TOWARDS A MORE INTEGRATED APPROACH TO WATER MANAGEMENT IN THE BURDEKIN DELTA IRRIGATION AREA

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ABSTRACT

The Burdekin delta is a major irrigation area with more than 35,000 ha of irrigated sugarcane and other crops. This system is unique because it overlies major groundwater supplies, is close to environmentally sensitive wetlands, waterways, estuaries, and the Great Barrier Reef, and employs water management practices that have evolved over the last few decades in response to local needs. These practices include the use of riverbed sand dams, extraction of river water to distribution channels, natural waterways and large recharge pits to assist with artificial replenishment of the groundwater systems. Farm water practices such as ‘recycling’, 'water spreading', and direct pumping from recharge channels have also evolved to play an integral role in the management of the groundwater systems. In this paper we describe a major new initiative in the Burdekin delta irrigation area involving a range of organisations and funding bodies. The aim of this initiative is to gain a better appreciation of current practices and their likely long-term impacts, and if necessary, to develop and implement new more effective water management practices at both the scheme and farm level. We highlight in particular approaches being employed to improve our understanding of links between on-farm management practices and response of the underlying groundwater systems.

INTRODUCTION

The Burdekin delta is a major irrigation area with more than 35,000 ha of irrigated sugarcane and other crops that fall within the North Burdekin Water Board (NBWB) and South Burdekin Water Board (SBWB) authority. It is situated in the dry tropics on the northeast coast of Queensland, Australia, approximately 90 kilometers southeast of the city of Townsville (Figure 1). The climatic and environmental conditions are ideal for the production of sugarcane, which started in the Burdekin in 1883. The Burdekin also has a reputation for producing the highest yields and highest quality sugarcane in the industry. The Burdekin delta system is unique because (1) it overlies shallow major groundwater supplies and relies heavily on these supplies for irrigation water, (2) it is situated in close proximity to environmentally sensitive wetlands, waterways, estuaries, and the Great Barrier Reef, and (3) water pricing and water management practices have evolved in response to local needs.

The challenge in the Burdekin, as in all other irrigation areas, is to continually review current management practices, and if need be to design and implement new and/or improved management practices to ensure the long-term wellbeing of the region in which irrigation is practiced. A new system for allocating and managing Queensland’s water resources, known as the WAMPs (Water Allocation and Management Plans), is being developed in an attempt to assist with this process. A key aim of the WAMPs is to focus on improving the balance between environmental, economic and social demands being placed on Queensland’s water resources. A new Burdekin research initiative is currently in place to assess and monitor land and water use practices within the delta, and to provide improved understanding and tools to assist with management of the resources in the future. In this paper we provide a brief overview of the Burdekin delta, contributions the Delta Water Boards have made in managing the Burdekin delta groundwater systems, and of work being progressed as part of the new Burdekin initiative.

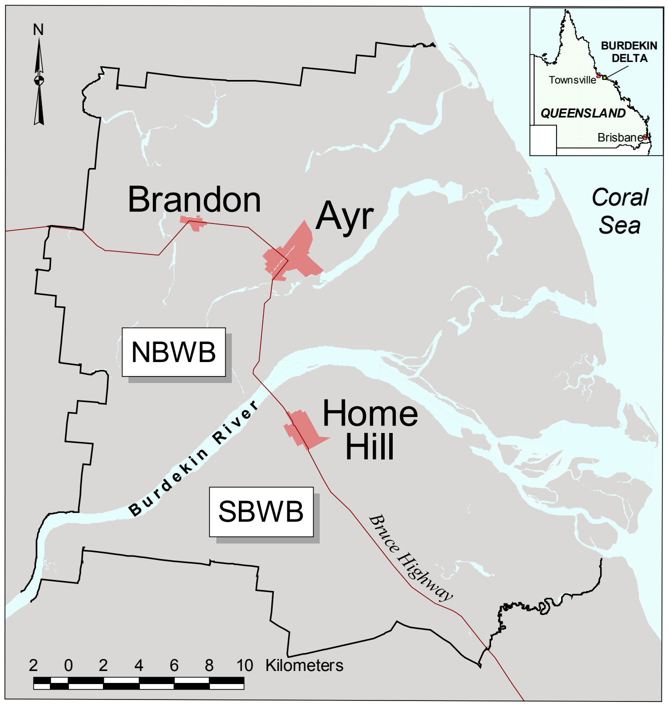

Figure 1: Map of Burdekin Delta.

