HERDSMAN LAKE
INTEGRATED CATCHMENT MANAGEMENT PLAN

Prepared by
the North Metro Conservation Group for the
City of Stirling
2007

nmcg
North Metro
Conservation Group Inc.

Executive Summary

The Herdsman Lake Integrated Catchment Management Plan provides a synopsis of the health of Herdsman Lake, including its assets, threats and issues as expressed by stakeholders and previous research. It investigates the physical, historical and social elements that have resulted in its present status. The catchment has a well documented history and has been subject to a number of studies, providing a fairly accurate insight into the processes that have resulted in its current issues.

Herdsman Lake is the largest remaining inner metropolitan wetland in the Perth metropolitan area and has regionally significant environmental, social and cultural values. The Lake has a Conservation Category status and is part of a Regional Park. The activities that occur throughout the catchment area manifest themselves in the lake and are the impetus for developing an approach that will treat the source rather than the problem. An integrated catchment management approach is suitable for this situation as it requires all of the stakeholders who are part of the cause to be involved in the creation and implementation of the solutions.

The Herdsman Lake Integrated Catchment Management Plan identifies the key threatening processes and issues facing Herdsman Lake and provides strategies to manage and reduce the effects of these processes and issues on the Lake. In April 2005, NMCG hosted a stakeholder workshop and catchment tour in order to identify the assets and threats within the catchment area. The outcomes from this process form the basis of this plan. Section 2.0 provides a detailed explanation of each of the threatening processes identified through the stakeholder workshop, including detailed information regarding the physical, chemical, biological and socio-economic characteristics of the catchment and also the existing legislation, policies and strategies relevant to the area. Section 3.0 provides the Integrated Catchment Management Plan, which includes the management strategies developed to remediate the identified threatening processes and issues. These management strategies are presented as implementation matrixes under five general headings;

1. Landuse Planning/Regulation;
2. Biodiversity Conservation;
3. Water Quality and Quantity;
4. Acid Sulphate Soils; and
5. Education.

Section 4.0 provides the Recommendations of the plan, including a prioritised listing of the suggested actions required to be undertaken in order to address the identified issues and problems. Management actions are listed in three priority categories; high (0-5 years), medium (5-10 years) and low (10-15 years).

Acknowledgements

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1.0 Introduction

1.1 Purpose and Aim of the Herdsman Lake Integrated Catchment Management Plan

The Herdsman Lake Integrated Catchment Management Plan was initiated at the request of the City of Stirling. It was also recommended as a High Priority strategy by the Department of Conservation and Land Management (now a part of the Department of Environment and Conservation) in the Herdsman Lake Regional Park Management Plan 2004 - 2013 as one of the subsidiary plans required to ensure the protection of Herdsman Lake (CALM 2004).

This document was developed by the North Metro Conservation Group (formerly the North Metro Catchment Group) as part of its annual work-plan with the City of Stirling. Liaison with the community occurred by the establishment of a stakeholder working group that included representatives from State and Local Government, Universities, the Swan Catchment Centre, developers, consultants and the community.

An Integrated Catchment Management Plan is an ideal scale to manage human impacts upon the natural environment because the activities within the catchment area have a direct impact upon the environment in that geographical area. The geology, geomorphology, hydrology, biological and physical characteristics of the catchment affect the processes that occur throughout the catchment area and directly influence the physical and chemical characteristics of the receiving waterways. The value of using an integrated approach is that it incorporates all echelons of the community in developing and implementing the plan.

The aim of this document is to identify all of the various processes occurring within the Herdsman Lake catchment area which are currently contributing to, or have the potential to contribute to, the degradation of the environmental quality of Herdsman Lake. Once these threatening processes and issues have been identified, this document aims to provide a range of strategies in order to reduce the impact these processes and issues are having on Herdsman Lake. By working with stakeholders in the development of these strategies, it is anticipated that those responsible will adopt this plan in order to ensure no further degradation of the environmental and social values of Herdsman Lake occurs and the quality of the environment at Herdsman Lake will continue to be maintained and improved into the future.

It is recognised that community awareness programs are vitally important to improving the long term health of the Lake. These programs will increase community understanding and appreciation of the area and its problems, and will work towards increasing community responsibility and involvement in protecting and improving the environmental quality of the Lake. Therefore, an emphasis of this plan is to develop a comprehensive community education strategy to engage the local community and decrease non-point sources of pollution. These strategies span each of the identified major problem areas (land use planning, water quality/quantity, acid sulphate soils and biodiversity conservation) and are presented in Section 3.3.

1.2 The Herdsman Lake Catchment Area

The Herdsman Lake catchment is located on the Swan Coastal Plain approximately 7km north-west of Perth City centre and 2km inland from the coast. The catchment covers an area of 3084ha and is linked to Herdsman Lake through a series of open and piped drainage channels (both Water Corporation and Local authority drains) and also groundwater flow. All land within this area is linked to Herdsman Lake and has the potential to contribute to the declining health of the Lake. Figure 1 indicates the location of the Herdsman Lake catchment in relation to the northern Perth Metropolitan area.

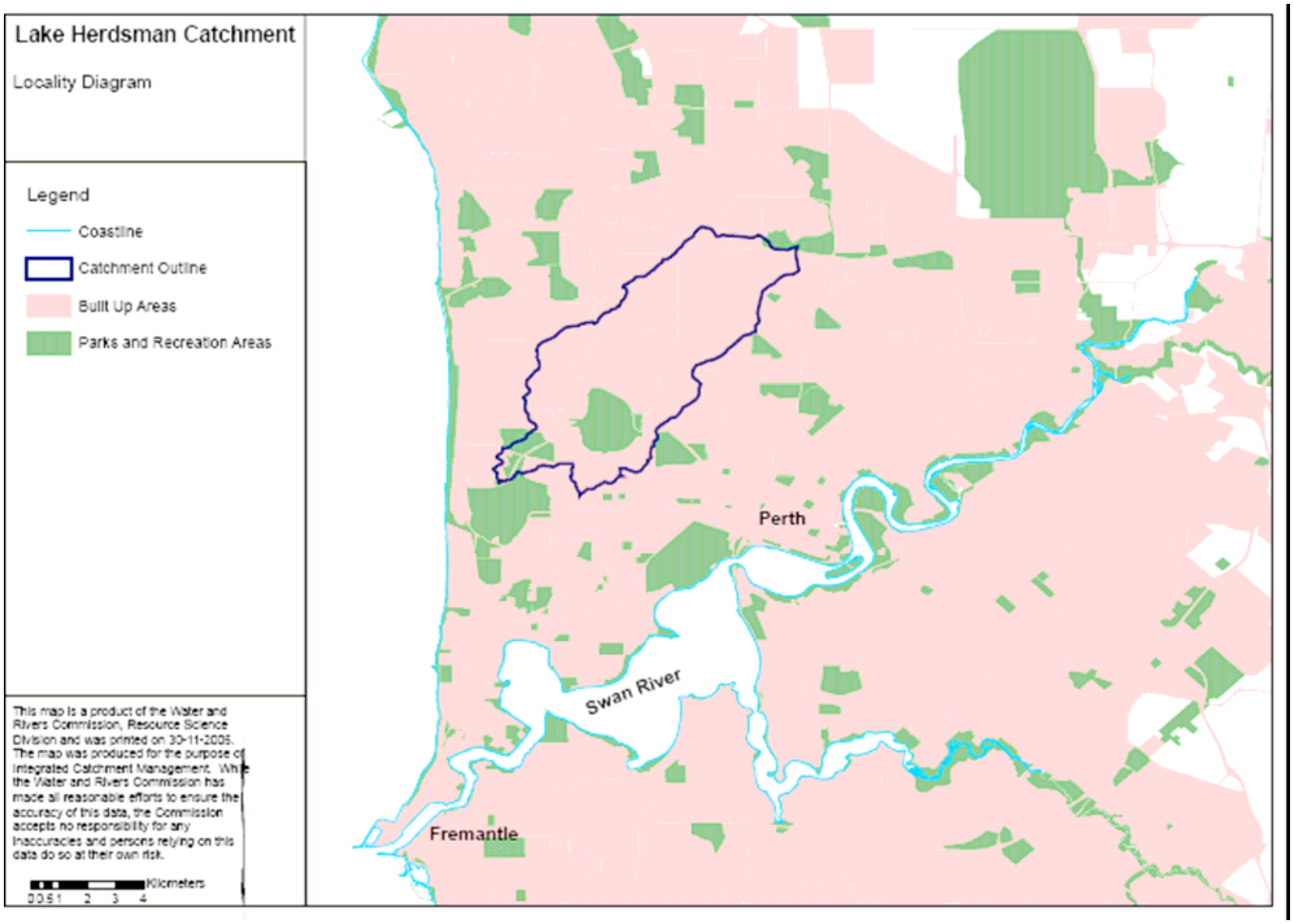

Figure 1: Location of the Herdsman Lake Catchment in the Perth Metropolitan Area
(Map supplied by the Department of Environment 2006)

The majority of the catchment lies within the City of Stirling boundary, with a small section in the lower southwest area being located within the Town of Cambridge (Figure 2). The catchment originates in the suburbs of Mirrabooka and Balga and connects to the Indian Ocean at City Beach, via an outfall pipe from Herdsman Lake (Water Corporation 2001).

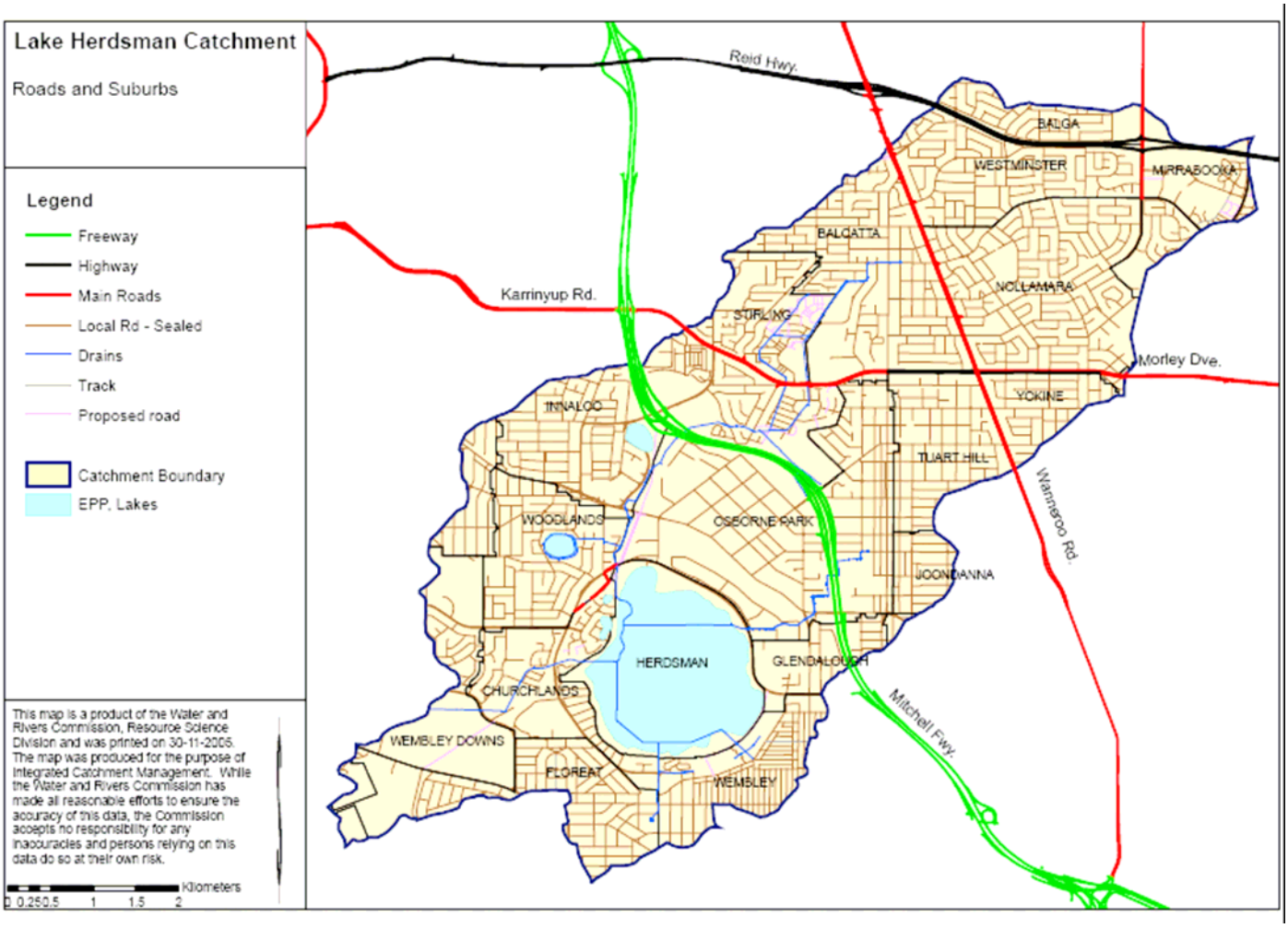

Figure 2: Boundaries and Suburbs of the Herdsman Lake Catchment.
(Map supplied by the Department of Environment 2006)

The Herdsman Lake catchment area has been mainly cleared and contains medium and high density residential, commercial, and industrial areas, as well as some public open spaces and natural areas. It is typical of urban catchments with a combination of land uses and the associated impacts. There is evidence of elevated nutrients, heavy metals and pesticides in stormwater, acid sulphate soils have been confirmed in the area and the loss of biodiversity due to clearing and habitat degradation are all issues that need to be addressed.

Herdsman Lake is the receiving water body for the Herdsman Lake catchment, meaning any water that falls throughout the catchment area has the potential to ultimately be discharged into Herdsman Lake (either through groundwater flow or stormwater inputs). Herdsman Lake contains an inner wetland (approximately 160ha in area) and a dredged outer moat consisting of four deep permanent waterbodies, joined by small channels restricting access to the central conservation area. Herdsman Lake is a regionally significant wetland on the Swan Coastal Plain, as it is the largest wetland in the inner metropolitan area and it supports a wide diversity of wildlife species, serves as an important bird breeding ground and is a summer refuge for trans-equatorial migratory birds (CALM 2004).

2.0 Background – Issues and Threats

2.1 Physical, Chemical and Biological Characteristics of the Catchment

2.1.1 Climate

The Swan Coastal Plain is characterised by a Mediterranean climate (Seddon 1972). The climatic conditions within the Herdsman Lake catchment are typical with wet, cool winters and dry, hot summers. The climate is mainly controlled by the movement of high pressure cells that move north in the winter and south in the summer at about 30°S. In summer the cells direct dry and hot easterly winds over the continent which are affected by local westerly sea breezes. In winter the prevailing winds are west-south westerly and bring cold moist air across the region.

Since the mid-1970's the south-west of Western Australia has experienced a general drying trend, with annual average rainfall volumes steadily decreasing across the region. Rainfall for the Perth region has been below average for the last 30 years and may be indicative of the predicted drying climate. The average annual rainfall has declined from 869mm (long term average 1876-2004), to 788mm (1976-2004) and even further in the last 8 years to 696mm (1996-2004). This drying trend has had a significant impact on groundwater levels and groundwater dependent ecosystems on the Swan Coastal Plain, including Herdsman Lake. The issue of groundwater level decline is discussed in greater detail in Section 2.1.5 (Hydrology).

2.1.2 Topography

There are two fairly distinct topographical elements within the Herdsman Lake catchment area, firstly the elevated areas including a ridge that occupies the Eastern section of the catchment and a smaller elevated area along the Western boundary, and secondly, the low lying area in the centre of the catchment. Within this area there are a variety of natural and constructed wetlands of varying environmental significance with the largest of these being Herdsman Lake. The topography of the catchment area is displayed in Figure 3 below.

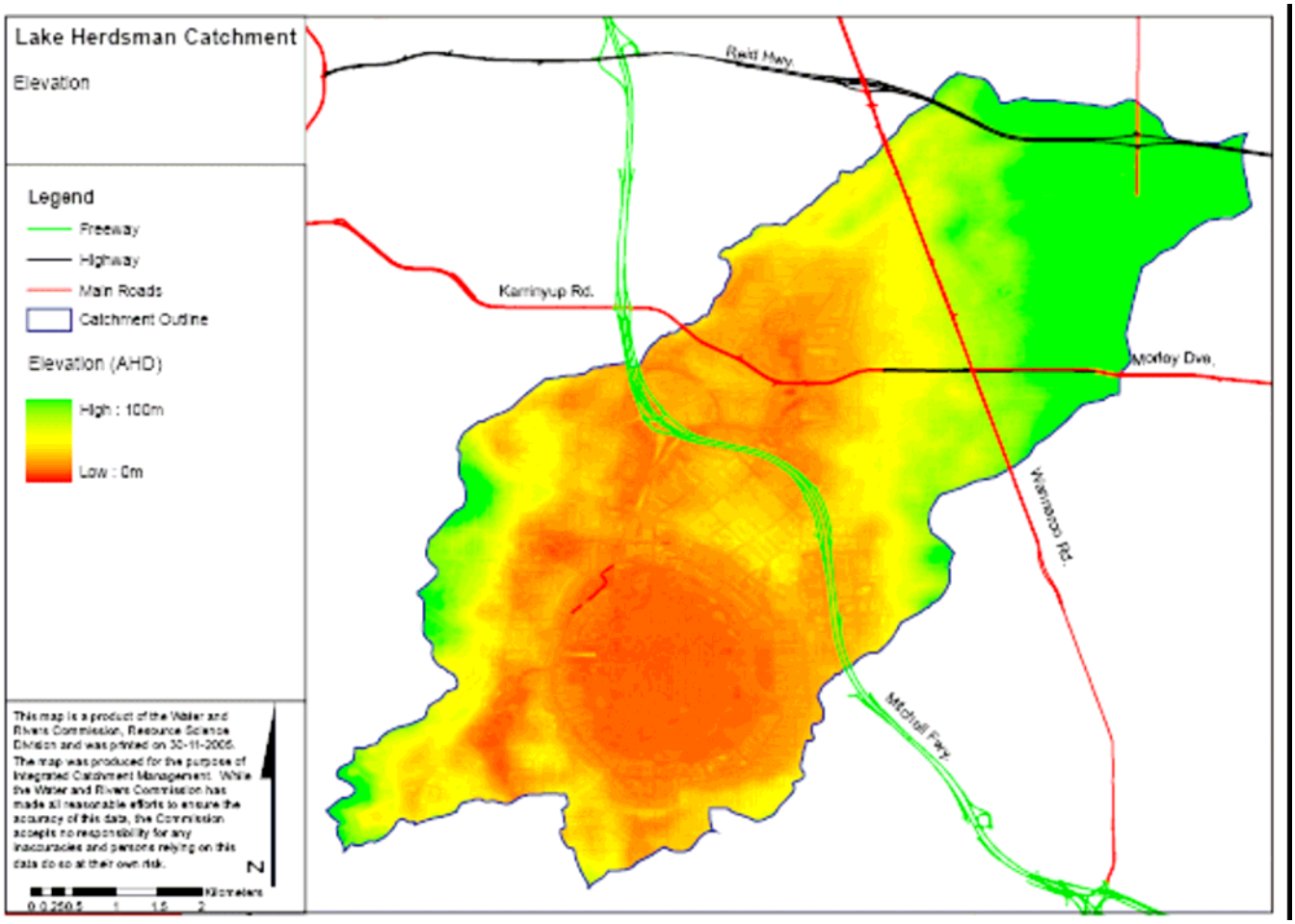

Figure 3: Topography of the Herdsman Lake Catchment
(Map supplied by the Department of Environment 2006)

2.1.3 Geology and soils

The Herdsman Lake catchment lies within the Spearwood dune system and overlies the Tamala limestone formation (Kobryn 2001). There are two dominant soil systems present in the catchment (Figure 4). The majority of the area consists of the deep yellow, leached quartz sand with small sections closer to the coast having a higher calcareous content. These are classified as the Karrakatta soil association (Seddon 1972) and are typical of this dune system. These soils have characteristically high permeability and historically would have been an important part of the groundwater recharge system. The remainder of the area is dominated by wetland soils which consist of Swan and lacustrine deposits. These soils are found around Herdsman and Jackadder Lakes and are present in areas that have been in-filled for urban development.

