continue over the next hundred years. The rate of retreat will depend on the rate of temperature increase. The reduced extent of glaciers and depth of snow cover can also affect the seasonal distribution of river flow and water supply for hydroelectric generation and agriculture.

Changes in the climate may also lead to an intensification of the global hydrological cycle and can have major impacts on regional water resources. Changes in the total amount of precipitation and in its intensity directly affect the magnitude and timing of run-off and the intensity of floods and droughts; however at present, specific regional effects are uncertain. Relatively small changes in temperature and precipitation, together with the non-linear effects on evapotranspiration and soil moisture can result in relatively large changes in run-off, especially in arid and semi-arid regions (IPCC, 1996). The quantity and quality of water supplies already pose serious problems in many regions, including some low-lying coastal areas, deltas and small islands (often with single aquifers) making countries in these regions particularly vulnerable to any additional reduction in indigenous water supplies.

Soil moisture is often overlooked in climate impact studies, in part because of the difficulty of accurately modelling the stocks and flows of water in the ground. An increase in precipitation does not necessarily mean a wetter land surface or more soil moisture because increases in evaporation may exceed the increase in precipitation leading to a net drying effect (IPCC, 1990). Most climate models suggest large-scale drying of the earth's

surface over the northern mid-latitude continents in summer owing to higher temperatures and either insufficient precipitation increases or actual reductions in rainfall. Drying in these regions would affect both the agricultural production and other water demands.

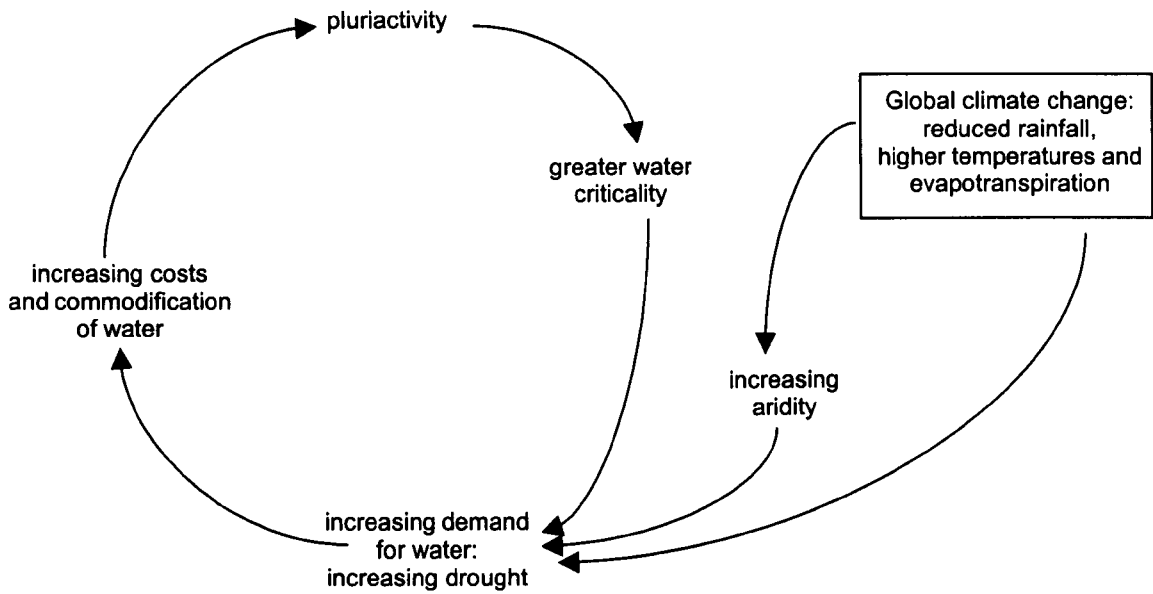
One of the most important hydrological impacts of climate change will be changes in snowfall and snowmelt behaviour. Temperatures increases in basins which have substantial snowfall and snowmelt at various times during the year will have three effects: 1) an increase in the ratio of rain to snow in cold months; 2) a decrease in the overall length of the snow season; and 3) an increase in the rate and intensity of snowmelt. As a result of this, average run-offs will increase. Peak run-off will possibly occur earlier in the year and there will be a faster and more intense drying out of soil moisture. One potential consequence of these effects is a substantial increase in the risk of floods – the greatest worry about increased temperatures being, increased probability and intensity of flood flows.

Another vitally important question is what will happen to the frequency and intensity of climate extremes. Of all natural disasters, tropical cyclones and typhoons are the largest killers, and 95 per cent of these deaths occur in the developing countries (Schneider, 1990). At the same time, intense monsoons bring much needed rain to countries like India during the growing seasons and without this rain, crop production is likely to decrease. There is some indication (Houghton, 1997) of possible reductions in day-to-day and inter-annual variability of storms in the mid-latitudes. But there is also contradictory evidence from other model simulations and empirical studies that the frequency, intensity and area of tropical disturbances may increase (Emmanuel, 1987). Although these and other changes in variability are likely, predictions of what will occur cannot be made with great confidence. Much more modelling and analytical efforts are needed in this area.

Lastly, freshwater run-off in rivers is crucial to maintaining human water supplies and natural ecosystems. Any changes in either the timing or the magnitude of run-off will have widespread ramifications for water supply, energy generation, human health, commercial and industrial development and environmental concerns. Less run-off in some places will increase pressures on remaining water supplies. More run-off could help water short areas or cause severe flooding. Further, in basins where demands for water are close to the limit of reliable supplies, such changes will have enormous implications for water supply and planning.

It is necessary to reiterate that uncertainties abound as regards exactly how climate change will impact water resources and it is perhaps this uncertainty that poses the greatest challenge to water resources management. This is partly due to limitations in the ability of large-scale climate models to incorporate and reproduce important aspects of the hydrological cycle. For example, the dynamics of clouds and rain-generating storms occur on spatial scales far smaller than can yet be modelled. At the same time, most hydrologic processes included in the models are far simpler than those in the real world (Gerholm, 1999). Despite these limitations, research in the last two years has revealed some important aspects about how hydrology and water supplies may be affected by climate changes as summarised in figure 2.4 below.

**Figure 2.4: Summary of Potential Climate Change Effects on Freshwater Resources**



Adapted from Watts (1997)

## 2.7 Climate Variation, Vulnerability and Impact in the Eastern Caribbean

Global and regional temperature and precipitation trends show that, for the Caribbean islands, average annual temperatures have increased by more than 0.5°C over the period 1900-1995; the seasonal data are consistent with this overall trend. Rainfall data for the same period show much greater seasonal, inter-annual, and decadal-scale variability, although a declining trend in average annual rainfall – of the order of 250 mm – is evident (IPCC, 2001b). Gray (1993) reports that, based on historical data for the Caribbean Sea, increases in sea-surface temperature of 1.5°C have been associated with an increase in hurricane frequency. Although there is some uncertainty in the data sample, projected increases of this magnitude represent approximately 40 per cent more hurricane activity than normal. More recently, Holland (1997) projected that the intensity of tropical cyclones could increase by 10-20 per cent under double CO<sub>2</sub> conditions.



However, as reported by the IPCC (2001b), given the constraints of scaling and resolution in the models with respect to small islands and the current status of inter-model agreement, such projections must be considered inconclusive at this stage.

Adaptive capacity is nevertheless generally low in small-island states, and vulnerability, high. These countries are likely to be among those most seriously impacted by climate change. Trinidad and Tobago and Barbados are particularly vulnerable to the effects of increases in temperature and sea levels because the populations, agricultural land and infrastructure are concentrated in the coastal zones. Possible impacts include:

- 1) Changes in precipitation effectiveness.
- 2) Coastal erosion and its implications for tourism and coastal resource management.
- 3) Salt water intrusion into water tables and its impact on potable water reserves and their quality.
- 4) Variations in agricultural yields and food production.

The potential socio-economic impacts of climate change on small-island developing states are the subjects of several vulnerability studies carried out by the IPCC. Trinidad and Tobago and Barbados are characterized by highly diverse ecosystems that are important as sources of food and as habitats for many species. Studies carried out by local environmental authorities suggest that exploitation of resources has led to a loss of resilience in the islands for coping with climate change and concomitant sea level rise. Indications are that a 1 metre rise in sea level would have severe negative impacts on tourism, freshwater supply and quality, aquaculture, agriculture, human health and settlements. In addition, low elevation reef islands and coral atolls are especially vulnerable to a rising sea level, rainfall, storm frequency and intensity. Inundation, flooding, erosion, drought and intrusion of seawater are among the likely impacts.

There have been varying degrees of effort at the national level in small-island states. Trinidad and Tobago and Barbados have ratified the UN FCCC and are acting to promote compliance through a co-ordinated series of projects. To date, the most significant initiative seeking to address the issue of climate change is that arising from the Caribbean Planning for Adaptation to Global Climate Change (CPACC) project being funded by the Global Environment Facility (GEF). Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Grenada, Jamaica, St. Kitts and Nevis, St. Lucia and Trinidad and Tobago are all participants.

### 2.7.1 Climate Change in Trinidad and Tobago

Certain sectors in Trinidad and Tobago are particularly vulnerable to changes in climate and sea level. These include the Caroni Basin, coral and other marine resources of Tobago, the freshwater resources, forestry and biodiversity.

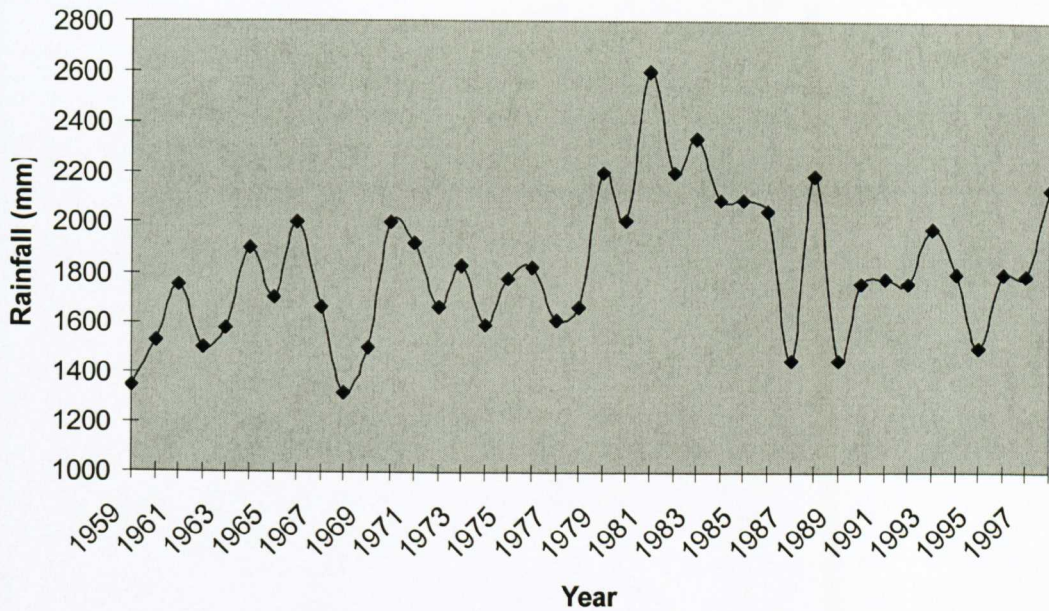
The Caroni Basin, an area located between the Northern and Central mountain ranges in Trinidad is already under threat from poor land use practices (see figure 5.2 for location). As a direct consequence, perennial flooding on the lower regions of the Basin already occurs. It is the most densely populated area of the country and also home to a concentration of critical biodiversity extending from the coastal mangrove and swamp fringes to the foothills of the forested Northern Range. In particular, the greatest reserves of surface and ground water that are used for supplying over 75 per cent of the island's needs are located here. The freshwater reserves in this region however are threatened due to siltation arising from upstream deforestation as well as pollution from a number of small-scale industries, particularly poultry rearing, quarrying, sugar cane and other forms of agriculture. Heavy rainfall together with extreme high temperatures could cause further erosion and silting, exacerbating the flooding in the Caroni basin and other low-lying areas.

Changing climate and sea level rise can alter the wetland areas through salt-water intrusion. Changes in the pattern and frequency of rainfall may cause shortages in freshwater supplies as these are mostly rainfall single-point sources such as boreholes (aquifers) or isolated reservoirs. The vulnerability arises due to the lack of redundancy in the system in the event of failure in primary sources.

Some evidence of changes in the climate has been observed from data, spanning approximately 40-50 years, gathered by the meteorological office at Piarco, Trinidad. The data show that within the last 10 years, conditions during the dry season were drier than normal, especially in 1988, 1995 and 1998. April in particular has become much drier within the last decade accompanied by a wide variability in rainfall patterns (figure 2.5). Occasionally, there has also been unusually heavy rainfall during the latter part of the year (September to December).

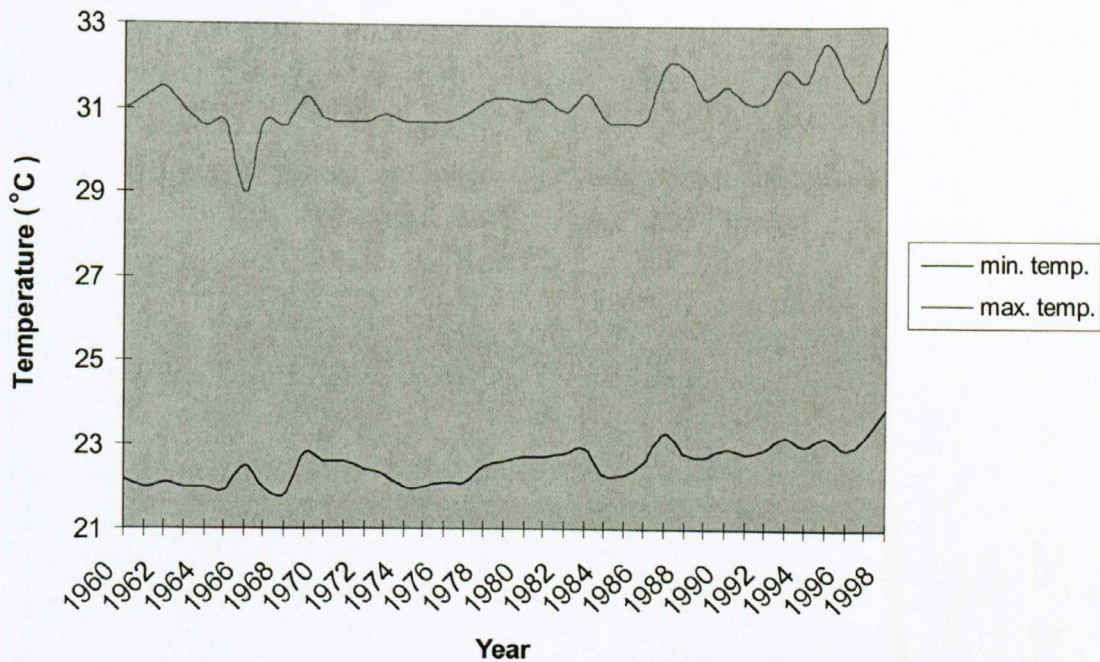
Indications are that generally temperatures have been increasing over the last 20 years or so. However it remains uncertain whether this increase has been consequential of natural climate variability or global warming. Figure 2.6 shows the temperature trends for the period 1960 to 1998.

Figure 2.5: Total Annual Rainfall for 1959-1998 for Trinidad and Tobago



Source: Adapted from T&T Met. Office Data (1959-1998)

Figure 2.6: Mean Minimum and Maximum Temperatures for 1960-1998 for Trinidad and Tobago



Source: Adapted from T&T Met. Office Data (1960-1998)

## 2.7.2 Climate Change in Barbados

Barbados, unlike Trinidad and Tobago is characterised by relatively scant seasonal and inter-annual precipitation. Fertile soils, vegetation and wildlife also tend to be scarce and the existing resources appear to be easily affected by changes in precipitation patterns and by human action.

At present, with an increase in global temperatures, the key changes in climate and other natural phenomena expected in Barbados are:

- 1) sea level rise;
- 2) decreased annual rainfall.

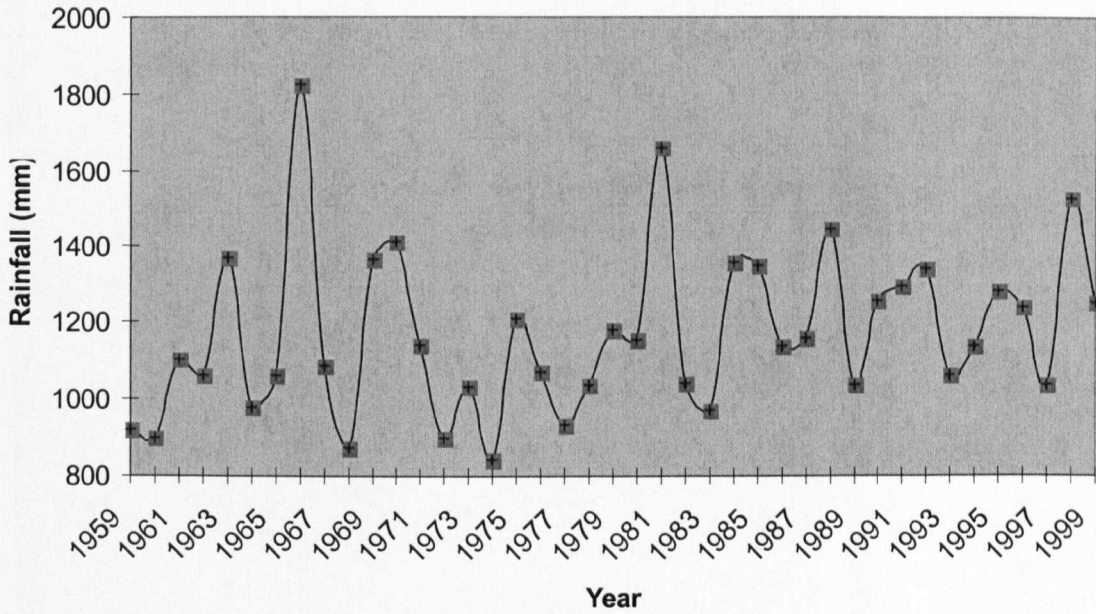
Other possible effects include:

- Convective precipitation intensities +1mm on rainy days;
- Longer, more intense droughts, especially in El Nino years;
- No major change in hurricane frequency, but strongest storms more intense.

Figures 2.7 and 2.8 illustrate the trends in annual rainfall and average maximum and minimum temperatures over the last 40 years respectively.

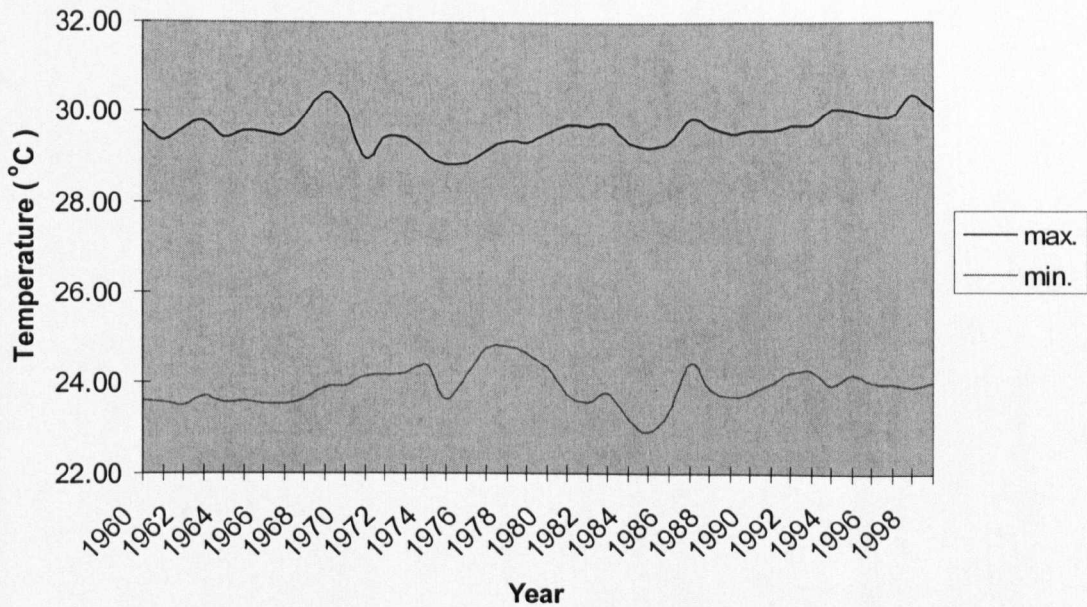


**Figure 2.7: Total Annual Rainfall for 1959-1999 for Barbados**



Source: Adapted from BMS (1942-2000)

**Figure 2.8: Average Minimum and Maximum Temperatures for 1960-1999 for Barbados**



Source: Adapted from BMS (1942-2000)

The implications of sea level rise are ranked most crucial since sea level rise can directly exacerbate the impacts of the other factors listed. For example, with groundwater acting as the only source of freshwater on the island, decreased rainfall means low aquifer recharge and increased chance of saline intrusion. Any increase in sea levels will move saline intrusion farther inland.

Based on known mean rates of tectonic uplift, derived from geological evidence for Barbados, as well as global and regional projections, a medium sea level rise (SLR) scenario of 5mm per year is considered to be the best current estimate (GOB, 2000).

The principal SLR impacts expected are:

- 1) coastal erosion;
- 2) inundation; and
- 3) salt water intrusion into coastal aquifers (salinization)

SLR induced erosion is expected to significantly impact water supply in the urban areas given that numerous wells which provide this supply are located in the coastal areas. Erosion may also damage water mains which could have serious implications for water quality and by extension, human health.

As previously stated, Barbados, a low coral island, without large natural bodies of freshwater, is completely dependent on its ground water supplies for domestic, agricultural and industrial purposes. All models for low limestone islands (e.g. Barbados, Antigua, Bahamas) and coral atolls show that a 1m rise in sea level would lead to salt water intrusion in the freshwater lens. Salinization of the island's freshwater lenses, in addition to the threat already posed by over-pumping, could therefore seriously endanger the availability of potable water on the island.

## **2.8 Managing under Uncertainty**

The global mean surface temperature has increased by  $0.6^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$  during the last century, of which 1998 is the warmest year on record since 1861 (IPCC, 2001a). This finding has not been widely challenged. But the IPCC's projected climate change scenarios, their effects and impacts continue to be the subjects of lively debate. The bases for the IPCC conclusions are presented in detail in the Technical Summaries for the Third Assessment Report (2001). Karlen (1993, 1999), Ahlbeck (1999) and Bottcher (1992) are just some of the opponents who question the relation between global warming and human activities, on the premise that observations for less than 20 years are far too short to establish whether or not human influence has contributed to global warming. Further, the scientific methods which are employed for the prediction of climate change are based on computerized numeric models that are still inadequate. Lack of data; the highly complex nature of the climate system; numerous assumptions and simplifications render the model predictions questionable. The largest limitations are due to the models' failure to deal adequately with clouds, humidity, soot and with the effects of ocean circulation. As a result, factors – such as regional patterns of changes in rainfall – that most influence the impact of climate change are as yet to be forecasted with certainty. Nevertheless, climatic models remain the best tools available and are capable of giving some useful and important information including general climatic trends.

According to the IPCC (1996, 2001) and Houghton (1997) some important general statements and conclusions can be made with reasonable confidence. Under a business-as-usual scenario of increasing carbon dioxide emissions this century, the rate of climate change is likely to be substantial. The most noticeable impacts are likely to be on the availability of water, on the global food production and on sea level rise in low-lying areas of the world (Houghton, 1997).



Exactly how Trinidad and Tobago, Barbados and the wider Caribbean region are going to be affected by global climate change is not precisely known at present. It is however envisaged that the impacts of climate change can be much more serious given the small size, high population densities, heavy reliance on forest reserves and agriculture as well as the generally fragile nature of the economies of the islands.

Expected effects, as suggested by Pastor and Fletcher (1991) include higher intensity rainfall in some areas and more powerful hurricanes. Higher siltations due to greater erosion may also warrant some consideration. Another possibility is the saline intrusion in the groundwater system, which will directly affect freshwater reserves. For the water resource manager, the risk to infrastructure is apparent and as the old adage recommends, "it's better to be safe than sorry".

The introduction of counter measures at an early date will create increased flexibility. The IPCC argues that "*the challenge confronting us now is not to find the best energy policy for the next hundred years but to choose a sensible strategy and then to gradually adjust in light of new knowledge*" (IPCC, 1996d, pp.20). The choice of mitigation and adaptation strategies is a matter of balancing the economic risk of postponing the measures, which may ultimately lead to more costly measures being required rapidly at a later date.

## **3.0 The Two Dimensions of Freshwater Management**

### **3.1 Introduction**

Conventionally, water has been taken for granted as a low-cost renewable resource. Until recently, an automatic positive correlation has been conceived between economic development and expansion of water supply capacity such that water sector engineers and managers anticipated water demand to rise linearly over time. The traditional view also held that eradication of 'water stress' was a techno-managerial problem to be resolved with the development of new sources of supply to meet changing demand for water provision. As Winpenny (1994) stated:

*"Faced with the evidence of future shortages of supply to meeting growing demand, the typical response has been to: commission a comprehensive study of resources; project the demand on an 'unconstrained' scenario; consider the various supply augmentation options; recommend that which meet projected demand at the least cost; and implement the scheme through public agencies, and at a subsidised price." (Winpenny, 1994, pp. 21-22)*

The 1990s have however witnessed the emergence of a critical debate regarding supply-led water management strategies. Concerns have grown over the environmental and economic costs of unrestricted infrastructure growth. At the same time, the global public sector was faced with a decaying infrastructure starved of vital investment, the scale of which was beyond government capabilities. This coupled with severe outbreaks of drought worldwide led to a new appreciation for water. An awareness of how little freshwater is actually available for use and our failure to manage the resource properly surfaced.

Prior to the late 1980s, governments and donor agencies tried to assure a minimal level of water services to as many people as possible, but under the new approach, the effective demand of consumers – their willingness to pay – will determine who gets what level of service.

### **3.2 Basic Needs or the Supply-driven Approach to Water Management**

Since the 1960s, both governments in developing countries and international donors have viewed water supply as an attractive area of investment. In evidence, is the shift in development assistance objectives and strategies in the 1970s by the World Bank, toward directing more aid to raising the standard of living of the poor, especially the rural poor. As an official World Bank document stated:

*“ The only practical hope, then, of reducing absolute poverty is to assist the poor to become more productive... A critical component of that approach is for governments of developing countries to provide better access for the absolute poor in their societies to essential public services, particularly basic education, primary health care and clean water.” (World Bank, 1980, preface)*

A manifestation of this policy revision was the World Bank commitment of some US \$3 billion since 1980, to water and sanitation projects in developing countries. Other economists and assistance agencies supported a basic needs strategy largely on moral grounds (ILO, 1977). They argued: the responsibility to ensure that the public, not just those with land and jobs, has access to the basic human needs, including water, resided with governments. Spurred on by the declaration of 1981-1990 as the United Nations Drinking Water Supply and Sanitation Decade, assistance from donor agencies to this sector began to increase. However, concern with the

“basic needs” explains not only *why* donors and governments increased their spending in this sector, but also *how* they delivered this assistance.

The international consensus was that access to less than 20 to 50 litres of safe and convenient water represented an unacceptable standard of living, and a health risk which would undermine the productive potential of households (World Bank, 1980, p.1). The consequent task for governments seemed obvious at the time: construct water schemes as rapidly as possible. The World Bank issued a document on the eve of the UN Drinking Water Supply and Sanitation Decade outlining its recommendations for tackling the problems of water supply (World Bank, 1980).

The following paragraphs provide synopses of the major points of this document as regards to the current thinking, at the time, on how governments should provide water services:

Lowering the costs of implementation represented one critical element in spreading coverage to as many people as possible, given available funds. The greatest scope for savings lay in choosing the minimum level of service appropriate for an area, for instance hand-pumps over piped systems in rural areas and communal standpipes over private connections in urban areas.

The second element in rapidly expanding water services was to build up the capacity of government agencies to appraise, implement and manage services. Offices would therefore need multidisciplinary staff in engineering, accounting, sociology and the like to plan programmes, conduct training, maintain spare parts and settle accounts. Attached to the offices should be a cadre of field workers to construct systems, undertake repairs and carry out general fieldwork.

The final element in meeting the basic supply of water would be subsidies. The general opinion held for both urban and rural areas was, “...especially

for the poor, willingness to pay can only be a partial indicator of value...” due to health externalities (World Bank, 1980, p.13). In order for urban systems to be self-financing, tariffs and management have to be structured so that the wealthier consumers would subsidise minimum services to poorer consumers. The government would have to provide subsidies to recover full capital costs or even some operation and maintenance costs.

### **3.3 Four Principal Failures**

Because water was, and still is considered a strategic resource and a public good, governments have always assumed central responsibility for its management. The variable quantity and quality of water and the highly interdependent character of water activities make it difficult to use unregulated markets to deliver water efficiently or to allocate it among sectors. Although reliance on market forces alone is not possible or even desirable, government mismanagement of water has led to serious misallocation and waste. Serageldin (1995) has identified four principal and related problems in the way governments have managed their water resources.

First, water management has been fragmented among sectors and institutions, with little regard for conflict or complementarities among social, economic and environmental objectives. There are multiple agencies for different uses – for example, irrigation, municipal water supply, power and transportation – and intersectoral relations within an interdependent system are usually ignored. Issues of water quantity and quality and concerns about health and the environment are treated separately, as is often the management of surface water and groundwater.

Second, there has been a heavy dependence on centralised administration to develop, operate and maintain water systems. This has resulted in

efficiency problems. The number of employees working in water utilities is one symptom of the problem. Typically, employees per 1,000 water connections range between 10 to 20 employees in inefficient utilities compared to 2 to 3 employees in efficient utilities. The agencies responsible for water management are severely overextended and have limited technical capacity to provide quality services. There is little stakeholder or private sector investment in water activities and consumers themselves are rarely consulted or otherwise involved in planning and developing the water sector. Too often, the result has been unreliable projects that have produced services which do not meet consumers' needs and for which they are unwilling to pay.

Third, most countries do not treat water as an economic good. Low-value users are allowed to consume large quantities of water paying little or nothing for it. The result is waste and depletion of the water resource base. The fact is, it is far easier politically to develop new water supplies than to charge constituents for water, resulting in investments in infrastructure that are not economically or environmentally sustainable. Farmers, for example, have few incentives to refrain from growing water-intensive crops or to conserve water because they often pay little or nothing for their water. Water is under-priced in most developing countries confronting users with little incentive to conserve. A 1993 review of World Bank-financed water supply projects found that the price charged for water covered only about 35 per cent of the average cost of supplying the resource. Irrigation charges are almost always far less – nil in the case of Trinidad and Tobago as the agricultural customers abstract water for irrigation from nearby streams or aquifers by their own means free of charge; and in Barbados, BD\$0.33/m<sup>3</sup> if supplied by the Barbados Water Authority's wells or BD\$0.44/m<sup>3</sup>, if supplied by the Barbados Agricultural Development and Marketing Corporation.

Serageldin (1995) maintained that the absence of financial discipline negatively impacted the incentives and accountability of public authorities

to provide high quality services, especially to the poor. As previously discussed in Section 1.4.6, of all the infrastructure sectors, water has the least cost recovery (figure 1.2), making this sector more dependent on public budget funds. Further, contrary to conventional wisdom, lack of pricing or under-pricing of water has a disproportionately negative effect on the poor, yielding a vicious cycle of unreliable service, low willingness to pay and further decline in capacity to provide services. Poor people who do not have access to mainstream water services often pay far more than everyone else does for the sub-standard services they receive. World Bank studies (1993) revealed that in most cities of the developing world, people who do not have access to water pay ten times more for it than people who have taps in their homes.

Finally, traditional water management practices have neglected linking the quality of water with health, the environment and economic development. Environmental degradation of water resources no doubt will cause problems and burden future generations with the costs of remedial actions.

Kleemeier (1995) opined that the previous approach to provision of water services would most aptly be termed 'basic needs approach' because it formed part of assistance programmes which were targeting aid at directly meeting the basic needs of poor people. At that time, the consensus was that governments and donors should try to alleviate poverty, especially in rural areas *inter alia* through providing potable water and that this social service should be largely free, at least in regard to capital costs. This approach is more often labelled 'supply-driven' in order to contrast it with the new 'demand-driven' approach.

### **3.4 Demand-driven Approach to Water Management**

Forty years ago, Hirschleifer wrote his seminal book *Water Supply: Economics, Technology and Policy* (1960) in which he criticised the conventional supply fix approach to water resources management. He characterised water managers in the USA as engineering empire builders who:

*“cast themselves in heroic mould as battlers for the cause of pure and adequate water...”*

and who neglected the much more drab prospect of improving the efficiency of water use by reducing waste and rationalising pricing procedures. The traditional supply-side options for meeting forecast demand increases – such as installing large capacity facilities to provide security against relatively rare drought conditions – favoured by water engineers may be seen as a predictable response given their training in providing engineering solutions and the conventional position taken by the industry to avoid public supply restrictions if at all possible. But, since the late 1970s and the introduction of the concept of sustainability, a softening of the supply-fix philosophy has been evident. Even before sustainable development had captured popular and political rhetoric, Hirschleifer questioned the sustainability of a management strategy which required the construction of increasingly more costly water collection and transmission facilities.

Yet, in 1986, Boland reported that:

*“...in the USA as elsewhere, it is the practice of the water industry to manage supply so as to satisfy demand at all times.” (Boland, 1986, p.37)*

In a similar vein, as recently as 1990, Brooks et al. wrote that in Canada,



*“...unlike most natural resources, water has generally been treated as something close to a free good.” (Brooks et al., 1990, p.40)*

Although all the writers quoted above were writing from a North American perspective, the analyses and conclusions are equally pertinent to Western Europe and indeed to virtually all of the developing world. It would however be wrong to suggest that water managers are still wedded to supply enhancement without regard for supply efficiency. Attitudes and management practices have undoubtedly been changing. Indeed they have had to do so, not only because of financial strains caused by the burden of continued capital investment and operating costs, but also due to diminishing supplies of readily accessible freshwater.

Further as Rees (1976) explained, other crucial elements need to be considered:

1. Reservoir development involves significant losses of agricultural areas, and land with recreational and other development potential. This is particularly important in the case of lowland reservoirs, which are shallow and must inundate large areas of land to achieve the required capacity.
2. Social disturbance results from some schemes, which may involve the flooding of small rural communities.
3. Adverse effects on the ecology or landscape value of the areas may result, although any attempts to measure the environmental costs of reservoir schemes are likely to be highly subjective.
4. Public opposition to new schemes is almost inevitably great and this in itself can incur large legal and administrative expenses.
5. Finally, it can be argued that premature investment in traditional supply facilities may incur costs by not allowing advantage to be taken of possible technological improvements, such as a breakthrough in the costs of desalination.

In view of all of these costs, many water supply authorities began investigating the possibilities of controlling the size of supposedly needed extra capacity, both by obtaining an increase in effective supply from existing facilities, and by managing the demands for water over time.

Noticeably, the shift in approach started in the later part of the 1970s when many developing countries experienced very poor growth and huge balance of payments deficits. The World Bank and other consultants attributed this largely to domestic policies and institutional arrangements that ignored or distorted prices. To restore growth, governments would have to initiate a process of structural adjustment, including measures such as restraining public expenditure, removing subsidies and allowing the private sector and market forces to deal with some of the functions previously carried out by government agencies (World Bank, 1981; 1984).

In so doing, the objective and main elements in the basic needs approach were altered to form a new strategy – the demand-driven approach. The differences between the two approaches are summarised in Figure 3.1 below.

**Figure 3.1: Major Differences between the Two Approaches to Water Management (adapted from Kleemeier, 1995)**

Aspect	Basic Needs Approach	Demand-driven Approach
Objective	Provide clean and convenient water supply to as many people as possible	Provide improvements to water supply which communities are willing and able to pay for
Service Level	Minimum service level (hand-pumps, public taps)	Service level provided which communities are willing to pay for
Role of Government	Appraisal, design, construction and maintenance, training	Mainly information, advice, regulation, training (most appraisal, design, construction operation and maintenance shifted to private sector)
Financing	Donor/government pays full capital costs, and subsidizes operation and maintenance in rural areas and other areas where necessary	Public/communities pay full capital, operation, and maintenance costs; possible subsidies on capital costs in low population/very low income areas

Originally, the long-run objective had been to improve the health of households through providing convenient and safe water. These health benefits justified heavy public investment, since households on their own might not be willing or able to make the investment. By the late 1980s however, critics began to argue that the health benefits from improved water sources only manifested themselves in the long-term and if many other changes were also made. Besides, there were less costly means to improving health. Briscoe and de Ferranti (1988) estimated that up to 1988, governments and donors were spending about US \$1.5 billion a year,

just on rural supply in the developing world. By the early 1990s, the World Bank had officially adopted the new approach to water supply. “Health benefits alone do not generally provide a rationale for public subsidy of water and sanitation” (World Bank, 1993, p.13). Rather, the benefits from improved water supply were those perceived by the beneficiaries, for example, time saved in water collection, or improved colour, taste or odour of the water, and such benefits should be financed by the consumers themselves (Serageldin, 1994).

The immediate objective therefore was not to supply everyone with minimum services, but to provide the desired level of service to those who were *‘willing to pay’*. This changed the perspective on how to lower costs. Previously, costs were kept down by providing a minimum service level, such as hand-pumps or public standpipes. Now the issue has changed to cost efficiency for each level of service delivery. Proponents argued that removing government subsidies by having consumers pay for their service would in itself promote this. One net result of the massive public investment in water supply had been “... bloated public agencies with low accountability to their customers and few incentives for improving efficiency” (World Bank, 1993, p.93). Making consumers pay would create such stimulus and accountability.

This new approach was based on evidence and research which documented that not only were poor people willing to pay for water, but, most of them were already paying high water rates through purchasing water from truck-borne vendors in urban areas. In other words, subsidies made to the water sector for the purpose of extending services to the poor were not actually reaching them. In practice, subsidies benefited mostly the well-to-do and also encouraged inefficiency as described above.

This scenario coupled with the dramatic elevation of environmental concern, is promoting a more integrated approach to water resource management. Rather than merely focusing on technical fix-it solutions

through massive supply-side investment, the efficiency of water systems through production, through distribution, supply and use is being more closely scrutinised. In the UK, a Department of Environment (DOE) publication, *Using Water Wisely*, set the new framework for debate around the management of water resources by arguing for substantial demand-side intervention:

*“We should not take it for granted... that the only answer to existing or predicted water shortage should be major increases in supply, especially when under the present charging system the extra costs of such supply would be spread across the bills of most customers according to property values and not related to the extra volume they are consuming. The better course may be action to cut waste or reduce demand.”* (DOE, 1992b, p.3)

*Using Water Wisely* identified a number of priority areas where demand management initiatives, also applicable outside the UK could help alleviate zones of water stress. These include reducing leakage levels, water recycling, reuse and more widespread metering.

Mediating the impact of new and expanding development on water infrastructure networks through demand management can make a vital difference to the resulting water system, allowing scope for the introduction of more environmentally sustainable water resource management and local economic development.

There is little doubt that better performance by providers of water services and more efficient use of water by beneficiaries can improve allocation of water among different users and achieve greater conservation. Performance and efficiency can be enhanced through proper incentives – the most important of which are based on price.

### **3.5 Efficiency in Water Use**

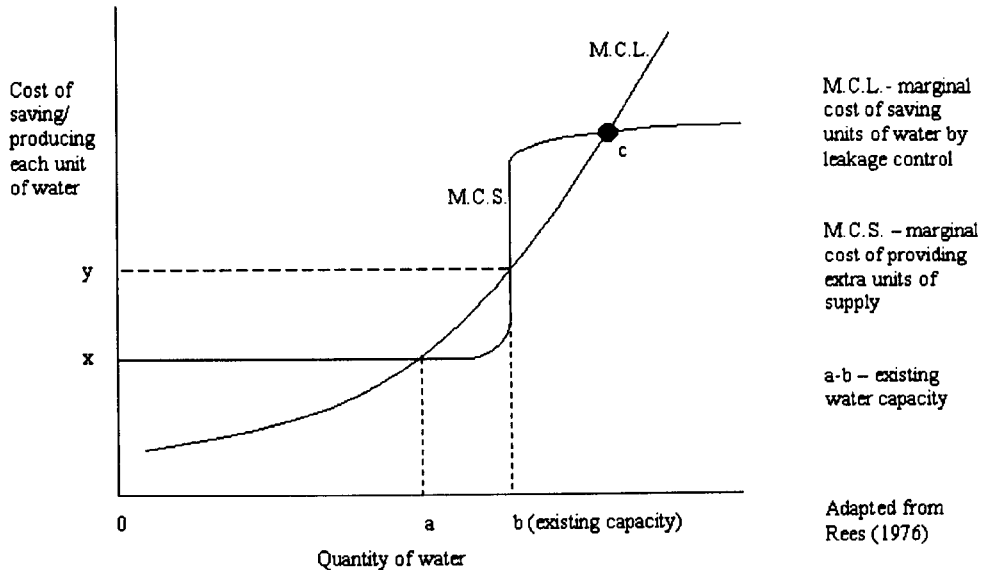
A range of techniques exist which make it possible to defer expenditure on new supply facilities. These include integrating the operation of reservoirs to allow transfers of supplies to meet varying local needs; reducing distribution losses in the supply system; providing non-potable water for uses which do not require a high quality supply and encouraging water re-use. Not all of these approaches have practical relevance to the cases of Trinidad and Tobago and Barbados; the ones that do however are discussed below.

The greatest losses from the water supply networks in Trinidad and Tobago and Barbados occur through pipeline leakage. Although expenditure on leakage detection and prevention is now increasing, losses remain high. At a minimum, they amount to over 40 per cent in Trinidad and Tobago and Barbados.

It is never physically or economically possible to eliminate all leakage. Nevertheless, an active and efficient waste detection programme can produce a marked reduction in loss levels. To this end, a systematic and economically rational approach must be taken to establish the appropriate level of expenditure for leakage detection in any time period.

The theoretical answer to this is that detection efforts should continue until the marginal cost of saving water equals the additional cost of supplying an extra unit of water. This is shown diagrammatically in figure 3.2, adapted from Rees (1976).

**Figure 3.2: Optimal Expenditure on Waste (leakage) Detection**



In principle, the cost of saving further units of water rises as the total levels of leakage decline (M.C.L. on figure 3.2). This means that some leakage will always be economically desirable, as there is no justification to using further labour and capital resources to eliminate leaks when the resource costs exceed the resulting benefits.

The value of the water saved depends on whether the supply network is operating below its reliable capacity, or whether new facilities are needed. In the short run, where the supply network is operating at less than optimal capacity, savings will be confined to the variable costs, comprising the main pumping and treatment expenses. All fixed costs, including interest on borrowed capital must be ignored as they remain the same irrespective of the quantity of water used. As a consequence, over the short run, these marginal variable costs are normally lower than average costs. However, once the need for new capacity is perceived, the savings from leak detection will be much greater as all costs (the long-run marginal costs) of adding units to the available supplies must be considered. It is therefore uneconomic to invest in new facilities if an effective supply increase (or an

apparent decline in demand) is attainable at less cost, e.g. through improvements in waste control.

As figure 3.2 shows, the savings that result from waste detection escalate when the limits to existing capacity are neared. Before embarking on capacity expansion, it would therefore be rational to increase the waste control effort to point "c", since up to this level the costs of saving extra units are below the costs of expanding facilities. The long-run optimum is where equilibrium between marginal expenditure on detection and marginal supply cost is attained and maintained. Officials at the water supply authorities in Trinidad and Tobago and in Barbados verified that they are not yet pursuing leakage control activities to anywhere near this optimal level, thus leaving considerable scope for improvements. This however will involve a change in attitude towards waste control as it is generally regarded as the "Cinderella of the distribution function" (Giles, 1973:2), so much so that some engineers consider themselves to be failures in the industry if assigned to leak detection rather than supply development work.

Efficiency of water usage can also be improved if customers use the appropriate quality of water for the task at hand. Potable water is often used for industrial processing, toilet flushing and garden watering, all of which can be adequately served from lower quality sources. Rees (1976) claimed that in most industrialised societies only between 10 and 25 per cent of water is used for functions requiring high purity and yet, the overall quality of municipal supplies is often dictated by this usage. The costs of providing such high quality for all purposes are high, usually much greater than is generally realised. Not only are extra treatment costs incurred, but additional expenditure escalates if capacity has to be expanded or developed some distance away from the demand centres.

Piped non-potable supplies are provided for a few large industrial customers in the UK and the USA. No such systems exist in Trinidad and Tobago or in Barbados. The development of widespread dual quality



systems has been resisted on two main grounds: the potential health dangers, and the high cost of duplicating distribution networks. Rees (1976) purported that the likelihood of any adverse effects on health are absolutely minimal as the non-potable quality would be disinfected and occasional inadvertent use would not create any problems. In Hong Kong, where sea water is provided for toilet flushing in many government-built high rise blocks and in Australia, where some New South Wales towns have a non-potable supply for all uses of water outside the home, such as garden watering and car washing, no health problems have been reported.

Rees (1976) further contended that the extra distribution costs incurred in developing dual supplies are generally below the cost of constructing new potable water reservoirs. It is unlikely that it will be economically feasible to redevelop completely the existing systems in heavily built-up areas, but potential for economical dual supply systems exists where new towns and housing zones are being developed as well as where industries are clustered together. Okun (1972) claimed that provision of two water qualities for new towns only increases the distribution costs by 20 per cent and this cost differential can be further reduced, for example, where population densities are high. Again, the extra costs of dual supply systems must be compared with the long-run marginal costs of expanding conventional potable supply facilities.

### 3.5.1 Managing the Demand for Water

As previously stated, it has been normal practice in the water industry to assume that all water requirements have to be met. In addition, the popular view has been that the level and rate of increase in water requirements are exogenously determined and are outside the control of the supply authorities. However, it is now widely recognised that although water usage is dependent on consumer habits, income levels and other related

factors, the supply authorities can exert a considerable influence on usage patterns.

There are a number of physical measures which could be taken to reduce the quantity of water demanded. These include the redesign of toilets and washing machines; installation of in-house storage tanks to facilitate re-use and restrict the level of garden watering. More so, the price mechanism can be employed both to reduce current consumption levels and to control the rate of increase in demand over time.

However, in applying the price mechanism to studies pertaining to supply and demand of water resources, understanding the economic theory is critical.

### **3.6 Consumer Demand Theory**

Increasingly knowledge and incorporation of the various elements of consumer demand theory are becoming important. Inadequate and inaccurate information on the levels of demand for water can adversely affect project design, in terms of technological choice, levels of service, the timing and scale of capacity extensions as well as the pricing structure. Not only is it possible to misallocate resources, the financial viability of the water system may be seriously misconstrued. Significant shortfalls in revenue and inability to attain cost recovery targets are commonplace, reducing capability to adequately finance repairs and maintain system operations. If water supply systems are to be both sustainable and replicable, an improved planning methodology is required that includes a procedure for eliciting information on the value placed on different levels of service. A key concept in such a methodology, which has already been referred to several times, is 'willingness to pay' (WTP). Consumer willingness to pay for a particular service is a clear indication that the

service is valued. Consequently, continued use is almost guaranteed and through proper pricing of the service, most likely, the funds required for sustaining and improving the service will be generated.

### 3.6.1 The Theory

Economic theory suggests that an individual's demand for a good or service is a function of: 1) the price of the good or service, 2) prices of substitute and complementary goods or services, 3) the individual's income and 4) the individual's tastes (measured in terms of the individual's socio-economic characteristics such as age, gender, wealth).

According to Mitchell and Carson (1989), demand in the traditional economic sense refers to the schedule of quantities that consumers would use per unit of time, at particular prices. It is assumed that the good is traded freely in a competitive market. In other words, it is a pure private good as opposed to a quasi-private (recreation parks) or pure public (water, air) good. Further details are explained in figure 3.3 below.

**Figure 3.3: Classification of Goods**

Class of Good	Characteristics	Example
Pure private	Ability to exclude potential customers in a competitive market	Beer, food
Quasi-private / quasi-public	Ability to exclude potential customers; Not traded freely in a competitive market	Recreation in parks
Pure public	Cannot exclude potential customers; Not traded in any organised market	Air, water, visibility, national defence

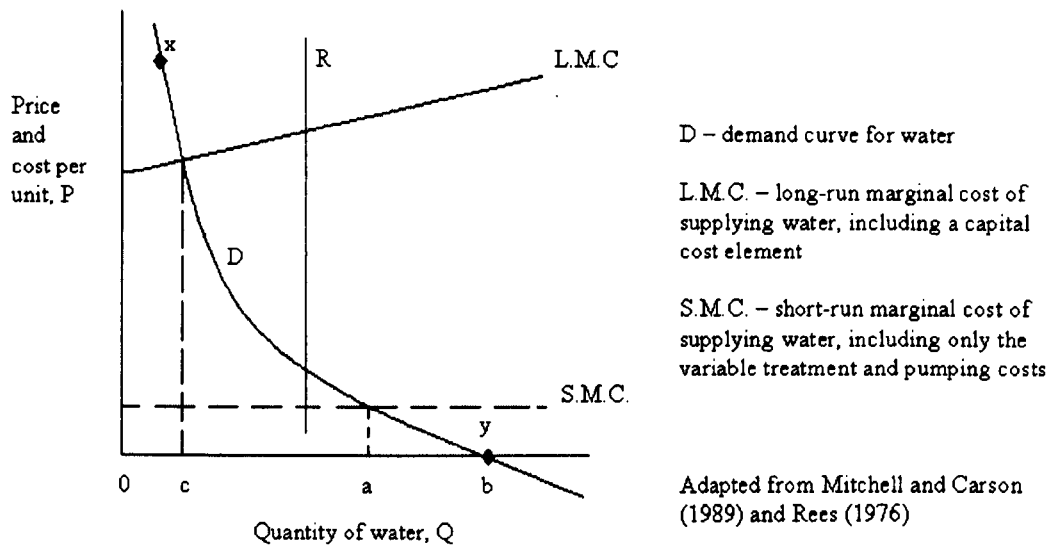
Adapted from Mitchell and Carson (1989)

Consumer demand theory as it relates to water therefore incorporates general economic theory and also the specificities of water as a public good.

In economic modelling, a distinction is made between 'demand' and 'requirement'. However, in general discussions of water usage, the term 'demand' is often used interchangeably with 'requirement' thus confusing two ideas that should be kept separate. Demand is a concept used by economists to denote the willingness of consumers or users to purchase goods or services, since that willingness varies with the price of the item being purchased (Kindler and Russell, 1984). In other words, demand refers to the quantity of a good or service a consumer is prepared to take at a particular price (as Curve D on figure 3.4 shows). It is generally found that for virtually every good, as price per unit increases, the quantity demanded decreases. Consumers indicate the value of a good by the price they are willing to pay for it.

When water is scarce, consumers are usually prepared to pay more and will reserve it for 'high value' uses such as drinking and basic hygiene ('x' position, figure 3.4). As more water becomes available, it will be used for progressively less valued tasks until with abundant supplies, consumers use water as if it has no value to them at all ('y' position, figure 3.4). The price charged for water services is therefore an important factor affecting the level of demand.

**Figure 3.4: Variation of Price/Cost with Quantity Water Used**



However, a requirement refers to an item that does not obey this rule. When ‘requirements’ are calculated, price is not regarded as a determining variable. It is assumed either that the quantity used will be the same irrespective of the price charged, or that the future price will remain at the same levels as in the past, in which case it will not affect the trend in consumption over time. This is illustrated by the line R in figure 3.4.

Further, there are many things in life that are unresponsive to price. Water is one such product and it is described as having an ‘inelastic demand’. Demand elasticity refers to a measure of the responsiveness of quantity taken/purchased to changes in the determinants of demand, for example, price. If the demand is inelastic, as the price of the good increases, so too will consumer expenditure. In other words, the good will still be purchased over a very wide price spectrum.

### 3.6.2 Consumer Demand Theory in Developed Countries

Most of the models designed to analyse consumer demand for water have been developed to fit North American and Western European countries.

These econometric models estimate and simulate consumer demand for water, emphasising the variability of per capita consumption and exploring the relationship between water rates or consumer income and water usage. However, the hypotheses of these models are not universally applicable since water-use behaviour in industrialised countries differs significantly from that in developing countries.

The model developed by Grima (1972) postulated that there are six major factors which influence consumer demand for water: physical factors; family income; other household characteristics; the type of service; management and cultural factors. While this model is useful in providing some of the explanatory variables which can be tested to determine a household's usage of water, the validity of the hypothesized relationships is questionable in the developing world context. The model is limited in its application to the developing world because it is based on the following assumptions:

- 1) all consumers have a piped in-house water service;
- 2) there is a single source of water (the municipal agency) for all households and;
- 3) all consumers have a metered supply.

These conditions do not hold true for most developing countries. Academics such as Fourt (1958), Howe and Linawear (1967); Linawear, Geyer and Wolff (1967), Sewell and Roueche (1975) have all done research relating to consumer demand models for municipal areas in Canada and the USA. But these models too have little relevance to the developing world.

### 3.6.3 Consumer Demand Theory in Developing Countries

In light of the limitations of the earlier theories, Whittington, Briscoe et al (1987) have developed models to explain consumer demand for water in developing countries. Most of the information used to advance their ideas was culled from households' WTP for water services in less industrialised nations, enhancing the relevance of their models to those countries.

Although the theory advanced by Whittington et al (1987) is predicated on similar explanatory variables to the model developed by Grima (1972), the basic assumptions differ as follows:

- 1) the level of service varies in developing countries;
- 2) several sources of water exist and;
- 3) water supply may be metered or un-metered.

Based on these main assumptions, the Whittington et al (1987) model was developed to include factors such as household's socio-economic characteristics; level of service; source characteristics; consumer's tastes and perceptions of water quality; culture and price for water.

Figure 3.5 lists the various influences on water usage as suggested by Whittington et al (1987).

**Figure 3.5: Influences on water usage according to Whittington et al model (1987)**

1. Household Socio-economic characteristics	<ul style="list-style-type: none"> <li>• Household income</li> <li>• Expenditure patterns</li> <li>• Household size and composition</li> <li>• Length in residence</li> <li>• Age of household structure</li> <li>• Education, gender, age of household members</li> </ul>
2. Source characteristics	<ul style="list-style-type: none"> <li>• Level of service</li> <li>• Reliability</li> <li>• Pressure</li> <li>• Quality</li> <li>• Time</li> <li>• Distance</li> <li>• Cost</li> </ul>
3. Price charged	
4. Perceived water quality (taste, colour, odour)	
5. Climate	
6. Culture	

Whittington, Briscoe et al (1987) examined in detail how these variables affected water consumption by the user. Some of the main findings included:

- 1) *Positive relationships were observed between the amount of water demanded and income available, household size and education level respectively.*
- 2) *If the water source is outside the home, and consumers must queue to fill containers and carry these to their homes or they receive*



*truck-borne supplies, less water is used. Water is used primarily for basic needs/functions and wastage is minimal.*

- 3) The amount of water consumed depends on whether water charges are flat rates or are volumetric-based. Where meters are absent, consumers use as much water as desired.*
- 4) Household habits such as lawn watering, cleaning, washing are also influenced by the climate and culture.*

### **3.7 Pricing Systems in the Eastern Caribbean**

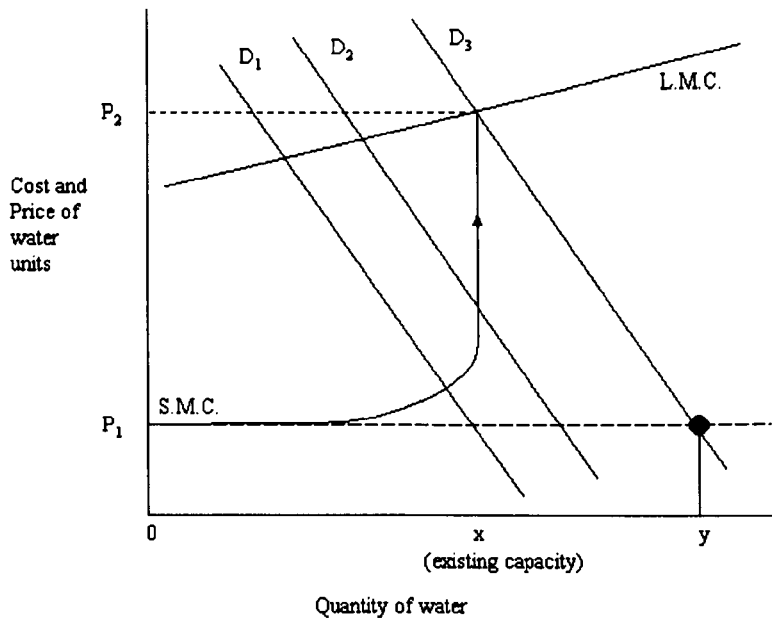
In the case of Trinidad and Tobago, the present arrangements for pricing water contain a number of elements which suggest consumers are currently using excessive quantities of water, in the sense that the costs of providing the water exceeds its value to the user. This position arises whenever the price paid per unit of water lies below the unit cost of supply, a situation which certainly occurs amongst domestic consumers. Water is supplied to this group of users against the payment of a flat rate charge, which, subject to availability, entitles them to take as much or as little as they like. The payment is, therefore, a service charge, and the unit price for water is zero. There is no incentive to avoid waste by such simple expedients as replacing worn washers or turning off taps during tasks like rinsing wares or clothes. There is also little or no encouragement to economise by installing water-saving equipment such as sprinkler taps or dual-flush toilets. The crucial point is that consumers are allowed to neglect the facts that water is not a free good and can only be provided at a cost.

As figure 3.4 shows, when existing capacity is under-utilised, the cost of providing extra water units will normally be small, covering only the additional expenditure on treatment and distribution. In this case, a-b units would be supplied at a cost which exceeds their value to the user. However, if new capacity must be constructed to provide an increase in

supplies, then the supply costs escalate as the investment expenditure must also be taken into account. These provision costs, shown by the curve L.M.C. will normally rise as the quantity supplied increases, because the cheapest, most accessible storage sites are invariably developed first.

If the pricing system were changed to allow unit charges to reflect the long-run supply costs, excess usage would be reduced and thus it should be possible to delay the need for investment in additional capacity for a number of years. This is shown diagrammatically in figure 3.6. With a zero unit price for water, it would be necessary to extend available capacity before year 5. But if the equilibrium price ( $P_2$ ) was charged, then the extensions could be delayed until year 13.

**Figure 3.6: Pricing Policy and Capacity Extension**



Adapted from  
Rees (1976)

In figure H above,  $D^1$ ,  $D^2$  and  $D^3$  represent demand curves for water at different periods of time: year 5, year 9 and year 13 respectively. Hypothetically,  $D^1$  is equal to the demand for water in year 5;  $D^2$  equals demand in year 9 and  $D^3$ , that in year 13. S.M.C. is the short-run marginal cost curve or running cost curve. This is usually low and will not increase until the limits of existing capacity are neared. Beyond that point, it rises

steeply becoming vertical at full capacity. L.M.C. is equivalent to the long-term marginal cost curve i.e. the costs of expanding existing facilities.

In Trinidad and Tobago, the water supply authority recoups the costs of capacity expansion by increasing the annual fixed charge paid by domestic customers and some commercial and industrial customers.

Normally, industries pay for water on the basis of the quantity taken. But even in this case the price per cubic metre/gallon is relatively low because they are calculated on the historic accounting costs of building supply facilities. Rees (1976) claimed that the use of past cost pricing suggests the likelihood that industrial demands are inflated and that often additional capacity is developed prematurely to meet apparent industrial needs.

In order for the price mechanism to be used to encourage economy in water use, it is essential for consumers to be metered and charged on a quantity-taken basis. This is the pricing system currently employed in Barbados.

The introduction of domestic metering has so far been rejected in Trinidad and Tobago. Although metering is technically feasible, four main arguments have been put forward to justify its continued rejection. The first is that water is a basic necessity and any attempts to restrict consumption can adversely affect health and hygiene standards. However, indications from countries where consumers are metered, including Barbados, show that there is little evidence to support this contention. A second argument against metering is that water 'should' be provided in abundance as a human right. This is a value judgement and it is difficult to rationalise why water used in a swimming pool, for example, should qualify as a human right when clothing does not.

A third anti-metering argument that directly contradicts the first is that householders will be completely unresponsive to price changes. If this were true, consumers in Trinidad and Tobago would be completely atypical

as evidence abroad suggests that the installation of meters produces an immediate and permanent decrease in consumption of between 20 and 50 per cent (Rees, 1973). Evidence from as far back as 1900 when meters were introduced in The Hague, demonstrates the drastic and lasting effect of metering on consumption. According to Wijntjes (1974), it was not until 1965 that per capita consumption reached the pre-metering level in The Hague. Similarly in Boulder City, Colorado, Hanke (1969) demonstrated that domestic water usage was reduced by 40 per cent. Information from the Barbados Water Authority indicates that metering in Barbados produced an initial reduction of about 19 per cent and an anticipated sustained average reduction in demand of about 10 per cent.

Although it is difficult to extrapolate from overseas evidence and determine exactly what percentage decrease in consumption may be expected in Trinidad and Tobago as a result of unit water pricing, it is certain that a significant reduction will occur. Nevertheless, per capita usage will increase in response to rising incomes and levels of development; metering will not stop this process, but it does appear to produce a permanently lower consumption trend over time.

The final argument against metering and perhaps the strongest is that, although users will reduce their demands, the savings to result from delaying the development of new capacity will be outweighed by the high cost of metering.

The Barbados case study directly refutes this argument. At inception in 1968, the implementation of a phased universal metering programme was estimated to cost BD \$2 million in total capital expenditure and BD \$80,000 in recurrent expenditure. In 1996, average capital investment was BD \$5.7 million and operating expenses, BD \$39.12 million. Gross annual revenue was reported at BD \$40 million, with the cost of production of water estimated at BD \$0.67/m<sup>3</sup> and an average revenue generation of \$0.73/m<sup>3</sup>. Most of this income was generated from metered customers,

who only accounted for 20 per cent of consumption by volume at that time and 30 per cent of the total number of customers.

The validity of this assertion cannot be tested for Trinidad and Tobago because to date the required empirical research on the cost and effect of metering has been insubstantial and piecemeal. The greatest immediate savings however are likely to be experienced by installing meters in new housing areas and new commercial and industrial centres where consumption tends to be higher and the installation costs significantly lower.

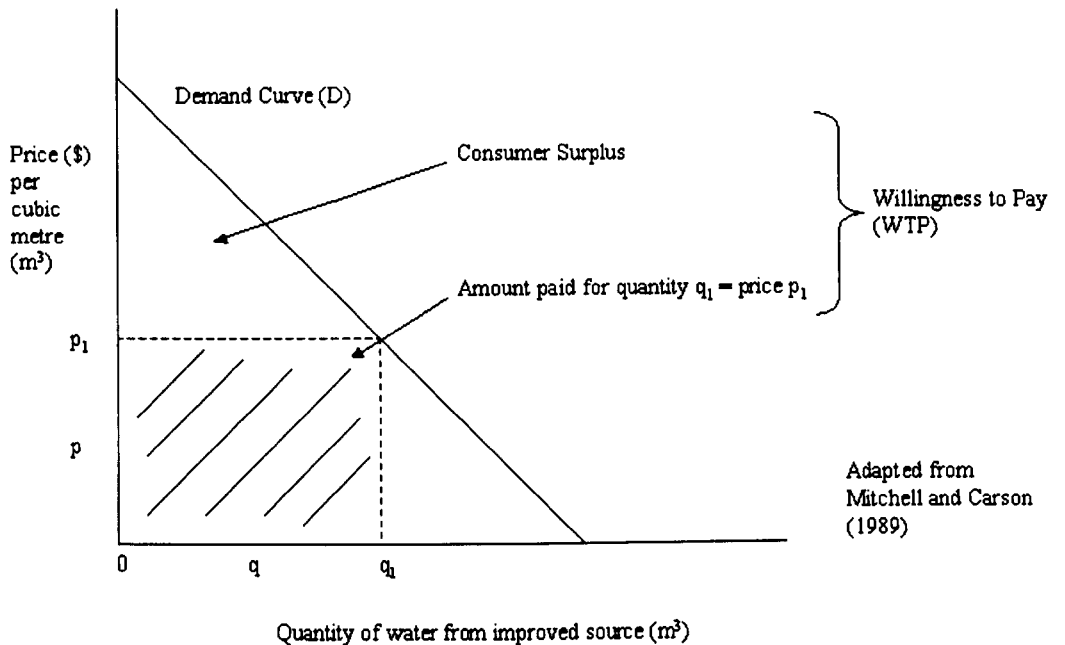
An immediate universal metering programme is impractical as in some areas – those with several old, short-life properties or very scattered, isolated dwellings – metering will not be viable. However, it would seem beneficial to investigate more thoroughly the possible savings which could result from introducing unit pricing gradually over the country as an alternative to automatically extending supply capacity to meet all conceivable requirements.