THE DELTA WATER BOARDS

A series of very dry years in north Queensland in the early 1960's and unprecedented pressures being placed on the Burdekin delta groundwater systems led to the formation of the North and South Burdekin Water Boards (NBWB and SBWB) in 1965 and 1966 respectively. The Delta Water Boards have a charter that requires them to manage replenishment of groundwaters contained in an open aquifer system that is subject to a constant threat of seawater intrusion.

The Water Boards currently use a number of strategies to manage groundwater replenishment, including the use of sand dams in the Burdekin River and a series of distribution channels and natural waterways together with large recharge pits. The sand dams are constructed and maintained in the Burdekin River and are used to help maintain practical operating levels at river pump stations by containing releases from upstream storages. Farm water practices such as ‘recycling’, and 'water spreading' or direct pumping from recharge channels to farms in some distal aquifer zones have also evolved to play an integral role in the management of the groundwater systems (Figure 2).

‘Recycling’ refers to the practice where irrigation water from private production bores that is not used by the plants (excess irrigation) returns through the soil back to the groundwater. It is felt that this helps with the recharge and maintenance of groundwater levels. ‘Water spreading’ refers to the practice where Board pumped river water that is too turbid to be used for artificial recharge via the recharge pits (because it clogs the pits making them ineffective) is made available across the scheme benefited area as surface water for farm irrigation. This helps spread the silt load across the farmland and, while keeping the silt out of the recharge pits, is thought to benefit the soils and assist the replenishment process.

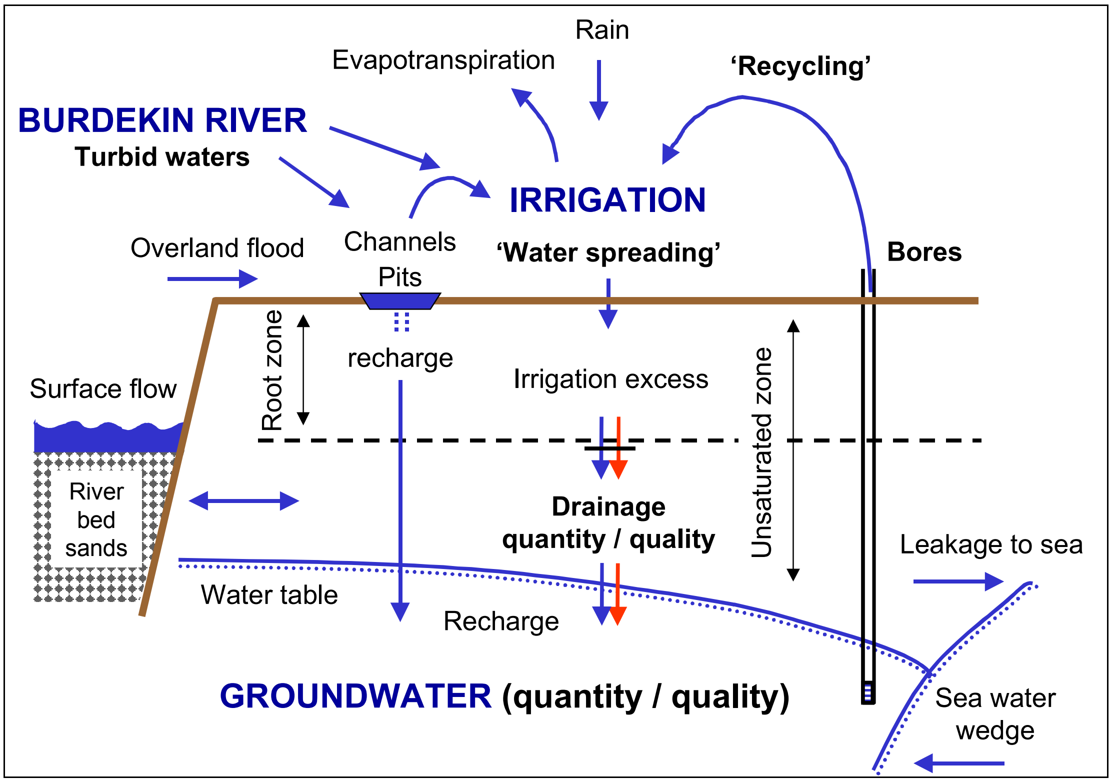

Figure 2: Schematic showing key factors of importance in the Burdekin delta irrigation area

The SBWB operates three main river pump stations and three relift stations while the NBWB operates 3 main river pump stations and 8 relift stations. The purpose of these pumping stations is to divert water from the Burdekin river into main supply channels to service additional works including secondary supply channels, natural waterways and lagoons, lagoons that serve as balancing storages, and recharge pits. In recent years, the NBWB has also started to shift its emphasis from pure recharge to groundwater management via conservation. The aim here is to encourage growers to take open water direct from the Board’s distribution system so as to reduce the net demand on the aquifer. To help achieve this the distribution system is currently being broadened. Although a perceived benefit of this approach is improved groundwater quality, there are currently insufficient data to demonstrate this one way or the other.

