



## 5. Decision Tree

To assist in the desalination selection process the following decision tree provides a good starting point. The final selection and design however will be dependant on site specific conditions.

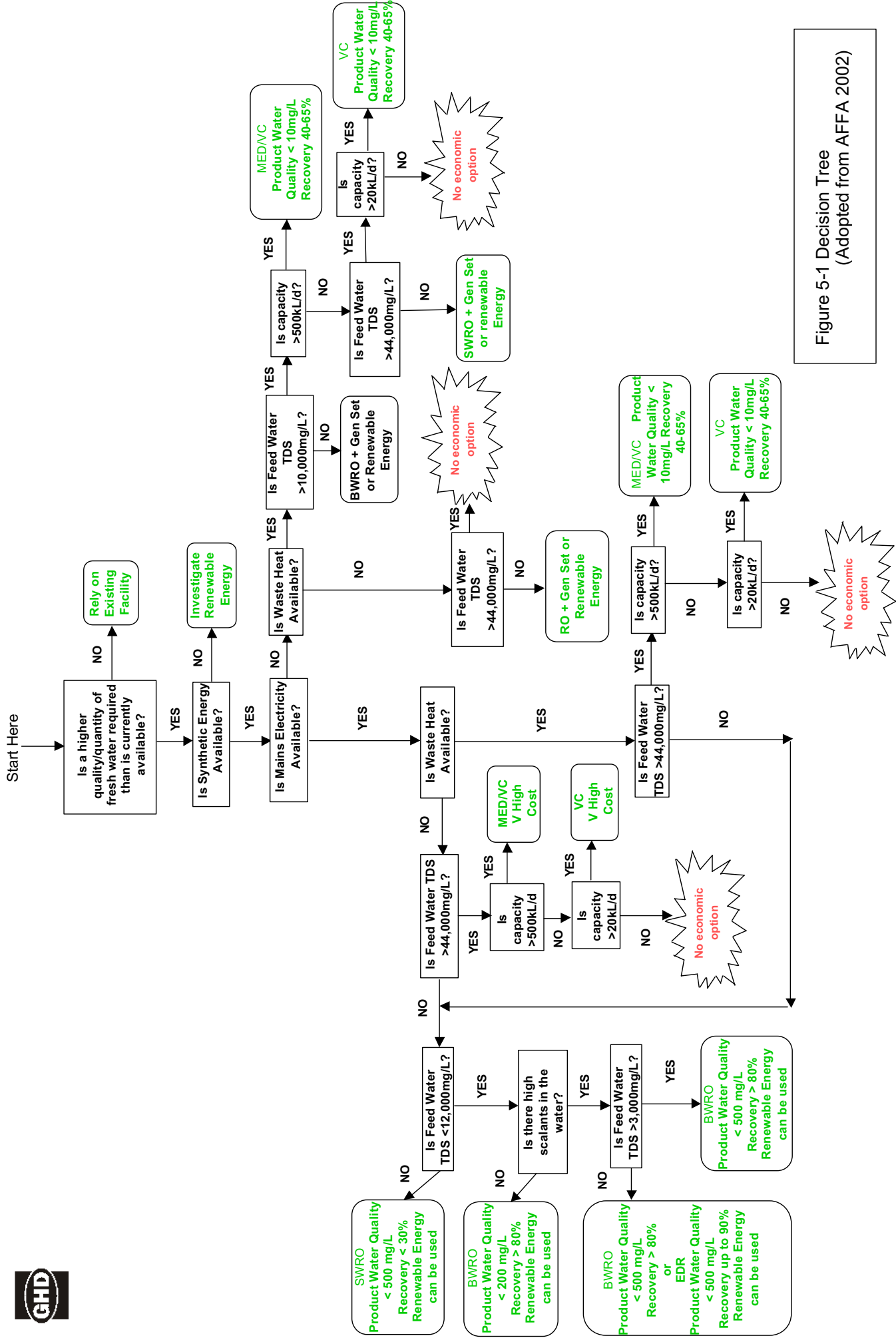


Figure 5-1 Decision Tree (Adopted from AFFA 2002)



## 6. Overview of Queensland Desalination Installations

Desalination installations currently operational in Queensland were identified and where possible reviewed. GHD initially identified 27 installations and the owners/operators of 21 facilities were successfully contacted. Each facility operator/manager contacted was asked a series of questions relating to the operation and maintenance of their desalination facility.

This section summarises the operating experiences of these 21 installations.

### 6.1 Location of Queensland Desalination Facilities

The locations of Queensland facilities are shown in Figure 6-1.

