

and alluvial aquifers (Figure 3b). Hence, any assessment of groundwater extraction needs to consider the impact on baseflow and any dependent ecosystems. It also needs to consider the impact of dry-season extractions from waterholes that are connected to the alluvial groundwater system.

### *3.2.2 Aquifer Characteristics and Hydrology*

Exposed fractured rocks in the Plan area comprise granites, metamorphosed sediments and extrusive rocks that store and transmit water through joints, faults and weathering zones. The most productive zones usually occur in the top 40 metres (i.e. within 40 m of the surface). The Mt Vince area, located in the centre of the alluvial system (Figure 4), is the most productive fractured rock area within the Plan area.

Recharge to the fractured rock aquifers occurs through the soil zone following rainfall. A contribution is also made by drainage from irrigation areas. Flow within these fractured rock aquifers is mainly towards the local watercourse or alluvium. Pumping rates are reported to be up to 3 500 cubic metres per day ( $\text{m}^3/\text{d}$ ) although they are usually lower than  $1500 \text{ m}^3/\text{d}$ . Hydraulic conductivities are reported to range from 4–60 metres per day (m/d) (Bedford, 1978). The broad distribution of the regional aquifers and their flow systems is shown in Figure 4.

The principal alluvial aquifers are contained in fluvial, unconsolidated to semi-consolidated clays, sands and gravels, coastal marine and sand dune deposits that are up to 40 metres thick. The alluvial deposit structure is complex, with channel sands and gravels not being laterally continuous and occurring at a number of levels throughout the alluvial section. The alluvium has been deposited in valleys eroded into the fractured rocks identified above. Clayey floodplain sediments between the channel sands are also subject to rapid lateral variations in clay content (*Murphy and Sorensen, 2000*).

The rapid lateral and vertical changes in sediment type mean that the hydraulic properties of the alluvium and bore pumping rates display considerable spatial variability. Hydraulic conductivity values are highly variable in the alluvial aquifers and are reported to range up to 950 m/d. Bore yields of up to  $2\,500 \text{ m}^3/\text{d}$  are reported (Bedford, 1978).

Recharge to the alluvial aquifer system is mainly from infiltration of rainfall through the soil profile. Irrigation also contributes inflow to the alluvial aquifers. In most areas the main streams

drain the groundwater system and contribute to recharge only when in flood. Hence, an important part of the Plan will involve dealing with the stream-aquifer interactions, particularly during the dry season.

Water level contours indicate that groundwater flows towards streams and down valleys towards the coast and main estuaries of the Pioneer River and Bakers and Sandy creeks. In the coastal and tidal zones of these streams, alluvial aquifers are influenced by the seawater interface. The position of the seawater interface is influenced by a number of factors (See Section 3.3.1), although in simple terms the amount of fresh water in the aquifer is the predominant influence.

### ***3.2.3 Social and Economic Character***

The dominant contributor to the region's economy is the production of sugar. Some 63 000 ha of sugarcane was grown in 2000 in the Racecourse, Pleystowe and Marian mill areas, covering most of the Plan area. Much of this production is dependent on irrigation using surface water and groundwater. Additional areas of cane are harvested and supplied to Plane Creek and Farleigh mills, which are outside the Plan area. The towns of Mackay, Mirani, Marian, Eton, Finch Hatton, Gargett and Walkerston and a significant number of rural residential and farming properties are to a varying extent dependent on groundwater for some or all of their domestic supplies.

Other important contributors to the economy of the region are the tourism industry and commercial and recreational fishing. Tourism and fishing benefit from groundwater baseflow which supports the fish lifecycle, and the riparian and National Park ecosystems that are an important drawcard for visitors.

## ***3.3 Issues in the Plan Area***

### ***3.3.1 Seawater Intrusion***

Several factors can influence seawater intrusion into the Pioneer Valley's coastal aquifers. In natural conditions, when a coastal aquifer discharges to the sea or a tidal estuary a dispersion zone develops where freshwater contacts seawater.

The shape and position of this zone is influenced by, among other things, the dimensions and structure of the aquifer, recharge rates, down-valley flow and aquifer properties such as hydraulic conductivity. At the coast, and along tidal estuaries, the tidal range is another factor.

If water levels within coastal aquifers are not maintained, seawater will infiltrate; conversely, if water levels rise, the seawater front will, given sufficient time, recede.

Superimposed on these regional effects are local effects created by pumping from individual production bores close to the seawater interface.

