Environmental Management, Sustainable Development and Human Health

Editors

E.N. Laboy-Nieves, F.C. Schaffner, A.H. Abdelhadi & M.F.A. Goosen

CRC Press
Taylor & Francis Group
A BALKEMA BOOK



ENVIRONMENTAL MANAGEMENT, SUSTAINABLE DEVELOPMENT AND HUMAN HEALTH

Environmental Management, Sustainable Development and Human Health

Editors

Eddie N. Laboy-Nieves & Fred C. Schaffner
University of Turabo, Gurabo, Puerto Rico, USA

Ahmad H. Abdelhadi
New York Institute of Technology, Amman, Jordan

Mattheus F. A. Goosen
Alfaisal University, Riyadh, KSA

CRC Press
Taylor & Francis Group
Boca Raton London New York Leiden

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business
A BALKEMA BOOK

Cover photo credits: Front cover (above): Ricardo Ríos-Menéndez, front cover (below) and back cover: Eddie N. Laboy-Nieves.

http://ciemades.org

CRC Press/Balkema is an imprint of the Taylor & Francis Group, an informa business

Typeset by Charon Tec Ltd (A Macmillan Company), Chennai, India
Printed and bound in Great Britain by Cromwell Press Ltd, Towbridge, Wiltshire.

Published by: CRC Press/Balkema
P.O. Box 447, 2300 AK Leiden, The Netherlands
e-mail: Pub.NL@taylorandfrancis.com
www.crcpress.com – www.taylorandfrancis.co.uk – www.balkema.nl

Library of Congress Cataloging-in-Publication Data

Environmental management, sustainable development, and human health / edited by Eddie N. Laboy-Nieves …[et al.].
p. ; cm.
Includes bibliographical references and index.
ISBN 978–0–415–46963–0 (hbk. : alk. paper)
1. Environmental health. 2. Environmental management–Health aspects.
3. Sustainable development–Health aspects. 4. Economic development–Health aspects.
I. Laboy, Eddie Nelson. II. Title. [DNLM: 1. Environmental Health.
2. Conservation of Natural Resources. 3. Developing Countries.
4. Ecology. 5. Environmental Medicine. 6. International Cooperation.
WA 30.5 E607 2009]
RA565.E516 2009
362.196’98–dc22

2008039742

ISBN: 978-0-415-46963-0 (hbk)
ISBN: 978-0-203-88125-5 (e-book)

Contents

Ecosystems and Environmental Health

Materials Recycling and Water Treatment

Assessment of Sustainability in Water Resources Management: A Case Study from the Dominican Republic

J.R. Pérez-Durán
Advisor on Water Resources, Instituto Nacional de Recursos Hidráulicos (INDRHI) – National Institute for Water Resources, Dominican Republic; EMR (Engineering, Management and Risk) Group

SUMMARY: This chapter presents an assessment of the water resources management system of a case study region, the Dominican Republic in the Caribbean, with a particular focus on sustainability. After a brief presentation on water resources management concepts, a methodology proposed for the assessment is developed and applied to country specific situation and issues of water resources. The "Building Blocks" assessment methodology, consisting of elements of the management functions or tools for water resources viewed in a simple graphic manner, helps to organize the assessment and is feasible to use in a participatory exercise due to its visual value and its potential to generate and guide discussions. Problems and issues related to water in the case study country are analyzed with reference to the tools or functions of water management as the evaluation unfolds. Results show that the water sector requires reform, which should be wisely based on the development of organization, planning and control tools for adequate administration of that resource in order to solve problems in water stressed regions of the country, identifying priority actions, and define strategies to solve current water quantity and quality issues, and to prevent aggravation of them in the future. Areas for improvement in water resources management are suggested.

1 INTRODUCTION

Concerns and interests on water resources issues are growing due to declining conditions in water quality, availability and climate variability. These have negative impacts on health and have diminished the potential for development, as well as increased suffering due to losses and damages caused by extreme hydrological events. Inherent to water resources is its geographic and seasonal variability and uncertainty, characteristics which are to be taken into account when water is to be managed for social and economic growth, while preserving the environment and natural patrimony. Water resources management has evolved from a partial focus or sectorial approach, with isolated actions in each particular sector making use of water, to a comprehensive view of a process which integrates all uses and conceives water itself as part of an ecosystem which is to be valued, preserved and used for the benefit of all. (Al Radif, 1999 and Jewit, 2001).

Given the not so optimistic view of the water situation in many countries, with forecasted worsening of shortages and growing conflicts (WMO/IDB, 1996, Biswas, 2004 and Al Radif, 1999), the capacity to make rational use of water and supply to all users in a coordinated and sustainable manner has been questioned, recognizing that solutions to water problems depend no only on water availability, but also on factors related to water management (Biswas, 2004). This is the case of the Dominican Republic, a developing country where an assessment of water resources management systems has been performed with the purpose of obtaining an insight concerning priorities and actions necessary for water conservation and to support improvement of living conditions of the poor and for sustaining economic activities, without threats to water bodies and the environment. To achieve this task of evaluating the situation of the water sector in the Dominican Republic, it has been thought both useful and necessary to develop a methodology that would guide the assessment in a simple, yet thorough way, brief and easy to understand, but without sacrificing neither conceptual nor technical depths of analysis.

Possibilities for improvement of living conditions, development of agriculture, tourism and many other important economic activities, are strongly dependent on the sustainability of water resources in the Dominican Republic. Management of water resources has to play a vital role in securing continued and sustainable use of water. Reforms and modernization of water resources planning and management are urgently needed. Different issues related to water resources management are briefly described trying to derive useful lessons from them and showing the priorities to be addressed. To convey a stimulating message of hope and potential for improvement of water resources management, some concrete experiences are highlighted and dealt with some detail, with refreshing lessons on participatory management and decentralization.

2 CHALLENGES AND TASKS FOR WATER MANAGEMENT

The importance of water is being increasingly highlighted as we gradually approach the limits of availability, or have probably trespassed it in some places, having passed from a safety to an unsafe area where this finite and vulnerable resource is becoming either unavailable (scarce or too polluted) or too difficult to fetch (too costly to access). While world population tripled during the twentieth Century, water consumption increased by a factor next to seven. It has been forecasted that population living in water stressed countries will increase from one third to two thirds (Global Water Partnership, 2000). Although access to water is considered a basic element for human life and a fundamental right, 1,100 persons do not have such access and 2,600 millions do not have proper sanitation conditions. An estimate of 1.8 million children die each year as a direct consequence of diarrhea, intestinal diseases and other diseases caused by unclean water or insufficient sanitation. Dysentery on its own is the second largest cause of deaths in infants (UNDP, 2006 and 2007). When adults are added to these tragic statistics, the figure rises to 5 million people dying annually from waterborne diseases, which is 10 times more than the amount of persons dying in wars all around the globe. Such dantean picture should be enough to motivate firm decisions to manage water more rationally and preserve its quality.

In developed countries diseases related to poor water quality and inappropriate wastewater disposal account for illness and loss of productivity equivalent to 2% of GDP **(Op. Cit, UNDP)**. Inversely, poor countries which invest in having better access to water and supply and sanitation, have a better economy (SIWI, 2005). Situations in the aforementioned scenarios are far from being all inclusive in relation to water problems. Extreme hydrological events like floods and droughts pose other great and menacing problems. Concerns on water pollution, irrational use of water, inefficient operation of existing infrastructure, climate change, institutional weaknesses and economic incapacities also add to the list.

3 WHAT IS WATER RESOURCES MANAGEMENT?

Water resources management is called to address several issues and problems. Where to get the required amount of water is in itself a challenge due to its evasive nature. The difficulty to identify and measure water has earned water a well deserved reputation as a "*fugitive resource*" (FAO, 1995 and UNDP, 2006). For its dynamic, changing and vulnerable nature, as well as its unequal distribution in time and space, it can be said that water resources management is therefore the management of variability and uncertainty.

To understand the dimension and challenge of variability in water management, it is useful to illustrate this issue considering that in Latin America, a richly water endowed region occupying 15% of the earth's surface, we have 30% of global precipitation and 13,120 million m^3/year flowing in surface water, equivalent to 33% of total water runoff in the world, for only 10% of the population on the planet. However, in this region 60% of the population live concentrated in 20% of its territory, where only 5% of all available water is (WMO, 1996). The per-capita estimate for renewable water resources in Latin America is 28,000 m^3/year, which is superior to the world average, more than four times the amount of water in the Central American and Caribbean region with an annual value of 6,890 m^3/hab, almost ten times the amount for the Greater Antilles of the Caribbean (Cuba, Haiti, Jamaica, Puerto Rico and the Dominican Republic), where average per-capita availability is 2,804 m^3/year, and ninety times the availability of Barbados with 313 m^3/hab/year. It is obvious that the regional value of available water and per-capita figure for the Latin American region disguise an uneven spatial distribution of water, which is well depicted by the fact that only one river, the Amazon, flows with 53% of all available water in the region (Ringler, Claudia et. al, 2000., and WMO/IDB, 1996). Spatial variability of water is also observed within one country, where territorial, demographic and water availability elements do not necessarily match.

Limited availability, whether seasonal or permanent, is a physical problem of water called scarcity. Growing population, rising economy and increase of industrial activities generate more demand and consumption of water. These factors, along with pollution of water bodies, increase with time and tend to diminish availability in such way that what was once a good source of water for a given population and for supporting economic activities in that area, becomes insufficient and inadequate. Another problem is the means to withdraw or divert and conduct water to the point of demand and distribute it among users. Not having the infrastructure or technology to carry and get water to where it is needed or not having the money to pay for this infrastructure or being deprived of it, which results in lack of access to water. The first case is a "physical scarcity of water" (probably also biochemical when considering water quality), while the second is what has been called the "economic scarcity of water". Other aspects like limited capacity of organizations, inappropriate institutional arrangements, inefficient infrastructure, low tariffs, losses and inefficient use of water and difficulties in procuring needed investment, plus other ingredients like lack of political will, are other dimensions to the water problems, which is not certainly limited to scarcity. At the Third World Water Forum (2003) it was recognized that water crisis is mainly a crisis of management. Water management is equivalent to administration of conflicts between human beings and amongst humans with their surroundings. A water management system is created to avoid and solve these conflicts (Dourojeanni, 2001).

With such diversity and magnitude of problems one has to agree that water management is an analytical and creative activity (Setti et al., 2002) oriented to the formulation and application of principles, policies, for establishing norms, structuring administrative systems and taking decisions for the use, control and protection of water resources.

For the management of water it is absolutely necessary to have a management model, where policy statements, norms and standards, organizations, administrative instruments (organizational system, licensing and permitting for water use, cadastre or registers systems, financial systems – water tariffs and investment schemes -, information systems, education, basin and national water planning, pollution control, vigilance and compliance mechanisms, among others), technology and infrastructure are oriented for optimizing the use of water, while at the same time preserving the quality and environmental value of water bodies, making water available in desired time and quantity for the use of present and future generations. Preparing plans, programming actions and investments, as well as implementing those policies, plans and actions are the activities of water resources management. To put it in business administration or management terms, water resources management requires applying organizations, planning, control functions to satisfy the needs of different uses, promoting rational use of water and optimizing objectives of social and economic development as well as conservation of quality and quantity of water.

It is also worthwhile to make a point in differentiating traditional water resources engineering and water resources management. While the first is an activity of specialized civil engineers, who provide technical and engineering solutions to the physical problems, water resources management is not exclusively limited to these specialist, and can involve several disciplines, trades and actors, including users, community organizations, farmers, businessmen, industries, journalists, government officials and politicians, working, ideally together or at least on same scenario, trying to find social, environmental and economic solutions to the problems and challenges that the world and communities face. The growing attendance of diverse crowds to World Water Forums, and the acknowledgement of the importance of water in several ministerial and presidential summits is a sign that water has become everybody's business. Prince Willem of Orange declared at the *World Summit on Sustainable Development* (WSSD) celebrated in Johannesburg in 2002, that from the previous WSSD in Río de Janeiro (1992) to Johannesburg, water climbed to the top of the agenda (IWMI, 2002).

More fashionable and "sustainable" terms like Integrated Water Resources Management (IWRM by its acronym), have become popular and conceive all users of water, including environmental demand, seeking a proper balance that would yield both economic benefits (profits) and social growth, including the poor, while not endangering the natural patrimony and securing conditions for it to continue to supply its valuable services for the enjoyment of life. As written in more a thoughtful definition, IWRM has been defined as "a process which promotes development and coordinated management of water, soil and related resources to have the results of maximizing economy and social wellbeing in a equitable manner without compromising the sustainability of vital or essential ecosystem" (GWP, 2000).

The trend in water management has shifted from a single purpose goal like agricultural development or hydropower development to a multipurpose development, where natural conservation and social equity lead to a wider vision and a more comprehensive and coherent approach of water resources management. Conceptual goals of IWRM is oriented to building a common platform in which all sectors using water would link their interest to a multisectoral coordination of water allocation and subordinate their proposals for intervention within a global context (ICWS, 2002). IWRM has promoted that the focus changes from exploitation of water resources to conservation and rational use, and from management of supply to demand management. The emphasis before was more in investing to build new canals and dams to supply water to more towns and irrigation fields. The aim now is to take into account all the demands, consider water availability and prepare an optimized plan for its use and conservation, weighing the effects of all proposed actions or requests for diversion of water and any discharge into water bodies in the context of the hydrographic basin's capacity to respond to that demand without harming the environment nor threatening natural resources.

Another important difference is that before there was an almost absolute participation of the government in all water management aspects, leaving to passive users a limited voice in this matter. Government was seen as responsible for performing all the tasks while now it is desired to have stakeholders become involved.

One key concept in IWRM's framework is the level of functions, calling for separation of roles and conceiving interventions of main water actors into three distinct areas of involvement. The Constitutional function has to do with developing and updating legislation, norms and standards, defining strategy and formulating policy and strategic plans. The Organizational function is where operational tasks of regulatory responsibilities are implemented, by an agency responsible for applying the norms, strategy, policy and strategic plans. The Operational function is the third level where water services are provided.

4 ASSESSMENT OF WATER MANAGEMENT SYSTEMS

The assessment of sustainability of water resources management has to be addressed in terms of how do the strategies, policies, norms and standards, strategic plans, institutions in the water sector and administrative instruments, which were previously mentioned as having to do with water resources management, help towards this aimed equilibrium of sustainable use of water resources. The key question is: How sustainable or unsustainable itself is the system called to preserve sustainability of the use of water for development for social and economic growth and preservation of water, as well as other associated natural resources and the environment? Considering that this is an important question to answer, an interest arises in being able to evaluate how the management model is leading, or misleading, to attain a proper use of water and tapping the benefits derived from its use, without harming the environment and guaranteeing water resources capacity to continuously sustain life and support development now and in the future. Water has been defined as a finite and renewable resource. In a way, with rapidly growing demand, scarcity of water in many places and contamination of water resources, what is pretended to be achieved by sustainable management of water resources is to monitor conditions pertaining to both attributes, finiteness and renewal, and where possible impose or promote discipline in the use of water so as not to approach limits of finiteness too soon and to better understand the natural processes of the water cycle not hampering this process of renewal, safeguarding quality and environmental conditions. Furthermore the term “sustainability”, where appropriate, would be particularly dealt with in consideration of its relationship to environmental and natural resources base, but would generally imply technical, financial, administrative as well as the environmental dimensions.

To achieve this purpose of evaluating the capacity of a water resources management system, a methodology is proposed based on the elements or components necessary for water management. Since these elements are all considered essential, we opt for “baptizing” this methodology as the “*Building Blocks*” for assessment of water resources management systems. The aim is not to measure and evaluate water resources productive potential or aspects related to water service, but rather to evaluate the management system. Results and performance of the applied management scheme and quality of water services are off course indicative of the sustainability of the administrative model. In order to understand the capacity of a system to respond to an objective like that of managing water properly, identifying the components of water management and the criteria and evaluation terms for judging of the soundness of their application must be set forth.

Garduño (2001) proposes that the administration of water rights calls for implementation tools: planning models; guidelines and procedures for the filing, processing, granting and control of water abstraction and waste discharge permits; information system to systematically safeguard, retrieve and release all documents involved in each application, databases and follow-up; capacity building (training and enabling working environment, competitive salaries and rational promotion approach); and communication to enhance public awareness and education.

While the above set of tools is more oriented to evaluating the success of implementing and enforcing water law, it provides an interesting suggestion towards the core elements or “building blocks” of water resources management, which requires off course more than “good” water law, as it has already been wisely considered in the previous paragraph with tools related to education and communication.

From the works of Trewatha and Newport, (1982), and Robles and Alcérreca, (2000), management is defined as a set activities directed for the planning of human, technological an economic resources and organizing structures with task assignments. Comparatively, the assessment of the quality of the water management system has to take into account how human, technological, economic, financial, organizational and other resources, are arranged to achieve sustainable use of water. The proposed methodology is not aimed at awarding a grade for development of water resources management system for a country, but rather oriented towards revealing issues and challenges to be addressed and overcome. The objectives of this methodology are to identify and qualitatively evaluate performance of different components of water resources management; identify the relationships among them; find out which instruments or tools are in place and which others need to be developed; and to raise awareness among decision makers of the need for reorientation, organization and renewal of water resources management targets.

Another source for identifying components of a water management systems is a water plan, whether at the national or at the basin scale. Commonly proposed components, activities or products of such plans:

- Management and dissemination of information on water and climate
- Participatory management: decentralization and delegation of responsibilities to users and community organizations.
- Demand management: plans and technology for improvement in water use efficiency.
- Risk management accounting for extreme hydrologic events, floods and droughts.

- Water allocation: regulation of the availability of water for users, and administration of water rights.
- River basin planning and formulation of projects for multipurpose use of water resources.
- Strategy and policy formulation and institutional arrangement for water resources management.
- Financing value of water and economic, water accounts.
- Characterization of water bodies and watersheds.
- Integrated water management.
- Natural resources and environmental protection and water conservation.
- Education and communication.
- Indicative plans for sectorial uses of water.

From the above, the administration instruments or components for water resources management that can be considered in a water resources management system are: basin planning, risk management, education, information, and monitoring, institutional and organizational arrangement (water regulation agencies, service providers). Some other instruments of water management systems, not necessarily included as specific components of water plans are research, vigilance and inspection, information, licensing, permitting and awarding of rights for water use, system, registration and cadastre of water users, financing water management (tariff structure), norms and standards.

By selecting, arranging and "shuffling" some of the elements in both sets above, we finally have the wall made of Building blocks as shown in Table 1. Individual blocks are organized in layers or components (strategy and policy, legal, institutional, planning, monitoring, environment and natural resources, water allocation and quality control, financing and risk management). The order of layers is important; conceiving that foundational layers should come before other developments in water resources management. In a group exercise or round of questionnaires it is evident that some discussion is to concentrate on whether or not these proposed set of components of a water management system are all the layers or all the elements necessary or if there are some still missing. It is also to be expected that arguing can be raised about the justification to include a given "block" or disagreement as to which level or layer it should occupy. New blocks or elements could be added and some could even be discarded. In fact, for generating participatory input to the assessment, it is advisable to have the participants define the levels (components) and the blocks, and later on, determine best location of each block.

Several considerations are basic to determine criteria and scale of evaluation, having in mind that the tool is proposed for a qualitative assessment. Color, numeric or combined scales can be used, but a simple numeric scale is proposed, assigning a number from 0 to 5 for each block, and final score in each layer as addition of all blocks in that layer. Quality, functionality or efficacy of water management instruments can be graded according to the following: 0 = Absent (inexistent); 1 = Obsolete or ineffective; 2 = Incipient concepts and actions, isolated experiences and with questions on sustainability; 3 = Existing initiatives and proposals to improve; 4= Satisfactory or promising experiences and good potential for more improvement; and 5 = Well developed and improving. Some warning as to the use of number ranking is that the objective is not to award a grade and that interpretation of results should only be made in general terms, not pretending to accurately measure the level of development of a water resources management system, but rather to identify missing or weak elements or components and the relationship between them. Results can be of help to set priorities for development.

Premises for interpretation and application of this methodology are: a-) all elements or "blocks" are necessary for water management; b-) Blocks will have a score, indicating in each case the degree to which that specific element in water resources management has been attained or satisfactorily developed, notwithstanding that there is always room for improvement; c-) if a numeric scale is adopted, instead color scale (filled or empty blocks), the higher the score awarded, the more successful that specific element stands in assessment; d-) the more "blocks" of the "wall" with good scores, the nearer to success in assessment is the water resources management system; e-) without one or several of these blocks (zero or low score) the wall would be unstable and water resources management system would be judged to be unstable or not so sustainable; f-) the more

Table 1. Building blocks of water resources management.

RISK	Early warning system	coordination with Civil defense and other emergency institutions	Flood control action plan	Droughts	Risk mapping	Zoning protection
FINANCING	Investment programmes	Tariffs structure	Cost recovery	Incentives	Private participation	Water accounts
WATER ALLOCATION and QUALITY CONTROL	Allocation mechanisms (award, licensing and permitting)	Demand management	conflict resolution mechanisms	Quantity and quality integation	Compliance	water reserves
ENVIRONMENT and NATURAL RESOURCES	Norms and procedure	Control and vigilance	Impact assessment requirements	Ecological flows or demand	Environmental management plans	Watershed management plans
MONITORING	Climate stations	Hydrometric network	water quality measurement	groundwater	processing and analysis	disemination and public access
PLANNING	Inventory and assessment of water	Water Balance plans	national, state or regional planning	Basin planning	Indicative sectorial plans	Project optimization
INSTITUTIONAL	Role definition	Institutional arrangement	Descentralization and users organizations	Public participation administration of	Education and communication law and regulation	Research and development
LEGAL	drafting law	law	cadaster registry	water rights	law enforcement	
STRATEGY AND POLICY	Strategy	Policy formulation	Principles and Norms	Policy statement	Priorities	Policy evaluation

"empty blocks" (zero score) or "weak blocks", the more unsustainable the water management system would be; g-) the order of layers (rows) is important with regards to steps or stages that have to be followed or be ordered – institutional, legal and policy aspects should be at the foundation and influencing result in instability of the system; h-) there is not an indispensable place for layers, since it is possible that in one country institutional progress or monitoring capacities has taken place without an explicit policy statement; i-) size of blocks do not take into account relative importance with respects to other elements and all blocks are drawn of equal size.

In visual terms empty blocks, half filled blocks, scanty areas of the wall, or unsupported "bricks", would all reveal challenges, weaknesses or instability of wall. This situation would be characteristic of an unsustainable water management system. If upper layers, in comparison to lower layers, would be with higher score or having more filled blocks, this will also be considered not to foster stability or sustainability. More precisely said, this reveals that some tools for water resources management have been developed and are used without having a clear vision as to goals and that there are uncoordinated efforts in the water sector. Some developments, like technological progress, having for example an early warning system, and are sometimes partially achieved prior to having well developed organizational capacities or water allocation mechanisms.

As a graphic tool it is considered valid for a participatory exercise. It would be recommended to have knowledgeable or informed participants doing the exercise, but it should not be a requisite to demand great expertise. It would be very useful to generate and stimulate discussions. Guided discussion for group work would lead to consensus on color or numeric score to assign to each element or instrument. Voting and averaging votes is one alternative when strong disagreement does not allow the group to reach a consensus, but this situation should be avoided, since it would reveal confusion among participants regarding the concepts of water resources management. Prior explanation of the purpose of the exercise and on elements and components required for water resources management system would help to diminish potential for such lack of consensus. Informed participants would rely less on detailed explanations before being ready to embark on the use of this simple assessment tool.

To explain the use of the methodology, a concrete case, that of the Dominican Republic, which is best known to the author, will be used with the understanding that it is far from being a model on water resources management. It does provide however, an excellent opportunity to see how real water management is put in place or is not adequately addressed in a developing country. It is intended that examples, both good and bad ones, are pedagogically useful to explain how the boxes are filled or ranked. Concrete and practical cases having a potential for conveying positive messages and clear lessons on water resources management practice have been selected. To give it both substance and shape, general background information and more detailed information on specific issues having some relationship to sustainability or to water management are presented. This however, is not a diagnosis or country assessment exercise.

One advantage with the methodology is that the main subjects of assessment are not the institutions. Instead of being an evaluation of the water sector (the actors), it is more focused on the system and the tools comprising that system, which are necessary for the scheme to work effectively.