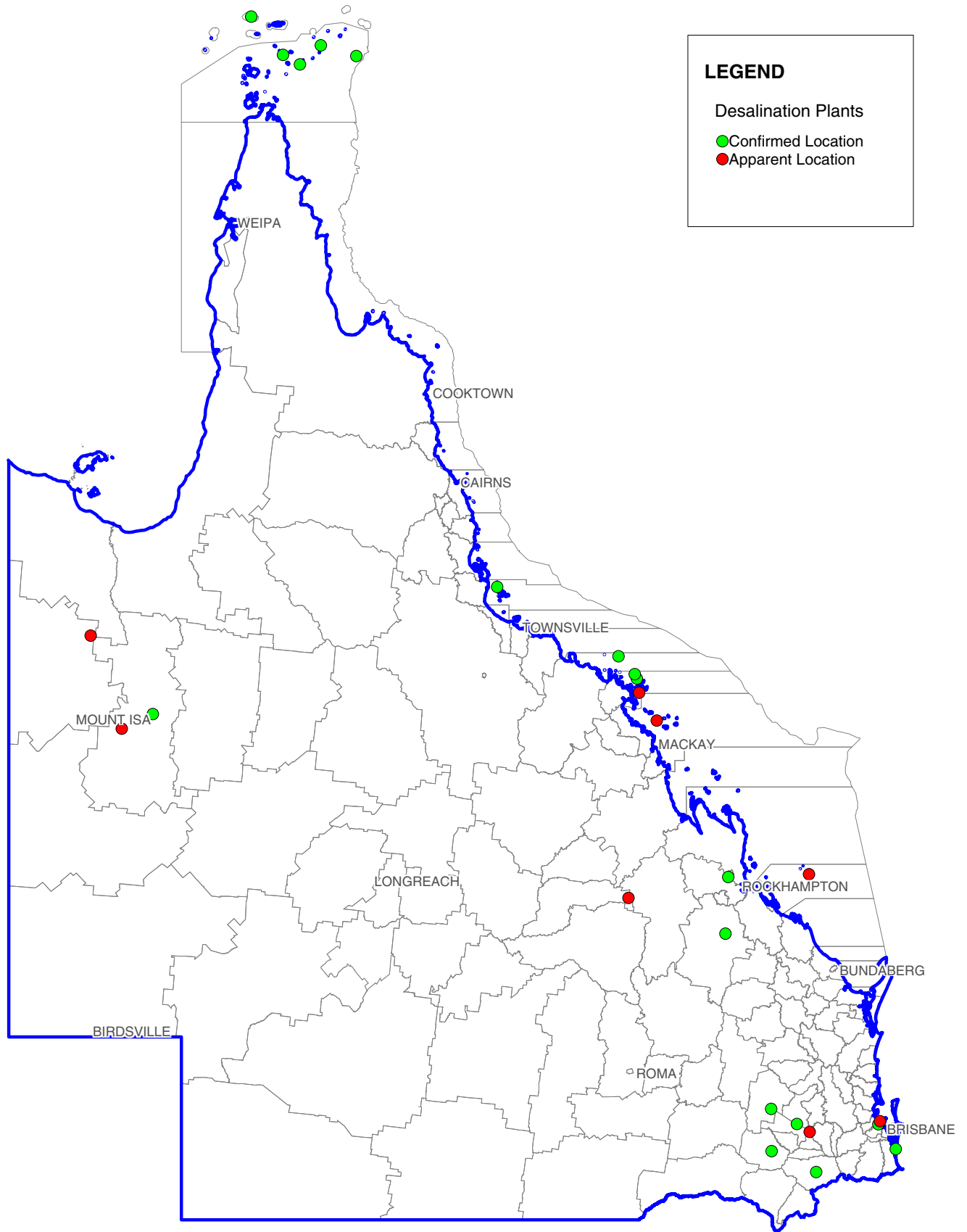
### 6.2 Desalination Technologies Employed

A breakdown of desalination technologies currently employed in Queensland is provided in Table 6-1 below:

**Table 6-1 Desalination Technologies Employed in Queensland**

Adopted Technology	Number of Installations	% By Product Water Volume	Supplier
Reverse Osmosis	17 plants	88	Sharklift Carnes Vivendi Pty Ltd (US Filters) Osmoflo Pty Ltd Sharplift Marine and Industrial Equipment A1 Filtration I.B.C Wendouree Water Treatment
Resin Exchangers	1 plant	9	Unknown as facility was in place when company took over the business
Thermal Mechanical Vapour Compression	3 plants	3	IDE Technologies (Israel) supplied by PECS Industries

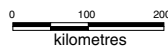
The majority of facilities investigated used reverse osmosis to desalinate saline feedwaters. Reverse osmosis is popular in Queensland due to the lack of available waste heat sources and the relative availability of electrical energy. A mobile diesel generator powered 80 kL/day RO unit exists in the Torres Strait to supplement the islands potable demands.