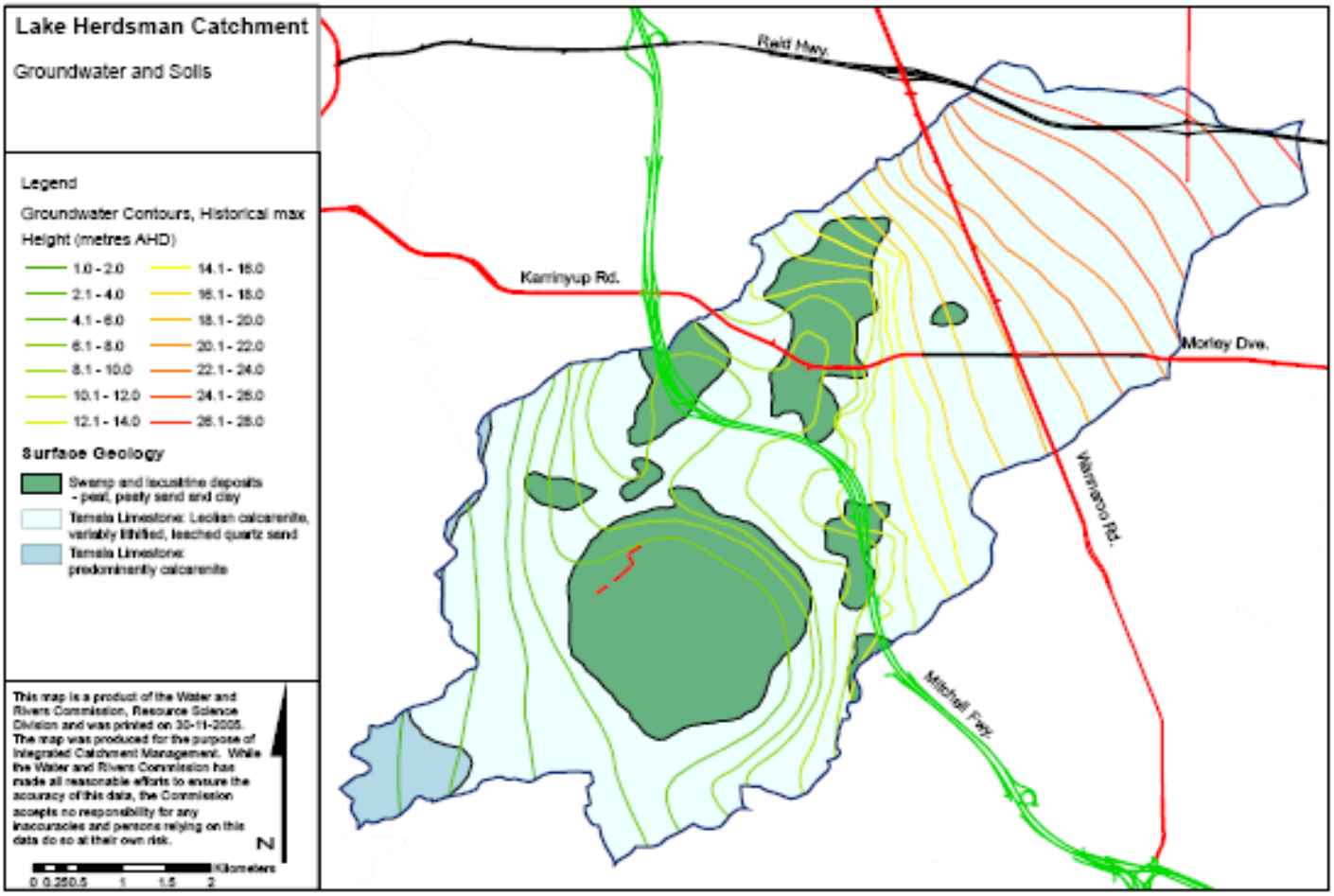

Figure 4: Geology and soils of the Herdsman Lake Catchment
(Map supplied by the Department of Environment 2006)

Teakle and Southern (1937) categorised these wetland soils into 3 general types; Colloidal to peaty sands and loams found around the margins of the lake, acid to strongly acid colloidal, pulpy peats of the sedimentary type and the marly peats of the colloidal type formed from the decomposition of molluscs and crustaceans. The variation in soil types is indicative of the changing water and environmental conditions that have formed the chain of wetlands in this area.

2.1.4 Land use

Prior to European settlement, the Herdsman Lake catchment area and Herdsman Lake itself were used by the Aboriginal people, most likely as a food and water source. Since European settlement, the land within the Herdsman Lake catchment area has been used for a variety of landuses. During the early 1900's large parts of the catchment were drained and used as market gardens. Due to the very acidic peat soils found in the central wetland, the area was never suitable for agriculture and was used mainly for stock grazing. The Osborne Park industrial area was developed in 1912 along the Northern boundary of Herdsman Lake, with drainage from the area being discharged into the lake. In the 1930's sections of Herdsman Lake were used for sanitary landfill and rubbish disposal. In the 1950's the area throughout the catchment began to be developed for residential purposes. The fastest period of development occurred between 1953 and 1964 where 27% of the catchment was converted into housing (Kobryn 2001). By 1964 over 45% of the area was urbanised and this rapid urbanisation continued until 1987.

By the mid-1990's much of Stirling was rezoned from low to medium density residential which is likely to have accelerated the rate of residential development. This increase in hard surfaces corresponds with increased imperviousness and subsequently lower groundwater recharge rates and higher surface water flows into wetlands.

Today, the most dominant landuse of the catchment area is residential, with more than half of that being medium density (Kobryn 2001). Typically, the most dominant contaminants from residential areas are nutrients (from fertilisers, garden debris, animal droppings), with other smaller contributions of detergents, motor oils, domestic cleaners, pesticides and herbicides. These contaminants find their way into Herdsman Lake either through groundwater infiltration or by entering the stormwater system through road drainage. With the increasing use of groundwater in residential areas for domestic garden use, this dominant landuse could also potentially be contributing to declining groundwater levels across the catchment area. Residential areas can also provide a weed source to the neighbouring reserve, either through seed dispersal from exotic garden plants or through dumping of garden wastes into the reserve or the Lake.

The next dominant landuse in the Herdsman Lake catchment area is industrial/commercial, with a large industrial/commercial area existing in Osborne Park, on the northern boundary of the Regional Park. This industrial area is connected to the regional drainage system and has the potential to contribute large quantities of various contaminants to Herdsman Lake. The types of potential contaminants originating from industrial and commercial areas are dependent on the type of industry and can include a wide range of toxic substances.

New residential and industrial developments throughout the catchment area also have the potential to impact upon the environmental quality of Herdsman Lake, namely through effecting groundwater quantity and quality via dewatering activities (particularly causing the activation of acid sulphate soils) and altering the natural hydrological regime (reduced groundwater infiltration rates).

Roads have the potential to contribute contaminants to the Lake, primarily debris, heavy metals and hydrocarbons. The type of contaminants contributed to Herdsman Lake from the road network would be dependant on the landuse of the area.

Other areas include public open space, reserves and small sections of market gardens, which could potentially contribute nutrients, pesticides and herbicides to the catchment area and could also contribute to groundwater drawdown.

Each landuse has the potential to contribute a wide range of contaminants to Herdsman Lake, therefore each area of the catchment needs to be managed to specifically address the contaminants originating from each landuse.

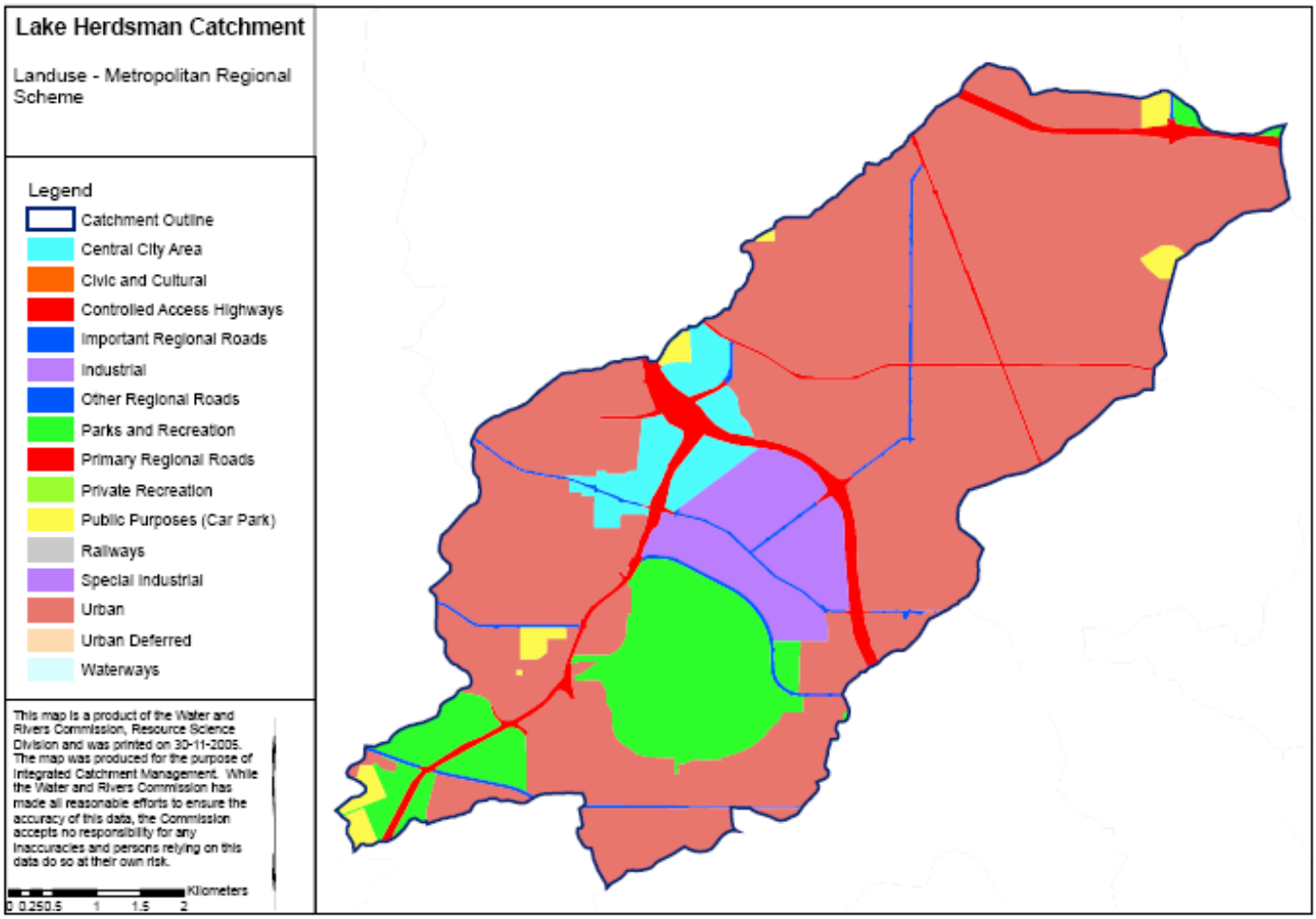

Figure 5: Land use in the Herdsman Lake Catchment in 1993
(Map supplied by the Department of Environment 2006)

The environmental quality of Herdsman Lake will continue to decline if the land throughout the catchment area is not managed effectively. Strategies that have

been developed by this plan in order to address the issues associated with landuses include:

- Identify polluting industries in the catchment area and implement the Swan Catchment Council's Regional Auditing program, which involves the auditing of industrial premises to ensure the appropriate disposal of waste products. This program should also incorporate the Unauthorised Discharge Regulations;
- Incorporate Water Sensitive Urban Design (WSUD) principles into all City of Stirling planning approvals in the catchment area and retrofit existing infrastructure to meet WSUD principles/guidelines. The principles of WSUD include the treatment of stormwater on site to mimic the natural drainage of the local area as closely as possible and preventing contaminated water from entering the regional drainage system. Retrofits can include the use of pervious paving and the construction of grass swales and infiltration basins to increase groundwater infiltration;
- Develop and implement a community education strategy. This strategy will allow for the education of the community of the catchment to prevent pollution entering Herdsman Lake via groundwater and stormwater systems from different landuses;
- Develop and apply fertiliser application plans for each park and reserve within the catchment area, to prevent the overuse of fertilisers and the subsequent leaching of nutrients to groundwater, or runoff into stormwater systems;
- Implement the Sustainable Landscaping Strategy, to encourage the use of local native plants in domestic and Council gardens, to prevent the overuse of fertilisers and provide some habitat for native fauna;
- Investigate the effectiveness of, and install (where appropriate) gross pollutant traps and sediment traps in drains throughout the catchment area to prevent contaminated water from entering the regional drainage system;
- Investigate and install stormwater treatment facilities in stormwater drains flowing into Herdsman Lake to trap particulates and pollutants and prevent these from being discharged into Herdsman Lake;
- Develop and implement targeted industry awareness strategies for industrial areas;
- Develop and apply water conservation plans for all parks and reserves in the catchment area to prevent the overuse of water, preventing groundwater drawdown and leaching of nutrients;
- Liaise with all stakeholders to manage groundwater drawdown to minimise shallow groundwater acidification and heavy metal contamination throughout the catchment area;
- Install vegetated strips/swales or other stormwater treatment facilities along road verges throughout the catchment to reduce the pollutant load originating from roads and vehicles from entering Herdsman Lake;
- Adopt formal protection of reserves and effective planning solutions throughout the catchment to prevent the further loss of native vegetation; and

- Apply the Keep Australia Beautiful Clean Site program to all new building projects in the catchment.

2.1.5 Hydrology

2.1.5.1 Water quantity and groundwater

The groundwater catchment boundary of Herdsman Lake extends for some distance to the North and East of the Lake, and does not have clearly defined boundaries. The depth to groundwater is highest at the top of the catchment (north-east) with levels of 28mAHD and is lowest at the most western point at 1mAHD. Groundwater flows through the catchment area from the north-east to the south-west, originating from the Gnangara mound. Therefore changes to the water quantity and quality of the Gnangara mound are likely to impact upon groundwater quantity and quality throughout the catchment of Herdsman Lake. Herdsman Lake is a groundwater flow-through lake and is a surface expression of the groundwater table. Therefore any change in the quality and/or quantity of the groundwater within the catchment area will cause a subsequent change in the quality and/or quantity of the surface water of Herdsman Lake.

In general, groundwater levels have been slowly declining across the south-west of Western Australia for the past 30 years, due to reduced rainfall levels and the increasing use of groundwater for domestic, agricultural, industrial and drinking purposes. Because the wetlands and much of the vegetation within the Herdsman Lake catchment area are groundwater dependent ecosystems, this trend could result in the permanent degradation of these areas.

The water levels of Herdsman Lake have been significantly altered following European settlement and the implementation of the Regional drainage system. The regional drainage system was developed in the early 1900's in order to drain the groundwater of the swampy catchment area to enable the development of the suburbs. Today, large volumes of groundwater are drained and are discharged through the regional drainage system into the ocean at City Beach. There has been much debate over the feasibility of redirecting or re-using this water (particularly allowing for groundwater infiltration to allow for an increase in regional groundwater levels) or if this drainage system is still necessary in a time of drying climate and lowering groundwater levels. This issue warrants further investigation and is an action recommended by this plan.

Prior to the 1920's, Herdsman Lake was primarily an expression of the groundwater table, with a considerable inflow of groundwater along the north and north-eastern boundary, from the Gnangara mound (CALM 2004). Very little of the surface water of the Lake originated from surface runoff. Today, however, the drainage system has been dramatically altered. Herdsman Lake receives surface water inputs from both local and regional stormwater drains and functions as a drainage compensating basin for a large catchment area (CALM 2004). The soils of the Herdsman Lake catchment area are sandy and highly porous, and traditionally rainfall infiltration rates (to groundwater) were high.

However, with more sealed surfaces in the catchment following development, runoff volumes have increased and groundwater infiltration rates have been significantly reduced (Kobryn 2001). As a result of this, the groundwater table and the Herdsman Lake groundwater levels (and therefore surface water levels) have fallen since development began in the catchment due to the smaller area available for groundwater recharge (CALM 2004). Other factors contributing to the reduction in Herdsman Lake water levels include:

- The extensive drainage and lake level controls implemented by the late 1920's (when only 5% of the catchment had been urbanised); and
- The large number of domestic and commercial bores accessing the upper, unconfined aquifer (Kobryn 2001).

The net result of this has been a slow, steady decrease in the water levels in Herdsman Lake (Kobryn 2001).

Changes in the water level at Herdsman Lake may influence the germination, survival and composition of fringing wetland vegetation communities (CALM 2004). Additionally, changes in the Lake environment would favour some fauna species at the expense of others due to their different breeding and feeding requirements (CALM 2004). A permanent increase in the water level at Herdsman Lake would most likely result in an increase in the area of open water, while much of the shallow water and mudflats used by wading birds would be lost (CALM 2004). Additionally, the rise in water level is likely to result in the loss of rush beds used by some species of birds for breeding (CALM 2004).

Alternatively, if water levels were to fall permanently at Herdsman Lake, preventing the central wetland area from flooding in winter, there would be a substantial loss of seasonally inundated wetland areas required by some birds for habitat (CALM 2004). It would be likely that only species that use the deeper areas of the moats (principally swans and ducks) would remain common (CALM 2004). A drop in the water level could also promote the activation of acid sulphate soils, triggering the release of acid, metals and nutrients into the water column. The causes and effects of acid sulphate soils are discussed in more detail in Section 2.1.7.

As can be seen in Figure 6, a section of the catchment lies within the Gwelup Underground Water Protection Control Area and has been designated as a Priority 3 Public Drinking Water Supply Area (PDWSA). The intention of protecting these areas is to reduce the risk of pollution to the water source. Priority 3 areas exist where land uses such as residential, commercial and light industry occur over a water supply area. The area is managed through the application of guidelines on how the land should be used to avoid contamination.

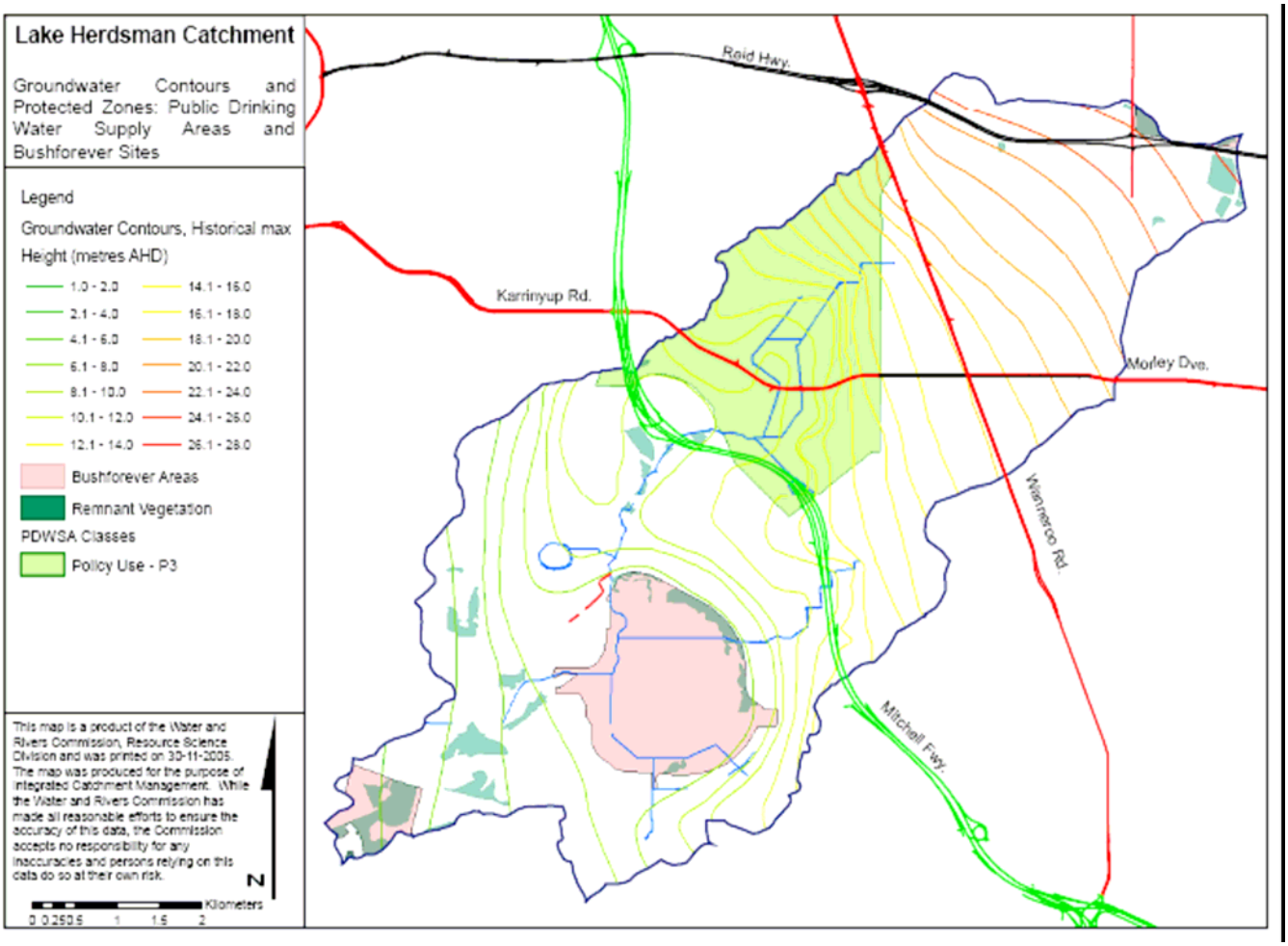

Figure 6: Groundwater Contours and Public Drinking Water Supply Areas in the Herdsman Lake Catchment
(Map supplied by the Department of Environment 2006)

Although groundwater levels are recorded on a regular basis, limited data on groundwater quality exists. A study of the groundwater quality surrounding Herdsman Lake was undertaken in 2001 (Kobryn), which analysed groundwater quality samples up and downstream of Herdsman Lake. The results indicated that:

- Nutrient concentrations (nitrogen and phosphorus) in the groundwater surrounding Herdsman Lake were generally elevated and exceeded ANZECC guidelines;
- Total oxidised nitrogen concentrations were particularly elevated, indicating a source of nitrates to the system; and
- pH was slightly acidic.

