



# Land and Water

## Preliminary Hazard Analysis and Critical Control Points Plan (HACCP) – Salisbury Stormwater to Drinking Water Aquifer Storage Transfer and Recovery (ASTR) Project

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**Preliminary Hazard Analysis and Critical Control Points Plan (HACCP) -  
Salisbury Stormwater to Drinking Water Aquifer Storage Transfer and Recovery  
(ASTR) Project**

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**Technical Report No. 20/05  
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## EXECUTIVE SUMMARY

The Aquifer, Storage, Transfer and Recovery (ASTR) project has evolved from earlier ASR projects at Andrews Farm, Bolivar and nine other sites in USA, Australia and the Netherlands that demonstrated substantial water quality improvements during storage of water in aquifers. If the minimum residence time in an aquifer can be assured by separating injection and recovery wells, then the aquifer treatment could become recognized as an accepted part of a treatment train capable of producing an ongoing safe supply of drinking water. Coupling this subsurface treatment to a reed-bed filtration system already in use to treat urban runoff within the City of Salisbury is known to have the potential to produce drinking quality water. This is the origin of the ASTR stormwater to potable project.

However, there may be a large difference between what is theoretically possible and the reality of operating an urban catchment for drinking water supply. There is so much potential for incidents such as accidents, spills, fires, floods, construction, changes in land use etc to impact on the quality of stormwater that it is essential for these hazards to be assessed and multi-barrier management controls identified before the project could be relied on to provide a sustainable drinking water supply. Hence a preliminary Hazard Analysis and Critical Control Point (HACCP) plan was developed to evaluate the viability of the ASTR project.

HACCP is a system which was developed to ensure the safety of food. It is systematic and based upon scientific principles which identify specific hazards, evaluates their risk and requires measures for their control. The focus of a HACCP system is on prevention rather than relying upon end point testing to demonstrate safety. The HACCP system has recently been developed and applied to potable water by a number of Australian water businesses.

The ASTR project partners chose to implement a preliminary HACCP system based upon the requirements described in the Codex Alimentarius Commission Recommended International Code of Practice General Principles of Food Hygiene (1999).

HACCP has been applied throughout the entire chain of producing potable water from the Parafield catchment to point of supply to the final consumer, which comprises:

- Parafield urban water catchment
- Parafield drain
- Inline pond
- Holding storage
- Cleansing reedbed
- Subsurface storage
- Third pipe mains to Mawson Lakes

The preliminary HACCP plan draws on the procedure specified in the Australian Drinking Water Guidelines (2004), where hazards and controls are considered from source to supply. Hazardous events identified included processes, circumstances, situations and activities which lead to microbiological, physical, chemical and radiological contaminants being created within or introduced into the water supply system. Preventative measures developed included establishment of effective approaches to manage activities and processes such as:

- Catchment / stormwater management
- Maintenance of the wetland treatment system

Data was collected on the number and types of industries in the Parafield and Ayfield subcatchments, the likely chemicals used by these industries, stormwater quality, operational procedures for stormwater management, and barriers to hazards entering stormwater and control points for pollutant management. The existing barriers and critical control points at

various locations in the catchment, in the wetland and in the aquifer are also identified. A preliminary risk assessment of some of the identified hazards was made to establish a basis from which a comprehensive HACCP plan could be developed. Some recommendations are made for development of additional barriers to stormwater contamination, where required to achieve an effective multiple barrier system.

It is expected that implementation of the HACCP system will strengthen the ASTR project's ability to consistently supply water that meets the needs of users including as a drinking water supply. Note that data acquired in fulfilling this preliminary HACCP plan is expected to produce information that will allow the plan to be periodically revised and improved.

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# 1 INTRODUCTION

This report outlines the concept of the HACCP methodology and provides details of a preliminary HACCP plan for quality assurance of wetland treated stormwater (from the Parafield and Ayfield catchments of the City of Salisbury) that is injected into a confined aquifer and recovered for drinking water supplies. The aim of the stormwater quality control and treatment is for production of water of potable quality that meets the Australian Drinking Water Quality Guidelines (ADWG) Water Quality Management Framework (2004).

The preparation of the preliminary HACCP plan is a component of a proposed project titled '*Stormwater to Drinking Water - Aquifer Storage Transfer and Recovery (ASTR)*', referred to as the ASTR project throughout this report. Project partners include CSIRO Land and Water, City of Salisbury Council, United Water International Pty. Ltd., SA Water Corporation and Delfin Lend Lease. Representatives from SA Human Services (Health) Department, the South Australian Environment Protection Agency and Department of Water, Land and Biodiversity Conservation have been involved in discussions on the policy and licensing requirements of the project.

Development of a preliminary HACCP plan for the ASTR project focuses primarily on understanding and assessing the discrete water supply processes involved in delivering potable water. Hazardous events and sources of hazards impacting on these processes are identified and the risk they pose is estimated using a simple qualitative model.

A more comprehensive approach to developing a HACCP plan requires a detailed understanding and assessment of the water supply system. Broadly this would require investigation of:

- Source water catchments
- Storage systems and intake structures
- Treatment systems, including the wetland and the ASTR component
- Distribution system including the reticulation system
- Consumers

The HACCP concept was originally established for the food industry and has more recently been applied to water supplies in Australia (Hellier, 2000). HACCP for potable water systems incorporates a multiple barrier approach for protection of water quality (NHMRC/ARMCANZ, 2002). The ultimate goal is to protect potable water quality from source to tap. This approach aims to reduce the overall treatment and operating costs for potable water supplies while maintaining water quality. A standardised approach for hazard analysis for public water supplies is presented in the Guide to Hazard Identification and Risk Assessment for Drinking Water Supplies (Nadebaum *et al.*, 2004), which has been adapted for use in this report.

In Australia, several water suppliers have developed HACCP plans, including Brisbane Water (Gray and Morain, 2000), Power and Water Corporation, Sydney Water and Melbourne Water Corporation (Hellier, 2000). Other suppliers (e.g. Gold Coast Water) have completed risk evaluations for management planning, with HACCP plans certified by third party auditors (source: Water ECO Science, 2002).

For the ASTR project a preliminary HACCP plan is developed and the process followed according to the application of twelve elements (five steps and seven principles) as shown in Table 1.

**Table 1 HACCP plan development - the 12 elements.**

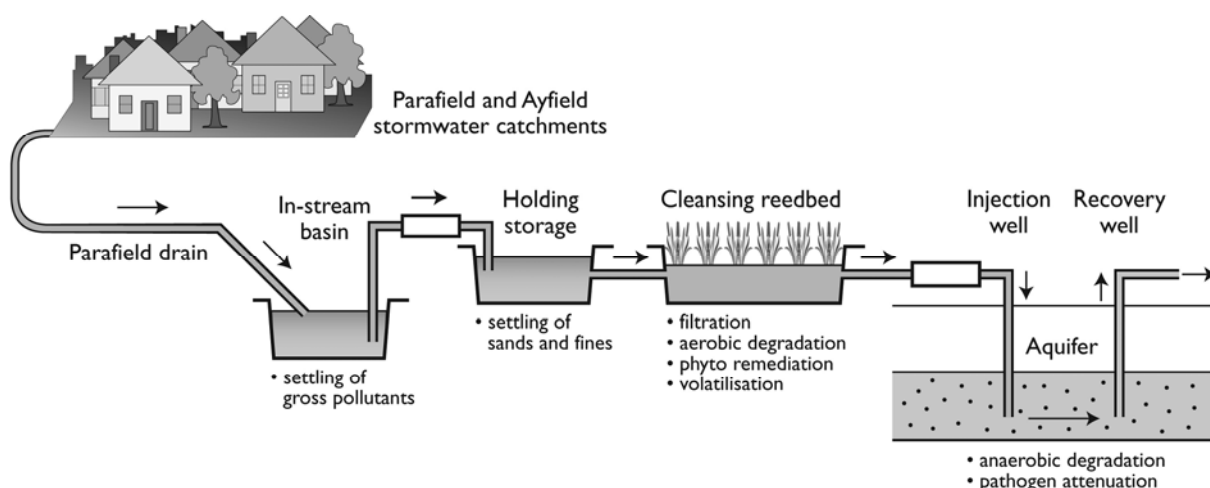
The 12 elements
1. Assemble a team
2. Describe the product
3. Document intended uses of the product
4. Construct a process flow diagram
5. Verify process flow diagrams
6. Identify hazards and preventative measures
7. Identify critical control points
8. Establish critical limits
9. Identify monitoring procedures
10. Establish corrective action procedures
11. Validate/verify HACCP plan
12. Establish documentation and record keeping

The scope of this preliminary HACCP plan covers the ASTR project from the Parafield urban water catchment from which the stormwaters are sourced, through to the interface with potential users of water recovered from subsurface storage.

It must be noted, that this preliminary HACCP plan does not detail the various supporting programs required to support HACCP. These will have to be developed by the HACCP team during the formulation and implementation of a more comprehensive HACCP plan.

## **2 ASTR PROJECT BACKGROUND**

Key goals of the ASTR project are to gain a sound scientific understanding of the processes affecting water quality and to develop management strategies for reliable, sustainable production of water of potable quality (based on the ADWG, 2004) sourced from stormwater (Rinck-Pfeiffer *et al.* 2005). In this case, this preliminary HACCP plan would provide a starting point for risk-based management of water quality from source to supply, incorporating wetlands and ASTR as treatment steps. A general diagram of the ASTR system including the catchment and storm sewer network, and the locations of the wetlands and proposed ASTR injection and recovery wells is given in Figure 1.



**Figure 1 ASTR project site and scope of the HACCP plan.**

On that basis, the source water quality at each identified treatment step needs to be determined in relation to the total system treatment capacities for removal of contaminants and the required quality of water to be supplied. Sources of stormwater in the Parafield and Ayfield subcatchments (part of the Dry Creek catchment) are in urban, residential, retail business and mixed industrial areas. Major transportation routes are in a north-south direction through the area, including roads and railway. A centralised water supply currently services the metropolitan area with new areas of residential growth in development. The Mawson Lakes Subdivision, currently in development in the southwestern part of the council area, represents potential users of potable water supplied by the ASTR project.

The catchment area in the vicinity of the Parafield Airport meteorological station, has warm dry summers and cool wet winters. The average daily air temperature ranges from a maximum of 29°C in January (average low of 16°C) to a minimum of 15°C in July (average low of 6°C). The majority of rain occurs in the winter months. Annual rainfall averages 461 mm, with monthly averages ranging from 18 mm in February to 61 mm in July.

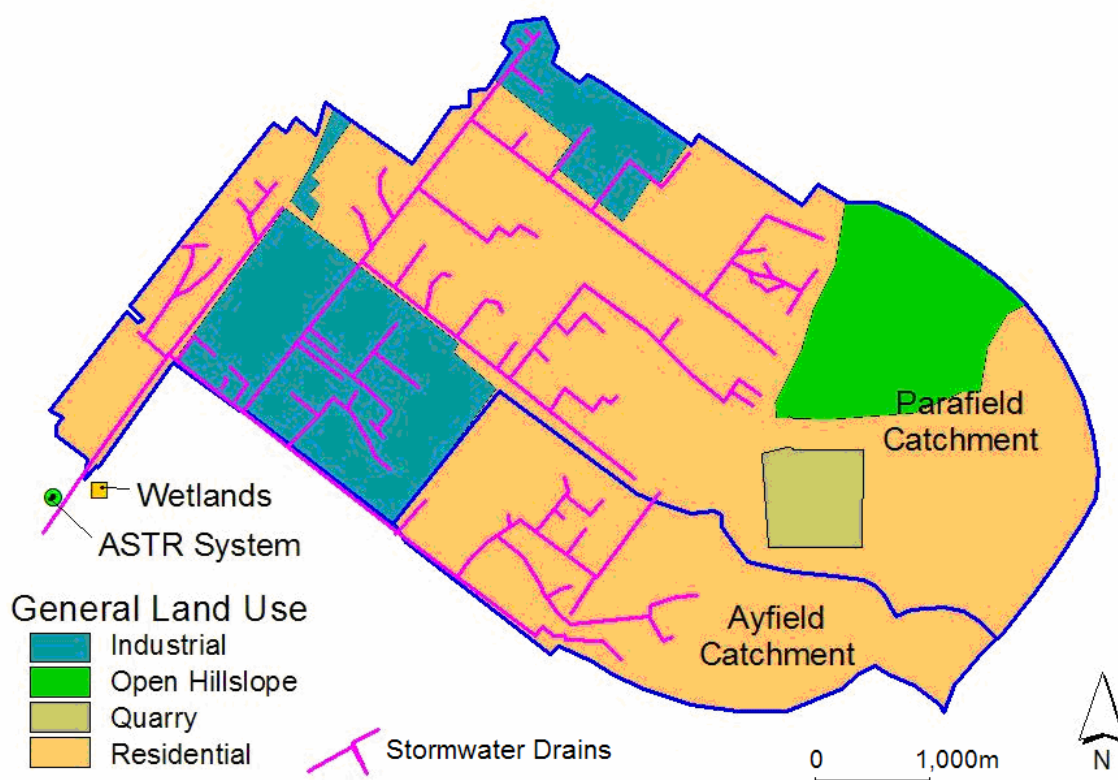
During the past decade, the Salisbury Council has developed 34 artificial wetlands to capture and treat stormwater prior to discharge to the sea. Many wetland areas are constructed with adjacent parkland to develop additional green areas for recreation and wildlife habitat as part of the water conservation efforts. There are nine ASR systems that provide non-potable water for local irrigation and industrial uses.

From the above summary, the ASTR project is further broken down conceptually into three sections for the remainder of this report: the catchment; the Parafield wetlands; and the ASTR system, each of which is described below in further detail.

## 2.1 Catchment - System Description

Stormwater derived from the Parafield catchment is expected to reflect impacts from a range of potential contaminant sources. The management of contaminant sources requires an understanding of the distribution and nature of the contaminants, the stormwater hydrology and the fate and transport properties of contaminants in the stormwater system. Background information on the catchment follows.

The water entering the Parafield stormwater harvesting system is derived from two local catchments within the larger Dry Creek Catchment area; the Parafield and Ayfield catchments (Figure 2).

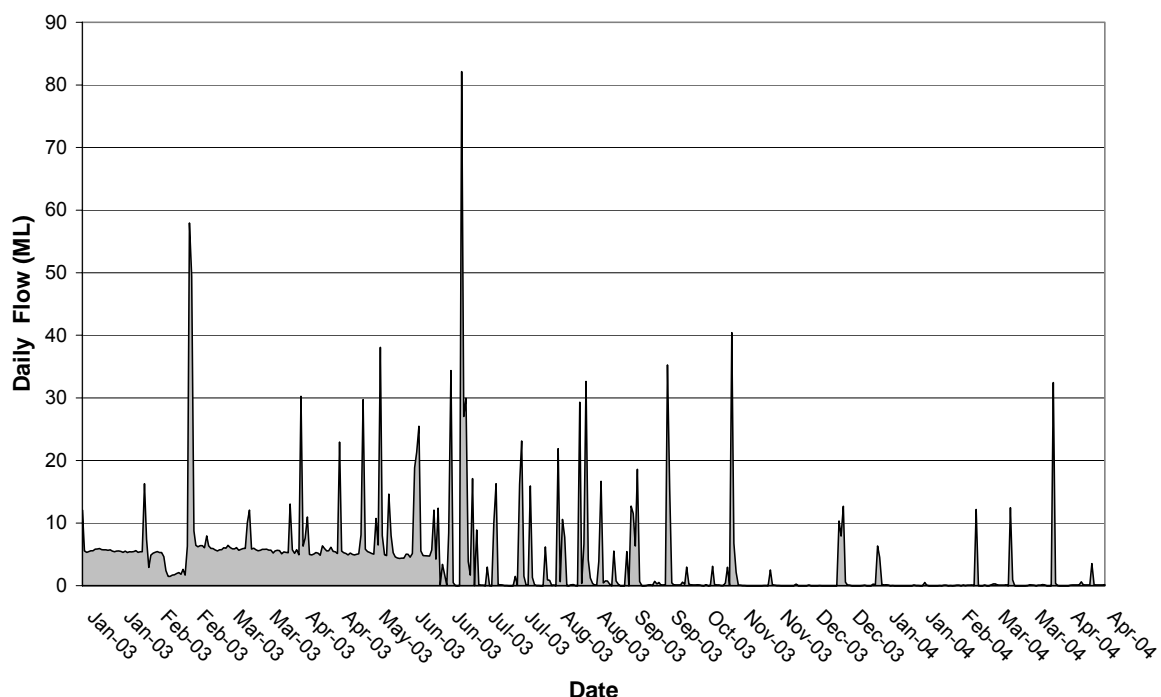


**Figure 2 Parafield and Ayfield stormwater catchments showing main stormwater drains**

Both catchments have stormwater directed to the Parafield drain, which supplies water to the Parafield Wetlands. After passage through the wetlands the water is intended to be used for the Greenfield Railway Station ASTR system.

