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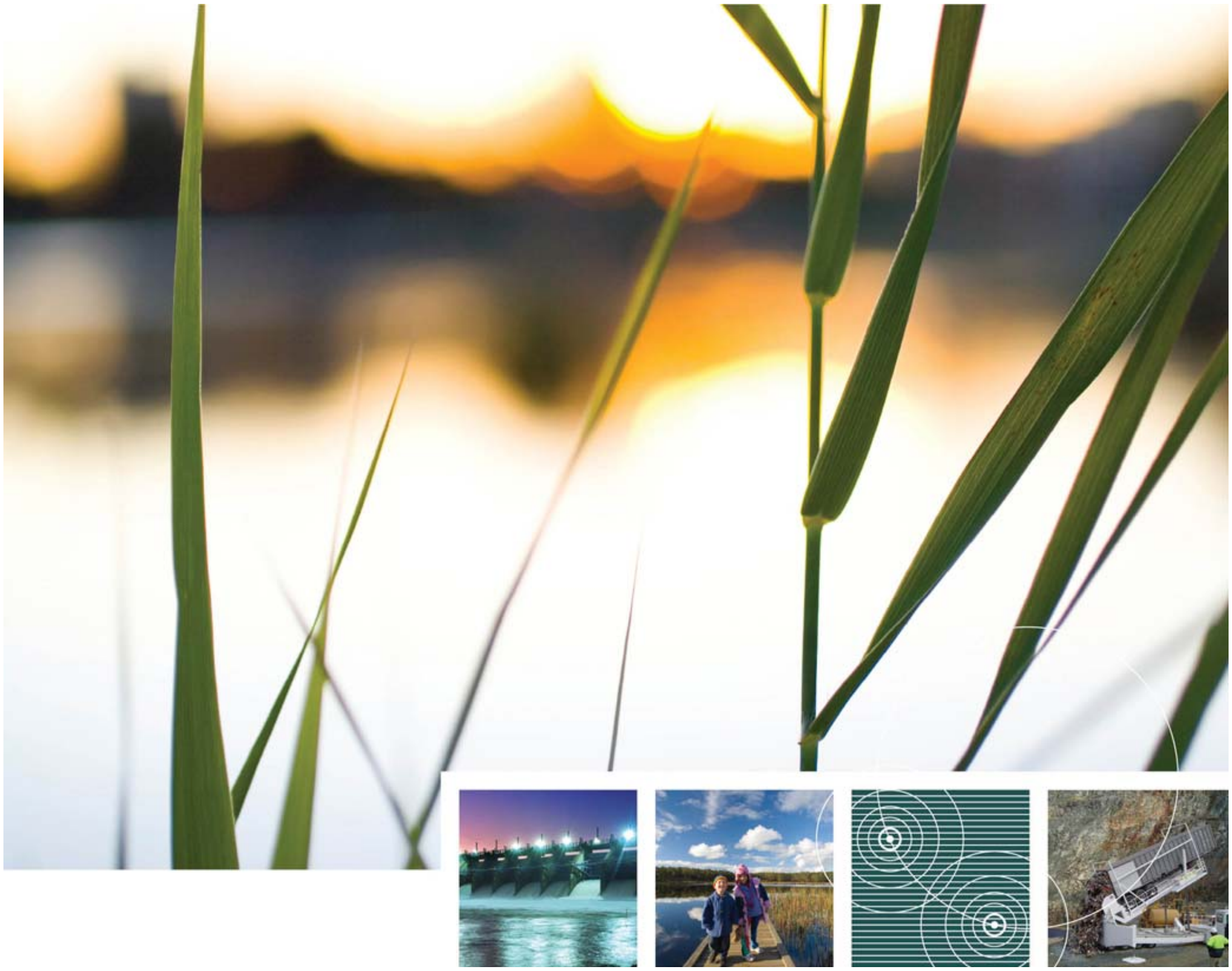

Lake Warden Wetland System (LWWS), Esperance

Initial Environmental Impact Assessment

Department of Environment and Conservation

1 July 2008

Department of Environment and Conservation

SOUTHCOAST NATURAL RESOURCE MANAGEMENT

Australian Government

Lake Warden Wetland System (LWWS), Esperance

Prepared for

Department of Environment and Conservation

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Executive Summary

The Department of Environment and Conservation (DEC) is investigating environmental impacts associated with the construction of engineering option (Alternative 5) to restore water levels in the Lake Warden Wetland System (LWWS). Currently the average water depth across the LWWS has approximately doubled since 1985 due to increased run-off and groundwater base flows seeping into the natural waterways, mainly because of clearing in the upper catchment for agriculture. Engineering based solutions are required for the LWWS in order to recover waterbird species diversity and living assemblages to a near natural state which has been benchmarked at early 1980's waterbird survey counts and hydrology records.

Proposed engineering 'Alternative 5' involves the construction of:

- A 900 metre gravity fed pipe system, which will siphon water from Lake Wheatfield and dispose water into Bandy Creek;
- Establishing a culvert flow management system temporarily preventing water from flowing from Lake Windabout into Lake Warden (Component 5); and
- A 6.9 kilometre pipe that will pump water from Lake Warden and dispose into Bandy Creek Boat Harbour.

Massenbauer and Robertson (2005) developed target depths for Lakes Warden and Wheatfield based on habitat preferences of different waterbird guilds and riparian vegetation condition. The dominant wading water bird guilds representative of the LWWS Ramsar values of international significance require a combination of large areas of shallow lake depths less than 25cm deep and exposed beach for feeding and nesting. Optimal depth range targets for wading water birds for Lake Warden has a target depth of 0.3 - 1.3 metres identified, requiring an estimated dewatering of between 6.0 to 9.0GL to recover habitat areas in the first instance and up to 3.0GL per annum to maintain these areas pending climate variability (DEC, 2006). The target for Lake Wheatfield is 0.8 - 1.6 metres, requiring ongoing dewatering of up to 2.5GL per annum (DEC, 2006).

The DEC has commissioned Maunsell Australia Pty Ltd (Maunsell) to assess the environmental impacts associated with engineering option, Alternative 5, which was chosen from five options presented in a Maunsell report in 2007. The study objectives are to expand further the detail of the Environmental Impact Assessment (EIA) components outlined in the Lake Warden Wetland System Engineering Scoping Proposal. This includes investigating the potential management issues at Lake Warden, Lake Wheatfield and the disposal site (Bandy Creek), as well as the potential pipeline route and operational issues including social impacts as a result of proposed works.

DEC provided a number of investigations and field surveys used by Maunsell as part of this assessment including Digital Multi Spectral Imaging (DMSI), vegetation ground-truthing surveys, acid sulphate soil assessments, water quality, engineering concept designs, water modelling, sedimentation studies, bathymetry mapping, *Phytophthora* Dieback, macro invertebrate and benthic in fauna surveys, heavy metal sampling, marine habitat surveys and biological database searches.

Biodiversity database enquiries and reviews of relevant current literature determined that there is potential for 47 Declared rare or Priority flora species to occur within the wider Esperance – Lake Warden Region. However, within the immediate vicinity of the two proposed pipeline corridors (Components 1A and 4E) there are no records of known locations of Declared Rare Flora or Priority Flora which occurs within or adjacent to the proposed pipeline corridors. Additionally interrogation of the DEC Threatened Priority Fauna database indicates that there is potential for two threatened and one specially protected or Priority species to occur within the immediate vicinity of the LWWS. Reviews of current literature have identified an additional 63 fauna species to occur within the LWWS. The *Environment Protection and Biodiversity Conservation (EPBC) Act, 1999* or the *Wildlife Conservation Act 1950* lists and protects all 66 fauna species identified within the wider catchment.

Results from wetland monitoring programs conducted triennially since 1997 by DEC and Edith Cowan University (ECU) of overstorey species such as *Melaleuca cuticularis* at Lake Wheatfield indicate that they are in decline. *Melaleuca cuticularis* is a good indicator species that grows in salty wetlands and is tolerant of both water logging and salt in the air and water. The deterioration is mainly attributed to increased periods of inundation that has resulted in vegetation decline and eventually death.

DEC vegetation condition monitoring across the LWWS also identifies that up to 60 percent of the common *Melaleuca brevifolia* associated plant communities are dead or in decline due to inundation tolerances being 18 and 36-month respectively.

The accumulation of salts within the LWWS would favour halophytic plants and generally diminish the vegetation community complexity. The increase of salt concentrations within the LWWS may affect groundwater quality, and in turn, influence water-uptake and health of deep-rooted vegetation. Changes in vegetation community composition impact the Terrestrial fauna.

Water in the LWWS ranges from brackish to very saline and water regimes range from almost permanent (only drying out occasionally at the end of summer) to intermittent. Salinity is influenced by seasonal and annual rainfall, evaporation, poor natural drainage, shallow basement geology to the west of the LWWS and saline surface flows during winter from the upper secondary saline catchment areas (DEC, 2006).

Implementation of engineering works to the LWWS will directly enhance recreational values particularly bird watching, bush walking and water based recreation. If engineering intervention does not occur, then recreational activities within the system will be restricted or diminished and will decrease the LWWS visual amenity.

1.0 Introduction

The Lake Warden Wetland System (LWWS) is located at the southern end of the catchment on the coastal floodplain immediately north of the Esperance town site, Western Australia (Figure 1). The LWWS is a wetland of international significance under the Ramsar Convention and the State Salinity Action Plan lists the Lake Warden Catchment as a Natural Diversity Recovery Catchment. Coastal dunes to the south and a granite escarpment to the north entrap the wetlands (DEC, 2007b).

The waterbird and riparian vegetation values of the LWWS are under immediate threat from rising water tables and excessive inundation. These physical changes have resulted from the broadscale clearing of perennial vegetation in the catchment and subsequent replacement with an agricultural system based largely on annual crops. Recent efforts have increased the number of perennial crops (blue gums, pines, etc.) in the catchment but the benefits of these landuse changes have not come into effect rapidly enough to prevent further, possibly irreparable, degradation of the LWWS. Targeted revegetation of the Lake Warden Catchment (LWC) with perennial vegetation and engineered dewatering of the LWWS are regarded as essential to ameliorate the impacts of the altered hydrology (Massenbauer, T., & Vogwill, R., 2007).

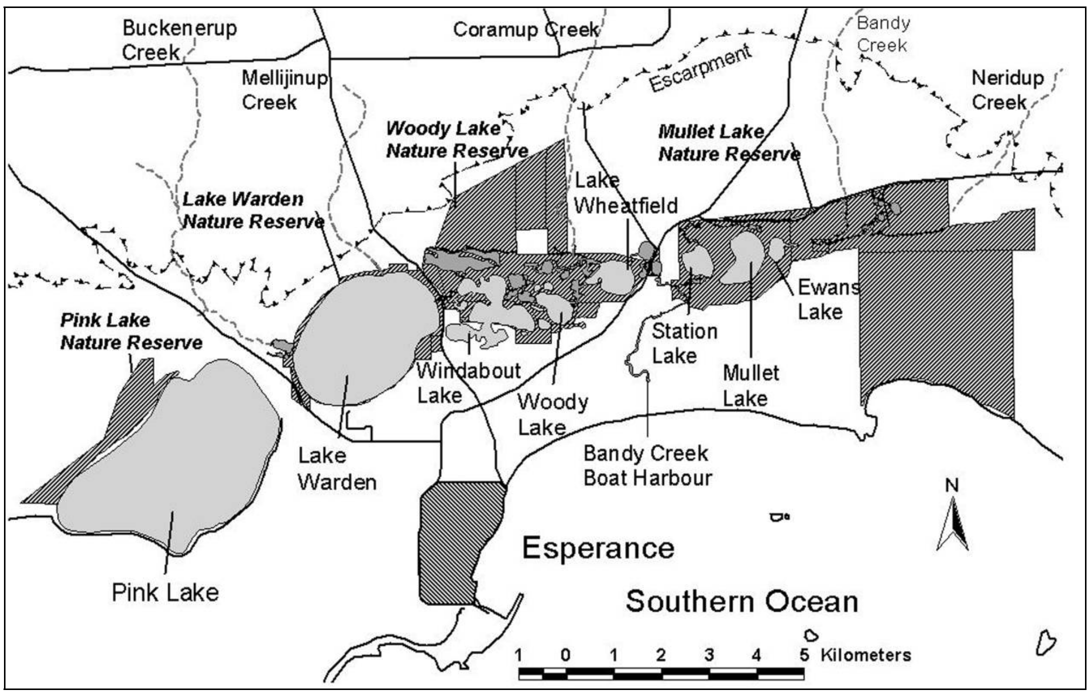


Figure 1 Lake Warden Wetland System (Source: DEC, 2007b)

The average water depth across the suites has doubled since 1985 due to increased run-off, mainly due to clearing in the upper catchment for agriculture. This has resulted in increased groundwater discharge into the inflow streams, a situation exacerbated by the poorly connected outflow system through the Bandy Creek weir. Groundwater recharge and evaporation are the only natural processes to drop water levels in all the major lakes once outflow of the suites to the Southern Ocean stops. The duration of the remaining high water-levels results in a lack of beach and shallow wading habitat for waterbirds and waterlogging of riparian vegetation that threaten important conservation values in the wetland system (CALM, 2006)

The Department of Environment and Conservation's (DEC's) management objective for the LWWS is to "recover the existing (2003) water bird species richness and abundance and its living assemblages, to a near natural condition (based on waterbird survey counts and hydrology records from the early 1980s) by the year 2030". (Massenbauer & Vogwill, 2007).

Research, modelling and uncertainty analysis carried out over an eight-year period led to comprehending the hydrological system affecting the LWWS and establish priorities for management actions (Massenbauer & Vogwill, 2007).

1.1 Project Description

Water balance and waterbird habitat models developed for individual lakes of the LWWS have demonstrated that the decline in vegetation condition and waterbird habitat has resulted from hydrological changes, particularly prolonged duration and increased volumes of inundation, and this degradation will continue if unmanaged. Massenbauer and Robertson (2005) have identified target depths of 0.4 – 1.3m for Lake Warden and 0.8 – 1.6m for Lake Wheatfield (based on habitat preferences of different water guilds).

DEC has worked extensively with stakeholders to develop a Recovery Plan (CALM, 2006) for the LWWS that is supported by empirical research and detailed scientific evaluation. Studies carried out to date in the LWWS provide a wealth of background information and data to assist in the development of revegetation and engineering strategies to ameliorate the impacts of the altered hydrology.

In June 2006, Maunsell evaluated a range of engineering options for managing water levels in the LWWS (Maunsell, 2007). The report assessed five alternatives (concept designs) against a range of options for achieving management outcomes in the LWWS. Of the five considered, Alternative 5 was identified as a preferred option and DEC requested that an EIA of this option be conducted in order to determine the outcomes of implementation.

Selection of the preferred option was based on:

1) Determining the minimum volume of water that needed to be removed from the lakes to achieve the management target;
2) Minimising the risk of social and environmental impact; and
3) The most cost-effective alternative for achieving removal of water from lakes to achieve management targets.

The proposed Alternative 5 involves:

- Siphoning of water from Lake Wheatfield using a gravity-fed pipe system and disposing water 900 metres away into the disposal site, Bandy Creek (Component 1A). ;
- Establishing a culvert flow management system temporarily preventing water from flowing from Lake Windabout into Lake Warden (Component 5); and
- Pumping water from Lake Warden and disposing 6.9 kilometres via a pipe into the Bandy Creek Boat Harbour (Component 4E);

Established hydrological objectives for the LWWS are supported by numerous studies, including:

- Detailed lake water balance modelling (Marimuthu *et al*., 2005).
- Catchment water balance modelling (Robertson & Massenbauer, 2005)
- Stream gauging of the four main catchment streams over five years.
- Extensive sampling, measurement and observations of physical and water quality parameters of the LWWS in presented in Appendix A (Marimuthu *et al*., 2004 & 2005)
- Sedimentation Study (Wilson, 2004).

Groundwater drilling programme (DEC, 2007c) and geophysical mapping including understanding the capacity and connectivity of hydro geological systems (Street & Abbot, 2004).

- Land-use mapping survey.
- Airborne LIDR terrain mapping of Esperance Coastal floodplain (DEC, 2007e, unpublished)
- Extensive and accurate RTK-DGPS survey. (DEC, 2003, unpublished)
- Bathymetry mapping of lakebeds.(DEC, 2007e, unpublished)
- Development of a high resolution digital elevation model of the LWWS and surrounding floodplain (DEC, 2007e, unpublished)
- Vegetation condition monitoring of the LWWS using airborne multispectral imaging (DEC, 2007e, unpublished)
- Waterbird threshold analysis that is linked to lake depth and identification of optimal levels for maintaining habitat (Robertson & Massenbauer, 2005).
- Construction of a Bayesian Belief Network management model for the LWWS (Walshe & Massenbauer, 2007)

The aforementioned studies were used to set management objectives for recovery of the LWWS. There are two basic parts to the strategy:

- Land use modification in priority areas of the catchment to effect hydrological changes in the long-term (20-30+ years); and
- Engineering intervention as an interim measure to remove excess water from the lakes.

All wetland suites undergoing engineering intervention would dispose of excess water containing diluted nutrients into the Southern Ocean during spring and early summer periods then allow lake evaporation and vegetation transpiration to balance the natural LWWS hydrology.

Section 38(5) of the *Environmental Protection Act 1986* (EP Act) provides that where a development proposal is likely to have a significant effect on the environment, the Decision Making Authority (DMA) may refer the proposal to the Environmental Protection Authority (EPA) for a decision as to whether or not the proposal requires assessment under the EP Act. This document has been prepared to accompany an EPA referral form (DMA) submitted in accordance with Section 38(5). It provides information about the existing environment of the project area, potential impacts of the proposal, proposed management measures to implement to minimise and mitigate such impacts and how to address the requirements of the EP Act. The DMA considers the information relevant in assisting the EPA to decide whether to assess the proposal, and, if assessed, the level at which such assessment is conducted.

This project will be referred to the EPA in two stages and will comprise:

- Stage 1 – Lake Wheatfield component; and
- Stage 2 – Lake Warden component

In accordance with the requirements stated in the EPA Referral Form, the information provided in this document is based on data known to the DMA at the time of preparation and provides the overall proposed project concepts. Additional information will be required for the assessment of Stage 2 and will include:
- mixing-dispersion modelling;
- marine seagrass-benthos assessment;
- new seagrass surveys; and
- re-sampling sites (for metals) and will be included at a later date, as part of the Lake Warden component (Stage 2).

1.2 Intent of Study

For the purposes of this study, DEC engaged Maunsell in July 2007 to assess the environmental impacts associated with the preferred engineering option for restoring water levels in the LWWS to optimal ranges for recovery of waterbird species diversity and living assemblages to a near natural state (Alternative 5).

This report focuses on the proposal's impact on Lake Wheatfield, Lake Warden and Bandy Creek. It, therefore, does not consider potential environmental impacts on Windabout, Woody, Station, Mullet, Pink, and Ewans Lakes (which form part of the LWWS). Additionally, this report only takes into account impacts on Lake Warden, Lake Wheatfield and Bandy Creek because of proposed engineering works

The objectives of this study are to expand further on the EIA in the Lake Warden Wetland System Engineering Scoping Proposal. These components are summarised as follows:

1) Investigate potential management issues at Lake Warden and Wheatfield and their disposal site, including:
    a) Erosion, particulate transport;
    b) Low pH; high acid water from potential acid sulfate soil (PASS) oxidation;
    c) Water levels and seasonality;

2) Investigate the potential pipeline route and operational issues, including:
    a) Vegetation disturbance
    b) PASS and actual acid sulfate soils (ASS)
    c) Pathogen risk (*Phytophthora* cinnamomi)

3) Investigate potential social Impacts

Currently, the pipeline routes are not detailed final designs and, therefore, impacts identified in this report are broad and generalised.

1.3 Relevant Legislation and Guidelines

State Government Legislation	Application
Aboriginal Heritage Act 1972	Provides provision for the preservation on behalf of the community of places and objects customarily used by or traditional to the original inhabitants of Australia or their descendents.
Agriculture ad Related Resources Protection Act 1976	Addresses the obligations for control, destruction, and notification of gazetted noxious plants and animals.
Conservation and Land Management Act 1984	Applies to certain reserved lands.
Environmental Protection Act 1986	Provides protection for the environment through an assessment and approval process.
Rights in Water and Irrigation Act 1914	Applies to all aspects of drainage.
Soil and Land Conservation Act 1947 and Soil and Land Conservation Regulations 1992	Applies to soil conservation, drainage and catchment clearing and encourages good farming practices.
Wildlife Conservation Act 1950	Conservation on all tenures irrespective of vesting in the Conservation Commission.
Conservation Commission of WA Drainage Policy July 2006	Includes issues and policies relating to drainage proposals in WA.
Salinity Investment Framework	Ensures that public investment is directed to the Project with the best potential to protect assets of high public value that are under threat from salinity.

State Government Legislation	Application
Western Australian Salinity Action Plan 1996	Report on biological surveys in the agricultural zone

2.0 Environmental Impact Assessment Methods

2.1 Review of Existing Information

Maunsell collated and reviewed the available, relevant documentation and existing survey information (vegetation ground-truthing surveys, acid sulfate soil assessments, water quality assessments, engineering concept designs, water modelling, sedimentation studies and bathymetry mapping) relating to the site to ascertain the potential issues, impacts and information gaps associated with the project.

2.1.1 Document Review

Review of the following documents occurred as part of this study:

- Esperance Lakes Nature Reserves Management Plan 1999-2009 No. 39 National Parks and Nature Conservation Authority (CALM, 1999);
- Lake Warden Wetland System Engineering Scoping Proposal (Massenbauer, T., & Vogwill, R., 2007);
- Decision framework for natural diversity recovery program (Implementation) (Walshe *et al*., 2007);
- Detailed water balance approaches in a coastal wetland system (Marimuthu, *et al*., 2005);
- Modelling the surface – Groundwater interaction in Esperance, Western Australia using a groundwater flow model (Stevenson, 2007);
- The impact of within storm temporal pattern on flood frequency (Kusumastuti, D *et al*., 2006);
- Lake Warden natural diversity recovery catchment, Draft Recovery Plan 2005 – 2030 (CALM, 2006);
- A Preliminary Assessment of the Recent Environmental History of the Lake Warden Wetlands, Esperance, Western Australia (Wilson, 2004);
- What to do? Deciding on actions when the benefits are uncertain (Walshe, T. and Massenbauer, T., 2007);
- Applying hydrological thresholds to wetland management for waterbirds, using bathymetric surveys and GIS (Robertson, D. and Massenbauer, T., 2005);
- Spatial water balance modelling for targeted perennial planting in south Western Australia (Robertson *et al*., 2005);
- Interpretation of airborne electromagnetic survey over Lake Warden Catchment, Esperance Western Australia (Street, G., & Abbot, S., 2004);
- Developing a land management decision support system for the Lake Warden Catchment. Natural Resource Management (Massenbauer, T. & Robertson, D., 2005);
- Esperance Lakes Catchment hydrographical and water quality review – June 1997 to August 2004 (Janicke, S., 2004);
- A conceptual hydrogeological model for the Lake Warden Recovery Catchments Esperance, Western Australia (Short, R., 2000);
- Use of physical, chemical and stable isotope techniques for constraining the conceptual model of a coastal wetland system in South Coast of Western Australia (Marimuthu *et al*., 2004);
- Deuterium concentration and flow path analysis as additional calibration targets to calibrate groundwater flow simulation in a coastal wetland system (Marimuthu, S., & Reynolds, D.A., 2005);

2.1.2 Data Review

Additional to the literature and document review, various data sets were examined:

- Water Quality Parameters (i.e. nutrients, pH, electrical conductivity and temperature);

- Monitoring Bore Data including locations and water levels; and
- Lake levels and depths;

2.1.3 Relevant Investigations and Studies

Maunsell has used data and information from related studies within the Esperance Plains to gain a better understanding of the regional soil and water quality (surface and groundwater). Maunsell would like to acknowledge the following studies and data sources:

- Department of Environment and Conservation;
- WIN database;
- Esperance Groundwater Area Water Management Plan (Department of Water, 2007).

2.2 Desktop Assessment

As part of Maunsell's EIA, a desktop investigation to identify any potential environmental and social issues associated with the construction of gravity-fed pipes and pipes and culverts required for Alternative 5 was undertaken. Table 1 provides the database information obtained for the study area. The comprehensive desktop assessments conducted for the Lake Warden Wetland System follow.

Table 1 Relevant Database/Dataset Information Reviewed

Data / Database	Custodian
Declared Rare and Priority Flora	Department of Environment and Conservation/WA Herbarium
Threatened Ecological Communities	Department of Environment and Conservation/WA Museum
Threatened and Priority Fauna	Department of Environment and Conservation
Fauna base	WA Museum
DEC Managed Lands	Dept of Environment and Conservation
Cadastral Boundaries/Land Tenure	Department of Land Information
Groundwater/Surface Water Monitoring – WIN Database	Department of Water
Digital Elevation Model (DEM)	Department of Land Information/DEC Information
Climate	Bureau of Meteorology
Pathogen Risk – Dieback Atlas	Department of Environment and Conservation

2.2.1 Flora and Vegetation Survey

A desktop flora and vegetation assessment of the study area was undertaken of the following:

- Department of Environment and Conservation (DEC) Threatened Flora Database;
- Western Australian (WA) Herbarium; and
- Literature and data provided by Massenbauer (DEC Esperance).

2.2.1.1 DEC Threatened flora database and WA Herbarium

To identify conservation status flora in the study area interrogation of the DEC and WA Herbarium Threatened (Declared Rare) Flora (DRF) databases was undertaken.
DEC maintains records of occurrences of DRF or Priority Species from vegetation surveys conducted across the State. It allocates Declared Rare or Priority Flora Conservation Status dependent on the level of perceived threat to a species. Where populations are geographically restricted, threatened by

local processes, have only a few known populations or poorly known, Declared Rare or Priority Conservation Status is given. Allocating Conservation Status to species deemed to be "under threat" acts as a regulatory tool to protect the species and the populations in which they occur.

Data from the WA Herbarium represents all specimens that have been collected and confirmed from within the search area and registered with the WA Herbarium. The DEC Threatened Flora Database represents known populations and individual specimens of Declared Rare or Priority Flora, collected during surveys not necessarily registered with the WA Herbarium. Both sets of data carry equal weighting in terms of importance.

Flora species considered 'Rare' are gazetted under subsection 2 of section 23F of the *Wildlife Conservation Act, 1950*. It is an offence to "take" or damage Rare Flora without Ministerial approval, potentially resulting in fines or imprisonment. Section 23F of the *Wildlife Conservation Act, 1950* defines "to take" as "to gather, pick, cut, pull up, destroy, dig up, remove or injure the flora or to cause or permit the same to be done by any means."

Species designated as Priority Flora are under consideration for declaration as 'Rare Flora' and are in urgent need of further survey (Priority One to Three) or require monitoring every 5-10 years (Priority Four). Appendix B presents the definitions of Declared Rare and the four Priority ratings as detailed under the *Wildlife Conservation Act, 1950* (as extracted from DEC, 2006a).

Any species listed in State and Commonwealth legislation as being of conservation significance are considered to be a significant species (EPA, 2007 and this designation includes species that are endangered, vulnerable or rare and those covered by international conventions. Species at risk of extinction are recognised at a Commonwealth level and are categorised according to the *Environment Protection and Biodiversity Conservation (EPBC) Act, 1999* (Appendix B). Significance is not limited to species covered by State and Commonwealth Legislation. It also includes species of local significance and species showing significant range extension or at the edge of their known range.

2.2.1.2 Literature and Data Provided by DEC

Interrogation occurred to identify the presence of Declared Rare and Priority Flora within the area from data provided by DEC Esperance. Discrepancies occurred between the literature and data provided by DEC Esperance, the WA Herbarium and the Threatened Species Database, and, therefore, a complete list utilising all available data and the composite information was considered.

2.2.2 Threatened and Priority Ecological Communities

A search of the DEC's database of Threatened Ecological Communities (TECs) to determine the presence of TECs within the study area was undertaken.

TECs are naturally occurring biological assemblages that occur in a particular type of habitat, which are subject to processes that threaten to destroy or significantly modify the assemblage across its range (DEC, 2001a). These communities are of conservation significance because they are likely to contain rare organisms or a group of rare organisms. TECs are identified by the Western Australian Threatened Ecological Communities and Scientific Advisory Committee (DEC) and defined as Presumed Destroyed, Critically Endangered, Endangered or Vulnerable (Appendix C).

English and Blyth (1997) have previously described the categories and the criteria for defining TECs. A publicly available database listing TECs within the state is maintained by the DEC and available via their website.

Ecological communities that do not meet the specific survey criteria for a TEC, or that are not adequately defined, are added to the Priority Ecological Community Lists under Priorities 1, 2 and 3 (DEC, 2001b). Ranking of the three categories are in order of priority for survey and/or definition of the community and evaluation of conservation status, thus providing consideration to their declaration as threatened ecological communities.

Communities that are adequately known and are rare but not threatened and communities requiring monitoring are also afforded protection and are placed as Priority 4 and Priority 5, respectively. Priority community definitions are summarized in Appendix C.

2.2.3 Fauna

The DEC's threatened and priority fauna database was examined to identify rare or priority fauna species occurring within the project area. Any rare, threatened or significant populations of species under threat from external processes are described in the database. These species require protection or are protected under an international agreement between federal and state governments (DEC, 2007a).

Additional to the searches of the DEC Threatened and Priority Fauna Database, a review of current literature and a search for environmental triggers of the EPBC Act identified the potential for additional species to occur within the wider area. The database of Triggers of the EPBC Act provides a broad search of regions and the information generated should only be used as an indication of what values are potentially supported by the searched area.

Under Section 16 of the *Wildlife Conservation Act, 1950*, it is an offence to "take, destroy or possess" threatened fauna without Ministerial approval. The *Wildlife Conservation Act, 1950* provides protection to species considered to be under an identifiable threat of extinction (DoIR, 2006). Species of fauna listed under Schedule 1 to 4 of the *Wildlife Conservation Act, 1950* are summarised in Appendix D.

The Government of Western Australia is also concerned about a number of other species that at this stage do not meet the International Union for the Conservation of Nature (IUCN) criteria to be listed under Schedule 1 to 4 of the *Wildlife Conservation Act, 1950*. Due to a lack of knowledge on the species or the poor geographical representation in secure populations, there are some concerns for the long-term survival of the species (Harewood, 2004) and these species are considered Specially Protected Fauna and recognised on a Priority basis (Appendix D).

Protection of fauna species under threat of extinction occurs under the EPBC Act, 1999 at a Commonwealth level (Threatened Fauna Species categories as summarized in (Appendix D).

2.2.4 DEC Managed Lands and Waters

The DEC's dataset of DEC Managed Lands and Waters within Western Australia identified any National Parks, Nature Reserves, Conservation Areas, Forests and other Reserves/lease and Freehold Areas managed by DEC.

2.2.5 Cadastre/Land Tenure

Sourced Cadastre and tenure information from the Spatial Cadastral Database(an integrated database comprising of a number of datasets (layers) of digital spatial data) shows all Crown and Freehold land parcels in the State as well as a subsidiary survey network control including an integrated administrative boundary dataset and a lodged layer showing recent surveys. This dataset allows for the identification of neighbouring landowners.

2.2.6 WIN Database – Groundwater & Surface Water Monitoring

Investigation of the WIN database obtained groundwater and surface water flow and water quality information related to the study area. The Department of Water (DoW) operates numerous surface water and groundwater monitoring sites throughout Western Australia. Data collection for quality, quantity and composition of groundwater and wetlands are listed in Appendix A.

DEC has 36 observation bores and piezometeres that are monitored monthly for depth to water table salinity and pH across the surrounding floodplain. DEC also monitors lake depth, salinity and pH on a fortnightly basis for Lakes Warden, Windabout, Woody, Wheatfield, Station, Mullet and Ewans.

Additionally, Marithmu *et al.,* (2004) conducted several studies in regards to chemical and stable isotopes within the LWWS. This included the use of transect boreholes, piezometeres and water level probes in order to collect new geological and hydro geological data to improve the understanding of regional groundwater flow, and to determine lake flow characteristics. Investigation of the temporal and spatial variations of chemical and isotopic composition in the water bodies occurred by sampling several water bodies within the LWWS. A total of 32 groundwater samples from inland, wetland and coastal plain, as well as lake and creek sources were collected. Rain samples, collected during rainstorm events, were cumulated to a weekly/monthly basis. In addition, six surface water samples (Lakes Warden, Wheatfield and Station, and Coramup and Bandy Creek) were collected.

2.2.7 Digital Elevation Model

A Digital Elevation Model (DEM) is a digital representation of the elevation of locations on the land surface. DEMs are used for the generation of terrain models, slope maps, aspect maps and contours. The DEM used for this study was supplied by DEC (Esperance) and was created using the following datasets.

- LIDAR DEM flown by Fugro in March 2006 - 5m cells;
- Townsite DEM generated from 1:7300 Scale photographs in November 2001;
- Elevation Models of the Lakes within the Lake Warden System - 5m cell (GIS Job No. 05026501);
- RTK GPS points collected by Massenbauer on the section of Bandy Creek from Station Lake to the ocean (post flood January 2007);
- Missing data areas filled with data from earlier LIDAR survey flown in May 2005; and
- Remaining missing data areas filled using the focal minimum function.

The raw data points used to develop the DEM have a vertical accuracy of +/- 20mm which has been incorporated into the upper and lower error bounds when used in models and setting management targets.

2.2.8 Climate information

The Bureau of Meteorology (BoM) provides historical records of climate information for numerous meteorological stations in Australia. Typically, each meteorological station provides climate averages and other statistics for a number of elements including:

- Maximum and minimum temperatures;
- Temperatures and humidity (nominally) at 9:00 am and 3:00 pm;
- Sunshine and evaporation, where available; and
- Rainfall for each calendar month.

2.2.9 Pathogen Risk (*Phytophthora cinnamomi, Phytophthora megasperma and Armillaria luteobubalina*)

Trained DEC Dieback Interpretation Officers conducted pathogen risk surveys of the project area between 23 February 2000 and 9 April 2002. The surveys involved detailed field investigations, based primarily on initial suspected sites of infestations derived from existing dieback mapping data from

DEC sources. This involved using DEC procedural sampling techniques where root and soil samples of suspected infested plants were collected and then sent for inoculation and confirmation in a DEC plant pathology laboratory. Susceptible species such as Grasstrees (Xanthorrhoea sp.) and Proteaceous species were used for analysis. Additional to DEC dieback surveys conducted between 2000 and 2002, the Dieback Atlas (DEC, 2006c) was also interrogated to identify potential dieback occurrences within the study area.

3.0 Bayesian Belief Network

Several tools can be used to gain an understanding of altered hydrological processes affecting a natural asset with important values. The Lake Warden Catchment project demonstrated why, when and how to use these tools to understand the hydrological threats to asset values (Walshe & Massenbauer, 2007).

The Department of Environment and Conservation has developed a Land Management Decision Support System and after extensive research found that economically viable perennial vegetation options integrated with engineering options has a high likelihood of recovering the hydrology of the LWWS (Maunsell, 2007).

Massenbauer and Robertson (2005) provided a methodology for analysing uncertainty and error in component data. Additional to the uncertainty analysis, Bayesian Belief Network (BBN) analysis for Lake Warden and Lake Wheatfield determined the probability of meeting biological targets.

For any monitoring program to be successful, it is essential to define the biological targets or indicators that require monitoring. This must be both in terms of the biological community of interest (in the case of Lakes Warden and Wheatfield: wader abundance and vegetation health) and the parameters that ensure their survival or condition (such as food availability and habitat and water levels and quality). The BBN used for the Lake Warden Catchment considers all these parameters and further explanation is provided in Appendix E.

Massenbauer and Robertson (2005) developed target depths for Lakes Warden and Wheatfield based on habitat preferences of different waterbird guilds. The authors assume that these target depths are necessary for observing 8000 waders and 4000 divers in Lakes Warden and Wheatfield, respectively, and approximately 20, 000 waterbirds overall. For Lake Warden a target depth of 0.4m-1.3m was identified, requiring an estimated dewatering of up to 9.0GL to recover habitat areas in the first instance and up to 3.0GL per annum to maintain these areas. The target for Lake Wheatfield is 0.8-1.6m, requiring ongoing dewatering of up to 2.5GL per annum. Lakes Woody and Windabout connect to Lake Wheatfield (at 1.6m depth) and are important habitat areas for diving waterbirds (Walshe, *et al*., 2007).

Management options to determine the probability of meeting biological targets as described above include engineering- based solutions and plant-based solutions. The relative merit of these options may be sensitive to climate change (Walshe & Massenbauer, 2007).

A summary of results from the BBN for both Lake Warden and Lake Wheatfield is provided by Massenbauer & Vogwill (2007) for the Department of Environment and Conservation (DEC) in Table 2. These results clearly indicate that only engineering based solutions offer reasonable prospects for achieving stated management objectives in the LWWS within a 25-year horizon. This treatise is provided in Appendix F.

Table 2 Summary of Results from the BBN for Both Lakes Warden & Wheatfield (Source: Massenbauer & Vogwill, 2007)

Probability of Meeting Resource Condition Targets				
	Lake Warden		Lake Wheatfield	
	Fringing Vegetation	Water Birds	Fringing Vegetation	Water Birds
Target revegetation only	1-4%	2-7%	3-8%	2-9%
Targeted revegetation and engineering solution (Alternative 5)	75-79%	69-74%	62-73%	73-79%

4.0 Site Visits

Data from a site inspection (21 September 2007) to identify and confirm potential terrestrial and aquatic impacts resulting from the proposed engineering works follows:

Lake Warden

- Inspection and documentation of aquatic vegetation on the fringes of the Lake.
- General observations of the surrounding area and water quality of the Lake.

Lake Wheatfield

- Observed evidence of previous lake levels through the presence of partially submerged Melaleuca trees.
- Observations on aquatic vegetation.
- General observations of the surrounding area and water quality of the Lake.

Bandy Creek (Release Site)

- General observations of the surrounding area and water quality of the Creek.
- Bottom substrate was considered in terms of erosion.

Bandy Creek Boat Harbour

- Spot dives undertaken to assess seabed habitat.
- Observations of the uses of the harbour.

There are three types of aquatic plants known to exist in the wetland system indicative of nutrient enrichment (Massenbauer, pers. comm., 2007). Plate 1 indicates the nutrient enrichment encountered in Lake Warden during the site visit in 2007.

Plate 1: Nutrient Enrichment at Lake Warden

5.0 Existing Environment

5.1 Location and Catchment Overview

The Lake Warden Wetland System (LWWS) is in the Shire of Esperance located approximately 5km north to north-east of the town of Esperance. It contains a coastal wetland system. Coastal dunes to the south and a granite escarpment to the north entrap the wetlands (DEC, 2007b). It is threatened by rising water tables and surface water levels, increasing salinity and acidity, waterlogging, eutrophication and sedimentation (CALM, 2006).

The project area lies within the Esperance Plains Biogeographical Region. Major land uses within the region include nature conservation (Fitzgerald River National Park, Nuytsland Nature Reserve), cropping (cereals, oilseeds, and oleaginous fruits), grazing of native pastures, minimal use (vacant crown land, other reserved crown land) and some native forestry (ANRA, 2001).

The five main waterways that flow into the LWWS are Bukenerup Creek, Melijinup Creek, Coramup Creek, Bandy Creek and Neridup Creek. There are 90 overflow satellite lakes and eight major lakes. The eight major lakes divide into three main hydrological suites. The eastern suite contains Ewans Lake, Mullet Lake and Station Lake. Neridup Creek and Bandy Creek flow into this suite through Ewans Lake. The central suite contains Lake Wheatfield, Woody Lake and Lake Windabout, and the western suite includes Pink Lake and Lake Warden. Pink Lake has no inflow creeks from the surrounding catchment and no surface water connectivity with Lake Warden. Bukenerup and Melijinup Creeks flow directly into Lake Warden, which also receives inflows from the central suite. Lake Warden outflows back into the central suite when the central suite begins to outflow to the Bandy Creek weir and catchment stream inflows subside (Maunsell, 2007).

The LWWS is one of 12 wetlands in Western Australia listed as a Wetland of International Importance under the Ramsar Convention based on the wetlands' importance for waterbirds. The LWWS is an excellent example of a south-coast wetland system, it has 5% of the global Hooded Plover population and more than 1% of the global population of Banded Stilts and it serves as an important drought refuge for up to 20,000 waterbirds (CALM, 2006).

The Lake Warden catchment was the third Natural Diversity Recovery Catchment (NDRC) established by DEC in 1996 as one of the actions under the Western Australian Salinity Action Plan (CALM, 2006). The catchment has a high diversity of wetland types including primary saline playa lakes, fresh and brackish wetlands, naturally acidic lakes, granitic rock pools, sand plain seeps and meandering braided saline channels. Other key biodiversity values include terrestrial vegetation associations, high representation of aquatic invertebrate assemblages, special flora taxa, a priority ecological community, threatened and priority fauna and important vegetation corridor links (CALM, 2006).

The Natural Heritage Trust, prior to 1997, financially assisted farmer coordinated landcare groups throughout the catchment to implement active tree plantings and native vegetation fencing projects. The drive for these projects was the increase in agricultural land affected by secondary salinity during the 1990s and, in particular, floods in 1989 that caused major erosion and waterlogging impacts across the catchment (CALM, 2006).

LWWS has a number of values important to local, state, national and international stakeholders and include:

- biological values, such as migratory waterbirds and macro-corridor linkages;
- water quality ecosystem functions and infrastructure protection values provided by LWWS during flood events;
- production values from salt mining on Pink Lake;
- Indigenous and European heritage;
- recreational tourism values with walk trails, bird watching and water sports;
- educational values supported by interpretative trails and a student curriculum package; and

- aesthetic landscape values of LWWS associated with southern Ocean, Recherche Archipelago, pristine white sandy beaches and granite headlands;

5.2 Land Use

Farming activities in the Lake Warden Catchment include grazing, emerging timber production and cropping. A 2004 survey of 120 landholders covering 90% of the LWC's agricultural land ascertained current and proposed land use. The data was analysed to gauge current and potential land use change and subsequent hydrological changes across the LWC.