Groundwater throughout the Herdsman Lake catchment has been shown to be contaminated with nutrients, most likely as a result of past and present landuses. Once pollutants have entered the groundwater system, it is very difficult to remove them, and therefore prevention of groundwater pollution is extremely important.

Groundwater quality is also under threat from acidification and heavy metal contamination from the activation of acid sulphate soils. This issue is discussed in greater detail in Section 2.1.7 (Acid sulphate soils).

Although climate change and the regional lowering of groundwater levels are out of the control of this plan, some consideration to the effects and management of changing groundwater levels at Herdsman Lake and throughout the catchment area needs to be undertaken in order to maintain current environmental values. The groundwater of the Herdsman Lake catchment area needs to be protected to ensure no further contamination occurs, protecting groundwater drinking supplies and the quality of water being discharged into the numerous groundwater dependent wetlands throughout the catchment area. Specific actions proposed by this plan to remediate the issues identified include:

- Implement the Sustainable Landscaping Strategy for the catchment to encourage the use of local native plant species in domestic and Council gardens, to prevent the contamination of groundwater caused by the overuse of fertilisers;
- Develop and implement fertiliser application plans for all parks and reserves within the catchment, to prevent the overuse of fertilisers and the subsequent leaching of nutrients to groundwater;
- Develop and implement an acid sulphate soils management plan, to prevent any further acid sulphate soil activation and to manage current acid sulphate soil issues (including acidic groundwater flows);
- Implement the Swan Catchment Council's Regional Auditing program, to prevent the inappropriate disposal of industrial wastes;
- Incorporate Water Sensitive Urban Design principles to new developments and retrofit existing infrastructure to allow for greater groundwater infiltration at source throughout the catchment. Investigate and install options such as pervious paving, vegetated/grass swales and infiltration ponds;
- Develop and implement a community education strategy to decrease non-point source pollution of groundwater and prevent the overuse of groundwater;
- Research into water levels and the quantity of water necessary to maintain the ecological function of Herdsman Lake;
- Develop and implement a total water management strategy; and
- Develop and implement water conservation plans for all parks and reserves in the catchment, to prevent the overuse of groundwater for irrigation purposes.
- Investigate the options of stormwater re-direction/infiltration (particularly the regional drainage system) and the effects this may have on Herdsman Lake;

- Incorporate options such as grass/vegetated swales, pervious paving and sedimentation ponds throughout the catchment area, to allow for greater groundwater infiltration; and
- Liaise with all stakeholders to manage drawdown to minimise shallow groundwater acidification and heavy metal contamination throughout the catchment.

These actions have been developed to prevent further alterations to the groundwater of the Herdsman Lake catchment area and hence the surface water levels of Herdsman Lake itself. These actions are outlined in Table 6 in Section 3.3, in relation to the threats/issues identified in the community consultation workshop.

2.1.5.2 Surface Water – Drainage

The hydrology and drainage of the Herdsman Lake catchment area has been extensively altered since European settlement, in order to convert the swampy and seasonally inundated area into productive agricultural and residential land. The boundaries of the Herdsman Lake catchment are defined by the Water Corporation drainage system and cover an area of 3084ha, consisting of 15 sub-catchments and 276ha of local authority drains. The drainage system was developed over a 60 year period and as a result, the planning has been fragmented and developed according to changing design guidelines and the information available at the time (Water Corporation 2001).

The suburb of Osborne Park was first drained around 1912 to provide suitable land for agriculture. Herdsman Lake was the receiving body for that water and an extensive drainage program was initiated to manage the water for multiple uses. The drainage design, which was commenced in 1921 and finished in 1925, was based on a north-south and east-west grid system and was controlled by a series of locks. The locks were used to maintain water levels in the drainage system to irrigate the market gardens in the Osborne Park area and to remove excess water from the wetland via an ocean outfall channel (Kobryn 2001). This was the beginning of the regional drainage system which was progressively extended and upgraded as the suburbs throughout the catchment area were developed. Today, the regional drainage system extends for approximately 10km to the North-East of Herdsman Lake, beginning in the suburb of Balcatta and travelling in a south-westerly direction, passing through Herdsman Lake Regional Park and then finally heading west and discharging into the Ocean at City Beach.

There are four Water Corporation Branch Drains that comprise the regional drainage system that enter Herdsman Lake Regional Park (Clark *et al.* 1990);

- Osborne Park Branch Drain – this drain is the largest of the regional branch drains and collects stormwater from as far away as the suburb of Balcatta. This drain enters Herdsman Lake Regional Park from the North and drains a sub-catchment of 1797ha. A large proportion of this sub-catchment is used for industrial and commercial purposes, with the remainder being used for residential areas;
- Balgay Branch Drain – this drain enters Herdsman Lake Regional Park from the East and drains a 254ha sub-catchment, where the dominant landuse is industrial, followed by residential areas;
- Herdsman Parade Branch Drain – this drain enters Herdsman Lake Regional Park from the South-East and drains the 83ha, mainly residential sub-catchment; and
- Flynn Street Branch Drain – this drain enters Herdsman Lake Regional Park from the South and drains a sub-catchment of 46ha, consisting of residential and commercial areas.

Of these drains, only the Herdsman Parade and Flynn Street Branch Drains discharge directly into Herdsman Lake (CALM 2004). The other two regional branch drains (Balgay and Osborne Park Branch drains) form channels which traverse through Herdsman Lake but do not directly discharge into it, connecting to the Herdsman Main Drain on the Western side of the lake (Figure 6). The Herdsman Main Drain discharges stormwater into the ocean at City Beach. Although these two drains pass through Herdsman Lake, they were not originally intended to discharge stormwater directly into the lake. However, the drainage waters are not fully isolated from the lake itself, and direct exchange occurs through the pervious nature of the banks of the channels and also when the drains overflow (CALM 2004).

There are also numerous local authority stormwater drains that discharge directly into Herdsman Lake, from the surrounding residential and industrial areas, and also numerous local authority drains which discharge into the regional drainage system.

Prior to European settlement, Herdsman Lake received very little water through surface water runoff, with the largest contributor of water being groundwater inflows. However, following the continued development of the catchment area and the development of the regional and local drainage systems, the relative contributions of groundwater and surface water runoff have been altered. Today, the lake receives a higher proportion of its surface water inputs via surface (stormwater) runoff than it did prior to the development of the catchment area. This is largely due to the increase in impervious surfaces throughout the catchment area, reducing groundwater recharge and increasing surface water runoff volumes (Kobryn 2001).

Modelling carried out by Water Corporation in 2001 indicated that the current drainage is under capacity in some of the sub-catchments. Since the Herdsman Main Drain Scheme Review (Water Corporation 2001) was completed the majority of the upgrades addressing identified flood issues have been installed (Davie 2006). In its review of the Herdsman Main Drain, the Water Corporation recognised the need to upgrade the current drainage system and in doing so acknowledged the possible presence of rare flora and fauna and significant ethnographical and archaeological sites. It also identified water quality and overflow breaches of some of the drains as issues that need to be incorporated into future upgrades or retrofits.

The drains throughout the Herdsman Lake catchment area have been identified as major contributors of pollutants to the lake (Kobryn 2001). The water quality of these drains is discussed in greater detail in Section 2.1.6 (Water Quality). Specific strategies and actions need to be developed in order to determine the pollutants entering the lake through the drainage system, and also strategies to remediate any pollution sources.

Actions proposed by this plan to combat these issues include:

- Implement the Sustainable Landscaping Strategy to encourage the use of local native plants in domestic and Council gardens, to prevent the overuse of fertilisers and subsequent nutrient leaching to groundwater or runoff into the stormwater system;
- Apply the Keep Australia Beautiful Clean Sites program to all new building projects within the catchment area, to prevent the inappropriate disposal of wastes from constructions sites into the stormwater system;
- Develop and implement fertiliser application plans for all parks and reserves within the catchment, to prevent the overuse of fertilisers and the subsequent leaching of nutrients to groundwater, or runoff into the stormwater system;
- Develop and implement an acid sulphate soils management plan, to prevent any further acid sulphate soil activation and to manage current acid sulphate soil issues (including acidic groundwater flows);
- Implement the Swan Catchment Council's Regional Auditing program, to prevent the inappropriate disposal of industrial wastes;
- Incorporate Water Sensitive Urban Design principles to new developments and retrofit existing infrastructure, to increase groundwater infiltration at source and prevent large volumes of stormwater flows. Investigate and install options such as pervious paving, vegetated/grass swales and infiltration ponds;
- Develop and implement of a Total Water Management Strategy;
- Develop and implement a Water Quality Monitoring Program for the catchment to determine the identity of pollutants existing in and entering Herdsman Lake, and the major contributors of these pollutants to the system;
- Investigate the need for, and construct stormwater treatment facilities, including vegetated/grass swales, sedimentation ponds, gross pollutant traps and sediment traps in stormwater drains (including the regional drainage system), to reduce pollutant loads entering Herdsman Lake through stormwater drains;
- Investigate the feasibility of redirecting stormwater drainage from entering Herdsman Lake, including increasing infiltration rates throughout the catchment;
- Survey the drainage system and prioritise sites for erosion control techniques (preferably rehabilitation works) to reduce the movement of sediment; and
- Develop and implement a Community Education Strategy, to reduce non-point sources of pollutants (namely nutrients) entering the stormwater system from domestic properties.

These management actions are outlined in Table 6 in Section 3.3.

2.1.5.3 Surface Water – Wetlands

Herdsman Lake is one of the largest lakes in the Perth metropolitan region. It consists of 160ha of shallow water that is covered with vegetation, mainly consisting of the weed *Typha orientalis.* Herdsman Lake itself consists of a large inner swampy area, with several permanent deep waterbodies around the perimeter of the lake (Figure 7). These waterbodies, known as Industrial Lake to the north, Floreat Lake to the North-west, Floreat waters to the south-west, and Powis Lake to the east, are artificial moats that were created through dredging in the 1970's during mining excavations for peat and diatomaceous earth (Kobryn 2001). Once mining had ceased, some dredging continued in an attempt to complete the moat to protect the conservation values of the interior of Herdsman Lake. These moats are groundwater fed and deep enough to be a permanent water body. One final section of the lake was proposed to be dredged to complete a deep water moat, between the Herdsman Main Drain and Floreat Waters. Due to concerns regarding acid sulphate soils, any further dredging in the Park would be subject to an ecological risk assessment to ensure water and sediment quality was not impacted upon.

Herdsman Lake is a receiving body for both Water Corporation and Local Authority drains and therefore its natural hydrology has been drastically altered. The increased runoff resulting from increased impervious surfaces and loss of vegetation within the catchment has resulted in higher surface water runoff to the lake than naturally would have occurred.

There are several other wetlands throughout the Herdsman Lake catchment area, most of which are connected to Herdsman Lake via the regional drainage system. The majority of these wetlands have been modified in order to provide a stormwater compensating capacity.

Several studies have been conducted on the water and sediment quality of the wetlands which comprise Herdsman Lake Regional Park. The major findings of these studies are discussed in Section 2.1.6 (Water Quality).

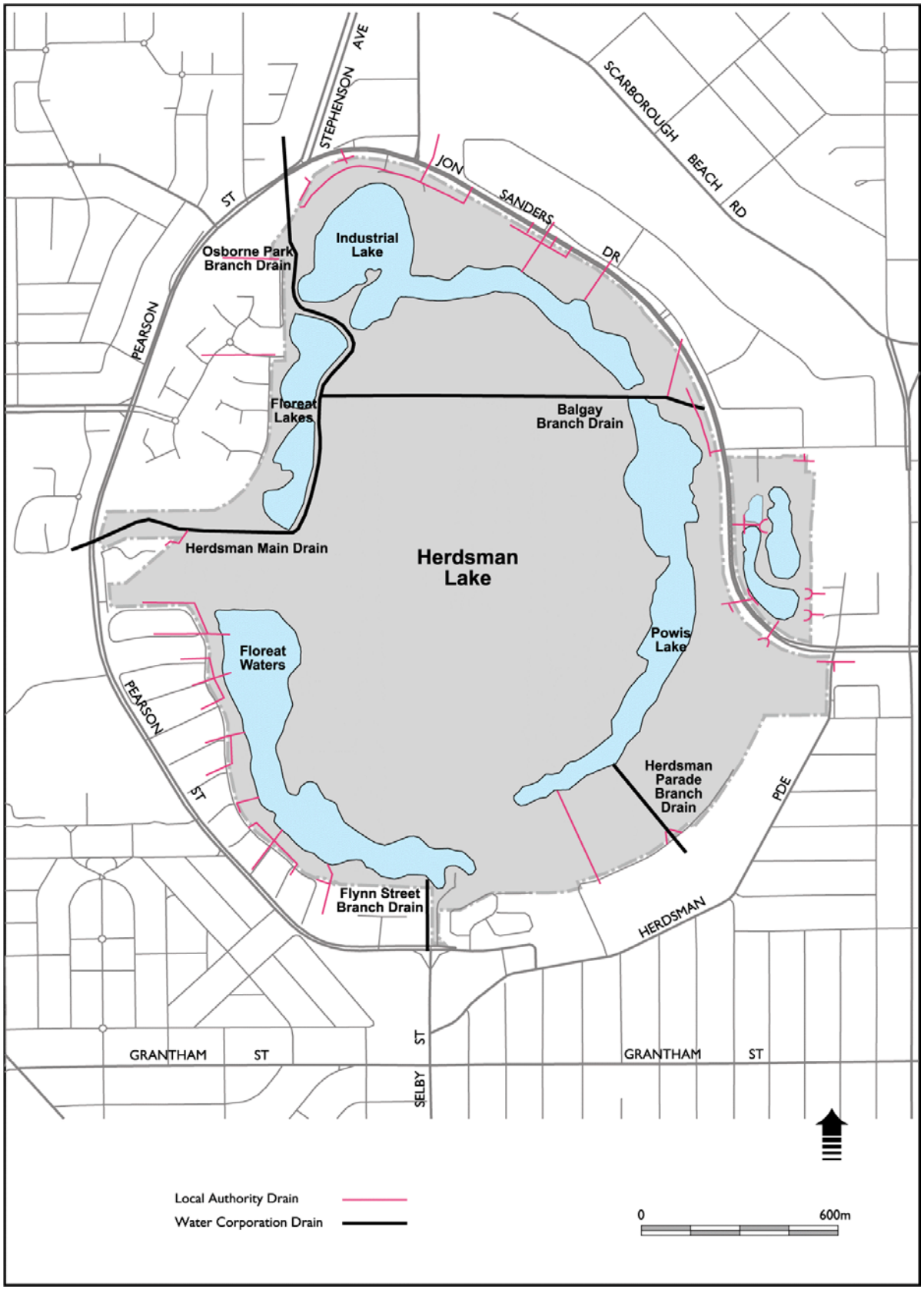

Figure 7: Waterbodies within Herdsman Lake and stormwater drainage inputs (Water Corporation and Local Authority Drains).
(Source: CALM 2004, original map sourced from Clarke *et al.* 1990)

2.1.6 Water quality

The wetlands of the Herdsman Lake catchment area have been monitored twice yearly since 1999 by the City of Stirling for physical parameters and nutrient concentrations. The results of this monitoring program have shown that generally the wetlands within the Herdsman Lake catchment area are eutrophic, with the majority being affected by algal blooms, midge problems and waterbird deaths.

Herdsman Lake itself has been affected by several water quality issues, namely;

- Eutrophication, leading to algal blooms, bird deaths and midge outbreaks;
- Acid sulphate soils activation, and the subsequent acidic drainage and heavy metal contamination;
- Water quality issues linked to the past landuses, including the landfill site, horticulture sites, and heavy use of pesticides and herbicides in the area.

The water quality of Herdsman Lake has been intensively studied through the Herdsman Lake Water Quality Study (Clarke *et al.* 1990), which involved an analysis of data collected by the State Planning Commission, collected between 1983 and 1988. Water samples were collected and analysed from three of the four waterbodies that make up Herdsman Lake (Floreat waters, Industrial Lake and Powis Lake). Nutrient concentrations and chlorophyll *a* concentrations were analysed to classify these wetlands based on trophic status. The trophic status of these waterbodies is listed in Table 1 below.

Table 1: Classifications of the three water bodies according to mean annual total phosphorus concentrations and chlorophyll a concentrations
(Clark *et al.* 1990)

Name of water body	Mean annual total phosphorus concentrations	Chlorophyll *a* concentrations
Floreat Waters	Eutrophic	Hypereutrophic
Industrial lake	Mesotrophic	Eutrophic
Powis Lake	Mesotrophic	Mesotrophic

This study highlighted the following water quality concerns:

- High concentrations of nutrients recorded in the various drains indicate that they are a significant source of nutrients to the Lake system.
- Dissolved oxygen and temperature profiles recorded at deep sites (>5m) in the Herdsman Lake system indicate thermal stratification occurs during spring and summer with overturning occurring during autumn. This is likely to cause increased algal blooms due to massive releases of nutrients which have been released under anoxic conditions.
- Concentrations of organochlorine pesticides, dieldrin, chlordane and heptachlor recorded in studies in 1982 and 1986-1988 all exceeded the recommended levels for the protection of aquatic fauna. The low number of predatory invertebrate species and the high concentrations of pesticides recorded in the fish and waterfowl indicate that aquatic food chain has been impacted. The most probable cause of this impact was the Argentine ant control program (1950's – 1980's) and commercial and domestic pesticide applications within the catchment (CALM 2004).

- High levels of pesticides were also recorded in inflowing drains indicating that pesticides applications throughout the catchment are a non-point source and are ultimately being discharged into the Lake. These levels were elevated in Autumn and Winter, most likely a result of increased rainfall.
- Stormwater drains have been identified as a major contributor of heavy metals to the Lake. Elevated concentrations (higher than those recommended for aquatic ecosystems) of cadmium, copper, lead and zinc were detected in Floreat Waters in 1982/83 and high concentrations of Zinc were recorded in some incoming drains (ESRI 1983). The Balgay Branch drain recorded high levels of Lead in 1985 (Clarke *et al.* 1990).

Several studies have been conducted on the water quality of the surface water of Herdsman Lake, the results of which are summarised below:

Nutrients and physical parameters

- In 1981 and 1983, Floreat Waters was recorded as having low oxygen concentrations and high concentrations of nutrients (ESRI 1983).
- Phosphorus concentrations in Floreat Waters and Industrial Lake were elevated in a study in 1989 and 1990 (Schmidt & Rosish 1993).
- Nitrogen concentrations are generally elevated and effected by seasonal variations and concentrations of chlorophyll *a.*
- Toxic cyanobacterial species *(Anabaena* and *Microcystis)* which are typical of thermally stable deep lakes with high pH and low CO_2 concentrations have been recorded.
- Drains entering the Lake have been identified as a major contributor of nutrients and algal blooms (Kobryn 2001).
- A high proportion of the nutrients entering the Lake were attached to suspended particles.
- Nutrients in groundwater were generally high, however the contribution of nutrients from groundwater was significantly lower than the contribution of nutrients from stormwater (Kobryn 2001).

Heavy metals

- High concentrations of zinc which exceed national guidelines have been detected in Floreat Waters and stormwater drains (ESRI 1983).
- The use of lead rich herbicides and insecticides was a significant source of lead to Herdsman Lake in the past. This has caused some of the soils to have lead concentrations that exceed 5000mg/kg (Merry *et al.* 1983*)*.
- Heavy metal concentrations in stormwater (particularly cadmium, copper, lead and zinc) entering the Lake are often elevated, exceeding national guidelines, and are mostly associated with suspended particles (Kobryn 2001).
- Lead concentrations in stormwater entering the Lake have been recorded at very high concentrations that exceed national guidelines (Kobryn 2001).
- Cadmium and Copper concentrations have been recorded at elevated concentrations in a few locations within the Lake.

- A large proportion of heavy metals entering the Lake through stormwater are being retained within the Lake (Kobryn 2001).

Suspended solids

- Herdsman Lake acts as a sedimentation basin, retaining the high concentrations of suspended solids being discharged into the Lake through the stormwater drains (Kobryn 2001).
- The most likely sources of Total Suspended Solids (TSS) to the drains and the Lake are septic tanks, illegal dumping, construction sites, road runoff, market gardens and nurseries.
- TSS inputs are high all year, with higher concentrations being recorded during rainfall events (Kobryn 2001).
- Contaminants, including heavy metals, nutrients and organic pollutants adsorb to the surface of particles and therefore high TSS concentrations often coincide with high pollutant loads.

Sediments

It is presumed that the sediments contain high concentrations of nutrients, heavy metals, pesticides and herbicides, based on the past landuses of the area and the current high level of these pollutants entering the Lake through stormwater drains. Therefore, an analysis of the sediment-water interactions would also be warranted.