### **3.8 Willingness to Pay**

In economics, 'willingness to pay' (WTP) is defined as the maximum amount that a person would be willing to pay for a service rather than do without it. Figure 3.7 illustrates that WTP is the area under the demand curve. That is, it is not simply the amount paid for a service, but, that amount plus the 'consumer surplus'. Introduced into mainstream economic theory by Alfred Marshall, consumer surplus denotes the difference between the maximum amount the consumer would be willing to pay for a product or service and the amount he/she actually pays.

The water demand function shown in figure 3.7 also provides water supply planners and managers with information concerning the amount of revenue that may be recovered if different prices are charged for water service provision.

**Figure 3.7: Willingness to Pay**



The importance of the WTP concept for water as it relates specifically to rural areas has been appreciated for some time now. Almost twenty years ago, the World Bank concluded that adequate information on the WTP for water in rural areas was “absolutely essential for any noticeable improvement in the rural supply situation in the developing world” (Saunders and Warford, 1976). According to Whittington et al. (1987) however, despite this long-standing recognition, little progress has been made in the field.

Most of the attempts to incorporate WTP considerations into project design were ad hoc, in large part because of the absence of validated, field-tested methodologies. Most earlier studies emphasized ability to pay and affordability, as opposed to WTP. Proposed water projects in the past evaluated whether potential users could afford the improvements based on

their earnings or ability to pay. However, even though users have an ability to pay, they may be unwilling to pay for it and as such do not pay, which results in poor cost recovery. WTP is influenced by actual and perceived utility as well as the benefits of an improved service.

Since the late 1980s, the World Bank has been incorporating WTP surveys to guide its planning and investment decisions on rural water supply projects. Having come to the conclusion that ignoring demand-side information in decision making has resulted in poor infrastructure development, low service utilisation and failures in cost recovery, the World Bank subsequently embarked on consumer demand studies in Ghana, Burkina Faso, Kenya, Uganda, Pakistan, The Philippines and Haiti (Lindsey, Paterson and Luger, 1995). These studies confirmed that residents were generally dissatisfied with the provision of public services and often resorted to private arrangements to raise the level of service on an individual basis. The higher than expected WTP confirmed earlier evidence from demand studies on water supply in rural areas (Briscoe and Garn, 1994).

In a study undertaken by Whittington, Briscoe and Mu (1987), it was discovered that progress in improving the quality and quantity of water used by households in developing countries had been unsatisfactory. The main constraints noted were: 1) systems that had been built were neither used correctly nor maintained properly; 2) the extension of improved service had been slow; and 3) projects were unsustainable and not replicable.

Whittington et al. (1987) argued that two of the major impediments to improved performance in the water sector were first, inadequate information concerning the response of consumers to new service options and second, the use of incorrect behavioural assumptions in model development as discussed in section 3.6.1. Their position was further substantiated by reviews undertaken by the World Bank, other bilateral

agencies and water supply agencies who confirmed that these models were flawed in their assumptions for the developing world (Sanders and Warford, 1976; Australian Development Assistance Bureau, 1983; Federal Republic of Germany, 1983; European Economic Community, 1983).

Whittington, Briscoe and Mu (1987) advocated that if rural water projects were to be both sustainable and replicable, an improved planning methodology was required that included a procedure for eliciting information regarding the value that households place on different levels of service. They were among the earliest proponents of the WTP concept in this planning methodology. These authors argued that if people were 'willing to pay' for a particular service, that would be a clear indication that 1) the service was valued and therefore will most likely be used and maintained, and 2) it was possible to generate the funds required to sustain and replicate the project.

The growing water supply problems faced by consumers, especially in the developing world has led to increasing work on the WTP methodology and incorporation of consumer demand-side influences into decision making processes for the water sector.

### **3.9 Valuing Water as a Public Good**

Most activities relating to water are neither strictly public nor strictly private, although they have largely been treated as public goods by many governments. The basic criteria for assessing the degree to which a good or service tends toward being public or private pertain to its subtract-ability and excludability. Subtract-ability refers to a decrease in the service or a reduction in value when several people use the same good. For example, if one person drinks a beer, another person cannot have it. One person's use of the good or service decreased or subtracted from its value to others who



use the same good or service. For public goods, there is zero subtractability as one person's use does not diminish the value of the good for other users. Public goods continue to provide the same benefits to everyone, as long as they are not damaged or congested. When use is increased without any cost to society or subtraction of benefits to other consumers – i.e. the marginal cost is zero – increased use adds to economic welfare. Low subtract-ability characterizes facilities such as water supply provided it lies within supply capacity.

The second characteristic of public goods is non-exclusion (or low excludability) or the high cost of preventing consumers who do not meet the conditions set by the supplier from using the resource. Provision of water is affected by the difficulty of excluding people from its use, particularly because of the health hazards that may follow.

The World Bank (1993a) has pointed out that private firms do not engage in activities with low excludability, because it is difficult to get consumers to pay. Thus governments have had to provide funding to establish and maintain such activities. This also applies where low subtract-ability exists and market forces do not produce an optimal level of output.

Water is largely regarded as a public good due to its low excludability and low subtract-ability characteristics. Provision of water services therefore has traditionally required government investment and subvention to the extent that consumers have never paid for its true cost. In some cases, it was even regarded as free. Treating it now as more of a 'private' good and attaching greater monetary value to it is consequently no easy task.

Economists have long been able to estimate the value of goods that are routinely bought and sold in the marketplace. But, ordinary markets do not exist for 'public' goods such as environmental amenities or water. For several decades, economists have been trying to find a way to value goods such as these and a number of methodologies have been subsequently

developed. One system, relevant to water, developed by Mitchell and Carson (1989) is discussed hereunder.

Mitchell and Carson (1989) undertook a comprehensive review of the WTP concept and they suggested that the value placed by customers on public goods may be determined by studying observed market behaviour or by examining responses to hypothetical markets, either directly or indirectly. Figure 3.8 is a matrix representation of the resulting four classes of behaviour-based methods for valuing public goods.

**Figure 3.8: Classes of Behaviour-based Methods for valuing Public Goods**

	<b>Indirect</b>	<b>Direct</b>
<b>Observed Market Behaviour</b>	<p style="text-align: center;"><b>Observed/Indirect</b></p> <ul style="list-style-type: none"> <li>• Household production</li> <li>• Hedonic pricing</li> <li>• Actions of bureaucrats and politicians</li> </ul>	<p style="text-align: center;"><b>Observed/Direct</b></p> <ul style="list-style-type: none"> <li>• Referenda</li> <li>• Simulated markets</li> <li>• Parallel private markets</li> </ul>
<b>Responses to hypothetical markets</b>	<p style="text-align: center;"><b>Hypothetical/Indirect</b></p> <ul style="list-style-type: none"> <li>• Contingent ranking</li> <li>• Willingness-to-behaviour</li> <li>• Allocation games</li> <li>• Priority evaluation techniques</li> <li>• Conjoint analysis</li> </ul>	<p style="text-align: center;"><b>Hypothetical/Direct</b></p> <ul style="list-style-type: none"> <li>• Contingent valuation</li> <li>• Allocation games with tax refunds</li> </ul>

Source: Mitchell and Carson (1989)

### 3.9.1 Observed/Indirect Methods

Observed/indirect methods for valuing public goods rely on data from situations where consumers make actual market choices, for example, as they do in purchasing a house. The proxy values of the public or non-market goods are inferred from market data for related goods – those with which they have a known or estimated linkage. In order to make this

inference, the researcher depends on several assumptions. The process of determining values by such methods is like “detective work; piecing together clues that people leave behind, as they respond to economic signals” (Freeman, 1979b).

Three observed/indirect approaches are known: household production function; hedonic pricing and actions by politicians.

The household production function advanced by Becker (1965) and Lancaster (1966) postulated that consumers purchase market goods (which have no utility in and of themselves) which are combined with each other or with non-market goods or with household inputs to produce ‘new’ goods and services that ultimately generate household utility. The WTP for water may therefore be estimated from the observed production activity/behaviour of consumers. So, in the case of house tap users, the costs of electric water pumps, water storage tanks, water filters and installation labour may be used as proxies to estimate how much households would pay to have water produced and distributed to them on a 24 hour basis. For households relying on public standpipes, different types of cost may have to be established. Such households may pay a particular price for water at the source, but certainly they will spend time going to the source, possibly waiting in a queue and returning to the house with the water – to which costs must also be affixed. Other inputs to which costs are attached may include buckets, jugs and other utensils required for transporting the water. Further, if a particular quality of water is desired, additional time and inputs may be necessary to improve its quality to the level required.

A variant of the household production function is the travel cost method (Clawson, 1959). The distance a householder must travel in going to a particular site is converted into a cost factor. This factor is used to represent what the consumer is WTP for these benefits. Such an approach can be used in measuring household WTP for different levels of water

service. The travel cost method is however not without problems as it is difficult to treat with the role of time – i.e. which elements of time are to be interpreted as costs and what monetary values are to be assigned to these elements.

Other drawbacks with the use of the household production function approach include:

- 1) As models are estimated with data based on observed behaviour, certain assumptions are required which may not be realistic and therefore yield poor predictions;
- 2) The results of this indirect analysis are obtained by extrapolation of the data covered thereby introducing some inaccuracy; and
- 3) Probable discrepancies between the revealed value of a commodity to a household and the payments which a household will actually make when the commodity is provided.

The household production function approach requires the researcher to collect household level information on the quantities of water consumed for different purposes; the time spent collecting water from different sources; perceptions of the quality of different sources and socio-economic characteristics of the household. This may require fieldwork to be undertaken in areas where water sources vary, thus providing households with options in choosing sources. The complexity and exhaustiveness of this type of study, to establish how much households would be WTP for improvements in the water service they receive is therefore evident.

Hedonic pricing is another common observed/indirect method in use (Adelman and Griliches, 1961; Ridker and Henning, 1967; Rosen, 1974), which assumes that the price of a marketed good is a function of its characteristics.

Freeman (1979a and 1979b) have used the hedonic property value in the environmental and economics fields to estimate the benefits from improvements in environmental quality. Conceptually it may be applied in a similar manner to estimate WTP for improved water services. The hedonic pricing value model describes a household as a bundle of neighbourhood, site and structural characteristics, of which one may be the type of water supply.

If different houses in an area have different water supply facilities, variations in the equilibrium housing prices over the site reveal the household's WTP for a change in the level of water services. The assumptions made here are that the household can freely search over all houses and locations to find the optimal level of housing attributes desired and, there is a competitive, active housing market with good information available.

The hedonic property value approach was used by North and Griffin (1993) to test WTP for water based on a very large sample of 1,597 rural households in one region of the Philippines. The study showed that the housing market in this poor rural area did not place a value on the water source which was capitalised in the price (or rental value) of the house. The hedonic property value approach has also been applied successfully to estimate WTP for water in El Salvador and Bogota (North and Griffin, 1993).

Whilst determining WTP indirectly by seeking out surrogate markets such as hedonic pricing is indeed useful, the method still requires, apart from a well-behaved market, adequate market data on total value and considerable statistical skill to distil the marginal effect of the particular characteristic associated with the commodity being valued (Hoogsteden and Williamson, 1991). Limitations of the hedonic pricing method are as follows:

- 1) Data requirements for a valid hedonic pricing study are unusually exacting. This may be possible to establish for all relevant characteristics (structure, neighbourhood) but, where many resources are already in public hands, this may not be possible;
- 2) Sufficient market data for reliable estimations are difficult to obtain; and
- 3) People must be aware of the actual physical differences in the levels of the characteristic being valued. To assume such awareness may be unreasonable when dealing with water quality characteristics such as colour and odour.

The final method in the observed/indirect class concerns the actions of politicians who make decisions about the provision of public goods. Bar and Davis (1966) have argued that voting for candidates is a useful means of imputed values for public goods. The assumption is that political representatives maximise their chances of re-election by identifying and carrying out the preferences of the electorate, in particular, the 'median voter' (Downs, 1957; Romer, 1975). With a sufficient number of observations on representatives' votes for different programme levels, demand for a specific public good may be derived by making assumptions about the distribution of the electorate's WTP for the good and the distribution of expected taxation. However, uncertainties about provision and taxation and the likelihood that most politicians have multiple objectives when they vote on a given measure suggest that the tortuous chain of assumptions needed to obtain the implied value is too fragile to yield valid estimates of WTP (Mitchell and Carson, 1989).

### **3.9.2 Observed/Direct Methods**

With the observed/direct class of methods, measurement of the value placed on a good is directly linked to people's preferences and these are revealed in observed markets. These characteristics represent the optimal

conditions for valuing goods and are rarely realised for public or quasi-private goods. Three approaches fall under this category: 1) actual referenda, 2) simulated markets and 3) parallel private markets.

In a referendum on drinking water, for example, voters may indicate their WTP to pay for improvements in water quality. Referenda are of particular interest to practitioners of contingent evaluation because they provide an institutional model for asking people to express their preferences regarding public goods. Actual referenda are known to be costly and time consuming to conduct.

Simulated markets may be set up by researchers in which people actually buy and sell goods under controlled conditions. Mitchell and Carson (1989) maintain that experimental markets have somewhat limited application as a technique for valuing public goods since they are designed for quasi-private goods (exclusion needed in order to institute the market). Further, they are difficult and costly to run.

It may be possible to use a private parallel goods market or a black market to estimate customers' WTP for a public good. For example, in Trinidad and Tobago, where an emerging shadow market exists for truck-delivered water by private contractors, the amount of money paid to the contractors for the service may be used as a proxy measure of WTP for improvements in water provision. Such shadow markets can be used to infer the value of the publicly provided commodity.

### **3.9.3 Hypothetical/Indirect Markets**

As the name suggests, by using hypothetical/indirect methods, people are asked to respond to hypothetical markets but, their responses are only indirectly related to valuing the good in question. Among the methods in

this class are contingent ranking (CR), allocation games, the priority valuation technique and indifference curve mapping.

The contingent ranking (CR) method requires respondents to rank a set of outcomes consisting of different combinations of goods and associated payment requirements. This method has been used to measure related benefits of improvements in water quality in Pennsylvania (Desvousges, Smith and McGivney, 1983). Proponents argue that the potential advantage of contingent ranking over contingent valuation (CV) is that the former tends to obtain more accurate answers because the task of addressing a small set of cards is less demanding for respondents as compared to answering a WTP questionnaire. Mitchell and Carson (1989) however found that there was no evidence to suggest that response rates were to the CR method were any better than those for the CV method in the Pennsylvania study.

A major disadvantage of the CR methodology is that it requires more sophisticated and less direct statistical techniques to estimate the value of the outcomes than those used for CV. In addition, it is often difficult to identify the decision rules that respondents have used in completing a CR exercise. Another problem is that preferences are elicited in the form of attitudes rather than behavioural intentions. In other words, instead of requiring respondents to declare unambiguously that they are willing to give up a specified monetary amount in order to receive the good in question, the CR technique requires respondents to make rank order preferences for a set of alternative choices.

Allocation games and the priority evaluation technique both require respondents to allot a fixed budget among a specified set of categories. Sinden and Worrell (1979) present an extensive discussion on these methods but generally, these approaches limit possibilities of strategic bias (as will be discussed in relation to the CV method) because the total budget



is fixed and respondents are explicitly required to consider the full range of possible allocations.

The last method in this group is the spend more-same-less methodology, an approach incorporating a basic survey questionnaire which ask the respondents to assess whether they spend too much, too little or just about the correct amount of money on public goods and services. Mitchell and Carson (1989) are of the view that as a result of interpreting the trichotomous responses in such a manner to mean: “spending too much equals a preference for less of the good and lower payments,” the researcher then uses superficial scenarios as the basis for estimating demand curves for public goods.

#### 3.9.4 Hypothetical/Direct Markets

The hypothetical/direct methods can be used to measure people’s valuation of particular changes in water quality or quantity. These approaches side-step having to make the large number of assumptions as required by the indirect methods. These methods which include contingent valuation (CV) and allocation games, have been described by Mitchell and Carson (1989) as the most flexible because the researcher can specify a variety of states for the good to be valued and the conditions of its provision.

In economic literature, the direct approach to estimating WTP is termed the ‘contingent valuation method’ (CVM). CVM first came into use in the early 1960s when economist Robert K. Davis used questions to estimate the benefits of outdoor recreation in a Maine backwoods area. Davis thought it possible to “approximate a market” in a survey by describing alternative kinds of areas and facilities to be made available to the public and simulating market bidding behaviour. This method he argued, would put the interviewer in the position of a seller who elicits the highest possible bid from the user for the services being offered. The bidding developed

from this approach, as the interviewer would systematically raise or lower bids from an arbitrary chosen starting point, until the respondent revealed his/her maximum WTP.

The methodology for conducting CV studies was further developed in the 1970s and 1980s, largely by environmental and resource economists working on problems of appraising the provision of public goods (Freeman 1979a; Cummings, Brookshire and Schulze, 1986; Mitchell and Carson, 1989). Most of the applications of CVM have involved attempts to measure the WTP of individuals for changes in environmental quality and have been conducted in the USA or Western Europe (Mitchell and Carson, 1984).

Prior to 1987, when a WTP survey for rural water supplies was undertaken in Haiti by Whittington, Briscoe and Mu (1987), no systematic attempts were made to determine the suitability of the CVM for assessing WTP for publicly provided essential goods in developing countries.

### ***Contingent Evaluation Methodology***

Asking CV questions is particularly challenging because of the number of misinterpretations and response bias which may affect the survey results. Several approaches have been used in asking CV questions. The simplest and most straightforward is to ask the individual directly the maximum amount he/she would be WTP for a service improvement. One disadvantage of this approach however, is that some individuals may not understand the idea that they are being queried to give the maximum amount. Another problem is that people often need time to reflect on the question and simply do not have an immediate response. They may need help in thinking about the question, such as information about how much they are paying for other public services. Furthermore, for a variety of reasons, the individual may not answer the questions accurately and thus not reveal his/her actual WTP for the goods or services.

Critics of the use of the CV method are primarily concerned with the types of biases – hypothetical, strategic, compliance and starting-point – that may arise in the respondents answers and with the means of estimating their magnitude. The conventional opinion has been that these various sources of bias make CV surveys unreliable and at best inferior to ‘hard’ market data (Cummings et al, 1986). In the specific case of rural water supplies, the World Bank were of the opinion about two decades ago that “the questionnaire approach to estimating an individual’s WTP has been shown to be virtually useless,” (Saunders and Warford, 1976). On the contrary, more recent evidence indicates that the magnitude of these biases is not as large as some economists initially feared (Cummings, Brookshire and Schulze, 1986). In a variety of situations, people in the USA and Western Europe appear to answer CV questions truthfully.

Whittington et al (1987) intimated that despite the potential problems posed by the various biases, the CV method has several advantages for estimating WTP for improvements in water supply in developing countries. First, it is relatively inexpensive to conduct, and a small fraction of the cost of the water supply system itself. Second, and perhaps more importantly, it enhances the possibility of public participation and helps ascertain the preferences of the population.

Alternative approaches have been used to elicit individuals’ WTP, including the bidding game, multiple choice questions, payment cards, take-it-or-leave-it and yes-no questions regarding a single price. As Mitchell and Carson (1989) pointed out, the choice of elicitation technique involves trade-offs on the researcher’s part between 1) the need to inform the respondent about relevant features of the hypothetical market and the need to avoid information overload; and 2) the desire to measure benefits in a manner that offers policymakers utmost flexibility in using the findings and the difficulties respondents have with scenarios that are too abstract.

The challenge in CV studies is essentially how to simulate a market for a good or service that is not sold under normal market conditions. Unlike a private goods market where consumers make informed purchases of familiar goods, a hypothetical market for public goods has to be created so as to gather meaningful information about how the respondents value these goods. The objective remains, however, how to quantify the respondents' 'consumer surplus' for the good or service – the maximum amount the good is worth to the respondent before he would prefer to go without it. As previously discussed, respondents often have difficulty with direct questions and estimating values, without some form of assistance. The open-ended format has a tendency to produce an unacceptably large number of non-responses or protest zero responses to the WTP questions (Desvousges, Smith and McGivney, 1983). To reduce the occurrence of this problem, researchers have experimented with elicitation techniques that try to ease the respondent's valuation process by simplifying the choices or by offering a context in which to value the good.

Of the various elicitation methods, the bidding game is not widely used as it is prone to starting point bias. The take-it-or-leave-it method has gained popularity because it does not require visual aids like payments cards and can thus be used in mail shots and telephone surveys. These methods have currency primarily in studies relating to private goods.

CV studies that deal with the valuation of public or quasi-private goods which is not familiar to the respondent are inherently more complex and therefore require some interaction between the researcher and respondent to explain what the survey is about. For this reason, mail or telephone interviews are also unsuitable. The payment card developed by Mitchell and Carson (1981, 1984) offers perhaps the best opportunities to minimize starting point bias and with the use of visual aids contain an array of potential WTP amounts. It also has the ability to generate higher response rates than other CV methods.

Further, this approach circumvents the need to provide a single starting point yet offers the respondent more of a context for his/her bid as compared to the direct question. In the benchmark version of the payment card, the context is enhanced by identifying some of the monetary amounts on the cards as the average amounts households in the respondent's income category are currently paying for other public goods.

The limitations of the payment card technique are 1) possible biases associated with the monetary ranges used on the cards, i.e. if the ranges are too narrow or too wide and 2) the location of the benchmarks.

### **3.10 Summary**

This chapter has examined the two dimensions of water resource management, focusing heavily on consumer demand theory and the concept of willingness to pay (WTP). It has emphasized that traditional models of consumer demand for water are not wholly applicable to developing countries because different conditions in water demand and supply prevail. As a consequence, a reconstructed consumer demand theory for water was explored in the context of less industrialized nations, which formed the basis for an examination of the WTP concept in relation to developing countries. Methodological challenges faced by researchers trying to establish consumers' WTP were then analysed as well as the limitations and advantages of several of these approaches. The contingent (CV) technique was validated and therefore employed in this study on the basis of its appropriateness to WTP studies which examine goods that do not operate within normal market conditions (i.e. public and quasi-private goods), of which water is an example. The importance of the use of appropriate elicitation techniques and the design of the CV questionnaire was stressed. It was concluded that the payment card technique offers the

best opportunities for establishing WTP for improvements in water provision.

## **4.0 Methodology**

### **4.1 Introduction**

Having reviewed the relevant literature and established the framework for the study, it is now appropriate to review the methodology adopted in carrying out this research as the subsequent chapters hinge on the application of the research agenda and the methodological approach outlined below.

Much of this has already been discussed in Chapter 3 under Consumer Demand Theory, including the concept of 'willingness to pay' (WTP) and the various methods of assessment for WTP. Contingent valuation (CV) techniques were selected as the most appropriate methods for establishing WTP for water improvements in Trinidad and Tobago.

The other methodological aspects such as case study justification, methods of data collection and analysis; limitations of the project and other problems encountered during the study are presented in this Chapter.

### **4.2 Case Study Justification**

Water resource management was selected as the research topic because it is currently a highly significant issue that is developing globally, both in terms of policy-making and academia. In addition, it embraces many of the environmental, economic and social concerns that are widely held to be important, particularly to developing countries.

The research undertaken focused on water resource management in the Eastern Caribbean as evidenced in Trinidad and Tobago and Barbados.

Case study design was selected for the project, as this approach is particularly suited to situations involving a small number of units of analysis (cases) with a large number of variables. The approach is appropriate when it is necessary to understand parts of the case within the context of the whole (de Vaus, 2001). Yin (1993) noted that the case must also be seen within the context in which it exists. By examining the parts within the context of the case and the context of the case within a particular phenomenon, a complete picture of the causal processes surrounding the phenomenon – in this instance, water resource management – can be realized. Case studies have been classified by Kitchen and Tate (2000) within the qualitative research design group because generally they are qualitative in nature, using detailed interviews and observation as the primary methods of data generation. However, case studies can also be quantitative or use a mix of both design approaches. They also noted that some of the necessary data are usually secondary, consisting of statistics, records and official reports and documents.

As explained by de Vaus (2001), the multi-case study is based on the logic of replication. This logic argues that each case must be selected so that it either produces contrary results for predictable reasons or similar results. The outcome demonstrates compelling support for initial propositions and/or a need to revise and retest the study. In addition, multiple case studies, strategically selected can provide a much tougher test of a theory than a single case and can help specify the different conditions under which a theory may or may not hold. Given sufficient resources and access to the cases, multiple case study designs are normally more powerful and convincing and provide greater insight than single case designs.

In light of the above, the choice of Trinidad and Tobago and Barbados as case studies for this project was informed by three main factors. First, it was anticipated that a comparative study of this type would be useful in that it would facilitate the identification of primary elements of causality for the unsustainable water management practices within situations made complex



and unclear by contingent factors. There are broad areas of commonality between these two case studies and they are generally representative of many small-island developing states. Small island states in addition to sharing some basic characteristics of developing countries suffer handicaps arising from the interplay of factors such as smallness, remoteness, geographical dispersion, economic and environmental vulnerability. In the last two decades, these characteristics were the subject of a number of international conferences, with the UN Conference on Sustainable Development of Small Island Developing States, held in Barbados in 1994 being the culminating point of this process. Here, small-island states banded together, calling themselves SIDS, and began addressing their special development needs.

As identified in the Barbados Programme of Action for the Sustainable Development of Small Island States (BPOA, 1994), SIDS have their own 'peculiar vulnerabilities and characteristics'. These include a narrow range of resources, which forces specialization (e.g. sugar, tourism, bananas); excessive dependence on international trade inviting vulnerability to global developments; relatively high population densities; overuse of resources leading to early depletion; relatively limited freshwater sources; costly public administration and infrastructure; and limited institutional capacities and domestic markets which are too small to provide significant economies of scale.

In addition, climate change is a critical issue for SIDS, as they are particularly vulnerable to climate variability and sea-level rise. Sea-level rise is the one of most dangerous threats since saline intrusion would reduce freshwater supplies further. Island systems are also extremely susceptible to any changes in the frequency or intensity of extreme events, whether droughts, floods, hurricanes or storm surges.

Small size means there is a close inter-relationship between the natural environment and development, thereby reducing policy options. This

condition is magnified with respect to freshwater supplies because such a broad range of social, economic and environmental factors hinge on its effective management.

Second, whilst Trinidad and Tobago and Barbados are in many respects typical, each of these islands also has a number of specific features which complicate and render unique, their issue of sustainable water resource management. The main difference is their primary freshwater supply sources – groundwater in Barbados; surface water in Trinidad and Tobago. Other significant differences include the economies, geographies, some climatic elements as well as water management philosophies of the two study areas which are extensively discussed in subsequent chapters.

Finally, the author is a resident of Trinidad and Tobago who has also spent considerable time in Barbados and as such is well placed to successfully perform an in-depth study of the subject in the two SIDS. She has a substantive appreciation of the political and cultural environment in the islands which enabled her to readily complete the empirical work in this project as well as provide interpretation and analysis informed by local conditions and suggest policy and development options suited to these Caribbean small-island developing states.

### **4.3 Project Design**

Kitchen and Tate (2000) and Unwin (1992) followed Habermas's taxonomy of the different types of science to structure the research approaches within geography. Habermas (1978) divided science into three different categories: empirical-analytical, historical-hermeneutic and critical. Empirical-analytical research tries to *explain* the geographical world. Historical-hermeneutic research aims to *understand* the geographical world of its inhabitants, whilst critical research attempts to be *emancipatory*,

seeking to change the socio-political landscape for the better. The first 2 categories seek to find answers to questions or provide solutions to technical problems, leaving the readers of the study to draw their own socio-political conclusions to the findings. Within the critical research framework, however, research aims to fulfill some wider purpose than just to add to knowledge of the geographical world: it should try to change it for the better (Kitchen and Tate, 2000). As explained by Kitchen and Tate (2000), the approaches to science differ because of the varying opinions on what purpose knowledge should serve and how it should be constructed and presented. Figure 4.1 summarises the research approaches for the 3 types of science with brief descriptions and main methodologies.

**Figure 4.1: Research Approaches in Human Geography**

<b>Type of Science</b>	<b>School of Thought</b>	<b>Description</b>	<b>Main Methodology</b>
Empirical-analytical (technical, work, material production)	Empiricism	<ul style="list-style-type: none"> <li>• facts are believed to speak for themselves and require little theoretical explanation;</li> <li>• empiricists hold that science should only be concerned with objects in the world and seek factual content about them;</li> <li>• normative questions re: the values and intentions of people are excluded as they are not measurable.</li> </ul>	Presentation of experienced facts.
	Positivism	<ul style="list-style-type: none"> <li>• Positivists argue that by carefully and objectively collecting data regarding social phenomena, laws to predict and explain human behaviour in terms of cause and effect can be determined;</li> <li>• Normative and metaphysical questions are rejected as they are not measurable;</li> <li>• Requires propositions to be verified or hypotheses falsified rather than only presenting findings.</li> </ul>	Verifying factual statements: surveys, questionnaires, secondary analysis of other quantified data sets.
Historical-hermeneutic (practical, language, communication)	Behaviouralism	<ul style="list-style-type: none"> <li>• Acknowledges that the human action is mediated through the cognitive processing of information;</li> <li>• Seeks to model spatial behaviour by explaining spatial choice and decision-making through the measurement of people's ability to remember, process and evaluate information.</li> </ul>	Verifying statements: surveys, questionnaires, specialised testing.

Figure 4.1 cont'd.

Type of Science	School of Thought	Description	Main Methodology
	Phenomenology	<ul style="list-style-type: none"> <li>• Rejects the scientific quantification of positivism and behaviouralism and concentrates upon understanding rather than explaining the world;</li> <li>• Goal is to reconstruct the worlds of individuals, their actions to understand their behaviour without drawing upon supposed theories</li> </ul>	In-depth interviews; ethnography.
	Existentialism	<ul style="list-style-type: none"> <li>• Based on the notion that reality is created by the free acts of human agents, for and by themselves;</li> <li>• Concerned with how individuals come to create and place meaning to their world and subscribe values to objects and to others.</li> </ul>	In-depth interviews; ethnography; participant observation.
	Idealism	<ul style="list-style-type: none"> <li>• Posits that real world does not exist outside its observation and representation by the individual;</li> <li>• Views reality as a construction of the mind;</li> <li>• Seeks to explain patterns of behaviour through an understanding of the thoughts behind them.</li> </ul>	In-depth interviews; ethnography;
	Pragmatism	<ul style="list-style-type: none"> <li>• Rather than focusing on individuals, attention is paid to society and the interaction of individuals within society;</li> <li>• Pragmatists argue that understanding must be inferred from behaviour and rooted in experiences, not knowledge;</li> <li>• The nature of the beliefs and attitudes that shape society are uncovered by exploring people within communities.</li> </ul>	Ethnography; participant observation.

Figure 4.1 (cont'd.)

Type of Science	School of Thought	Description	Main Methodology
Critical (emancipatory, power, relations of domination and constraint)	Historical materialism	<ul style="list-style-type: none"> <li>• Marxists suggest that society is structured so as to perpetuate the production of capital;</li> <li>• They are concerned with investigation of the political and economic structures that underlie and reproduce capitalist modes of production and consumption.</li> </ul>	Dialectics; observation; interpretation of secondary sources.
	Realism	<ul style="list-style-type: none"> <li>• Concerned with investigation of the underlying mechanisms and structures of social relations, and identifying the 'building blocks' of reality;</li> <li>• Concerns the identification of how something happens (causal mechanisms) and how extensive a phenomenon is (empirical regularity);</li> <li>• Seeks to find out what produces changes, what makes things happen and what allows or forces changes.</li> </ul>	Mixed qualitative (interviews, observation) and quantitative methods.
	Postmodernism	<ul style="list-style-type: none"> <li>• Based on the notion that there is no one answer, that no one discourse is superior or dominant to the other and no-one's voice should be excluded from dialogue;</li> <li>• No one absolute truth and no truth outside interpretation;</li> <li>• Rather than seeking 'truth', offers 'readings' not observations, 'interpretations' not 'findings'.</li> </ul>	Deconstruction of culture and societal practices.

Figure 4.1 (cont'd.)

Type of Science	School of Thought	Description	Main Methodology
	Poststructuralism	<ul style="list-style-type: none"> <li>• Suggests that the relationship between society and culture is mediated through language;</li> <li>• The way humans live their lives within society, the constraints and empowerment that operate take effect in language.</li> </ul>	Deconstruction of language.
	Feminist Critiques	<ul style="list-style-type: none"> <li>• Feminism suggests that science is dominated by, and reflects the position of men, specifically white Western men;</li> <li>• Suggests that there needs to be renegotiation of the role and structure of institutions and the production of knowledge.</li> </ul>	Mixed qualitative and quantitative.

Adapted from Kitchen and Tate (2000)

Realism was chosen as this method serves to identify causality and as such, considered an appropriate approach to realise the aims of the project. Realism shares with positivism the aim of explanation rather than understanding. Under the realist school of thought, there is a 'real' world that exists independently of our senses, perceptions and cognitions however, the 'social' world does not exist independently of knowledge and this knowledge, which is partial or incomplete affects our behaviour (May, 1993). Realists argue that the task of research "is not simply to collect observations, but to explain these within theoretical frameworks which structure people's actions" (May, 1993:7). Rather than studying the relationships between actors (individuals/groups), realism seeks the underlying mechanisms of *policy* and *practice* that made these relationships possible in the first place (May, 1993). As such, realism is concerned with the identification of how something happens (causal mechanisms) and how extensive a phenomenon is (empirical regularity) (Unwin, 1992). Realists

want to find out “what *produces* changes, what *makes* things happen, what *allows* or *forces* changes” (Sayer, 1984:163).

Sayer (1984, 1992, 2000) in particular has championed the realist approach within geographical research. He suggested that geographers could engage with four different types of realist study:

- a) *Abstract* – theoretical research concerned with structures and mechanisms; it concentrates on developing a theory that might explain circumstances or lead to possible scenarios.
- b) *Concrete* – practical research focusing upon events and objects produced by structures and mechanisms and thus seeks to explain a circumstance or scenario.
- c) *Empirical generalizations* – concerned with the establishment of the regularity of events.
- d) *Synthesis research* – combines all of the above types in order to explain entire subsystems.

Sayer (1984) also described how realist research can be undertaken using either intensive research aimed at producing causal explanations and/or extensive research aimed at producing descriptive generalisations.

A concrete realist approach employing predominantly intensive techniques (observation and interviews) was used for this project. Some extensive methods were however also utilized such as the WTP questionnaire. The study was divided into 4 phases. The first phase of the research involved:

- an extensive review of the relevant academic literature to provide background theories and data on water management practices and ideologies at a global level;



- a review of primary and secondary sources documenting the hydrology, water supply, demand and management systems operating on the islands; and
- a review of the relevant academic literature to determine the range of measures and instruments for water resource management that are theoretically available.

The second phase of the research involved an evaluation of the current freshwater scenarios existing on the two islands. The empirical component of the project was not primarily designed to survey taxonomically defined or representative groups or individuals, but rather to focus on actors who affect – i.e. are a part of or interact with – the water resource management problem, referred to as *causally significant groups* (Sayer, 1984). To this end, interviews were conducted with a wide range of individuals/groups in both Trinidad and Tobago and Barbados. In effect, the sample of interviewees included individuals both within and outside the water sector, in order to explore a wide cross-section of personal interpretation of events, conditions and relationships. The need to extend the interview process beyond actors directly involved in the water supply industry was considered important because of the significant broader context in which water management relates, e.g. tourism, industry, agriculture, politics and health.

The interview is probably the most commonly used qualitative research technique. It allows the researcher to produce a rich and varied data set in an ‘informal’ setting. In practice, 36 taped semi-structured interviews were conducted. This interviewing technique was selected because of its versatility. Within the semi-structured interview, the interviewer largely controls the conversation and the questions are highly structured. However, rather than consisting of *closed* questions which would transform the interview into a questionnaire, the questions are *open-ended*. As May (1993) noted, the semi-structured method of interviewing involves the interviewer posing specified questions about the topic and based on the

answers, the interviewer can seek both clarification and elaboration. This technique also affords the interviewer more latitude to probe beyond initial responses. The respondents are also not totally constrained to the categories provided by the interviewer, but are free to respond on their own terms and in their own words (Kitchen and Tate, 2000). Using this category of interviewing, all interviewees are asked the same basic questions to try and increase the comparability of responses. General advantages of this interview technique include (Burns, 2000):

- A greater length of time (than questionnaires) spent with the informants, which increases rapport;
- The informants' perspective is provided rather than the perspective of the researcher being imposed;
- The informants use language natural to them and do not have to fit into the particular concept of the study;
- The informants have equal status to the researcher in the dialogue rather than being guinea pigs.

This strategy also has its weaknesses. Because the interview is so structured, it allows little flexibility for relating the interviews to particular individuals or circumstances and may also constrain and limit the naturalness of the interview process. In an attempt to minimize this, some questions tailored to the interviewee's circumstances were also introduced to elicit relevant information and establish context.

Candidates interviewed included water sector managers and staff from the technical/production, financial and administrative departments; politicians, other government officials and regulators; consumers (hoteliers, farmers, industry, households); academics and other specialists and consultants. In Trinidad and Tobago, the interviewees were:

- 1) Four representatives at the Water and Sewerage Authority (WASA)
- 2) Two representatives at the Water Resources Agency (WRA)
- 3) Two representatives at the Ministry of Public Utilities

- 4) One representative at the Institute of Marine Affairs (IMA)
- 5) Two representatives at the Environmental Management Authority (EMA)
- 6) One representative at the Point Lisas Port Development Corporation Limited (PLIDECO)
- 7) One representative at the Tourism and Industrial Development Company (TIDCO)
- 8) One representatives at the Environmental Engineering Department and the Sustainable Economic Development Unit (SEDU) at the University of the West Indies (UWI)
- 9) Two representatives in the Industrial sector
- 10) Two farmers
- 11) One representative at the Caribbean Agricultural Research Development Institute (CARDI)

In Barbados, candidates included:

- 1) Four representatives at the Barbados Water Authority (BWA)
- 2) One representative at the desalination company – a partnership between Ionics, Inc. and Williams Industries, Inc.
- 3) Two representatives at the Ministry of Agriculture and Rural Development
- 4) One representative at the University of the West Indies, Cave Hill Campus
- 5) Two representatives at the Ministry of Power, Transport, Communication and Works
- 6) Two farmers
- 7) One representative in the Manufacturing sector
- 8) Three hoteliers
- 9) One representative at the Ministry of Health and Environment

Little difficulty was experienced in gaining access to interviewees in either Trinidad and Tobago or Barbados. Significant insight into the current freshwater scenarios was also gleaned from the many other informal

'interviews' and discussions held with actors related to the water sector, including meteorologists, staff at the water authorities, environmentalists and water resource management consultants.

Still under the realist umbrella, in order to establish generality or commonality of characteristics (e.g. WTP) in relation to a wider population, an extensive approach was needed which in turn called for a quantitative methodology. Hence a questionnaire was employed. The questionnaire was selected because of its aptness to asking very specific questions concerning quantifiable information such as age, family size, income and for converting general information into a closed form through rating or ranking. The consumer willingness to pay for water improvements was tested by consultants hired by WASA using a questionnaire that incorporated three contingent valuation (CV) approaches: contingent ranking, payment card valuation and the household production function. The author was able to join the study team as a voluntary participant for the last round of interviews and the preliminary analysis of the findings. The survey results and analyses were made available for incorporation into this study. The CV method and the reasons for selecting it have previously been discussed in Section 3.9.4. 420 households in the East-West Corridor (the main urban area) of Trinidad were surveyed. Under the contingent ranking method, respondents were asked to rank in order of importance, the feature of the water service they valued most, amongst reliability, pressure and quality. In the valuation section, respondents were shown a payment card of different water rates and were asked to indicate the maximum amount they were willing to pay for an improved service (i.e. improved pressure, reliability and quality). The household production function was employed to examine the production activity or behaviour of the households and this was used to give some indication of the value placed on the various features (as above) of the water service.

As part of the second phase, the two dimensions of water resource management – the supply and demand sides – have been investigated and

evaluated. Links, competing and/or common features were established, highlighting the inadequacies and other weaknesses.

The third and fourth stages of the project involved the analysis and interpretation of the data collected and collated during the fieldwork, and a reinterpretation of the literature reviewed earlier in the research process, respectively. It was possible to identify and, to some extent, substantiate a number of important causal mechanisms and to relate particular conditions.

De Vaus (2001) emphasized that all research designs should be internally and externally valid, should produce reliable results and should be amenable to replication. Internal validity deals with how well the research findings match reality. Case studies have the potential for good internal validity because an attempt is made to thoroughly understand the significance of particular factors within the context of the whole case rather than by screening out this context. On the other hand, while case studies may provide excellent internal validity, they have been widely criticized because of low external validity and the absence of inferential statistics (Burns, 2000). External validity refers to whether the study's findings are generalisable beyond the immediate case(s) to a wider population. However, as explained by de Vaus (2001), case studies are used to generalize to a theory rather than to a population and external validity is based on the logic of replication rather than on quantitative sampling methodology. The goal of case study analysis is theoretical generalization rather than statistical generalization. In other words, because the focus is on individual cases, it is inappropriate when analysing case data, to count the number of cases that had particular characteristics or behaved in a particular way. The small number of cases makes it meaningless to do so. This is not to say that case study analysis cannot have quantitative and statistical elements. Certain characteristics of Trinidad and Tobago and Barbados have been described statistically, such as, GDP, unemployment rates, population, water consumption and the like. But, the focus of the

analysis has been to evaluate the freshwater situations, i.e. to build up the water resource management scenarios for the two SIDS.

In addition, where cases included embedded units of analysis – the WTP study for Trinidad and Tobago – the data analysis involved the use of descriptive and inferential statistics. Descriptive statistics were employed to summarise patterns and trends in WTP for improvements in water service provision; while inferential statistics established if the findings for the sample could have been extrapolated to the wider population of Trinidad and Tobago. SPSS computer software was used to perform the descriptive tests (e.g. mean, variance, standard deviation, frequency, minimum and maximum values) on the WTP data. This survey analysis however, formed only one piece in the jigsaw to build up the whole case – water resource management in Trinidad and Tobago.

In accordance with realist research design, the data from the case studies were analysed within an explanatory framework, such that the current freshwater situation in each of the SIDS was explained by a set of causal links about it. ‘Notes’ were the most common form of data, derived from interviews, observation and documents. These notes were continually organised as the study progressed. The analysis of the two SIDS centered on the theoretical concepts and other pertinent questions uncovered in the literature review. The aim of the first stage of the analysis, as suggested by Stake (1994) was to understand each case as a whole. Following this, it was then suitable to compare the cases and the various pieces comprising water resource management therein. Initially patterns and regularities, which could form basic categories for the classification of data were sought. In addition to coding units of data, the analysis involved the development of conceptual categories at a higher level (e.g. problems, problem causes, improvement options) in order to integrate the material and develop themes. Other tools employed in the analysis included charts, graphs, maps and diagrams, and frequency tabulations. SPSS and Microsoft Excel computer software were used to perform statistical tests where appropriate.

The overall process of data analysis and interpretation was informed by the purpose of the study, the author's knowledge and the constructs revealed in the verbalisation of the informants.

#### **4.4 Limitations of the Study**

A significant proportion of the data that form the backbone of this study were culled from field investigations (primary sources) and an extensive review of the relevant literature published on the subject (secondary sources). Some data and information obtained in the research process are not necessarily complete and totally accurate. For example, rainfall data for Barbados is abundant but regional disparities exist. Significantly less rainfall information is available for Trinidad, and even less for Tobago. In some instances, due to the lack of current data, reference has unavoidably been made to material that is rather dated. Despite this however, informed by the empirical findings, the information though old, was confirmed to be relevant and applicable.

In practice, the information obtained at the head office of the Water Authority in Trinidad and Tobago was at times inconsistent with that obtained at the district and sub-division offices. Generally, in the case of Trinidad and Tobago, there was much more limited data than Barbados on accurate water production and consumption; and supply system specifics (such as pipeline and other system component information). Access to information was also more restricted in Trinidad and Tobago than in Barbados. For both study areas, total and specific water demand data are at best estimates. Future demand has still been practicably forecast and is used as an input in making recommendations.

Three of the potential respondents were not interviewed as they were either abroad or unavailable due to heavy workloads. Substitute interviewees

were then sought and unfortunately in some cases, the necessary degree of detail and insight were not obtained. Nevertheless, most interviewees tended to open and usually quite happy to discuss their involvement with and their perceptions of the water industry.

#### **4.5 Expected Outcomes of the Research**

The subsequent chapters of this thesis provide a general description of the freshwater industry in Trinidad and Tobago in Chapter 5, and similarly in Barbados in Chapter 7. These two largely descriptive chapters are each followed by chapters where the research data collected are analysed to present a clear picture of the current freshwater scenarios in the case studies. The discussion in the analytical chapters, Chapters 6 and 8 respectively, draws heavily on transcripts of the interviews conducted in both Trinidad and Tobago and Barbados. A significant number of verbatim quotations are included because these serve to elucidate the respondents' own interpretations of current conditions and causality. Chapter 9 attempts to synthesize the analysis of the case studies and to identify general insights regarding sustainable water resource management. The final section of this report presents the conclusions and suggestions for improved water resource management in Trinidad and Tobago and Barbados.

The aim has been to explain in depth, water resource management in two cases – Trinidad and Tobago and Barbados – and not what is generally true for all or most SIDS. Generalisability has largely been left to the reader, but this is assisted by the study providing a rich description so that readers can assess applicability to other situations over a range of factors. As is normally the case with research such as this, the product is a complex picture involving plural causal mechanisms that are not completely correlated to the conditions prevailing in the case studies to which there are no simple explanations and solutions. Still, it can be argued that a



‘practically adequate’ evaluation has been produced in line with the research aims and objectives.

Notwithstanding the unavoidable limitations, the project has provided an opportunity to study how water resource management is being addressed in light of the circumstances experienced by Caribbean small-island developing states. Further, the comparative element of the research design demonstrates how an approach and moreover, policy tailored slightly to the specific conditions prevailing on each of the islands is needed for more effective water resource management. The project can also claim to address issues of clear academic interest and policy relevance.

## **5.0 The Freshwater Sector of Trinidad and Tobago**

### **5.1 Introduction**

A country's physical features, socio-economics as well as the freshwater supply and demand components are critical determinants of its water resource management.

Unit use of water tends to be higher in warm, dry climates than in humid climates. This has been attributed to increased bathing, lawn watering, washing, and other domestic consumption. (Linsley and Franzini, 1972). Trinidad and Tobago experiences a tropical climate, but the temperatures are mostly tempered by the moderating effect of the sea. The rainfall pattern for this twin-island republic is moderate (1,000 to 2,000 mm per year) in the coastal regions and heavy (2,000 to 5,000 mm per year) on the upper mountainous slopes.

Notwithstanding the importance of the physical features of the islands, the socio-economic factors tend to have the greatest effects on water usage and despite this, these factors remain some of the least researched and are seldom incorporated in water resource planning. According to Linsley (1979) traditionally the social scientist has been excluded from this area but there is little doubt that characteristics such as degrees of urbanisation and population density affect water consumption.

Another important determinant of unit use of water is the configuration of a country's economy. Industrial and service-oriented communities, in particular the tourist industry, tend to have greater water demands than agricultural communities.

On a broader spectrum, the level of national wealth is also an important factor, as it not only impacts the demand for water but, the capacity of the

country to meet such demand. This concept brings to the fore the actual system set up to manage a country's water resources, which has the greatest effect on water security.

## **5.2 Physical Features**

### **5.2.1 Physiography**

Trinidad and Tobago is an island country with an area of 5,128 square kilometres (km<sup>2</sup>). The island of Trinidad lies approximately 13 km off the north-eastern coast of Venezuela and it is about 105 km long and 77 km wide, with an area of 4,828 km<sup>2</sup>. The capital city of Trinidad is Port of Spain, situated at 61° 31' west longitude and 10° 41' north latitude. The sister island of Tobago lies about 33 km to the north-east of Trinidad and is separated therefrom by a channel of ocean about 29 km wide. Tobago is 51 km long and 18 km wide, having an area of 300 km<sup>2</sup>. Scarborough, the capital city of Tobago is situated at 60° 44' west longitude and 11° 11' north latitude.

Trinidad and Tobago is located at the southern end of the chain of Caribbean islands. Both islands are situated on the continental shelf of South America, from which they became separated in geologically recent times: approximately 11,000 years in the case of Tobago and 1,500 years in the case of Trinidad. Figure 5.1 illustrates Trinidad and Tobago's location.

There are three mountain ranges in Trinidad: the Northern, Central and Southern Ranges. The area between the Northern and Central Ranges is flat, whilst in the rest of the island, that is between the Central and Southern Ranges, the topography is broken and represents a pattern of partly flat, partly rugged and mildly undulating terrain. These Ranges decrease in

altitude from north to south, and these geological units are mainly sedimentary, with some metamorphic formations being present.

The topography of Tobago is broken with a chain of peaks running along the centre of the island. This Main Ridge is a metamorphic and volcanic central back-bone, which runs for about two-thirds of the length of the island in a south-west to north-east direction. The watershed is continued to the south-western third of the island by lower hills which give way to a flat coral (limestone) platform. The highest point in the Main Ridge is about 550 m above sea level.

The physiography of the islands is shown in figure 5.2 on page 144.

**Figure 5.1: Trinidad and Tobago – Caribbean Setting**

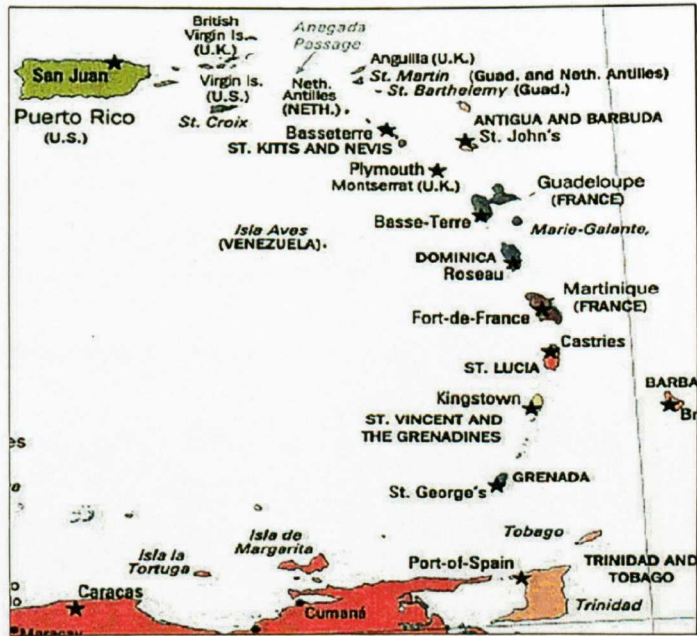
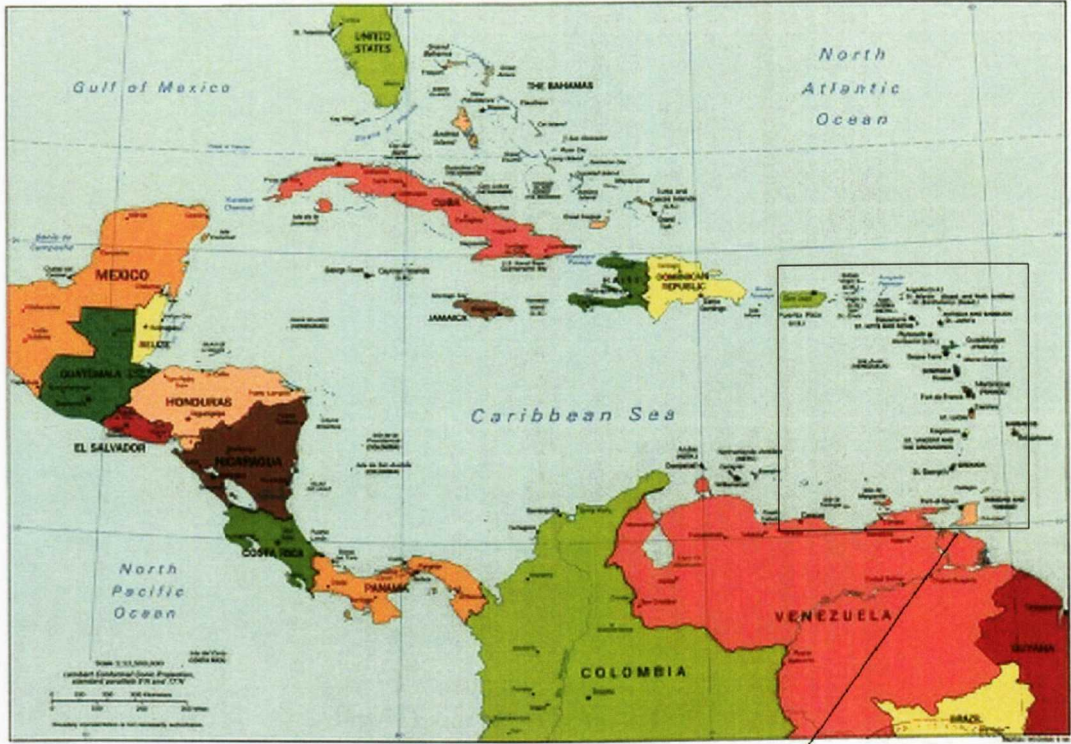
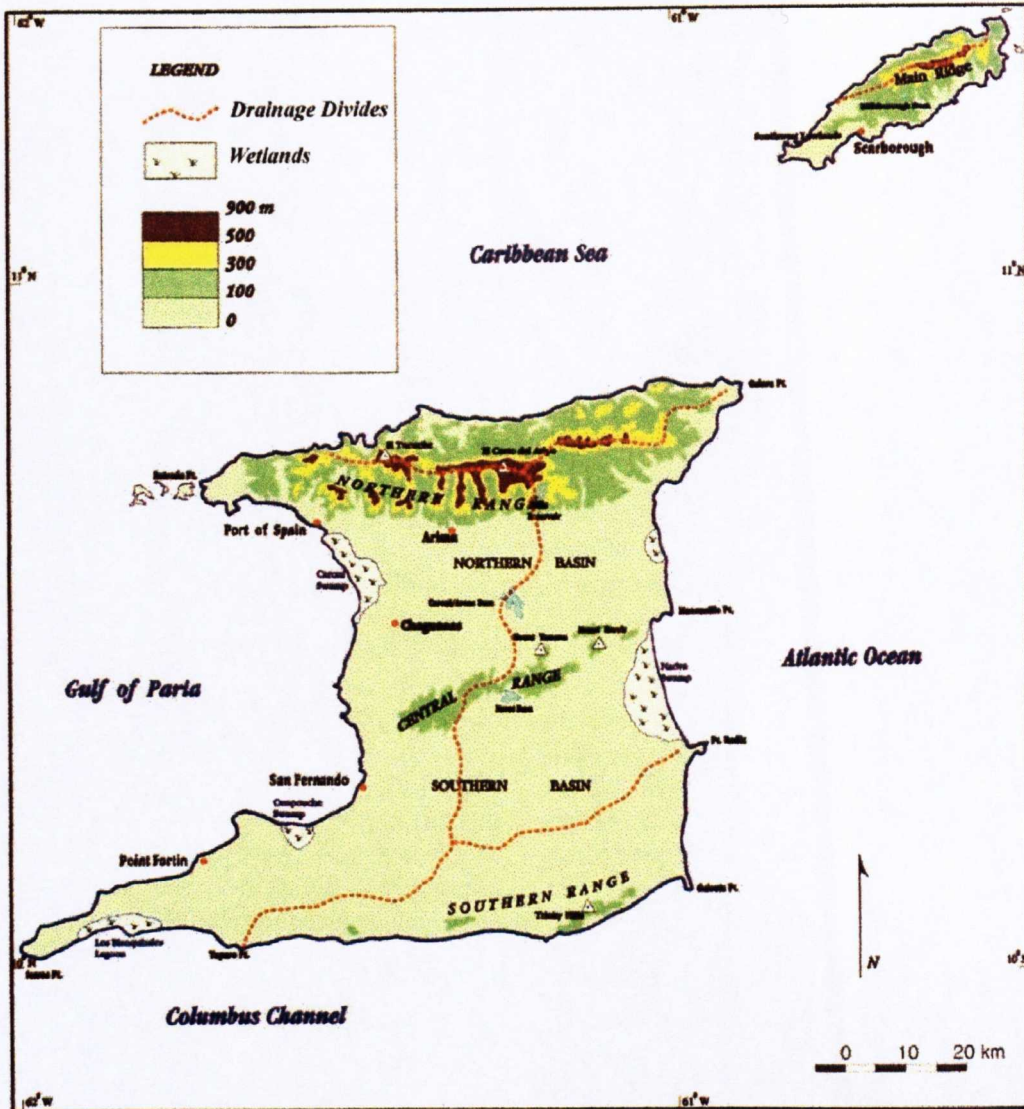


Figure 5.2: Trinidad and Tobago - Physiography



Compiled by the Department of Surveying and Land Information, UWI.

Environmental Management Authority  
Trinidad and Tobago  
State of the Environment (1998) Report



### 5.2.2 Hydro-geology

Trinidad and Tobago lies on the plate boundary between the South American and Caribbean plates. Hence, the islands are in an earthquake zone. Typically, Trinidad's geology comprises folded and faulted sediments and low-grade metamorphic rocks. Fissured limestone in the north-western area of the Northern Range allows the development of small springs. Alluvial fill deposits in the metamorphic rock of these valleys form coastal aquifers. As alluvial fans at the mouths of the valleys coalesced, a series of aquifers known as the Northern Gravels formed (Home, 1980).

The Northern Gravels consists of wedge-shaped alluvial deposits and gravel-fans along the southern foot of the Northern Range. These extend from east of Port of Spain to approximately 3 km east of Arima and southward onto the Caroni Plain. Located to the east of the Northern Gravels are the Northwest Peninsula Gravels. These aquifers consist of gravel fans, limestone beds and alluvial deposits consisting of inter-bedded sand, gravel and clay boulders. In addition there are some water-bearing limestone areas in the Northern Range such as at St. Ann's, Dorrington Gardens and Paramin. Recharge occurs via the many rivers that flow over them as well as direct infiltration from the surface during the wet season.

The other major aquifers are the Central and Southern Sands. Unlike the Northern and Northwest Peninsula Gravels, these are described as 'confined' since discharge is limited. The Central Sands are located on the southern limb of the Caroni syncline. The aquifers consist of blanket sands differentiated as Sum Sum sand, Mahaica sand and Durham sand. The sands are divided into a series of isolated pockets, which are not generally hydraulically connected. The Southern Sands are multiple sand aquifers divided into two formations – the Erin formation and the Morne L'Enfer formation. The two formations are divided into a series of hydraulically

discontinuous basins. Figure 5.3 illustrates the hydrogeological areas of Trinidad.

Tobago is largely composed of igneous and metamorphic rocks that are hard and impervious and thus offer little potential for groundwater development. Groundwater is however abstracted in the south-western part of the island where there are sedimentary deposits of coral limestone underlain by impermeable sedimentary clays. Figure 5.4 maps the geology of Tobago.

### 5.2.3 Climate

The climate of Trinidad and Tobago is tropical, warm and humid with two distinct seasons: a dry season from January to May, with March usually the driest month; and a wet season from June to December, with July and August usually the wettest months. Typically, a short dry spell of about three weeks, called “Petite Careme” occurs in the middle of the wet season in September to October.

#### ***Rainfall***

Rain falls in all seasons but, more than three-quarters of all precipitation is recorded in the wet season. The pattern of wet and dry seasons is largely determined by the annual north to south migration of the Inter-Tropical Convergence Zone (ITCZ), an organised weather system which brings heavy showers and high rainfall intensities in the latter part of the year. Rainfall in the dry season tends to be in the form of isolated, localised showers (Garstang, 1959).

Mean annual rainfall is estimated at 2,200 mm but depending on location and topography, there is wide variation. For example, in Trinidad, mean annual rainfall of 3,800 mm occurs in the eastern Northern Range and the north-eastern part of the Central Range compared to 1,400 mm along the



western side of the island. The average annual rainfall in Tobago varies from 2,800 mm in the Main Ridge to less than 1,300 mm in the south-western lowlands.

The western coast of Trinidad and the south-western plains in Tobago are in a rain shadow and hence exhibit low mean annual rainfall when compared with the north-eastern areas of Trinidad or the north-facing slopes of the Main Ridge in Tobago where most rainfall is concentrated. The seasonal pattern is similar for Trinidad and Tobago. Figure 5.5 illustrates the major rainfall variances.

### ***Temperature***

The average temperature ranges from 25 degrees Celsius ( $^{\circ}\text{C}$ ) in January, the coolest month to  $32^{\circ}\text{C}$  in May, the hottest month. The maximum temperature recorded is  $34^{\circ}\text{C}$ . Diurnal variations in temperature between night and day average  $7^{\circ}\text{C}$ .

### ***Humidity***

Average relative humidity is approximately 80 per cent but ranges between 50 per cent in the dry season and 100 per cent in the wet season.

### ***Winds***

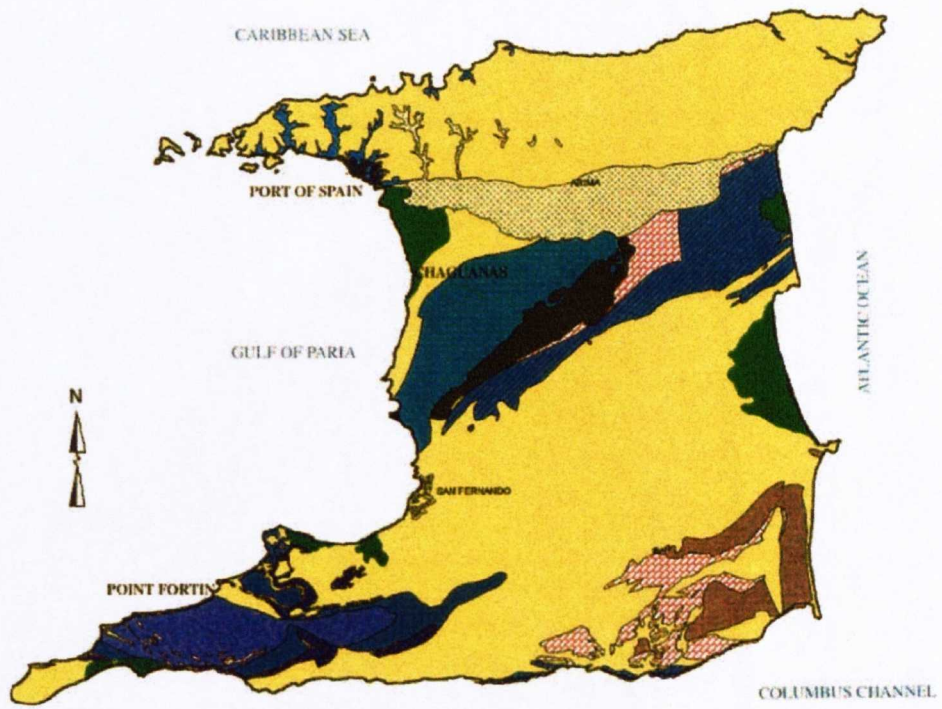
The Easterly Trade Winds dominate the wind regime, showing great steadiness throughout the year. The average wind speed ranges from 20 to 28 km per hour, with the lowest speeds in the rainy (wet) season. There is considerable local variation in wind direction, related to a range of factors including topography, the diurnal cycle and thunderstorm activity.

### ***Evapotranspiration***

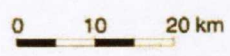
Evapo-transpiration rates are relatively high – about 70 per cent of average annual rainfall is lost in this manner totaling approximately 6,300 million cubic metres a year. Average values per annum range from 910 mm in the

south-western parts of Tobago to 2,660 mm in eastern parts of the Northern Range in Trinidad.