The survey found that landholders had implemented more than 18,000ha (10% of the LWC) of perennial vegetation into the LWC. These plantings include about 10,000 ha of perennial pastures, 4,000 ha of agro forestry, 2,000 ha of farm trees and 2,500 ha of biodiversity plantings. Landholders have proposed to plant a further 6,000ha of perennials over the next five years (Figure 2)

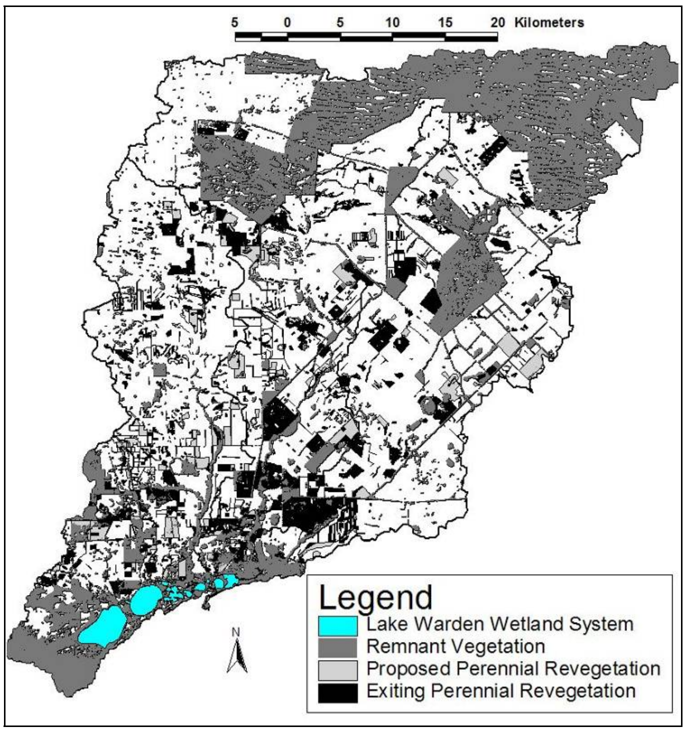


Figure 2 Existing & Proposed Perennial Vegetation Cover of the LWC (Source: Massenbauer & Robertson, 2005)

5.2.1 DEC Managed Lands and Waters

The dataset of DEC managed lands and waters identified the LWWS contains five nature reserves:

- Lake Warden, Reserve No. A32257 (709.7 ha);
- Reserve No. C32259
- Woody Lake, Reserve No. A15231 (565 ha);
- Mullet Lake, Reserve No. A23825 (1917.4 ha); and
- Pink Lake, Reserve No. C24511 (175.9 ha)

5.2.2 Cadastre/Land Tenure

All lands surrounding the LWWS are Crown Reserves, Crown Land, Freehold and Other. Nature Reserves include:

- Lake Warden Nature Reserve No. A32257, first gazetted for the purpose of 'Recreation and Conservation of Flora and Fauna' in 1973, became an 'A' class reserve in 1978. Adjoining Reserve No. 32259 (7.3 ha), formerly a Western Power pole dump, had its purpose changed to 'Conservation of Flora and Fauna' in 1993 (CALM, 1999).

- Woody Lake Nature Reserve No. A15231, originally gazetted as an 'A' class nature reserve in 1970, incorporates most of Windabout Lake, Woody Lake and Lake Wheatfield (CALM, 1999). This was later gazetted in 1978 for the purpose of 'Recreation and Conservation of Flora and Fauna' when a 300m wide limited access area on the northeast side of Lake Wheatfield was gazetted for recreational use.

- Mullet Lake Nature Reserve No. A23825, originally gazetted in 1970, became an 'A' class reserve for the 'Conservation of Flora and Fauna' in 1972. Mullet Lake Nature Reserve incorporates Ewans Lake, Mullet Lake and Station Lake (CALM, 1999).

- Pink Lake Nature Reserve No. C24511, gazetted as a 'C' class reserve in 1956, and later gazetted for the purpose of 'Conservation of Flora and Fauna' in 1993.

5.3 Climate

The study area is characterised by a Mediterranean climate of cool wet winters and hot, dry summers. There are wide variations in the weather, from hot summer days when northerly winds arrive from the interior of the state, to cold, wet winter days with southerly winds from the Southern Ocean (BoM, 2007).

The high-pressure band known as the sub-tropical ridge strongly influences climatic changes and seasonal variations are attributed to the north - south movement of the ridge. Persistent east to southeast winds prevail in summer when the ridge is south of the state. The ridge moves north in the cooler months allowing the moisture-laden westerly winds south of the ridge to deliver much of the annual rainfall (BoM, 2007)

The average annual rainfall varies from 600mm in the South of Esperance to 420mm at Scaddan. The long-term average annual rainfall at the Esperance Bureau of Meteorology Station (009789), located approximately 500m south east of Lake Warden, is 618 mm and is representative of the study area. Studies conducted by CALM (2006) indicate that the driest year since 1975 was 1994, when all areas received two thirds or less of their average annual rainfall. The highest annual rainfall in Esperance occurred in 1999 with 270mm more than average, while Scaddan and the Esperance Down Research Station (EDRS) at Gibson received the highest annual rainfall in 1992 (CALM, 2006).

Approximately 65-75% of rain falls during May to October (CALM, 2006). There is a 20% chance (one in five years) that Esperance will receive annual rainfall above 690mm (wet year) or below 510mm (dry year) (CALM, 2006). Periodic summer rainfall occurs because of thunderstorm activity or tropical cyclone rainfall-bearing depressions.

Average annual potential evaporation is approximately 1600mm at the coast. Evaporation is generally greatest during the summer months (January and February) and lowest during winter months (June and July) (Department of Water, 2007).

Data from the BoM suggests that there was an increased rainfall event (flood) in January 2007, receiving in excess of approximately 169.7mm more than the average rainfall for the month.

Additionally, 2006 data suggests there was significantly less than average mean rainfall received between May to October (Table 3 and Table 4). These figures indicate the typical wide variations in Esperance weather.

Table 3 Rainfall Data for 2007

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.	Years
Mean rainfall (mm)	26.2	25.3	27.4	47.5	72.5	82.3	96.0	83.2	60.5	47.2	33.2	18.1	618.0	39
Statistics	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**	**Years**
Rainfall (mm) for year 2007	196.4	0.2	8.4	125.4	49.2	41.8	84.0	86.4	86.6	84.2	1.8	45.4	809.8	1

Table 4 Rainfall Data for 2006

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.	Years
Mean rainfall (mm)	26.2	25.3	27.4	47.5	72.5	82.3	96.0	83.2	60.5	47.2	33.2	18.1	618.0	39
Statistics	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**	**Years**
Rainfall (mm) for year 2006	48.4	23.4	30.4	83.8	47.4	52.6	73.4	27.0	40.4	6.4	27.6	11.4	472.2	1

5.3.1 Temperature

The temperatures throughout the LWWS catchment range from average daily highs in summer of 25–28oC, to average winter highs of 16–18oC. The average winter minimum temperature is 7–9oC and the average summer minimum temperature is 13–16oC (CALM, 2006).

5.4 Geology

The LWWS, all within areas shown in published geological mapping (Figure 3) as:

Qra Recent alluvium (silt and clay deposits along rivers, floodplains and lakes).

The section of land between LWWS and the ocean falls within the following published surficial geology units:

Qrd Recent coastal dune sand (coastal sand forming long parallel dunes on the coastal plain);
Qrf Recent foredune sand (mobile coastal sand, coastal foredunes, blowouts);
Qrc Recent coastal hill dunes (coastal sand heaped on coastal hills);
Qpl Eolianite (submerged beach rock and marine sand; carbonate-cemented eolianite forming coastal hills. Shelly beach rock forming submerged bars at various depths, concealed shelly marine sand); and
pєg Granite (coarse, even-grained to porphyritic, pink lath feldspar granite).

The section of land north of the LWWS falls within published surficial geology units (from lakes facing north):

Qpa Dissected alluvium (high level flood plains and river terraces, partly dissected);
Qrd Recent coastal dune sand (coastal sand forming long parallel dunes on the coastal plain);
pєg Granite (coarse, even-grained to porphyritic, pink lath feldspar granite); and
Tep Pallinup Siltstone (yellow to grey claystone, siltstone, silty sandstone, with fossil sponges and molluscs).

Figure 3 Geology of the Esperance Area

From the above geological descriptions, it is evident that the study area is characterised by three distinct geologic units that deposited over three different geological periods:

- Proterozoic basement rocks of the Albany-Fraser Orogen emplaced 2,400 million years ago;
- Tertiary sediments from the Plantagenet Group (Bremer Basin sediments); and
- Quaternary surficial sediments (sandplain) deposited from 1.6 million years ago to present day (CALM, 2006).

5.4.1 Proterozoic

Proterozoic rocks of the Albany-Fraser Orogen form the basement rocks that underlie the entire area. Sediments of the Bremer Bay Basin form a veneer infilling palaeovalleys incised into the bedrock. The basement rocks consist of highly deformed granitoid gneiss and granitoid rock. These basement rocks are poorly exposed due to extensive surficial cover and deep weathering (Johnson and Baddock, 1998).

Deep weathering of most of the basement rocks has typically led to a thin laterite duricrust developed over a variable thickness of dense, kaolinitic clay. The weathering profile on the granitoid and gneissic rocks developed through chemical breakdown of the crystalline bedrock during Tertiary and Quaternary times. Erosion of the upper portion of the weathered profile is largely a result of drainage rejuvenation (Johnson and Baddock, 1998).

5.4.2 Tertiary Sedimentary Rocks

Tertiary sediments from the Plantagenet Group of the Bremer Bay Basin form a discontinuous cover over the basement rocks. The Plantagenet Groups consists of two distinct formations laid down in shallow marine environments: the Werillup Formation and the Pallinup Siltstone (Johnson and Baddock, 1998).
The Werillup Formation consists of predominantly fluvial and lacustrine sediments deposited as basal units within the pre-existing Cretaceous valleys (palaeochannels) and broad topographic depressions in the weathered bedrock. The Werillup Formation is pale brown, grey or dark brown and consists of fine to coarse-grained quartz that may be carbonaceous, silty or clayey (DoW, 2007).

The Pallinup Siltstone is more widespread and consists of siltstone and spongolite overlying either the Werillup Formation sediments or weathered basement rocks. It deposited in a shallow-marine environment during a major marine transgression in the late Eocene period. The Pallinup Siltstone is typically a dark brown, carbonaceous siltstone, but may also consist of pale grey and pale green clay, brown micaceous siltstone, or pale brown clay (DoW, 2007).

5.4.3 Quaternary Sediments

Quaternary sediments, which form part of the present day sandplain, occur as a thin (<10m) surface veneer overlying the tertiary sediments (CALM, 2006). These comprise coastal deposits, sandplain deposits and alluvium.

Coastal deposits trend parallel to the coast, forming large ridges of dune sand overlying calcareous shelly limestone. The shelly limestone comprises white, fine to coarse-grained, calcareous quartz sand with variable cementation and abundant shells at some localities. Dune sediments blanket the coastal area and are coloured white to cream, unconsolidated, very fine-grained quartz sand (DoW, 2007).

Sandplain deposits occur inland from the coast and comprise eolian, fine-grained quartz sand and silt, derived from the reworking of coastal sediments and the Pallinup Siltstone. The sand dunes range in thickness from a few centimetres to several metres in height and have an irregular distribution (DoW, 2007).

Alluvium is present within lower parts of mature drainage systems and is in the chain of lakes behind the coastal dunes. The alluvial deposits, consisting of grey to brown silt and clay, are up to eight metres thick north-east of Lake Warden (Johnson and Baddock, 1998).

5.5 Geomorphology

Flat to gently undulating sand plains, characterise the topography of the Esperance area, which rises gradually from sea level to about 150m Australian Height Datum (AHD). The coastal plain extends up to 10km inland and includes the wetland system, which acts as an outlet for Melijinup, Coramup, Bandy and Neeridup creeks. A gently curved escarpment, up to 40m high, marks the inland extent of the coastal plain where it merges with the Esperance sandplain that extends approximately 30 to 40km inland from the coastal plain (Marimuthu *et al*., 2004).

5.6 Acid Sulphate Soils and Buffering Capacity of Lake Warden Wetlands

Acid sulfate sampling was performed for both Lake Wheatfield and Lake Warden, with four samples taken in each lake (Figure 4). An auger was used to sample each site and characterise the soil to 1m below ground level (BGL). The soil profile for each sample location was characterised and interpreted. For some locations, sampling to 1m depth was not possible due to the intrusion of rock or other hard substrate.

Four samples were taken from each of Lake Wheatfield and Lake Warden (Table 5). Samples were located along the border of the lake, which is the area that will be exposed for drainage activities.

Table 5 Acid Sulphate Soils Sampling Locations

Sample	Location		Description
	Easting (mMGA94, Zone 51)	Northing (mMGA94, Zone 51)	
LW1	394107.41	6257443.77	North-west edge of Lake Warden
LW2	396241.27	6256528.64	Southern edge of Lake Warden
LW3	39867.77	6258167.89	Eastern edge of Lake Warden
LW4	396879.76	6257863.71	Eastern side of Lake Warden, slightly further into the Lake than LW3
WF1	400535.86	6258313.41	South-west edge of Lake Wheatfield
WF2	400311.27	6258475.7	Western edge of Lake Wheatfield
WF3	401126.87	6258518.81	Eastern edge of Lake Wheatfield
WF4	400653.38	6258262.67	South-west edge of Lake Wheatfield adjacent to WF1

Each sample's stratigraphy was characterised and field pH testing was conducted for approximately 0.25m intervals (pHF and pHFOX). Nineteen samples from the eight cores were sent for SPOCAS and ANC laboratory testing full results listed in Appendix G.

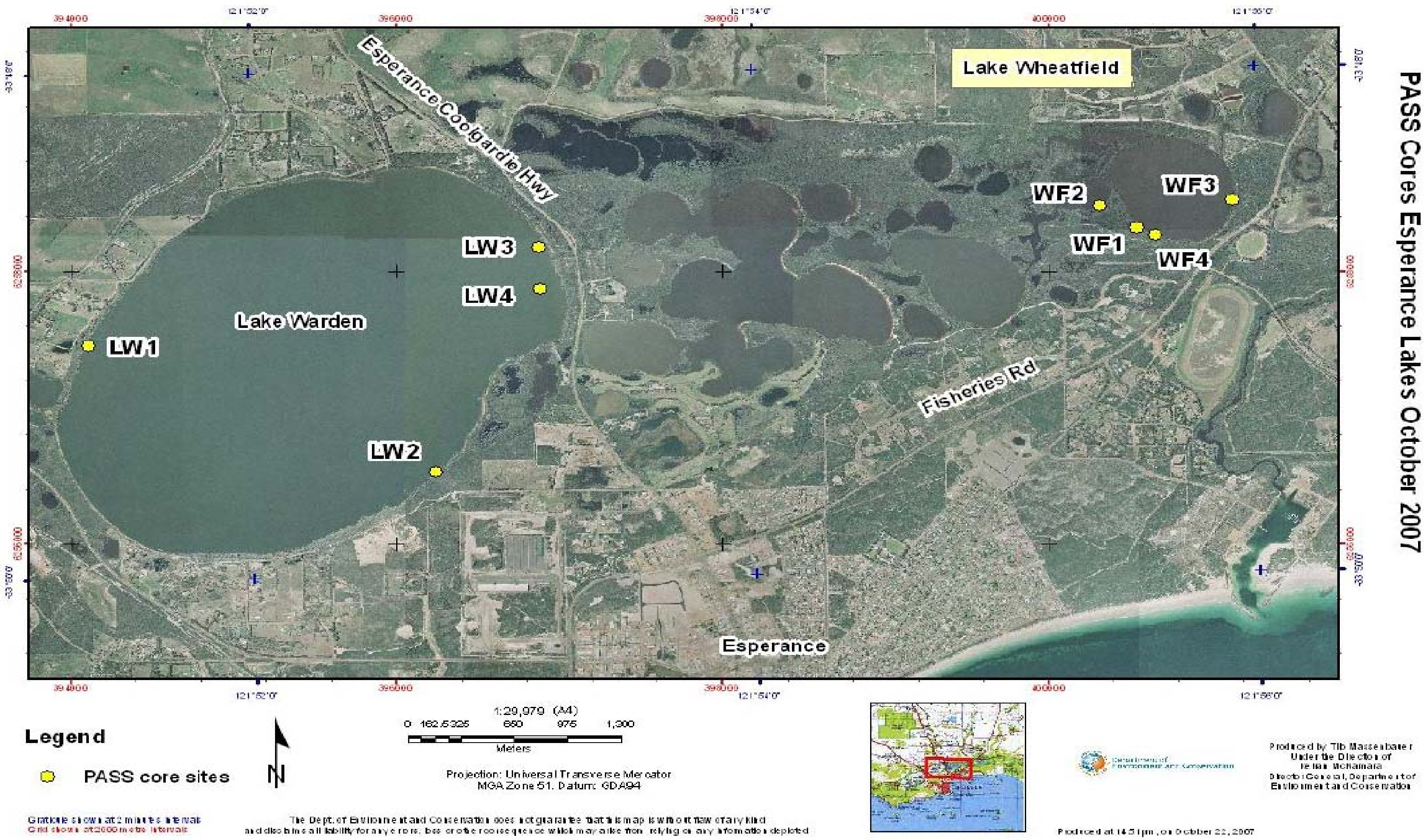


Figure 4 Acid Sulphate Soil Sampling Sites (Courtesy of DEC, 2007)

5.6.1 Soils

The soils in and around lake warden wetlands all have calcareous material disseminated throughout the soil profile and soft and hard carbonate segregations, usually concentrated in the subsoil. These are strongly alkaline soils (pH ≥ 8), often with moderate to high levels of soluble salts in their subsoils. Inherent fertility is low. Zinc, manganese, copper and iron deficiencies are common (Hubble, G. D. *et al*, 1993).

Base forming factors that encourage high levels of exchangeable bases forming cations such as Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}, will contribute toward increased alkalinity (Bohn, McNeal, & O'Conner, 1979). The percentage of base saturation of theses soils remain high, deficiencies of Fe, Mn, Zn, Cu, Co deficiencies occur (Brady, 1990). Micronutrients availability increases with acidity, as soil pH increase their availability to plants decrease. Optimal pH for micronutrients is slightly below 7, the soil pH for the Lake Warden Wetland is greater than 8.5 (McAuther, 1991).

The soils are typically yellow duplex soils (Albaquic Hapludalf), which have 2 % lime present in the B horizon. The exchangeable cations Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}, contribute toward the inherent alkalinity of these soils. The typical cation exchange capacity is approximately (CEC) 19 cmol (+)/kg (McAuther, 1991). Conditions that permit the exchangeable base-forming cations to remain in the soil will encourage high pH values. This is consistent with the current soil testing (Appendix G).

5.6.2 Subsurface Conditions

The subsurface stratigraphy encountered throughout Lake Warden and Lake Wheatfield consisted mainly of an upper organic layer of approximately 0.25m. The underlying materials were primarily light to dark grey siltstone. The sample on the north-west edge of Lake Warden (LW1) was underlain by yellow sand with patches of grey sandy loam. Some samples had distinct marine shell deposits (LW3). Half of the Lake Wheatfield samples were characterised by heavy loam and clay siltstone beneath the organic layer.

5.6.3 Field and Laboratory Analysis

Lake Warden

The majority of the qualitative results for the Lake Warden soils indicated waterlogged, unoxidised materials (pHF>7) with no strong indication of PASS (pHFOX>3) (Appendix G). One exception was a sample from LW2 (south-east side) at 0.75-1.0m of dark grey siltstone with organics. The pHFOX<3 (ΔpH=5.59 & 5.90) and a strong reaction with peroxide is a strong indication of PASS. Quantitative testing confirmed that this sample had the highest PASS generation with the greatest total peroxide acidity (TPA) and net acidity (SPOS) of all the Lake Warden samples (TPA = 260 moles H+/tonne; SPOS=0.41%S). Other layers of organics and silt stone in LW2 and LW3 had net acidity values indicating PASS, although these samples had TPA values below the trigger values (<2 moles H+/tonne) and lower SPOS values (maximum of 0.22%S). In total, four samples indicated PASS with net acidity values above the trigger limit. Three samples were from LW2 and one sample was from LW3 (Appendix A).

Table 6 Acid Sulphate Soils Sampling Results Lake Warden

Sample location	Total Potential Acidity Mole H+/tonne	Acid Neutralising Capacity Mole H+/tonne
LW1	<2	370
LW2	260	3500-4200
LW3	<2	128-490
LW4	<2	190-370

Lake Wheatfield

Qualitative sampling for Lake Wheatfield was not strongly indicative of PASS. As with Lake Warden, pHF samples were indicative of waterlogged, unoxidised soils. Field pHFOX data were generally >3, which did not provide conclusive indications of PASS. However, quantitative analysis indicated high to moderate levels of total sulfur in all soil layers. The upper most organic layer showed both high TPA and low TPA values with half of the sample exceeding the trigger limit for TPA (18 moles H+/tonne). Three quarters of the samples at Lake Wheatfield exceeded the trigger value for SPOS. In total, five samples exceeded the trigger level for net acidity, and each of the four bores had samples with net acidity above the trigger level (Appendix G).

Table 7 Acid Sulphate Soils Sampling Results lake Wheatfield

Sample location	Total Potential Acidity Mole H+/tonne	Acid Neutralising Capacity Mole H+/tonne
WF1	400	<2
WF2	29-520	<2
WF3	0.03-1.1	31-84
WF4	<2	2800

5.6.4 Buffering Capacity or Acid Neutralising Capacity

All lakes and ground waters have some buffering capacity due to the presence of dissolved salts from the water catchment. The buffering capacity is the ability of a solution to resist a change of pH. Correct buffering capacity for potential acid sulphate oxidation has been defined by the following equation, which characterises lakes sensitivity to acidification in terms of acid neutralising capacity (ANC) and/or Carbonate alkalinity (Snoeyink& Jenkins, 1980; Chapman, 1992)

Carbonate alkalinity = $[HCO_3^-] + 2[CO_3^{2-}] + [OH^-] – [H^+] \approx [HCO_3^-]$ for pH 6.5-10.5
(Snoeyink & Jenkins, 1980)

ANC = ∑strong base cations - ∑strong acid anions
ANC = $\sum([Ca] + [Mg]) - \sum([SO_4]$
(Chapman, 1992)

There are two buffering components of the waters of the Lake Warden Wetland system. The first is the carbonate alkalinity, which calculated by the amount of carbonate species in the system. The second is the Acid Neutralising Capacity, which is determined from the strong base forming cations correcting for the strong acid anions in the solution. Calculating and defining these two components expresses a reasonable estimate of how much H^+/tonnes will be required to exhaust the buffering capabilities of these wetlands before the pH will start to decrease. This is determined from the carbonate alkalinity and ANC. The ANC inhibits the formation of H_2SO_4. Both calcium and magnesium will react preferentially with the sulphate anion than the H^+ cation (Bohn, McNeal, & O'Conner, 1979). These base forming cations will react with the sulphate anion on a 1:1 basis. (Snoeyink & Jenkins, 1980; Bohn, McNeal, & O'Conner, 1979). Millequivalents of these cations indicate how likely sulphuric acid can be created or maintained in a system. This estimate only account for solutes dissolved in the lake or groundwater. This estimate does not take into account any dissolution reaction of carbonaceous material or previously precipitated material that may enter the wetland system creating additional buffering capacity. Both the carbonate alkalinity has been calculated and defined in terms of H^+ /Tonne to neutralise the carbonate in Lake Warden, Lake Wheatfield and each lakes groundwater aquifers. Acid neutralising capacity has been calculated and defined in term of parts per million of sulphate required to precipitate out the Ca and Mg cations in Lake Warden, Lake Wheatfield and their respective groundwater aquifers (Table 8)

Table 8 Buffering Capacity of Lake Warden, Lake Wheatfield and Groundwater Interface

Lake Warden	**Carbonate Alkalinity** $[HCO_3^{1-}] = [H^{1+}]$		**Acid Neutralizing Capacity** $\sum$measured $([Ca^{2+}] + [Mg^{2+}] - [SO_4^{2-}])$ = potential $[SO_4^{2-}]$		
lake water	Meq/L	H^+/tonne	Meq/L	H^+/tonne	SO_4 (ppm) g/tonne
2002 summer	3.12	3120	101	100500	2094
winter	3.6	3600	99	98960	2062
2003 summer	3.68	3680	115	115380	2404
winter	3.6	3600	99	98960	2062
average	**3.5**	**3500**	**103**	**103450**	**2155**
ground water					
2002 summer	3.4	3400	264	263580	5491
winter	3.1	3120	271	271140	5649
2003 summer	3.3	3250	239	239390	4987
winter	3.4	3400	264	263580	5491
average	**3**	**3293**	**259**	**259423**	**5405**
Lake Wheatfield	**Carbonate Alkalinity** $[HCO_3^{1-}] = [H^{1+}]$		**Acid Neutralizing Capacity** $\sum$measured $([Ca^{2+}] + [Mg^{2+}] - [SO_4^{2-}])$ = potential $[SO_4^{2-}]$		
lake water	Meq/L	H^+/tonne	Meq/L	H^+/tonne	SO_4 (ppm) g/tonne
2002 summer	2.0	2020	12	11740	245
winter	2.1	2100	9	9280	193
2003 summer	2.8	2800	16	16310	340
winter	2.1	2100	9	9280	193
average	**2**	**2255**	**12**	**11653**	**243**
ground water					
2002 summer	7.4	7400	142	142140	2961
winter	6.4	6370	129	128980	2687
2003 summer	7.7	7670	119	118510	2469
winter	7.4	7400	142	142140	2961
average	**7**	**7210**	**133**	**132943**	**2770**

Ground water values were an average of samples LW35 A & B for Lake Warden and LW 54 A & B for Lake Wheatfield

lake volumes are 3.0 GL for Lake Warden and 2.4 GL for Lake Wheatfield.

Groundwater volumes are 0.8 GL per annum.

$H^{+/tonne}$ calculation = [(Meq/L] x [(volume of water)/(volume of water/1000)]

SO_4^{2-}g/tonne (ppm) = [(Meq/L x Charge/Ion)/ Ion MW] x [(volume of water)/(volume of water/1000)]

As demonstrated in Table 7 there are two sites, which have high Total Potential Acidity values with little soil ANC values. The sites are WF1 (400 H^+/ tonne) and WF2 (29-520 H^+/tonne). Buffering capacity has been calculated and defined in Table 8. Carbonate buffering power for Lake Wheatfield waters is 2255 H^+/ tonne, which are 4.3X that of the TPA. Additional carbonate buffering occurs with the groundwater interaction, which is 7210 H^+/ tonne, approximately 14X that of the TPA. The proposed activity to restore the Lake Warden Wetland System does not include disturbing soil or lake sediment. Dewatering the lakes exposes only top few centimetres of soil/sediment. This has the potential to oxidize creating acid sulphate soils. The carbonate alkalinity ensures if this happens, it will only be a localised effect and any acid generated is effectively neutralised. It can be argued that periodic flushes of acid in the wetlands help ensure a healthy system as it makes trace metals and micronutrients bio-available to counter the metal deficiency. The historical state of the wetlands has been summarised in the following paragraph.

"Prior to hydrological change when the wetlands were healthy pre mid 1980's the wetlands frequently exhibited the odour of hydrogen sulphide under drying conditions during summer and autumn, which was part of a healthy system. Since the wetlands have become permanently inundated post 1980's the wetlands only infrequently emit hydrogen sulphide odours for very short periods (less than a week at a time) during extreme droughts events where minor lowering of lake water levels occur exposing small amounts of beach".(Massenbauer, per comm., 2008).

5.7 Hydrology

The LWWS is hydrologically very complex, with eight main large lakes and over 90 satellite lakes driven to varying degrees by groundwater flow and surface inflows resulting in a very high diversity of wetland habitats (ISRW, 1998). The hydrological components of surface water and groundwater have been partitioned into catchment and the Lake Warden Wetland Coastal floodplain hydrology (CALM, 2006).

The LWWS contains three wetland suites. The hydrology of the LWWS shows a complex relationship between surface and groundwater interactions. The groundwater system under the lakes is complex, with two main aquifers present: the shallow, perched Pallinup aquifer and the deeper Werrillup aquifer.

The western suite that comprises of Lake Warden and Pink Lake is predominantly driven by local groundwater and surface water systems. The central suite (Lake Wheatfield, Woody Lake and Lake Windabout) contains a combination of local groundwater and surface water lakes driven by stream flow carrying run-off and groundwater base flows from the Coramup Creek catchment. The eastern suite (comprised of Ewans, Mullet and Station Lakes) contains primarily surface water lakes driven by stream flow transporting run-off and groundwater base flows from the Bandy Creek Catchment.

There is very little groundwater connection between the eastern wetland suite and the central and western suites. Furthermore, stream flow from the surrounding catchment into Bandy Creek and Coramup Creeks contains up to 60% groundwater base flows and only 40% surface runoff flows (Massenbauer and Robertson, 2005).

Marimuthu and Reynolds (2005) determined that a single conceptual bucket model does not represent the complex hydrological processes of the LWWS. Further support of this conclusion is by the geophysics Electromagnetic survey, groundwater-drilling program, stream gauge data and analysis of existing geospatial datasets.

5.7.1 Catchments

The Lake Warden Catchment, divided into four major sub-catchments, drains into the Lake Warden Wetlands on the Esperance Coastal Floodplain. The total Catchment area is 212,408ha and partitioned as follows (CALM, 2006):

- Esperance Western Lakes Catchment 18, 160ha
- Coramup Creek Catchment 39, 480ha
- Bandy Creek catchment 73, 463ha
- Neridup Creek Catchment 81, 305ha

5.7.2 Wetlands, Lakes and Streams

The Lake Warden Catchment contains a variety of wetlands systems, with numerous small saline wetlands in braided channels to the north. There are numerous circular, seasonal wetlands outside of the braided channels and further to the north that were formerly fresh but are now saline (CALM, 2006). Springs in the area also give rise to small, shallow, brackish wetlands such as those at the eastern end of the wetland areas (ISRW, 1998).

The mid catchments contain larger wetlands, formerly fresh and supporting Eucalypt trees such as *Eucalyptus occidentalis*, but are now saline. The incised streamlines on the lower part of the catchment on the mid slopes contain freshwater damplands with Banksia occidentalis, *Taxandria linearifolia* and Sedgelands. These wetlands also occur as hillside seeps at the edge of certain salt lakes and valley floors. Mullet Lake and wetlands to the east of it are located in a large samphire marsh (CALM, 1999).

Water in the LWWS lakes ranges from moderately to very saline and water regimes range from almost permanent (only drying out occasionally at the end of summer) to ephemeral. Salinity is influenced by seasonal and annual rainfall although the hydrology of coastal lakes such as the LWWS is affected by marine groundwater. The high salinity in the lakes is partly due to poor flushing which results in concentration of salt due to evaporation (CALM, 1999). Seasonal and annual rainfall determines the average maximum depths of the lakes.

Water flows into Lake Wheatfield, and, in wetter years into Lake Warden, from Coramup Creek, which originates 45km north of the lakes. Lake Warden also receives flow from creeks originating 9-14km north-northwest, including the Melijinup, Buckenerup and Monjingup Creeks. Water flows into Station and Mullet Lakes from Neridup Creek and Bandy Creek, which originates 60km north. Mullet Lake and Station Lakes overflow into the Southern Ocean in wetter years (CALM, 1999).

5.8 Bathymetry

The DEM for the LWWS indicates that both Lake Warden and Lake Wheatfield have a gradual and generally uniform depth gradient (Figure 5 & Figure 6) indicating that lower water levels would reveal shoreline habitat relatively uniformly around each lake. A lowering of 1m from Lake Wheatfield would expose, however more shoreline habitat along the western edge.

Further exploration of the DEM revealed that the maximum flood level (Maunsell, 2007) results in extensive flooding of surrounding floodplain and wetland areas and, Lake Wheatfield in particular, become indistinguishable from the surrounding floodplain and wetland areas (shown in red dashed line).

Figure 5 Lake Warden Bathymetry

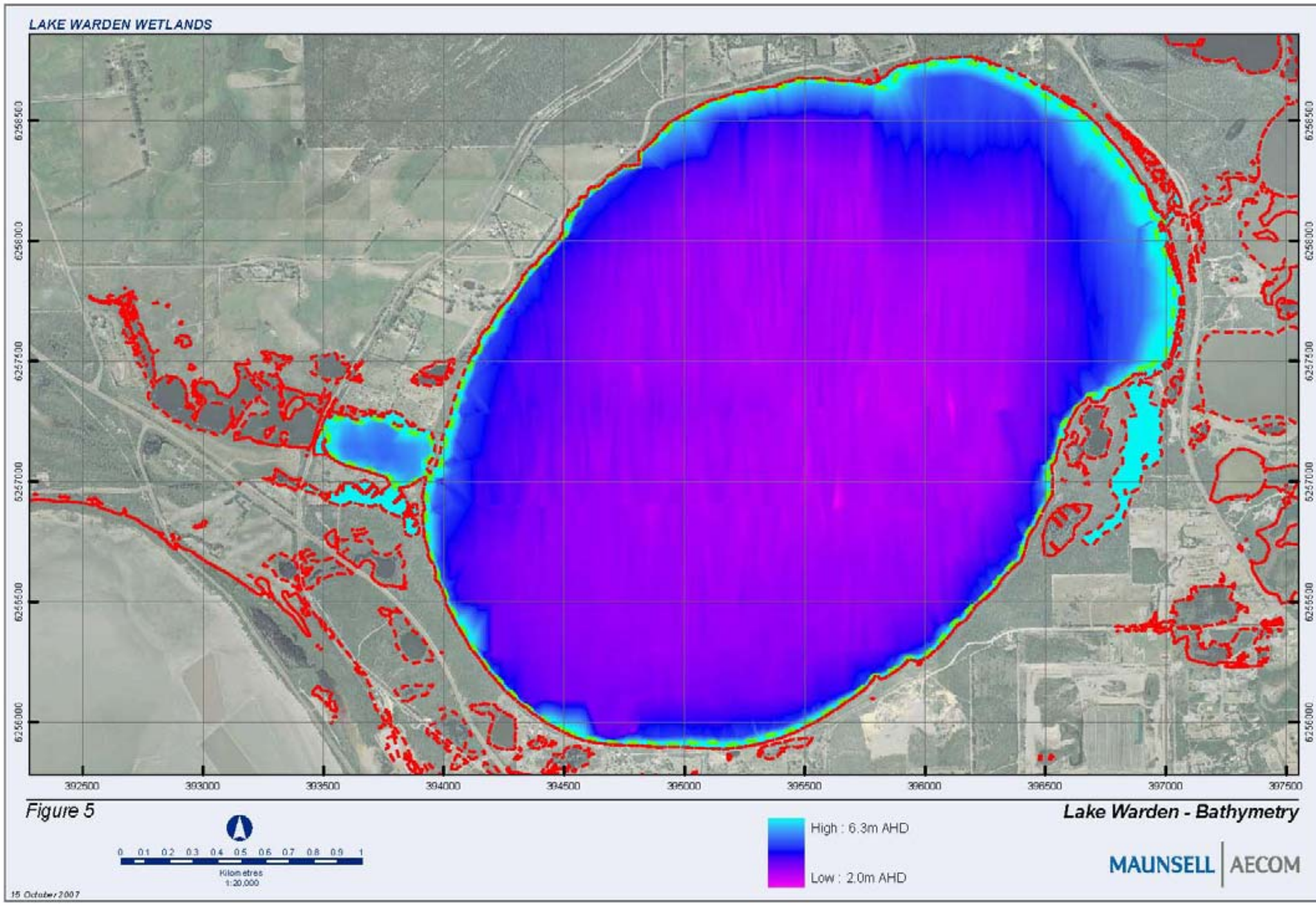
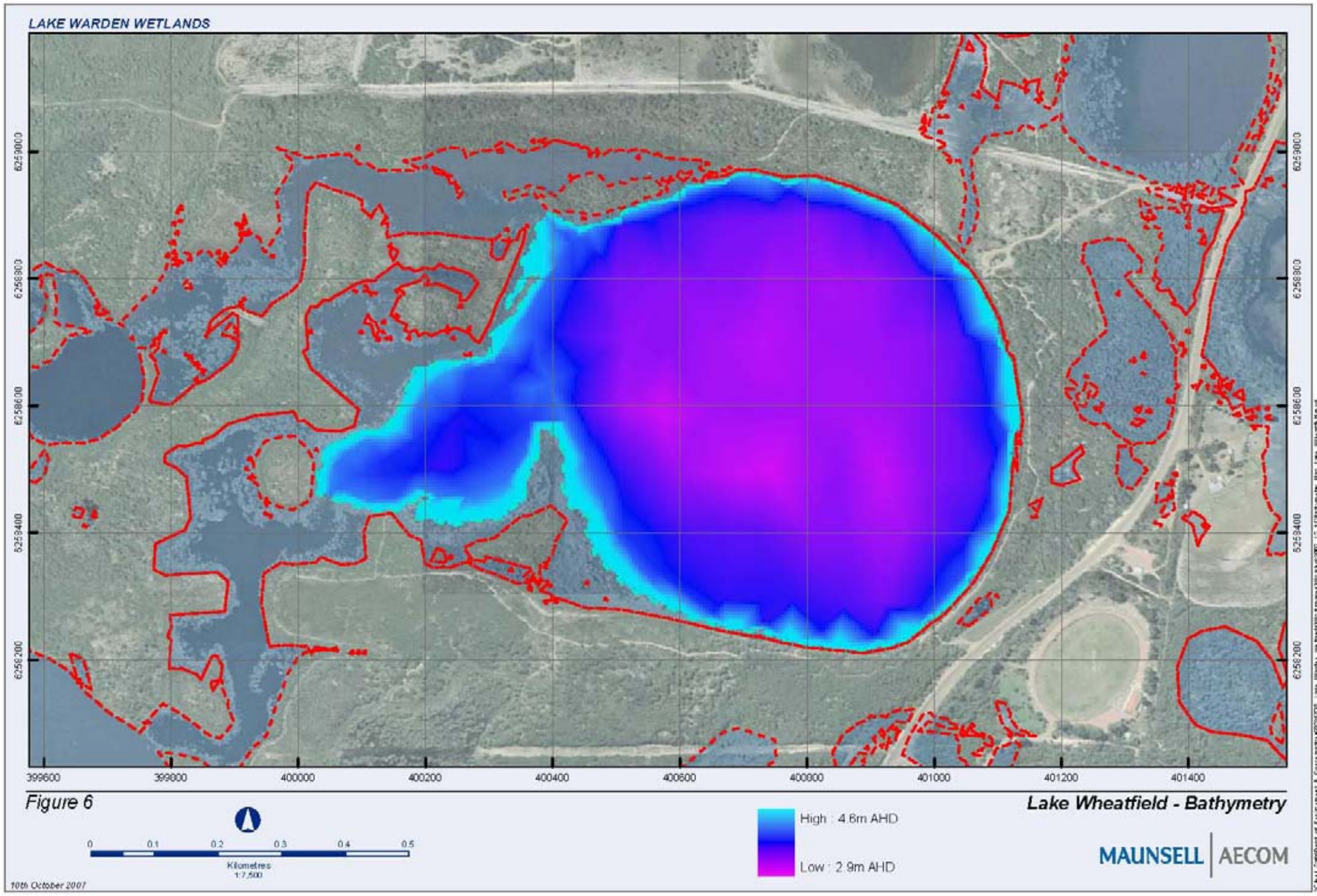


Figure 6 Lake Wheatfield Bathymetry



5.9 Water Quality

DEC (Esperance) baseline data for LWWS provides an indication of the levels and variability of basic water quality parameters including total nitrogen, total phosphorous, total suspended solids (TSS), turbidity, pH and electric conductivity (EC). These data have been compared to trigger values for physical and chemical stressors for south-west Australia for slightly disturbed ecosystems (ANZECC & ARMCANZ, 2000).

Table 9 Default trigger values for physical and chemical stressors for South-West Australia for slightly disturbed ecosystems.[1]

Ecosystem type		Chl *a* ($\mu g\ L^{-1}$)	TP ($\mu g\ P\ L^{-1}$)	FRP ($\mu g\ P\ L^{-1}$)	TN ($\mu g\ N\ L^{-1}$)	NO_x ($\mu g\ N\ L^{-1}$)	NH_4^+ ($\mu g\ N\ L^{-1}$)	DO (% saturation)[i] Lower limit	DO (% saturation)[i] Upper limit	pH Lower limit	pH Upper limit
Upland river[f]		na[a]	20	10	450	200	60	90	na	6.5	8.0
Lowland river[f]		3–5	65	40	1200	150	80	80	120	6.5	8.0
Freshwater lakes & reservoirs		3–5	10	5	350	10	10	90	no data	6.5	8.0
Wetlands[d]		30	60	30	1500	100	40	90	120	7.0[e]	8.5[e]
Estuaries		3	30	5	750	45	40	90	110	7.5	8.5
Marine[g,h]	Inshore[c]	0.7	20[b]	5[b]	230	5	5	90	na	8.0	8.4
	Offshore	0.3[b]	20[b]	5	230	5	5	90	na	8.2	8.2

na = not applicable

a = monitoring of periphyton and not phytoplankton biomass is recommended in upland rivers — values for periphyton biomass (mg Chl *a* m^{-2}) to be developed;

b = summer (low rainfall) values, values higher in winter for Chl *a* (1.0 μgL^{-1}), TP (40 $\mu g\ P\ L^{-1}$), FRP (10 $\mu g\ P\ L^{-1}$);

c = inshore waters defined as coastal lagoons (excluding estuaries) and embayments and waters less than 20 metres depth;

d = elevated nutrient concentrations in highly coloured wetlands (gilven >52 $g_{440}m^{-1}$) do not appear to stimulate algal growth;

e = in highly coloured wetlands (gilven >52 $g_{440}m^{-1}$) pH typically ranges 4.5–6.5;

f = all values derived during base river flow conditions not storm events;

g = nutrient concentrations alone are poor indicators of marine trophic status;

h = these trigger values are generic and therefore do not necessarily apply in all circumstances e.g. for some unprotected coastlines, such as Albany and Geographe Bay, it may be more appropriate to use offshore values for inshore waters;

i = dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability (see Section 3.3.3.2).

5.9.1 Nutrients

Nitrogen compounds are essential for living organisms as an important constituent of proteins (Chapman, 1992), but increased levels of nutrients (such as nitrogen) can trigger excessive weed and algal growth which can lead to fish death, toxin production (in some cases) and general diminishing of water quality (EPA, 2007). The different levels of nitrogen for the LWWS have been plotted against the

[1] Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Data derived from trigger values supplied by Western Australia. Chl *a* = chlorophylla, TP = total phosphorus. FRP = filterable reactive phosphate, TN = Total nitrogen, NO_x = oxides of nitrogen, NH_4^+ = ammonium, DO = dissolved oxygen.

nitrogen wetland and river trigger values (TV) outlined in the Australia and New Zealand Environment and Conservation Council (ANZECC) Guidelines for South-west Australia (Figure 7). Both Lake Wheatfield and Lake Warden average nitrogen measures exceed trigger values, but Bandy Creek falls below the trigger value.