Water balance and stormwater flows in the Dry Creek Catchment have been estimated by Richard Clark & Associates (2001) using the WaterCress Model. The model's output is based on classified land uses, types of surfaces and their coverage and the catchment topography. In this model the average annual rainfall over the catchment area is used to estimate runoff volumes. Total runoff estimates were calibrated by using data from the adjacent Paddocks Catchment. Runoff and infiltration coefficients were determined for different land type areas within the Paddocks Catchment, which were then applied to the study area. The study did not provide details related to rainfall from specific rain events. The results indicate that the Ayfield Catchment (area - 373 ha) will yield an estimated 340 ML/year and the Parafield Catchment (area - 1,248 ha) will yield an estimated 1,180 ML/year, for a total annual yield of 1,520 ML.

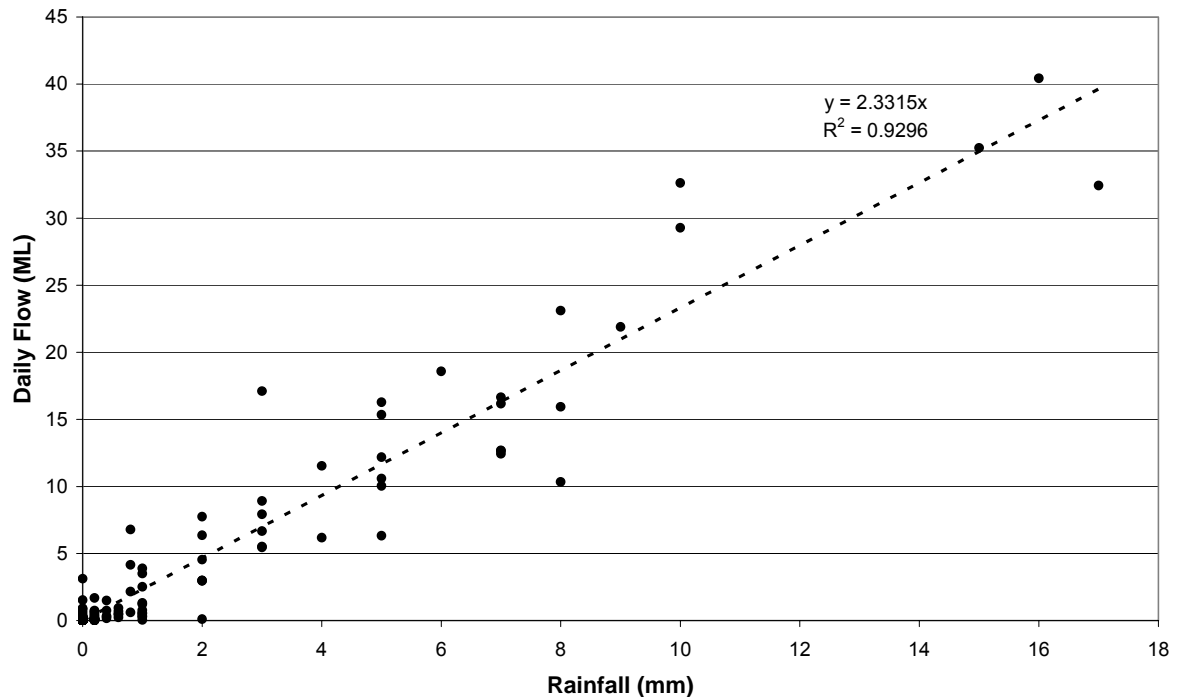
Surface water volumetric flow rates are needed in the assessment of the transport, dilution and fate of sediment, chemicals and pathogens. Daily flow data measured in the Parafield Drain near the Parafield Wetlands from the period from January 2003 to April 2004 are shown in Figure 3.



**Figure 3 Hydrograph of daily flow in Parafield Drain at Parafield Wetlands (Source: City of Salisbury).**

Daily flow readings were taken by continuous measurement of the head in a pool created by a concrete V-notch weir in the Parafield Drain about 450 m upstream of the main diversion weir adjacent to the In-stream basin. The cause of the base flow during the period from 1 January 2003 to 15 June 2003 (where there was little recorded rain) has not been determined although City of Salisbury staff have reported that there was no blockage on the weir notch.

Daily flow data for the Parafield Airport (CBM, 2004) are compared to daily rainfall data in Figure 4 with a linear regression coefficient of 2.33 ML flow per mm of rainfall.



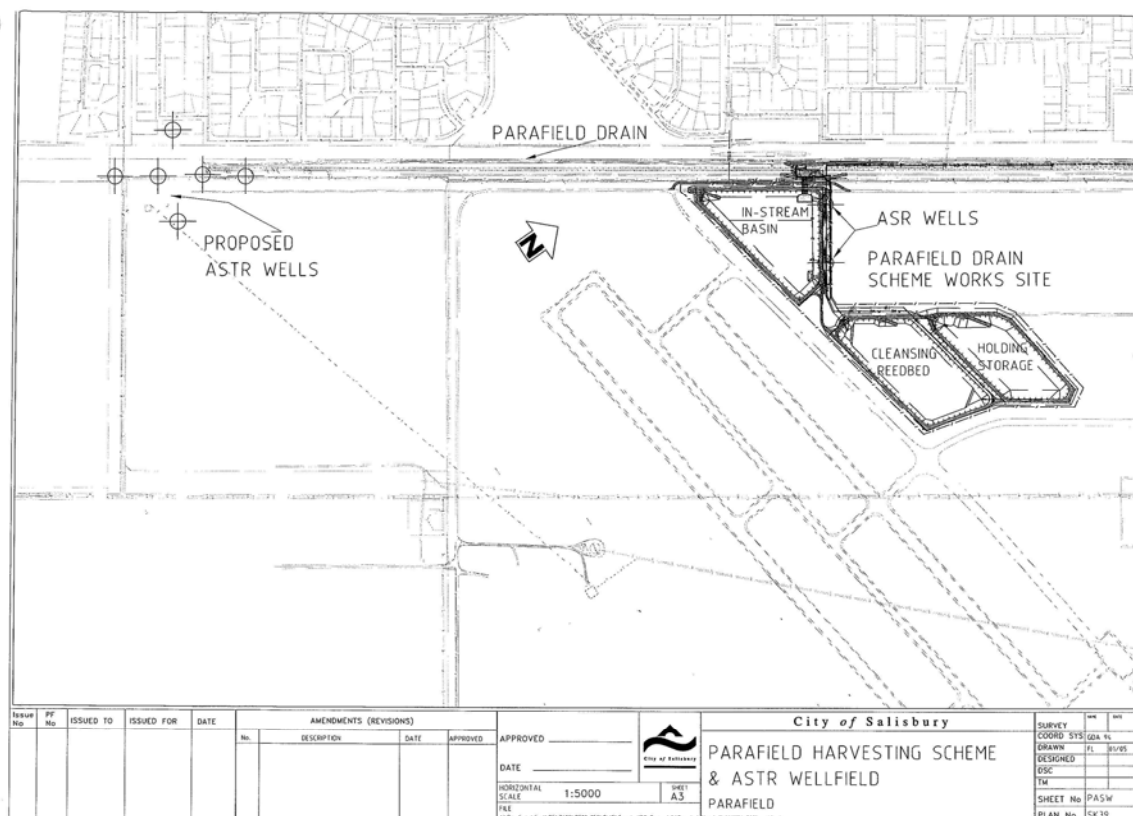
**Figure 4 Comparison of daily flow in Parafield Drain with daily rainfall**

Assuming that this flow is derived from both catchments, the mean runoff co-efficient is 14% and the revised estimated mean annual runoff is 1070 ML/yr (Richard Clark and Associates 2001). This relationship can be used for preliminary planning purposes regarding system operation, though it does not reflect flow characteristics related to individual events.

Averages of water quality parameters from the Parafield Drain for the period from March 2003 to April 2004 are given in Appendix 1. Samples were collected by a composite sampler during storm events located upstream of the diversion weir. However, samples were not able to be collected for organic chemical analyses.

## 2.2 Parafield Wetlands - System Description

The Parafield Wetland system comprises three components, an in-stream basin, a holding storage and cleansing reedbed (Figure 5).



**Figure 5 Parafield wetland system diagram (Source: City of Salisbury Council).**

All three ponds have netting to limit access by birds. Continuous monitoring of water parameters flow, pH, electrical conductivity and turbidity in the Parafield drain potentially provides input but currently are not used in this way to manage current operations. Monitoring is linked to a SCADA system, which could stop or redirect flow between the various ponds if the measured water quality parameters fall outside specified values.

A weir diverts water from the Parafield Drain into the 50 ML in-stream basin, which is the first of three stages of the wetland system. The in-stream basin serves as an initial settling basin for the stormwater. Water from the in-stream basin is pumped to the holding storage as water moves through the system. The residence time of water in the in-stream basin varies as a function of water availability and use.

Water flows into the In-stream basin during a storm event and is pumped at 3 ML per hour to the Holding storage until capacity of the holding storage is reached or the In-stream basin is drained. Excess flow overtops the diversion weir and continues to flow in the stormwater drain. Water flows by gravity from the holding storage into the cleansing reedbed. The holding storage has a capacity of 50 ML, and is maintained at capacity when water is available in the in-stream basin. Water quality (conductivity and turbidity) is measured continually during transfer from the in-stream basin to the holding storage. Flow from each pond may be diverted back to the Parafield drain as needed. The holding time in each pond varies with system use. Water quality analyses were obtained for samples collected from the in-stream basin between June and November 2003, Appendix 1. The same parameters were determined for samples from the cleansing reedbed. These samples were not timed in such a way to enable water quality improvements to be accurately gauged.

The cleansing reedbed is vegetated with seven different species of reeds, planted in parallel rows that are perpendicular to flow across the pond. The capacity of the reedbed is approximately 25 ML. The cleansing reedbed is designed to achieve a minimum holding time

of 7 days; however, the actual holding time varies with use. Discharge from the cleansing reedbed is monitored continuously for conductivity and turbidity prior to discharge into the ASR and in the future for the ASTR systems. A summary of water quality data for samples collected from the cleansing reedbed between November 2002 and June 2004 is shown in Appendix 1. A database of water quality parameter values is currently maintained by the City of Salisbury Council.

The system is designed to provide treatment for an average supply of 1,100 ML per year, based on the estimated annual yield of the Parafield and Ayfield Storm Catchments (Richard Clark and Associates, 2001). The system currently provides process water to Michell Australia (a wool processing plant), with additional water recharging an ASR system adjacent to the wetlands. Water for the ASTR system represents an additional use of water from the facility.

Water quality data for water samples collected from the Parafield drain and the cleansing reedbed outlet are shown in Appendix 1, with preliminary calculations of the percent reduction across the wetland system, based on the mean concentrations (Rinck-Pfeiffer *et al.* 2005). Plots of the contaminant reduction are available in the City of Salisbury database.

The Parafield Wetlands treats stormwater and is currently configured to provide virtually potable grade water for non-potable uses, including irrigation and for use by Michell Australia, a wool processing plant. The system operates in conjunction with a two-well ASR system for storage of excess water. When operating at capacity, the system processes water at a maximum rate of 7.5 ML/day, which meets the needs of Michell Australia and is also the maximum injection rate into the aquifer from the current wells.

## 2.3 ASTR - System Description

The ASTR system is proposed to provide storage and additional treatment of water sourced from the Parafield Wetlands (Figure 6).

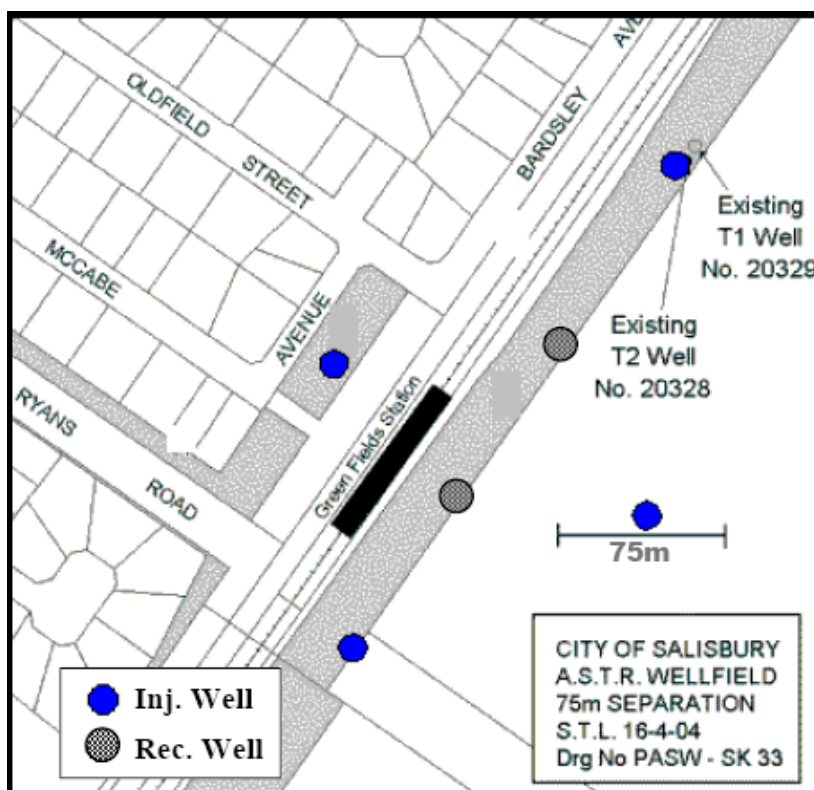


Figure 6 Proposed layout of ASTR well-field at the Greenfields Railway station site (after Pavelic *et al.* 2004).



Background information on the ASTR system, including ground water modelling for system design is given in Pavelic *et al.* (2004). The modelling process considers ground water flow patterns, solute travel times and mixing with native groundwater to determine the best arrangement for wells. Additional modelling of contaminant attenuation in the aquifer was undertaken. The system is designed to provide an aquifer residence time sufficient for inactivation of pathogens that potentially may be present in the injectant water.

The intended ASTR will utilize the T2 aquifer, a confined limestone aquifer at an approximate depth of 150 - 200m below the surface. TDS in this aquifer range from 500 - 2,000 mg/L (Gerges, 1999; Zulfic, 2002) across the Northern Adelaide Plains. The T2 aquifer at the adjacent Parafield ASR site was initially brackish with 2,000 mg/L TDS. Water sampling and analyses indicate levels of sodium, chloride and iron above the ADQG, and a concentration of arsenic at approximately the drinking water guideline value (0.007 mg/L), refer to Appendix 1.

The ASTR system when completed is expected to comprise four injection wells surrounding two recovery wells (Figure 6). The wells will be installed so there is an aquifer travel distance of approximately 75 meters from the injection wells to the recovery wells. The development of the system for use as a potable water supply will require several stages, as described by Pavelic *et al.* (2004). Ground water monitoring will be conducted during the ASTR development to verify that changes in water quality with transfer are consistent with model predictions and expected water quality. Some observation wells will be established between injection and recovery wells, at locations that provide best information on the development of a fresh water lens in the aquifer and to provide early warning in the event of water quality issues. This will improve prediction of salinity and other water quality parameters of recovered water.

After the wells have been installed, water from the Parafield Wetlands will initially be pumped into the two recovery wells in order to displace the saline groundwater with the fresher wetlands water. Water will be pumped into the aquifer until a sufficient volume occupies the aquifer in the area encompassed by the outer injection wells. Injection into the aquifer through the four outer injection wells will occur subsequently. It is anticipated that the volume of water recovered will reach 80% of the injected water volume. The balance is needed to maintain a buffer zone with the ambient brackish water.

The final water produced by the system will comprise at least 90% injected stormwater mixed with no more than 10% ambient ground water to sufficiently dilute the salts present in the natural groundwater and achieve potable water quality. The use of the system for pathogen attenuation is an important part of the design criteria for the system. The well configuration was designed to produce a mean residence time in the aquifer of 300 days. This could be achieved with a 75 m spacing for the current well layout. Actual residence times will be shorter in more permeable parts of the aquifer. Studies reported in Dillon *et al.* (2005) describe measurements of attenuation rates in aquifers of pathogens, natural organic matter and some synthetic organics and model these processes. Dillon *et al.* (2002) describe a similar situation for bank filtration in a brackish aquifer where residence time and the proportion of native groundwater are two constraints on the system design.