**Figure 5.3: Hydrogeological Areas of Trinidad**



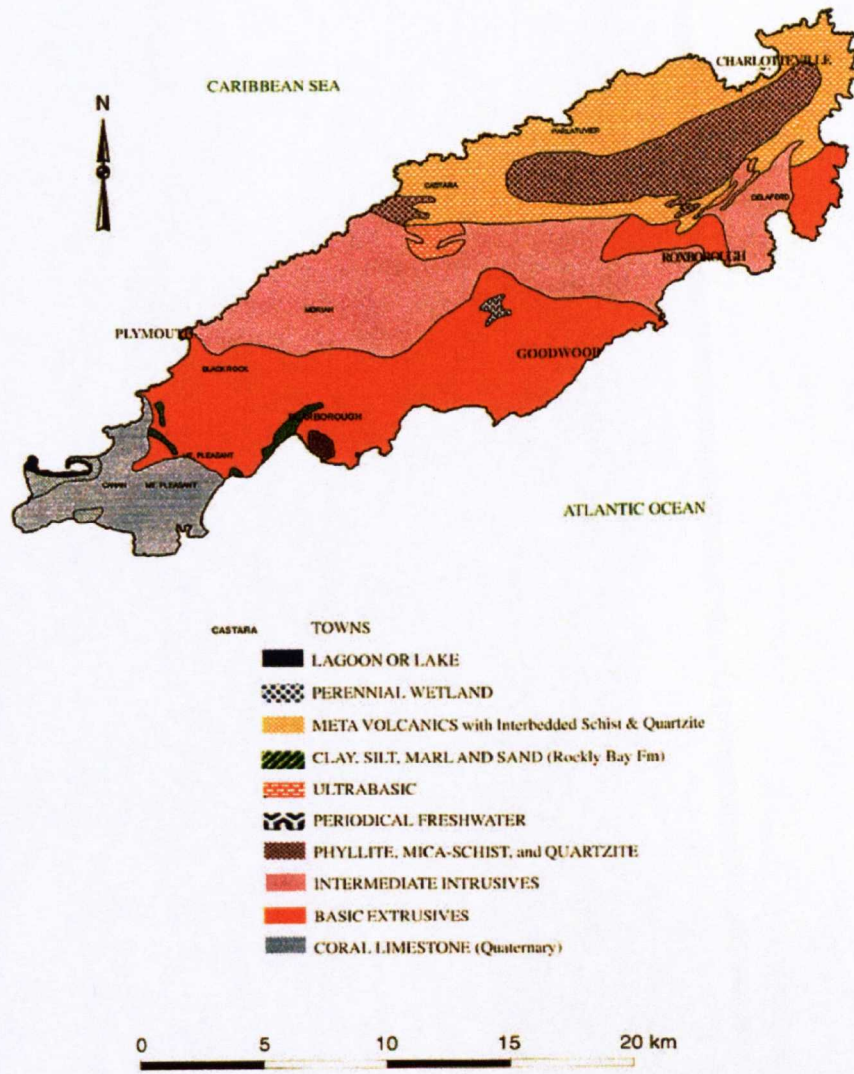
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| <p><b>ATLANTA TOWNS</b></p> <ul style="list-style-type: none"> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #000080; border: 1px solid black; margin-right: 5px;"></span> NORTH WEST PENINSULAR GRAVELS</li> <li><span style="display: inline-block; width: 15px; height: 10px; background: repeating-linear-gradient(45deg, transparent, transparent 2px, #cccccc 2px, #cccccc 4px); border: 1px solid black; margin-right: 5px;"></span> NORTHERN GRAVEL</li> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #008080; border: 1px solid black; margin-right: 5px;"></span> SUM SUM / MAHAICA SANDS</li> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #800000; border: 1px solid black; margin-right: 5px;"></span> DURHAM SAND</li> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #000080; border: 1px solid black; margin-right: 5px;"></span> UPPER MORNE L'ENFER SAND</li> </ul> | <p style="text-align: center;"><b>LEGEND</b></p> <ul style="list-style-type: none"> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #000080; border: 1px solid black; margin-right: 5px;"></span> LOWER MORNE L'ENFER SAND</li> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #000080; border: 1px solid black; margin-right: 5px;"></span> ERIN FORMATION</li> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #800000; border: 1px solid black; margin-right: 5px;"></span> MAYARO FORMATION</li> <li><span style="display: inline-block; width: 15px; height: 10px; background: repeating-linear-gradient(-45deg, transparent, transparent 2px, #cccccc 2px, #cccccc 4px); border: 1px solid black; margin-right: 5px;"></span> STRATA WITH LOCAL AND LIMITED</li> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #000080; border: 1px solid black; margin-right: 5px;"></span> POTENTIAL AQUIFER TO BE INVESTIGATED</li> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #008000; border: 1px solid black; margin-right: 5px;"></span> SWAMPS</li> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #ffff00; border: 1px solid black; margin-right: 5px;"></span> NO INFORMATION</li> </ul> |
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Trinidad and Tobago  
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**Figure 5.4: Geology of Tobago**

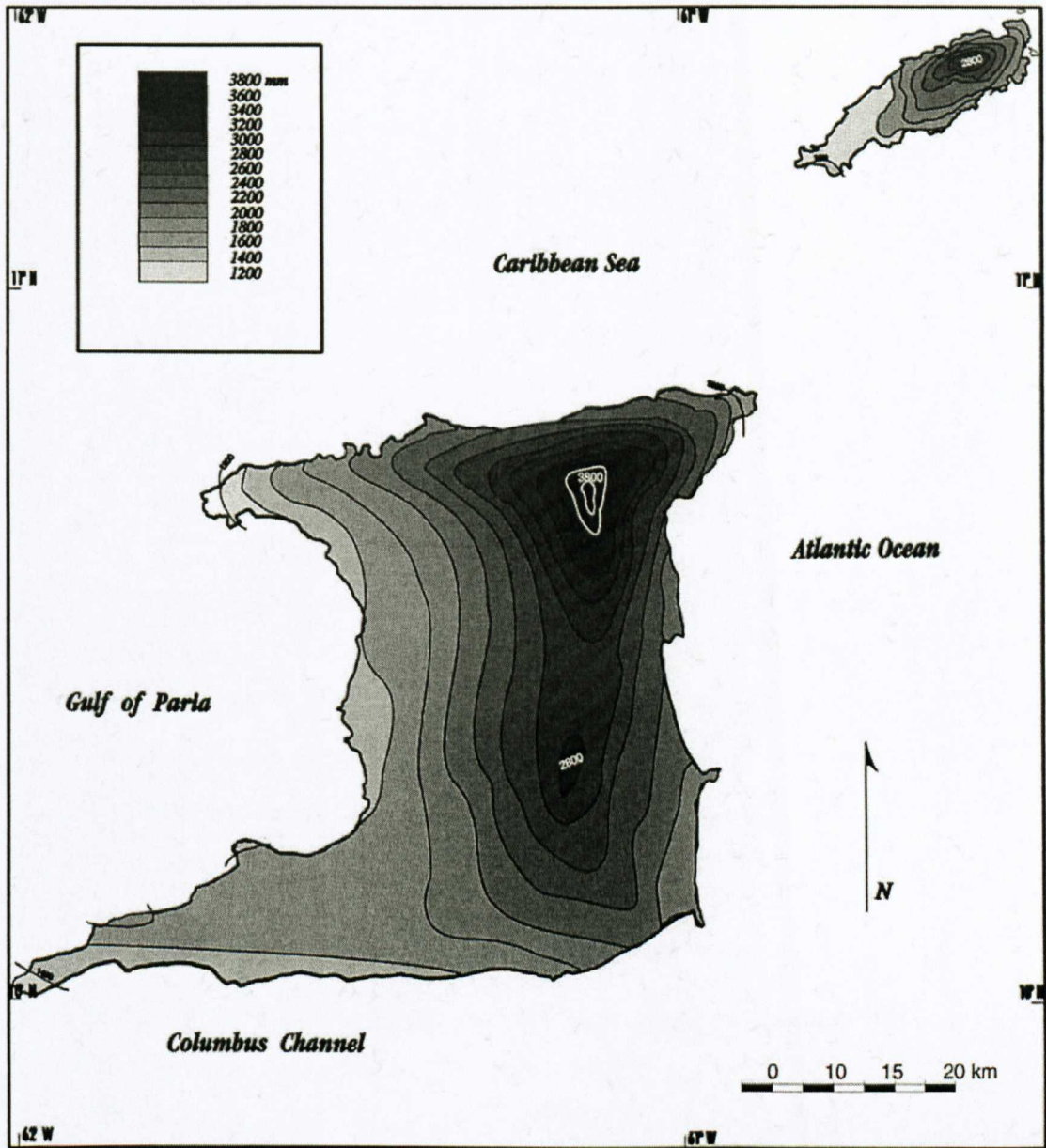


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Figure 5.5: Average Rainfall Variation across Trinidad and Tobago



Environmental Management Authority  
Trinidad and Tobago  
State of the Environment (1998) Report

WASA, Sept., 1990. Source:  
Water Resources Agency

## **5.3 Socio-economic Conditions**

### **5.3.1 History and Culture**

Trinidad and Tobago was originally populated by two Indian tribes: the Igneri, a relatively peaceful Arawak sub-group and the more fierce Caribs. Explorer Christopher Columbus stumbled upon Trinidad and Tobago in 1498 and the island, Trinidad was settled by the Spanish a century later. In 1776, the Spanish government offered land grants and tax incentives to Roman Catholic settlers; in response, numerous French planters from the French Caribbean countries poured in to establish farms. Although it attracted the French and other non-Spanish settlers (Syrian, Lebanese), Trinidad remained under Spanish rule until the British captured it in 1797. During the colonial period, Trinidad's economy relied largely on sugar and cocoa.

Tobago's development was similar to other islands in the Lesser Antilles and quite different from Trinidad's. During the colonial period, French, Dutch and British forces fought over possession of Tobago, and the island changed hands 22 times, more often than any other West Indian island. Tobago was finally ceded to Great Britain in 1814. Trinidad and Tobago were incorporated into a single colony in 1888.

In 1958, the Federation of the West Indies was established, comprising most of the British West Indies, including Jamaica and Barbados. Jamaica and Trinidad and Tobago withdrew in 1961 and the Federation collapsed shortly thereafter. Trinidad and Tobago achieved full independence in 1962 and joined the British Commonwealth. In 1976, the country adopted a republican constitution, replacing Queen Elizabeth as chief of state with a president elected by parliament.

The country retains the Westminster Parliamentary style of democratic government, with a 36 member House of Representatives (Lower House)

and a 31 member Senate (Upper House). The members of the Lower House are elected for 5-year terms unless Parliament is dissolved earlier. In 1980, a Tobago House of Assembly was created with legislative powers to manage most of the domestic affairs of the island.

Trinidad and Tobago has a relatively stable and mature political climate. The first political party in Trinidad and Tobago – the People’s National Movement (PNM) – emerged victorious under Dr. Eric Williams in the 1956 general elections and remained in government until 1986. The PNM was succeeded in office by the National Alliance for Reconstruction (NAR) which won a landslide victory by capturing 33 of the 36 seats contested in the 1986 general elections. But, their term in government was short-lived as the NAR began to break down in 1988 with Basdeo Panday, the deputy political leader, withdrawing to form a new political party, the United National Congress (UNC). The PNM was returned to office in 1991, but lost power to a UNC/NAR coalition following the general elections of 1995. The UNC won the 2000 general elections and Basdeo Panday became Prime Minister and A.N.R. Robinson, President with the PNM in opposition. But, due to the resignation of certain UNC members of parliament, elections were again called in December 2001. A tie (18 seats won by the PNM and UNC respectively) resulted, requiring the President to nominate a ruling party and Prime Minister. The PNM was chosen and Patrick Manning is currently the Prime Minister. Basdeo Panday and the UNC are still contesting this decision.

Trinidad and Tobago has a multi-racial population that was estimated at 1,290,083 in 2000 (CSO, 2000) with major concentrations in the Northern Range valleys, in the foothills along the west coast and within the Southern basin. Population projections indicate that at the national average growth rate of 1.2 per cent, the population is expected to grow to 1.78 million by 2025. Trinidad and Tobago’s people are mainly of either African (39.5 per cent) or East Indian (40.3 per cent) descent. The remainder of the population is mixed (18.4 per cent), European, other Eastern or Chinese

(1.6 per cent). Africans were brought as slaves to work on the plantations, but slavery was abolished in 1833. So, from 1854 to 1915, many East Indians came as indentured labourers to fill the labour shortage created by the emancipation of slavery, and most of them remained. Trinidad and Tobago's cosmopolitan society has also introduced a variety of religions. Christianity, Hinduism and Islam exist peaceably side by side.

Literacy is high (97 per cent) and the infant mortality rate is 15/1,000. Trinidad and Tobago has two main folk traditions: Creole, a mixture of African, Spanish, French and English colonial elements, and East Indian. Virtually all speak English and small percentages also speak Hindi and French Patois. Figure 5.6 shows the locations of the main cities and towns.



Figure 5.6: Main Cities and Towns in Trinidad and Tobago



### 5.3.2 Economy

Traditionally, the economy of Trinidad and Tobago was agricultural-based, with production of sugar cane playing the dominant role. Other cash crops of import were cocoa, coconut and coffee. However, with the discovery of oil early in the twentieth century and the tremendous growth in drilling and refining operations that followed, the economy was quickly transformed into an oil-dependent one.

Trinidad and Tobago became one of the most prosperous countries in the Western Hemisphere during the oil boom of the 1970s and the government used enhanced revenues from the petroleum sector to embark on a rapid industrial and infrastructural development programme.

With the collapse in oil prices in the early 1980s, Trinidad and Tobago slumped into a recession from which it only began to emerge in 1994. With the help of a stringent adjustment programme introduced under the NAR government in 1988, Trinidad and Tobago's economy has shifted from central planning to free market policies, with extensive trade and investment liberalisation, divestment of state enterprises and an emphasis on economic diversification and export-led growth.

After a protracted period of decline from the mid-1980s to early 1990s, the Trinidad and Tobago economy has experienced positive growth in recent years. Economic expansion has been complemented by decline in inflation and positive fiscal and external balance. Over the last six years, real GDP growth averaged 5.30 per cent, as figure 5.7 details. GNP (at market prices) stood at TT\$47,890 million in 2000 (US\$7,614 million), a 67 per cent increase from 1995. This equates to a GNP of TT\$36,782 per capita (US\$5,848 per capita). Such expansion has produced increased levels of employment with the unemployment rate down to 12.1 per cent in 2000, the lowest in 16 years.

**Figure 5.7: Gross Domestic Product (Percentage Sector Contribution)**

Sector	1995	1996	1997	1998	1999	2000
Gross Domestic Product (constant 1985 prices TT\$ million)	17,265	17,950	18,507	19,634	21,024	22,470
Petroleum	27.6	28.2	26.7	20.2	23.2	25.9
Non-Petroleum	72.4	71.8	73.3	79.8	76.8	74.1
Agriculture	2.22	2.20	2.18	2.04	1.95	1.67
Manufacturing	8.35	7.74	8.47	8.50	8.24	7.72
Services (financial, hotels, construction etc.)	61.83	61.86	62.65	69.26	66.61	64.35

Adapted from Ministry of Finance, Review of the Economy 1999 and CSO (2000)

Nevertheless, Trinidad and Tobago's economy remains tied to the hydrocarbon sector as Government derives approximately 25 per cent of its recurrent revenues from the oil industry. Petroleum products constitute more than two-thirds of the country's gross exports and an average of 24 per cent of the annual GDP. Natural gas is rapidly becoming another pillar for the economy as it now serves as the input or power source for ammonia, urea, methanol and steel production.

Trinidad and Tobago has been located within the Middle Human Development category in the UNDP's 1998 Human Development Report and the World Bank classifies Trinidad and Tobago as an upper-middle income country. The Trinidad and Tobago economy is today the largest and most industrialised in the Caribbean with a diversified structure including heavy industry (25 per cent GDP), medium/light manufacturing, agriculture (2 per cent GDP) and tourism (3 per cent GDP).

### 5.3.3 The Place of Water in the Economy

Demand for water is generally described in terms of consumptive (use in homes, institutions, factories, agriculture, etc.) and non-consumptive (the in-stream requirements of rivers and minimum flow requirements of swamps/wetlands) needs. The former category usually takes priority and is further sub-divided into domestic, charitable, industrial (major and minor), commercial and agricultural customers.

Domestic demand is largest among the categories with current demand estimated at 330,000 cubic metres per day ( $\text{m}^3/\text{day}$ ), expected to rise to 550,000  $\text{m}^3/\text{day}$  by the year 2025. Current demand for industrial and agricultural water is estimated to be 200,000  $\text{m}^3/\text{day}$  and projected to increase to 350,000  $\text{m}^3/\text{day}$  by the year 2025.

The current demand is approaching maximum yields and consequently, provisions need to be made for increasing the production of freshwater, primarily to meet the increasing domestic requirements but also for continued economic development.

## 5.4 History of Freshwater Development

Organised water supply came into effect in 1853, with the construction and commissioning of the Maraval waterworks as the first surface water source of supply for the city of Port of Spain. In 1902, the River Estate Waterworks were developed to provide water for the western part of Port of Spain. The development of the country's water resources continued in the 1920s to improve supplies for three main urban communities in Trinidad – Port of Spain, San Fernando and Arima – and for Scarborough in Tobago. In 1936, the Hollis Waterworks had been commissioned as the first island-wide project and major surface water source in Trinidad. Water from this

source served the population of 413,000 and was piped to remote areas to the east, west and south of Trinidad.

There was also some activity in the development of groundwater supplies during the early 1940s to provide the wartime requirements of the military and naval personnel of the British and American governments stationed in Trinidad at the time. The U.S. forces provided for their own requirements and handed over the facilities to the local government at the end of the second World War. At the end of the 1940s, total potable water production was approximately 69 m<sup>3</sup>/day for a population of about 620,000.

Despite the afore-mentioned infrastructure developments, water problems in Trinidad and Tobago have been notorious. In 1903, there was a riot in Port of Spain due to the inadequacy of the water supply. In 1937, social discontent again erupted over the shortage of potable water throughout the country and the West India Royal Commission (1938-1939) stepped in to assist in eradicating the deficiencies (Bennett, 1991).

Between 1935 and 1944, using a British model as the basis, water supply and distribution were consolidated under a Central Waterworks Board. In 1950, the government issued a council paper setting out its policy for the provision of an adequate supply of wholesome water for domestic and other uses for every inhabitant of the country at rates as low as possible. This council paper has laid the foundation for the programme of development for the water resources in Trinidad and Tobago.

Implementation of the programme commenced in 1953 and by the middle of 1965, significant gains had been made. The development of new borehole fields, in particular the El Socorro waterworks, together with the installation of a number of small intakes throughout the country had been completed and the construction of another system – the Navet Waterworks – was nearing completion. The new facilities increased daily production from 73 m<sup>3</sup>/day at the end of 1953 to 251 m<sup>3</sup>/day by mid-1965. During this

period, a decentralised system was used for water production and/or distribution. Three municipal agencies were responsible – the Port of Spain City Council, the San Fernando and Arima Borough Councils – as well as the Government Water Department and the Central Water Distribution Agency (CWDA) (WASA, 1990). The Government Water Department supplied water in bulk to the three municipal authorities which distributed the water and collected the rates in their areas respectively. Rural areas were serviced by wells and rivers.

Unfortunately, this system of supply and distribution did not keep pace with the increasing demand. Government therefore, found it necessary to create a single agency for the development and management of the country's water resources (M&E International, 1970).

## **5.5 The Water and Sewerage Authority**

The Water and Sewerage Authority (WASA) is a state-owned utility and is the sole agency now responsible for water supply and sanitation in Trinidad and Tobago. It was incorporated in September 1965 with the assistance of the Pan American Health Organisation (PAHO) by the Water and Sewerage Act of the same year. The new Authority was added to the portfolio of the Minister of Public Utilities.

WASA is charged with the responsibility for development and control of water and sewerage facilities and related matters of sanitation as well as promotion of the conservation and proper use of water resources. WASA was vested with all the properties of the State (under the Waterworks and Water Conservation Act), the CWDA and the Port of Spain City Council.

The overarching mandate delegated to WASA was to carry out the policy of the Government in relation to water and sewerage and to exercise such

functions, powers and duties as are conferred on it by the Water and Sewerage Act. Specifically, its responsibilities as stated in the Act are:

- 1) To provide an adequate and reliable water supply;
- 2) To effectively collect, treat and dispose of wastewater; and
- 3) To promote conservation and effectively manage the country's water resources.

The Act also prescribes, among other things, WASA must ensure that its water rates are sufficient to cover the costs that attend: operations, maintenance, depreciation and long-term debt interest expenses; long-term debt that exceeds depreciation and for future expansion.

#### 5.5.1 Jurisdiction

WASA owns all the water reserves located in the country, regardless of locality, be they on private or public lands. According to the Act, WASA is responsible for monitoring and developing the waterworks and other related properties and promoting the conservation of the water resources of Trinidad and Tobago.

At the same time, WASA may authorise any person or industry to supply water to the public, through granting them a license. WASA is also responsible for maintaining and developing the sewerage systems.

The National Housing Authority and some private developers are however involved in the construction of water distribution systems, sewage collection networks and treatment plants. WASA is responsible for their approval. The Ministry of Public Health is responsible for setting water quality and wastewater effluent standards.

#### 5.5.2 Regulation

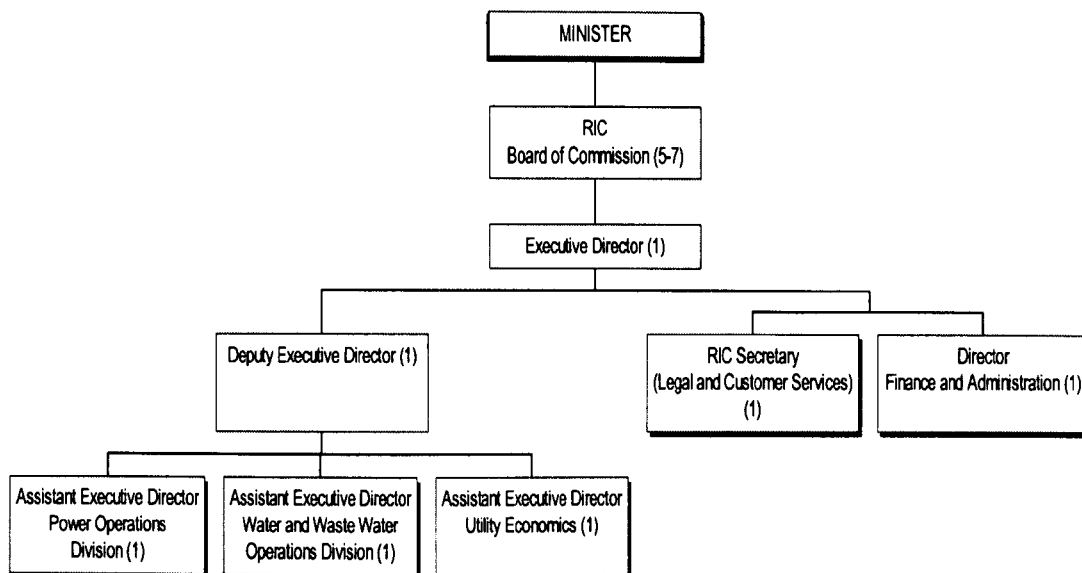
Administratively, WASA is under the control of the Ministry of Public Utilities. WASA is managed by a Board of Commissioners appointed by the Government. Under the Ministry of Public Utilities, a separate body – the Public Utilities Commission (PUC) – was created in 1966 by Parliament to control rates, tariffs and fares charged by the various public utilities for the services provided as well as to regulate their operations. This became necessary in light of the fact that large amounts of government funds were being disbursed to them. Moreover, this was part of an attempt by Government to rationalise the operations of the public utilities and to take the matter of rate-setting out of the political arena. According to the Public Utilities Act 1966, the PUC had power to:

- 1) determine rates set by any utility;
- 2) obtain basic financial and other information about the operations of all the utilities on an annual basis or at shorter intervals if required; and
- 3) conduct research on its own into the operations of a utility relating to its economy and efficiency.

On June 1<sup>st</sup>, 2000, the Regulated Industries Commission (RIC) Act was proclaimed and repealed the PUC Act, thereby establishing the RIC in place of the PUC. Although retaining most of the functions of the PUC, the RIC's main purpose is the regulation of service providers operating under monopolistic conditions, whether publicly or privately owned, where the services are of a public utility nature and vital to the population. The RIC's involvement in rate setting would be to establish principles and methodologies, which would couple compensation for productivity increases with disincentives for inflationary increases. The Act also aims to represent the interests of the consumer such as establishing a system for the review of complaints relating to rates, billing and standards of service. Figure 5.8 shows the institutional regulatory arrangement that is currently in place.



Figure 5.8: Regulatory Structure Via RIC



Adapted from RIC Act (1998)

Under this structure, WASA makes an application to the RIC who reviews the application and makes an award for rate increases or an adjustment. The law does not provide the Minister of Public Utilities with the authority to decide on rates to be set for the utilities or other matters falling within the purview of the Commission, although he is responsible to Parliament for acts performed by the Commission (Public Utilities Report, 1996).

The traditional structure has been plagued with many problems (e.g. inefficient and irregular rate increases) and therefore needed to be redefined, not only to correct the inherent weaknesses, but also to cater to changes in the current business environment.

### 5.5.3 Institutional Structure

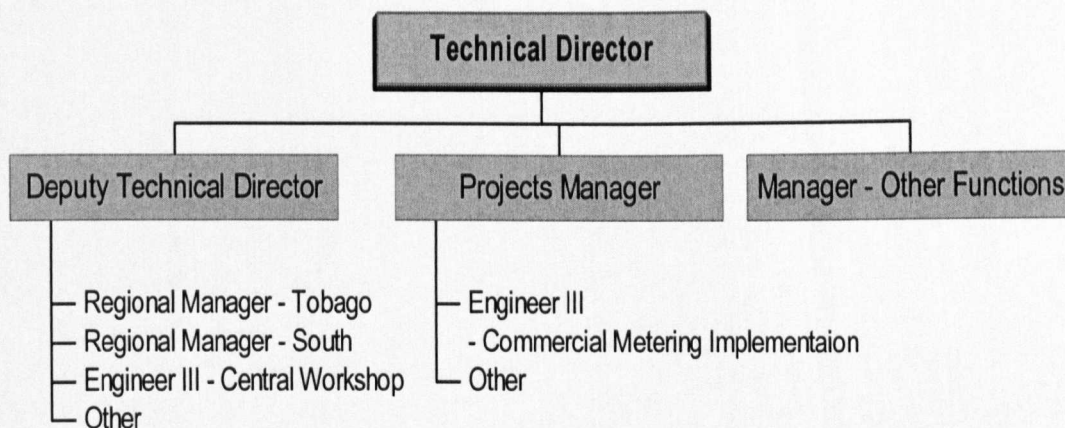
WASA is managed by a nine member Board of Directors appointed upon the advice of the Minister of Public Utilities. The executive director has ultimate responsibility for the management of WASA. The Internal Audit Unit, Corporate Planning and the Corporate Secretary fall under his direct

supervision. The Deputy Executive Director is responsible for the daily goings-on and the operations of the five technical and management departments: technical; administration; water resources; finance and accounting; and information systems.

The Technical Division is headed by the Operations Manager and is divided into four regional offices: North, South, Caroni and Tobago. The staff complement also includes a Chief Chemist for Quality Control maintenance. Figure 5.9 shows the staff structure of the Technical Division.

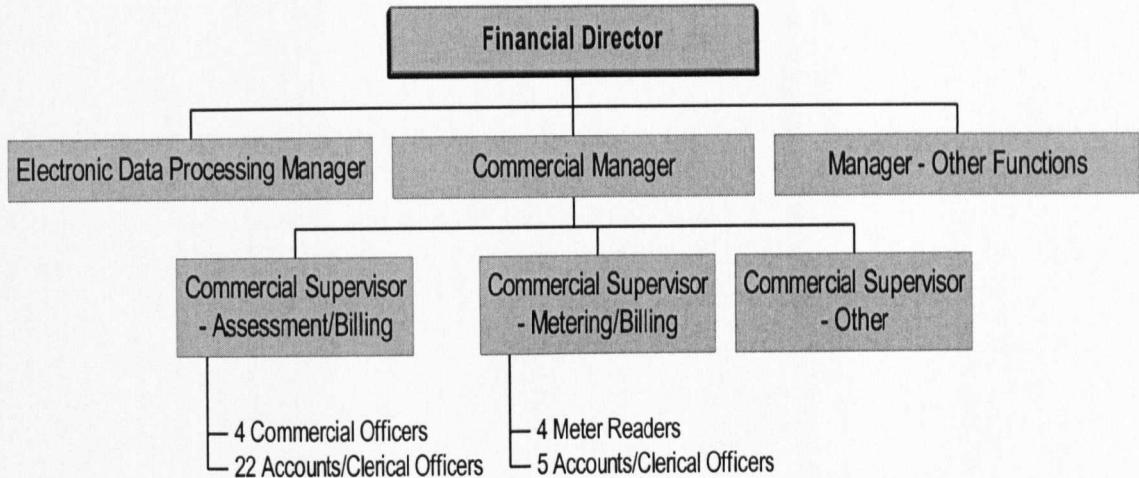
The Financial and Accounting Division is set up as shown at figure 5.10. The functions of this Division include: billing, meter reading, rates assessments, handling customer queries, payment receipts and revenue collection.

**Figure 5.9: Structure of WASA's Technical Division**



Source: WASA, 1994

Figure 5.10: Structure of WASA's Financial Division

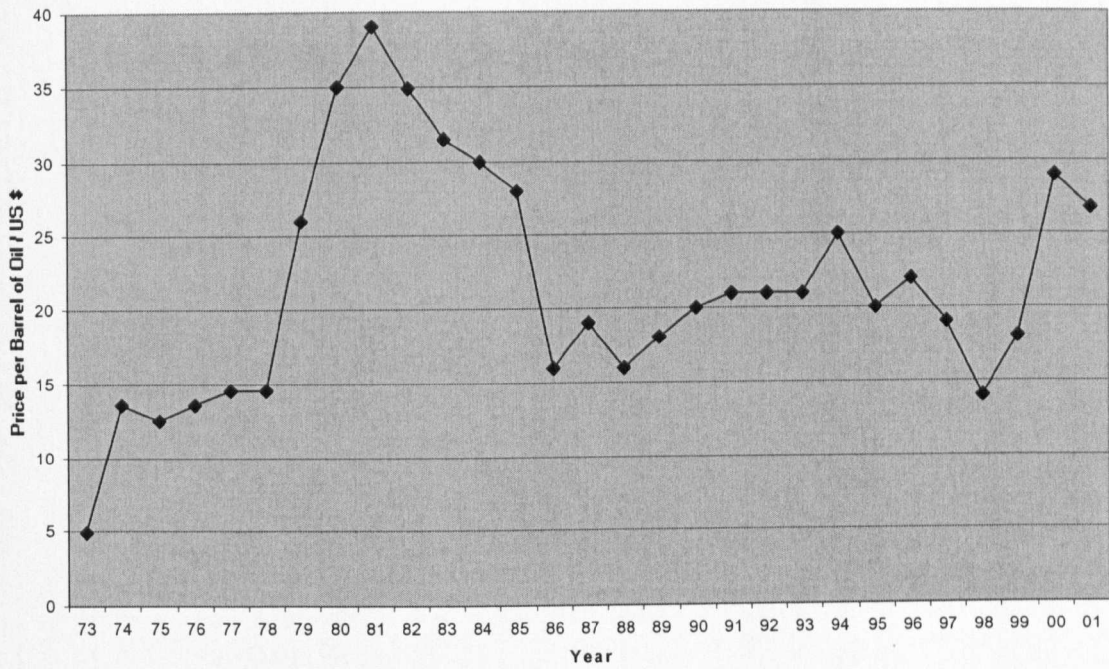


Source: WASA, 1994

#### 5.5.4 Financial Status

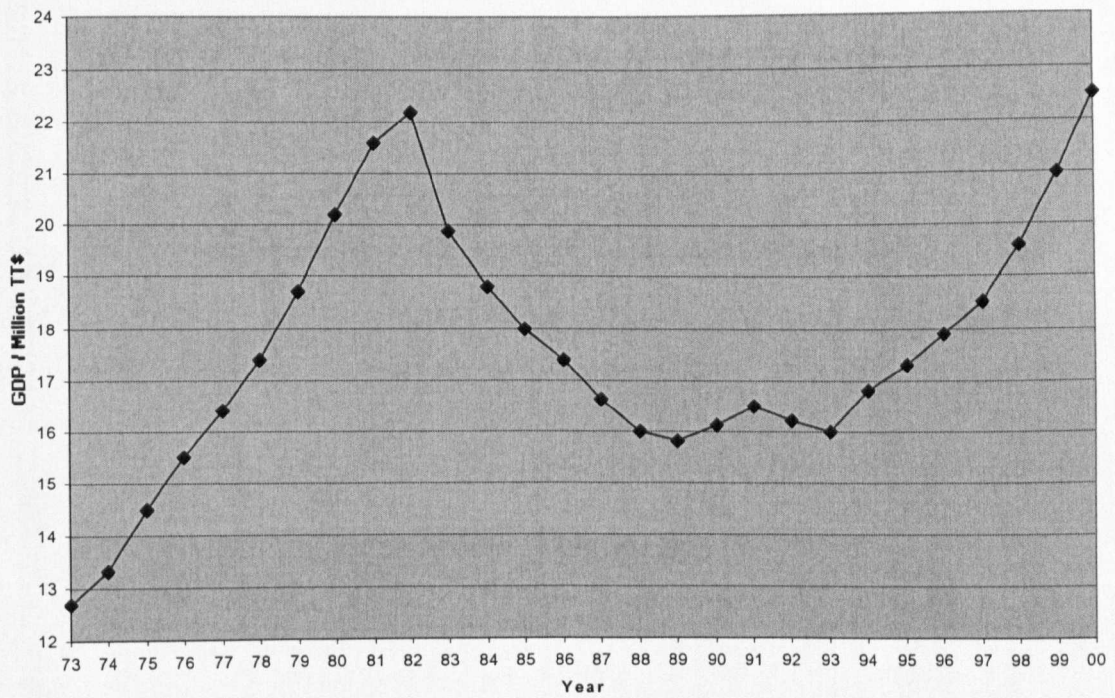
The public utilities have traditionally provided their services at prices below costs of production as they were being subsidised heavily from the Government to finance both their operating deficits and capital investments. This was possible during the 'oil boom' of the 1970s and early 1980s. However, beginning in 1982, the economy of Trinidad and Tobago fell into a depression due to a major decline in oil export earnings caused by the effects of a sharp fall in international oil prices coupled with reduced oil production. Falling GDP, growing debt to international agencies and several currency devaluations characterised the mid-1980s to early 1990s (See figures 5.11 and 5.12).

**Figure 5.11: Historical Trends in World Oil Prices 1973-2001 in US\$ per barrel**



Adapted from GOTT(1994) and CSO(2000)

**Figure 5.12: GDP of Trinidad and Tobago at Constant 1985 Prices**

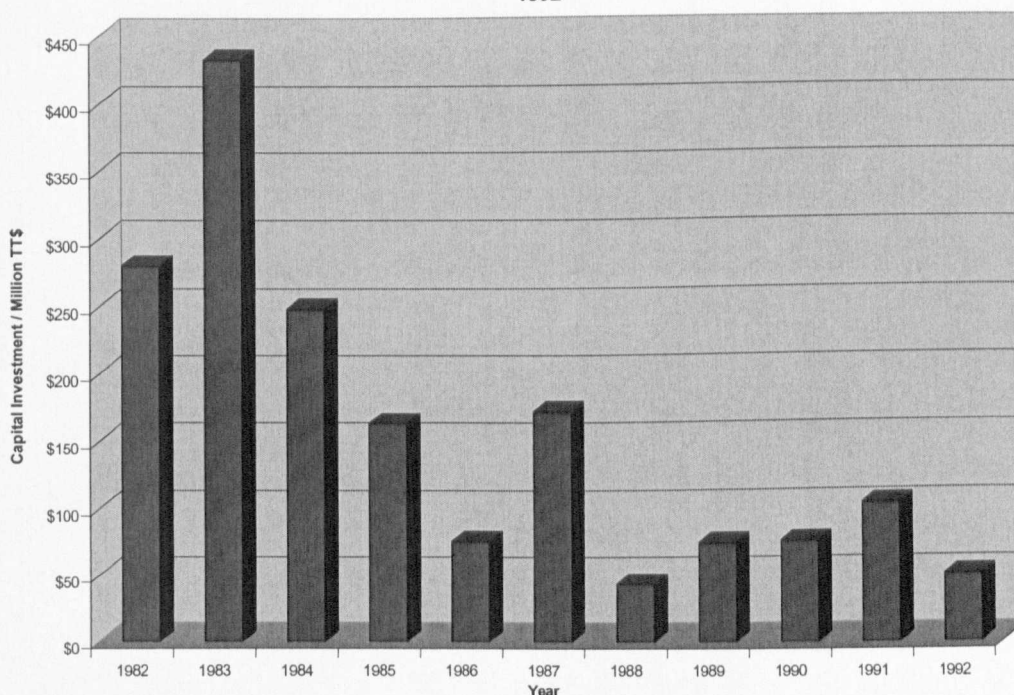


Adapted from GOTT (1994) and CSO (1997, 2000)



The Government began experiencing difficulties in providing the public utilities with the financial assistance needed for their operating deficits and capital investment. Government capital expenditure declined from 48 per cent of total revenue in 1982 to 8.3 per cent in 1989 and to 5.1 per cent in 1999. In 1983, the Government's capital investment in the utilities peaked at TT\$433.7 million, which represented 27 per cent of its total expenditure. The utilities together received TT\$5.4 billion from the Government for the period 1982 to 1992 (figure 5.13). In the case of WASA, Government's financial assistance decreased drastically from TT\$380 million in 1982 to TT\$234 million in 1985 then to about TT\$40 million in 1995.

**Figure 5.13: Capital Investment in Public Utilities in Trinidad and Tobago for 1982 - 1992**



Adapted from GOTT (1992)





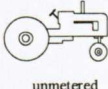




With contractions in government expenditure, WASA was unable to adequately maintain existing supply facilities, provide an uninterrupted water service to consumers as well as invest in new facilities and expand service into new areas.

A low-pressure water service or 'scheduled' rationing was therefore the norm for many years. In 1994, water rationing was severest as WASA fell into bankruptcy. As a consequence, WASA was forced to restructure its financial operations which has yielded encouraging results over the last 6 years. The operating revenue, most of which comes from water charges has steadily increased. This revenue increase was achieved both by an increase in volume of water produced for sale and greater effort made for collection of water charges. At the same time, the operating expenditure has been decreased by over 20 per cent, mainly through a reduction in the number of employees.

#### 5.5.5 Water Tariffs

Most of the operating revenue of WASA is raised by water rates. Since its inception in 1965, the water tariff was not adjusted until 1986 when financial assistance from the Government became insufficient. The amendment in 1986 included a 25 per cent increase in water charges, becoming effective in 1987. This was followed by another increase in 1995. Users are divided into four different categories: 1) industrial/commercial and public buildings, 2) agriculture, 3) churches and 4) domestic. For domestic water use, the water rates are set for two categories of users: 1) standpipe users and 2) premises users. The premises users are further divided into those served by a single yard tap and those served with internal plumbing. The water rates currently charged by WASA are shown in figure 5.14 below.

**Figure 5.14: Water Rates of WASA (TT\$)**

<u><b>Industrial, Commercial, Public</b></u>				<u><b>Domestic</b></u> (Standpipe users)																
	unmetered	Buildings and water for re-sale 12.5% of ATV (Annual Taxable Value) Minimum bill per month	\$474		Consumers without a service connection but whose premises are within 400m radius of a standpipe	\$33.75 per quarter														
	metered	\$3.50 per cu metre Minimum bill per month	\$474		premises served by a single yard tap	\$67.50 per quarter														
		<u><b>Agricultural</b></u>																		
	unmetered	15% of ATV (Annual Taxable Value) Minimum bill per month	\$105																	
	metered	\$2.25 per cubic metre Minimum bill per month	\$105																	
				<u><b>Domestic</b></u> Premises with internal plumbing																
																				
				<table border="0" style="width: 100%;"> <thead> <tr> <th>ATV (Annual Taxable Value)</th> <th>% of ATV</th> <th>Minimum</th> </tr> </thead> <tbody> <tr> <td>up to \$500</td> <td>95</td> <td>\$108.00</td> </tr> <tr> <td>from \$501 to \$1,000</td> <td>81</td> <td>\$118.00</td> </tr> <tr> <td>from \$1,001 to \$2,000</td> <td>54</td> <td>\$203.00</td> </tr> <tr> <td>over \$2,000</td> <td>47</td> <td>\$270.00</td> </tr> </tbody> </table>		ATV (Annual Taxable Value)	% of ATV	Minimum	up to \$500	95	\$108.00	from \$501 to \$1,000	81	\$118.00	from \$1,001 to \$2,000	54	\$203.00	over \$2,000	47	\$270.00
ATV (Annual Taxable Value)	% of ATV	Minimum																		
up to \$500	95	\$108.00																		
from \$501 to \$1,000	81	\$118.00																		
from \$1,001 to \$2,000	54	\$203.00																		
over \$2,000	47	\$270.00																		
				unmetered	Maximum bill per quarter	\$304.00														
		<u><b>Churches</b></u>																		
	and Registered Charitable Organisations		\$108 per quarter	metered	up to 150 cubic metres	\$1.75 per cu metre														
						\$3.30 per cu metre														

Source: WASA (1996)

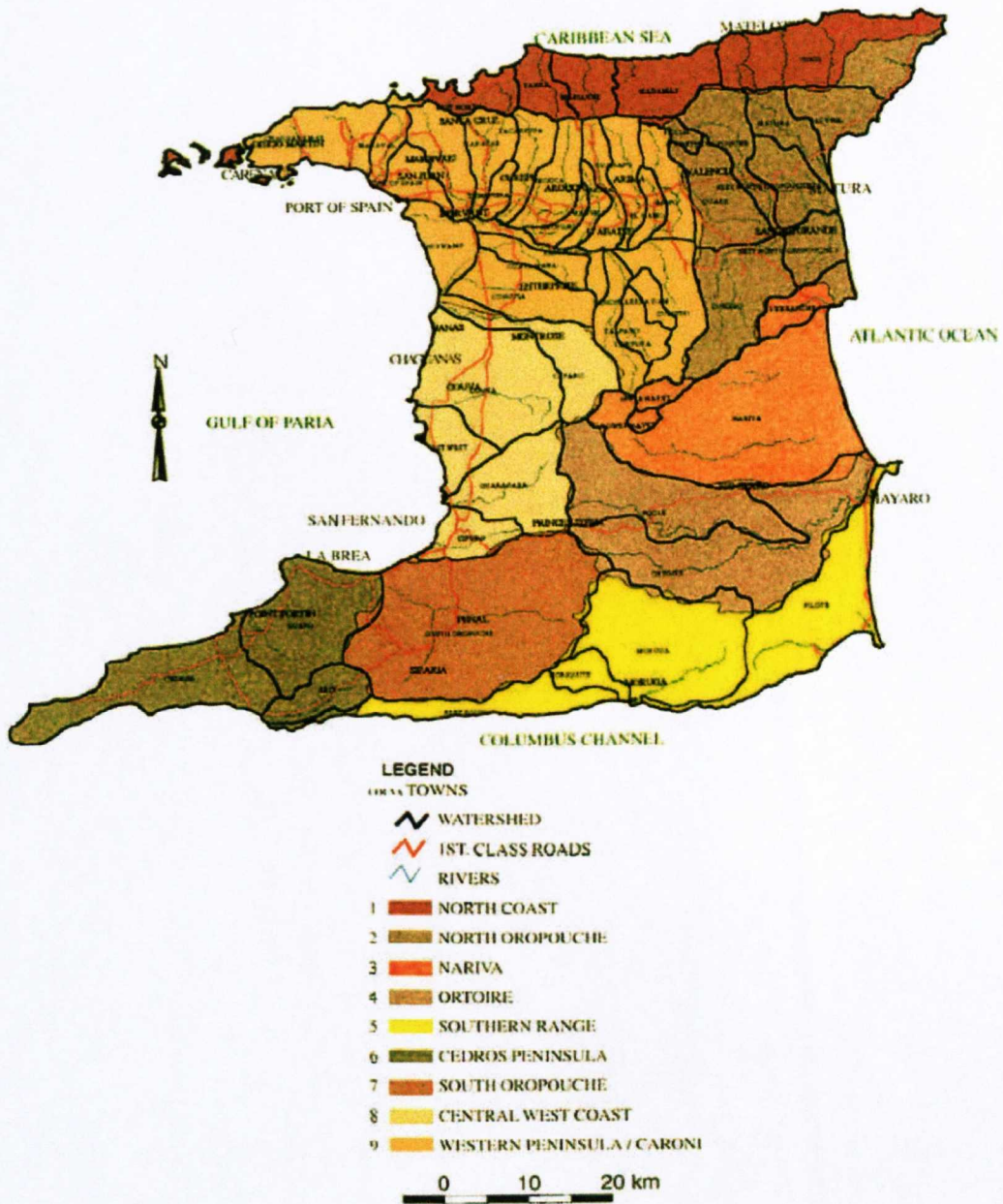
Excluding the water used in churches, water rates are classified into metered and un-metered use. For the un-metered use, the annual taxable value (ATV), which is the value of the property as set by the tax office forms the basis for the billing. Very few – about 2.2 per cent – of WASA’s customers are metered. The non-metered customers (those who do not pay for water on a per unit of consumption basis) pay a flat charge for unlimited consumption. And, under a flat rate system all costs are calculated as average costs. Marginal costs are disregarded, so price is equal to average cost less subsidy. This means that above a certain level of consumption, that is, above average cost, the price of water is virtually zero.

## **5.6 The Water Supply Dimension**

For the purpose of harnessing and managing the freshwater resources, Trinidad and Tobago has been sub-divided into 14 hydrometric areas, 9 in Trinidad and 5 in Tobago. Each hydrometric area is a major hydrologic unit which groups a number of watersheds drained by rivers and streams. There are 54 watersheds in Trinidad and 15 in Tobago. The six major hydrometric areas in Trinidad are the Caroni, North Oropouche, Guaracara/Central South, Ortoire, Nariva and South Oropouche. The remaining three units are the northern slopes of the Northern Range or North Coast, the Moruga/Southern Range area and the Cedros peninsula. The five hydrometric areas in Tobago are: the Windward/Hillsborough area, Louis D'Or/East Coast, Courland, Bloody/North Coast and the Lowlands or South-western Coast. These areas are illustrated in figures 5.15 and 5.16 for Trinidad and Tobago respectively.



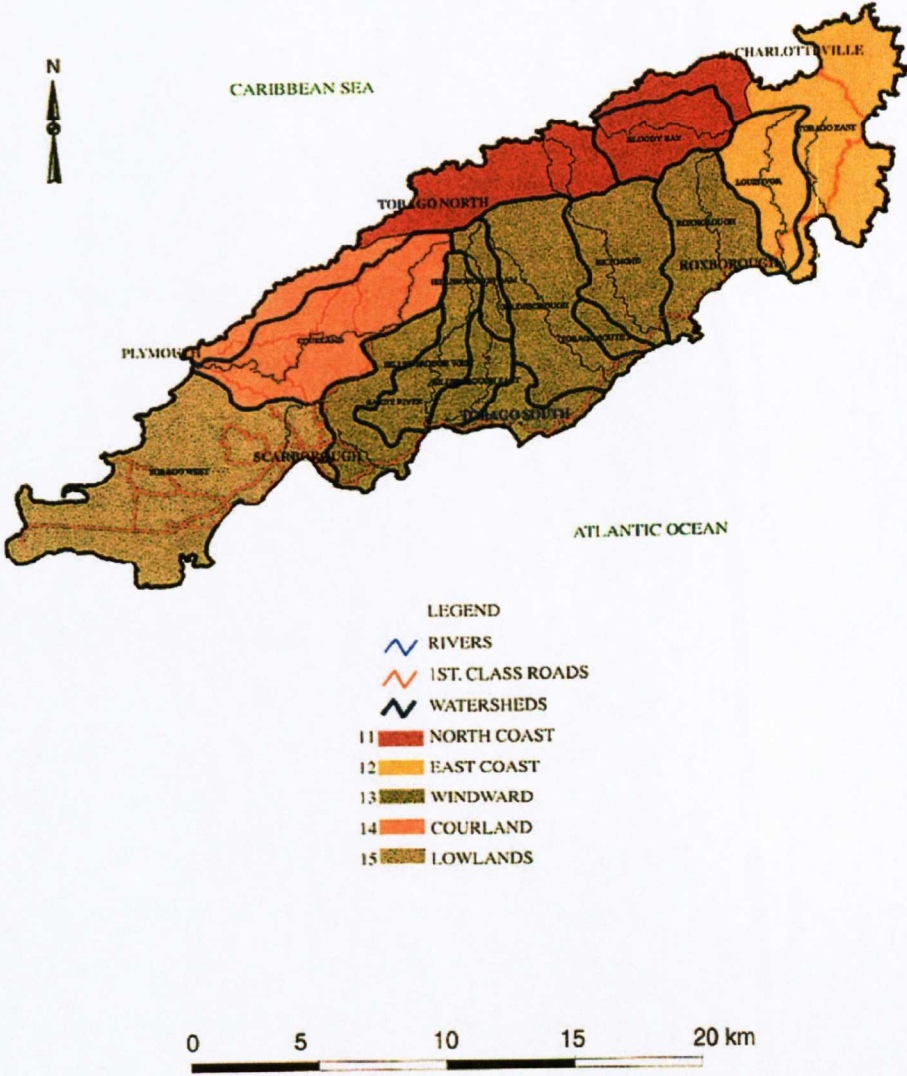
**Figure 5.15: Trinidad – Watersheds and Hydrometric Areas**



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**Figure 5.16: Tobago – Watersheds and Hydrometric Areas**



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### 5.6.1 Sources of Supply

Rainfall is the source of freshwater which facilitates both surface water and groundwater development in Trinidad and Tobago. The earliest public water supplies came exclusively from surface water sources. The use of groundwater was initiated shortly after World War II with the successful development of groundwater aquifers by the U.S. forces then based in Trinidad. Today, the groundwater supply systems only account for about 25 per cent of total freshwater production.

### 5.6.2 Surface Water

#### *Watersheds*

Total annual rainfall is estimated at 9,000 million cubic metres (MCM) but about 70 per cent (6,300 million m<sup>3</sup>) is lost by evapo-transpiration. As previously mentioned, mean annual rainfall is unevenly distributed, ranging from highs of about 3,800 mm in mountainous regions to lows of about 1,300 mm on the north-western and south-western peninsulas.

The three mountainous ranges in Trinidad divide drainage to the north, east, south and west. The largest watersheds are those flowing to the west into the Gulf of Paria and to the east into the Atlantic Ocean. The main rivers in the former are the Caroni, Navet and Ortoire. Although draining substantially smaller areas, several other rivers flow to the north from the highest rainfall areas in the Northern Range. These include the Yarra, Marianne, Paria, Matelot, Shark and Grand Riviere Rivers. All are perennial and important sources of good quality water. Of the rivers draining to the south from the Southern Range, only three are perennial: the Erin, Moruga and Pilote Rivers. (See figure 5.17).

In Tobago, the Main Ridge separates windward and leeward facing watersheds. Rivers in Tobago are generally smaller than those in Trinidad. Five minor river systems have their head waters in the Main Ridge and are

perennial in their upper courses. These are the Bloody Bay, Castara, Englishman's Bay, Parlatuvier and Courland Rivers. Draining south to the Atlantic Ocean are the major rivers – the Richmond, Goldsborough and Hillsborough. These systems are illustrated in figure 5.17.

### ***Standing Bodies of Freshwater***

There are no natural, permanent standing bodies of freshwater in either Trinidad or Tobago. Nevertheless, in Trinidad, extensive areas of freshwater do appear seasonally in the wetlands, particularly in major ones such as those at Nariva, Caroni, North and South Oropouche, Rousillac and Los Blanquizales. These generally retreat during the dry season and some occasionally dry out completely. Where topography permits, there may be permanent standing water at river mouths, such as is found at the mouths of the Marianne and Yarra rivers in Trinidad and the Courland river in Tobago.

There are four relatively large artificial lakes – reservoirs – established for accumulation and storage of surface water. These are the Hollis, Navet and Caroni/Arena reservoirs in Trinidad; and the Hillsborough reservoir in Tobago (See figures 5.17, 5.18 and 5.19).

Private interests have constructed and operate other small impoundment reservoirs for water supply, especially in south Trinidad. Numerous small freshwater ponds for aquaculture and use in industry are also scattered around the country.

### **5.6.3 Groundwater**

Significant sources of groundwater are available and utilised in Trinidad, especially in the northern region. The most important aquifers lead from the southern side of the Northern Range into the gravel deposits in the floors of the valleys and in the Caroni Plain. Groundwater reserves are also

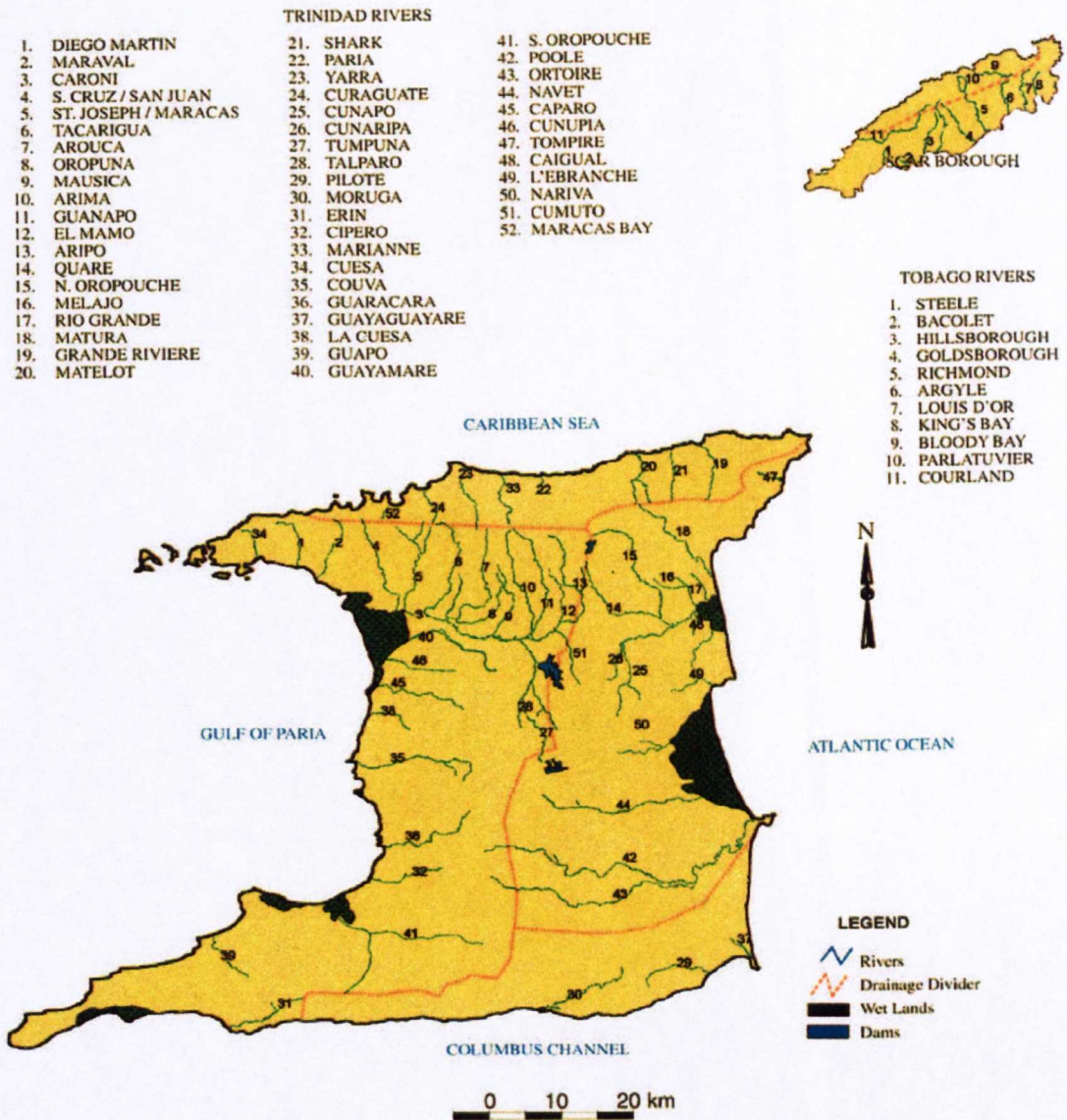
to be found in the coarse sand beds along the flanks of the Central Range. There are also a few scattered perennial artesian outflows in and around the Central Range as well as in the fine sand beds in south Trinidad which have been exploited.

The aquifers themselves, as previously discussed in Section 5.2.2, are the Northwest Peninsula Gravels, the Northern Gravels, the Central Sands and the Southern Sands. The Northwest Peninsula and Northern Gravels as well as the Central Sands are the major producing aquifers.

Many aquifers exist in the south-western part of Tobago where the coral limestone deposits underlain by sedimentary clays exist. Some groundwater is extracted but these systems have not been exploited as are those in Trinidad. No aquifer is known to exist within any of the river catchment areas in Tobago.



Figure 5.17: Trinidad and Tobago – Surface Water Systems



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#### 5.6.4 Water Supply Systems

WASA has 92 separate sources of freshwater, of which 79 are located in Trinidad and 13 in Tobago with a total production capacity of 861,484 m<sup>3</sup>/day (25,300 m<sup>3</sup>/day is the estimated production in Tobago). According to the Water Resources Agency (WRA), surface water sources provide approximately 75 per cent of WASA's production, (WRA, 1995). The remaining portion (25 per cent) is supplied from groundwater sources and most of the wells are located in the northern part of Trinidad where groundwater of good quality is available. Several boreholes have been developed and connected to the distribution network to help meet increasing demands but, this arrangement has introduced other supply problems by complicating the transmission and distribution pipeline system. Figures 5.18 and 5.19 illustrate the waterworks and intakes for Trinidad and Tobago respectively.

##### *Large-scale Systems*

The large-scale sources with a design production capacity in excess of 30,000 m<sup>3</sup>/day are the Caroni/Arena, Navet, Hollis and North Oropouche systems. These four sources contribute approximately 60 per cent of the total island water production.

With current production of 35,000 m<sup>3</sup>/day, the Hollis system now serves Port of Spain, the eastern portion of the East-West Corridor and Sangre Grande. The Navet system is the principal source of supply for San Fernando and the south of Trinidad. This system yields a daily output of 77,000 m<sup>3</sup>/day. The most recent and largest water production facility in Trinidad is the Caroni/Arena system with a capacity of about 340,000 m<sup>3</sup>/day – approximately 40 per cent of the total water production – rendering it the nation's most crucial facility. The Caroni River itself has a significant natural dry season flow as a result of groundwater contributions to its base flow. The North Oropouche system which draws from the North Oropouche River in north-eastern Trinidad is interconnected with the

Caroni/Arena system and yields approximately 90,000 m<sup>3</sup>/day potable water. Each system generally consists of intake, treatment facilities, transmission and distribution pipes and service/storage reservoirs.

### *Medium-scale Systems*

The medium-scale system has a production capacity between 1,000 m<sup>3</sup>/day – 30,000 m<sup>3</sup>/day. There are 38 such systems in total, of which 14 extract river (surface) water and 24, groundwater. Eight of the systems dependent on surface water are in Trinidad contributing a further 6 per cent to the total production; whilst 6 are located in Tobago, contributing over 95 per cent to that island's total production. In Tobago, the largest direct river intake is the Courland Waterworks with a production capacity of about 7,500 m<sup>3</sup>/day. There are no medium-scale groundwater sources in Tobago.

### *Small-scale Systems*

The small-scale systems produce less than 1,000 m<sup>3</sup>/day. There are 50 in total; 38 surface water systems – 32 in Trinidad; 6 in Tobago – and the remaining 12 are groundwater or spring sources – 11 in Trinidad and 1 in Tobago. These sources are generally defined as isolated sources which are not linked to the distribution network, but supply water directly to a number of rural areas.

## 5.6.5 The Reservoirs

On average, the annual surface water availability for Trinidad is estimated at 2,500 million cubic metres (MCM), only 513 MCM of which is available in the dry season. Estimates for Tobago are 140 MCM and 28 MCM respectively. The water production from groundwater sources, unlike surface water sources, is relatively constant throughout the year. Yet most of the production comes from the surface water sources as groundwater reserves are limited. Storage during the rainy season is therefore critical to the dry season supply. Hence, WASA developed 4 impoundment



reservoirs – the Hollis, Navet, Caroni/Arena in Trinidad and the Hillsborough in Tobago – to save river discharges during the wet season and so provide a constant annual output.

#### ***Caroni/Arena Reservoir***

The Arena Reservoir is the largest in Trinidad and Tobago, with a capacity of about 46.6 MCM. Located at the Arena Reservoir is the Tumpuna Pump Station via which WASA draws water from the Caroni River during the wet season when river levels are high and diverts it to the reservoir for storage. The reverse happens in the dry season when river levels run low and water is then pumped back into the river.

#### ***Navet Reservoir***

There are three streams that flow down from nearby hillsides that feed the main Navet River, which has been dammed to form the Navet Reservoir. The Navet Waterworks was commissioned in 1962. Between 1962 and 1976, the capacity of this system was increased from 55,000 m<sup>3</sup>/day to 77,000 m<sup>3</sup>/day. The entire reservoir has a capacity of 18.6 MCM.

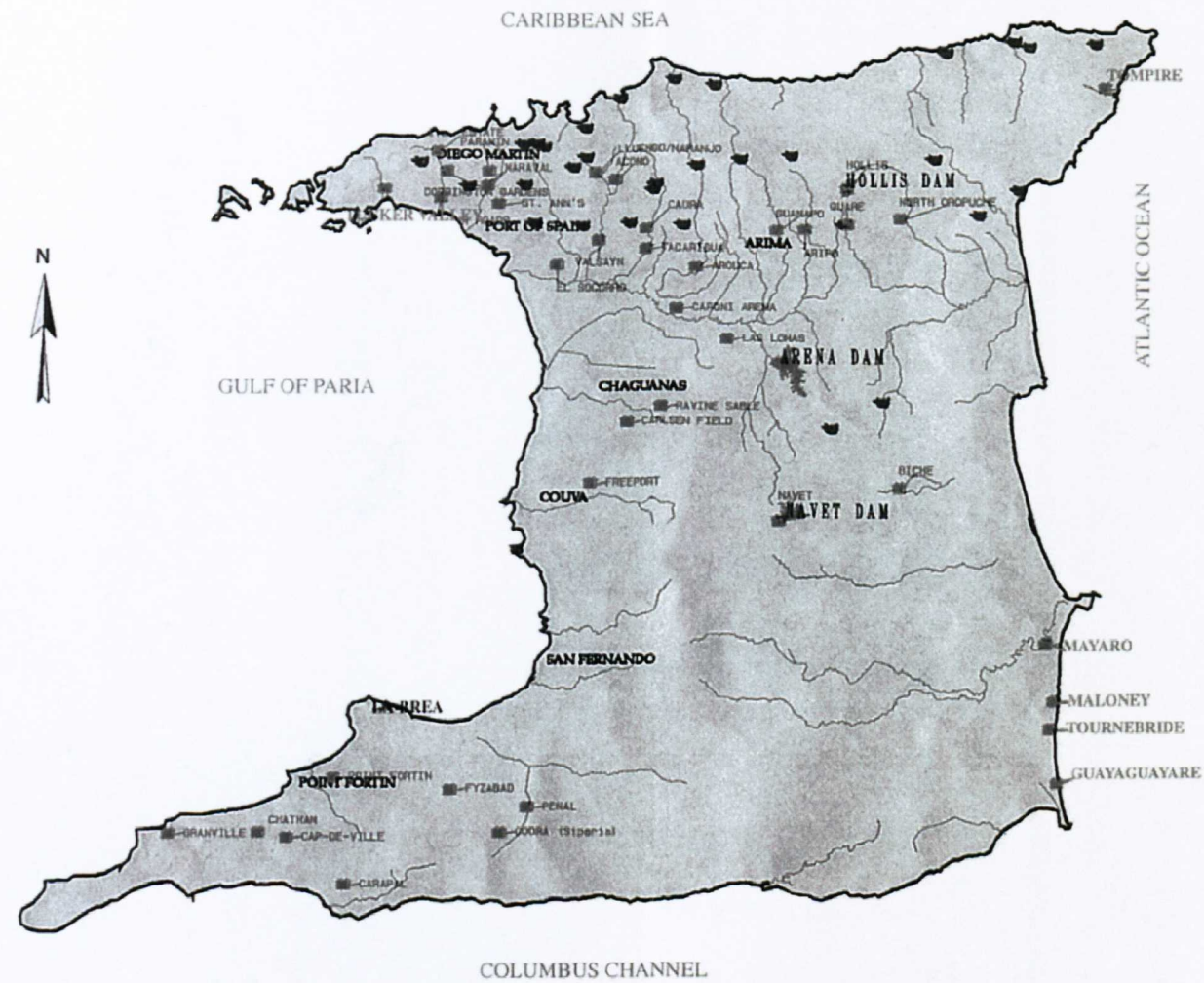
#### ***Hollis Reservoir***

The Hollis reservoir is the oldest system in Trinidad. The reservoir has a capacity of 4.75 MCM and the areas which benefit from this supply include Arima and Arouca.