5 BACKGROUND INFORMATION ON THE DOMINICAN REPUBLIC

The Dominican Republic is located in the island of Quisqueya, called Hispaniola by Spaniards who settled after 1492, being this the second largest island of the Caribbean (77,914 Km^2). Its territory, occupying the eastern side of the island shared with Haiti, is 48,670 km^2. It has 1,389 km of coast with 70% of cities above 10,000 habitants and 75% of industry and most of tourism. Population is 8.5 millions and density of population is 169.31 hab/Km^2. Human development Index is 0.738 which would have the country in position 97. Average schooling is 5.4 years of education and analphabetism is 10.4%. Contribution to the GDP of agriculture is 11.67% (include agriculture, livestocks, fisheries and forest), crops 4.85% and water and electricity sector 1.82%. Weather is tropical and the island is in the route of hurricanes which frequently strike the country (needs references for all these data)

Water resources are a key factor that has supported the expansion of agriculture of the Dominican Republic, an activity that generates 30% employment and contributes to the economy with 12% of the GDP. Water is also a relief in energy generation with hydropower plants, which though small in capacity, alleviate dependence on imported oil, gas and carbon. Furthermore, tourism which accounts for 30% of all income has been based on natural richness, with particular preference to coastal environmental and natural attractions. There are signs of serious water problems threatening sustainability of development and justified concerns of possibilities of water conditions becoming aggravated if current tendencies in the water use efficiency, soil erosion, pollution of rivers and reservoirs, vulnerability to floods are not attended.

Flora is characterized by a high biodiversity with more than 5,500 species and high endemism (could you define % of endemism?). Such richness must be preserved. Both flora and fauna are affected by land use patterns, extensive cattle raising, pollution by agrochemicals, poor irrigation and drainage practices, deforestation and degradation of environment by pollution of rivers and coastal waters, due to discharge of untreated wastewater.

Payment balance is greatly impacted by the need to import oil used for generation of electricity and fuel. The country does not enjoy a stable electricity supply and several episodes of crisis have made it clear that it is vulnerable. It would be good for the country to expand the hydropower capacity which will be both for improvement of the energy deficit, reducing dependency on imported oil and alleviate the economy.

The uncontrolled growth of water demand, the progressive deterioration of watersheds and pollution of water and degradation of water bodies, with many unsatisfied segments of the population without access to water supply or with only limited access to it, is a risk and challenge for development and is threatening the natural patrimony of the country. On the other hand it is necessary to define strateges for investment in hydraulic and sanitary works to expand coverage of service and make a more efficient operation of existing hydraulic and sanitary systems, improving services in harmony with environment, making a rational use of water, identifying reserves within a growth plan.

Surface water resources potential for the Dominican Republic is estimated to be 19,000 million m^3/year, while potential for groundwater is has been estimated as 2,500 million m^3/year. Rainfall pattern is influenced by eastern winds and average precipitation is 1,450 mm/year, with low value of 422 mm/year and maximum average value of 2,305 mm/year. About 65% of the population has access to water supply services and only 21% have access to sewage systems. Irrigation area is 301,700 hectares, mostly irrigated by gravity by 89,317 farmers. There area 34 dams, 20 of which have a storage capacity above 1 million m^3, for a total storage volume of 1,500 millions m^3 and an installed hydropower capacity of 524.5 MW, annual generation being 1,340 GW – hr/year, which represents 17% of national demand and consumption of energy. These data, and wherever there are data with technical numeric information, needs references.

Infrastructural development, including dams and irrigation systems, has been prioritized in the 3 major basins, the Yaque del Norte, Yaque del Sur and Yuna river basins (Figure 1). As interpreted from Table 2) Yuna is the region with the highest proportion of irrigated land with 15.31 Ha/Km^2 (surface of irrigation system/area of watershed or group of basins) followed by Yaque del Norte with 12.70 Ha/km^2 and Yaque del Sur with 8.17 Ha/km^2.

6 WATER SUPPLY AND SANITATION

Access to the services of water supply systems is 79% of total population. Accumulated design capacity of all water supply systems in the country is 32 m^3/s. Half of the population in the rural area (50%) do not have access to water supply systems. As much as 6,000 communities and 1.565 millions are reported to be without water supply systems. Urban population that is served by water supply systems is 83% of urban dwellers. These figures are to be judged optimistic due to the fact

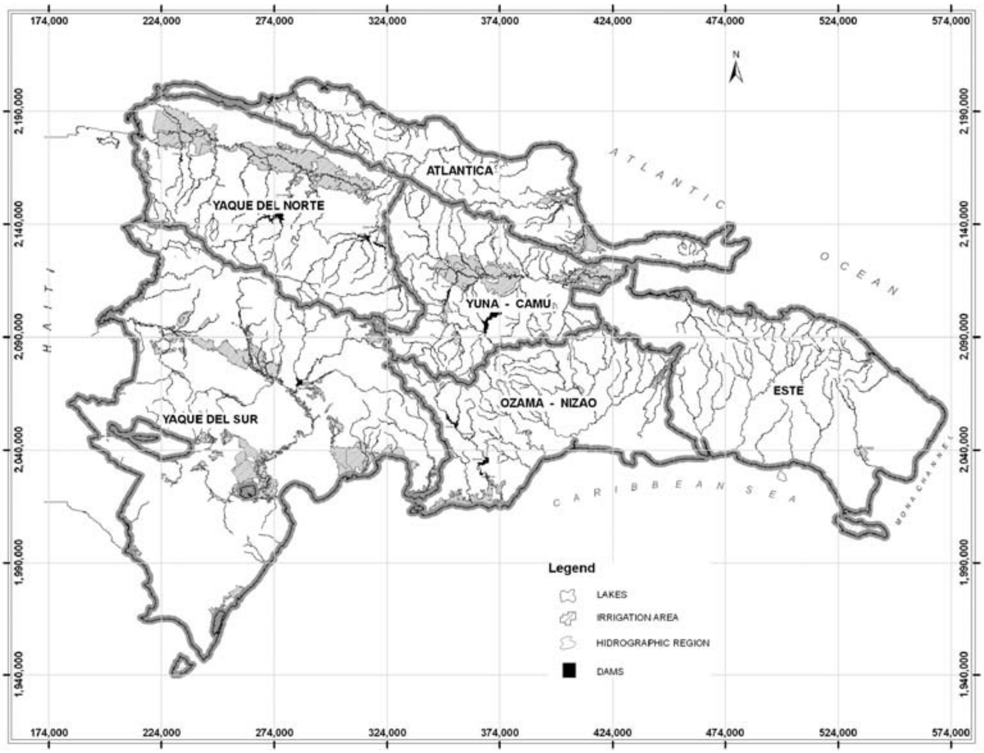

Figure 1. Irrigation areas and reservoirs of Dominican Republic by hydrographic regions.

Table 2. Infrastructural development by regions.

		Dams				Irrigation	
Region	area (km^2)	quantity	Storage capacity (million m^3)	Installed capacity (MW)	Generation (GW-hr/year)	Area (Ha)	(Ha/km^2)
Yaque del Norte	7,788.85	7	818.19	166.00	377.25	98,886.15	12.70
Yuna	5,258.38	4	517.96	68.10	282.90	80,505.09	15.31
Yaque del Sur	15,211.99	2	478.00	19.40	73.80	124,353.41	8.17
Ozama Nizao	6,221.93	4	360.30	204.00	401.11	18,167.74	2.92
Este	8,120.22	0	0.00	0.00	0.00	6,850.25	0.84
Atlántica	5,060.52	0	0.00	0.00	0.00	18,840.27	3.72
Total	47,661.89	17	2,174.45	457.50	1,135.06	347,602.91	7.29

that it includes access to water within 500 m and includes systems which have serious deficiencies in their treatment of water and quality control (CYE, 2003). Service is discontinuous and it is common in many areas that water is not available at the tap during 24 hours. In some areas people receive water only a few days during the week. An estimated 90% of population served by aqueducts have their own (in-house) regulation deposits, which is an indication of that the water supply systems are not dependable.

Almost 30% of water supply aqueducts do not have chlorination treatment. The average index of "potability" (percentage of samples with presence of total coliforms in relation to all samples analyzed) is below 80%. Water corporations of Santo Domingo and Santiago, two largest cities in the country, report higher values for this index (90 to 95%). It is estimated that as much as 60% of the population drink bottled water, which is a booming business with dramatic increase in consumption during the last 10 years. This is due to a combination of growing concern on water pollution, interest on improving healthy habits and a sense of social promotion. In any case, people generally distrust quality of water served by water utilities.

There is a big gap between access to water supply and sewage systems. Only 21% of population has access to sewage systems. The use of latrine and domestic wastewater disposal into septic wells are the sanitary conditions for 74.6% of the population, while 4.4% have do not have access to basic sanitation. This means a significant danger of pollution of groundwater. In some cases wastewater is discharged to the sea, being a source of pollution in beaches. Less than 50% of collected wastewater receives any treatment. Existing water treatment plants operate with serious deficiencies.

The Instituto Nacional de Aguas Potables y Alcantarillado (INAPA), created in 1962, is the State regulator of water supply system and sewage systems in the country, with responsibilities to design, build and operate these systems in all the country except for five municipalities which have created their own corporations, public or state owned, to manage water supply and sewage services (Santo Domingo in 1973, Santiago in 1977, Puerto Plata in 1997, Moca in 1997 and La Romana in 1998). Sewage services are very limited even in the capital city of Santo Domingo. Performance of the water corporations has been rather weak. Cost recovery is too low and subsidies from government support their operation. Only CORAASAN in Santiago reports above 80% of fee collection. Tariffs is low, there are great losses due to low efficiency of the pipe network (60%) to which illegal connections accounts for above 60%.

High inefficiency values are typical in Santo Domingo, were design capacity of all intakes from dams, rivers and ground water, to serve a population of 2.3 millions, is 16.00 m^3/s. This would mean that average water supply is nearly 600 l/d per person, which is more than twice recommended design value for water supply systems in developed countries. It is true that discontinuous service, leaks, and low flow – low pressure operation of network can prove this figure wrong (false), but real waste of water does provoke excess volume of water to run through drains.

INAPA has legal competence for regulation of the rest of corporations, but does not exercise this right. Following this model of detachment of INAPA, eleven other cities have proposed creation of their own corporation with the idea that in this way they will be able to have better services. The National Congress approved the creation of three new such corporations, but these systems are still under control of INAPA for operation.

INAPA currently operates 363 aqueducts, 255 of them serving 1,587,766 inhabitants from 764 rural communities and 108 systems covering 347 towns and cities with a joint population of 2,679,756 (INAPA, 2008). The intake for these aqueducts are 105 by gravity, 224 by pumping and 34 have both gravity and pumps. This factor makes operations costly and/or vulnerable to power failures, which are common. INAPA has currently in operation 111 water treatment plants for purification of water. Only 47 of them are reported to be operating satisfactorily or regularly. There are 28 sewage systems in the area served by INAPA and 15 wastewater treatment plants.

INAPA operates 133 small rural water supply systems. Since 1997 it has been training community organizations to become involved in administration and operation of these systems promoting decentralization. Some have stronger participation and are showing improvement in cost recovery. There are neraly 150 communities operating their own systems, which were built with aid from foundations or development agencies, usually channeled through local non- governmental organizations.

Case studies by Pérez and Segura for INDRHI (2006a, 2006b as well as more recent data from INAPA (2008) in several small water supply systems, have been analyzed examining organizational, financial and operational aspects, trying to extract useful lessons for water supply and sanitation reform and design of rural water supply programs. The main findings from this analysis are:

- When communities are organized and trained, they are able to operate the systems – some were able to expand the service to new areas and improve level of service, transforming and upgrading the systems from public taps to in-house taps after commissioned;
- Strengthening efforts of transfer process and existing community organizations should focus on organizational leadership, administrative and accounting systems, cadastre updating, measurement of flows, control devices and demand management arrangement, training of technical staff responsible for administration and operation, improved management of information (consumption, costs), benchmarking and quality certification, keeping stock and inventory of spare parts and tariffs structure based on consumption – organizational support and educational efforts are key topics and part of the strategy towards sustainability;
- Subsidy is still an important issue in some of them on items such as investment for infrastructure, energy to run pumps, replacement of equipment, but much less than bigger systems in cities;
- The smaller the community payment and fee collection is better;
- Timely and precise invoicing and fee collection mechanisms are key factors to success.
- Use of appropriate technology is important – traditional and conventional water supply systems are too costly solutions – designers are to be trained to design smaller systems (solar energy pumps for small communities are a good solution).
- Promotion strategy and stronger technical assistance should be provided by government agency. (please, reduce all this information and try to be accurate, brief and clear to comply with space)

Achieving water supply targets and millennium development goals is not a technical issue, but rather a financial and a social problem. A project law for the reform and modernization of the water supply and sanitation sector was drafted and has been subject of discussion at the National Congress since 2001. This proposal allows for private investment and awarding of license for private companies to operate water supply systems. The creation of two new entities, if passed by Congress, one acting as rector of the sector and the other would regulate operators. The future of INAPA was not well addressed in this project law, but ideas for its decentralization into 8 regional water utilities companies have been discussed. Even if by provisions of such legal reform and novelties it is made possible to attract private investment, it is clear that with without access to water and the great lack of sewage services, lagging way behind, the government would still need to have a strong participation in construction of water supply and sewage systems.

The water utility corporation of Santo Domingo (CAASD) has engaged private companies to provide commercial management services. Two companies invested in installation of meters and where made responsible for invoicing, fee collection, clients accounting, updating cadastre, incorporating new clients and client – point of contact services for specific areas in the city. In the areas where these companies work, invoicing is done on the basis of consumption (volume of water). Usual practice was at CAASD, and still is for the rest of nation, based on a fix sum of money (bill) per month. Assuming that a family used 30 m^3/month, applied tariff was RD$4.00/$m^3$ and fees were RD$120/month. Income generation has increased from RD$19 million to RD$60 millions per month, with no significant increase in tariffs. Residents in Santo Domingo are starting to save water to cut down the bills, by correction of leaks and control of valves, and CAASD reports important savings in water (Table 3).

7 IRRIGATION

Irrigation contributes to 43.77% of total agricultural production (INDRHI, 2006a and 2006b) in weight (tons) and 88.48% in value (Dominican pesos). Irrigation area expanded from 54,000 hectares in 1973 to 278 hectares in 1995 and it is currently 301,700 hectares, which is about 50% of the potentially irrigable land, taking onto account slopes, soil characteristics and water availability. This increment has not been accompanied by improvement in efficiency of use of water in irrigation

Table 3. Rural Water Supply Systems (reference).

No.	Community	Families	Population	Technical and Financial assitance	Invoicing (RD$/month)	Tariff (RD$/month) per family	Fee Collection (RD$/month)	Fee Collection (%)
1	Vuelta Grande	55	213	CARE, FUNDASUR, LEMBA, Bosque Seco.	1,100	20	1,000	92%
2	Cabeza de Toro	742	4,452	Visión Mundial, PNUD, FUNDASUR, LEMBA, Bosque Seco.	14,840	20	4,500	30%
3	El Granado	97	485	FUNDASUR, USAID	1,335	15	1,200	92%

systems, which is estimate be 25% as average value of combined efficiency in distribution network and field irrigation done by gravity. Irrigation is by far the largest user of water with a demand of 6,429.86 million m^3/year (reference). The cumulative growth of water demand for irrigation, municipalities and industries, including tourism, along with operational losses of water, create great pressure on water, which is evident in some regions exhibiting water deficits and where level of conflicts among users have increased.

Rice, a high water demanding crop, is the main crop in irrigation systems, occupying an area with 144,692 hectares, which is 47.96% of total area covered by irrigation systems. Rice, which is irrigated by inundation of fields, requires 1,572.99 million m^3/year of water (net requirement). Other important crops, as shown in Table 3, are plantain and banana which grow and are cultivated in an area of 43,115 hectares, vegetables with 21,252 hectares, sugar cane with 15,905 hectares (more cane goes under non irrigated agriculture) and beans with 10, 964 hectares.

Important results in water savings, reduction of production costs and use of less fertilizer in rice crop were achieved by Project PROTECAR, the Spanish acronyms for Technological Improvement Project in Irrigated Agriculture. This initiative was financed from 2001 to 2005, by the Japan International Cooperation Agency and the Dominican Government. PROMTECAR experiences offer an alternative with significant achievements reached through training of farmers and motivation to change traditional irrigation habits and adopt both water management and crop management techniques (Table 4).

Water distribution was significantly improved and programmed according to irrigation area and stage of crop requirements. Turns of shifts were organized from tails of the system, guaranteeing of service throughout crop cycle, which resulted in reduction of conflict in water allocation. Less water, less operational costs and less labour (8 hours, before 3 days) are successful exhibits of this Project. Reducing 65% of production costs and increased productivity are stimulating results.

Most outstanding results are that water savings of 44% and 24% reduction on the use of fertilizers. Water consumption was reduced from 25,000 m^3/Ha to 14,000 m^3/Ha. If this would be projected for the entire surface area of irrigation systems servicing rice crop, 692.08 million m^3/year, water that could be made available for other crops or other uses. This value is more than water supply demand for population in the whole country (679.86 million m^3/year) and such savings (692.08 million m^3/year) all by itself would be almost enough to cope with projected increase in water demand in the next 45 years, for the period 2005 to 2050 (704.22 million m^3/year), and along with present water demand be able to satisfy water demand for population in the year 2050 (1,384.08 million m^3/year). This was achieved within a typical gravity irrigation system fed by a canal. On better use of fertilizers, quantity of total nitrogen dropped form 124 Kg/Ha to 94 Kg/Ha. (INDRHI 2006a, 2006b)

The National Institute for Water Resources (INDRHI) is responsible for the management of irrigation systems and as provided by law has a expressed mandate to organize water users and

Table 4. Irrigation Net Water demand by major Crops (reference).

Crop	Region (million m^3/year)							% Vol crop water Requirement/ Total volume for Irrigation
	Yaque del norte	Atlantica	Yuna	Este	Ozama	Yaque Del sur	Total	
Rice	978.44	52.15	533.39	4.65	4.36	–	1,572.99	31.54
Musace as	626.52	5.30	–	0.04	75.11	747.01	1,453.98	29.16
Legums	13.99	0.17	–	0.05	0.95	161.64	176.79	3.55
Vegetables	19.03	0.15	6.69	0.14	4.02	73.95	103.99	2.09
Tuberculus	10.17	0.38	0.31	0.00	1.20	39.16	51.21	1.03
Grass	215.01	0.38	–	–	14.88	327.23	557.50	11.18
Sugar cane	–	–	–	–	13.39	793.32	806.71	16.18
Others	112.66	0.98	10.21	0.16	10.63	128.95	263.59	5.29
							–	
Total	1,975.82	59.50	550.60	5.04	124.54	2,271.25	4,986.76	100.00
% Vol crop water Requirement/ Total volume for Irrigation	39.62	1.19	11.04	0.10	2.50	45.55	100.00	

have them become involved in cleaning and maintaining canals. INDRHI has zonal delegation in 10 Irrigation Districts, but since 1987 has been transferring the administration, operation and maintenance of irrigation systems to the Water Users Associations (WUA). There are 89,317 farmers organized into 178 associations of irrigators, which are in turn organized into 28 Irrigation Boards and three independent associations, covering the totality of irrigated area as of 2006, having in this completed an era in irrigation management transfer, which should be consolidated with additional targets. The irrigation management and transfer program, promoted and conducted by INDRHI, has helped in the creation of WUA and capacity building of these organizations. The WUA have shown significant improvement and positive signs of maturity and development. They decide and establish their own tariffs and collect fees without intervention from INDRHI, making use of funds according to their annual operational plan in operation and maintenance of canals.

WUA has contributed to the elimination of gate delinquency (breaking of locks in gates at irrigation canals and bribery of government appointed personnel at canal gates to access more water than agreed or authorized, were typical situations in the past), to the improvement of operational efficiency in irrigation systems, to improvement of water distribution and irrigation programming, to a better handling of seasonal shortages of water, to reduce conflict among users and tensions between farmers and INDRHI, and to increase cost recovery. WUA seems to be more effective than INDRHI in the collection fee (average increase from 17% to 72%).

Chalas (2007) has proposed to measure impact of WUA's management of irrigation systems by analyzing the soil use index, the evolution of water depth applied in irrigation, and usage efficiency. Improvement in efficiency in the use of water depends on several aspects, some of them being irrigation technology, physical conditions of infrastructure, regulation mechanisms and tariffs. Maturity and stage of development of WUA's also has great influence. Yet from the study of the 3 first mentioned variables, it can be seen some WUA's are achieving good results in terms of amount of water used. In some of the irrigation systems area has increased and they are using less water. From the study of Chalas (Op. Cit) some illustrative data can be arranged to show that less water (water depth in mm) per hectares is being used (Table 5). Such is the case of the Azua Valley WUA, where the main channel operated with 16.00 m^3/s and now runs with 7 to 10 m^3/s, serving the same area. At the Fernando Valerio WUA the irrigation water depth per unit area relationship has been reduced in 88.96%. However, this improvement cannot be overstretched as an evidence

Table 5. Use of Water per Unit Area in selected Water Users Associations.

WUA	Initial year	Reduction in Water Depth (mm)	% of Reduction in Water Depth	Area increase (Ha)	% Increase in Area	Water depth/area (mm/Ha) initial	depth/area (mm/Ha) 2006	Difference in water depth/area (mm/Ha)	% Reduction water depth/area
Fernando Valerio	1992	2,238.10	59.82	21,044.10	260.63	0.46	0.05	0.41	88.86
YSURA	2001	−984.20	−43.24	1,120.69	13.13	0.27	0.34	−0.07	−26.61
UFE	1994	646.90	3.50	1,042.59	41.31	7.32	5.00	2.32	31.71
Mao	1992	−532.20	−22.77	1,304.86	15.60	0.28	0.30	−0.02	−6.21
Nizao – Najayo	1992	1,154.70	18.19	281.58	31.92	7.20	4.46	2.73	37.99
J. J. Puello	2001	−852.30	−109.99	167.70	2.06	0.10	0.20	−0.10	−105.74
Total		1,671.00		24,961.52		0.93	0.53	0.40	43.53

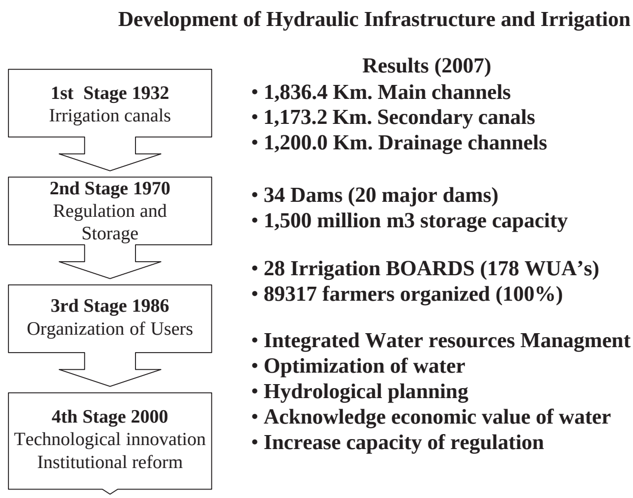

Figure 2. Development of irrigation and water resources management.

of proper management, since reduction of the use of water consumption is sometimes a result of water shortages due to different water allocation than originally foreseen and increase in number of users for example. In the case of Fernando Valerio, soil salinity problems as indicated bellow, are a probable sign of using less water than necessary. If such levels of salinity are confirmed, more quantity of water, more than crop requirements, is necessary for leaching of salts from soil.

Development of irrigation and water resources management is a three stages process (Figure 2). The first was the building of canals which took place since the late 1890's but was specially promoted after creation of the National Irrigation Service in 1932. The second stage is the era of dam development which took of in 1970. In the third stage there is a change in the pattern, shifting from infrastructural development to human and water management development with a milestone in decentralization. This stage, originating in 1987 with the creation of the first two water user associations in Azua and Santiago, is the stage of irrigation management transfer, which has been something INDRHI has done consistently and progressively, even with political changes in administration. A fourth stage is to follow in the 21st century, demanding institutional innovation, implementation of integrated water resources management, consolidation of irrigation management transfer, improvement of efficiency in the use of water, better use of technology, hydrological planning and further improvement in cost recovery and new financial schemes for the water services and infrastructural development.