Water flowing through the aquifer will undergo some mixing with ambient groundwater. As contaminants migrate through the aquifer they may be retarded by detention of particulates or sorption processes with the aquifer matrix and be degraded by microbial activity. Pathogens will be attenuated in the aquifer, with different pathogens undergoing different rates of attenuation (Dillon *et al.* 2005). Specific metal mobilization and organic compound degradation rates in relation to redox conditions, pH and temperature vary in the aquifer (Vanderzalm *et al.* 2004). A rigorous assessment is required during the verification of a more comprehensive HACCP plan.

### **3 DEVELOPMENT OF A PRELIMINARY HACCP PLAN – THE 12 ELEMENTS**

Development of a preliminary HACCP plan for the ASTR project encompasses the twelve elements described in Table 1. These twelve elements are expanded here.

#### **3.1 Assembling a HACCP team**

To develop a comprehensive HACCP plan for the ASTR project an in-house team will need to be assembled and convened on a number of occasions ahead of a workshop conducted to review the preliminary risk assessment. Broadly the team will need to be represented by relevant stakeholder groups and possess expertise in the areas of:

- Catchment and stormwater management
- Potable water risk management
- Wetland treatment, ASTR treatment, disinfection and other forms of water treatment
- Microbiological, physical and chemical water quality, water quality monitoring
- Water supply system operation e.g. security, storage operation, mains flushing
- Constructor/contractor management
- Technical writing e.g. policy, specifications, standard operating procedures
- Quality management systems

The HACCP team members are responsible for the implementation of the HACCP plan and are required to:

- Contribute as required to the development and documentation of the HACCP plan
- Input on areas of technical expertise
- Implement the requirements of the HACCP plan where required
- Perform verification tasks where required
- Undertake the review of the HACCP plan

Ideally this HACCP team will draw from member of all relevant stakeholders. For the ASTR project, stakeholders are likely to be drawn from the following groups:

- City of Salisbury Council
- United Water International Pty. Ltd.
- SA Water Corporation
- CSIRO Land and Water
- SA Department of Health Services
- SA Environmental Protection Agency
- Northern Adelaide Barossa Catchment Water Management Board
- Delfin Lend Lease
- Community groups / industry groups / general public

It is proposed that a specific HACCP team will be a technical subcommittee of the ASTR project. The HACCP team when convened will have a high level project champion in the form of the ASTR steering committee. The ASTR steering committee responsibilities with respect to HACCP are:

- Be chief champion of the project
- Have accountability for the project and ongoing accountability for the outcomes
- Advocate the project internally and externally
- Facilitate and support policy and funding recommendations
- Provide overview and direction for the project
- Resolve issues identified by the project manager when requested and agreed

During ASTR project design, establishment, testing and commissioning, the project manager appointed by the ASTR project steering committee has oversight of the HACCP plan. Once the project reaches the routine operating phase project management and responsibility for reporting on and updating the HACCP plan will rest with the site operator. The HACCP plan manager has responsibility to:

- Direct attention to the HACCP plan at a strategic level
- Resolve issues or procedures where required
- Ensure the alignment of other supporting programs with the HACCP plan
- Report on the progress of development and implementation of supporting programs
- Ensure the strategic integration of the HACCP system with other management systems (e.g. ISO 9001)
- Ensure the project's overall objectives, targets at various key stages, and individuals' responsibilities are clearly understood by all concerned
- Organise and facilitate HACCP team meetings, as appropriate
- Ensure appropriate communication between/to project participants including sponsor, clients, members of the HACCP teams, as well as other project stakeholders and involved parties
- Assist with development and refinement of HACCP plans prepared by HACCP teams
- Coordinate auditing of the HACCP plan
- Consider the results of audit reports and initiate action upon recommendations
- Initiate development and improvement of supporting programs
- Facilitate organisational education and training needs to support the HACCP plan

Finally the auditors (whether an independent third party or not) are required to:

- Undertake the auditing HACCP plans and specifically use of systems and procedures
- Provide advice on controls

### **3.2 Description of the product**

Prior to implementation of the HACCP plan, the product, potable water, must be described; an example specification is given in Table 2.

**Table 2 Potable water - product specifications**

Raw stormwater specification
Stormwater comprises surface runoff extracted from the Parafield diversion weir. An overview of the physical, chemical and microbiological characteristics, along with the associated <i>ADWG</i> (2004) health and aesthetic guideline values are presented in Appendix 1.
Finished potable water product specification
The ASTR project's objective is to produce good quality potable water that is safe and aesthetically acceptable. Consistent with this objective, the product's specification for potable water is derived where relevant from the <i>ADWG</i> (2004). However initially during the proof of concept phase, water quality must meet the specification of the Mawson Lakes third pipe scheme.
Dilution water for a recycled water supply to Mawson Lakes product specification
An interim use of the product water until potable water quality has been demonstrated to be consistently achieved will be as dilution water for recycled water in the Mawson Lakes third pipe system. This required quality is for a maximum of 300 mg/L TDS, and otherwise to meet the criteria of the water supply agreement with SA Water to meet Class A under the South Australian Reclaimed Water Guidelines: treated effluent, SA EPA and DHCS (1999).

### 3.3 Documentation of the intended use of the product

Similarly, the intended uses and users for the product, potable water must be documented prior to implementation of the HACCP plan, an example is given in Table 3.

**Table 3 Intended uses and users of the product**

Intended uses of the product
The ASTR project's specification for potable water is determined to ensure that it is suitable for immediate human consumption by ingestion by the general population without further treatment or boiling. However, initially during the proof of concept stage, water will be only used for the Mawson Lakes third pipe scheme and for industrial processes such as wool processing.
Intended users of the product
The ASTR project will initially supply water to the general population of Mawson Lakes via the third pipe system and industrial users in the Salisbury region. Approval will be required from SA Department of Human Services before SA Water would be allowed to admit this water into the mains supply.

### 3.4 Development of the process flow diagram

The process flow diagram identifies the water supply system from catchment to water user and provides a broad overview of the process. A preliminary process diagram is shown in, Figure 7, greyed area represents future development of ATSR system that has not yet been built. Symbol descriptions of the processes relating to Figure 7 are given in Table 4.

Certain steps within a process flow diagram consist of a combination of two or more symbols indicating that more than one event or activity occurs at that step in the process. These steps are further detailed in Table 4.

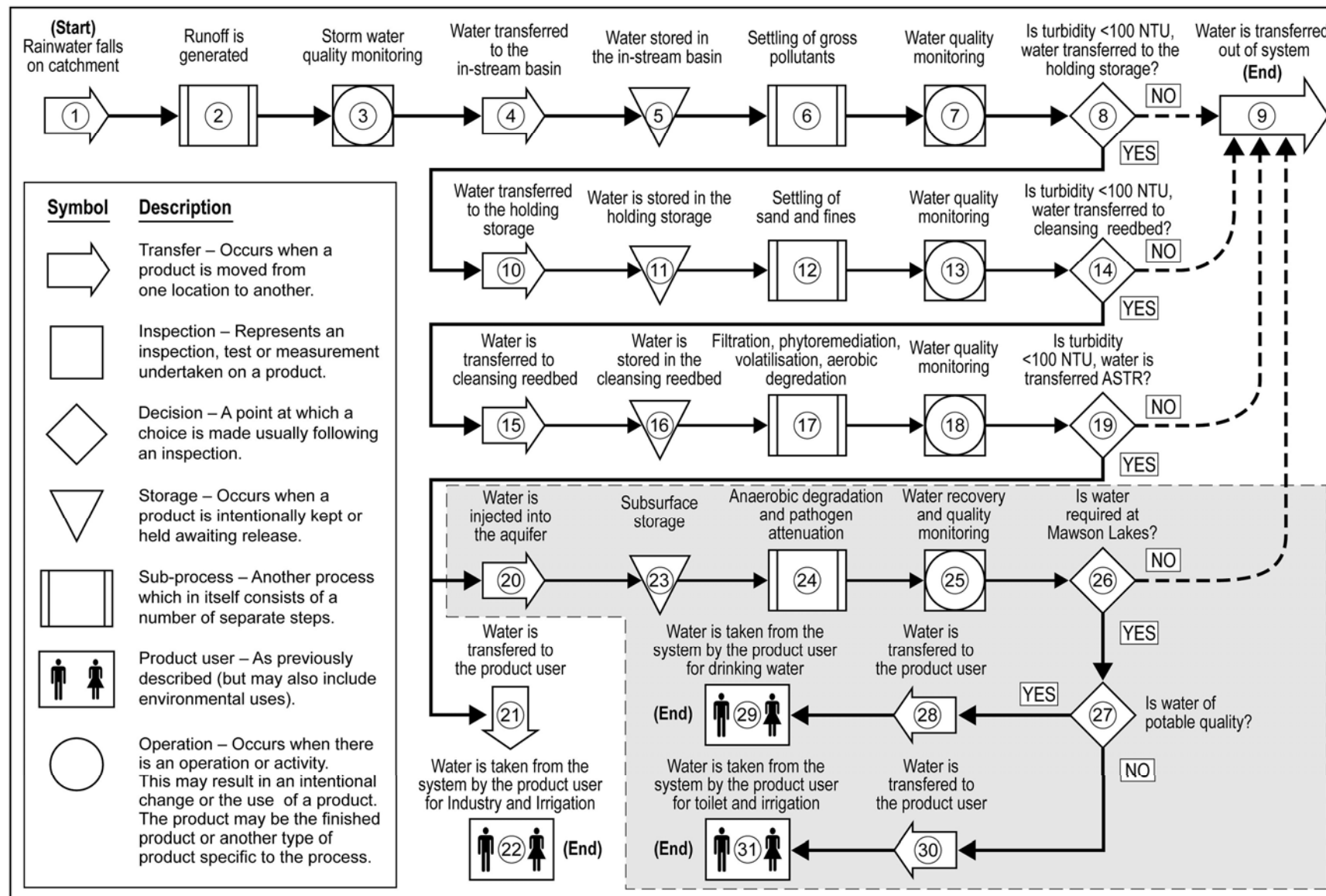


Figure 7 Preliminary process diagram, greyed area represents ASTR component which is not yet operational.

**Table 4 Process flow diagram symbol descriptions from Figure 7.**

Number	Symbol	Description
1	Transfer	(Start) Water (rainfall) is captured by the catchments
2	Sub-process	Stormwater runoff is generated by the catchment.
3	Inspection / Operation	Water quality (turbidity, pH and flow) is monitored 400m, upstream of the diversion weir.
4	Transfer	Water is diverted at the weir to the in-stream basin.
5	Storage	Water is stored in the in-stream basin.
6	Sub-process	Settling of gross pollutants occurs in the in-stream basin.
7	Inspection / Operation	Water quality (turbidity, pH and conductivity) is monitored, water can be pumped to the holding storage.
8	Decision	If turbidity < 100 NTU?, water is pumped to the holding storage. If turbidity > 100 NTU, water is released to downstream of the diversion weir.
9	Transfer	Water is pumped to downstream of the diversion weir and exits the system (End).
10	Transfer	Water is pumped to the holding storage basin.
11	Storage	Water is stored in the holding storage basin.
12	Sub-process	Settling of sand and particulates.
13	Inspection / Operation	Water quality (turbidity, pH and conductivity) is monitored; water can be released to the cleansing reedbed.
14	Decision	If turbidity < 100 NTU?, water is pumped to the holding storage. If turbidity > 100 NTU, water is released to downstream of the diversion weir.
15	Transfer	Water is transferred by gravity to the cleansing reedbed.
16	Storage	Water is stored in the cleansing reedbed.
17	Sub-process	Colloidal material settles, removal of some pathogens and pollutants.
18	Inspection / Operation	Water quality (turbidity, pH and conductivity) is monitored; water can be released to the ASTR injection well.
19	Decision	If turbidity < 100 NTU?, water is pumped to the holding storage. If turbidity > 100 NTU, water is released to downstream of the diversion weir.
20	Transfer	Pump water to ASTR injection well.
21	Transfer	Pump water to product users.
22	Product user	Water is taken from the system by the product user for industry or irrigation (End).
23	Storage	Water is stored in the subsurface storage.
24	Sub-process	Subsurface storage removes pathogens, nutrients and generally improves quality.
25	Inspection / Storage	Water quality is monitored via observation wells.
26	Decision	Is water is recovered and required at Mawson Lakes?
27	Decision	Is water of potable quality?
28	Transfer	Water is transferred to the potable water system at Mawson Lakes
29	Product user	Water is taken from the system by the product user for drinking water (End).
30	Transfer	Water is transferred to the third pipe system at Mawson Lakes
31	Product user	Water is taken from the system by the product user for the third pipe system (End).

### 3.5 Verification of the process flow diagram

The HACCP team will verify the preliminary process flow diagram (Figure 7) as being a true and accurate representation of the ASTR project supply system and other important processes.

### 3.6 Identification of hazards and preventative measures

Risk assessment is the sixth element in HACCP plan development. A hazard represents any chemical, organism, activity or circumstance that can result in a detrimental impact on water quality and consequently on the user and/or on the environment. Four general categories of hazard types exist: 1) physical, 2) chemical, 3) microbiological and 4) radiological (ADWG 2004). Each hazardous event was examined and determined to result in one or more of these four hazard types.

The risk of the hazard is determined from the relative likelihood of the hazard occurring and the consequence of the occurrence. A generalized qualitative approach for hazard analysis for public water supplies is presented in the *Guide to Hazard Identification and Risk Assessment for Drinking Water Supplies* (Nadebaum *et al.* 2004) and the *Draft National Guidelines for Water Recycling: Managing Health and Environmental Risks* (NRMMC / EPHC 2005). The hazard analysis used for ASTR follows these guidelines. Additional criteria such as residual risk were developed to assess risk from properties or land use activities that have specific potential contaminant sources.

#### 3.6.1 Risk Assessment Framework

The qualitative risk analysis model shown in Table 5 and Table 6 and is used by the HACCP team to calculate the risk factor (i.e. score) for each identified hazard(s) arising from a hazardous event. The risk factor is defined as:

$$\text{Risk Factor} = \text{Likelihood (L)} \times \text{Severity of Consequences (S)}$$

A simple numerical rating (i.e. score between 1-5) was assigned to the different levels of likelihood and severity of consequences. To perform the risk analysis the existing controls were determined and the risks analysed in terms of likelihood and severity of consequences in the context of those controls. For each event, relative hazards are evaluated based on the general likelihood of an event occurring (Table 5) compared with the potential consequences or impacts of the event to the system (Table 6).

**Table 5 Risk assessment likelihood scale.**

Likelihood Rating	Descriptor	Example Description
1	Rare	May occur only in exceptional circumstances.
2	Unlikely	Could occur at some time.
3	Possible	Might occur at some time/the event should occur at some time.
4	Likely	Will probably occur in most circumstances.
5	Almost Certain	Is expected to occur in most circumstances.

**Table 6 Risk assessment severity scale.**

Severity Rating	Descriptor	Example Description
1	Insignificant	Insignificant impact, little disruption to normal operation low increase to normal operating costs.
2	Minor	Minor impact, some manageable operation disruption, some increase in operating costs.
3	Moderate	Minor impact, significant modification to normal operation but manageable, operating costs increased, increased monitoring.
4	Major	Major impact, systems significantly compromised and abnormal operation if at all, high level of monitoring required.
5	Catastrophic	Major impact, complete failure of systems.

This approach recognises that qualitative rather than quantitative information may be all that is available for decision making. However, the qualitative level of relative risk determined based on the likelihood and potential impacts of an event is evaluated using a matrix shown in Table 7.

**Table 7 Risk factor score matrix**

<i>Risk Factor Matrix:</i>		<i>Severity of Consequences</i>				
Likelihood		Insignificant <i>Rating: 1</i>	Minor <i>Rating: 2</i>	Moderate <i>Rating: 3</i>	Major <i>Rating: 4</i>	Catastrophic <i>Rating: 5</i>
	Rare <i>Rating: 1</i>	Low	Low	Moderate	High	High
	Unlikely <i>Rating: 2</i>	Low	Low	Moderate	High	Very High
	Possible <i>Rating: 3</i>	Low	Moderate	High	Very High	Very High
	Likely <i>Rating: 4</i>	Moderate	High	High	Very High	Very High
	Almost Certain <i>Rating: 5</i>	Moderate	High	Very High	Very High	Very High

This approach provides a relative measure of potential risk that allows hazards present in a system to be prioritized for evaluation. Filtering was applied to distinguish significant hazards from those considered to be of less significance, and to separate hazards related to aesthetic concerns which did not result in potable water becoming unsafe to consume. Risks with a risk factor equal to or greater than moderate were classified as significant risks to water



quality and were assigned a higher priority for further investigation. Risks with a risk factor less than moderate (i.e. risks with a risk factor score of “low”) were classified as risks that did not pose a significant risk to water quality. These hazards were assigned a lower priority for further investigation. The risk score has previously been used by other Australian water suppliers that have implemented HACCP systems using the above method of evaluating risks (Nadebaum *et al.* 2004).