Wells supplying Mackay City in the 1930s were reportedly affected by seawater during the 1935 drought, presumably as a result of seawater intrusion (Bedford, 1978). Anecdotal evidence (Bedford, 1978) suggests coastal landholders have encountered saline water during test drilling and sometimes have had to move bores because of rising salt levels.

In some instances, landholders have moved bores away from the seawater front only to discover that the seawater front simply advances into the new bore.

Figure 5 indicates that the seawater front cannot be held in an acceptable position under the average extraction that has occurred since 1975. Unless extraction is reduced, seawater intrusion will continue to move inland. Figure 5 also shows trends in groundwater salt content as measured by electrical conductivity.

Between 1975, when it was first located, and early 2003 the front is estimated to have intruded under about 5 000 hectares. In the Bakers Creek estuary, the front is west of the Bruce Highway – about 5 km from the coast. In the Sandy Creek estuary the seawater front is about 10 km from the coast.

In some cases, there is a seasonal improvement at the end of the irrigation season or following a recharge event (Murphy and Sorensen, 2000). Regionally the front does not retreat after major recharge events, but continues its advance with each dry cycle (Figure 5).

Seawater penetrates aquifers under south-eastern Mackay through tidal open drains built to the north and north-east of the airport. In addition, reduction of freshwater stream flows to tidal zones has increased tidal surface intrusion and the risk of penetration.

Arthington *et al.*, (2001), provide evidence of this increased seawater intrusion into Pioneer Valley estuaries, although the extent of any impact on the groundwater system along the Pioneer estuary is not known. Anecdotal evidence suggests that during the

1940s, saline water impacted Mackay water supply bores along the Pioneer River. More recently there are reports of seawater impact on production bores on the north bank of the Pioneer River in the Fursden Creek area.

The amended Plan will need to establish rules and criteria for establishing and operating production bores in the zone at risk from seawater intrusion. The amended Plan can be expected to identify minimum performance levels for the aquifer and to set water allocation security objectives against which Plan performance and any proposals for new bores or additional use could be assessed.

### *3.3.2 Managing Current Water Demand and Sources*

Use in several alluvial aquifers is at or exceeds the resource's ability to meet demand. Users in some of these areas also have access to supplemented flows in watercourses such as the Pioneer River or Bakers Creek, while others can access surface supplies from unsupplemented streams such as Sandy Creek.

These water sources have differing levels of reliability and at varying times of the year. The amended Plan will need to evaluate options for managing existing demand when access to multiple water sources is available. The process will consider access to other water sources at particular times of the year or confining extractions to a maximum rate of take to soften the impact of over-extraction – particularly in the coastal zone.

### *3.3.3 Water Resource Regulatory Arrangements*

In the past, there was limited opportunity for planning to manage aquifers. Licensing took little account of environmental factors and the terms and conditions placed on water licences were sometimes inconsistent from one part of an aquifer to another.

More rigorous and consistent definition of water licences in terms of maximum annual diversion volume, bore separation distances and other access conditions are needed to improve the security of all entitlements. Where water resources are becoming scarcer, there is no simple mechanism to provide water for future higher value production. Mechanisms that enhance potential benefits such as water trading will need to be evaluated.

The Pioneer Valley aquifers support significant private investment in farm water supply infrastructure such as bores, pumps and pipelines. Uncontrolled development will pose a risk to this

investment by reducing supply reliability. Current arrangements offer limited protection for these investments and do little for groundwater dependent ecosystems.

Current arrangements for monitoring groundwater resources have provided much of the hydrologic information on which the amended Plan will be based. However, there may be a need to improve monitoring and reporting of groundwater management and use to ensure the Plan is effective.

The amended Plan will therefore:

- improve specification of water licences;
- allow transparent sharing of water between riverine and other groundwater dependent ecosystem processes, and human requirements;
- provide a framework and simple mechanisms for allowing permanently tradeable water allocations to be created;
- establish minimum requirements for water users and riverine processes against which future management and allocation decisions can be assessed; and
- improve monitoring and reporting of basin groundwater management and use.