Aspects to improve are operation of irrigation systems, which needs to be optimized so as to program water distribution as a function of the water demand from crops, installation of measuring and control devices, improve efficiency in irrigation systems and on- farm water management. Administrative and financial reform is needed to carry out development of accounting and management system, build more on more human resources and administrative talent, develop business and commercial culture of the WUA's, make better use of technology for handling cadastre, production and market information systems, introduce economic incentives to promote increase in water use efficiency, change tariff structure to correlate, where possible, invoicing to water consumption, design financial mechanism so that farmers have better access to credit for improving irrigation practice, introduce users certification and auditing instruments, create benchmarking to evaluate progress of WUA's, and optimize operational expending and increase investment among others.

Heavy duty equipment from INDRHI borrowed by the WUA's for their cleaning and maintenance of canals was one key component of subsidy, which has been reduced in some WUAs which bought their own machinery. Even so, there is opportunity for improvements so that WUAs be more self-sustainable with regard to operations and services. Another area where there still is a strong subsidy from the government is the cost of energy to run pumps for irrigation areas, bills which are paid by INDRHI. WUA's should also have to pay INDRHI for the water they use, and although have conceive this in their strategic planning, and even think of introducing fees for environmental services, this does not take place as yet. Tariffs structure need to be addressed, being still too low.

Use of technology and research would be assets to achieve better water resources management in irrigation systems. Increased support to WUA's is needed through effective extension services, oriented at augmentation in land use index, productivity and profitability of agricultural activity, modernized measuring and control structures, improvement of irrigation programming, clean production and environmental management plans.

More strengthening effort is required to consolidate the WUA's in order to reach higher levels of performance. A survey conducetd by CITAR-INDRHI (2008a and 2008b) evaluated WUAs performance. It revealed that WUAs need improvements in formulation of projects, public outreach, strategic planning, and assessment of organizational, administrative, logistic, and operational and financial outcomes and plans.

Other issues of concern to be resolved are water allocation and rights, urban growth, water quality, waste management and soil degradation. Competition from the water supply sector in some areas, having priority in water allocation defined by law, is depriving farmers and WUAs of pre-existing rights with no provisions for compensation.. This has been the case of the Rincón Reservoir where increased water demand for the city of San Francisco in the Yuna basin was committed for the water supply system. Likewise is the case of the Santana Diversion in the Yaque del Sur lower basin, where a new water supply for three provinces was built and affected the water balance in an already water stressed region. Urban growth, progressively expanding into areas under the influence of irrigation systems, has been acquiring lands where agriculture is no longer the use of that land, but rather housing projects. Some water quality problems occur in towns where a canal is passing through or nearby and has become the dumping site for both solid waste and wastewater. Use of agrochemicals is known to affect drainage water which is reutilized as well as groundwater. Salinity in soils caused by irrigation of land with poor drainage conditions in arid and semiarid zones or sub-humid areas irrigated with water with salt content. Such problem was identified in 1993 at the Fernando Valerio irrigation system with a surface area of 19,291.67 hectares. Evaluation rendered that 7,944.98 hectares were affected by salinity and speed of degradation was 200.63 Ha/year. This problem is estimated to be now affecting 10,553.19 hectares, which is 55% of (INDRHI, 2006) with light, moderate or strong salinity problems, but again more research is required for better and more precise assessment of these problems.

8 TOURISM

Tourism contributes to the economy with 7% of GDP and almost 30% of hard currency income (US Dollars and Euros), employment, geographically diversifying job offer, creating opportunity for service and construction of hotels and related infrastructure in the periphery of hotels. Tourism has grown from 5,800 beds in 1980 to 165,571 hotel rooms in 2007, with over three millions tourists visiting the Country each year. Development of tourism, mostly based on the sun – sea – sand recipe, occurs in fragile ecosystems and some areas have been cleared to make space for buildings violating the legal requirement of buffer zone area of 60 meters. Construction of hotels and golf courses have sometimes been done without consideration of environmental and natural values, cutting mangrove, desiccating wetlands and destroying coral reefs with great impact on marine biodiversity. Potential for growth in tourism will depend on water quality, including guarantee of water supply, clean beaches and well managed protected areas (World Bank, 2004). Diminishing water quality of rivers and beaches are a result of poor environmental conditions which is a hazard for tourism stability and potential in Puerto Plata. In the eastern tip of the island, the Bávaro and Punta Cana area, environmental degradation will restrict tourism in the future due to unsustainable water resources management. Overexploitation of groundwater has caused salt intrusion within 20 to 50 km inland. High water consumption of pools, gardens, laundry services and 30 golf courses in the country (350 m^3/year in an 18 holes golf course, where fertilizers are also applied) makes tourism a high water consumer, above demand for industry. Inappropriate discharge of wastewater and solid waste disposals are other challenges which demand specific planning and actions to be addressed in policy and strategy formulation.

Water supply and sanitation services are essential for hotels. Due to poor public water supply services or to location of tourist attractions, hotel developers and operators prefer to depend on their own water supply systems, usually by making wells. Overexploitation of groundwater resources however has been a problem and to avoid saline intrusion at the coast, they have had to drill other wells further from the coast, moving away from brackish water sources. Some hotel establishments are not a good example on wastewater discharge, but have been more and more assuming responsibilities to control pollution, some have been building their wastewater treatment plants, so as to protect rivers and sea. Bayahibe, in La Romana, is working on obtaining the “Blue Flag” award or category, meaning that it is a clean and safe beach, having as well environmental education activities. This is a good signal to join other 40 countries were blue flag is working.

Other demand management initiatives have started to be implemented in hotels, installing water saving devices in their plumbing and garden irrigation systems. Some hotels, as in other countries are inviting guests to contribute in reducing water and energy consumption on such specific habits as less demanding laundry services by les frequent change of blankets on beds and towels in bathrooms. For the more environmental and nature exploring preferences of the eco-tourist, water resources management is also important, since they value clean rivers and forested scenarios for health, mental or spiritually uplifting.

9 WATER BALANCE

Water balance is the accounting or inventory of the hydrologic cycle. Among the influx components of water balance that have to do with availability are natural elements like precipitation and related runoff, groundwater flows and storage in natural lakes or artificial reservoirs and return flow from wastewater that is added back to runoff. Efflux components in the hydrologic cycle are naturally occurring “losses” like evaporation and evapo-transpiration and natural stream requirements. Other efflux components, related to the use of water, are man made abstractions from rivers, lakes, reservoirs and wells for use in domestic water supply, municipalities, industries, livestock production and agriculture.

There are different techniques and approaches to water balance, some relying on comparison between runoff estimates to atmospheric variables like water vapor flux (evaporation) and transport

Table 6. Precipitation and Evapo-transpiration averages by regions in the Dominican Republic.

Region	Precipitation (P) or average rainfall (mm/year)	Evapotranspiration (ETP) average (mm/year)	P – ETP (mm/year)
Yaque Del Norte	1,263.00	1,379.28	−116.28
Atlántica	1,783.10	1,402.33	380.77
Yuna	1,641.40	1,339.11	302.29
Este	1,534.70	1,297.88	236.82
Ozama-Nizao	1,605.50	1,390.05	215.45
Yaque Del Sur	1,028.40	1,517.67	−489.27
Average	1,373.74		

for basins with big areas, continental or global scales, while others employ soil water budget model or a "bucket model" handling precipitation, potential evapotranspiration and soil water-holding capacity. A more commonly used method is the surface water balance study when precipitation and runoff measurements are available and evaporation can be reasonably estimated. For point from precipitation and available runoff stations of interest in the basin where there are no measurement stations, estimates of runoff from precipitation and available runoff stations, by more simple means or by more elaborate calculation using precipitation – runoff models can also be used (Reed et al., 1997).

Employing a hydrologic planning terminology, a water balance is the quantity of water available in a given location or region once water demands of different sectors have been met. It is an arithmetic net result of subtracting uses from inflows. This type of water balance, or comparison of total annual volume of surface water and groundwater available to total volume demanded for consumptive use in given regions or basins, is simply the difference between available water and demand and is a general – on average – description of the situation of the water availability in a given basin or region.

The water balance based on climate balances, uses an equation derived from the mass conservation principle ($Q = P - ETP$) (INDRHI 2006a and 2006b) (Table 6). The surface water balance as calculated in 1994, had some geographic limitations, since it is a general vision interpreting inflow as mean discharge at exit point of basin and outflow as accumulated water demands, the latter occurring at different specific points throughout the basin, not considered in their spatial distribution. Other inaccuracies requiring adjustments are that stored water in reservoirs is not taken into account and the fact that return flow from wastewater is also part of measured discharge at downstream – extreme – point. Average discharge values would grow progressively downstream in the basin unless abstractions take place along the river. To have a real water balance at the intake for a water supply system or an irrigation system, discharge value at that point would have to be determined.

Estimates for water demand for municipalities are based on population statistics and per-capita water consumption, distinguishing the urban from the rural area. Ecological demand has been estimated as excess water flows in rivers exceeding the 95% occurrence, either calculated from percentile values or from flow duration curves. Industrial demand comes from amount and types of industries with corresponding water demand estimated for each one of them at their location. Water demand for tourism has been estimated on the basis of existing locations of hotels, number of rooms and level of occupancy throughout the year and the water consumption estimates per tourist. Records of existing livestock population have been examined along with estimates of water demand to raise different types of animals to arrive at values for water demand for cattle (88.33% of total), sheep, pigs, goats, poultry, rabbits and horses. Water demand for irrigation in each irrigation district takes into account cultivated area, the crop demand month by month, and efficiency in the use of water (a global efficiency which includes efficiency of channels, application and varies from

Table 7. Water demand by region and sector in 2005.

Sector	Water Demand 2005 by Region (million m^3/year) Yaque del Norte	Atlántica	Yuna	Este	Ozama – Nizao	Yaque del Sur	Total	Percentage of total demand (%)
Water supply	107.08	42.69	81.63	64.14	312.67	71.65	679.86	5.85
Irrigation	2,380.73	78.05	882.53	7.11	190.03	2,891.41	6,429.86	55.30
Livestock	86.74	84.28	93.17	99.95	85.73	88.36	538.23	4.63
Ecological	216.38	323.64	991.39	420.38	587.40	1,136.41	3,675.60	31.61
Industrial	40.65	15.99	30.61	24.96	119.60	27.29	259.10	2.23
Tourism	2.15	13.20	0.82	22.07	4.82	0.65	43.71	0.38
Total	**2,833.73**	**557.85**	**2,080.15**	**638.61**	**1,300.25**	**4,215.77**	**11,626.36**	**100.00**

Table 8. Projection of water demand from 2005 to 2025.

Sector	Water Demand (million m^3/year) 2005	2010	2015	2020	2025
Water Supply	679.86	760.76	843.8	928.5	1,013.08
Irrigation	6,429.85	6,429.85	6,429.85	6,429.85	6,429.85
Livestock	538.24	835.8	1,133.35	1,430.91	1,728.47
Ecological	3,675.60	3,675.60	3,675.60	3,675.60	3,675.60
Industrial	259.1	586.07	659.88	716.8	793.02
Tourism	43.71	94.29	124.8	165.98	221.57
SUB-TOTAL	**11,626.36**	**12,382.37**	**12,867.28**	**13,347.64**	**13,861.59**

Table 9. Projected water demand for 2025.

Region	Water Demand (million m^3/year) Water Supply	Irrigation	Livestock	Ecological	Industrial	Tourism	Total
Yaque del Norte	158.66	2,380.73	285.12	216.38	148.79	1.90	3,191.58
Atlántica	63.31	78.05	282.65	323.64	56.57	10.02	814.24
Yuna	123.51	882.53	291.54	991.39	58.33	0.94	2,348.24
Este	97.76	7.11	298.32	420.38	47.71	197.50	1,068.78
Ozama-Nizao	461.30	190.03	284.11	587.40	429.77	10.68	1,963.29
Yaque del Sur	108.53	2,891.41	286.73	1,136.41	51.85	0.53	4,475.46
Total	**1,013.07**	**6,429.86**	**1,728.47**	**3,675.60**	**793.02**	**221.57**	**13,861.59**

10% to 32% according to conditions of irrigation systems and type of irrigation practiced in each one of them).

Estimates from the updated water balance (INDRHI – GRUSAMAR, 2007) providing information on water demand by sector and region are shown in Table 7. Results from projection of water demand by sector and regions, from 2005 to 2025, are shown in Tables 8 and 9, each with their respective growth expectation, except for irrigation where it is supposed that savings due to efforts of investment for improvement of infrastructure, modern technology for on – farm irrigation, and

Table 10. Water Availability in surface flow, groundwater, storage in reservoirs and reuse.

Region	Available Surface water (million m^3/year)	Potential groundwater (million m^3/year)	Storage (million m^3/year)			Reused water (million m^3/year)		
			Reservoirs (Dams)	Small reservoirs	Total	Irrigation	Water Supply	Total
Yaque Del Norte	2,905.46	181.00	786.18	0.53	786.71	463.27	85.66	548.93
Atlántica	4,634.73	216.00	0.00	0.00	0.00	9.11	34.15	43.26
Yuna	3,600.96	236.00	550.33	0.05	550.38	83.98	65.3	149.28
Este	3,125.95	758.00	0.00	0.00	0.00	5.03	51.31	56.34
Ozama-Nizao	4,459.08	457.00	314.41	0.05	314.46	14.03	250.14	264.17
Yaque Del Sur	4,771.51	621.00	426.54	0.42	426.96	442.73	57.32	500.05
Total	**23,497.69**	**2,469.00**	**2,077.46**	**1.05**	**2,078.51**	**1,018.15**	**543.88**	**1,562.03**

improvement of operational techniques in irrigation systems will keep demand at same level even with limited expansion of irrigated area.

Available surface water is 23,497.69 million m^3/year and has been quantified from available records of water flows (discharges in m^3/s) from the existing network of 85 flow measurement stations distributed in the different basins of the country. Specific discharge values, calculated as a type of average of m^3/s per km^2 of surface area of basin for each basin, combined with precipitation records are used to define discharge values at given points and for the basins with limited measurement. In the case of groundwater, base flow, aquifers recharge values and potential for groundwater extraction are considered, having as a result that the total available water from aquifers is 2,469 million m^3/s, while recharge value is 4,161 million m^3/year. Reservoir storage capacity in 34 existing dams is 2,077 million m^3. Table 10 show available water data from updated water balance by INDRHI – GRUSAMAR (2007). Table 11 compares water availability with population to estimate per capita availability of water with average flows and with a firm guarantee of supply, considering this to be estimated as 80% probability of occurrence of flows records.

While the Country's general average figures is 2,628 million m^3/hab/year, it is evident from data in the above tables that the Ozama – Nizao region, where the major city of Santo Domingo with high concentration of population is located, exhibits stressful signs of shortages, with a per capita availability of 1,251 m^3/hab/year counting on average flows. This would be classified as a "water stress" condition applying the Falkenmark – Widstrand Index. If a firm guarantee condition would be considered, an average country value of 960.73 m^3/hab/year would have it classified as a "chronic water problem" and the 391.53 m^3/hab/year for the Ozama – Nizao region would mean an absolute scarcity. This already existing critical situation for some regions can still become considerably worse when water demand increase in the future.

Water balance figures for the Dominican Republic are shown in Tables 12 and 13 for the year 2005 and for projected increase in demand for 2025. Applying a scarcity index or degree of pressure index suggested by OMM/UNESCO (OMM No. 857) the country faces a strong pressure on water as shown in the tables for each region.

These results have not taken into account stored water in reservoirs, so there probably is a 2,078.51 million m^3/year margin depending on runoff regimes nor reuse of water, if properly treated, of 1,562.73 million m^3/year. Another favorable margin would come from excess flows during great floods, which are normally not measured in existing stations and consequently not appropriately taken into account. Nevertheless, the situation is critical for the Yaque del Norte and Yaque del Sur basins, where the 97.53% and 88.35% of the total available water, respectively, is already being used. WMO degree of pressure index of WMO (considers strong water pressure above 40%) should

Table 11. Per capita water availability.

No.	Region	Availability (Million m^3/year)	Potential for Groudwater (million m^3/year)	Total surface + groundwater available (million m^3/year)	% of Total available water	Population	% of population	Avalilability per capita (m^3/hab/year)	Firm water availability – 80% occurrence (million m^3/year)	Per capita availability with firm gurantee of supply
1	Yaque del Norte	2,905.46	181.00	3,086.46	11.89	1,478,113	14.96	2,088	789.00	533.79
2	Atlántica	4,634.73	216.00	4,850.73	18.68	661,581	6.69	7,332	1,245.00	1,881.86
3	Yuna	3,600.96	236.00	3,836.96	14.78	1,579,036	15.98	2,430	1,850.00	1,171.60
4	Este	3,125.95	758.00	3,883.95	14.96	919,613	9.31	4,223	1,712.00	1,861.65
5	Ozama-Nizao	4,459.08	457.00	4,916.08	18.93	3,930,708	39.78	1,251	1,539.00	391.53
6	Yaque del Sur	4,771.51	621.00	5,392.51	20.77	1,313,040	13.29	4,107	2,359.00	1,796.59
	Totals/ Average	**23,497.69**	**2,469.00**	**25,966.69**	**100.00**	**9,882,091**	**100.00**	2,628	9,494.00	960.73

Table 12. Water balance for 2005.

Region	Availability (million m^3/year)	Demand (million m^3/year)	Water Balance (Offer – Demand in million m^3/year)	Demand/Availability	
				Percentage (%)	Degree of Pressure
Yaque Del Norte	3,086.46	2,833.72	252.74	91.81	Strong
Atlántica	4,850.73	557.84	4,292.89	11.50	Moderate
Yuna	3,836.96	2,080.15	1,756.81	54.21	Strong
Este	3,883.95	638.61	3,245.34	16.44	Moderate
Ozama-Nizao	4,916.08	1,300.26	3,615.82	26.45	Medium
Yaque Del Sur	5,392.51	4,215.77	1,176.74	78.18	Strong
Total	**25,966.69**	**11,626.35**	**14,340.34**	**44.77**	**Strong**

Table 13. Water balance for 2025.

REGION	Availability (million m^3/year)	Demand (million m^3/year)	Water Balance (Offer – Demand in million m^3/year)	Demand / Availability	
				Percentage (%)	Degree of Pressure
Yaque Del Norte	3,086.46	3,191.58	−105.12	103.41	Strong
Atlántica	4,850.73	814.24	4,036.49	16.79	Moderate
Yuna	3,836.96	2,348.24	1,488.72	61.20	Strong
Este	3,883.95	1068.78	2,815.17	27.52	Medium
Ozama-Nizao	4,916.08	1,963.29	2,952.79	39.94	Moderate
Yaque Del Sur	5,392.51	4,475.46	917.05	82.99	Strong
Total	**25,966.69**	**13,861.59**	**12,105.10**	**53.38**	**Strong**

consider classifying this situation as critical rather than strong. Forecast in the Yaque del Norte region, very important for agricultural production, with high population and high water demand for irrigation (second largest in both) will be of deficit. Another region with water problems is Yaque del Sur, a poverty stricken region and therefore important for poverty alleviation policies, also having the largest demand of water for irrigation (2,891.41 million m^3/year), which represents 44.97% of total water demand for irrigation, and the second lowest water supply demand for population. Other regions that have favorable conditions according to the above results and tables, are also facing problems, like the Eastern region where most of the water for domestic, agricultural and tourism comes from wells and have absolutely no storage capacity, since there is no dam in that region. In the case of tourism, with all management of tourist attractions and facilities is concentrated at the coast, and projected to require in the year 2025 as much as 197.50 million m^3/year, or 89.13% of total water demand for this sector (221.57 million m^3/year), over exploitation of aquifers is degrading groundwater and making it difficult.

What will likely happen in the future, without adequate water allocation mechanisms, no demand management tradition, inefficient use of existing water infrastructure and proper water resources planning, is that water needs for ecological and agricultural purpose will suffer. As pointed out before such episodes are already taking place in certain locations and impact on natural resources and environment, with disregard of ecological flows and no control of pollution in water bodies, is putting at risk sustainability of many economic activities and even safe drinking water and its supply for population.

It is absolutely necessary to modernize irrigation infrastructure, improve efficiency in the use of water in all sectors, invest in better technology, implement demand management policies and techniques, strengthen institutions for regulation of water resources, develop research capabilities, water information management systems and plan for the future. Even with moderate increase in efficiency Storage capacity in reservoirs can mean an important safety margin. Countries like the United States of America and Australia have 5,000 to 7,000 m^3 of water stored per inhabitant in reservoirs, while Ethiopia only has 70 m^3 per person (references). In the Dominican Republic, increasing this value from actual 210.20 m^3 per person (only 17.9% of total available water is from regulated sources) and provide that environmental and social assessments and feasibility studies are carefully done, can mean an important difference and improvement of water security and avoid precarious conditions.

More studies are necessary in order to acquire more knowledge in the availability and needs of water. Wise investments and capacity building for hydrologic network, establishing modern measurement and control structures and devices of flows in water supply and irrigation systems, environmental education and water education for the population, and training of human resources, in particular in hydrology and better use of information technology (hydroinformatics) are advised. A revision of investment policy in infrastructure should be addressed, not to promote more investment in creating more capacity of water intake to cope with demand increase in existing towns and cities, as well as for new or expanded irrigation systems, without improvement on efficiency in distribution network, reduction of unaccounted water and illegal users and better tariff structure. Water allocation according to a basing planning will be useful to avoid improvising projects after project.

10 ENVIRONMENTAL AND WATER QUALITY ASPECTS

Some have compared evaluation of flow of water in a basin and its quality in relationship to other natural resources and environmental conditions in the watershed, with blood test on human bodies which serve to diagnose health conditions and detect health problems as if rivers were arteries and veins of the basin. Among many natural resources and environmental aspects that can be reflected in water courses there are physical, chemical and biological pollutions of water due to discharge of wastewater and solid waste, deforestation and erosion problems and inappropriate handling of mining residuals. Important aspects like evaluation and sanitary inspection for innocuity and acceptability of water supply and examination of physical, biological and chemical characteristics of water are basic for pollution control of water supply systems. Water quality monitoring and vigilance are essential tasks for adequate water resources management.

Laboratory facilities and monitoring programs are provide by INDRHI and other institutions.This facilities serve for quality and pollution testing. INDRHI's water quality monitoring has been carried out with irregularity for major river basins like Yaque del Norte, Yaque del Sur, Ozama and Higuamo. Measurement network has been well conceived and properly designed, but better logistics and improved operational capabilities are needed to carry out measurement and analysis campaigns more regularly. Initiatives to install floating gauges with transmission capacities via satellite for measurement of water quality in reservoirs and fixed river stations have not been successful. These would prove to be quite useful in treatment plants for water purification in water supply systems, since treatment can be adapted according to specific conditions of water coming from reservoirs or measured at rivers upstream and optimization of quality and treatment costs would be more probable. Analytical capacity of existing facilities and programs have been limited to basic parameters and management of information has also been limited to specialists engaged in the programs with access to the public somewhat restricted.

Proper assessment of water quality faces obstacles due to great voids in information and lack of identification of pollution sources, making it difficult to develop, calibrate and run predictive water quality models (SEMARN, 2001). This in turn, also makes difficult the evaluation of alternatives for the management of domestic and industrial effluents and for non-point pollution generated by wastewater runoff from agricultural lands and urban areas. Such stage of development in water quality control would improve both certainty and precision and achieve a better understanding of the effects of possible measures to counteract or lessen impact of pollution on health, environment and water quality.

Regarding norms they are considered updated and complete, although some recommendations from World Health Organization guidelines to include tests for fecal coliform (thermal-resistant) to evaluate risks on health due to transmission of intestinal diseases should be integrated, as well as some inorganic parameters. Laboratory capacities should improve in tests for inorganic parameters with significant health implications (nitrates and fluorides) and parameters like pesticides trihalomethane and heavy metals (INDRHI – GRUSAMAR, 2007). Revising norms for each specific use of water and development of indicators are necessary actions.