#### ***Hillsborough Reservoir***

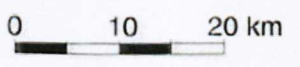
In Tobago, the Hillsborough reservoir is the largest and most reliable source of potable water. The reservoir has a maximum storage capacity of 0.9 MCM and the Hillsborough system remains the principal source of supply for the Scarborough and south-west areas, accounting for 9,000 m<sup>3</sup>/day (40 per cent) of water production.

Figure 5.18: Trinidad – Waterworks and Intakes



**LEGEND**

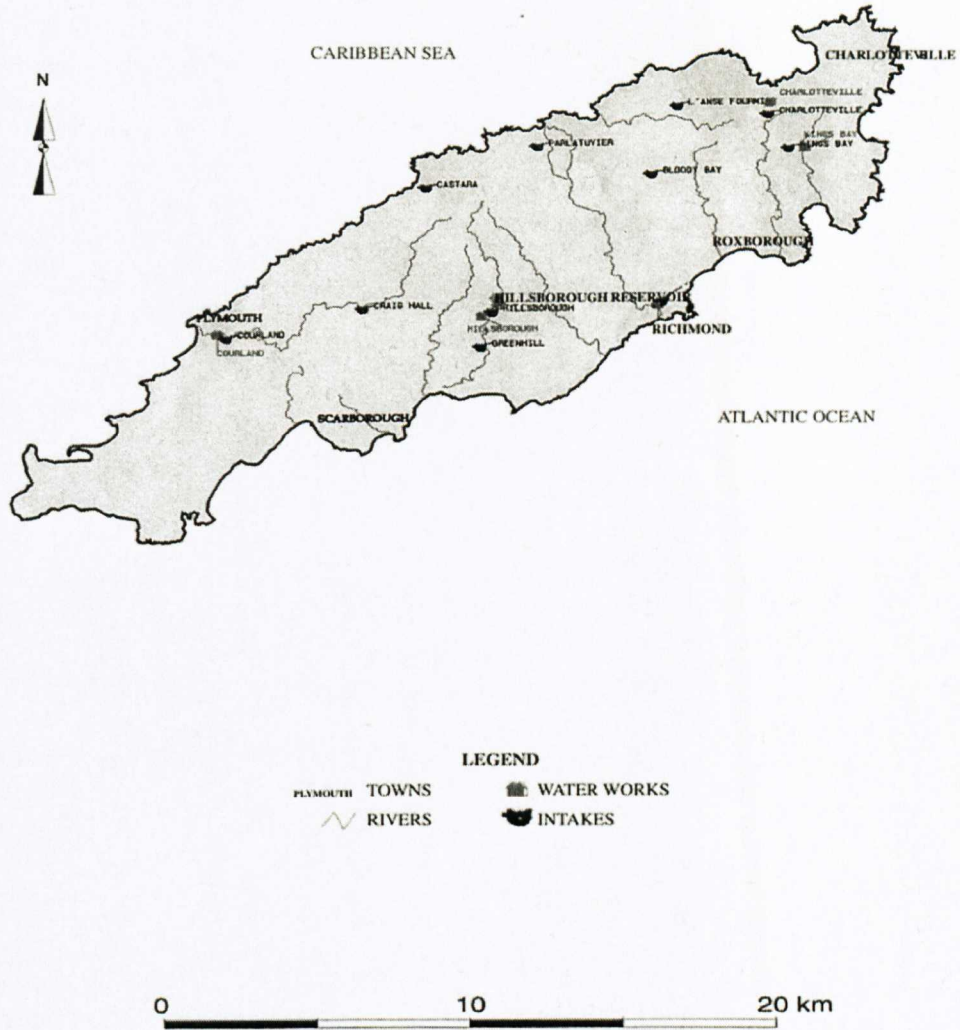
ARIMA	TOWNS	■	WATER WORKS
∩	RIVERS	●	INTAKES



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Figure 5.19: Tobago – Waterworks and Intakes



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**Total Production Summary**

**Figure 5.20: Total Water Production by WASA from 1996-2000**

	Year				
	1996	1997	1998	1999	2000
<b>Daily average production (m<sup>3</sup>/day)</b>	700,098	763,743	768,744	776,472	861,484
<b>Total production (MCM)</b>	255	279	280	282	310
<b>Tobago only (MCM)</b>			9.8		

Source: CSO (1997, 2000)

**5.6.6 Treatment**

Except for the untreated supplies from rural intakes, which are relatively small, all other water streams receive some form of treatment. Various combinations of treatment processes, contingent on differences in the raw water quality are applied at existing production facilities. The processes are grouped largely into two, based on the method applied. These are a) plants that apply only chlorination and b) plants that employ a full treatment process such as aeration, coagulation, sedimentation, filtration, chlorination and if needed, other specialist treatments. The following are the salient features of the treatment facilities.

Among the 56 production facilities which treat surface water, 15 large and medium-scale facilities apply a combination of coagulation, sedimentation and filtration processes before chlorination. Generally, water of satisfactory quality in accordance with World Health Organisation (WHO) guidelines is produced, regardless of any conditions of raw water turbidity.

Second, a number of the small and medium-scale systems that treat surface water by applying only chlorination suffer from seasonal fluctuations in the raw water quality because the filtration system used is inadequate for handling the increased turbidity that occurs after heavy rainfall. This can result in water of a poor quality entering the public water mains.

Finally, in Trinidad, of the 32 production facilities that take raw water from boreholes, 16 abstract relatively clean groundwater from the Northwest Peninsula Gravels and the Northern Gravels aquifers. The remaining 16 obtain iron-bearing groundwater from the Central Sands and Southern Sands aquifers which require a more rigorous treatment, that is, a combination of aeration, sedimentation and filtration before chlorination.

#### 5.6.7 Distribution

The distribution system comprises those mains which deliver water from the principal transmission mains or distribution storage reservoirs to the customer's service connections. In general, distribution mains are smaller than 305 mm (12 inches) except in the rural areas where transmission and distribution mains are one and the same. It is only in the well-developed urban areas that a true distinction can be made between transmission and distribution pipelines. These areas are Port of Spain, Diego Martin, San Fernando, Arima and a few other communities. The standard size is 102 mm (4 inches) but 152 mm (6 inches) pipelines are also used. Service pipelines, which carry water into dwellings, are usually 12 mm (1/2 inch) or 20 mm (3/4 inch) in size. The transmission pipelines range in size from 305 mm (12 inches) to 1,372 mm (54 inches), the most common sizes being 305 mm (12 inches), 610 mm (24 inches) and 914 mm (36 inches).

The major distribution pipelines extend from the large-scale sources and are connected with smaller pipelines from the medium-scale water sources. These constitute the distribution network. As previously stated, the small-

scale water systems are isolated and direct feed sources which are not linked to the main distribution network.

The existing transmission/distribution system consists of 106 service storage reservoirs, 6 high-lift pumping stations, 52 booster pumping stations and the lengths of transmission and distribution pipe.

The transmission/distribution pipelines, a large portion of which have been installed since commissioning the Maraval Waterworks in 1853, are consequently substantially aged. A variety of pipe materials are in use, namely, steel, cast iron, concrete, asbestos cement and polyvinylchloride (PVC). This is consistent with a policy of purchasing pipes by competitive tendering over a range of material types, rather than standardising on a limited range. This approach has resulted in the need for a variety of fittings and repair materials, which has caused difficulties in ordering, stock holding as well as additional expenditure.

The present pipeline conditions vary to a large extent reflecting their ages, materials, soil conditions and maintenance. The cast iron, asbestos cement and galvanised steel pipes, all installed over 30 years ago are seriously deteriorated and causing several problems. For example, conveyance capacity is reduced, frequent pipe breakage occurs and there is a significant amount of leakage.

In addition, many of the existing pipelines are plagued with particular deficiencies: piping systems not clearly identified and lack of rehabilitation and replacement work on the old distribution pipe network. Consequently, the continued utilisation of such deteriorated mains has been causing major reductions in the transportation capability. This has not coincided with the supply expansion plans for affected demand zones, resulting in heavy leakage. Finally, only a few flow meters have been installed on the pipelines and amongst these, several are inoperable. This means that actual system flows, water demands and even water production amounts cannot be

identified or monitored accurately. Adequate distribution has also been hampered by pumping station failures and low water levels in the service storage reservoirs.

Mostly in the hills of the Northern Range, housing developments have taken place above the levels of the service storage reservoirs. It is therefore not uncommon for water to pass through three separate booster pumps in order to reach high properties (TWI, 1991). In 1994, booster pumping stations were failing regularly due to the lack of maintenance, leaving many communities without a reliable water supply.

The service storage reservoirs range in size from 40 m<sup>3</sup> to 45,000 m<sup>3</sup>. Most are horizontal, cylindrical tanks located at higher elevations near water demand zones which utilise gravity flow. In 1991, JICA reported that 22 of the then 99 reservoirs were not in use. This was attributed to:

- 1) the failure of treated water from the waterworks to reach the storage reservoirs;
- 2) difficulty in financing the implementation of comprehensive schemes for rehabilitating/upgrading wells and pumping equipment; and
- 3) large amounts of leakage on the transmission/distribution pipelines.

This scenario still exists eleven years later.

## **5.7 The Water Demand Dimension**

Estimates of future water requirements are based on population projections, trends in past and current water use and economic forecasts of industrial development. These estimates are made according to use clarification. Based on the data available, three classifications have been identified: domestic, industrial and irrigation/agricultural.



A little over half the population is served by direct connections on the premises. The other half gets their supply from standpipes, from private sources or from truck-borne deliveries. For most direct connections, the utility charge is a flat fee based on the Annual Taxable Value (ATV) of the property; however a few domestic connections (small commercial customers) in Port of Spain are metered. Outside the capital, only the large industrial users are metered. Figure 5.21 is a summary of customer accounts according to WASA's customer classification system.

**Figure 5.21: Customer Accounts according to WASA's Classification System**

	Domestic	Industrial		Commercial		Agricultural		Total
	Unmetered A3	Unmetered E3	Metered B4	Unmetered C3	Metered C4	Unmetered E3	Metered E4	
Number of Customers	222,070	136	288	1,563	4,305	538	449	229,349
% of Total Customers	96.8	0.1	0.1	0.7	1.9	0.2	0.2	100
% Unmetered by Category	100.0	32.1		26.6		54.5		97.8
% Metered by Category	0.0		67.9		73.4		45.5	2.2

WASA (2000)

### 5.7.1 Population

Trinidad's population of about 1.29 million is concentrated in and around its two largest cities, Port of Spain and San Fernando. The Central Statistical Office (CSO, 2000) has recorded the average population density as 252 persons per km<sup>2</sup> with the greatest densities in three urban centres: Port of Spain (4,601 persons per km<sup>2</sup>), San Fernando (3,572 persons per km<sup>2</sup>) and Arima (2,861 persons per km<sup>2</sup>). Approximately 90 per cent of the population live along the west coastal area and the foothills of the Northern Range, of which 41 per cent resides along the 'East-West Corridor', an urban strip that runs from Chaguaramas in the west to Arima in the east. The average annual population growth rate is 0.5 per cent and future population expansion is expected to occur in upcoming urban areas where employment opportunities, educational and other facilities are growing, as in Chaguana where the population has been increasing at a significant rate



since the 1980s. This is mainly due to its convenient, central location and its proximity to the industrial estate in Point Lisas.

In Tobago, the population is located largely in scattered settlements in the south-western half of the island. Scarborough has the only large concentration of population.

### 5.7.2 Population Served

Water supply may be via direct house connections, private standpipes (yard taps), public standpipes or truck-borne deliveries. Based on studies carried out by Saunders and Warford (1976), it was found that consumers with house connections generally use more water per capita than those served by standpipes. Interestingly, for Trinidad and Tobago, the unit use of water at public standpipes is noticeably higher than for other countries. This reflects the wastage at public facilities and it is not unusual for public standpipes to be left running at all times.

A survey conducted by WASA in 1994 placed the number of persons served by piped water systems at approximately 90 per cent of the population. The breakdown by percentage from this survey is as shown at figure 5.22 below:

**Figure 5.22: Breakdown of Water Services provided by WASA**

<b>Type of Service</b>	<b>Per cent</b>
Direct connections	54
Yard taps	20
Standpipes	15
Other – springs, streams, ponds or trucks	11
<b>Total</b>	<b>100</b>

Source: WASA (1994)

In the category 'other', 3 per cent are supplied by private concerns; the County Councils as agents of WASA serve another 4 per cent by truck; leaving approximately 4 per cent (about 52,000 persons) so isolated as to be not supplied either directly or indirectly by WASA. This latter group obtain potable water primarily from rainwater collection (usually via drums); some may have private wells.

### 5.7.3 Freshwater Demand

#### *Domestic Water Use*

Small commercial customers, churches and residential customers have been included in the domestic use category and account for about 96.8 per cent of WASA's billed consumers. The current demand is estimated at 333,500 m<sup>3</sup>/day or 120 MCM annually.

According to a study performed by Thames Water International (1994), the average domestic water consumption in the Caribbean is 225 litres per capita per day (lpcd) compared with Trinidad and Tobago's which is around 258 lpcd. It is important to note however that consumption varies with the level of service, such that the estimate for non-metered domestic users is 348-370 lpcd whilst metered customers use 227 lpcd, standpipe users, 361 lpcd and yard tap users, 305 lpcd.

#### *Agricultural Water Use*

Agricultural users account for only 0.4 per cent of WASA's billed customers, although irrigation is practised widely in Trinidad and Tobago. This is due to the fact that WASA does not furnish irrigation water. It is supplied by diversions from creeks and streams built by private individuals.

Therefore the estimated agricultural demand of approximately 2,500 m<sup>3</sup>/day is only for other miscellaneous farm activities such as cleaning.

WASA is however responsible for approving the withdrawal of water from any stream or groundwater aquifer so as to prevent indiscriminate development from interfering with the existing or proposed supplies of the Authority.

In the past, irrigation was not a competitive use as the water supplies were more than adequate to meet the demand. Today however, the quantities of water required by the other sectors have increased significantly, so much so that in the fifty-year period, 1949 to 1998, WASA's production has increased ten-fold. The available groundwater resources are also close to full exploitation. These factors are compelling WASA to mobilise supplies in order to continue to meet the increasing demand.

#### ***Industrial Water Use***

180,000 m<sup>3</sup>/day is the current estimated demand for industry and this sector accounts for 2.8 per cent of WASA's users. The industries located in the Point Lisas Estate include over 80 companies involved in a range of activities from heavy processing industries such as steel and petrochemicals to ammonia and methanol, engineering services, food manufacture as well as ancillary services like banking and telecommunications. Further, new ammonia and other downstream petrochemical plants are presently being installed and plans are in place to expand the Estate northwards to include even more industries under consideration for location in that area. Needless to say, this region has become vital to Trinidad and Tobago's economic welfare and is expected to play an even more significant role in the future. The availability and reliability of the utilities is crucial to their operations, especially the water supply. The Point Lisas Industrial Estate's current demand is just about being met, so provisions to increase the supply to this area are being feverishly pursued, including the introduction of a desalination facility.

### 5.7.4 Water Shortages

In 1995, WASA in collaboration with the CSO conducted a survey to determine the adequacy and quality of the water supply to households as well as to public, industrial and commercial establishments. 1,200 households throughout the country were selected by random sampling and 600 commercial and industrial establishments were chosen, taking into consideration sectors, sizes and areas. Based on these results, it was found that about 28 per cent of the households enjoyed a 24-hour water supply, whilst 25 per cent of the households receive water on days less than half of the week. It was also found that about 50 per cent of the customers in the northern region of Trinidad enjoy a 24-hour supply. But, only 20 per cent of the customers in Tobago and the southern part of Trinidad have such a favourable supply.

To distribute the available water resources, WASA rations the water supply by manual controls depending on the severity of the situation. This process is known as scheduling. Figure 5.23 shows a detailed breakdown of the percentage of the population served by each type of supply.

**Figure 5.23: Percentage of Population served by each type of Supply**

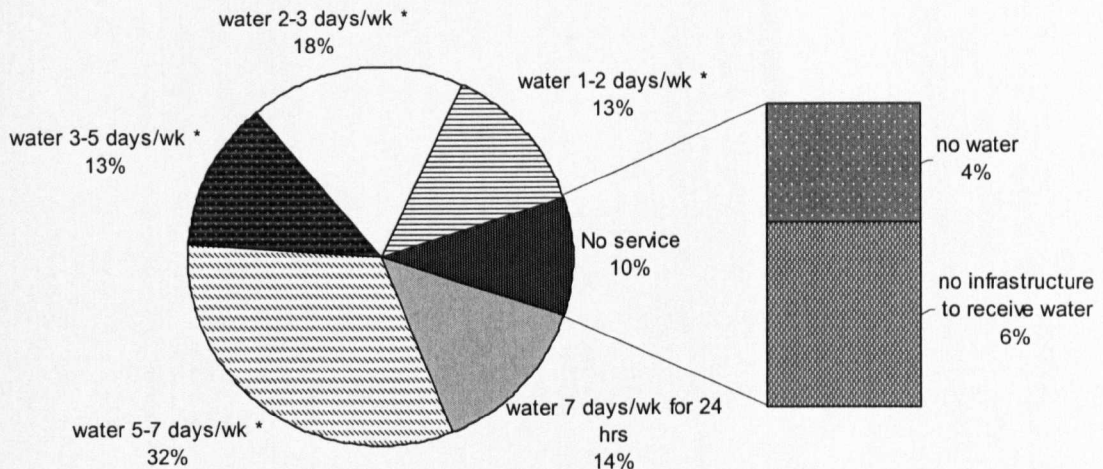
<b>DISTRICT</b>	<b>24 HOUR SUPPLY (per cent)</b>	<b>SCHEDULED SUPPLY (per cent)</b>	<b>TRUCK-BORNE SUPPLY (per cent)</b>
Port of Spain	51	49	0
North West	44	54	2
North Central	70	30	0
North East	46	51	3
San Fernando	20	80	0
South East	0	94	6
South West	5	93	2
Tobago	20	79	1
<b>Overall</b>	<b>22</b>	<b>76</b>	<b>2</b>

Adapted from WASA (1996)

It is no surprise that the survey also found that large sections of the population possess their own storage facilities. The largest percentages – 54 per cent, 71 per cent and 92 per cent – were recorded in Diego Martin, south Trinidad and Tobago respectively.

The Minister of Public Utilities and Environment recently reported that according to the January 2002 ‘State of Utility – WASA Report’, the water supply situation is now worse than was reported 5 years ago, with only 14 percent of the population currently receiving water everyday on a 24 hour basis. The complete service statistics are shown at figure 5.24 below.

**Figure 5.24: Levels of Service received from WASA by Population Percentage**



\* - not necessarily 24 hrs/day

Adapted from WASA (2002)

### 5.7.5 Watershed Status and Water Quality

The condition of watersheds and their waterways is extremely varied. In Trinidad, many of the Northern Range rivers, especially those draining to the North in the eastern part of the Northern Range are pristine, not prone to flooding even though they arise in high rainfall areas and support a rich

biota. In contrast, many south flowing rivers of the Northern Range, especially those in the western part of the Range reflect the serious deforestation, industrialisation and urbanisation, which has taken place over the last century (EMA, 1998).

As previously explained, Trinidad and Tobago has variety of industries which include oil and sugar refining, rum distillation, petrochemicals, agro-processing and other light manufacturing. Rivers along the 'east-west corridor' and the western coast of Trinidad are the recipients of the largest quantities of industrial effluents. These include the Maraval, San Juan, Arima, Caroni and Couva rivers. The Guapo, Erin and Ciperu rivers in south Trinidad are affected by petroleum activities and sugar cane refining, especially from increased run-off during the rainy season. Other pollutants include farm wastes, sewage, domestic chemicals and refuse. Industrial activity in Tobago is small compared to Trinidad but is located primarily in the south west of the island, where several groundwater aquifers exist. Although the EMA (1998) found no polluted rivers in Tobago, the primary pollutants of concern are sewage, solid wastes, farm wastes and agricultural chemicals. These water quality findings are illustrated at figure 5.25, whilst figure 5.26 shows the location of the freshwater systems (surface water and groundwater) in relation to the pollutant sources.

Unfortunately, some signs of watershed deterioration resulting from forest removal for officially sanctioned activities such as timber harvesting, housing, urban expansion and road construction; as well as unofficial or private activities such as squatting for housing and agriculture, and quarrying are also becoming evident throughout the eastern portion of the Northern Range in Trinidad, (CARIRI, 1997). The recurrence of fires, particularly on steep hillsides also results in the loss of vegetative cover. It is instructive to recall that the three most important water storage facilities in north Trinidad are located in the eastern Northern Range or its foothills. These are the Hollis Reservoir, the North Oropouche Waterworks and the

Caroni/Arena Reservoir. The negative activities cited above have been observed in the catchment areas of two of these facilities.

According to the EMA (1998), the catchments of the Northern and Central Ranges have been significantly affected by the above activities, which have led to high sediment loading in the rivers which drain them. Some of these sediments remain suspended in the watercourses or are transported to the flood plains and wetland areas where they may reduce light penetration, smother species when they settle and generally affect species composition, abundance and normal interrelationships in ecosystems. The Diego Martin, Maraval, Maracas/St. Joseph, Tacarigua, Aripo, El Mamo, Guanapo, North Oropouche and Arima rivers and the Caroni Swamp have been receiving increased sediment loads as a result of these activities. (See figure 5.26)

Figure 5.25: Trinidad and Tobago – Surface Water Quality Assessment

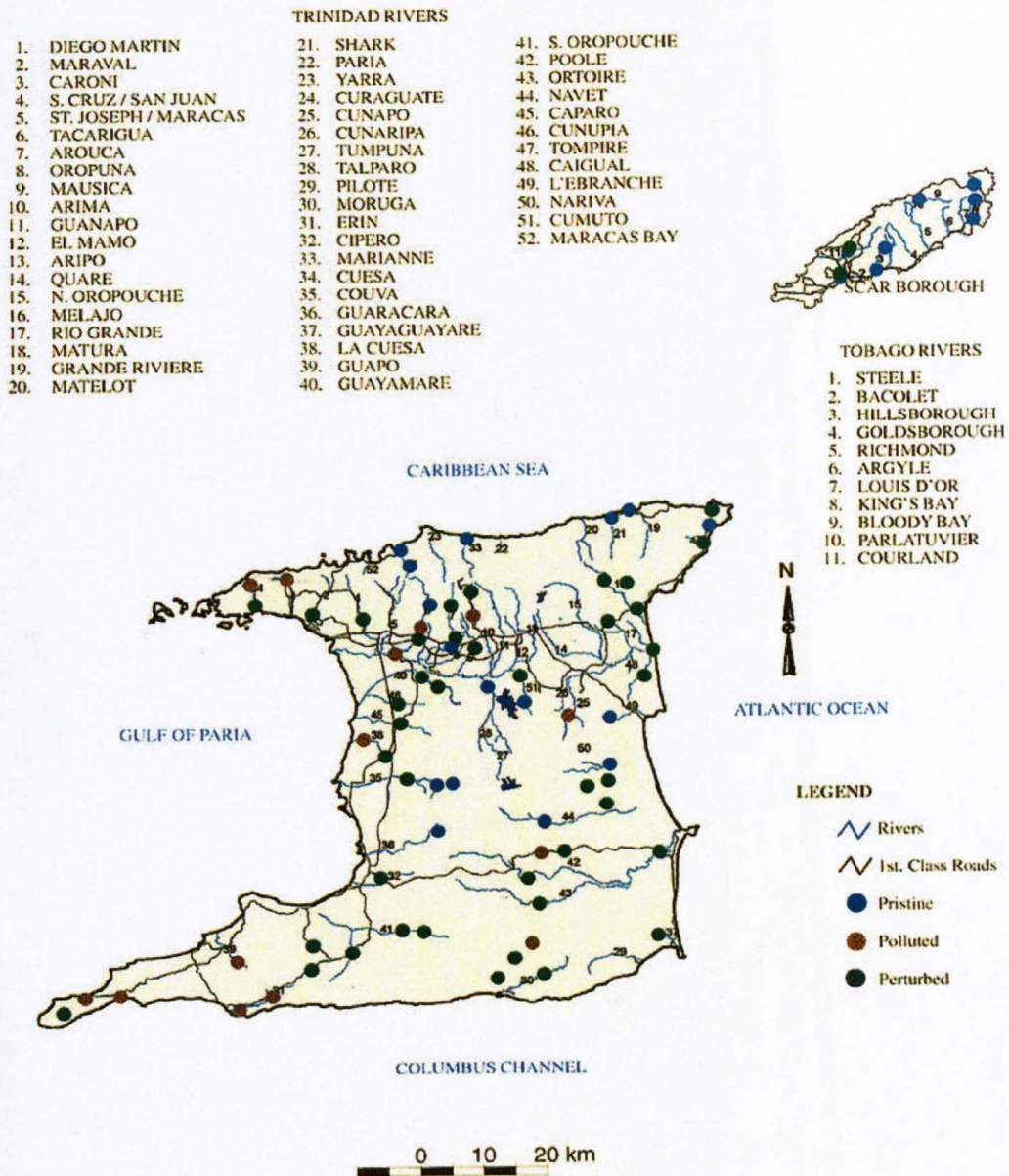
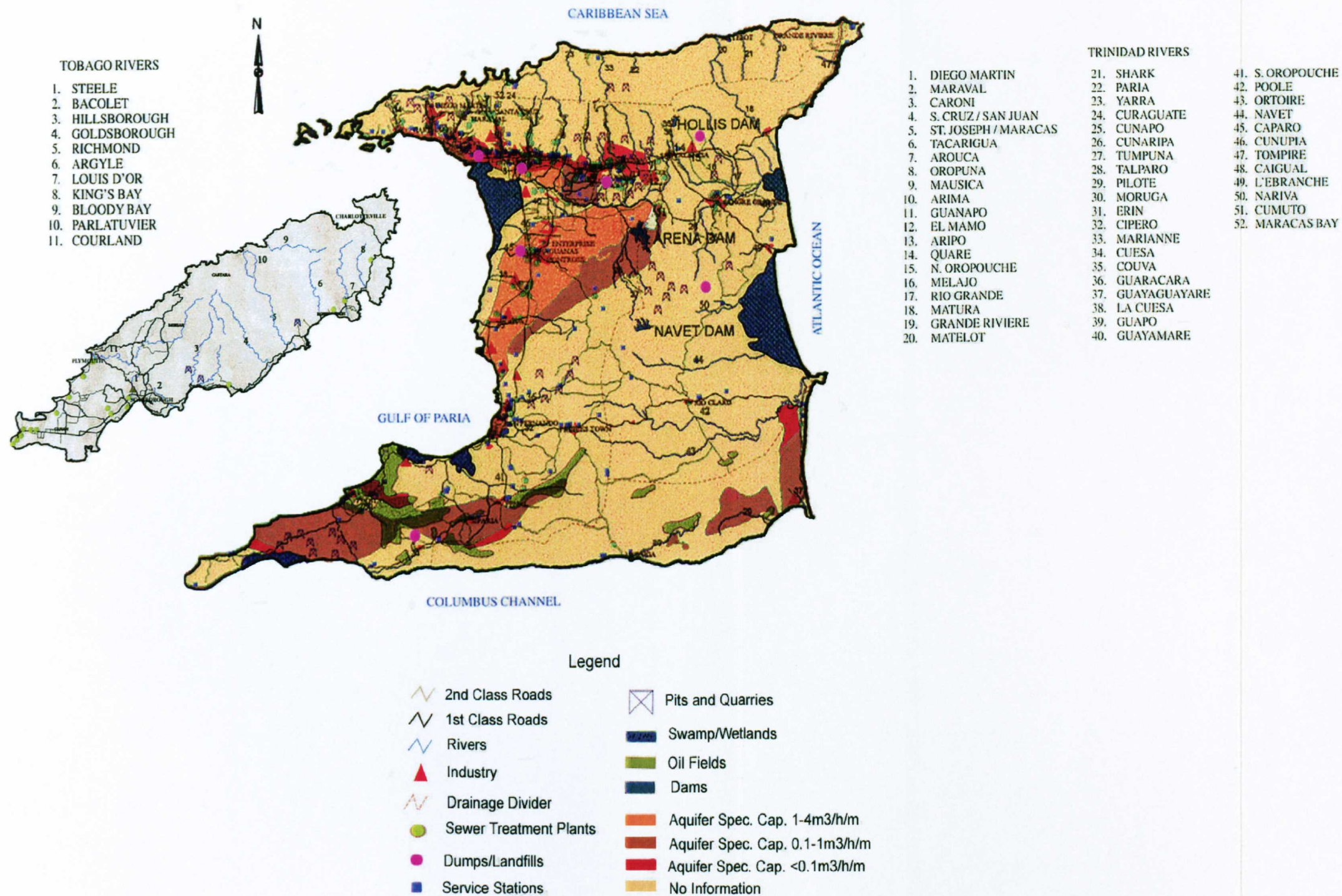




Figure 5.26: Trinidad and Tobago – Major Water Systems and Potential Pollution Sources



Prepared by Water and Sewerage Authority

Environmental Management Authority  
Trinidad and Tobago  
State of the Environment (1998) Report

Figure 5.27 shows the erosion status of watersheds in the 1960s. The information indicates that at that time, 15 per cent of the watersheds in Tobago had lost their entire topsoil and 42 per cent lost more than half of their topsoil. In Trinidad, only 1 per cent of the watersheds had lost all of their topsoil, while less than 10 per cent had lost more than half. Based on the urban and industrial development during the last 4 decades, concomitant with the increased population, it is estimated that this situation has worsened by several degrees.

The major wetlands in Trinidad (Caroni, Nariva and South Oropouche Swamps) are affected mainly by drying out and salinization resulting from structural interventions to the hydrologic regimes of these areas. Drainage and flood protection works, as well as water diversions for large-scale agriculture have reduced their freshwater supplies and storage capacity and encouraged saline intrusion. Sediments, agricultural and industrial chemicals, organic pollutants and salt water have impaired the natural functioning of these systems. The EMA (1998) revealed the recent mangrove die-back on the Point Lisas Industrial Estate was caused by the combined effects of ammonia, high temperature and salinity associated with the discharge of industrial effluents from the Estate. Thus, the interactions of soils, water and biota, which enable wetlands to perform vital functions such as water storage, purification and recharge are being disrupted in this region and other areas.

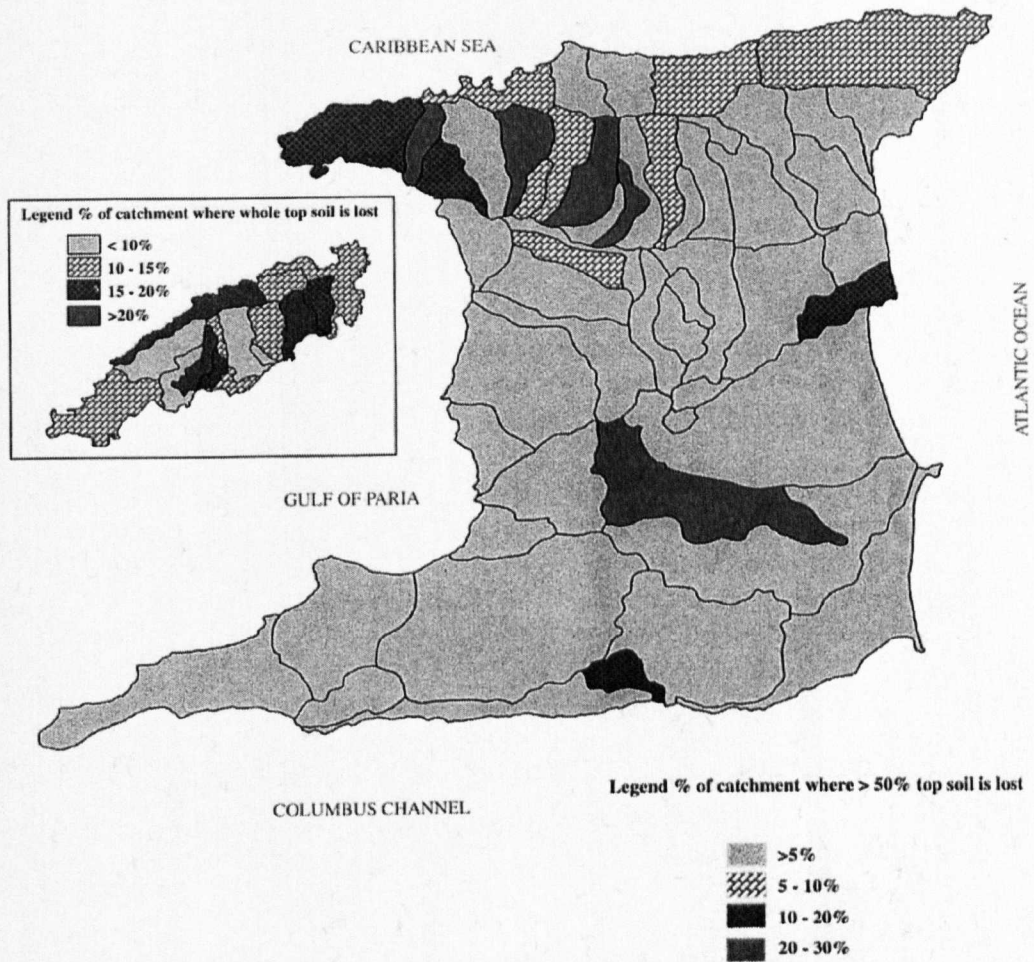
The forests are also essential vehicles for creating and maintaining groundwater supplies, since one critical effect of watershed deforestation is the reduction of infiltration to aquifers in the long-term, due to faster run-off. Where aquifers are being tapped in deforested valleys, such as the Santa Cruz Valley for example, recharge may be less than the extraction rate, as has been shown in the National Report on Environment and Development (1992). In other valleys, perennial streams may simply disappear underground, upstream of rural boreholes during the dry season.

There have been no confirmed instances of significant groundwater pollution but because of the proximity of several productive aquifers in Trinidad and Tobago to landfills, garbage dumps, sewer treatment plants, underground fuel storage tanks, petroleum production activities as well as oil and natural gas pipelines, (see figure 5.26), the risk is acute and constant monitoring is required.

Citing the extensive squatting in the Southern Watershed Forest Reserve and Wildlife Sanctuary as another example, the unofficial development which is occurring, is affecting the official water supply from the 35 wells in the area. The wells are also being polluted with faecal matter from livestock-rearing and unplanned housing along with chemicals from the use of pesticides and fertilisers by the agricultural squatters, which will gradually seep into the aquifers. This reserve was established since 1901, not only to set aside for posterity areas of unique forest tree associations, such as the *Acurel-Moussara* Association that only occurs in this forest reserve, but also to ensure a continuous supply of water to south-west Trinidad. But, within recent times, the rate of removal of trees from upland forested areas has been increasing significantly and multiple spin-off effects of this will no doubt be felt in the short-term.



Figure 5.27: Trinidad and Tobago – Erosion Status of Watersheds (1960s)



Prepared by Water and Sewerage Authority

Environmental Management Authority  
Trinidad and Tobago  
State of the Environment (1998) Report

### ***Caroni Hydrometric Area***

As seen earlier, the Caroni River Basin is a critical water catchment in Trinidad, no doubt because of its size and importance to the potable water supply on the island. The Caroni River drains heavily developed agricultural and built-up areas and is consequently a receiver of a wide range of pollutants. Most of the other rivers and streams which flow into this Basin, receiving discharges from the urban areas within the region are also polluted with a variety of wastes from domestic refuse and agricultural and industrial activities (EMA, 1998). Rivers such as the Mausica, Arima, Guanapo, El Mamo, Aripo, Cumuto and Tumpuna are so affected.

In June 1997, the contamination of the raw water was such that the water treatment disinfecting equipment did not have enough capacity to adequately disinfect the public supply. This has happened on a few other occasions (CARIRI, 1997). Another incident reported in this study which further highlighted the severity of the problem, occurred in 1987, when the sedimentation volume was so great that the sedimentation basins were grossly overloaded. This resulted in substantial damage to the mechanical flocculators, excessive production of clay/aluminium sludge and massive repairs. TT\$5 million was spent to restore the sedimentation tanks to working condition. This problem arose from the quarrying activities of five plants that were allowed to operate without license at short distances upstream of the Caroni/Arena waterworks system.

The production of potable water from polluted sources is very expensive due to the increased costs of treatment to render it safe for consumption. The treatment of water from the Caroni River – which as previously mentioned is the source of about 40 per cent of the country's potable water supply and is known to contain various pollutants – costs WASA approximately TT\$36 million annually. The possibility exists to reduce this cost if the raw water was to be less polluted.

## **6.0 The Current Scenario in Trinidad and Tobago: Interpretation and Analysis**

### **6.1 Introduction**

Trinidad and Tobago cannot be described as a water-scarce country, with water availability on a per capita basis of approximately 2,500 m<sup>3</sup>/year. It has a history of providing low-priced water to its population and approximately 90 per cent of the population has some form of access to a potable water supply. Nevertheless, water shortages abound and everyday water services remain inadequate and unreliable. On average, water has been available less than 12 hours a day.

The Water and Sewerage Authority (WASA), a publicly owned and managed utility provides the only service for Trinidad and Tobago's 1.29 million inhabitants. WASA has been plagued by the problems of a typical public utility: widespread failures in the distribution system; poor customer accounting; severe cash flow and other financial difficulties; as well as institutional and management problems.

However in 1999, WASA embarked on a mission to provide *“water for all by the end of the year 2000”*. New policies and programmes were established to reduce leakage; reduce the levels of truck-borne water service provision; improve the levels of service to customers and in so doing, “... seek to attain customer satisfaction, employee satisfaction and profitability.” (Newsday Newspaper, 28/01/00). ‘Water for all’ however, has to date not yet been achieved. It was reported in the January 2002, State of Utility report, that only 14 per cent of the population receive a 24 hour, 7 days/wk water supply; whilst 76 per cent receive a scheduled supply and 10 per cent have no water supply at all.

## **6.2 The Danger of the Current Situation**

Studies undertaken by the Central Statistical Office in 1992 found that approximately 70 per cent of the population suffered from water shortages. WASA blamed this on insufficient supplies. As a consequence, WASA's management formulated plans to develop two new large-scale water sources as well as expand one of the existing sources.

Financing for these projects was secured through the Inter-American Development Bank, who in turn retained Thames Water International (TWI) to carry out pre-qualification studies. These consultants estimated in 1994 that the total installed design production capacity in Trinidad and Tobago was 810,000 m<sup>3</sup>/day, with an estimated dependable yield of 721,000 m<sup>3</sup>/day in the dry season and 771,300 m<sup>3</sup>/day in the wet season. Demand was approximated to 712,000 m<sup>3</sup>/day including losses. Indications are that if WASA had proceeded with its original plans, already scarce financial resources would have been misallocated, with only short-term relief of the water shortage problems. Current installed capacity is 864,000 m<sup>3</sup>/day and projected demand to the year 2025 is not expected to exceed 1.23 MCM/day.

Reviewing reports by JICA (1991) and TWI (1994), the consultants agreed that the level of system leakage, although difficult to determine accurately was approximately 40 to 50 per cent of the water produced. Reasonable, acceptable levels of leakage for Trinidad and Tobago have been put at between 15 to 25 per cent of the water produced.

The high level of leakage demonstrated the severe lack of system maintenance. During the early 1990s, WASA denied that system leakage was in excess of 20 per cent, even though some of their own studies showed otherwise and they continued to pursue plans for expansion. Interestingly, a similar situation arose again in 1998 at the Utility with management maintaining that leakage was no greater than 20 per cent and

significant system expansion and development was needed to meet the increasing demand, including the introduction of a desalination facility. However the Minister of Public Utilities and Environment, Martin Joseph, recently revealed that current leakage is still high (approximately 44 per cent), as reported in the State of Utility Report (WASA, 2002). It was also reported that in addition to the heavy system leakage, as much as 6 per cent of the water produced is lost to customers who are not registered with WASA. Further, a large number of 'off-takes' or branches from the main distribution and transmission pipelines supply water to the newer customers. Therefore, because of the increased consumption - illegal and legal - and moreover the method of supply, compounded by the substantial leakage, water supply volumes decrease rapidly before reaching the original demand zones.

Under such circumstances, WASA has been constrained to ration or 'schedule' the water supply. But, this makes the problem even worse as the intermittent operation of the distribution system is undesirable for a number of reasons. First, while an area is not in supply, the mains are empty, allowing potential for infiltration of groundwater via the many leaks within the network. This can create a major health risk which is countered by WASA chlorinating the supplies 5 to 10 times higher than the dosing rate generally accepted as satisfactory for a normal potable supply. This overdosing has a high cost implication and would not be necessary if areas were in constant supply. Second, when the supply is re-established, air can be trapped in the pipework. Entrained air will increase the number of burst mains due to pressure surges and also exacerbate any leaks that may already exist in the system. Damage to customers' valves and consequent incorrect readings can also result. Finally, the operation of schedules subjects the distribution system to considerable pressure fluctuations, both in the scheduled areas and in adjacent areas of continuous supply. Large pressure fluctuations put unnecessary stress on the pipework, leading to an increased number of bursts. Fluctuations also place stress on service connections, creating the potential for further leaks.



Apart from the distribution/transmission pipelines, much other mechanical and electrical equipment has been malfunctioning and are in dire need of repair. According to WASA officials, this is due primarily to the severely constrained cash flow and past governmental policies. Other contributing factors include the limited availability of spares, many of which are not accessible locally, and the lack of a systematic maintenance programme, including replacement of mains.

High levels of pilferage and sabotage; an average of 3-4 strikes per annum and other institutional problems have also contributed to the current situation. In addition, political interference has undermined WASA's autonomy and eroded its management and planning capabilities. WASA in the past has also been expected to act as an agent for implementing public sector social policies, namely the provision of employment.

The propagation of the concept of water as a 'free' public good has required heavy government subsidisation for service provision, and for almost 50 years, water rates remained unchanged largely due to this ideology. The Public Utilities Commission (PUC) was also seen as a hindrance to rate increases and cost recovery and the implementation of charges on the basis of actual consumption (metering) is still regarded as a politically sensitive issue. Moreover, it conflicts with public service provision doctrines so a rate system based largely on the Annual Taxable Value (ATV) has been maintained with the result that the full costs of water service provision are still not recovered.

### **6.3 Water Supply System Problems**

The main supply system problems are high levels of leakage in the distribution network, malfunctioning equipment and lack of general maintenance.

### 6.3.1 Unaccounted-for-Water

Unaccounted-for-water (UFW) refers to the difference in volume between the quantity of water produced and the quantity of water consumed by legitimate consumption. Although the extent of leakage in Trinidad and Tobago cannot be accurately measured due to the lack of pipeline flow-meters, WASA (1994) estimated leakage at approximately 50 per cent. Studies conducted by the Environmental Management Authority (EMA) in 1998 obtained similar results, shown at figure 6.1. It is to be noted that the UFW category exceeds the domestic demand category – domestic consumers account for approximately 40 per cent by volume of WASA’s production, whilst UFW accounts for 42 per cent. The most recent report (WASA, 2002) confirmed that current UFW averages 50 per cent of total water production.

**Figure 6.1: Total Public Water Consumption (MCM/year)**

<b>Year</b>	<b>Domestic</b>	<b>Major Industrial</b>	<b>Minor Industrial</b>	<b>UFW</b>	<b>Total</b>
1997	118	36	9	124	287
2000	121	52	10	127	310
2025 (projected)	203	112	15	141	471

MCM – million cubic metres

Adapted from EMA (1998) and CSO (1999)

Studies done by the World Bank (1993) established that UFW levels in most developing countries are 3 to 5 times higher than typical levels in industrialised countries. But, the level recorded for Trinidad and Tobago is still atypically high compared to some other developing countries: for example, UFW in Singapore is estimated at 10 per cent and in Bangkok, 30 per cent (McIntosh, 1994). Studies done by Yepes (1990) also showed that average UFW levels for the more efficient Latin American utilities were 34 per cent, 22 per cent in the USA and 12 per cent in Canada.

UFW in Trinidad and Tobago comprises water lost through leaking pipelines and other malfunctioning water handling facilities and illegal connections to the supply distribution system.

### ***Leakage***

On average, 44 per cent of total water production (379,000 m<sup>3</sup>/day) is lost because of leaks (WASA, 2002). Leakage occurs at the reservoirs, valves, fittings and other connections, but most occurs throughout the transmission and distribution pipelines (TWI, 1991). A large portion of the cast iron and steel pipes are seriously deteriorated because of corrosion, whilst the asbestos cement pipes are brittle and the inner walls encrusted with calcium and rust deposits. These factors are causing frequent pipe breakage, reduced conveyance capacities and high levels of leakage. Leakage losses are particularly high in residential areas, ranging from 32 per cent (Arima) to 84 per cent (Diego Martin), mainly due to faulty valves and leaks at service connections.

According to TWI (1991), repair work has been lacking because of inadequate and inappropriate equipment for pipe repairs and re-laying of mains as well as lack of vehicles to transport repair gangs and equipment to the sites. For instance, there are more backhoes than compressors in virtually every WASA district office and the vast majority of all repair jobs are pipe repairs, which require a compressor, not a backhoe. Neither is a backhoe required for laying and relaying of pipelines at 450mm cover, as trenches are of narrow width and shallow depth. In addition, limited compaction equipment is available so trenches are either left un-compacted after backfilling or partially compacted by driving any vehicle on site over the trench. Pipes inevitably are subjected to non-design stresses from ground movement resulting in leaks and bursts. In addition, at least 45 per cent of WASA's transportation fleet is 10 years old or older and generally in poor condition.

Many distribution pipelines have been laid at a very shallow depth, sometimes less than 100 to 150 mm deep and often in the sub-base of the road surface. This has increased the risk of failure as these pipelines are susceptible to traffic loads. Lack of compaction equipment has also led to trenches not being properly re-filled after laying resulting in pipelines suffering greater stresses due to ground movement.

On account of the general shortage of materials and the lack of funds to pay suppliers, an ad hoc repair and maintenance programme has been instituted. This inevitably adversely affects the repair rate and also results in repair jobs being wrongly prioritised, in that leak repairs have become dependent on the availability of materials and funds, rather than the nature and size of the leak. It has become common practice at WASA to salvage and reuse pipe fittings and other materials where possible but this 'quick-fix' only exacerbates the problem in the long-term and repair of recurrent leakage is even more costly. Response times are also reliant on the availability of materials, equipment and transportation.

As argued by Ostrom, Schroeder and Wynne (1993), no facility can operate efficiently for its expected life without some level of routine and emergency maintenance. They stress that the most important maintenance tasks are the routine, scheduled activities as opposed to emergency repairs that are performed in response to unexpected failures. WASA's equipment is generally left without routine maintenance checks and 'fire fighting' is the order of the day. WASA admitted to the PUC in 1992 that preventive maintenance was not being undertaken because of depleted stocks of spare parts at most stores and the Authority lacked the funds to replenish them (PUC, 1992).

### ***Illegal Connections***

A large portion of UFW is as a result of illegal or 'ghost' consumers. The incidence of piracy is high, judging from 1994 data when it was estimated that there were approximately 44,000 illegal customers connected to the

public distribution system. According to the State of Utility January 2002 Report, 6 per cent of the water produced (51,700 m<sup>3</sup>/day) is currently lost to illegal customers.

### 6.3.2 High Distribution Costs

Urban planners contend that the cost of distributing water is affected by pipe length, urban sprawl, low population density, topographical constraints and inappropriate service standards and technology.

Urban sprawl refers to the development of urban peripheries characterised by scattered low-density communities. In Trinidad and Tobago, residential development has sprawled to areas outside the main distribution network. The new sources of water supply needed to satisfy demands of these growing urban areas are located at increasingly farther distances from the main supply network which results in the need for more and/or greater booster pumping to maintain adequate water flow pressures. The large distances between urban centres and waterworks also require longer pipeline systems. Densely populated areas are also more economical to service because the infrastructure (the supply network) costs are spread over a larger consumer base.

Water service provision to developments along hillsides is significantly more costly than on the ground. The National Physical Development Plan of Trinidad and Tobago (1984) and the Capital Region Plan (1975) prohibit development above the 91.4m (300 ft.) mean sea level contour line and on slopes steeper than 1 in 6, primarily to contain settlement expansion into the Northern Range and thereby protect the major watersheds. However, these regulations are largely ignored and not enforced, resulting in hillside squatter and other urban development. These developments incur higher distribution cost, both in terms of capital outlay and operation and maintenance, as booster pumps must be introduced to the supply system to

raise the water to the required height. Laying of pipelines and maintenance of same are also generally more costly along slopes.

### 6.3.3 Water Shortages

Many parts of Trinidad suffered severe water shortages in November 1999 due to industrial disputes at WASA. While many homes and businesses were inconvenienced during that period, there are many districts where pipe-borne water remains a luxury and, they are not all remote rural districts. Areas such as Belmont, Gonzales and Petit Valley located on the outskirts of Port of Spain have been without a reliable water supply for as long as 20 years. Penal, Moruga and other southern environs experience similar problems. In Tobago, Charlotteville, Bacolet and Carnbee are some of the areas that have also suffered critical water shortages over the last 25 years.

Tanks, drums and 2-litre soft drink bottles are some of the paraphernalia residents in water-deprived areas use to combat the problem. Some residents are forced to travel to other areas to collect water; others pay the Fire Services or private contractors and opportunists to deliver water to their homes, at much greater costs than WASA's average rate for domestic consumers of TT\$1.50/m<sup>3</sup>. In the rural districts, the problems are even worse. Residents in Moruga complain of receiving high water rate bills, in excess of TT\$2,000 (which most ignore as they have not received pipe-borne water in over 3 years) and having to pay exorbitant prices, for example TT\$400, to have their barrels and tanks filled from truck-borne water sources. Many residents rely on rainfall to satisfy their freshwater requirements.

Some rural areas, especially in South Trinidad have never had a pipe-borne water supply. As WASA Chairman Nazir Khan commented, "I was going down to Mayaro and stopped off in a little village called Agostini, past Rio Claro. They have never had water, and you wonder how they survive." In

addition, there are no operational storage facilities in South Trinidad so the supply is always a 'live' one, directly from a production/water treatment plant. As a result, when there are system failures or maintenance to be carried out, customers do not receive water whilst the supply is switched off.

In other areas such as Petit Valley and certain sections of Belmont and Diego Martin, where scheduling is carried out, consumers complain that it is done haphazardly and they have no notice of when the water will and will not be available. At times, there is no water supply on weekends or for entire days during the week. In some districts, water is only supplied late at night (after 10 p.m.), early morning (4 a.m.) or midday, which is inconvenient for most consumers. Moreover, often when water is made available, it is only for a short period (20 minutes) and the flow pressure is low.

A typical case-in-point was the two week water outage in Belmont in December 1999. As reported in the daily newspapers, WASA explained that the water supply was cut off due to a series of circumstances, including industrial relations problems; increased levels of turbidity at the North Oropouche dam from nearby quarrying activities; valve tampering at the Caroni Treatment Plant, which also had high levels of employee absenteeism; and a leak on the 24-inch transmission line at Beetham Estate (Trinidad Express, 6/12/99).

This case details all the problems that have traditionally affected the water industry and consumers in Trinidad and Tobago for the last 25 years. After years of unreliable service provision, many customers have resigned themselves to going without a pipe-borne water supply and endure the hardships and inconvenience. They have assumed the responsibility for securing a potable water supply, working their lives around WASA's problems one way or another. As one Belmont resident stated, "all we

want is for them (WASA) to give us the water at least two or three days every week and we'll be happy. That's all we asking."

## **6.4 WASA's Organisational Problems**

### **6.4.1 Financial**

Given that when the Authority was formed in 1965, there were inadequate supply facilities, a rapidly growing population, and a governmental policy of providing water services to everyone at minimum cost, it is not difficult to understand why WASA has faced financial problems since inception. The public utilities generally followed a rate philosophy of socio-political pricing and consequently costs were recovered primarily from government subventions and grants. This arrangement was possible during the 1970s to early 1980s when substantial oil revenues enabled the Government to subsidise WASA's operations.

However, with the decline in oil revenues from 1982 onwards, the Government found it increasingly difficult to provide the operating subsidy necessary to maintain the existing level of service and water rates, far less meet the requirements for the large capital expenditures needed to modernise and expand WASA's supply system.

Customers continue to pay only a fraction of the cost of water production, in the form of rates. Domestic consumers constitute the largest demand category (approximately 40 per cent by volume; 96.8 per cent by number of accounts) and only 2.2 per cent of the total customer accounts are metered. The vast majority pay a fixed rate based on the property value.

#### ***Revenue Shortfalls***

Shortfalls in revenue have resulted mainly due to the water tariff system in use, infrequent rate adjustments and the high level of accounts receivable.



Revenues generated in the early 1980s averaged 7 per cent of total recurrent expenditure. Since then, significant improvements have been made (e.g. in billings and collection and staff reduction) and in 1994, revenues accounted for just over 50 per cent of total recurrent expenses.

Despite improvements in revenue collection, by 1993, accumulated debt was estimated at TT\$516 million, which prompted the Authority to declare bankruptcy one year later.

A balance sheet showing WASA's revenue and expenditure relating to water provision is represented at figure 6.2. Thackray (1992) reported that on average, labour costs accounted for 60 per cent of WASA's total operating expenses, compared with 30 per cent for efficiently run water companies.

**Figure 6.2: Summary of WASA's Revenue and Expenditure in TT\$ million for 1988-1993**

	1988	1989	1990	1991	1992	1993
<b>Revenue from Water</b>	127	132	128	125	149	154
<b>Expenditure on Water</b>	268	246	290	356	287	316
a) production	51	51	53	62	64	69
b) distribution	41	37	44	54	42	37
c) transmission	13	10	13	14	12	9
d) administration	55	50	69	96	59	96
e) common services	71	65	78	98	89	72
f) depreciation	37	33	33	32	32	33
<b>Government transfers</b>	71	63	67	68	66	45

Source: WASA (1994)

### *User Charges*

J.E Thackray (1992) defines four basic strategic approaches to paying for water: 1) use of taxation, 2) use of charges or tariffs, 3) inclusion of environmental responsibility and 4) charitable giving.

The first option may be administered through general taxation or through levying of a special tax which is independent of actual use and often based on the sale or rental value of a property or on the number of taxpayers resident in the property. This approach resembles WASA's annual taxable value (ATV) pricing system. But, one problem with the flat rate method is that there is generally no incentive to conserve water. Leaks and other wastage also generally go unchecked.

The second option is what is normally referred to as a tariff and it represents a price or charge that bears some relationship to the capacity provided or used. It is generally based upon the cost of providing the service. Integral to this system is metering of customer premises, which is mainly lacking in Trinidad and Tobago.

The third option suggests that water authorities usually neglect or fail to include the externalities or social costs associated with the provision of the service. Thus the direct charge issued to the consumer is lower than it should be as the utility accepts responsibility for issues such as environmental impacts.

Option four is applied principally for humanitarian reasons, usually to non-profit and other welfare organisations. WASA incorporates this approach for the customer class comprising churches and charitable organisations such as the Salvation Army and Red Cross.

Options 3) and 4) are not really complete alternatives to options 1) and 2) but are often used in conjunction with them.

Overall, WASA uses a hybrid variation of all of the above approaches in its current water pricing structure. As previously mentioned, non-metered customers are charged based on the Annual Taxable Value (ATV), which is the assessed annual rental value of the property, generally used for real estate taxation purposes. Approximately 98 per cent of WASA’s customers are charged according to the ATV. The tariff is oriented towards an imputed ability to pay, rather than the amount of water used. The ATV system generates a large number of relatively small bills from which the total income is insufficient to cover recurrent costs, debt service obligations as well as service enhancements and expansion.

Although the table below (figure 6.3) only shows an ATV breakdown for the domestic customers, these account for approximately 97 per cent of WASA’s billed customers and it provides some explanation as to how many bills are generated and what little income is realised.

**Figure 6.3: Profile of the Domestic Consumer Category based on Annual Taxable Values**

ATV	A3 Domestic	
	Number	%
0-500	103,758	46.7
501-1000	43,174	19.4
1001-1500	28,076	12.6
1501-2000	14,637	6.6
2001-2500	8,293	3.7
2501-3000	5,378	2.4
3001-3500	3,917	1.8
3501-4000	3,304	1.5
4001-6000	6,947	3.1
6001+	4,586	2.1
<b>Total</b>	<b>222,070</b>	<b>100.0</b>

Source: WASA (2000)

From the table above, it can be seen that almost half (46.7 per cent) of the domestic customers were billed according to the minimum \$0-500 ATV range and therefore paid the minimum charge of TT\$108 per quarter. This however required the generation of 103,758 bills every quarter, whilst only

11 per cent (24,132 bills per quarter) collected the maximum charge which is equivalent to an ATV range of \$2,501 and above. In addition, according to WASA officials, approximately 40 per cent of un-metered industrial customers (B3) and over 70 per cent of un-metered commercial customers (C3) respectively, pay the minimum bill of TT\$474 per month.

The potential for revenue generation is further limited by the low water tariffs. Although the following information is somewhat dated, it provides some indication of how low Trinidad and Tobago's water tariffs have been: In 1993, the cost of producing water was US\$0.43/m<sup>3</sup> and the rates charged to all categories of users were below this amount. Hence, the considerable levels of subsidisation required. In comparison to most other Caribbean and Latin American countries, there is clear evidence that Trinidad and Tobago's tariffs have been consistently lower, as figure 6.4 shows below.

**Figure 6.4: Comparison of Water Rates in US\$/m<sup>3</sup> for 1993**

Country	Commercial	Industrial	High Domestic	Low Domestic
Columbia	0.06	0.06	0.65-1.25	0.20-0.60
Costa Rica	0.70	0.82	0.40	0.51
Barbados	0.85	0.85	0.85	0.06
<b>Trinidad &amp; Tobago</b>	<b>0.36</b>	<b>0.36</b>	<b>0.21</b>	<b>0.03</b>
St. Lucia	0.84	0.84	0.63	0.33

Source: WASA (1994)

Currently, Trinidad and Tobago's tariffs are still on average at least 50 per cent lower than those charged in Barbados (see figure 6.5).

**Figure 6.5: Comparison of Current Water Tariffs for Trinidad and Tobago and Barbados (US\$/m<sup>3</sup>)**

Country	Commercial		Agricultural		Domestic	
	metered	non-metered	metered	non-metered	metered	non-metered
Trinidad and Tobago	0.56	>75.36/ month	0.36	>16.69/ month	0.28< 150m <sup>3</sup>  0.54> 150m <sup>3</sup>	17.17< bill per quarter  < 48.33
Barbados	1.06	N.A.	1.06	N.A.	0.75< 34 m <sup>3</sup>  1.06> 34m <sup>3</sup>	20.00< bill per quarter  < 80.00

N.A. – not applicable

Adapted from WASA (1996) and London(1994)

Infrequent rate adjustments have also contributed to WASA's poor financial situation. Water rates remained unchanged from 1937 to 1985, even though costs exceeded revenue, mainly for political reasons. With the concept of water as a 'free' good, water charges tended to be resented and the government although not necessarily believing in a similar ideology, has been reluctant to raise rates, especially when incomes are low and unemployment high. Ayub and Kuffner (1984) reported similar findings in Algeria, Morocco and Tunisia. Further, as Ryan (1992) explained, it is possible that the political costs of raising water rates in Trinidad and Tobago have been considered too high in terms of securing election votes, even more so in the early 1980s when the economy was in decline.

After recording a deficit of TT\$308 million at the end of 1984, WASA applied to the PUC for a rate increase that would have enabled 80 per cent recovery of operating and maintenance costs. Capital costs would continue to be met by government. A six-fold rate increase was granted in 1986

after 9 months of deliberation and resistance. WASA however was still unable to meet full operational costs thereafter.

In 1991, after realising another substantial recurrent budget deficit and a steep reduction in government subvention, WASA applied for another rate adjustment. The PUC granted a 20 per cent increase in the rates of all 1) metered customers, 2) non-metered non-domestic customers and 3) private water abstractions.

Deterioration of the utility's revenue position continued along with growing costs and the collapse of many of its water supply and distribution systems propelling the application for a further rate increase in 1993. However, there was outcry from many consumers who felt the desired rate increase was unjustified because of the inadequacy and unreliability of the water service. But, under great pressure from government who were trying to secure a private operator to take over WASA's management, the PUC awarded a 35 per cent rate increase for domestic consumers, which took effect in early 1995. The 1995 tariff system is still currently in use.

#### ***Accounts Receivable***

Non-payment of water bills is a major problem that has affected WASA's cash flow. Delcan (1992) reported that uncollected accounts were about 25 per cent of annual billings and at the end of 1990, the outstanding accounts were approximately \$231 million of which \$50 million was considered bad debt. Between 1988 and 1992, while annual revenues increased by 15 per cent from rate increases, accounts receivable increased by 40 per cent. Faced with a worsening cash flow situation, WASA opted to increase its short-term borrowing and postpone payments to creditors. As illustrated at figure 6.6, between 1988 to 1992, creditor balances increased by 337 per cent and bank overdraft by 101 per cent.

**Figure 6.6: Indicators of WASA's Collection Efforts for 1988 and 1992**

	1988	1992	Change	
	(TT\$ million)	(TT\$ million)	(TT\$ million)	(%)
Accounts Receivable	126.5	176.6	+50.1	40
Revenue	150.4	172.5	+22.0	15
Bank Overdraft	7.6	15.3	+7.7	101
Accounts Payable	77.4	338.7	+261.2	337

Source: WASA (1994)

Cost recovery has been poor at WASA for the last 30 years. One factor is that Board policies and ministerial directives failed to encourage and enforce the collection of outstanding rates. Ryan (1992) reported that one of the earliest attempts at improving cost recovery was quashed after Members of Parliament protested in 1985. Between 1979 and 1983, less than 50 per cent of the money owed to the utility was collected. By 1992, there was only a 10 per cent improvement in collections.

Disconnection, as a result of non-payment of water rates, was not enforced for several reasons. First, was because of the health implications of going without a potable water supply. Second, because the customer charge for disconnection and subsequent reconnection in the early 1990s was TT\$500, whilst the cost to WASA often exceeded TT\$1,000 (Delcan, 1992). Third, disconnection often required excavation of the roads and then re-filling and re-surfacing which was found to be tedious and too much trouble for the fee earned. Finally, poor customer records hampered the serving of notices to correct persons and/or addresses.

Until 1997, WASA's accounts receivable were approximately 11 months outstanding. Yepes (1990) opined that high levels of accounts receivable are indicative of: problems in the commercial system (billing and collection), insufficient effort in collections and inadequate policies in dealing with overdue accounts (including low or no penalties for late payment). Receivables due to WASA were highest among domestic

consumers and government organisations. This situation is not unique to Trinidad and Tobago as studies by McIntosh (1994) showed that in most of the larger Asian cities, government agencies are also defaulters in paying water bills.

