Integrated Water Resources and Coastal Areas Management

Combining sound science, legal action and stakeholder involvement to protect a vulnerable coastal aquifer on the island of St. Kitts

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1. Introduction

The unconfined coastal aquifer underlying the Basseterre Valley is a significant environmental, economic and social asset for the people of St. Kitts-Nevis. The potable water extracted from this aquifer represents over 40% of the total water supply for St. Kitts. The area is subject to urban encroachment, inappropriate land use and threats from pollution. A project was devised and implemented using an integrated approach to help government and communities take practical actions to protect this vulnerable aquifer by demonstrating proper management and protection. The project is supported by the Global Environment Facility (GEF) as part of the Integrating Watershed and Coastal Areas Management (IWCAM) project for Caribbean Small Island States. The two major outcomes of the project are a water resources management plan and establishment of a National Park in the well-field area. The key elements of the project will be discussed in this paper. Sections 2 and 3 cover the hydrogeologic evaluation and land use survey. Section 4 highlights main findings and actions in the review of water policy, laws and institutional frameworks. Section 5 focuses on the transformation of the well-field into a National Park as a means of protecting the aquifer. Finally, section 6 attempts to assess the overall sustainability of the project.

2. Hydrogeologic Survey

A comprehensive hydrogeologic survey of the Basseterre Valley Aquifer was undertaken. The survey included various elements not limited to:

1. Review and evaluation of all existing hydrogeologic data;
2. Mapping of the aquifer using a novel geophysical technique;
3. Recording of water levels and video survey of existing wells;
4. Sampling of wells for various water quality parameters; and,
5. Construction of a computer simulation model.

This paper will only discuss elements of points 2, 3 and 4. The Basseterre Valley Watershed covers over 8 square miles and is located on the island of St. Kitts in the Eastern Caribbean. The groundwater flows south and recharges the Basseterre well-field. There are currently 10 supply wells and several monitoring wells within the Basseterre Valley well-field (Figure 1).

Figure 1: Location of major wells and MER transects

The Basseterre Valley Aquifer is an unconfined coastal aquifer. The location of the well-field on a peninsula surrounded by salt water makes delineation of the fresh/salt water interface critical for appropriate long-term water supply use. The aquifer is recharged directly by rainfall, and has a defined zone of capture and volume. The main challenge of pumping water from an unconfined aquifer is the balance between water withdrawn via pumping versus the recharge rate. Excessive pumping rates or extended pumping in a given area can cause dewatering of the aquifer, pump cavitation, well collapse, and saltwater intrusion. However, with the proper well-field configuration, well pumping schedule, well-field management, and appropriate monitoring system, coastal aquifers can be developed to provide a long-term source of potable water.

2.1 Geophysical mapping of the aquifer

In trying to delineate the fresh/salt water interface, the critical first step is to differentiate the underground stratigraphy, and to spatially correlate geologic units. Traditionally, these aquifer parameters are estimated from direct observation and data collection from drilling of multiple boreholes and installation of monitoring wells. However, drilling is a time consuming, labour intensive and expensive activity. Instead a novel geophysical technical named Multi-Electrode Electrical Resistivity (MER) was used to map the aquifer. Each hour of mapping with MER is equivalent to drilling 56 boreholes without the data gaps between boreholes. MER was used to delineate:

1. The thickness and distribution of sediments throughout the aquifer;
2. Zones of increased porosity (areas where water can flow more easily);
3. Zones of possible contamination; and,
4. The fresh/salt water interface (freshwater floats on seawater because seawater is about one-fortieth more dense than freshwater).

Geophysical techniques such as MER measure the differences in resistivity of earth materials. Resistivity is the property of a material to resist the flow of electrical current. Electric current is introduced into the ground using pairs of electrodes and then the electrical fields that flow through the various layers of earth in the subsurface are observed. The electrodes are typically arranged in a linear array (called a "transect"). Transects are shown in Figure 1. As the distance between the electrodes is increased, more data on subsurface resistivity from successively greater depths can be achieved. MER is a useful technique in groundwater hydrology because each type of earth material (sand, clay, rock etc.) exhibits a different resistivity. Also, the resistivity of earth materials is very sensitive to water content. In turn, the resistivity of water changes as its salt content increases. The MER technique identified three units in the Basseterre Valley Aquifer:

- **Unit I**: A high resistivity unit of dry sands, clayey sands and volcanic rock. Unit I was an average thickness of 5.5 meters.
- **Unit II**: A layer of intermixed sand, clay and rock similar to Unit I but its resistivity signature is different due to partial saturation with water. Unit II is approximately 14 meters thick.
- **Unit III**: A unit of gravels, coarse sands and boulder rocks which is the water storage unit of the aquifer system. This unit begins at about mean sea level and has an average thickness of about 22 meters. The lower part of Unit III exhibits markedly lower resistivity material that represents the saltwater saturated part of the aquifer. This contact of the high resistivity fresh water aquifer with the very low resistivity of the salt water at the base of Unit III marks the fresh/salt water interface across the entire area. An example of this is shown in Figure 2 (the interface is shown as the dashed red line).

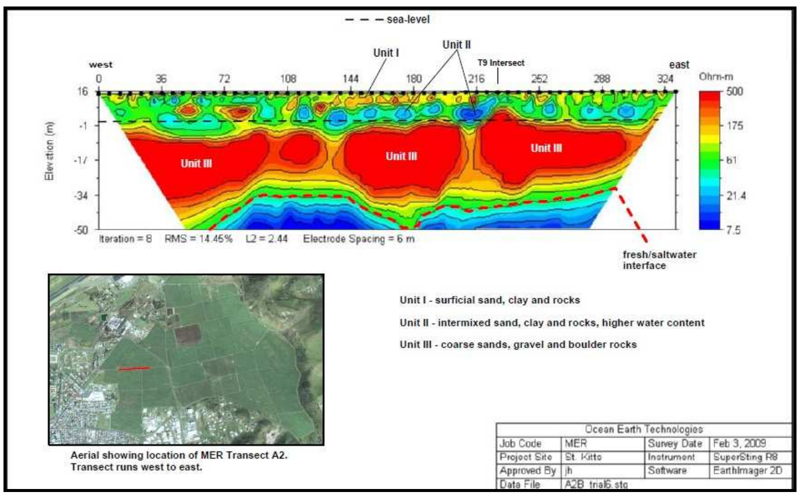

Figure 2: Example of MER transect

Figure 3 shows a map of the elevation of the fresh/salt water interface for the whole well-field area. This information is incredibly useful in terms of managing pumping levels in the aquifer and to understand the likelihood of salt water intrusion in the future especially with the likely impacts of climate change and sea level rise. Together with water level and water quality monitoring, an assessment of the likelihood of saltwater intrusion can be made.

2.2 Water level monitoring

Figure 4 plots a time-series of measured static water levels in production wells along a west to east transect across the well-field. This graph displays the temporal and geographic changes in the water level elevations from five water supply wells (1-48, 1-47, 1-41, Ponds 1, and Ponds 2). While this is not a high-resolution record through time, there is a clear declining trend in static water levels relative to sea-level seen in each of the five wells plotted. The average decline in water level is on the order of 0.5 to 0.6 meters (1.5 to 2 feet) since the 1980's and greater than

0.6 meters (2 feet) for wells 1-47 and 1-41 that have been in production since the 1970's. The water levels also slope nearly 0.6 meters (2 feet) from the west side of the well-field to the east side. These declines indicate that the long term water withdrawals from the Basseterre Valley Aquifer well-field are gradually dewatering the aquifer in this area, with the concentration of dewatering taking place in the eastern part of the well-field.