### 3.6.2 Residual Risk Determination

The residual risk from a hazard or a hazardous event is expected to be influenced by the number and effectiveness of barriers that are in place to reduce the impact from a release of contaminants to the water supply. There are several types of barriers that may reduce the relative risk from hazard(s) of a specific facility. Barriers can be classified in the different categories, summarized as follows:

- Natural barriers, those that will naturally stop or attenuate the hazard or cause it to be removed. For stormwater, an example would be a buffer zone of vegetation separating a spill area from the drain system. The vegetated buffer zone would intercept all or part of the spill or contaminated stormwater flow.
- Incident response planning to minimize impacts from uncontrolled hazard releases. These might include local and major emergency response plans and would include detailed procedures, contacts for external emergency response organizations and internal staff training.
- A management program with an aim to minimize the frequency and extent of use of hazardous agents and potential impacts from hazardous chemical spills. Examples include the application of processes that minimize hazardous chemical use and recycling practices for process chemicals. Another is the storage of minimal quantities of raw and waste chemicals on an industrial site in secured areas with protocols for disposal that minimize hazardous release to the environment.
- Engineered physical barriers constructed to reduce the impact of any release of chemicals to stormwater. Examples include a concrete pad with bunding for a chemical storage area, or an overhanging roof and stormwater flow diversions to prevent stormwater from coming into contact with specific chemical storage areas.

Significant hazards arising from each of the conceptual components of the system are now examined, then summarised in a risk assessment schedule (Table 8).

### 3.6.3 Catchment Hazard Analysis

For the catchment, the risk assessment process qualitatively evaluates the known hazards and helps to prioritize pollution prevention and planning activities. The methodology for the catchment risk assessment is further elaborated in Appendix 2. Table 8 presents several examples demonstrating how residual risk is determined based on the preliminary risk, and the barriers currently present. In many cases, the likelihood and consequences of listed hazards are subjective and may be interpreted at different levels. For purposes of this assessment, a “worst-case” scenario is generally followed; however, planners may wish to assess the hazard under both “normal” conditions and as a “worst-case” scenario for comparative purposes. Those residual risks which are considered unacceptable by the HACCP team will be mitigated by further barriers that will be outlined and evaluated as this preliminary HACCP plan is refined.

General hazards were identified based on the guidelines presented in Nadebaum *et al* (2004) and procedures for identification of sources of non-point source pollution include those detailed in the *State methods for delineating source water protection areas for surface*

*water supplied sources of drinking water* (USEPA 1997). A list of hazards with preliminary risk assessment information is shown in Table 8. These hazards may be broadly described as follows:

Industry and businesses in the area use a wide range of chemicals at varying concentrations and amounts. Industries in the catchment include wool processing, pharmaceutical, automobile paint and repairs workshops, metal and machine shops. Waste chemicals are discharged either into the sewer system, where approved, or are removed by waste removal contractors. However, there is evidence of stormwater contamination from about 20% of workplaces (L. Dahl-Helm, personal communication). Large volumes of waste may be collected and stored on site for recycling and/or disposal. Sources of uncontrolled chemical release may be from above ground storage tanks, piping from underground storage tanks, and/or from process waste streams.

Urban and residential land use may involve the application of fertilizers, pesticides, and herbicides for lawn maintenance. Additional contaminants may include automotive waste oils or other chemicals spilled to the ground in low volumes, hydrocarbons from vehicle use on roadways, metals from roofs and railways, and various household chemicals. Construction activities for new buildings are frequently associated with sediment disturbance with the potential for sediments to be transported with stormwater. At larger construction sites, potential contaminant sources such as above-ground fuel tanks and portable toilets may be present.

Animal facilities may contain concentrated animal waste, which can release nitrogen compounds and pathogens into stormwater. In certain areas, animal waste may also be used as a fertilizer, moving the hazards into the field areas. Agricultural practices include the use of fertilizers, pesticides and herbicides. Irrigated lands may pose a greater threat during a storm event when higher overland flow is generated. Another hazard from agricultural land use, especially from horticultural practices is sediment runoff causing turbid water. The sediment load in stormwater may carry other contaminants that are sorbed to the sediment. Agricultural practices are minor (e.g. nurseries) in the study catchment.

Transportation routes are potential contaminant sources from traffic and accidental chemical spills from vehicles and vehicle accidents on the roads or railway. Chemical and fuel transportation trucks pose a significantly greater risk than smaller vehicles, since a large accidental chemical or fuel spill may cause a major detrimental impact on stormwater quality. The Parafield and Ayfield subcatchments have a major arterial road (Main North Rd) as well as an extensive network of smaller roads throughout the industrial and urban zones. Transport of hazardous chemicals by rail may also pose a risk to water resources in the catchment.

Gravel pits and stone quarries are mining activities in the catchment. The quarry in the eastern part of the catchment represents a potential source of sediment to stormwater if not properly managed. Fuels for system operation may be stored at the facilities representing an additional hazard.

Natural events such as a bushfire, flood, drought and earthquake may cause uncontrolled release of chemicals that could migrate into stormwater. For the purposes of this assessment, they are considered in a “worst-case” scenario that may result in the greatest impact from the contaminant source.

Vandalism or sabotage to industries and businesses in the catchment may result in uncontrolled release of chemicals and hence poses a hazard to stormwater quality.

#### **3.6.4 Parafield Wetlands Hazard Analysis**

Constructed wetlands and settling ponds have been recognized as an efficient means of managing water quality at locations around the world. Vegetated wetlands provide a

mechanism for nutrient removal from the effluent from domestic wastewater treatment facilities. Vegetation in wetlands helps induce sedimentation of suspended particles, and inhibit resuspension from wave action, resulting in the removal of particulate phase contaminants. Settling ponds allow for suspended particulate matter to settle by reducing the flow velocity.

Wetlands are used to treat various water sources (industrial wastes, stormwater, sewerage etc) for water quality improvement. For example, removal of nutrients (McCarey *et al.* 2003, Kaseva, 2004, Silvan *et al.* 2004), COD (Kaseva, 2004), faecal coliforms and pathogenic micro-organisms (Kaseva, 2004, Karim *et al.* 2004), DBP's (Rostad *et al.* 2000, Keefe *et al.* 2004), VOC and BTEX (Keefe *et al.* 2004) have been reported in the literature. Removals appear to be site specific depending on a range of factors such as whether the wetlands are vegetated or not, type of vegetation utilized, climate, season, temperature and hydraulic retention time.

A hazard analysis of the Parafield Wetlands should include the normal operating conditions as well as the potential for natural disasters and vandalism. A summary table of the risk assessment for the Parafield Wetland is given in Table 8. Hazardous incidences identified include the dying of reed beds that would result in a reduction in the treatment of the stormwater and improper operation of the system resulting in an insufficient holding time. Insufficient treatment may occur if the influent water contains unacceptably high levels of contamination. There is also for potential for treatment efficacy to change with time as organic material and other constituents accumulate in the base of the cleansing reed bed. Additional hazards may result from system failure such as equipment or material breakdown e.g. in pond lining, transfer pumping or pipe leakage. All of these hazards are considered unlikely to occur, but if they did, potentially they may lead to significant impacts.

### **3.6.5 ASTR Hazard Analysis**

Potential hazards include excessive mixing of the injected stormwater with the ambient groundwater, resulting in a salt or metal concentration that exceeds the target value when the water is recovered and/or geochemical reactions that lead to non-compliance with ADWG (2004). Another potential hazard is the water not meeting the required residence time for removal of pathogens in recovered water. If this is found to be the case, then a disinfection step should be integrated prior to the water being used for drinking purposes. A summary of these risks for the ASTR system is given in Table 8. All of these hazards are considered unlikely to occur, though with significant impacts if any did occur. Further data is needed to more reliably assess the potential incidence and impact of these and other hazards that may in future be identified.

### **3.6.6 Risk Assessment Schedule**

The list in Table 8 is not meant to be a definitive list of all possible hazards. It is instead a starting point in this preliminary plan. The HACCP team will have to systematically review these risks and assess others to compile a more comprehensive risk schedule.

**Table 8 Preliminary HACCP risk assessment schedule**

Hazard number	Hazard Type	Potentially Hazardous Event	Likelihood	Consequence	Risk Score	Barriers	Residual Risk Score
Catchment							
1	C	Chemical spill (road, plane or train)	1	5	High	None	High
2	C	Household chemicals, pesticides	2	2	Low	None	Low
3	P, C	Construction site spill, sediment	2	3	Moderate	None	Moderate
4	C	Pharmaceutical factory spill	2	5	Very High	Engineered spill protection	Moderate
5	C	Auto-parts store spill	2	3	Moderate	Response plans	Low
6	M	Sewer overflow or cross connection	2	3	Moderate	None	Moderate
7	P	Erosion	3	2	Moderate	None	Moderate
8	C, P, M, R	Sabotage	1	5	High	Site security measures	Low
9	C, M, P	Animal waste/ operations	3	2	Moderate	None	Moderate
Wetland							
10	P, C, M	High turbidity or TDS water entering system	3	2	Moderate	Standard operating procedures	Moderate
11	M	Contamination by birds	5	3	Very High	Bird nets	Moderate
12	C, P	Sabotage (e.g. fire in the wetlands)	1	5	High	Site security measures	Moderate
13	C, P	Reed-bed drying	2	5	Very High	Standard operating procedures	High
14	C, P	Improper operation	2	5	Very High	Standard operating procedures	High
15	C, P	System failure (e.g. leakage)	1	5	High	Standard operating procedures	Moderate
16	P	Short circuiting or high turbidity pulse leaving the reed bed.	3	2	Moderate	Standard operating procedures	Low
ASTR							
17	C, P	Excessive mixing with native groundwater	2	4	Very High	None	High
18	M	Short circuiting	2	4	High	None	High

C, Chemical; M, Microbiological; P, Physical; R, Radiological.

### 3.7 Identification of critical control points

A critical control point (CCP) is defined as a step at which control can be applied and is essential to prevent or eliminate a hazard or reduce it to an acceptable level. Examples of CCP's include treatment and disinfection systems. CCP's must be carefully developed and documented. The decision making methodology used to determine if a point, step or procedure is a CCP utilises the Codex (1999) decision tree shown in Figure 8.

#### CODEX Decision Tree to Identify CCPs

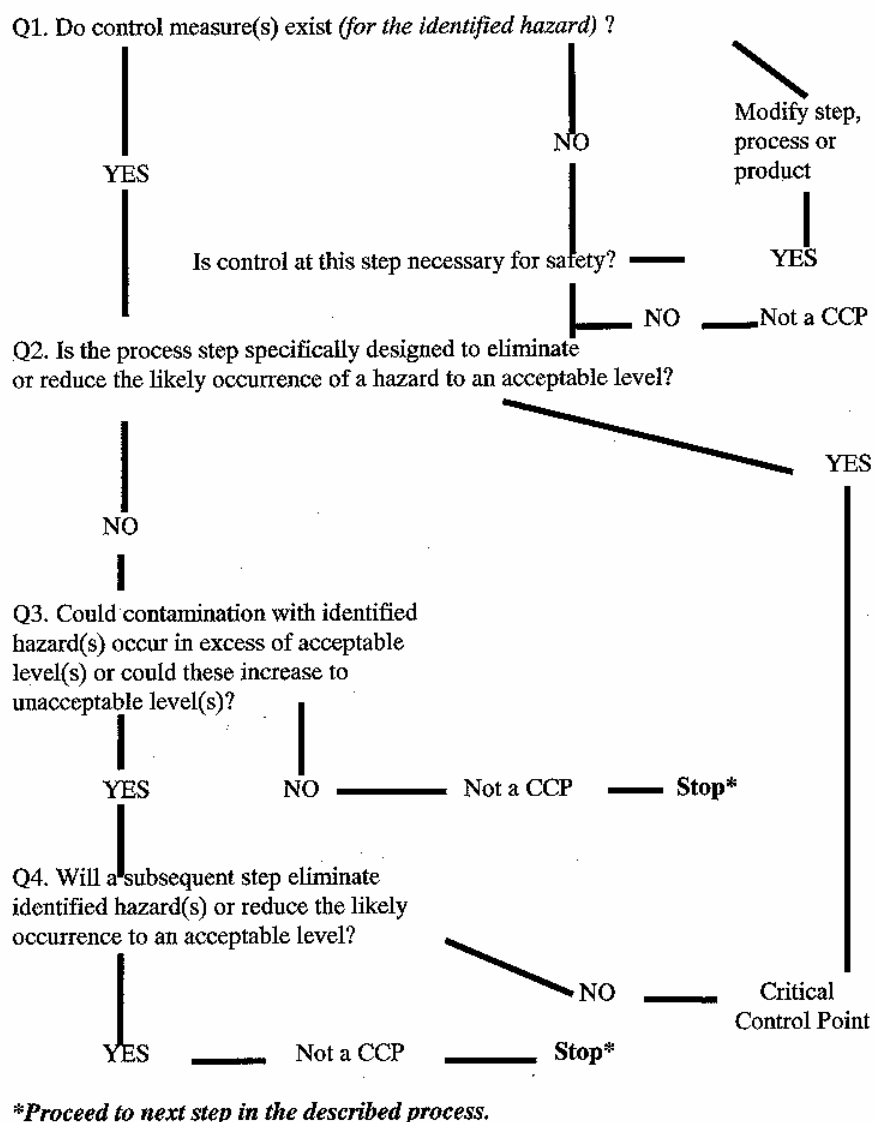


Figure 8 Codex (1999) decision tree to identify CCP's

Each CCP should be examined in detail to identify the following requirements:

- Monitoring requirements necessary to track adherence to target or exceedence of action critical limits;
- Corrective actions/responses taken in the event of action critical limits being exceeded; and
- Provision and storage of records forming evidence of adherence to procedures, collection of data/information, adherence to target or exceedence of critical limits.

In some cases, a step whilst import in managing risk, can not technically be considered a CCP as it was not practical to monitor to enable prompt corrective action. Instead the step was considered to be either a quality control point (QCP) or a supporting program (SP). A good example of such a QCP is the monitoring of *E. coli* in the in-stream basin. Typically several days are required for laboratory processing and results to be received. While this step cannot be used to operationally manage the system, the QCP is still very valuable in demonstrating that the wetland barrier is working effectively. Similarly, the catchment / stormwater pollution management program (employed by the City of Salisbury Council and the Northern Adelaide Barossa Catchment Water Management Board) is a good example of a supporting program. The catchment management / stormwater quality program can be also assigned target and action performance limits such as the EPA licensing of business and compliance reporting. Such SP's can also act as barrier to risk and thereby lend themselves to treating hazardous events or threats that can occur at more than one step in the process and the occurrence of which cannot be predicted by conventional monitoring (this then also results in a lower residual risk).

The decision tree was applied to all risks in Table 8 even those where the risk factor was determined to be low. In the following section SP/CCP/QCP's for each of the three system conceptual parts are discussed and then summarised in Table 9

### 3.7.1 Catchment – CCP's

Barriers that reduce the risk of hazardous materials entering into stormwater include SP's such as adherence to industry codes of practices for waste management, EPA licensing and education programs. Below are SP practices or physical structures that can be considered as barriers refer to Appendix 2 for a more detailed description of the catchment hazards:

- Pollution control program conducted by the NABWCMB and the City of Salisbury Council.
- EPA licensing for major industry waste disposal.
- Emergency response planning for chemical spills arising from industrial and vehicle transport accidents by the City of Salisbury Council, State Emergency Service (SES), Salisbury Country Fire Service (CFS) with SA-EPA involvement. Planning includes actions and mechanisms for rapid isolation of hazardous materials and restriction of discharge to stormwater drains.
- Adherence by industry to industrial codes of practice for operations including chemical handling and storage, where they exist.
- A council or state authority managed industrial chemical waste disposal facility and program in addition to EPA trade waste licensing for discharge to sewer, and light-medium industry self-administered procedures for chemical disposal.
- Civil engineered barriers (with defined capacities) for the isolation of hazards from liquid flow-paths to stormwater drains during normal industrial operations and accidental spills. These are part of industrial planning permits for particular industries and operations.

- State authority and/or self imposed restrictions on domestic water use activities that could cause water with contaminants (e.g. detergents, fertilizers, automotive oils, fuels) to flow to stormwater drains, such as: the washing of cars, pathways and roads, excessive watering of gardens (as part of potable water conservation practices).
- Education program for the awareness of the value, current and intended use of stormwater, the risks of contaminants from urban activities to stormwater and the general environment, and actions that minimize the risks to stormwater quality from urban activities.
- For individual industries and businesses, site specific critical controls should be identified as existing or to be developed. This could then be part of an inventory for a council-based pollution control program and self-organizational control. These will be most relevant to the individual organization for hazard control. Identification of these as part of pollution prevention programs will also assist emergency response organizations in their response planning.