The Delta Water Boards are non-profit making organisations and have since inception had all operational, maintenance and infrastructure costs funded by the serviced industries. The bulk of the revenue raised by the Boards is by way of a levy per tonne of sugarcane produced annually, contributed by the millers and growers in a ratio of 1/3 : 2/3. Other crops grown are rated on the basis of a levy equivalent.

The Water Boards promote the view that no matter how well things are going there is always room for improvement, and they work continuously to facilitate and support studies and projects aimed at improving understanding and management of both surface and groundwaters in the Burdekin delta. They promote a total systems approach, and with user involvement, aim to review, promote and encourage best practice towards problem solving with decisions tailored to meet local needs.

LINKING GROUNDWATER QUANTITY/QUALITY AND ON-FARM PRACTICES

As mentioned above the Water Boards promote a policy of continual review and improvement and have through this philosophy initiated and progressed research work within the Burdekin delta. A major concern in recent years has been the realisation that there is insufficient data and knowledge of the interaction between current scheme and farm activities and groundwater quality / quantity and other offsite impacts. It is therefore difficult to assess whether the practices and hence continued use, or increased use, of the groundwaters are indeed sustainable in the long-term. Of particular importance are questions relating to the impacts of current and improved irrigation efficiency on ‘recycling’ and ‘water spreading’ and the subsequent interactions with nutrient, salt and chemical loading of the groundwaters (Figure 2). From a long-term sustainability point of view, these are likely to be the most critical issues affecting the natural system.

Addressing these issues requires a thorough understanding of the impacts of policies on practical and economic water management at the scheme and farm level, and on how irrigation waters are stored and transported through the unsaturated zone. This is essential, as the fate of nutrients, salts and chemicals and their impacts on the groundwater systems will be integrally linked to soil type and water movement through the unsaturated zone. Their fate once they enter the groundwater systems will depend largely on how the groundwater systems behave, so it is imperative that understanding of the local groundwater systems be improved and captured within a modeling framework that can be used to assist with various long-term scenario analyses. If a groundwater model is to prove successful for these applications it needs to facilitate analysis of the interactions between water supply, water demand, and water quality in the face of rising demand, changing land use, weather variability, and long-term climate changes. An understanding of the local hydrogeology will be fundamental in assessing various aspects of the groundwater system that control or impact on the system. Progress with the groundwater modeling work is highlighted in the next section.

It is clear that no one group or organisation has the wherewithal to tackle all these issues, and this has lead to the establishment of the recent Burdekin initiative. Organisations already involved in or interested in contributing to this effort include the NBWB, SBWB, CSIRO, BSES, Department of Primary Industries and Natural Resources (DPI and DNR), James Cook University (JCU), Australian Centre for Tropical Freshwater Research (ACTFR), Australian Institute of Marine Science (AIMS), Canegrowers, CRC Sugar, Burdekin Landcare, National Program for Irrigation Research and Development (NPIRD), Rural Water Use Efficiency (RWUE) Initiative and others. Burdekin farmers are also playing a key role in this work and as evidenced by the experimental work being carried out on various farms. The first Burdekin Initiative Co-ordination meeting, held recently, brought a large number of the above groups and farmers together to 'fine-tune' the co-ordination and collaboration to encourage maximum return from effort invested.

Work already underway includes soil mapping, implementation of demonstration sites, selection and instrumentation of new field sites for experimental work, and economic and groundwater modeling studies. Although focussed initially in the Delta, it is hoped that this effort will in time expand out to include the whole Burdekin irrigation system and provide a benchmark for sustainable aquifer management nationally.

GROUNDWATER MODELING

The purpose of the groundwater model is to simulate the behaviour of the groundwater system underlying the Burdekin River Delta area. As the groundwater model develops it will be used to assist with development of water use efficiency measures and other management strategies to ensure that irrigation in the Burdekin delta is sustainable. To achieve this, activities such as operation and maintenance of artificial recharge works, provision of irrigation water to farms and the use of water on farms have to be carefully examined. The aim of the groundwater model is to assist in determining the real or potential long-term effects that changes in water management might have on the sustainability of the groundwater systems.