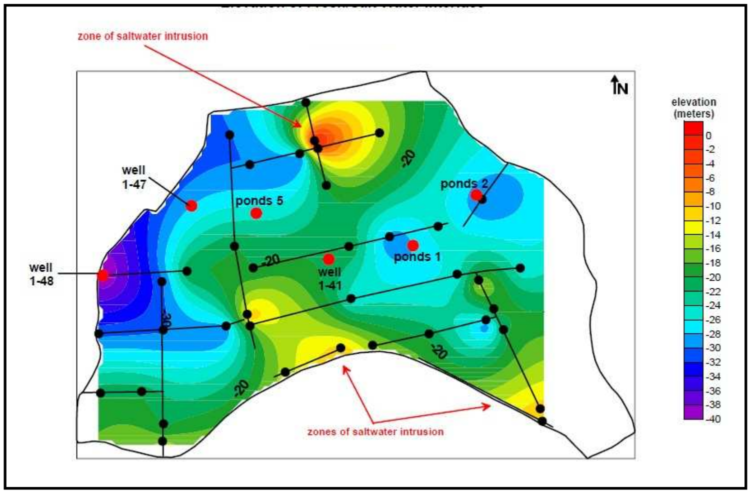

Figure 3: Elevation of fresh/salt water interface over the entire well-field

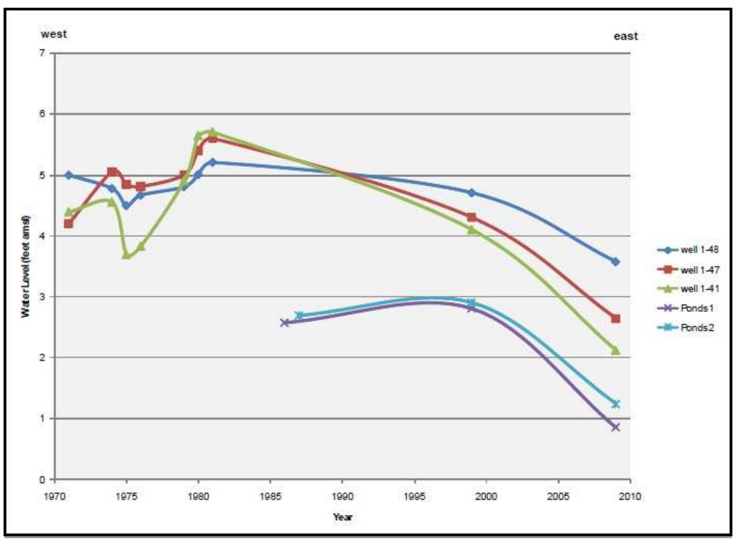

Figure 4: Static water levels 1970-2009

2.3 Water quality sampling

Water samples were taken from a total of ten supply wells and three surface water sites. The analyses were designed to evaluate potential contaminant levels in the supply wells, observe salinity and total dissolved solids (TDS) levels that may be related to salt water intrusion. There were no measurable levels of pesticides, herbicides, semi-volatile or volatile organics in any of the well water samples analyzed. This section will discuss only the results that are relevant to salt water intrusion.

Several production wells (Conaree, Ponds 2 and 1-48) exhibited elevated TDS concentrations that are up to twice as high relative to other supply wells sampled. Historical data show that there is a clear increase over time in both the chloride levels (data not shown) and TDS levels (Figure 5) in the majority of the wells. These temporal relationships indicate that over time, the pumping within the Basseterre well field has resulted in increasing trends of TDS and chloride, potentially indicating gradual saltwater intrusion. Furthermore, these trends directly correlate to the decline in static water levels across the valley from 1976-2009 (Figure 4).

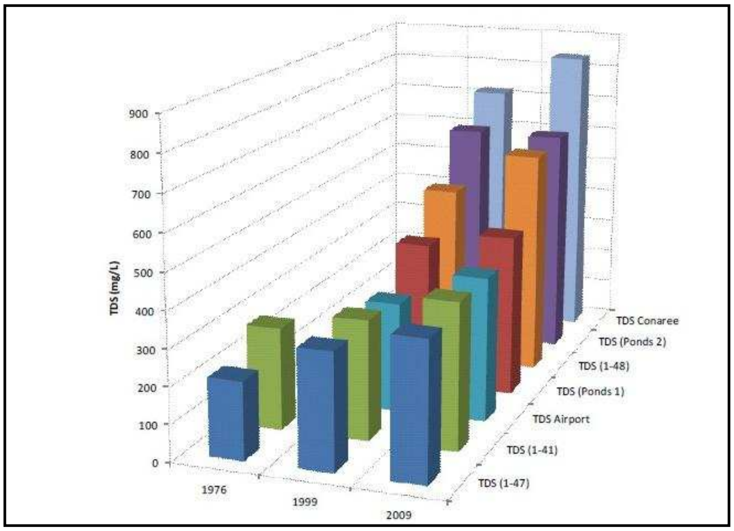

Figure 5: Total dissolved solids concentrations 1976-2009

Overall, the use of MER provided a wealth of new information about the Basseterre Valley Aquifer for a reasonable cost. The results of the MER analysis have proven to be an excellent method for delineating the upper parts of the aquifer as well as the depth and variations in the fresh/salt water interface in response to long-term pumping. Together with declining static water levels and increasing chlorides and TDS, the early signs of saltwater intrusion have been documented. This knowledge is grounded in sound science and provides the foundation upon which an integrated approach to water management in the aquifer can take hold.