Potability index (percentage of samples with negative results for presence of coliforms) in water supply systems, analyzed during the 1992 – 2002 period, shows an increase from 1992 to 1994 but dropped to 77.6% in 1996. Last official figure in 2004 is 73.6%, which is far from the 95% target established in norms for human consumption. Some water supply systems are off course doing better than others with index values varying from 40.0% to 96.0%. Only 61.4% of water supply systems apply chlorination with adequate disinfection elements for purification processes and the situation for rural water supply systems is poorer with only 47.4% of existing systems doing disinfection by application of chlorine (Abreu, 2004). Water utility companies (state owned) do have infrastructure with 143 treatment plants, but with serious operational deficiencies and poor quality control.

The incidence of diarrhea has been studied in comparison to an index of quality of water supply service, considering population served by water supply system (easy access to water), access to sanitary – sewage -service (adequate excreta disposal) and water quality (percentages of water supply systems with chlorination systems). Relationship between the prevalence of diarrhea diseases in demographic and health survey of 2002 (ENDESA 2002) for children under five years of age and this indicator of quality of service are compared (Abreu, 2002). Results indicate that where more than 40% of population use water from aqueducts for drinking and quality index are lowest, diarrhea incidence is above 16% in children under five years. Where a greater percentage of the population is using bottled water for drinking, the incidence of diarrhea is less. People are gradually and increasingly changing their drinking water habits with a clear preference for bottled water. Percentage of population using bottled water for drinking varies from region to region, with a range of 16.2 to 77.9%. Ironically, where the quality of water service index is higher, people are depending less on the water from tap for drinking and do not used it for consumption. This manifestation of distrust in water quality from aqueducts is due to poor performance of water supply services and increased awareness of health implications, as well as new life patterns related to interest in a better social standard.

Monitoring water quality parameters like dissolved oxygen is important due to the fact that living organisms depend on oxygen to sustain their metabolic processes which produce energy for growth and reproduction. Bacteriological and microorganisms control tests are also important, particularly to control discharge of untreated water from urban wastewater and drainage into rivers, so as to avoid bacteriological pollution from fecal origin and transmission of infectious diseases, making water unsafe even for direct contact with body and submergence.

Microbian organisms are indicators of fecal pollution. Fecal coliforms are evidence of pollution from urban wastewater discharged into rivers, while total coliforms are indicators of insufficient treatment process of water. Another usual test is for *Pseudomona aeroginosa*, a pathogenic germ that can affect children, old aged and weak individuals. Inorganic components nitrites and nitrides, ions part of the nitrogen cycle, could be indicators of pollution due to inorganic fertilizers and sodium nitrite from food conservatives. Concentration of nitrates in water might be due to drainage water from agricultural lands and drainage runoff from open garbage disposal in open sites.

At reservoirs, monitoring water quality parameters is important so as to know the trophic level (conditions of eutrophication, a natural process of nutrient enrichment in water bodies, having as main indicators nitrogen and phosphorus). Systematic limnology studies (physical, chemical and biological characteristics of rivers and freshwater lakes) are recommended.

Main problems in the Dominican Republic related to environmental degradation and pollution of rivers and aquifers are due to solid waste and wastewater disposal from municipalities, agricultural lands and industries, and erosion and sediment transport in rivers due to watershed problems. Main pollution sources in Ozama, Yuna, and Yaque del Norte rivers are related to metallurgical , food elaboration, textiles, alcoholic and non-alcoholic beverages industries.

In the Yaque del Norte river basin (area 7,070 km^2 and length 207 Km) chemical characteristic of water at the upstream of the Tavera Dam is good (meet the standards?) for main uses. Microbiological pollution however is restrictive of use for recreation and direct contact. It is important to measure pesticides and agrochemicals due to intense cultivation of vegetables and flowers in Jarabacoa, to monitor risks of these elements to be transported with drainage runoff. Downstream of the Tavera Dam, (refer to Figure 1) an intake of major irrigation system (UFE), shows low salinity and sodium. Electro-conductivity, chlorines, total dissolved solids are dramatically incremented along the Las Charcas (160 μS/cm) – Otra Banda (220 μS/cm) – Quinigua (756 μS/cm) – Navarrete (704 μS/cm) – Jinamagao (796 μS/cm) reach with a clear effect of discharge of wastewater from the city of Santiago and withdrawals for irrigation system becoming a factor for increasing concentration of pollutants. Salinity of water is caused by agricultural drainage and discharge of wastewater from urban areas in Santiago with measurement at drainage flows between 1,000–1,350 μS/cm. Due to water from rivers Ámina (mean flow 10 m^3/s) and Mao (mean discharge 22 m^3/s), which are among the most important tributaries of the Yaque del Norte, water quality parameters improve downstream, but still keeping relatively high electro-conductivity values between San Rafael station (633 μS/cm) and Montecristi (503 μS/cm). Total dissolved solids show a similar behavior along the basin. Dissolved oxygen is above required level of 5 mg/l, all throughout – in all stations – the basin, which means that the Yaque del Norte river has favorable conditions for aquatic life. Favorable conditions are also found for nutrient content (nitrogen and phosphorus). These data needs technical references.

An important microbiological pollution has been detected in the Yaque del Norte River upstream from the Tavera reservoir due to wastewater from town of Jarabacoa and other communities in its vicinity. Total coliforms increase from 60 to 4,300 NMP/100ml at La Cienaga de Manabao station to 24,000 NMP/100 ml at Jarabacoa and above 110,000 NMP/100 ml at Jimenoa river in Hato Viejo. Measurement in other tributaries like Bao at La Placeta station has 9,300 NMP/100 ml and Jagua rivera t Higüero station (9,300 NMP/100 ml) and highest concentration at Jánico river above 110,000 NMP/100 ml due to discharge of domestic wastewater into the river and lixiviates from solid waste. Downstream of the dam the situation is better until the city of Santiago with colifroms concentration rising aguan above 110,000 NMP/100 ml due to wastewater discharge. At Navarrete is again 21,000 NMP/100 ml, and Jinamagao above 110,000 NMP/100 ml keeping this level of pollution until it reaches Montecristi. Health risks especially when no disinfection of water is carried out are high.

Vertical stratification profiles of Electro-Conductivity and Total Dissolved Solids variations with depth have been analyzed at the Tavera and Bao reservoirs in the Yaque del Norte river basin, with significant variation of approximately 5 μS/cm. Termoclines varied continuously from water surface to bottom between 24 and 21 degress celcius. Oxyclines (variation of Dissolved oxygen with depth) showed a different behaviour, with the Tavera reservoir showing progressively diminishing values form surface to bottom, while at the Bao reservoir there is clear jump of the oxycline at a depth of 5 meters, where it reaches anoxia levels and anaerobic conditions were indicated by concentration of sulphur and characteristic odour of methanogenesis. This reservoir is used for water supply regulation for the city of Santiago, second largest in the country. The limit of photic zone (transparency of water) was less than 2 meters (INDRHI – GRUSAMAR 2007).

Urban and industrial discharges of the city of Santo Domingo, since colonial times located in the estuary of the Ozama river (area 2,686 km^2 and length 148 Km) contributes to organic matter and a low concentration of dissolved oxygen, less than 1 mg/l in fresh water area and area of mixed fresh water and saline water. Topographical conditions which influence backwater effects and DBO_5 concentrations above the levels of for protection of aquatic life, generates septic processes. Dissolved oxygen is higher in upper watershed (5 mg/l) and careful study of salt wedge behavior was necessary for design of new intake facilities for the Water supply system of Santo Domingo. The Ozama river, due to dissolved oxygen, nutrients loads, heavy metals and other parameters which are indicators of pollution, is considered an ecosystem in crisis (González and Gutiérrez, 2000). It is the major polluter of littoral waters providing high quantities of organic matter, greases, hydrocarburs, heavy metals and micro – organisms. All stations along the Ozama river have higher values than allowed by norms for recreation and conservation of aquatic life.

As can be expected, microbiological pollution is greater in the upper part of the Ozama basin with is an evidence of human intervention (revealed by analysis of coliforms and total coliforms, biological indicators of discharge of fecal matter into water bodies which was registered in all tests for all stations. In the estuary presence of heavy metals can be explained by activities related to the harbour, loading and unloading of ships, and abandoned wrecks.

Haina river, bordering the western side of the city of Santo Domingo, also has a complicated scenario in terms of water quality, affected by activities of several industries, including of the biggest port of the country and the oil refinery. Surface dissolved oxygen (4.4 mg/l) is bellow the limit for aquatic life protection in all stations. It is this basin that we find a fourth ranking for a world record for lead pollution, which is affecting a community of nearly 3,000, specially children. Source of such high lead concentration is a car battery recycling factory, whose residuals make the name of the town, "*El Paraiso de Dios*" (God's Paradise), a blasphemy.

The impact of mining activities (Gold, Nickel, Ferro-nickel, Aluminum and Bauxite) at the Yuna River basin (area 5,235.63 Km^2) has raised concerns on possible presence of cyanide, trophic level of reservoir in Hatillo, and other forms of pollution in streams flowing through mining areas of the Yuna river basin. This has motivated studies with results confirming acidity of water, which is characteristic of lixiviation process of soils in areas of open mining and high concentration of dissolved salts, evidenced by electro-conductivity values above 1000 μS/cm, and higher concentrations than allowed of heavy metals (Nickel, Iron). Anoxia conditions were detected as of 10 meters depth at the reservoir. Low concentration of cyanides were found, which is dangerous for animals and humans (0.05 mg/l CN- bellow allowable Standard for drinking water, irrigation).

Another concern in the Yuna basin is salinity problems in agricultural land in the lower part of the basin near the coast, due to inflow of salt water intrusion via natural and man made drainage courses. Test results indicated medium salinity levels for the Limón del Yuna irrigation area, making still possible to use this water for irrigation, provided there is a moderate degree of leaching and consideration of possibilities to promote plants which tolerate some level of salts. Electro-conductivity and dissolved solids are within admissible values. Systematic measurements of salinity are necessary to analyze penetration of salt wedge into streams and how this can affect losses in rice crops (Figure 3).

One other issue that demand attention is the sediment transport of the Yuna river discharging into sea at the Samaná bay, where this is affecting marine flora and fauna, threatening biodiversity, fishing and tourism.

In the San Juan River of the Yaque del Sur basin (area 4,800 km^2 and length 183 Km), dissolved salts indicated by high concentration of electro-conductivity has to be monitored since it can affect potential of productivity of irrigated crops, due to poor drainage of agricultural lands.

Dissolved oxygen values , which is one of the most valuable pollution tests due to the fact that living organisms depend on oxygen to sustain their metabolic processes which produces energy for growth and reproduction, has bellow 5 mg/l in some areas for San Juan river, but generally sufficient to promote fish and in the rest of the basin.

In given specific points of the basins untreated water from urban wastewater and drainage is causing bacteriological pollution from fecal origin which is dangerous for human consumption, direct contact with body and submergence. Results showed values of fecal coliforms between 2,300 and above 110,000 NMP/100 ml in all stations, which is an important sign of microbiological pollution. The river receives urban discharge when passing through city of San Juan and increases organic matter and microbiological pollution and lixiviates of garbage deposits on river banks have an important effect. Monitoring is to be carried out also during low flows – dry periods – when pollution conditions might be worse. Use of agrochemicals and pesticides is also to be monitored.

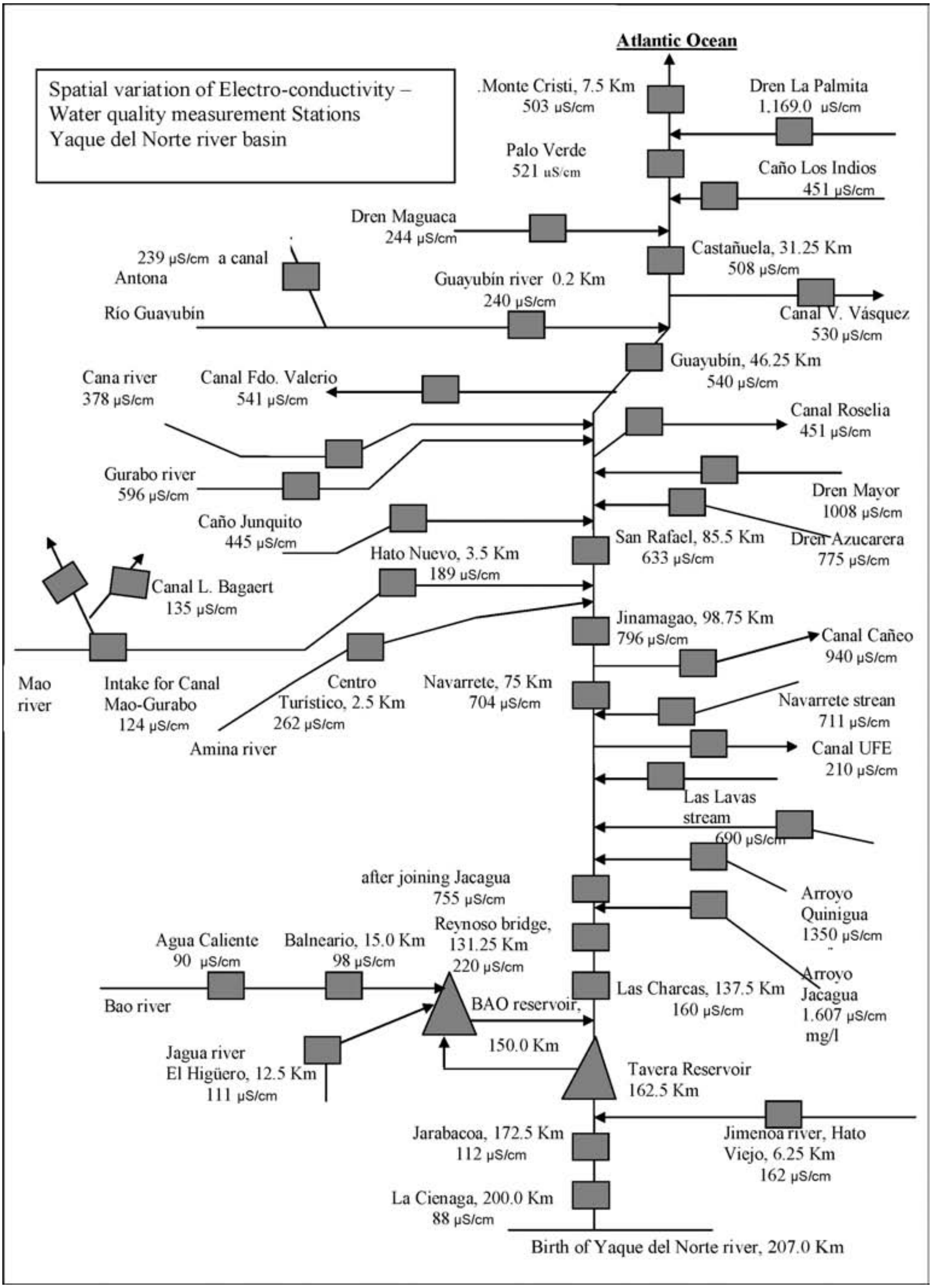

Figure 3. Spatial variation of Electro-conductivity along Yaque del Norte River (INDRHI, 2007).

Groundwater quality has been measured in 395 points in the southern part of the country, during 4 campaigns (1997 to 2000) with analysis of major ions. Samples from 40 wells used for water supply was made determining physical, chemical and microbiological analysis (total and fecal coliforms, enterococos and aerobios mesofilos), monitoring main indicator of pollution due to liquid of biological origin. Consistent presence of fecal coliforms, enterococus and estafilococus, which according to the norms should be absent, has been detected with quantities more or less of concern and some pseudomonas were found in some simples. More studies are required but unfortunately little follow up has been given to these stations. During 2001 to 2003, other 260 points for groundwater quality were studied in Northern part of the country in a one year testing for chemical and physical characteristics, including presence of heavy metals and pesticides. Results indicate that 29% of samples had laboratory results above allowable standard for human consumptions in different parameters (calcium, magnesium, sodium, chlorides, sulfates, ammonium, hardness and total solids).

Although results of bacteriological analysis are only considered to be preliminary and of seasonal effects, again coliform presence of NMP/100 ml reaches was detected and some stations had values above 1,100 NMP/100 ml. Pollution of groundwater due to Nitrogen possibly coming from agricultural activity or from wastewater from domestic sources and industry, have been found in some of the samples (5%) of samples in the Cibao Valley, Constanza and Cordillera Septentrional, with values above 45 mg/l, registered. Pollution due to pest control products is one of greatest concerns. Mineral and medicinal potential of springs was also explored.

Mineral waters and thermal patrimony of spring waters was confirmed in some sites with recommendations for deeper analysis of their chemical properties. Possible commercial value or exploitation of thermal waters is feasible especially for medicinal and cosmetic purpose.

Deforestation and soil use conflicts, manifested also in erosion and consequent sedimentation, are among main degrading factors affecting watersheds. Results from satellite imagery technology indicate that there is an alarming loss of vegetable cover, from 14.1% in 1980 to 27.5% in 1996, according to the USDA/Michigan State University cooperation programme for inventory and use of vegetable cover in the Dominican Republic (LandSat). Most studies confirmed deforestation with figures for rates of loss of forest cover up to 26,400 ha/year and a progressive desertification process from western border extending to the eastern side.

Some recent studies however question that traditional evaluation and mention increase of forest cover (ABT, 2002). While some discussions are currently going on for confirmation of this favorable change in trend, some probable causes are to be recognized including efforts to increase protected area (from 9 locations which covered 4.2% of national territory in 1980, to 19 areas covering 11.2% of country surface in the 1990 decade, to 70 areas covering 19.5% of the territory with the passing of environmental and natural resources law in the year 2000, to 86 areas covering 22% of land with provisions of a specific law on protected areas – SEMARN, 2004). Implementation of this regulation is a real challenge and objectives biodiversity conservation need to be clarified. Other possible reasons for a slow down on deforestation or stabilization of forested areas are reduction of migratory – subsistence – agriculture in upper parts of the watershed and increased migration from mountain areas to urban dwellings and costal areas. Most of the watershed management projects, due to small scale, no baseline studies and/or no monitoring system nor impact measurement, as well as prevailing unavailable information, cannot exhibit concrete impact on reduction of erosion and pollution (INDRHI, 2006a), nevertheless having good impacts promoting organizational capacity building at community level, achieving general educational goals regarding conservation of natural resources and attaining important rural – infrastructural – development objectives.

Estimates for erosion rates do maintain an increase however, with figures varying from 20 to 500 Ton/Ha per year for loss of soils. Many reports are loaded with estimates but there is little support for most of them. Calculations for Yaque del Sur river basin resulted in estimates of 184 Tm/Ha-year. Nagle (2005) using radioactive isotopes (cesium 137), estimated plots in hill slope erosion in 14 sites of the Nizao river basin, determining erosion rates in the 1963 to 2005 period, varying from 6.7 to 59 Tm/Ha-year and average 27 Tm/Ha-year. Applying Universal equation for loss of soils for the Nizao watershed would yield a higher value of 125 Tm/Ha-year. If accumulated sedimentation

Table 14. Reservoir Sedimentation.

No.	Reservoir	Initial Storage capacity (million m^3)	Current Storage Capacity (million m^3)	Volumen of Accumulated Sediments (million m^3)	Percentage of Reduction in Storage capacity (%)
1	TAVERA (Feb 1993)	173	137.1	35.9	20.75
2	VALDESIA (2006)	186	137.1	48.9	26.29
3	SABANETA (May 1999)	76.5	63.1	13.4	17.52
4	SABANA YEGUA (Dec. 1992)	479.9	422.3	57.6	12.00
5	RINCON (Dec. 1993)	74.5	60.1	14.4	19.33
6	HATILLO (Apr. 1994)	441	375.3	65.7	14.90
7	AGUACATE	4.3	1.2	3.1	72.09
8	BAO (Apr 1994)	244	150.7	93.3	38.24

in 3 reservoirs in this watershed is considered average erosion rate would be 41.6 Tm/Ha-year, above Nagle's estimate but less than other estimates (INDRHI, 2006a). Deforestation and migratory – low productivity – agriculture in mountain slopes have been blamed for most of the erosion, but recent studies point out that earth movement for construction of roads in hilly areas is thought to be among important contributing elements. The relationship between soil erosion in the watershed and reservoir sedimentation is not so clear, but sedimentation of reservoirs is definitively fast paced.

Reservoir sedimentation is critical in at least 6 dams, where level of sediments is dangerously reaching level of invert of intake structures or conduits for water supply, irrigation or powerhouse (hydropower), becoming a menace for operational functionality and diminishing socioeconomic benefits of these dams due to premature silting. Factors contributing to high sedimentation rates are high slopes of rivers, frequent floods, deforestation and absence of watershed management – soil conservation – projects upstream of dams. Forecasts of sedimentation and provision for accumulated sediments within dead storage when dams were designed, has been dwarfed by reality. Table 14 show accumulated sediments in 8 reservoirs, calculated by last batimetric survey, being evident that these surveys should be updated and become a regular routine and after extraordinary floods provoked with hurricane.

Accumulated silt is of concern at Bao, Aguacate and Valdesia, with 38.24%, 72.09% and 26.24% of volume is occupied by sediments respectively. Dead storage space is completely (100%) filled at Tavera dam, 60.8% filled at Valdesia and 57.6% filled in Sabaneta. Sediments have occupied 32.9% of useful storage volume in the Bao reservoir, and more than 15% of useful storage in Tavera, Hatillo and Rincón. Figures in Table 1 for other dams, except for Sabaneta and Valdesia, do not take into account hurricane Georges in 1998. Such high rates of sedimentation and buried intake structures within reservoir, motivated dredging at Valdesia dam in Nizao river to be carried out in 1984, but with limited results.

The Nizao river, a 132 Km long river flowing from elevation of 2,800 m.a.s.l to sea level, with a catchment area of 1,036.02 Km^2, is regulated by 4 dams Jigüey (167 million m^3), Aguacate (4.3 million m^3) Valdesia (186 million m^3) and Las Barias (6.1 million m^3). The first two having hydropower as single purpose (combined generation of 203.96 GW-Hr/year) came into operation in 1991, while Valdesia which is a multipurpose dam and Las Barias dam for irrigation, were both commissioned in 1975. Valdesia is the source of water supply for the city of Santo Domingo (6 m^3/s), provides water for irrigation systems (14,000 ha in Nizao – Najayo and Baní areas) and generates electricity (62.75 GW-hr/year). In Valdesia bottom outlet used for releasing water for irrigation and for bottom flush operation is buried under 14.4 m of sediments (INDRHI, 2007). Intake for penstock to powerhouse, which could be the next victim, is only 3.75 m above actual sediment level. Similar trends are observed at the Tavera and the Rincón dams, with sediment level are already 3 to 4 meters above the invert for water supply intake. Rincon and Sabana Yegua

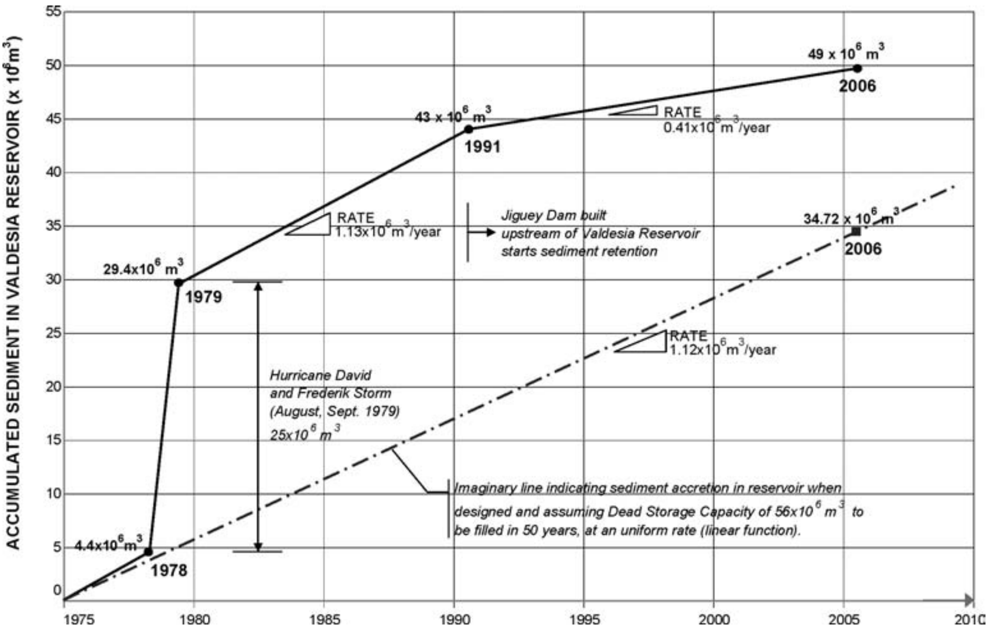

Figure 4. Evolution of Sediment Accumulations at the Valdesia Reservoir in Nizao River.

have sediments 5 to 8 meters above bottom outlets. If sediment wedge would move downstream, blocking of these intakes is possible.