Key objectives in developing the groundwater model are to assist with

1. Identification of areas at risk from environmental degradation (seawater intrusion, rising water table, etc.) and to help develop improved management strategies to minimise these risks
2. Identification of improved practices for operating and managing the artificial recharge schemes
3. Studies of the availability of water which would facilitate farm expansion (where achievable) and improved production, thereby contributing to economic growth within the Burdekin delta, and
4. Promotion of ecologically sustainable development principles to ensure the long-term future of farming operations in the Burdekin delta.

Model Development

Conceptualisation and characterisation are the fundamental steps in groundwater model development. These processes start with gathering information from existing sources and organising the data to understand the Delta groundwater systems based on general hydrogeologic principles.

The Delta groundwater storage can be viewed as being finite, so if the amount of water withdrawn from the aquifer exceeds the amount of water recharged, then that “stored” groundwater will be depleted. It is therefore necessary to evaluate the amount of recharge to the aquifer and the water withdrawn from it to properly assess the sustainability of demands for irrigation and other water uses. Identification of other discharge/recharge pathways (eg. across the sea/aquifer interface) will help ascertain wider environmental interactions.

Land and Water Use Survey

The Burdekin River Delta water area is an unproclaimed district, so information on groundwater use is at this stage rather limited. Understanding the groundwater dynamics of the delta requires information on groundwater extraction, as well as an understanding of irrigation scheduling exercised by farmers. In 1998-99, a Land and Water Use Survey was conducted in order to develop an understanding of the agricultural and irrigation activities throughout the Delta. The information collated from this survey helped to provide necessary data on the extent of surface water and groundwater use, as well as understanding the history and distribution of water using facilities. In particular, the changes in water use practice over the past few decades were identified. The Survey data provides information on the bore locations, properties served from each bore, irrigation scheduling, and the proportion of the irrigation water supplied from surface water and groundwater in each property. These have been used to quantify spatial and temporal variations in groundwater extraction and recharge in the Delta.

Hydrogeologic Characterisation

Prior to developing a numerical groundwater model, the aquifer system needs to be conceptualised to provide a qualitative framework from which to establish hydraulic parameters. The initial step in this process was to characterise the hydrogeology of the system using available techniques and data sources. The Burdekin River Delta contains a wide network of monitoring observation bores, and these were used to reconstruct the geometry and extent of the aquifer system, as well as the interpretation of some hydraulic parameters.

Groundwater within the delta is constrained by the unconsolidated alluvial and deltaic sediments deposited by the Burdekin River and its distributaries. The sediments of the delta comprise a complex combination of clean sands and gravels with silts, clay, organic mud, and loam. Typical cross-sections of the delta sediments (Figure 3) shows that strata layers usually are laterally discontinuous, making cross-bore correlations difficult to identify. Nonetheless, it is apparent that there is a significant amount of vertical hydraulic connection between sandy units. For modeling purposes, the delta is being simulated as a single-layer unconfined aquifer, with a base defined by the position of the granitic bedrock surface.

The hydraulic conductivity of the delta's soils and unsaturated zone sediments have been estimated using a deterministic procedure based on strata log records of bores from the GWDB. For both horizons, the proportion of sand and clay in each borehole was derived from individual assessment and the resultant effective clay thickness determined for each site. These data were interpolated, contoured and reclassified into three hydraulic conductivity zones for both the soil layer and unsaturated zone layer. These zones provide the current input data required by the model to make initial calculations of groundwater movement and storage. Ongoing improvements in hydraulic characterisation will be carried out through the current soil mapping and soil characterisation work.