***a) Improved specification of water licences***

The amended Plan will consider simultaneously the interests of groundwater users in the Pioneer Valley. This will lead to better accounting and understanding of the interactions between upstream and downstream groundwater users and water user impacts on interactions between streams, connected aquifers, the seawater interface and groundwater dependent ecosystems. Many licences already have consistently and rigorously specified terms and conditions attached to them while others do not. Until all licences are defined in such terms, the security of all water users' entitlements in the basin cannot be determined. There is a trade-off, however, in making water users' access to water supplies more secure. Improved security over water entitlements requires the details on what water users can do under an entitlement (access conditions) to be clearly specified, although in the past they might have enjoyed a relatively open-ended benefit from the entitlement. The benefits of having clearly specified entitlements, increased security and the ability to trade water outweigh any perceived disadvantages that may arise through having access conditions more clearly specified.

In the Eton Water Supply Area, some groundwater licences specify access conditions that limit access to periods when other sources

such as surface water are limited or specify that water may be taken from a range of sources up to the limit of the entitlement. Such arrangements create uncertainty over the reliability of the supply. Development of the amended Plan will need to consider these arrangements and clarify access conditions to the respective water sources.

***b) Providing water for groundwater dependent ecosystems***

Groundwater dependent ecosystems are those whose ecological processes and species composition are determined by the presence of groundwater (adapted from Commonwealth of Australia, 1996). The level of dependency depends on how rainfall, stream flow or groundwater supports the ecosystem. Examples of ecosystems that rely to a lesser or greater extent on groundwater include lagoons, wetlands, cave systems, terrestrial vegetation, springs and riverine ecosystems.

In addition to the many plant and animal species whose existence depends on groundwater, there is a range of little-known aquatic invertebrates and other microscopic organisms that live within aquifer systems. Some of these inhabit the interface between surface water and aquifers (hyporheic zone) and others live deeper within the aquifer system. Until their ecology and their role in maintaining aquifer health and water quality are better understood, caution should guide groundwater management and how groundwater is provided to support ecosystem health.

In the Pioneer Valley, the extent to which the relevant types of aquatic ecosystems depend on groundwater is poorly known and will need to be determined by a Technical Assessment Panel (TAP). The existing Pioneer Valley Water Resource Plan as it now stands has determined low-flow objectives that provide for the water requirements of riverine ecosystems and processes.

Much of these low flows are derived from groundwater discharged from alluvial and fractured rock aquifers. The Pioneer Valley Water Resource Plan contains strategies for managing water take from Sandy Creek during low-flow periods together with strategies for surface water supplemented areas such as the Pioneer River, parts of Cattle Creek, Palm Creek, and McGregor and Barkers creeks. The link to the groundwater systems will be through the management of baseflows as they relate to surface water extraction and through the direct management of groundwater extractions so that they do not adversely impact on the Plan's environmental flow objectives. Brizga *et al.*, (2001) provide detailed information on Pioneer Valley environmental streamflows.

A water resource plan that includes groundwater will need to consider the location of bores in relation to streams and groundwater dependent ecosystems and their impact on these features.

***c) Tradable water allocations***

Much of the groundwater system in the Pioneer Valley is fully allocated and there is little scope for additional development, particularly on dryland farms, unless alternative ways of sourcing water, such as trading, are found.

In the past, water entitlements were tied to land and therefore could not be traded permanently and independently from land. The *Water Act 2000* now allows water allocations to be created from several types of water entitlements and separated from the land to which they apply.

A water resource plan provides in many instances for the level of specification necessary to create tradable water allocations. Permanent trades of either the whole or part of a water allocation can occur only under conditions established under a resource operations plan, through which a water resource plan is implemented.

Once these criteria have been met, surplus water – resulting either from improved efficiency or unused entitlement— can be bought and sold to meet unsatisfied demand, without increasing the allocation base.

Safeguards ensure that trading is not detrimental to other users' entitlements or to a water resource plan's environmental flow objectives.

In summary, trading may provide a way of increasing productivity from an aquifer's existing water entitlement base and for driving greater water use efficiency.

***d) Monitoring and reporting of water management and use***

A water resource plan defines monitoring and reporting requirements for water users and water managers within a Plan area. Monitoring and reporting are essential for measuring Plan performance and ensuring compliance with its objectives and requirements. This means that people can be assured that their water entitlements are being protected and that environmental flow outcomes are not compromised.

The monitoring requirements for many water users have already been fulfilled by the installation of water meters on larger extraction facilities.

### *3.3.4 Dewatering Bores to lower High Seasonal Water Tables*

After high recharge seasons, water tables reach ground surface in several areas in the Pioneer Valley, making access to cane fields difficult at harvest. To overcome the problem, some bores are used to pump excess water from the soil to streams or drains. Although the effects of this dewatering are localised and may not have a regional effect, the issue will need to be considered in developing the draft amended Plan.