When estimating year averages of sedimentation rates it should be considered that one single event like Hurricane David in 1979, a one in a hundred year flood in Nizao river, can fill for several years. It has been estimated that this sole extreme event (hurricane david was followed by FrederickStorm in less than a week, August – September of 1979), brought 23 to 25 million m^3 of sediments into the reservoir. In only 4 years of operation, Valdesia dam had 18% of reservoir volume occupied by accumulated sediments (Jiménez and Farias, 2002). After building of Jigüey dam, located upstream of Valdesia, sediment rates at Valdesia have decreased from 1.63 to 0.59 million m^3/year, considering input of hurricane (INDRHI, 2007).

Using data from 5 surveys of batimetry made by INDRHI at the Valdesia reservoir in the Nizao river, during 1975 to 2006, a graph of accumulation of sediment has been constructed (INDRHI, 2007). This has been drawn in upper "curve" of Figure 4 which is the real sediment trapped or accreted at the reservoir. Rates of sediment accumulation vary and there are reasons for it. For example, the Jigüey dam started retention of sediment as of 1991, and this influences a slower pace of silting of reservoir in the down stream dam of Valdesia due to sediment trapped upstream in the Jigüey reservoir. Just for the sake of comparison, if it is assumed that estimated volume of 56 million m^3 of dead storage contemplated in the design of the Valdesia dam, were to be filled in a 50 years period, as superimposed on the real sediment in reservoir measured by surveys traced by the author in a lower line of Figure 5, a clear illustration provides lessons of accelerated rate of reservoir sedimentation prematurely filling reservoir, of the great effect that a flood has, of the positive effect in sediment control that upstream retention structure can have, of the limitations of existing methods to estimate silting of reservoirs and of the lack of knowledge of its relationship with watershed erosion. One would like to suppose that deceleration of sediment accumulation rate is possible when sediment control measures are applied. Research on process of sedimentation trapped by a reservoir is necessary for better forecasting capacity in hydrologic design of reservoirs

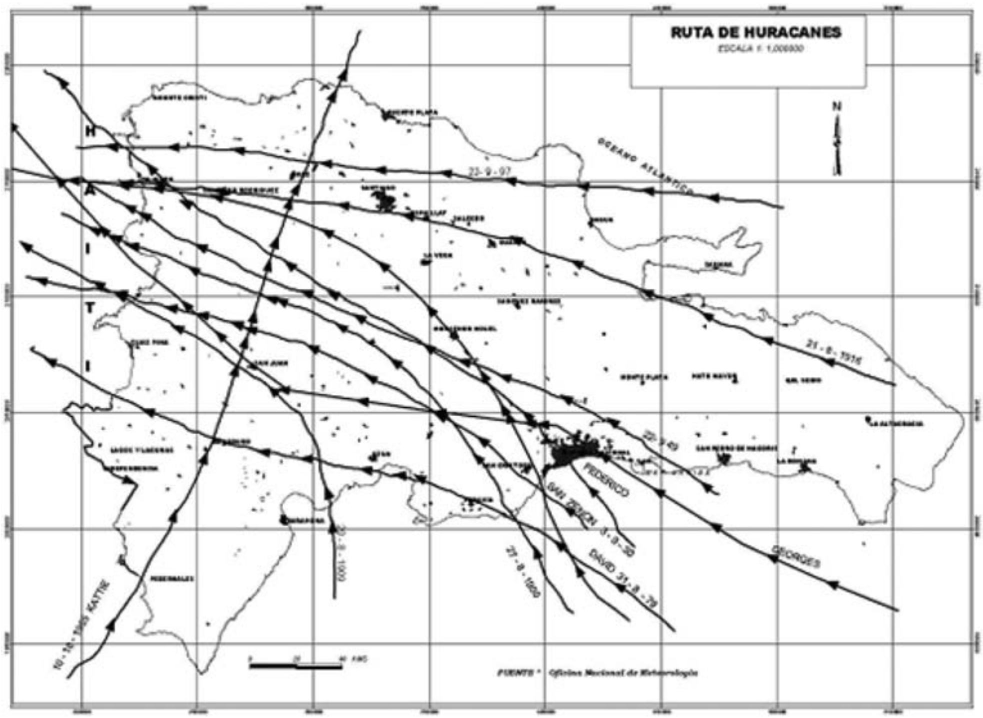

Figure 5. Routes of major Storms and Hurricanes in Dominican Republic.
Source: Oficina Nacional de Meteorología (ONAMET).

and more precise assessment of risks and impact of sedimentation in analysis of economic revenues of dams and of watershed protection projects.

Sediment extraction has also been planned and designed, recommending dredging of reservoir after analysis of several options because objective could be achieved in a shorter time and in a more effective manner than sediment removal by flushing, routing and by-pass. Sediment control via watershed protection (soil conservation practices) and sediment retention dams are sustainable solutions, which were judged to be discarded for high costs and limited effectiveness (Jiménez and Farias, 2002).

Rivers discharging waters with high sediment content and high concentration of fecal coliforms and other pollutants are affecting estuaries, beaches and associated ecosystems. There are 196 beaches with area 433 Km^2, which make up 95% of tourist attractions in the country. Other natural assets in a 1,389 Km of coast are 25 locations of sand dunes (60.4 Km), coral reefs (133 Km^2 up to 10 m depth, 610 Km^2 up to 30 m depth and 1,350 Km^2 in obscure zone more than 30 m depth), 325.3 Km^2 of mangrove, 55 locations of marine prairie (Geraldez, 2002) and two santuaries for marine mammals, including famous humpback-whales. Study by González et al. (2004) revealed that 29% of beaches have higher values for total coliforms than allowed by norms for skin contact (1,000 NMP/100 ml). In the Northwestern coastal reach (Montecristi – Puerto Plata), out of 19 beaches affected, 4 have values of total coliform in the order of 2,400 NMP/100 ml, and 6 have values between 60,000 and 110,000 NMP/100 ml.

Costal and marine resources are impacted by significant environmental pressure due to construction, excessive fishing and tourism. Growing population (70% of cities above 10,000 inhabitants are located at the coast), economic development, industrial development (75% of heavy industries located near the coast), sedimentation, lack of sewage systems and treatment plants and other means of land pollution due to mining, agriculture, industry, shipping activity and tourism continue to press beaches, coral reefs, mangrove, lagoons, estuaries and fisheries. Main problems now is excessive production of solid waste and inadequate handling of them depositing in open with problems of wash away and decomposition polluting surface and groundwater bodies.

11 FLOODS

Significant damages are caused by tropical storms and hurricanes in the Dominican Republic. Being hit and smitten by these extreme atmospheric phenomena is something out the control of humans, since the Hispaniola Island is in the path of hurricanes traveling through the Atlantic Ocean and originating in it north tropical area next to Africa's northern coast. The Dominican Republic is affected by one moderate to high intensity meteorological event every two years by one and by no less than four hurricanes in a decade. Figure 5 shows the routes of major storms and hurricanes in the Dominican Republic

Tropical storms and hurricanes have slashing wind speeds (150 miles per hour during Georges in 1998) and abundant rainfall, which usually results in floods and land slides. Intensive rain, which can come from a more regular as well, in turn causes greater flows than can be contained in normal river cross section, overflowing banks and passing on to flows in the flood plane. The flood magnitude is measured or evaluated in terms of total amount of rain during the meteorological event (mm), maximum amount of rain in 24 hours (mm/hr), maximum rainfall intensity (mm/hr), the evolution of discharges as seen in a hydrograph and peak discharges (m^3/s), and when available, the area flooded of a flood map. If there is a dam in river basin hydrologist are keen of elaborating and examining the in – flowing and out – flowing hydrographs (two curves) and peak discharges derived from this graphs, representing peak flow entering the reservoir and maximum discharge, if any, over or through the spillway. During some of the greatest flood events experienced in the country, David (1979) and Georges (1998) peak discharge values between 3,500 to 8,000 m^3/s have been estimated in rivers or calculated in hydrographs flowing into reservoirs. Highest discharge through a spillway has been in the order of 5,500 m^3/s. It is clear from this magnitude and frequency of events that flood prevention should be of highest priority in the country.

The impact of a flood is measured in terms of losses and damages. Losses include those aspects that cannot be recovered, like the unfortunate loss of human life, which though impossible to value, has an incalculable value for the country and in particular to families affected. Social inequalities are revealed or undressed by floods, and people suffer calamities loosing their loved ones, being wounded or harmed, loosing their houses or having to abandon it temporarily to looking for shelter (4% of the population during Georges in 1998) and becoming ill due to rise in diseases and epidemic episodes after floods suffer calamities. Costs of hospital emergencies and humanitarian aid (food and medicine distribution, sustaining camps for refuge) continue to add to damages. There are official records indicating remarkably related increased incidence of malaria after hurricanes David (1979) and Georges (1998) and of a leptospirosis outbreak killing 40 persons as one of the aftermaths of Noel tropical storm in October 2007. Damages also include affected roads, houses, and loss of productivity in different economic activities. There are direct damages as loss in crops and indirect damages include production income lost or not able to obtain due to direct damages, diminished income during recovery period and expenses for recovery itself. Cost of repairing a road (building back damaged stretch), costs of providing an alternative route while road is restored to normal or previous conditions, cost on additional miles or kilometers, more fuel consumed and extra time to drive through a rougher roadway or with a tougher and slower traffic are among possible consequences of floods. Health, education, communications, tourism, fishing, livestock production, irrigation, water supply (pumps and treatment plants out of service), forest and environmental sector, each have their own damages. There are also economic effects of disasters which contemplate macroeconomic implications like slow down of economic dynamics, exports reduction, increased government expending for relief, reprogramming debts payments and related fiscal impacts.

Table 15. Impact and dimension of risks of Storms and Hurricanes in Dominican Republic.

Name of Event	Date	Number of deaths	Estimated Direct Damages (USD Millions)
San Zenón	03 September 1930	4,500	15.00
Flora	October 1963	400	60.00
Inés	29 September 1966	70	10.00
Beulah	11 September 1967	N.A.	N.A.
David	31 August 1979	2,000	829.00
George	22 Sepetember 1998	283	1,337.00
Jeanne	September 2004	23	341.27

In the case of tourism, the ECLAC report (2004) after Jeanne in September 2004, highlights that the biggest lessons to learn was the damages related to hotel establishments with tourist in the eastern region of the country having to climb to roof tops to keep alive, were due to building of hotel infrastructure in the wrong place without proper consideration of the functioning on natural ecosystems, as it happened with the Bávaro lagoon and mangrove systems (ECLAC, 2004). There were environmental losses, costs for restoring water movement in the lagoon system, infrastructural damages, unforeseen expenses to face emergency and a probably well deserved drop in hotel occupancy. Drying of wetlands and destruction of mangrove areas are among sadly common criminal practices of some developers affecting fragile ecosystems and diminishing capacity of natural conditions to act as a buffer zone for storm and hurricane induced waves or surge tides, which can aggravate and prolong risks (ECLAC, 2004).

It has been estimated that different types and magnitudes of natural disasters have an annual estimated costs for the Caribbean of USD 1,500 millions and almost 6,000 lives (ECLAC 1998). Rodríguez (2005) considers losses and damages in selected extreme hydrologic events in the Dominican Republic are shown in Table 15.

Some determinant factors exposing or building vulnerability, are natural conditions as in the case of geographic location of the country and climate typical of the Caribbean, while others are "man-made". When natural factors meet pre-existing vulnerability caused by anthropogenic and risk augmenting factors like deforestation and erosion of watersheds, which cause a different response in the rain – runoff regimes with more "sudden" flows and floods (flash floods), inappropriate reservoir operation, execution of infrastructure projects (roads, bridges, canals, buildings) with no hydrologic, hydraulic nor environmental considerations, unplanned urban development, and conflicting land use, which is well illustrated by occupation of flood plain areas (for dwelling or crop growing) and the inappropriate use of soils in river basins, vulnerability is increased, making floods more dangerous.

An example of risky human settlement growth is the case of *Jimaní*, a town at the border with Haiti, right at the closure of the Soliette river basin, shared by Haiti and the Dominican Republic. Soliette river, runs from a height of 1,670 m.a.s.l. on Haitian ground and discharges into the Enriquillo lake, which is at the Dominican Republic's lowest elevation (−40 m.a.s.l.). The floods of the 24th of May of 2004 are one of the most tragic episodes in the history of the country and this time it was not caused by a hurricane, but a low pressure center combined with stationary front and a tropical disturbance, bringing 227 mm of rain in 12 hours (248 mm in 24 hours) measured downstream in Jimaní. Rain should have been higher upstream as it is in fact reported and recorded as 462 mm measured in 24 hours by a pluviograph in *Forest des Pins* on Haitian territory (Brath, et al, DISTART – UNIBO, 2007). This amount of rain, which has been estimated as the one in 100 to 200 years rain intensity in this catchment area of 165.78 Km^2, and a peak flow of hydrograph of 2,270 m^3/s according to reconstructed hydrology of the event,

(a)

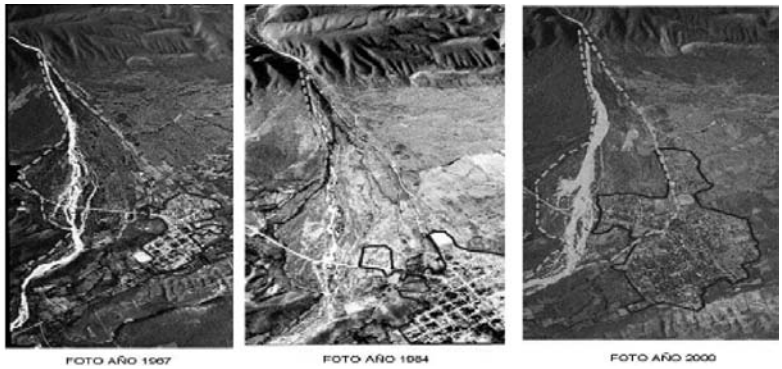

Figure 6-a. Evolution of Growth of the town of Jimaní, Dominican Republic, and flood area of the 24th of May 2004.

affected specially the most populated towns of the basin in *Fond Verrettes* in Haiti and *Jimaní* in the Dominican Republic. The loss officially recorded was 397 dead bodies found, plus 272 missing and 291 homes destroyed, 71 houses damaged and 300 families that were awaked without a house on the Dominican side. Human loss in Haiti surpassed these dramatic numbers (1,059 dead and 414 missing). This was a flash flood moving great quantities of sediments that surprised people in Jimaní who were sleeping at 1:00 a.m. when stroked by an alluvial phenomenon. This devastating force swept away with people and homes and also caused longer anguish to survivors suffering scarceness of water supply and electricity services and affected roads for several day after. One key lesson here was that even relatively moderate *climatic perturbations* have major consequences.

In trying to identify other factors apart form extreme hydrologic conditions, that contributed to build this horrifying situation, Pérez (2004) analyzed the growth pattern of the town of Jimaní, with available aerial photographs from different dates (1967, 1984 and 2000), from which it was easy to see evolution or spatial variation of the area of the town during a 33 years period and comparing with the area of river's floodplain during the night of may 2004, whose mark was clearly seen at the site and superimposed on the photographs. The results show, as seen in Figure 6, that the torn part of the town had been gradually growing into the floodplain.

The Italian cooperation (cooperazione Italiana allo Sviluppo – Istituto Italo Latino Americano – IILA) provided technical assistance by Universitá di Bologna for hydrologic and hydraulic study, training of engineers from both countries and drafting an action plan with structural and non-structural solutions to reduce hydrologic risks. The findings of the study highlight that high hydrologic vulnerability is due to: i-) intense deforestation that has flagellated Haitian territory (and also some part of valley area in Dominican side) notably augmenting propensity to disaster; ii-) expansion of unplanned or inadequately planned housing areas invaded the river's floodplain; and iii-) technical weaknesses by local and national institutions incapable of providing territorial safety. Technical support and human capacity building was precisely a main objective of a project that brought together institutions from both nations (INDRHI from the Dominican Republic and Ministère de l'Agriculture, des Ressources Naturelles et du Développement Rural from Haiti) to find a solution to a common problem. This hopeful cooperation strategy has great potential for transboundary water management and can be an example to other basins and to address other water management issues.

These type of situations amid the high frequency of tropical storms and hurricanes, with such sad records of losses and damages, require a well conceived set of actions to identify vulnerable areas, reduce risks and stimulate citizens, communities, local authorities, industries, business and financial sectors and high level government officials for preparedness. A flood management

(b)

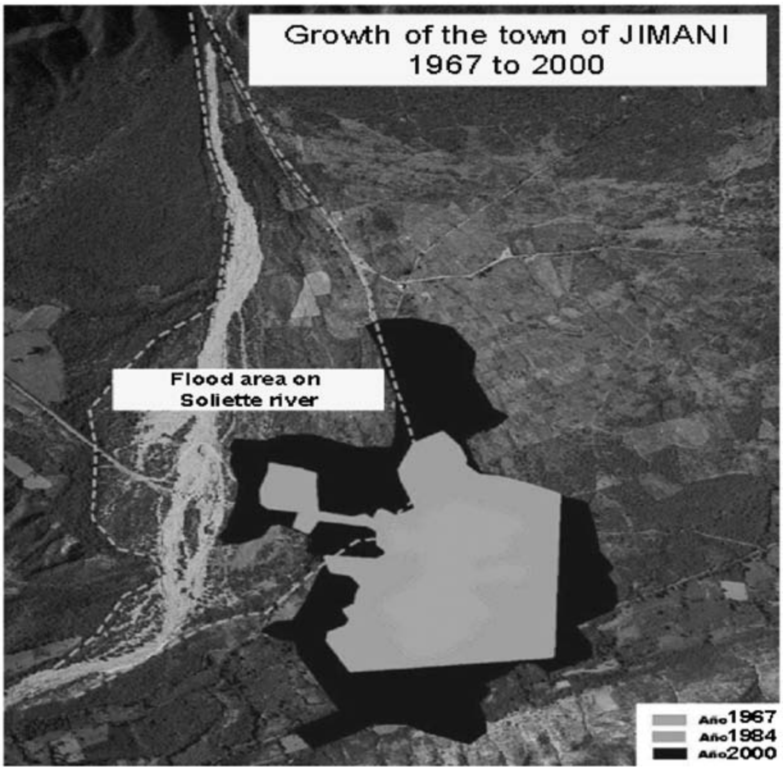

Figure 6-b,c. Evolution of Growth of the town of Jimaní, Dominican Republic, and flood area of the 24th of May 2004.

strategy and plan are urgent needs and these would have to consider studies, monitoring, warning mechanisms, investment for defense infrastructure and improvement of watershed or catchment, conditions, as well as pertinent norms and regulations.

The most complete flood control study in the Dominican Republic has been done for the Yaque del Norte river basin and was financed by the World Bank, resulting in a flood map for different magnitudes of floods defined by return periods (25, 50, 100 and 500 years). One pitfall of the study is that its flood map is a static picture, for floods of given magnitudes, not being able to use it for predictive for purposes of determining flooded areas for any other different discharge value, rather than guessing through interpolation of curves. Ideally, when rainfall estimates are forecasted, the watershed response to that rain could be worked out by virtue of hydrologic models that can supply estimates for discharge, which in turn can be processed, via hydraulic simulation, to provide water levels and flood maps. Another application could be for the operation of the Tavera dam on the Yaque del Norte basin, upstream of the city of Santiago, related to impact of discharge of spillway, which in fact has demanded serious decisions to be made without these advantageous tools. In this case there is a calibrated hydrologic model, but due to the fact that technology transfer was absent in this project and the use of the specific model developed and calibrated for the watershed is based on a software unknown to INDRHI's staff and of reserved rights by consultant providing the service (study), it is not possible to use it. In any case the flood maps for the fixed return periods can serve for planning and possibly for promoting actions to protect vulnerable areas and people at risk. This map was handed to authorities and several organizations in the basin. The study also contains a proposal with a proper balance of structural and non – structural actions and projects for flood protection.

A flood control study was also done for the Yaque del Sur basin, but flood maps were not elaborated. Hydrologic analysis and modeling, as well as hydraulic simulation of different magnitudes of discharges were also done. Flood control studies were performed for the cities of Bonao and La Vega in the Yuna river and Santo Domingo in the Ozama river (USACE, 2003), properly identifying risk zones by flood maps and also offering structural solutions.

Structural solutions for flood control like building dams to regulate river flows have been applied. The *Hatillo* dam in the Yuna River and the *Sabana Yegua* dam in the Yaque del Sur river, the two largest reservoirs (volume), are examples of dams with flood control purposes. INDRHI is frequently involved in building levees and small dikes of relatively small lengths to protect crop lands, roads, houses and buildings, as well as in fluvial works for river training, but also in relatively short distances. As to preventive Non structural solutions, including watershed management projects, displacement of people living in river flood plane, sirens alert systems, and early warning system have been planned, but applications are been exceptionally tried to a limited scale and with various degree of success.

INDRHI installed in 2005 an early warning system originally composed of 120 stations, some being there were pluviometric stations measuring rain intensity, others were stations to measure water depths, others were climate stations for temperature, relative humidity atmospheric pressure, solar radiation, wind speed and direction, and a few were tide gauge. This network allows for stations recording of hydrologic data and transmission in real time via GOES satellite and NEDIS approval, to two receiving stations, which meant a significant advancement for the country. More effort is required to enhance data processing capacities and to provide better access and sharing of this information to interested parties, including civil defense and meteorological service, as well as the general public. The fate of the stations is of great concern due to vandalism, theft, logistical support for adequate maintenance and some other operational difficulties. Currently there are not more than 40 of these stations transmitting. Financial, organizational and technical sustainability have been put to test. Doppler station has been installed by private tourist developers in Punta Cana in the eastern tip of the island, more for aviation purposes, but obviously of great use for rain forecasting, being still necessary to link this to INDRHI's routine and processing. Another such radar is said to be necessary in the extreme northwestern part o the country to cover the whole island and servicing Haiti as well.

Rodríguez (2005) has suggested several actions to improve flood management, including definitions of a national plan and sectors planning to prevent flood damages, strengthening of early warning system, human resources training, community education and a more participatory approach, optimizing operation of reservoirs, zoning and insurance for infrastructure and to protect crop production for farmers, regulations and requirements of flood risks assessment for infrastructure projects and revision and upgrading of construction codes so that roads, bridges, hospital buildings, water supply systems, tourist development, would be more securely designed and located to avoid risks and withstand effects of floods, and that these infrastructure do not increase risk nor unfavorably modify ecosystems due to lack of understanding or "voluntary ignorance" of fluvial dynamics and environmental conditions. Furthermore he proposes well articulated integration and more effective involvement of concerned agencies, including the army in the prevention and response to natural hydrologic disasters, since water and floods are topics of national security and should be a major defense issue.

One of the greatest challenges would be to induce and regulate zoning. Planning and enforcing territorial marshalling requires search for a solution with legal schemes, financial mechanisms, control and enforcement. Jimaní's insecurity was revealed by intense rainfall and a valid question is if vulnerability of other towns are to be known after a tragic flood event. Flood insurance, lending and mortgaging incentives from banks for safely located properties could possibly be useful tools, but would require demonstration of impacts and financial convenience for the insurance and credit institutions. Alternate restrictions for unsafely located and designed buildings could serve as a negative reinforcement for pedagogic stimulus. Flood insurance of estate infrastructure does not exists and though there was a project law drafted to make this compulsory, feasibility of such requirements is yet to be deeply analyzed and discussed. An attempt to introduce crop insurance in 1984 was short lived with closing of the agricultural insurance company (ADACA: Aseguradora Dominicana Agropecuaria) created mostly with state investment. Another investment of the state gave birth in 2002 to a new company (AGRODOSA: Aseguradora Agropecuaria Dominicana), offering insurance for a few crops (rice, plantain, banana and beans) in specified areas of the country, including coverage for losses due to floods, droughts, tornados and pests. Making reference to models of other countries as the FCIC (Federal Crop Insurance Corporation) in the United States of America for example, it has been suggested that instead of providing insurance directly, the State's involvement should be more a program of reinsurance and subsidy of insurance prime obtained through private companies.