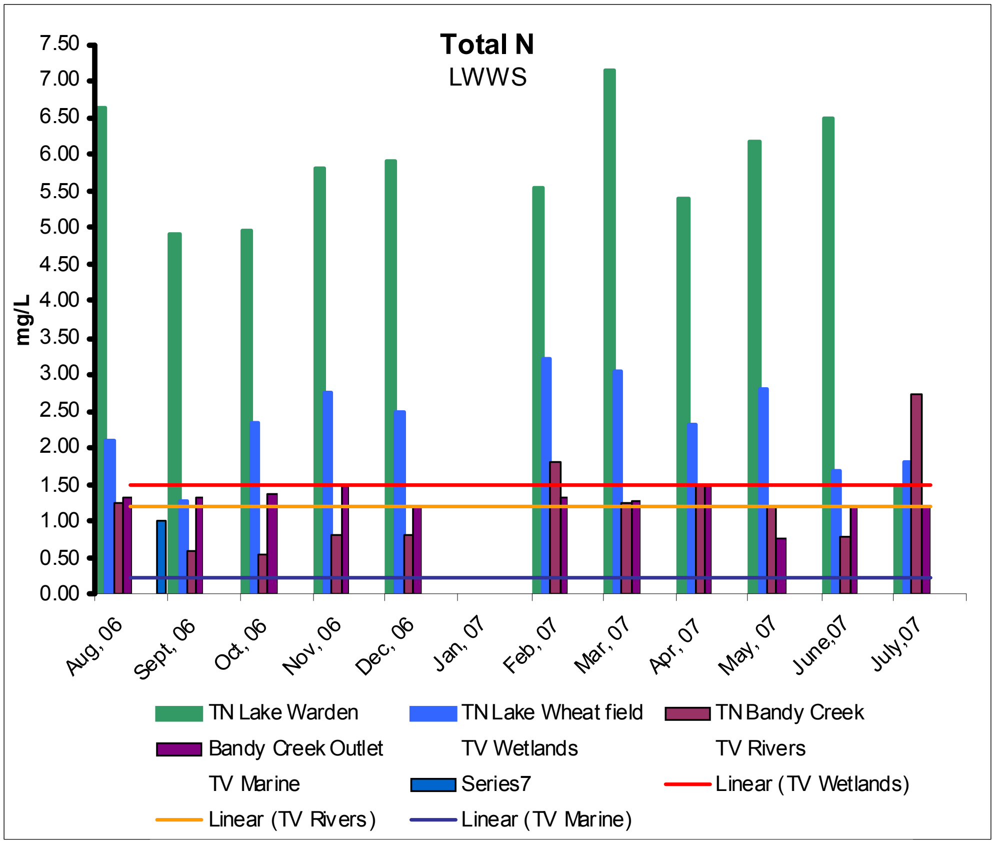


Figure 7 Total Nitrogen measured for the three water bodies over the period August 2006 to July 2007

The dominant form of nitrogen compounds detected in the Lakes is Kjeldahl nitrogen (Table 10), which is organic nitrogen (Chapman, 1992). Organic nitrogen is primarily formed by phytoplankton and bacteria in the water, and levels will fluctuate naturally in the environment. The types of organic nitrogen compounds include; amino acids, nucleic acids, humic acids, fulvic acids and urea. These nitrogen compounds undergo microbial mineralization into inorganic nitrogen (ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-).

Table 10 Different Nitrogen Average Levels at Lake Warden, Lake Wheatfield and Brandy Creek

Nitrogen Compound	Lake Warden	Lake Wheatfield	Bandy Creek	Bandy Creek Out fall
Nitrate-N	> 1%	> 1%	7 %	> 1%
NH_4/NH_3	> 1%	> 1%	7 %	> 1%
NOx	> 1%	> 1%	6 %	> 1%
Total Kjeldahl-N	99.7%	100%	73 %	100%
Total N	Avg, 5.83 mg/L	Avg, 2.48 mg/L	Avg, 1.1 mg/L	Avg, 1.6 mg/L

Phosphorus compounds are also important nutrients for living organisms, and these compounds control the primary productivity of a water body (Chapman, 1992). Excessive levels of inorganic phosphorous, however, can lead to eutrophication (Chapman, 1992), an increase in chemical nutrients which results in excessive plant growth. Phosphorus levels of the water bodies are measured against wetland and river trigger values (TV) outlined in the ANZECC Guidelines for South-West Western Australia (Figure 8).

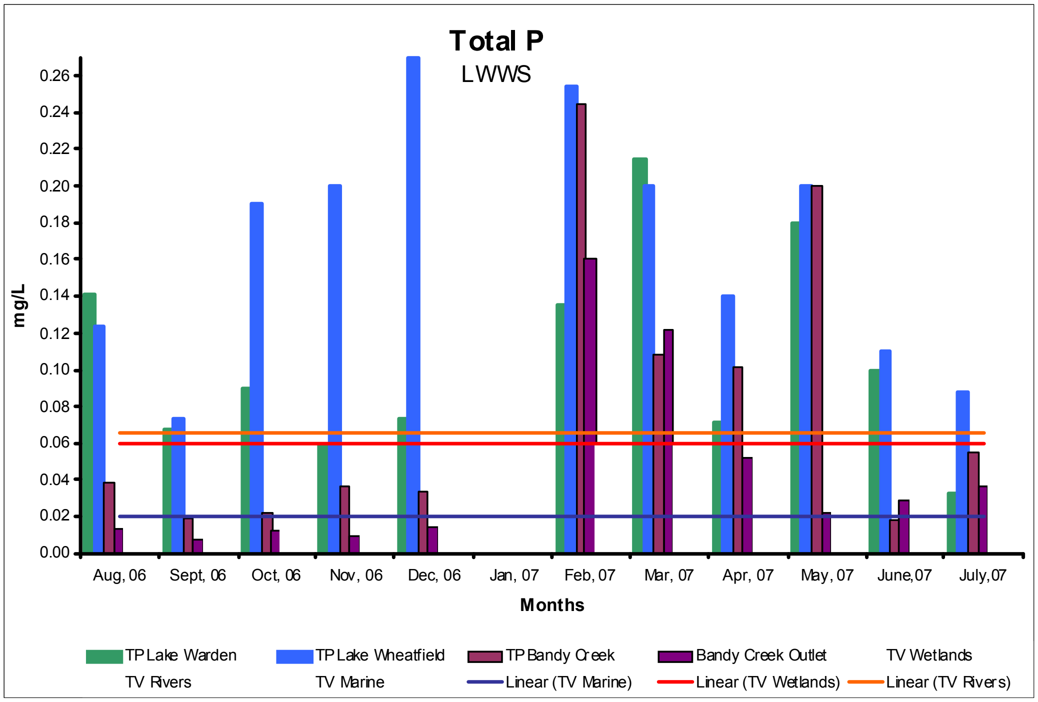


Figure 8 Total Phosphorus levels for Lake Warden, Lake Wheatfield and Bandy Creek between August 2006 and July 2007

The dominant species in both Lake Wheatfield and Lake Warden are organic phosphorus, which is associated with particulate matter which are less likely to contribute to eutrophication. These organic phosphorus compounds undergo microbial mineralization into inorganic phosphate, the major species in Bandy Creek. At the pH level of Bandy Creek, the dominate form is HPO_4^{2-}.

Table 11 Total Phosphorus Average Levels for Lake Warden, Lake Wheatfield and Bandy Creek

	Lake Warden	Lake Wheatfield	Bandy Creek	Bandy Creek Out fall
Total P (mean)	0.11 mg/L	0.18 mg/L	0.07 mg/L	0.01 mg/L
Phosphate-P	11%	6%	64%	70%

Lake Windabout and Wheatfield are naturally high in nutrients and have a potential for blue/green algae. Lake Wheatfield, in particular, has very high nutrients, but the cause of this elevated nutrient level is unknown (Massenbauer pers. comm., 2007). A potential, although not investigated source is the adjacent golf course, which uses secondary treated sewage waste to fertilise their grounds.

5.9.2 Total Suspended Solids, Turbidity, pH and Electric Conductivity

Suspended solids consist of silt, clay, fine particles of organic and inorganic matter, soluble organic compounds, plankton and other microscopic organisms (Chapman, 1992). High levels of TSS decrease the amount of light reaching the sediment and increase the turbidity of the water column, which impacts plant growth. The average TSS for Lake Warden and Lake Wheatfield are significantly higher than Brandy Creek, which may be due to the high levels of organic nitrogen and phosphorous detected in the two lakes (Figure 9).

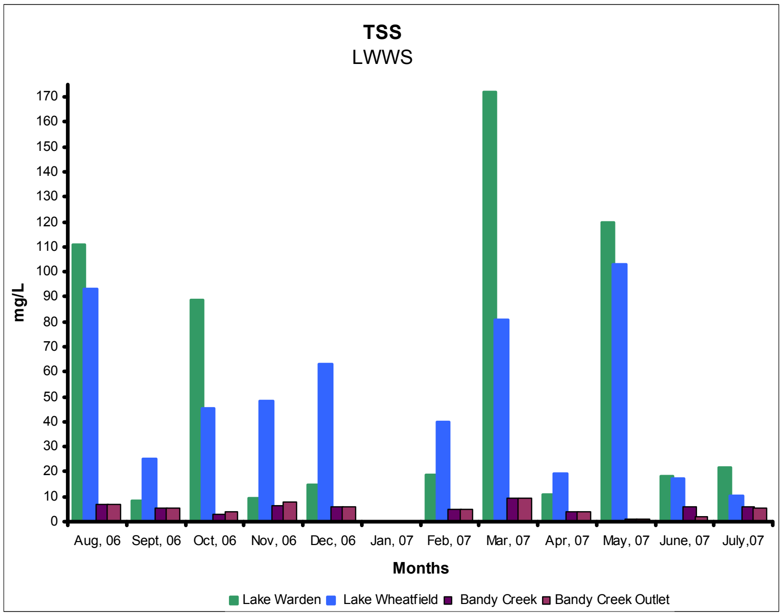


Figure 9 Total Suspended Solids (TSS) for Lake Warden, Lake Wheatfield and Bandy Creek measured for the period of August 2006 to May 2007

Turbidity is used to measure the clarity of the water column, with a measure of less than 15 indicating low levels of turbidity (clear water), and measures of more than 45 indicating very high levels of turbidity (cloudy water). The results indicate that Bandy Creek is classified as 'Clean' under the ANZECC Guidelines for south-west Australia (Figure 10). Both Lake Warden and Lake Wheatfield turbidity levels fluctuate between 'Clean' (<15) and 'Very High' (>45) which means that, at times, the Lakes are very cloudy. This may be due to the high readings of TSS in the two Lakes, which would reduce the clarity of the water.

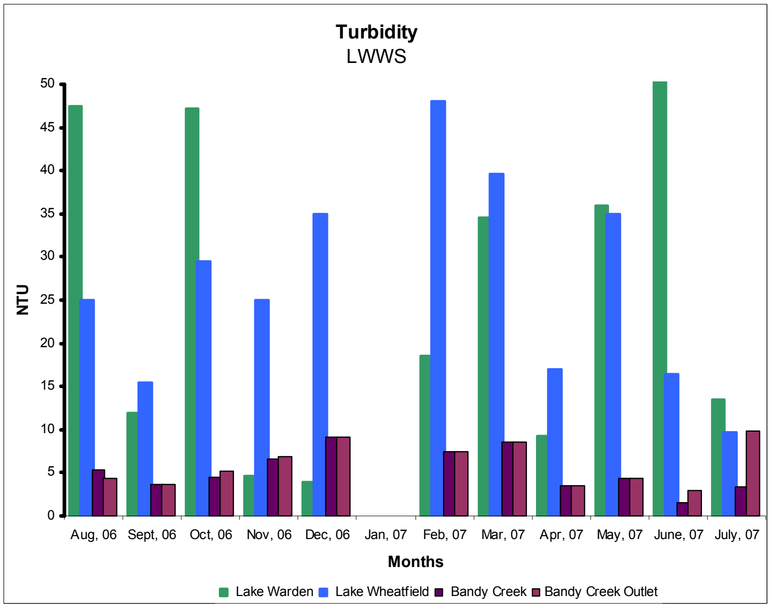


Figure 10 Turbidity levels for Lake Warden, Lake Wheatfield and Bandy Creek between August 2006 and May 2007

Acidity (pH) is an important measure of water quality. Acidification can mobilise heavy metals and other compounds that can cause ecological damage to aquatic and riparian ecosystems and structural damage to infrastructure (EPA, 2007). A pH measure is useful in the assessment of water quality as pH levels can affect both biological and chemical processes within a water body (Chapman, 1992). Suitable lower and upper limits for pH levels in wetlands are 7 and 8.5, respectively according to ANZECC Guidelines for south-west Australia.

A time series of pH for Lake Wheatfield, Lake Warden and Bandy Creek indicates a fluctuation of pH with averages of neutral to alkaline for all three locations. The five readings for each month have been plotted, with a monthly average pH shown in black. The yearly average pH for Lake Wheatfield is 8.09 ± 0.57, which is within suitable limits for wetland pH levels (Figure 11). There is a significant variation between the pH readings in all months but highest for October through December. Esperance region had both a significant drought and floods between 2002 and 2007. It is these natural past climatic conditions which contributed to the monthly variation. .The pH trends represent the natural fluctuation within Bandy Creek and the LWWS wetlands and any management strategy has to account for the natural variability of this system.

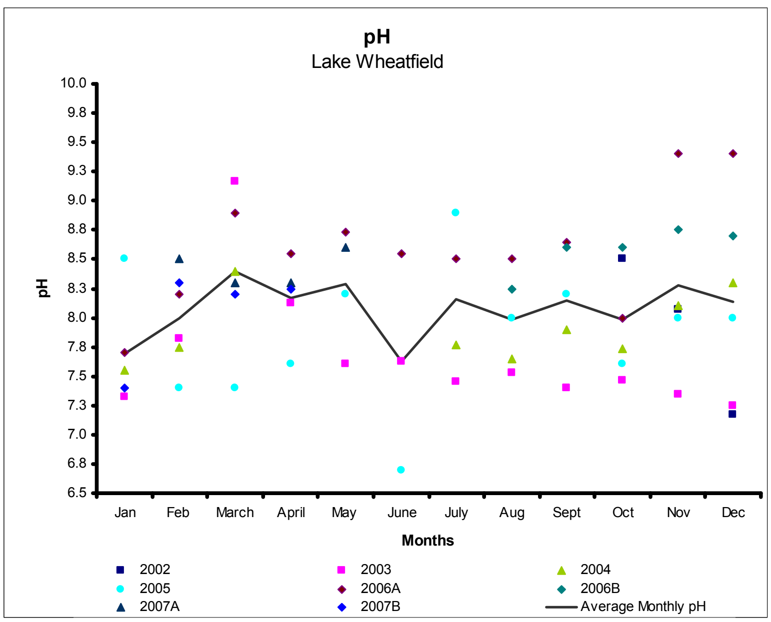


Figure 11 pH levels for Lake Wheatfield measured each month between 2002 and 2005, and twice a month for 2006 and 2007

The average pH for Lake Warden is 8.07 ± 0.55, which is within suitable limits for wetlands (Figure 12). During March, October, November and December of 2004 and 2006, pH levels exceeded trigger values for both wetlands and rivers. There also appears to be a greater variation in pH from September to December.

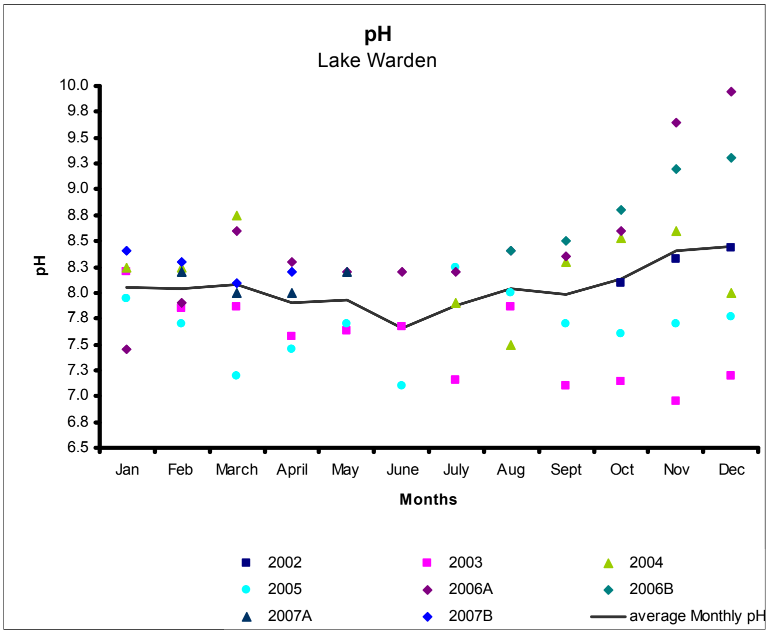


Figure 12 pH levels for Lake Warden measured once a month between 2002 and 2005, and twice a month for 2006 and 2007

The average pH for Bandy Creek is 7.82 ± 0.36, which is within suitable limits for wetlands (Figure 13). During October to December 2006, the pH levels exceeded trigger values for both wetlands and rivers.

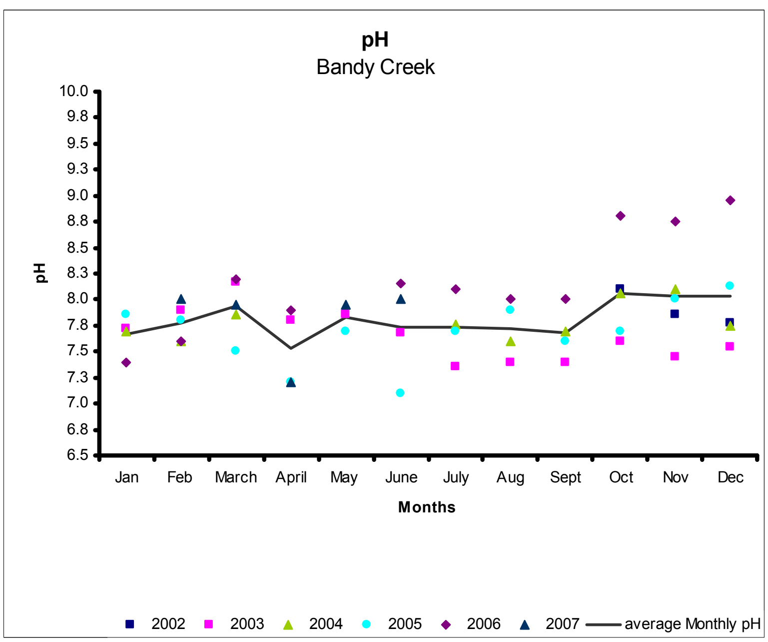


Figure 13 pH levels for Bandy Creek measured between 2002 and 2007.

The conductivity levels of water (i.e., electrical conductivity) is a measure of the ability of water to conduct an electrical current, and this measure is sensitive to variations in dissolved solids, mostly mineral salts (Chapman,1992). It is expected that seawater has a higher electrical conductivity (EC) than water found within wetlands or rivers. The EC for the Lakes was compared to the EC for seawater, which is displayed as a horizontal purple line (Figure 14). The average shows EC (12.9 ± 4.5) for the Lake Wheatfield is significantly lower than the EC for seawater.

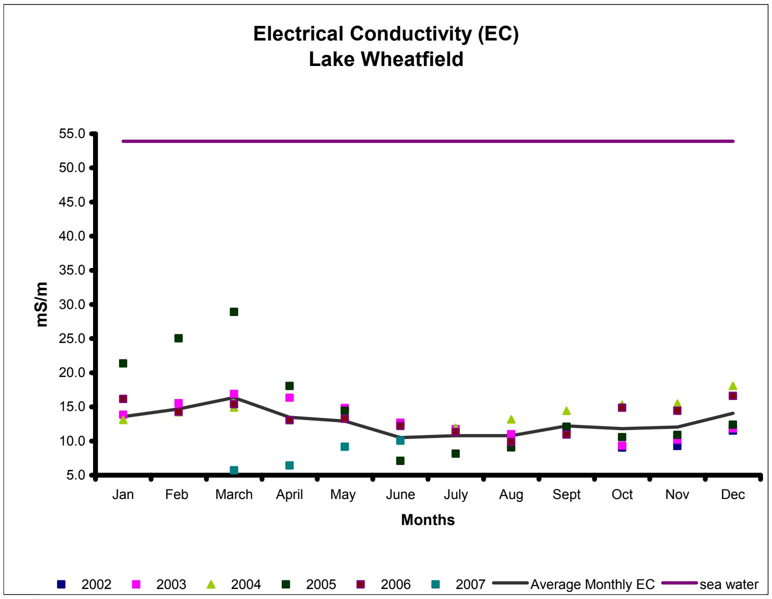


Figure 14 EC of Lake Wheatfield measured for each month between 2002 and 2007, with the monthly average shown as a black line

Displayed as a horizontal brown line, Figure 15, compares the EC for the Lake Warden to the EC for seawater. It shows the average EC (81.1 ± 16.8) µ for Lake Warden is significantly higher than the EC for seawater, implying that the water within the Lake is hyper-saline.

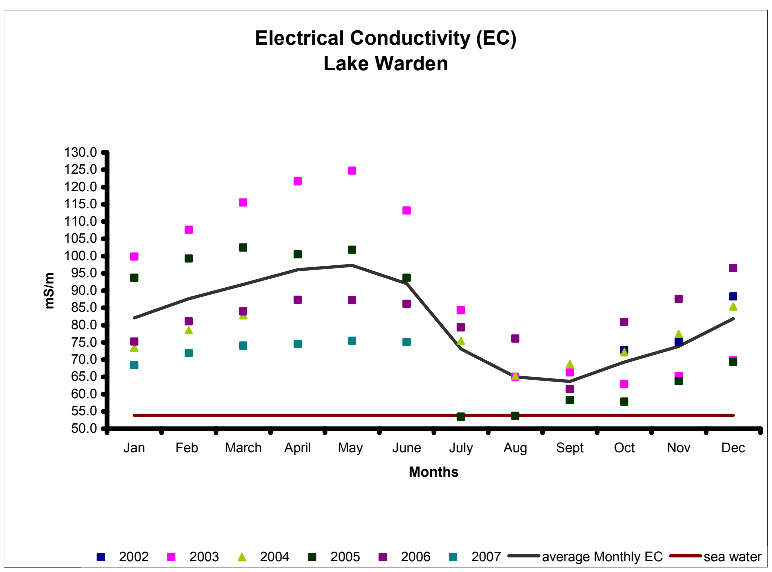


Figure 15 EC of Lake Warden measured for each month between 2002 and 2007, with the monthly average shown as a black line

The EC of the Bandy Creek was compared to the EC of seawater, which is displayed as a horizontal brown line (Figure 16). This shows that the average EC (16.5 ± 7.1) for the Creek is significantly lower than the EC for seawater.

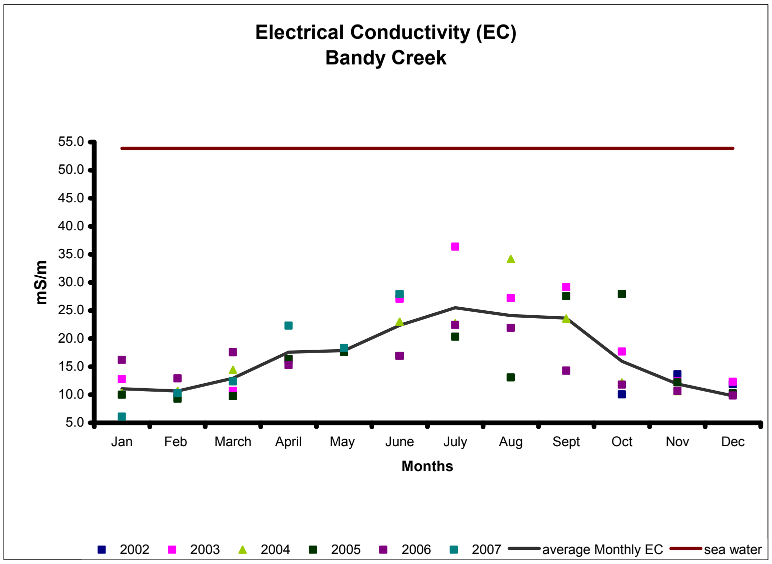


Figure 16 EC of water within Bandy Creek measured for each month between 2002 and 2007, with the monthly average plotted as a black line

5.9.3 State Salinity Strategy Monitoring

The State Salinity Strategy (now replaced by State Salinity Action Plan), incorporated the South-West Wetlands Monitoring Program which commenced in 1979. Wetland depth, salinity, groundwater monitoring and vegetation were recorded four times a year during the early 1980s and then reduced to one record in each of September and November. The program includes wetlands throughout the south-west, two of which fall within the LWWS (Lake Wheatfield and Station Lake). A more recent monitoring program established under the Recovery Catchment program began in May 2002, involving the collection of fortnightly depth records for all major lakes within the LWWS.

As part of the State Salinity Strategy's wetland monitoring program, canopy condition and basal area of overstorey species at Lake Wheatfield have been monitored triennially since 1997 by DEC and Edith Cowan University (ECU). Four radial transects were established to sample representative stands of trees and shrubs in the wetland basin and riparian zones (Figure 17). Two or three contiguous 20 x 20m plots were located on these transects and each plot was subdivided into five 4 x 20m subplots. Within transects, all trees and large understorey shrubs were marked and tagged.

Taxa such as (but not limited to) *Melaleuca cuticularis* (Saltwater paperbark) were used for analysis, as they are a good indicator species that grow in salty wetlands and are tolerant of both water-logging and salt in the air and water (Water and Rivers Commission, 1997). Results from the wetland monitoring program by DEC suggest that *Melaleuca cuticularis* within some transects subject to prolonged inundation (i.e. localised to parts of transect within the inundated basin) is in decline. This can be mainly attributed to increased periods of inundation which results in vegetation decline and eventually death (DEC, 2007c).

The wetland monitoring program has limitations in its methodology, as transects may have limited representation for the entire LWWS. In order to account for this limitation, preliminary vegetation surveys (observing vegetation structure, composition and condition) have been conducted over the last six years within the Lake Warden Catchment (CALM, 2006)

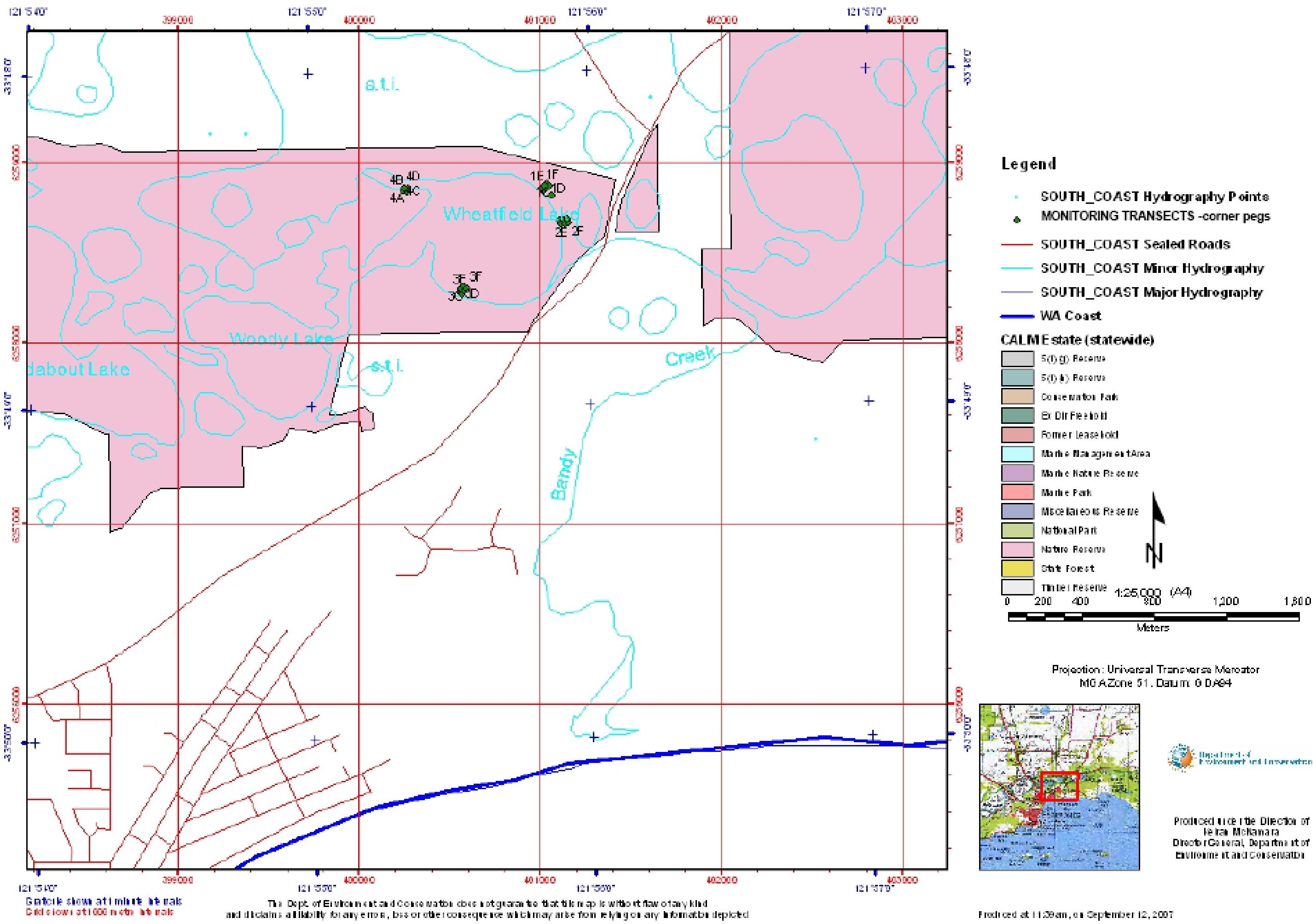


Figure 17 of monitoring transects at Lake Wheatfield (Courtesy of DEC, 2007).

5.9.4 Total Metals and Dissolved Metals

Metals naturally occur in the environment are commonly referred to as either micro or trace nutrients. These elements are essential for enzymatic and biochemical reactions. However, these same elements in excess quantities can become extremely toxic to humans, wildlife and have serious detrimental effect upon aquatic ecosystems.

The metals that have the highest potential to pollute are heavy metals. Excessive levels of heavy metals are frequent by products of mineral extraction, refining, or transport and industrial processes. An alternative source of pollution is the erosion of contaminated soil, or spoil heaps, combined with acid drainage into nearby waterways or the leaching of the polluted soil into the groundwater.

5.9.4.1 Sampling Locations

Figure 18 shows the sampling locations.

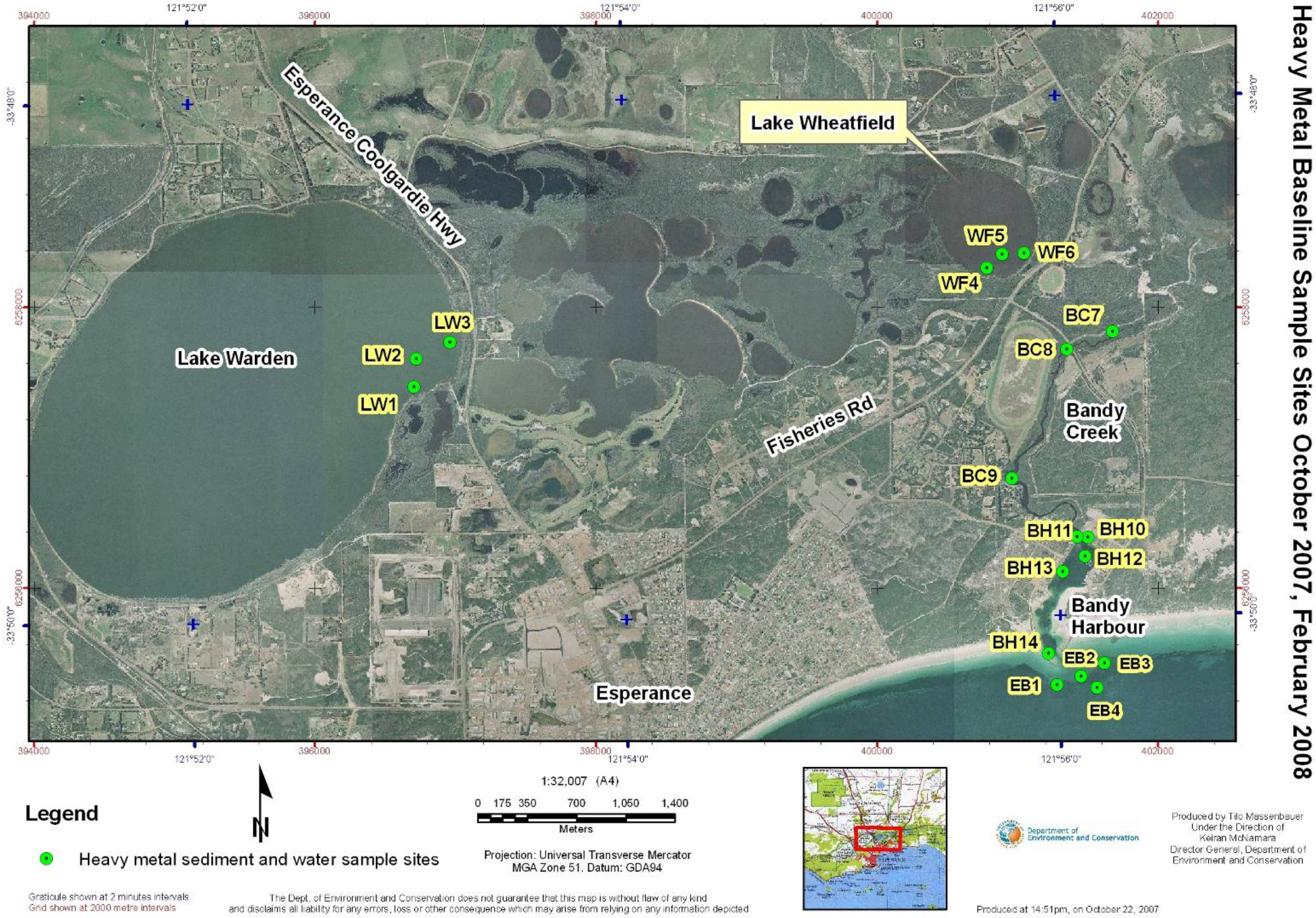


Figure 18 and Dissolved Metal Sampling Locations (Courtesy of DEC, 2007)

5.9.4.2 Laboratory Results

Samples were analysed using more than one laboratory; ALS Laboratory Group (ALS) for the first samples and Marine and Freshwater Research Laboratory (MAFRL) for the second batch, therefore the Limit of Reporting (LOR) for the same parameters has the potential to differ between the two batches of analyses. For some parameters, the LOR was found to be higher than the Ecological Trigger Values, however it is considered that some of the trigger values selected may be too low for the purposes of this study. Other results of the study indicate that the LWWS consists of mainly marine water (Tables 14and 15) and one of the trigger values adopted is aimed to achieve 99% protection of species in freshwater. Generally, freshwater systems have stricter trigger values for the majority of parameters tested. However, there are several exceptions; for example, the trigger value for copper in marine systems is lower than for in freshwater systems. When the LOR is lower than the trigger value, whether or not the pollutant presence has been exceeded the trigger value is unknown.

It is important to note that the parameters tested in the two separate rounds of sampling were different. Dissolved and total potassium, mercury, phosphorus, and total sodium were not tested in the second round of sampling.

Results from the first round of sampling showed that some levels for dissolved parameters were higher than total metals. Results for Site BC 8 for the Aluminium are questionable, as the dissolved Aluminium level far exceeds the levels for total Aluminium. It is worth mentioning the November sample was collected (unknown at the time) next to an engine block and car batteries which were dumped into Bandy Creek .(Massenbauer, per comm., 2008). Similar discrepancies have been noted Copper at Site BH13 all during the November sampling round, which were not present in the February samples.

5.9.4.3 Tabulated Results of November 2007 Water Sampling

Table 12 Laboratory Analysis Results of November 2007 Water Sampling

Dissolved Metals	Unit	LOR	Trigger Levels (FW 99%)	Trigger Levels (FW 80%)	Trigger Levels (SW 99%)	Trigger Levels (SW 80%)	LW1	LW2	LW3	WF4	WF5	WF6	BC7	BC8	BC9	BH10	BH11	BH12	BH13	BH14
Iron	mg/L	0.05	–	–	–	–	<0.05	0.24	<0.05	<0.05	0.06	0.07	0.12	1.79	0.32	0.98	0.46	0.63	0.12	1.01
Aluminium	mg/L	0.01	0.027	0.15	–	–	<0.10	<0.10	<0.10	4.48	<0.10	<0.10	<0.10	56.9	<0.10	2.41	1.21	<0.10	2.23	<0.10
Arsenic	mg/L	0.001	0.001	0.36	–	–	0.012	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.013	<0.010	<0.010	<0.010	<0.010	<0.010
Cadmium	mg/L	0.0001	0.00006	0.0008	0.0007	0.036	0.0022	<0.0010	0.0028	0.0025	0.0012	<0.0010	0.0014	0.0077	<0.0010	<0.0010	0.003	0.0024	<0.0010	0.0017
Chromium	mg/L	0.001	0.00001	0.04	0.00014	0.085	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	mg/L	0.001	–	–	0.000005	0.15	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.014	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper	mg/L	0.001	0.001	0.0025	0.0003	0.008	<0.010	<0.010	<0.010	0.16	<0.010	0.044	<0.010	<0.010	0.012	<0.010	<0.010	<0.010	0.598	<0.010
Lead	mg/L	0.001	0.001	0.0094	0.0022	0.012	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Nickel	mg/L	0.001	0.008	0.017	0.007	0.56	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.028	<0.010	<0.010	<0.010	<0.010	0.01	<0.010
Mercury	mg/L	0.0001	0.00006	0.0054	0.0001	0.0014	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Tin	mg/L	0.001	–	–	–	–	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium	mg/L	0.01	–	–	0.05	0.28	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc	mg/L	0.005	0.0024	0.031	0.007	0.043	<0.050	<0.050	<0.050	0.251	<0.050	<0.050	<0.050	<0.050	<0.050	0.06	<0.050	<0.050	0.405	<0.050
Total Metals																				
Iron	mg/L	0.05	–	–	–	–	0.23	0.08	0.84	81.1	40	0.88	1.23	1.97	7.61	<0.05	0.16	<0.05	0.34	
Aluminium	mg/L	0.01	0.027	0.15	–	–	0.14	0.15	0.76	47.4	22.6	0.57	1.21	0.8	5.26	<0.10	0.21	<0.10	0.34	
Arsenic	mg/L	0.001	0.001	0.36	–	–	<0.010	<0.010	<0.010	0.014	0.008	0.002	0.005	0.003	0.008	<0.010	<0.010	<0.010	<0.010	
Cadmium	mg/L	0.0001	0.00006	0.0008	0.0007	0.036	<0.0010	<0.0010	<0.0010	0.0005	0.0003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0010	<0.0010	<0.0010	<0.0010	
Chromium	mg/L	0.001	0.00001	0.04	0.00014	0.085	<0.010	<0.010	<0.010	0.117	0.055	<0.001	0.003	0.005	0.019	<0.010	<0.010	<0.010	<0.010	
Cobalt	mg/L	0.001	–	–	0.000005	0.15	<0.010	<0.010	<0.010	0.022	0.011	<0.001	<0.001	<0.001	0.002	<0.010	<0.010	<0.010	<0.010	
Copper	mg/L	0.001	0.001	0.0025	0.0003	0.008	<0.020	<0.020	<0.020	0.036	0.022	0.003	0.004	0.003	0.011	<0.020	<0.020	<0.020	<0.020	
Lead	mg/L	0.001	0.001	0.0094	0.0022	0.012	<0.010	<0.010	<0.010	0.059	0.031	<0.001	0.012	0.008	0.053	<0.010	<0.010	<0.010	<0.010	
Nickel	mg/L	0.001	0.008	0.017	0.007	0.56	<0.010	<0.010	<0.010	0.061	0.03	0.003	0.005	0.004	0.011	<0.010	<0.010	<0.010	<0.010	
Mercury	mg/L	0.0001	0.00006	0.0054	0.0001	0.0014	<0.0001	<0.0001	<0.0001	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
Tin	mg/L	0.001	–	–	–	–	<0.010	<0.010	<0.010	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.010	<0.010	<0.010	<0.010	
Vanadium	mg/L	0.01	–	–	0.05	0.28	<0.10	<0.10	<0.10	0.08	0.05	<0.01	<0.01	<0.01	0.01	<0.10	<0.10	<0.10	<0.10	
Zinc	mg/L	0.005	0.0024	0.031	0.007	0.043	<0.050	<0.050	<0.050	0.067	0.044	0.014	0.016	0.01	0.03	<0.050	<0.050	<0.050	<0.050	
Dissolved Non-Metals																				
Phosphorus	mg/L	1	0.06*	–	0.02	–	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sulphur as S	mg/L	1	–	–	2,700	–	487	<1	17	60	29	3	36	242	28	166	10	9	39	11
Selenium	mg/L	0.01	0.005	0.034	–	–	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Total Non-Metals																				
Phosphorus	mg/L	1	0.06*	–	0.02	–	<1	<1	<1	2	1	<1	<1	<1	1	<1	<1	<1	<1	
Sulphur as S	mg/L	1	–	–	2,700	–	1140	1160	1130	192	174	155	489	426	527	866	932	910	923	
Selenium	mg/L	0.01	0.005	0.034	–	–	<0.100	<0.100	<0.100	0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.100	<0.100	<0.100	<0.100	

5.9.4.4 Tabulated Results of February 2008 Water Sampling

Table 13 Laboratory Analysis Results of February 2008 Water Sampling

Dissolved Metals	LOR	Trigger Levels (FW 99%)	Trigger Levels (FW 80%)	Trigger Levels (SW 99%)	Trigger Levels (SW 80%)	EB1	EB2	EB3	EB4	WF4	WF5	WF6	BC8	BC9	BH12	BH13	BH14
Iron	0.002	–	–	–	–	<0.002	<0.002	<0.002	<0.002	0.007	0.008	0.008	0.18	0.025	<0.002	0.077	<0.002
Aluminium	0.01	0.027	0.15	–	–	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	0.01	0.001	0.36	–	–	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	0.0006	0.00006	0.0008	0.0007	0.036	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Chromium	0.001	0.00001	0.04	0.00014	0.085	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001
Cobalt	0.002	–	–	0.000005	0.15	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper	0.001	0.001	0.0025	0.0003	0.008	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	0.01	0.001	0.0094	0.0022	0.012	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	0.004	0.008	0.017	0.007	0.56	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Mercury																	
Tin	0.02	–	–	–	–	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	0.001	–	–	0.05	0.28	<0.001	<0.001	<0.001	<0.001	0.005	0.005	0.004	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	0.002	0.0024	0.031	0.007	0.043	<0.002	<0.002	<0.002	0.006	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	0.007
Total Metals																	
Iron	0.01	–	–	–	–	<0.01	0.01	<0.01	0.23	1.7	2.8	1.3	1.6	1.4	0.02	0.07	<0.01
Aluminium	0.01	0.027	0.15	–	–	<0.01	0.01	<0.01	0.23	1.7	2.8	1.3	1.6	1.4	0.002	0.007	<0.01
Arsenic	0.01	0.001	0.36	–	–	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	0.0006	0.00006	0.0008	0.0007	0.036	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Chromium	0.001	0.00001	0.04	0.00014	0.085	<0.001	<0.001	<0.001	<0.001	0.004	0.006	0.003	0.002	0.005	<0.001	<0.001	<0.001
Cobalt	0.002	–	–	0.000005	0.15	<0.002	<0.002	<0.002	<0.002	0.003	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper	0.001	0.001	0.0025	0.0003	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Lead	0.01	0.001	0.0094	0.0022	0.012	<0.010	<0.010	<0.010	0.059	0.031	<0.001	0.012	0.008	0.053	<0.010	<0.010	<0.010
Nickel	0.004	0.008	0.017	0.007	0.56	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Mercury																	
Tin	0.02	–	–	–	–	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	0.001	–	–	0.05	0.28	<0.001	<0.001	<0.001	<0.001	0.007	0.009	0.006	<0.001	0.002	<0.001	<0.001	<0.001
Zinc	0.005	0.0024	0.031	0.007	0.043	<0.005	<0.005	<0.005	<0.005	0.007	0.009	0.007	<0.005	0.01	0.005	0.008	<0.005
Dissolved Non-Metals																	
Phosphorus																	
Sulphur as S	0.05	–	–	2,700	–	880	880	900	870	190	190	190	940	700	890	870	870
Selenium	0.02	0.005	0.034	–	–	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Total Non-Metals																	
Phosphorus																	
Sulphur as S	0.05	–	–	2,700	–	990	970	960	1000	160	160	160	1100	740	970	980	950
Selenium	0.02	0.005	0.034	–	–	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