These studies have all classified Herdsman Lake as nutrient rich, with the main contributors of pollutants (namely nutrients, suspended solids, heavy metals, pesticides and herbicides) originating from the several stormwater drains which discharge into the Lake. This pollutant load problem is then exacerbated by the fact that a large proportion of the surface water of the Lake now originates from stormwater inputs from these drainage channels. Therefore, management of the water quality of these drains would potentially provide the greatest benefit to the water quality of Herdsman Lake. Actions proposed by this plan to mitigate the effects of declining water quality at Herdsman Lake include:

- Develop and implement a water quality monitoring program for the catchment to determine the identity of the pollutants existing in and entering Herdsman Lake, and the major contributors of these pollutants to the system;
- Implement the Sustainable Landscaping Strategy to encourage the use of local native plant species in domestic and Council gardens, to prevent the overuse of fertilisers;
- Develop and implement fertiliser application plans for all parks and reserves within the catchment, to prevent the overuse of fertilisers and the subsequent leaching of nutrients to groundwater and/or runoff into the stormwater system;

- Develop and implement an acid sulphate soils management plan, to prevent any further acid sulphate soil activation and to manage current acid sulphate soil issues (including acidic groundwater flows);
- Implement the Swan Catchment Council's Regional Auditing program, to prevent the inappropriate disposal of industrial wastes;
- Incorporate Water Sensitive Urban Design principles to new developments and retrofit existing infrastructure to allow for greater groundwater infiltration, including options such as pervious paving, vegetated/grass swales and infiltration basins;
- Investigate the need for and construct stormwater treatment facilities including vegetated/grass swales, sedimentation ponds, gross pollutant traps and sediment traps in stormwater drains entering Herdsman Lake to reduce pollutant loads entering Herdsman Lake via stormwater;
- Develop and implement a community education strategy to reduce non-point sources of pollution to Herdsman Lake;
- Develop and implement a total water management strategy; and
- Apply the Keep Australia Beautiful Clean Sites Program to all new building projects within the catchment, to prevent inappropriate disposal of wastes from construction sites into the stormwater system.

These management actions are displayed in Tables 6 and 7 in Section 3.3

2.1.7 Acid Sulphate Soils

Acid sulphate soils occur naturally in many parts of the world. They are most common in waterlogged swampy environments, particularly near the coast, where peaty soils are formed. These peaty soils contain naturally occurring iron sulphide minerals, especially pyrite (FeS_2), and are benign if not disturbed or exposed to oxygen. However activities where the soils are exposed to oxygen, including dewatering for development, excavation and the lowering of the groundwater table, cause the sulphide minerals to oxidise and form sulphuric acid (H_2SO_4). Once formed, this acid can then flow into groundwater and move with the groundwater flow, causing acidic groundwater plumes. These peaty soils are also a rich store of nutrients, and the oxidation of these materials can cause high concentrations of nutrients to also be released into the groundwater flow.

Acidic groundwater has the potential to strip naturally occurring metals (particularly arsenic and aluminium) from the soil structure, converting them to a soluble form, which then enter the groundwater and travel with the groundwater flow. These metals can be toxic to aquatic life and are a serious public health issue. The acidic and contaminated groundwater can cause severe environmental and public health concerns, particularly at areas where groundwater is accessed by the public (including public bore water use), or at groundwater discharge points, including lakes, wetlands, rivers and drains. Acidic groundwater flows into wetlands can cause the death of aquatic flora and fauna, heavy metal contamination of the surface water, increased toxicity of certain heavy metals, and also the destruction of infrastructure such as boardwalks, signage and retaining walls. Once the peaty materials are oxidised and acid flows are established, the effects can be almost impossible to remediate.

As is evident in Figure 8, there are extensive areas of the Herdsman Lake catchment that have a high risk of acid sulphate soils or potential acid sulphate soils, less than 3m from the surface, including Herdsman Lake itself.

In December 2001, concern about the groundwater quality was raised by a local Stirling resident whose garden began to die after irrigation with groundwater. The Department of Environment was involved in taking several groundwater samples throughout the area to determine the cause. The results of the investigation indicated that the groundwater was extremely acidic and contained elevated concentrations of heavy metals, particularly arsenic. An intensive testing program was initiated in January 2002, which assessed a total of 802 domestic bores in the Stirling area. Of these, 49 showed low pH levels and were further tested for arsenic and heavy metal contamination. A further 22 bores were found to contain arsenic levels greater than the Australian drinking water guideline value of 7µg/L. In February 2002, 13 investigation bores were installed to ascertain the sources of the contamination. The results highlighted that the new adjacent residential developments on the Roselea and Hamilton Lakes (particularly the stockpiling of excavated peat) and the excavated wetlands at Spoonbill Reserve were the main sources of the contamination (Figure 8).

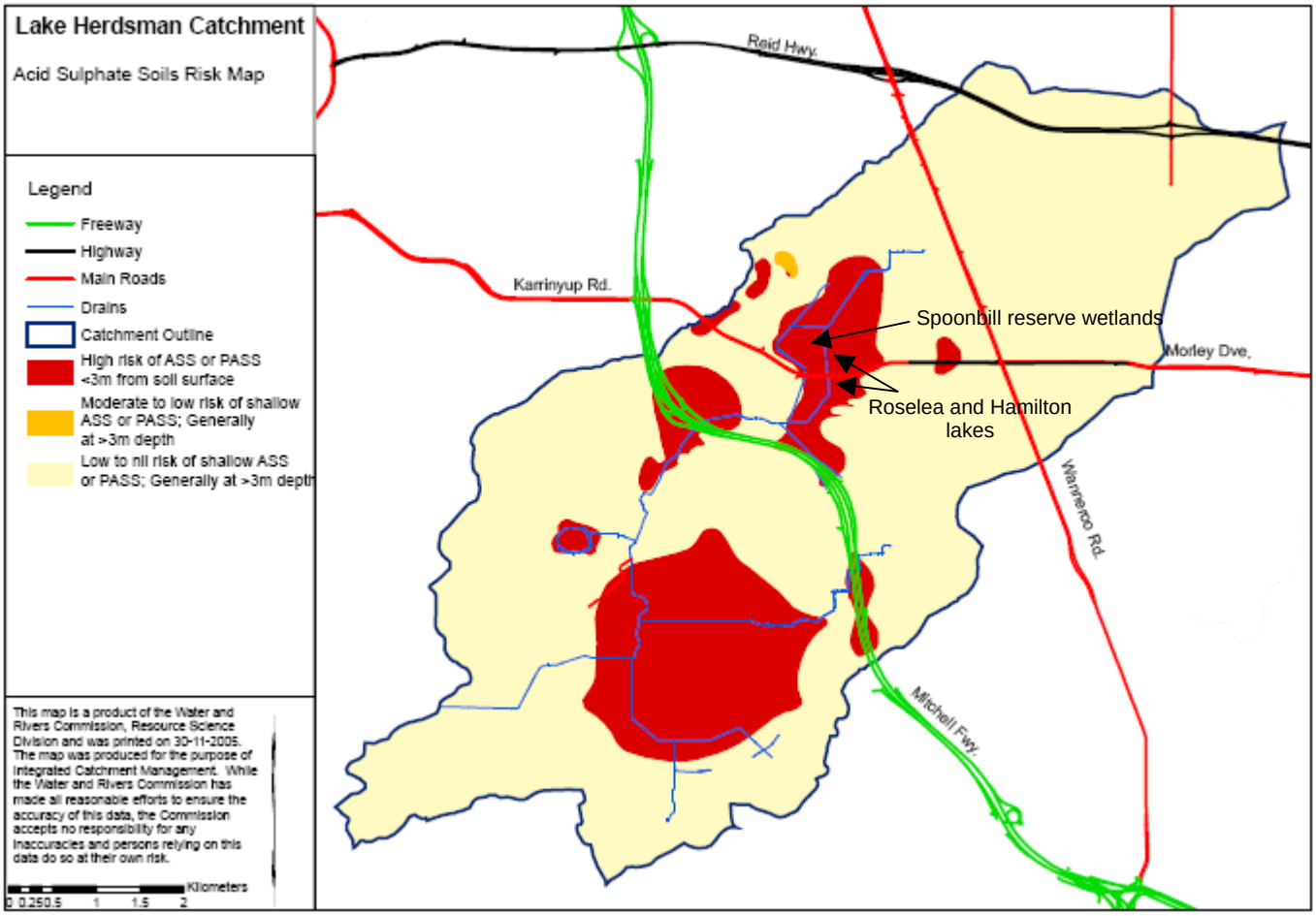

Figure 8: Acid Sulphate Soils Risk Map for the Herdsman Catchment
(Map supplied by the Department of Environment, 2006)

The analyses of groundwater down-gradient of the peat stock piles and excavated lakes indicated that the pH level between 3-5m depth was acidic but at 6-7m was equivalent to the background values (WRC 2002). In this case, the main cause of activating the potential acid sulphate soils to actual acid sulphate soils was dewatering, which was part of the residential development process and required the water table to be dropped by 6m to allow removal of the peat as it was not suitable as a housing foundation. This was further exacerbated when the sewerage infrastructure was installed. The peat that was stockpiled on the development site had high acid generation potential which was accelerated by a fire in the peat that smouldered for a three week period. The wetlands in the nearby Spoonbill Reserve were created by excavating soils to the water level and stockpiling the spoil into the centre of the lake. This exposed the soil to oxygen and initiated the acidification process (WRC 2002).

The effects of the drying climate and the lower than average water table in the area for the 2001/2002 period combined with these human activities have all been instrumental in the oxidisation of sulphide rich soils generating acid sulphate soils in the area (WRC 2002).

In addition to generating acidic groundwater flows and increasing heavy metal concentrations and toxicity in groundwater, the activation of acid sulphate soils also leads to several other problems, which are briefly outlined below.

1. Deoxygenation of iron monosulfide black oozes

Monosulfide black oozes (MBO's) form when dissolved iron and sulphate released from acid sulphate soils are discharged into an anoxic environment where there is a significant amount of organic material. Under anoxic conditions these MBO's provide a benefit to the environment by releasing bicarbonate ions which help to neutralise acidity. Many of the heavy metals co-precipitate with the MBO's reducing their toxicity in the water column for surface waters. The formation of iron sulphides also reduces the concentrations of soluble and hydrogen sulphides. However, when MBO's are exposed to oxygen, they release large amounts of acid and stored heavy metals that can continue to be released into the water column for decades. If disturbed *in situ* they can release 'blackwater' which is anoxic and has a very high oxygen demand, stripping oxygen from the surface water of lakes and wetlands.

2. Subsidence

Subsidence is generally triggered by urban drainage in peaty soils and can cause the land surface to drop by varying degrees on an annual basis. Acid sulphate soils have gel-like properties and low load bearing capacities, and therefore foundations built on these materials may settle or subside unevenly and slowly over time. Drainage of these areas is required to stabilise the land, however this is often a cause of activating the acid sulphate soils and leads to acidic drainage and further subsidence. Similar soils in Torbay (WA) are subsiding by 5mm per year. This has been identified as a problem throughout the Herdsman Lake catchment area, due to the large area of acid sulphate soils and potential acid sulphate soils in the catchment.

3. Swelling and Heaving

The oxidation of pyrite creates minerals such as gypsum, which occupies a larger volume that the pyrite in the soil structure. This can create an expansion force that is capable of cracking concrete and lifting house pads, roads and other stable structures.

4. Chemical Attack

When pyrite oxidises it produces sulphuric acid, which weakens the structure of concrete and cement products. This strong acid has been shown to attack any infrastructure that comes into contact with it, including roads, retaining walls, fences and concrete pylons.

Acid sulphate soils have been identified as a major problem throughout the Herdsman Lake catchment area, and therefore need to be carefully managed to reduce the impact that current acid sulphate soil areas are having on the environment and also to prevent potential acid sulphate soil areas from activating. Actions proposed by this plan to effectively manage these areas include:

- Ground-truth the current acid sulphate soil/potential acid sulphate soil risk maps;
- Develop and implement an acid sulphate soil management plan for the Herdsman catchment to prevent any further acid sulphate soil activation and to manage current acid sulphate soil issues. This plan should also include remediation and management options for identified sites and also for the effects of acid sulphate soils (chemical attack, subsidence, MBO's and heavy metal contamination);
- Develop a remediation plan for acidic surface waterbodies;
- Assess the degree of disturbance of swelling, heaving and subsidence;
- Develop and implement a water quality monitoring program to determine the identity of pollutants existing in and entering Herdsman Lake (including acid sulphate soil related pollutants) and identify the major contributors of these pollutants to the system (hotspots);
- Develop techniques to reduce the exposure of MBO's and/or the release of blackwater;
- Incorporate the assessment of acid sulphate soils/potential acid sulphate soils into all City of Stirling planning approvals.

These actions are outlined in Table 7 in Section 3.3.

2.1.8 Biodiversity

2.1.8.1 Vegetation

Most of the vegetation in the Herdsman Lake catchment area was cleared following European settlement for agricultural purposes, and residential, commercial and industrial development. Prior to European settlement in the Osborne Park district, low areas were occupied by swamps while higher in the topography, sandy loams supported Jarrah, Marri, Banksia, Tuart, Zamia palm and Grass trees (Easton 1971). Areas of remaining bushland and native vegetation are displayed in Figure 9 below.

Apart from the City of Stirling's parks and reserves within the catchment, very few remnant native vegetation areas remain. The exceptions to this include bushland in the Hale School grounds at Wembley Downs, Tuscany Way and Newman College/Edith Cowan University in Churchlands, plus a City of Stirling reserve south of Churchlands Senior High School. Another significant area containing remnants of original vegetation is the Wembley Golf Complex (within the Town of Cambridge).

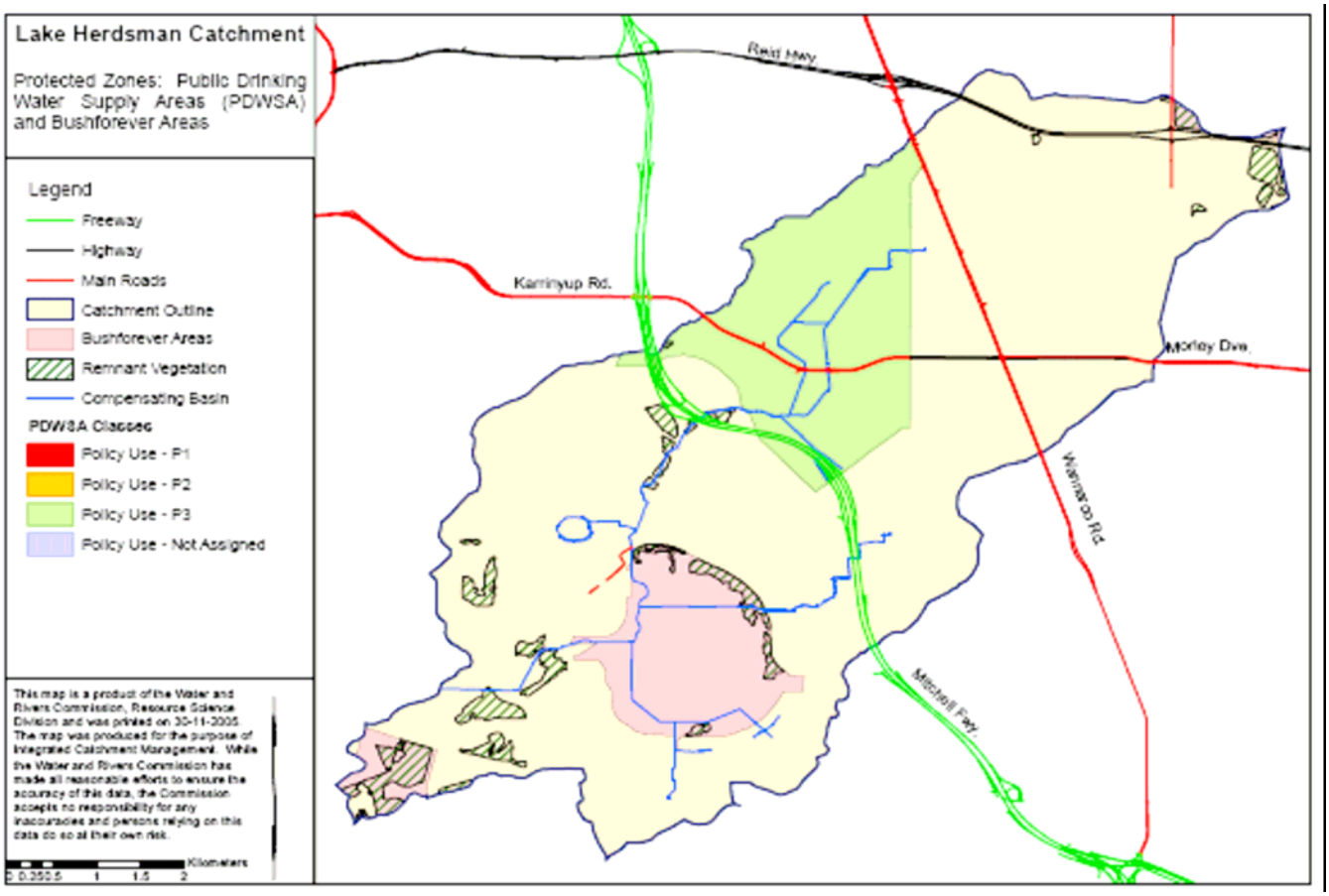

Figure 9: Bushforever Areas and Remnant Vegetation in the Herdsman Lake Catchment
(Map supplied by the Department of Environment 2006)

The vegetation of Herdsman Lake has changed drastically since European settlement. Currently the lake includes several open water sections with fringing rushes and paperbarks (*Melaleuca rhaphiophylla*), swamp banksia (*Banksia littoralis*) and flooded gum (*Eucalyptus rudis*) with understorey shrubs (CALM 2004).

The three vegetation types associated with Herdsman Lake can be broadly described as:

- Upland vegetation: Most has been removed and is now characterised by areas of open parkland with isolated remnant trees (CALM 2004).
- Wetland vegetation: There is little of this original vegetation left. The *Baumea articulata* and *Schoenoplectus validus* sedgeland communities are threatened by *Typha orientalis*. The *Typha* community is the most dominant and extensive, forming a monoculture. There are small pockets of original woodland communities which includes the *Melaleuca rhaphiophylla* community which is typical of the type of vegetation that would have existed across the wetland (CALM 2004).
- Aquatic flora: Species listed are fennel pondweed (*Potomogeton pectinatus*) and the prickly water nymph (*Najas marina*) plus a mixture of planktonic, benthic and filamentous algae (CALM 2004).

There are no CALM declared rare flora or threatened ecological communities within the Herdsman Lake Regional Park boundary.

The vegetation of the Herdsman Lake catchment area is fragmented, degraded and under pressure from increasing urbanisation and public use. Much of the reserve around the Herdsman Lake has been cleared for public open spaces and parklands, with only minimal fringing vegetation remaining that is generally highly degraded and infested with weeds. Weed control and revegetation works have been undertaken in some sections within the Herdsman Lake Regional Park, with some areas showing improvement in bushland quality and biodiversity values. This vegetation is also under pressure from declining water tables, declining water quality, and increased public use and the associated impacts. The threats to the remaining vegetation within the reserve around Herdsman Lake are listed below.

1. Water quantity and quality

Wetland vegetation can be effected by declining water quality, particularly increasing acidity and increasing heavy metal concentrations, which can be toxic and cause vegetation deaths. Outbreaks of cyanobacteria, which can be attributed to increased nutrient concentrations in the surface waters of the Lake, are relatively common during late summer and represent a significant threat to the local aquatic flora of the Lake (CALM 2004).

Most of the vegetation within the reserve around Herdsman Lake is groundwater dependant, meaning that as groundwater levels decline, vegetation dependant on that groundwater will become stressed and begin to die. Also, as discussed previously in Section 2.1.5.1 (Water Quantity and Groundwater Levels) the vegetation of the Herdsman Lake Regional Park is dependant upon the water levels in the Lake and vegetation communities will be severely impacted upon following significant changes in these water levels.

Actions developed to manage water quantity and water quality are outlined in Sections 2.1.5.1 (Water Quantity and Groundwater Levels) and 2.1.6 (Water Quality), and are displayed in Table 6 of Section 3.3.

2. Weeds

Weeds modify natural processes, resulting in the decline of the native communities they invade. Weeds are a major problem in the Herdsman Lake Regional Park and require immediate action by the managing agencies. The invasion of weeds is a major threat to the conservation values of the Park and it is vital that measures are introduced to limit or control the degradation process (CALM 2004).

Sources of weeds to the Herdsman Lake Regional Park include (CALM 2004):

- Past landuses;
- Soil disturbance;
- Construction of paths and other facilities or drainage channels which allow weeds to establish;
- Frequent fires;
- Drainage outlets that carry stormwater from adjoining weed infested areas;
- Dumping of garden refuge and aquarium contents; and
- Grasses planted for amenity purposes in parklands invading wetland areas.

Weeds in the Herdsman Lake Regional Park can also originate from exotic plants in gardens throughout the catchment area and through seeds being dispersed from other weed infested areas by birds and the wind.