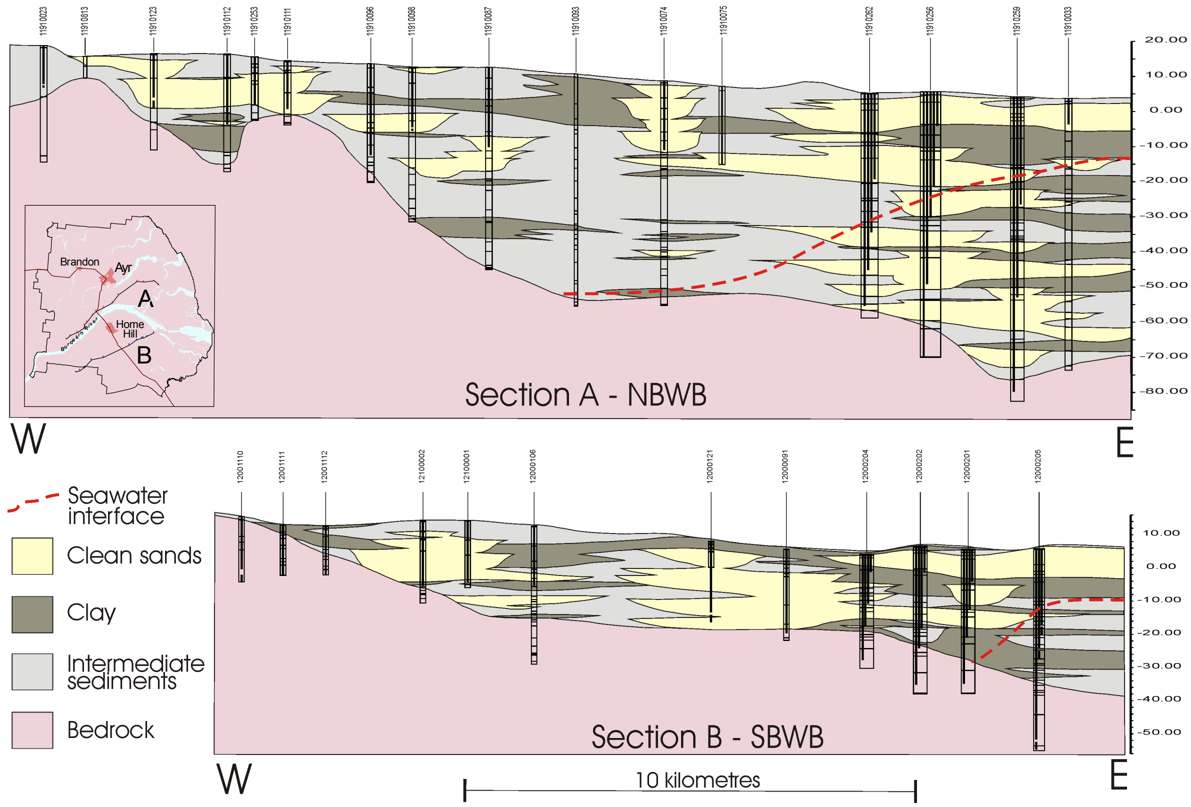

Figure 3: Cross-sections of the Burdekin River Delta showing sediment distribution and approximate position of the seawater interface.

Delta Groundwater System

A preliminary groundwater budget for the Burdekin Delta Area has been prepared based on general hydrogeologic principles involving monthly inflows and outflows, and changes in groundwater storage. The inflows include groundwater recharge from rainfall, flooding, irrigation and recharge from surface water bodies such as the Burdekin River, artificial recharge pits and diversion channels. The outflows include groundwater pumping, groundwater discharge to sea and lateral outflow to the Burdekin River Irrigation Area.

The SPLASH soil-water model (Arunakumaren, 1997) has been used to simulate a time series of irrigation use, percolation through the root zone and recharge through the unsaturated zone for different land-use conditions. SPLASH takes into account the soil and land use variations of the region along with the daily rainfall and pan evaporation to calculate the daily recharge and demand. The Delta area has been divided into 18 hydrological response units (HRU) based on the unique combination of root zone soil characteristics, vegetation types and unsaturated zone soil characteristics. From this information, a daily soil water balance for each of the HRUs has been developed using daily rainfall and pan evaporation data.

Artificial Recharge

At this stage the average artificial recharge rate in the Burdekin delta has been estimated as 96,000 ML/yr. This is a 15 year average derived from a combination of data sources and time frames, and will be updated as more data becomes available.

Uncertainities

Simulation of the entire groundwater system requires a series of assumptions and estimations to be made about some of the various parameters involved. It is important that the uncertainties in the model input data such as historical groundwater extraction and recharge be resolved before any development and calibration of the groundwater model can be completed. SPLASH was used to assist in simulating groundwater extraction and recharge from excessive irrigation, between 1981 and 1997. There are no volumetric metered records for groundwater pumping rates in the Burdekin River Delta, and this is an important weakness in the current groundwater modeling. Efforts are now being made to use available energy metered bores to address this deficiency.