However, beginning in 1995, through improved collections and new stringent disconnection policies, including public sector agencies in arrears, WASA's accounts receivable have now been brought to within 3-6 months outstanding.

### ***Expenditure***

Capital expenditure has traditionally been financed by government subsidies and grants from international agencies. However, as much as 55 per cent of the funds provided for capital development was sometimes used to meet daily operating requirements which led to erosion of WASA's asset base and its physical plant (WASA, 1994).

Recurrent costs – operation and maintenance and in particular, personnel costs – have been greatly reduced over the last 5 years. From 1988 to 1992, personnel costs increased significantly due to heavy overtime and retrenchment compensation. According to Yepes (1990), personnel costs among the more poorly operated water companies in Latin America accounted for more than 50 per cent of total operating costs. WASA's labour costs were 51 per cent and 60 per cent of total operating expenses in 1990 and 1992 respectively. These ratios contrast with those observed over the same time period for utilities in England, France, Germany and Spain, which are all under 30 per cent.

Yepes (1990) argues that one of the reasons for labour costs being such a high proportion of operating costs is that public enterprises are key elements of patronage systems. Over-staffing is customary and appointments to senior management are frequently made on the basis of political connections rather than merit. Ryan (1992) opined that in



Trinidad and Tobago's case, "the anxiety to pour water on all areas of political combustion", especially after the 1970 Black Power Riots obliged government and WASA's board to employ large numbers of people at the utility.

The ratio of staff per 1000 water connections (S/1000wc) is often used as an indicator of a company's performance. Connection refers to the physical pipe connection to the building from the water supply. In 1994, WASA had an S/1000wc ratio of 16-18 employees per 1000 water connections, which as the World Bank (1994) claimed is 2 to 3 times greater than the ratio found in well-run utilities. The current S/100wc ratio is 13-15 employees per 1000 water connections (WASA, 2002). Yepes (1990) noted the average S/1000wc ratio for the more efficiently operated Latin American water companies was 5; whilst those that performed poorly had a ratio of 10-20 employees per 1000 connections. Spain, France, USA and Canada were found to be 2, 2, 3 and 2 per 1000wc respectively. More modern equipment and technology as well as better trained staff are critical factors in lowering the ratio of staff per 1000 water connections as well as improving the overall efficiency of the company.

High personnel costs that are not matched by productivity gains reduce the utility's sustainability since far more funds need to be allocated to cover wages and salaries than operation and maintenance of the supply system. This also raises equity issues when such high labour costs are at the expense of service provision, which is itself inadequate, especially for the poor.

### ***Accounts Payable***

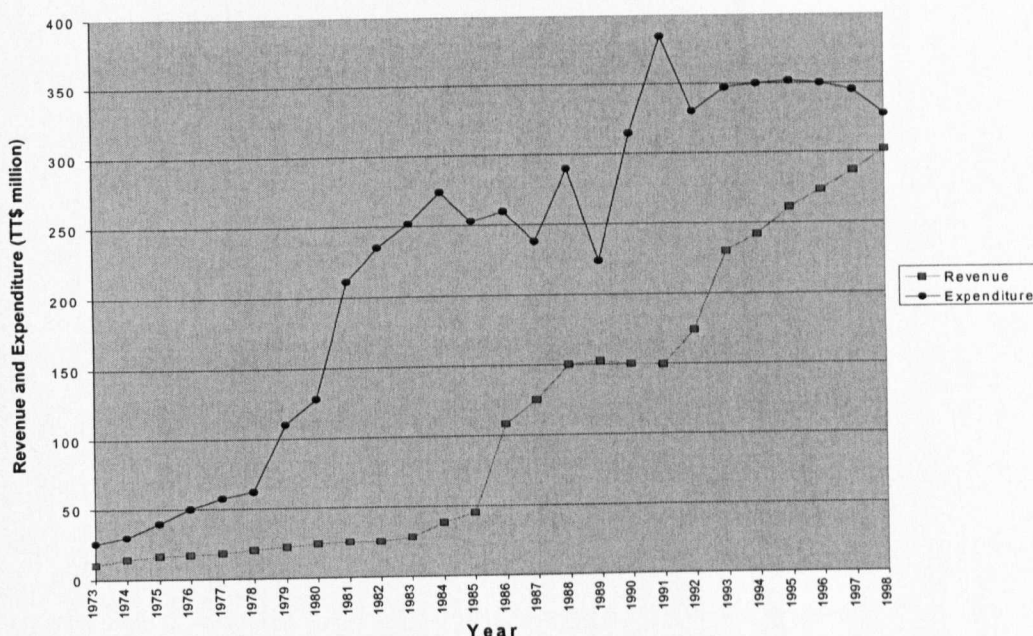
WASA's debt has been attributed to: outstanding claims by trade creditors, repayment of loans and compensation packages for retrenched and retired staff. Claims by creditors grew from TT\$13.9 million to TT\$344 million from 1983 to 1993. By the end of 1993, over 200 water service contractors

and service and equipment suppliers ceased conducting business with WASA because of outstanding payments.

***Recurrent Operating Deficit***

For the last 25 years, operating expenses have exceeded revenue at WASA. The recurrent operating deficits are shown at figure 6.7. Some of the highest deficits in excess of TT\$200 million were recorded in the early 1980s and again in 1991 when expenses skyrocketed.

**Figure 6.7: Operating Deficit of WASA from 1973-1998**



Adapted from WASA (1999)

As previously mentioned, WASA was reliant on government transfers to cover its operating deficits. As observed by the World Bank (1988), these subsidies had an unfavourable effect in that the incentive to reduce costs and/or increase revenues was removed. This in turn led to further inefficiency, greater deficits and a need for continued subsidisation. In addition, heavy subsidisation has often resulted in substantial ‘leakage’ of the monies into higher levels of staffing, wages and other remuneration.

### ***Inaccurate Customer Records***

Yepes (1990) explained that a pre-condition for good financial management is an accurate cost accounting and financial forecasting system that provides timely and reliable information. This hinges on a properly maintained customer database.

Duplicated accounts; errors in customer names and addresses; unaccounted-for legitimate customers; illegal customers; and primitive systems of record-keeping are some of the problems faced by the billing section of the commercial department at WASA.

While the number of customers on WASA's database has increased over the years, the system remains very primitive in design. The updating of the customer listing is based on the Warden's Assessment Rolls, so any errors in these are replicated in WASA's records. The number of customers on WASA's register was 229,349 in 2000 and WASA officials estimate that about 6,750 consumers in the database could be duplicated accounts. In addition, there are several reported cases of new connections being legitimately made but which are not added to the customer register because of incomplete paperwork by WASA's staff or stalled document flows between departments. Illegal customers perhaps present the greatest problem, in particular squatters, because although not officially recognized, they are unofficially tolerated.

Ultimately WASA's revenue stream has suffered because of its inadequate consumer information system.

## **6.4.2 Management**

WASA's management and fiscal inefficiencies can to some extent be attributed to political interference and lack of autonomy. Board members have traditionally comprised members or close associates of the ruling

political party, at times some of whom have not been skilled or trained for the tasks at hand (Ryan, 1992).

As reported by Ryan (1992), a Working Group on the Organisation and Streamlining of Public Service Practices and Procedures in Trinidad and Tobago, raised the issue of autonomy in utilities such as WASA. The committee expressed itself as being:

*“Unable to determine in what way these corporations differ essentially from the average government department. Given the range and extent of the administrative and financial controls exercised over these corporations, their boards.... The management, the staff are all frustrated because real authority, all real decision-making capacity... rests outside the corporation. The Working Group accepts that commercial judgement and objectives must sometimes yield to considerations of the public interest. The Working Group considers, however, that there are far too many controls exercised over these corporations which, as a result, function as Government Departments, and very expensive ones at that.” (Ryan, 1992, pg.53)*

WASA’s autonomy is also limited by the lack of control with respect to its budget. Contingent on budgetary allocation by Parliament, the Ministry of Finance generally regulates financial disbursements to WASA. Invariably, the allocation is insufficient and WASA would usually request additional funds through the Ministry of Finance.

Political interference and lack of autonomy have also surfaced in the prioritisation or go-ahead of supply projects and the decisions to expand services to particular housing and other industrial development schemes and areas. The intrusion of party politics in the affairs of the Authority has led to continuous chaos including entanglement of the lines of communication and management directives, with the result that clear signals as to what was to be done at the Utility have been lacking.

In March 2002, the recently appointed PNM government chose to install a new board for WASA. Soon after, as reported in the daily newspapers on May 10, 2002, rumours began to circulate that the appointment of the new board was part of an 'indian' or UNC political party cleansing of the Utility. Mr. Errol Grimes – the only non-Indo-Trinidadian director of the Authority's former 9 member executive board – was appointed to replace Mr. Kansham Kanhai as Chief Executive Officer, and Mr. Roland Baptiste replaced Mr. Nazir Khan as Chairman. Kanhai claimed he received notice for paid leave from March 4, 2002 but was never told why and has since resigned. Two months later, Ken Mahabir, director of human resources, and Harry Bisram, director of finance were also sent on leave. Mr. Grimes however insisted that Kanhai and Mahabir chose to leave WASA and were not pressured into doing so.

WASA director of capital investment, Tewarie Tota-Maharaj was next to be suspended on May 14, 2002, pending investigations into the award of a contract according to a letter from Roland Baptiste, WASA's chairman. The letter to the newspapers stated the suspension was based on Tota-Maharaj's "conduct and role in the award and management of the provision of engineering audit services by Trinsult Associates Ltd. For the North Water Project Tranche 2." The letter alleged that he:

- 1. Caused the execution of a contract to Trinsult Associates Ltd. in violation of WASA's tender rules by failing to disclose conflicts of interest on his part.*
- 2. Wilfully misled the Board on the substantive issue relative to the award of the contract.*
- 3. Breached WASA procedure and acted outside of his authority in issuing letters to commence the Trinsult project.*
- 4. Acted outside his scope of authority and violated the WASA Act by engaging the services of an external auditor and causing the preparation of statements and reports on the Board's affairs as well as further issuing of directions to the auditor.*
- 5. Exposed WASA to undue risk by the preceding.*

Tota-Maharaj declined to comment except to say that he was not going to allow his name to be tarnished and was seeking legal advice.

Corruption throughout WASA's rank and file has also contributed to the utility's inefficiencies and tarnished its public image. Occurrences of sabotage and graft have been taking place since the 1970s mainly due to poor internal accounting practices. Poor record-keeping of equipment maintenance; ineffective stock controls; inaccurate project cost estimations; and minimal internal auditing have all encouraged graft and malpractice. In 1973, a Commission of Inquiry into WASA reported a totally collapsed accounting system. The Auditor General has repeatedly declared his inability to certify WASA's accounts due to missing files, requisition and payment vouchers and other financial records.

In 1994, media coverage brought to the surface some of the suspicions held by residents regarding water shortages in their areas. Some consumers felt that if they were located in an opposition constituency, they were sidelined. Others indicated that they had witnessed WASA employees performing acts of sabotage by tampering with pipelines and valves. Some consumers were of the opinion that the incidence of sabotage and graft intensified after the government announced its intentions to privatise the Utility.

### ***Industrial Relations***

Poor industrial relations and strike actions by employees at WASA have also contributed to water outages across Trinidad and Tobago. This has served to further diminish public confidence and increase frustration with the Utility. In October 1999, virtually all of North, East and Central Trinidad was without pipe-borne water for 9 days due to an impasse between monthly-paid workers and management at WASA. The employees were requesting management to immediately include in their collective agreement an allowance for driving vehicles to operate the turncock valves that regulate the supply in various areas across the country. An estimated 200 monthly-paid operators engaged in a work-to-rule action

refusing to leave their stations to go out into the field to turn on the valves, claiming that the Authority's vehicles were defective.

The Express Newspaper reported on October 23, 1999, that for the past 12 years the operators who duplicated as drivers received a special allowance and the Authority intended to formalise this arrangement in a new organisational structure which was due to become effective from December 1, 1999. To this end, a letter of understanding was signed between management and the Public Services Association (PSA), which represents the workers, on October 2, 1999 with a clear commitment by both parties to implement the new structure at the approved date.

Despite this, strike action ensued and the workers extended their grievance to include the lack of adequate health and safety measures at their workplaces and compensation for doing work outside their normal duties. This affected the supply to a number of areas. Among the areas affected by the impasse were Arima, Cascade, Caroni, Chaguanas, Diego Martin, Maracas, Woodbrook and Port of Spain. Several businesses and schools were forced to close.

During this period, acts of sabotage were reported in San Fernando and in Port of Spain, where water lines were broken. Vehicles were also tampered with at several of the production plants. Manpower shortages at the Caroni Water Treatment Plant, the nation's largest, forced production to be reduced and valves on the 54-inch transmission pipeline from this facility which supplies the Point Lisas Industrial Estate (the largest industrial park) and other areas in Central and South Trinidad were turned off.

After intensive discussions between WASA management and the PSA, a memorandum of understanding was signed on October 30, 1999. It was agreed that operations would immediately return to normalcy; committees were set up to investigate and resolve all the issues identified by the PSA; workers would be appointed to the new organisational structure by

December 1, 1999; and workers who were identified as having taken action during the period of the impasse would not be victimised or made to suffer any adverse consequences.

The then Chief Executive Office (CEO) of WASA, Ashram Beharry maintained that sabotage and unlawful industrial action were the reasons for the service disruption. In an internal communiqué, the CEO informed employees that “WASA is an essential service” and they were “prohibited from engaging in any action that may be considered industrial action in accordance with the Industrial Relations Act (1972).” (Trinidad Express Newspapers, 29/10/99)

Nevertheless, in November 2000, protest action by employees again resulted in widespread water shortages across Trinidad for a period of a week. This caused the closure of schools and businesses as well as reductions in services at a number of major health institutions, including the San Fernando General Hospital, which is the main medical facility in the southern part of the island.

The impasse was again triggered by WASA’s plans to adopt the new organisational structure. Public Utilities Minister, Ganga Singh, explained that in August 1997, WASA requested Cabinet approval for amendments to the organisational structure to incorporate revised departmental arrangements and reduce staffing levels. The aim was to maximise efficiency.

On September 11 that year, Cabinet agreed to:

- *approve the new organisational structure and reduce staff numbers from 3422 to 2033;*
- *approve the separation of approximately 800 workers through a Voluntary Employment Separation Plan (VESP);*



- *account for a further 644 employees through attrition; reduction of temporary/leave-relief workers; discontinuation of non-specialised contracts; reduction of the retirement age to 60; and out-sourcing of services.*

According to Mervyn Fletcher, chairman of the WASA section of the PSA, WASA's management and the PSA met frequently between 1997 and 1999 to work out the proper arrangements for implementing the new structure. As mentioned earlier, an agreement was finally signed in October 1999 after much dispute and protest action. The agreement stated that employees would be appointed in their new positions temporarily with letters to that effect being issued by December 1, 1999. The process for permanent appointment thereafter should take no longer than 6 months, so that restructuring was to be completed by June 2000.

According to Fletcher, in May 2000, WASA wrote to the PSA requesting an extra two months to introduce a new Customer Service Division in keeping with Government's desire for a more customer-driven service. The PSA agreed with the proviso that the matter should have been finalised by August 25, 2000. The PSA gave WASA's management a further 3 weeks to submit the final report for the introduction of the new structure to the Minister of Public Utilities to present to Cabinet for consideration. But Fletcher said: "It was only on October 17, after writing, begging and pleading, that we were told that the document would be sent to the Minister on the 18<sup>th</sup>."

WASA wrote to the Public Utilities Minister on October 18, 2000 stating that it could not achieve maximum efficiency with the reduction in staff originally agreed to in 1997. Instead the utility proposed that:

- *the number of employees be increased from 2033 to 2533;*
- *the monthly-paid contingent be increased from 1478 to 1637 posts and reclassified according to an agreed table; and*

- *the number of divisions within WASA be expanded from 7 to 9 by adding a Customer Service Division and a Corporate Service Division to the overall structure.*

Cabinet failed to approve these new proposals, deciding instead that a six member team of management consultants should conduct an independent assessment of WASA's staffing arrangements over the next 3 months.

Fletcher claimed the delay was deliberate. The union (PSA), he said, was aware that in order to qualify for a loan from the IADB to upgrade WASA's plants and equipment, the Government needed to contract a private operator to run the utility and he claimed the Government was negotiating with the French water company, Vivendi. If the deal was struck, it would have been easier to dispatch temporary employees. Hence, the stalling tactics by WASA and the Government in implementing the new organisational structure. The Ministry of Public Utilities denied these allegations.

As a direct consequence, the workers abandoned their posts in protest. But, after a week, the Government invoked the Industrial Relations Act and obtained an injunction from the Industrial Court ordering an end to the protest action.

On the one hand, acting CEO at WASA since March 31, 2000, Kansham Kanhai, claimed that intimidation and lawlessness were part of the culture under which WASA traditionally operated. Workers on the other hand disapproved of his appointment to the helm as they felt he did not empathise with their plight. Further, he seemed unwilling to treat with the Union, the legitimate bargaining unit for the employees.

In the final analysis, whether it is because of the strong-arm tactics of the employees or the politicking of WASA's management and the Government, the resultant internal problems continue to cause WASA's

poor public image to be further diminished and severely disrupts water service provision across the country, threatening the nation's welfare.

## **6.5 Options for Reformation**

### **6.5.1 Institutional Strengthening**

In Trinidad and Tobago, perspectives among stakeholders regarding an appropriate module for institutional strengthening of the water sector are varied. Trade unions and some politicians fear that partnerships with the private sector are another form of neo-colonialism. This nationalistic view has encouraged decades of heavy government expenditure on, and control of, infrastructure provision in the water sector of the country. Other opponents opine that, like in many developing countries, private sector involvement in the water sector, simply satisfies the mandate of multilateral lending agencies such as the World Bank and the IMF and are not based on appropriate ideological convictions. On the other hand, a growing number of consumers and WASA officials favour private sector involvement as the best means of resolving the ongoing problems at the Utility.

The three major institutional arrangements available are: 1) corporatisation, 2) public-private sector partnerships and 3) privatisation.

#### ***Corporatisation***

Corporatisation, as a means of restructuring the operations of the Utility has had little success in transforming WASA into an efficient commercial entity. Although WASA was established as a quasi-independent public sector entity (statutory agency), commercial practices such as proper accounting and employment practices remained poor, and political interference, high. Performance agreements, another commercialisation tool have also failed because managerial autonomy and rewards for

managers and workers in exchange for fulfilling agreed performance targets were lacking. Firing non-performing staff from WASA has also been difficult. Figure 6.8 below summarises the views held by the various actors involved in the water sector on corporatisation.

**Figure 6.8: Actors views regarding Corporatisation**

Actor	Perspective re: Corporatisation
Government	Public utilities are already run based on commercial principles, but this has not encouraged the water sector to become more efficient
Water Sector Managers	Autonomy received is too limited to be effective and too easily revoked
Water Sector Employees	Have little incentive to be efficient as good and poor performances tend to be treated equally
Consumers	Corporatisation has not resulted in adequate improvement (better access, reliability etc.) to water services

Source: World Bank (1994)

A third way of reforming water agencies without changing the public utility structure is by contracting out services such as maintenance, fee collections and meter reading. However, corruption in the award of service contracts at WASA rendered this method ineffective.

Theodore (1992) argued in favour of keeping WASA as a public utility on the grounds of social equity. He opined that only the public sector can guarantee that social welfare objectives are met. Nevertheless, Theodore (1992) maintained that WASA needed a) managerial autonomy in areas such as technical and staffing decisions; b) to be self-financing and; c) consumers to pay the full costs of water service provision.

Yet, commercialisation efforts within the public utility structure have only resulted in token improvements and WASA, operating as a public utility

with a monopoly has made it an inefficient agency protected from competition and unaccountable to consumers. In addition, if public agencies such as WASA are more responsive to political pressures than consumer requirements, possibilities for welfare failure will also exist.

### ***Public- Private Sector Partnerships***

One public-private sector partnership involves the transfer of management (operation and maintenance) of the utility to a private entity with the Government retaining ownership of capital assets. Triche (1993) argued that the benefits of such an arrangement include less political interference in the day-to-day operations of the utility; a more innovative management structure; more effective decision-making which incorporates demand-side measures; and better overall integrated water sector management.

Private financing and participation may also be tapped as suggested by Kessides (1993) and Israel (1992) under leases, concessions and build, own, operate and transfer (BOOT) arrangements. Under a lease, government provides the financing for any major investments and the private contractor pays for the right to use the facilities to provide the service. Leases are usually awarded for 6-10 years. Concessions incorporate all the features of a lease but the contractor has the added responsibility of financing any extensions, capacity expansion or replacement of fixed assets. According to Triche (1993), during the initial stages of sector reform, concessions are generally unattractive to private entities as they consider the risks of investment too high. Another drawback with leases and concessions is that they may not provide sufficient incentives for the private entity to maintain and expand the facilities in their charge.

Alternatively, the various activities in water service provision can be unbundled and contracted out to private operators. Unbundling can promote cost minimization, especially when used to generate competition among suppliers. In addition, it facilitates detailed activity-based

accountability whereby transparency of cross-subsidies between different production entities and accurate identification and assessment of the quantum of subsidies required to meet the needs of the poor become more apparent.

Two types of unbundling exist: vertical and horizontal. In the water sector, vertical unbundling involves separating production, transmission and distribution. It is recommended that transmission and distribution be retained as monopolies as it is economically impractical to develop more than one distribution supply network. However, alternative producers can compete for the right to supply consumers with water from their facilities over a common distribution network. Horizontal unbundling separates activities by markets, either geographically or by service categories (e.g. house taps, stand-pipes etc.) and private contractors are responsible for complete service provision (production and distribution) to their market. However, having several companies undertaking core activities such as billing and collection, production, treatment, distribution is difficult unless coordination and control is guaranteed. Further, these arrangements may result in higher user charges as each company has to charge a mark-up over costs to cover all overhead expenses and ensure a profit.

Based on the above as well as economies of scale and geographical wealth distribution in Trinidad and Tobago, a public-private sector partnership where there is competition *for* the market even though there is no competition *in* the market, seems to be the most suitable option for the country. In other words, private firms bid and compete for a contract to produce water for, or provide a complete service to, the entire market rather than individual consumers or sectors within the market.

### ***Privatisation***

Full privatisation of water services has not been widely undertaken in developing countries. Research done by Triche (1993) found that governments were generally reluctant to cede to private investors,

(especially foreign ones) complete control of such a strategic sector. Second, private investors appeared unwilling to purchase supply system assets given their poor condition, the general lack of accurate operational information and the high political involvement in the sector. Third, while privatisation by a local investor is preferred, in cases such as Trinidad and Tobago, where the existing private sector is limited, capital markets are thin and local firms are unwilling or unable to meet the high levels of capital investment involved.

Fear of political interference by certain investors could also hamper full privatization of WASA in the short run. Though privatization can improve efficiency in water supply, it can lead to consumer exploitation in terms of excessively high water rates. Where increase in consumer satisfaction does not compensate for the increases in water charges, public pressure could make government intervention again politically expedient.

### 6.5.2 Regulation

Regulation of service providers, in particular private ones, is generally new to developing countries. The general aspects of regulation discussed hereunder in respect of Trinidad and Tobago, are also relevant to the Barbados water sector.

There are 3 main considerations which influence the regulatory task: 1) the provision of sufficient resources, autonomy and credibility for the regulator, 2) where price regulation is required, the appropriate selection of instruments and 3) the creation of consumer constituencies, (World Bank, 1994).

#### ***Regulatory Resources, Autonomy and Credibility***

Detailed knowledge and continual monitoring of the activity concerned are critical aspects of regulation. This requires adequate access and resources

for information gathering and monitoring, as well as operational autonomy. Regulatory agencies are also susceptible to capture by the service industry and/or may favour incumbents. Therefore, the delicate balance required is to allow the regulatory agency autonomy whilst maintaining its accountability.

The WTO specification for utility regulation calls for independence of the regulator from any single provider. To avoid/minimise regulator capture (due to information, financing, human resource requirements, etc.), the WTO underlines the importance of legislation to a) enforce compliance of the incumbent and other service providers regarding the information requirement, and b) enable the regulator to be self-financing in order to engage the resources needed to effectively execute its mandate.

In Trinidad and Tobago, 2 options for a regulatory structure exist:

- *Regulation via the Ministry of Public Utilities with or without authority to review operational and management decisions; and*
- *Regulation via a separate body, namely a commission such as the Regulated Industries Commission (RIC).*

Under regulation by the Ministry of Public Utilities, a section or department within the Ministry will have regulation of the water utility included in its portfolio. The three major advantages of this regulatory structure are first, it allows maximum input by the Government in the ratemaking process. Second, the Government can use the rate structure to fulfil social goals and finally, it avoids having to incur costs associated with setting up a separate regulatory body.

On the other hand, there are several disadvantages associated with regulation through the Ministry of Public Utilities. It provides an avenue for excessive political intervention in the managerial and rate-making process. Moreover, political pressure may encourage inclusion of cross-subsidies in the rate structure, thus reducing transparency. Further,



political intervention may contribute to delays in the introduction of rate increases. Separately or conjointly, these factors can adversely affect the efficiency of the utility.

Regulation under the RIC coincides with the status quo in Trinidad and Tobago. Section 5.5.2 describes the regulatory process under this arrangement, which is depicted at figure 5.8.

The potential for heavy political intervention in the ratemaking process is reduced under this structure and it also allows regulators to develop detailed 'expertise' more readily as they do not have other ministerial duties. Nevertheless, the costs for establishing and administering a separate regulatory body can be relatively high and there still remains some opportunity for political influence to seep in.

It is important to note however that the costs for regulation in this way though high, are small in comparison to the overall financial requirements of the utility. In Britain and the USA, the costs of the regulatory agency, including staff and all administrative costs are the responsibility of the water utility (Dowers, 1995). These costs are recoverable through water rates, as an operating expense, depending on the type of regulatory mechanism or instrument employed.

### ***Regulatory Instruments***

The ubiquitous instrument of regulation used in most service sectors is the Rate-of-Return (ROR) mechanism. In essence, this type of regulation ensures that the financial return received by the service provider covers all expenses (operations, maintenance, depreciation, taxes etc.) as well as guaranteeing a negotiated return on investment.

Opponents argue that it is difficult to implement the strict ROR regulation because obtaining accurate information on costs of production and the allocation of such costs between various services is difficult. As a result,

much controversy surrounds how an appropriate ROR is determined due to misrepresentation of information and the adoption of inefficient technologies that inflate the base on which a ROR is calculated. Further, “because all costs are covered and a ROR is guaranteed, private management may become complacent about making the right investments and keeping costs down” (World Bank, 1994, pg.70).

New ‘incentive’ regulatory instruments such as the Price Cap or RPI-X formula and the ROR Benchmark have therefore been designed for overcoming the shortfalls of the strict ROR mechanism. The general concept is that the price the water utility is allowed to charge, is not hinged only on the costs incurred. In other words, inflation and productivity can impact changes in water rates and in turn, the profit margins realised.

Although its main application has been in the telecommunications sector, the use of the price cap formula is becoming increasingly popular in the water sector. Based on USA experience, the main advantages of using price caps include lower service prices than ROR regulation and greater carriage of financial risk by infrastructure providers.

Yardstick or Benchmark competition is another ‘incentive’ type of regulatory instrument. If direct competition or competition from producers of substitute products is not feasible, competitive forces may be simulated through comparisons with performance elsewhere. It has found practical application where the performance of utilities located in different regions can be compared and used to motivate them to perform even better. The two best known examples of benchmark regulation of the water industry are France and the UK.

Other more modern regulatory instruments are being designed and tested for application in developing countries. One new approach offers the service provider a choice between a stiff price cap coupled with minimal monitoring of profit margins or freedom to increase prices significantly

coupled with close profit monitoring. Potential regulation is another approach whereby the provider is not actually regulated if consumers are satisfied with the service. However, the regulator stands ready to intervene should problems arise. It is perhaps too soon to establish the effectiveness and suitability of the latter regulatory instruments to developing country scenarios, and the thorough examination and analysis of regulatory mechanisms is beyond the scope of this study.

### ***Consumer Constituencies***

Although customers have a critical input to ensuring that service provision is adequate and efficient, particularly since regulators often have limited information, their involvement in the regulatory process is often overlooked. Consumers tend to be the best monitors of service quality and consumer feedback may be used directly to oblige suppliers to provide high quality service. Consumer involvement also strengthens accountability and aids in the acceptance of utility reform such as the introduction of higher tariffs or private sector involvement.

## **6.5.3 Willingness to Pay and Pricing of Water Services**

### ***Willingness to Pay (WTP) Survey Implications***

The WTP survey revealed that most households were spending on average TT\$31/month on water services and were willing to pay approximately twice as much (TT\$67/month) for an improved service. The prices paid by the various regions surveyed and the WTP values obtained are shown at figure 6.9 below.

**Figure 6.9: Summary of Average Existing Prices and the WTP Values for the Areas surveyed in Trinidad**

Area	Total Number of Households in survey area according to CSO	Average Price currently paid for water services (TT\$)	Average Price willing to pay for water services (TT\$)	Percentage Increase (%)
Goodwood Park	287	41	83	102
Alice Glenn	173	41	83	102
Barataria	2,495	25	50	100
St. Barbs	381	0	55	∞
Valsayn	173	39	72	85
Malabar	2,332	15	28	87

Source: WTP Survey (1998)

The survey also found that poor and low-income households were spending a higher percentage of their income on water services than high-income households (see figure 6.10 below).

**Figure 6.10: Percentages of Household Income spent on Water Services**

Household	Percentage (%) Income spent on Water
Very low income	0
Low income	0.79
Medium income	0.53
High income	0.43
Very high income	0.34

Source: WTP Survey (1998)

It is important to note that ability to pay is as important as willingness to pay for water services. Approximately 90 per cent of the respondents indicated they could afford the payment values they chose.

While most low-income households showed willingness to pay and the ability to pay for service improvements, the very poor (18-22 per cent of the population) will require some financial assistance and subsidization. The voucher system is a novel approach to ensuring equal access and equity in water service provision. In this way, the Government provides very low-income households with a voucher for receipt of water services (similar to food stamps). This prevents the occurrence of any health hazards and maintains the notion that water provision involves a cost (i.e. is not cost-free).

While households indicated a willingness to pay more for improvements in water services, there was little confidence that paying higher water rates would ensure that WASA provided a better service. Many households are no longer fully reliant on WASA for a secure water supply, having installed water tanks and pumps at their own expense. Some respondents perceived that a rate increase would reward WASA for its inefficiency and safeguard the Utility's employees from retrenchment. Some level of private sector involvement was welcomed by approximately 60 per cent of the respondents surveyed.

The ability to introduce an effective tariff system depends on consumers' willingness to pay, which in turn is dependent on observed improvements in service reliability, flow rates and quality. A strategy that therefore effects both (service improvements and higher tariffs) is suggested for Trinidad and Tobago.

#### **6.5.4 Water Rates based on the ATV**

As mentioned previously, 99 per cent of Trinidad and Tobago's domestic consumers are billed based on the annual taxable value (ATV) of the inhabited property. Households therefore do not pay water rates based on

consumption but on a proxy measure – the ATV – which is used as a barometer of income and potential consumption.

The ATV as a suitable pricing system for water services has been evaluated below against the criteria of economic efficiency, equity, administrative feasibility and political acceptability (Bahl and Linn, 1992).

### ***Economic Efficiency***

Economic efficiency in resource allocation is usually the primary objective of pricing policy. This is achieved when the price equals the cost of supplying the next additional unit of usage. In other words, the price should equal the marginal cost for a system to be economically efficient.

Charges should be responsive to growth in population and income levels when these factors increase the marginal cost of service provision. However, WASA's increasing revenue levels have continually lagged behind increasing property levels, one of the reasons being that although property values increased significantly since the mid-1970s, most of the annual taxable values in documented assessment rolls bear little relation to current rental or market values.

In addition, property valuations are carried out infrequently and many recently improved properties have not been updated on the register. According to the Land and Building Taxes Act, properties should be reassessed every five years. In Port of Spain and San Fernando, assessments are done triennially and every fifteen years for the other counties, which, is where most development has taken place in the last 20 years.

### ***Equity***

Equity refers to allocating public expenditure to sections of the community in proportion to their ability to pay (McMaster, 1991).

In theory, using property value as a proxy for income and thereby a basis for classification of water consumers and water charges appears equitable since there may be a closer correlation between property value and income than between water consumption and income. Unfortunately, where adjustments to property values fail to keep pace with actual changes in income, achieving equity via this pricing system is, at best, a very difficult exercise. As such, the property value system has rendered WASA's fee structure largely regressive, in that the percentage of income paid in water rates declines with increasing income levels, as revealed in the WTP survey (recall figure 6.10). Further, under the ATV pricing system, approximately 50 per cent of domestic consumers are billed at the minimum rate (TT\$108.00/quarter) and only 7 per cent pay the maximum rate.

Geographical inequities also exist as lower property values are set for those located in suburban areas. This generally rationalised on the grounds that these localities are not as well serviced as inner-city regions. However in Trinidad's case, the result is unfair as there are many low-income groups living in the inner city districts and high-income groups living in the suburbs. Current rates therefore do not reflect ability to pay and low-income groups living in urban areas are unfairly burdened with the cost of infrastructure provision.

The ATV system is also rendered inequitable because appraised property values do not approximate to market values. This is largely as a result of poor and infrequent assessments and the failure to update the property assessment rolls.

#### ***Administrative Feasibility***

Since the majority of water rates are based on assessed property values, in the absence of an accurate and complete fiscal cadastre, many customers are not paying just water rates and some, which WASA estimates to be approximately 40,000 are not paying any water rates at all.

Incomplete tax rolls; inadequate property ownership information; dated information regarding property improvements and expansion; duplicate records; and poor filing and maintenance of records have rendered the ATV as a means of charging for water services administratively unfeasible.

Chung, Glenn and Wolfe (1992) revealed that underlying these problems is a lack of co-ordination and communication among the various government offices involved (The Office of the Assessor, The Registrar of Deeds, The Building and Permits Department). Land records have been kept manually and there is no unique parcel identification system. Consequently, searches can only begin from the deed reference number of the present owner and cross-referencing is not possible.

### ***Political Acceptability***

The acceptability of a system of water rates is another equally important criterion often overlooked by policy-makers, particularly those from the developed world and those associated with international agencies. Charges for water services continue to be a sensitive matter for most governments of developing countries.

With a forty-six year period of no water rate increases from 1937 to 1985; a policy until 1985 whereby water rates were a deductible expense for personal income tax purposes; no serious disconnection policy for customers in arrears, it is not difficult to understand why any changes in the pricing system for water services poses a dilemma for political leaders. Adjustments to pricing systems will impose additional costs on consumers and they also involve a paradigm shift from 'the old view' to the 'new' – a shift that politicians with elections to win, and interest groups to satisfy find awkward to make. Often the opaqueness of water pricing policies and the failure to prepare the population for changes in the tariff system result in protests.



In large measure, WASA has been unable to provide a satisfactory service to consumers because its charges have been insufficient to generate the capital required to meet the costs of service provision. As such, the utility is weak and has found itself in a vicious cycle in that increased tariffs seem unjustifiable since service provision is poor, and services are poor due mainly to under-pricing of the service.

The success of price adjustment measures may depend on careful sequencing with respect to political as well as economic objectives. WASA needs to phase in projects to simultaneously improve water services whilst modifying the tariff system thereby ensuring that consumers quickly realise the benefits. If the public and the Workers' Union perceive rate increases to be externally caused and adjustment policies to be externally imposed, there is a high risk of losing political support.

Although some politicians and policy-makers argue that water rates cannot be raised because of macro-economic adjustment difficulties and the impacts on the poor, less pressure on the Utility to become self-financing discourages not only financial discipline but also service improvements.

Generally, the public accepts charges for specific, tangible services provided charges are understood and just. According to McKinley and High (1988), people make appropriate decisions to protect their health and welfare, and are willing to pay a fair price for something they value. Based on the WTP survey, it is clear that WASA can aim for a higher level of cost recovery through an improved rate system.

#### **6.5.5 A Framework for Cost Recovery**

Flat-rate water charges do not generate sufficient revenue for water companies because charges have usually been set well below the marginal cost of the service. In particular, the use of the ATV in Trinidad and Tobago has been plagued with problems. As a result, insufficient revenue

was generated to meet WASA's capital investments as well as operations and maintenance requirements. Further, the flat-rate system of charges does not serve to modify behaviour in terms of efficiency in water consumption since there are no price increases or penalties for excessive use. The only apparent advantage of the flat-rate system is that it is politically acceptable. It has failed to meet the other criteria of economic efficiency, equity and administrative feasibility.

A system of water rates based on the ATV is a form of average cost pricing, defined as total cost divided by the number of water units produced. The resultant price charged is however below the average incremental cost, which is the change in cost due to a change in water output, and/or new capital investment. A situation then arises which demands Government subsidization and cross-subsidization of services. Further, flat rate water prices do not promote conservation and nor reduce consumer wastage.

Marginal cost pricing is a more appropriate means of establishing user charges. Consumption is charged at the unit cost of meeting any additional demand (refer Section 3.6.1, figure 3.4). This system satisfies economic efficiency and administrative feasibility and can be appropriately implemented to also fulfil equity considerations and gain political acceptability.

In applying the principles of marginal cost pricing, it is necessary to unbundle water services as follows:

### ***Consumption Charges***

Charges based on consumption require the installation of meters to accurately measure water usage. This use-related price should include marginal costs of production (treatment, labour, maintenance) and distribution (pumping, storage, pipeline maintenance).

A case for social equity consideration and subsidization arises where consumers are unable to afford water services at the marginal cost price based on their income levels. Research by WHO (1980) showed that 20-40 lpcd are sufficient to meet essential needs and attain the main health benefits associated with water.

One option is to charge only those categories of users who can afford the marginal cost price and subsidize the low-income users. Alternatively, the authority can subsidize all consumption to a certain level but beyond which market pricing then applies. This is described by the World Bank as the “lifeline” approach. For example, the first 40 lpcd may be charged at a low rate below cost; and consumption above 40 lpcd is charged at the full marginal cost.

Rising block rates, which may be defined as progressive increases in unit prices in relation to successive blocks of consumption, are often used in conjunction with lifeline tariffs to achieve equity. It is important to note however, if water demand has a low income elasticity, then rising block rates will not be equitable. In other words, if poor households use significantly more water than the lifeline block, they will then pay the rates pertaining to the higher consumption blocks and may actually end up paying a greater percentage of their income on water than high-income households.

A second drawback is that household income is not the only variable influencing consumption. Variables such as family size and the number of households per connection must also be considered. Rising block rates may therefore be more burdensome to larger rather than wealthier households.

### ***Connection charges***

Connection fees are common in many countries, but the basis for charging varies. In most countries (Canada, USA and Barbados) a flat charge

related to installation costs is imposed, whilst in Bangkok and Jakarta, the connection fee relates to the size of the connecting pipeline.

The connection charge should capture the marginal costs of connection, including administrative functions such as billing, meter reading and maintenance. WASA currently charges a lump-sum connection fee that is high by developing country standards (US\$118). Alternatively, an initial connection fee to cover installation costs followed by a regular fee to cover recurrent maintenance costs can be charged. The latter approach may be preferable to a high lump-sum upfront connection fee as it will facilitate easier legal connection to the water system by low-income users.

### ***Development Charges***

A development charge is sometimes levied against new developments to cover the marginal capital costs for installing and expanding the distribution system. The development charge may be imposed on all individual properties at the time the water supply system is being installed, whether or not the residents elect to connect to the system at that particular time.

### ***Spatial Charges***

Three categories of spatial costs are defined by Bahl and Linn (1992): a) sectoral – rural or urban, b) inter-regional – one region/city to another, and c) intra-regional – one neighbourhood to another within a region/city.

Costs in service provision may vary because of sectoral differences. Some rural areas may have lower population densities than urban areas resulting in higher unit costs of distribution due to the low economies of scale. Inter-regional differences may affect the cost of water supply due to variations in water resource endowment, geologic conditions, technology in use and size of supply operation. Intra-regional variations include differences in population density, topography (elevation, soil conditions), and accessibility.

Water utilities generally do not explore or incorporate the variations in cost of service provision resulting from locational/spatial differences. However, if marginal spatial cost differences are not directly reflected in service prices but averaged across locations, then development in areas difficult and costly to service will not be discouraged.

### ***Seasonal and Peak-time Charges***

The need to reflect seasonal cost differentials in water tariffs depends on the extent of the cost differences. For example, service provision may be more costly in the dry season due to increased pumping costs but this may be offset by the increased water treatment costs in the wet season as a result of higher soil erosion and sedimentation levels.

Excess demand commonly infers investment in new supply facilities and capacity expansion. But, if this demand is only at peak times and not based on peak-load pricing, the investment may be oversized and premature. In India, Korea and Columbia, peak-load charges are borne by large commercial and industrial users, as they are the major consumers at peak periods (World Bank, 1994).

Both seasonal and peak-time charges require a high level of consumer usage information and administrative skill and capability. Universal metering is also mandatory.

### **6.5.6 The Financial Independence of the Water Utility**

Despite the application of marginal cost pricing, a fiscal gap may develop. The experience of water companies in Singapore, Chile and Botswana suggests that a multi-part tariff consisting of 1) a consumption charge, 2) a connection charge and 3) a development charge is the best fee system for meeting any financial deficits (World Bank, 1993). Such a system readily facilitates updating of water rates to reflect price changes caused by

inflation and changes in the cost of service provision. Such a multi-part tariff structure can achieve economic efficiency, equity, political acceptability and administrative feasibility. It is aimed at making the water utility financially self-reliant via adequate cost recovery and revenue generation practices.

Important factors in restructuring water authorities towards financial autonomy include:

- *Effective authority to charge and collect suitable fees;*
- *Tight budget constraints that promote fee collection and services that consumers want and 'are willing to pay for'; and*
- *Little political interference.*

Ultimately, reliance on uncertain monetary transfers from Government is removed facilitating greater certainty with respect to operational and capital investment planning. By avoiding utilization of the general tax fund, a foundation for reducing political intervention is also laid. Further, the development of appropriate standards in service provision is encouraged and a sense of fairness is achieved as customers' ability and willingness to pay are also considered.

This is not to say that Government does not have a role to play in the water sector. On the contrary, Government has a crucial and legitimate part to serve by establishing policies and regulation for: water quality and service standards; adequate access by the public, especially the poor, to water; environmental protection; and overall fiscal matters relating to the water sector. The new role of Government is to provide an incentive environment with appropriate and protective legislation and regulation within which the water utility operates independently and self-sufficiently.

## **6.6 Steps toward reforming WASA**

Under immense pressure for better service and dwindling funds for subsidisation, in early 1994, the government began to recruit a private operator to take over WASA's operations (Nankani, 1997). There were several complications. First, although privatisation was the 'buzz word' at the time and had much political support, a long-term, thirty-year concession, typical for the water sector was daunting, in part because it would require the time-consuming task of amending the company's authorisation act in the months preceding the general election in 1995. Second, the impending election put pressure on the government not only to improve performance, but also to secure the best deal possible. Third, on account of deficient regulatory capacity and limited information on the condition of the system or water consumption patterns, the Government needed time to establish an effective rate setting mechanism.

These circumstances led the government to opt for a two-phase strategy. In the first phase, under an interim management contract, WASA would contract a private operator to provide a management team to meet operational, maintenance and investment targets and follow an agreed business plan over the term of the agreement. WASA would collect service fees as before, but the new operator would have to fund any operating deficits through a loan to WASA, thereby giving the operator an incentive to minimise deficits. A World Bank loan to the government would provide funds over the interim management contract's 5 year term to enable the operator to maintain the system, expand coverage of water and sewage services, improve billing and collection, and install pipeline flow meters – all in accordance with proposed targets. The operator was also required to provide government with the information it would need to design a long-term regulatory regime. The operator received a fixed management fee, a variable fee contingent on its meeting annual targets and first rights to the full concession. Under the long-term concession in the second phase, responsibilities of the private operator's would be extended to include

operation and maintenance and financing capital expenditure. Under both the interim and long-term arrangements, ownership of assets remains with the Government.

While the recruitment of a private operator went ahead, the government began a series of initiatives to improve WASA's economic viability. In 1994, WASA was granted the right to increase tariffs by 35 per cent for customers receiving water for more than 12 hours a day. The tariff increase was introduced in 1995, before the new operator came on board. The timing was meant to ensure that the politics of the increase would not sour the arrival of the new operator in the eyes of the public.

Staff numbers were reduced through voluntary separations and early retirement programmes. The Government assumed responsibility for a large share of WASA's debt service and the World Bank loan provided in August 1994 assisted WASA with emergency repairs and purchases of essential equipment.

The Government also undertook some institutional reforms. It made the Water Resources Agency (WRA), the division of WASA responsible for water quality, an independent government body. Efforts to reorganise the PUC were made focusing water regulation activities in one entity and setting up better means for monitoring monopolistic service operators.

Severn Trent/Wimpey was selected at the end of April 1995 as the winning bidder. But, the PNM government lost the November 1995 elections to the UNC/NAR alliance so the management contract did not take effect until April 1996, after the new government had time to examine and endorse the contract.

Although significant improvements were made under the Severn Trent/Wimpey interim operating agreement (IOA), including bringing WASA's financial status to a profitable standing and improvements in



levels of service provision, the Government opted not to move to the long-term arrangement.

The beleaguered utility which public perception held as a perennial non-performer turned a slight profit in 1999, as a surplus of TT\$16 million was recorded. WASA's chairman Nazir Khan also confirmed that WASA was again seeking another international partner to succeed Severn Trent/Wimpey for the long-term agreement (LTA). He further explained, "The Government and WASA want to move on. We feel that we can get WASA in good shape so that in a year or so we can have a long-term operator and have better benefits" (Trinidad Publishing Co. Ltd., 26/08/99).

#### 6.6.1 New Projects

"A wind of change" has been blowing through the entire water utility sector, according to Public Utilities Minister, Ganga Singh, on January 28, 2000 at the commissioning ceremony of a pipeline-laying project in South Trinidad. WASA chairman, Nazir Khan also boasted, "For the first time in the history of this country we have a plan for getting water to Moruga and La Lune and Marac."

Since 1998, WASA has embarked on a number of projects to bring some measure of relief to the water-deprived areas across Trinidad and Tobago. The mission was to provide "*water for all by the end of the year 2000.*" By this statement, WASA meant that consumers who were not receiving water at all and those who received water only up to 84 hours a week, would receive some level of improved supply by the end of 2000. However, to achieve this goal, WASA needed to procure an additional 151,417 m<sup>3</sup>/day (40mgd).

Cabinet in October 1997 approved a TT\$643 million South Water Project (SWP) which was carried out under the Severn Trent/Wimpey Interim Operating Agreement (IOA).

Other aspects of the “water for all by 2000” programme include a TT\$660 million North Water Project (NWP), a TT\$635 million Tobago Water Project (TWP) and the commissioning of a desalination plant at the Point Lisas Industrial Estate.

In April 2002, the Minister of Public Utilities and Environment, Martin Joseph, announced that in addition to the initiatives above, by the former UNC administration’s ‘water for all’ programme, some TT\$500 million would be spent on a short-term investment plan to improve WASA’s water supply. In a televised address to the nation, he revealed that according to the WASA State of Utility Report, January 2002, current water service provision was still poor with only 14 per cent of the population receiving a continuous supply; and UFW at 50 per cent of total water production. The plan is to be carried out in three stages – phase 1, which is a six-month programme, geared towards benefiting 123,000 citizens in the hardest-hit areas; phase 2 which is a one-year programme, geared to benefit some 81,000 citizens receiving water less than 3 days/week; and phase 3, a three-year programme to benefit an additional 138,000 scheduled citizens – and will involve the rehabilitation of booster pumping stations and wells; the refurbishment of water treatment plants; laying of pipelines; and the installation of communal tanks in the most-severely affected areas where no service is available. The details of this latest plan are currently being established.

### ***South Water Project***

TT\$343 million was raised in the local capital market by Republic Finance and Merchant Bank through a 20-year bond to institutional investors to

help finance the South Water Project (SWP). A loan to WASA under the IOA provided the remaining TT\$300 million.

The SWP was undertaken in 29 months and it included:

- *The drilling of 13 new wells and the refurbishment of another 4 to provide an additional 10,978 m<sup>3</sup>/day (2.9mgd);*
- *The refurbishment of 6 water treatment plants at Granville, Chatham, Point Fortin, Fyzabad, Siparia and Mayaro/Guayaguayare;*
- *Construction of a new Penal water treatment plant with a supply capacity of 5,678 m<sup>3</sup>/day (1.5mgd);*
- *The refurbishment of the Caroni/Arena and Navet water treatment plants;*
- *The construction of a second train at the Caroni/Arena water treatment plant to provide an additional 56,781 m<sup>3</sup>/day (15mgd), of which 18,927 m<sup>3</sup>/day (5mgd) were to be pumped into the north system to supplement supplies in Belmont, Gonzales and environs and the remainder to Central and South Trinidad;*
- *The refurbishment of the San Fernando booster station (the main one servicing south Trinidad with a throughput of approximately 160,000 m<sup>3</sup>/day potable water); and*
- *The laying of 150km of transmission (mainly 914mm and 1,219mm sizes) and distribution mains (102mm and 152mm sizes).*

With the completion of the SWP, Penal and many other rural areas in deep south Trinidad – accounting for approximately 780,000 residents – stretching from Mayaro and Guayaguayare in the east to Icacos in the west, now have water flowing in their taps, some after more than a 35-year wait. Areas such as San Francique and Batcyia which previously had no water

supply, now receive water 12 hours/week. Residents in other villages in Granville, Point Fortin, Chatham, Fyzabad, Siparia and Mayaro now have an improved supply from 48 hours/week to between 84-120 hours/week.

In addition to the SWP, WASA acquired the state-owned oil company, Petrotrin's, Trinity dam located in Point Fortin. By laying transmission and distribution mains, upgrading the St. Mary's booster station and linking in the Trinity dam, WASA is now able to supply 946 m<sup>3</sup>/day (250,000 gal/day) to approximately 8,000 customers in Moruga and nearby communities.

Public Utilities Minister, Ganga Singh commented in February 2000 that the Government's initiative was to alleviate years of "rural neglect, replacing it with a paradigm that makes no distinction between rural and urban areas." (Newsday Newspaper, 28/02/00)

### ***North Water Project***

The North Water Project (NWP) was approved by Cabinet to be undertaken in 2 phases with WASA providing the project management. Similar to the SWP, funds were raised via the floatation of a TT\$330 million bond. The bond issue is for 20 years and was underwritten by the Trinidad and Tobago Unit Trust Corporation.

Major work on the project includes:

- *A TT\$205.6 million programme of pipeline replacement (305mm, 457mm and 610mm transmission lines, and 102mm and 152mm distribution lines);*
- *TT\$16.75 million on rehabilitation of booster pump stations at Aripo, Caura Royal Road, O'Meara (Arima), Diego Martin and Paramin;*

- *A TT\$32.97 million rehabilitation programme for 2 water treatment plants at North Oropouche and Matura;*
- *TT\$32.76 million on the refurbishment of 7 service reservoirs and tanks at North Oropouche (45,500m<sup>3</sup>), Knaggs Hill (27,300m<sup>3</sup>), St. Joseph (13,600m<sup>3</sup>), Maraval (22,700m<sup>3</sup>), O'Meara, Gonzales and Valley View; and*
- *TT\$9 million to be spent on rehabilitation of existing wells in El Socorro (19,500 m<sup>3</sup>/day), Tacarigua (17,000 m<sup>3</sup>/day), Valsayn (17,000 m<sup>3</sup>/day), Chaguaramas/Tucker Valley (15,000 m<sup>3</sup>/day) and Queens' Park Savannah, Port of Spain (9,700 m<sup>3</sup>/day).*

The project implementation schedule included *inter alia*: disbursement of funds for drilling 27 wells at Santa Cruz, Las Lomas (12,600 m<sup>3</sup>/day), Cameron, Freeport (14,500 m<sup>3</sup>/day), Wallerfield, Arima, and other areas along the East/West Corridor as well as the construction of a water treatment plant at La Filette, located on the northern coast. A new sewage treatment plant to be located at Beetham is also part of the NWP.

The first phase of the NWP was completed at the end of 2000 and WASA reported that an estimated 277,000 customers in 9 sub-systems – Navet, Freeport, Caroni North, North Oropouche, Hollis, Valsayn, El Socorro, Four Roads and Matura – now receive an improved supply, with water available more than 72 hours a week. The second phase is currently being undertaken.

### ***Tobago Water Project***

The TT\$635 Tobago Water Project which was to span over 3 years, from 1999 to 2001, but is still ongoing, aims at providing an additional 7,571 m<sup>3</sup>/day (2mgd) of new water for Tobago. The projects include:

- *Refurbishment of the Courland Waterworks (7,500 m<sup>3</sup>/day) at a cost of TT\$27 million;*
- *Richmond (4,500m<sup>3</sup>/day) and Hillsborough (9,000 m<sup>3</sup>/day) refurbishment and upgrades;*
- *Rehabilitation of Government Farms well field (3,500 m<sup>3</sup>/day);*
- *L'Anse Fourmi to Charlotteville water extension;*
- *Groundwater exploration and drilling of new wells at Government Farms, Bacelot (2,700 m<sup>3</sup>/day), Belmont (2,000 m<sup>3</sup>/day) and Carnbee (3,000 m<sup>3</sup>/day) at a cost of TT\$15.6 million; and*
- *Laying of pipelines (≤610mm transmission lines and 102mm and 152mm distribution lines).*

WASA has claimed that the major problem in Tobago is that the treatment plants, in particular, the Courland and Hillsborough waterworks were not initially built to treat the current intake of water. With the recent increase in development, the water now has significantly more silt, which the plants cannot treat. As a result, frequent and lengthy interruptions have been occurring at the Courland, Greenhill and Hillsborough waterworks in the recent past. These plants supply about 30,000 persons, inclusive of hotels located on the south-western part of Tobago. In the interim, government has been tackling the problem with the provision of truck-borne water. Five water trucks were obtained at a cost of TT\$856,800.

A 'no find, no pay' contract was awarded to Lennox Petroleum Company Ltd. in a joint venture partnership with Earthwater Technologies Inc. This means that only upon successful location and development of the aquifers within WASA designated geographic areas, followed by hand over of the wells to WASA, would the contractor receive payment.

In July 2000, a new well with a supply capacity in excess of 2,271 m<sup>3</sup>/day (600,000 gal/day) was drilled at the Government Farms complex located just south of the capital, Scarborough. It is said to be the most prolific water supply well to be discovered in Tobago and it yields more than the outputs of all previous wells drilled on the island.

The Lennox/ETI team also completed test drilling of two bedrock wells in Charlotteville, an area where critical water shortages have existed for more than 25 years. According to Lennox Petroleum Co. Ltd., initial test results indicate that significant supplies of high quality groundwater have been discovered.

***Desalination: A promise in the pipeline***

The final project in WASA's effort to meet its promise of '*water for all by 2000*' is the construction of a desalination plant at Point Lisas to supply the requirements of the Point Lisas Industrial Estate.

In August 1999, WASA awarded a 'build-own-operate-transfer' (BOOT) contract to the Desalination Company of Trinidad and Tobago (Desalcott), a joint venture of the US firm, Ionics Inc. and a local firm, Hafeez Karamath Engineering Services Ltd., which has a 60 per cent equity stake in the company. Under the BOOT arrangement, Desalcott has full responsibility for construction and financing the plant, whose cost was initially estimated at US\$120 million, but Christian Miller, managing director of Desalcott has stated that the final cost will be close to US\$130 million. The initial term of the contract is 20 years with a 5-year extension option, at which point Desalcott will transfer ownership to WASA. WASA also has the option of purchasing the plant at an earlier date at an agreed price. Under the terms of the contract, WASA has agreed to pay for up to 80 per cent of the plant's production, even if the water is not used.

The actual cost of building the plant is US\$80 million, with another US\$50 million added to the price tag by insurance and interest on a US\$60 million

bridging loan obtained from the Republic Finance and Merchant Bank (FINCOR). The shareholders (Ionics and Karamath) contributed US\$20 million towards funding the project. Desalcott is still in consultation with several companies including Mitsui and the World Bank to secure permanent, long-term financing.

It was planned that approximately 190m<sup>3</sup> per minute (50,000 gal/min) of seawater will be drawn from the Gulf of Paria via a turn basin and pumping station at Hydro Agri, an ammonia complex on the Estate, to be converted into freshwater using reverse osmosis technology. The pure water will be stored in a 37,854m<sup>3</sup> (10mg) storage tank and pumped into the distribution system for the Point Lisas Industrial Estate.

The plant, which will be the largest seawater desalination facility in the Western Hemisphere, was scheduled for completion by October 2000, at which time an initial supply of 30,283 m<sup>3</sup>/day (8mgd) was to be provided. On a phased basis thereafter, the volumes produced would increase, so that by January 2004, the plant is expected to be producing 90,850m<sup>3</sup>/day (24mgd).

At present, the Point Lisas Industrial Estate uses 45,425 m<sup>3</sup>/day (12mgd), which it receives via a 54-inch pipeline from the Caroni/Arena Water Treatment Plant. With the commissioning of the desalination facility, WASA intends to reallocate and redistribute the water it supplies to the industrial plants at Point Lisas to domestic customers in more than 300,000 households. Miller claims the amount of water used by the Estate is equivalent to 379-757 l/day (100-200gd) for each household.

The Water and Sewerage Act states that water cannot be sold privately, so WASA will purchase the water from Desalcott at TT\$4.45 per m<sup>3</sup> and then sell it to customers at Point Lisas for TT\$7.50 per m<sup>3</sup>. Water sales from this project are estimated to generate TT\$120 million in annual profit for WASA. According to the Utility's Chairman, some of the surplus from the



sale of the water will be used to offset some of the expenses of upgrading the water distribution system on the Estate. Some of the profit would also be diverted to several on-going initiatives to repair, expand and upgrade WASA's existing infrastructure across Trinidad and Tobago.

However, to date the desalination facility is still not operational. Financing difficulties and changes in planning were foremost among the setbacks to the commissioning of the plant. From inception, the award of the contract to Desalcott was severely criticised as being wasteful and unnecessary. In the Independent Newspaper for the week of September 20, 1999, Powergen manager, Larry Porter, openly accused WASA and the Government of prejudice against their bid, adding that Ionics received favourable treatment. One week later, US Filter/Enerserve NV, which teamed up with Cayman Waters and local firm Bhagwansingh's to bid for the desalination plant, also accused WASA of unfair practices and of "virtually throwing away TT\$900 million" (Trinidad Express, 26/09/99).

According to Willem Barendsen, president of US Filter, whereas the cost of construction of the plant by Ionics/Karamath was US\$120 million, US Filter had committed itself to building a plant of the same size for US\$80 million, thereby having lower residual values. This would mean that at the end of the BOOT arrangement or any option to purchase before the end of the contract, the facility would cost the government and by extension, the people of Trinidad and Tobago much less than under the Ionics/Karamath contract. Barendsen added that WASA stood to make even more profit had it adopted the cheaper US Filter/Enerserve proposal as they guaranteed a purchase price to WASA of TT\$3.32 per m<sup>3</sup> compared to TT\$4.45 per m<sup>3</sup> proposed by Ionics/Karamath. Profit to WASA would be TT\$4.18/m<sup>3</sup> – an increase in the margin of profit over the Ionics/Karamath contract of approximately 38 per cent. "This means in addition to the anticipated profits indicated by WASA, they would have gained a further TT\$45 million (and in say 20 years, TT\$900 million), a colossal saving for the

nation... which could be used in other much needed areas such as hospitals, schools, infrastructure, etc.” (Trinidad Express, 26/09/99)

Officials at the Ministry of Public Utilities as well as WASA’s chairman and acting CEO refuted the arguments posed by Barendsen on the grounds that the bids were evaluated relevant to many criteria: price of plant; residual values of the facility; price of water; technology; water quality; expertise and reputation. And, after assessment, the Ionics/Karamath bid was found to be superior.

Barendsen however questioned the Government’s rationale for accepting the Ionics/Karamath bid on the bases of output rates and technology differences. He claimed that had the same contract revisions been passed on to US Filter/Enerserve, they would have been able to guarantee a supply of similar quality in the desired timeframe but at a lower cost increase. US Filter is also part of the Vivendi group of companies, which is one of the largest world-wide with experience in desalination plants.

Finally, Barendsen told the Express Newspaper: “I do not believe that agencies like the World Bank and Exim Bank, which fund many such projects in developing countries, will be happy with the way the bidding process went in this instance. It’s almost as if the project was intended for Ionics/Karamath from the start, and the rest of us were only wasting time bidding for it.”

The controversy surrounding the desalination plant continued with members of the public and the Opposition labelling the plant as “the most ludicrous scheme” to be foisted on the people of Trinidad and Tobago. They contended that desalination of water remained the most expensive method of freshwater production and was usually considered as a last resort. Opposition Member of Parliament, Dr. Keith Rowley, contended that there was no need for increased water production as the shortfall could be met by repairing the deteriorated transmission and distribution pipelines.

Such maintenance will have to be carried out irrespective of the construction of the desalination plant as it makes little sense to increase production if as much as 50 per cent will continue to be lost through leakage.

Between 1999-2000, the Government spent TT\$130 million to upgrade the Caroni/Arena Treatment Plant to produce an additional 56,781 m<sup>3</sup>/day (15mgd). This clearly demonstrates the high cost of desalination as a means of freshwater production as compared to the more conventional methods – TT\$750 million to produce a maximum of 90,850m<sup>3</sup>/day (24mgd) – more than 5 times the cost for less than twice the volume of water produced.

The crux of the contention has been that the 45,425 m<sup>3</sup>/day (12mgd) of water consumed by the industries at the Point Lisas Industrial Estate was earning more than half of WASA's total revenue and some of these monies were being used to subsidise the domestic demand sector. In essence, WASA relinquished water provision for the Estate – which it was able to produce at approximately TT\$1.00/m<sup>3</sup> – to a private operator, only to repurchase the water at TT\$4.45/m<sup>3</sup>. According to Opposition MP Keith Rowley's calculations, WASA would have to secure TT\$200 million annually to pay for the water under the proposed arrangement with WASA then ending up in a net revenue loss position of the order of TT\$55 million. He added that such circumstances would force WASA to increase water rates. This increase is even more likely, if the Point Lisas Industrial Estate does not utilise all of the water produced so that the remainder is fed into the domestic supply, as WASA sells water to the domestic sector for approximately TT\$1.50/m<sup>3</sup>, whilst it would still be purchasing the desalted water from Desalcott at TT\$4.45/m<sup>3</sup>.

Although the water that WASA now supplies to the Estate will be re-routed to augment supplies to water-deprived regions in Central and South Trinidad, there will be an insubstantial increase to WASA's revenue as

most of these consumers are already included in WASA's customer base, and they pay a flat rate for unlimited usage.

Further, the environmental risks posed by the disposal of about 14 tonnes of solid waste, primarily composed of salt were not thoroughly considered, and cause for concern. This volume is likely to triple once the plant begins operating at full capacity. As at April 2000, no waste disposal site had yet been found. Gary Aboud, secretary of local environmental group, Fishermen and Friends of the Sea, also cautioned against the risks of the desalinated water being used for domestic supply in the longer term since the seawater in the Gulf of Paria is heavily polluted with metals, chemicals, oil residues and other toxins.

Nevertheless, officials at WASA and the Ministry of Public Utilities held firmly to the position that for minimum government investment and minimum implementation time, desalination was part of the solution to mitigate the short-term water problems in Trinidad.

The facility was expected to be fully functional in December 2001. The 5-phase plan which called for step-up increases in water production was fast-tracked to 2 phases so that by October 31, 2001, water production in the first phase should have been 83,279m<sup>3</sup>/day (22mgd). The plant only began supplying the Point Lisas Industrial Estate with 8mgd of water on March 10, 2002. Total plant production reached 22mgd in April 2002, but the facility was shut down again due to bursts in the distribution system. The second phase is still supposed to follow with plans to produce 90,850m<sup>3</sup>/day (24mgd) by January 2004.