12 WATER AND ECONOMICS

Water contributes to social and economic development in several ways. It is beyond doubt, that investments in water supply and sewage systems improve health and hygiene. Water is essential for food security also. Agricultural production for example is only possible in certain areas when water is provided for irrigation of crops. Irrigation, which fosters augmented yields or increased productivity, and consequently more profitability of agricultural production, is a catalyst for improvement of economic standard of farmers and their families, also stimulating general economy of rural areas by way of promoting increased opportunities of employment and other associated and diverse income generating activities.

In spite of the centrality of water to development, national scale indicators of economy, macroeconomics, development and poverty alleviation policies, do not reflect real contribution of water. This statement is not exclusive to the Dominican Republic, since the Water and Poverty Initiative (WPI), launched and supported by Asian Development Bank in February 2002 to explore the linkages between poverty and water security, elaborated interesting conclusions from shared experiences and discussions during 3rd World Water Forum in 2003 in Japan, emphasizing that: "A more complete understanding of the relationship between water security and poverty reduction is needed to improve the management of water resources and the delivery of water services"; Existing national policies for poverty reduction and development do not reflect potential contribution of water to poverty reduction". From one of the key sessions organized by WPI during the 3rd World Water Forum, we extract: "While only one of the millennium development goals mentions water specifically, all are impacted by access to water in one way or another. For example, halving the worldwide hunger by 2015 heavily depends on better water management". While better water management on its own is insufficient to alleviate poverty, none of MDGs can be achieved without better water management" (ThirdWWF 2003).

There is a strong need in the Dominican Republic for conciliation of the national development and poverty reduction policies and strategies, as well as government priority statements, to the investment programme of the government and to the country assistance strategies from development and donor agencies, as well as some multilateral banks, regarding real water problems and needs of the country and potential contribution of water to social wellbeing and economy. Water, which had a higher priority in investment before, is poorly recognized in the current sector preference agenda for international cooperation and financing.

The poor are the most afflicted segment of population during hurricane and floods disasters, as well as other water related dangers like droughts and pollution. Risk and vulnerability of the poorer is often exposed by these extreme events. They also tend to throw their lots in farming on river flood planes and hills. The first is subject to frequent flooding and the second involves cutting forest to plant, reap and later abandon plots as eroded and diminished soil fertility areas in a survival and predatory pattern of agriculture in mountain slopes. Small scale fishers are more impacted by biodiversity and environmental degradation affecting fishing potential and creating economic instability of their business. Better water management can make a key contribution to poverty reduction. This is recognized in internationally agreed targets to halve the proportion of people without access to drinking water and improved sanitation by 2015.

But water is also a key input to many industrial and other larger economic activities and thus water benefits both the rich and the poor.

To bridge the knowledge gap and attain a better understanding of relationships between water management and poverty, WPI has recommended (ThirdWWF, 2003) the development of effective indicators and monitoring systems to assess progress in realizing water-poverty targets. There is also a need for major advocacy programs to increase political and public awareness and support for pro-poor water management. The concrete suggestion is to “argue the case more effectively” for creating awareness among population, and especially politicians and economists, usually leading decisions in policy formulation and investment development.

To initiate the road that leads to that “better understanding” between water and wealth or poverty, the author has made an exercise analyzing the relationship between poverty and water availability. The first variable, poverty, was assumed to be represented by the percentage of poor population by provinces, using data from the Poverty Report elaborated by the National Planning Office (ONAPLAN, 2005). Water availability is thought to be well represented by the rainfall minus evapo-transpiration, accepting this to be some form of “effective rain” with data from the recently updated Water Balance (INDRHI – GRUSAMAR 2007).

This discussion should be expanded to take into account water infrastructural development and economy, since Yaque del Norte and Yaque del Sur are among the regions having more irrigation systems per surface area (Table 2) and have important percentages of their watersheds under dry conditions. This has to be interpreted as confirming justification of investment policy priority in irrigation to the drier areas, but measurement and analysis of impact of investment in irrigation as related to poverty alleviation and economic growth in those areas is a still pending issue. Another needed explanation is why the Yuna river basin, with largest proportion of area of irrigation systems per surface of catchment area, while being the rainiest region. Economic effectiveness and justification of seasonal supplementary irrigation to rice fields, main rice growing area in the country, would have to be clarified.

While there is a good, inversely proportional match of rain and poverty in the southwestern and northwestern regions, some eastern provinces however, like Hato Mayor and El Seybo, which are amongst the provinces with highest percentages of poor population (as much as 68.5% of families are considered poor), have abundant rain. In those provinces, topographical conditions, lack of infrastructure (economic poverty of water) and lack of reservoirs to regulate flow, which is true for the whole eastern region, can be probable factors of influence in great poverty exhibited in those two provinces. Abundance of water nor water scarcity cannot on its own explain richness nor poverty, since so many other aspects are involved in a situation that is still elusive to analytical reasoning. This exercise is only a limited approximation, linking only two variables, to try to identify possible relationships of certain factors involved in a much more complex reality.

A sector analysis of the economy indicates that tourism, commerce, construction, communications are the rising stars of the Dominican economy, while sectors like agriculture and manufacturing have been declining in their contribution to GDP. Agricultural production has been dropping from 25% of GDP in the 1960s to 13.4% of GDP in 1993 and to 11.5% of GDP in 2005. This includes livestock, forests, fishing and crops. Crop agricultural production was 7.6% of GDP in 1991 and 4.3% of GDP in 2005. Agriculture still keeps an important place when it comes to employment, with 14.6% of economically active population working in agricultural activities. For the rural area agriculture is on of the largest employer sector, representing 29% of employment.

Energy, hydropower plants contributed a record high 1,879 GW-hr/year, which is 18.7% of total energy generated, but average annual generation is about 1,200 GW-hr/year.

According to figures from the Central Bank, the relative importance in the economy of the water sector is indicated by its aggregate value in relation to total GDP, which represented 0.07% of GDP in 1995 and 0.04% in 2005. The contribution of water to the economy has been underestimated (INDRHI – GRUSAMAR, 2007). ADEAGUA, the Dominican association of private companies dedicated to the business of purifying and bottling water, have declared investments in the order of RD$4,000 millions pesos (approx. USD 126 millions). Surveys by National Statistics Office (ONE, 2006) revealed that 51% of total population are using bottled water for drinking and average expenses in buying those bottles of water is 30.98% of the amount of their water bills. This figure could be higher, since the cost of a 5 gallons bottle of purified water is at least 40% of a monthly water bill. It is not clear either if the figures from the Central Bank consider invoicing of water utilities companies, apparently out of their equation for aggregate value.

Other economic issues related to water management should be addressed. One of them is profitability of water supply services. Economic inefficiency is definitively a disgraceful characteristic of the water supply and sanitation sector. Tariffs in water and sanitation sector are low. The relationship between production of purified water over amount of water finally invoiced to consumers is high, which means that a good proportion of treated water is either lost or stolen. According to INDRHI – GRUSAMAR (2007) and assessment reports of the water supply and sanitation sector, the water utility company in Santo Domingo (CAASD) produced 378.605 million m^3 of water in 2005, but only invoiced 123.462 million m^3 (only 32.6%). Amount of total collected fees by CAASD in that year were 73.7% of total value of invoices and 41.94% of their operational costs and expenditures to purify, distribute water, maintain the water supply system and cover administrative and commercial management expenses. The difference is assumed by the government. Production costs (operational costs – in pesos – over production volume – m^3) is RD$ 3.63/m^3 (approximately USD 0.11/m^3). In spite that savings in expending is possible and justified, tariffs for water service, about RD$ 6 /m^3 (approximately USD 0.18/m^3) for a residence (house), would indicate that tariff structure is adequate to cover O & M expenses. The gaps are in inefficacy of invoicing, unaccounted water due to illegal connections and loss in the network, and poor fee collection. Operational costs per volume of water invoiced is RD$ 11.54/m^3 (approximately USD 0.34/m^3). Final annual fee collection income over costs of water service would make the price of water RD$ 15.11/m^3 (approximately USD 0.45/m^3).

A Fixed tariffs criteria for tariff structure in water and sanitation services are applied by INAPA and the most of the other five state owned water utilities, each having their own structure but generally taking into account the type and category of users (residential, commercial, industry, hotels, government institutions and poor communities), the location of establishment, type of building, the number of taps and estimates for volume of consumption. In part of Santo Domingo (CAASD) and Santiago (CORAASAN), there are residents which are charged by volume of consumption according to metered services and invoicing, having one tariff (RD$6/$m^3$ for a house) up to about 32 m^3 per month per house and an additional and increased tariff (133.33% higher) for consumption in excess of that basic volume. Some charge additional amounts for sewage service, but only CORAASAN does provides that service. They also charge for wells installed by home, business and industry owners, and the tariff is higher, the rationale apparently being that these users would be out of control as to the volume they consume.

In the case of irrigation, it is estimated that 60 to 80 percent of total annual agricultural production came from production in the irrigated areas during 1991 to 2004 (INDRHI, 2006a, 2006b, 2007). Importance of water used for irrigation however, is poorly recognized. Table 16 shows the statistics from the *Banco Agrícola de la República Dominicana*, a state owned bank providing financial services for promotion of agricultural production. For the analysis of loan applications, this bank

Table 16. Production Costs and Cost of Water of Irrigated Crops.

		Costs per tarea (RD$ Pesos / Tarea), 15.85 tareas = 1 Hectare									Cost of water		
No.	Name of Crop	Agricultural services (RD$/Ta)	Inputs (RD$/Ta)	Labor (RD$/Ta)	Subtotal (RD$/Ta)	Subtotal + unforseen 10% (RD$/Ta)	Finantial charges (RD$Ta)	percenrage of Finantial charges (%)	Finantial charges	Total, including unforseen and financial costs (RD$/Ta)	(RD$/Ta)	% of inputs	% of total production cost
1	Potato	855.67	7,562.20	3,383.34	11,801.21	12,981.33	778.88	6.00%	2,336.64	13,760.21	10.67	0.32	0.08
2	Sweet potato	658.50	347.10	1,596.88	2,602.48	2,862.73	257.65	9.00%	515.29	3,120.38	16.00	1.00	0.51
3	Banana	802.00	1,850.10	2,779.58	5,431.68	5,974.85	1,075.47	18.00%	1,075.47	7,050.32	32.00	1.15	0.45
4	Platain	711.00	1,474.50	2,723.32	4,908.82	5,399.70	971.95	18.00%	971.95	6,371.65	32.00	1.18	0.50
5	Cassava	769.00	519.10	2,029.46	3,317.56	3,649.32	656.88	18.00%	656.88	4,306.19	32.00	1.58	0.74
6	Red Beans	731.50	967.20	1,145.84	2,844.54	3,128.99	140.80	4.50%	563.22	3,269.79	8.00	0.70	0.24
7	Onion	633.33	5,179.40	4,137.64	9,950.37	10,945.41	985.09	9.00%	1,970.17	11,930.50	13.33	0.32	0.11
8	Garlic	841.00	11,500.63	4,091.58	16,433.21	18,076.53	1,626.89	9.00%	3,253.78	19,703.42	16.00	0.39	0.08
9	Pepper	630.67	4,712.81	1,934.52	7,278.00	8,005.80	480.35	6.00%	1,441.04	8,486.15	10.67	0.55	0.13
10	Rice	1,228.50	1,591.40	727.50	3,547.40	3,902.14	351.74	9.01%	702.39	4,253.88	23.50	3.23	0.55
11	Rice transplant	1,228.50	1,589.33	1,052.41	3,870.24	4,257.26	383.15	9.00%	766.31	4,640.41	23.50	2.23	0.51

uses data and analysis of production costs, which consider water as an input. As can be seen adduced importance of water is denied by the facts. Cost of water represents less than 4% of costs of all inputs and less than 1% of total production costs in all 11 crops considered.

Water tariff for irrigation is based on surface area and tariff structure differentiates between rice, pasture and other crops (vegetables and fruits, including plantain and banana) and take into account size of land in two categories, less than 10 hectares or above 10 hectares). Each WUA fix its own tariff, based on budget or total O & M costs per year. For the year 2007 tariffs for rice varied from RD$56 to RD$108 per tarea per year (approximately USD 26.50 to 51.10 per hectare per year), while tariffs for other crops were RD$34 to RD$63 per tarea per year (approximately USD16.09 to 29.81 per hectare per year). A study of CITAR related to tariffs for irrigation service (Ramírez and Chalas, 2008) analyzing tariffs of 11 WUAs covering an area of 163,168 Hectares (53.2 of total irrigated area in the country), translated water tariff in price per surface area (RD$/Tarea) is to its equivalent volumetric tariff by means of analyzing crop water requirements minus effective precipitation and multiplied by a coefficient to consider efficiency of the irrigation system in each area under study. Applying these concepts, tariffs for irrigation service in rice is calculated as RD$ 0.08 to RD$ 0.19 per cubic meter (approximately USD 0.0024 to USD 0.0057 per cubic meter) and that of other crops as RD$ 0.07 to RD$ 0.24/m^3 (approximately USD 0.0021 to USD 00.72/m^3). Average results seem to show that a similar price per volume of water is charged for rice (RD$0.11/$m^3$) as for other crops (RD$0.10/m^3). Water consumption in paddy fields will make the difference. When considering costs of O & M of both the WUA and INDRHI's Irrigation Districts, whose costs are not considered in the tariff of the WUAs, in those same 11 areas of selected WUAs for the study, average equivalent volumetric tariff would be RD$ 0.24/m^3, which exceeds 118 to 140 percent higher than the volumetric tariff calculated for rice (RD$0.11/$m^3$) and for other crops (RD$0.10/$m^3$) respectively. Implied average government subsidy, according to the study, is so that for every cubic meter of water delivered for irrigation of crops, INDRHI covers two thirds of the cost. One of the heavy loads borne by INDRHI is cost of electricity for operating pumps. More research is recommended to fine tune estimates of real costs structure of operating irrigation systems and to accurately determine composition of subsidy.

In terms of productivity the irrigation sector also needs to find better justification for investments. While it would still be true to say that irrigation increases yield in production, better outcomes would be expected in difference between rain fed agriculture and "irrigated" agriculture.

There is not a clear vision as to who should charge for water from rivers and wells. It is common that industries extracting water from wells and deriving waters from rivers, are approached by personnel of INAPA, the water supply institute and other water corporations (water utilities) of municipal jurisdiction, charged and invoiced in search for more income and better economic balance in this institutions. The water utilities nor the hydropower generation company (Empresa Generadora de Electricidad Dominicana – EGEHID) do not pay for using water either, which is defined, as well as other natural resources, as a state property by law.

INDRHI used to charge farmers for water served via irrigation systems, but after transferring all of the irrigation systems to water users associations (WUAs), these corporate organizations do not pay for water, although some have conceived to pay INDRHI in the future and even pay for "environmental services". Even when the farmers used to pay INDRHI, price for water was so low that accumulated income only made 5% of INDRHI's budget, the rest coming from government allocation in national budget.

Water fess of water utilities is significantly low in comparison to production costs (purifying and distributing water to house taps). In other words, the tax collected from all citizens is the major source for government expending and investment in providing water services. Some agencies promote users participation in investment in water supply facilities in small scale projects in the rural area and although the sense of appropriation that is derived from this is invaluable for sustainability and absolutely important, an interesting argument about why the government builds water supply systems for large cities without any requisites to financially better-off citizens, since investment is never a part of water tariffs. Again, the subject of water tariffs and justifications for sunk costs of investment and tax payment, and who benefits more from government paternalism, deserves some attention.

The legal provisions requires that people benefiting from government investments in canals are responsible for costs of operation and maintenance of infrastructure. Water titles are tied to land, making land-title holding in an irrigated area important. The effect of irrigation canals to economic appreciation of land is another economic benefit. In the early part of the ninety seventies, a legal scheme was designed to support agrarian reforms policies, in particular assigning land to the landless. This law, still kept ruling through successive amendments, means that when government builds canals that pass through properties of area above 100 hectares, landowners should pay for such benefit in kind, as much as half of their land, or in cash. This was an instrument in implementation of redistribution of land, which is now questioned because of effectiveness of in kind payment versus what would mean a cash contribution of landowners and the rights of the government to impose such payments.

Discussions on impact of large projects are also necessary. Dams generating electricity transmit their input into the national grid and poor communities, some having been displaced from what is now the impounded reservoir site, do not have a stable electricity services or have no electricity at all, nor have any other form of compensation, apart from having received a house and a small size land or having been paid for the land they had. It is paradoxical that remotely located and marginal economy communities in areas of hydropower projects have been frequently neglected or excluded from electrical power supply or services and only see the booming business around it and richness derived thereof, pass through their villages without none to non significant benefits. People living in the big cities are more benefited than poor villagers. One benchmarking experience that might be a model for other hydropower projects is that of "*Los Toros*", a small community located besides an existing water canal where a 9.2 MW hydropower plant (no reservoir) was built with funds from European Union.

Discussions and search for references on the topic of participatory decision making and stakeholder participation can find an interesting example in the *Los Toros Fund* (LTF). Approval and disbursement for development projects financed by the LTF are decided by a Provincial Commission heading the Fund, created by a Decree from the Executive Power in 2005 (485 – of September 2005), and composed by 13 members, with 8 of them from the private sector, including a representative from the Los Toros community, leaders of WUAs, two clergymen (a priest and a pastor), business sector and mutual cooperative representatives. Nine of the members live in the Province of Azua, which is an important factor since they are permanently in close contact with demands of communities. The other 5 members, including the Governor of Azua (appointed by the President), are government institutions related to the Project.

LTF is not a remedy fund, since there were no damages nor loss by the population, and displacement was not really an issue, with only two houses relocated due to construction. There was no resistance from the community and the LTF started after hydropower plant was built. Construction site was an existing canal built in the early 1980s and required no storage reservoir. It is indeed a good example for dam projects and can serve as a model to establish regional development funds, according to compensation policy principles and as a monetary benefit sharing mechanism where part of monetary flows generated by operation of dams is distributed to affected or concerned communities (UNEP, 2007), not necessarily exclusive of affected people. In the case of the LTF all, not part of, of the net income or benefit, is benefiting the whole province of Azua, not only the Los Toros and surrounding communities. The LTF is also considered to be an alternative model to think about when speaking of environmental services.

The LTF has a protocol to guide decisions, but lacking more standardized processes has not impeded the Provincial Commission of the LTF from working out a process for project selection as of December of 2005, holding community meetings and hearing the representatives of organizations from the communities in the different municipalities of the Province of Azua. The members of the Commission prefer to avoid bureaucratic formalities due to urgent needs in the province and are inclined to smaller projects with a reasonable geographic distribution of investment. Promoting replicable projects and fund generating activities or recovery of allocations from the LTF are among the ideas discussed for establishing future selection criteria.

One important area of improvement of the LTF is establishing formal project selection instruments and processes with norms and standards clearly known by the communities and potential applicants. Enhancing communication and public knowledge and acceptance of projects are elements that will benefit the consolidation of the LTF. Most urgent need is to formulate a development plan to guide decisions and programme investments. It is important to decide on a model for management of funds, leaving some room for the LTF to operate as a competitive fund, where project approval and investments decision will be based on demand. Selection criteria should be clear to all as well as information requirements (benefits and costs details). Improvement of transparency and accountability instruments of the agencies entrusted with the re-distribution of benefits is a key factor for successful implementation of LTF's objectives. Accounts receivable from CDEEE, which has been slow paying its dues to the fund, is one issue to resolve, having accumulated more than RD$300 millions in debts. Some pressure was and is necessary for regulating these payments. Ensuring compliance and strengthening the enforcement mechanism, which is a financial agreement and has a 15 year horizon (2015), and possibilities of becoming a permanent mechanism is a matter of discussion. The LTF is definitively creates jurisprudence in project financing. Profitability is by far outstanding. Energy generated from January 2001 to October 2007 (322,402.86 MW-hr) had a net income of RD$675,749,306.20, which is twice the cost of the hydropower project, more than "recovered" in 7 years.

Financing projects is one important issue to resolve, in particular as to the procurement of funds. Traditional sources of money like multilateral development banks, under "soft" conditions or terms (low interest rates and longer grace and repayment periods), are not longer financing dams or have serious concerns about evaluations to accept this type of projects and are only recently thinking of renewing their long ago faded support to the agricultural sector. The government's recourse has been to exploit the willingness of commercial banks to provide funds at higher interest rates, shorter grace period and shorter repayment horizon. Concession of roads has already been accepted and applied in two projects, but concessions for hydropower plants and water utilities is prohibited by law and will require more congressional discussions.

Discussion is going about environmental payment. In Yaque del Norte river basin and Yaque del Sur, some non-government organizations (NGOs) are promoting and trying to replicate experiences from Costa Rica of agreements made by the hydropower company and water utilities with individual farmers or residents in the upper watershed, for a careful exploitation of natural resources, so that they observe and practice conservation measures to either increase vegetation cover on their land and reduce soil erosion, or simply leave the land like it is. While some believe that this is a good model, others argue that a national system, not based on individual and voluntary agreements, but rather a compulsory scheme, except for tariff structure which should be negotiated between corporate parties, the water agency and hydropower supply company (only one state institution of national jurisdiction operating all existing dams), and transferring part of collected fee for water to the natural resources and environmental protection agency (Secretariat of Environment and Natural Resources) to finance watershed conservation projects for example, would be better. The water agency (INDRHI) has advocated for this type of model and thinks that the aforementioned *Los Toros* experience is a good argument of this other type of developmental approach. One other argument by the water agency is that this type of funds could also serve for sustainability of weather service and hydro-measurement network (installing, operating and maintaining stations), which is fundamental to measure the impact of conservation practices applied, but are in reality often neglected items in national budget allocation with consequent inefficiencies.

In any case, need for development and implantation of a reasonable model for financing water and soil conservation activities is necessary and would make good business sense for reduction of reservoir sedimentation, which is costly to resolve. Pertaining to analysis of benefits of sediment control activities is the consideration of costs to be avoided and functionality of dams. Costs of sediment extraction in Valdesia and Aguacate in the Nizao river, to recover bottom outlet capacity and prolong useful life of reservoirs, previously mentioned, is estimated as USD 16.814 millions. Notwithstanding, feasibility analysis indicate that in a 40 year period, with capital investment and operational costs of USD 28.79 millions (present value for costs of sediment control activities at a discount rate of 3 %), there would be a gross profit estimated as USD 581 millions. Considering annual benefits from generation of hydropower in the 3 dams in this one basin (Jigüey, Aguacate and Valdesia in the Nizao river basin) as USD 21.973 millions and benefit for irrigation USD 3.40 million/year. Costs for control of sedimentation would only be 5% of estimated benefits (INDRHI, 2007).

13 WATER AND EDUCATION

Every single person on earth uses water and the behavior of every individual, each organization, community, institution and industry, can affect rivers, aquifers, lakes and coastal waters. In a varied array of aspects and forms that goes from the quantity of water used, either at home, at the farm, at the office, or in a hotel, to energy consumption patterns, garbage and wastewater disposal habits and facilities, and even eating preferences, the values and behaviour of every person can make a difference in the growth or abatement of pressure on water resources or water degradation.

Water is everybody's business. The need for water conservation has intensified the call to integrate, in a wide spectrum, government's specialized institutions with responsibilities on water management or water services and other branches of national authority, local authorities, organized groups, communities, as well as the private, the industrial and financial sectors. Development of a new way of thinking on the importance of water and the need to have better institutional arrangement, improved legal frameworks and more stakeholder involvement for a more sustainable use of water, has required decades of talks, lengthy and unfinished debates, hundreds of seminars and conferences, and tons of papers written and exchanged among specialists of different fields, including water resources managers and planners, hydraulic engineers, irrigation specialists, environmental engineers, some sociologists, economist and even a few experts on water law. To translate experience and accumulated knowledge on water problems and concerns to the population, the common person who uses water at home or at work, will demand a special effort to bring about desired results of rational use of water. Putting water on the agenda of politicians, economists, youth, teachers and school children, cannot be postponed.