The Herdsman Lake Regional Park Weed Control and Revegetation Plan (Regeneration Technology 2002) identifies the following as priority weed species which impact upon the ecology and visual amenity of the Park:

Common name	Botanical name
Arum lily	*Zantedeschia aethiopica*
Blackberry nightshade	*Solanum nigrum*
Buffalo grass	*Stenotaphrum secundatum*
Bulrush	*Typha orientalis*
Cape lilac	*Melia azedarach*
Couch grass	*Cynodon dactylon*
Flame tree	*Erythrine sykesii*
Geraldton carnation weed	*Euphoriba terracina*
Giant reed	*Arundo donax*

Common name	Botanical name
Great Brome	*Bromus diandrus*
Hares tail grass	*Lagurus ovatus*
Japanese pepper	*Schinus terebinthifolia*
Kikuyu grass	*Pennisetum clandestinum*
Pampas grass	*Cortaderia selloana*
Perennial veldt grass	*Ehrharta calycina*
Poplars	*Populus alba*
Rose Pelargonium	*Pelargonium capitatum*
Willow tree	*Salix babylonica*

The aquatic weed Salvinia (*Salvinia molesta*) has also been observed within the Herdsman Lake Regional Park. This is recognised as a declared plant (Priority 1 and Priority 2) by the Department of Agriculture (Department of Agriculture and Food 2006).

Although these weeds are impacting upon the ecology of Herdsman Lake Regional Park, it is important to note that some species (particularly *Typha orientalis*) cover vast areas and provide valuable habitat for local fauna. Therefore, all works to remove these weeds should be undertaken in such a way to ensure that these habitats are maintained throughout the weed removal process, by removing the weed species at a gradual rate, and replacing them with a native species.

Actions proposed by this plan to control and manage the weed problem at the Herdsman Lake Regional Park include:

- Implement the CALM Herdsman Lake Regional Park Weed Control and Revegetation Plan to control weed growth and improve the biodiversity of the Herdsman Lake Regional Park;
- Develop and implement a biodiversity strategy for the catchment;
- Develop and implement a community education strategy to prevent the dumping of weeds/garden wastes and debris;
- Develop and implement a weed control and revegetation plan for the parks and reserves within the catchment area;
- Actively manage remnant vegetation across the catchment to prevent further fragmentation and enhance biodiversity and functionality; and
- Implement the Sustainable Landscaping Strategy for the catchment, in order to encourage the establishment of native gardens throughout the catchment area and to prevent the planting of potential environmental weeds.

These actions are displayed in Table 5 in Section 3.3

3. Urban interface and uncontrolled access

Inappropriate clearing of vegetation and wilful damage to vegetation in upland areas in the reserve around Herdsman Lake has been a problem in the past (CALM 2004). Much degradation can be caused by inappropriate use of the reserve by the public, including vandalism, dumping of rubbish and garden wastes, uncontrolled access (leading to trampling and vegetation destruction) and littering. Dog excreta being left on paths throughout the Regional Park and its catchment has also been identified as an issue at the Herdsman Lake Regional Park.

Actions proposed by this plan to manage urban interface and uncontrolled access issues in the Park are detailed in Table 5 in Section 3.3, and include:

- Facilitate appropriate human access infrastructure (including fencing of sensitive areas, provision of paths and bins) throughout the Regional Park; and
- Develop and implement a community education strategy to increase the community awareness and appreciation of the Herdsman Lake Regional Park, leading to reduced incidences of dumping, vandalism, trampling of vegetation and littering.

4. Fire

Wildfire is a significant threat within the Herdsman Lake Regional Park (CALM 2004). Fires can threaten biodiversity, human life, property and cultural values. Fires at Herdsman Lake have decreased following the development of the surrounding residential areas and the construction of the moats.

Fire at Herdsman Lake is considered undesirable due to the poor adaptation of wetland vegetation, as frequent fires will prevent the establishment of paperbark vegetation and lead to an even greater dominance of *Typha orientalis* (CALM 2004). Of considerable concern are fires in areas of the Park with heavy infestations of *Typha orientalis*, as fires in these areas are difficult to control, promote the growth of the *Typha,* and can cause severe damage to fringing vegetation (CALM 2004). Wildfires in the Herdsman Lake Regional Park need to be quickly controlled. A fire response plan has been developed by CALM in conjunction with FESA and the City of Stirling to ensure effective response to unplanned fire by the responsible agencies and outlines practices such as (CALM 2004):

- Fire control actions and strategies that protect environmentally sensitive areas from unplanned fire;
- Undertaking pre-suppression activities including reducing fuel loads by moving or slashing large open grassed areas (while taking care not to damage native vegetation);
- Maintaining a fire record system of all fires in the Park, including date and cause; and

- Ensuring the effective network of firebreaks is maintained.

Actions proposed by this plan to reduce the occurrence of fires at the Herdsman Lake Regional Park are displayed in Table 5 in Section 3.3. These include:

- Implement the CALM Herdsman Lake Regional Park Weed Control and Revegetation Plan, to reduce fuel loads and improve biodiversity;
- Develop and implement a community education strategy to increase community awareness and appreciation of the Herdsman Lake Regional Park, reducing the number of arson events; and
- Implement the existing CALM fire response plan.

5. Disease

Phytophthora dieback refers to the deadly introduced plant disease caused by *Phytophthora cinnamomi* (DWG 2005) and is considered to be a significant threat to a number of vegetation communities on the Swan Coastal Plain (CALM 2004). Phytophthora dieback spends its entire life in soil and plant tissues and attacks the roots of plants, causing them to rot and limiting their water and nutrient uptake, usually resulting in death (DWG 2005). When Phytophthora dieback spreads to bushland, it kills many susceptible plants, resulting in a permanent decline in the diversity of the bushland, the alteration of the composition of the bushland (increased number of grasses and decreased number of shrubs), and a subsequent reduction in the abundance and diversity of the native animals that rely on susceptible plants (DWG 2005).

Human activity causes the most significant, rapid and widespread distribution of the pathogen. Construction, earth moving, driving infected vehicles on bush roads, human access to infected and non-infected areas, bush restoration projects and stock movement can all contribute to spreading of the pathogen (DWG 2005).

No sampling for Phytophthora dieback has been undertaken within the Herdsman Lake Regional Park and the risk of Phytophthora dieback at Herdsman Lake is relatively low, as existing plant communities in the park have few susceptible upland species (eg, jarrah, banksia and grasstrees) (CALM 2004). The risk of Phytophthora dieback can be reduced by modifying activities that spread the pathogen, or controlling access to high priority areas (CALM 2004) and ensuring service vehicles entering the Regional Park are clean and are not carrying soil from others areas which may be effected by the disease.

Phytophthora dieback is the most common disease on the Swan Coastal Plain, however other diseases may also become prevalent in the future.

Actions proposed by this plan to prevent the spread of Phytophthora dieback in the Herdsman Lake Regional Park, and to identify and control outbreaks of other diseases include:

- Identify and manage infected areas throughout the catchment, to identify diseased areas and prevent infections spreading; and
- Develop and implement an infectious disease management strategy including a monitoring system for future outbreaks throughout the catchment.

2.1.8.2 Fauna

The decline in the species diversity of fauna within the Herdsman Lake Regional Park reflects the history of habitat clearance. Loss of native habitat around the park has had significant impacts on the fauna. The continued degradation and fragmentation of the remaining habitat are the main threats to fauna which are attributed to:

- Weeds;
- Fire;
- Changing water levels and water quality;
- Competition and predation by introduced animals and pests; and
- Inappropriate human use and recreation activities.

A brief description of the fauna types typically found at the Herdsman Lake Regional Park is provided below.

1. Avian fauna

Birds Australia have recorded the presence of 107 species of birds at Herdsman Lake through recent surveys, and the Gould League of Western Australia has confirmed 162 species recorded since 1929 (CALM 2004).

Curry (1981, CALM 2004) found that there is an abundance of bird species at Herdsman Lake, resulting largely from the variety of habitats available. These habitats include:

- Deep open water (approximately 1.5 - 2.5m in depth);
- Shallow water and seasonally inundated areas (including mud flats and sedge lands);
- Grassy banks of drains and the exposed sandy shorelines;
- Dense stands of rushes; and
- Established trees.

Two species which occur are listed as specially protected - the Australasian bittern (*Botaurus poiciloptilus*) and the Peregrine Falcon (*Falco peregrinus*), with the Freckled Duck (*Stictonetta Naevosa)* being listed as threatened. Also, a number of migratory birds are listed under the Japan-Australia Migratory Birds Agreement (JAMBA) and the China-Australia Migratory Birds Agreement (CAMBA). At least 20 species of waterbirds breed at Herdsman Lake including three species which are rarely found breeding in the southwest of Australia. The presence of some other species is also considered important.

Ten species of birds of prey have been observed and numerous insectivores.

2. Terrestrial and aquatic fauna

- Mammals: Apart from bats, which may be present, no native mammals have been observed at Herdsman Lake since the late 1960's (CALM 2004). However, anecdotal evidence suggests that Brushtailed possums may still be utilising the area, as there have been sightings of the possums in roof spaces in the residential area adjacent to the Lake.
- Reptiles and Amphibians: There are several reptile species at Herdsman Lake with the Mourning Skink (*Egernia luctuosa*) considered significant (CALM 2004). The Oblong Tortoise and Tiger Snakes have also been noted. In 1989, a study recorded 11 species of lizards at the Lake, including Gould's Sand Goanna *(Varanus gouldii*), the marbled gecko (*Christinus marmoratus*) and the bobtail skink (*Tiliqua rugosa*) (Maunsell & Partners 1989). Six species of frogs have been recorded (CALM 2004).
- Fish: Three species of fish have been recorded of which one, the Swan River Goby (*Pseudogobius olorum*), is native. The introduced species include the Mosquito Fish (*Gambusia holbrooki*) and the Goldfish Carp (*Carassius auratus*). The Mosquito fish is an aggressive species and has most likely contributed to the decline of native fish, amphibians and aquatic invertebrates (CALM 2004).
- Invertebrates: There is little data on terrestrial invertebrates although numerous species are expected to occur. The introduced Argentine ants are a problem which may have an impact on other ant species and perhaps other invertebrates (CALM 2004). A study conducted in 1986-87 highlighted that when compared to other wetlands on the Swan Coastal Plain, the variety of species of aquatic macroinvertebrates of Herdsman Lake was intermediate (Clark, Davis & Murray 1990). It lacked two of the largest groups of predatory insects, *Odonata* (dragonflies and damselflies) and *Coleoptera* (beetles). It was suggested that this is a reflection of the aquatic food chain and also an indicator of wetland health (CALM 2004). Recent anecdotal evidence suggests that aquatic invertebrates which are sensitive to water quality (particularly the dragonfly and damselfly larvae's) have been recorded at the Lake, however their current abundances are unknown.

Surveys may be necessary to determine the status of fauna within remnant bushland away from Herdsman Lake. Surveys should initially concentrate on the larger bush remnants such as Hale School, the reserve south of Churchlands Senior High School, Tuscany Way and Newman College/Edith Cowan University School and Wembley Golf Complex. This is especially important if there has been little or no surveys conducted previously.

The fauna of the Herdsman Lake catchment area has been significantly impacted upon following European settlement and wide-scale clearing of the catchment area. Today, much of the fauna remaining throughout the catchment and at the Herdsman Lake Regional Park is under increasing pressure from loss of habitat through clearing, degradation of natural areas (weeds, poor water quality, fire) and human influences/inappropriate human use of the area.

These threats are discussed in greater detail in the previous section (2.1.8.1 Vegetation). Native fauna are also under threat from introduced species, including the mosquito fish and feral bees, road deaths by vehicles, and through attacks and disturbances from domestic animals (cats and dogs).

Actions proposed by this plan to combat these threats and improve the biodiversity of fauna at Herdsman Lake include:

- Enforce the Cat Control local law and the Dog Control local law;
- Implement the CALM Feral Bee control policy;
- Investigate and implement fauna underpasses/fencing or other options, incorporating native animal friendly design for new road construction or road extensions throughout the catchment;
- Implement the CALM Herdsman Lake Regional Park Weed Control and Revegetation Plan to control weed growth and improve the biodiversity of the park;
- Develop a biodiversity strategy for the catchment area;
- Implement the Sustainable Landscaping Strategy to encourage the use of local native plant species in domestic and Council gardens, to provide some habitat for native animals and prevent the use of potential environmental weeds in gardens;
- Develop and implement a community education strategy, to increase community understanding and appreciation of the area, including the native wildlife; and
- Facilitate appropriate human access to the Herdsman Lake Regional Park (ie, paths, bins, fencing).

2.2 Socio-economic characteristics of the Catchment

2.2.1 Aboriginal heritage

Aboriginal people used the resources of Herdsman Lake and its catchment area for at least 5,000 years before European settlement in Western Australia and, similar to other wetlands on the Swan Coastal Plan, Herdsman Lake has important spiritual significance (CALM 2004). “Ngurgenboro” is the Aboriginal name for Herdsman Lake and it was most likely used as a food and water source.

There are a number of ethnographical and archaeological sites in the area pertaining to mythological and ceremonial sites associated with natural features such as wetlands and burial sites (Butler 2006). Sites registered as significant with the Department of Indigenous Affairs are displayed below (Butler 2006):

- 3159
- 3158
- 3161
- 3208
- 3209
- 3210
- 1207
- 4405
- 3234
- 3756
- 3185
- 3164
- 3318
- 21537
- 21538
- 20178

All public works proposed to be undertaken at Herdsman Lake or throughout its catchment area are required to be submitted to representative Aboriginal bodies, registered native title bodies (corporate) and registered native title claimants for CALM managed land/waters, for comments (CALM 2004). A ‘public work’ includes buildings, structures which are fixtures, roads, bridges, wells, bores and major earthworks (CALM 2004). Additionally, notification is required for the preparation of management plans in the same manner as for public works.

2.2.2 European heritage

The first known European activity in the catchment area occurred in 1854 when a group of Benedictine monks were granted a large tract of land and built a monastery on Lake Monger. By the 1900’s the area around Herdsman Lake was owned by the Roman Catholic Church and used mainly for stock grazing. In 1903 Osborne Park was subdivided and the area made accessible by the construction of tramlines from Main Street to Royal Street and from Oxford Street along Scarborough Beach Road. In 1912 the area was made suitable for market gardening by draining swampy areas into Herdsman Lake.

After the First World War, the land around Herdsman Lake was sold to the Returned Soldiers League as part of a settlement scheme. An extensive drainage system was installed between 1912 and 1925 and further land was released for sale. However due to the poor soil quality and the propensity to flooding the area was never fully developed (Blyth and Halse 1986).

In 1921 Osborne Park was established as a permanent settlement and by the 1950's had become an industrial area. The State Housing Commission was instrumental in opening areas for residential development from the 1900's into 1960's with the settlement of Churchlands, Wembley Downs and Woodlands. The catchment was progressively urbanised throughout the late 1990's with the total land area being fully allocated to various landuses.

In 1955 the Stephenson and Hepburn Report was released and it recommended that Herdsman Lake and the surrounding area be reserved for parks and recreation. This was subsequently implemented in the 1963 Perth Metropolitan Region Scheme (MRPA 1976). In the following years several plans were released that built upon those recommendations and looked at the improvement of Herdsman Lake and the surrounding area. The deep water lakes that enclose the wetland and act as a moat were constructed through mining operations with the intention of providing fill for the adjacent real estate developments and to provide protection to the central wetland. Due to the deepness and open nature of the lakes they have also provided an alternative habitat for bird life. In 1998 the land tenure for Herdsman Lake was transferred to the Department of Conservation and Land management who published the 'Herdsman Lake Regional Park Draft Management Plan 2001-2011' (CALM 2001), followed by the final 'Herdsman Lake Regional Park Management Plan 2004-2013' (CALM 2004) which deals with the management of the area contained within the regional park boundary.

2.2.3 Community values

The Swan Region Strategy for Natural Resource Management (2004) was developed by the Swan Catchment Council following an extensive community consultation process, to identify the environmental values of the community within the Swan Region. The consultation was conducted through the sub-regional catchment groups of the Swan Region, and involved representatives of key environmental organisations, local governments and the community. From this regional consultation process, community values and environmental targets were developed as well as the threats perceived by the community to those values.

The Swan Region Strategy developed three tiers of targets:

- Aspirational targets – 50 years;
- Resource Condition Targets – 10-20 years, and
- Management Action Targets – 0-5 years.

These targets are detailed in the Swan Region Strategy (2004). The community values identified through the Swan Region Strategy have been applied on both a regional and local level in the development of environmental management plans.

In developing the Herdsman Lake Integrated Catchment Management Plan, NMCG used a similar community consultation process to identify local community values, specifically associated with the Herdsman Lake and its catchment.
NMCG hosted a Community Consultation workshop with representatives from a wide range of stakeholder groups. The outcomes of this workshop provided the

values, threats and assets of Herdsman Lake, which formed the basis of this ICM plan. Details of the Community Consultation workshop are discussed in Section 3.1 (Preparation of the Herdsman Integrated Catchment Management Plan – Stakeholder involvement and community consultation). Through the Community Consultation Workshop, community values were identified as predominantly:

- Local knowledge;
- The Indian ocean;
- Groundwater, lakes and wetlands;
- Open spaces;
- Cultural heritage;
- Aesthetics;
- Community;
- Employment;
- The commercial area;
- Biodiversity;
- Residential housing;
- Drainage, sewage and industrial infrastructure; and
- Roads.

The community consultation identified the following as the main threatening processes to Herdsman Lake:

- Inappropriate drainage design and management;
- Climate change;
- Activation of acid sulphate soils;
- Urbanisation;
- Recreational use;
- Inappropriate land use;
- Inappropriate planning;
- Pollution;
- Biological threats – diseases and introduced species;
- Current and historical pesticide use;
- Fire; and
- Road deaths of fauna.

These values, threats and issues have been used by NMCG to develop the Herdsman Lake Catchment Management Plan, and are listed, together with specific goals/objectives, targets, priorities, responsibilities and key performance indicators in Section 3.0.

2.3 Existing and relevant legislation, policies, strategies, plans and recommendations

Table 2 below provides a comprehensive list of International, Federal, State, Regional and Local policies, strategies, plans and recommendations that support the strategies and actions within this document.

Appendix 2 provides further information on these plans which are particularly relevant to Herdsman Lake, summarising the recommended new plans and policies that need to be developed, and existing plans and policies relevant to Herdsman Lake that need to be implemented.

Table 2: International, Federal, State, Regional and Local legislation, policies, strategies, plans and recommendations applicable to the Herdsman Lake catchment

International, Federal, State, Regional and Local legislation, policies, strategies & plans
INTERNATIONAL
Japan Australia Migratory Birds Agreement (Australian Treaty Series 1981 No.6)
China Australia Migratory Birds Agreement (Australian Treaty Series 1988 No.22)
FEDERAL
National Action Plan for Salinity and Water Quality (2000)
Towards Sustainability: Achieving Cleaner Production in Australia (1998)
National Greenhouse Strategy
National Local Government Biodiversity Strategy (1999)
National Weeds Strategy: A Strategic Approach to Weed Problems of National Significance
National Water Quality Management
Environment Protection and Biodiversity Conservation Act (1999)
National Framework for the Management and Monitoring of Australia's Native Vegetation (2000)
National Strategy for the Conservation of Australia's Biological Diversity
STATE
Western Australian Greenhouse Strategy "Draft" (2003)
Western Australian State of the Environment Report. Environmental Protection Authority, Perth (1998)
Government Response to the State of the Environment Report. Government of Western Australia (1998)
Agriculture and Related Resources Protection Act
State Weed Plan. Department of Agriculture (2001)
Urban Water Management Strategy
Bike Ahead: Bicycle Strategy for the 21st Century (1995)
Contaminated Sites Act
Environmental Protection Act (1986)
Proposed Amendments to the Environmental Protection Act for the Protection of Native Vegetation in Western Australia
Health Act (1911)
Local Government Act (1995)
Town Planning and Development Act (1928)
Wildlife Conservation Act (1950)
STATE (continued)
Western Australian Planning Commission Act
Western Australian State Sustainability Strategy
State Water Quality Management Strategy
Statement of Planning Policy No 2: Environment and Natural Resources Policy
Soil and Land Conservation Act (1945)

International, Federal, State, Regional and Local legislation, policies, strategies & plans
Aboriginal Heritage Act (1972)
Native Title Act (1993)
Wetland Conservation Policy for Western Australia (1997)
Conservation and Land Management Act (1984)
Herdsman Lake Regional Park Management Plan 2004-2013 (2004)
REGIONAL
Swan Region Strategy for Natural Resource Management (draft). Swan Catchment Council (2004)
Swan Canning Clean-Up Action Plan
Perth Metropolitan Transport Strategy 1995-2029
Implementation of Perth's Air Quality Management Plan
Riverplan: An Environmental Management Framework for the Swan and Canning Rivers
Local Government Biodiversity Planning Guidelines for the Perth Metropolitan Region. Perth Biodiversity Project – Western Australian Local Government Association (2004)
Bush Forever 2000. Western Australian Planning Commission
Caring for the Canning Management Plan (2001)
Swan River Trust Act
Environmental Protection (Swan and Canning Rivers) Policy (1998)
Local Government Natural Resource Management Policy Development Project. Swan Canning Clean-Up Program
LOCAL
Dog Control and Cat Control local laws
Green Plan
Local Planning Strategy (DRAFT)
Wetlands Protection Policy (DRAFT)
Local Environmental Strategy (In progress)

3.0 The Integrated Catchment Management Plan

3.1 Preparation of the Herdsman Lake Integrated Catchment Management Plan – Stakeholder involvement and community consultation

Community input into the Herdsman Lake Integrated Catchment Management Plan was facilitated through the formation of a working group, with members who were selected from key stakeholder groups. A number of stakeholders participated in this process, including representatives from:

- City of Stirling;
- Town of Cambridge;
- Sub-regional catchment groups;
- Water Corporation;
- Sherwood Overseas Pty Ltd;
- Department of Environment and Conservation (formerly the Department of Environment and the Department of Conservation and Land Management);
- WA Gould League;
- Herdsman Lake Regional Park Community Advisory Committee;
- Community groups;
- Swan Catchment Centre; and
- Murdoch University.