**LEGEND**

Desalination Plants

- Confirmed Location
- Apparent Location



**DESALINATION IN QUEENSLAND**

**Figure 6-1  
Locations of Desalination Plants**

Copyright: This document is and shall remain the property of Gutteridge Haskins & Davey Pty Ltd. The document may only be used for the purpose for which it was commissioned and in accordance with the terms of engagement for the commission.

Unauthorised use of this document in any way is prohibited. ©

Source Information:  
Data Supplied by DNRM and QSID.



Three thermal based desalination technologies are currently being used in Queensland to provide a potable drinking water source from seawater for an Island Resort. When the island resort was initially constructed 18 years ago, power was supplied by a purpose built power station which was also located on the island. This power plant provided a suitable waste heat source, which could be used to power a thermal desalination plant. The mechanical vapour compression unit proved successful, and as the demand for potable water grew, two subsequent units were purchased in 1986 and 1996. Mainland power has since been provided to the Island eliminating the waste heat source. The mechanical vapour compression units however were converted to run on mains electricity and remain operational.

The third desalination technology identified as currently in use was a Resin Exchanger. Anecdotal evidence indicated that this technology is very effective and reliable but is extremely labour intensive. This has been partly attributed to the age of the facility, which is believed to be 15-20 years old. As a result the organisation is planning to decommission the resin exchanger and install a reverse osmosis system within the next few months.

Of the facilities investigated, it was found that the majority of desalination plants were operated on a continuous basis at permanent installations. The choice for continuous operation was generally based on the following two advantages:

1. Increased membrane life spans associated with RO systems
2. Reduced water production costs, based on a cost per kilolitre of water produced.

The majority of facilities were also found to be permanent installations. The exception was one unit located in the Torres Strait that was designed as mobile units. These units are further discussed in section 6.3

### **6.2.1 Pre-treatment**

A number of different approaches to pre-treatment were taken in the facilities investigated. Pre-treatment steps generally consisted of a combination of disc filtration systems, multimedia filters, sand filtration and UV treatment. No issues were identified by any of the operators with their choice of pre-treatment system.

## **6.3 Mobile Desalination Facilities**

Two fully containerised mobile units were identified in Queensland. Both systems use RO technology and are rated at 180 kL/d. These RO units are maintained by DNR&M on behalf of the Department of Aboriginal & Torres Strait Islander Policy and the Islander Co-ordinating Council for use within the Torres Strait.

Of the facilities investigated, one RO unit was responsible for recharging surface water supplies for two island communities. Each community has permanent infrastructure established to source feed water and dispose of waste brine streams. Initially mobile units were situated at each Island location but due to the drop in demand as a result of the natural recharge of the surface water supplies one of the desalination units was decommissioned. It is the intention of the operators of the desalination unit to transfer it to the other site for a period of time, if the needs arises again in the future.

Daily inspections are undertaken by local council officers who report any issues back to the operators who themselves undertake monthly inspections. The original suppliers also participate in the upkeep of the facility by undertaking quarterly inspections. This ongoing maintenance has seen the unit operate at



high efficiencies at all times with only a few minor problems resulting in down time for repairs. Some issues were associated with power brown outs but this is due to the fact that diesel fuel must be continually resupplied for the unit to operate continually. The unit is quite labour intensive and has significant operational and maintenance costs owing to the remote location and necessity to transport fuel to the site. Anecdotal evidence indicates that no significant maintenance problems have been experienced.

#### 6.4 Reasons for Desalination

The majority of facilities were utilised to produce potable water for inland and Island communities where remaining facilities produced product water for a range of industrial processes.

**Table 6-2 Reasons for Desalination**

End Use	Number of Units	Total Volume Treated (kL/d)	Size of Units kL/d of Permeate
Potable Water <sup>2</sup>	16	4,510	22 – 1,170
Process Waters <sup>3</sup>	6	33,442	24 – 16,048

Of the installations investigated, it was found that units used for potable water purposes are generally smaller than those used for generating process waters.

#### 6.5 Feedwater Quality

Over half of the feedwater used by the facilities investigated was sourced from the ocean. This is due to the high proportion of desalination undertaken for island communities, where surface water sources are not readily available. Table 6-3 below provides a breakdown of feedwater sources.

**Table 6-3 Source of Feedwaters**

Water Source	Number of Plants	Percentage by Volume
Seawater	11	15
Brackish Water (Ground water)	6	29
Highly Treated Water <sup>4</sup>	4	56

<sup>2</sup> One of the units in this category is a pilot plant utilised to determine the requirements for the full scale potable desalination facility.

<sup>3</sup> While Luggage Point has been excluded from the rest of the section, the volume of water treated has been included here.

<sup>4</sup> Highly treated waters are those treated by traditional water treatment plant methods or are reclaimed effluent waters.



The quality of inland groundwater sources was reported as ranging from saline to mildly brackish. Anecdotal evidence suggested that the quality of groundwater sources remained relatively constant throughout the year, and no noticeable negative impacts on the desalination processes were reported.