As such, no actual CCP's were identified within the catchment. However it is incorrect to assume that SP's are any less effective in reducing risks, more to the point it is difficult to use SP's to manage a system in real time, and primarily for this reason they are not deemed CCP's.

### **3.7.2 Parafield Wetlands – CCP's**

The Parafield wetlands comprise three ponds (in-stream basin, holding storage and cleansing reedbed) and in the main drainage line there is the diversion weir pool. The diversion weir in the Parafield drain is directly connected to the In-stream basin by seven 1050mm diameter open concrete pipes without any gates or other closures. Therefore there is no hydraulic barrier between the drain and the in-stream basin.

Water can be pumped from both the in-stream basin and the cleansing reedbed back into the drain downstream of the weir. The holding storage can be drained by gravity into the drain downstream of the weir. The current ASR extraction well water can be pumped into the In-stream basin which can then be pumped into the drain. Water can also be pumped from the cleansing reedbed back to the holding storage if re-treatment is required. There is a 300 mm by-pass pipe with a valve through the base of the weir to by-pass any un-wanted low flows in the drain.

The wetlands system and the supply of water to it can be considered as barriers to the transport of contaminants that could otherwise reach the ASTR injection wells.

For example, the in-stream basin and holding storage are structural barriers that have a capacity to retain water of unsuitable quality for ASR or ASTR. Further it is likely that these ponds allow for contaminant removal mechanisms such as volatilization, adsorption to sediments and potentially some microbial degradation. The cleansing reedbed is a recognized treatment process where concentrations of potential pollutants are reduced. The Parafield wetland system comprises a number of control points. These being the ability to:

- Pump water from the in-stream basin to the drain downstream of the weir pool.
- Drain water from the cleansing reedbed to the in-stream basin.
- Drain the holding storage by gravity back to the in-stream basin.

These water transport control mechanisms can be activated where the water quality is determined to be unsatisfactory for treatment by the wetlands or for ASR/ASTR or for use of water of drinking water quality. Monitoring of water quality of the wetlands is needed to determine the trigger values for action of these CCP's.

### **3.7.3 ASTR – CCP's**

The CCP controlling water into the ASTR component is at a water quality monitoring point on the pipe between the red-bed pond and the ASTR system. Continuous water quality recording with programmable logic control of a flow valve would help prevent poor quality water entering the aquifer. A CCP based on monitoring of recovered water is also warranted to ensure that the quality of the water complies with its intended uses.

Monitoring of observation wells between injection and recovery wells would also allow early warning of the potential for recovered water to fail to meet its required water quality specifications and instigate recovery back to the stormwater drains. Such a monitoring well may be designated as a CCP in future revisions of this preliminary HACCP plan.

Table 9 gives a summary of the CCP derivation for the preliminary HACCP plan utilising the Codex (1999) decision tree (Figure 8) based on the risks identified in Table 8.



**Table 9 CCP, QCP and SP derivation summary**

Hazard Number (refer Table 8)	Hazard Type	CCP Decision Tree (refer Figure 8)				CCP / QCP / SP - details
Catchment		1	2	3	4	
1	C	Y	N	Y	n.d.	SP#1 – stormwater and catchment pollution management program.
2	C	Y	N	Y	n.d.	SP#1 - stormwater and catchment pollution management program.
3	C, P	Y	N	Y	n.d.	QCP#1 – water quality monitoring station upstream of the diversion weir.
4	C	Y	N	Y	n.d.	SP#1 - - stormwater and catchment pollution management program.
5	C	Y	N	Y	n.d.	SP#1 - - stormwater and catchment pollution management program.
6	M	Y	N	Y	n.d.	SP#2 - - sewer leak detection and repair program.
7	P	Y	N	Y	n.d.	QCP#1 – water quality monitoring station upstream of the diversion weir.
8	C, M,P, R	Y	N	Y	n.d.	SP#3 – site security.
9	C, M, P	Y	N	Y	n.d.	SP#1 - - stormwater and catchment pollution management program.
<b>Wetland</b>						
10	C, M, P					QCP#2 – SCADA linked DSS
11	M	Y	N	Y	n.d.	SP#4 – maintenance program.
12	C, P	Y	N	Y	n.d.	SP#3 – site security.
13	C, P	Y	N	Y	n.d.	SP#4 - maintenance program.
14	C, P	Y	N	Y	n.d.	SP#5 – standard operating procedures and staff training.
15	C, P	Y	N	Y	n.d.	SP#5 – standard operating procedures and staff training.
16	C, P, M	Y	Y	n.d.	n.d.	CCP#1 - SCADA linked DSS
<b>ASTR</b>						
17	C, P	N	Y	n.d.	n.d.	n.d.
18	M	N	Y	n.d.	n.d.	n.d.

C, chemical; P, physical, M, microbiological, R, radiological, n.d. not determined.

Analysis of the system indicates that a CCP is required after extraction of the water from the ASTR well to ensure that it is of potable quality. This is especially important in regard to microbial contaminants.

### 3.8 Establishment of critical limits

A critical limit is a maximum and/or minimum value to which a radiological, biological, chemical or physical parameter must be controlled at a CCP to prevent, eliminate or reduce to an acceptable level the occurrence or consequence of a hazard. A critical limit is used to distinguish between safe and unsafe operating conditions at a CCP. Establishment of these critical limits is vital in ensuring the quality of the finished product. Table 10 gives a brief summary of the currently available critical limits for the ASTR project.

CCP / QCP/ SP	Critical Limits		Monitoring	Reference	Corrective Procedure
	Target	Action			
QCP#1- Upstream water quality monitoring station.	Water turbidity and conductivity	Water turbidity and conductivity	On-line monitoring turbidity & conductivity of raw water and data monitored via SCADA system can be linked to DSS	None	None.
QCP#2 – water quality monitoring station at the in- stream basin.	Water turbidity < 10 NTU	Water turbidity ≥ 100 NTU	On-line monitoring turbidity & conductivity of raw water and data monitored via SCADA system can be linked to DSS.	Agreement with Department of Health on turbidity limit, AWDG (2004) conductivity guideline.	Rostered duty officer(s) to divert water back to the stormwater system downstream of the weir.
	Water conductivity > 500 µS/cm.	Water conductivity > 1000 µS/cm.			
CCP#1 - Cleansing reed bed water quality monitoring station.	Water turbidity and conductivity	Water turbidity and conductivity	On-line monitoring turbidity & conductivity of water and data monitored via SCADA system can be linked to DSS	None	Rostered duty officer(s) to divert water back to the stormwater system downstream of the weir.

Table 11 gives suggested additional CCP's, critical limits and monitoring protocols that could be established in future HACCP plans.

**Table 10 CCP and QCP critical limits for the current system**

CCP / QCP/ SP	Critical Limits		Monitoring	Reference	Corrective Procedure	Records	Action Schedule
	Target	Action					
SP#1 – Catchment and stormwater management.	All businesses in the catchment comply with best practices and EPA licensing requirements.	Issues of non-compliance or best practices not used.	Regular auditing as part of the pollution control program, education and awareness campaigns.	EPA licensing and pollution control program, NABWCMB pollution control program.	Engage businesses to comply with stormwater best practice program.	Records maintained by EPA and Salisbury City Council.	Regular audit of catchment and businesses.
SP#2 – sewer leak detection and repair program.	No sewer leaks in the Parafield catchment.	Sewer leaks detected in the Parafield catchment.	Regular monitoring as part of SA Water's sewer rehabilitation program.	SA Water sewer rehabilitation program.	Rehabilitate sewers / sewer lining.	Records maintained by SA Water.	Regular sewer rehabilitation as part of SA Water asset management program.
SP#3 – site security.	No security breaches.	Detected security breach.	Monitoring by security contractor.	Salisbury City Council security policy.	Case by case for each security breach, involve SA police.	Records maintained by SA police and security contractor.	Regular security audit, appropriate signage.
SP#4 – maintenance program.	No unscheduled maintenance.	Infrastructure or system failure.	Salisbury City Council maintenance program.	Salisbury City Council maintenance policy.	Maintenance as required.	Salisbury City Council maintenance policy.	Routine inspection of infrastructure, asset management plan.
SP#5 – standard operating procedures.	All systems operated correctly.	Incorrect operation.	Salisbury City Council SOP's.	Salisbury City Council SOP's.	Staff training and SOP development/ review.	Salisbury City Council records.	Regular staff training and SOP review.

CCP / QCP/ SP	Critical Limits		Monitoring	Reference	Corrective Procedure	Records	Action Schedule
	Target	Action					
QCP#1- Upstream water quality monitoring station.	Water turbidity and conductivity	Water turbidity and conductivity	On-line monitoring turbidity & conductivity of raw water and data monitored via SCADA system can be linked to DSS	None	None.	SCADA system, linked to DSS.	Establish target and action critical limits.
QCP#2 – water quality monitoring station at the in- stream basin.	Water turbidity < 10 NTU	Water turbidity ≥ 100 NTU	On-line monitoring turbidity & conductivity of raw water and data monitored via SCADA system can be linked to DSS.	Agreement with Department of Health on turbidity limit, AWDG (2004) conductivity guideline.	Rostered duty officer(s) to divert water back to the stormwater system downstream of the weir.	SCADA system, linked to DSS.	Review target limit.
	Water conductivity > 500 µS/cm.	Water conductivity > 1000 µS/cm.					
CCP#1 - Cleansing reed bed water quality monitoring station.	Water turbidity and conductivity	Water turbidity and conductivity	On-line monitoring turbidity & conductivity of water and data monitored via SCADA system can be linked to DSS	None	Rostered duty officer(s) to divert water back to the stormwater system downstream of the weir.	SCADA system, linked to DSS.	Establish target and action critical limits.

**Table 11 Proposed CCP and QCP critical limits for future HACCP plans**

CCP / QCP/ SP	Critical Limits		Monitoring	Reference	Corrective Procedure	Records	Action Schedule
	Target	Action					
CCP#2 – ASTR monitoring wells water quality monitoring station.	Water turbidity < 5 NTU	Water turbidity ≥ 100 NTU	On-line monitoring turbidity, conductivity, pH, regular testing for pesticides and chemicals and data monitored via SCADA system linked to DSS	AWDG (2004) and Mawson Lakes third pipe water quality guidelines, consideration for water quality of industrial users.	SCADA system linked to DSS diverts water from the recovery well back to drain below the weir.	SCADA system, linked to DSS.	Develop SCADA and DSS. Install on-line monitoring equipment and analyser. Sampling program to investigate pollutant loads and functioning of ASTR system.
	TDS < 100 mg/L	TDS > 300 mg/L.					
	6.5 > pH < 9.5	6.5 > pH < 9.5					
	Detection of pesticides or chemicals.	Detection of pesticides or chemicals above the ADWG (2004)					
CCP#3 – ASTR recovery well water quality monitoring station.	Water turbidity < 5 NTU	Water turbidity ≥ 100 NTU	On-line monitoring turbidity, conductivity, pH and Cl <sub>2</sub> residual and data monitored via SCADA system linked to DSS	AWDG (2004) and Mawson Lakes third pipe water quality guidelines, consideration for water quality of industrial users.	SCADA system linked to DSS diverts water from the recovery well back to drain below the weir.	SCADA system, linked to DSS.	Develop SCADA and DSS. Install chlorine injection and analyser. Sampling program to investigate pollutant loads and functioning of ASTR system.
	TDS < 100 mg/L	TDS > 300 mg/L.					
	6.5 > pH < 9.5	6.5 > pH < 9.5					
	Cl <sub>2</sub> residual > 0.5 mg/L	Cl <sub>2</sub> residual < 0.2 mg/L					

### 3.9 Establish monitoring procedures

Monitoring is a planned sequence of observations or measurements to assess whether a step is under control and to produce an accurate record for future use in verification.

Monitoring serves three main purposes:

- First, monitoring is essential to water quality management in that it facilitates tracking of the operation. If monitoring indicates that there is a trend towards loss of control, then action can be taken to bring the process back into control before a deviation from a critical limit occurs.
- Second, monitoring is used to determine when there is a loss of control and a deviation occurs at a CCP. When a deviation occurs, an appropriate corrective action must be taken.
- Third, it provides written documentation for use in verification.

Ideally, monitoring should be continuous, which is possible with some types of physical and chemical methods (e.g. turbidity or pH levels). Most monitoring procedures need to be rapid because they relate to on-line "real time" processes and there will be no time for lengthy analytical testing. Personnel who are responsible for the monitoring process are often associated with production. They must be trained in the monitoring technique for which they are responsible, fully understand the purpose and importance of monitoring, be unbiased in monitoring and reporting, and accurately report the results of the monitoring.

In addition to on-line monitoring, completion of a comprehensive HACCP plan for the ASTR project will require a detailed understanding of the processes involved in hazardous material releases, fate, and control within the catchment. As part of attaining this understanding, it is recommended that a literature review of studies on stormwater quality of urban and industrial zones and hazard reduction be conducted.

In addition, water quality data from the various stormwater catchment sources and throughout the season need to be determined to assess pollutant inputs to stormwater. These should be obtained in relation to known accidental spills, first autumn rains and usual stormwater flows throughout the various seasons and in relation to variability of flow rate. The stormwater quality range needs to be established in relation to the treatment capabilities of the wetlands and ASTR for removal of pollutants to achieve potable water quality. To date, a series of stormwater grab samples have been analysed for a suite of organic and inorganic analytes (Appendix A). However, in order to better assess the water quality compared with that from grab sampling alone, flow trigger autosamplers, in-stream - pollutant absorbing samplers and biological indicators might also be used.

The hydrology of stormwater flow needs to be better understood including the relationship between the intensity and magnitude of specific storm events and the volume of water generated by the catchment and capturable by the stormwater harvesting system. This includes building upon the yield assessment detailed by Richard Clark and Associates using the WaterCress Model (2001). Using this model surface runoff is estimated from rainfall, type of surface and area and the runoff co-efficient for different area (zone) types e.g. heavy industry, residential and natural. Similarly, surface water flow can be modelled using the Rational equation (Linsley *et al.* 1992), which incorporates surface area and gradient with the magnitude of a rainfall event. For permeable surfaces, infiltration rates will need to be determined. This method will support modelling of specific flow volumes through certain areas and helping to determine loading factors for specific contaminants from various industrial and other areas. Finally, contaminant attenuation will occur in the Parafield Drain as a result of dilution with lateral inflow mixing waters, longitudinal dispersion along the flowpath, volatilization to the atmosphere through the turbulent flow process, and potentially

from sorption processes. Some chemicals may absorb to other organic matter and inorganic particulate material such as clay and iron oxides under specific conditions.

### **3.9.1 Catchment Monitoring Requirements**

The following specific sampling activities are proposed for the ASTR project. The aim is to provide sufficient data for better knowledge of the transport and fate of stormwater pollutants over a wide range of stormwater flow conditions and treatment efficiencies of the wetlands. This would also support modelling developments by provision of calibration data.

A detailed set of flow measurements should be made in conjunction with rainfall measurements throughout storm events. The goal is to obtain sufficient data to construct detailed stream flow hydrographs which depict the relationship between rainfall duration and magnitude, and associated changes in the flow system. This assessment should be coupled with a sampling program to assess water quality, as described below.

The water quality sampling program needs to include both a storm event sub-program and another to assess the average quality of inflows in relation to the various seasons at the Parafield Drain. The sampling program may include both grab and auto-set (time and volume) samples dependant data requirements. The water quality data should be sufficient to determine the magnitude of the “first-flush” effect on stormwater from the catchment. Additional sampling can determine the contaminants present in stormwater under normal conditions (without a major spill present).

Stormwater quality data should be determined for water in stormwater drains that are closely associated to the various industries (based on type and size) and urban areas. The transport (and fate) of any identified contaminants can be determined with subsequent measurements in drainage lines leading to and in the wetlands. Initial data collection should be to determine the range of contaminants present in stormwater sources. Subsequently, analyses may be more targeted to those contaminants that are found to be significant in relation to the provision of water for potable use.

### **3.9.2 Wetland Monitoring Requirements**

While some data enables current average treatment efficiency to be estimated (Appendix 1) it is recognized that this is inadequate to reliably forecast removal efficiency in future, and understand seasonal variations and consequences of accumulation of contaminants in pond sediment in the longer term. The application of the Parafield Wetlands for treatment of stormwater requires determination of the efficiencies of each compartment of the system for adequate removal of contaminants (physical, chemical and biological). These efficiencies need to be assessed in context of the systems configuration, its operation and maintenance and these should be documented.