Recharge

Recharge to the groundwater system is by a number of different processes as outlined earlier (Figure 2). These include infiltration of rainfall, artificial recharge through pits and channels, river recharge, flooding, and irrigation return flows. From an assessment of these mechanisms, the SPLASH-simulated annual groundwater recharge between 1981 and 1997 varied between 330,000 and 650,000 ML/year.

Flood Recharge: Recharge resulting from flooding is one of the major sources of inflow to the Delta groundwater system. SPLASH reads the inundation information along with the daily rainfall data and if the day is subject to flooding, the soil water in the root zone is assigned as saturation. In the absence of any flood mapping information, the whole of the model area was assigned as one flooding zone. Based on the Barratta Creek hydrodynamic model results, it was assumed that when the flood levels were above 8.2m on the Barratta stream gauge, the model area was subjected to inundation.

Artificial Recharge: The Burdekin Delta Artificial Recharge Scheme is a direct recharge system where yield of the aquifer is increased by spreading river water on permeable soil deposits. As the spreading area matures, clogging of the surface soil occurs and the infiltration rate is substantially reduced from unclogged conditions. Clogging of the surface soil is primarily caused by suspended material in the surface water and biological factors that are as yet not well understood. Because surface clogging has been identified as a major problem in the operation and maintenance of the artificial recharge scheme, further study is needed to determine the physical, chemical and biological characteristics of suspended sediments in the Burdekin River to assess the extent of the pre-treatment requirement of river water before recharge.

Burdekin River Recharge: The Burdekin River contributes water to the delta aquifer system or drains water from it depending on the head gradient between the river and the groundwater system. Since no recorded river stage data is available beyond the Clair Weir gauging station, the river stage and width have been estimated by using the recorded flow data available at that station, as well as the sand dam heights along the river. The interaction between the river and the groundwater system has been quantified using simple flow equations for every 200 m. The Burdekin River stage and width will in the future still need to be monitored at some locations downstream of the gauging station to help improve confidence in the accuracy of the recharge estimation.

Groundwater Extraction

Since no historical groundwater extraction records were available, the groundwater extraction for the period from 1981 to 1997 has been estimated. The model area was divided into three zones based on the average crop water usage and the farm efficiency factors in the SPLASH model were calibrated so that the SPLASH-simulated irrigation matched the average irrigation in the respective zones. The simulated annual historical pumping between 1981 and 1997 varied between 440,000 and 830,000 ML/year and this now needs to be verified with any available records.

While furrow irrigation is the most widely used irrigation system in the Delta moves are being made by growers to improve the efficiency of irrigation (Tilley & Chapman, 1999). The proportion of farmers that have moved towards new management practices is summarised in Table 1.

Table 1: Percentage of the Burdekin Delta growers changing management practices to improve water use efficiency (Tilley & Chapman, 1999).

Management Practices	**Delta %**
Changed furrow shape	52
Reduced tillage	24
Mixed irrigation water	36
Using surface gypsum	36
Changed inflow rates	20
Installed a tail water recycling pit	8

Despite improvements in irrigation practices groundwater extraction has increased in recent decades in response to the expansion of farming land within the delta area. Figure 4 illustrates the increase in groundwater pumps in the delta since 1981. This information is based on data recorded by the Land and Water Use Survey, and is sourced from contributions by local irrigators. Knowledge of the locations of these pumps (groundwater extraction points) will assist in configuring the groundwater model to simulate water extraction from the groundwater systems. Shortcomings of this approach however need to be acknowledged as they impact on the reliability of the groundwater simulations. Some of the problems with the existing data include the fact that there are no records for some 13% of delta farmers and the locations and history of abandoned bores are not known, which leaves a gap in current knowledge of water extraction.