Search for sustainable solutions to the problems has to focus on the social and cultural dimensions of the water problems and the contribution of water users themselves towards a solution. Economic and technological inputs for solutions necessarily need to be envisioned with complementarities of education and cultural values, if decisive change in trends and durable effects of sustainable use of water resources are to be achieved. Participation and decentralization are strategic to integrated water resources management, but people need to be well informed and prepared to participate effectively.

In an effort to highlight the importance of water, raise awareness and motivate social action to face the present or future critical situation on water, an educational program was launched by INDRHI with collaboration of Secretariats (equivalent of ministries) of Education and Health, as well as water utilities, in the year 1997. The program is called *Programa Cultura del Agua* – water culture – (PCA), a common name in Latin America for such activities, and had as a reference model for its initial formulation and actions (Texas Water Watch program, 1997).

The PCA started actions with the "*Vigilantes de la Calidad de Agua*" (water quality guardians) sub-programme, whose main objective is to involve communities in the defense and preservation of water bodies in their surrounding territory. Awareness of conditions of water and identification of real or potential sources of contamination, is achieved by means of training community leaders and monitoring of water quality. The villages are and given an appropriate technology water quality kit for measurement of temperature, PH, electro-conductivity, dissolved oxygen, chlorine, nitrates and nitrides. Other parameters can be added to this kit. INDRHI worked with universities (Universidad Central del Este, Instituto Tecnológico de Santo Domingo) and NGOs (Asociación Para el Desarrollo, Inc, in Santiago, FUNDEJANICO and others) in approximately 80 rural communities located in the Yaque del Norte, Yaque del Sur, Higuamo and Soco river basins and established a network of Vigilantes del Agua (voluntary service) in several villages. Follow up on results of measurements and refills for the measuring kit is poor. Continued support of the programme is not guaranteed, but financing for new projects have been arranged to restart the VCAs.

One interesting project of PCA was the integration of water within the school syllabus, not seing water as a separate subject, but within each subject. With assistance of an expert from the German service for social and technical cooperation (DED), guidelines for teachers were developed with concepts and topics and classrooms and outdoor activities for each grade in primary and secondary school. The Secretariat of Education collaborated in this effort and guidelines were developed with intensive exchange between educators, environmentalists and graphic designers. Unfortunately, these materials, carefully conceived and designed, have not been printed nor applied at the classrooms.

Most identifiable strategy has been to focus on primary and secondary school population. Having children at school age is a key element, since, according to educational experts and psychologists, value and cultural learning is most effective during 4 to 6 years of age.

Another assistance of an expert provided by DED was the development of the *Saprobian* index to measure water quality, which is based on the quantity and type of living organisms – macro invertebrates – present in water (INDRHI, 2006a and 2006b). The Universidad Central del Este (UCE) in San Pedro de Macorís, also collaborated in calibration and local application of this model and a manual was developed for identifying representative species and determining water quality via a simple biological analysis demanding only a net and a minifying glass. Implementation of this biological test however, has been limited to initial stages of validation of methodology.

A recent initiative under the PCA is the "*Sala del Agua*" or Water Expo Hall created in 2006, which is a permanent exhibition receiving up to 12,000 visitors each year, that already deserved a recognition award from the regional Office for Latin America and the Caribbean of the International Hydrologic Programme (IHP) of UNESCO in February 2007. Children from schools or clubs are able to walk through five modules of water education guided by trained staff, raising their awareness on water problems, becoming acquainted with concepts on water (like the watershed and physical properties of water), learning about types of water measurement equipments, being informed through interactive methods of water pollution and floods, expressing their views on the centrality of water for development, needs for conservation and concerns on mismanagement of water at home and pollution of rivers, through game playing, writing poems, songs and sketches, drawing and painting, and finally making individual and collective solemn commitments to preserve water. Surprisingly, adults, university students and even graduate students that have also visited the Water Expo hall have been amused and enthusiastically engaged during the tour, which is adapted to their level by the guide.

"*Agua Móvil*" (water mobile), is a new sub-programme of the PCA started in 2007, having 12 trucks equipped with modern audio visuals technology, tents and chairs to accommodate their audience, visiting communities, organizations and schools, spreading the gospel on water conservation. Talks and group dynamics, are usually stimulated with a video – documentary on one of different topics of water and even fragments of popular films with scenes that touch water related issues. The activities of Agua Móvil are oriented to socialization and animation of community members towards water conservation. Proper staff selection, adequate training for the trainers and keeping high motivation in staff are among fundamental factors for success and expansion of this new subprogramme that seeks to make "water conservation converts".

Camps meetings of children, youth and nature explorers clubs are also among activities and strategies used by PCA. A recent pilot project was performed during 4 moths, working with the daughters and sons of farmers, members of an irrigation water users association (WUA) in Pedernales, a province in the southwestern extreme end of the country, bordering Haiti, where water, nature conservation and agricultural concepts were combined with drilling exercises, wilderness survival and camping techniques, covering a set of requirements in a different modality of explorers clubs classes or scouting levels. This experience, which had as one of its objective to get the next generation of farmers motivated with sustainable farming, should be further evaluated, developed and promoted. Explorers clubs and scouting activities are a good opportunity to use recreational active learning for water related issues.

Under the motto "*No more future than the one we build*", PCA has also worked with catholic churches and other Christian fellowship groups, in spiritual retreats of young parishioners. A one weekend programme covering topics of leadership and moral values is carried out, with the topics of water conservation neatly woven around the other learning objectives.

The water utility corporation of Santo Domingo (CAASD) also has an educational programme for children, focused on saving water at home and threats of unclean water. The educational department of CAASD makes a balanced use of videos and field trips to a water purification plant as learning experiences.

An interesting experience in the implementation of the *Sandwatch Project* in the Dominican Republic is reported by the Dominican National Commission to UNESCO. Through the network of associated schools of UNESCO and involvement of ministries of education, environment and culture, an national aquarium, provision of equipment for measurements, manual on the use of tools, training for teachers and working with students on monitoring environmental quality of beaches.

Among the PCA's most usual topics and messages are forest and watershed preservation and its relationship with flow of water, scarcity and pollution of water sources, water conservation, hygiene and prevention of diseases, and other general environmental and natural resources topics. Some field visits to dams have been done, but due to logistical and budgetary reasons, these have been too few. A few specific subjects should be developed and added to the programme, as special topics and concepts. Among this vulnerability to floods and a better understanding of downstream communities of dam safety issues.

Tools and strategies have been employed with varied degree of development and effectiveness. Use of printed graphical materials like posters, pamphlets and flyers, has been poorly developed and designed. Messages in flyers and brochures are not clear and have an unbalanced combination of words, too many, and pictures, too little and few. Utilization of mass communication means shows varied domain of production and consequently quality of products and effectiveness are varied. Radio and television have not been used by educational programmes. Sur Futuro, an NGO working with watershed conservation projects, did produce interesting, creative and attractive posters in the year 2003, officially declared as the national year of water. Some private companies and Sur Futuro had a few good television advertisement, but in general, the potential of television publicity campaign are yet to be tapped. The matter of costs involved in marketing water conservation is one factor probably restricting a better use of TV and radio.

One thing that should be clarified is the difference between an educational programme and a publicity campaign, whose messages are transmitted via posters and radio or television. Sometimes confusion and emotion over a "nice" slogan or isolated inspiring phrase invades and pervades educational objectives and degenerate in poor performance educational programmes and waste of efforts and resources. The other pervasive thing is that some private companies only use water or nature conservation as a means to create a good corporative image of environmental concern, and some of these companies are among main polluters of rivers discharging untreated water into it.

The production of local documentaries and films is one worthy project to embark on, since most materials of PCA for example, are videos and documentaries produced in other countries. The Secretariat of Environment and Natural Resources has produced some dealing with ecological and other natural aspects, not directly associated with water issues.

Music and folklore have not been exploited in educational campaigns, but experiences from other Caribbean countries like Barbados, where traditional festivals have taken motives of water in costumes, games and popular songs (Parsram, 2007), should further stimulate this idea. One critique about educational programmes is that the staff tend to try do everything. Proper space should be made for important contributions that talented musicians, visual artists, graphical designers, publicists, actors and cinematographers, can make to the water conservation advocacy and cultural movement. Music for example, has interesting characteristics that it does not ask for permission to get into your brains. If we are speaking of "water culture", we should let the cultural experts speak. Perez (2004) and Perez et al., (2004) have recommended that very popular and gifted artists or sports stars, who are very influential in the youths, can become allies to the water conservation campaigns. It is known that some have wisely joined to campaigns to promote aids or cancer prevention, combating abortion, illegal migration and other purposes, due to the strong public opinion influence they naturally exert. Having them on the water conservation movement would serve to promote and amplify awareness of citizens and society.

Some actions have been limited to scope and horizon of specific projects, not having continuity nor permanency. Main challenges of educational programmes are sustainability, creativeness and innovation, consistency and coherency. Sporadic and isolated messages and ephemeral support for educational projects are risks to. Avoid and overcome. There are voids in analysis of impact of promotional campaigns and room for improvement in the evaluation of teaching methods, and lack of measurement on how attitude of people towards water is changing. Exchange of experiences among different programmes is acsrse opportunities can and needs to grow. Use of educational and pedagogical tools and strategies are incipient degree of development, not specifically oriented or designed for community awareness.

Members of WUAs, youths and university students, not always so aware or concerned as one could suppose, are among important target groups. Institutional capacity building is necessary at rural level so that local organizations are able to develop their own programmes and seek funds for it, provided that technical assistance and some initial financial support is agreed with the water agencies or water utilities. Fostering and sponsoring of educational programmes is an important issue for sustainability.

The content and scope of University programmes for undergraduate studies in civil engineering should be revised. Water related subjects like hydraulic engineering and sanitary engineering, are probably focusing on creating knowledge and skills to solve the conventionalities of design for big cities and big structures like dams, not so environmentally and socially oriented and leaving aside certain issues that the students are more like to encounter in the professional careers. As for the rest of careers and programmes, although some environmental ingredients have been added to their requirements, more can be done to have the water issues permeating through course contents.

Training of staff involved in educational programmes should be planed and organized. Cooperation from publicity and marketing companies, radio and television stations should be sought to provide courses, workshops and internships. Other aspects to improve are publication and visibility of results. Net work of water educators and publicists, is one idea to promote for exchange of experiences. Research on education, psychology and sociology, are necessary to verify the feasibility and effectiveness of methodologies and analyze cultural and behavioral aspects and how educational strategies are able to impact communities. Topics like gender, culture are also to be studied and explored.

14 INSTITUTIONAL ARRANGEMENTS

The institutional arrangement to face the enormous challenges of timely and wisely satisfaction of society's diverse demands of water in appropriate quantities and of good quality is a central issue. Possibilities of successful implementation of an integrated approach to water resources management, or at least well coordinated, will depend, to a great extend, on the legal and institutional framework. The absence or insufficiency of capable institutions responsible for integrated water resources management has been recognized as one of the root causes of deficient water resources management (Lamoree et al., 2005). Traditional institutional schemes and past legal provisions have not helped to solve the problems. New dogmatic formulas of "in style" organizational set up for the water sector on integrated water resources management are not necessarily feasible in a given country. There is no universal solution to institutional arrangement and in each country there is an "*institutional ecosystem*" (Raast, 2005) which must be known in order to design the most suitable and effective framework, analyzing the institutional, social and political context within national reality. Even more important is that the institutions of the water sector have the capacity to implement the normative, regulatory or operational tasks assigned to them. Having the most adequate institutional framework to put integrated water resources management into practice is only half of what it takes for the story to have a happy end. There is an equally difficult question on how to bring about necessary changes in legal – institutional arrangements (Lamoree et al., 2005).

A few of the key components to consider for the assessment or design of the institutional framework are: policy and strategy formulation process and implementation capacities, water allocation and conflict resolution mechanisms, development of planning tools, legal and regulatory instruments, a monitoring network (water quality and quantity), water quality management, environmental assessment (norms, plans, control and vigilance), financial mechanisms, risks management capabilities and participatory approach.

In the Dominican Republic the existing institutional framework for water resources management is characterized by fragmentation of responsibilities among agencies, poorly developed regulatory framework, weak implementation of the very few existing regulatory mechanisms and meager enforcement capacity. Policy for the water sector is not explicitly defined no concrete effort to formulate it can be recalled. Information is disperse or unavailable and access to it is hazardous. The state agencies have been instruments for considerable investment for infrastructural development, but they have had poor performance and have been less successful in operation of water supply systems, water purification plants, sewage treatment plants and irrigation systems. As said before tariff structure, fee collection and economic performance are weak.

The "Instituto Nacional de Recursos Hidráulicos" (INDRHI: national institute for water resources) was created by Law No. 6 of 1965, having as main functions the planning for hydraulic development, performing hydrologic studies and operation of hydrologic network, management of irrigation systems with the participation of users and the construction of water infrastructure, including dams and irrigation systems. The "Secretaría de Medio Ambiente y Recursos Naturales" (SEMARN: secretariat of environment and natural resources) was created by Law No. 64 – 2000 in August of 2000, having several mandates related to water resources, most relevant ones related to groundwater management, surface and groundwater assessment in basins, water pollution control, approving or determining wastewater disposal locations, approving reuse of wastewater, establishing restrictions on the use of water and approving the plans and projects of INDRHI. SEMARN will take time to build capacity to be able implement these and for the time being water resources assessment and groundwater management capacities remain with INDRHI.

Most important effect of this Environmental and Natural Resources Law are a change in the Law 487 of 1969 (and subsidiary law – bylaw No. 2889 of 1977) for regulation of the use of groundwater, whereby SEMARN takes a role previously assigned to INDRHI of managing groundwater, permitting for drilling of wells and other control tasks, for which INDRHI is still better prepared. One positive development brought about by Law No. 64 – 2000 is the requisite of environmental impact studies for projects, including dams, irrigation systems, roads, housing complexes, and many others, having SEMARN the responsibility to rule on this process and to award licenses and permits. SEMARN has gradually developed norms and standards for environmental protection, including control of pollution. The creation in 2004 of an environmental court where to ventilate claims, examine lawsuits and prosecute trespassers of environmental offenses and deal with breach of the law, is also a significant achievement. Vigilance and enforcement capacities however are still under development and incipient. Getting lawyers acquainted with environmental and natural resources issues and having environmentalist become familiar with provisions of law is an important bridge to be built in order to get across in a two ways road.

It would seem that INDRHI is managing surface water and SEMARN has control of groundwater, but neither fulfills these tasks as such. Except for water users associations and those corporate users (water supply companies) deriving water from dams, INDRHI has little control of abstractions from surface waters or use of water. Informality reigns in matters related to legal entitlement to water and there is weakness in the enforcement of procedures to obtain or maintain rights to use water. INDRHI did develop a "hydro-agricultural" information system on a GIS platform to manage production statistics and use of water in the irrigation systems, but the potential of this tool in water management has not been tapped.

Existing water law (Law 5852 – 1962 on Domain of inland waters and distribution of public waters) requires that before proceeding to study or design any civil work on the river bed or before allocating a demand of water for a new user, the implementing agency would need to authorize a permit based on a prior application for the use of water. Permitting procedures are rarely enforced. Users like water corporations expand existing (operating) water system and build new ones without requesting a permit or right to use water or informing neither INDRHI nor SEMARN about it. Projects are not seen in the context of the water availability in the basin and on a project by project basis, frequently improvising and compromising future options.

The requirements of environmental studies and an environmental license has been, in some cases, an opportunity to have INDRHI, in coordination with SEMARN, approving planned use of water in a project or make observations about a project next to a reservoir site or too close to a river. These corporations as well as the hydropower company (state owned) plan, design and build their plants or systems, which sometimes include transfer of water from one basin to another, without an assessment of water reserves and existing water rights in the context of the basin. It also happens that the Secretariat (ministry) of Public Works builds bridges or new roads without consideration of legally established permitting and not taking into account hydrologic and hydraulic aspects.

Before the year 2000 INDRHI was under the secretariat (ministry) of agriculture and is now under SEMARN, which means a change and having INDRHI more involved or concentrate on the conservation of water, instead of being engaged with operational activities of managing irrigation systems. A careful design of that change process is necessary. INDRHI was the sole water agency, but is now legally defined as maximum authority of hydraulic infrastructure. Provisions of Law 64 – 2000 are not sufficiently detailed as to clarify relationship with INDRHI and with existing water law of 1962 (Law No. 5852 – 1962), nor have adequately taken into account INDRHI's role in hydrologic network, water quality monitoring and its capacity to carry out regulatory tasks. A need to harmonize the roles of SEMARN and INDRHI and the environmental and natural resources law with the water law is a priority. There are several issues where SEMARN and INDRHI need to reconcile their thoughts so as to have a common agreement in matters like river basin organizations, environmental payment services and most important the tasks which INDRHI is to perform as a regulator of water resources and its relationship to the sub-secretariat of Soil and water of SEMARN.

The Environmental and Natural Resources Law itself orders an updating of water law and a project law for a new water law was drafted and submitted to Congress in 2003. This proposal for a new water law is inspired in principles of integrated water resource management and the establishment of management instruments such as the river basin planning, water resources national master plan, licensing for the use of water and discharge of waste into water bodies, risk management, financial mechanisms, water information systems, education and research. This draft for the new water law proposes the separation of functions (normative, regulatory and operational), having SEMARN concentrate on policy, strategy, norms, standards and legal issues (constitutional function), while INDRHI would perform regulatory activities or the organizational function (hydrologic network, water assessments, water allocation, administration of procedures to award water rights and others). At the operational function levels the project law recognizes the role of water utilities (water supply corporations, irrigation – waters users associations). The draft also proposes that INDRHI is responsible for the subject of management of multipurpose dams.

Rodríguez (2006), analyzing the legal reforms initiatives and examining the structure, capacity and efficiency of the process, state that the irrigation management transfer process was ignore and suggests that the consolidation of this process be carefully considered and that consultation of this proposal with WUAs is an important step and recommending not to underestimate the capacity of farmers to contribute to this project law.

One objection posed to INDRHI's claims to be the regulator of water resources is that this it represent the main water use sectors, irrigation, and that if INDRHI is to be responsible for regulation of water resources, no operational tasks should be assigned to INDRHI. This, to many is to be both "the judge and party (plaintiff or defendant)". One other argument is that INDRHI should not be engaged in the construction of dams or irrigation systems if it is to regulate water resources, calling for a pure dedication to water regulation, since having both functions will always make infrastructural development be a priority within INDRHI and commitment to regulatory or conservation tasks is not guaranteed. The call for such an aseptic concept of water resources management is probably beyond practical convenience.

The water supply and sanitation sector has the "Instituto Nacional de Aguas Potables y Alcantarillados" (INAPA: national institute for water supply and sewage systems), created by Law No. 5994 de 1962, as the institution of national jurisdiction and mandate for building, operating and maintenance of water supply and sewage systems. INAPA should be a regulator of existing water supply corporations in Santo Domingo (Corporación de Acueductos y Alcantarillados de Santo Domingo – CAASD – created by Law 498 of 1973), Santiago (Corporación del Acueducto y Alcantarillado de Santiago – CORAASAN – created by Law 582 of 1977), Moca (Corporación del Acueducto y Alcantarillado de Moca – CORAAMOCA – created by Law 89 of 1997), Puerto Plata (Corporación del Acueducto y Alcantarillado de Puerto Plata – CORAAPPLATA – created by Law 142 of 1997) and La Romana (Corporación del Acueducto y Alcantarillado de La Romana – COAAROM – created by Law 385 of 1999). These corporations in practice act as independent operators with no regulation. New project laws have been submitted to the Congress for the creation of new corporations and some have been passed but not implemented. This, rather than a decentralization process, is a detachment not related to a strategy of better performance and is due to individual and independent interests of different municipalities not necessarily aiming at operational and economic efficiencies.

Following a study of the water supply and sanitation sector, financed through a non – reimbursable technical cooperation by the Interamerican Development Bank, a reform process was proposed and a law for this specific sector was drafted and submitted to Congress in 2001. Items in this proposal include the creation 2 new institutions a normative and planning entity and a regulating agency, allowing private operators to become involved in providing water supply and sanitation services through different kinds of contracts (BOT, BOO and others).

Rodríguez (2006 Op cit) considers that following subjects are to be revised in the law proposal: the future of INAPA is not properly addressed; links between with proposal for a new water law with missing links on topics like request of water rights, payment of operators for use of water and some provisions for environmental services; the risk of creating two new institutions for regulation of the sector and time for them to build competence are disregarded; investments in small towns where the private companies will not be interested in investing due to small size of the market and continued need of the government for infrastructural development has not been taken into account. A loan operation approved by Congress was tied to approval of the project law for the water supply sector and proposed reforms. Convenience of this loan driven approach to reform should be analyzed.

In spite of the fact the project law remains as a proposal, CAASD in Santo Domingo made contracts with 2 private companies to do the commercial tasks in its name (install meters and do invoicing and fee collections). Investments in meters and administrative costs are to be covered by collected fees. It is thought that good results have been achieved both in terms of savings in water and fee collection, especially considering that the government did not have to invest to buy or install the meters. Information on results however is not available and it is strongly recommended that a communication policy be established to overcome such stealth and for demand management measures to gain more acceptance.

Institutional aspects of hydropower generation are legally defined in the General Law on Electricity (Law No. 121 of 2001). The state owned "Empresa Generadora de Hidroelectricidad Dominicana" (EGEHID), created by this law as part of the holding of "Corporación Dominicana de Empresas Eléctricas Estatales" (CDEEE) operates all hydropower plants. The Superintendence of Electricity is to regulate private thermal power generators (gas, charcoal, oil), but the law defines exclusive right of the government to operate hydropower plants. In 2007 the Congress passed an Incentives Law for renewable energy allowing private companies to invest and operate small hydropower plants or solar or wind energy plants, up to 5 MW of installed capacity with several incentives, including some specific tax exemptions. Future discussion for updating of water law should consider issues as tariffs for the use of water in hydropower, project planning requirements for water allocation.

Concerning hydropower and water resources management one question to address with a clear and concise answer is: Who owns the dams and who is to operate it? Law 125 of 2001 creating EGEHID states that ownership of hydropower house is for EGEHID / CDEEE, while previous laws of 1975 state that ownership of dams are transferred to INDRHI. Except for two dams built by CDEEE, INDRHI has been all the rest of dams in the country, including dams whose main or sole purpose is hydropower generation and has also built most of small hydropower plant not requiring reservoirs. Whether the different components of the dam can be separated having the dam's body (earth or concrete structure), spillways, bottom outlets, and other civil works belong to INDRHI and only the penstock and powerhouse belonging to EGEHID / CDEEE is an interesting discussion.

Regarding reservoir operation, in practice EGEHID / CDEEE operates all gates and valves, including spillway gates for controlled spillways, Some tension often arises between the interest of farmers who prefer to save water for dry periods and the generation interests to generate all electricity possible to cover the deficit of electricity input into the national grid, specially when some thermal generators, consuming imported oil and other derivatives, are out of service. Strict adherence to priority of the use of water (water supply, livestock, irrigation, hydropower) is not always applied, having as apparent reasoning for temporal and emergency deviation of priorities the crisis of energy sector of the country, mostly depending on more costly (operational costs) thermal generation, and comparative economics of hydropower with respect to other productive uses of water, with higher prices for electricity and the non-consumptive use argument of hydropower sector, sometimes outweighing decisions over the irrigation sector due to its low or indirect economic return of the use of water. Inversely, during alert of hurricanes or tropical storms, decisions on safety measures would normally tend to suggest doing early preventive "discharges" to make available volume to effectively damp possible flood wave coming into the reservoir, while interests of electricity generation would try to prolong decisions so as not to "throw out" water through a spillway or bottom outlet. This situation of independently maximizing benefits for any specific does create serious conflicts in water management (Lamoree, 2005).

The Commission of the House of Representatives now studying both the water law proposal and the project law for the water supply an sanitation sector, is of the opinion that the Water Law should be considered and passed first. This is in line with thinking that "*intersectorial water allocation issues should be resolved before intrasectorial reforms are undertaken in the water use sectors*", but in reality experiences in Latin America show that in some countries a few water supply reforms which even include some levels of privatization, have been advanced before having a clear framework for the intersecorial water resources management level (Lamoree et al., 2005).