The quality of seawater sourced from the ocean however appeared to experience seasonal fluctuations in both temperature (affecting conductivity and the salinity levels in permeates) and total suspended solids levels. Elevated suspended solids levels were particularly evident in tropical regions due to coral spawn and increased storm events.

## 6.6 Product Water (Permeate) Quality

None of the facilities contacted had experienced problems with their permeate quality. Post-treatment however was required when it was used for potable use as the high water quality was found to negatively impact on taste.

Post-treatment usually consisted of minor pH adjustment (addition of bicarbonate soda), degassing (CO<sub>2</sub> extraction) and the addition of sufficient chlorine to create a residual concentration at the end of the pipe.

Issues in water quality were found to arise when inexperienced operators were in control of plant operations or when the facilities were not maintained to a level that was consistent with the manufacturer's recommendations.

## 6.7 Energy Usage and Source

Detailed power consumption (\$/kWh) information was not readily available from facility operators due to:

1. General apprehension by operators/managers to provide financial data.
2. Accounting procedures often failed to provide a break down of desalination costs and rather only a total operation and maintenance cost or budget was known for each facility.
3. The facility may have been in place when the operator purchased the business and as a result they were unsure of power consumption details (e.g. pump sizes, membrane operating water pressures).
4. Power obtained from a large power plant onsite, results in overall desalination plant costs being relatively insignificant compared to total power usage.

Table 6-4 below provides a breakdown of the power sources utilised for the desalination processes investigated.

**Table 6-4 Power Sources**

Power Source	Number of plants	% by Volume
Mains Electricity	10	27
Gas Engines	1	4
Diesel Generator <sup>5</sup>	8	6
Power Plant	2	63

<sup>5</sup> It should be noted that the diesel generators listed here are primarily used to run desalination facilities



Mains electricity was the most common choice of power followed by on-site diesel generators. Diesel generators were generally only used where mains power was not available, with diesel generators being a popular choice for the desalination facilities located on islands.

Gas engines were used to provide electrical power to one reverse osmosis plant, as a gas source was available and it was considered a clean energy alternative.

## 6.8 Chemical Usage

For reasons similar to those identified for energy costs, limited information was available on actual dosage rates and chemical costs. Details on the type and reason for chemical use however was more readily available:

- ▶ **Pre-treatment chemicals** Flocculants were often used prior to sand filtration to assist in the removal of suspended and biological matter. Most RO systems also used antiscalant chemicals (such as Palmide, Hyperspers) to prevent the build-up of calcium and biological scales within the RO unit. In facilities that used potable water or reclaimed effluent as the feedwater, sodium bisulphite was often used to de-chlorinate the water prior to the RO process.
- ▶ **Post-treatment:** Calcium hydroxide (hydrated lime) was often added to permeates, to either enhance the flavour of permeate or adjust the product water pH. pH adjustment was also achieved with the addition of bicarbonate soda or by degassing the product water (ie removal of CO<sub>2</sub>). Chlorination was also regularly undertaken to provide a disinfection barrier throughout the potable water reticulation system.
- ▶ **Cleaning Chemicals** Acidic solutions were often flushed through desalination units to remove the build up of scale material. This solution is continually flushed through the system until the reaction between the alkaline scale and the acidic solution ceases. The wastewater from this process is generally neutralised and disposed of in conjunction with brine and backwash waters.

## 6.9 Performance Reliability

Plant operators were generally satisfied with the reliability of and performance achieved by their desalination installations. Minor problems were encountered with:

- ▶ Replacement of membranes
- ▶ Level sensors in tanks
- ▶ Valves and seals throughout the facilities pumping and pipe network.

It was however generally acknowledged that the majority of problems arose as a result of inadequate maintenance and/or training in the operation of the facility.

It was also found that facilities susceptibility to failure increased proportionally with its age, as did its maintenance requirements. In many cases the suppliers conducted quarterly inspection of the systems and replaced any degrading hardware. This ongoing maintenance ensured that the older systems performed in a similar fashion to newer installations.

For RO systems, membrane life was generally agreed to be about 3 – 4 years.



### **6.9.1 Operation and Maintenance**

It appeared that operators with a good general knowledge of their system carried out most day-to-day operations of the facilities. Any minor issues encountered were resolved by the operator or directed to more highly trained personnel within the company. Suppliers often provided training encompassing all aspects of the operation of desalination facilities.

Minor issues such as the replacement of sensors, valves and seals and in some cases membrane replacement were handled by company employees.

Major issues such as membrane and high pressure pump replacement were handled by the supplier.