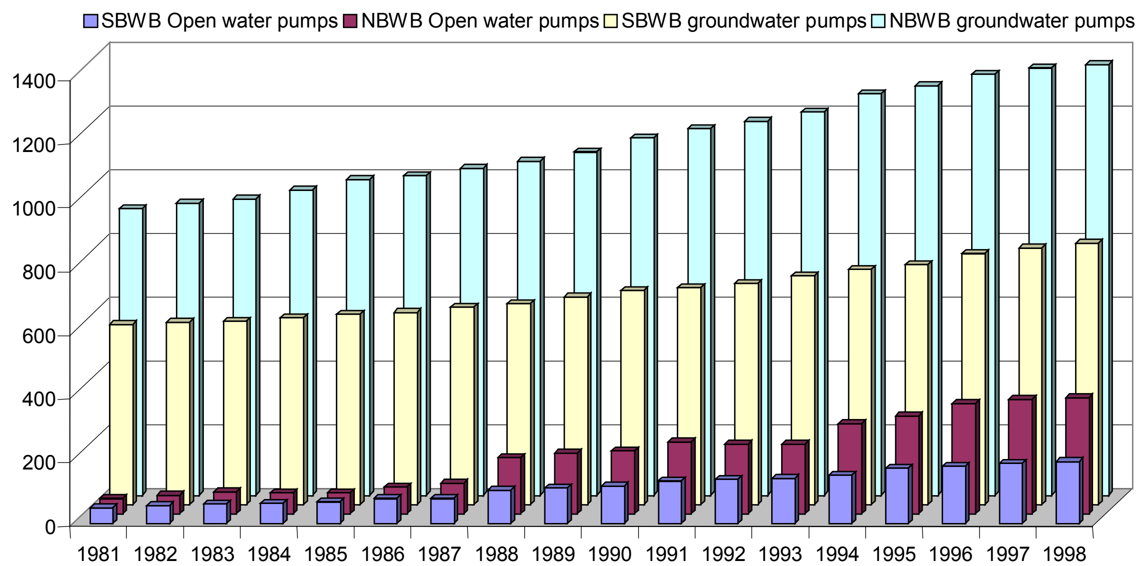

Figure 4: Increase in groundwater and open water pumps for the North and South Burdekin Water Boards between 1981 and 1998.

The Groundwater Model

A predictive model based on the USGS MODFLOW (McDonald & Harbaugh, 1988) code is being developed to study the water management strategies for the Burdekin Delta. The groundwater model includes spatial and temporal variation of hydrogeologic characteristics and hydrologic responses in the Delta aquifer system. The model area is discretised with a finite-difference grid of rectangular cells 350 x 350 m. Each of the cells have been assigned with grid independent and dependent data. The grid independent data was compiled from a geographic information system and includes locations of pumping bores, artificial recharge pits and trenches, creeks and rivers. The grid dependent data consists of areally distributed parameters such as recharge, storage properties, hydraulic properties, aquifer structure and surface elevations.

A forward model run has been carried out to check the performance of the current prototype model. This was done to ensure that the conceptual model data had been transferred correctly into the numerical model. During the forward modeling, a uniform specific yield of 0.15 was assigned to each model cell and the model area was divided into six hydraulic conductivity zones (with conductivity values ranging from 375 – 500 m/d), which were based on estimates across the delta. Figure 5 shows the comparison between the observed groundwater storage and the model simulated storage. The simulated storage in the 1990s was found to be below the observed storage. This is possibly an indication of the improvement in water use efficiency adopted by farmers in the early 1990s. The assessment of the improvement in water use in the delta, and subsequent model calibration is an example of the type of investigation that will improve the ability of managers to make more informed decisions about the maintenance of the region's water resources.