3. Land Use Survey

At present, the majority of the Basseterre Valley watershed is vegetated land with over 30% representing disused government-owned sugar cane fields. In fact, approximately 70% of lands in the watershed are owned by the government. As a result, there is a lot of pressure to develop these lands. In recent times, there is an increasing trend towards medium to high density development. An increase in informal settlements has also been observed. Figure 6 shows the distribution of state lands within the watershed boundaries (areas in grey are private lands while the area in green is proposed National Park area). Increased urbanization in the watershed poses serious challenges related to solid waste disposal, municipal wastewater treatment, and urban runoff.

Figure 6: Distribution of state lands

The municipal capacity for collection and sanitary landfill disposal of the solid waste generated by Basseterre and environs is near maximum capacity. The survey indicates a growing practice of informal dumping on vacant lands and waterways.

There is no municipal sewage collection or treatment facility for the town of Basseterre which has over 5000 residents. Almost all of the homes use septic/soakaway systems. Fortunately, more than 50% of the population resides in the lower parts of the watershed, where sewage leachates may not pose a significant bacterial to water quality in the aquifer. However, rural settlements that have developed in linear patterns along the main access roads that follow the river valleys also use soakaway systems and associated bacterial loads may directly threaten the aquifer if settlement densities increase in the future.

Urban run-offs from parking lots, industrial areas (machine shops and dumps), and roadways may also increase hydrocarbon loads. This includes the airport runway which represents a major impermeable area immediately above the well-field. These pollution threats can be mitigated through careful and integrated physical planning starting with the actions outlined below.

3.1 Residential developments

Future residential development in the upper watershed (see dividing line in Figure 6) should be medium to low density. The hillsides forming the southern watershed boundaries presently are not part of the proposed protected area. It is critical that physical planning constraints be imposed on these areas if they are to be developed. It is recommended that only medium density housing be allowed (half acre lots or greater). Further, any housing in this area should have a tertiary level treatment plant because of the thin soils, proximity to the aquifer, steep slopes and relatively low infiltration capacity.

3.2 Industrial development

Zoning policy should limit the development of industrial developments with polluting trade effluents in the western sub-basin. The present industrial/commercial estate (CAP Southwell Industrial Site) should be rehabilitated to include centralized engineered waste processing. Establishments such as car-washes, mechanic shops and larger scale industries should also be relocated there.

3.3 Agriculture

Small-scale agricultural zones should be designated as part of the physical plan so they do not develop on an *ad hoc* basis. Small-scale agriculture is acceptable in the watershed provided that best management practices in respect of soil conservation, irrigation, and fertilizer/pesticide application are implemented. Organic farming can also be promoted for local tourism market, as there is an increasing market for this kind of produce. Livestock grazing (cattle, goats, sheep) should be banned in recharge areas that may be connected the well-field.

These recommendations are currently being studied and discussed by a wide range of stakeholders in the watershed.

4. Review of water policies, legislative and institutional framework

A comprehensive review of the legal enabling environment was undertaken. Although there are over five separate statutes with various functions for water resources management in St. Kitts and Nevis, there are several critical gaps in the legislative framework. A few of these issues are listed below:

- The Waterworks and Watercourses Ordinance is outdated (pre-independence).
- There is a need for the redefinition of the water services department (WSD) as established by law. Presently the WSD is not a statutory authority with the statutory powers.
- There is no statutory requirement for the preparation of a National Water Resources Master Plan or Water Sector Policy, hence there is no periodic master planning for the country's water resources. A five to ten year Water Resources Master Plan would serve to advise and inform the national physical planning and the development permitting processes and to ensure alignment of the plans towards the common goal of sustainable development. Issues such as urban encroachment into the aquifer lands and the expansion of supply to meet population growth or developments could be more effectively addressed through improved strategic water resources planning.
- Groundwater, recharge areas and well-head areas are not specifically protected in the law.
- The WSD's primary function now is water supply to domestic and industrial customers. There is no legislative provision for hydrological assessment (flooding and storm water disposal) and stream monitoring. This precludes integrated master planning for the nation's water resources. There are presently more than six separate agencies involved in water resources management.
- There is no formal provision for the licensing of private abstraction or companies seeking to supply water to the public (e.g. resort or residential sub-divisions developers), and there is no requirement for them to meet any standard.

- There are no formal water quality standards or legislative provision to recognize those of the World Health Organization.
- There is no provision in the law for trade or sewage discharge licenses, and no effluent discharge standards to monitor these.

A new comprehensive Water Act is needed to facilitate modern integrated water resources management. This project has provided a roadmap for revamping of the legal enabling environment in St. Kitts-Nevis as it relates to water resources management. Another significant legal step will be the designation of the well-field area (as shown in Figure 6 in green) as a protected area under the National Conservation and Environment Protection Act (1987). Cabinet has already provided approval in principle and actions are now being taken to publish notice of the designation. The establishment of a National Park around the sensitive well-field area is a novel approach to aquifer protection by involving community stakeholders.

5. National park planning

The vision for the St. Kitts National Capitol Park is to be an icon of national pride for all and a renowned attraction for visitors to St. Kitts. Towards that end, the management goals for the Park are to:

1. Protect the water aquifer in the Basseterre Valley;
2. Restore and maintain native flora species for education and recreation purposes;
3. Provide open space in an increasingly urban setting;
4. Provide active and passive outdoor recreation opportunities;
5. Serve as a high-valued tourist attraction to experience and enjoy St. Kitts;
6. Contribute to economic welfare and development;
7. Serve as an outdoor classroom and laboratory.

5.1 Enabling environment for the management of protected areas

The main findings of a review of the enabling environment for protected areas management in St. Kitts-Nevis are:

1. The Government of St. Kitts and Nevis does not have adequate legislation, management policies, and institutional capability to support protected areas management.
2. It is not realistic, or necessary, to fund the operations and management of a St. Kitts National Capitol Park, or a larger Protected Areas Conservation System, through government appropriations.
3. The level of general public understanding for the benefits and values of protected areas is low. At a more technical level, the current level of professional competency in protected area planning and management is lacking.

A plan which provides a set of integrated and comprehensive management policies addressing all the critical issues outlined above has been devised. The plan includes a draft version of the St. Kitts Protected Areas Conservation Trust Act and outlines an innovative sustainable financing mechanism for the park. The plan is very much a working document to stimulate focused discussion among officials and stakeholders for the purpose of developing a better set of management policies as the vision for the National Park becomes a reality.

5.2 Design Criteria

Community stakeholders and government officials provided their thoughts about how to develop and design the St. Kitts National Capitol Park. They provided thoughtful insights that provided a framework for the Park plan. The following words were recorded which reflect the spirit and criteria used to develop the site plan and recommended facilities (as shown in Figures 7 and 8).

- open space
- a simple place to walk and play
- quiet contemplation
- a place of stark contrast to downtown or the airport or the port
- uncluttered, charming natural setting
- natural beauty, nature smells and sounds
- no heavy-handed commercialism
- a chance to experience what was
- learning, wonderment, informative
- a place to exchange cultures (two-way)
- eventful and memorable
- healthy, fitness, exercise
- connecting children with nature