The wetland system should be described in detail including its hydrology, physical condition (e.g. depth, sediment type and loading) vegetation development and maintenance, water quality profile throughout the ponds and seasonal cycles. Water quality needs to be documented together with the specific conditions of the wetlands at the time of sample collection. This should enable the establishment of relationships between the treated and influent water quality and relate treatment efficiencies to the characteristics of the wetland. By doing so and with a suitably sized data base, site specific models could be developed that enable prediction of treated water quality. Various approaches could be attempted from those based on physico-chemical characteristics of contaminants, site-specific empirical models, mechanistic models or artificial neural networks where there is an extensive database established. For example, the OTIS model has been used for evaluating wetlands (Appendix 3) including the assessment of hydraulics with transient storage (Martinez and Wise, 2003) and VOC reduction by Keefe *et al.* (2004).



The following studies are proposed to meet the technical data needs identified above, and to support calibration of models.

- Detailed flow measurements should be collected, together with determination of holding times and evaporative losses. This information will be used to determine the relationships between the flow rates and treatment efficiencies, and will be needed for modelling purposes.
- Data on the potential contaminants of concern should be collected for the three ponds of the wetlands system and the sampling program should correspond with flow rates and seasonal variations. Effluent samples should be taken at mean residence time after collecting influent samples. The final database should be sufficient for statistically significant analyses that can be used for modelling treatment efficiency. Further field and laboratory studies on contaminant attenuation may provide degradation constants that can be incorporated into models of the system.
- Sediments in the in-stream basin, holding storage and cleansing reedbed should also be studied to determine the fate of any contaminants and potential for remobilization from the sediments. This may be an issue in the economic assessment of operation and maintenance of the system.

### 3.9.3 ASTR System Monitoring Requirements

The site specific hydro-geological properties such as stratigraphy, hydraulic conductivity, effective porosity and hydraulic gradient, taking account of interference effects with Parafield ASR injection and recovery operations, should be determined to confirm or refine ground water modelling simulations conducted for ASTR development. The lithological and chemical properties of the aquifer should be determined by coring and geophysical logging and should include mineralogy, clay content and type, total organic carbon concentration and distribution through the thickness of the T2 aquifer. Downhole velocity meter logging is strongly recommended to identify zones of high permeability and assist with a priori evaluation of the residence time and potential for mixing with native groundwater. The flowpath travel times within the aquifer system should be determined to ensure the required aquifer residence times are attained. Tracer techniques should be applied to validate estimated residence times.

The geochemistry of the system should be determined for modelling of the reactions of injected water with ambient ground water. The chemical properties of groundwater in the injected plume should be determined by monitoring the mixing with injected water, and to ensure that contaminants are not present that may adversely impact the recovered water. This should account for changes in the redox status of the aquifer and consequent metal mobility and contaminant biodegradation rates. Pathogens within anaerobic aquifer conditions are attenuated with residence time. Microbial activity may destroy pathogens and degrade organic contaminants. Studies have been conducted on the degradation of organic chemicals under both anaerobic and aerobic conditions (Aronson and Howard, 1997; Aronson *et al.*, 1998, Toze, 2001, Pavelic *et al.* 2005; Dillon *et al.* 2005).

The degradation of chemicals and the destruction of pathogens within the aquifer system can be modelled as a first order decay process (Miller *et al.*, 2002). CSIRO has developed a model that evaluates degradation rates based on aquifer characteristics and contaminant properties. The model, 'Aquifer Storage and Recovery Risk Index (ASRRI)' (Miller *et al.* 2002) uses a simple spreadsheet to predict contaminant attenuation using exponential degradation rates and compares this with drinking water guideline values (ADWG) or USEPA. For the ASTR system, sorption is not considered except in allowing more time for biodegradation, since the aquifer is assumed to have a finite capacity to sorb contaminants and the model only takes account of sustainable removal processes. The output from a

series of ASRRI example runs for benzene, toluene, ethylbenzene, and xylene, as representative contaminants from a petrol spill are given in Appendix 3.

Generally, attenuation rates are determined where there has been prior exposure to a contaminant and therefore some adaption of the microbial community which pre-disposes it to a capability to assimilate the contaminant. Loadings of a previously undetected contaminant may result in initially slower biodegradation rates (Sandrin *et al.* 2001).

Wells comprising ASTR will include those for monitoring to assess the performance of the overall system. This will enable sample collection as injectant water travels from injection to recovery wells. The rate of water quality improvement can be assessed from water quality data of samples collected from monitoring wells. Hence based on modelled information and expected travel times of injected water and storage, sampling and analyses will provide information on the progressive improvement in water quality changes. Notionally a three month sampling interval is practical and allows for analysis and reporting in time to give early warning of potential water quality problems in recovery wells. Higher sampling frequencies may be required in the commissioning stage of the project to validate system understanding.

Future development of observation wells in the vicinity of the injection wells will be able to provide additional information and their monitoring will need to be incorporated into later revisions of this preliminary HACCP plan.

### **3.10 Establishment of corrective procedures**

Establishment of appropriate corrective procedures as a response to deviations from CCP target and action limits is fundamental in establishing a comprehensive HACCP plan. Corrective procedures can be partially automated by linking on-line water quality monitoring via SCADA systems and an appropriately configured DSS. The corrective actions are to ensure that:

- The cause of the deviation is identified and eliminated.
- The CCP will be under control after the corrective action is taken.
- Measures to prevent recurrence are established.
- No product that is injurious to health or otherwise adulterated as a result of the deviation is distributed to users.

The corrective actions may be included in forms that are created to address:

- The cause of the deviation so that it can be identified and eliminated.
- The CCP so it will be under control after the corrective action is taken.
- The establishment of appropriate measures so that a recurrence may be avoided.
- The affected product so that no water that does not meet the specifications as a result of the deviation is allowed to reach consumers.

Table 10 gives examples of possible corrective actions that can be implemented to the currently identified CCP's and QCP's. These will need to be rigorously reviewed in light of operating constraints to ensure a HACCP plan is developed that balances risks with efficient operating protocols.

### 3.11 Validation / verification of the HACCP plan

Verification is defined as those activities, other than monitoring, that determine the validity of the HACCP plan and that the system is operating according to the plan. One aspect of verification is evaluating whether the ASTR project is functioning according to the HACCP plan. An effective HACCP plan requires minimal end product testing, since sufficient validated safeguards are built in early in the process. Therefore, rather than relying on end product testing, the ASTR project should rely on frequent reviews of its HACCP plan, verification that the plan is being correctly followed, and review of CCP monitoring and corrective action records. Another important aspect of verification is the initial validation of the HACCP plan to determine that the plan is scientifically and technically sound, that all hazards have been identified and that if the HACCP plan is properly implemented these hazards will be effectively controlled.

Information needed for validation of the HACCP plan often include expert advice and scientific studies and system observations, measurements, and evaluations. In addition, a periodic comprehensive verification of the HACCP system should be conducted ideally by an unbiased independent authority. Verification activities are carried out by competent individuals, third party experts, and regulatory agencies. It is important that the individuals doing verification have appropriate technical expertise to perform this function and auditing skills. Some benefits that the ASTR project can derive from verification include: assurance that all CCP's are identified, assurance that the plan is being followed, a mechanism for third party to assess the program, a means of measuring the success of the HACCP plan, and a source of information on trends in the frequency and reasons for deviations from critical limits. Typical verification activities with their frequency in the HACCP plan include:

- Overall verification. The HACCP team will need to verify that the HACCP plan is adequate to control product safety hazards that are reasonably likely to occur, and that the plan is being effectively implemented. Verification includes:
  - Reassessment of the HACCP plan. A reassessment of the adequacy of the HACCP plan whenever any changes occur that could affect the hazard analysis or alter the HACCP plan in any way or at least annually. Such changes may include changes in the following: raw stormwater source, processing methods or systems, finished product distribution systems, or the intended use or consumers of the finished product. The HACCP plan should be modified immediately whenever a reassessment reveals that the plan is no longer adequate to fully meet its requirements.
- Ongoing verification activities. These include:
  - A review of any consumer complaints that have been received to determine whether they relate to the performance of CCP's or reveal the existence of unidentified CCP's;
  - The calibration of on-line process-monitoring instruments.
- As determined by the HACCP team, performance of periodic end-product or in-process testing:
  - Records review, including signing and dating, by an individual who has responsibility for review and operation of the HACCP plan.
  - The monitoring of CCP's, to ensure that the records are complete and to verify that documented values that are within the critical limits;
  - The taking of corrective actions, to ensure that the records are complete and to verify that appropriate corrective actions were taken in accordance with the HACCP plan have been implemented;

- The calibrating of any on-line monitoring equipment used at CCP's and the performing of any periodic end-product or in-process testing that are part of the verification activities. The purpose of these reviews is to ensure that the records are complete, and that these activities occurred in accordance with the written procedures. These reviews need to occur within a reasonable time after the records are made.
- Reassessment of the hazard analysis by the HACCP team whenever there are any changes that could reasonably affect water safety and at least annually. Such changes may include, but are not limited to changes in: raw materials or source of raw materials, product formulation, processing methods or systems, finished product distribution systems, or the intended use or consumers of the finished product.
- Recordkeeping, including calibration of process-monitoring instruments, and the performing of any periodic end-product and in-process testing.

### **3.12 Establishment of documentation and record keeping**

Generally, the records maintained for the ASTR project should include the following:

- A summary of the hazard analysis, including the rationale for determining hazards and control measures.
- The HACCP Plan:
  - Listing of the HACCP team and assigned responsibilities
  - Description of the product, its distribution, intended use and consumer
  - Verified flow diagram
- HACCP plan summary that includes information for:
  - Steps in the process that are CCP's
  - The hazard(s) of concern
  - Critical limits
  - Monitoring
  - Corrective actions
  - Verification procedures and schedule
  - Record keeping procedures
- Support documentation such as validation records.
- Records that are generated during the operation of the HACCP plan.

The records generated will need to be reviewed at least on an annual basis in conjunction with the review of the HACCP plan. They will provide valuable inputs for review of the HACCP plan and are essential for audits, either internal or by an external third party.

## 4 DISCUSSION ON THE IMPLEMENTATION OF THE HACCP PLAN

### 4.1 Preliminary assessment of risk.

The ASTR Project is the first intentional attempt for storage of stormwater and its treatment in an aquifer with the aim of achieving water of potable quality, although this has occurred for more than 100 years unintentionally in Mt Gambier with recovery in Blue Lake (Vanderzalm *et al.* 2004). The success of the project relies on the water quality consistently meeting the ADWG (2004), and community and government acceptance of ASTR for potable water supply.

Available data of water quality from the Parafield Drain and after passing through the wetlands indicate similarities to the water quality of a Murray River source used for Adelaide drinking water supply. A comparison of water quality from the River Murray at Murray Bridge, Parafield Drain, Cleansing reedbed outlet and the T2 aquifer natural groundwater and ADWG (2004) values is shown in Appendix 1.

It should be noted that the number of analytes in this table is not exhaustive and the number of samples relating to the ASTR project is small. However, it is evident that for all analytes, the wetland-treated stormwater has neither higher concentrations nor coliform numbers than the River Murray at Murray Bridge. For the samples collected the salinity and turbidity of the stormwater was of higher quality than of Murray River water.

It is evident that the salinity of the native groundwater is an issue and unless recovered water contains less than 10% native groundwater it will not meet the 300 mg/L TDS target for recovered water. Similarly, arsenic, boron and iron were recorded to be higher than the ADWG (2004) values for a single grab sample. Further analyses are needed to determine how representative these values are for the T2 aquifer water. Based on the data available the required dilution of T2 aquifer water with cleansing reedbed treated stormwater to meet the salinity target for the recovered water should lead to arsenic, boron and iron meeting the ADWG (2004) levels, however a geochemical evaluation is required.

*E. coli* was found to be the only water quality parameter of the reed-bed outlet water that exceeded the ADWG (2004). *E. coli* measured in the River Murray source water also exceeded the guideline level. The T2 aquifer is expected to remove pathogens that pass through the wetland. Turbidity is also an issue for River Murray water but for the few samples available from the wetlands, it does not appear to pose a problem.

Finally, Appendix 1 data says little of the variability of the quality of Parafield and Murray waters, nor of the concentrations of trace organics. Data in Appendix 1 therefore should be treated in that context though the preliminary analysis did not detect any immediate problem in using wetland treated stormwater as a source water for ASTR to produce potable supplies. It also suggests a lack of information on trace organics in River Murray water as well as Parafield water.

The fate and transport of identified contaminants will need to be determined. Field chemistry data are required for modelling of specific processes with input variables representative of actual conditions. In an example using one modelling approach outlined in Appendix 3, benzene present at a concentration of 0.1 mg/L for 2 hours in the Parafield Drain 500 m from the intake weir will result in a maximum concentration of 0.026 mg/L being taken into the In-stream basin. Without allowing for further dilution, modelling of volatilization in the wetlands with an influent of 0.026 mg/L indicates that the effluent concentration may be 0.018 mg/L. Finally, injecting the aquifer with benzene at a concentration of 0.018 mg/L continuously may result in recovery of water with less than 0.001 mg/L into the potable mains, which is within

the ADWG (2004) value. This approach could be repeated for the range of compounds identified within the catchment for any release scenarios.

This example is based on literature values for degradation rates and volatilization and uses assumed situations in the drain, wetlands and aquifer which may differ from actual conditions. This suggests aquifer has a capacity to remove a continuous 18 µg/L benzene concentration in injected stormwater. This amounts to 12.3 L benzene in 600 ML annual injection. However, factors such as evading capture of free BTEX product by appropriate design of transfer pump intakes may significantly reduce the risk of contamination by free product that enters the In-stream basin. VOC sensors are also available to give real time detection of dissolved phase organics. Recently real time hydrocarbon sheen detectors have become commercially available. The example demonstrates both the vulnerability of this system and means by which risks of failure can be mitigated. Conventional water supply systems are not immune from such risks.

## **4.2 Knowledge gaps to be addressed.**

This report details a preliminary HACCP plan for the ASTR project. In this preliminary plan the knowledge gaps that need to be addressed for completion of a HACCP plan were identified. These are summarised below.

The hydrology of the stormwater system, with total available yield, needs to be determined to ensure that adequate water supply is available for the planned uses of water in the catchment. Once the ASTR system has begun operation to provide potable water, continued operation of the system is needed. Minimum, as yet unspecified annual injection volumes are required to ensure that the operating bubble of treated water is maintained around the wellheads and that excessive mixing with ambient ground water does not occur. The extent to which this may constrain the system is unknown.

A wider data base on stormwater quality is needed to determine contaminants present that may pose a threat to producing drinking water supplies. Other unknowns include the water quality variations arising from industrial activities in the catchment and seasonal impacts, treatment efficiency of the Parafield wetlands and whether the processes during aquifer storage and transfer can treat the range in water quality sourced from the wetlands.

A fate and transport model that includes a capability of handling major chemical spills within the catchment should be considered as part of a SP for the HACCP plan. The model should include input data on rainfall and stormwater flow. The output can be used to estimate time of travel within the drain system to the intake weir, and the contaminant concentrations in the stormwater and operationalise the emergency response plan. The procedures should be documented and provided to emergency service organizations. These response plans should minimize the risk of transfer of spilled contaminants into the stormwater drains, and include notification mechanisms to ASTR system operators to initiate the use of control measures at CCP's or corrective actions that may be necessary to ensure long-term continued operation of the system.

A GIS based system could be developed which details barriers to contamination, CCP's, various activity zones (such as industry, urban development, retail) roads and the stormwater drainage system. The GIS system can support emergency responses to chemical spills or accident by providing specific information on chemical type and storage locations, and the locations of the stormwater drain and surface drains. This task represents an ongoing effort that should be updated on a regular basis.