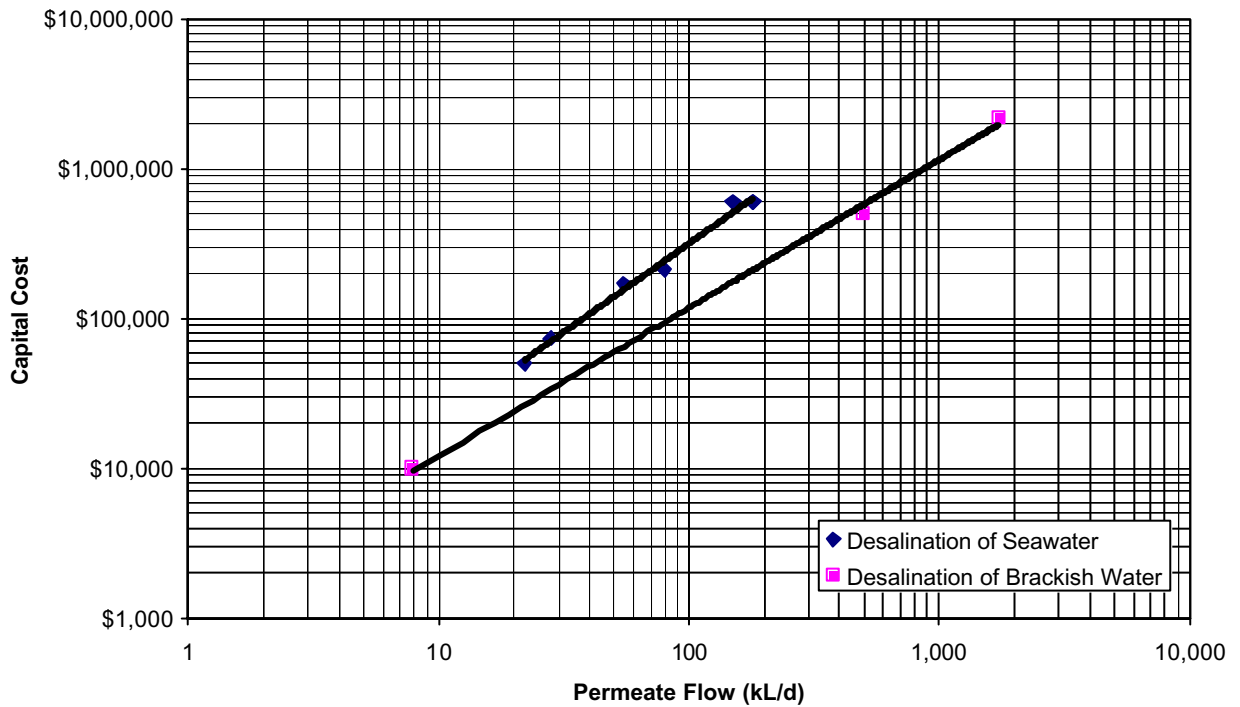
### **6.10 Costs**

For the reasons listed in Section 6.7, acquiring an accurate breakdown of capital, operating and maintenance costs for many of the facilities investigated was difficult. However from the data made available the following can be concluded:

- ▶ Reverse osmosis appears to be the most cost effective option for environments where waste heat sources are not available.
- ▶ If an inexpensive heat source is available, thermal units are most applicable as they are extremely robust, require little maintenance and have higher recovery rates than compared with RO facilities.
- ▶ The capital cost for RO facilities is typically less than that for a thermal unit. Generally the maintenance requirements for RO facilities are considerably higher than for thermal units (due to membrane replacement), the costs are recovered by the lower operating costs (energy).
- ▶ RO facilities were more applicable in environments where the feedwater contains low levels of salinity. This is due to the lower operating pressures required within the facility and hence the power consumed.

No operating or maintenance costs were available for the Resin Exchange facility however the facility manager indicated that the operation was extremely labour intensive and required the full attention of at least one of their operation engineers. As a result of the age (10 – 20 years) of the facility and the maintenance requirements the company will be moving to a RO process in the next couple of months.

From information collected from Queensland based RO facilities, the following two capital and O&M cost curves have been generated.



**Figure 6-2: Capital Cost of Queensland RO Facilities**

The capital cost of Queensland installations are very similar (marginally lower) to those reported elsewhere around the world.

Care should be taken when using the cost data provided above, as the capital costs for each installation are site specific and would depend on many factors including:

- ▶ Distance from the desalination facility to the feedwater source and end users.
- ▶ Pre and post treatment requirements.
- ▶ Locality issues.

It is therefore recommended that individual budget costs are attained for each proposal. Alternatively the above costs can be used, provided an assumption is made that the costs only represent RO equipment costs. Pre-treatment, post treatment, pumping and piping costs are considered as additional.

The O&M costs are even less reliable due to current accounting practices and responses obtained from facility owners.