	Exceeds Freshwater 99% Trigger Value
	Exceeds Saltwater 99% Trigger Value
	Exceeds Freshwater 80% Trigger Value
	Exceeds Saltwater 80% Trigger Values
	Below LOR & LOR Exceeds Any Trigger Value, where further investigation recommended

5.9.4.5 Graphic Comparison of Two Water Sampling Events

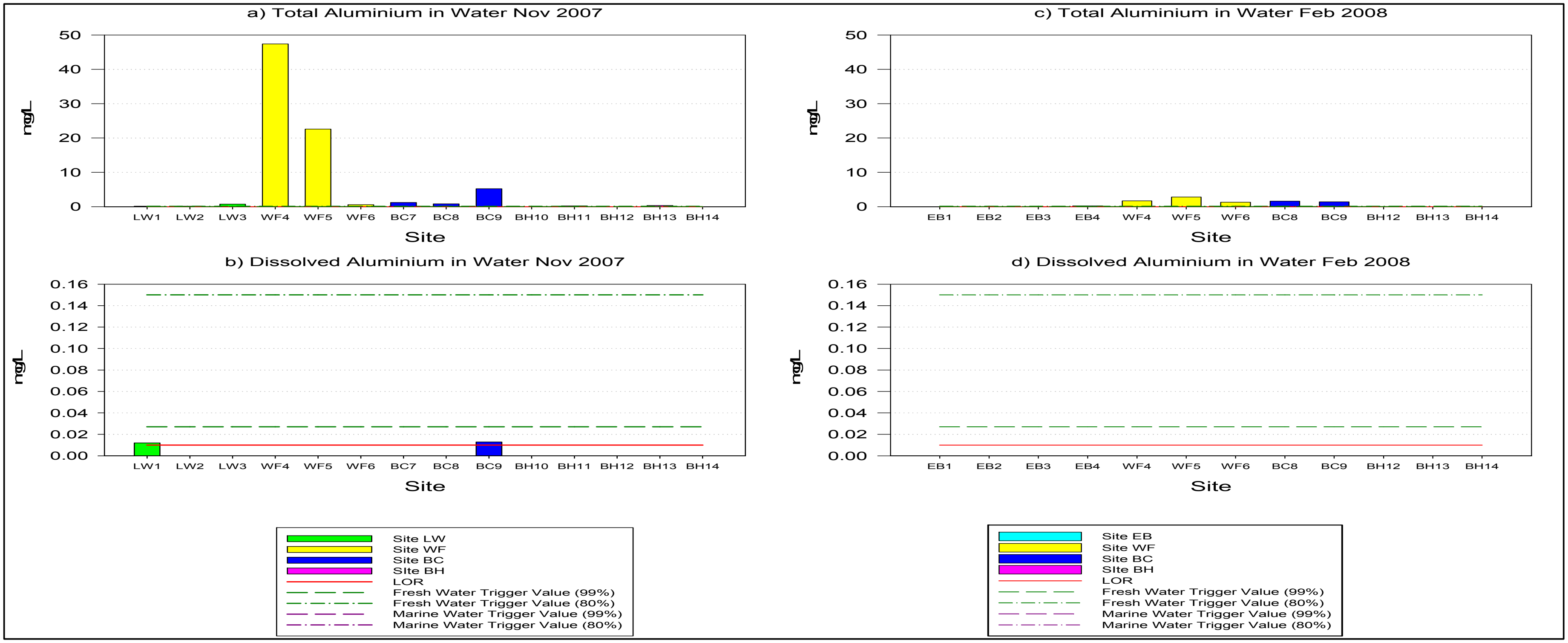


Figure 19 Aluminium in Water

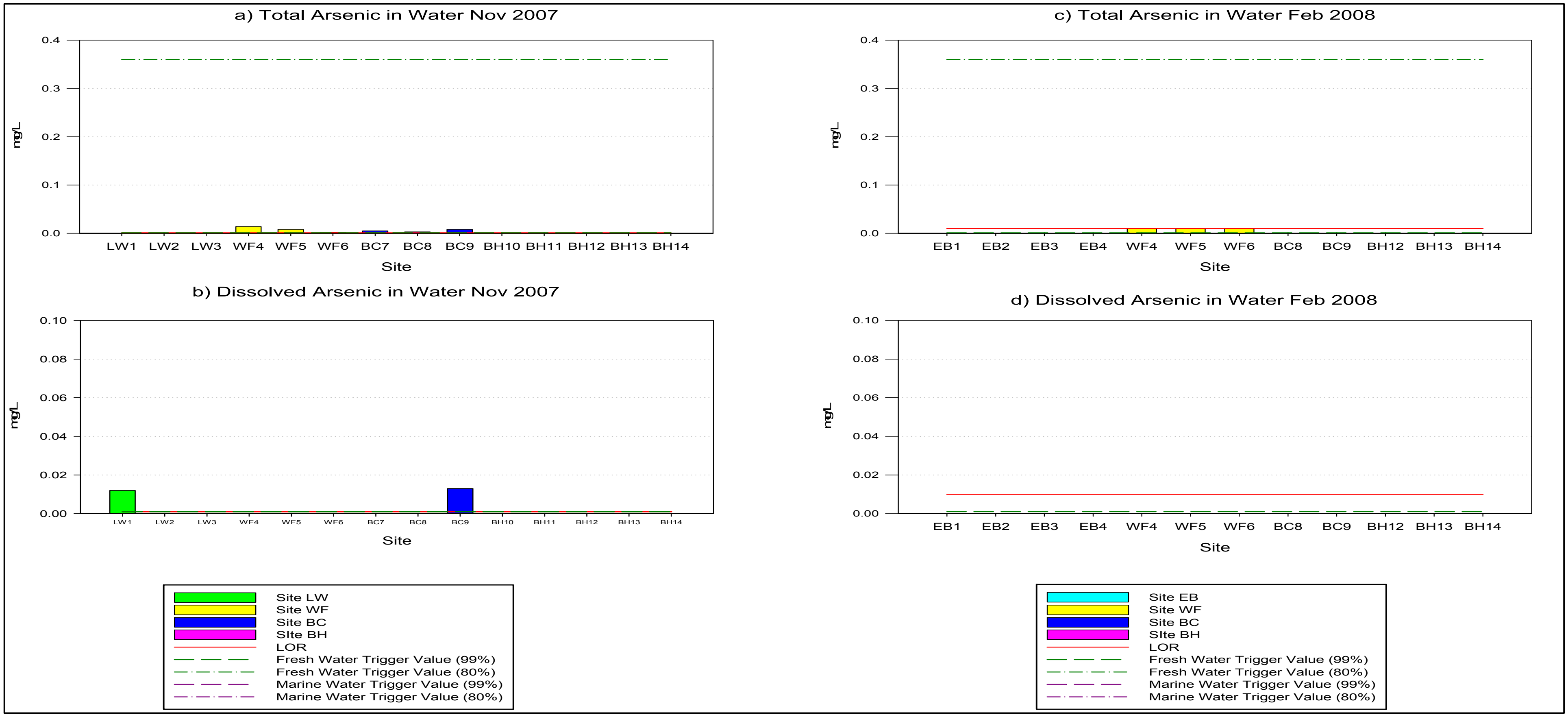


Figure 20 Arsenic in Water

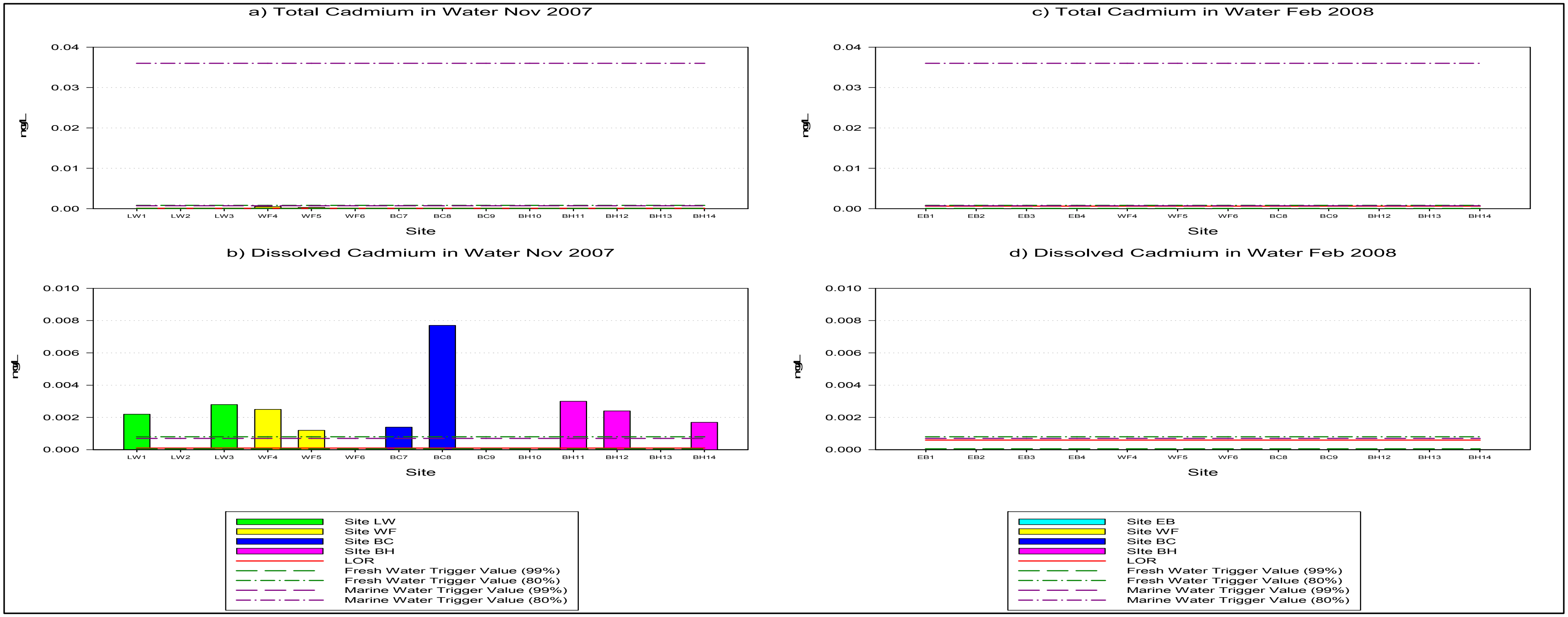


Figure 21 Cadmium in Water

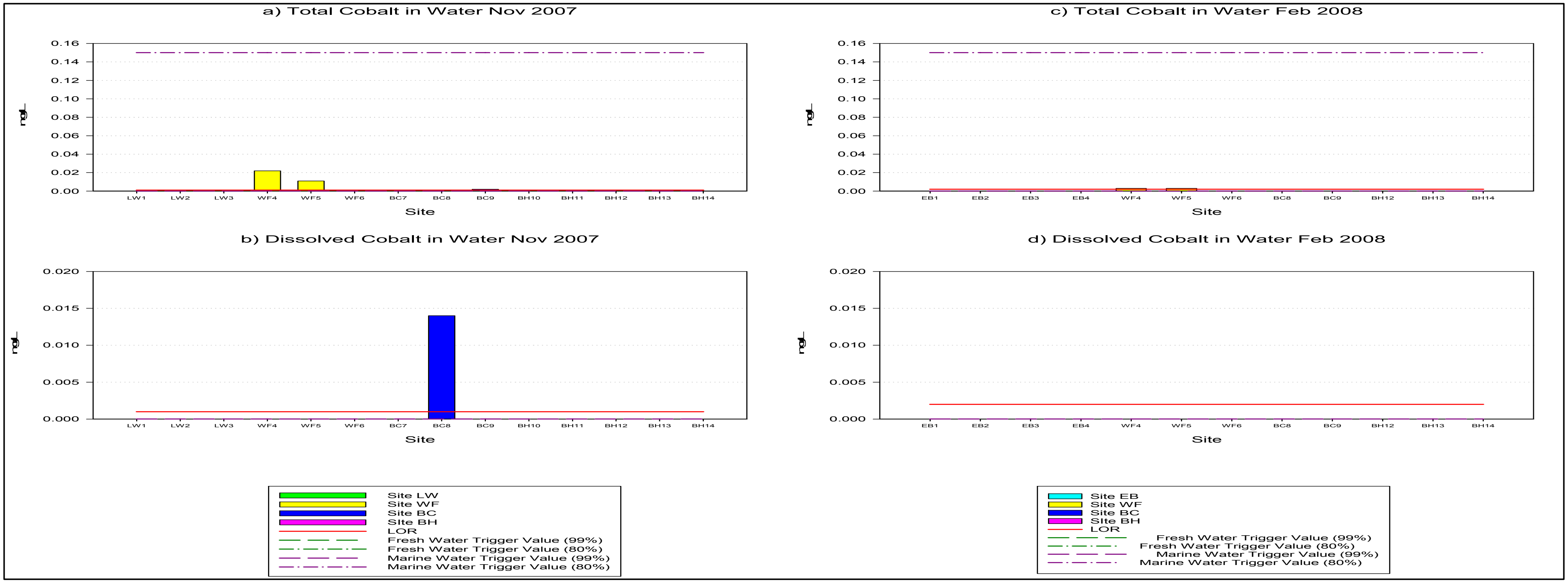


Figure 22 Cobalt in Water

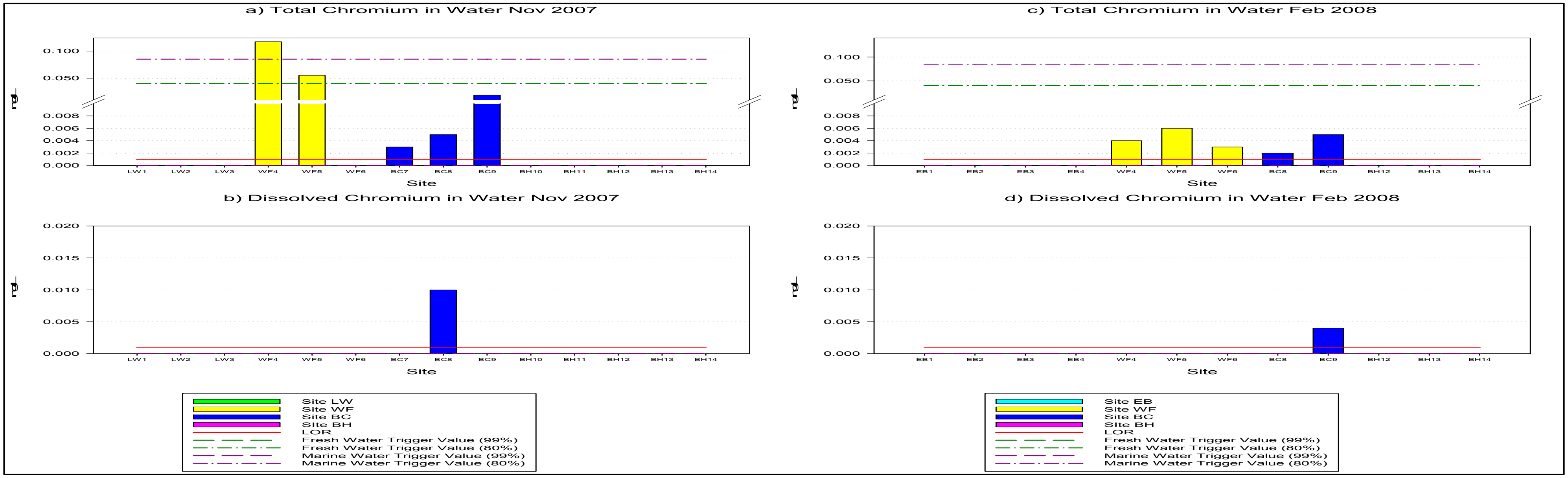


Figure 23 **Chromium in Water**

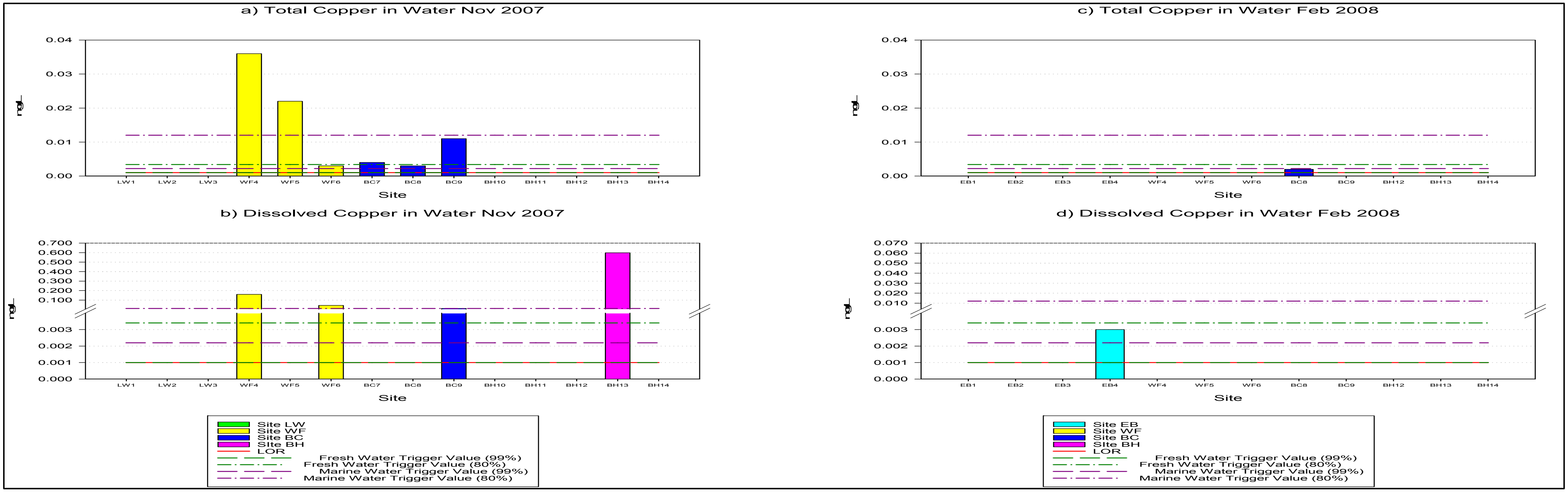


Figure 24 Copper in Water

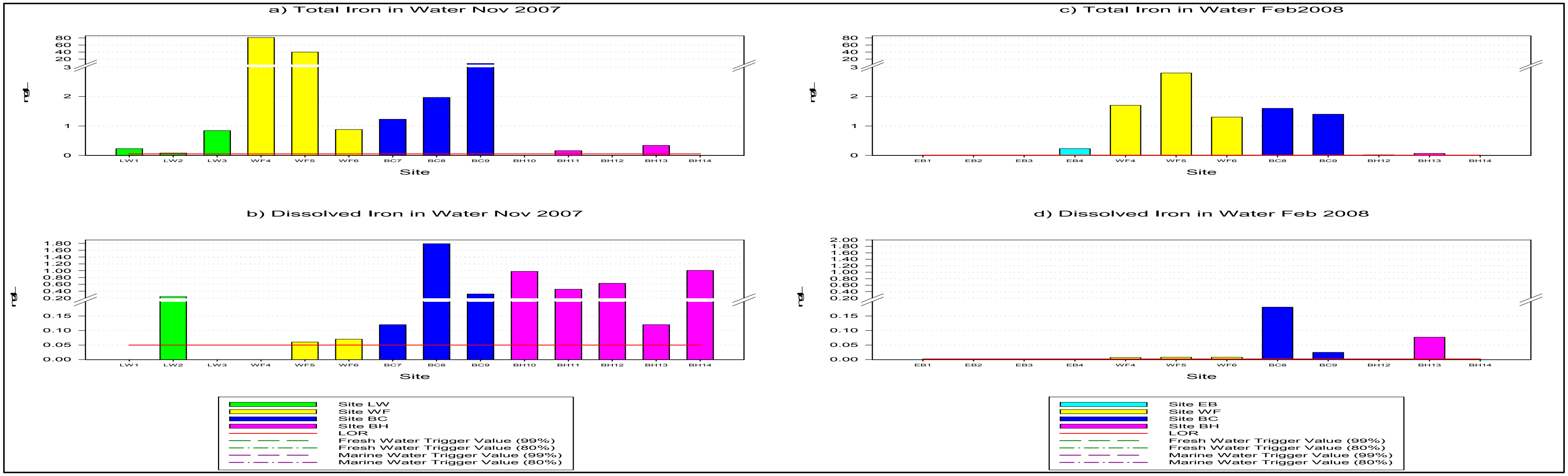


Figure 25 Iron in Water

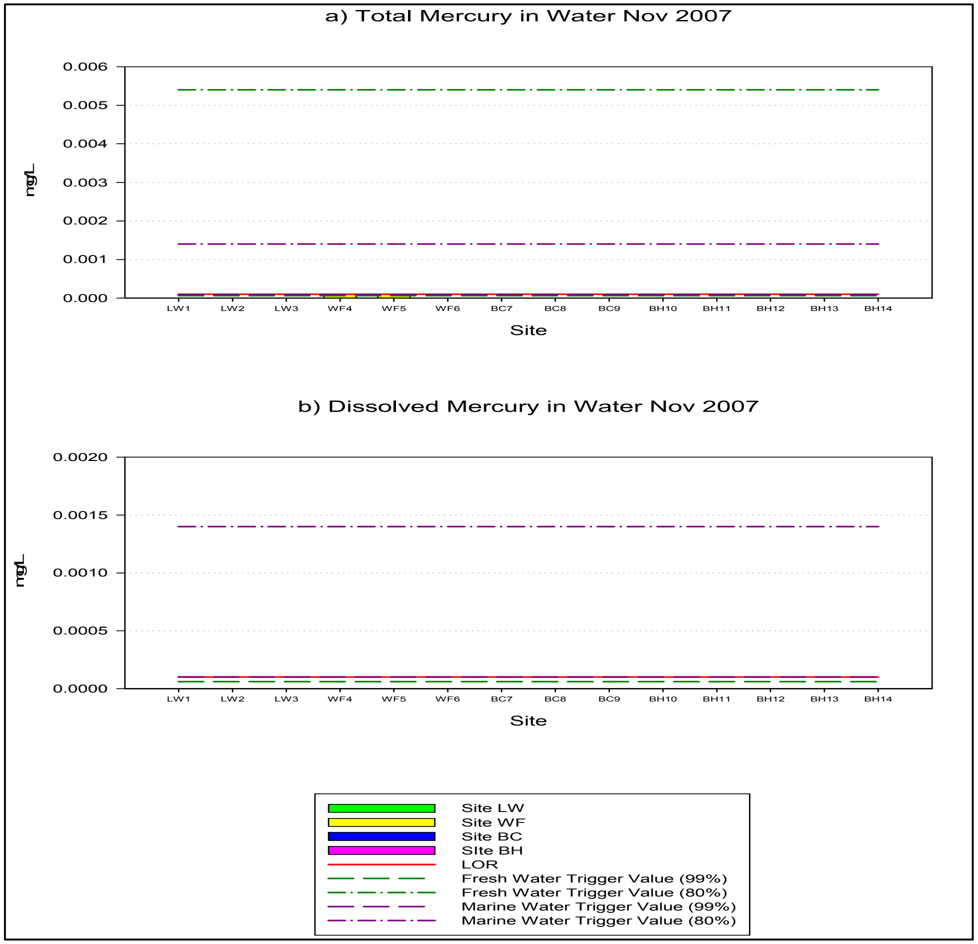


Figure 26 Mercury in Water

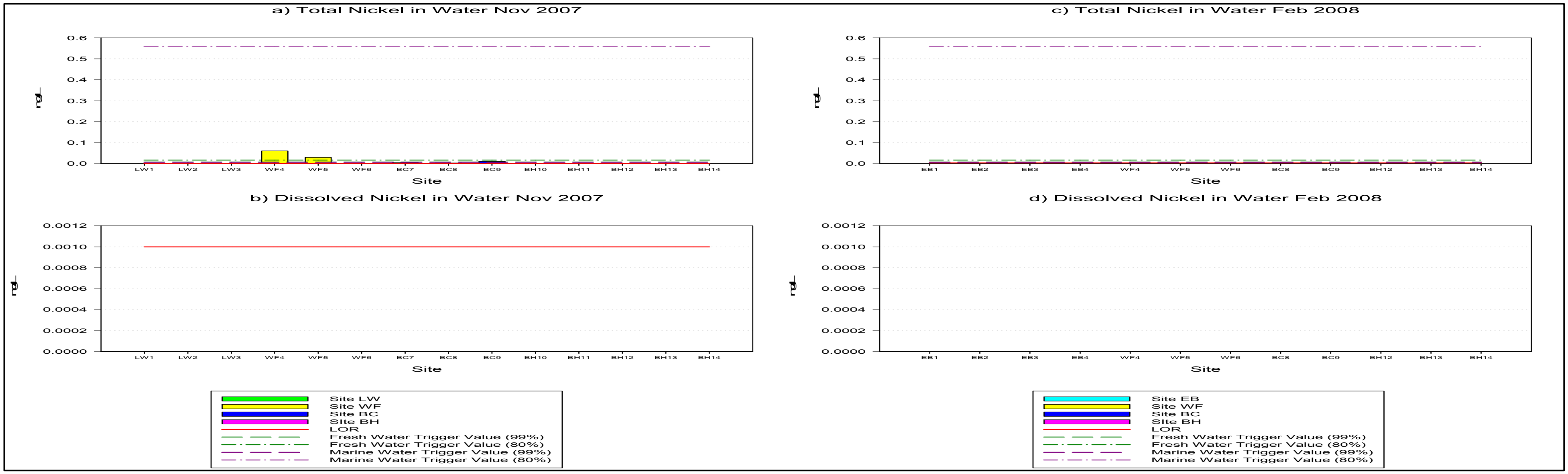


Figure 27 Nickel in Water

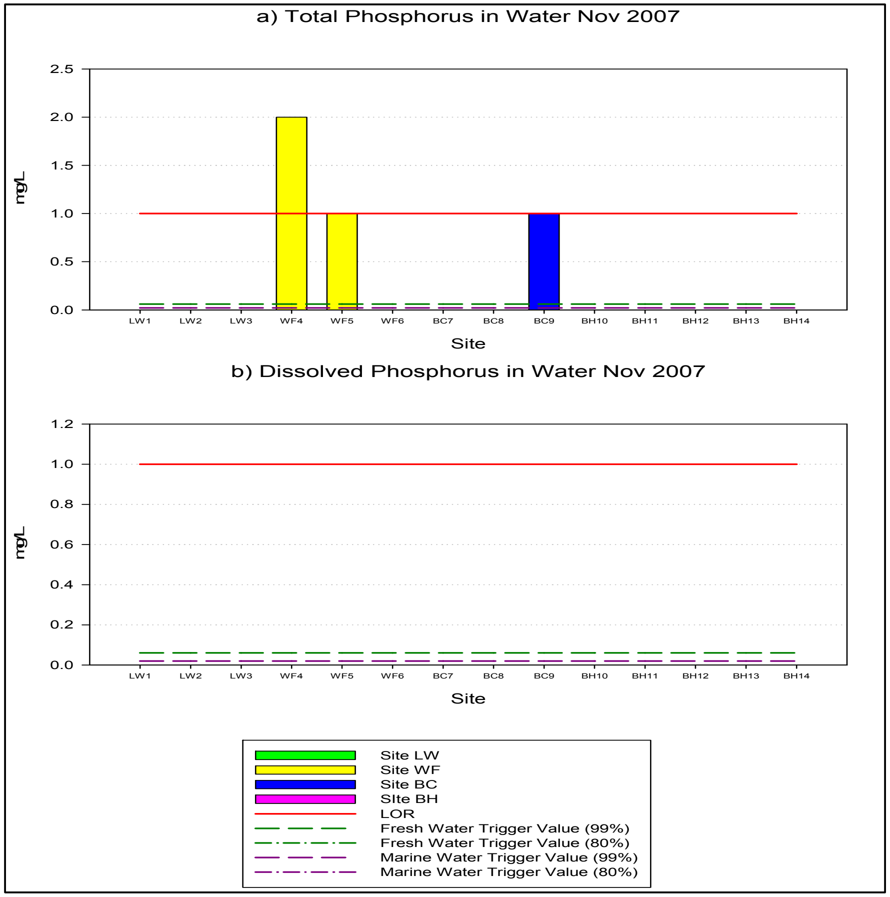


Figure 28 Phosphorus in Water

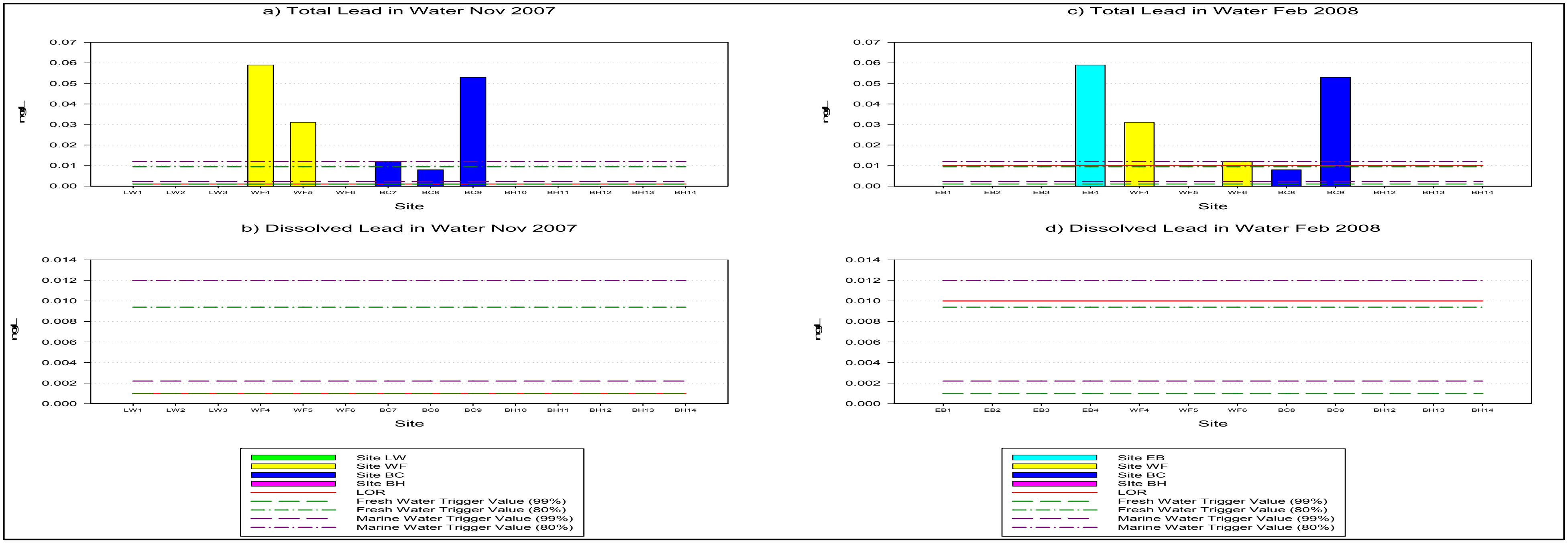


Figure 29 Lead in Water

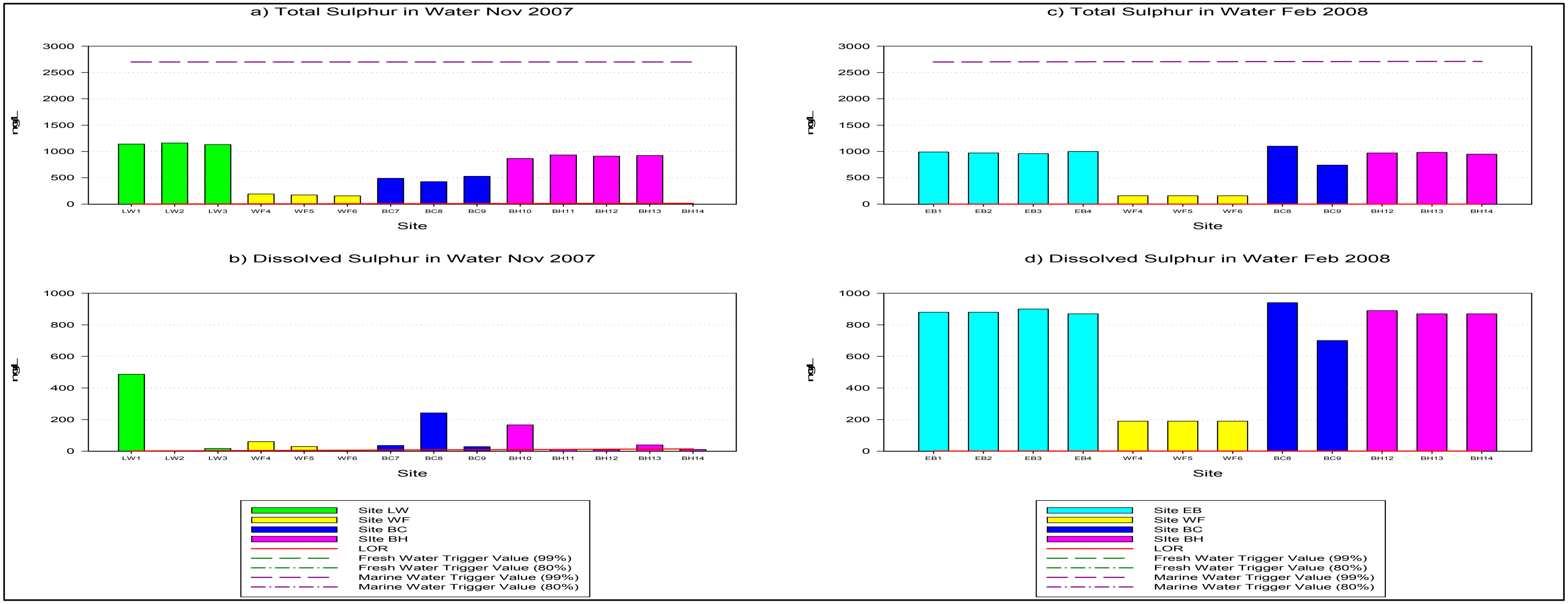


Figure 30 Sulphur in Water

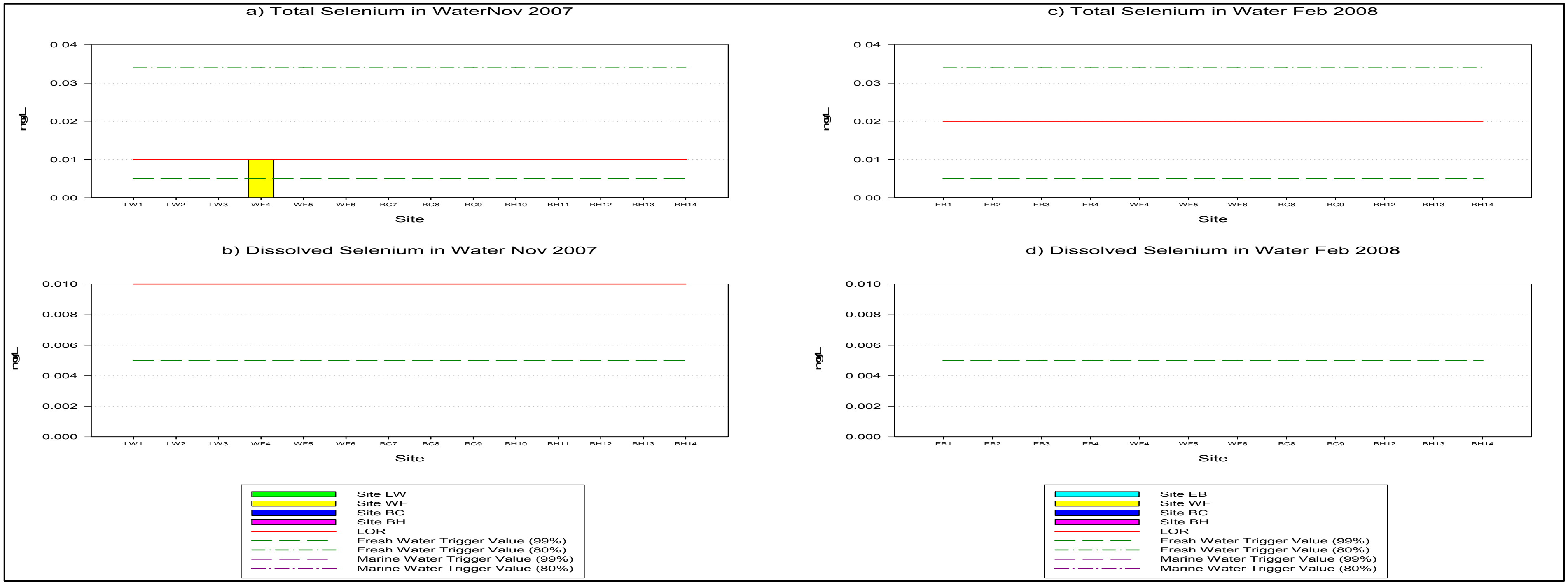


Figure 31 Selenium in Water

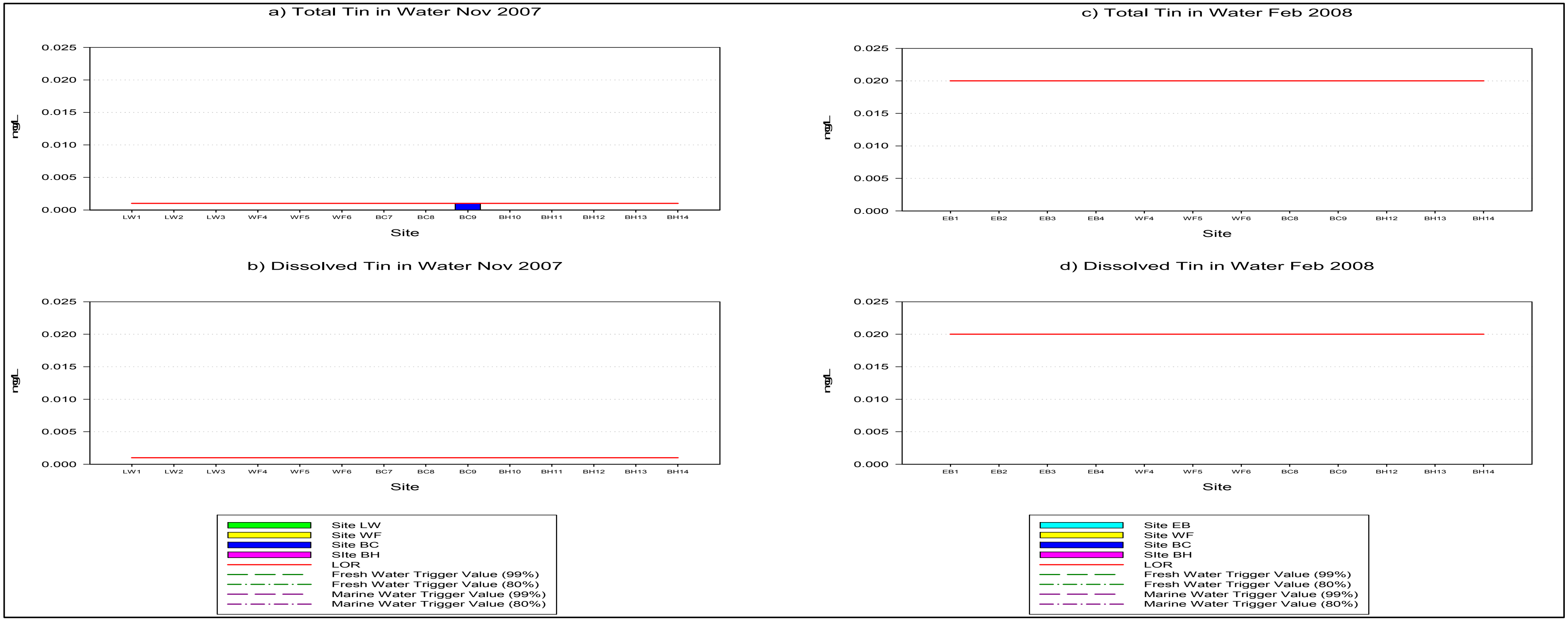


Figure 32 Tin in Water

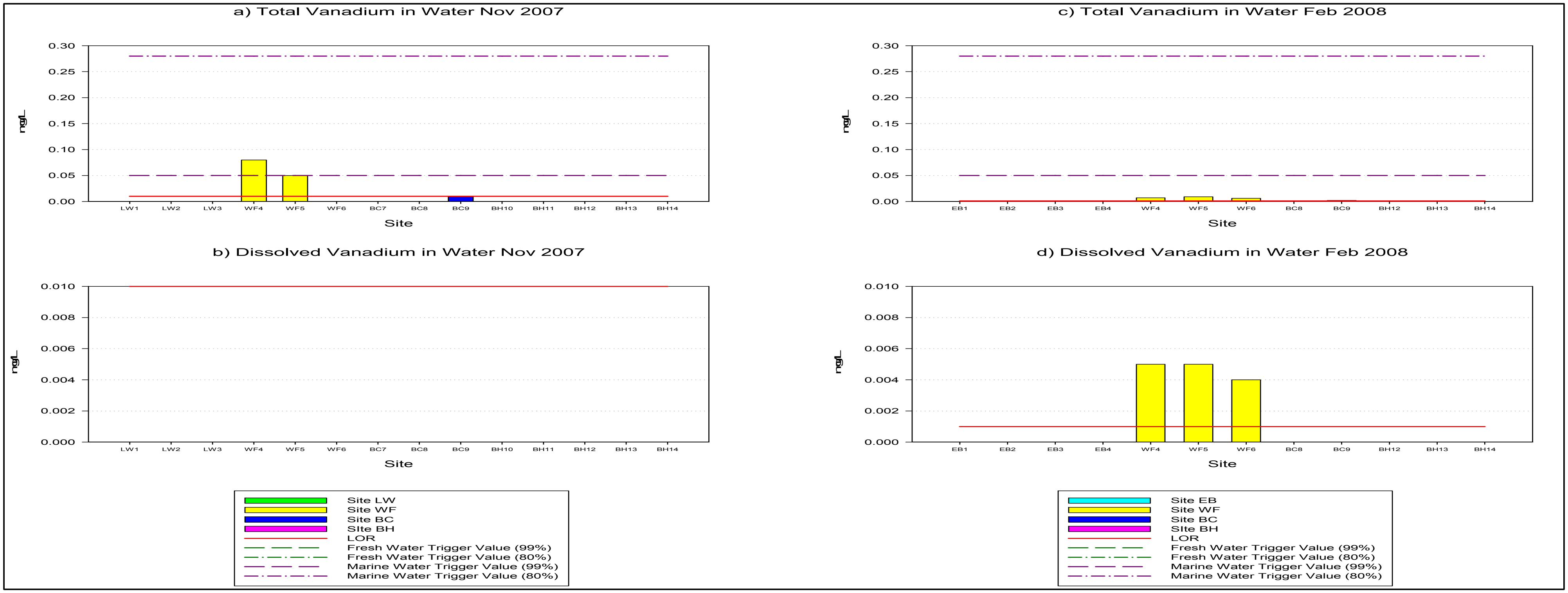


Figure 33 Vanadium in Water

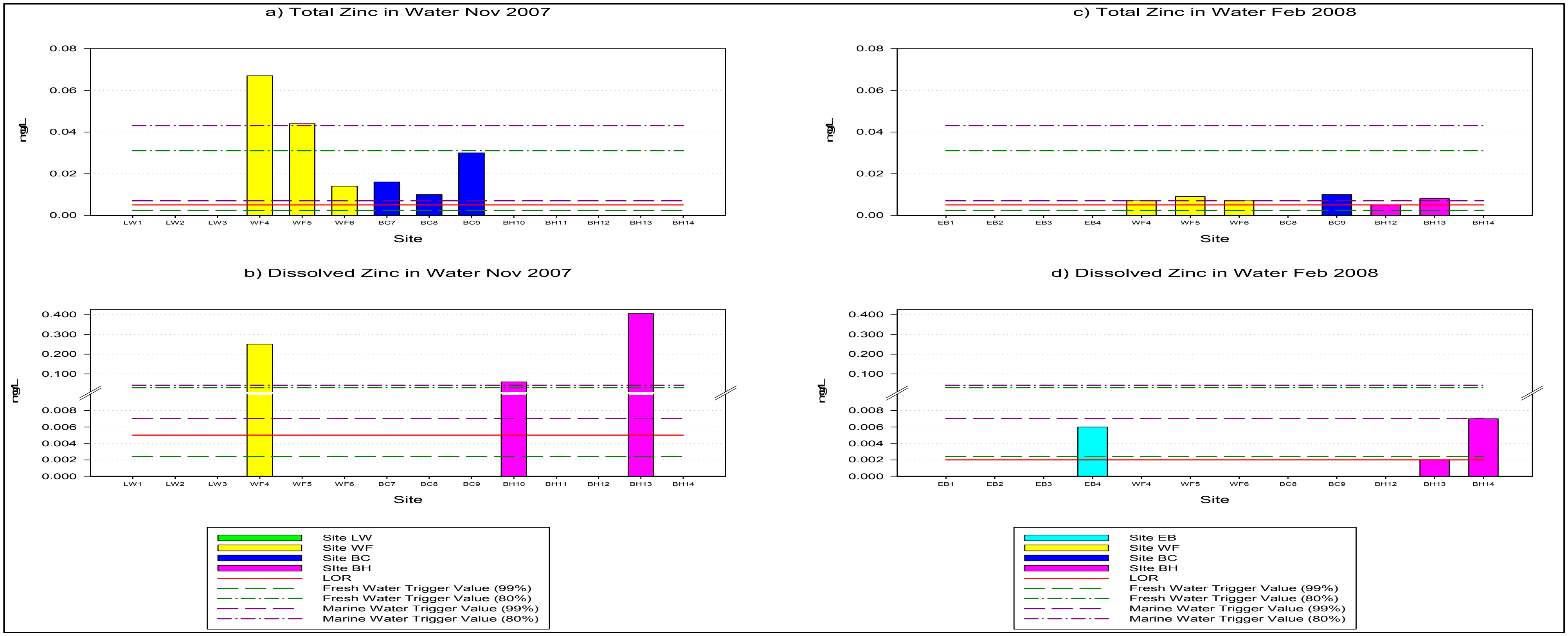


Figure 34 Zinc in Water

5.9.4.6 The Summary of Two Sampling Events

Table 14 Sites of the Three highest Total Metal Concentration Levels Measured Against Anticipated Background Levels for Lake Warden Wetland System (LWWS)

Total Metal	Background level for LWWS (mg/L)	1st Priority Site (mg/L)	2nd Priority Site (mg/L)	3rd Priority Site (mg/L)
Al	0.10	Site **4** (47.40)	Site **5** (22.60)	Site **9** (5.26)
As	0.01	Site **4** (0.014)	-	-
Cod	0.001	-	-	-
Cr	0.01	Site **4** (0.117)	Site **5** (0.055)	Site **9** (0.019)
Co	0.01	Site **4** (0.022)	Site **5** (0.011)	-
Cu	0.02	Site **4** (0.036)	Site **5** (0.022)	-
Pb	0.01	Site **4** (0.059)	Site **9** (0.053)	Site **5** (0.031)
Ni	0.01	Site **4** (0.061)	Site **5** (0.030)	Site **9** (0.011)
Se	0.10	-	-	-
Sn	0.01	-	-	-
V	0.10	-	-	-
Zn	0.05	Site **4** (0.067)	-	-

Table 14 results indicate that Sites 4, 5 and 9 consistently record high concentrations of total metals when compared with other sites at Lake Warden, Lake Wheatfield, Bandy Creek and Bandy Creek outfall. Where metal concentrations data is available , Site 4 always records the highest concentration, generally followed by Site 5 and then Site 9. There were also instances where no sites recorded concentration levels above anticipated background levels for LWWS: this is marked above with a dash (-).