## **6.7 Sweating out the Dry Season**

In the 1890s, the Peruvian fisherman noticed that the ocean became warmer usually around Christmas time, and for this reason they nicknamed the phenomenon El Niño (the Christ Child). Meteorologists at the Piarco International Airport Meteorological Service have claimed that this phenomenon caused drier than normal conditions in 2001 and during the 1998 dry season which extended just beyond June. Rainfall for the period January to March 2001 was recorded to be 77 per cent below the annual average. The Caroni/Arena reservoir had less than half its 37,850 MCM capacity (17,400 MCM) in April 2001 and the intense dry season caused approximately 19,000m<sup>3</sup> of water to evaporate daily – enough water to supply the island of Tobago.

Almost one month into the rainy season, drought conditions still existed and the projection by meteorologists was that approximately 60 per cent less than average rainfall was expected until the end of July 2001. WASA officials claimed that at that time, there was just 30 days supply of water remaining in the reservoirs and the amount of rain which fell over the past month (100mm) did little to alleviate the crisis. According to WASA, the rain was not falling in the catchment areas and close to 300-400mm of rainfall was needed for the reservoirs to return to normal levels. WASA was forced to set up 2,000 and 1,000 gallon water tanks in Penal, Mamoral, Brasso Seco and Flanagin Town to supply the residents of these areas and environs. The Utility claimed to have also spent more on truck-borne water supplies in 2001 than any other year in the recent past.

Although on average, the annual surface water availability for Trinidad and Tobago is estimated at 2,500 MCM and 140 MCM respectively, only about 20 per cent of annual surface water is available in the dry season. Storage during the rainy season is therefore critical to the dry season water supply and drought is a real source of concern to WASA. Usage of water from the four main impounding reservoirs – Navet, Hillsborough, Arena and Hollis

– is calculated at having about 200 days of supply at the start of the dry season, which only covers the country's requirements under normal conditions to just beyond June.

The availability of water is the most important issue. Surface water sources in general are more vulnerable to the effects of low rainfall and evaporation than groundwater sources, but the former provides over 70 per cent of the country's potable water supply. In severe dry seasons, some treatment works are forced to cut back production by as much as 50 per cent and in the worst cases, like in 1998, small rural intakes dry up completely.

Under these conditions, very careful management of the water sources is required by WASA so that the Authority can quickly respond if there is a hint that raw water supplies are reducing at a rate faster than projected.

Minimising the abundant loss of water through leaks has become a key factor in dry season planning. The weather is also more conducive to maintenance at this time. Notwithstanding this, and the other initiatives to advance WASA's goal of providing customers with a continuous water supply, rationing remains a necessary tool to equitably distribute the available water in several areas, especially during the dry season. Over 700 communities receive water on a scheduled basis and in some regions, water is made available only on specific days. To help alleviate the dry times, hose pipe bans are strictly enforced and truck-borne supplies are delivered to some areas. Public participation in the conservation of water is also encouraged.

While the ultimate aim to eliminate water rationing altogether is theoretically possible based on source yields, this practice will only begin to be reduced after major capital investment works to expand and rehabilitate water treatment, service reservoir and distribution systems are carried out.

## **6.8 Green Issues**

The social and economic development processes that have taken place in Trinidad and Tobago during the past few decades have not been without pronounced negative effects on the freshwater environment. In the built environment, the most striking effects are to be seen in widespread pollution of waterways, associated with haphazard dumping of solid and liquid toxic wastes, unplanned housing, commercial settlement and development and mismanaged industrial activity. These activities have led to degradation of the lower courses of rivers including the Maraval, Diego Martin, Arima and Caroni rivers.

There has been extensive deforestation in critical watersheds, associated with shifting cultivation, hillside agriculture, inappropriate and illegal logging and sand and gravel extraction. These activities cause siltation in watercourses and lead to flooding.

A recent attempt by the EMA (1998) at ranking river basins in Trinidad and Tobago by degree of degradation revealed that the Maraval, St. Ann's and Diego Martin basins in Trinidad and the Courland and Hillsborough in Tobago are the most degraded. The absence of confirmed reports of significant groundwater pollution is somewhat curious in light of existing pollutants in surface waters and the proximity of productive aquifers to landfills, underground storage tanks, oil-based activities and malfunctioning sewage systems.

The key problems have been enforcement of law and development of adequate preventive and punitive measures for the protection of the watersheds and watercourses. Commitment of resources, both financial and human, has also been lacking.

## **7.0 The Barbados Freshwater Sector**

### **7.1 Introduction**

Like all other countries, freshwater is critical to the sustainable economic and social development of Barbados. With a population of 265,000 persons and a land area of only 430 km<sup>2</sup>, Barbados is one of the most densely populated countries in the Western Hemisphere and almost entirely dependent on groundwater for its freshwater supply.

Although its long-term average rainfall is 1,500 mm per annum, high evapo-transpiration and some small surface run-off significantly reduce the amount of water available for aquifer recharge. The net result is that the total freshwater resources of this island amount to only 350 m<sup>3</sup> per person per year and of this quantity, groundwater represents more than 85 per cent. Such a per capita quantity of water renders Barbados one of the poorest countries in terms of water resources in the Caribbean. It has about 6.25 per cent of the per capita resources of St. Lucia and 14 per cent of the per capita resources of Trinidad and Tobago (2,500 m<sup>3</sup> per person per year). As such, it is widely accepted that the water resources on the island are very limited and this situation is currently placing major constraints on developmental plans.

### **7.2 Physical Features**

#### **7.2.1 Physiography**

Nestled between the Caribbean Sea and the Atlantic Ocean, Barbados is the most easterly West Indian island, located at 13° 10' North Latitude and 59° 32' west longitude. Barbados is only 430 km<sup>2</sup> in area and it is about 34 km long and 23km wide at its widest point. It can be divided into two



distinctive physiographic regions. To the leeward, there is a series of gently sloping step-like coral terraces rising from the south and west coast to a height of 337m above mean sea level in the north central area. This summit is called Mount Hillaby. From there, the land falls steeply and erratically to the windward eastern coast, in a non-coralline area known as the Scotland District.

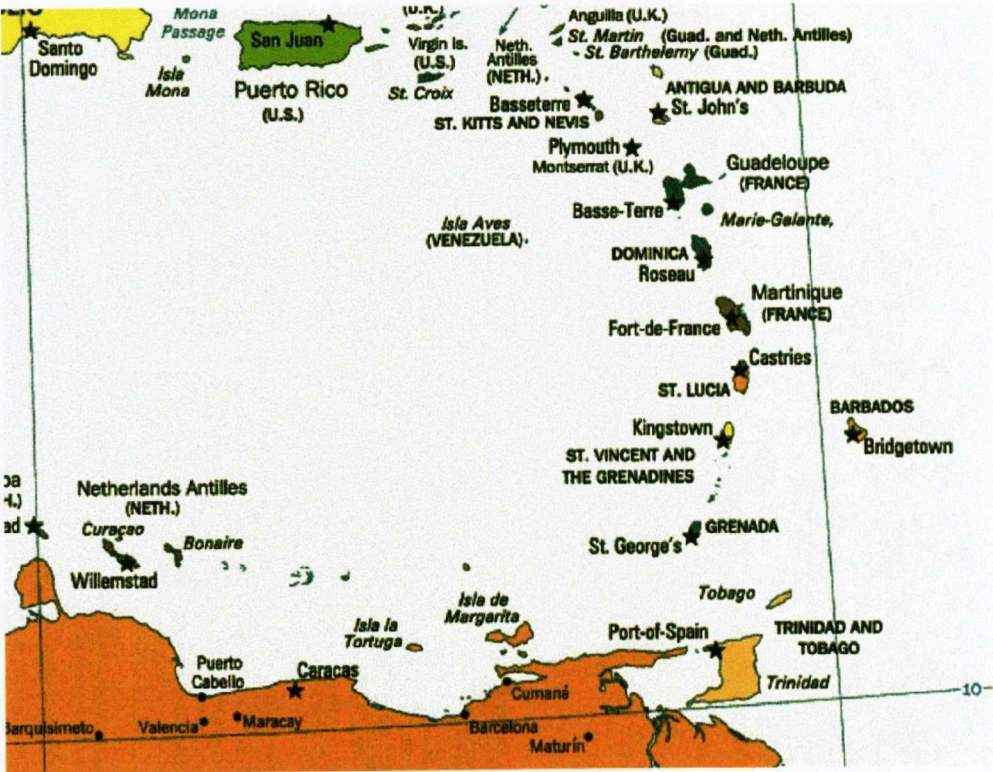
Figures 7.1 and 7.2 illustrate the location and physiography of Barbados respectively.

Coral rock, averaging some 92 m in thickness covers 370km<sup>2</sup> (86 per cent) of the island and forms an undulating land surface. Interrupted by exposed vertical cliffs of old coral reefs, the landscape is severed by numerous old steep-sided gullies and ravines, with depths as great as 31m. This gives the landscape its gently rolling appearance.

The remaining 60km<sup>2</sup> (the Scotland District) on the eastern side of the island, is steep rugged terrain where the coral limestone is almost totally absent. This area comprises steeply-eroded sands, shales and clays of the Lower to Middle Eocene Oceanics Group, forming sharp v-shaped valleys, some prone to landslipping (Poole and Barker, 1983).

The largest river on the island is the Constitution River, which drains a largely coral-covered catchment area of about 78km<sup>2</sup>. It discharges to the sea at Carlisle Bay. In the Scotland District, the principal rivers are Joe's River and Bruce Vale River.

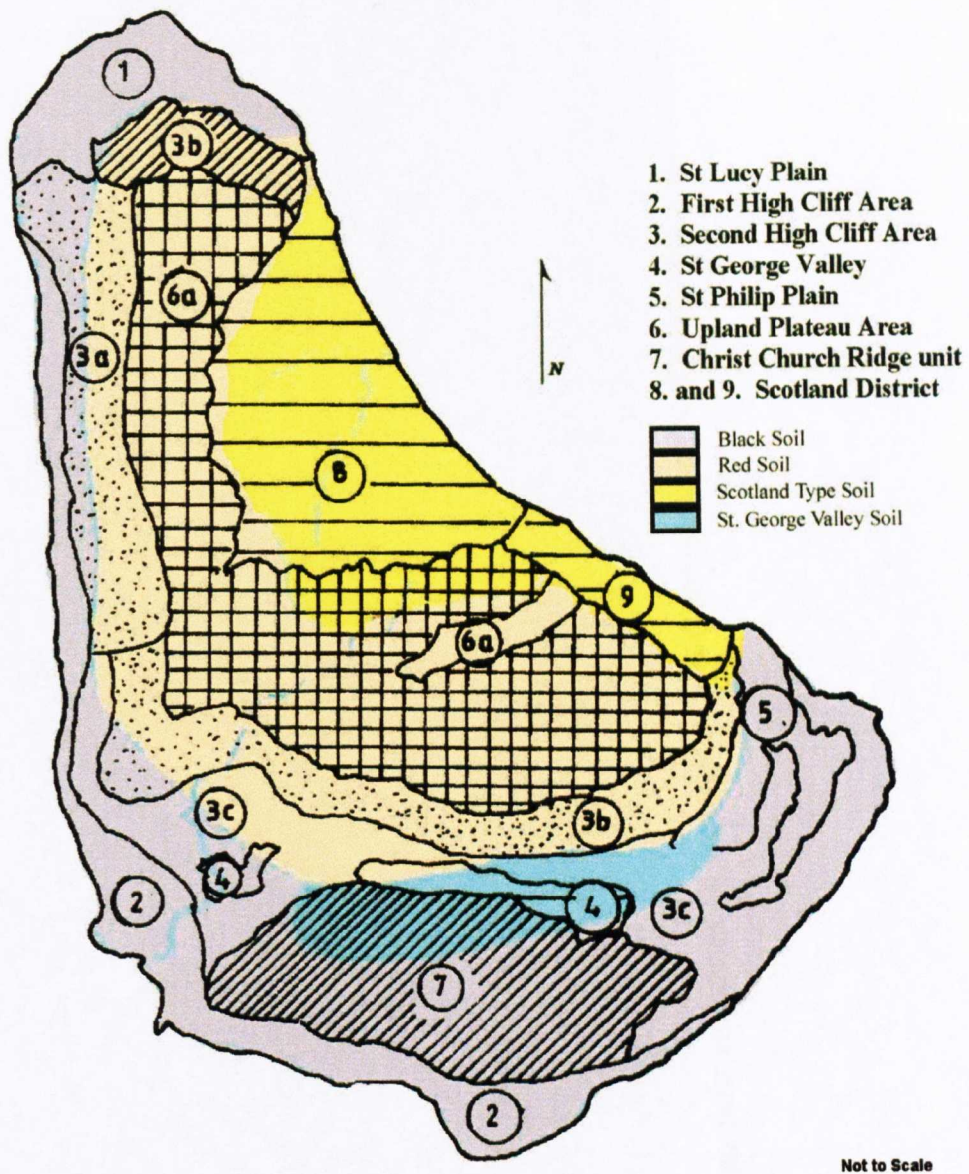
Figure 7.1: Location of Barbados within the Eastern Caribbean



Not to Scale

Source: World Atlas (1999)

**Figure 7.2: Physiography of Barbados**



Adapted from Ministry of Health, EED (1991)

## 7.2.2 Hydrogeology

Unlike most of the Caribbean islands of the Antilles group of the West Indies, which form part of the volcanic arc associated with the north coast of South America, Barbados and Trinidad and Tobago belong to a sedimentary part of the primary arc extending into the Brownson Deep.

Layers of clay, silt and sand were built from deposits emptied from the rivers of northern South America. Gradually these layers thickened and formed stone resulting in a mass of material some 915m deep and approximately 92m below sea level. Upon this sub-base, encrustations of calcium carbonate (limestone) were left from certain plants and animals. Thus a limestone layer, commonly referred to as coral rock developed. Gradual uplift due to volcanic forces, or maybe changes in ocean levels finally caused the island to emerge above sea level approximately 1 million years ago. Variable weathering of the coral by wave action, wind, rain and man has formed the land surface as it exists today.

Except for the Scotland District, Barbados is capped by the Pleistocene coral rock formation composed of reefal limestones as deep as 100m in thickness. These lie with minor unconformity on a sequence of mainly marly beds, which range up to several hundred metres in total thickness and which are termed the Oceanics Group. The age of the Oceanics is upper Eocene to Oligocene. The Scotland District's oceanics are a lower to middle Eocene (58-64 million year old) flysch deposit – mainly clays and sands – a few thousand metres in thickness and these rest with marked unconformity amongst the shales and sandstones.

The coral rock has been subject to updoming, the highest part being seen in the sharp slope that defines the boundary of the Scotland District. A subsidiary east-west structure occurs in the Christ Church district located to the south of the island, which is reflected in the well-defined valley

extending from the capital city, Bridgetown to the St. Philip coast, and the Christ Church ridge to the south.

Two prominent features, the first and second cliffs, which are eroded former sea cliffs, can be traced in the coral rock. These run parallel to the shoreline and can be used to separate the coral limestone into three groups, coinciding with the three terraces on the island – the Upper, Lower and Middle Coral Reefs.

The coral rock is a jointed cavernous and porous material, while the rocks in the Scotland District, whose structure is complex due to pronounced folding, faulting and thrusting are relatively impervious, highly erodable and unstable.

Figure 7.3 delineates the extent of the coral rock and the adjoining Scotland District.

### ***Aquifer Development***

Coral rock is porous because of the many, often interconnected holes throughout its structure. Moreover, coral is dissolved by water containing carbon dioxide, so as the rainfall seeps through it, the pores are widened thereby allowing greater amounts of water to flow through. Areas of softer coral are more readily dissolved in this manner. Shallow holes or 'sucks' and caves have been formed in this manner and these can be found in many places on the island.

The coral rock, in essence, therefore provides practically perfect under-drainage for lands under cultivation; takes surface water run-off into 'sucks'; accepts water as intermittently as it comes; stores it and from this storage maintains the flow of the springs and underground streams on which the public water supply depends.

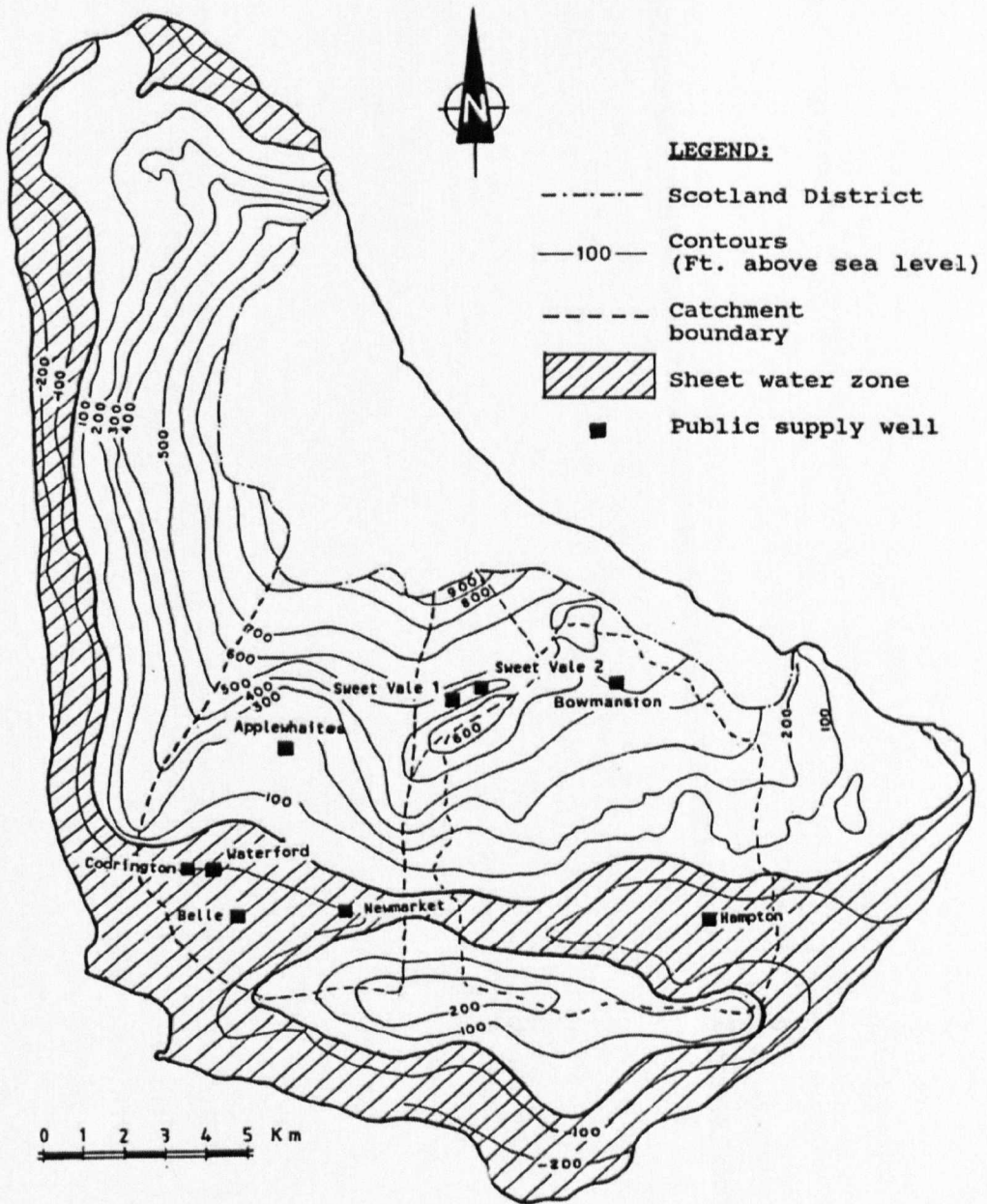
While the porous coral rock cap is however the primary factor in the hydrology of Barbados, it develops its storage effects because of the characteristics of the sub-base formation. The very dense clay, salt and sand deposits which underlay the coral are impervious and the varying elevations and inclinations of this layer are such that a number of underground catchments or aquifers have formed.

Having porous rock sitting on impervious clay means that any water will seep or flow through the coral until it reaches the clay/coral interface and will then flow along this interface in the direction in which it slopes, until it reaches the point where it meets sea water or it creates or finds a cave. In Barbadian terms, the former occurs close to the coastline and is referred to as 'sheetwater', whilst the latter occurs farther inland and is aptly coined 'streamwater'.

From a large number of observations, Dr. Alfred Senn established the contours of the base of the coral rock and developed the 'sheetwater' theory in 1946. As freshwater is less dense than salt-water, sheetwater occurs as a thin layer or 'lens' of freshwater floating on top of the sea water, with only a small amount of mixing at the interface. Underground aquifers therefore consist of freshwater stored in the openings of the coral below sea level and above the salt-water/freshwater interface. This is illustrated in figure 7.4, which is a simplified geological section across the island.

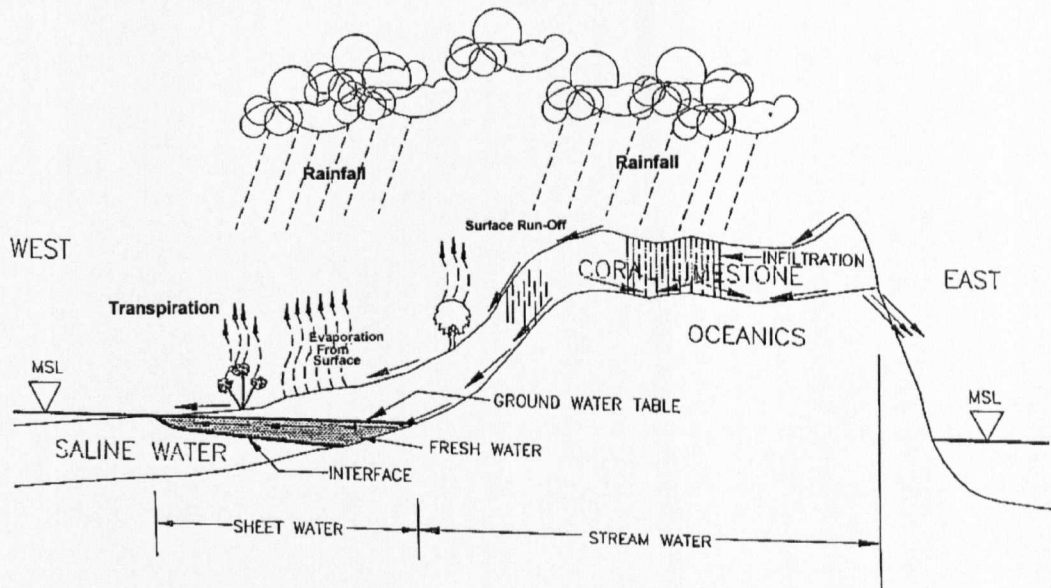


Figure 7.3: Coral Rock Regions and the Adjoining Scotland District



Source: Ministry of Health, EED (1991)

**Figure 7.4: Geological Cross-Section Across the Island**



Source: BWA (1997)

### 7.2.3 Climate

Barbados lies within the humid tropics and its climate is most strongly influenced by the north-east Trade Winds.

#### ***Rainfall***

Consequent upon significant areal variation within the island as well as considerable annual and seasonal variation, rainfall is the most variable parameter. Barbados suffers relatively frequently from droughts, some of which are severe, as in 1994 and 1995. Other recent droughts include those experienced in 1996 and 2001. June to November are the wettest months as over three-quarters of the mean annual precipitation falls therein when the Inter-tropical Convergence Zone (ITCZ) is near the island. The dry season normally runs from December to May, with February to April usually the driest months as the ITCZ lies very much south of the island. Normally, some rain falls in every month and the mean annual island-wide



rainfall is 1,400mm (1999 estimate), varying from a minimum of 1,200mm at the south coast to over 2,000mm on the high ground in the Scotland District.

Of import is the minimal difference in the amounts of rainfall during the day or night. Garstang (1959) suggested that Barbadian patterns may be similar to those in Trinidad and Tobago where night-time precipitation is caused mainly through trade wind advection and day-time precipitation through over-land surface heating.

Most rainfall occurs in short duration showers. However, some extremely heavy and prolonged storms (usually lasting 24 hours or less) occur at times, mainly during the rainy season due to the passage of weak low pressure waves in the trade winds.

Perhaps the most significant aspect of the rainfall patterns in Barbados is the variation in the distribution of areal precipitation over the island. The higher central region stands out as a zone of particularly heavy rainfall, in fact, most rain falls close to the rim of the Scotland District, which faces the on-coming north-east trade winds. In marked contrast, all the coastal districts experience a degree of relative aridity. Therefore, indications are that even small differences in elevation are sufficient to induce substantial changes in precipitation totals, due to the great amount of moisture carried by the trade winds (Watts, 1966). Figure 7.5 shows the rainfall variance across the island.

### ***Temperature***

In contrast to the rainfall patterns, air temperature is fairly constant, with average daily values from 24<sup>0</sup>C in January to 31<sup>0</sup>C in June, with a 5-10<sup>0</sup>C drop during the night. The absolute minimum and maximum temperatures recorded over the last 20 years are 21.3<sup>0</sup>C in January 1985 and 32<sup>0</sup>C in September 2000, respectively.

### ***Humidity***

The relative humidity is high throughout the year, with average daily values ranging from 65 to 80 per cent.

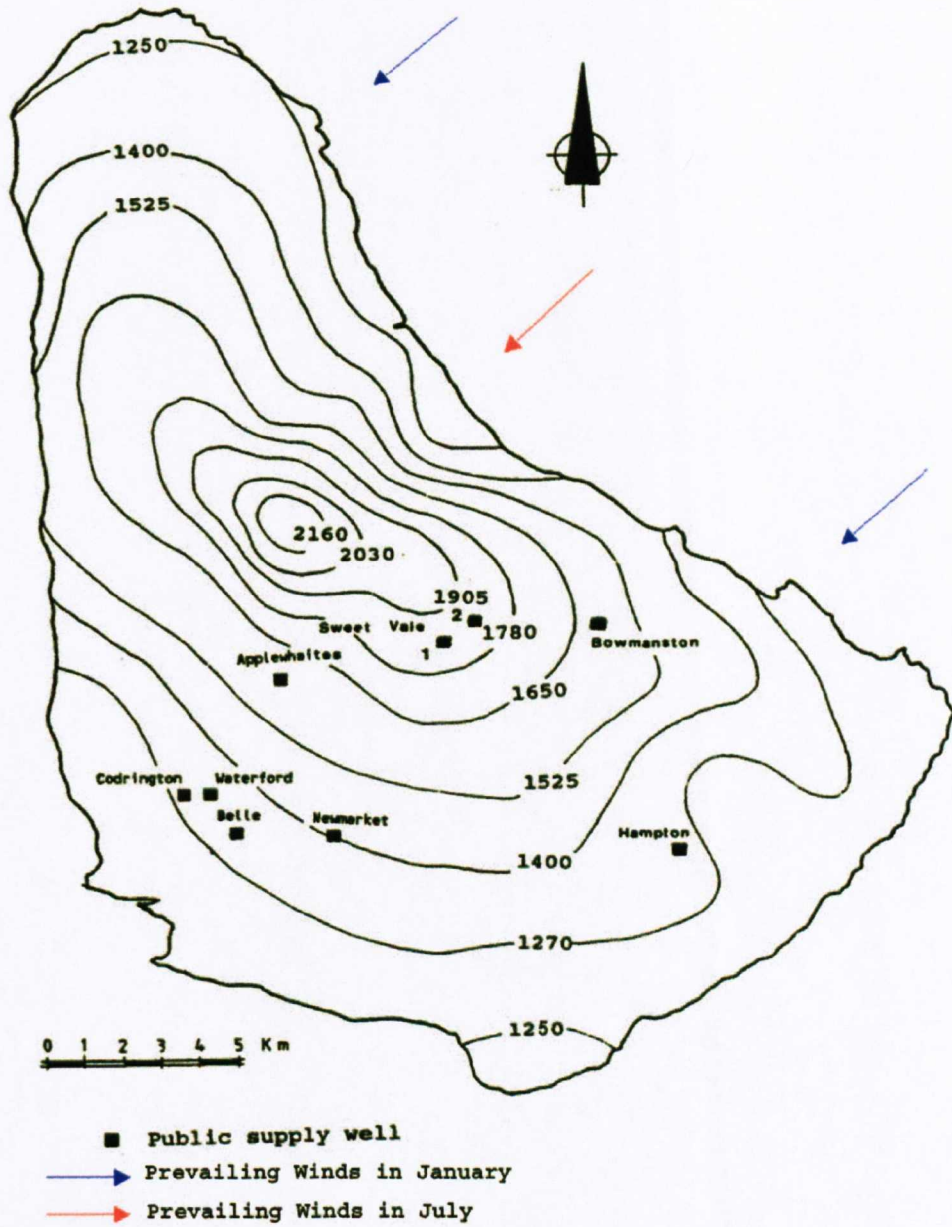
### ***Winds***

The mean annual wind speed is 16 kilometres per hour (km/h), with average monthly values ranging from 11km/h in October to 19km/h in June. These northeast trade winds blow relatively strongly throughout the year, except when the ITCZ is nearby or when low pressure waves or hurricanes break up its flow. Although Barbados lies to the south of the main hurricane zone of the eastern Caribbean, infrequent hurricanes and tropical depressions at times bring heavy rain and high winds, sometimes in excess of 160km/h. The most recent hurricane to directly hit the island was Janet in 1955. But during the 1990s, several other hurricanes affected the island. These include Jose and Lenny in 1999 which caused heavy rain, flooding and rough seas; Erica in 1997(flooding); Caesar in 1996 (rough seas); Iris and Marilyn in 1995 which also caused rough seas and associated coastline damage.

### ***Evapotranspiration***

Evapotranspiration rates – a most important climatic characteristic in water resource evaluations – are high throughout the year due to the persistent strength of the trade winds and the high temperatures. Annual actual evapotranspiration accounts for up to 86 per cent of annual rainfall on average. Average values per annum range from 1,030mm in the lower coastal areas in the south east of the island to 1,400mm in the central highland.

Figure 7.5: Rainfall Variance across the Island



Adapted from Ministry of Health, EED (1991)

## **7.3 Socio-economic Conditions**

### **7.3.1 History and Culture**

Barbados is thought to have been originally inhabited by Arawak Indians but by the time Europeans first explored the island in the fifteenth century, it was uninhabited. Barbados was settled by the British in 1627. Unlike most of the other Caribbean islands that came under periodic control of a succession of different European powers prior to attaining political independence, Barbados remained a British colony until independence in 1966.

Beckles (1990) explained that early prosperity among the colonists was based largely on the production of tobacco, although Barbadian tobacco was never of high quality. A glut in the market for tobacco in 1631 and tension with producers in Virginia pre-empted a move to cotton production (Beckles, 1990, pg.14). But, interest in cotton was again short-lived and waned when prices on the London cotton market fell rapidly in 1639. After experimentation with alternative crops such as indigo and bananas, sugar cane growth became established on Barbados in the early 1640s. In that early period, sugar proved to be an extremely profitable commodity and “by 1645, Barbadian planters believed that they had found, at last, a truly profitable staple, one which was free from short-term price fluctuations” (Beckles, 1990, pg. 21).

As the sugar industry developed into the main commercial enterprise, Barbados was divided into large plantation estates which replaced most of the small holdings of the early British settlers. Slaves were brought from Africa to work on the sugar plantations and from that time onwards, the population has been at least 80 per cent black. Slavery was abolished in 1834 and in 1838, slaves on the island gained their freedom.

Local politics was dominated by plantation owners and merchants of British descent. It was not until the 1930s that descendants of emancipated slaves began a movement for political rights. One of the leaders of this movement, Sir Grantley Adams, founded the Barbados Labour Party (BLP) in 1938.

From 1958 to 1962, Barbados was one of 10 members of the West Indies Federation, and Sir Grantley Adams served as its first Prime Minister. When the Federation was terminated, Barbados reverted to its former status as a self-governing colony, gaining independence on November 30, 1966. Under its constitution, Barbados is a parliamentary democracy modelled on the British system. The Governor General represents the British Crown as head of state. Actual government of the country rests with the Cabinet, headed by the Prime Minister and responsible to parliament. The bicameral parliament consists of a 21 member Senate appointed by the Governor General; and a 28 member House of Assembly elected by the public. Elections are held every 5 years. The two major political parties, are the Democratic Labour Party (DLP) which held uninterrupted power from 1966 to 1976 and the Barbados Labour Party (BLP) who won the 1976, 1994 and 1999 elections. BLP leader Owen Arthur currently serves as Prime Minister.

The island is divided into 11 administrative sectors or parishes and Bridgetown, which is in the parish of Christ Church, is the capital and largest city. Prior to 1969, each parish had its own local government system called the Vestry. The vestries were later abolished and the island divided into three areas – two districts served by councils and the third, the City of Bridgetown was given a City Council and a Mayor. In 1967, the councils were abolished and local government affairs were administered by an Interim Commissioner for Local Government. Two years later, the system ended and the functions of the local government service were transferred to central government and statutory boards. Health, education and welfare provision are all relatively well developed. Literacy rates are

very high, averaging approximately 97 per cent. Although the total population in 1999 was estimated at only 265,000, population density is relatively high, standing at approximately 600 persons per km<sup>2</sup>. Perhaps in recognition of this, population growth has been kept consistently low, averaging less than 0.5 per cent per annum for the last 25 years. As a direct consequence of slavery, about 80 per cent of the population are of African decent; approximately 4 per cent are white (2.5 per cent expatriates, 1.5 per cent local-born Barbadians). The remaining 16 per cent of the population comprise other races such as Indian, Chinese or mixed. About 70 per cent of Barbadians are Anglican and the rest is divided among Roman Catholic, Methodist, Baptist and Moravian. A few very small Jewish and Muslim communities also exist. A life expectancy rate of 75 years and an infant mortality rate of 16 per 1,000 live births were estimated in 1999. Figure 7.6 shows the locations of the parishes, towns and roadways.



**Figure 7.6: Parishes and Towns of Barbados**



Source: Barbados Tourist Information (1999)

### 7.3.2 Economy

Until relatively recently, the Barbadian economy was dominated by 'king sugar'. As Worrell (1982) explains: "In 1946.... sugar production dominated, accounting for over one third of GDP and bringing in two thirds of receipts from the sale of goods and services abroad" (Worrell, 1982, pg.1). Throughout the post-independence period, however, Barbados has transformed itself from a low-income economy dependent on sugar production to a middle-income tourism-centric economy.

The economy went into deep recession in 1989 after 3 years of steady decline brought on by fundamental macro-economic imbalances. The inflation rate stood at 14 per cent in 1980 and fell consistently up to 1986, when it was less than 2 per cent, but, by 1991 it had climbed again to 6 per cent (GOB, 1993). Unemployment rates which were approximately 10 per cent in 1981, averaged 19 per cent in the late 1980s and early 1990s. The visible trade balance deficit peaked at US \$43 million in 1990. International debt had also risen quite dramatically, climbing from US \$381 million to almost US \$1,000 million in 1992.

After a difficult readjustment process, Barbados's economy began to recover in 1993, showing growth in real output and in international reserves as well as improvements in the balance of payments. Real GDP which had fallen to US \$395.5 million in 1992 has risen to US\$402 million in 1993 and to US\$428.4 million by 1995. The main sectors of the economy that contributed to this growth were tourism, manufacturing, wholesale and retail trade, business and general services. The former sectors were considerably more significant than sugar by this time. Problems associated with sugar on the world market, the low price fetched for this commodity against its high production costs, along with the need to reduce the island's high food import bill have led to the general decline in sugar production and increased efforts towards crop diversification. Recently, offshore banking and financial services have also become an



important source of foreign exchange and economic growth. Growth rates have averaged 3-5 per cent since 1995.

Within less than 30 years, Barbados has moved from almost total dependence on a single agricultural commodity – sugar – to a largely similar dependence on its tourist industry, placing heavy demands on its limited water resource base. Tourism, which accounted for only 2 per cent of GDP in 1956, rose to 12 per cent in 1980, becoming the leading export earner (Worrell, 1982, pg.8). Rapid growth in the tourism sector further occurred between 1992 to 1995, with annual revenues from tourism rising from US\$56.8 million to US\$65.4 million.

The tourist industry continues to be the linchpin of the economy, having contributed 11.2 per cent of GDP and accounted directly for 12.5 per cent of the labour force, which in 2000 stood at about 136,900. During 2000, approximately 545,027 long-stay visitors came to Barbados, an increase of 5.9 per cent over 1999. For the same period, 533,278 cruise ship passengers visited, an increase of 23.2 per cent over 1999. Total tourist expenditure for 2000 was US\$707 million.

Various light industries accounted for 16 per cent of GDP, agriculture 5 per cent (of which sugar contributed 1.4 per cent) and services, 79 per cent respectively in 1999.

The continued economic success of Barbados is reflected in the increase in GDP in 1999 by 3.1 per cent over the previous year and the relatively low inflation rate of 1.6 per cent. GDP at current factor stood at US\$2,069 million in 1999 and per capita incomes, US\$7,897, which are relatively high in comparison to other Caribbean countries, including Trinidad and Tobago (US \$5,247 per capita income for the same period). The unemployment figure (as a percentage of the labour force) was 9.2 per cent in 2000.

### 7.3.3 The Place of Water in the Economy

*“The per capita consumption of water in Barbados is presently at an alarmingly high rate of 416 litres – population 250,000, compared to 151 litres for St. Lucia – population 110,000; 110 litres for Antigua – population 72,000 and 182 litres for Dominica – population 75,000” (General Manager, Barbados Water Authority, 1981).*

Between 1981 and 1990, the population had grown by 2.8 per cent and there were approximately 75,170 households in Barbados. Domestic consumption stood at 128,000 m<sup>3</sup>/day and approximately 94 per cent of the households had piped water.

Current demand for domestic water is approximately 145,000 m<sup>3</sup>/day whilst the demand for the agricultural sector is 45,000 m<sup>3</sup>/day. Other consumers such as hotels, industry and commerce and golf courses collectively demand 24,000 m<sup>3</sup>/day.

Total demand is therefore estimated at 214,000m<sup>3</sup>/day, just within supply capabilities which stand at approximately 226,000m<sup>3</sup>/day. Consequently, a desalination facility has recently been commissioned by the Barbados Water Authority to augment the supply obtained from aquifer production.

## 7.4 History of Public Water Supply

From the early 1600s to mid-1800s, the water supply was derived entirely from ponds (which were much more numerous than at present), springs and rainwater collected in tanks. Prior to 1855, not even Bridgetown had a formal system of public water supply. Potable water for the city was obtained from depression springs in the vicinity, mainly from the Beckles Spring on the Bay Estate. This water was sold by the owners of the spring, that is, the Estate owners, to persons who made a trade of carting it in casks

to different parts of the city where it was sold at the then relatively dear rate of 2 cents (BD\$) for 15 litres.

In 1857, the government and a private firm contractually formed what was known as the Bridgetown Waterworks Company. The joint stock company was guaranteed an annual government subsidy of approximately US \$8,300 to supply Bridgetown only with 2 million litres (2,000 m<sup>3</sup>) of potable water per day. The Ben Spring, located at Newcastle, St. John, was first used as a gravity source to fulfil this requirement. The Waterworks Act, also passed in 1857, reserved the rights for the government to purchase this company at the end of 20 years.

Initial supply came from the Newcastle Springs, but some time later, a spring at Codrington was incorporated into the system. The pipeline laid from Newcastle to Bridgetown is still in use today.

Conditions in Bridgetown were improved considerably, but the rural population was still dependent on ponds for their freshwater supplies. Due to serious drought during 1870 to 1872, 189 of the 257 ponds in use in six parishes dried out, resulting in acute water shortages for the residents. Disaster struck again in January 1880 when landslides carried the Codrington College and Newcastle mains away and Bridgetown was left without water for twelve days. This incident demonstrated how dangerous it was to rely on only two sources for the supply to Bridgetown, particularly because of the long distance over which the water had to be transported.

In 1886, a Water Supply Act was passed and another joint stock company was formed under the name of the Barbados Water Supply Company. The primary remit of this Company was to construct and maintain a complete water system supplying the remaining parts of the island with potable water, including the rural districts up to 229m above sea level. 400 'free' public standpipes were distributed throughout the rural areas and the

government again guaranteed the company US \$8,300 per year to maintain this service. The sources of water used were: Coles Cave, Harrison's Cave, Bakers Cave, Edghill and Plumtree Gullies.

The Bridgetown Waterworks Company supplies dwindled during a drought in 1885 and they were forced to augment their supply, so they purchased the rights to supply water from Bowmanston's Cave in St. John. The Barbados Water Company also had difficulty locating sufficient water and eventually they purchased 2 acres (8,100m<sup>2</sup>) of land at Everton, just north of Bowmanston and sank a well there. This well intercepted the Bowmanston stream above the well of the Bridgetown Waterworks Company, thereby reducing the latter's supply.

Inevitably, conflict ensued which resulted in a series of law suits and court battles. Consequently, in 1895, the Barbados Government purchased both companies at a cost of US \$583,000 and formed the Waterworks Department.

Until 1980, the Waterworks Department was run as a government-subsidised department, which was directly responsible to, but not integrated with the Ministry of Communications and Works. The department held the responsibility for investigating, designing and commissioning new waterworks as well as maintaining existing systems.

In 1980, the Barbados Water Authority (BWA) was formed and in addition to performing the tasks of the Waterworks Department, it was also charged with some regulatory functions. The BWA falls under the umbrella of the Ministry of Power, Transportation, Communication and Works (MPTC).

Two other important dates in the history of freshwater development in Barbados are 1953 and 1963. In 1953, the Underground Water Control Act was passed which made licenses mandatory for water abstraction and in 1963, the UNDP zoning policy came into effect for groundwater

protection. Five zones were identified for the island, with Zone 1 having the most stringent restrictions.

## **7.5 Policies and Legislation for Groundwater Management**

A substantial body of applicable laws and policies exists to address groundwater development and management. However, the Government of Barbados still has not adopted a policy pertaining to public and private groundwater rights and recourse has had to be sought from the English Common Law when such issues have arisen.

The applicable Acts and policies are as follows:

- **Three Houses Spring Act, 1713**

This Act relates to the Spring and Rivulet located in the parish of St. Philip, known as the Three-Houses Spring. It provides for adjacent inhabitants through whose lands the said rivulet runs to construct a dam and obtain water for his/her/their own private use; provided no such dam, drain or channel causes the rivulet to dry up below, and sufficient water continues to flow downstream to keep the pond at the end of the rivulet full at all times for the parishioners of St. Philip to satisfy their freshwater requirements.

- **Porey's Spring Act, 1864**

This Act was established to facilitate better provision for the collection and delivery of the water from Porey's Spring in the parish of St. Thomas. It gives power of authority to the Vestry of the St. Thomas parish to construct and maintain works for the collection and distribution of water from Porey's Spring, and to charge a fee for the delivery of this water to persons other than the inhabitants of the St. Thomas parish.

- **Underground Water Control Act, CAP. 283, 1953**

This piece of legislation provides a framework for the control and use of underground sources of water supply on the island and other related matters. The Act provided for the establishment of a Water Board with powers to control and regulate the development and use of the groundwater resources, through licensing and provision of necessary regulations. This includes control over abandonment of wells, which however has not been fully exercised.

- **Barbados Water Authority Act, CAP. 274A, 1980**

By this Act the Barbados Water Authority was established as a statutory corporation under the purview of the Ministry of Power, Transport, Communication and Works. All water resources, apart from the two main spring sources that are controlled by the Three Houses and the Porey's Spring Act, are regulated under this Act. The Act gives power to the Barbados Water Authority to provide water and sewerage services and jurisdiction to make regulations, educate, advise and operate systems to manage, allocate and monitor the water resources of Barbados with a view to ensuring their best development, utilisation, conservation and protection in the public interest. The Act also empowers the Authority to obtain and analyse information and maintain records of the total water resources of Barbados as well as conduct research programmes and prepare statistics for management processes.

The Barbados Water Authority, administered through a Board of Directors has assumed the role and power of the Water Board to license wells under the Underground Water Control Act and provision has been made to extend the provisions of the Act relating to the control of underground water to apply 'mutatis mutandis' to the control of surface water.

## **7.6 The Barbados Water Authority**

The Barbados Water Authority (BWA) is responsible for the management of water resources on the island. BWA was established in October 1980 by the Barbados Water Authority Act of the same year. Except for the two spring sources controlled by the Three-Houses and Porey's Spring Acts, BWA is responsible for managing and monitoring the water resource base with a view to ensuring their best development, utilisation, conservation and protection for the public. The Authority is also responsible for island-wide distribution of water and the safe handling, treatment and disposal of sewage in Bridgetown.

The formation of a single autonomous water authority had been mandated by the Inter-American Development Bank (IADB) and formed part of the agreement that IADB made with the Barbados Government to secure financing for the sewerage of Bridgetown.

A section of the same Agreement stipulated that within 3 years of the sewerage of Bridgetown, water rates were to be gradually increased to effect viability of the Authority by the end of the 3 year period. This was achieved and BWA is currently completely self-sufficient. Except in exceptional circumstances, the Authority no longer receives any financial assistance from Central Government.

### **7.6.1 Jurisdiction of BWA**

The Barbados Water Authority is charged with all of the above activities as mandated by the Barbados Water Authority Act, 1980. There are three other main agencies whose responsibilities impact groundwater use, monitoring and control:

1. The Ministry of Agriculture and Rural Development

This Ministry has a Land and Water Use Unit, which is responsible for developing and delivering water for irrigation, and through the Barbados Agricultural Development and Marketing Corporation (BADMC) operates a number of wells for this purpose.

2. The Ministry of Health and the Environment

The Environmental Engineering Division of this Ministry is responsible for monitoring and control of conditions likely to affect the quality of land, air, water, general health and environmental well-being of the inhabitants of Barbados.

The Ministry is also required to review all developmental applications to ensure compliance with the groundwater protection zoning policy. They currently perform monthly monitoring for BWA and some private wells.

3. The Town and Country Planning Office

This agency also has responsibilities relating to the enforcement of the groundwater protection zoning policy. It monitors development schemes under the Development Order to ensure compliance with both zoning and the island's development policies. No exemptions from development control apply to Zone 1 areas.

Under the current arrangement, BWA has responsibility for both regulating and licensing groundwater abstractions as well as water supply and distribution. These are potentially conflicting areas of interest.

### 7.6.2 Institutional Arrangement

The Barbados Water Authority is administered through a Board of Directors who are charged with overall responsibility for the Authority. A

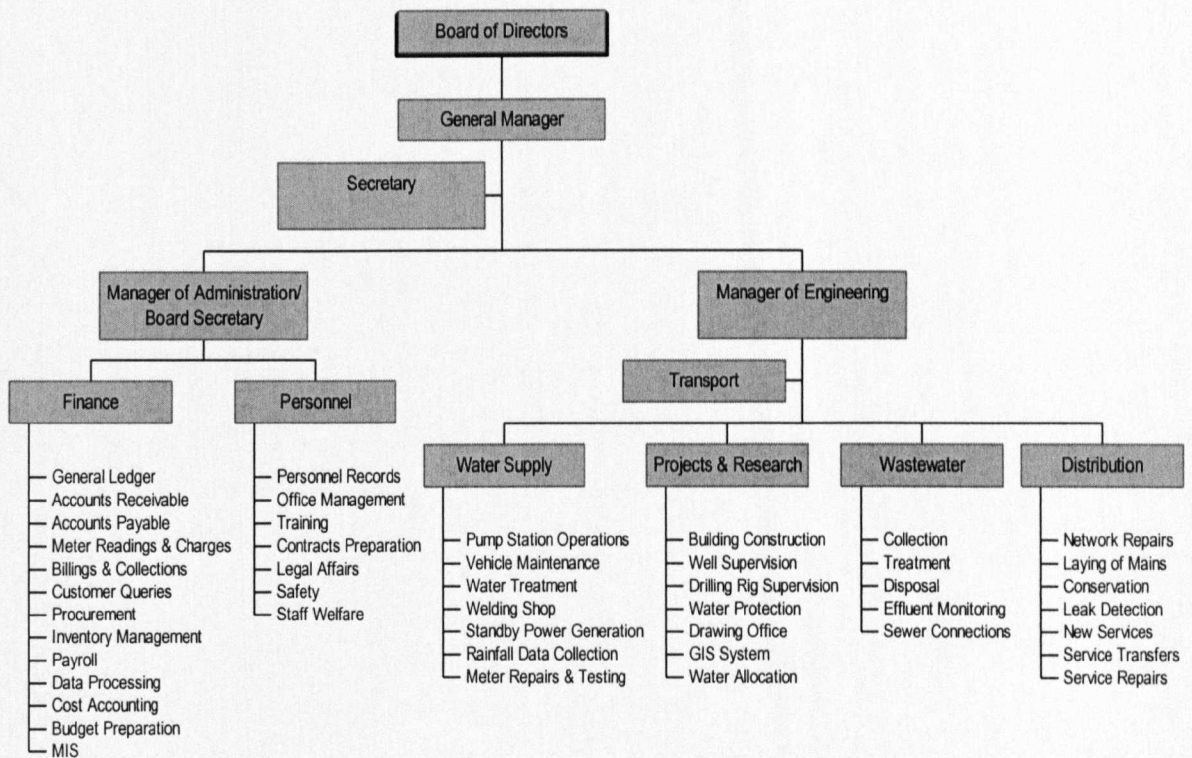


Chief Executive Officer/General Manager is appointed by the Board to carry out its policies and manage the day-to-day operations of the Authority. Various functional divisions are responsible for finance, administration, water supply, distribution and wastewater.

The Authority is responsible to Parliament through the Minister of Power, Transport, Communication and Works.

Figure 7.7 illustrates the organisational relationships, the principal staff positions and main divisional functions of BWA.

**Figure 7.7: Organisational Chart of the Barbados Water Authority**



Source: K-C Consultants Ltd. (1997)

### 7.6.3 Financial Status

The Waterworks Department and BWA were heavily subsidised by the Government prior to 1985. The Waterworks Department realised a budget deficit which fluctuated between 28 per cent to 42 per cent of total expenditure over the years 1958 to 1979. The average annual government subvention over this period was approximately BD\$0.5 million (US\$0.25 million). To further augment government subsidies in the early 1980s, soft loans by the Canadian International Development Agency (CIDA) and the United States Basic Needs Programme were obtained. This amounted to a total of BD\$24 million (US\$12 million).

By agreement with IADB, from 1980 onwards, water rates were gradually increased and viability excluding full depreciation was achieved by 1985. Subsequently, water rates were reduced in certain consumer categories which resulted in a reduction of revenue from the sale of water by 20 per cent. A net loss situation of approximately BD\$0.5 million was recorded in 1987 which gradually worsened to the substantial figure of BD\$5 million in 1991.

Consequently, water rates were again increased in 1991 and a financial turn-around was achieved in 1992 with BWA showing a net profit of BD\$5.2 million. Since then, profitability has been maintained with net profit values of BD\$7.05 million and BD\$9 million recorded for 1994 and 1998 respectively. The BWA has become financially self-sufficient with a current gross annual revenue in excess of BD\$40 million.

### 7.6.4 Water Tariffs/Rates

The current tariff structure, in effect since October 1, 1991, is a hybrid of metered rates and fixed rates. Metered consumers are categorised into a) domestic up to 34m<sup>3</sup> per month, b) domestic over 34m<sup>3</sup> per month, c) commercial and d) ships.

The rates for non-metered consumers (fixed rates) are based on the Net Annual Value of the property and the number of fittings present, such as water closets, showers, bathtubs etc. A complete schedule of the current charges is shown in figure 7.8 below.

**Figure 7.8: Water Rates (Effective October 1, 1991)**

<b>Basis</b>		<b>Annual Charge/Rate</b>
<b>NON-METERED CUSTOMERS</b>		
(total of net Annual Value basis plus Traps basis – Maximum bill BD \$640 per annum)		
<b>Net Annual Value Basis (NAV) / BD \$</b>		
0 to 114		\$160 per annum
114 to 150		\$160 per annum + \$1.40 per \$1 NAV over \$114
150 to 336		\$225 per annum + \$1.06 per \$1 NAV over \$150
336 and over		\$447 per annum + \$1.13 per \$1 NAV over \$336
<b>Trap Basis</b>		
Water Closet		\$70.31 per annum
Shower Bath		\$35.15 per annum
Other Bath		\$50.62 per annum
<b>METERED CUSTOMERS</b>		
(minimum charge \$20 per month)		
Residential	0 to 34 m <sup>3</sup> per month	\$1.50 per m <sup>3</sup>
	Over 34 m <sup>3</sup> per month	\$2.12 per m <sup>3</sup>
Commercial		\$2.12 per m <sup>3</sup>
Agricultural		\$0.33 per m <sup>3</sup>
Ships *		\$3.50 per m <sup>3</sup>

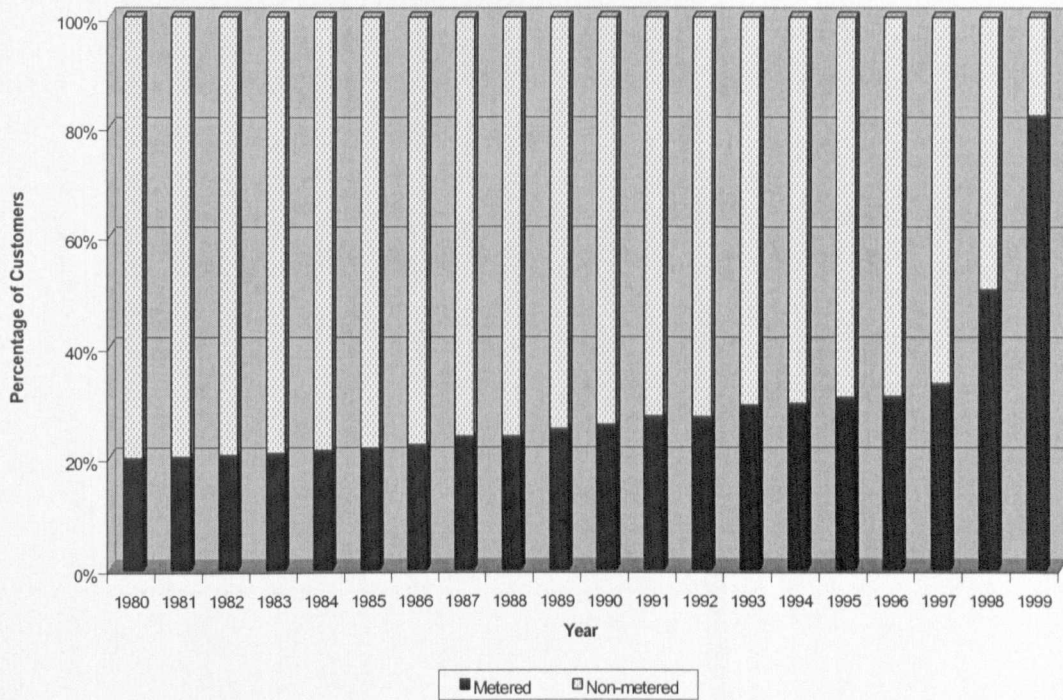
\*Price at which water is sold to the Port Authority

Adapted from London Ltd. (1994)

The Barbados government first introduced metering in the 1970s but up to 1996, fewer than 30 per cent of all consumers were paying for water on a

per volume taken basis. The introduction of a comprehensive water-metering programme in 1999 had the effect of reducing water consumption by 7.5 per cent. Metered consumers now account for over 82 per cent of total consumers. Figure 7.9 shows the percentages of metered and non-metered consumers from 1980 to 1999.

Figure 7.9: Percentage of Metered and Non-metered Customers for 1980-1999



Adapted from Barbados Economic and Social Report (1999)

## 7.7 The Water Supply Dimension

Groundwater accounts for most of the potable water for Barbados. About 70 per cent of the total groundwater available on the island is extracted from the natural underground reservoir termed ‘sheetwater’; the remainder is extracted via wells which are sunk into the ‘streamwater’ regions. These wells intercept water in underground streams before it reaches caves or ‘sheetwater’ reservoirs. As previously stated, the ‘sheetwater’ zone is Barbadian terminology for the area where the freshwater lens floats on top

of seawater and the 'streamwater' zone is the remainder of the aquifer channels farther inland.

The seminal study on groundwater resources in Barbados by Dr. Alfred Senn, published in 1946, has served as a basic reference for similar subsequent studies on the island. Dr. Senn's report indicated that in an average rainfall year, total groundwater for the island should be of the order of 305,000 m<sup>3</sup>/day while in a 1 in 15 year drought year, with approximately 1,000mm of rainfall, this amount would fall to 180,000m<sup>3</sup>/day (60 per cent). Successive studies by Tulstrom (1964), Sealy (1968) and Stanley Associates (1978) have modified these figures to 225,410m<sup>3</sup>/day and 156,227m<sup>3</sup>/day respectively. These values are now considered the developable natural water resources of the island.

#### 7.7.1 Sources of Supply

In Barbados, the available water occurs in three modes: 1) groundwater, 2) surface run-off and 3) spring water. Surface run-off is minimal and spring water is essentially groundwater which flows out of the ground naturally at points along the surface where the bottom of the coral rock meets the oceanic material below it or where the ground-surface level falls below the water table. As a result, Barbados is said to be virtually dependent on groundwater reserves for its potable water supply. Figure 7.10 gives a breakdown of the water resources available on the island.

**Figure 7.10: Breakdown of Available Water Resources**

Source	Available Water Resources (m <sup>3</sup> /day)	
	Under Average Rainfall Conditions	In the 1 in 15 Design Drought Year
Groundwater	202,591	137,182
Surface water	15,909	13,136
Springs	5,455	5,909
Run-off	1,455	0
<b>TOTAL</b>	<b>225,410</b>	<b>156,227</b>

Source: Mwansa (1997)

The surface water value quoted above is the estimated amount of water that can be impounded behind dams in the eastern part of the island - the Scotland District - where rainfall is more abundant. The run-off value is the amount of water that can be prevented from running off the ground surface into the sea by damming gullies thereby inducing the water to recharge the aquifers.

At present, BWA utilises 21 wells – 16 sheetwater and 5 stream wells – as well as 2 spring sources to supply the public with freshwater. At present, there are also approximately 120 privately-owned, operating wells, which abstract water mainly for irrigation. (See figure 7.11 for public well locations and figure 7.12 for the locations of the private wells).

Based on ground-surface elevations, the locations of the well and spring sources and the top water levels set for the reservoirs, the island's water supply system has been sub-divided into 19 sub-systems. This arrangement facilitates linkage of certain sources, associated reservoirs and distribution trunk mains exclusively with particular sub-systems.

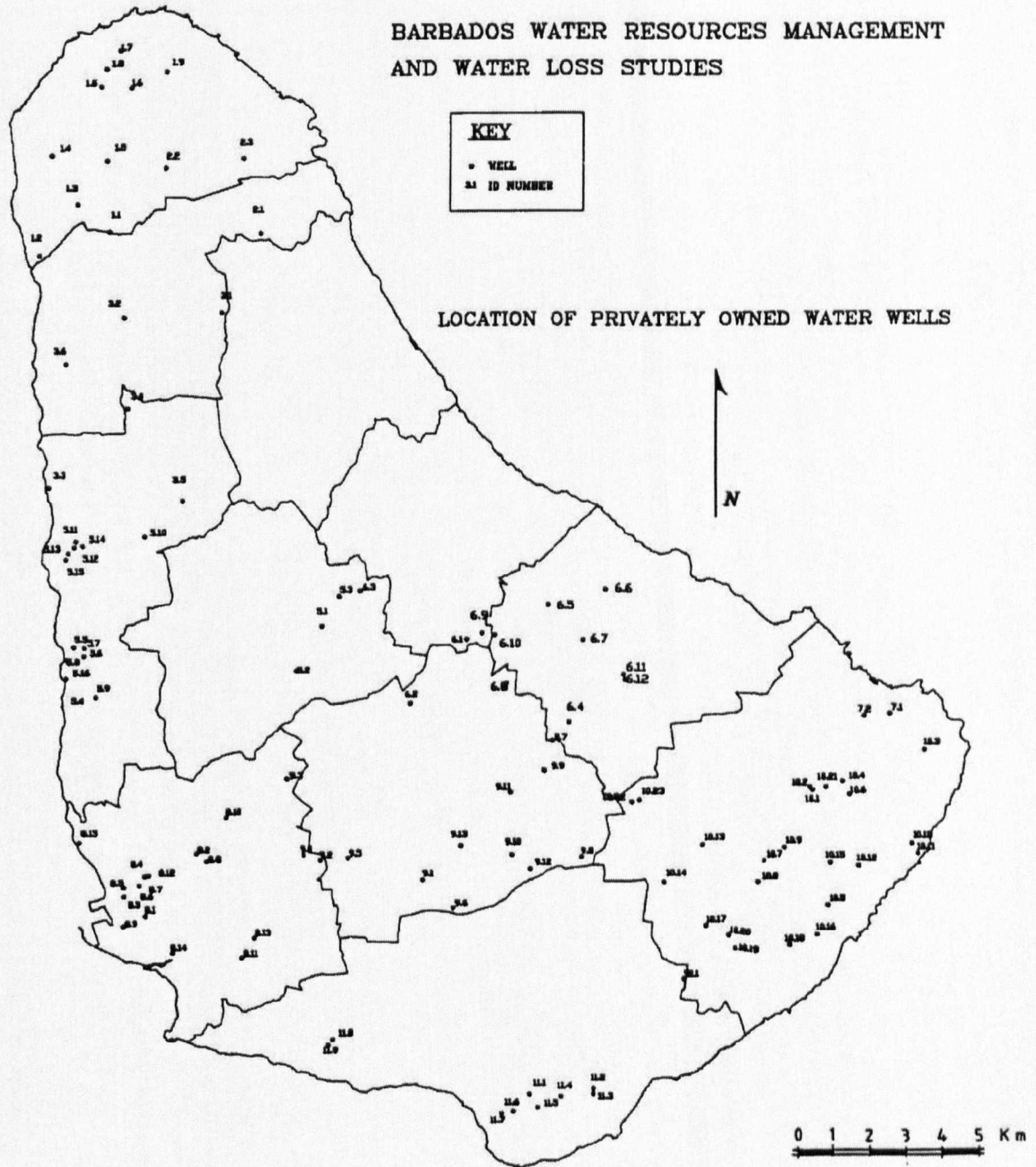


Figure 7.11: Locations of Public Wells on the Island



Source: Klohn-Crippen Consultants Ltd. (1997)

Figure 7.12: Private Well Locations on the Island



Source: Klohn-Crippen Consultants Ltd. (1997)



## 7.7.2 Groundwater Abstractions

According to BWA (1999), total abstractions amounted to 159,791m<sup>3</sup>/day, of which 54,545 m<sup>3</sup>/day were withdrawn from the Belle Pumping Station and 27,273 m<sup>3</sup>/day from the Hampton Pumping Station. This means that approximately 51 per cent of the island's public water supply is obtained from these two wells. Public well locations are shown in figure 7.11, whilst figure 7.13 lists the production/abstraction quantities from the various public wells.

Currently, BWA wells are either pumping at maximum capacity or with little reserve capacity. In other words, almost all groundwater abstractions equal or exceed the safe yield for average annual rainfall conditions. In addition, the heavy dependency on the two wells cited above puts the island at risk in the case of pump failure, as evidenced in 1983 when prolonged repair work had to be done at the Belle Pumping Station, resulting in Bridgetown and most of St. Michael having no water supply. This risk is even greater in the event of a pollution incident.

At present, there are also approximately 120 privately owned, operating wells, which abstract water mainly for irrigation. The amount licensed for private abstractions is approximately 36,364 m<sup>3</sup>/day. However, since only about 30 per cent of these wells are metered, the abstraction quantities are estimated based on pump installed capacity which amounts to approximately 54,545 m<sup>3</sup>/day. Metered private wells include those operated by the Ministry of Agriculture and Rural Development (MAR), the Barbados Agricultural Development and Marketing Corporation (who operate approximately 20 wells) and a few agricultural plantations. All public supply wells are metered.