Key stakeholders from the business community were also invited to be involved in this workshop, however chose not to participate. It is recommended that the business community is consulted further, prior to the implementation of any recommended strategies (where relevant).

In April 2005, working group members attended a catchment tour followed by a workshop to identify the assets and threats within the catchment area. The outcomes from the workshop are displayed in Appendix 1 and these form the basis of the ICM plan strategies and recommendations.

During the catchment tour, acid sulphate soils were identified as a major concern and this was further supported by the workshop outcomes. As a result of this, a second catchment tour was held in July 2005. The invitation list was extended to include City of Stirling Councillors and staff, members of the wider community and acid sulphate soil experts from the Department of Environment. This tour more closely investigated the acid sulphate soils problem areas throughout the Herdsman Lake catchment area and provided working group members with an excellent understanding of one of the major problems facing the Herdsman Lake catchment.

NMCG also undertook specific consultation with the Herdsman Lake Regional Park Community Advisory Committee, seeking comment during the development stages of the Vision and Strategies Tables and on the draft document.

The outcomes from the Community Consultation workshop and feedback from the working groups are displayed in Tables 9 – 12 and Figure 10 in Appendix 1.

3.2 Vision for the Herdsman Lake Catchment

The vision for the Herdsman Lake Integrated Catchment Management Plan was developed as part of the community consultation process and agreed to by all working group members.

The Vision for the Herdsman Lake catchment is:

"That the activities in the catchment will protect and enhance the biodiversity, water quality and ecological function of the area and support the educational and environmental values of Herdsman Lake".

3.3 Management Strategies

A number of strategies have been developed to manage the issues and threats faced by Herdsman Lake. These issues and threats have been discussed in detail in Section 2.0 and were identified through the community consultation workshop.

Tables 4 – 8 were developed by the staff at the North Metro Conservation Group, which were later commented on by members of the Herdsman Lake Regional Park Community Advisory Committee and working group members from the Community Consultation Workshop. The issues displayed in the tables were developed by the working groups, through the Community Consultation process, and each issue has a specific target and action required to remediate the issue. Key Performance Indicators (KPI's) are also included in the tables, so that some indication of success or progress of the strategies can be documented.

The suggested timing of each of the actions listed for each issue are conveyed through the Priority rating. Those actions with a High priority rating are recommended to be completed within 0-5 years. Those actions with a Medium priority rating are recommended to be completed within 5-10 years, and those with a low priority rating are recommended to be completed within 10-15 years. The success of each of the actions can be determined using the key performance indicators.

For each strategy recommended in the following tables, it is expected that the responsible organisation/s will include relevant stakeholders to implement the strategy successfully. Stakeholders include (where applicable) private landholders, the business and industrial community, schools, universities, community groups and the general public. For each of the actions in the Strategy tables, a list of responsible agencies is included under the 'Responsibility' column, with the lead agency being highlighted in Bold text.

Refer to Table 3 for an explanation of the abbreviations used in the strategy tables.

Table 3: Abbreviations used in the Strategy tables.

Abbreviation	Meaning
ASS	Acid Sulphate Soils
BMP	Best Management Practice
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CoS	City of Stirling
DEC	Department of Environment and Conservation (formerly Department of Environment and Department of Conservation and Land Management)
DoW	Department of Water
DPI	Department of Planning and Infrastructure
EWP	Environmental Water Provision
GPT	Gross Pollutant Trap
KPI's	Key Performance Indicators
MR	Main Roads
PAH	Polycyclic Aromatic Hydrocarbons
PASS	Potential Acid Sulphate Soils
PL	Private Landowners
Priority H	High priority – should be implemented within 0-5 years
M	Medium priority – should be implemented within 5-10 years
L	Low priority – should be implemented within 10-15 years
SCC	Swan Catchment Council
ST	Sediment Trap
TPH	Total Petroleum Hydrocarbons
TSS	Total Suspended Solids
UDR	Unauthorised Discharge Regulation
WAPC	Western Australian Planning Commission
WC	Water Corporation
WSUD	Water Sensitive Urban Design

The management strategies displayed in Tables 4 to 8 propose the development and implementation of several new plans/strategies, in order to remediate the effects of the identified issues. A brief description of each of these new plans/strategies is provided below:

1. Acid Sulphate Soils Management Plan

This plan will identify and assess the extent of the acid sulphate soils risk area throughout the catchment area, and determine suitable measures for the remediation of activated areas and the management of undisturbed acid sulphate soils areas to prevent activation.

2. Biodiversity Strategy

A Biodiversity Strategy is an over-arching strategy providing for the retention, protection and management of existing natural areas throughout the City of Stirling. Each natural area in the City of Stirling will be assessed for its biodiversity value and assets using the Perth Biodiversity Project (PBP) templates. The biodiversity strategy will then provide a ranking of all of the natural areas which were assessed, based on these biodiversity values, thus allowing the City of Stirling to prioritise funding and on-ground works to the most important areas. The biodiversity strategy therefore provides a more effective and efficient method of protecting and enhancing the biodiversity of the area.

3. Community Education Strategy

The environmental degradation of Herdsman Lake Regional Park (including Herdsman Lake) can be caused indirectly by the community through non-point source pollution throughout the catchment area and inappropriate recreational use of the area. A community education strategy should be developed to cover all aspects of human use impact on the Regional Park (including the lake). This strategy should be catchment-scale and aim to increase community understanding, appreciation and involvement in the area and work towards evoking positive behavioural changes. This strategy should provide methods and actions in order to prevent the following problems:

- Arson events;
- Feeding of native animals;
- Inappropriate recreational use of the park, including littering, trampling of vegetation and uncontrolled dogs;
- Vandalism;
- Illegal dumping of rubbish and debris;
- Nutrient and other pollutant export from residential properties; and
- Overuse of groundwater.

4. Fertiliser Application Plans

These plans should be implemented for all parks and reserves in the catchment area. These plans should identify management actions required to provide for the better management of parks and reserves in order to reduce fertiliser use in these areas (and subsequent nutrient run-off and groundwater infiltration).

5. Infectious Disease Management Strategy

This strategy should be developed in order to control, manage and prevent the spread of infectious diseases throughout natural areas in the catchment, particularly *Phytophthora* (dieback). This strategy should involve actions to prevent the spread of dieback, including measures for cleaning service vehicles from all agencies accessing the reserve (DEC, FESA, Water Corporation, City of Stirling and contractors).

6. Remediation Plan (for contaminated sites)

These plans need to be developed in response to the results of the water quality monitoring program which will identify the location of any polluted areas. This strategy will particularly relate to the historical use of pesticides around Herdsman Lake, and hotspots need to be managed and reduced to improve biodiversity. This strategy needs to be developed in accordance with the provisions of the Contaminated Sites Act 2006.

7. Sustainable Landscaping Strategy

The Sustainable Landscaping Strategy promotes the use of native gardens through Local Councils, by the development of demonstration native gardens and brochures for residents. These gardens promote the use of local native plant species specific to local soil types, to prevent the overuse of fertilisers and water and provide some habitat to native animals. The aim of this program is to increase the number of native gardens in residential areas and Council gardens and verges, to reduce nutrient runoff to stormwater and groundwater and reduce water use.

8. Total Water Management Strategy

This strategy is intended to cover all aspects of the water cycle at Herdsman Lake, and was identified as a strategy through the Herdsman Lake Regional Park Management Plan. Total Water Management Strategy will:

- Review the existing drainage scheme for Herdsman Lake;
- Define pollution containment devices (including water control structures);
- Detail emergency pollution response procedures;
- Estimate water volumes entering and leaving Herdsman Lake;
- Detail drainage requirements of the Water Corporation and the City of Stirling;
- Establish a program to manage water levels for the protection of wildlife habitat and other conservation values; and
- Outline works required to the drainage network to improve water quality entering Herdsman Lake.

9. Water Conservation Plans

Water conservation plans need to be developed for all parks and reserves throughout the catchment area. These plans should identify strategies in order to reduce water use at all parks and reserves to prevent groundwater drawdown and the associated impacts.

10. Water Quality Monitoring Program

A water quality monitoring program should be developed for the Herdsman Lake and its catchment. The aim of this program will be:

- To determine the identity of the pollutants entering Herdsman Lake;
- To identify the major contributors of pollutants to the Lake, ie sub-catchments, stormwater, groundwater and/or the sediments;
- To calculate the pollutant loads; and
- To determine the sediment-water interactions.

This program should include all major drainage lines entering the lake, groundwater, surface water of the lake and the lake sediments. The results of this program will determine the priorities of other management actions, such as locations for stormwater treatment facilities and targeted community education programs.

It is recommended that the program be developed in accordance with the Department of Water, to Department of Water standards and using accredited laboratories, to ensure high quality data is achieved.

Table 12 in Appendix 2 provides a summary of these recommended new plans/strategies (from Section 3.3) to address the identified threats. This table also includes a summary of the existing relevant policies and plans which are also recommended to be implemented.

Table 4: Strategies for Land Use Planning/Regulation – Implementation Matrix

Goal: To ensure that all future urban development within the Herdsman Lake catchment area is sustainable.

Objectives:

1. To develop and implement regulations that protect the environmental values in the catchment;
2. To ensure the community contributes to reducing excessive nutrients and pollutants entering Herdsman Lake;
3. To prevent any unauthorised discharges into the stormwater system; and
4. To protect groundwater and prevent future contamination of Public Drinking Water Protected Zones.

Issue	Action Target	Action	Priority	Responsibility*	KPI's
Residential zoning	To ensure the appropriate management of drainage systems throughout the catchment area	Incorporate WSUD in all planning approvals throughout the catchment area and retrofit existing infrastructure with WSUD techniques	H	**CoS**	• No. of planning approvals with WSUD principles incorporated. • No. of retrofits installed.
	To reduce the export of nutrients and other pollutants from residential areas and developments into Herdsman Lake	Develop and implement a community education strategy for the catchment	H	**CoS,** **DEC** (Herdsman Lake Regional Park)	• No. of actions implemented.
		Implement the Sustainable Landscaping Strategy for the catchment	H	**CoS**	• No. of activities implemented.
		Apply the Keep Australia Beautiful Clean Sites Program to all new building projects in the catchment	M	**CoS**	• No. of sites that adopt the Clean Sites program. • Reduction in TSS levels entering Herdsman Lake.
Increased land value	To achieve effective planning solutions that protects the most significant areas of bushland in public open space or the conservation estate	Develop and implement a biodiversity strategy for the catchment	H	**CoS**	• Biodiversity strategy completed. • No. of strategy actions implemented.
		Implement the City of Stirling Green Plan	M	**CoS**	• No. of management plans implemented. • No. of hectares of bushland protected
		Adopt formal protection of reserves and effective planning solutions throughout the catchment	H	**CoS**, WAPC	• No. of reserves formally adopted.
Industrial area	To eliminate contaminants leaving industrial premises and entering Herdsman Lake	Identify polluting industries in the catchment area and implement the SCC Regional Auditing Program	H	**CoS**	• No. of industries involved in the Regional Audit. • No. of BMP's implemented. • Reduction in levels of heavy metals. • Achieve concentrations below ANZECC trigger values for heavy metals.
		Develop and implement targeted industry awareness strategies in industrial areas	H	**CoS**	• No. of industries involved. • No. of BMP's implemented.
		Adopt and apply UDR's in industrial areas	H	**CoS**	• Reduction in unauthorised discharge.
	Protect the groundwater of the catchment area from contamination	Develop and implement a community education strategy	H	**CoS**, **DEC** (Herdsman Lake Regional Park)	• Community education strategy developed. • No. of actions implemented.
		Liaise with all stakeholders to manage drawdown to minimise shallow groundwater acidification and heavy metal contamination throughout the catchment	H	**DoW**	• Reduction in activation of PASS and heavy metal concentrations
		Implement the SCC Regional Auditing program	H	**CoS**	• No. of industries involved in the Regional Audit. • No. of BMP's implemented.

*Note: In the Responsibility column all responsible agencies will be listed, with the lead agency being shown in bold text

Issue	Action Target	Action	Priority	Responsibility*	KPI's
Parks and reserves	Minimise environmental impacts from management practices in parks and reserves throughout the catchment	Develop and apply water conservation plans for all reserves and parks within the catchment	H	**CoS,** **DEC** (Herdsman Lake Regional Park),	• Water conservation plans developed. • No. of strategy actions implemented.
		Develop and apply fertiliser application plans for all parks and reserves within the catchment	H	**CoS,** **DEC** (Herdsman Lake Regional Park)	• Fertiliser application plan developed. • No. of strategy actions implemented.
Transport	Reduce the environmental impacts of vehicle traffic throughout the catchment area	Adopt and implement the Travel Smart Program	L	**CoS**, DEC	• Reduction in No. of vehicles using the road system.
		Investigate and install vegetated strips/swales or other stormwater treatment options along road verges throughout the catchment	H	**CoS**, MR	• No. of stormwater treatment options installed. • Reduction in nutrient, TSS and heavy metal concentrations.
	Reduce environmental impacts from increased hard surfaces throughout the catchment area	Implement WSUD features in all future developments in the catchment and retrofit existing infrastructure with WSUD techniques	H	**CoS**	• No. of WSUD features installed. • Reduction in nutrient, TSS and heavy metal concentrations in drains entering Herdsman Lake.
		Investigate and install stormwater treatment facilities to trap particulates and pollutants in stormwater drains flowing into Herdsman Lake	H	**CoS**, **WC**	• No. of stormwater treatment facilities installed. • Reduction in nutrient, TSS and heavy metal concentrations in drains.
		Investigate and implement GPT/ST's in drains entering Herdsman Lake	L	**CoS**, **WC**	• No. of GPT/ST's installed. • Reduction in TSS concentrations in drains entering Herdsman Lake.
Natural areas	Prevent clearing of bushland and buffer zones and prevent filling in or draining of wetland areas	Adopt formal protection of natural areas and effective planning solutions throughout the catchment	H	**CoS**, WAPC	• No. of natural areas formally protected.

*Note: In the Responsibility column all responsible agencies will be listed, with the lead agency being shown in bold text

Table 5: Strategies for Biodiversity Conservation – Implementation Matrix

Goal: To protect and enhance the biodiversity of Herdsman Lake.

Objectives:

1. To conserve current levels of biodiversity;
2. To enhance biodiversity;
3. To increase community awareness and ensure land uses, activities and management practices conserve and enhance biodiversity wherever possible; and
4. To conserve, maintain and enhance the functionality of ecosystems.

Issue	Action Target	Action	Priority	Responsibility*	KPI's
Fragmentation	To create links between viable areas of remnant bushland	Support the establishment of regional ecological linkages	L	**WAPC**, **CoS**, DEC	• No. of partnerships established. • No. of hectares revegetated/protected that form linkages.
		Implement the Sustainable Landscaping Strategy for the catchment	H	**CoS**	• No. of activities implemented.
		Investigate and implement fauna underpasses/fencing or other options, incorporating native animal friendly design for new road construction or road extensions throughout the catchment	L	**CoS**, DEC, MR	• No. of actions implemented/developed
	To restore buffer zones around Herdsman Lake	Implement the CALM Weed Control and Revegetation Plan for the Herdsman Lake Regional Park	H	**DEC**, **CoS** (Maurice Hamer Park), WC	• No. of actions implemented.
Loss of habitat	To protect remaining remnant vegetation, to ensure no decline in bushland condition and prevent further clearing at Herdsman Lake Regional Park	Develop and implement a biodiversity strategy for the catchment	H	**CoS**	• Biodiversity strategy implemented. • No. of strategy actions implemented.
		Implement the CALM Weed Control and Revegetation Plan for the Herdsman Lake Regional Park	H	**DEC**, **CoS** (Maurice Hamer Park), WC	• No. of actions implemented.
		Implement the City of Stirling Green Plan and existing management plans for the catchment	M	**CoS**	• No. of management plans implemented. • No. of hectares of bushland protected.
		Manage remnant vegetation to promote ecological functionality and increase biodiversity at Herdsman Lake	M	**CoS**, **DEC**, PL, WC	• No. of hectares of bushland managed.
Disease	Identify and effectively manage priority diseases that impact native flora and fauna, eg. *Phytophthora cinnamomi*	Identify and manage infected areas throughout the catchment	M	**CoS**, **DEC** (Herdsman Lake Regional Park)	• Identification of infected areas completed. • No. of infected areas managed.
		Develop and implement an infectious disease management strategy including a monitoring system for future outbreaks throughout the catchment	M	**CoS**, **DEC** (Herdsman Lake Regional Park)	• Infectious disease management strategy developed.

*Note: In the Responsibility column all responsible agencies will be listed, with the lead agency being shown in bold text

Issue	Action Target	Action	Priority	Responsibility*	KPI's
Non-native species	Control exotic weeds to reduce impacts on remnant vegetation at Herdsman Lake Regional Park	Implement the CALM Weed Control and Revegetation Plan for the Herdsman Lake Regional Park	H	**DEC**, **CoS** (Maurice Hamer Park), WC	• No. of hectares of remnant vegetation rehabilitated. • Reduction in % weed cover per site.
		Develop and implement a weed control and revegetation plan for all natural areas within the catchment area (not including Herdsman Lake Regional Park)	M	**CoS**	• Weed control and revegetation plan completed. • No. of actions implemented. • Reduction in % of weed cover per site.
	Control feral animals to reduce impacts on native fauna at Herdsman Lake	Enforce the Cat Control local law and Dog Control local law throughout the catchment	M	**CoS**	• Reduction in the No. of cat and dog sightings in protected areas.
		Apply CALM Feral Bee Policy to whole catchment	L	**CoS**, DEC (Herdsman Lake Regional Park)	• Reduction in No. of feral bee hives.
Pollution	Improve water quality in Herdsman Lake	See Water Quality section			• See Water Quality section
Fire	Manage fire regime to meet ecological requirements and management of fuel loads at Herdsman Lake	Implement the CALM Weed Control and Revegetation Plan for the Herdsman Lake Regional Park to control flammable species	H	**DEC**, **CoS** (Maurice Hamer Park), WC	• Reduction in % weed cover per site • Reduction in No. of fires within bushland.
		Develop and implement a community education strategy	H	**CoS,** **DEC** (Herdsman Lake Regional Park)	• Community education strategy developed. • No. of actions implemented.
		Implement and update (when necessary) existing CALM Fire Response Plan	L	**DEC**	• No. of sites managed for fire.
Human impacts	Reduce human impacts on the natural environment of Herdsman Lake	Facilitate appropriate human access infrastructure (eg paths, bins, fencing) throughout the Regional Park	M	**DEC**, **CoS** (Maurice Hamer Park)	• No. of kilometres of fencing erected. • No. of metres of paths laid.
		Develop and implement a community education strategy	H	**CoS,** **DEC** (Herdsman Lake Regional Park)	• Community education strategy developed. • No. of actions implemented.

*Note: In the Responsibility column all responsible agencies will be listed, with the lead agency being shown in bold text

Table 6: Strategies for Water Quality and Quantity – Implementation Matrix

Goal: To maintain and improve the health of the aquatic ecosystems of Herdsman Lake.

Objectives:
1. To reduce the concentration of nutrients (nitrogen and phosphorus) entering Herdsman Lake;
2. To reduce the concentration of heavy metals and other pollutants entering Herdsman Lake;
3. To increase the level of awareness of the impacts of excessive nutrients in Herdsman Lake; and
4. To manage stormwater *in situ*.