Table 15 Sites of the Three Highest Dissolved Metal Concentration Levels Measured Against Anticipated Background Levels For Lake Warden Wetland System (LWWS)

Dissolved Metal	Background level for LWWS (mg/L)	1st Priority Site (mg/L)	2nd Priority Site (mg/L)	3rd Priority Site (mg/L)
Al	0.10	Site **8** (56.90)	Site **4** (4.48)	Site **10** (2.41)
As	0.01	Site **9** (0.013)	Site **1** (0.012)	-
Cd	0.001	Site **8** (0.0077)	Site **11** (0.003)	Site **3** (0.0028)
Cr	0.01	-	-	-
Co	0.01	Site **8** (0.014)	-	-
Cu	0.01	Site **13** (0.598)	Site **4** (0.16)	Site **6** (0.044)
Pb	0.01	-	-	-
Ni	0.01	Site **8** (0.028)	-	-
Se	0.05	-	-	-
Sn	0.01	-	-	-
V	0.10	-	-	-
Zn	0.05	Site **13** (0.405)	Site **4** (0.251)	Site **10** (0.06)

From Table 15 it can be seen that Sites 8, 13, 9, 4 and 10 record high concentrations of dissolved metals when compared with other sites at Lake Warden, Lake Wheatfield, Bandy Creek and Bandy Creek outfall. Where high concentrations of a metal are observed, Sites 8, 13 and 9 record the highest concentration, generally followed by Site 4 and then Site 10. There were also instances where no sites recorded concentration levels above anticipated background levels for LWWS: this is marked above with a dash (-)

5.9.5 Sediment Quality

5.9.5.1 Tabulated Results of November 2007 Sediment Sampling

Table 16 The Laboratory Analysis Results of November 2007 Sediment Sampling

Total Metals	Unit	LOR	Trigger Levels ISQG-Low	Trigger Levels ISQG-High	LW1	LW2	LW3	WF4	WF5	WF6	BC7	BC8	BC9
Iron	mg/kg	50	_	_	1060	980	750	18900	17000	1310	180	2730	310
Magnesium	mg/kg	50	_	_	6540	5470	4580	12200	32600	1080	950	1090	5100
Potassium	mg/kg	50	_	_	390	350	340	5970	5360	360	90	910	170
Sodium	mg/kg	50	_	_	6930	5490	6550	8730	7750	1200	1180	3010	2490
Aluminium	mg/kg	50	_	_	910	750	620	16500	15200	1000	410	4820	360
Arsenic	mg/kg	5	20	70	<5	<5	<5	<5	<5	<5	<5	<5	<5
Cadmium	mg/kg	1	1.5	10	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chromium	mg/kg	2	80	370	2	<2	<2	40	32	2	<2	15	4
Cobalt	mg/kg	2	_	_	<2	<2	<2	6	7	<2	<2	<2	<2
Copper	mg/kg	5	65	270	<5	<5	<5	16	11	<5	<5	<5	<5
Lead	mg/kg	5	50	220	<5	<5	<5	16	8	<5	<5	<5	<5
Nickel	mg/kg	2	21	52	<2	<2	<2	17	24	<2	<2	2	<2
Mercury	mg/kg	0.1	0.15	1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Tin	mg/kg	5	_	_	<5	<5	<5	<5	<5	<5	<5	<5	<5
Vanadium	mg/kg	5	_	_	<5	<5	<5	34	25	<5	<5	<5	<5
Zinc	mg/kg	5	200	410	<5	<5	<5	18	12	<5	<5	<5	<5
Total Non-Metals													
Phosphorus	mg/kg	50	_	_	<1	<1	<1	2	1	<1	<1	<1	1
Sulphur as S	mg/kg	50	_	_	1140	1160	1130	192	174	155	489	426	527
Selenium	mg/kg	5	_	_	<0.100	<0.100	<0.100	0.01	<0.010	<0.010	<0.010	<0.010	<0.01

(yellow)	Exceeds ISQG-Low Level

5.9.5.2 Tabulated Results of February 2008 Sediment Sampling

Table 17 The Laboratory Analysis Results of February 2008 Sediment Sampling

Total Metals	LOR	Trigger Levels ISQG-Low	Trigger Levels ISQG-High	EB1	EB2	EB3	EB4	WF4	WF5	WF6	BC8	BC9	BH12	BH13	BH14
Iron	5	_	_	420	380	410	190	23000	14000	1300	6500	380	310	310	1100
Magnesium	2	_	_	10000	11000	12000	1600	28000	33000	1500	2900	4000	7400	16000	8100
Potassium															
Sodium	10	_	_	6100	5500	5300	2200	7800	7300	1400	5600	2000	3000	7800	8500
Aluminium	1	_	_	470	450	470	240	19000	16000	1300	5400	600	380	280	1100
Arsenic	5	20	70	2	1	2	<1	3	3	<1	1	<1	<1	<1	1
Cadmium	0.006	1.5	10	0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Chromium	0.2	80	370	8.9	9.3	9.7	1.7	37	28	2.5	18	3.8	6.6	9.7	8.2
Cobalt	0.2	_	_	0.2	0.2	0.2	<0.2	8	5.1	0.7	1.4	<0.2	<0.2	<0.2	0.3
Copper	0.2	65	270	0.7	0.4	0.4	<0.2	13	8	0.8	0.5	0.4	<0.2	0.3	2.5
Lead	1	50	220	<1	<1	<1	<1	10	7	1	5	<1	<1	<1	1
Nickel	0.4	21	52	1.3	0.9	1.1	0.9	27	18	1.4	3.7	<0.4	<0.4	0.5	1
Mercury															
Tin	2	_	_	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Vanadium	0.1	_	_	1.1	1.4	1.1	0.5	27	21	1.8	9.2	0.8	0.9	0.8	2.3
Zinc	0.5	200	410	2.2	1.9	1.9	1	17	11	1.8	3	1.1	1.1	1.8	5.4
Total Non-Metals															
Phosphorus	2	_	_	230	230	230	51	150	100	13	47	73	130	280	180
Sulphur as S	10	_	_	1600	1600	1800	440	11000	5900	740	6300	550	790	2300	1900
Selenium	2	_	_	3	3	3	<2	<2	<2	<2	<2	<2	<2	<2	<2