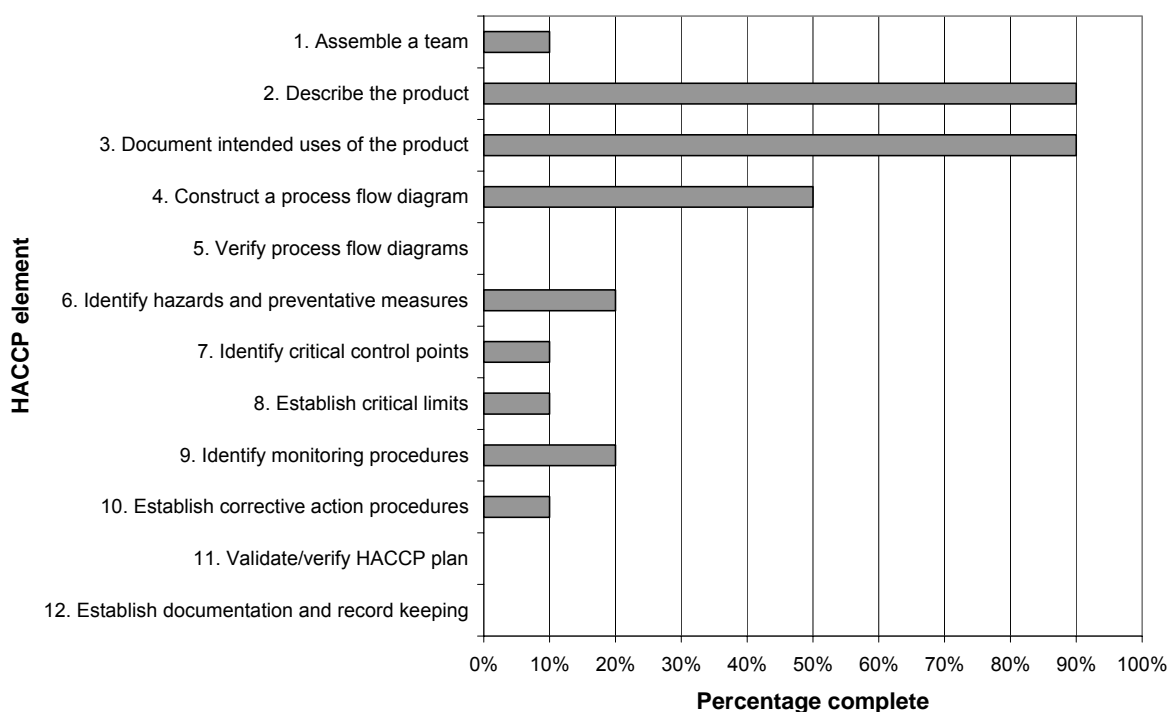
### 4.3 HACCP plan refinement.

The implementation of the HACCP plan will require a consensus from relevant stakeholders including state government departments such as health and environment protection agencies, City of Salisbury Council, SA Water, United Water International. An education/awareness program to ensure stakeholders and interested community members are suitably aware of the features of the ASTR relevant to them. These include:

- Reporting on compliance of industry with recommendations of stormwater pollution control officers and the SP's.
- Reporting on compliance of industry with requirements of EPA licenses.
- Reporting on engineering measures (e.g. grease/oil traps) and emergency response plans for preventing, containing and removing pollutants from entering or being conveyed in stormwater drains.
- Reporting on training of council staff, emergency service workers and others on the emergency response plans and the SP's.
- The ASTR project has provisioned for periodic revisions of the HACCP plan as more information emerges during system establishment and monitoring.

### 4.4 Conclusions

This report has described a preliminary HACCP plan for the ASTR project. The report has explicitly utilised the 12 elements of HACCP as outlined by the Codex in derivation of the HACCP plan. A summary of the progress of this preliminary HACCP plan in fulfilling those twelve elements, as currently assessed, is presented in Figure 9.



**Figure 9 Progress of the preliminary plan against the 12 HACCP elements.**

Identification of CCP's indicates that the ASTR project could be operated by HACCP principles with minimal modification. Addition of a CCP after the ASTR treated water is

recovered would increase the security of the system with respect to identified contaminants. Recommendations for future studies and monitoring programs are also presented.



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## GLOSSARY

**ADWG:**

An acronym for the Australian Drinking Water Guidelines.

**ANSI:**

An acronym for American National Standards Institute.

**ANZFA:**

An acronym for Australia New Zealand Food Authority.

**ANZIC:**

An acronym for Australia New Zealand Industrial Classification.

**ARMCANZ:**

An acronym for the Agriculture and Resource Management Council of Australia and New Zealand.

**ASR:**

An acronym for Aquifer Storage and Recovery.

**ASTR:**

An acronym for Aquifer Storage, Transfer and Recovery.

**ASRRI:**

An acronym for Aquifer Storage and Recovery Risk Index.

**Audit:**

A systematic comparison of a defined procedure with the actual process. In water safety terms a check on documentation and procedures whether the hazards have been identified and effectively controlled. An audit may be internal or external.

**BOD:**

An acronym for Biological Oxygen Demand.

**BTEX:**

An acronym for Benzene, Toluene, Ethylbenzene, Toluene.

COD:

An acronym for Chemical Oxygen Demand.

Codex Alimentarius:

Latin meaning “food code” or “food law”.

Codex Alimentarius Commission:

An organisation created in 1963 by FAO and WHO to develop food standards, guidelines and related texts such as codes of practice under the Joint FAO/WHO Food Standards Programme. The main purposes of this Programme are protecting health of the consumers and ensuring fair trade practices in the food trade, and promoting coordination of all food standards work undertaken by international governmental and non-governmental organizations. Australia is represented on the Commission. Shortened to Codex.

Control:

Verb – To take all necessary actions to ensure and maintain compliance with criteria established in the HACCP plan, Codex (1999).

Noun – The state wherein correct procedures are being followed and criteria being met, Codex (1999).

Control measure:

Any action and activity that can be used to prevent or eliminate a water safety hazard or reduce it to an acceptable level.

Corrective action:

Any action to be taken when results of monitoring at the CCP indicate a loss of control, Codex (1999).

Critical control point (CCP):

A point, step or procedure at which control can be applied and is essential to prevent or eliminate a water safety hazard or reduce it to an acceptable level.

Critical limit:

A criterion which separates acceptability from unacceptability, Codex (1999). Used for monitoring parameters associated with CCP's and QCP's.

Deviation:

Failure to meet a critical limit, Codex (1999).

DBP:

An acronym for disinfection by-product.

DO:

An acronym for dissolved oxygen.

Drinking water:

Potable water

DSS:

An acronym for decision support system. A tool or process for decision making.

FAO:

An acronym for the Food and Agriculture Organisation of the United Nations.

Flow chart/diagram:

A systematic representation of the sequence of steps or operations used in the harvesting, treatment or distribution of water.

HACCP:

An acronym for hazard analysis and critical control point. A system which identifies, evaluates and controls hazards which are significant for water safety.

HACCP plan:

A document prepared in accordance with the principles of HACCP to ensure control over hazards which are significant for water safety.

Hazard:

A biological, chemical, radiological or physical agent in, or condition of, water with the potential to cause and adverse health effect.

Hazard analysis:

The process of collecting and evaluating information on hazards and conditions leading to their presence to decide which are significant for water safety and therefore should be addressed in the HACCP plan.

Hazard characterisation:

The qualitative and/or quantitative evaluation of the nature of the adverse health effects associated with biological, chemical, radiological and physical agents which may be present in water.

Hazard identification:

The identification of biological, chemical, radiological and physical agents capable of causing adverse health effects and which may be present in water.

Incident:

An incident is any event or circumstance within our operation that causes or is likely to cause any of the following impacts: a) interruptions of services to water users; b) threat to our systems; c) threat to community health and safety; d) threat to the environment; e) threat to private or public property; or, f) creation of the need for urgent action under statute or legislation.

Initial Risk:

Risk in the absence of preventative strategies.

Monitor:

The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a CCP [or QCP] is under control, Codex (1999).

NACMCF:

An acronym for the National Advisory Committee on Microbiological Criteria for Foods.

NHMRC:

An acronym for the National Health and Medical Research Council.

Non-conformity:

The non-fulfilment of specified requirements, AS/NZS ISO 9000 (2000).

NRMMC:

An acronym for the Natural Resource Management Ministerial Council.

Performance limit:

A criterion which separates acceptability from unacceptability. Used for monitoring parameters associated with SP's.

pH:

A measure of the acidity or alkalinity of water.

Pollutant:

A hazard causing contamination and lowering the quality of water (or stormwater).

Pollution:



The contamination of water (or stormwater) causing lowering of quality.

Potable water:

Water that is safe to drink.

Process:

In relation to water, means activity conducted to harvest, store, treat, process, distribute or a combination of these activities.

Quality control point (QCP):

A point, step or procedure at which control can be applied and is essential to prevent or eliminate a water quality hazard not associated with water safety, or reduce it to an acceptable level, e.g. turbidity, colour etc...

Raw water:

Water that has not been treated in any way. It is generally considered unsafe to drink.

Risk:

The probability of a specified hazard causing harm; estimated in terms of consequences and likelihood, AS/NZS 4360 (1999).

Risk analysis:

A systematic use of available information to determine how often specified events may occur and the magnitude of their consequences, AS/NZS 4360 (1999).

Risk assessment:

The overall process of risk analysis and risk evaluation, AS/NZS 4360 (1999)

Risk communication:

The interactive exchange of information and opinions concerning risk among risk assessor, risk managers, consumers and other interested stakeholders.

Risk evaluation:

The process used to determine risk management priorities by comparing the level of risk against predetermined standards, target risk levels or other criteria, AS/NZS 4360 (1999).

Risk management:

The culture, processes and structures that are directed towards the effective management of potential opportunities and adverse effects, AS/NZS 4360 (1999).

Risk management process:

The systematic application of management policies, procedures and practices to the tasks of establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risk, AS/NZS 4360 (1999).

Residual Risk:

Risk can be assessed at two levels (1) maximum risk in the absence of preventive strategies; and (2) residual risk assuming that existing preventive strategies are operating effectively.

SCADA:

An acronym for Supervisory Control and Data Acquisition. A telemetry system that continuously monitors and down loads real time information from monitoring points throughout the water supply system.

SOP:

An acronym for standard operating procedure which is documented procedure for performing a particular task or activity. Such a procedure may include measures to reduce the risk of various types of hazards occurring including those to water quality, personnel, infrastructure, service reliability etc...

SP(HS) or SP(A):

An acronym for supporting program and identifying that the associated water quality hazard(s) was either a health/safety concern or an aesthetic concern. Supporting programs are defined as required foundation activities that ensure good water quality.

Step:

A point, procedure, operation or stage in the water production chain from catchment to tap. The included definitions of CCP and QCP recognise the Codex (1999) definition of step.

TDS:

An acronym for Total Dissolved Solids.

TOC:

An acronym for Total Organic Carbon.

Treated water:

Disinfected and/or filtered water served to water system water users. It must meet or surpass all potable water standards to be considered safe to drink.

TSS:

An acronym for Total Suspended Solids.

UCL:

An acronym for upper control limit.

Validation:

Obtaining evidence that the elements of the HACCP plan are effective, Codex (1999).

Verification:

The application of methods, procedures, tests and other evaluations, in addition to monitoring to determine compliance with the HACCP plan, Codex (1999).

VOC:

An acronym for volatile organic compounds.

WHO:

An acronym for the World Health Organisation.

## APPENDIX 1 WATER QUALITY DATA

PARAMETER	PARAFIELD DRAIN**					CLEANSING REEDBED***						RIVER MURRAY**	T2 AQUIFER	ADWG (2004)
Suite Taken	No. Samples	Max	Min	Mean	Median	No. Samples	Max	Min	Mean	Median	Percentage reduction (Mean)	Mean	Single sample	
General*														
Conductivity	15	1,250	182	483	457	13	352	149	207	191	57%	606	3,390	
TDS	15	690	100	265	250	12	190	82	113	100	57%	333		500
pH	15	8.8	6.9	7.8	7.70	13	7.2	6.2	6.9	7.0	11%			6.5-8.5
TSS	15	134	2.0	32	13	13	9	< 1	4.3	3.0	87%			
TOC	15	22.9	6.1	10.7	8.9	10	10.3	3.9	5.4	4.4	50%			
Turbidity	15	100	0.62	20	8.1	10	3.5	0.8	2.0	1.7	90%	58		5
Major ions														
Calcium	15	54.3	13.1	29.1	29.9	9	24.8	14.2	17.3	15.7	41%			
Magnesium	15	17.4	2.2	6.8	5.4	9	7.1	3.2	4.1	3.5	40%			
Potassium	12	14.4	2.3	6.2	5.1	8	3.2	1.4	2.1	2.1	66%			
Sodium	12	126	17.5	59.0	57.4	8	28.6	14.6	19.0	18.9	67%			180
Bicarbonate	12	156	43	85	83	8	69	51	60	59	30%			
Chloride	15	167	16	78	78	8	50	14	27	25	65%			250
Fluoride	12	0.91	0.20	0.52	0.55	8	0.80	0.10	0.26	0.20	51%			1.5
Sulphate	12	196	10.9	54.9	47.6	8	19.8	9.0	12.6	10.6	77%			250
Nutrients*														
Ammonia as N	12	2.6	< 0.005	0.28	0.033	9	0.014	< 0.005	0.01	0.013	96%			0.5
Phosphorus - Total P	15	0.546	0.030	0.140	0.067	11	0.029	0.014	0.020	0.024	83%	0.14		
TKN as Nitrogen	15	5.66	0.51	1.19	0.77	13	0.37	0.028	0.26	0.26	78%	0.86	0.16	
Total nitrogen as N	12	5.78	0.53	1.30	0.74	10	0.51	0.26	0.32	0.30	75%	0.12	0.01	10
Nitrate + Nitrite as N	15	0.454	< 0.005	0.14	0.095	11	0.034	< 0.005	0.02	0.021	84%			50
Microbiological														
<i>E. Coli</i> (cfu/100 mL)	8	14,000	1	1,822	83	11	91	7	39	29	98%	250		0
Metals*														
Aluminium	3	4.15	0.833	2.67	3.02	4	0.093	< 0.02	0.031	0.010	99%			0.2
Arsenic	15	0.006	< 0.001	0.0013	0.0005	10	0.006	< 0.001	0.0012	0.0005	10%		0.120	0.007
Boron									0.006				0.689	4
Cadmium	12	0.0011	< 0.0005	0.0003	0.00025	8	< 0.0005	< 0.0005	0.00025	0.00025	22%	0.0003	< 0.0005	0.002
Copper	15	0.014	0.005	0.008	0.008	12	0.004	< 0.001	0.002	0.002	72%	0.0105	< 0.001	1
Iron	14	3.54	0.042	0.62	0.28	11	0.323	0.002	0.16	0.16	74%		0.805	0.3
Lead	15	0.0346	0.0007	0.0078	0.0034	12	0.0009	< 0.0005	0.0006	0.0006	93%	0.0080	< 0.0005	0.01

Manganese	15	0.140	0.003	0.034	0.013	9	0.023	0.002	0.008	0.004	77%			0.1
Mercury		< 0.0005	< 0.0005	< 0.0005	< 0.0005		< 0.0005	< 0.0005	< 0.0005	< 0.0005		0.0002	< 0.0005	0.001
Zinc	15	0.210	0.026	0.078	0.056	12	0.066	0.015	0.034	0.029	57%	0.0274	0.0110	3

\*The determination of means and statistics for the data uses one half of the detection limit when specific analytes were not detected during sampling events.

\*\*River Murray data (n=87) at Murray Bridge obtained from Cugley *et al.* (2002), Parafield data provided by Salisbury Council.

\*\*\*Data are means of measurements taken between March 2003 and April 2004.

## APPENDIX 2 SPECIFIC LAND USE WITHIN THE CATCHMENT

For industrial properties within the Parafield catchment, chemical hazards were characterised based on the volume and toxicity of chemicals present and how they are utilized within processes. Chemicals used for normal operating processes are identified as present in stored containers for use, and as part of the waste stream from the facility. The waste may comprise air emissions, solid waste, liquid waste in storage containers, or as part of a water waste discharged to the sewer system. Preliminary risk levels were that applied to industrial properties are listed in Table A2.1.