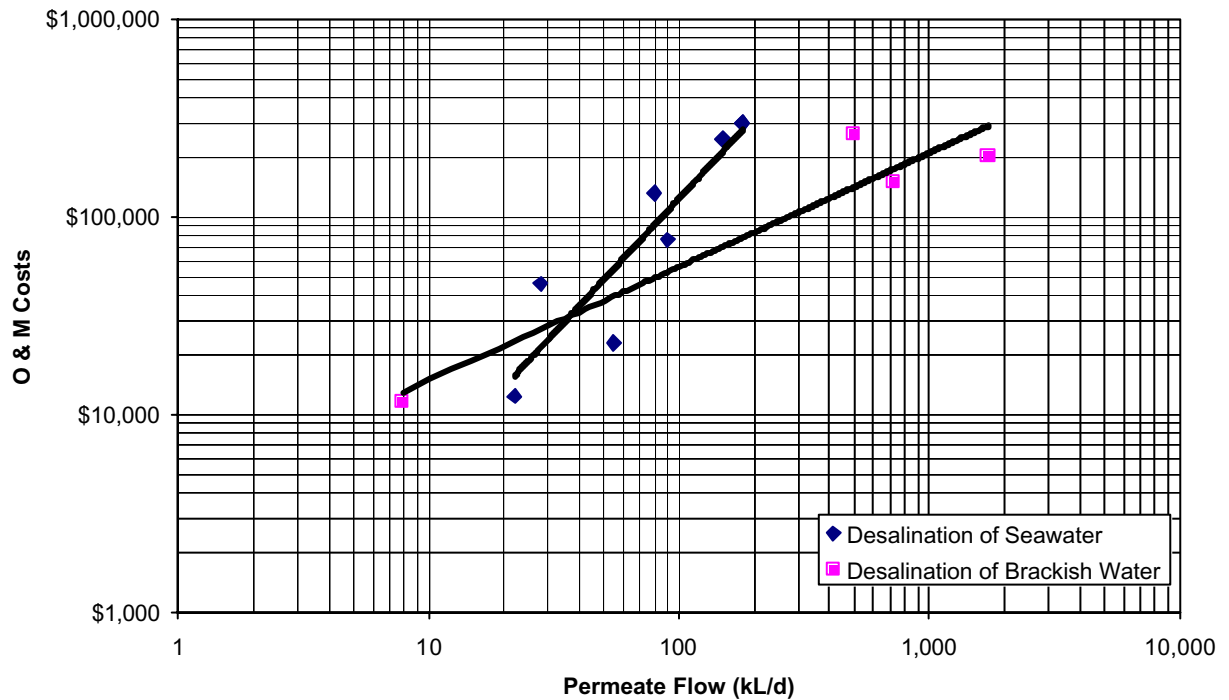


Figure 6-3: O&M Costs for Queensland RO Facilities

## 6.11 Waste Management

Three waste streams are generated from the desalination process:

1. Pre-treatment wastes (RO and Resin Exchange only)
2. Brine solution
3. Unit cleaning wastes

Waste management practices adopted in Queensland installations varied, depending on the size and location of the desalination facility.

The disposal methods adopted by island communities for pre-treatment and brine wastes included:

- ▶ Irrigation
- ▶ Disposal to ocean via a natural dry creek
- ▶ Mixed with brine and discharged to sea.
- ▶ Piped to the ocean via gravity

Cleaning wastes (acidic solutions) were generally neutralised and disposed of to the ocean. In one instance more aggressive cleaning chemicals were utilised and the waste was placed into drums and shipped to the mainland for treatment and disposal.



Power stations and wastewater treatment plants (WWTP) treated their wastes in the following ways:

- ▶ Pre-treatment wastes (including the organic and particulate matter recovered from pre-filtration equipment) were dewatered prior to disposal.
- ▶ Wastewaters (brine) were disposed of via evaporation ponds.



## 7. Delivery and Operational Options

### 7.1 Intermittent versus Continuous Operation

Desalination facilities are typically operated on a continuous basis, with most facilities operating 24 hours a day, 7 days a week. Downtime is generally only experienced during maintenance periods. Intermittent units are only encountered where the demand for potable water is not constant.

The reasons why most facilities are operated in a continuous mode include:

- ▶ Desalination plants are expensive and the cost of supplying and operating equipment increases as the size of the unit increases. To operate a desalination facility only 8 hours a day, it would be necessary to invest in equipment that is three times as large as would be required if the same unit was operated 24 hours per day. Wangnick Consulting (2001) have reported that the cost of desalinating water increases by approximately 19% for a plant that operates 80% of the time compared with a plant that operates 95% (availability is based over a year). Economics therefore drives the plants to continuous operations versus intermittent. Typically the cut off for economic utilisation of plants is 70% (pers comm. Mr Terry Fagg).
- ▶ Membranes used in RO and EDR processes deteriorate if allowed to dry out. Specific preservatives are required to ensure the membranes are adequately preserved between operations. Suppliers do not guarantee the life or performance of membranes that are left non-operational for periods longer than two days, without the use of preservatives and the life of membranes generally decreases with intermittent operation.
- ▶ Thermal systems have flexibility (compared with membrane systems), with respect to intermittent operation and suppliers have indicated that these systems should perform equally as well operating intermittently and continuously. Economic considerations generally drive the decision towards continuous operations. Thermal systems however do not like to be heated and cooled a lot, as this will cause “thermal cycling” of materials, resulting in failure.