5.9.5.3 Graphic Comparison of Two Sediment Sampling Events

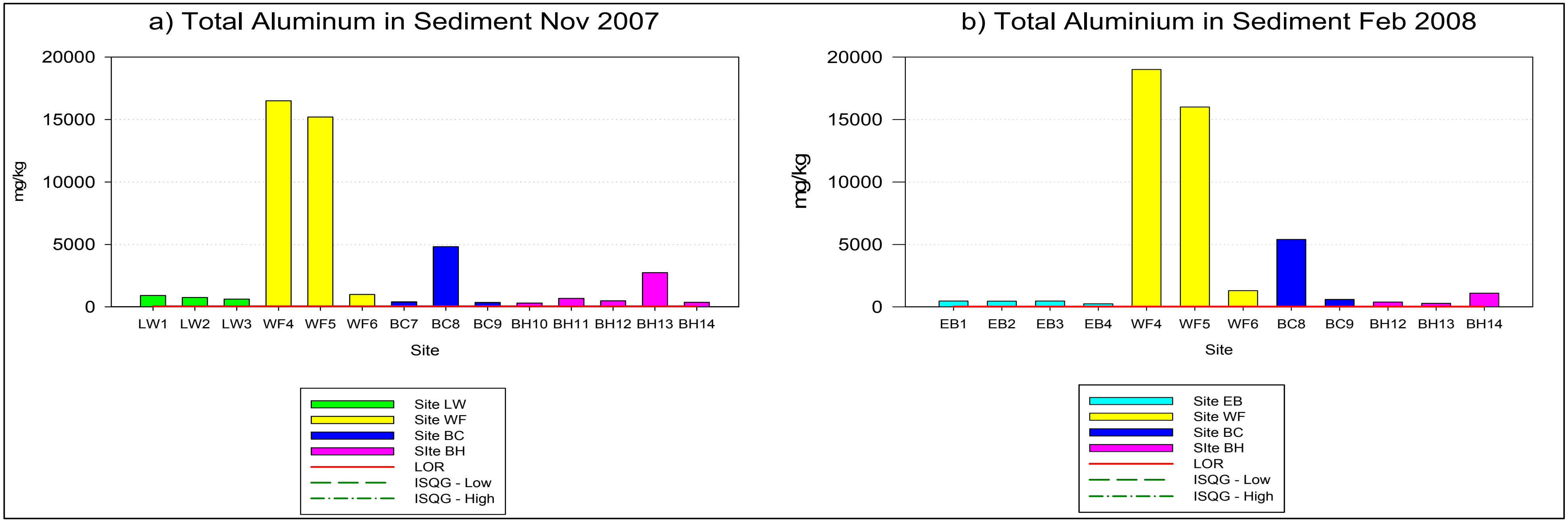


Figure 35 Aluminium in Sediment

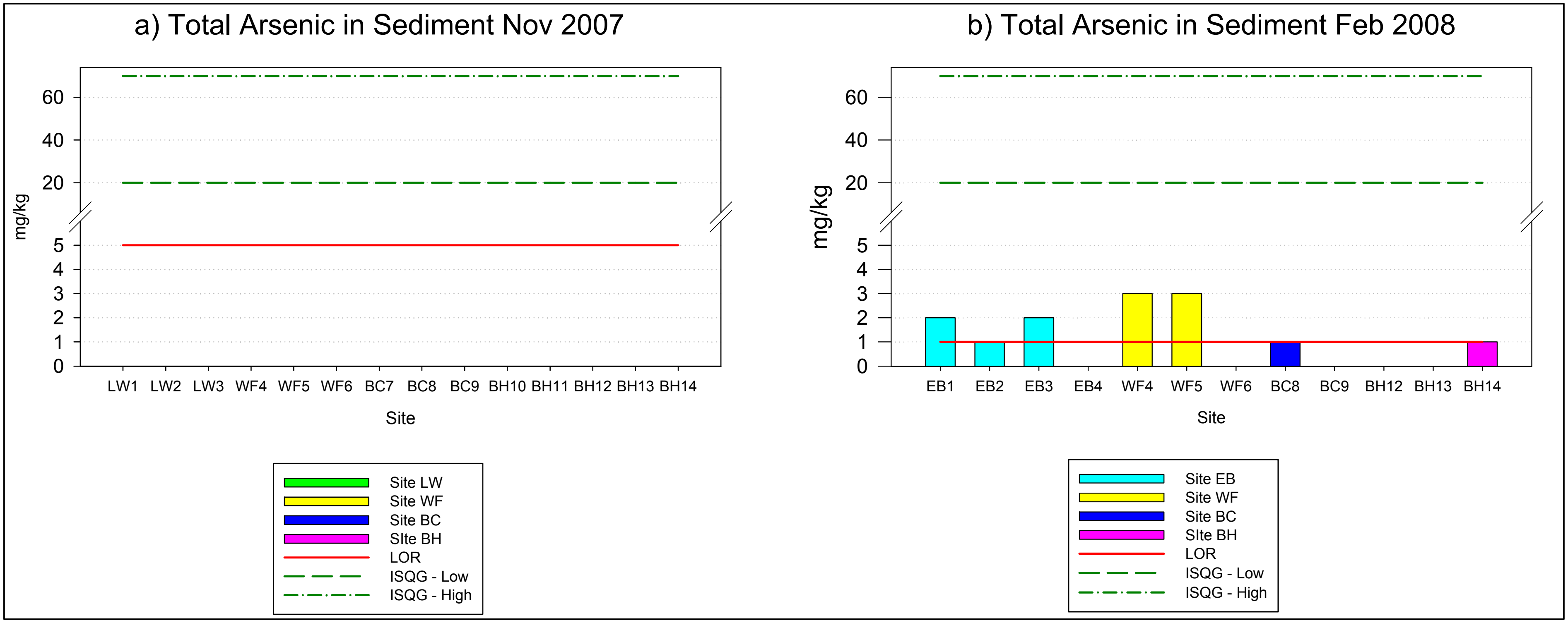


Figure 36 Arsenic in Sediment

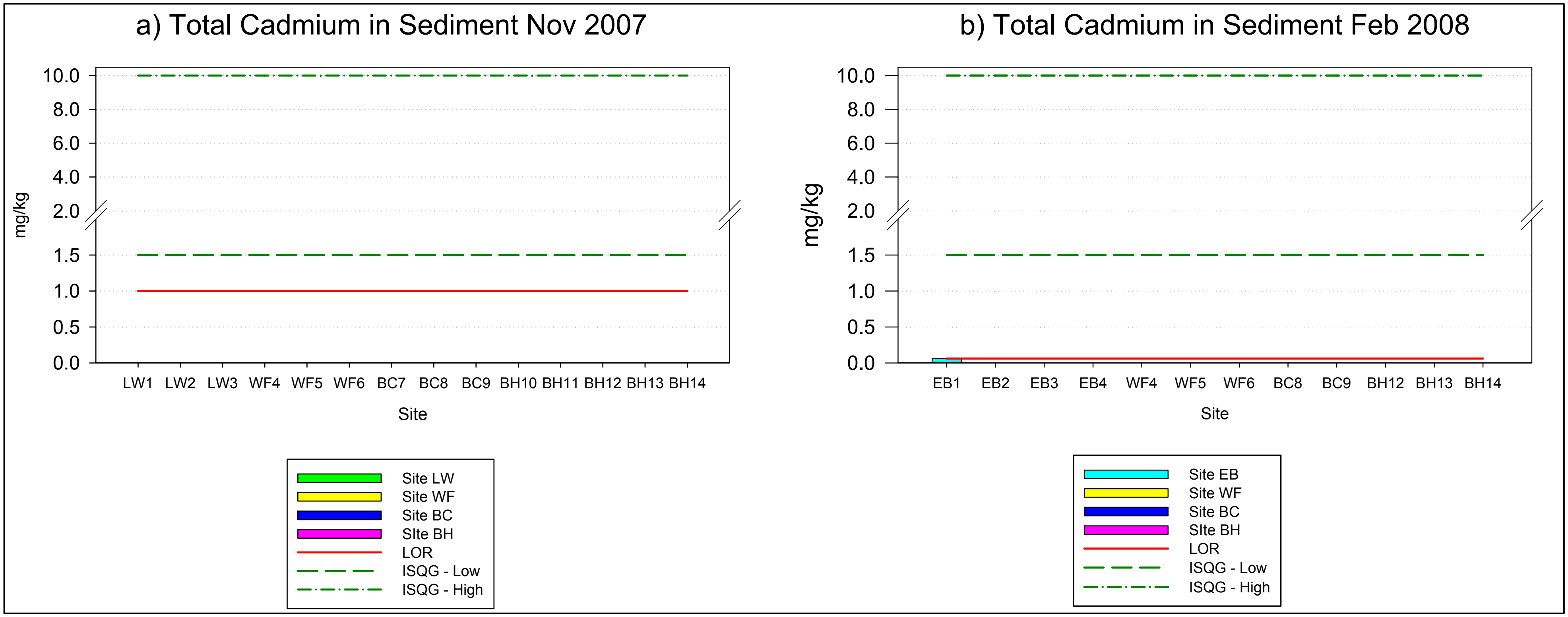


Figure 37 Cadmium in Sediment

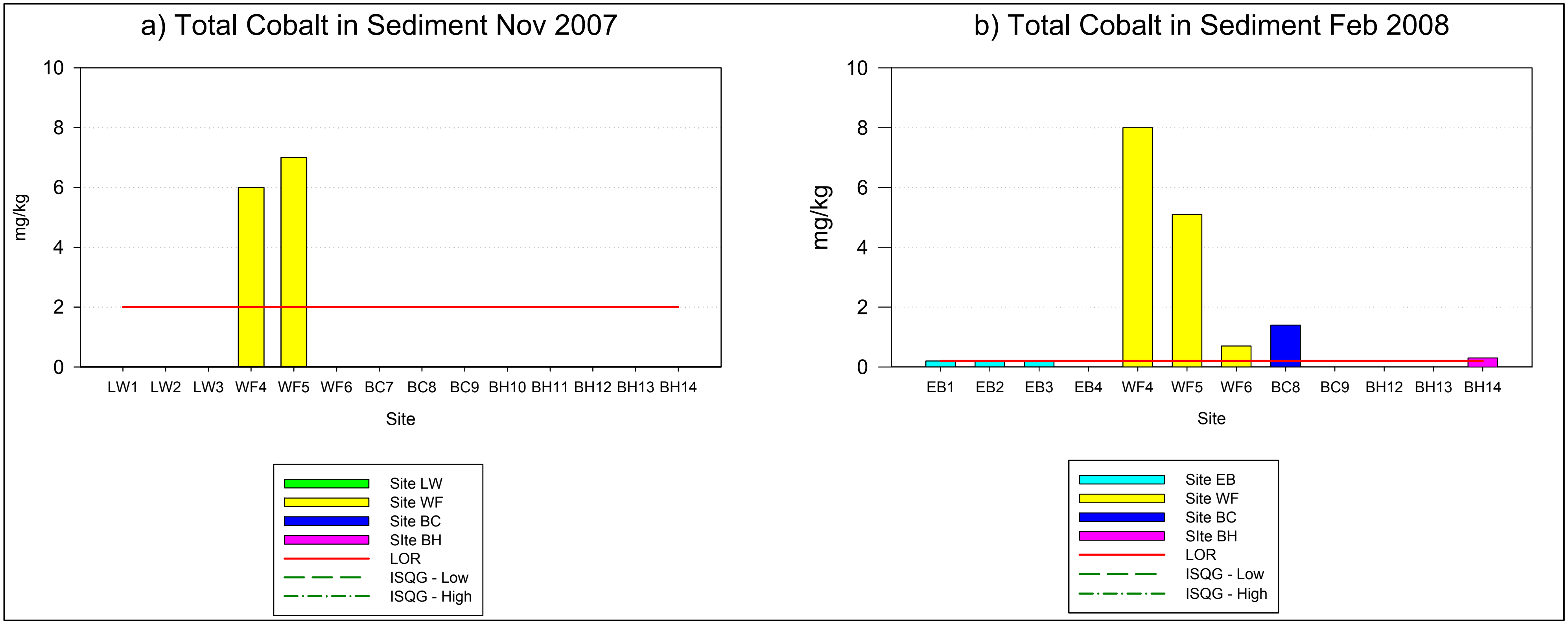


Figure 38 Cobalt in Sediment

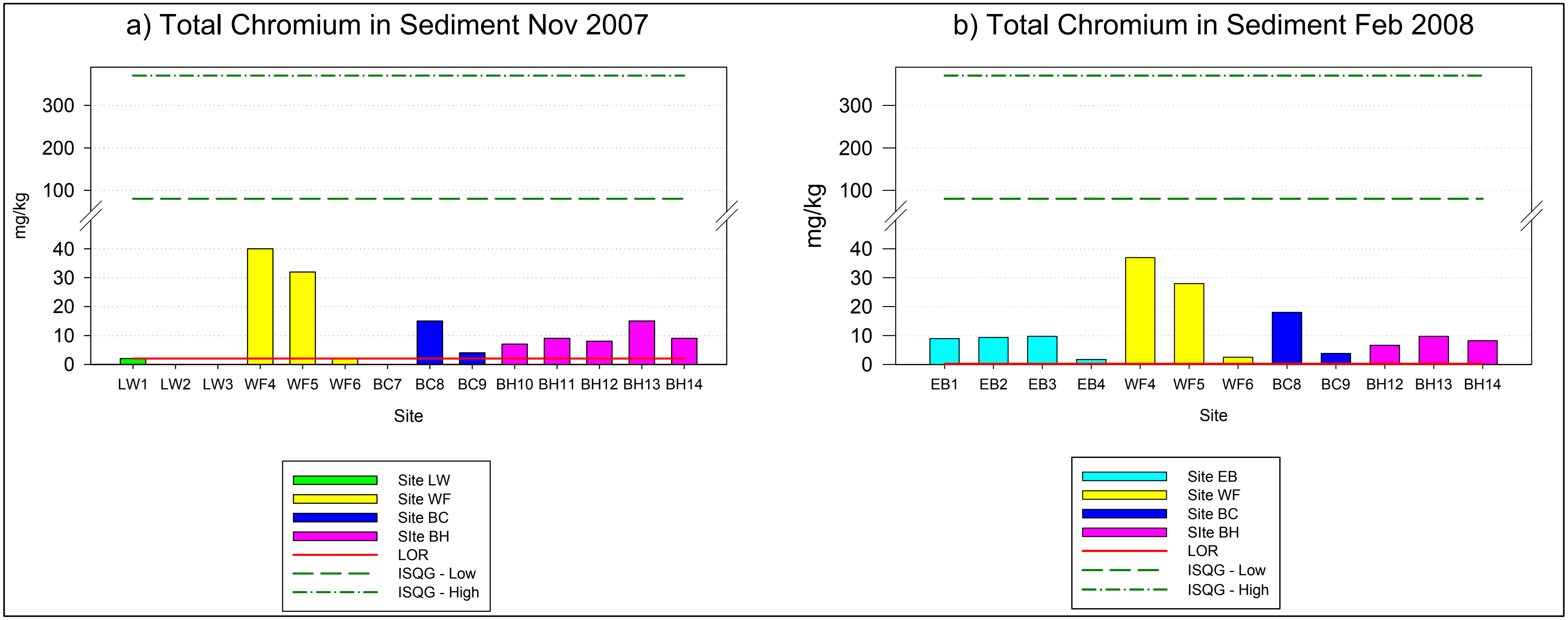


Figure 39 Chromium in Sediment

MAUNSELL | AECOM

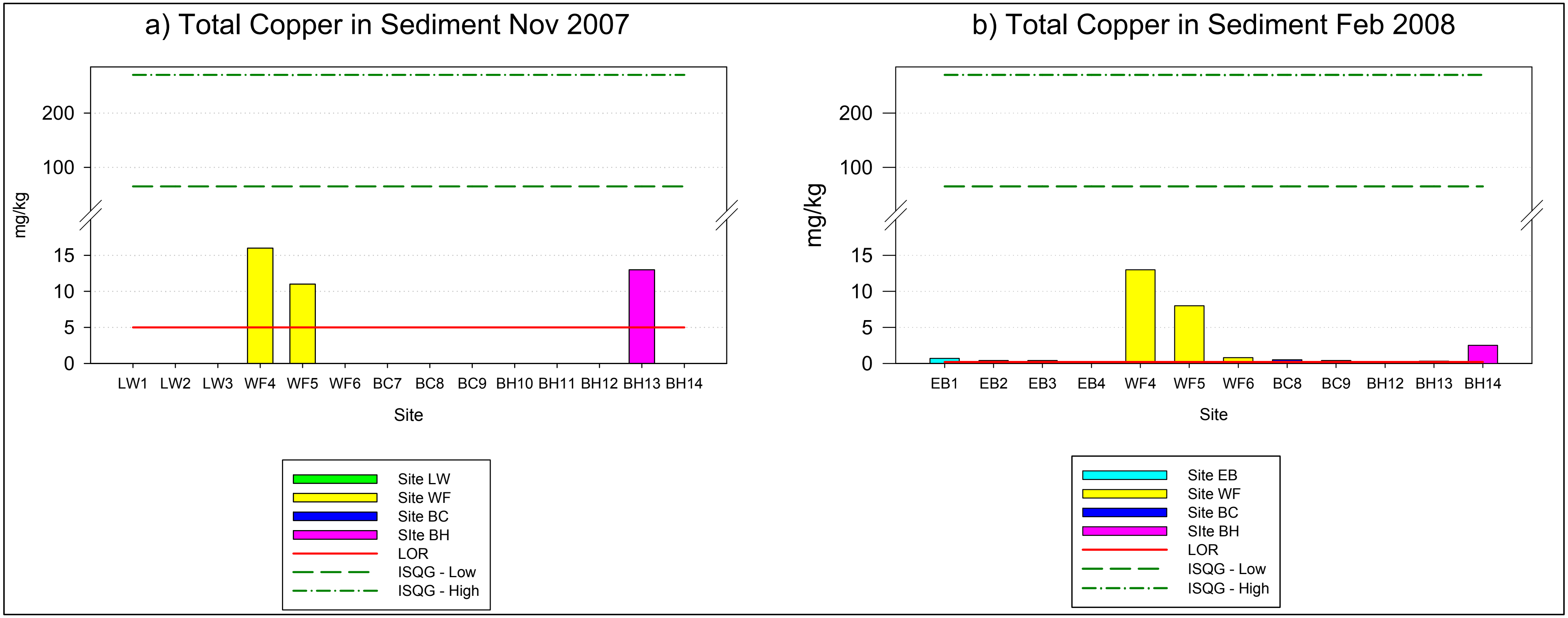


Figure 40 Copper in Sediment

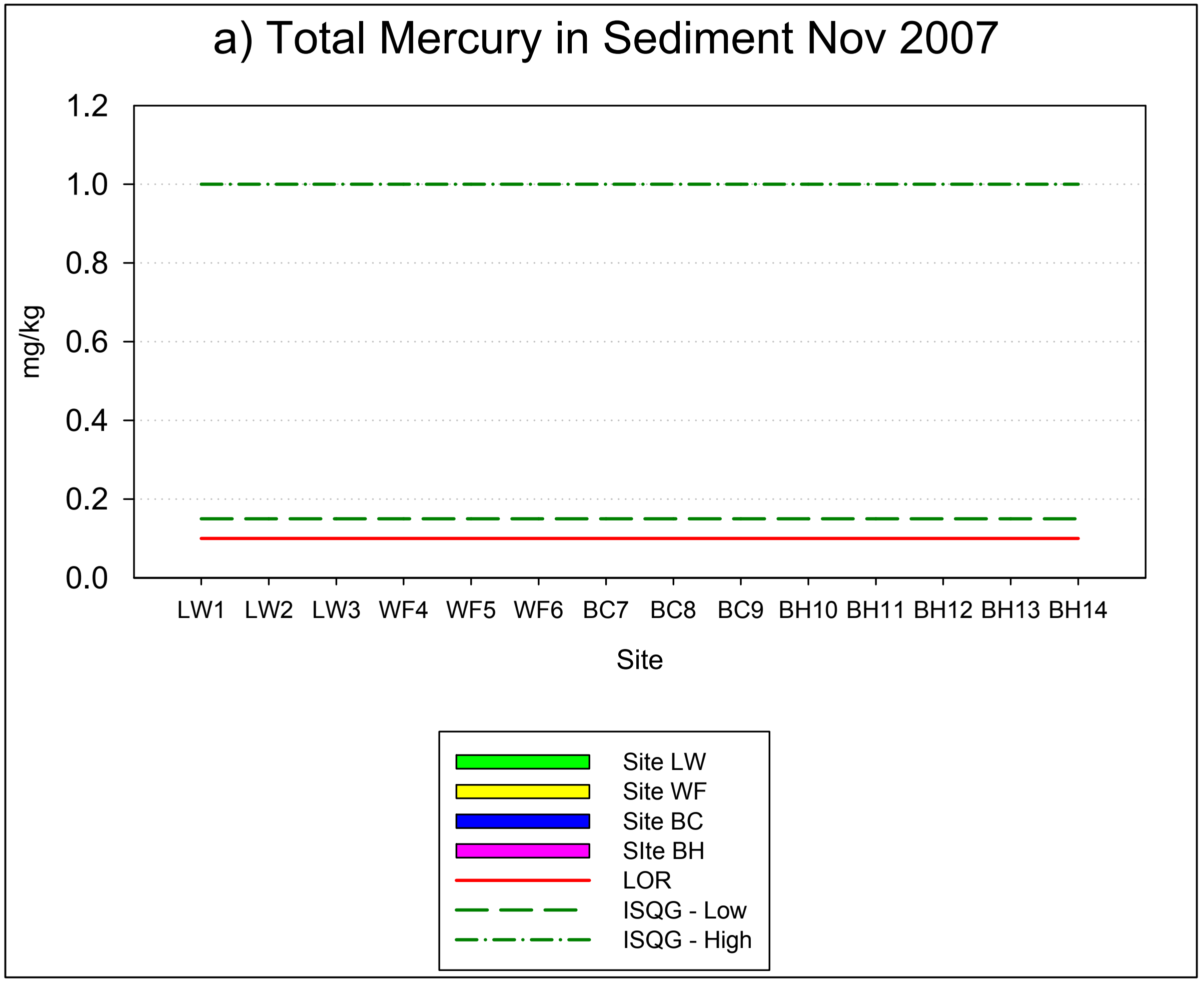


Figure 41 Mercury in Sediment

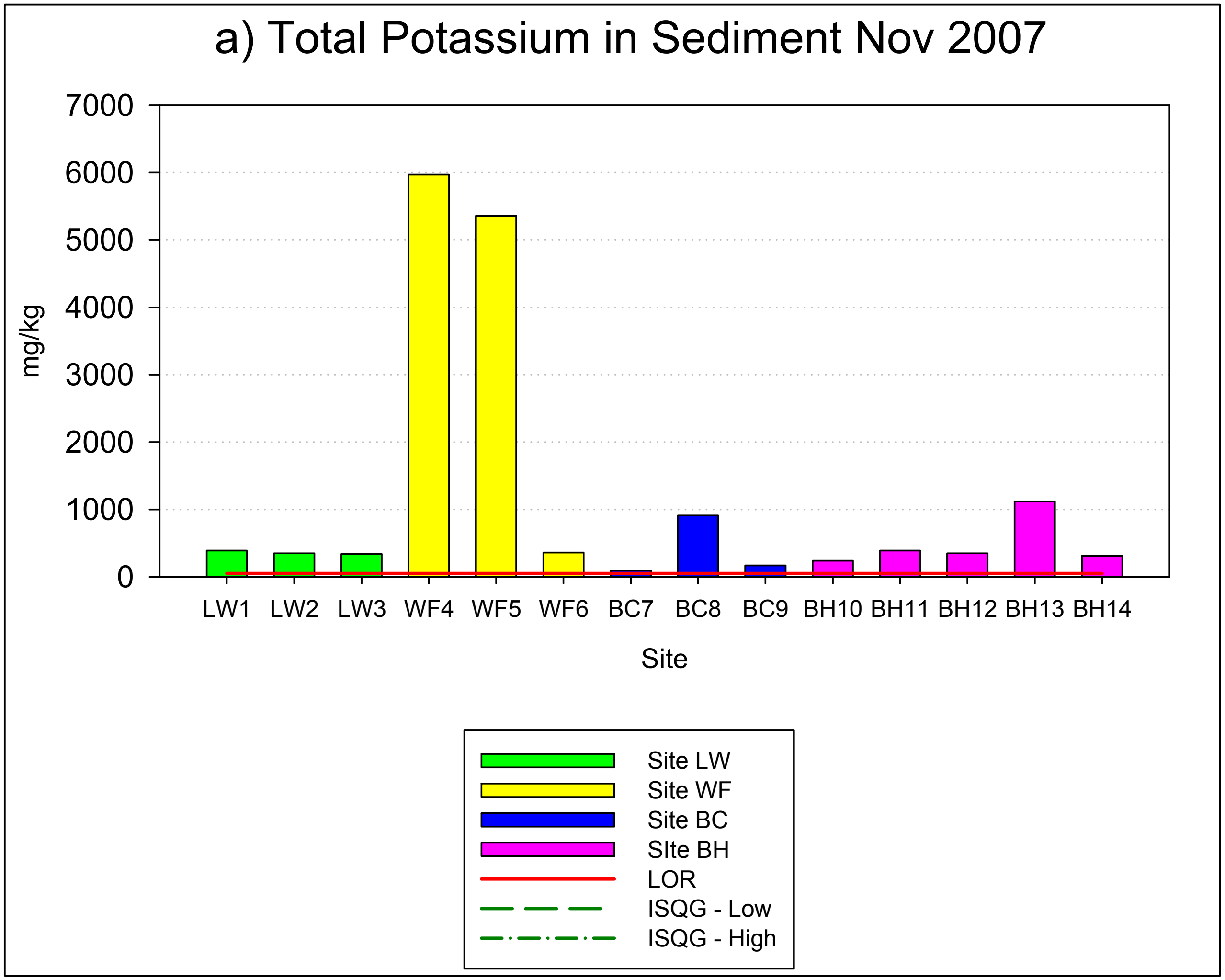


Figure 42 Potassium in Sediment

MAUNSELL | AECOM

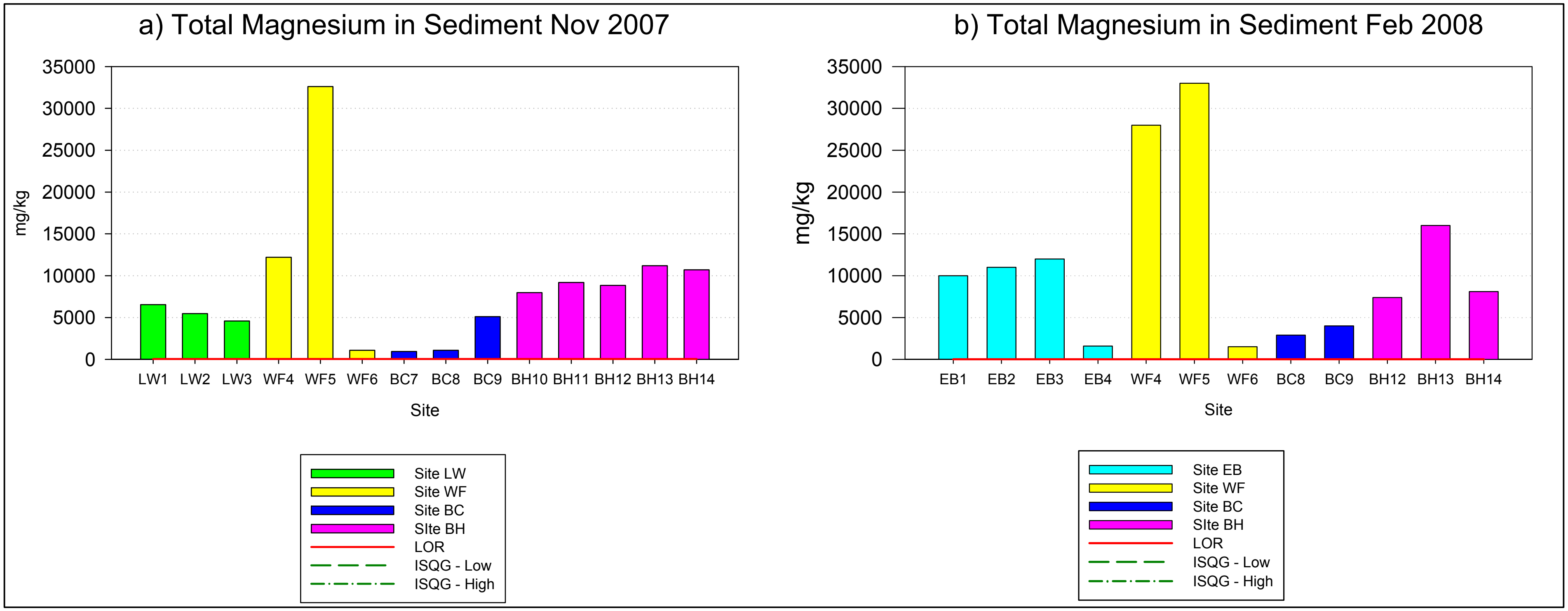


Figure 43 Magnesium in Sediment

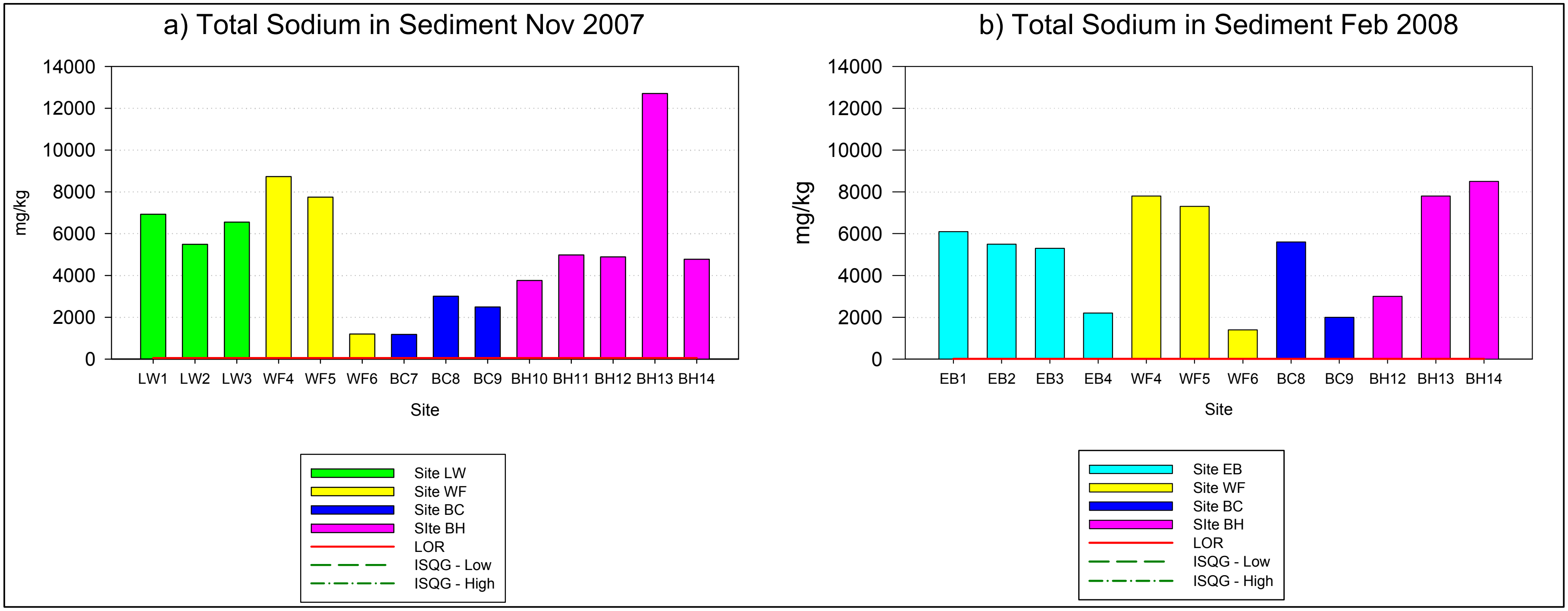


Figure 44 Sodium in Sediment

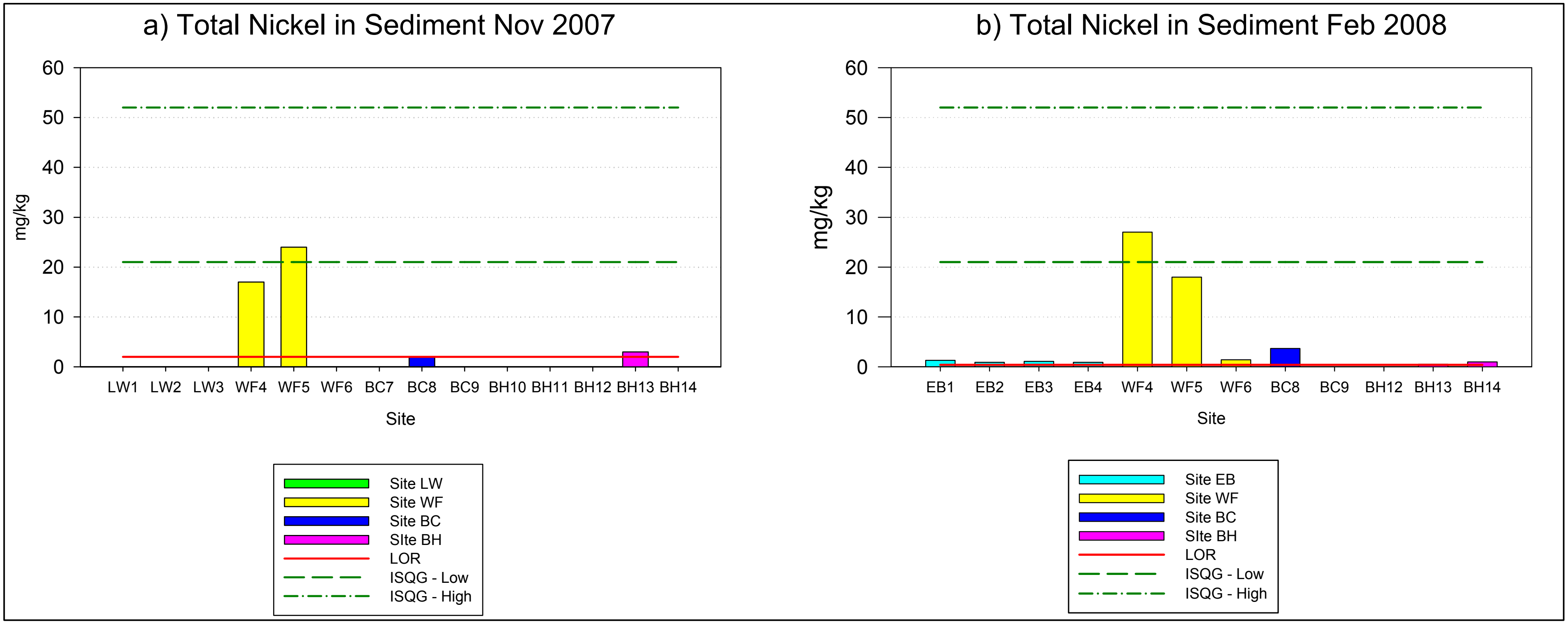


Figure 45 Nickel in Sediment

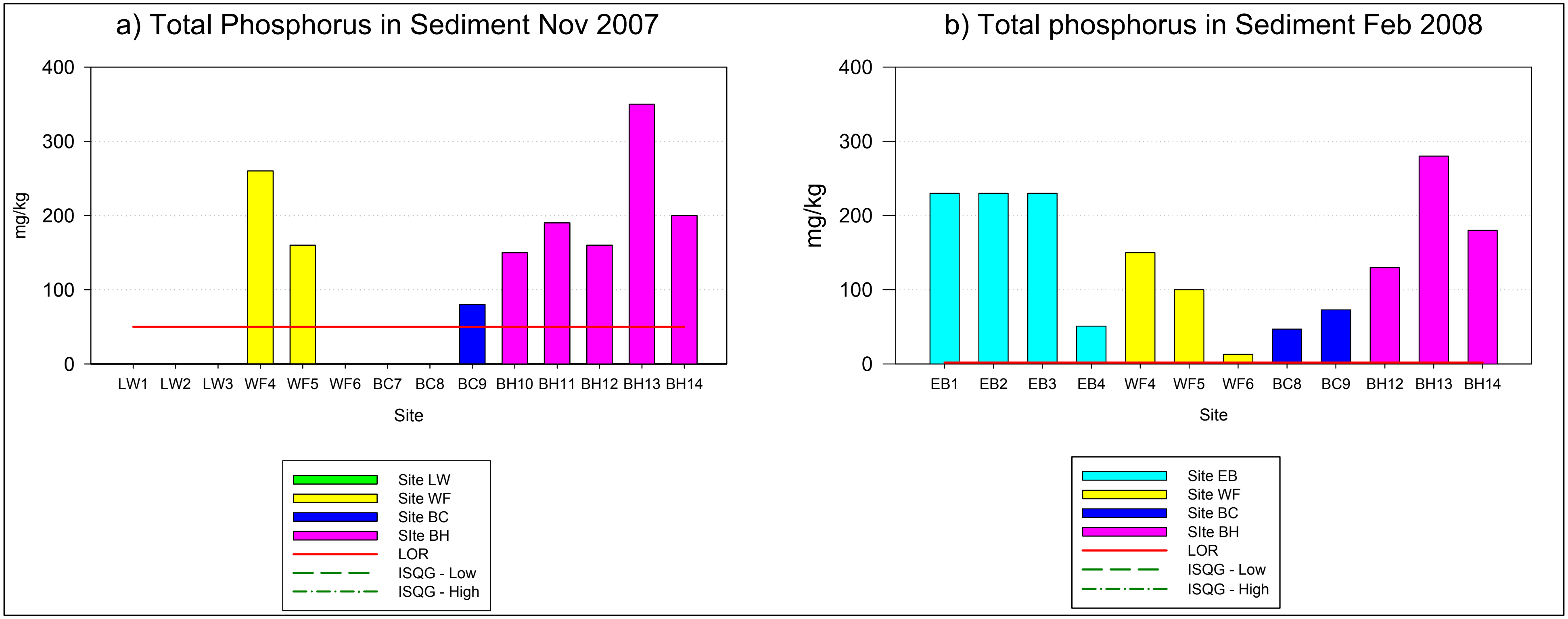


Figure 46 Phosphorus in Sediment

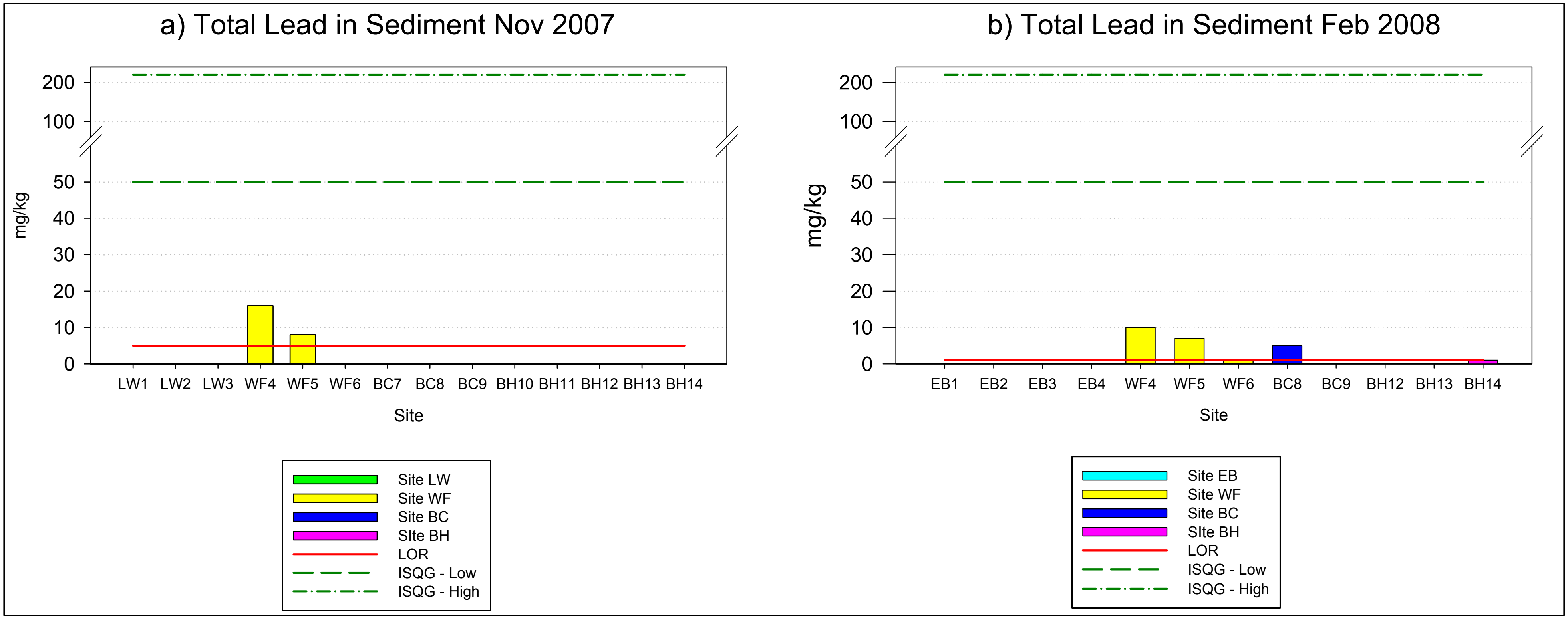


Figure 47 Lead in Sediment

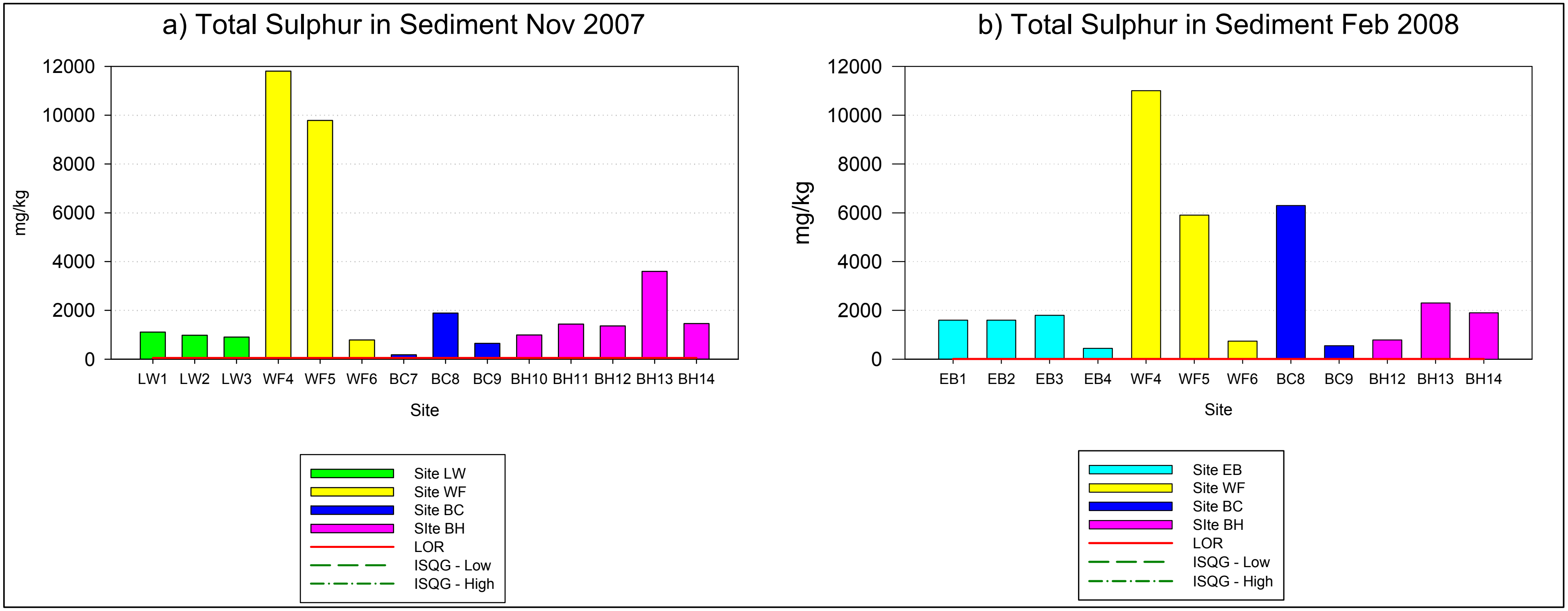


Figure 48 Sulphur in Sediment

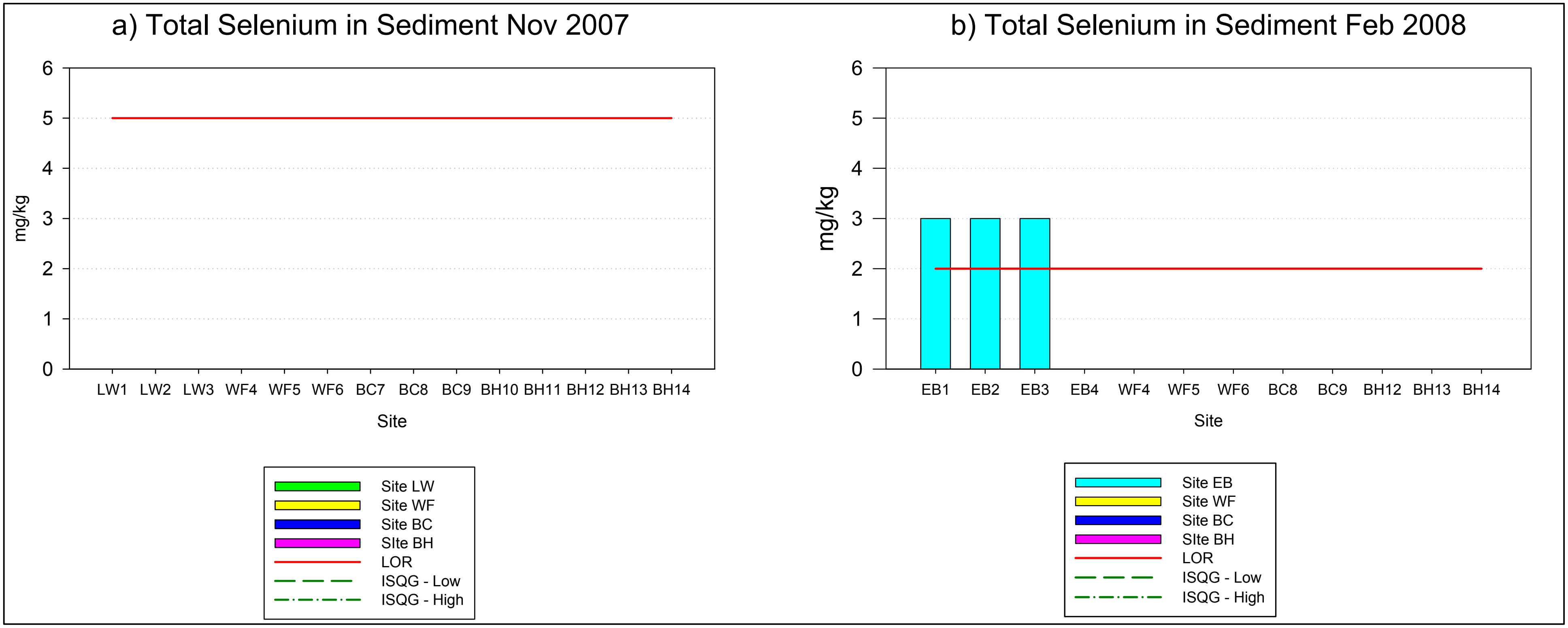


Figure 49 Selenium in Sediment

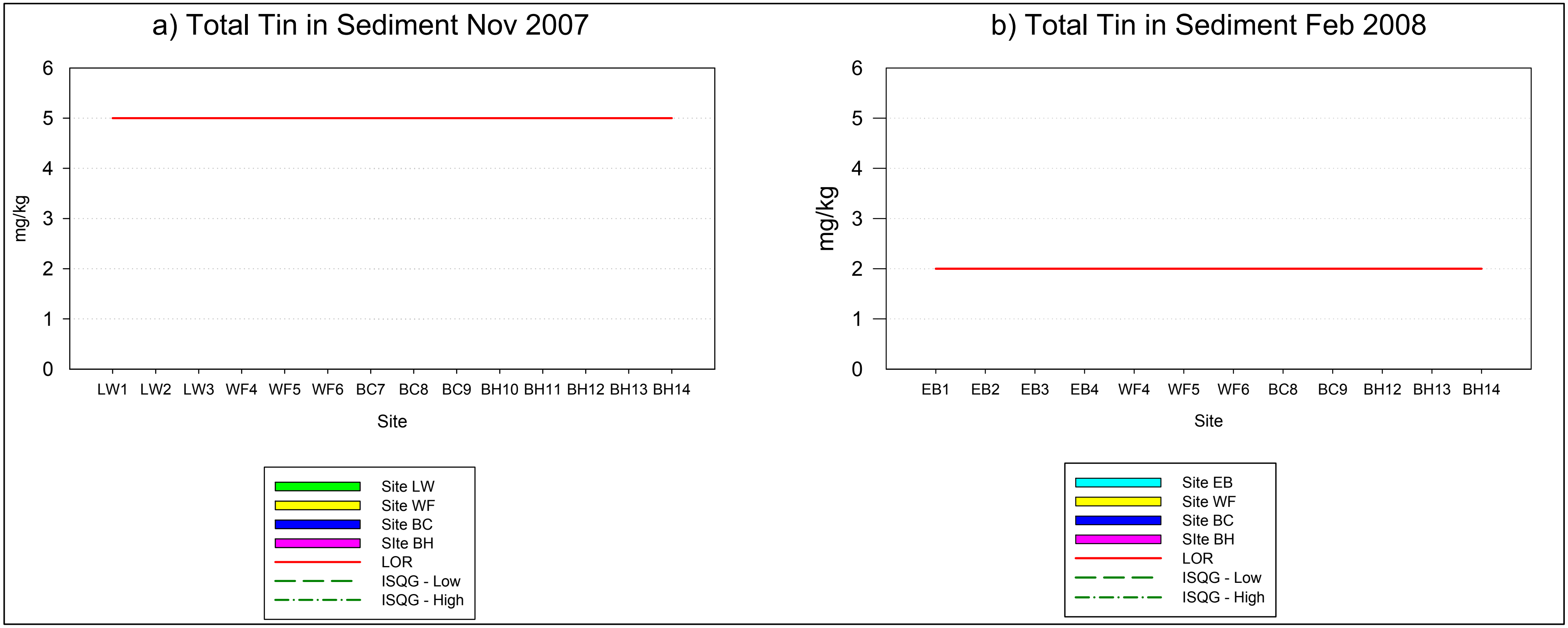


Figure 50 Tin in Sediment

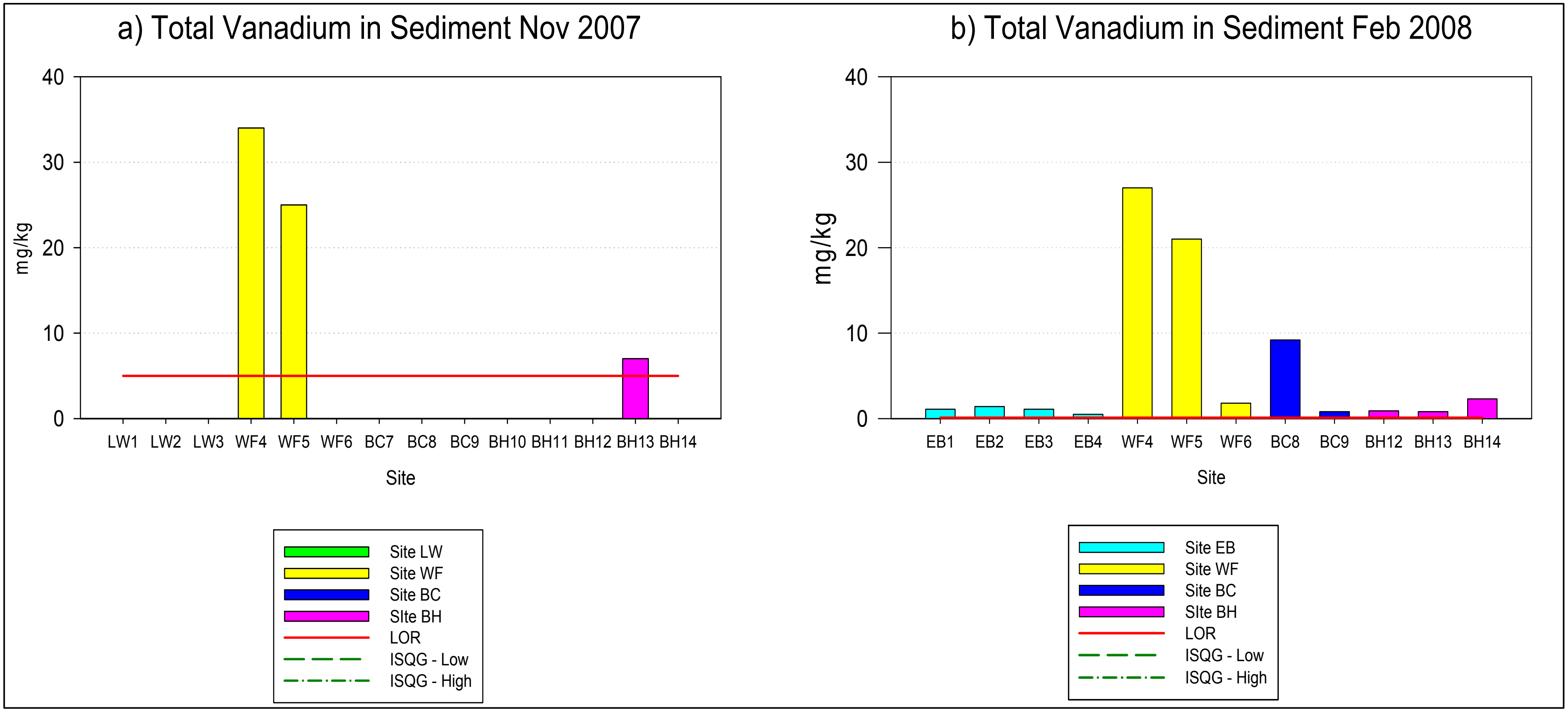


Figure 51 Vanadium in Sediment

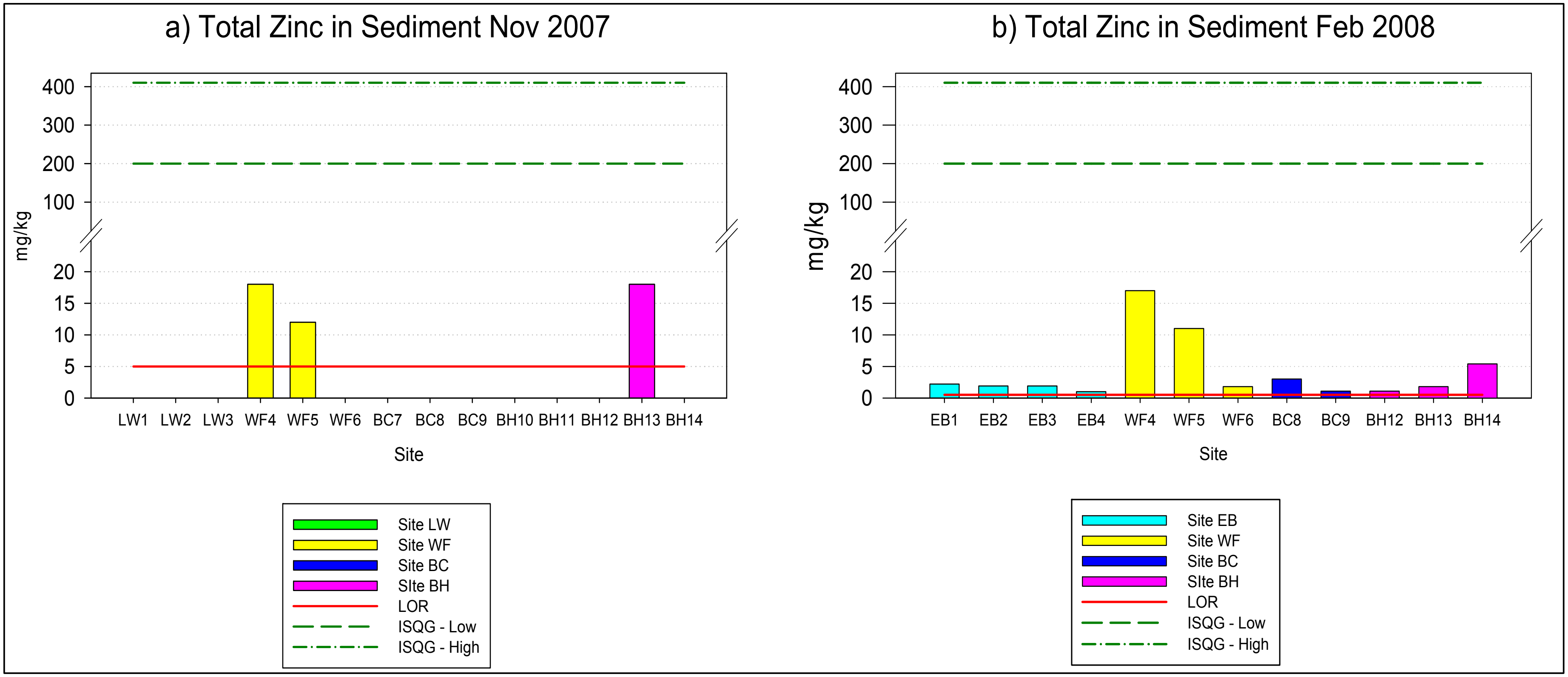


Figure 52 Zinc in Sediment

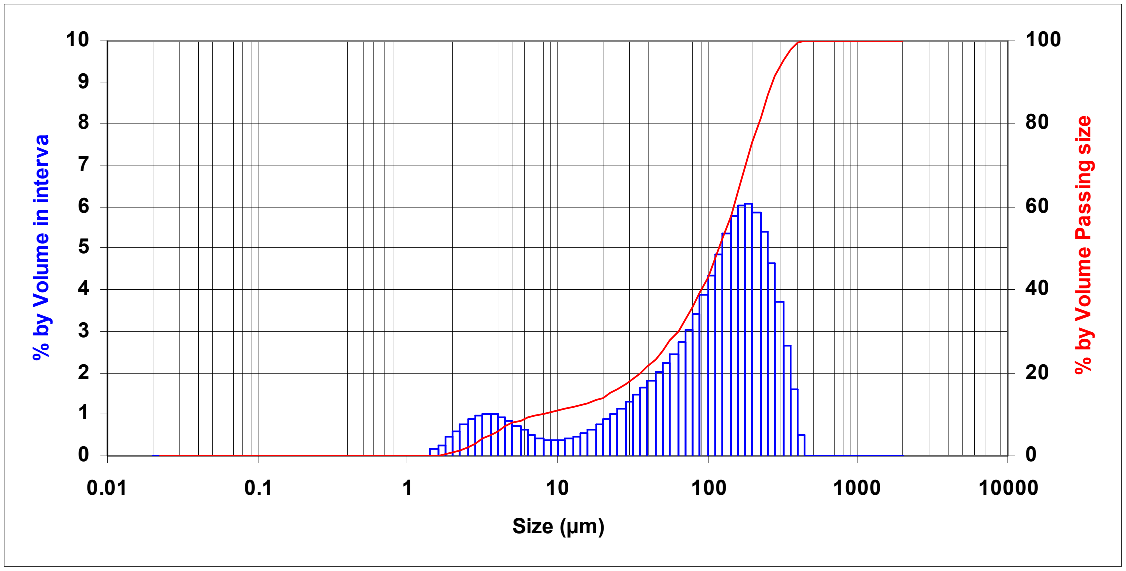


Figure 53 Lake Warden Particle Size Distribution (Source: CSIRO, 2008)

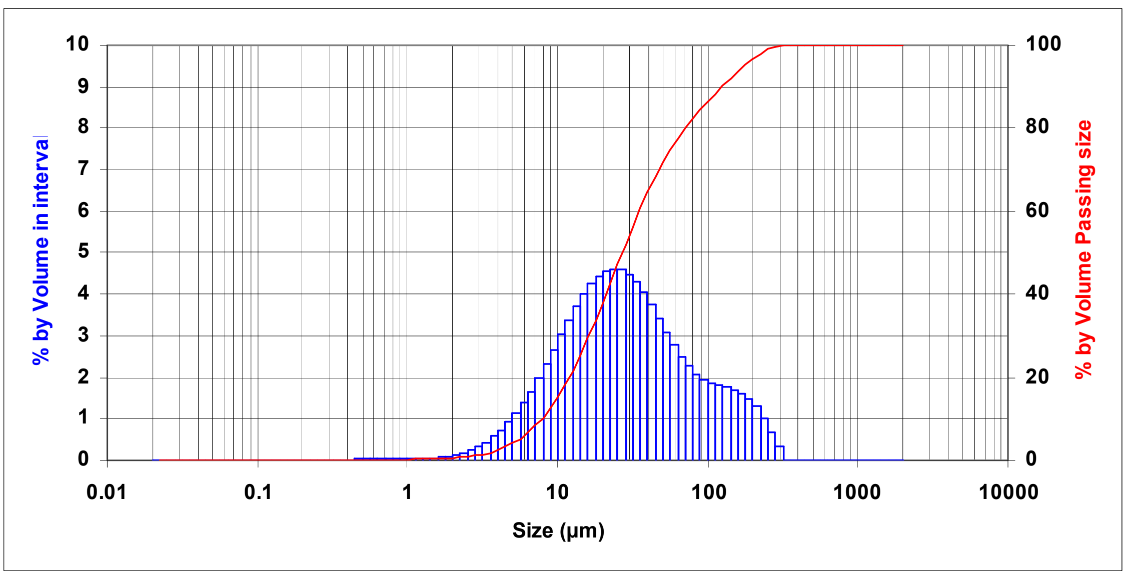


Figure 54 Lake Wheatfield Size Distribution (CSIRO, 2008)

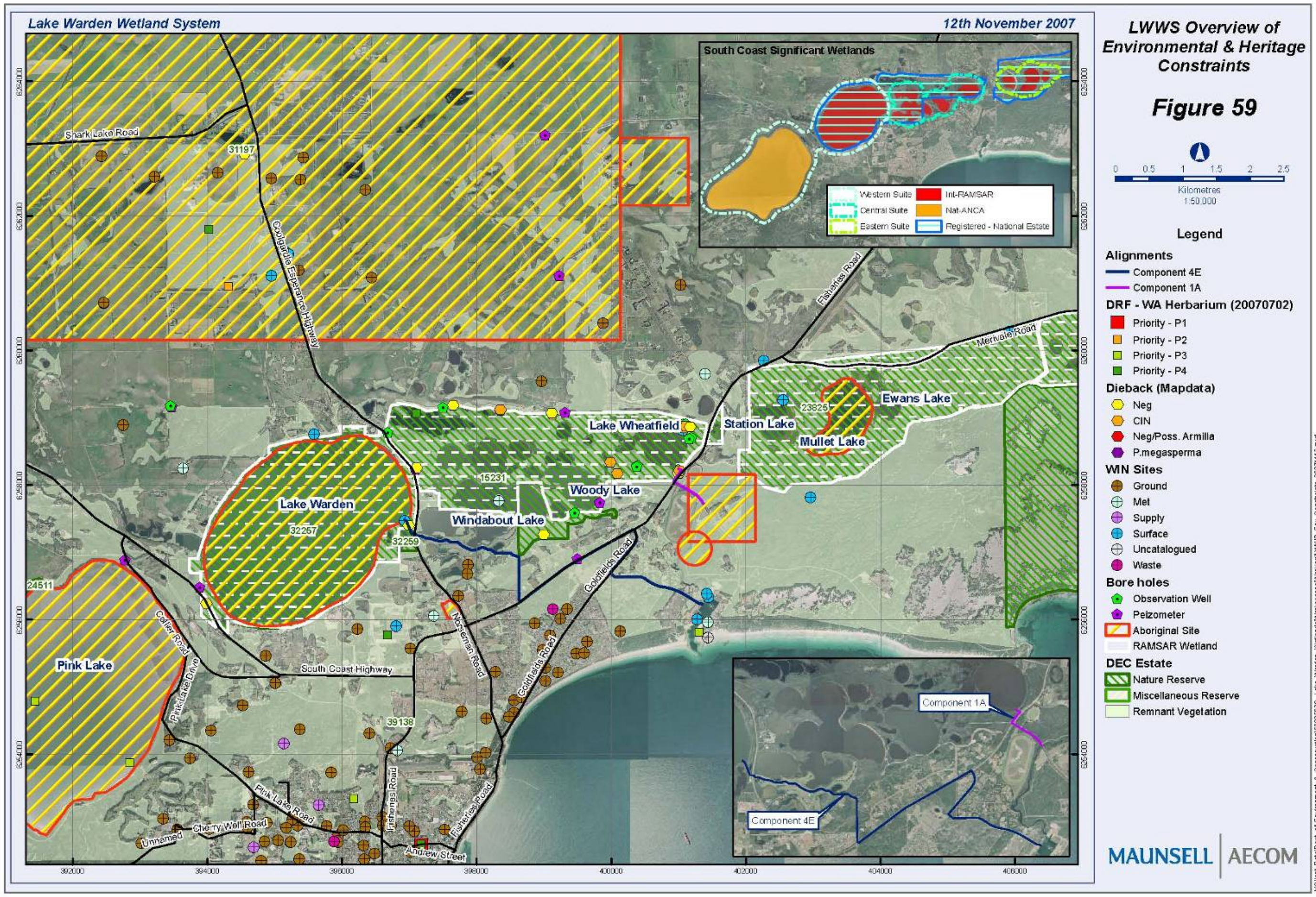


Figure 55 Water Quality & Sampling Locations

5.10 Flora and Vegetation

5.10.1 Biological Context of the Study Area

Esperance township lies within the Eyre Botanical District of the South-West Botanical Province, which largely corresponds to the Esperance Plains Biogeographic Region. The Eyre Botanical District is generally characterised by scrub heath and mallee heath on sand plains dominated by Blue Mallee (*Eucalyptus pleurocarpa*). Deeper sands support a shrub heath community characterised by Showy Banksia (*Banksia speciosa*) and Chittick (*Lambertia inermis*) (CALM, 2006).

Within the Eyre Botanical District, the study area lies at the interface between the Fanny's Cove Vegetation System and the Esperance Vegetation System. The LWWS predominately lies within two vegetation units of the Fanny Cove Vegetation System: Coastal Dune Scrub and Scrub heath with Banksia on coastal plain. To the north, the vegetation unit is comprised of Scrub heath with Banksia on sandplain (within the Esperance Vegetation System).

A high proportion of vegetation within the Esperance Plains has been cleared for pasture and is devoid of remnant vegetation, with only 52% of the remnant vegetation remaining. However, only 26% of the original vegetation remains within the Lake Warden Catchment (CALM, 2006).

5.10.2 Declared Rare and Priority Flora

Interrogation of the DEC Threatened Flora database and a review of relevant current literature identified the potential for 47 Declared Rare or Priority Flora species to occur within the wider Esperance – Lake Warden Region. This includes 3 Declared Rare Flora (DRF), 8 Priority 1, 6 Priority 2, 17 Priority 3 and 13 Priority 4 flora species (Table 18). Additionally, four species (*Acacia pritzeliana*, *Andersonia macranthera, Baeckea crassifolia* var. *isocandra* and *Grevillea plurijuga* subsp. *superba*) previously identified as DRF or Priority Flora (DEC, 2006a) were removed from the Declared Rare and Priority Flora list in 2006 yet considered Significant.

Table 18 Declared Rare or Priority Flora With Potential To Occur Within the Study Area

Family Number	Family Name	Species	Conservation Status
55	Haemodoraceae	*Anigozanthos bicolor* subsp. *minor*	DRF
185	Euphorbiaceae	*Stachystemon vinosus*	DRF
273	Myrtaceae	*Eucalyptus merrickiae*	DRF
90	Proteaceae	*Dryandra longifolia* subsp. *calicola*	P1
138	Brassicaceae	*Lepidium fasciculatum*	P1
226	Dilleniaceae	*Hibbertia carinata*	P1
226	Dilleniaceae	*Hibbertia turleyana*	P1
273	Myrtaceae	*Astartea* sp. Esperance (A Fairall 2431)	P1
273	Myrtaceae	*Eucalyptus balanopelex*	P1
273	Myrtaceae	*Eucalyptus missella*	P1
341	Goodeniaceae	*Dampiera sericantha*	P1
66	Orchidiaceae	*Paracaleana parvula*	P2
165	Papilionaceae	*Daviesia pauciflora*	P2
273	Myrtaceae	*Angasomyrtus salina*	P2
273	Myrtaceae	*Melaleuca eximia*	P2
273	Myrtaceae	*Melaleuca viminea* subsp. *appressa*	P2
54F	Anthericaceae	*Thysanotus parviflorus*	P2
32	Cyperaceae	*Lepidosperma pruinosum*	P3

Family Number	Family Name	Species	Conservation Status
39	Restionaceae	*Hopkinsia adscendens*	P3
90	Proteaceae	*Isopogon alcicornis*	P3
90	Proteaceae	*Persoonia cymbifolia*	P3
163	Mimosaceae	*Acacia euthypyhylla*	P3
183	Polygalaceae	*Comesperma calcicola*	P3
273	Myrtaceae	*Astartea* sp. Hopetoun area (AS George 10594)	P3
273	Myrtaceae	*Melaleuca incana* subsp. *tenella*	P3
273	Myrtaceae	*Eucalyptus foliosa*	P3
273	Myrtaceae	*Melaleuca dempta*	P3
276	Haloragaceae	*Gonocarpus pycnostachyus*	P3
281	Apiaceae	*Trachymene anisocarpa* var. *trichocarpa*	P3
288	Epacridaceae	*Leucopogon rotundifolius*	P3
288	Epacridaceae	*Conostephium marchantiorum*	P3
313	Lamiaceae	*Pityrodia chrysocalyx*	P3
331	Rubiaceae	*Galium migrans*	P3
341	Goodeniaceae	*Goodenia laevis subsp. laevis*	P3
90	Proteaceae	*Grevillea baxteri*	P4
163	Mimosaceae	*Acacia aemula* subsp. *aemula*	P4
215	Rhamnaceae	*Siegfriedia darwiniodies*	P4
273	Myrtaceae	*Eucalyptus preissiana* subsp. *lobata*	P4
273	Myrtaceae	*Eucalyptus x erythrandra*	P4
273	Myrtaceae	*Eucalyptus x missilis*	P4
273	Myrtaceae	*Verticordia vicinella*	P4
273	Myrtaceae	*Darwinia polycephala*	P4
273	Myrtaceae	*Darwinia* sp. Mt Burdett (NG Marchant 80/42)	P4
273	Myrtaceae	*Eucalyptus dolichorhyncha*	P4
273	Myrtaceae	*Eucalyptus goniantha* subsp. *goniantha*	P4
273	Myrtaceae	*Eucalyptus varia* subsp. *salsuginosa*	P4
326	Myoporaceae	*Eremophila serpens*	P4

5.10.3 Threatened and Priority Ecological Communities

A database search of DEC's listed TECs and Priority Ecological Communities (PECs) established that no TECs occur within or in the vicinity of the proposed study. The database search did reveal that there is an occurrence of a DEC Priority 1 Ecological Community, *Stromatolite like microbialite* community of a Coastal Hypersaline Lake (Pink Lake), within approximately 2km of the LWWS study area, but this will not adversely impact any TECs.

5.10.4 Digital Multi Spectral Imaging (DMSI)

Digital Multi-Spectral Imaging (DMSI) assists with baseline vegetation mapping, and it provides an accurate estimation of vegetation compositions, diversity, distribution and condition across broad scales (Specterra, 2006). This imagery, compared over time, can detect and map subtle changes in vegetation composition, density and condition (Specterra, 2006). DMSI coupled with ground truthing, enables accurate and efficient mapping of large areas.

Preliminary vegetation surveys collecting data on vegetation structure, composition and condition have been carried out over the last six years within the Lake Warden Catchment (CALM, 2006). Ground truthing surveys to validate the DMSI occurred during 2004 and 2007. The vegetation change over the three years was determined by producing a vegetation change detection image to provide a comparison between the two sets of DMSI data (Figure 56).

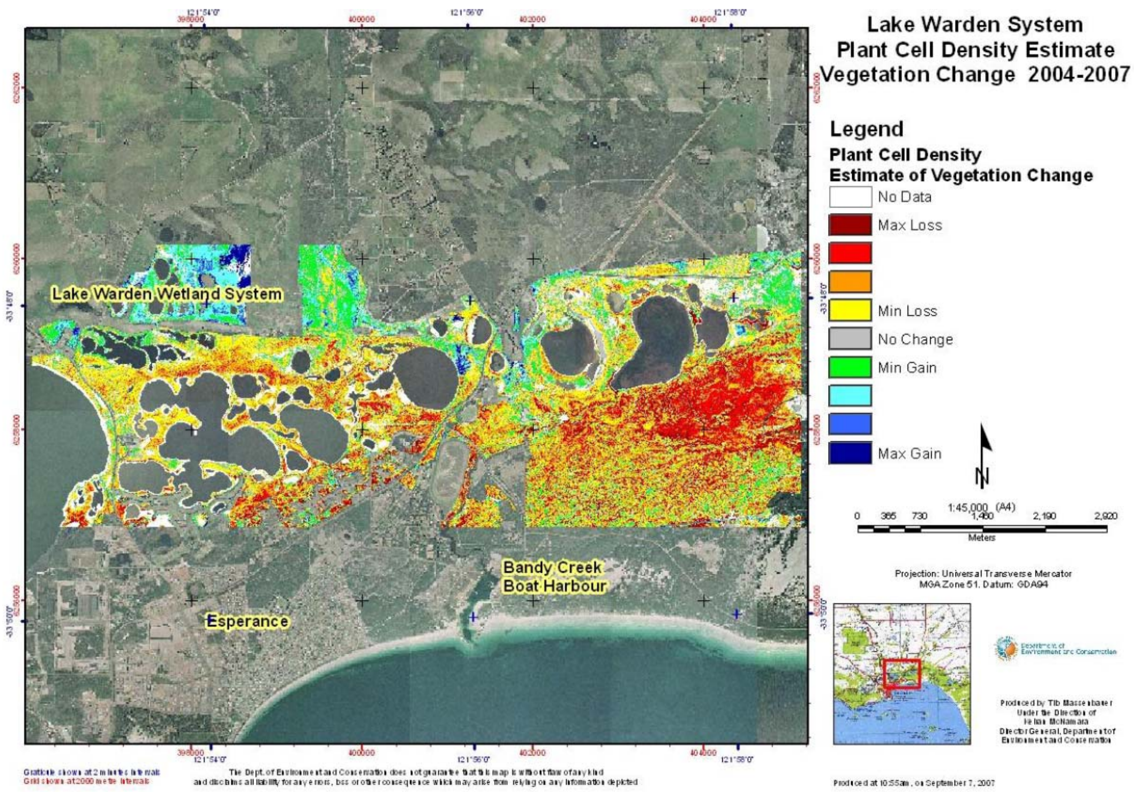


Figure 56 Vegetation Community and Change Analysis of Remote Sensing Imagery (DEC, 2007e)

The change in vegetation was evaluated as a measure of plant cell density, where a higher plant cell density usually indicates healthier plant communities. Evaluation of the vegetation change image indicated that a high proportion of vegetation immediately fringing the LWWS has suffered a loss in plant cell density over the three-year period. These areas contain remnant vegetation and previously mapped by the DEC as Banksia Woodland, Eucalypt Woodland, *Melaleuca* Woodland and *Nuytsia* Mixed Heath (Figure 57). The loss in plant cell density over this period is due to an increase in water depth within the LWWS and salinity. The accumulation of salts within the LWWS will favour halophytic plants and generally diminish the vegetation community complexity. The increase in salt concentrations within the LWWS will affect groundwater quality, and in turn, influence water-uptake and health of deep-rooted vegetation. Changes in vegetation community composition would also affect the Terrestrial fauna.