### *3.3.5 Managing Pumping Capacity and Water Restrictions*

In the past, rules for issuing water licences sometimes varied from one part of the aquifer to another and may have varied over time. For example, allocations may have been issued on the basis of 1 200 hours of pumping at a design rate or at 3.5 megalitres per annum, whichever is the lesser.

In some situations and in certain locations or times – such as during periods when water restrictions are applied in the coastal areas – this has led to some landholders being unable to meet full demand.

For instance, when restrictions apply, while some properties have insufficient bore pumping capacity to meet demand, others are able to meet their needs within the restriction period because pumping capacity is adequate. In many cases, these anomalies reflect an inability of the local aquifer to support the required pumping rate and there may not be a simple solution.

The resource operations plan will establish the day-to-day pumping arrangements that make the best use of the available resources subject to constraints and objectives established in the amended Plan.

### *3.3.6 Managing Future Demand*

The amended Plan will identify minimum performance levels for environmental flow and water allocation security objectives against which proposals for new allocations, movement of water allocations or changes in operating rules will be tested.

#### *Factors that affect demand include:*

- *population growth;*
- *changed rural and urban use trends;*
- *world commodity markets;*
- *new enterprises;*
- *climatic variability and conditions.*

Any future proposals would be approved only if the proposals were shown to be consistent with the range of outcomes defined in the Water Resource Plan. In addition to the proposals being tested against the above important objectives, a number of other assessment criteria including setback distances for production bores would need to be accounted for as part of the decision-making process. For example, these criteria might relate to, but may not be limited to, seawater intrusion impacts, impacts on the interaction between groundwater and surface water including weir storages, minimising adverse impacts on cultural values, aesthetic or recreational values, existing bores and water use efficiency.

### **3.3.7 Water Quality**

The alluvial aquifers of the Pioneer Valley support many land uses, with sugarcane production predominating. Other uses include town water supply, stock and domestic water needs, the needs of dependent ecosystems and irrigation of crops other than sugarcane. Each use has distinctive water quality requirements.

Water quality assessments show that, with the exception of areas impacted by seawater intrusion, groundwater is generally suitable for domestic, stock watering and cane irrigation. However, in isolated parts of the Mt Vince area poor water quality limits the usefulness of groundwater for domestic use and irrigation.

Monitoring data for nitrates are not uniformly available throughout the Plan area, although the data that are available suggest that nitrate levels at some locations – mainly in the shallow aquifers – may be rising. There are also some locations where nitrate is above the recommended threshold for long-term sugarcane irrigation. In a few places, nitrate levels exceed recommended drinking water thresholds. A small sampling survey involving about 46 bores undertaken by the Bureau of Rural Sciences and reported by Baskaran *et al.*, (2001) also detected the presence of one or more pesticides in 30 per cent of samples and the presence of one or more faecal indicator bacteria in 40 per cent of samples. No sample detected pesticide levels above drinking water thresholds and about 11 per cent of samples were above nitrate and faecal coliform thresholds.

Activities with the greatest potential to impact on aquifer water quality are: pumping in areas vulnerable to seawater intrusion; leaching of nitrogen and phosphorus from mill mud applied to cane paddocks – particularly when used in conjunction with inorganic fertilisers; inappropriate fertiliser management practices;

leaching of pesticides below the crop root zone; and inappropriate management of treated sewage and abattoir effluent used to irrigate cane. While it is better practice to irrigate with recycled effluent rather than release treated waste into waterways, the practice must be managed to minimise impacts on other water values.

The amended Plan will need to consider, to the extent possible under the *Water Act 2000*, the amount and water quality of flows needed to provide for the needs of any groundwater dependent ecosystems.

While the amended Plan will need to establish strategies for managing how water is taken and will consider closely-linked non-water issues in a limited way, it does not itself deal with the major sources of impact such as land management and use. These will need to be dealt with using other processes and initiatives. The amended Plan will, however, deal with the major impacts of seawater intrusion and will need to identify objectives, management strategies and criteria for use of groundwater in areas at risk.

### *3.3.8 Water Use Efficiency*

It is recognised that because of the limitations on water availability in Australia, the community must optimise efficiency gains from supplies already allocated before contemplating provision of new infrastructure such as dams. Collaboration between state agencies and water users through initiatives such as the Rural Water Use Efficiency Initiative, WaterWise and the Queensland Water Recycling Strategy have played a key part in developing strategies to help water users improve efficiency.