Issue	Action Target	Action	Priority	Responsibility*	KPI's
Nitrogen and Phosphorus contamination	To achieve and maintain nutrient concentrations in Herdsman Lake below the ANZECC trigger values for wetlands	Develop and implement a water quality monitoring program for the Herdsman Lake catchment	H	**CoS**	• Water quality monitoring program developed. • Annual report completed. • No. of sites monitored. • Achieve concentrations of nitrogen and phosphorus below ANZECC trigger values for nutrients in surface waters in SW Australia (wetlands).
		Investigate and install stormwater treatment facilities to trap particulates and pollutants in drains entering Herdsman Lake	H	**CoS** (Local drains) **WC** (Regional drains)	• No. of stormwater treatment facilities options installed. • Reduction in concentrations of nitrogen and phosphorus. • Achieve ANZECC targets for nitrogen and phosphorus in surface water of Lake and drains.
		Develop and implement a community education strategy	H	**CoS,** **DEC** (Herdsman Lake Regional Park)	• Community education strategy completed. • No. of strategies/actions implemented.
		Implement the Sustainable Landscaping Strategy for the catchment	H	**CoS**	• No. of activities implemented. • Reduction in concentrations of nitrogen and phosphorus in Herdsman Lake. • Achieve ANZECC targets for nitrogen and phosphorus in Herdsman Lake.
		Develop and implement fertiliser application plans for all parks and reserves in the catchment	H	**CoS**, **DEC** (Herdsman Lake Regional Park)	• Fertiliser application plans developed. • Area of turf managed according to guidelines. • Reduction in concentrations of nitrogen and phosphorus in Herdsman Lake. • Achieve ANZECC targets for nitrogen and phosphorus in Herdsman Lake.

*Note: In the Responsibility column all responsible agencies will be listed, with the lead agency being shown in bold text

Issue	Action Target	Action	Priority	Responsibility*	KPI's
Heavy metal contamination	Reduce and maintain heavy metal concentrations in Herdsman Lake to below ANZECC trigger values	Develop and implement an ASS management plan for the Herdsman catchment (including Herdsman Lake Regional Park)	H	**CoS**, **DEC** (Herdsman Lake Regional Park)	• ASS Management Plan completed. • No. of sites effectively managed. • Annual report completed. • Reduction in concentrations of heavy metals in surface waters. • Achieve concentrations below ANZECC trigger values for heavy metals for surface waters.
		Implement SCC Regional Auditing Program for industrial areas	H	**CoS**	• No. of industries involved in the Regional Audit. • No. of BMP's implemented. • Reduction in concentrations of heavy metals in surface waters. • Achieve concentrations below ANZECC trigger values for heavy metals in Herdsman Lake and drains.
		Develop and implement a water quality monitoring program for the catchment	H	**CoS**	• Water quality monitoring program developed. • Annual report completed. • No. of sites monitored.
Total Suspended Solids (TSS)	To reduce the concentration of TSS in Herdsman Lake to the interim DEC guideline of 6mg/L	Develop and implement a water quality monitoring program for the catchment – include TSS as a parameter	H	**CoS**	• Water quality monitoring program developed. • Annual report completed. • No. of sites monitored.
		Apply the Keep Australia Beautiful Clean Sites Program to all new building projects in the catchment	M	**CoS**	• No. of sites that adopt the Clean Sites program. • Reduction in TSS concentrations entering Herdsman Lake.
		Survey the drainage system and prioritise sites for erosion control techniques (preferably rehab works) to reduce movement of sediment	L	**CoS** (Local drains) **WC** (Regional drains)	• Survey completed. • No. of sites treated for erosion control. • No. of plants in ground from rehabilitation projects.
		Investigate and install stormwater treatment facilities to trap particulates and pollutants in drains entering Herdsman Lake	H	**CoS** (Local drains) **WC** (Regional drains)	• No. of stormwater treatment facilities installed. • Reduction in concentration of TSS to below DEC guideline for Herdsman Lake and drains.
Pesticides	To identify the presence and concentrations of pesticides throughout the catchment and to reduce pesticide concentrations in Herdsman Lake to ANZECC trigger values	Develop and implement a water quality monitoring program for the Herdsman Lake catchment – include pesticides	H	**CoS**	• Water quality monitoring program developed. • Annual report completed. • No. of sites monitored.
		Develop and implement a remediation plan for contaminated sites – link to ASS Management Plan	L	**CoS**, **DEC** (Herdsman Lake Regional Park)	• Management Plan and remediation techniques developed. • No. of actions/strategies implemented.

*Note: In the Responsibility column all responsible agencies will be listed, with the lead agency being shown in bold text

Issue	Action Target	Action	Priority	Responsibility*	KPI's
Other pollutants	To identify, monitor and reduce the concentrations of other pollutants (ie TPH, PAH, BTEX and surfactants) to ANZECC levels or below for Herdsman Lake	Develop and implement a water quality monitoring program for Herdsman catchment - include organic toxicants	H	**CoS**	• Water quality monitoring program developed. • Annual report completed. • No. of sites monitored. • Achieve concentrations below ANZECC trigger values for organic toxicants in Herdsman Lake and drains.
		Investigate and install stormwater treatment facilities to trap particulates and pollutants in drains entering Herdsman Lake	H	**CoS** (Local drains), **WC** (Regional drains)	• No. of stormwater treatment facilities installed. • Reduction in concentrations of Nitrogen and Phosphorus in Herdsman Lake and drains. • Achieve ANZECC targets for nitrogen and phosphorus in Herdsman Lake and drains.
		Identify polluting industries in the catchment area and implement the SCC Regional Auditing Program	H	**CoS**	• No. of industries involved in the Regional Audit. • No. of BMP's implemented.
First flush and storm events	To manage water quality issues associated with first flush and subsequent driven rainfall events	Develop and implement a water quality monitoring program for Herdsman catchment - include first flush and storm events	H	**CoS**	• Water quality monitoring program developed. • Annual report completed. • No. of sites monitored.
		Investigate and install stormwater treatment facilities to trap particulates and pollutants in drains entering Herdsman Lake	H	**CoS** (Local drains), **WC** (Regional drains)	• No. of stormwater treatment facilities developed. • Reduction in nitrogen, phosphorus, TSS and heavy metal concentrations in surface waters to ANZECC guidelines.
Increased hard surfaces	To increase on-site retention of rainfall and stormwater	Incorporate WSUD in to all future residential developments	H	**CoS**	• No. of WSUD strategies implemented.
		Incorporate WSUD into all retrofits of the drainage system	H	**CoS** (Local drains), **WC** (Regional drains)	• No. of WSUD strategies implemented.
		Investigate and install pervious paving in future developments and retrofits throughout the catchment	M	**CoS**	• Area of pervious paving installed.
		Investigate and install stormwater treatment facilities to trap particulates and pollutants in drains entering Herdsman Lake	H	**CoS** (Local drains) **WC** (Regional drains)	• No. of stormwater treatment facilities implemented.
Changes to regional hydrology	To identify appropriate environmental water provisions for wetland habitats	Research into water levels and quantity necessary to maintain ecological function of the Herdsman Lake Regional Park, consistent with proposed total water management plan	M	**DoW**, DEC	• EWP's developed for Herdsman Lake.
		Investigate feasibility of redirecting stormwater drainage from entering Herdsman Lake	L	**CoS**, **WC**, DEC	• Feasibility study completed.
		Develop and implement a total water management strategy	M	**CoS**, **DEC**, DPI, WC	• Total water management strategy completed • No. of actions implemented.
		Develop and implement water conservation plans for all parks and reserves in the catchment	H	**CoS**, **DEC** (Herdsman Lake Regional Park)	• Water conservation plans completed for each reserve. • No. of strategy actions implemented.

*Note: In the Responsibility column all responsible agencies will be listed, with the lead agency being shown in bold text

Table 7: Strategies for Acid Sulphate Soils – Implementation Matrix

Goal: To reduce the impact of acid sulphate soils on the natural and built environment of Herdsman Lake.

Objectives:

1. To identify and define the extent of acid sulphate soils in the Herdsman Lake catchment area;
2. To avoid disturbance of acid sulphate soils throughout the catchment, wherever possible;
3. To mitigate the impacts when disturbance of these soils is unavoidable; and
4. To rehabilitate environmental impacts caused by the disturbance of acid sulphate soils.

Issue	Action Target	Action	Priority	Responsibility*	KPI's
Impact of ASS on Herdsman Lake	To identify, prioritise and manage the affects of ASS on Herdsman Lake	Ground truth ASS/PASS Risk map for the catchment	H	**CoS**	• No. of sites ground-truthed against ASS/PASS risk map.
		Develop and implement an ASS management plan for the Herdsman catchment	H	**CoS**, **DEC** (Herdsman Lake Regional Park)	• ASS management plan completed. • No. of actions implemented.
		Develop a remediation plan for acidic surface waterbodies throughout the catchment	M	**CoS**, **DEC** (Herdsman Lake Regional Park)	• Remediation plan for acidic surface waterbodies developed. • No. of actions implemented.
Heavy metal contamination	To reduce the concentrations of heavy metals in Herdsman Lake to those recommended by ANZECC guidelines	Develop and implement an ASS management plan for the catchment, include management of heavy metal contamination	H	**CoS**, **DEC** (Herdsman Lake Regional Park)	• ASS management plan completed. • No. of actions implemented.
Excessive nutrient release	To ensure peat is not oxidised throughout the catchment area	Develop and implement an ASS management plan for the catchment	H	**CoS**, **DEC** (Herdsman Lake Regional Park)	• ASS management plan completed. • No. of actions implemented.
		Develop and implement a water quality monitoring program	H	**CoS**	• Water quality monitoring program developed. • Annual report completed. • No. of sites monitored.
Deoxygenation of MBO's	To identify and manage areas where MBO's exist throughout the catchment area	Develop and implement a water quality monitoring program	H	**CoS**	• Water quality monitoring program developed. • Annual report completed. • No. of sites monitored.
		Develop techniques to reduce exposure of MBO's or release of 'blackwater'	L	**CoS**, **DEC** (Herdsman Lake Regional Park)	• Techniques developed. • No. of areas where MBO's are present effectively managed. • Annual report completed.
Subsidence	To identify and manage areas where subsidence occurs throughout the catchment area	Assess the degree of disturbance in areas surrounding drainage infrastructure	L	**CoS** (Local drains), **WC** (Regional drains)	• Assessment of subsidence in the catchment completed. • Maintenance schedule developed and implemented. • No. of sites remediated. • Annual report completed.
		Incorporate assessment of ASS and PASS into all City of Stirling planning and approval processes	H	**CoS**	• Assessment of PASS and ASS included in all planning and approvals processes.

Issue	Action Target	Action	Priority	Responsibility*	KPI's
Swelling and heaving	To identify and manage areas where swelling and heaving are occurring throughout the catchment	Assess the degree of disturbance	L	**CoS**, **DEC** (Herdsman Lake Regional Park)	• Areas of disturbance assessed and prioritised.
		Develop a management plan and remediation techniques for disturbed areas in the catchment	L	**CoS**, **DEC** (Herdsman Lake Regional Park)	• Management plan and remediation techniques developed. • No. of areas where chemical attack is present remediated. • Annual report completed.
		Incorporate assessment of ASS and PASS into all City of Stirling planning and approval processes	H	**CoS**	• Assessment of PASS and ASS included in all planning and approvals processes.
Chemical attack	To identify and manage current sites where chemical attack is occurring throughout the catchment	Assess the sub-surface infrastructure throughout the catchment	L	**CoS** (Local drains), **WC** (Regional drains)	• Sub-surface infrastructure assessment completed in No. of sub-catchments.
		Develop a management plan and remediation techniques for identified sites throughout the catchment	L	**CoS**, **DEC** (Herdsman Lake Regional Park)	• Management plan and remediation techniques developed. • No. of areas where chemical attack is present remediated. • Annual report completed.
		Incorporate assessment of ASS and PASS into all City of Stirling planning and approval processes	H	**CoS**	• Assessment of PASS and ASS included in all planning and approvals processes.

*Note: In the Responsibility column all responsible agencies will be listed, with the lead agency being shown in bold text

Table 8: Strategies for Education and Community Awareness – Implementation Matrix

Goal: To increase community awareness and understanding of the environmental issues effecting Herdsman Lake.

Objectives:

1. Educate business owners and reduce pollution leaving industrial premises;
2. Evoke positive behaviour change in the general community; and
3. Reduce incidences of negative human impacts upon Herdsman Lake and the reserve.

Issue	Action Target	Action	Priority	Responsibility*	KPI's
Industrial area	To eliminate contaminants leaving industrial premises and entering Herdsman Lake	Develop and implement targeted industry awareness strategies in industrial areas	H	**CoS**	• No. of industries involved. • No. of BMP's implemented.
	Protect the groundwater of the catchment area from contamination	Develop and implement a community education strategy	H	**CoS,** **DEC** (Herdsman Lake Regional Park)	• Community education strategy developed. • No. of actions implemented.
Fire	Manage fire regime to meet ecological requirements and management of fuel loads at Herdsman Lake	Develop and implement a community education strategy	H	**CoS,** **DEC** (Herdsman Lake Regional Park)	• Community education strategy developed. • No. of actions implemented.
Human impacts	Reduce human impacts on the natural environment of Herdsman Lake	Develop and implement a community education strategy	H	**CoS,** **DEC** (Herdsman Lake Regional Park)	• Community education strategy developed. • No. of actions implemented.
Nitrogen and Phosphorus contamination	To achieve and maintain nutrient concentrations in Herdsman Lake below the ANZECC trigger values for wetlands	Develop and implement a community education strategy	H	**CoS,** **DEC** (Herdsman Lake Regional Park)	• Community education strategy developed. • No. of actions implemented.
		Implement the Sustainable Landscaping Strategy for the catchment	H	**CoS**	• No. of activities implemented. • Reduction in concentrations of nitrogen and phosphorus in Herdsman Lake. • Achieve ANZECC targets for nitrogen and phosphorus in Herdsman Lake.
Residential zoning	To reduce the export of nutrients and other pollutants from residential areas and developments into Herdsman Lake	Develop and implement a community education strategy for the catchment	H	**CoS,** **DEC** (Herdsman Lake Regional Park)	• Community education strategy developed • No. of actions implemented.
		Implement the Sustainable Landscaping Strategy for the catchment	H	**CoS**	• Sustainable Landscaping Strategy developed • No. of activities implemented.

*Note: In the Responsibility column all responsible agencies will be listed, with the lead agency being shown in bold text

4.0 Recommendations

The environmental quality of Herdsman Lake will continue to decline if it is not effectively managed on a 'whole of catchment' approach. Section 2.0 of this document provides background information to this plan, outlining the issues and problems faced by Herdsman Lake. Section 3.0 then provides specific strategies recommended in order to manage the identified threats and work towards the improvement of the environmental quality of Herdsman Lake. Therefore it is recommended that this ICM plan is adopted and these strategies followed in accordance with the timeline provided. A summary of the recommended actions is provided below, with the responsible organisation for each action being displayed in brackets. For each action provided, all responsible agencies are listed, with the lead agency being in bold text.

1. High Priority actions (0 – 5 years)

Landuse Planning:

1.1 Incorporate WSUD in all planning approvals throughout the catchment area, implement WSUD features in all future developments and retrofit existing infrastructure with WSUD techniques [**CoS**, **WC** (regional drainage system)]
1.2 Develop and implement targeted industry awareness strategies in industrial areas [**CoS**]

Biodiversity Conservation:

1.3 Develop and implement a biodiversity strategy for the catchment [**CoS**]
1.4 Adopt formal protection of reserves and effective planning solutions throughout the catchment [**CoS**, WAPC]
1.5 Implement the CALM Weed Control and Revegetation plan for the Herdsman Lake Regional Park [**DEC**, **CoS** (Maurice Hamer Park), WC]

Water Quality and Quantity:

1.6 Identify polluting industries in the catchment area and implement the Swan Catchment Council's Regional Auditing Program [**CoS**]
1.7 Adopt and apply UDR's in industrial areas [**CoS**]
1.8 Develop and apply water conservation plans for all parks and reserves within the catchment [**CoS**, **DEC** (Herdsman Lake Regional Park area)]
1.9 Develop and apply fertiliser application plans for all parks and reserves within the catchment [**CoS**, **DEC** (Herdsman Lake Regional park area)]
1.10 Develop and implement a water quality monitoring program for the Herdsman Lake catchment [**CoS**]
1.11 Liaise with all stakeholders to manage drawdown to minimise shallow groundwater acidification and heavy metal contamination throughout the catchment [**DoW**]
1.12 Investigate and install vegetated strips/swales or other stormwater treatment options along road verges throughout the catchment [**CoS**, MR]
1.13 Investigate and install stormwater treatment facilities to trap particulates and pollutants in drains flowing into Herdsman Lake [**CoS**, **WC**]

Acid sulphate soils management:

1.14 Ground truth current acid sulphate soil/potential acid sulphate soils risk map for the catchment [**CoS**]
1.15 Develop and implement an acid sulphate soils management plan for the Herdsman Lake catchment [**CoS**, **DEC** (Herdsman Lake Regional park area)]
1.16 Incorporate acid sulphate soils and potential acid soils into all City of Stirling planning and approvals processes [**CoS**]

Education:

1.17 Develop and implement a community education strategy for the catchment [**CoS**, **DEC** (Herdsman Lake Regional Park)]

1.18 Develop and implement the Sustainable Landscaping Strategy for the catchment [**CoS**]

2. Medium Priority actions (5 – 10 years):

Landuse Planning:

2.1 Implement the City of Stirling Green Plan and existing City of Stirling management plans for the catchment [**CoS**]

Biodiversity Conservation:

2.2 Develop and implement an infectious disease management strategy including a monitoring system for future outbreaks throughout the catchment [**CoS**, **DEC** (Herdsman Lake Regional Park area)]

2.3 Enforce the Cat Control local law and the Dog Control local law throughout the catchment [**CoS**]

2.4 Manage remnant vegetation to promote ecological functionality and increase biodiversity at Herdsman Lake [**CoS**, **DEC**, PL, WC]

2.5 Identify and manage infected (disease) areas throughout the catchment [**CoS**, **DEC** (Herdsman Lake Regional Park area)]

2.6 Facilitate appropriate human access infrastructure (eg, paths, bins, fencing) throughout the reserve around Herdsman Lake [**DEC**, **CoS** (Maurice Hamer Park)]

2.7 Develop and implement a weed control and revegetation plan for all natural areas within the catchment area [**CoS**]

Water Quality and Quantity:

2.8 Apply the Keep Australia Beautiful Clean Sites program to all new building projects in the catchment [**CoS**]

2.9 Investigate and install pervious paving in future developments and retrofits throughout the catchment [**CoS**]

2.10 Research into water levels and quantity necessary to maintain ecological function of the Herdsman Lake Regional Park, consistent with the proposed total water management strategy [**DoW**, **DEC**]

2.11 Develop and implement a total water management strategy [**CoS**, **DEC**, WC, DPI]

Acid sulphate soils:

2.12 Develop a remediation plan for acidic surface waterbodies throughout the catchment [**CoS**, **DEC** (Herdsman Lake Regional Park area)]

3. Low priority actions (10 – 15 years):

Landuse Planning:

3.1 Adopt and implement the Travel Smart program [**CoS**, DEC]

Biodiversity Conservation:

3.2 Support the establishment of regional ecological linkages [**WAPC**, **CoS**, DEC]
3.3 Implement and update (when necessary) existing CALM fire response plan [**DEC**]
3.4 Apply CALM feral bee policy to whole catchment [**CoS**, **DEC** (Herdsman Lake Regional Park area)]
3.5 Investigate and implement fauna underpasses/fencing or other options, incorporating native animal friendly design for new road construction or road extensions throughout the catchment [**CoS**, DEC, MR]

Water Quality and Quantity:

3.6 Investigate and implement GPT's / ST's in drains entering Herdsman Lake [**CoS**, **WC**]
3.7 Develop and implement a remediation plan for contaminated sites (pesticides) [**CoS**, **DEC** (Herdsman Lake Regional Park area)]
3.8 Survey the drainage system and prioritise sites for erosion control techniques (preferably rehabilitation works) to reduce the movement of sediment [**CoS** (Local drains), **WC** (Regional drains)]
3.9 Investigate feasibility of redirecting stormwater drainage from entering Herdsman Lake [**CoS**, **WC**, DEC]

Acid sulphate soils:

3.10 Assess the degree of disturbance (subsidence, swelling and heaving) [**CoS** (Local drain, **WC** (Regional drains)]
3.11 Develop a management plan and remediation techniques for disturbed areas (for subsidence, swelling and heaving and chemical attack) in the catchment [**CoS**, **DEC** (Herdsman Lake Regional Park)]
3.12 Assess the sub-surface infrastructure throughout the catchment for evidence of chemical attack [**CoS** (Local drains), **WC** (Regional drains)]
3.13 Develop techniques to reduce the exposure of MBO's or release of 'blackwater' [**CoS**, **DEC** (Herdsman Lake Regional Park)]

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APPENDIX 1: Outcomes of the Community Consultation

Table 9: Assets of the Herdsman Lake Catchment, Identified in the Community Consultation Workshop

Working Group	Assets	Rationalised into
Built Environment	Drainage infrastructure	Drainage infrastructure (flood control)
	Industry	Industry infrastructure
	Sewerage infrastructure	Sewerage infrastructure
	Roads	Transport infrastructure
	Community	*Human Social Value*
	Residential housing	Residential housing
	Accessibility	*Human Social Value*
Human Social	Cultural heritage	Cultural heritage
	Open spaces	Open spaces
	Lifestyle	*Value created by Open Spaces, Natural Env, accessibility*
	Aesthetics	Aesthetics
	Recreation	*Value created by Open Space/Natural Areas*
	Local knowledge	Local knowledge
	Community	Community
	Tourism	*Outcome of the assets*
	Business	Commercial area
	Employment	Employment
	$ Value of land	*Outcome of the assets*
	Education	*Outcome created by Natural Env.*
	Research	*Outcome created by Natural Env.*
	Natural environment	Natural environment
Natural Environment	Lakes	Lakes/wetlands
	Herdsman Lake	Lakes/wetlands
	Jackadder Lake	Lakes/wetlands
	Water/wetlands	Lakes/wetlands
	Habitat	Biodiversity
	Flora	Flora
	Wildlife	Wildlife
	Indian ocean	Indian Ocean
	Groundwater	Groundwater

Table 10: Threats identified in the Community Consultation Workshop – grouped by Working Group.