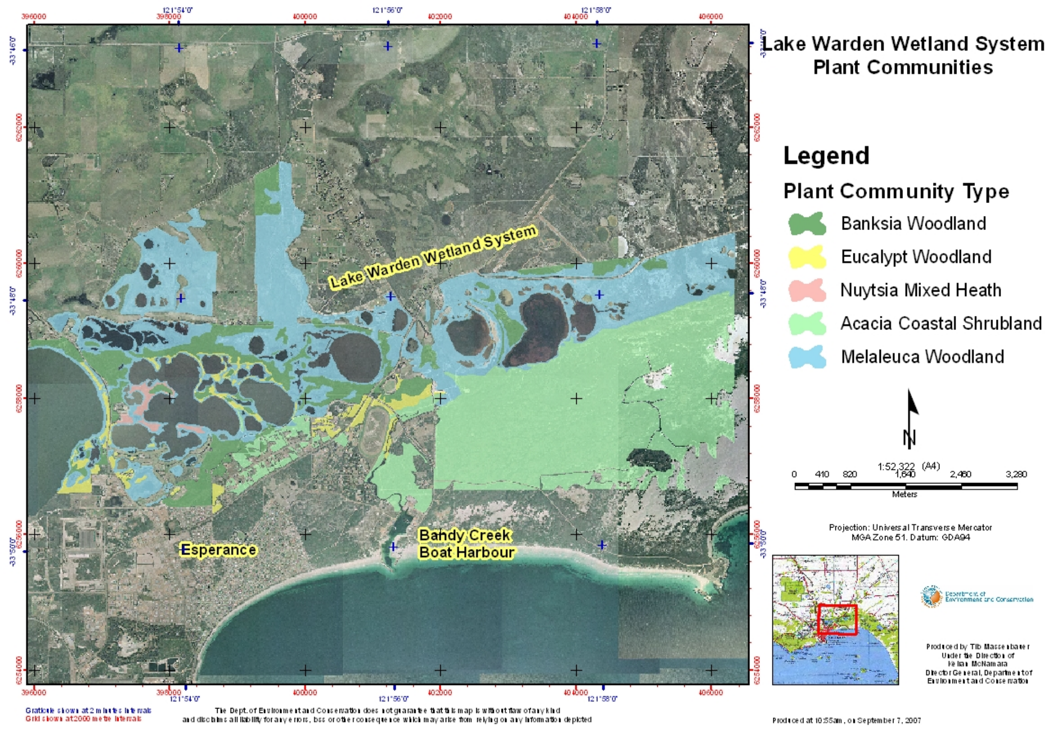


Figure 57 Lake Warden Wetland System Plant Communities (Courtesy of DEC, 2007d)

The reduction in plant cell density within each of the remnant vegetation communities indicates the decline in vegetation health, which is associated with are increase in water levels in the LWWS. Similarly, statistical analysis conducted by the DEC indicates an increase in degraded vegetation communities (Figure 58).

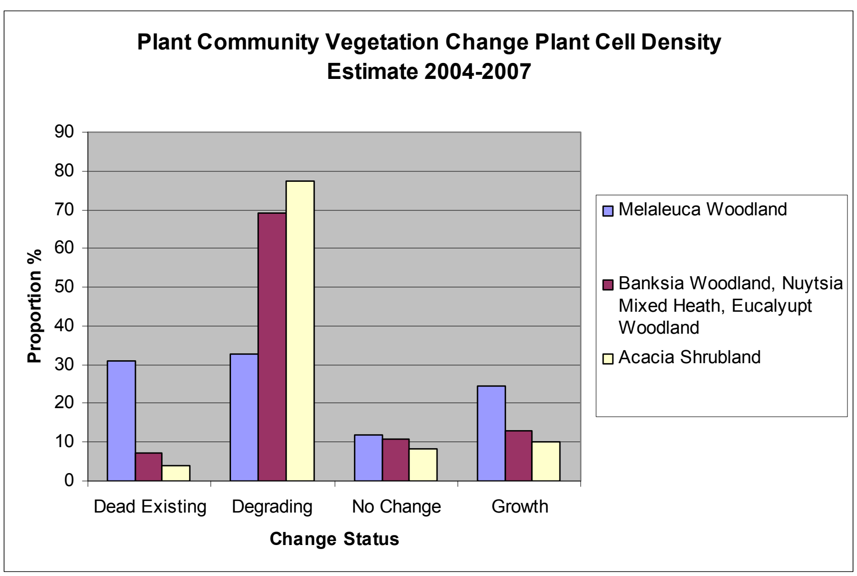


Figure 58 Plant Community Vegetation Change in Plant cell Density Estimate 2004-2007 (Courtesy of DEC, 2007e)

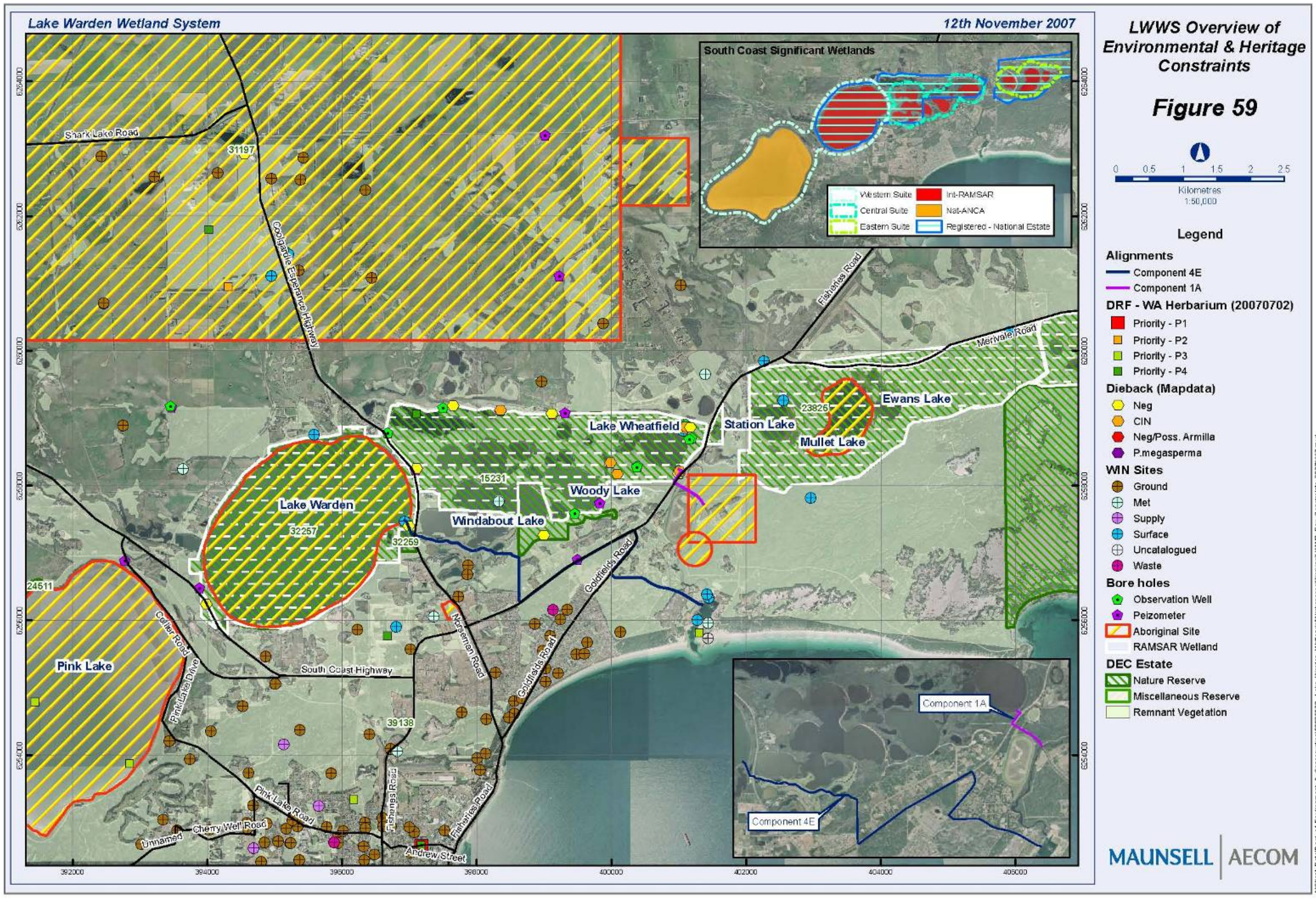


Figure 59 LWWS Overview of Environmental & Heritage Constraints

5.11 Fauna

5.11.1 Birds

The LWWS is listed as a Ramsar Wetland, which is recognised as a matter of national significance under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Under the Act, a Ramsar Wetland is an Australian wetland on the List of Wetlands of International Importance kept under the Ramsar Convention (Department of Environment and Water Resources (DEWR), 2007). The criteria of RAMSAR convention qualifies a wetland system to be of International importance if the wetland regularly supports 20,000 or more waterbirds or greater than 1% of the world's population of a species, particularly migratory species.

Wetlands in the LWWS are some of the most important in the south of Western Australia for Hooded Plovers, Banded Stilts, Australian Shelducks, Black Swans, Chestnut Teals, Musk Ducks and Australasian Shovelers (CALM, 1999). Bird count records for LWWS indicate that the abundance of birds regularly approached 20,000 and, prior to 1980, the system supported greater than 1% of world's Banded Silt and Hooded Plover population. These numbers have since declined substantially due to diminished habitat through excess surface water and groundwater discharge associated with historical land clearing within the Shire.

5.11.2 Aquatic Invertebrates

Benchmark data of macro and micro-invertebrate assemblages were collected in 2006 for Lake Warden, Lake Wheatfield, Ewans Lake and Station Lake (Cook *et al*., 2007). Of the four lakes, Lake Warden had the lowest species richness, most due to the differences in water quality and particularly due to its higher salinity (Cook, *et al*., 2007).

5.11.3 Threatened and Priority Fauna

Interrogation of the DEC Threatened and Priority Fauna Database suggested the potential for two threatened fauna species and one specially protected or Priority species to occur within the immediate vicinity of the LWWS (Table 19).

Table 19 Threatened and Priority Fauna Species Potentially Present Within The Lake Warden Wetland Area (DEC, 2007)

Species	Common Name	WA Conservation Category	EPBC Conservation Category	IUCN Threatened Species Category	Potential to occur in the area
Cereopsis novaehollandiae grisea	Recherche Cape Barren Goose	Schedule 1	Vulnerable	Least Concern	Likely
Calyptorhynchus latirostris	Carnaby's Black-Cockatoo	Schedule 1	Vulnerable	Endangered	Likely
Charadrius rubricollis rubricollis	Hooded Plover	Priority 4	N/A	N/A	Likely

Additionally, a review of current literature and a search for environmental triggers under the EPBC Act has identified the potential for an additional 63 species to occur in the LWWS. All of these 66 species identified within the wider catchment are listed under international treaties or protected under the EPBC Act or the *Wildlife Conservation Act 1950*.

Appendix H presents a comprehensive list of all potential species as well as a number of marine species also protected under the EPBC Act. These species have not been excluded from the list of potential Threatened and Priority fauna since the discharge point of the engineering option leads to the ocean (via Bandy Creek).

Plate 2: Water Birds at Lake Wheatfield

Plate 3: View of Lake Wheatfield

5.12 *Phythophthora* cinnamomi

Phythophthora cinnamomi (Pc) Dieback (also known as 'Dieback' or 'Jarrah Dieback') was first observed in Western Australia in 1921 as unexplained death of shrubs and Jarrah trees. It is believed to have been introduced to horticultural plants soon after European settlement in the South West (Government of Western Australia, 2007). It was not until the mid 1960s that the causal relationship between large scale tree decline and death and the pathogen *Phythophthora cinnamomi* was established. Over 40% of South West flora is susceptible to infection by Pc dieback (Government of Western Australia, 2007).

Many root pathogens are known to cause disease in Australian flora species, but Pc has had the greatest effect and poses the greatest threat. Disease in natural ecosystems of Australia, caused by Pc is listed as a 'key threatening process' under the Commonwealth's *Environment Protection and Biodiversity Conservation Act (EPBC) 1999* effective from 16 July 2000 (CALM, 2004). The Act requires the Australian Government to prepare and implement a threat abatement plan for nationally coordinated action to mitigate harm caused by Pc to Australian species, particularly threatened flora, fauna and ecological communities. The 'National Threat Abatement Plan for Dieback Caused by the Root-rot fungus *Phythophthora cinnamomi'* was released in 2001 (Environment Australia, 2001).

The three organisms that result in Dieback disease in Western Australia, and investigated by DEC in the LWC within the study area are:

- *Phythophthora cinnamomi (Pc);*
- *Phythophthora megasperma; and*
- *Armillaria luteobubalina.*

5.12.1 Phythophthora cinnamomi

Commonly known dieback is a disease caused by the soil pathogen *Phytophthora cinnamomi (Pc). Pc* is spread by soil and water movement and infects susceptible native plant species via the roots and preventing the uptake of water and soil nutrients. Western Australian native plant species most susceptible to *Pc* dieback infection include Jarrah, *Banksia and Grasstrees*. Since its initial identification in Western Australia in 1964, Pc has spread at an epidemic rate, causing permanent changes in plant communities, leading to the destruction of susceptible species and loss of fauna habitats.

5.12.2 Phythophthora megasperma

Phytophthora root rot, caused by the fungus-like pathogen *Phytophthora megasperma* (Pm) can cause rapid thinning of vegetation stands. Pm causes root and collar rot and also produces brown to black necrotic lesions in woody plants. Pm is a homothallic fungus-like pathogen that does not require two mating strains in order to produce sexual spores (Bradley, 1990).

Pm can carry over in the soil as zoospores or as fungal growth (mycelium) on infected plant tissue. Irrigation water or free flowing water after heavy rain, can carry zoospores that have been released from spore producing sacks (sporangia) formed on infected roots. Pm is favoured by wet, poorly drained soil conditions, during periods of excessive rainfall and or flooding, and high soil temperatures (Clarke, 1999). When active, Pm has high impact on species contributing to habitat structure, e.g. *Banksia attenuata* in the northern sandplain and *B. speciosa* on the south coast (Bellgard *et al*., 2003).

Investigations conducted recently by the Centre for *Phytophthora* Science and Management (Murdoch University) and DEC, and earlier work conducted by Bellgard (DEC), has determined that Pm found in WA is in fact a complex of several species. Most infestations originally thought to be *Pm* (based upon the microscopic identification of Phytophthora isolates from their morphological characters) have now been shown (by ITS DNA sequence analysis) to be undescribed species of *Phytophthora.* For the majority of WA isolates tested, Pm is morphologically indistinguishable from *P. megasperma* but *phylogenetically* it is not *P. megasperma* (Hardy, 2007 and Stukely, 2007. per. comm). In the wider Esperance region there may be several genetically-distinct *Phytophthora* species which were originally thought to be *Pm* that are still to be investigated to identify the extent of the threat they pose to vegetation (Stukely per. comm., 2007).

5.12.3 Armillaria luteobubalina

Armillaria luteobubalina is a native soil-borne fungus-like pathogen that causes root rot and subsequent dieback of a wide variety of plants including many native and introduced ornamental plants. The large host range of the fungus-like pathogen is poorly defined and for this reason field detection on a broad scale is difficult. It usually relies primarily on sighting the mushroom-like fruiting bodies (olive brown to yellow in colour, up to 12 cm in diameter with a stipe (stalk) up to 15 cm high) produced in May-June (Botanic Gardens Trust, 2007).

Many symptoms similar to those arising from dieback caused by Pc are known to result in plants infected with *Armillaria*, including yellowing of foliage, splits in the trunk of infected trees, poor vigour and exudates from the trunk (kino production). Determination of the cause of dieback symptoms (from either *Pc* or *Armillaria*) is therefore also difficult, due to the similar visible impacts, similar distribution and similar host range (Botanic Gardens Trust, 2007).

Infection occurs via the roots, usually as a result of infected roots coming into contact with uninfected roots and the fungus-like pathogen growing across. The fungus-like pathogen is able to infect new areas by several means, rarely via air movement and more commonly by the transportation of infected material such as plants, roots, mulches or soil. Hygiene is obviously important in minimising the spread of this fungus-like pathogen (Botanic Gardens Trust, 2007.

5.13 Marine Environment

5.13.1 Background

Since 1983, Bandy Creek Boat Harbour, positioned approximately 10km to the east of the town centre of Esperance, has been an operational boat harbour. The Eastern section of the harbour accommodates a commercial area with commercial pens and a land-backed service wharf. The Western side of the harbour accommodates the recreational boating community including pens and a boat ramp (DPI, 2007).

Plate 4: Service slipway

Plate 5: View across the harbour towards commercial facilities

Plate 6: Recreational Facilities

The construction of Bandy Creek Boat Harbour converted the coastal site from a uniform stretch of open sand beach and a usually closed small creek mouth and tidal inlet to a sheltered marine harbour (Kohn and Blahm, 2005). Since then the littoral drift sand has been accumulating at the harbour entrance (Hedderick, 2006). The main sediment transport mechanisms in the Bandy Creek vicinity are wave action and wave induced currents. In winter, these predominate from the west to east, while in summer they tend east to west (Hedderick, 2006).

Dredging, usually conducted between October and March, takes place approximately every two years. On the beach 1300m to the east is material deposited from the dredging thus allowing it to continue to deposit further down the coast.

The depth of the water within the turning basin of the harbour and at the land backed service wharf is approximately 4.2m below datum. However, it varies due to shoaling caused by littoral sand movements. The depth of water in the area of the Commercial pens is approximately 3.5m, and at the Recreational pens is approximately 2m (DPI, 2007).

Historically, control of the flow from Bandy creek into the boat harbour has been through a weir. In January 2007, a major storm hit Esperance that broke the banks of the weir, causing sediment from the creek to flood into the harbour. The implementation of dredging to maintain the harbour occurred quickly yet the weir is not mended.

Plate 7: January Storm event²

Plates 8, 9 &10: Bandy Creek Weir in its current state

5.13.1.1 Wind

An eastward moving subtropical high-pressure belt, causing southwesterly winds in winter, and southeasterly winds in winter dominates the prevailing weather conditions. This system is periodically disrupted by storms in the winter with average wind speeds between 15-29ms-1 and periodic stronger gusts (Steedman 1982, as cited in Hedderick, 2006). Wind directions resulting from these storms range from north-west to south-west, with the strongest winds from the north-west (Silvester 1987, as cited in Hedderick, 2006).

In summer, the southerly sea breeze has a major influence on local conditions. Speeds estimated at 10ms-1, increasing up to storm conditions (Clark 1955 as cited in Hedderick, 2006). Periods of calm winds are few (Fisheries WA 1999 as cited in Kendrick *et al*., 2005)

5.13.1.2 Waves

For most of the year, the Recherche Archipelago has strong, relatively consistent swells from the south-west (Van Hazel *et al*., 2001 as cited in Kendrick *et al*., 2005) reinforced by the wind waves and this produces a net eastward littoral drift along the south coast (Fisheries Western Australia, 1999).

5.13.1.3 Tides

A diurnal tidal cycle occurs in Esperance ranging from around 0.4m to a maximum spring tidal range of 1.1m (Van Hazel *et al*. 2001, as cited in Kendrick *et al*., 2005).

[1] The plates were taken from the abc news website (http://www.abc.net.au/rural/content/2006/s1825679.htm 17/10/2007) illustrate the extent of the sediment plume created.

5.13.1.4 Currents

Tides have less of a current impact than the wind in the area. Surface currents are therefore stronger (Kendrick *et al*., 2005). The Leeuwin current flows eastward along the shelf and has a large influence on the circulation and physical characteristics of the region. The Leeuwin current prevents winter sea temperatures from falling below 13˚C and maintains summer temperatures around 22˚C (Li *et al*., 1999, as cited in Kendrick *et al*., 2005).

5.13.1.5 Water and Sediment Quality

In common with other oceanic waters of southern Western Australia, the waters off the Archipelago are nutrient poor (Kendrick *et al*., 2005). Nitrogen is the nutrient limiting primary production in temperate waters and its availability plays a dominant role in regulating macro algal growth and production (Duarte, 1991, as cited in Phillips, J., 2005).

5.13.1.6 Invertebrates

In a study of the harbour area in Esperance, Kohn and Blahm (2005) found 43 intertidal species of invertebrates. They concluded that complex infaunal communities have developed where human construction activity has created suitable habitats that afford protection from the Southern Ocean. Polychaetes dominate the assemblages, with gastropod molluscs and bivalves in significant concentrations.

Invertebrates that feed on the particulate organic matter in suspension or deposited on the bottom dominate the benthic community in Bandy Creek Boat Harbour (Kohn and Blahm 2005). At the innermost northeast embayment, where diversity and abundance far exceed other localities, sediments were finer, supporting the deposit feeding polychaetes.

The rich invertebrate community is a result of the deepening and construction of Bandy Creek Boat Harbour, having altered the environment from one that was rarely exposed to the ocean (except possibly after heavy rain and waves), to a marine environment (Kohn and Blahm, 2005). The boat harbour prevents benthic infauna being flooded with fresh water when Bandy Creek discharges are large.

During the field investigation (November, 2007), a number of spot dives indicated that the invertebrate community of Bandy Creek Boat Harbour has persisted through the storm and dredging clearly displaying evidence of polychaete inhabitants (as shown in Plate 11).

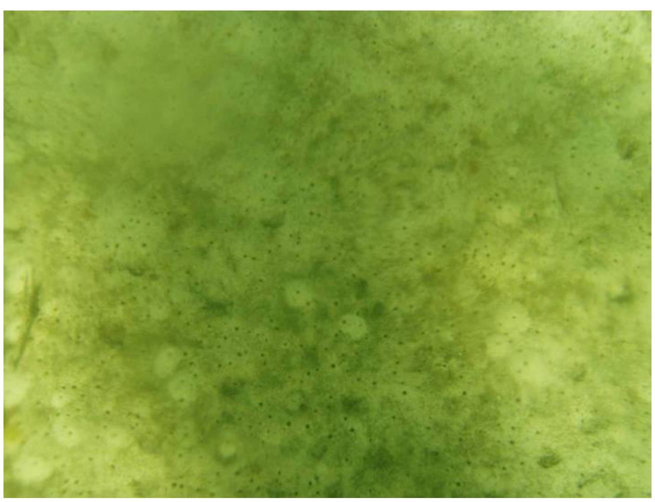


Plate 11:Dominate invertebrate habitat in Bandy Creek Boat Harbour

5.13.1.7 Seagrass

Of the sixty species of seagrasses known worldwide, one third of these are in Southern Australia (Kendrick *et al*., 2005). Changes in the distribution of vegetated habitats (seagrasses and reefs) in Esperance Bay were studied between 1956 and 2001 (Heggie and Kendrick, 2005). Seagrasses in Esperance Bay appear robust where recovery has been demonstrated despite being physically disturbed by increasing levels of port and coastal development between 1956 and 2001.

Temperate seagrasses of the genera *Posidonia* and *Amphibolis* carpet the subtidal habitats in Esperance Bay. To the east of Bandy Creek, patches of reef were more common. In Esperance Bay, assemblages of *Posidonia coriacea* and *Amphibolis* with 50 to 75% cover were observed.

Large, unvegetated sand patches have historically occurred onshore of Bandy Creek. In 1977, marine vegetation was lost to the south of Bandy Creek and, in 1995, the shoreward edge of the vegetated area had moved offshore to form a 'halo' (dominated by *Posidonia sinuosa*) adjacent to the new breakwaters of the Bandy Creek Boat Harbour

Spot dives undertaken during the field investigation (clearly illustrated in Plate 12A) revealed that unattached seagrass was abundant in the entrance to the harbour. These deposit in the lower energy harbour from the outer bay proceeding rough conditions. *Posidonia estralis* clearly dominates the assemblage with a small percentage of *Posidonia australia, Amphibolis antarctica* and *Sargassum fallax*. All four species are common within the Esperance region and have a wide distribution throughout the state.

Plates: 12A, 12B and 12C illustrate the unattached seagrass present in Bandy Creek Boat Harbour.

Increased nutrient loading and a decline in water quality resulted in Seagrass loss in areas such as Cockburn Sound (Heggie and Kendrick, 2005). In Esperance, impacts have mostly been dredging and land reclamation, as water quality has not visibly declined in the past 50 years (Heggie and Kendrick, 2005).

5.13.1.8 Social Uses

Abalone fishery is the most important fishery in Esperance and Recherche Archipelago. Other fisheries include southern rock lobster and pilchards (Kendrick *et al*., 2005). Over the past 50 years, the town has expanded greatly both as a rural coastal community and as a major port (Heggie and Kendrick, 2005). Bandy Creek Boat Harbour provides support to the fishing industry in the region (Heggie and Kendrick, 2005).

5.13.1.9 Benthic Habitat

The Fisheries Research and Development Corporation (FRDC) are currently mapping benthic habitats around the Archipelago. Benthic habitats present in the area include seagrass, sand and reef.

5.13.2 Esperance Bay Marine Habitat Survey Using Sonar and Video

Commissioned in October 2003, the Esperance Marine Institute undertook a habitat survey to map the seafloor habitats between Bandy Creek and Wylie Head in Esperance Bay. The Marine Science Group of the University of Western Australia completed the survey (Appendix I). This research is part of a project funded by the FRDC in order to characterise the fish habitats of the Archipelago.

Sidescan sonar produce almost photo realistic pictures that assist in delineating habitats and their spatial boundaries, as well as detecting patterns in seabed morphology (Baxter and Bickers, 2004). It is an acoustic imaging device that uses sound waves to provide wide-area, high resolution images (<10cm) of 'backscatter' which in turn infer information about the textural features of the seafloor substrate and consequently the dominant marine habitat type. Although considered relatively old technology Sidescan sonar was used in seafloor mapping to characterise fish habitats of the Archipelago.

Underwater towed video was used to obtain independent data in order to 'ground-truth' the Sidescan imagery and appropriately classify habitat types in the Archipelago. In-house software was then used to record a unique positional identifier on the video. This links the video to a Global Positioning System (GPS) position and a text file records other data. Classifications of community, or habitat, type determined from the video are added to the text file with relation to their recorded position, unique identifier or time. The information that is associated with each point, such as habitat classification, forms a table of attributes to each recorded position then importing into a Geographic Information System (GIS) displayed with other spatial data occurs. This allows the viewing of the video tracks and subsequent habitat classifications along the track. Nine video tows were completed and classified within the study area (Bandy Creek to Wylie Head), totalling a distance of 6.4km. Delineated areas are based on those that can be easily distinguished from the Sidescan record (Baxter and Bickers, 2004).

Baxter and Bickers (2004) found that certain habitats and community structures were easily identifiable from the Sidescan record and included seagrass, sand and reef habitats. Seagrasses within the study area grow on flat sand areas, or along raised sand ripples or hummocks. The study area contains both reef and sand substrates that were either bare or vegetated. Observed bare and rippled sand features showed a predominant cover of seagrasses, namely *Posidonia sinuosa, P.coriacea, P. ostenfeldii, P. kirkmannii, Amphibolis griffithii, Halophila* and *Heterozostera*. Dense seagrass tend to dominate, although varying degrees of patchiness, which occurred in some areas of the Sidescan record (sparse to medium), were difficult to separate (Baxter and Bickers, 2004).

Low profile limestone reef pavement was also present within the study area and macroalgae such as *Scaberia, Cystophora, Sargassum, Osmundaria, Caulerpa* and *Ulva* were observed growing on the reef. Other organisms that usually depend on hard substrates such as sponges, ascidians and bryozoans were also present. Exposed to the prevailing swell, the study area is dynamic and consequently, regions of low profile reef have become partially inundated with sand. Seagrasses, such as *Amphibolis griffithii*, and *Posidonia* species were found growing in the sand inundated regions amongst other typical reef-occupying organisms (Baxter and Bickers, 2004).

In conclusion, *Macroalgae* found on the reef and seagrasses growing on the sand form a complex mix of vegetation that is similar in height. The outcome is a combination of different substrates, which results in gradations of habitat types. Interpretation of boundaries is not easy from the Sidescan record. Due to the dynamic nature of the site and the subsequent sand movement, it could be possible that there is more underlying low relief reef pavement than can be clearly observed in the Sidescan. Therefore, further video validation will be required to make finer distinctions between substrate and habitat boundaries in this complex region (Baxter and Bickers, 2004).

6.0 Environmental Impacts and Management: Lake Warden, Wheatfield and Bandy Creek

6.1 Environmental Framework

LWWS currently holds too much water, which has resulted in a loss of water bird habitat. For effective management of the wetland system, environmental water requirements (EWR) were developed to ensure that any management techniques implemented are not going to reduce the integrity of the entire system. To achieve this, a comprehensive understanding of the inter-relationship between the hydrological and ecological functions of the wetland is required.

The EWR derived for LWWS are both ecologically and hydrology driven. The primary goal of management is to re-establish the waterbird habitat, through implementing the restoration of the previous hydrological regime as previous data has shown this to be an appropriate target.

Further consideration to determine the effectiveness of EWR includes:

- Hydrology - water balance modelling undertaken by Maunsell in 2006 to demonstrate the feasibility of a sustained drop in lake water levels through pumping from Lakes Warden and Wheatfield.

- Ecology - Performance targets for water balance modelling were based on waterbird threshold studies linking depth/volume in the lakes to optimum levels for maintaining habitat (Robertson and Massenbauer, 2005) (Other ecological features include aquatic plants and invertebrates, although these are not considered to be significant or threatened populations.)

- Uses – Recreational activities at LWWS include nature appreciation, bushwalking, bird watching, picnicking and barbecuing and water based recreation. Proposed engineering works will enhance many of these activities through increasing bird populations.

- Values
  - Indigenous Heritage: Eight Aboriginal sites of significance occur within the wider Esperance Region. Two of these, will be directly impacted during the implementation of the proposed engineering works.
  - European heritage: Lake Warden forms part of the Esperance Lakes Nature Reserve, which is on the Register of National Estate and therefore recognised as part of Australia's natural and or cultural heritage and merits its conservation.

- Threats - Lake levels and hydroperiods in LWWS will be altered which raises the following concerns:
  - Excessive dewatering, altering the natural seasonal trends
  - Reduction in water quality of lakes and receiving marine environment
  - Acidity from oxidation of acid sulfate soils and
  - The release of phosphorus by distribution of lakebed sediments if exposed or excessively bioturbated.

6.1.1 Management Objectives

The primary aim for the engineering works is to recover the existing water bird species richness and abundance and its living assemblages, to a near natural condition by the year 2030.

6.1.2 Performance Indicators

Performance indicators based on water balance and bird habitat modelling provide a guideline from which to measure performance (Figure 60 and Figure 61). The blue line represents ideal lake levels once reduction from their current levels occurs. As levels are reducing, implementing more intensive monitoring needs to ensue when reaching the green line 'monitoring level'. Potentially this will enable early action before reaching critical levels.

6.2 Lake Warden

6.2.1 Water Level and Seasonality

The preferred engineering option (Alternative 5) design will maintain water levels in Lake Warden within an ideal range that accounts for seasonal fluctuations (Figure 60). The expectation is that this water level is to provide an overall environmental benefit, based on data collection, analysis and system modelling. Massenbauer and Robertson developed a model in 2005 that used historical waterbird and water depth surveys over the previous 25 years. Results indicated that an annual depth range of 0.3 to 1.3m (actual lake depth) conceptually provided the optimum habitat for both diving and non-diving waterbirds.

Lake Warden has increased in depth by approximately 1m since 1979 (Massenbauer and Robertson, 2005). This increase has been associated with a loss in waterbird abundance and species diversity. Depth data and associated bird surveys date back to the 1980's, with consistent data since 1996. This data at Lake Warden shows notable impacts at 1.4m lake depth and above. Maximum bird species recorded in the early 1980s, which pre-dates any major changes to lake depth, provides a target for optimum water depths.

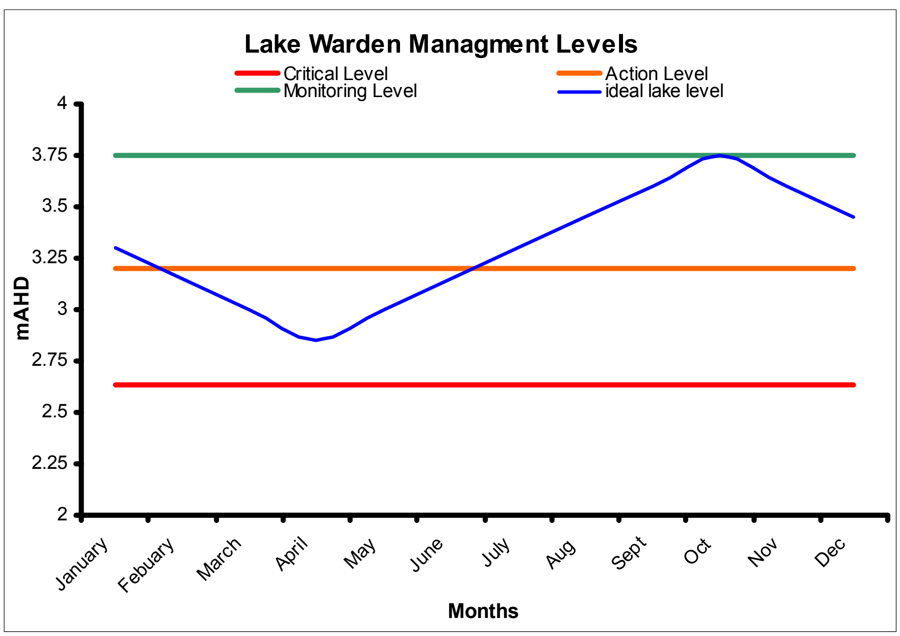


Figure 60 Lake Warden Management Levels

Water balance and waterbird habitat models developed for individual lakes of the LWW demonstrate that the decline in vegetation condition and loss of waterbird habitat has resulted from hydrological change, particularly prolonged duration and increased volumes of inundation, and that degradation will continue if unmanaged (Massenbauer and Robertson, 2005). Uncertainty and analysis of the model's components and outcomes give certainty that the hydrological targets are robust (Maunsell, 2007). The modelling uncertainty provides upper and lower bounds in the predicted water quantities required meeting hydrological targets, and thus achieving the management goal for the LWWS.

6.2.2 Water Quality and Seasonality

Lowering lake levels will marginally increase local groundwater inflow and possibly change lake chemistry or seasonality (ratio's and loading of common anions, cations, nutrients etc) dependant on:

- pumping/discharge
- rainfall and inflow.

Monitoring of water quality will be required to determine potential changes in lake ecology.

6.2.3 Effect of oxidation to Potential Acid Sulphate Soils for Lake Warden

Table 20 Acid Sulphate Soil Conversion (Dear, 2002)

(based on 1 mol sulfide producing 2 mol sulfuric acid and corresponding liming rates)

Oxid. Sulfur S (%)	moles H^+/kg (S % x0.6237)	moles H^+ / t or moles H^+ /m^3 (S % x 623.7)	kg H_2SO_4/tonne or kg H_2SO_4 /m^3 (S % x 30.59)	kg lime/tonne soil or kg lime/ m^3 Safety factor =1.5	Approx. lime cost/tonne soil or Cost/ m^3 of soil $	Cost/ha/m depth of soil @ $50/t of lime $
0.01	0.0062	6.237	0.306	0.47	0.02	234
0.02	0.0125	12.47	0.61	0.94	0.05	468
0.05	0.0312	31.19	1.53	2.3	0.12	1,170
0.1	0.0624	62.37	3.06	4.7	0.23	2,340
0.2	0.1247	124.7	6.12	9.4	0.47	4,680
0.3	0.1871	187.1	9.18	14.0	0.70	7,020
1.0	0.6237	623.7	30.6	46.8	2.34	23,410
5.0	3.119	3119	153.0	234.0	11.70	117,000

Note 1: Assumes a bulk density of 1.0 g /cm^3 or 1 tonne/m^3 (range can be 0.7-2.0 and as low as 0.2 for peats). Where bulk density is > 1 g /cm^3 or 1 tonne/m^3 then the safety factor will increase for lime rates/m^3 soil (eg. if BD=1.6, then 1 m^3 of soil with 1.0 % S_{POS} will require 75 kg lime/m^3 instead of 47 kg).

The potential impact of acid sulphate soils found at Lake Warden depends on a number of complex factors including the net acidity of the soil, the effective buffering capacity of the soil, the exposure of the acid sulphate soils to oxidation and the heavy metals in the soil that could be mobilised in acidic conditions.

Net acidity data for Lake Warden revealed that acid sulphate soils are in strata of LW2 and in the organic strata of LW3 (0.25-0.5m). Most of these ASS revealed significant buffering capacity (ANCe > 490 moles H^+/tonne). The high ANCe value indicates available buffering capacity. Additionally, water quality data shows that Lake Warden is alkaline, which also contributes to buffering capacity for acid generation and minimise bacterial assisted oxidation (Dear *et al*., 2002).

Table 21 Net Acidity and Buffering Capacity of Lake Warden Wetlands

	Net Acidity			**Soil ANC**	**Lake Water Carbonate Buffer Capacity**	**Ground Water Carbonate Buffer Capacity**
Lake Warden	Strata	%S	H^+/tonne	H+/tonne	H+/tonne	H+/tonne
LW2	0.02	0.18	112	4200	3500	3293
	0.5	0.2	125	3500		
	0.9	0.41	256	<2		
LW3	0.25	0.22	137	490		
Lake Wheatfield						
WF1	0.05	0.6	374	<2	2255	7210
WF2	0.1	1.36	848	<2		
	0.5	0.14	87	<2		

The organic layers in LW2 and LW3 will be located within the future water level management range (2.64-3.74m AHD). Therefore, these acid generating soils will experience some oxidation and potentially some mobilisation of acid and ions. The higher risk siltstone in LW2 (showing negligible buffer capacity in the soil) is located close to the minimum water management level (at 2.7m AHD). Therefore, this acid sulphate soil will have less frequent exposure to air and less oxidation activity.

Generation of some acidity from acid sulphate soils at Lake Warden may occur. Any acidity generated will likely be localised effects as the Soil ANC, carbonate alkalinities for both lake and ground water have the capacity to neutralise the generated acid (Table 21). Although the acid sulphate soil sampling indicates that there may be variability in the acid generation of the lake soils. Therefore, it is difficult to ascertain the specific quantity of acid generation, regardless there is considerable amount of buffering capacity for Lake Warden.

The high pH of the soils and lake water (< 8) promote conditions that are conducive for micronutrient deficiencies periodic release of acid will help mobilise and bioavailability of metals (micronutrients) (Brady, 1990: Bohn *et al*., 1979).

Careful environmental management is required when dealing with PASS. Sampling of pH is necessary. If the pH drops significantly there is an agricultural lime quarry 40 km, from Esperance. Liming application are outline in Table 20.

6.2.4 Management Actions

If detected, water quality changes need to be correlated across the wetland suite and compared to EWR's.

- species richness
- abundance
- distribution
- micro and or macro invertebrates
- waterbirds
- fringing vegetation
- aquatic vegetation

Water quality should be reported biannually at lake high's and lows. Water quality triggers geared to specific management actions which negate or minimise detrimental impact.

Modelling of pumping scenarios showed lake levels to drop below minimum levels at Lake Warden and Woody Lake. This re-enforces the need for a monitoring program to enable a timely response to falling lake levels. This will occur at monthly intervals, and increase to fortnightly once 'monitoring levels' have been reached (Figure 60 and Figure 61).

Monitoring will be undertaken at all four lakes for depth to ensure they do not go below the lower optimum depth range.

Monitoring of vegetation condition and distribution of aquatic vegetation (including algae) and then compared to water levels and bird numbers and EWR's.

6.3 Lake Wheatfield

6.3.1 Water Level and Seasonality

Alternative 5 provides an overall environmental benefit to the entire LWWS, including Lake Wheatfield. Massenbauer and Robertson's (2005) target depths for Lake Wheatfield (based on habitat preferences of different waterbird guilds) are necessary for observing 8000 waders and 4000 divers in Lakes Warden and Wheatfield, respectively, and approximately 20, 000 waterbirds overall. The target for Lake Wheatfield is 0.0-1.6m, requiring ongoing dewatering of up to 2.5GL per annum (Figure 61). At 1.6m depth, Lake Wheatfield connects with Lakes Woody and Windabout, which are important habitat areas for diving waterbirds (Walshe *et al*., 2007)

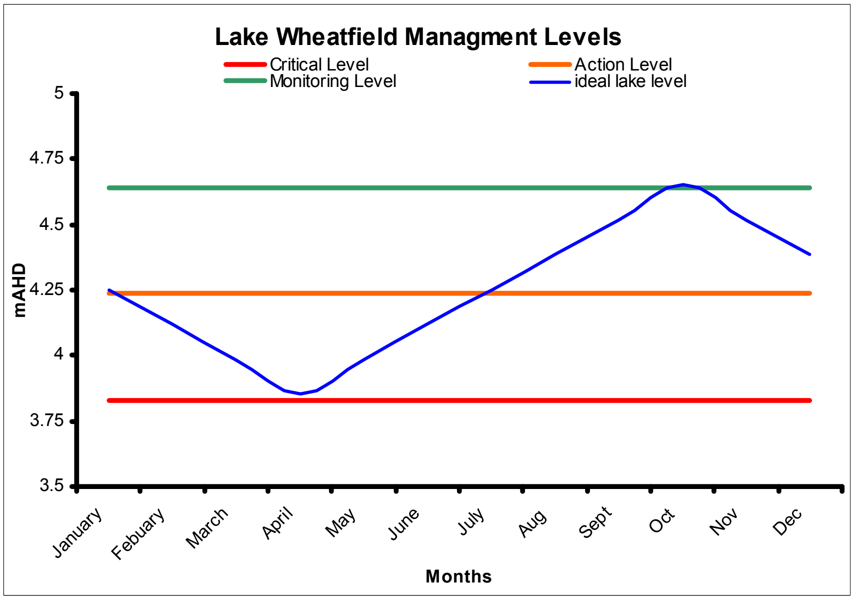


Figure 61 Lake Wheatfield Management Levels

6.3.2 Water Quality and Seasonality

Lowering lake levels will marginally increase local groundwater inflow and possibly change lake chemistry or seasonality (ratio's and loading of common anions, cations, nutrients etc) dependent on:

- pumping/discharge
- rainfall and inflow.

Monitoring of water quality will be required to determine potential changes in lake ecology.