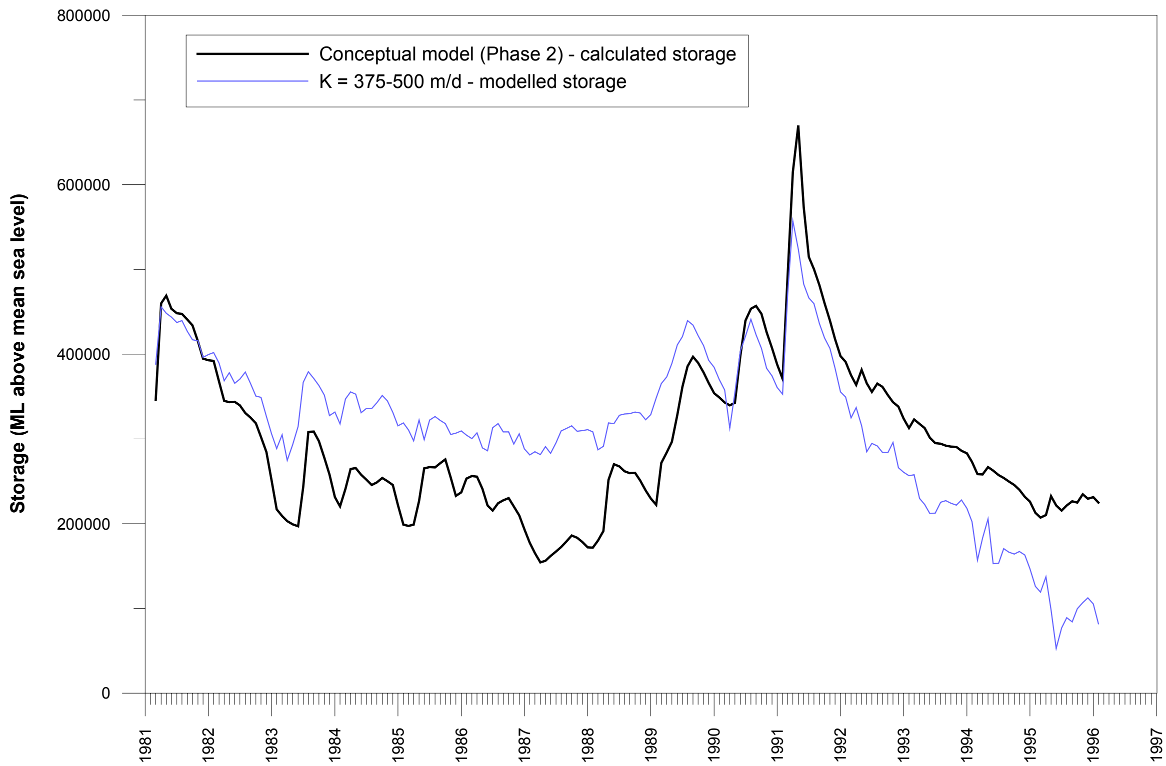

Figure 5: Comparison between calculated and modelled storage volumes (above mean sea level)

Since there are no metered use records available for groundwater pumping, it is difficult to accurately assess the improvement in water use until the uncertainties in data are addressed. The uncertainties in the model input data such as historical groundwater extraction and recharge have to be resolved before calibration of the groundwater model can be completed. During the model calibration, a set of model parameters will be obtained such that simulated water levels match observed water levels within a pre-established 'error'.

The calibration of the groundwater management model will incorporate the results from a range of investigations undertaken as part of the new Burdekin initiative. For example, the detailed soil mapping hydraulic property characterisation will improve our understanding of the hydraulic properties that control recharge to the groundwater. The selective metering of representative pumps will provide insight into the extraction volumes and scheduling of irrigation practices, and the installation of new drainage detectors will help provide improved quantification of deep drainage from key soil types. As these data become available the groundwater model will be updated and re-run to provide improved confidence in the simulation results.

After successful validation of the groundwater model it will be used to test various water management scenarios that may impact on groundwater levels in the delta. The baseline case will represent a 50-year future simulation period (2000-2050) using 1981 initial conditions, and with 1998 land use conditions continuing until 2050. The various scenarios will involve variations in operations including changes in land use, water allocations, artificial recharge operations, and conjunctive water use strategies. Typical model runs will include scenarios such as 1) A reduction in irrigation use by 20% in high use areas, 2) A reduction in the Burdekin River allocation by 10%, 3) An increase in open water use by 30%, 4) Replacement of all pumping bores with open water licences within a certain distance of the coastline, and 5) A reduction in the open water use by 50% in areas not subject to seawater intrusion. Clearly there will be opportunity to explore impacts of many other scenarios as well.

TOWARDS A MORE INTEGRATED APPROACH TO WATER MANAGEMENT

The Burdekin delta groundwater model is the key structure around which the various Burdekin Initiative activities are being organised. Most of the activities are being specifically designed to address data uncertainties identified thus far. Those activities currently in progress include:

1. Groundwater modeling (DNR and Water Boards)
2. Metering of a sample of groundwater extraction pumps (DNR and Water Boards)
3. Soil mapping (DNR)
4. Soil characterisation (NPIRD, CSIRO and CRC Sugar)
5. Measurement of on-farm recharge rates and quality (CSIRO and BSES funded through the National Program for Irrigation Research and Development NPIRD)
6. Analysis and improvement of on-farm management practices (BSES and CSIRO funded through the Queensland RWUE initiative), and
7. Economics of a range of alternate irrigation and water management scenarios (CRC Sugar)

The vision of the Burdekin Initiative is to produce a robust modeling framework based on accurate information that can be used to highlight strengths and weaknesses of current and potential irrigation and water management practices, and to provide direction for future research. By doing this the Burdekin Initiative will help the region face growing demands for water and implementation of social, economic and environmentally sustainable management practices with confidence.

ACKNOWLEDGMENTS

Our thanks to the many organisations and Burdekin delta farmers who have joined forces to help ensure the long-term sustainability of the Burdekin groundwater systems, and ultimately the region as a whole.

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