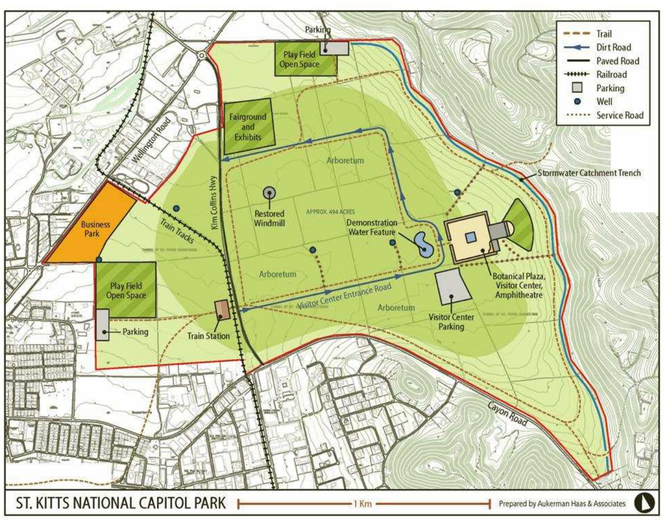

Figure 7: Proposed site plan

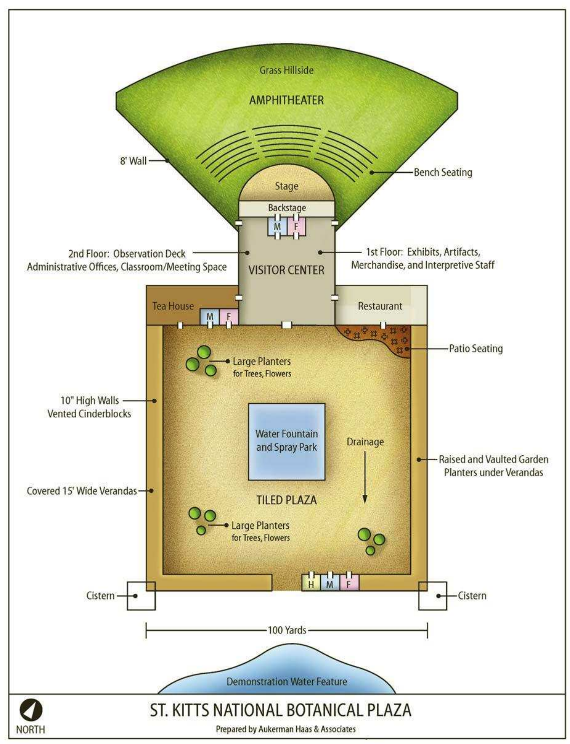

Figure 8: Visitor centre complex

6. Sustainability assessment

Although this phase of the project is coming to an end, it is really only the beginning of an iterative and collaborative process which is one of the hallmarks of sustainable development. Part of this process is periodic evaluation in order to ensure one is aligned with the overarching goals set at the onset of the project. A preliminary attempt is made here to assess the overall sustainability of the project by analyzing the social, economic and environmental contributions.

6.1 Social

Various opportunities for stakeholder involvement were exploited in both the planning and operational phases of this project especially as it related to the National Park. An advisory committee which comprised NGO and government stakeholders worked together to conceptualize this project. During the project, community stakeholders were consulted on numerous occasions and their expressed priorities were incorporated into the draft National Park Management Plan and in the initial design of the Park itself. As the plan for the National Park becomes a reality, it is envisioned that positive opportunities for sustainable livelihoods would be actualized. In addition, as noted in section 5.2, the community itself views the National Park as a way to facilitate positive cultural exchange.

6.2 Economic

The project activities as described in this paper have not yet directly contributed to sustainable economic activity related to conservation. However, the vision and plan for the National Park has already built into it various opportunities for positive economic impacts especially as it relates to the creation of a Protected Areas Conservation Service and various activities related to the Visitor Centre.

6.3 Environmental

The MER technique is an innovative and effective technology for identifying the fresh/salt water interface of coastal aquifers. The colourful output graphics are an effective communications tool for aiding stakeholders to visualize and deepen their awareness of the vulnerability of the groundwater resource. Although on-the-ground activities related directly to solid waste and soil conservation best management practices were lacking, the WSD has undertaken strategic bulk metering in order to better assess and manage water losses from the aquifer. Also, various public education activities reached out to the communities in the Basseterre Valley and focussed particularly on school children. Such activities lead to an increased understanding of watersheds and the need to protect the aquifer as one of the main sources of potable water for St. Kitts.

In conclusion, the National Park serves to unify the scientific data uncovered as part of the water resources assessment, the legal actions taken to update water legislation and to declare the protected area and the involvement of key stakeholders, all of which are key ingredients for success. This project is novel and multi-faceted in its approach to protect a vulnerable coastal aquifer.