(Items in bold represent the threats used in the Herdsman Lake Integrated Catchment Management Plan)

Working group	Threats	Rationalised into	Results in	Threat to
Built Environment	Flooding	**Inappropriate drainage design & management**	Property Damage	Buildings
	De-watering		Activation of ASS	Buildings, roads, built infrastructure
	Septic tanks	*This is a threat to the natural environment*	*Environment (N/A)*	*Environment (N/A)*
	Conflicting land use	**Inappropriate planning**	Land rezoned to residential - industry is squashed out	Industry
	Cultural environmental values	*This is a threat to future built environments, not current*	Increase in the value of natural environment to the community	Prevent further development
Human Social	Planning	**Inappropriate planning**	Changes in land use	Open spaces, commercial areas, natural environment, aesthetics, employment
	Urbanisation	**Urbanisation**	Reduced open spaces	Open spaces, aesthetics
			Removal of industry	Commercial area, employment
			Increased use impacts (litter etc)	Aesthetics
	Drainage	**Inappropriate drainage design & management**	ASS activation	Natural environment, open spaces, aesthetics
			Land subsidence	
			Flooding	
			Reduction in environmental health	Natural environment, aesthetics

Working group	Threats	Rationalised into	Results in	Threat to
Natural Environment	Acid sulphate soils (ASS)	**Inappropriate drainage design & management**	Activation of ASS	Lakes, wetlands, groundwater, biodiversity
	Drainage		Activation of ASS	Lakes, wetlands, groundwater, biodiversity
	Fragmentation-loss of links	**Urbanisation**	Reduction of biodiversity	Biodiversity
	Population increase	**Urbanisation**	Housing developments, increase impacts - pollution	Biodiversity
	Urbanisation	**Urbanisation**	Housing developments	Biodiversity, wetlands
	Introduced species	**Biological threats - diseases, introduced species**	Reduction of biodiversity	Biodiversity
	Climate change	**Climate change**	Reduced rainfall, activation of ASS	Lakes, wetlands, groundwater
			Reduced rainfall, lowering of water table	Lakes, wetlands, biodiversity
	Fire	**Fire**	Removal of endemic species	Biodiversity
	Land use	**Inappropriate landuse**	Pollution/eutrophication	Lakes, wetlands, groundwater
	Eutrophication	**Pollution**	Pollution, loss of flora/fauna	Biodiversity, lakes, groundwater
	Recreational use	**Recreational use**	Pollution/eutrophication	Lakes, wetlands, groundwater
	Biodiversity decrease	*This is an outcome*	*This is an outcome*	
	Bioaccumulation	**Historical pesticide use**	Loss of susceptible species	Biodiversity
		Activation of ASS	Loss of susceptible species	Biodiversity
	Diseases/ Pesticides	**Biological threats - diseases, introduced species**	Loss of fauna and flora	Biodiversity
	Road deaths	**Road deaths**	Loss of fauna	Biodiversity

Table 11: Summary of Threats Identified in the Community Consultation Workshop and Existing Management Strategies

Threats	Symptom	Secondary Symptom	Assets threatened	Existing Management Strategies, Plans, and/or Investigations
Inappropriate drainage design & management	Flooding	Property damage	Buildings	Monitoring: • Water Corporation – Newman College Gauging station on Herdsman Main Drain. Management Plan: • Herdsman Lake Regional Park – CALM Regional Parks
	Localised lowering of groundwater	De-watering of peat - Activation of ASS (refer to this threat), acidification of groundwater	Infrastructure, lakes, wetlands, groundwater, biodiversity	Reports: • Acid Sulphate Guidance Series – Guidance for groundwater management in urban areas on acid sulphate soils, DOE, December 2003 • Herdsman Main Drain Scheme Review, Water Corp. 2001 • Drainage Reform, Monitoring and Reporting. DoE. 2004
		De-watering of peat - land subsidence	Infrastructure	
		Reduction in environmental health and appearance of surface waters	Aesthetics	
		Reduction in surface water expression	Lakes, wetlands, biodiversity	
Inappropriate planning	Inappropriate changes to landuse	Clearing of wetlands/bushland	Open spaces	Management Plan: • Green Plan – City of Stirling
		Infill housing	Commercial areas	
		Industry in wrong places	Wetlands, lakes, ocean, groundwater	
		Inappropriate activities - e.g. horse clubs	Aesthetics, wetlands, groundwater	
		Pollution	Biodiversity, cultural heritage, employment	

Threats	Symptom	Secondary Symptom	Assets threatened	Existing Management Strategies, Plans, and/or Investigations
Unsustainable urbanisation	Clearing for housing developments	Fragmentation - loss of links	Biodiversity	Management Plan: • Green Plan – City of Stirling
		Removal of natural areas	Biodiversity, wetlands	
		Loss of open spaces	Open spaces, aesthetics	
	Infill housing-population increase	Reduced open spaces	Open spaces, aesthetics	
		Increased impacts of human activities (recreation) eg pollution, litter	Aesthetics, lakes, groundwater, biodiversity	
	Rezoning: displacement of industry, commerce	Removal of industry and commerce	Commercial area, employment, community	
Biological Threats: - Diseases - Introduced species - Road deaths	Influx of non-indigenous flora and fauna	Reduction in indigenous fauna and flora populations	Biodiversity	Management Plans: • Herdsman Lake Regional Park – CALM Regional Parks. • Wetland Protection Policy - City of Stirling. • Green Plan – City of Stirling. • The use of aluminium sulphate to control algal blooms and chironomids in Jackadder Lake, Western Australia. Lund & Chester
	Loss of flora and fauna through disease	Reduction in indigenous fauna and flora populations	Biodiversity	
Human induced climate change	Reduced rainfall, lowering of water table	Oxidation of PASS - activation of ASS	Lakes, wetlands, groundwater	Reports: • Acid Sulphate Guidance Series – Guidance for groundwater management in urban areas on acid sulphate soils, DOE, December 2003
			Biodiversity	
			Infrastructure	
		Subsidence of peats	Infrastructure	
		Decrease in surface water expression	Lakes, wetlands, biodiversity, aesthetics	

Threats	Symptom	Secondary Symptom	Assets threatened	Existing Management Strategies, Plans, and/or Investigations
Inappropriate fire regimes	Removal of indigenous, fire sensitive species	Increase in fire tolerant, indigenous and non-indigenous species	Biodiversity	
Inappropriate landuse	Pollution/eutrophication	Decrease in water quality	Lakes, wetlands, groundwater, aesthetics, biodiversity	Management Plans: • Wetland Protection Policy - City of Stirling. • Green Plan – City of Stirling
Pollution	Eutrophication	Decrease in water quality	Lakes, wetlands, groundwater, aesthetics, biodiversity	Reports: • Herdsman Industrial Estate. Phase 1 Environmental monitoring report. ESRI, 1983 • Herdsman Lake Industrial Estate Environmental Monitoring Report. P. Collins 1982 • Herdsman Lake Water Quality Study. Murdoch Uni. Clarke, Davis & Murray 1990 • Jackadder Lake Water and Nutrient Balance study, City of Stirling
	Litter	Creates an eyesore	Aesthetics	
Inappropriate recreational use	Pollution/eutrophication	Decrease in water quality	Lakes, wetlands, groundwater, aesthetics, biodiversity	
	Litter	Creates an eyesore	Aesthetics	
Activation of ASS	Release of arsenic and heavy metals	Loss of susceptible species	Biodiversity	Reports: Acid Sulphate Guidance Series – Guidance for groundwater management in urban areas on acid sulphate soils, DOE, December 2003
		Pollution of groundwater	Groundwater	
		Creates an eyesore	Aesthetics	
	Acidification of groundwater	Damage to infrastructure	Infrastructure	
		Decrease pH of lake	Lakes, wetlands, biodiversity	

Threats	Symptom	Secondary Symptom	Assets threatened	Existing Management Strategies, Plans, and/or Investigations
Historical aspects of land management - Herbicide and pesticide use - Agriculture	Bioaccumulation of pesticides	Loss of susceptible species - Reduced rainfall infiltration – decrease in groundwater recharge - Erosion - Loss of natural regenerative capacity	Groundwater, biodiversity	Reports: • Herdsman Lake Pesticide Study. J. Davis 1986.
	Loss of soil structure and undesirable changes in soil nutrition			
	Pasture improvement	Increase in distribution of environmental weeds	Biodiversity	

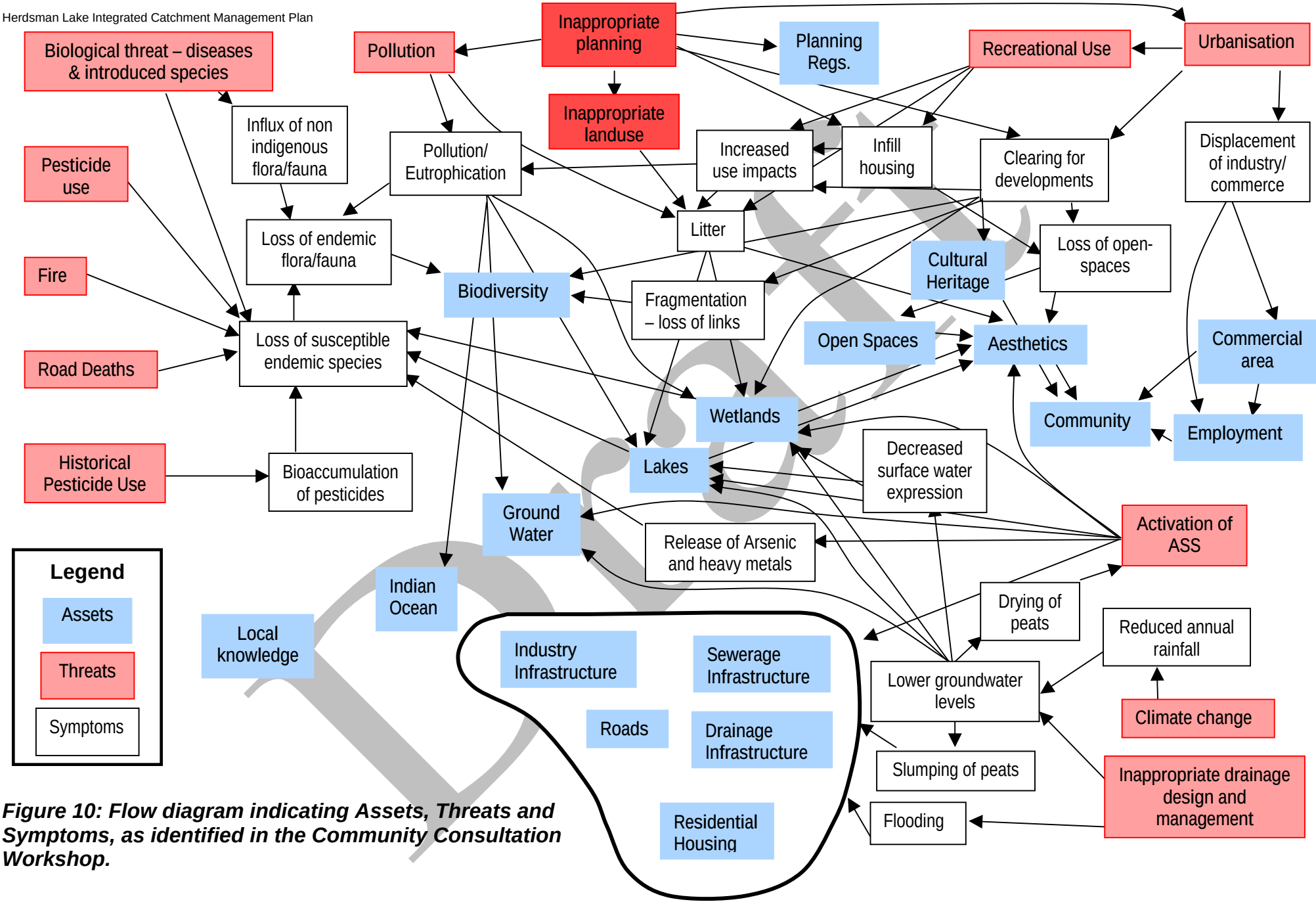

Figure 10: Flow diagram indicating Assets, Threats and Symptoms, as identified in the Community Consultation Workshop.

APPENDIX 2: Summary of recommended new plans and policies, and existing plans and policies that are recommended to be implemented.

Table 12: Summary of recommended new plans/policies and existing plans/policies for the Herdsman Lake Catchment Area

Threats	Symptom	Summary of new and existing plans		
		City of Stirling existing plans to be implemented, relevant to Herdsman Lake	**Existing external plans and policies to be implemented**	**New plans and strategies recommended**
Inappropriate drainage design & management	Flooding	Local Planning Strategy: • 3.1.3 - Metroplan. • 3.1.4 - Network city – review of Metroplan. Wetlands Protection Policy: • 8.1 • 8.2 • 8.5 Green Plan: • 5.1.6 - Mitigation of stormwater drainage.	Herdsman Lake Regional Park Management Plan: • 15.3 - Prepare an implement an overall water management plan for Herdsman Lake. • 15.7 - Promote the implementation of wetland and water sensitive urban design techniques for developments within the Herdsman Lake catchment area. • 17.2 - Undertake weed control in drains that flow into the Park. • 33.2 - Review existing drainage facilities to improve water quality in the Park, reduce the risk of weed infestation and to improve the aesthetics of the outlets. Herdsman Main Drain Scheme Review, Water Corp, 2001.	• Total Water Management Strategy
	Localised lowering of groundwater		Herdsman Main Drain Scheme Review, Water Corp, 2001.	• Total Water Management Strategy • ASS Management Plan
Inappropriate planning	Inappropriate changes to land use	Local Planning Strategy: • 3.1.1 - State Planning Strategy. • 3.1.2 - State Sustainability Strategy. • 3.1.3 - Metroplan. • 3.2.1 - Metropolitan Region Scheme. Wetland Protection Policy: • 5.1 • 6.2 • 6.3 • 7.1		

Threats	Symptom	Summary of new and existing plans		
		City of Stirling existing plans to be implemented, relevant to Herdsman Lake	**Existing external plans and policies to be implemented**	**New plans and strategies recommended**
Unsustainable urbanisation	Clearing for housing developments	Local Planning Strategy: • 3.1.1 - State Planning Strategy. • 3.1.2 - State Sustainability Strategy. • 3.2.1 - Metropolitan Region Scheme. Wetland Protection Policy: • 6.2 • 6.3		• (PBP) Biodiversity Plan
	Infill housing-population increase	Local Planning Strategy: • 3.1.1 - State Planning Strategy. • 3.1.5 - Bushforever. • 3.2.4 - WA Planning Commission Development Control Policies (No28). • 4.6.3 - Density zoning. • 4.6.5 - Housing costs and trends. • 4.7 - Population and housing. Wetland Protection Policy: • 6.2 • 6.3		
	Rezoning: displacement of industry, commerce	Local Planning Strategy: • 3.1.3 - Metroplan. • 3.2.1 - Metropolitan Region Scheme. • 5.1 - Commercial centres, overview.		• Community Education Strategy

Threats	Symptom	Summary of new and existing plans		
		City of Stirling existing plans to be implemented, relevant to Herdsman Lake	**Existing external plans and policies to be implemented**	**New plans and strategies recommended**
Biological threats: - Diseases - Introduced species - Road deaths	Influx of non indigenous flora & fauna	Wetland Protection Policy: • 5.3 • 10.4 • 11.6 Green Plan: • 5.1.5 - Weed control and eradication. • 5.1.6 - Mitigation of stormwater drainage.	Herdsman Lake Regional Park Management Plan: • 16.1 - Implement the Herdsman Lake Regional Park Weed Control and Revegetation Plan. • 16.6 - Ensure local species are used for landscape and amenity plantings within the Park. If non-local species are required, non-invasive species are to be used. • 18.1 - Implement Herdsman Lake Regional Park Weed Control and Revegetation Plan. • 18.2 - Undertake weed control in drains that flow into the Park. • 16.7 - Provide information and interpretive material to the public that promotes the understanding and appreciation of the Park's flora and ecosystems and encourages the planting of local species in areas surrounding the Park.	• (PBP) Biodiversity Plan • Weed Management Plan • Disease Management Plan
	Loss of flora/fauna through disease	Wetland Protection Policy: • 5.3 • 6.4	Herdsman Lake Regional Park Management Plan • 16.5 - Reduce the risk of introducing and spreading plant diseases in the Park.	• Biodiversity Plan • Weed Management Plan
Human induced climate change	Reduced rainfall, lowering of water table	Wetland Protection Policy: • 7.1 • 8.5		• Acid sulphate soils Management Plan
Inappropriate fire regimes	Removal of indigenous, fire sensitive species	Local Planning Strategy: • 3.1.5 - Bushforever (site 281). Green Plan: • 5.1.9 - Fire prevention and control.		• (PBP) Biodiversity Plan

Threats	Symptom	Summary of new and existing plans		
		City of Stirling existing plans to be implemented, relevant to Herdsman Lake	**Existing external plans and policies to be implemented**	**New plans and strategies recommended**
Inappropriate landuse	Pollution, eutrophication	Green Plan: • 5.1.6 - Mitigation of stormwater drainage. Wetland Protection Policy : • 6.1 • 6.2 • 6.3 • 8.5	Herdsman Lake Regional Park Management Plan • 15.3 - Prepare and implement an overall water management plan for Herdsman Lake • 15.4 - Adopt management practices throughout the Park that do not add nutrients and pollutants to the wetland system • 15.5 - Provide interpretive material to the community: outlining the effects of pollution on the wetlands, appropriate use of fertilisers and discouraging the feeding of waterbirds	• Total Water Management Strategy • Community Education Strategy • Sampling Analysis Plan
Pollution	Eutrophication	Wetland Protection Policy: • 6.1 • 8.5 • 9.1 • 9.2 • 9.3 • 9.4 • 10.3	Herdsman Lake Regional Park Management Plan • 15.3 - Prepare and implement an overall water management plan for Herdsman Lake • 15.4 - Adopt management practices throughout the Park that do not add nutrients and pollutants to the wetland system • 15.5 - Provide interpretive material to the community: outlining the effects of pollution on the wetlands, appropriate use of fertilisers and discouraging the feeding of waterbirds • 15.6 - Protect and re-establish wetland fringing vegetation in disturbed areas • 15.7 - Promote the implementation of wetland and water sensitive urban design techniques for developments within the Herdsman Lake catchment area.	• Total Water Management Strategy • Community Education Strategy • Water Quality Monitoring Program
	Litter	Wetland Protection Policy: • 6.1 • 8.1 • 8.5 • 9.1 • 9.2		• Community Education Strategy

Threats	Symptom	Summary of new and existing plans		
		City of Stirling existing plans to be implemented, relevant to Herdsman Lake	**Existing external plans and policies to be implemented**	**New plans and strategies recommended**
Inappropriate recreational use	Pollution, eutrophication	Local Planning Strategy: • 3.1.5 - Bushforever (site 281). Wetland Protection Policy: • 6.2 • 6.4 • 9.1	Herdsman Lake Regional Park Management Plan • 28.1 - Implement the Recreation Masterplan that allocates appropriate facilities and services to those areas of the Park best able to accommodate them in a sustainable manner.	• Total Water Management Strategy • Community Education Strategy • Water Quality Monitoring Program
	Litter	Wetland Protection Policy: • 6.4 • 8.1		• Community Education Strategy
Activation of ASS	Release of arsenic and heavy metals			• Total Water Management Strategy • Acid sulphate soils Management Plan
	Acidification of groundwater			• Total Water Management Strategy • Acid sulphate soils Management Plan
Historical aspects of land management - Herbicide and pesticide use, - Agriculture	Bioaccumulation of pesticides		Herdsman Lake Regional Park Management Plan • 14.2 - Liaise with the Department of Agriculture regarding the presence of pesticides in the soils of the Park prior to the development of recreation facilities. If pesticides exceed safe levels, refer the matter onto relevant authorities.	• Total Water Management Strategy • (PBP) Biodiversity Plan • Water Quality Monitoring Program
	Loss of soil structure and undesirable changes in soil nutrition			• Total Water Management Strategy • (PBP) Biodiversity Plan • Water Quality Monitoring Program
	Acidification of groundwater			• Total Water Management Strategy • Acid sulphate soils Management Plan
	Pasture improvement			• Weed Management Plan