**Figure 7.13: Evaluation of Output from Public Water Wells**

<b>Well Name</b>	<b>Output m<sup>3</sup>x10<sup>3</sup>/day</b>	<b>Cumulative M<sup>3</sup>x10<sup>4</sup>/day</b>	<b>Individuals as % of total</b>	<b>Cumulative as % of total</b>
Belle	54.5	5.45	34.00	34.0
Hampton	27.3	8.18	17.03	51.0
Newmarket	14.0	9.58	8.73	59.8
Bowmanston	10.6	10.64	6.61	66.4
Waterford	6.3	11.27	3.93	70.3
Whim	4.5	11.72	2.81	73.1
Applewhaites WF	4.4	12.16	2.74	75.9
Codrington	4.0	12.56	2.50	78.4
Haymans	4.0	12.96	2.50	80.8
Applewhaites	3.9	13.35	2.43	83.3
Alleynedale	3.8	13.73	2.37	85.7
Sweet Vale II	3.5	14.08	2.18	87.8
Ashton Hall	3.2	14.40	2.00	89.8
Molyneux	2.3	14.63	1.43	91.3
Codrington College	2.2	14.85	1.37	92.6
Carrington	2.2	15.07	1.37	94.0
Carlton	2.1	15.28	1.31	95.3
Newcastle	1.8	15.46	1.12	96.4
Trents	1.4	15.60	0.87	97.3
Colleton	1.3	15.73	0.81	98.1
Constant	1.2	15.85	0.81	98.9
Sweet Vale I	1.0	15.95	0.69	99.6
Hope	0.6	16.01	0.37	100.0

Source: K-C Consultants Ltd. (1997)

### 7.7.3 The Water Supply System

The main components of the water supply system are:

- 19 pumping stations with 21 well sources and 2 spring sources supplying approximately 160,000 m<sup>3</sup>/day potable water;
- 11 re-pumping stations capable of further lifting 37,000 m<sup>3</sup>/day an average height of 91m;
- 2,575km of transmission and distribution mains ranging from 75 to 500mm in diameter; and
- 27 reservoirs whose total volume of 136,000m<sup>3</sup> is about 15 per cent under a single day's storage.

The system has been configured so that a pumping station consigned to service a particular area or sub-system cannot be used effectively to supply water to another area. To do so would require upgrading the pumping facilities at source and/or in conjunction with re-pumping or transfer stations located at strategic points in the distribution network.

The majority of the 11 re-pumping stations in the distribution system are however not used to transfer water from one sub-system to another, but to boost the water pressure in the mains within their assigned sub-systems.

Most of the reservoirs have been designed to 'float' on the system, which means that the reservoirs can only receive water when the customers serviced by the water mains which also lead to these storage units are using less water than is being pumped into the system. This arrangement although sensible, creates problems during drought periods or in cases of excessive water consumption by some users and also during peak demand hours, as the areas mostly serviced by water stored in the reservoirs will inadvertently suffer from water shortages and outages.

#### 7.7.4 Distribution

The water distribution network is divided into 6 service zones based on the location of the source wells or springs and the potential for being self-contained. As previously mentioned, these 6 services zones have been further sub-divided into 19 sub-systems, as illustrated at figures 7.14 and 7.15 respectively.

The main features of the 6 service zones are as follows:

##### ***Hampton Service Zone***

This Zone is supplied with water from the Hampton Well, Codrington College Spring, Carrington Well and possibly in future, the Buttals Well. The service zone is divided into 4 sub-systems:

1. This area is served from a 12in. gravity line from the Codrington College Spring and as well as from the Hampton pumping station and the Carrington well via another 12in. (Sunbury) pipeline. There are no storage facilities in this sub-system.
2. Sub-system 2 is served mainly from one 6in. pipeline off the 12in. Sunbury main and from a 12in. main off the 15in. main from Hampton to Spencers. The Vineyard reservoir, capacity 8,600m<sup>3</sup>, is located within this sub-system.
3. 12in. and 16in. mains from Hampton into the Rising Sun reservoir (capacity 4,300m<sup>3</sup>) serve this area. The international airport is located within this sub-system.
4. The 15in. pipeline from Hampton to Spencers which is reduced to a 12in. and then a 10in. pipeline serves sub-system 4. Providence reservoir is located within this area and it has a storage capacity of 8,600m<sup>3</sup>.

### ***Belle-Waterford Service Zone***

This system conveys water from the Belle, Waterford, New Market and Constant wells. The Waterford and Belle wells supply some of the same areas but the former is being operated separately from the latter system by shutting off existing cross-connections in the network. The zone is operated in 9 sub-systems and each one is serviced as follows:

1. This area is fed through a 20in. main from Belle pumping station to Grand View reservoir and a 15in. main to Brittons reservoir, after the Grand View draw off. Water is supplied to the Greater Bridgetown area via 12in. and 14in. mains from the Grand View reservoir and to the Hastings area through 16in. and 9in. mains from the Brittons reservoir. Grand View reservoir capacity is 5,000m<sup>3</sup> and the Brittons reservoir capacity is 5,250m<sup>3</sup>.
2. From the Hanson reservoir, sub-system 2 is fed from two sources: the Belle pumping station through a 9in. main and the New Market Well through 16in. and 12in. mains. Some water is pumped to Fort George storage tank. The capacity of the Hanson reservoir is 2,900m<sup>3</sup>.
3. From the Fort George water tank, through a number of mains. The capacity of the tank is 4,300m<sup>3</sup>.
4. This area is serviced from a 9in. main coming from the Belle pumping station. There are no storage facilities in this branch of the network.
5. The area between Turnpike corner and Bowmanston pumping station is served through an 11in. pipeline. This sub-system ends at the Bowmanston reservoir which has a capacity of 2,150m<sup>3</sup>. Water from here is supplied to the Applewhaites-Golden Ridge-Bowmanston service area.
6. From an 18in. main that becomes a 15in. and then 12in. Some water is diverted to the St. Stephen reservoir (capacity of 17,200m<sup>3</sup>). The area located along the lower west coastline is fed from a 16in. main from St. Stephen reservoir, ultimately reaching the Port in an 8in. pipeline.
7. The water for this sub-system comes from the Waterford Well.

8. This area is fed by a 12in. main from the Waterford Well distributed from the Lodge Hill reservoir (capacity of 2,125m<sup>3</sup>).
9. Via water from the Waterford Well re-pumped at the Lears pumping station; the Applewhaites wells and Warleigh reservoir; and Molyneux and Trents wells to the east, this area is serviced. The Shop Hill reservoir floats on the sub-system, with a capacity of 5,590m<sup>3</sup>.

***Applewhaites-Golden Ridge-Bowmanston Service Zone***

This service zone is supplied from a well and a field of borehole wells at Applewhaites; Sweet Vale 1 and 2 wells; and the well at Bowmanston.

This zone has been divided into 2 operational sub-systems:

1. The Applewhaites-Bowmanston sub-system is served by 2 mains - an 8in. and a 10in. pipeline from the Applewhaites pumping station into the reservoir system at Golden Ridge. Two 9in. mains from Bowmanston Well and reservoir supply water to the Golden Ridge reservoir system and to the Verdun and Martin's Bay areas. The Golden Ridge system consists of reservoirs 1 and 2 with capacities of 4,950m<sup>3</sup> and 5,625m<sup>3</sup> respectively.
2. The other sub-system obtains water from the pumping station at Golden Ridge which also feeds water to the Castle Grand reservoir (1,250m<sup>3</sup> capacity) through 12in. and 19in. pipelines.

***West Coast Service Area***

The Molyneux, Trents, Carlton and Aston Hall wells supply this service zone with water via a pipeline running along the coast road, which begins at 6in. in the north becoming 8in. farther south. A second south-north line (16in. into 12in.) runs inland and is interconnected with the former in 9 places. This service zone contains 2 reservoirs: Aston Hall, with a capacity of 1,120m<sup>3</sup> and Carlton, with a capacity of 8,600m<sup>3</sup>. This area is operated as an integrated, self-contained service zone.

### ***New Castle Service Zone***

This zone, another self-contained area, located on the east coast (Scotland District), is supplied from the New Castle or Ben Springs. The distribution is by gravity, through a 10in. main which becomes an 8in. pipeline going north along the coast, then a 5in. main to Shorey Village, where it is capped off. At Ozone, a branch pipeline off the 5in. main feeds a booster station that pumps water into the higher areas and into Joe's River water tank (capacity 1,075m<sup>3</sup>). A 5in. pipeline branches off before Shorey Village towards Haggatts, where another booster station pumps water up to Chalky Mount and to the twin water tanks located at Bissex Hill. The combined capacity of these two tanks is 430m<sup>3</sup>. Beyond these tanks, water is prevented from looping back into the Ozone area.

### ***Warleigh-Boscobel Service Area (North Point)***

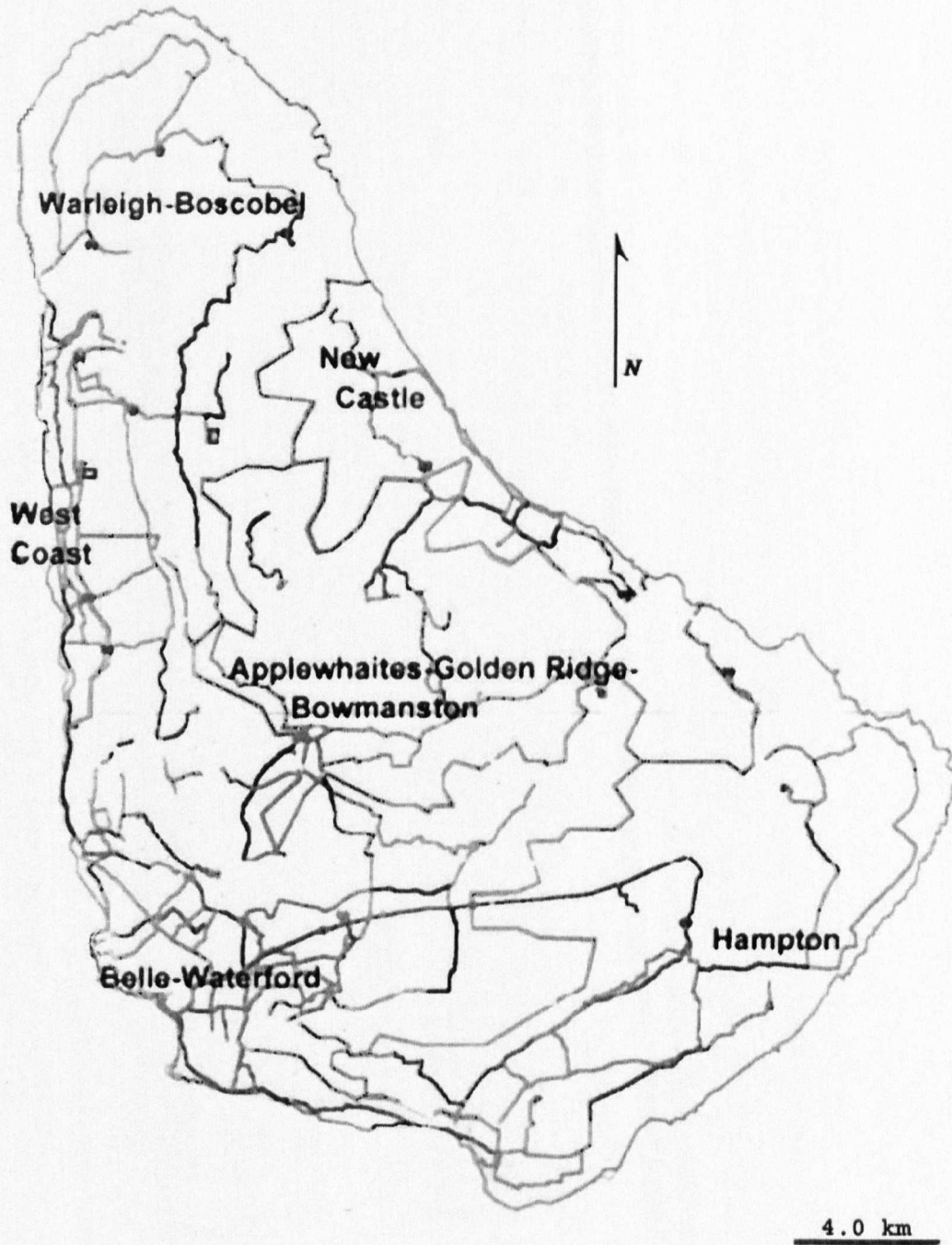
This northern zone is supplied from the following wells: Haymans, Whim, Alleyndale, Colleton and Hope. These wells also help supply the neighbouring West Coast Service Zone via a 10in. main from the Warleigh pumping station to the Shop Hill reservoir. There are 3 sub-systems:

1. The southern part of the first sub-system is supplied from the 10in. main between Warleigh pumping station and Shop Hill reservoir, fed from the Haymans and Whim wells. Shop Hill reservoir capacity is 4,730m<sup>3</sup>. The northern section gets water from two 6in. pipelines laid along Highway 2A, between Warleigh pumping station and Hannay Plantation, St. Lucy.
2. From the Warleigh reservoir, water is pumped through an 8in. main into Rock Hall water tank to supply the areas at higher elevations. The capacity of the Rock Hall tank is 2,150m<sup>3</sup>. A compensation water tank is located at Indian Ground (capacity 34m<sup>3</sup>).
3. The sub-system north of Speightstown to Boscobel is supplied from the Alleyndale, Colleton and Hope wells. The distribution of water is through 8in. and 10in. mains. This area has two reservoirs – Half Acre (8,600m<sup>3</sup>) and Lamberts (7,740m<sup>3</sup>) – and one tank floating on the

network. The tank is located at Boscobel and has a capacity of 4,300m<sup>3</sup>. Towards the end of the sub-system, a small compensation tank is located in Mount Stepney (65m<sup>3</sup>).

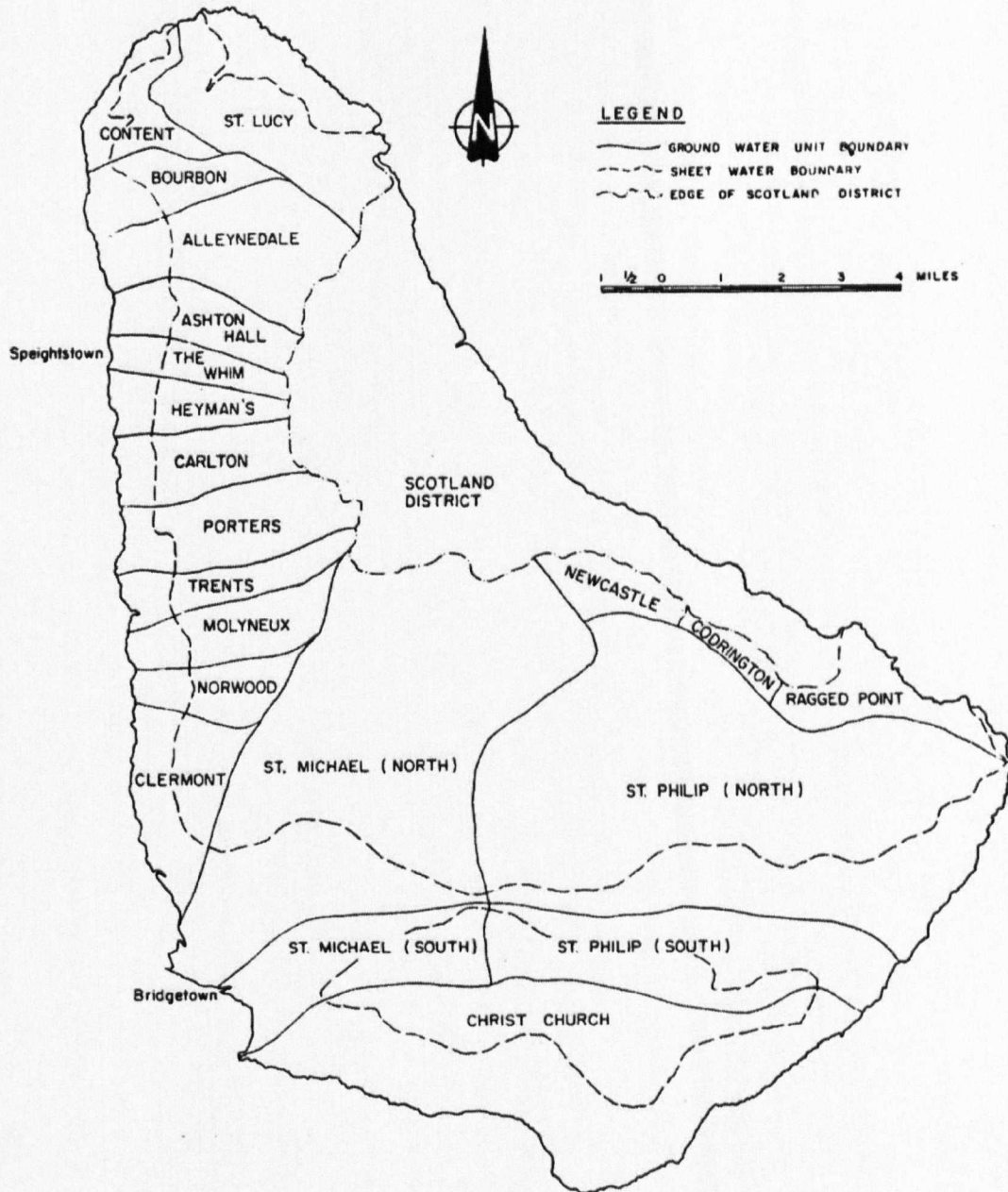


Figure 7.14: Locations of the Six Service Zones



Source: Klohn-Crippen Consultants Ltd. (1997)

Figure 7.15: Locations of the 19 Groundwater Distribution Sub-Systems



Source: Ministry of Health, EED (1991)

The largest asset owned by the Barbados Water Authority is the 2,600km of pipelines which have a present day value of approximately BD \$130 million. About 873km (34 per cent) of the water mains are less than 30 years old and these include a significant portion of the major 16in. (400mm) and 18in. (450mm) trunk/transmission pipelines. About 85 per cent of the pipelines are made of cast-iron or ductile iron. There are also some asbestos-cement and PVC pipelines. According to Johnson (1969), vertically cast iron pipes were used until 1922; spun cast iron was used between 1922 and 1970; and ductile iron was used after 1970. PVC was introduced in the 1990s.

Based on a study performed by Klohn-Crippen Consultants Ltd. (1997), it was found that generally the internal condition of the existing pipes is fairly good, having relatively little inside roughness. Tests were carried out on sections of all pipes including the older pipes such as the 12in. (300mm) gravity main at Coral Land Development, Haggatt Hall, St. Michael. In some of the smaller distribution pipelines however, such as the 4in. (100mm) or less, large encrustations were found and the hydraulic section had been reduced by at least 50 per cent. This is the problem being experienced in St. Patrick, Christ Church and in Sunset Crest, St. James, where the 4in. (100mm) and the 3in. (80mm) distribution pipelines respectively contain inner encrustations as large as 40mm. This phenomenon was noted mostly as rust in the iron pipes, and at higher altitudes - above 240m - where the encrustations were found to be crystalline calcium carbonate deposits. In both cases, the carrying capacity of the pipelines was significantly reduced.

According to observations made by K-C Consultants in 1997, bursts are usually caused by the cracking of pipes or failures at the joints. These cracks seem to have developed over time as a result of improper laying of pipelines. Differential settlement and defective base preparation (levelling, selection of base materials, compaction) for the bedding of the pipelines was found to be the main cause. This situation was observed at Drax Hall.

Frequent causality for burst pipelines has also been explained as the aggressive capacity of the immediate surrounding soil. This type of failure was observed primarily along the south-eastern part of the island, including distribution mains at Coles, East Point and Merricks in St. Philip.

It must be noted however that due to the relative thinness of soil cover (0 to 0.6m) and the hardness of the coral rock throughout the island, proper laying of water mains (levelled, compacted, adequate cover etc.) is generally difficult. Pipeline contractors also confirm that trenching machines do not function well in the very hard coral encountered in the Barbados sub-surface.

Unaccounted for water (UFW) refers to the difference between average consumption and the volume of water pumped into the supply system. UFW for Barbados is estimated at around 50 per cent. Studies carried out by Klohn-Crippin Consultants (1997) found that losses from water fixtures inside dwellings is almost nil, from which it could be concluded that the bulk of UFW is either water taken by illegal connections or from leaks in the distribution system. Several areas of the island were subject to reconnaissance, in search of non-registered high volume consumers, but little success was achieved. It was then perceived that the majority of UFW is due to high leakage in the distribution system. This hypothesis was later confirmed in several sub-systems including Drax Hall and Castle Grant where UFW has been estimated to be as high as 80 per cent and 76 per cent respectively. Figure 7.16 shows the quantities of UFW obtained for the 6 service zones.

**Figure 7.16: Water Balance for the Sub-systems within the Distribution Network**

Location	Sources and Gains  (l/s)	Consumption and Transfers  (l/s)	Losses	
			(l/s)	(%)
<b>Service Areas</b>				
<b>Applewhaites-Golden Ridge Bowmanston</b>				
• Applewhaites-Golden Ridge Bowmanston	227.79	23.06	204.73	89.9
• Castle Grant	81.43	19.05	62.38	76.6
<b>New Castle</b>				
• New Castle-Ozone Haggatts	29.00	13.76	15.24	52.6
<b>Hampton</b>				
• Codrington College-Hampton	57.30	23.87	33.43	58.3
• Wilcox-Providence Reservoir	56.40	20.82	35.58	63.1
• Hampton-Rising Sun	165.11	69.89	95.22	57.7
• Hampton-Vineyard	127.80	35.55	92.25	72.2
<b>Belle Waterford</b>				
• Turnpike-Ellerton-Bowmanston	70.68	21.87	48.81	69.1
• Lears-Waterford	34.75	15.41	19.34	55.7
• Dash Valley-Hanson	34.96	5.78	29.18	83.5
• Fort George	160.67	62.08	98.59	61.4
• Grand View-Britttons	225.65	122.55	103.10	45.7
• St. Stephens	220.00	119.86	100.14	45.5
• Lodge Hill	129.87	68.15	61.72	47.5
• Warleigh-Shop Hill	99.47	29.97	69.50	69.9

**Figure 7.16 cont'd.**

Location	Sources and Gains	Consumption and Transfers	Losses	
			(l/s)	(%)
<b>Service Areas</b>				
<b>West Coast</b>				
• Molyneux-Trents- Carlton-Ashton Hall	69.40	21.99	47.41	68.3
<b>North Point / Warleigh-Boscobel</b>				
• Whim-Haymans- Warleigh	53.85	20.51	33.34	61.9
• Warleigh-Rock Hall	49.25	19.36	29.89	60.7
• Alleyndale-Lamberts- Boscobel	57.79	26.98	30.81	53.3
<b>TOTAL</b>	<b>1,951.17</b>	<b>740.51</b>	<b>1,210.66</b>	<b>62.0</b>

Source: K-C Consultants Ltd. (1997)

## 7.8 The Water Demand Dimension

The Barbados Water Authority sells water to customers via metered and non-metered connections. All non-metered connections are domestic consumers who pay a flat rate for unlimited usage. Other sectors on the island demanding water include agricultural, industrial, tourism and other commercial and government institutions. BWA currently supplies all of the domestic demand, most of the requirements related to the tourist industry and some of the industrial and agricultural demands.

Figure 7.17 gives a summary of water use by category based on 1999 BWA records.

**Figure 7.17: Water Usage in 1999**

Use Category	Consumption (m <sup>3</sup> /day)
Domestic *	145,220
Industrial and Commercial	16,864
Hotels and Ships	4,636
Agricultural **	44,685
Golf-course Irrigation	2,453
<b>TOTAL</b>	<b>213,858</b>

\* - this category also contains the bulk of UFW water

\*\* - approximately 30% of the agricultural irrigation water usage is from the public supply system i.e. 13,406 m<sup>3</sup>/day

Adapted from Mwansa (1997)

### 7.8.1 Population Served

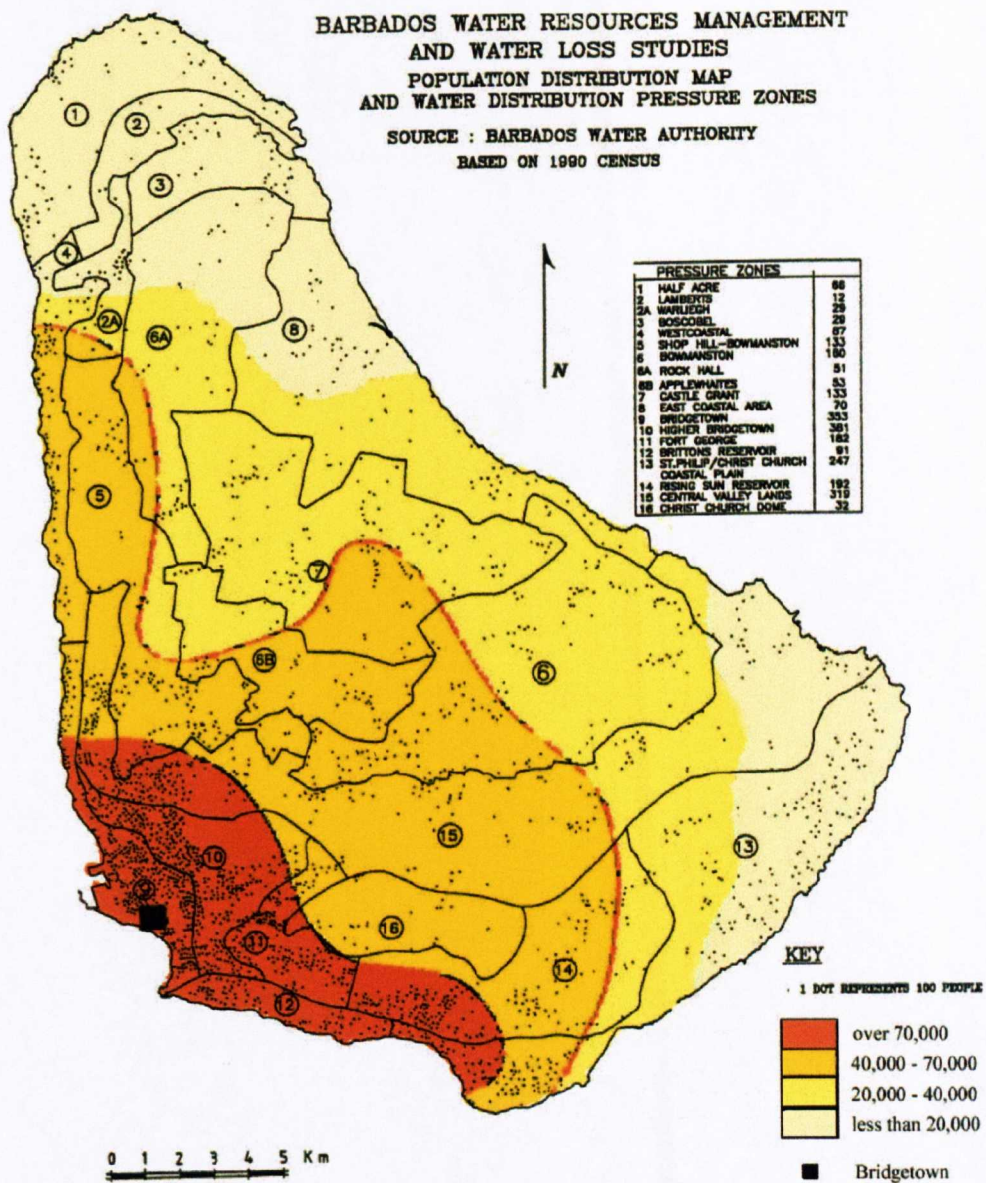
Present estimated population is 265,200 persons which by 2015 is expected to increase to 273,000 persons according to projections by the Barbados Statistical Department. London (1994) in a Report on Metering for Barbados developed a pressure zone map of water distribution and indicated population numbers within each distribution pressure zone. This map was revised and updated by Klohn-Crippen Consultants Ltd. in 1997. Figure 7.18 is a modified basic dot map of the island's population distributed into the water pressure zones.

Water consumption has grown steadily commensurate with the growth in the economy and the increase in living standards. The total number of listed customers recorded in 1999 was 95,367. Metered consumption has also increased as a result of continuous conversion schemes of non-metered connections into metered ones. As a direct result, water production has also grown to meet the increasing consumer needs but groundwater abstractions are close to their safe withdrawal limits. The annual numbers of customers listed from 1980 to 1999 are shown at figure 7.19 and the

trends in water consumption and production for 1981-1999 are shown at figure 7.20.

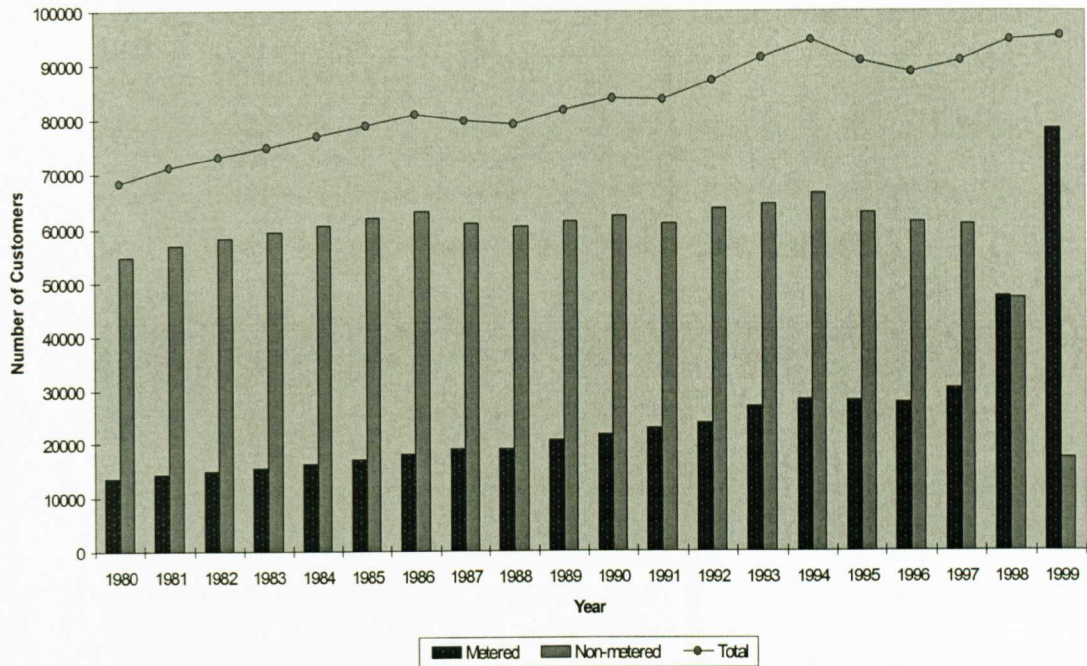


Figure 7.18: Population Distribution into Water Pressure Zones



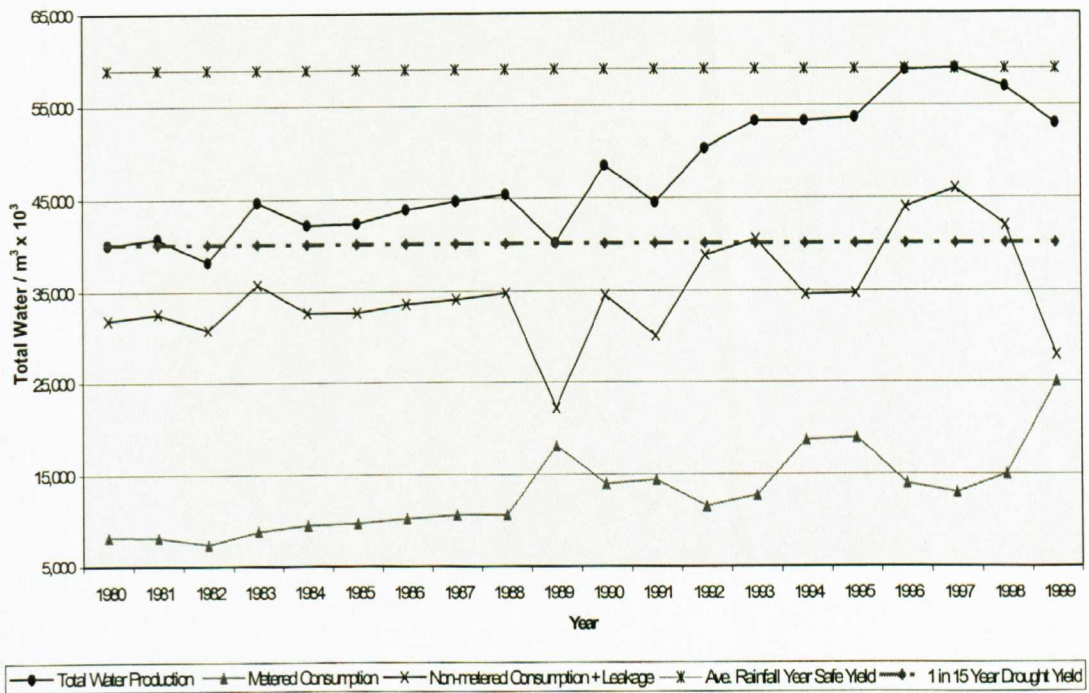
Adapted from Klohn-Crippen Consultants Ltd. (1997)

Figure 7.19: Number of Metered and Non-metered Customers for 1980-1999



Adapted from Barbados Economic and Social Report (1999)

Figure 7.20: Trends in Water Production and Consumption for 1980-1999



Adapted from K-C Consultants Ltd. (1997)

This scenario suggests that immediate consideration be given to the development of alternative sources of potable water for augmentation of the existing groundwater resources. In recognition of this critical situation, the Barbados Government has recently commissioned the first desalination facility on the island. This enhancement option, as well as the other alternatives being considered, requires the introduction of a new approach and new technology for water management to the island. They are explored fully in Section 8.

### 7.8.2 Freshwater Demand

#### ***Domestic Consumption***

The water use/audit survey carried out by K-C Consultants Ltd. (1997) indicated that per capita domestic water usage varied according to income level. Estimates of water consumption for each income level are as listed in figure 7.21.

**Figure 7.21: Domestic Water Consumption by Income Level**

<b>Income Level (BD \$)</b>	<b>Percentage of Population (%)</b>	<b>Average per capita consumption (lpcd)</b>
High (average weekly gross earnings > BD\$1,100)	2	320
Medium (500 < average weekly gross earnings < 1,099)	10	225
Low (200 < average weekly gross earnings < 499)	12	190
Low-low (average weekly gross earnings < 200)	76	140

lpcd- litres per capita per day

Source: K-C Consultants Ltd. (1997)

Water consumption by government offices, also referred to as institutional customers and by statutory corporations was estimated at 17 lpcd and 3 lpcd respectively.

Figure 7.22 shows the number of households per parish and the corresponding type of supply received based on the 1995 Housing Consensus performed by the Barbados Statistical Department.

**Figure 7.22: Occupied Dwelling Units by Parish and Type of Water Supply Received**

Parish	Total No. Dwellings	Piped Into Dwelling	Piped into Yard	Public Standpipe	Other Supply (e.g. well)	Not Stated
St. Michael	27,712	22,959	3,150	587	587	429
Christ Church	15,063	13,085	1,389	112	322	155
St. George	4,702	3,532	856	72	193	49
St. Philip	6,039	4,475	1,133	69	290	72
St. John	2,662	1,826	630	62	107	37
St. Thomas	3,077	2,224	619	81	108	45
St. James	6,688	5,821	574	80	128	85
St. Joseph	2,030	1,394	384	105	115	32
St. Andrew	1,519	969	378	75	76	21
St. Peter	2,970	2,243	513	63	113	38
St. Lucy	2,749	1,864	675	77	103	30
<b>Grand TOTAL</b>	<b>75,211</b>	<b>60,392</b>	<b>10,301</b>	<b>1,383</b>	<b>2,142</b>	<b>993</b>
<b>as a %</b>	<b>100%</b>	<b>80.3%</b>	<b>13.7%</b>	<b>1.8%</b>	<b>2.8%</b>	<b>1.3%</b>

Source: Barbados Statistical Service(1996)

### ***Commercial Consumption***

Based on data obtained from BWA (1999) and Coopers and Lybrand (1996), average consumption by this sector was approximated at 64 lpcd. In 1993, annual water consumption by this sector was estimated to be 3,552,000m<sup>3</sup> (37 lpcd). Current (1999) consumption stands at approximately 6,152,000 m<sup>3</sup>, a 73 per cent increase in just 6 years. This clearly illustrates the rapid and vast growth undergone by this sector, initiated by the Barbados Government to compensate for the drastic reduction in sugar production.



### ***Tourist Sector Consumption***

Water consumption by hotels is most conveniently measured in terms of litres per occupied hotel bed (bed-night). Current consumption is estimated at 678l/bed-night.

BWA data showed water purchased by ships as 288,000m<sup>3</sup> in 1994 and 275,000m<sup>3</sup> in 1995. Beyond 2000, the Caribbean Tourism Organisation advised that increases in long-stay visitors and cruise ships passengers would only continue to grow at 1 per cent because of constraining hotel and berthing capacities.

### ***Consumption by Private Wells***

Water consumption by private well users totalled approximately 14,800,000m<sup>3</sup> in 1999. This was composed of:

- Private agricultural irrigation                      11,300,000 m<sup>3</sup>/year
- Golf course irrigation                                      900,000 m<sup>3</sup>/year
- Industrial water use                                        2,600,000 m<sup>3</sup>/year

Industrial water use from private wells is mainly to fulfil cooling requirements, as in some of the sugar factories and the electricity generation plant. It is forecast that water consumption by this category of user will increase at the same rate as the increase in population.

Proposals have been made for an increase in the number of golf courses, as this is seen as a strategy for attracting 'higher spending' tourists. Projections are that these new courses and extensions would increase private irrigation demand by approximately 13 per cent.

At least 70 per cent of the water for agricultural irrigation is supplied from private wells. However a few farmers, such as those in St. Lucy on the Spring Hall Land Lease Project are supplied by BWA wells; and in the southern part of the island, most irrigation water is supplied from the 'private wells' owned by the Barbados Agricultural Development and

Marketing Corporation and then sold to the farmers at BD\$0.44/m<sup>3</sup> under the Integrated Rural Development Project. Water consumption for agricultural irrigation is forecast to increase at an average rate of 1 per cent per annum.

### 7.8.3 Groundwater Quality and Protection

Concern has been present for many years regarding the possible impact of disposal of domestic and industrial waste on groundwater quality. In Barbados, an estimated 400 tonnes of solid waste is generated daily. Most of this refuse is disposed of at the approved landfill site but, a significant portion is illegally dumped in gullies and other secluded areas. The coral aquifer is currently also the recipient of all wastewater generated on the island with the exception of Bridgetown (ocean outfall) and the Scotland District (surface drainage).

To protect the bacteriological and chemical quality of groundwater in use for public supply, the Barbados Government established in 1963 a zoning policy of restricting development around existing and proposed public supply sources (Tullstrom, 1964). Five categories of protection zones were established and development policies were set out restricting domestic waste disposal and industrial activities for each zone. Restrictions range from virtually no restrictions in Zone 5 to strict limitations in Zone 1. The zoning and development management policies are jointly referred to as the Barbados Groundwater Protection Policy.

#### ***Groundwater Protection Policy***

The five development control zones were established based on a simplified concept of pollutant travel time through the aquifer, that is, the time of travel for the pollutant from contaminant source to freshwater extraction point.

Zone 1 immediately surrounds all existing and potential sites for public supply wells on the island, and is based on a 300-day travel time to the well. No new residential or industrial development or new water connections are permitted in Zone 1. Existing buildings must continue to use existing sewage disposal systems and no changes should be made, except where BWA takes steps to secure improvements. Only minor extensions or alterations are permitted.

In Zone 2, the outer boundary of which is based on a 600-day travel time, restrictions have been placed on waste disposal practices. In the case of waterborne sewage, a well-designed septic tank must discharge its effluent to a soakaway pit, known locally as a 'suckwell'. No new petrol or fuel oil storage facilities are permitted.

In Zone 3, suckwells should not exceed 13m in depth and petroleum storage tanks are required to be of approved leak-proof design. In Zone 4, there are no domestic waste disposal limitations, but petroleum storage is regulated as for Zone 3. Zone 5 occupies the land areas down gradient from the Zone 1 areas and essentially does not contribute to the recharge of aquifers used for public water supply. Therefore, there are no restrictions in this zone in relation to domestic waste disposal, but the siting of new fuel storage facilities is subject to the approval of the Water Authority and the Ministry of Health.

In Zones 2 to 5, industrial wastes must be dealt with according to specifications set out by BWA. Wells or pits used for industrial waste disposal should not exceed the respective depths for domestic waste suckwells.

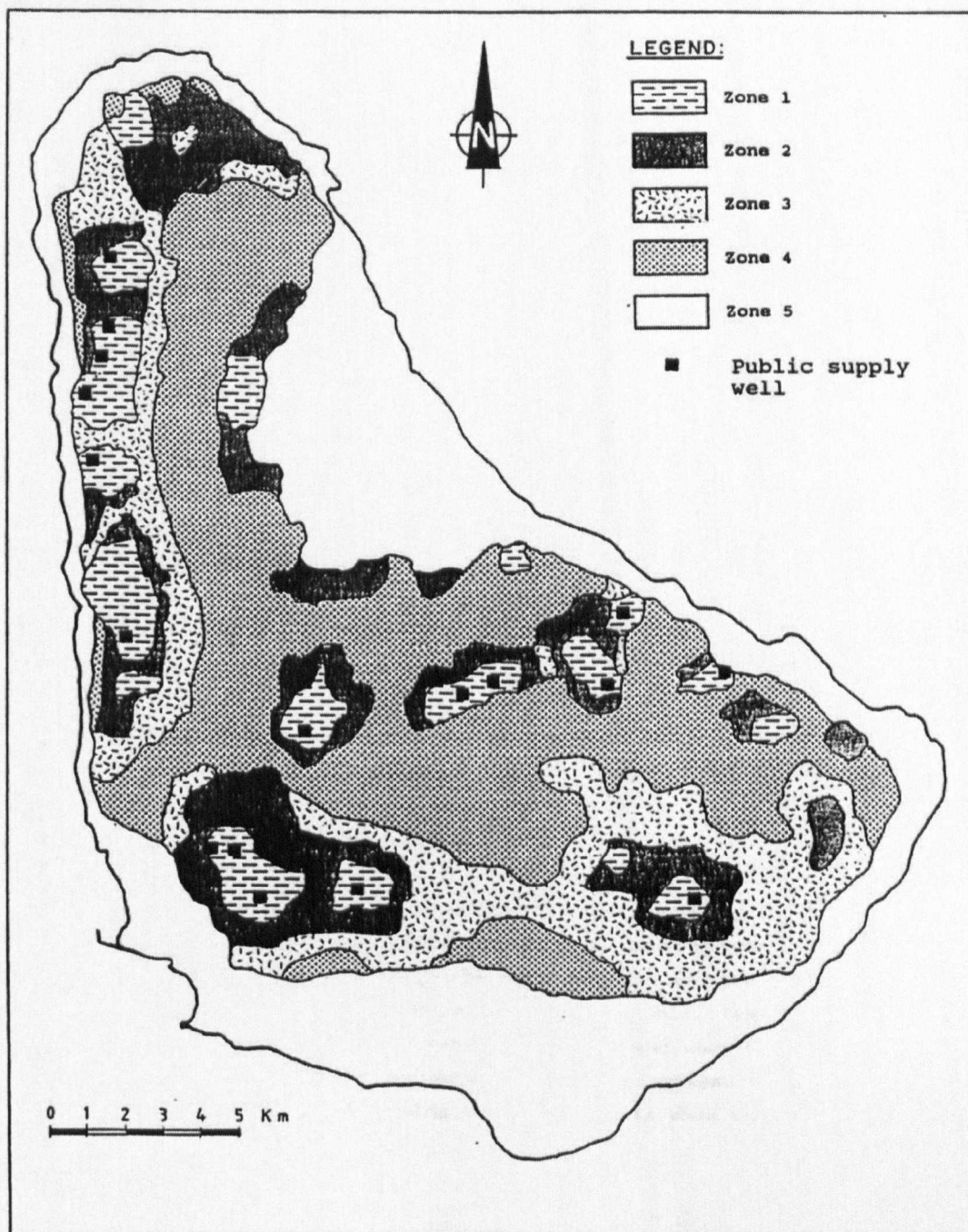
The five zones with relevant features and controls are listed at figure 7.23 and their locations on the island are shown at figure 7.24.

**Figure 7.23: Principal Features of Development Control Zones**

<b>Zone</b>	<b>Definition of Outer Boundary</b>	<b>Maximum depth of Soakaway pits</b>	<b>Domestic Controls</b>	<b>Industrial Controls</b>
1	300 day travel time	None allowed	<ul style="list-style-type: none"> <li>• No new housing or water connections</li> <li>• No changes to existing wastewater disposal except when BWA secures improvements</li> </ul>	<p>No new industrial development</p> <p>No Quarrying</p>
2	600 day travel time	6.5 m	<ul style="list-style-type: none"> <li>• Septic tank of approved design, discharge to soakaway pits</li> <li>• Separate soakaway pits for toilet effluent and other domestic wastewater</li> <li>• No storm run-off to sewage soakaway pits</li> <li>• No new petrol or fuel oil tanks</li> </ul>	<p>All liquid industrial wastes to be dealt with as specified by BWA</p> <p>No quarrying</p>
3	5-6 year travel time	13 m	<ul style="list-style-type: none"> <li>• As above for domestic wastewater</li> <li>• Petrol or fuel oil tanks to approved leak-proof design</li> </ul>	<p>Maximum soakaway pit depths as for domestic waste</p>
4	Extends to all high land	No limit	<ul style="list-style-type: none"> <li>• No restrictions on domestic wastewater disposal</li> <li>• Petrol or fuel oil tanks to approved leak-proof design</li> </ul>	
5	Coastline	No limit	<ul style="list-style-type: none"> <li>• No restrictions on domestic wastewater disposal</li> <li>• Siting of new fuel storage tanks subject to approval by BWA</li> </ul>	<p>Source: Ministry of Health (1991)</p>



Figure 7.24: Location of Groundwater Protection Control Zones



Source: Ministry of Health, EED (1991)

The zoning policy established since 1963 has essentially remained unchanged to date. Since the development of the original Zone 1, a number of additional areas have been added to this category to facilitate potential future development of public water supply sources and reservoir sites. Development within the respective zones is controlled by the *Revised Policy of Private Sewage and Wastewater Disposal System Regulations*, largely administered under Town and Country Planning legislation.

Generally, this system of water protection zones has served Barbados well since the water quality has been maintained within acceptable WHO limits. Nevertheless, although the population growth is low, there has been a steady rise in housing development. This, together with changes in agricultural practices and rapid commercial and industrial development, has been placing increased pressure on the zoning regulations. Furthermore, the Barbadian population 'live' on top of their potable water supply. The aquifers are open to the effects of the activities directly above. The threat of water quality degradation is always close and potentially detrimental. An evaluation of the continuing effectiveness of the Groundwater Protection Zoning Policy is thus opportune (see Chapter 8).

## **8.0 The Current Scenario in Barbados: Interpretation and Analysis**

### **8.1 Introduction**

Water resources in Barbados were considered in 1994 to be adequate and unlikely to become scarce before 2005 (BWA, 1997). However, groundwater yields have already reached critical levels and this situation merits immediate concern. Barbados' total developable water resources are estimated at 225,410 m<sup>3</sup>/day. This means that renewable water resources per person per year are only 350m<sup>3</sup>, a statistic that places the island into the WHO main worldwide group (including Libya, Somalia and Kuwait) of 'water stressed' countries.

The drought of 1994, the worst in 150 years is well remembered and documented in Barbados (BWA, 1995). Since then, drought conditions were also experienced in 1995, 1997 and 2001. At such times, the vulnerability of the freshwater supply to the vagaries of nature is apparent due to increased water demand and widespread outages experienced across the island.

Pollution from the heavy use of pesticides and herbicides and improper water disposal, plus the encroachment of housing and other development into prohibited areas all add to the sustained threat on the freshwater resource base.

### **8.2 The Current Threat**

According to officials at the Barbados Water Authority (BWA), current groundwater abstraction levels either equal or exceed the sustainable groundwater yields for the average rainfall year conditions of 1,422mm. It

is however possible for the St. Michael and St. Philip groundwater catchments to meet the shortfall in a drought year for a one-year period. However, based on evidence of rising salinity levels in the groundwater during the 1993 and 1994 droughts, it is unlikely that supply via this carry-over storage can be sustained for a longer period.

None of the existing private wells has the capacity to replace a major BWA well and even if private wells had comparable capacity to BWA wells, their general location is inappropriate and would require connection to the supply network to effect water transfers.

Deduction from the above discussion suggests the necessity for immediate consideration to be given to the development of alternative sources of potable water in order to augment existing groundwater resources. This situation gives relevance to an examination of the critical contributory factors to the present freshwater situation on the island. These factors include uncontrolled usage resulting from non-metered supplies and the incidence and quantum of leakage. Estimates made by Klohn-Crippen Consultants (1997) place the level of unaccounted-for-water (UFW) between 55-75 per cent and excessive usage by non-metered consumers as high as 20 per cent.

### **8.3 Water Supply System Problems**

#### **8.3.1 Water Losses**

As explained in Section 6.3.1, unaccounted-for-water (UFW) is the equivalence of the difference between the volume of water delivered into the distribution network and the volume of water accounted for through legitimate consumption.

The two main categories of UFW are:

- Non-physical loss, including water consumed but not recorded, such as water consumed through illegal connections. This category of loss is reflected in lost revenue to the water utility; and
- Physical loss representing water lost through leakage, which is a resource loss reflected in the unit cost of production.

Investigations carried out by Klohn-Crippen Consultants Ltd. (1997) showed that UFW was as high as 78 per cent in some localities (e.g. Applewhaites-Golden Ridge-Bowmanston Service Area) and an overall figure of 60 per cent is likely for the island, representing mainly physical loss through leakage.

With such high levels of UFW, extensive leakage control measures are imperative if significant progress is to be made into solving the water loss problem. Major network rehabilitation is required in areas such as Verdun, Warleigh and Sandy Lane where leakage has been recurring frequently due to the poor condition of pipework and fittings.

Even though UFW reduction is critical to the sustainable management of the freshwater resource base, and is the cheapest alternative for freeing up additional water, there are many uncertainties involved in meeting projected demand. The likelihood exists that the savings realised could be exhausted by existing demands that are currently not being met. Therefore, considering the lack of reserve capacity in the groundwater supply system, alternative options and measures for enhancing the island's freshwater supply are still required.

## **8.4 Institutional Problems**

### **8.4.1 Financial**

Under normal circumstances, the BWA does not obtain subsidies from Government and must generate enough revenue to cover its full costs (both operational and capital). The BWA is also required to pay: full duties on its equipment and materials; corporate taxes; and value-added tax (VAT) on its supplies and services, which BWA cannot recover because of its rating as a statutory organization.

The collection of outstanding arrears (approximately BD\$26 million in 1998) remains a very serious problem for the BWA. Domestic consumers are the major defaulters, accounting for almost two thirds of the debt. Minister of Public Works, Rommell Marshall contended among the most critical woes confronting the BWA are:

- consumers receiving a free (illegal) service; and
- inaccurate billing of consumers.

According to the Minister: “There are also instances where people are being charged domestic rates when they should be paying business rates and there are those who have never paid any water bills at all.” (Daily Nation, 3/06/00).

The main challenges in this respect include:

- Convincing the stakeholders (mainly the consumers) that water is valuable and thus should be paid for;
- The setting of appropriate tariffs; and
- Installation of suitable valves (ball valves) to facilitate disconnection in a relatively easy and timely manner coupled with a consistent disconnection programme to collect the outstanding arrears.

It is worthy of noting, subsequent to September 2000, several measures were instituted by the BWA to improve its financial management. The Authority began disconnecting customer accounts that were more than 60 days in arrears, regardless of the balance. Customers owing BD\$500 or less were only reconnected upon full payment of the amount owed plus a reconnection fee of BD\$63.25. Customers owing in excess of BD\$500 were required to make a minimum payment of BD\$500 plus the reconnection fee in order to resume receiving their water supply. By the end of 2000, BWA had also installed meters on virtually all remaining fixed rate services (over 90 per cent now metered), thereby eliminating wastage and encouraging conservation among all its users.

#### 8.4.2 Human Resources

The BWA has a staff complement of almost 900 employees of which less than 2 per cent fall in the professional range. Many of the employees in supervisory and middle-management positions were promoted without adequate training. This poses major challenges to implementing sustainable management practices and as such, the implementation of a structured organisational strengthening programme should be undertaken.

#### 8.4.3 Joint Operational and Regulatory Functions

At present, the BWA performs a dual role of manager of the freshwater resource and the main user of same. This situation has created problems, in particular those resulting from:

- 1) Periodical compromise of proper management practices to meet increasing water demands; and
- 2) Non exercise of control (in periods of drought) over private abstractors, who can, and in many instances, continue to withdraw water at normal

levels to the overall detriment of the aquifers and the public supply wells.

In addition, as a major user of the resource, there is a potential conflict in allocating these resources, since BWA is also the licensing and regulatory authority for groundwater abstractions. This is discussed in further detail in Section 8.5.1.

## **8.5 Legislative Problems**

### **8.5.1 Groundwater Rights**

As under English Common Law, there is no property right to groundwater in Barbados. And although a substantial body of law, applicable to groundwater exists, no formal policy pertaining to public and private groundwater rights has been adopted. A property owner may abstract water as he/she pleases, notwithstanding that his abstraction may be to the detriment of another owner. BWA also does not have the jurisdiction to levy fees on groundwater usage.

Further, based on a 1980 amendment of the Barbados Water Authority Act, BWA has assumed from the presently inoperable Water Board, the duty to license the construction and use of wells under the Underground Water Control Act (1953). Several interviewees, including BWA employees, expressed concern that BWA has or is seen to have a conflict of interest as an agency with high water requirements that also allocates water among competitors for the resource, including itself. Interviewees were also concerned that BWA's monitoring and regulatory functions were secondary to its primary role as a water supplier and that BWA lacked the necessary resources to carry out the former effectively.



### 8.5.2 Zoning and Water Quality Protection

The existing groundwater protection policy was enunciated by Cabinet as Government policy in 1963 and later revised in 1973. But, the enforcement of these regulations has not been without problems. Economic development has increased the standard of living significantly in the last 20 years and as a result, new housing developments have spread from the suburbs of Bridgetown, the south and west coasts into traditionally agricultural areas, especially in the southern part of the island. The principal restriction on new housing has been the developmental control zones around the main water supply sources. Recently however, Zone 1 areas have been criticised for occupying too much of the limited land resources (8 per cent of the total land area) and for causing undue hardship to those citizens whose only plots of land are located in Zone 1 areas.

In some instances, illegal encroachment has been tolerated under the assertion that “one or two more houses in Zone 1 make little difference”. Zone 1 landowners are finding more ingenious ways of concealing their infringement and perhaps their plight needs to be examined if illegal housing encroachment in prohibited areas is to be contained.

In addition, although the Zoning Regulations have served a useful function, the Policy is heavily biased towards protecting the groundwater resources from bacteriological contamination. The regulations are silent on addressing chemical contamination except from petroleum products. Therefore, under the existing legislation, the Town and Country Planning Office can prohibit the erection of new houses in Zone 1 areas, but they cannot restrict the usage of fertilisers or pesticides if, as an alternative, a land-owner pursued agricultural activity on the same plot.

The two non-sewage (bacteriological) related activities/conditions currently affecting water quality in Barbados are:

- A change in agricultural practices, including the widespread application of agricultural chemicals such as pesticides and fertilisers; and
- Increasing salinity of aquifers resulting from on-going high groundwater abstraction levels.

Neither of these issues can be satisfactorily addressed under the Groundwater Protection Policy.

Agriculture, particularly sugar cane production, dominates land use in Zone 1 areas. Contaminants arising from the usage of agricultural chemicals (nitrates, pesticides) are considered 'conservative' in groundwater. They are not easily degraded once present in the limestone aquifer and therefore not readily susceptible to attenuation by the 'time of travel' zoning approach.

In February 2002, BWA announced that the island's largest water source – The Belle – had a high level of nitrate-nitrogen in the water. The Belle supplies 10 mgd (of the total 35 mgd water production) to 33 per cent of the population. In 1996, the BWA reported the nitrate-nitrogen level to be between 6.0 and 8.0 ppm. In 2000, it peaked at 9.4 ppm and in 2001, measurements ranged between 8.6 and 9.8 ppm. These levels are just under the WHO's standard of 10 ppm for drinking water. BWA did not reveal the February 2002 level. A news report of February 16, 1996, quoted Bob Dawson of Stanley and Associates Ltd., as saying that one theory was that the bulk of the nitrate pollution might have been coming from populations in the rural areas, upstream of the underground watercourses. BWA is still uncertain as to what proportions of the nitrate pollution are due to human and agricultural activities.

Nevertheless, in the wake of these most recent tests of water from the Belle, the Town Planning Department launched a major assault on illegal housing

in The Belle, St Michael in March 2002. Chief Town Planner, Mark Cummins, while not disclosing how many houses would be removed or when his department would take action, told the Nation newspaper on March 8, 2002, that the move was necessary, especially in light of the serious threat posed to the island's drinking water supply. "We have been serving and will continue to serve enforcement notices on all unauthorised development in The Belle." He expressed disappointment that the Cabinet decision in 1973 not to permit any further housing development in the area was not being enforced, resulting in the serious problems now being faced by the water and planning authorities. However, Mr. Cummins made it clear that no illegal structure would be allowed to remain in that area or any other Zone 1 region.

Another pollution problem was reported by The Daily Nation on May 13, 2002. The newspaper claimed that atrazine was now being found in dangerously high levels in The Belle (St Michael) and Hampton (St Philip) wells. The Barbados Water Authority confirmed that although atrazine was first discovered some 13 years ago in the wells, significant increases had recently been found in the water supply. The maximum amount permitted in potable water by the United States Environmental Protection Agency (USEPA) whose standards are used in Barbados, is 3.0 micrograms per litre of water ( $\mu\text{g}/\text{l}$ ) and this was the level at which the BWA reported atrazine was "consistently" found in Barbados. It has increased from 0.2  $\mu\text{g}/\text{l}$  found in 1989 and 1991. Atrazine, an herbicide used primarily by the sugar industry, has the potential to cause cancer. "The matter of atrazine is entirely within the domain of the Pesticide Control Board and the Barbados Water Authority is not a member of that board," an official of the BWA told the Daily Nation, implying that the BWA was without influence and jurisdiction to control its usage and disposal. Officials at the Town and Country Planning Department are similarly handicapped.

Salinity increases have also been evident in most of the West Coast water catchments and more so, in the sheetwater wells. These increases are primarily due to seawater intrusion beneath the freshwater lens due to over-pumping. The Groundwater Protection Policy has no control measures for saline intrusion.

Finally, officials at the Ministry of Power, Transport, Communication and Works, explained that there is no legislative authority for the adoption of the Groundwater Protection Policy. Since the Policy appears to interfere with private rights, it is not on its own enforceable. One aspect of the Policy however – the prohibition of new development in Zone 1 – has been incorporated in the Development Order under the Town and Country Planning Act, 1973 and therefore has the force of law. However, as cited by the Chief Town Planner above, it has not been stringently applied. Overall, the Groundwater Protection Policy has been ‘enforced’ through general administrative practice and interviewees seemed largely satisfied that it is working well. Little concern was expressed about the lack of legal foundation for the Policy.

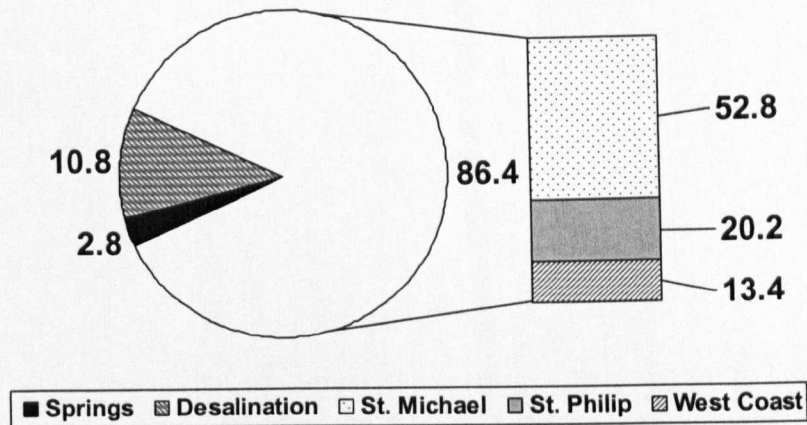
## **8.6 Water Scarcity – the primary problem**

Forecasts, based on knowledge and understanding of the freshwater situation in Barbados are that of total rainfall income on the coral limestone, 86 per cent will go into evapotranspiration, only about 0.25 per cent in run-off and 13.75 per cent into the underground aquifers (Mwansa, 1997). In addition, very little is preserved for long in soil moisture and a relatively small amount is available for aquifer replenishment. In the non-coraline Scotland District, most of the underlying substrate is impermeable, so run-off rates are high, at approximately 14 per cent of incoming precipitation. However, little of this water can be used as seasonal flow is highly variable and the water is high in suspended solids

and silts. Therefore, only 225,410 m<sup>3</sup>/day (49.59 mgd) of water are available for use. This applies to an average rainfall year – a year in which at least 1,524mm (60in.) of rain falls. It has also been estimated that in a drought year (a year with 1,016mm (40in.) of rainfall) and which has a 1 in 15 year frequency of occurrence, the available water resources are 156,227 m<sup>3</sup>/day (34.37 mgd).

As previously mentioned in Section 7.7.2, BWA withdraws approximately 160,000 m<sup>3</sup>/day (35 mgd) and of the 19 groundwater units, only four have reserve capacity. However, the total volume of water being extracted equals or exceeds the safe yields due to over-pumping in some of the units during the dry season, e.g. Allenynedale, Haymans and Trents in the West Coast catchment. Under present conditions, 10.8 per cent of the island's freshwater supply is obtained from the desalination plant, 86.4 per cent from the groundwater catchments and 2.8 per cent from springs. Figure 8.1 shows a detailed breakdown of the supply.

**Figure 8.1: Supply Breakdown by Source Percentages**



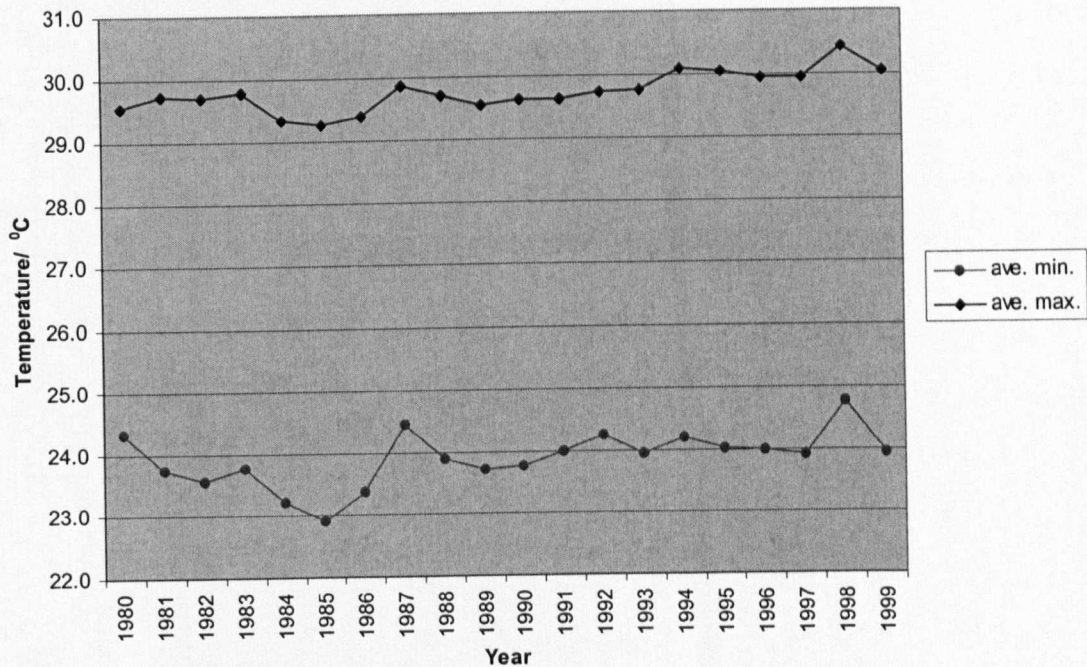
Adapted from Ministry of Environment (2001)

The groundwater aquifers are recharged by rainfall, but the rain does not fall uniformly, either spatially or temporally. In particular, there is a marked dry season and a wet season, and there is nearly 80 per cent more rainfall in the higher parts of the island than near the coast.