Within existing legal framework there are good elements that have not been enforced or seldom applied or neglected. Not having a new water law, though necessary to introduce concepts and instruments of integrated water resources management, should not be an obstacle to implement decentralization, improve cost recovery in water supply and irrigation systems, agree on water tariffs to be paid by corporative water users pay for water they are consuming of using, make water resources basin planning a standard for water allocation of new projects, define a national policy for water resources and develop and information system.

Findings of a study for implementation of integrated water resources management (ICWS, 2002) summarized characteristic of the Dominican water sector in this way: Principles of integrated water resources management are not well understood and separation of roles is unknown to many officials of the water sector; INDRHI has mixed functions performing organizational tasks (manager of water resources) and at the same time represents a water use sector (irrigation); no strategic inter-sectorial planning of water resources management takes place; water use planning at the operational level takes place through the "*Comité de Operación de Embalses*" (reservoir operation committee), and ad – hoc committee presided by INDRHI where other water use sectors participate (water supply and sanitation, hydropower); conflict resolution mechanism are poorly developed; there is no systematic water quality monitoring; there is no system of pollution licenses; there is no mechanisms for water policy and strategic water development plans; river basin authorities are non-existent; the system of water use right is not well developed; there is no operational enforcement mechanisms; there is no water resources regulation at basin level; and there are several on – going initiatives of reform process and proposals mainly productive sector oriented (water supply, irrigation and hydropower), but here is lack of coherence between various reform process.

Six years later, the principles of integrated water resources management are more familiar and except for planning, the rest of findings of 2002 are still valid. The existing institutional and legal frame work was designed with independent objectives and interests (sectorial approach) and the legal reforms initiatives remain much the same. Unfortunately, when the different sectorial law projects are discussed and compared, the institutional aspects catch all the attention, with representatives of each water use sector actively advocating for their share of power, with discussions across the table on who builds (infrastructural development), who controls awarding of bigger price contracts, and in essence negotiating which piece of the cake everyone is getting. Matters related to water rights, water allocation, river basin planning, pollution control, environmental protection, deserve much less attention of contestants.

In practical terms the only real action of water allocation is within the reservoir operation committee (ROC), having representatives of main water use sectors (INAPA, CAASD, CDEEE, INDRHI and ONAMET - meteorological office – and for hurricane season and specifically for hurricane alerts the committee is expanded) meeting every month to decide on volumes of water for each sector and at each dam. INDRHI and CDEEE play leading roles while the rest of institutions have a low profile (Lamoree, 2005). The proposal for the new water law considers the establishment of one ROC at each dam or reservoir to increase decision making participatory process involving more stakeholders dealing with more regional issues, rather than only one ROC at national level. The aforementioned assessment (ICWS, 2002) considers the ROC as rudimentary and authority oriented not conflict preventive.

Reservoir operation has to improve, developing operational rules curves, with a better link to early warning pluviometric and flow measurement stations and using well calibrated hydrologic and hydraulic simulation models for incoming flood and effects of discharge downstream respectively. The operation is now based on levels of the reservoir as indicated in the existing manuals, which are more reactive rather than proactive and predictive. The only legal base of the ROC is an agreement between CDEEE and INDRHI signed in 1974 with amendments in 1980, 1988 and 1991, having as objectives the "programming, implementation and control of reservoir operation to meet different demands (water supply, industry, irrigation, energy and ecological uses) and maximize energy production without affecting other users and minimized damages during extreme events – scarcity and abundance of waters" (text of the agreement). It also provides some negotiating ground for the fixing of tariffs, an issue never discussed.

Irrigation management transfer stands out as a positive example of decentralization and participatory solutions for management of water services, in this case irrigation. Transferred responsibilities to WUAs by INDRHI including administrative and operational tasks (the property is not transferred), have been performed without requiring a sectorial law on irrigation, since provisions of existing water law (Law No. 5852 of 1962) do foster the involvement of what was called "*irrigation societies*" in the cleaning and maintenance of irrigation and drainage canals; and INDRHI had a clear vision and a strong decision to make progress in delegating power to farmers in the irrigation systems, that showed continuity through out political changes and turnovers along two decades. Consolidation of this process is necessary and promoting WUAs is worthy of support. Innovation and strengthening in commercial aspects are priorities for the reinvigorating this process.

One interesting development is the formulation of the National Water Resources Plan (NWRP) carried by INDRHI since 2005, with technical assistance of the Spanish Government. The objectives of the studies for the NWRP are to diagnose the water situation of the country (updated water balance already available), identify priority actions and define an action plan and pertinent projects to solve current problems concerning water quantity and water quality, as well as to avoid future complications in the water sector, contemplating rational and sustainable use of water. It is expected that the NWRP will become an instrument for programming investment and solving problems affecting or threatening socioeconomic development of the country. One remarkable experience during the formulation of the plans has been the integration of community representatives with a participatory approach in the planning process having stakeholders identify main problems and issues within a watershed or a region and also rank those problems and perform problem analysis by means of several methodologies including GOPP (Goal Oriented Project Planning) and others, in order to identify measures and actions that can turn out into projects. The first time in the country that involvement of stakeholders goes this far and the first time planning is reaching this level. The participatory experience has been successful and outcomes of regional workshops and group exercises show that stakeholders do know the problems and interrelationships between those problems and possible alternatives for solutions. Hopes of continued participation of stakeholders at other stages of the NWRP, indicative sector plans, basin and/or regional perspective of water resources planning and project optimization based on water availability in the basins are high.

15 RESULTS OF ASSESSMENT

Having reflected on the issues described above on the country specific situation, one can proceed to examine the water resources management systems by making use of the proposed building blocks methodology. It must be taken into consideration that specific situations related to water stress, pollution detected in rivers, sedimentation of reservoirs, are not to be measured and that assessment concentrates on the management systems, rather than physical situation. Assembling and organizing available information on water problems is required. Nevertheless, existing problems are a reflection of weaknesses of the management system or aspects that could be addressed with improved approaches and tools to make water resources management components or elements, whether it be planning, monitoring or water allocation mechanisms, more sustainable. Having this in mind, the building blocks were individually evaluated and a color or numeric score was assigned to them. Using the more simple coloured blocks alternative as a first attempt or to initiate the scoring process provides a general picture of missing elements and facilitates a good start for the exercise, being able to identify the elements with extreme scores (inexistent or well developed) and making it easier to pass on to a numeric score, once it is decided which elements would have a 0 (absent), 4 (satisfactory or promising experiences and good potential for more improvement) or 5 (Well developed and improving) score.

The results of the coloured blocks approach are shown in Table 17, where we immediately realize that the important foundational layer of “Strategy and Policy” have voids; as well as those of water

Table 17. Results of Assessment – Coloured Building Blocks.

RISK	Early warning system	coordination with Civil defense and other emergency institutions	Flood control action plan	Droughts	Risk mapping	Zoning protection
FINANCING	Investment programmes	Tariffs structure	Cost recovery	Incentives	Private participation	Water accounts
WATER ALLOCATION and QUALITY CONTROL	Allocation mechanisms (award, licensing and permitting)	Demand management	conflict resolution mechanisms	Quantity and quality integation	Compliance	water reserves
ENVIRONMENT and NATURAL RESOURCES	Norms and procedure	Control and vigilance	Impact assessment requirements	Ecological flows or demand	Environmental management plans	Watershed management plans
MONITORING	Climate stations	Hydrometric network	water quality measurement	groundwater	processing and analysis	diseminaiton and public access
PLANNING	Inventory and asessment of water	Water Balance	national, state or regional planning	Basin planning	Indicative sectorial plans	Project optimization
INSTITUTIONAL	Role definition	Institutional arrangement	Descentralization and users organizations	Public participation	Education and communication	Research and development
LEGAL	drafting law	law	cadaster registry	administration of water rights	law and regulation	law enforcement
STRATEGY AND POLICY	Strategy	Policy formulation	Principles and Norms	Policy statement	Priorities	Policy evaluation

Table 18. Results of Assessment – Building Blocks with Numeric Scale

Components	Elements						Total (out of 30)	%
RISK	Early warning system 3	coordination with Civil defense and other emergency institutions 3	Flood control action plan 3	Droughts 1	Risk mapping 2	Zoning protection 0	12	40.00
FINANCING	Investment programmes 2	Tariffs structure 2	Cost recovery 1	Incentives 1	Private participation 3	Water accounts 1	10	33. 33
WATER ALLOCATION and QUALITY CONTROL	Allocation mechanisms (award, licensing and permitting) 2	Demand management 2	conflict resolution mechanisms 2	Quantity and quality integation 0	Compliance 0	water reserves 0	6	20.00
ENVIRONMENT and NATURAL RESOURCES	Norms and procedure 4	Control and vigilance 0	Impact assessment requirements 4	Ecological flows or demand 0	Environmental management plans 2	Watershed management plans 2	12	40. 00
MONITORING	Climate stations 4	Hydrometric network 3	water quality measurement 2	groundwater 2	processing and analysis 3	diseminaiton and public access 3	17	56. 67
PLANNING	Inventory and asessment of water 3	Water Balance 4	national, state or regional planning 2	Basin planning 1	Indicative sectorial plans 3	Project optimization 0	13	43. 33
INSTITUTIONAL	Role definition 2	Institutional arrangement 2	Descentralization and users organizations 4	Public participation 2	Education and communication 3	Research and development 2	15	50. 00
LEGAL	drafting law 3	law 1	cadaster registry 3	administration of water rights 0	law and regulation 2	law enforcement 0	9	30.00
STRATEGY AND POLICY	Strategy 0	Policy formulation 0	Principles and Norms 3	Policy statement 0	Priorities 3	Policy evaluation 0	6	20.00

allocation and quality control. These components should be priorities in any initiative for the improvement or reform of the water management system. Other priority components should be the environment and natural resources and financing. This graphic assessment also suggests an order for development of the water resources management system, being relatively easy to visualize the stages and process to follow. First items on the agenda should be strategy and policy formulation to arrive at an explicit policy statement. Some recent initiatives like the establishment of a research centre at INDRHI and current national water plan under way have made the picture better, but it is to be recognized that future periodic assessment is to prove if these elements can sustain achieved progress or make more advancements.

The graph results in Table 17 also show strengths or achievements in elements like water balance, due to recent update, decentralization and users organizations, due to progress and success in irrigation management transfer, and development and application of legal requirements on environmental impact assessment. These success stories can also provide clues as to the strategies for improvement in other elements.

When using a numeral scale it is then possible to assign an assessment score to all the elements or blocks and an accumulated score for the component (layer). Results are shown in Table 18, with a final percentage in each layer. Now, after those "light gray" blocks have been identified, one can proceed to assign them a more precise numeric evaluation score. The numbers or percentages should not be interpreted as approving or failure grades, but rather as revealing an order of magnitude of efforts needed to improve water resources management. It is evident that lowest ranking components are, again, "Strategy and Policy" (20%) and "Water Allocation and Quality Control" (20%), followed by "Legal" (30%), "Financing" (33%), "Environmental" (40%) and "Risks" (40%) components.

Elements such as Law, Cost Recovery, Incentives, Water Accounts and Droughts, are all considered being obsolete or inefficient, and should therefore be acknowledged as main items to be prioritized in an action plan for the modernization of the water resources management system. In the case of the "Monitoring" component, where there is more tradition and some modernization efforts have been made with luxury technology like "real time network of an early warning system", the score could have been higher. Difficulties with maintenance of hydrologic network and the early warning system, irregular water quality (surface and groundwater) and groundwater monitoring, make the final score to be lower than could have been expected, meaning that advances made are not sustainable or not being able to use them more effectively. It is believed that hydrologic monitoring has been debilitating in the last years and one underlying factor, as well as for most of the other components of the water management system, is lack of human resources. Renewal of and "cultivating" talented staff is a priority. Lastly, development of systematic management of hydrologic information is vital to water resources management.

16 CONCLUDING REMARKS

Problems and concerns of water resources in the country case study are related to signs of water stress, contamination of rivers and coastal waters with microbiological pollution, overexploitation of aquifers, poor quality of water for aquatic life in river reaches passing through cities, fast paced reservoir sedimentation and impact of uncontrolled urban growth and extreme hydrological events. Lack of sanitation services, insufficient wastewater infrastructure and irresponsible industrial and municipal discharge of solid and liquid wastes into rivers, are reasons for pollution and health problems. Low efficiency in the use of water and distribution network, losses of water due to non-accountability of users, subsidy dependent water services and poor cost recovery by service operators are characteristics of water quantity mismanagement. All these physical and economic water problems are related to the management system. It is necessary to allocate water having in consideration water availability, to improve monitoring and control of water pollution and adequately integrate or reconcile infrastructural and tourism developments. The absence of a policy statement and formulation process and water allocation mechanisms need to be solved.

Important topics to put on the agenda for improvement of the institutional framework are: weak control and weaker enforcement capacities, lack of rules to allocate water and informality on water rights. The existing institutional and legal frame work was designed with independent objectives and interests. Harmonizing reforms and working towards a common vision is recommended for any progress to be made in improvement of the water resources management system. There are signs of hope in water management with progress made in irrigation management transfer, educational programs on water conservation and environmental education, water balance update and the national water plan initiative.

The building blocks assessment tool, whose objectives are to identify missing elements of the water management system and evaluate the capacity of a country to face water challenges, can be useful for rapid appraisal exercises of water management capacities and is ideal for participatory assessment. Further testing and practical applications in other countries is relevant for its development and refinement. Results of the building block methodology indicate that strategy – policy formulation and water allocation mechanisms are top priorities to work on for the development of water resources management systems.

REFERENCES

Abreu, R.U. 2004. Informe Situación Actual de la Salud Ambiental Infantil en la Rep. Dominicana. Presentación Taller Definición Lineamientos Plan Nacional de Salud Ambiental Infantil, Santo Domingo, Julio, 2004.

Al Radif, Adil. Integrated water resources management (IWRM): an approach to face the challenges of the next century and to avert future crisis. (Conference on Desalination and the Environment, Las Palmas, Gran Canaria, November 9–12, 1999). Desalination 124, 1999 pp. 145–153.

Biswas, Asit K. Integrated Water Resources Management: A Reassessment. A Water Forum Contribution. International Water Resources Association. Water International, Volume 29, Number 2, June 2002. pp. 248–256.

Brath, A., Brandimarte, L., Castellearin, A., Di Baldassarre, G. DISTART – Universitá di Bologna. 2006. Proyecto de capacitación para la defensa Hidrogeológica del Territorio en la República Dominicana y Haití. Relazione Conclusiva. December 2006. pp. 1–4, 79–85.

Centro de Investigación en Tecnología de Agua para Riego (CITAR) – INDRHI. January 2008a. Estudio Diagnóstico de Desempeño de Juntas de Regantes 2007. pp. 1–22.

Centro de Investigación en Tecnología de Agua para Riego (CITAR) – INDRHI, Research Report – Calidad de las Aguas cuenca Ozama – Isabela, Santo Domingo (August 2007).

Centro de Investigación en Tecnología de Agua para Riego (CITAR) – INDRHI, Research Report AERH/08-08 – Análisis de las Tarifas y el Costo del Agua en Áreas bajo Riego en la República Dominicana (March 2008b). Santo Domingo. pp. 1–3, 11–16.

Chalas, J.R. 2007. Impacto de las Organizaciones de Usuarios en las áreas bajo riego de la República Dominicana *(Análisis Preliminar). July 2007. Centro de Investigación en Tecnología de Agua para Riego (CITAR) Instituto Nnacional de Recursos Hidráulicos (INDRHI. Santo Domingo, Dominican Republic.* (this seems not to be a bibliographic reference)

CYE Consult s.n.c. Estudio de Identificación y Formulación del Plan Indicativo de Trabajo del Sector Agua del 9no FED September 2003. (this seems not to be a bibliographic reference)

Dourojeanni, Axel 2001. Water management at the river basin level: challenges in Latin America. (Economic Commision for Latin America and the Caribbean, LC/L.1583—P, agosto de 2001, *Serie Recursos Naturales e Infraestructura Nº* 29)

ECLAC (Economic Commision for Latin America and the Caribbean) quoting Jovel and Zapata, 1993 in ECLAC's report on Damages evaluation caused by Hurricane Georges, 1998). (this seems not to be a bibliographic reference)

ECLAC (Economic Commision for Latin America and the Caribbean), Secretariado Técnico de la Presidencia, Programa de naciones Unidas para el desarrollo (PNUD). Octubre 2004. (this seems not to be a bibliographic reference)

Food and Agricultural Organization (FAO) of the United Nations. 1995. Water sector policy review and strategy formulation, A general framework, FAO Land and Water Bulletin No. 3, United Nations Development Programme (UNDP), World Bank and FAO, Rome, Italy, ISBN 92-5-103714-0. pp. 1–3.

Foro de Ministros de Medio Ambiente de Iberoamérica I, celebrado en La Toja, Reino de España, 21 y 22 de septiembre de 2001. (this seems not to be a bibliographic reference)

Garduño, H. 2001. Water Rights administration, experience, issues and guideline, Development Law Service of the Food and Agricultural Organization (FAO) of the United Nations, FAO Legislative Study No. 70, Rome, Italy, pp. 1–3.

Global Water Partnership (GWP) September 2000. Integrated Water Resources Management, TEC Background Papers No. 4, GWP, Stockholm, Sweden. ISSN: 1403-5324, ISBN: 91-631-0058-4. pp. 7.

González, G., Gladis, R. and Valdez, N. Calidad de las Aguas de las Playas de la República Dominicana. Santo Domingo, Secretaría de estado de medio Ambiente y Recursos Naturales, 2004. (this seems not to be a bibliographic reference)

Instituto Nacional de Recursos Hidráulicos (INDRHI)–OTS Corp, for Inter American Development Bank, Diagnóstico, Componente de Validación de Opciones y Prioridades, Análisis de factibilidad y Diseño del Programa de Manejo de Cuencas y Zonas Costeras, Santo Domingo. March, 2006. pp. 20, 94.

Instituto Nacional de Recursos Hidráulicos (INDRHI) 2007 Water Management Consultants (WMC), Análisis de la Rehabilitación de los Embalses y Represas de valdesia y Aguacate, Cuenca del Río Nizao, República Dominicana for Inter American Development Bank. pp. ii, xii, 5–12.

INDRHI, El INDRHI en el Desarrollo Nacional. 2006b. Editora Taller, Santo Domingo, Rep. Dominicana. pp. 107, 123.

International Centre for Water Studies (ICWS). May 2002. Elaboration of an Institutional Framework for Integrated Water Resources Management – Final Report to the Inter-American Development Bank, Amersfoort, The Netherlands.

International Water Management Institute (IWMI 2002). Final Report of the World Summit on Sustainable Development. 28th of August – 3rd of September. Johannesburg. ISBN: 92-9090-510-7. pp. 5, 7, 15, 16, 17, 21.

Jewit, Gram. Can integrated Water Resources Management sustain the provision of ecosystem goods and services. 2nd WARFSA/WaterNet Symposium: Integrated Water Resources Management: Theory, Practice, Cases; Cape Town, 30–31 October 2001.

Jiménez, O. and Farias, H., Problemática de la Sedimentación en el Embalse de Valdesia. Report for CDEEE, Santo Domingo, 2002, pp. 1–4, 27–29.

Lamoree, G. Bem, García, Luís, Pérez Raúl, Castro, Edmundo. Methodology for the Assessment of Institutional Frameworks for Water Resources Management, Experiences from Latin America. Water International Vol. 30, Number 3. September 2005. pp. 283–293. International Water Resources Associations (IWRA).

Nagle, Gregory. 2005. Los Efectos de un huracán sobre la pérdida de suelos en parcelas cultivadas en una cuenca tropical montañisa. 16, Ithaca, N. Y. Cornell University. (this seems not to be a bibliographic reference)

Oficina Nacional de Planificación (ONAPLAN), Informe General sobre Focalización de la Pobreza en República Dominicana, July 2005. (this seems not to be a bibliographic reference)

Oficina Nacional de Estadísticas (ONE), ENHOGAR 2006, Informe de Avances de Resultado, diciembre 2006 (this seems not to be a bibliographic reference)

Parsram, Kemraj, Educación sobre Conservación de Agua. Foro Nacional del Agua, February 2007. Santo Domingo. pp. 120–130. (this is not a bibliographic reference)

Pérez, R., González, E., Sánchez, M., Suero, M., Martínez, E. and Tavárez, V. 2004. (INDRHI). Inundaciones Jimaní–Río Soliette. Diagnóstico del Problema. June 2004. (this seems not to be a bibliographic reference)

Pérez, R. 2004. Programa Iberoamericano de Educación sobre el Agua. IV Conferencia General de Directores Generales Iberoamericanos del Agua (CODIA). Santo Domingo, March 2004. (this seems not to be a bibliographic reference)

Raast, Walter. 2005. Institutional design for water resources management. I Seminar on Integrated Transboundary Water Management. Lima, 2005. (this seems not to be a bibliographic reference)

Reed, S., Maidment, D. and Patoux, J. 1997. Spatial Water Balance of Texas, Center for Research in Water Resources University of Texas at Austin June 1997, pp. 1–4.

Ringler, Claudia, Rosegrant, M.W. and Paisner, M.S. Irrigation and Water resources in Latin America and the Caribbean: Challenges and Strategies. International Food Policy Research Institute, EPTD Discussion Paper No. 64. June 2000. pp. 11–17.

Robles, G. and Alcérreca, C. 2000. Administración, un enfoque interdisciplinario, Prentice Hall – Persons Educación de México, Mexico. ISBN: 968-444-421-4, p. 31.

Rodríguez, F. 2005. Floods in the Dominican Republic: Lessons Learnt. 1st Army Conference on Relief Operations in case of Disasters. Santo Domingo. 2005. (this seems not to be a bibliographic reference)

Rodríguez, F. 2006. Challenges of Legal Reform of the Water Sector in the Dominican Republic. World Bank session on assessment of water management systems 4th World Water Forum, Mexico, March 2006. (this seems not to be a bibliographic reference)

Secretaría de Estado de Medio Ambiente y Recursos Naturales (SEMARN), Atlas de los Recursos Naturales de la República Dominicana, Santo Domingo, 2004. (this seems not to be a bibliographic reference)
Secretaría de Estado de Medio Ambiente y Recursos Naturales (SEMARN) 2001, "Diagnóstico Económico Fiscal" (this seems not to be a bibliographic reference)
Setti, Arnaldo Augusto; Werneck Lima, Jorge Enoch Furquim; Goretti de Miranda Chaves, Adriana; de Castro Pereira, Isabella. 2002. Introdução ao gerenciamento de Recursos hídricos, Agencia Nacional de Energia Elétrica (ANEEL), Agencia Nacional de Águas, Organizao Meteorológica Mundial, Brasília, Brasil, pp. 90–93.
Stockholm International Water Management Institute (SIWI) and World Health Organization (WHO). Making Water a part of Economic Development: The economic benefits of improved water management and services. 2005. (this seems not to be a bibliographic reference)
Trewatha, R.L. and M. Gene Newport, Management, Business Publications, Inc., Plano Texas, 1982 ISBN 0-256-02713-7, pp. 5–8.
United Nations Development Program (UNDP) 2005 República Dominicana. Informe Nacional de Desarrollo Humano, Hacia una inserción mundial incluyente y renovada. 2005. ISBN 99934-55-81-4. pp. 86, 87.
United Nations Environmental Program (UNEP), Dams and Development: A compendium on Relevant practices for Improved Decision Making on Dams and their alternatives. Nairobi, 2007. ISBN 978-92-2816-3. pp. 11, 69–79.
United Nations Development Program (UNDP) 2006. Repot on Human Development, 2006, Beyond Scarcity, Power, Poverty and the World Water Crisis, Summary pp. 5, 41.
WMO/IDB (World Meteorological Organization and Inter-American Development Bank), 1996. Water Resources Assessment and management strategies in Latin America and the Caribbean. Proceedings of the WMO/IDB Conference, san Josè, Costa Rica, May 6–11.
World Meteorological Organization (WMO) and Inter-American Development Bank, 1996. (this seems not to be a bibliographic reference)
Third World Water Forum–Session report water, the MDGs and PRSPs Mainstreaming poverty reduction in water management. 19 march 2003. 3rd World Water Forum, Japan.