The feasibility of using intermittent desalination systems will depend predominately on the demand for potable water in the supply region.



## 7.2 Mobile versus Permanent Installations



Desalination facilities can be fabricated as either mobile or permanent installations. The main limitation would be the size of the unit. Many RO and ED(R) suppliers package their smaller units (including pre and post filtration equipment) as skid mounted units or build them into shipping containers, which are conducive to mobile applications. ED(R) mobile units are only economically feasible when pre-treatment costs are very high.

The advantages and disadvantages of mobile membrane type installations are summarised Table 7-1 below.

**Table 7-1 Advantages and Disadvantages of Mobile Membrane Installations**

Issue	Advantages	Disadvantages
Financial Considerations	<ul style="list-style-type: none"> <li>▶ Minimises installation costs protection is inherent in containerised packages.</li> <li>▶ Compact installation that reduces overall footprint.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Connection and start up costs when moved.</li> </ul>
Process Performance		<ul style="list-style-type: none"> <li>▶ Membranes require preservation during transit.</li> <li>▶ Risk of damaging membrane during transit.</li> </ul>
System Configuration	<ul style="list-style-type: none"> <li>▶ Possibility for rapid start up, assuming the reticulation (ie intake and brine disposal infrastructure) is already installed.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Membranes are specific to the quality of feed water. Membrane systems can only be used on similar quality water</li> <li>▶ Size limitations.</li> <li>▶ Power, intake, brine disposal and permeate recovery infrastructure is required at each installation site.</li> </ul>



---

#### Community Issues

- ▶ Readily available emergency water supply.
  - ▶ Multiple communities can benefit from single mobile installations. Opportunity to share costs. This would require planning agreements between both communities.
  - ▶ What happens when two communities require use of the mobile unit at the same time (e.g. drought conditions)?
- 

### 7.3 Feasibility of Intermittent and Mobile Installations

As with most issues associated with desalination projects, it is recommended that each site be evaluated in terms of the feasibility of intermittent and/or mobile operation. The increased cost of producing water associated with intermittent operation should be considered. However specific situations exist when intermittent installations are a necessity, such as

- ▶ When a town's population increases for 3 months of the year and the community relies financially on the tourist influx.
- ▶ Alternate (but cheaper) water sources cannot be used for several months of the year. From an operating perspective it may be cheaper to use the lower cost water supply when possible and only use the desalination equipment when required.

Mobile installations offer several advantages for small communities. However for larger capacity plants, the advantages diminish rapidly.

### 7.4 Project Delivery and Operational Options

#### 7.4.1 Project Delivery

There are many forms of Project Delivery available, involving various combinations of individual delivery methods for design, construction, operations, finance and ownership. Common terms have developed from these combinations, which include:

- construct to design;
- design and construct (D&C);
- alliance contracts;
- design, build and operate (DBO);
- build, own and operate (BOO), optionally with transfer of the asset at the end of the operational period (BOOT)
- Leasing.

The features of these basic options are summarised in Table 7-2. The reader is referred to recent Department of Local Government and Planning (DLGP) publications (DLGP, 2001) for more detailed information regarding this matter.



**Table 7-2 Summary of Basic Delivery Methods**

Name	Finance	Ownership	Design	Construction	Operation
Construct to Design	Council	Council	Consultant	Contractor	Council
Design and Construct	Council	Council	Contractor	Contractor	Council
Alliance	Council	Council	Alliance	Alliance	Council
Design, Build, Operate	Council	Council	Contractor	Contractor	Contractor
Build, Own, Operate (Transfer)	Contractor	Contractor	Contractor	Contractor	Contractor
EPCM	Council	Council	Consultant	Contractor	Council

There are many variations to the above. One particular variation is the "process systems" approach. This approach involves the equipment supplier undertaking the process design, and Council's consultant designing the civil and structural aspects of the plant to suit the process equipment supplier's requirements. This approach is intended to place all responsibility for process performance with one party, in this instance the process equipment supplier.

Engineering Procurement and Construction Management (EPCM) is recommended for complex desalination systems where multiple contracts are required to complete the project. For example, a large coastal desalination facility built a distance from the ocean would require two contractors: a desalination technology specialist; and a civil contractor to construct the necessary pipelines for brine disposal.