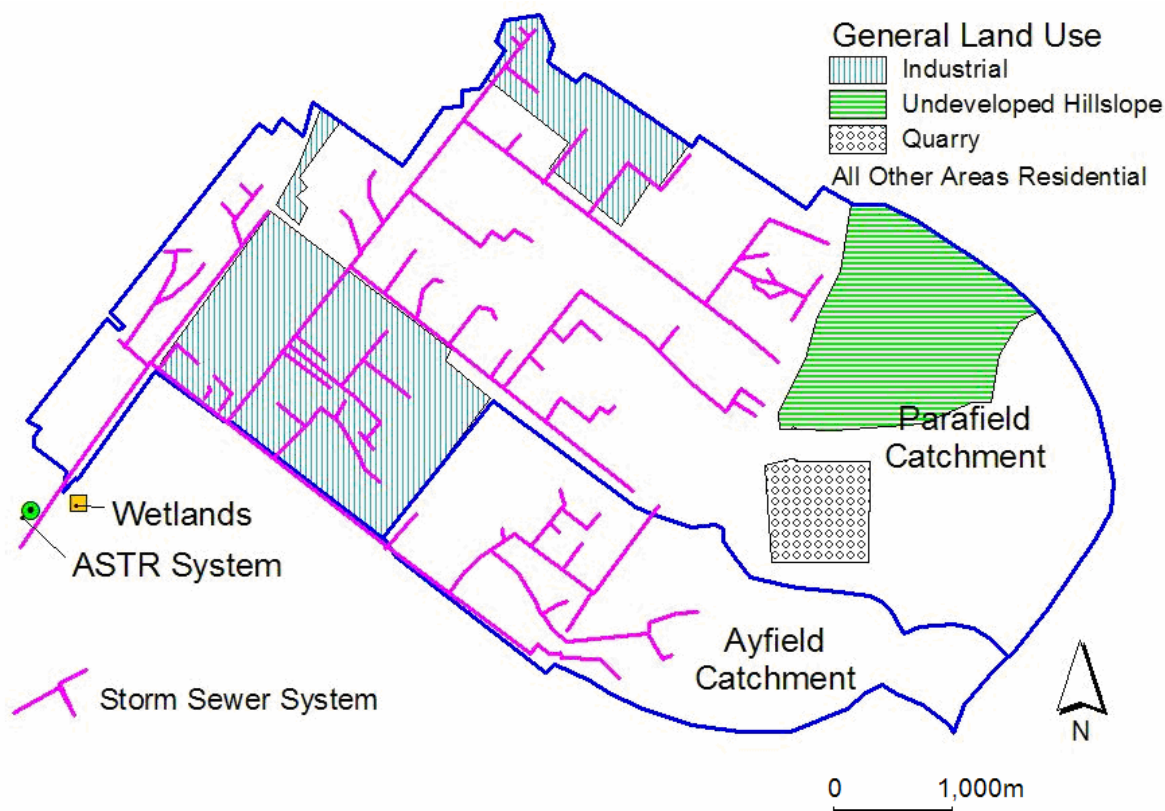
**Table A2.1 Examples of preliminary risk from properties using industrial chemicals.**

Description	Toxicity	Risk Level
Large quantities used/stored on site. Chemicals in process waste stream from site.	High	Very High
Large quantities used/stored on site. Chemicals in process waste stream from site.	Low	Moderate
Moderate quantities used/stored on site. Chemicals in process waste stream from site.	High	Very High
Moderate quantities used/stored on site. Chemicals in process waste stream from site.	Moderate	High
Small quantities used/stored on site. Chemicals not part of normal waste stream.	High	High
Small quantities of chemicals stored on site for retail sale.	Moderate	Moderate
Small quantities of chemicals present at facility.	Low	Low

After barriers to these risks were identified, the residual risk was estimated based on the effectiveness of relevant barriers. The hazard analysis and the determination of residual risk levels are to enable prioritizing of control measures for potential contaminant sources. The qualitative nature of the assessment is meant to provide a method for non-technical people to prioritize efforts in protecting water quality. Relevant to the ASTR project, is the local catchment Pollution Prevention Program of the City of Salisbury Council and the Northern Adelaide and Barossa Catchment Water Management Board. This program contributes to implementing multiple barriers to protect stormwater quality in the Salisbury area.

In order to identify specific potential contaminant sources, an inventory was made of businesses and industries which transport and /or store chemicals within the catchment area. The inventory was made as follows:

Land use classification within the catchment area. Major land use areas were defined for the water balance model of the catchment. The primary categories for the initial characterization were industrial, residential, extractive industry (quarry), and undeveloped hill slope. This information is shown in Figure A2.1.



**Figure A2.1 General land use classification**

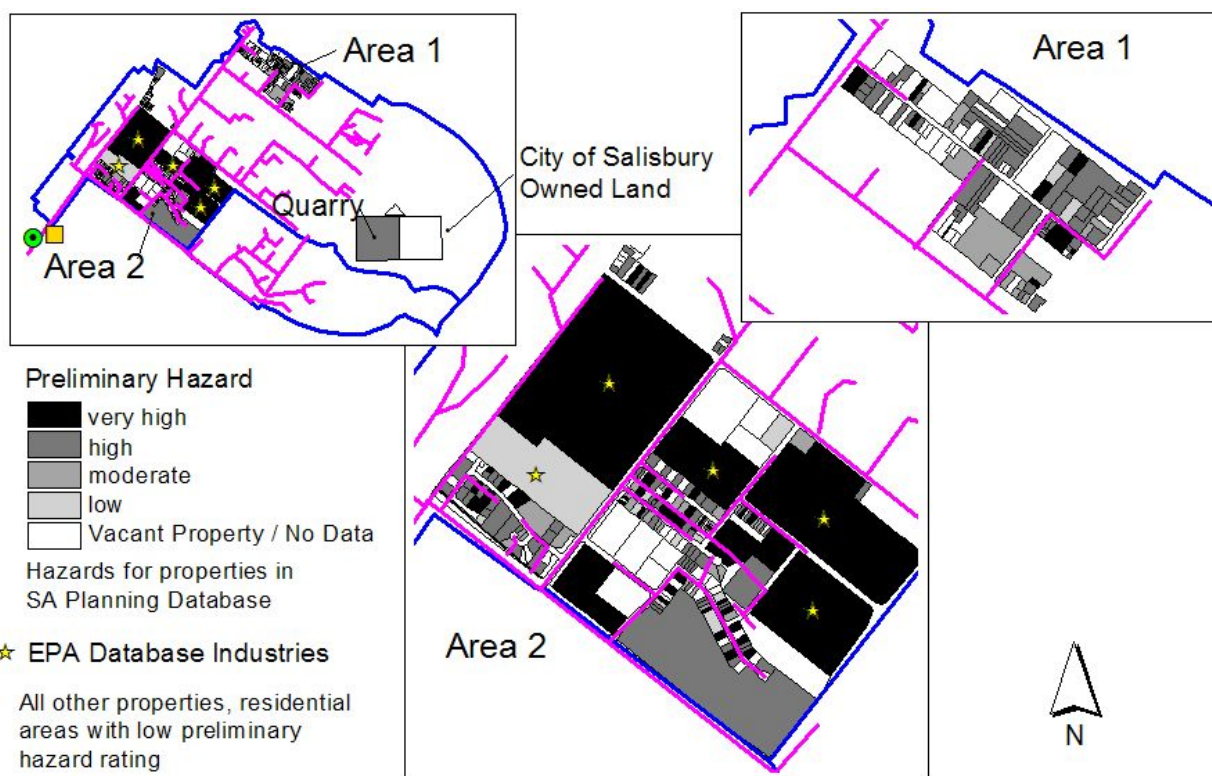
Property use within non-residential industrial and other developed areas was evaluated using a GIS based approach (SA Planning 2002). Specific businesses and industries were classified based on the Australian and New Zealand Standard Industrial Classification (ANZSIC) codes, which provides a classification system on business type. Potential chemical usage was generalized based on industrial processes. Generalised chemical use information is obtained from the United States Environmental Protection Agency (USEPA, 2004) website for Source Water Protection, a program designed to provide information to support management planning activities to protect the water source for public potable water systems.

Approximately 269 businesses were evaluated, with initial hazard classifications as follows:

- 66 – Very High Hazard (e.g. Mayne Pharma)
- 138 – High Hazard (e.g. Crash Repair Shops)
- 49 – Moderate Hazard (e.g. Auto Parts Shops)
- 16 – Low Hazard (e.g. Library)

The preliminary hazard assessments of businesses are included in Figure A2.2.

The South Australian – Environmental Protection Authority (EPA) National Pollutant Inventory (NPI) Database was electronically queried via the internet for pollutant air emissions (<http://www.environment.sa.gov.au/epa/npi.html>). Additional supporting information on the facilities was provided by representatives of the EPA. This information is considered reflective of chemicals used on site. The locations of the five major facilities and preliminary hazard assessments are also shown in Figure A2.2.



**Figure A2.2 Preliminary hazard classification of businesses in the catchment**

Additional data on specific businesses was obtained from the database of the Pollution Prevention Project implemented by the City of Salisbury Council in cooperation with the Northern Adelaide and Barossa Catchment Water Management Board. Representatives of industry and businesses are provided with education in regulatory compliance and pollution prevention issues. The database includes information on industry processes, types of chemicals stored and used at a facility, and barriers to preventing contamination of stormwater.

It is important to recognize any limitations in the database of pollution (potential contaminant) sources in the catchment. The collection of chemical-specific data for each industry and property represents an ongoing task, particularly as those industries alter their operations and practices. When site-specific information is not available, the default values are selected that represent a conservative estimate based on the characteristic chemicals used by the particular industry. While this task may incorporate chemicals not used or stored, this conservative approach is used to ensure that all potential chemicals in the catchment are identified, and all hazards and related risk are appropriately evaluated. Databases of the types of businesses and industries in the study catchment and some of the chemicals used and/or are released into the environment are maintained by the City of Salisbury Council, through their Pollution Prevention Program and by the South Australian EPA under the National Pollution Inventory (NPI). The NPI is an Internet database containing information on the types and quantities of pollutants being emitted to air, land and water from a range of industrial, commercial, transport and household activities. While the NPI is a federal initiative, each state is responsible for implementing the program (SA-EPA website, 2004).

A pollution prevention program helps to identify specific chemicals used by industries and businesses in the catchment. This information, coupled with comprehensive sampling and analysis of stormwater quality may provide sufficient data to enable a reduction in the list of contaminants of concern to only those that have been demonstrated to be present in the



catchment. The target list may be used to develop an economic monitoring program that focuses on the relevant pollutants.

## APPENDIX 3 POLLUTANT TRANSPORT MODELLING

A model of the change in pollutant concentration with time that is based on first order differential equations is described by Runkel (1998) (For this assessment, sorption is not considered). This model is as follows:

$$\frac{\partial C}{\partial t} = -\frac{Q\partial C}{A\partial x} + \frac{1}{A} \frac{\partial}{\partial x} \left( AD \frac{\partial C}{\partial x} \right) + \frac{qLIN}{A} (C_L - C) + \alpha (C_s - C)$$

**Equation 1 Change in pollutant concentration with time**

$$\frac{dC_s}{dt} = \alpha \frac{A}{A_s} (C - C_s)$$

**Equation 2 Simplified change in pollutant concentration with time**

Where\*:

- A      -main channel cross-sectional area [L<sup>2</sup>]
- AS     -storage zone cross-sectional area [L<sup>2</sup>]
- C      -main channel solute concentration [M/ L<sup>3</sup>]
- CL     -lateral inflow solute concentration [M/ L<sup>3</sup>]
- CS     -storage zone solute concentration [M/ L<sup>3</sup>]
- D      -dispersion coefficient [L<sup>2</sup>/T]
- Q      -volumetric flow rate [L<sup>3</sup>/T]
- qLIN   -lateral inflow rate [L<sup>3</sup>/T –L]
- t      -time [T]
- x      -distance [L]
- α      -storage zone exchange coefficient [/T]

\*note – unit types are indicated in parentheses, with L = length, M = mass and T = time

For stormwater modelling the storage zone factors are not included. However this technique can be used for modelling in the Parafield wetlands, where these factors can be utilized. The analytical solution to these equations is presented in the United States Geological Survey Report One-Dimensional Transport with Inflow and Storage (OTIS): ‘*A Solute Transport Model for Streams and Rivers*’ (Runkel, 1998). Use of the model for wetlands will be reviewed in the discussion of data needs for wetlands in this report. A review of recent literature indicates use of the model for applications where steady state flow is modelled without transient storage (Keefe *et al.* 2004). This study modelled the attenuation of volatile organic chemicals in constructed wetlands using volatilization, evaporation and longitudinal dispersion in the system. This approach is applicable to flow in a stormwater channel, with the single differential equation for steady state flow as follows (Keefe *et al.* 2004).

$$0 = -\frac{Q}{A} \frac{\partial C}{\partial x} + \frac{1}{A} \frac{\partial}{\partial x} \left( AD \frac{\partial C}{\partial x} \right) + \frac{q_{evap}}{A} C - k_{vol} C$$

**Equation 3 OTIS transport equation**

Where:

qevap - evaporation rate [M3/SM]

kvol - volatilization rate coefficient for the main channel [/S];

Keefe *et al.* (2004) gives the relationship between kvol and Henry's law constant as follows:

$$kvol \text{ (2-film)} = kwo/Y = 1/Y[RT/kHVa,comp + 1/VW,comp]-1$$

where kvol (2-film) is the two-film first-order volatilization rate coefficient, kwo (cm/S) overall rate of transfer of compound through both aqueous and gas boundary layers at water surface, Y (cm) depth of water column, Va,comp, (cm/S) transfer velocity through the air layer, VW,comp transfer velocity through the water boundary layer (cm/S), R is the ideal gas constant (0.082 atm L/mol.K), kH (atm L/mol) is Henry's Law constant.

An example of an application of the OTIS model to a stormwater channel is shown in Figure A3.1. The sample run simulated a release of benzene into the storm channel at a distance of 500 m from the Parafield wetland intake. The release occurred for a total of two hours, with an input concentration of 0.1 mg/L into a steady state flow of 12.5 L/s in the storm channel 2.4 hours after the beginning of the simulation. Assuming a density of 0.8787 g/mL (ATSDR, 2004), this corresponds to a total release of 10.2 mL into the drain over a two hour period. Attenuation of benzene occurs as a result of volatilization (Henry's Law co-efficient: 5.55 atm L mol<sup>-1</sup>) and longitudinal dispersion within the flow system. Figure A3.1 depicts the results of the simulation, with the modelled concentration of benzene present at locations 100, 300, and 500 meters downstream from the injection point. The effects of longitudinal dispersion are apparent with mixing along the flow path. Volatilization creates a reduction in the total mass of benzene present in the system, which is not visually apparent in this simulation.

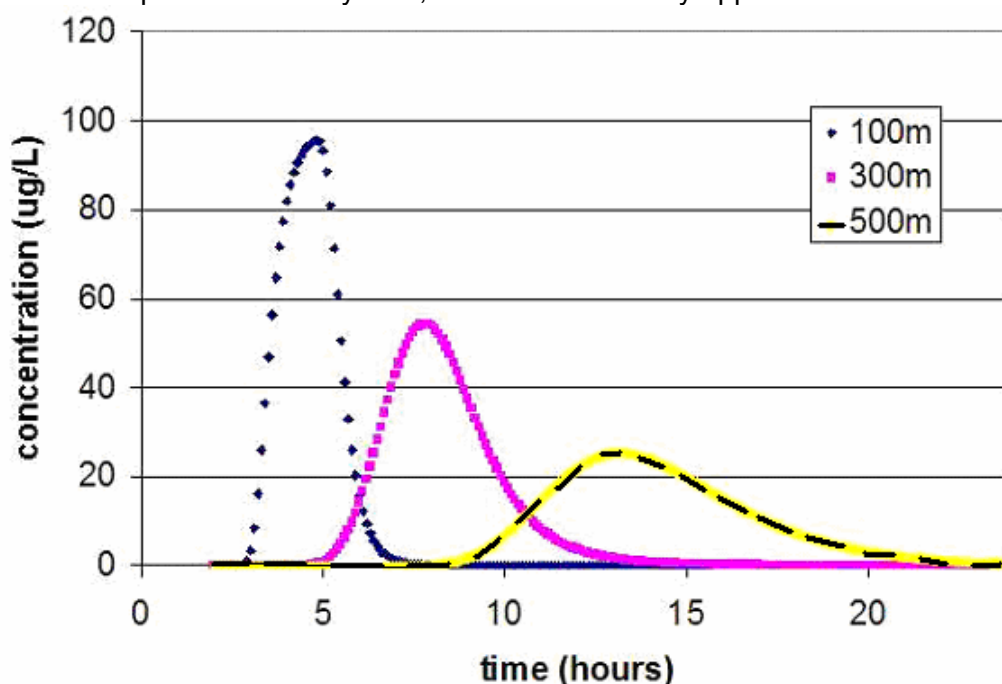


Figure A3.1 OTIS simulation results.

The simulation results indicate both maximum concentrations in the stormwater and the time for the contaminated water to migrate downstream. More detailed knowledge of the stormwater system would be required in order to use the modelling as a realistic assessment tool. Stormwater flow systems may be modelled as transient with variable flow, based on the magnitude and duration of flow expected from specific storm events. A complete model

represents a tool that emergency responders could utilize to predict both concentrations with distance from the spill, and the time for the contamination to reach specific distances from the spill. However, the input variables would need to be known in sufficient time (and application of the model) to enable the critical control point measures to be applied.

Due to the variable nature of stormwater flow and the large number of potential contaminants in the catchment, modelling capability for prediction of the transport and fate of pollutants is recommended for use with an emergency response plan. A flow calibrated model would provide a framework for modelling contaminant behaviour in the flow stream based on the physico-chemical properties of specific contaminants. Use of a validated model could support management decisions in establishment and operation of critical control point measures. For example, after an uncontrolled chemical release, the emergency response team might have an estimate of the time needed to close the intake weir in order to prevent contaminated stormwater from entering the wetland system.