Studies performed by Tullstrom (1964), Stanley (1978) and BWA (1999) found that evapotranspiration accounts for over 80 per cent of incoming precipitation in the dry southern and western coastal areas and approximately 60 per cent in the wetter, central highland.

Generally, rainfall in the Eastern Caribbean is variable and fickle – the incomes for which on both a monthly and annual basis may range from 30 per cent either side of the mean. Long-term climatic records dating from 1847 suggest cyclical changes of rainfall income with a duration of approximately 54 years (Hudson (1972); Skeete (1963)). Over a smaller time scale, the island is now in a much drier phase than normal (see figure 8.2) and rainfall income is highly variable both seasonally and annually as illustrated at figure 8.3.

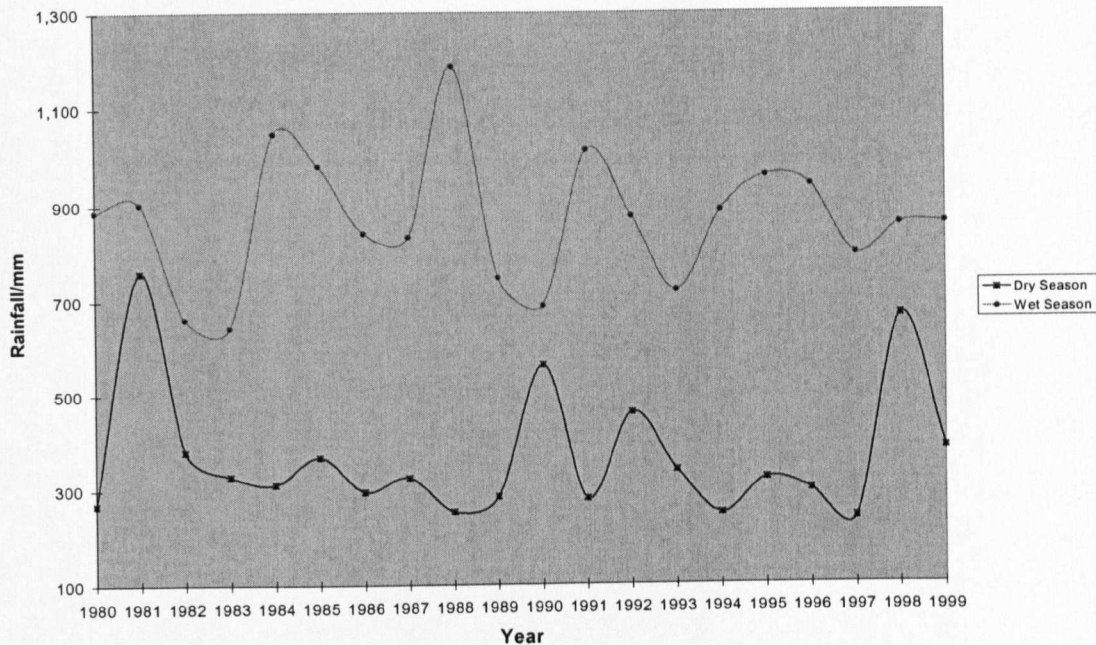
Figure 8.2: Average Minimum and Maximum Temperatures for 1980-1999



Source: Adapted from BMS (1942-2000)



Figure 8.3: Annual Seasonal Rainfall for 1980-1999



Source: Adapted from BMS (1942-2000)

A consideration of the extremes of rainfall income is also relevant. Prolonged dry spells create severe stresses which reduce water availability; whilst storm frequency, duration and density lead to erosion and flooding which may negatively affect water quality. Precipitation extremes normally occur during the wet season, when storms and hurricanes can bring very heavy rainfall. Storms, moving from the east in the trade winds can occur as frequently as once per week. Contrariwise, hurricanes are relatively rare, the last one which directly hit Barbados was in 1955. It is important to note however, in Barbados as elsewhere, that erosion and flood-related problems tend to be correlated more with rainfall intensities and localised storms rather than annual rainfall amounts. The decline in agriculture and farming is also a contributing factor. Hence, these problems can occur even in an overall dry year.

As previously mentioned, the most severe drought experienced in 150 years was in 1994. By August 1994, total precipitation recorded was only 470mm, with almost no rainfall recorded in May and June of that year. The

drought ended in September, when a storm brought over 100mm of precipitation to the island. In subsequent pronouncedly dry years, 1995 and 1997, total precipitation levels were as low as 1,282mm and 1,037mm respectively.

Severe drought conditions were again experienced in 2001. January to April of this year was the second driest period in the history of record keeping for rainfall in Barbados. According to the Director of the Barbados Meteorological Service, Chester Layne, only 90.7mm (3.57in.) of rain fell and this was 53.5 per cent below the long-term average for the same period. A mere 7.4mm (0.29in.) of rain was recorded for March, making it the driest March in history, while April with 13.2mm (0.52in.) of rainfall was the second driest April. Precipitation for May, June and July continued to be approximately 60 per cent below average.

The BWA manager of marketing and communication, Stetson Babb, said the Authority started a television campaign to increase national awareness on the importance of water conservation, particularly during the dry season. The Irrigation Unit reported that water levels in their wells fell between 17 and 34 per cent and this led to some 'scheduling' being implemented whereby farmers got water every other day. BWA officials also confirmed that some of the public supply aquifer levels had fallen and a system of nightly shut-offs was instituted to allow reservoirs to be replenished.

Layne explained that the island managed to survive the drought due to excess rainfall from November 2000, but up to September 2001, there was no significant rainfall to recharge the aquifers.

Evidently, the problems caused by reduced water potential due to drought conditions tend to recur relatively frequently in Barbados. In a normal Gaussian Distribution Curve, the likelihood of having less than average rainfall is 40 per cent, 4 years in every 10, or almost every other year. In



the circumstances, the urgency for implementing groundwater supply augmentation schemes in Barbados is beyond apparent. It is real.

## **8.7 Alternatives to Groundwater**

The practicable methods proposed by the BWA in 1996 for augmentation of groundwater supplies were:

- a) Impoundment of surface run-off.
- b) Development of Scotland District surface waters.
- c) Purchase and barging of water from neighbouring islands.
- d) Wastewater reuse.
- e) Desalination of brackish groundwater.
- f) Desalination of seawater.

Analysis undertaken by a BWA study team eliminated alternatives a) and b) on account of small yields and high costs, in particular, water treatment costs. Alternative c) was found to be the most expensive option, being highly capital intensive for what could end up only a temporary 'interim' measure. The cost of seawater desalination is almost double that of brackish water desalination and since good quality brackish water is available in reasonably large quantities, economics dictates the preference for brackish water desalination.

The only alternative left to be considered is d) and the general applicability of this technology depends on the geography of the land in question. In Barbados, owing to the karstic nature of the coral rock aquifer system, groundwater contamination by reused wastewater is likely, unless the wastewater is properly treated. At present, there are only a few facilities with a suitable effluent quality. However, the hotel belt along the south and west coasts, down-gradient from the line of public supply wells are possible

candidates for the application of wastewater reuse technology as they pose the least danger of contamination to the groundwater aquifers.

Figure 8.4 gives a comparison of the per cubic metre costs for the alternatives discussed above.

**Figure 8.4: Unit Production Costs for Supply Augmentation Schemes**

Alternative Source	Cost	Capacity	
	BD\$/m <sup>3</sup>	m <sup>3</sup>	mgd
<b>Desalination:</b>			
Brackish water	1.63 to 1.87	Up to 18,200	4.0
Seawater	3.40 to 3.82		
<b>Wastewater Reuse: *</b>			
Primary treatment baseline	5.84 to 9.84	6,400	1.4
Secondary treatment baseline	1.10 to 5.10		
Surface Impoundments	3.21	6,360	1.4
Importation of Water	6.52	4,545	1.0

\* - based on supplying water for 185 days per year for irrigation

Source: Adapted from BWA (1999)

### 8.7.1 Desalination of Brackish Groundwater

*“...The drought of 1994-1995 served to put the nation on notice that no longer could we continue to take our water supply for granted, and that it was necessary for us to take very serious stock of the situation...” (Daily Nation, 12/06/00)*

This was a statement made by Minister of Public Works, Rommell Marshall at the dedication ceremony of the brackish water desalination facility located at Spring Garden, St. Michael on June 10, 2000.

Desalinated water has been flowing from the taps of customers spanning from Grazzettes, in the parish of St. Michael to Prospect, St. James, since February 2000.

The desalination plant has been built and financed at a cost of BDS\$24 million (US\$12 million) by Ionics Freshwater Ltd. and a local joint venture partner, Williams Industries. The water supply agreement covered design, engineering, manufacturing, installation, start-up, commissioning and operation of the facility. This plant is the largest brackish water desalination facility in the Caribbean with a capacity of 30,000 m<sup>3</sup>/day. A Build, Own, Operate (BOO) contract with the BWA allows the private sector partnership of Ionics Ltd. and Williams Industries to operate the plant for 15 years after which time BWA can exercise its option to purchase the facility. BWA purchases the desalinated water at price of BDS\$1.20/m<sup>3</sup>, whilst the cost of production is less than BDS\$1.00/m<sup>3</sup>.

On March 15, 1999, construction of the plant began and by February 15, 2000, the plant began producing potable water. Ionics' desalination system employs reverse osmosis (RO) technology. RO is now a widely accepted membrane-based method that separates the brackish feedwater into two separate streams – a desalted stream for public consumption and a concentrated brine stream which is returned to the sea via deep well injection. “The brine or salty water is disposed of down a deep bore hole, below the junction of the sea and freshwater, where it mixes gently with the seawater, continuing the process which gives rise to the freshwater bay condition. The water fed to the plant has a salt content of about one thousand parts of salt in every million parts of water, while the brine stream contains approximately four thousand parts of salt in every million parts of water,” explained Ambrose Johnson, BWA consultant project manager.

The salt content of the brine stream is only about one-ninth of that of seawater. Nevertheless, the brine is not put directly into the sea where, because of minor temperature differences, or locally higher flow velocity, it

could interfere with the ecology of the specific environment of the discharge. No other by-product or waste is produced. Up to 75 per cent of the pressurized feedwater is recovered as potable water, whilst the remaining portion of the high-pressure feedwater passes through an energy-recovery turbine, rendering the process highly efficient.

The site at Spring Garden is near an area which supports a large reservoir of brackish water, making it a convenient and economical location for the facility. It is also strategically positioned to supply water to a large section of the island through a series of lift stations and intermediate reservoirs, including a 9,464 m<sup>3</sup> (2.5 million gallon) reservoir constructed at Cave Hill. Other initiatives undertaken in support of the desalination facility were the laying of approximately 12.9 km (8 miles) of water mains and the building of 2 re-pumping stations. BWA Chairman, David Millington said that the costs of the civil works and acquiring the old rum refinery site on which the plant was situated cost BWA BDS\$16 million (US\$8 million).

The start-up of the facility was however not without some hiccups. For some residents, particularly in Black Rock, the taste and texture of the water required some adjustment. Residents of St. Stephen's and Black Rock also complained of vomiting and diarrhoea due to consumption of the water. The BWA's director of marketing and communication, Stetson Babb confirmed that some residents initially complained about the water, but he stressed that the desalted water conformed to all WHO drinking water quality standards.

Counterpart, Ambrose Johnson, BWA's consultant project manager added "customers may detect a slight difference in the texture and taste of the water which will generally appear lighter in texture with a tingle in the taste." He also said that it was ironic that the very factors (lime and salt removal), which made the desalinated water of better quality, caused it to taste and feel strange. He further explained: "...because it's a much softer water, bathing and shampooing will require much less soap and the slimy

feel is actually the result of more of the natural body oils being left on the skin.”

With the opening of the Cave Hill Reservoir in June 2000, the desalinated water is now being mixed with the regular groundwater prior to distribution so as to ensure a balance between the two types and customer satisfaction.

As at December 2000, the plant was operating at 50 per cent capacity, providing about 13,500m<sup>3</sup>/day (3mgd) and Stetson Babb, BWA’s marketing and communications manager confirmed that no additional reports of problems with the water were received.

The additional supply provided by the desalination facility serves to ensure that there is a continuous supply of good quality water, even in drought conditions. Further, as BWA Chairman, David Millington stated at the opening ceremony of the facility:

*“The Barbados Government was determined that the island’s economic development would not be held back by the lack of availability of freshwater.” (Daily Nation, 12/06/00)*

### 8.7.2 Treated Wastewater Reuse

Sam Lord’s Castle Hotel is located on the south-eastern coast of Barbados, in the parish of St. Philip. It lies within the coral section of the island where the coral cap thickness is about 2.44m (8ft.). With an average annual rainfall of only 1,143mm (45in.), this is one of the driest areas of the island, and except for August to November, the average evapotranspiration rate, 114.3mm (4.5in.) per month exceeds the monthly rainfall.

The hotel was formerly supplied with freshwater from a groundwater well, but because of the high water demand, especially for the irrigation of large

expanses of lawns and garden plants, saline groundwater intrusion occurred to the point where the freshwater supply was virtually exhausted.

In 1988, a decision was made to abandon the use of the well and the Ministry of Health and Environment granted permission to use treated effluent from its aeration sewage treatment plant for irrigating lawns and garden plants.

Effluent consisting of kitchen, laundry and domestic sewage is fed to the treatment plant where it undergoes a process of aeration, clarification and disinfection before being stored in 4 suckwells.

The only government involvement in this program has been the licensing, monitoring and administrative control, exercised through the Environmental Engineering Division (EED), which is charged with the responsibility of approving and monitoring the performance of all packaged wastewater treatment plants. The Sam Lord's Castle Hotel plant is entirely privately owned and operated, except for the monthly inspections and sampling for BOD (biochemical oxygen demand) and TSS (total suspended solids) conducted by the EED.

At present, there are twelve wastewater treatment facilities in use in Barbados – 11 at hotel facilities (8 extended aeration plants; 3 rotating biological contactor plants), ranging in size from 13m<sup>3</sup>/day to 170m<sup>3</sup>/day; and 1 contact stabilization plant operated by the BWA with a capacity of 2,700 m<sup>3</sup>/day. The combined total treatment capacity amounts to 3,576 m<sup>3</sup>/day. Two more BWA sewerage systems are planned for the south and west coasts.

However, the reuse of treated wastewater for the irrigation of plants and lawns is currently limited to Sam Lord's Castle Hotel. Another resort, Almond Beach Village Hotel in St. Peter on the West Coast, is almost

ready to start irrigating a 9-hole golf course. Other major irrigation users, such as Sandy Lane Hotel, Royal Westmoreland, Kingsland and the proposed Apes Hill golf course developments, render themselves amenable to the use of treated wastewater. Based on analyses done by the West Coast Sewerage Project and the Water Resources Management & Water Loss Studies in 1998, the water demands of these users can be met from treated wastewater generated along the west coast of the island.

The applicability of wastewater technology depends partly on the nature of the land. In Barbados, owing to the karstic nature and topography of the coral rock aquifer system, groundwater contamination is a potential risk but can be avoided once the wastewater is properly treated. At present, there are very few facilities with a suitable effluent quality. However, the hotels in the belt along the south and west coast, down gradient from the line of public water supply wells, would be suitable candidates for application of this reuse technology since they pose the least danger of contamination to the groundwater.

The viability of wastewater reuse as an alternative for irrigation will be enhanced by the adoption of secondary treatment, in accordance with the Caribbean Environmental Health Institute (CEHI) Sewage Effluent Standards, as the minimum level required, since this reduces the incremental cost attributable to wastewater reuse. For irrigation of golf courses or groundwater recharge in an aquifer used for potable public water supply, the treatment level should be tertiary with nutrient removal. Figure 8.5 below summarises the different applications of treated wastewater and the corresponding level of treatment necessary.

**Figure 8.5: Applications for Wastewater Reuse and corresponding CEHI treatment requirements**

<b>Application of Wastewater Reuse</b>	<b>Treatment Level</b>
Groundwater recharge	tertiary
Irrigation: food crops	secondary/tertiary
Irrigation: non-food crops e.g. golf courses	tertiary plus nutrient removal
Animal foliage	secondary
Industrial cooling water	secondary

Source: BWA (1999)

The use of treated effluent could result in substantial savings in irrigation water costs and reduces the likelihood of water pollution, assuming that the effluents would otherwise have been disposed of through sea outfalls. Furthermore, it eliminates the need to use potable water from the BWA public domestic supply system for irrigation, thereby giving the BWA greater reserve capacity and/or additional supplies for essential potable water purposes.



## **9.0 Beyond the Status Quo**

### **9.1 Introduction**

The ultimate aim of water resources management is sustainable development. Integrated water resource management (IWRM) has been actively promoted by the UN and other water resource specialists, including Hufschmidt and Tejwani (1993) and McDonald and Kay (1994) as a means of linking the development and protection of both natural and human resources within a 'basin' under one overarching management structure. Problems caused by piecemeal developments have been all too common, especially in developing countries (Hufschmidt and Tejwani, 1993). The Dutch government has actively embraced IWRM to ensure that all water uses operate harmoniously, especially with a view to restoring natural habitats and restricting 'over-engineered' solutions (Jones, 1997).

Since 1970, the main elements of the water resource system have evolved from a linear structure (a single source supplying a single demand) to a network structure (a system of multiple demands supplied from multiple sources). In the developed nations, a significant move away from single purpose water agencies to integrated, decentralised, river basin-like, management units has been evident (McDonald and Kay, 1994). Water management agencies are placing more emphasis on resource conservation through demand management and the days of water being considered a free good in the developed world are virtually gone, for example, even water-rich countries like Canada, Sweden, The Netherlands and Germany use metering and consumption-based pricing as a means of controlling demand.

Leakage reduction is also now a priority for most water companies. Comparison of leakage in two European countries shows that it varies from an average 25 per cent in Britain to 5-10 per cent in Germany. Significant advances have been made for more efficient water-based appliances,

including washing machines, toilets and dishwashers. Currently only a few countries with a dire shortage of water, like Namibia operate recycling on an urban scale. But, the extension of recycling and reuse could make a valuable contribution towards controlling demand and supply augmentation.

With regard to supply expansion, desalination offers a potential supply of water, limited more by technology and costs than by the amount of saltwater available or the ecological considerations. There are now over 1,800 desalination plants worldwide. The largest desalination plant in the world at Al-Jubail in Saudi Arabia produces approximately 2.3 million litres a day, mainly for Riyadh. Other plants are located in the Scilly Islands, California, the Greek Islands, the Florida Keys and the Caribbean – Bahamas, Antigua, Barbados and Trinidad and Tobago.

Despite the number of positive examples of movement toward better water resource management, there is still a long way to go. Regionally, Asia and Africa will need far greater international support to meet even basic levels of water provision, in terms of developing management frameworks and implementing strategies to reduce water stress. Transitional countries in Europe and Central Asia need to pursue the adoption and enforcement of EU water directives, particularly regarding pollution control and urban water demand management. More generally in Europe, there is a need to develop and strengthen green taxation for water pollution, reduce subsidies, and build enterprise capacity to incorporate environmental concerns into water resource development. In North America, excessive water use from inefficient practices requires greater institutional accountability at all levels. The USA has fairly extensive national laws, but these may need to be better linked to other regulations. Latin America and the Caribbean need to develop economic instruments to meet funding gaps for better service provision, national water legislation, regulatory institutions and monitoring systems. With better 'ring fencing' of such approaches, water management infrastructures can be further developed and education and information

strategies enhanced. The challenges are considerable and water sector stakeholders in each region will have to accept greater roles and responsibilities for sustainable development to be achieved.

## **9.2 Small Island Developing States**

Small Island Developing States (SIDS) vary significantly depending on distinct bio-physical, socio-cultural and economic characteristics. Nevertheless, their efforts for sustainable development are constrained by common disadvantages such as limited natural resources, fragility of ecosystems, vulnerability to natural hazards and peculiar population dynamics.

SIDS have limited options when developing their freshwater resources due to a number of factors: relatively short lengths of surface water circulation; dependence of groundwater sources on regular aquifer recharge; their geophysical setting which leaves them vulnerable not only to extreme climatological events, but more critically, to periods of low recharge and adverse environmental impacts, including pollution, saline intrusion and soil erosion. Furthermore, the relative fragility of the hydrological cycles means that the evaluation, planning and development of freshwater have to be approached with special care within their hydro-environmental limits.

Substandard management structures and insufficient resources (both human and financial) are fundamental issues of water resource management in SIDS and most of the developing world. Water resources management in SIDS however, involves other unique challenges, most notably, limited freshwater resources (as indicated above) and patterns of development circumscribed by severely limited habitable landmasses.

The SIDS of the Caribbean share a common history of European colonization, slavery and plantation economies, but they also exhibit substantial variation in both geomorphological and socio-economic conditions. These characteristics, as well as cultural and political differences, affect the utilization and rate of exploitation of each island's natural resources. The post-colonial period witnessed rapid urbanization, heavy tourism and industrial development consistent with the construction of transport (land, sea and air), petroleum and hotel facilities. As a result, these micro-states suffer from diminishing resources and biological diversity, and the abandonment of traditional practices.

While all of the Caribbean islands are in the 'tropics', with respect to water resources the situation is as varied as the countries themselves. Some are very arid, such as Barbados, and even though the region is generally considered to be relatively well endowed with precipitation, aridity is present in specific regions or zones of the region's larger countries (e.g. Cuba). The climate is strongly influenced by the El Niño Southern Oscillation, the ITCZ and the Trade Winds, and the availability of freshwater is directly associated with climate vulnerability. The varied geology, topography and size of the islands also influence the availability of water and patterns of water resource development. Surface water is the main source of supply in St. Lucia, Grenada, and, Trinidad and Tobago whilst groundwater provides the bulk of potable water supplies in Jamaica, Barbados and St. Kitts and Nevis. National water availabilities estimated by the World Resources Institute of the World Bank over the period 1980-1998 are 3,131 m<sup>3</sup>/capita for Cuba, 2,430 m<sup>3</sup>/capita for Dominican Republic, 1,460 m<sup>3</sup>/capita for Haiti and 3,869 m<sup>3</sup>/capita for Trinidad and Tobago. Many of the region's water supply systems date back to the nineteenth century. In Trinidad, the first public water supply system, the Maraval Waterworks, dates from the 1850s, utilizing surface water, while Jamaica's first system utilizing groundwater dates from 1854, whilst in Barbados, the date is 1850 and the source was a spring. In Cuba, the Albear Aqueduct, built in 1892, still serves some Havana City zones. The

first water infrastructure, whether for domestic or agricultural use, was constructed on agricultural plantations, which were very large in some cases. Sugar plantations were the first non-domestic consumers in the region and the forerunners of an industrial water supply. Later industrial freshwater systems were also used for home consumption around the mining, refining and oil and gas production centres, for example in Jamaica and Trinidad. The growth of the tourism industry in the Caribbean has placed huge demands on the islands' water resources. However, a workshop on 'Water Resources Management in Small Island States', held in Barbados in August 1995, concluded that there was insufficient data to accurately evaluate water resources for most of the Caribbean islands. Only the larger states (Cuba, Trinidad, Barbados and Jamaica) had the equivalent of a functioning Water Resources Agency.

Nevertheless, the known facts about freshwater management in the Caribbean highlight a highly stressed environment. Many small islands have virtually no freshwater ecosystems (e.g. Virgin Islands, Netherlands Antilles, Barbados). Groundwater resources in many islands, especially the smaller islands (e.g. Antigua, St. Kitts and Nevis) are being exhausted, polluted or displaced by saltwater intrusions. Polluted surface and ground water are major causes of degradation of coastal and near-shore marine ecosystems, including critical salt-pond, mangrove, estuary, sea grass and coral reef systems. Due to the lack of investment in the water sector, in particular investment in maintenance, most water utilities in the region are unable to account for approximately 50 per cent of total water production. Increasing rates of deforestation (e.g. 21 per cent, 31 per cent and 66 per cent natural forest lost in Trinidad and Tobago, Bahamas and Jamaica respectively) are thought to be contributing to severe drought-and-flood cycles in several of the islands during the annual dry and wet seasons (FAO, 1997b). Tourism is a major consumer of water, with many resorts in Antigua, Barbados and Virgin Islands, for example, showing water consumption 5 or 10 times higher than other residential areas. Expensive infrastructure, such as the Roseau Dam in St. Lucia and a proliferation of

desalination plants have been developed to provide freshwater to meet the increasing demands of agriculture, urbanization and tourism. Water conservation measures – recycling and reuse (such as the commercial use of domestic wastewater for irrigation) – are generally uncommon.

### **9.3 The Issues**

The main issues therefore facing small-island developing states, in particular Trinidad and Tobago and Barbados with respect to sustainable development and management of water resources include:

#### **9.3.1 Limited Water Storage Capacity**

Despite the relatively abundant rainfall that most islands receive, they have few permanent streams, lakes or springs. There is also limited capacity to store water for use during the dry season. Generally building reservoirs in SIDS, even when land is available, is fraught with complex geotechnical and hydraulic problems. For example, the combination of high rainfall intensities, variable topography and short river channels requires structures and spillways to accommodate flash floods; and easily erodable soils tend to cause rapid siltation of reservoirs, further decreasing their live storage capacity. As in Barbados, many SIDS depend on regularly recharged groundwater aquifers. Such resources exist in the form of freshwater lenses that effectively sit on higher density saline water. Such lenses have to be carefully skimmed with low-yielding pumps, taking account of tidal effects. Water withdrawals at rates that exceed recharge can cause upconing of the underlying saline water, effectively destroying the freshwater lens.

### 9.3.2 Increasing Demand

Irrigated agriculture is important to both Trinidad and Tobago, and Barbados. Bulk water demands are made on an already limited resource base, and often compete with demands for potable supplies. The expansion of irrigated agriculture is already polluting local surface and groundwater sources, as fertilizers and pesticides are applied in increasing amounts.

High water consumption by tourists and consequent production of wastewater, particularly in coastal settings poses problems for disposal. This contention is also relevant to industrial activities, as at the Point Lisas Industrial Estate in Trinidad, which are also clustered in the coastal areas.

Increasing population and higher standards of living are also stretching the freshwater resource base to its limit.

In order to address the acute water scarcity problem, precipitated in large measure by increased demand due to population growth, hotel and industrial expansion, pressure to implement costly energy intensive desalination plants has been mounting.

### 9.3.3 Financing and Regulating Water Supply Services

Economies of scale in providing water supply and sanitation services are limited under the physical and socio-economic constraints typical of SIDS. The financing and management of water supply utilities is difficult when concentrations of population and the sources of water are small and relatively widely dispersed. The procurement cost of water-related equipment is high, given the high transport costs and little opportunity for bulk discount negotiation. For low to moderately populated areas, usually in more rural districts, the overhead costs associated with running water services are particularly high, and the consumer base is often so poor that

setting tariffs at levels that would recover the cost of the water services is virtually impracticable.

The management and regulatory regimes in many SIDS are yet to give serious consideration to the dynamic and integrated approach required to address the specifics of the islands' hydro-systems. In general, the sectoral approach to water resource management has proven inadequate in treating with a number of developmental and environmental issues, particularly sanitation and pollution of waterways.

#### 9.3.4 The Knowledge Base

Technical and scientific data are either missing or insufficient, primarily because of a lack of regular systematic fieldwork investigation and/or shortfalls of expertise to collect and analyse data. Financial constraints also hamper the development of a detailed knowledge base. Generally SIDS are considered too small to justify the establishment of modern technical institutions, resulting in a shortage of trained technical and other relevant experts. Thus water projects are often implemented ad hoc without accurate knowledge of the availability and sustainability of the water resource systems.

#### 9.3.5 Culture and Public Awareness

The level of public awareness regarding the importance of water resource management issues, in particular costs of service provision, is generally very low in the islands. Demand management is sometimes rendered ineffectual when cultural expectations (e.g. water is 'free' and abundant) and habitual practices linked to water provision prove difficult to change in times of increased demand and severe patterns of drought. However, the relatively small size and spatial concentrations of the populations in the



islands can make the task of public education more manageable with potentially high benefits.

#### **9.4 Re-thinking the Approach to Water Resource Management**

The drought conditions experienced in 2001 and in the recent past in Trinidad and Tobago, and Barbados have heightened awareness of water as a limited resource. All too frequently in the past, water has been taken for granted, regarded as a virtually free good and utilized with no thought to economy. The traditional 'supply-side' approach to freshwater management has relied primarily on technical and engineering approaches as a water shortage panacea. However, plant expansion and/or development of new methods of supply to satisfy water demand forecasts and secure large supply safety margins are extremely costly, especially in terms capital outlay.

With growth in acceptance of the idea that water is a valuable and costly resource that should be utilized efficiently, 'demand-side' management has been emerging as a viable alternative. Fundamental to this management concept is that efforts to minimise all forms of wastage of freshwater are imperative.

As a direct consequence, a 'new' holistic approach known as integrated water resources management (IWRM) has been developed. IWRM requires the involvement of all those who have a stake in water allocation and its use, to manage the resource in association with other related sources (e.g. land) so that economic and social welfare is maximized without compromising the sustainability of the vital resource systems.

## **9.5 Barbados: A Model for Caribbean SIDS?**

In September 1999, the first stakeholder meeting on integrated water resources management (IWRM) hosted by the National Council for Science and Technology, Barbados, in cooperation with the Commonwealth Science Council, London and the World Bank was held in Barbados. The meeting which was formally approved by Cabinet was an indication of the Government's resolve to implement IWRM policies in Barbados in a participatory way. This pilot initiative for Barbados illustrates how harmonized policies and action can help SIDS to deal with limits on the availability of freshwater of adequate quality.

The starting point for discussion at the meeting was a *Draft Policy Framework for Water Resources Development and Management* produced by the Barbados Water Authority. This BWA study recognised the need to treat water as an economic good and the importance of a balanced (supply-demand) approach to water sector management. In this regard, the BWA team developed a framework for water resource management to facilitate the optimal allocation, utilization and protection of the resource base as well as meeting projected demands for the island. At the core of the draft policy framework was the formal recognition of water as a national resource with serious potential to restrict future socio-economic growth as well as adversely impact the driving forces of the economy. Concurrent with this, is the requirement for BWA to fulfil its mandate as stated in the BWA Act Cap. 274A, 1980 to develop and implement policies that will result in an integrated water resources development and management approach, in line with national and sustainable development principles.

The results and findings with respect to the freshwater situation in Barbados, previously discussed in Chapters 7 and 8, have formed the basis for the development of the IWRM framework. This policy framework proposes a comprehensive water resources management plan for Barbados to the year 2016 and beyond, with primary objectives as follows:

- *Provide a continuous supply of water (24 hour) to all its customers except in cases of emergencies, drought, and repair and maintenance;*
- *Provide a supply of water in adequate quantities which meets the appropriate water quality standards for its intended use;*
- *Provide a supply of water at adequate pressure (minimum of 20psi, average of 35psi per household).*

### 9.5.1 Delivering Change: The Proposed Policy Framework

The proposed framework outlines a package of technical, financial, institutional and policy strategies to achieve the above objectives. The major elements are discussed below. As detailed in Chapter 8, the BWA has already commenced implementation of some of the recommendations.

#### ***Technical Requirements in terms of priority are:***

##### **1. Reducing UFW**

The reduction of UFW is compulsory. The recommended target is a 50 per cent reduction i.e. a reduction in UFW from 60 per cent to 30 per cent over a 20-year period. This reduction in UFW will provide reserve capacity for an average rainfall year but will only just meet the requirements for a 1-in-15 year drought situation.

Because of the severity of the water loss problem in Barbados, implementation of extensive leakage control measures is justifiable. It is recommended that 'pressure control' and 'active leak detection and repair' measures be used for reducing water losses from the supply system. Reducing flow pressures in the supply system is a simple and effective means of reducing leakage and can be achieved by lowering pump heads, throttling valves or more commonly, by installing pressure reducing valves on water lines. Active leak detection encompasses testing and monitoring of the water distribution system on a regular basis in order to promptly

detect and repair leaks. Programmes should include district metering and measurement of night flows. In addition, in areas where water mains are badly deteriorated or have high background leakage (many relatively evenly dispersed minor leaks), rehabilitation or replacement of the mains is recommended.

## 2. Optimal Development of Groundwater Resources

Rationalization of the distribution system including relevant mains installations and the construction of appropriately placed reservoirs and re-pumping stations is required. Improved extraction practices and investigations into options for greater groundwater recharge are also to be considered.

Water source augmentation opportunities using artificial recharge seem to have limited potential in Barbados, due to the presence of sink holes, suck wells and natural exposures in the ground that already promote recharge. Minor local initiatives however, such as clearing suckwells and improving drainage to these infiltration areas may be useful in a) providing small increases in recharge and b) sensitising the public to the workings of the supply system. This would be a suitable activity outside Zone 1 areas.

Sewage effluent has provided significant groundwater recharge along the south and west coastal strips of Barbados. This recharge must be maintained to prevent aquifer degradation as the freshwater lens thins along the coast. To this end, injection of tertiary level treated sewage into the aquifers may be required to maintain performance.

## 3. Building Reserve Capacity and/or Alternative Supplies

Additional capacity is needed for protection against drought conditions as well as against the high risk associated with dependence on the Belle and Hampton wells, which collectively provide over 50 per cent of the groundwater produced. Suggested measures include:

- Desalination of brackish groundwater to supplement the potable water supply;
- Wastewater reuse that will provide non-potable reserve capacity and replace unnecessary use of potable supplies;
- Greater encouragement and incentives for the implementation of rainwater roof catchment systems. (Enforcement of the Town and Country Planning regulations, updating the Plumbing Code and public education programmes will also aid in promotion and implementation)

#### 4. Implementation of Conservation Measures

Recommendations to improve water conservation include a ban on all non-low flow water fixtures with a corresponding rebate programme to encourage their installation; implementation of a new tariff/rate structure and public education programmes.

Metering of water services is already an accepted policy in Barbados with universal implementation currently underway. This approach provides the best means to long-term conservation, as consumers will seek to control their consumption and use water more efficiently when unavoidable increases in tariffs are implemented.

The BWA has a programme of providing free of charge low-water use showerheads and kitchen faucet aerators to domestic customers of good standing. Studies carried out by Klohn-Crippen Ltd. (1997) showed that approximately 40 per cent of households have installed these fittings. This programme demonstrates a positive attitude on behalf of consumers to conserve water and should be continued. The use of low-flush toilets should also be encouraged. A similar programme should be developed for retrofitting of hotels with low-flow water devices.

Another recommendation is to issue private abstractors with new licenses with set monthly and annual maximum abstraction volumes. Abstractions in excess of these limits should be severely penalised.

Adoption of efficient irrigation techniques and equipment should be promoted through education. An increase in extension services provided by the Ministry of Agriculture may be needed for proper knowledge dissemination.

### ***Financial Requirements***

The management strategy should make use of economic instruments for achieving sustainable levels of water demand and supply. In particular, a new tariff structure which moves towards full cost pricing of water, that is, reflects not only its economic but also its opportunity costs (e.g. costs of environmental degradation) is needed. The implementation of such a system requires universal metering of services and should allow for differential pricing that takes into account the needs of the lower and other vulnerable income groups. Subsidised use of water by the agriculture sector should also be discouraged.

Other economic incentives such as the provision of concessions to BWA by the Government; effluent charges and abstraction charges can also be combined with existing management tools.

### ***Institutional Capacity Building***

#### **1. National Water Council**

It is recommended that a national water council or water management board with representation at the highest levels, from all stakeholder groups including NGOs, BWA, tourism, agriculture and industry be established. The council/board should aim to integrate the concerns of all stakeholders as well as ensure transparency with respect to its operations and the operations of BWA.

## 2. Training

BWA should be empowered with improved training and incentives for staff to facilitate the management of water as an economic good, in an integrated and holistic manner.

### ***Policy and Legislative Requirements***

#### 1. IWRM

The proposed policy framework should identify the inter-relationships and ensure integration between the following:

- Water quality
- Water supply systems (e.g. groundwater, desalination, reuse)
- Storm drainage
- Land use
- Demand sectors (e.g. tourism, industry, agriculture)

Individual stakeholder roles and accountability should also be made clear.

#### 2. Pollution Prevention and Abstraction Rights

The development of legislation relating to pollution prevention and private abstraction of water is also recommended.

The Barbados Groundwater Protection Policy is not adequate in its scope or approach to addressing the water quality concerns faced by the island today. The existing zoning policy and development regulations were not designed to address groundwater contamination arising from agricultural chemicals and have only been partially effective in managing potential contamination from petroleum hydrocarbons and hazardous materials. A broad-scale groundwater protection policy, which includes measures of source control, resource management initiatives and public education is required. A possible protection strategy is presented in figure 9.1 and this model can combine all, some or different elements that can also be weighted differently, if desired.

**Figure 9.1: Outline of Proposed Barbados Groundwater Protection Policy**



Based on the current groundwater situation, no new licenses or approvals by the private sector for abstraction should be allowed. This ban combined with punitive penalties for over-abstractions should mandate private abstractors to use water more efficiently.

## 9.6 Trinidad and Tobago: An Agenda for Change

Experts in Government and the water sector agree that in Trinidad and Tobago there are sufficient water reserves to serve the public and there is no need for more than one water authority. Most are of the opinion that WASA is capable of providing adequate water services to the various sectors of the country once changes are implemented to make the Authority's operations efficient and financially self-sufficient.

In order to address the problems of inadequacy in water service provision in the country, it is necessary to introduce measures to enable:

- *improvement in production efficiency and thus customer service;*
- *improvement in the utility's institutional and regulatory frameworks; and*



- *implementation of a pricing system which includes a reasonable balance on terms of efficiency, equity, financial and administrative feasibility as well as political acceptability.*

As indicated above, a primary goal for WASA should be to become competitive in the pricing of its services to the public yet supported by systems that can make these services affordable to the low-income consumers. An appropriate pricing system should be set by the regulator, with Government subsidising services to customers living below the poverty line. In addition, private joint venture equity participation should be encouraged so as to benefit from both the capital and managerial expertise of the private sector. The Government should however maintain part ownership and directive. Arrangements like the Interim Operating Agreement from 1996 to 2000, where Severn Trent brought no capital into WASA should not be repeated (some TT\$350 million, made available through loans that are still outstanding, was secured by the Government).

#### 9.6.1 Recommendations for Improved Water Resource Management

The essential mission of the management of WASA should be simultaneous improvement of the water supply and customer service as well as costs recovery. Attainment of this goal entails: reduction of UFW; improvement in operations and maintenance; introduction of a universal metering and consumption-based tariff system; institutional and regulatory strengthening; public education; and initiating incentive schemes to promote water conservation.

As the Minister of Public Utilities and Environment, Martin Joseph, announced in a national speech on April, 5, 2002:

*"I cannot emphasise too much that a genuine solution to the country's water problems for the most part, **will not be found** in the apparently*

*simple options of privatisation and investment in desalination plants. Instead the solution lies in the reduction of leakages and wastage, changes in consumption patterns, conservation, increased efficiency and accountability, the adoption of an integrated approach to the management of our water resources, and the willingness and commitment of all stakeholders to work together in the national interest. And of course leadership from this Administration, through our Ministry. With respect to the vexing issue of rate increases, we the responsible citizens of this country must acknowledge in a normal adult and mature way, that there are costs involved in the supply of water and the collection, treatment and disposal of wastewater.”*  
(GOTT, 2002)

### ***Technical Improvements***

The neglect of routine maintenance has led to deterioration of WASA's transmission and distribution facilities and as a direct consequence, at least half the water produced is lost through pipeline leakage. Programmes to reduce UFW and facilitate equipment repair are urgently required.

#### **1. Reduction of UFW**

A comprehensive programme aimed at reducing physical leakage through the rehabilitation and replacement of deteriorated pipelines and fittings is recommended. This should include mapping the location of leaks and establishing a prioritised repair schedule with specific targets. An overall target to reduce leakage to below 30 per cent in the next 15 - 20 years is suggested. The implementation of an 'active leak detection and repair' programme will recover full function and capability of existing transmission/distribution facilities, possibly deferring the need for developing new potable water sources.

The phased installation of a macro-metering system throughout the supply network, with continuous monitoring of flow rates and pressures will

provide accurate, relatively inexpensive, vital management information on the levels of leakage.

Efforts must also be heightened to reduce the number of illegal connections and other unbilled customers. An aggressive, consistent disconnection programme and complete update of the consumer database are recommended.

Reducing UFW in general will increase revenue and according to WASA officials: an overall reduction in UFW will generate sufficient revenue to defray expenditure on a metering system in less than 5 years.

## **2. Equipment Repair**

Mechanical and electrical equipment throughout the supply network are malfunctioning and left in disrepair. A programme of routine maintenance and rehabilitation of booster pumps, water treatment equipment, well devices etc. should be introduced. The programme should provide for adequate allocation of financial and human resources to effect maintenance, periodical calibration and general overhaul of installed equipment. This will strengthen the safety and reliability of the supply system.

## **3. Metering**

To reduce customer wastage and other excessive use, the phased implementation of universal metering (covering the entire range of domestic, industrial and commercial customers) is recommended. Such a system will also generate more accurate demand data facilitating better water resource management and the introduction of a tariff system based on consumption within the affordability of consumers.

## **4. Water Saving Technologies**

A water conservation ethic that incorporates reduction, reuse and recycling needs to be promoted in Trinidad and Tobago.

The main sources of water for recycling include storm water, sewage and industrial wastewater. Storm water is easily made appropriate for irrigation purposes. Some industrial wastewater can be utilized within the industries themselves for cooling, toilet flushing, general cleaning and maintenance. With appropriate treatment, municipal effluent and sewage can be used for irrigation of crops, plants and golf courses.

According to Cook (1993), a variety of water efficient fixtures is now available at a marginally higher price range than that of traditional equipment. Figure 9.2 compares the different water-saving and conventional fixtures and the volumetric savings to be realised. Government should provide incentives for the installation of low-flow devices as well as the replacement of the standard fixtures with water-saving ones.

**Figure 9.2: Water Saving Devices vs. Conventional Devices**

Device	Consumption litres (l)	Water Saved	
		lpcd	% per flush or min
Standard toilet	20-28 l/flush		
<b>Low-flush toilet</b>	<b>6 l/flush</b>	<b>70</b>	<b>75</b>
Standard shower head	20 l/min		
<b>Flow-restricting shower head</b>	<b>10 l/min</b>	<b>63</b>	<b>50</b>
Standard kitchen faucet	14 l/min		
<b>Reduced-flow kitchen faucet</b>	<b>8 l/min</b>	<b>4</b>	<b>43</b>
Standard bathroom faucet	14 l/min		
<b>Reduced-flow bathroom faucet</b>	<b>5 l/min</b>	<b>20</b>	<b>64</b>

Adapted from Friedman et al. (1993)

### ***Financial Improvements***

Methods to improve both cost reduction and cost recovery are required at WASA, as these issues are equally critical. Many critics of WASA's operations are of the view that there is no justification for raising water tariffs or changing the tariff structure unless introductory or synchronous efforts are made to lower costs and improve service provision.

## 1. Capital Investments

Current demand for water is assumed to be determined, in large measure, by the number and category of users. Future demand is normally projected on the basis of rates of growth of each type of user, allowing for increases in per capita usage. In practice, the estimated supply capacity requirements include an allowance for UFW and a safety margin for periods of drought and other contingencies. The resulting total forms the aggregate demand for water.

Demand estimates using these methods often exceed actual demand sector and UFW growth for a long period. Garn (1994) opined that if investments were tied to more accurate demand forecasts, an investment cost saving of about 20 per cent could be realised. Further, he contended that if new capital investment was tied to effective UFW reduction programmes, savings may be of the order of 25 to 30 per cent.

## 2. Operation and Maintenance

Fox's (1994) research on urban infrastructure management revealed that maintenance tended to be under-provided by many public utilities. He argued that officials preferred to concentrate on visible construction and that political leaders are often myopically focused on agency costs during their tenure in office rather than on life-cycle costs of the utility. A history of poor operational and maintenance practices, over-staffing and political interference have imposed higher long-term running costs on WASA.

### a) Overstaffing

Up to 1998, wages and salaries accounted for over 50 per cent of total operating costs. WASA also has a very high ratio of 13 to 15 employees per 1000 service connections. Recent efforts to downsize the labour force must be commended and it is recommended that personnel costs be reduced to less than 30 per cent of operating costs over the next 10 years.

b) Maintenance

A programme to streamline operations and maintenance is recommended, the details of which have been previously discussed under the *Technical Improvements* section.

c) High Distribution Costs

A strict enforcement of land use regulations that discourage spatial fragmentation between neighbourhoods is recommended, as this will promote high-density development thereby lowering the cost of infrastructure provision. In addition, focusing urban development in zones where the physical features do not demand more elaborate systems, for example, steep or rugged terrain, poor drainage areas or areas with low access to water sources, is suggested. Such zoning policies will also assist in watershed protection.

Use of appropriate service standards will also lower supply system costs. In Trinidad and Tobago, the service standards in poor areas are largely unnecessary. Often complete networks are constructed, while delaying actual house connections as opposed to laying an initial network to serve standpipes that can later be extended or upgraded to serve house connections. Expenditure is significantly higher for the former case, without achieving corresponding increased revenues. The objective should be on one hand, to avoid an unsatisfactory service whilst on the other hand, to forestall excessively expensive equipment, design or construction imposed by misdirected efforts to produce a high quality service. The overriding consideration is to select standards that take into account affordability and ability to pay, whilst not compromising the function and serviceability of a development.

3. Tariffs

Marginal cost pricing, coupled with universal metering is recommended as the method for establishing user charges rather than flat fees based on the annual rateable value of a property. A multi-part (four-tiered) tariff that

unbundles charges into consumption fees, connection fees, development fees and spatial costs is suggested for Trinidad and Tobago. Water rates should reflect WASA's actual expenditure and assets so far invested. Regular updating of water rates to reflect changes in general prices caused by inflation as well as changes in the underlying cost structure of water service provision is also important. As cost unbundling has been recommended, all recurrent charges (metre reading, operations and maintenance, billing etc.) should be allocated on the basis of activity-based costing and form part of the consumption charge.

#### *Consumption Charges*

These include:

- A baseline or 'lifeline' tariff which provides the first 40 lpcd at a minimal cost to achieve social equity and to avoid public health risks;
- Above 40 lpcd, a rising block rate based on volume consumed so as to discourage wastage;
- Provision of water vouchers to the 18-20 per cent of the population living below the poverty line. These will be used to pay for a specified volume of water (similar to food stamps/vouchers).

#### *Connection Charges*

A connection/access charge, i.e. a one-off charge levied to connect the consumer to the supply network is recommended.

#### *Development Charges*

A one-off development fee should be charged to property developers for any newly constructed development outside the main supply network to recoup the capital costs for installing/extending the distribution system so as to service them. The development fee should equal the incremental capital cost per property.

### *Spatial Costs*

A charge that reflects spatial cost differences for service provision due to difficult topography or remoteness is also recommended in an attempt to contain/channel development to areas where services can be provided more efficiently. This charge can be incorporated in either the connection or development fee, if desired.

### ***Institutional Strengthening***

#### **1. Utility Operation**

The institutional arrangements available for improving WASA's inefficiencies have been discussed in Section 6.5.1. The public-private sector partnership has recently been hailed as the new way forward. WASA has already experimented with one such partnership with Severn Trent/Wimpey under an IOA from 1996 to 1999 and significant visible improvements were made in several operational sectors, namely those of maintenance; service provision; billings and collection; and customer relations.

Another public-private sector partnership is recommended, if only as a short-term measure to allow the Utility 'to come onto firm ground'. One option is to unbundle supply activities, that is, separate production from transmission/distribution and open up one activity to private sector participation.

Alternatively, a joint venture management contract, similar to the IOA, whereby the private partner is responsible for operations and maintenance, whilst Government retains ownership of assets can again be undertaken.

These arrangements should result in significant efficiency improvements, substantial cost reductions and facilitate easier implementation of universal metering and a volume-based tariff structure with limited political interference.



## 2. Regulation

The role and function of regulation was discussed in Section 6.5.2 in light of the new regulatory structures and mechanisms that have been emerging on the international scene.

Although thorough analysis and selection of a specific regulatory mechanism is beyond the scope of this study, a comprehensive, transparent well-defined regulatory system is undoubtedly required. A legal and regulatory framework that protects consumers by ensuring that water service provision is adequate in terms of access, water quality and reliability is the primary objective. The basic needs of the poor must also be met. To this end, it is recommended that Trinidad and Tobago retain its current regulatory structure, namely via the Regulated Industries Commission (RIC) so that excessive political intervention is curtailed but Government still retains some role in rate-setting and can ensure that prices are structured or subsidised so that services reach the low-income groups.

Consideration should also be given to the guiding principles of regulation offered by the World Bank (1994) for water agencies:

- *It is important for the regulatory body to report to the legislature rather than solely to a Minister of Government.*
- *Regulating the regulators is critical, especially for an essential service such as water provision.*
- *The head of the regulatory body should be appointed for a fixed term, preferably out of cycle with political elections.*

The World Bank contends that scrutiny should be regular and should systematically assess a utility's performance in achieving its goals. Transparency is also critical to regulatory accountability since the process and policies must be known and published in order to permit effective evaluation of the regulators. Incorporation of consumer feedback into the regulatory process is also important, as consumers are often the best

monitors of service quality. Moreover, if the service provider has a monopoly on the market, the regulatory role of consumers is vital.

### 3. Administration

The pricing system for water services will only achieve its defined objectives, if administered effectively. Meter reading, collection and billing systems need to be appropriately designed and carried out on an accurate and timely basis. A strict disconnection policy should also be adhered to for customers in arrears.

### 4. Public Campaigning and Consumer Involvement

Historically public participation in policy formation and decision-making with respect to water services has been low. There is a general lack of knowledge, service expectations are low and incentives for collective action are limited.

Intensive marketing and public campaigning by WASA via the media – television, radio, newspaper, and brochures – is therefore another key recommendation to inform the populace of WASA's activities, policies and plans. This also provides WASA with the opportunity to educate the public regarding the costs of producing and transporting a potable water supply in an attempt to gain understanding and reduce resistance to rate increases or changes in tariff structure.

Two-way communication routes between the public and WASA will enable the transfer of useful information and customers can air complaints and suggestions for improvement that they are 'willing to pay for'. Conservation measures can also be promoted in this way.

### ***Legislative Reform***

The WTP study demonstrated that poor households with illegal housing and land tenure were in most cases willing to pay for water services. Therefore, legislative reform that allows squatters to connect to WASA's

system will significantly reduce the number of illegal customers and increase revenues.

The development of a land-use zoning policy which focuses urban expansion into areas whose physical geographical features permit easier and more economic service provision is recommended. Spatial fragmentation within developments and urban sprawl should also be discouraged through regulation. Such a policy should designate areas for use, e.g. industrial development, agriculture, residence etc. based on potential impacts to the freshwater resource, i.e. harmful effects to watercourses, groundwater aquifers and watersheds resulting from pollution and other forms of degradation.

The Water and Sewerage Act of 1965 also needs to be reviewed. Greater emphasis must be placed on environmental issues such as pollution control, deforestation, conservation and river flow regulations.

Given the accumulated deterioration over the past few decades, and bearing in mind the importance of funding, one of the most difficult policy decisions will be the dedication of resources to the very high costs of remediation. At the same time, prevention of further damage to the remaining natural watersheds must also be addressed. Existing legislation for watershed management and pollution prevention therefore needs to be updated and streamlined.

Some protection of the freshwater resource base is already being done. The current initiatives include the introduction of the Water Pollution Programme, the Certificate of Environmental Clearance and a joint research programme between the EMA and the University of the West Indies on the scientific collection of data to determine freshwater quality using biological indicators (EMA, 1998). But, these efforts represent only the starting point for the development of an adequate mix of tools essential to ensuring water security.

Other issues in need of addressing include:

a) Low Penalties

Penalties for violations of various laws are generally low and do not act as disincentives.

b) Inadequate Regulations and Resources

Supporting regulations for legislation is absent in some cases and as such the laws are not enforceable. In addition, there is a general lack of specificity, standards as well as resources for enforcement (human and operational).

c) Dissipation of Authority

The presence of multiple agencies with similar, joint or complementary activities relating to freshwater management but who have little or no interaction and collaboration is proving ineffective. A framework for IWRM as developed for Barbados is recommended with roles and responsibilities for all stakeholder groups clearly identified.

***Desalination: solution or new problems for the freshwater sector?***

Anyone living in close proximity to the sea, and experiencing acute difficulty in sourcing an adequate supply of freshwater, is likely to entertain the possibility of deriving needed freshwater from the sea. This contention holds in SIDS such as Aruba and Barbados, where desalination systems have been built to meet shortage of potable water. The prospect is without question technically feasible.

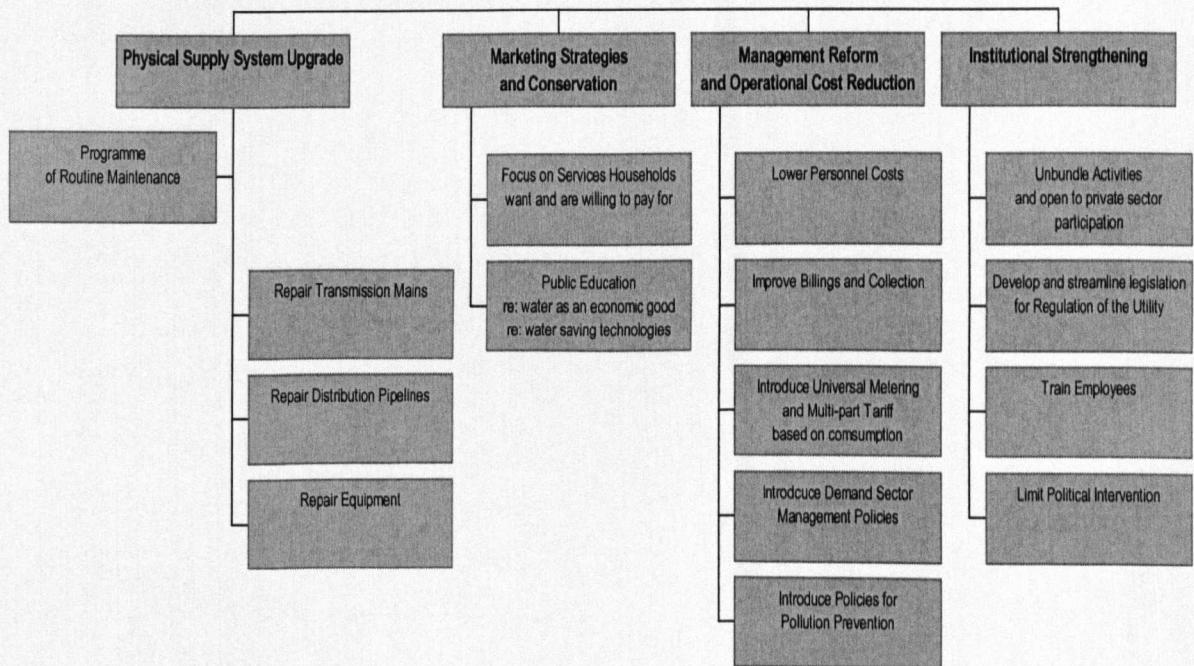
The most fundamental limiting factor is cost. Costs for desalination are multi-dimensional, many of which, are determined by the feedwater, the process employed and the anticipated use of the product. Essential cost elements include in-take and pre-treatment systems – which largely depend on the specific site chosen and the characteristics of the saline water supply – as well as the actual desalting process used and storage requirements. As

previously mentioned, a seawater desalination facility costs almost twice that of a brackish water desalination plant of the same size.

W. Hall (1990) found in his research that in countries where desalination was being used or considered, the other classical sources of freshwater (rivers, groundwater, lakes etc.) were essentially fully developed and the demand was still not being met. Desalination then became the next least marginal cost source to serve the unmet demand, virtually by default, as in the case of Barbados. This however is not the circumstance in Trinidad and Tobago, which has abundant freshwater resources yet to be exploited and much scope for further classical type development and potable water production. Nevertheless, seawater desalination to supply the Point Lisas Industrial Estate may be an interim solution, while WASA tries to address some of its many problems.

Figure 9.3 below summarises the proposed recommendations for WASA.

Figure 9.3: Summary of Recommendations for WASA



## **9.7 Managing Water Resources under Uncertain Climate Conditions**

Global climate change further complicates sustainable water resource management and future planning. Over the period 1990-1999, mean annual temperature in the Caribbean increased by approximately 0.5°C. During the same period, mean annual total rainfall decreased by about 250mm, though throughout, the rainfall record has been characterised by large variability.

Simulations using ocean-atmospheric general circulation models (GCMs) are not presently conducted at fine horizontal resolution so the ability to generate climate change scenarios for small-island states is somewhat limited. However, because of the strong influence of the surrounding oceans on the climate of these islands and because the oceans are projected to warm in the future [1-2°C for the Caribbean Sea and the Atlantic with a doubling of CO<sub>2</sub> (IPCC, 1996b)], small islands are also expected to experience moderate warming in the future. Mean rainfall intensity is projected to increase by about 20 per cent over tropical oceans with doubled CO<sub>2</sub> concentrations.

At this stage, there is much uncertainty in climate model projections with respect to possible changes in the distribution, frequency, and intensity of tropical cyclones and El Niño Southern Oscillation (ENSO) events. The most significant climate-related projection for small islands is sea-level rise. Current estimates of future global sea-level rise of 5 mm/yr (with a range of 2-9 mm/yr) represent a rate that is 2 to 4 times higher than what has been experienced globally over the past 100 years (IPCC, 2001a). Considerable local and regional variations in the rate, magnitude, and direction of sea-level change can be expected as a result of thermal expansion, tectonic movements, and changes in ocean circulation. However, although the level of vulnerability will vary from island to island,



it is expected that practically all small-island states will be adversely affected by sea-level rise.

Adjustments in the global hydrological cycle as a result of climate change, could affect the distribution and availability of water resources. Climate variability on seasonal and inter-annual time scales can cause changes in precipitation that can impact the magnitude, rate and timing of run-off as well as the frequency and intensity of floods and droughts. Temperature variations can result in changes in evapotranspiration, soil moisture and infiltration rates.

In many small-island states (including the islands of the Eastern Caribbean), the annual rainfall regime is characterised by pronounced wet and dry seasons, where as much as 65 per cent of the annual rainfall occurs during the wet season (e.g. Barbados). Therefore, to the extent that the availability of water resources in these islands is dependent on seasonal heavy rainfall events, changes in the occurrence of these phenomena inevitably will impact water supplies.

Still, the most important aspect of climate change as it relates to water resources is the great increase in the overall uncertainty associated with the management of the resource. The science of hydrology has almost always been performed assuming that climate is stationary – that the patterns of climate experienced in the recent past will continue into the future. Global climate change however, may effectively make all the old assumptions about the behaviour of the water supply obsolete. It may not be known precisely what will occur nor when, but changes in climatic conditions are becoming evident and the institutional structures in place for managing water resources in Trinidad and Tobago and Barbados will have to be made more resilient than they are at present.

## **9.8 The Way Forward: IWRM**

Regional experts agree that what is now required is the development of national strategies for economic and social growth, which recognise the interdependencies of the environment and development, and at the same time recognise the need for sustainable trade-offs between them.

IWRM combines the scientific focus on water resources and their links with the soil and biota, with careful consideration of their value to society and a country's economic and social objectives. The basic aim is to avoid developments in one field, such as urban expansion or forest clearance, which might have serious detrimental impacts upon other developments.

IWRM has three guiding principles: *multiple purpose*, *multiple objectives* and *multiple means*. Integrated plans must balance a range of water uses and management purposes. As such, they include objectives that balance economic productivity, environmental quality, health and social considerations, and they strive to achieve these ends by combining physical structures with regulations and economic incentives (Jones, 1997). According to Jones (1997), smaller river basin units, as in the Philippines or the Caribbean offer great opportunities for success of IWRM.

National accounting exercises of Trinidad and Tobago do not include values for natural resources such as forests or watersheds. The valuation of forests is unfortunately still largely associated with the timber trade. The essential ecological services of water production are not reflected in water service nor forest management economic analyses.

Measures for controlling demand have also largely been excluded from water management practices perhaps in part due to the fact that available water resources were still in excess of the forecast demand until 2005 in Barbados; and still are in excess of the forecast demand for Trinidad and Tobago. However, in the latter case, the present supply is unevenly



distributed, many areas experience frequent water shortages and cases of major disruption and fluctuation in supply, primarily due to operational problems at WASA. Wastage both at WASA and BWA in terms of the high levels of UFW permitted and by consumers who treat potable water as a never-ending resource underscores the narrow traditional supply-led approach to water management in the Eastern Caribbean.

With the conventional view of water as a free commodity now emerging as a misleading concept, water resource management must start at the source and encompass both supply- and demand- side measures in order to be sustainable. Another key challenge is incorporating the uncertainty posed by climate change into water resource planning and management practices. Integrated water resources management will enhance the potential for adaptation to change, and it appears to be more flexible than conventional water resource management. Many lessons can be learnt from the operations of the Barbados water sector, which as this study demonstrated, has already begun making significant strides towards IWRM.

## **9.9 Concluding Remarks**

The successes and failures of the past two or three decades demonstrate that water management should be based on much sounder policies, greater economic incentives for achieving efficiencies and for providing services to the poor, and far more effective institutional arrangements than currently exist.

These lessons are reflected in the global consensus – endorsed at the United Nations Conference on the Environment and Development (UNCED) in Rio de Janeiro and elaborated in subsequent international gatherings – to move away from an emphasis on developing new water supplies toward a focus on comprehensive management; economic behaviour; policies to

overcome market and government failures; incentives to provide users with better services and technologies to increase the efficiency of water usage. This new focus on demand stresses integrated water management based on the perception of water not just as a basic human need, but also as an integral part of the ecosystem, a natural resource and a social and economic good.

The new approach calls for policies that are formulated in the context of a comprehensive analytical framework that takes into account the interdependencies among sectors and ecosystems. Incentives for financial accountability and improved performance should be created through greater use of pricing, decentralisation of administration and services, financial autonomy, user participation and private sector involvement. Furthermore, consistent rules and regulations and co-ordination among agencies responsible for water services should be established to ensure policy cohesion and public support.

In the past, supply-side approaches dominated water resources management practices with a traditional reliance on capacity expansion programmes to solve all problems of imbalance between the supply and demand for freshwater. However, the era of meeting growing demand by simply developing new supplies is ending. In the current water sector, extremely high costs are incurred in service provision, including the supply in peak and drought periods. In addition, there are several competing claims (e.g. household consumption, irrigation, tourism and industry) to limited water resources and it is no longer technically or economically feasible to serve all uncontrolled future demand. Finally, central governments in SIDS can no longer afford to finance the magnitude of capital investment for infrastructure maintenance and development in the water sector. Innovative measures are needed to achieve optimal revenue generation and cost reduction. However, water authorities in small-island developing states generally lacked the institutional and financial capacity to achieve this. This situation emerged due to lack of direct control over finances and



investment as well as modern technical expertise. Government subsidies also provided little incentive to improve performance.

Consequently, water resource management has been shifting away from treating water as a 'free good'. Water utilities are becoming more self-reliant and self-sufficient. The primary goal is no longer capturing more water, but designing integrated water resources management approaches that include both supply and demand factors. Focus is being placed on increasing the effective supply from existing production facilities and managing demands for water through conservation, reuse and recycling. The possibilities of reducing losses from the distribution system, providing dual quality water supplies and employing the price mechanism are all options that SIDS like Trinidad and Tobago and Barbados need to consider for sustainable water resource management.

The four main management recommendations appropriate to the current conditions in Trinidad and Tobago and Barbados include:

- 1) Supply augmentation through reduction of UFW and implementation of alternative technologies.
- 2) Demand management through universal metering and multi-part tariff systems based on consumption, whilst protecting the basic needs of the public, especially the poor.
- 3) Legislative reform and development of standards and regulatory instruments to protect the consumer, prevent surface and groundwater pollution and watershed degradation.
- 4) Public education to promote water as an economic good and conservation practices.

The aim of sustainable development is much discussed in many areas these days and, like many other over-used phrases, it has come to mean different things to different people. Perhaps a more useful, more specific aim is 'the sustainable use of natural resources', of which none is more vital than

water. Closely allied to this phrase is the concept of stewardship, which refers to the adequate management of the resource regarding the needs of current and future generations.

Better understanding of the relationships between supply and demand as well as between water and all other concerns, such as socio-economic development and the environment will lead to more appropriate and successful stewardship or water resource management. This will in turn result in more sustainable use of the resource or improved water security in Trinidad and Tobago and Barbados.

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