#### **7.4.2 Operational Contracts**

As with the project delivery options there are a number of ways in which the desalination equipment can be operated. These options include:

1. Contractor operation and maintenance if DBO or BOOT contracts are adopted.
2. Contractor operation and maintenance as part of an independent service package.
3. Owner operation and maintenance.

There are also variations on the above where the owner may undertake partial operation and maintenance with critical items serviced by specialised contractors.

From our discussions with suppliers and operators the following trends have been noted:

- ▶ Companies generally tend to purchase their own equipment. However in a few circumstances, where there is low potable water demand for short time periods, the installations have been leased from suppliers.
- ▶ Out-sourcing the operation and maintenance of the desalination facility to a private company does not appear to be a common arrangement. Of those installations investigated, one was operated by a private contractor.
- ▶ Day-to-day operation and minor maintenance activities are typically undertaken by the plant owners.



- ▶ Suppliers tend to be responsible for, or provide support for the major maintenance activities.

The advantages and disadvantages for each of the various operation and maintenance options are discussed further in Table 7-3.

**Table 7-3 Operational Contract Options**

<b>Option</b>	<b>Description</b>	<b>Issues for Consideration</b>
<b>Ownership Options</b>		
Own	<ul style="list-style-type: none"> <li>▶ All process equipment is purchased outright from a supplier.</li> </ul>	<ul style="list-style-type: none"> <li>▶ All capital and operating costs are the responsibility of the purchaser.</li> <li>▶ Financing of asset</li> </ul>
Hire	<ul style="list-style-type: none"> <li>▶ All process equipment (or individual items) is leased from a supplier.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Good option for short term, low demand requirements.</li> <li>▶ Charges associated with leasing equipment may not be financially viable if long-term supply required.</li> </ul>
<b>Operational Options</b>		
In-house	<ul style="list-style-type: none"> <li>▶ Day to day operation of the facilities is handled in-house.</li> <li>▶ Maintenance activities conducted in-house or out-sourced as the complexity exceeds in-house expertise.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Operational responsibility and risk remains with the facility owner.</li> <li>▶ Time and costs associated with labour, including training suitable personnel. Depending on the complexity of the desalination process, labour can represent a significant O&amp;M cost item.</li> <li>▶ Spare parts availability. Some installations have found it necessary to have spare parts on-site due to the remoteness of the location of facility and time delays in receiving spare parts.</li> <li>▶ Process proving period where the supplier is responsible for operation and maintenance should be considered.</li> </ul>
Privately Contracted	<ul style="list-style-type: none"> <li>▶ All operation and maintenance activities are outsourced to a privately contracted company or persons.</li> </ul>	<ul style="list-style-type: none"> <li>▶ Careful planning and contract management required upfront to ensure client risks are managed.</li> <li>▶ Ownership of product water quality needs to be considered.</li> </ul>



---

Supplier service package

- ▶ The equipment supplier is responsible for all operation and maintenance activities.
- ▶ Careful planning and contract management required.
- ▶ Spare parts availability should be written into service contract.
- ▶ Service contract should include response times, particularly in remote locations.

---

The fundamental issues that need to be considered in out-sourcing contracts (privately contracted or supplier service package) are:

- ▶ Extent of facilities to be included in the contract. Does the scope of works include pre-treatment, intake and disposal infrastructure, and the desalination equipment?
- ▶ Duration of contract. Risks associated with long contracts are: changes to licence conditions; need for major augmentation; foregone technological improvements and lack of contestability in future extensions of contract.
- ▶ Scope of operations responsibility. Contractors will generally only take responsibility for outcomes where they have control over input parameters. Contractors will have difficulty taking responsibility or will charge a premium for outcomes they have little control such as: licence conditions; energy and chemical costs; changes in raw water characteristics; existing equipment for which condition is difficult to verify.
- ▶ Scope of maintenance responsibility. There needs to be a clear understanding of the extent to which the contractor has responsibility for maintaining equipment, structures etc. The condition of existing materials has to be defined.
- ▶ Penalties and fee. Penalties or reduced fees in case of non-conformance need to be carefully defined.
- ▶ Incentives. Just as there are penalties there should be incentives to achieve cost reductions, through the introduction of new technology or changes in process.
- ▶ Laboratory analysis. Given the extensive testing that can be required by regulatory authorities, the cost of testing can be significant. To what extent is in-house testing adequate? What happens when there are discrepancies between tests and audit tests?
- ▶ Knowledge sharing. The contract should have a good knowledge sharing agreement so that the authority has access to the contractor's maintenance management system and maintenance history in order to maintain sufficient knowledge of the performance of the facility.
- ▶ Raw water variation. Define the level of variation in raw water quality for which the contractor is responsible. Consider subsequent impacts on treated water quality and process parameters.
- ▶ Other standard contract issues may include: existing employment agreements, employee unions, superannuation, long service leave; indemnity agreements; terms of payment; insurance requirements; right of inspection; and type of contract.