Significant gains are being made by the irrigation industry under the Rural Water Use Efficiency Initiative through strategies that include increasing furrow inflow rates under surface irrigation; reducing row length; recalibration of sprinkler jets and spacings; and construction of on-farm storages to their optimum economic depth to minimise evaporation.

Gains are also being identified through improved water use monitoring using water meters and irrigation scheduling, which ensures that crops are watered to promote maximum growth while avoiding the productive losses that can arise from under- or over-watering. Research and development has identified additional opportunities through improved weather forecasting, partial root-

zone drying and analysis of high efficiency irrigation systems. Recycling treated wastewater from town water is another area of water use efficiency improvements. The potential reduction in demand for water resulting from these programs will be considered in preparing the amended Plan.

Water use efficiency strategies may also arise through the *Water Act 2000*, which provides for water use plans and land and water management plans to be prepared in certain circumstances. Land and water management plans will be required before water created under new allocations, or an interim water allocation is used, or when water is moved to a new location, or if required under a water use plan. Water use plans may be required when water use involves a risk of land and water degradation through rising watertables, waterlogging, salinisation, deteriorating water quality, soil erosion or environmental harm. Water use plans would be developed through a process similar to that used for water resource planning.

### ***3.3.9 Land and Water Use Impacts***

#### ***a) Rising Water Tables and Salinity***

Where aquifer inflow exceeds discharge, water levels can be expected to rise. Activities that can increase recharge above natural levels include land clearing and inappropriate irrigation practices. Apart from excessive watering, leaky channels, drains and off-stream farm storages can be contributors.

When watertables reach the root zone or ground level, problems that include crop yield loss, paddock access problems and salinity can occur. At a few sites at Victoria Plains on the lower slopes of the Mt Vince area and the Brightly and Marwood areas, localised surface salinity caused by high water tables and rising water tables has been reported.

Although water use practices are outside the scope of water resource planning, the impact of water use on rising watertables may be addressed in the Plan through allocation strategies. The Plan might allow allocations to be increased in areas prone to rising watertables so that by balancing groundwater extractions with inflows, any tendency for watertables to rise would be held in check.

#### ***b) Irrigating with Poor Quality Water***

All water contains some salt and therefore irrigation adds salt to soil. However, with proper management to ensure that salt leaches

below the crop root zone and other strategies, salt accumulation or damage to soil structure can be limited. As the salt content of irrigation water rises, the risk of harm to soil, aquifer water quality and cane yields increases. Once electrical conductivity reaches 2 200 microsiemens per centimetre ( $\mu\text{S}$  per cm) the usefulness of water is limited to sandy soils. Above 3 000  $\mu\text{S}$  per cm, water is not suitable for regular irrigation use at all.

If saltwater is used long term in conditions that promote deep leaching, salt will accumulate in the aquifer system.

In the Pioneer Valley the use of water with electrical conductivities above 3 000  $\mu\text{S}$  per cm, particularly in areas experiencing seawater intrusion, is likely to lead to adverse impact on soils and cane yield. While this is an issue that should be dealt with in Water Use or Land and Water Management Plans, the draft amended Plan will need to consider the developing groundwater management strategies to address the issue.

### **3.4 Current Level of Use and Allocation**

There are currently some 84 000 megalitres per annum of groundwater allocated within the proposed Plan area – about four-fifths for irrigation, with the remainder being used for municipal and industrial purposes. Small volumes are also accessed for domestic and pastoral purposes, with no licence requirements. Although metered use data do not capture all groundwater users because metering applies only to entitlements of more than 20 megalitres per annum, it does give an indication of the magnitude of use for the main users. During the 2001 – 2002 water year, some 47 000 megalitres of groundwater were extracted from metered industrial, irrigation and town water supply bores. The water level contours presented in Figure 4 give an indication of the groundwater condition at the end of 2002.

The groundwater level record of bores presented in Figure 5 shows the broader rises and falls in the Pioneer Valley aquifers in response to variations in the climatic cycle, including droughts, together with the impacts of water extraction and natural losses. In the drought of the early 1990s, groundwater levels were at record lows throughout much of the Pioneer Valley. Electrical conductivity data from bores in the coastal zone (Figure 5) indicate that with water levels in parts of the coastal zone falling to within 2 metres of sea level or below sea level, seawater has intruded further into the coastal aquifers.