6.3.3 Effect of oxidation to Potential Acid Sulphate Soils for Lake Wheatfield

The assessment for impacts from ASS at Lake Wheatfield depends on information on net acidity of the soil, the effective buffering capacity of the soil, the exposure of the acid sulphate soils to oxidation and the heavy metals in the soil that could be mobilised in acidic conditions

The risk of ASS oxidation is easier to ascertain for Lake Wheatfield than for Lake Warden, partially due to the minimal change in post-management water levels (from 4.8-3.8m AHD pre-management to 4.63-3.83m AHD post-management; Maunsell, 2007). At the target management water levels, ASS in WF1, WF2 and WF4 will be largely underwater. WF1 will have some exposed ASS organic strata at the lowest planned water level, and this will have some acid production that should be considered in future management (estimated to be 374 H+ /tonne of soil).

WF3 is located at the highest elevation of all the monitoring locations at Lake Wheatfield (at 4.7m AHD). The location of ASS at this sampling point is consistent with the depth of ASS at the other three sampling locations (approximately 3.8m AHD). The expectation is that this ASS is to continue to flood in the post-management water level regime.

Other characteristics of Lake Wheatfield may minimise acid generation. Laboratory testing revealed that some ASS (organics in WF2) has buffering capacity (Table 21). Any acidity generated will likely be a localised effect due to the presence of adequate carbonate buffering from the lake and ground waters (Table 21).

The expectation is that the risk of a detrimental impact from acid generation at Lake Wheatfield is minimal. Regular monitoring of pH for Lake Wheatfield is essential for sound adaptive management. In the event neutralisation is required, an agricultural lime quarry is located 40 km from Esperance. Liming rates required are listed in Table 20.

6.3.4 Management Actions

Water removal from each lake will cease when the lower optimum depth range occurs. For Lake Wheatfield, monitoring of the water quality will occur on a fortnightly basis. Water quality triggers geared to specific management actions which negate or minimise detrimental impact. Ensuring management actions are able to be effectively implemented and within a short time frame.

6.4 Bandy Creek

6.4.1 Water Level and Seasonality

Increased input into Bandy Creek is unlikely to affect the system due to discharge volumes versus the volume of water already moving through the system. Station lake outfall drives 90% of bandy Creek outflow. Lake Wheatfield only overflows to bandy Creek approximately 10 % of the year. Any reduction in the flow of Bandy Creek will be compensated by the existing inline channel lakes at the Gun Club site.

Comparing previous data of water level monitoring at the weir cannot occur as the destruction of the Bandy Creek Weir causes greater tidal influence.

6.4.2 Water Quality and Seasonality

There is a limited potential to create negative impacts from erosion, sedimentation and potential weed transport. However, an erosion and sediment control measure requirement will need to be part incorporated into final design.

6.4.3 Low pH, acid water from potential acid sulfate soils (PASS) oxidation

Analysis of ASS sampling from Lake Wheatfield revealed that acid generation is expected to be minimal if water levels are maintained at the median range of the management levels. Minimising the generation of acidity in Lake Wheatfield will minimise the potential impacts on the outfall area at Bandy Creek.

6.4.4 Management Actions

Develop water level based EWR's for the disposal site to the weir section of Bandy Creek.

These will be used as criteria, of which breaches will result in a changed operational strategy or remedial levels. Need to monitor creek depths up the creek and behind weir and at outfall.

Continuous water level measurements should be undertaken for 2 – 5 years in the proximity of the outflow and then reassessed.

Modelling of the likely water levels under a range of pumping/flow scenarios haqs been previously studied and a risk assessment has been completed (Maunsell, 2007).

6.5 Marine Environment

6.5.1 Water Level, Water Quality and Seasonality

The engineering concept design involves disposal of excess water into the Southern Ocean (Esperance Bay) via Bandy Creek and Small Boat Harbour. There are concerns that the waters discharged contain nutrients and salts, introducing some risk of impact on sea grass communities in Esperance Bay, eutrophication of Bandy Creek and the Small Boat Harbour, and the release of hydrogen sulphide odours along Bandy Creek near tourism facilities. This study does not consider such environmental concerns in detail, but focuses specifically on the technical feasibility of concepts for 'moving water' in the LWWS. To minimise these impacts it is acknowledged that there is a preference for discharge from the lakes (particularly Lake Warden) to occur mainly during the late winter, spring and early summer periods, allowing lake evaporation and vegetation transpiration fluxes to balance the LWWS hydrology. However, to achieve maximum discharge performance from the pumping systems proposed (in Components 1A and 4E) the systems may need to run for up to 345 days per year. This figure allows for considerable annual variability in hydrological conditions and it is not expected that the pumping systems would routinely be operated for 345 days each calendar year.

6.5.2 Management Actions

There should be periodic inspections for iron staining and bio-fouling, nutrient related algal blooms in close proximity to outflow.

An assessment on the potential for this to impact near shore marine ecology should be completed with a focus on seagrass.

Water Quality based EWR's and biannual monitoring of water quality for Bandy Creek disposal site. There should be an ecological assessment coupled with this.

6.6 Erosion and Particulate Transport

The following information is a general discussion that relates to erosion and particulate transport at Lake Warden, Lake Wheatfield and Bandy Creek (disposal site).

Soil erosion and particulate transport are natural processes that have significant impact during and following flood events. Land lying on or adjacent steep slopes and friable soils in high rainfall areas are particularly susceptible to erosion and can contribute large amounts of soil to waterways and wetlands.

Erosion is exacerbated by human activities that remove vegetation cover or cause soil disturbance. When eroded soil is deposited into waterways and wetlands it becomes sediment. Fine sediments (e.g. silt) can be suspended in water and carried quickly downstream and out to sea. Coarser sediments (e.g. sand, pebbles and rocks) slowly move along the alluvium and deposit in pools, wetlands and river channels, this movement also has the potential to alter the stability and other characteristics of the alluvium and streambeds.

During low flows, sediments begin to settle out of the water in a process termed 'sedimentation'. In contrast, during large flows and floods, sediments are scoured from the riverbed or banks of waterways and transported downstream or out to sea. Over time this dynamic process of sediment deposition and scouring contributes to the reshaping of waterways. In wetlands, sedimentation is more problematic, contributing to the gradual filling of wetlands over time. Excessive erosion can damage fringing vegetation and undermine infrastructure such as bridges, weirs (i.e. Bandy Creek Weir), roads and buildings located close to the waterline.
High levels of suspended sediment can make the water muddy, affecting aquatic fauna functions and effectively reducing habitat. Sedimentation can also exacerbate flooding of nearby land, fill water reservoirs, foul water supplies and clog irrigation and drainage pipes. Often nutrients and contaminants are bound to eroded soil and may contribute to contamination or eutrophication problems.

Turbidity and suspended solids are commonly used as indicators of levels of erosion and sedimentation in waterways and wetlands. 'Suspended solids' refers to the amount of sediment or organic matter in the water column. Turbidity is a measure of the light scattering properties of water, which may be affected by sediment, organic matter or colour of the water. With the proposed works for the LWWS these will be valuable indicators if the drainage system is causing potential erosion and particulate transport.

6.6.1 Inlet

The inlets to the pumping or syphoning pits to transfer water from Lake Wheatfield (phase 1) and Lake Warden (phase 2)to Bandy Creek design should minimise the amount of sediments entering the system. The proposed engineering should skim the water from the surface of the lake, which should be relatively clean and free of sediments. Install a coarse filter in the pit around the intake pipe to exclude floating debris. The pit design should facilitate the “mucking out” of sediments that may collect over time and thereby reduce the volume of the pit. Pump stations should be fitted with start and stop switches as used in sewer pump stations.

6.6.2 Outlet

The outlets design into Bandy Creek of the pipelines from Lake Wheatfield (phase 1) and Lake Warden (phase 2) should discharge water below the water surface of Bandy Creek through diffusers to maximise the mixing of the discharge with the receiving waters. Install “Flexmat” or other similar erosion mat below the diffuser and along the banks of Bandy Creek as necessary to avoid erosion in the discharge zone.

6.6.3 Conclusions

Artificial wetlands are a potential possibility for consideration for incorporation into engineering designs for management of the Lake Warden (phase 2). The volumes are much greater and have a larger concentration of nitrogen.. Depending upon the water quality and types and levels of metal ions present, this is often an economically viable and effective way of stripping nutrients (N & P from aquatic environments. The additional benefit of the nutrient stripping and contaminants bound to eroded soil that may contribute to contamination or eutrophication of down stream marine environment.

Anionic Polyacralymaide (PAM) is a biodegradable long chain hydrocarbon that has shown great success in treating irrigation overflow of surface waters. The ability for PAM treatment to attach to the particles and then attach to the soil in the furrow results in a clearing of muddy water by simply aiding in “settling” (Dale, 2005). Soil particles in water, manure particles, nutrients (Nitrogen and Phosphorus), metals and some chemical pollutants cling to the PAM molecules. *Polyacrylamides* have undergone years of testing and have demonstrated success in improving the water quality by removing weed seeds, soil borne diseases (fungi), *algae, streptococci, coliform* bacteria, nutrients, metals and certain chemical pollutants (Dale, 2005).

The application of PAM treatment to the LWWS warrants consideration for a range of reasons as they greatly improve water quality of surface water runoff from district-wide catchment flows. PAM treatments for erosion control results in reduction of Sediment, Phosphorus, Nitrogen, biological and chemical oxygen demand, pesticide content, weed seed and micro-organism content of irrigation return flows. PAM treatment is, and will continue to be, a powerful environmental benefit if used responsibly and correctly as there has been no negative environmental impacts from PAM treatments used at recommended rates for surface waters or soil demonstrated.

6.7 Modelling

6.7.1 Preliminary Calculations

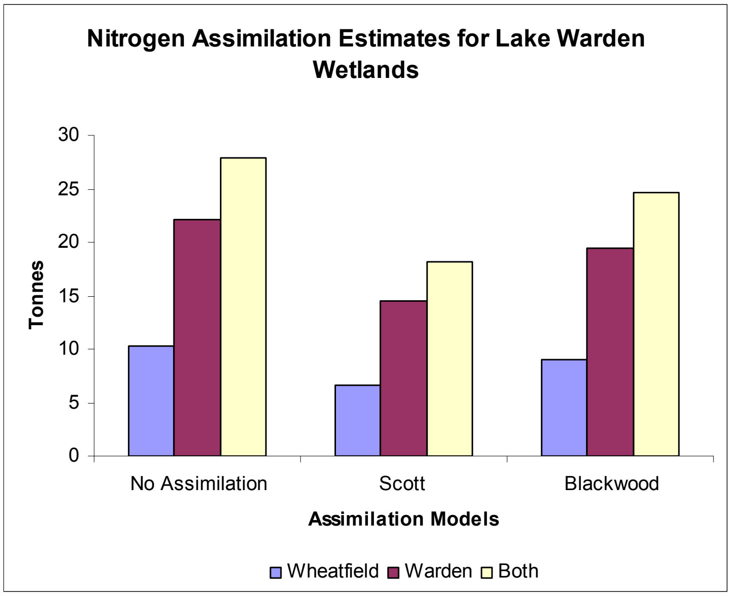


Figure 62 Nitrogen Assimilation Estimates for Lake Warden and Lake Wheatfield

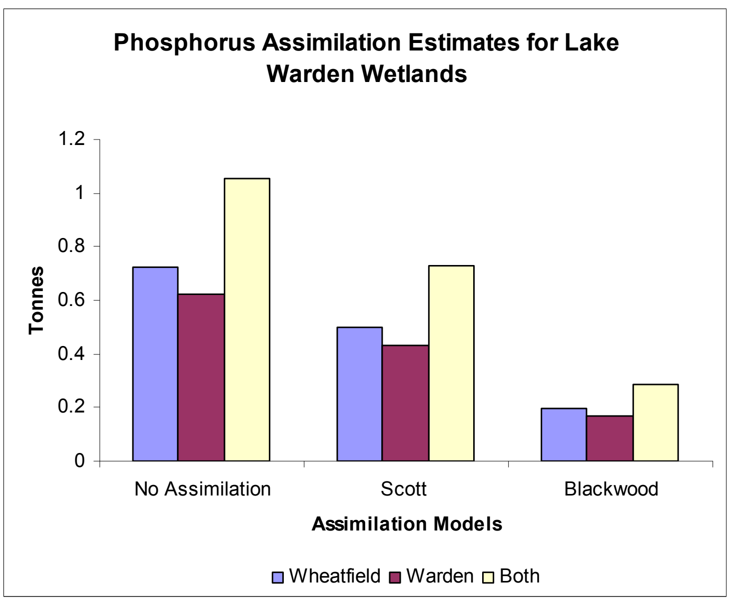


Figure 63 Phosphorus Assimilation Estimates for Lake Warden Wetlands

Figures 62 and 63 display the amount of nitrogen and phosphorous entering the marine environment from both Lake Warden and Lake Wheatfield. Approximately 28 tonnes of Nitrogen will be discharged into the marine environment from the proposed dewatering targets. The amount of phosphorous discharged is approximately 1.1 tonnes from the proposed dewatering targets. The Lake Wheatfield estimate (phase 1) is approximately 10 tonnes of nitrogen and 0.7 tonnes of phosphorous. Assimilation calculations were calculated using equations derived for two other West Australian catchments (Scott and Blackwood) both calculations lowered the amount of nutrients entering the marine environment (Kelsey, 2002).

6.7.2 Modelling

The modelling aims to determine the environmental impact of the release on the hypersaline water pumped from Lake Warden to the Bandy Creek Harbour. The modelling intends to provide an answer to the following questions:

- Water quality consequences of discharge of hypersaline and nutrient enriched water from a lake to a Harbour
- Consequence of the discharge of hypersaline and nutrient enriched on the Bay downstream of the point of discharge
- Consequence of the discharge of the same water for the upper freshwater part of the stream discharging in the harbour
- Determination of the salt, sediments and nutrient loading to the bay, to the Harbour and to the upper freshwater stream.

The modelling will start once a scope for the hydrodynamic model has been completed as well as completion of data collection (Bathymetry, Met Data etc). The modelling component is expected to last 3 months and will be implemented in the next six months.

6.7.3 Marine Benthic Habitat Mapping

Conducting marine benthic habitat mapping over the next 12 months will occur. Which will be used to establish appropriate baseline values which to monitor and evaluate habitat response to potential impacts.

7.0 Environmental Impact and Management: Potential Pipeline Route and Operational Issues

7.1 Impacts on Vegetation

7.1.1 Pipeline Component 1A

Forming part of the recommended engineering Alternative 5, Pipeline Component 1A, is the proposal to transport water from Lake Wheatfield to the discharge site, Bandy Creek (Figure 59). It has been determined that a 6m (maximum) wide corridor will be required for the 1A Pipeline Component.

Component 1A is the shorter of the two pipeline components and is approximately 900m in length, running from Lake Wheatfield in an easterly direction to Fisheries Road, south west along Fisheries Road, then running south east along Bandy Creek Road, terminating at Bandy Creek (Figure 59).

Previous DEC vegetation mapping of the Esperance region has identified that a large area of remnant vegetation occurs adjacent to the proposed alignment (Figure 59). The entire pipeline route runs adjacent to areas of remnant vegetation, with the majority of the proposed corridor lying within the boundaries of the gazetted road reserve. Only the northern-most section of the pipeline, running between Lake Warden and Fisheries Road, does not lie within the road reserve.

Another section of the proposed pipeline route that does not lie within the road reserve is between Lake Wheatfield and Fisheries Road. This gazetted A Class Nature Reserve , Woody Lake Reserve, also forms part of the Ramsar Wetland Chain. The status of the A Class Nature Reserve (Woody Lake) is for Recreation and Conservation of Flora and Fauna. Actions within A Class Reserves are required to be limited to the specific purpose/s as prescribed, until that purpose is changed under section 41 of the *Land Administration Act, 1997*.

The pipeline route will utilise existing cleared tracks through the Nature Reserve. However, the proposed track is only approximately 3m wide and the maximum width required for construction of the pipeline corridor is 6m. It is likely to be necessary to clear additional vegetation beyond the width of the current track.

Vegetation within the A Class Woody Lake Nature Reserve consists of *Melaleuca cuticularis* woodland over an understorey of rushes and sedges including *Lepidosperma* species and *Ficinia nodosa*. Further south of the immediate fringing Lake Wheatfield vegetation *Banksia speciosa* woodland occurs.

Field investigations conducted by Maunsell during September 2007 identified the vegetation directly adjacent to the track as heavily invaded by introduced (weed) species, particularly annual grasses such as *Briza* species. Minimal clearing will be required within the Woody Lake Nature Reserve, and due to the significant weed invasion and the poor condition of the vegetation in this location, the area is not considered of environmental significance and the impacts from the construction of the pipeline are not anticipated to result in a loss of environmental values.

Depending on the project approval process, where vegetation clearing is required, it will be necessary to apply for a clearing permit, particularly within the A Class Nature Reserve and Ramsar Wetland site. Exemptions under the Environmental Protection (Clearing of Native Vegetation) Regulations 2004 do not apply in Environmentally Sensitive Areas.

The remainder of the pipeline, along Fisheries and Bandy Creek Road, occurs within existing cleared areas that have already been subject to heavy disturbance. This area consists of regenerating vegetation primarily approximately 50cm tall with some taller remnant vegetation (to 2m high) beyond the clearing zone.

Figure 64 indicates that the major vegetation communities along Pipeline Component 1A and 4E, namely *Banksia Woodland, Nuytsia Mixed Heath and Eucalypt Woodland*, have degraded since 2004. Figure 64 specifically illustrates the worsening condition of these areas since 2004.

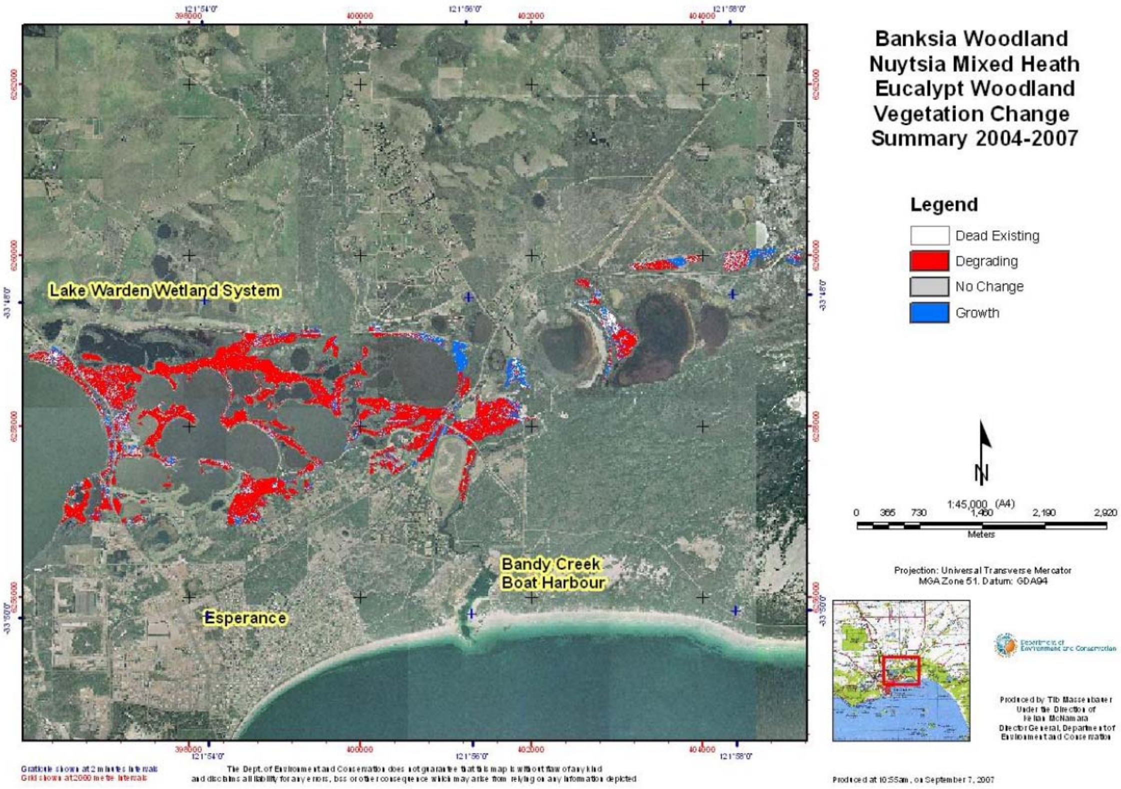


Figure 64 Change in *Banksia* Woodland, *Nuytsia* Mixed Heath and Eucalypt Woodland between 2004 and 2007 (Courtesy of DEC, 2007

7.1.2 Pipeline Component 4E

The planned Pipeline Component 4E is to be approximately 7km long and to span between Lake Warden and Bandy Creek Boat Harbour (Figure 59). To the east of Lake Warden, the pipeline will traverse the Esperance Golf Club then travels south along Claire Road to Fisheries Road, along Fisheries Road, Goldfields Road and Daw Drive. The proposed pipeline route is within the gazetted road reserve for the majority of its length, excluding the portion that traverses Esperance Golf Club.

A large proportion of the proposed corridor is within cleared or developed areas and, where possible, the corridor will utilise existing tracks and firebreaks. For this reason, it requires minimal vegetation clearance to accommodate the pipeline.

Between the Esperance – Coolgardie Highway and Lake Warden the pipeline will traverse an A Class Nature Reserve. The status of the Lake Warden A Class Nature Reserve is for Recreation and Conservation of Flora and Fauna. The existing track within the A Class Nature Reserve traverses three differing vegetation communities including, *Banksia* Woodland, *Melaleuca* Woodland and *Eucalyptus* Woodland.

Similar to Component 1A, this pipeline component will also utilise an existing track within the Reserve to minimise the amount of clearing required for the pipeline. A cleared firebreak approximately 20-30m wide occurs directly adjacent to the track and will be utilised for the pipeline and pumping station

(Plate 13). Additional vegetation clearing will not be required for the pump station as it will occupy the area already cleared, adjacent to existing electricity transmission lines.

Regenerating vegetation within the cleared firebreak consists of sapling *Eucalyptus* spp., *Gastrolobium* spp., rushes and sedges with numerous weed species on white sandy soil.

Plate 13: Firebreak within Lake Warden A Class Nature Reserve

A 60m length of remnant vegetation will be required to be cleared immediately east of the Esperance Golf Club (Plate 14). Depending on the environmental assessment process for this proposal, a clearing permit may be required for this area. This remnant vegetation, previously identified as Banksia Woodland (DEC, 2007d), will require clearing. The western-most area of this remnant that abuts cleared paddocks and the golf course is heavily infested with introduced weed species such as Victorian Tea Tree *(*Leptospermum laevigatum*). The western end of the remnant that will require clearing is regenerated vegetation (five years post fire disturbance)

Plate 14: Remnant *Banksia* Woodland - East of Esperance Golf Club, looking north west towards Golf Course

Plate 15: Remnant *Banksia* Woodland East of Esperance Golf Club, looking south-west towards Esperance

The remainder of the proposed pipeline alignment traverses areas that have previously been subject to clearing, such as firebreaks or Main Roads clearing zones. Vegetation that may potentially be present along the pipeline alignment is regenerated vegetation to a minimum of one metre in height. Some areas within the Main Roads clearing zone are completely lacking in vegetation, whilst some areas support a thin strip of vegetation considered unsustainable and of little conservation value.

7.1.3 Operational Issues

Operation of the constructed pipelines and pumping station has the potential to impact adjacent native remnant vegetation. Indirect impacts on vegetation, as a result of operation of the pipelines are unlikely. However, as mentioned previously, the vegetation within the proposed corridors is of little environmental significance, as the areas are either mostly cleared or support only regenerating remnant vegetation.

A potential indirect impact to vegetation outside of the pipeline corridor may include the effects of leaked flows, in the event of a leak. Such impacts would include erosion and/or potentially water logging that may impact vegetation not tolerant to significant or prolonged inundation. Although such impacts are unavoidable in the end, it is anticipated that any leaks in the pipe should be detected during regular monitoring and asset inspection and then repaired.

Clearing of and vegetation, including regenerated vegetation has the potential to promote weed invasion and spread, particularly in the sandy soils characteristic of the area. The previously cleared area has the probability of weed occurrence greater than in areas not previously cleared. Specifically within the Lake Wheatfield Nature Reserve, where there is the potential for additional vegetation clearance beyond the current track, the understorey vegetation is heavily infested with weeds.

Drawing power from existing power lines to run to the pumping station may necessitate the clearing of taller vegetation such as tree branches to ensure that these are a safe distance from transmission lines and the connection to the pumping station. The existing transmission corridor occupies a maintained cleared corridor.

Disruptions to local roads may occur during the construction of the pipelines due to transportation of pipes and equipment, and excavations along the pipe route. Additionally, disruptions may occur within the new housing estate where horizontal drilling will be required to lay the pipe underneath new roads accessing the estate. Construction activities are recommended to be limited to normal business hours as practicable in order to minimise disturbance to local residents. Additionally liaison with the Shire of Esperance and other relevant agencies such as Main Roads will be required.

7.1.4 Declared Rare and Priority Flora

The Department of Environment and Conservation's Threatened Flora databases and a review of relevant current literature identified the potential for 47 Declared Rare or Priority flora species to occur within the wider Esperance – Lake Warden Region.

However, within the immediate vicinity of the two proposed pipeline corridor no records of known locations of DRF or Priority Flora occur within or adjacent to the proposed pipeline corridor.

7.1.5 Potential for Weed Invasion

Within Western Australia, over 1200 weed species are recognised. Of the 328 species of weeds known within the Esperance Plains Bioregion, 73% have been classified as Environmental weeds (EPA, 2007). Environmental weeds establish in natural ecosystems and adversely modify natural processes, resulting in the decline of the invaded community.

Under the *Agriculture and Related Resources Protection Act, 1976*, 50 species are listed as declared plants within the Shire of Esperance. Under the Act, these species are subject to restrictions on movement or sale and landholders are obliged to carry out control measures to prevent the spread of these weeds. Weed species known to be effective in colonising areas can rapidly invade natural sites where the soil has been disturbed where there has been clearing.

The proximity of the pipeline corridor to the road increases the likelihood of weeds to be present prior to pipeline construction. This is due to the increase of potential weed and weed seeds transported by traffic within the corridor by machinery or out of the corridor through water run-off or wind and seed spreading into the natural environment by waterways, wind, water, people, vehicles, machinery, birds and other animals (EPA, 2007). If weeds, particularly Declared Plants (pest weeds), occur within the corridor the likelihood of weed transportation will be increased.

Documented vegetation mapping of the Esperance Region, sourced from DEC, indicates that the Component 1A corridor currently traverses an area devoid of remnant vegetation. This area, adjacent to the Esperance Bay Turf Club, will increase the potential for weed invasion to occur along the route.

Similarly, for Component 4E, a large proportion of the pipeline corridor and the areas directly adjacent to the proposed corridor have previously been cleared or disturbed. This may increase the likelihood of weed invasion and maximise edge effects from weeds between infested areas and better quality vegetation.

7.1.6 Fauna

The effects of vegetation disturbance along the alignments as previously discussed due to the operations of construction, particularly heavy earthmoving equipment, and other machinery combined with increased human traffic and activity has a significant potential to disturb in-situ fauna habitats, such as burrows and nests. The recommendation is that following confirmation of route selection, a foot survey, by a qualified zoologist, to locate significant fauna habitats that may be avoided or that impact upon may be minimised be completed. Depending on specific fauna species habituating the area, relocations may need to be considered.

An increased level of noise during the construction period, vehicle movement, dust creation and increased traffic may also contribute to fauna mortality or vacation of the area.

Clearing of both remnant and regenerated vegetation may result in a loss or reduction in habitat and food source for native fauna. Therefore, the recommendation is that significant sized or isolated trees that may provide fauna habitat, which occur adjacent to the corridor be retained wherever possible.

Excavations of the pipe trenches, done in sections, and backfilled as soon as possible, will prevent a potential pitfall trap-effect on fauna. If fauna becomes trapped and unable to access water or shelter, they are likely to die, particularly during the heat of the day. Small animals trapped in trenches are also vulnerable to predation. If it is unavoidable to leave trenches open for a period of time, a one in three ramp installed to provide a means for fauna, particularly native mammals to escape is necessary.

7.1.7 Constraints

The identified potential constraints occurring along the proposed pipeline alignment are as follows:

- Vegetation clearing required east of the Esperance Golf Course requiring acquisition of a Clearing Permit from DEC;
- Potential spread of weeds from areas heavily degraded areas to less degraded areas;
- Temporary impacts on the natural environment during construction from dust, spill risks, and equipment exhaust fumes.

7.1.8 Management Actions

The most important recommendation arising from the evaluation of the two pipeline components for engineering alternative 5 is that careful planning, stringent environmental management and liaison with the EPA and other relevant authorities will be required.

Recommendations for areas of remnant vegetation within the road reserve and particularly within the A Class Nature Reserve and fringing vegetation of the Ramsar Wetland are:

- Liaison with Government Authorities with regards to vegetation clearing and clearing permits required within Environmentally Sensitive Areas;
- Clearing of vegetation is avoided where possible;
- Revegetate disturbances with local vegetation;
- Maximise conservation management of remnant native vegetation areas within and adjacent to the pipeline routes;
- Where clearing is unavoidable; clearing is to be minimised to reduce the loss of vegetation and potential habitat and food source, and not extend beyond the regenerated vegetation zone;
- Limit construction activities to normal business hours as far as practicable in order to minimise disturbance to local residents;
- Liaison with the Shire of Esperance and other relevant agencies such as Main Roads in order to minimise construction related traffic impacts;
- Ensure compliance with all statutory requirements;
- In areas of significant weed infestation, stripped topsoil is disposed of or stockpiled away from clean stockpiles of areas of good quality vegetation, to prevent weed spread;
- Implement weed control measures within susceptible areas within the proposed pipeline routes;
- Reduce impact to native fauna by staging excavation activities and back-filling trenches as soon as possible; and
- Conduct detailed clearance surveys of the specific pipeline alignment to determine accurately the presence or absence of flora or fauna species of conservation significance, particularly disturbance opportunists that may emerge post clearing and to determine locations of fauna habitat that may require management.

7.2 Acid Sulphate Soils

The ASS risk for the pipeline route depends on the presence of acid generating capability in the disturbed soils and the disturbance level of the project. Acid sulphate soils risk mapping is currently unavailable for Esperance, and no acid sulphate soil sampling occurred on the pipeline route. However, the eolian calcarenite sands fringing Esperance Bay are low risk for PASS (Lillicraps. A. pers. comm., 26 July 2007). At this preliminary design stage, the amount of dewatering for pipeline construction is uncertain. There may be scope for aboveground pipe routing, but this will depend on final route design, topography and engineering constraints. If areas of medium to high risk of PASS are found to occur along the pipeline routes and significant disturbance (such as through dewatering) is expected to occur, then further acid sulphate soil management will be required.

7.3 Pathogen risk (Phytophthora dieback)

7.3.1 Pipeline Component 1A - Dieback

Broad scale mapping of dieback obtained from the DEC's Dieback Atlas, has identified the presence of dieback within the LWC. The Dieback Atlas provides results of extensive surveys conducted in the area and shows dieback occurrences identified around the majority of the Lake Wheatfield area.

Dieback testing conducted by DEC interpretation officers between 23 February 2000 and 9 April 2002 confirmed a positive result for Pc within Woody Lake Nature Reserve (A Class Nature Reserve). This Pc occurrence is located at the northern-most portion of the proposed pipeline, near the walking trail for Lake Wheatfield (Figure 59).

7.3.2 Pipeline Component 4E - Dieback

Qualified DEC officers undertook dieback interpretation exercises of the remnant vegetation along the entire proposed pipeline route and no diseased, susceptible plants were identified. Part of the dieback interpretation entails sampling diseased or recently dead vegetation. Additionally, the DEC's Dieback Atlas indicates that no dieback occurrences exist along the proposed 7km pipeline route. In conclusion, no identifiable infestations of dieback along the proposed pipeline route by either DEC interpretation officers or the Dieback Atlas are noted (Figure 59).

7.3.3 Constraints

There have been minimal Pc occurrences and no occurrences of *Phytophthora megasperma* or *Armillaria luteobubalina* detected along the proposed pipeline alignments (Components 1A and 4E). Only Component 1A has recorded a Pc infection along the proposed pipeline route, whilst the remainder of the alignments remain Pc free.

The Esperance Lakes Nature Reserve Management Plan 1999-2009 identifies other areas within the LWC that are infected. This includes an occurrence of *Armillaria luteobubalina* within the Woody Lake Nature Reserve, located at the junction of Norseman Road and Lakes Road. Additionally dieback occurrences near Lake Wheatfield Carpark, in the Coramup Creek area at the east end of Lakes Road and within Woody Lake Nature Reserve have also been confirmed (Figure 59). These infected areas have the potential to spread to uninfected areas if not carefully managed.

Armillaria luteobubalina is not believed to be as much of a threat to native vegetation when compared to Pc. The fungus-like pathogen is spread by root to root contact, in infected soil and by airborne spores. Management strategies implemented for Pc control, where soil movement is a feature of the operation, is also an effective control measure of *Armillaria luteobubalina*. No known strategies can be implemented to control the spread of airborne spores (CALM, 1999).

7.3.4 Management Actions

Clearing operations related to the creation and upgrades to infrastructure (i.e. pipelines and pumping stations), construction related traffic, transportation of machinery and ongoing utilisation and maintenance access have the potential to spread dieback (from *Pc*, and *Armillaria)* from disturbed areas to adjacent vegetation. In order to minimise this impact, activities along Component 1A will require adherence to the dieback hygiene and management guidelines already in place and enforced by DEC. This will ensure that uninfected areas remain Pc free during and after construction.

Although there has been minimal dieback identified or confirmed along the proposed pipeline routes (Figure 59), it is recommended that in order to ensure uninfected dieback areas remain free of disease, the following points be adopted:

- Management of the disease should be carried out in accordance with the Department of Conservation and Land Management (CALM's) Policy Statement No. 3 Threat Abatement for *Phytophthora cinnamomi* (CALM, 2004);
- Hygiene strategies and a Hygiene Management Plan for construction activities should be developed to ensure that non-infested areas remain free of dieback;
- Further investigation regarding potential Pm infestation should be conducted in the wider Esperance area, particularly along the proposed pipeline routes. This is due to the fact that Pm is thought to be a complex pathogen which may contain more distinct species within the local area and thus requires further investigation;
- Limit development construction and maintenance activities to periods of dry soil conditions when conditions optimum for the spread of Pc are minimal (November – March);
- Educate project personnel (both on-site and off) about dieback and project specific dieback management via:
  - inductions;
  - on-site visual tools (e.g. posters, signs); and
  - personal reference material (e.g. information cards);
- Stockpile soil and vegetative matter only within the area of dieback classification from which it came (i.e. infested or disease free);
- Minimise soil disturbance and consider mowing, slashing or use herbicide, rather than ploughing and grading, whenever possible;
- Complete construction and maintenance activities in non-infested areas then moving to infested areas, where possible;
- Install signage at strategic locations to ensure those accessing the area are aware of dieback infestations and required management actions;
- Ensure vehicles and machinery are 'clean on entry' (free of soil and mud) prior to entering non-infested areas; and
- Plan for, construct, manage, supervise and audit high quality clean-down points (Hygiene Stations) where necessary during construction and other similar activities or when significant access and impact is required to take place, to achieve the 'clean on entry' objective.

The best management tool for controlling the spread and devastation of Pc is to ensure appropriate hygiene practices in and around infested areas. A range of legislative initiatives are in place to enforce appropriate management and should be considered.

8.0 Social Values & Impacts

The implementation of the proposed engineering works in the Lake Warden Wetland System may affect the local community for it holds important social significance in the following ways

8.1 Heritage

8.1.1 Aboriginal Heritage

Through interrogation of various databases, it was determined that eight known Aboriginal sites of significance occur within the wider Esperance Region. Two of these will be directly impacted during the implementation of the proposed engineering works.

Site No 1713 - Barndi Creek, considered of Aboriginal significance as a camping and hunting place, is located along Bandy Creek, where Pipeline Component 1A terminates. Through excavation and laying of the pipe in the eastern most portion of this pipeline component, the site will be encroached and disturbed.

Site No 20607 - Lake Warden holds mythological significance for the creator serpent the "Waugal" (Yorgum, 2007). The Waugal inhabits special areas, which are sacred to the Aboriginal people, and created landforms such as rivers, valleys, hills and lakes during ancient times. Engineering works, through the siphoning of water from the wetland and discharging it into the Bandy Creek Boat Harbour, will impact Lake Warden. As this area holds mythological significance consent to use the land may be sought under Section 18 of the Act for all sites of Aboriginal significance protected under the *Aboriginal Heritage Act, 1972* where alteration or damage to a site cannot be avoided.

8.1.2 European Heritage

The Esperance Lakes Nature Reserve, listed on the Register of National Estate, recognises it as a part of Australia's natural and/or cultural heritage, and merits its conservation. . Lake Warden is one of the many lakes forming part of the Esperance Lakes Nature Reserve and therefore protected under the *Environment Protection and Biodiversity Conservation Act, 1999*.

8.2 Recreation

A number of recreational activities currently occur within the LWWS and includes activities such as nature appreciation, bushwalking, bird watching, picnicking and barbecuing and water based recreation. The primary aim for the engineering works is to recover the existing water bird species richness and abundance and its living assemblages to a near natural condition by the year 2030.

Implementation of engineering works to the LWWS will directly enhance recreational values particularly bird watching, bush walking and nature appreciation. If implementation of engineering works does not occur, then current recreational activities within the LWWS may be detrimentally affected. For example, further degradation to the LWWS due to increased water levels may lead to a reduction in recreational values.

8.3 Aesthetics

The Maunsell (2007) report identified a track that connects the Coolgardie-Esperance Highway to a suitable site on the south eastern shore of Lake Warden for establishing the pumping station. The site is approximately 1km from the closest residential property.

Additionally, the degrading health of the LWWS impacts the stunning visual landscape of the Esperance region. Some minor local deterioration in amenity values may occur due to the construction of the pipelines outflow structure but these are anticipated to be minimal (DEC, 2007e). The recommendation is that appropriate revegetation programs consider incorporating local endemic species and create visual screens to conceal the potentially unsightly pipeline corridor.

8.4 Education and Knowledge

The Lake Warden Wetland System is used extensively as a school education resource and as a resource for developing and testing salinity management techniques (DEC, 2007). Continual water inundation will further degrade these values. The engineering works will form the basis of a useful scientific study to reduce water levels and contribute to salinity management in other areas of the state.

8.5 Noise

For portions of the proposed Pipeline Component 4E, the pipeline route comes in close proximity to urban residential areas (Figure 59). Residents will experience some disturbance as a result of construction of the proposed Pipeline Component 4E but this will be temporary and of short duration.

8.6 Traffic

Through implementation of the proposed engineering works an increase in haulage vehicles transporting materials and other equipment via local roads will occur. Furthermore, local traffic along council roads adjacent to the proposed pipeline routes may increase because of construction activities.

8.7 Management Actions

In summary, continued sustainable ecological function, along with the enjoyment of social values by visitors to the LWWS, can only be assured while these areas are managed to protect their conservation values and to maintain the natural environment. Recommendations for adoption are the following:

- Liaison with the local Indigenous groups and the Department of Indigenous Affairs concerning impacts to areas of Aboriginal significance, particularly in relation to Site No. 1713 which will be directly impacted through excavation of the pipeline.
- Consultation with the community and stakeholders about noise and Contractor environmental management in regards to the Environmental Protection (Noise) Regulations.
- Pumping stations should have a low profile, have acoustic fittings to minimise noise impacts and surrounded by vegetated earth bunds to reduce visual amenity impacts.
- Ensure compliance with all applicable statutory requirements.
- Limit construction operations to normal business hours as practicable.
- Maximise separation between noisy/vibration inducing activities and adjacent residential areas as operationally practicable.
- Adopt construction techniques that will minimise vibration impacts within nearby residential areas.
- The Shire of Esperance should advise if significant increases in traffic on minor roads are expected.

Minimise heavy vehicle movement as far as practicable.

9.0 Consultation

9.1 Public Consultation

Maunsell conducted a feasibility assessment of a series of engineering options to dewater the Lake Warden wetland system to meet set hydrological and biologically targets throughout June 2006. The feasibility included an uncertainty analysis of all options. Upon selecting the most feasible option, DEC further applied a risk assessment using the Australian risk assessment standard, Bayesian Belief Networks and Info Gap Analysis to refine further the robustness of the option.

A scoping document providing summation of the feasibility analysis, risk assessment and potential environmental impact issues occurred in February of 2008. Technical comment from various government stakeholders occurred and then adapted into existing PowerPoint presentations. Preparation of more detailed information regarding the EIA issues outlined in the DEC scoping document occurred in July 2007, with the engagement of Maunsell. Over a 12 month period an extensive information awareness raising program, involving engaging various audiences from technical to community based backgrounds was conducted by the DEC Catchment Conservation Officer.

The Esperance Regional Forum conducted an open public forum and DEC presented the Lake Warden Wetlands Engineering Scoping document and EIA findings with a question and answer session. A summary of the results of the community forum are in Appendix J.

Table 22 outlines the different stakeholders and numbers of people presented to over a 12-month period.

Table 22 Stakeholders for the LWWS Project

Stakeholder	Number	Place	Date
Lake Warden Project Management Committee • Comprises agency reps, ERF reps, farmers, small landholders, Esperance Shire council and technical staff	12	DAFWA Office	3/4/07 15/11/07
Lake Warden Project Technical Committee	8	DAFWA Office	19/3/07
Lake Warden Project Management sub Committee • DEC Catchment Conservation Officer and Senior Hydrologist, • DAFWA Senior Hydrologist and Land and Water Development Officer, • Esperance Shire Senior Engineer	5	DAFWA Office, DEC Office and Lake Wheatfield	
South Coast NRM • Regional Biodiversity Facilitator • Implementation Working Group	6	Albany DEC Office and Lake Wheatfield	30/7/07 28/3/07
Esperance Regional Forum/Esperance Land Conservation District Committee	15	Esperance St Johns Centre	29/3/07 22/11/07
Esperance Noongar Representatives • TO’s, ERF DEC	7	Lake Wheatfield	21/12/07

Stakeholder	Number	Place	Date
Esperance Shire Council • Full Council Meeting and Corporate shire staff	23	Esperance Shire Council	27/11/07
Bay of Isles Rotarians?	25	Esperance Yacht Club	18/1/07
Esperance Rotarians?	55	Esperance Travelers Inn	14/1/08
Esperance Shire Engineering Staff	6	Esperance Shire Council	19/9/07
Esperance Water Ski Club	65	Esperance Travelers Inn	10/12/07
Quarry Road Flood Group 10 people	9	Lake Wheatfield and DAFWA	10/12/07
Open Community Forum– • advertised in the Esperance Express and on ABC Radio. Refer to report	80	Esperance Golf Club	16/12/07
WA Governor General	4	Lake Wheatfield	14/11/07
DAFWA Regional NRM Group	25	Esperance St Johns Centre	30/11/07
Department of Water • Regional Manager, Program Manager for Waterways, Land Use Planning and Water Resource Protection, Program Manager for Water Information, Senior Natural Resource Management Officer Wetlands	5	Albany DoW Office	30/7/07
DEC Executive Director	5	DEC Office and Lake Wheatfield	18/7/07
DEC South Coast – • District Manager, District Nature Conservation Coordinator, • South Coast Regional Manager and Regional Nature Conservation Officer, Regional Marine Planning Coordinator, Senior Technical Wetlands Officer	6	Albany DEC Office	30/7/07
DEC Natural Resource Branch • Senior Hydrologist • Natural Resource Coordinator • Manager	3	Esperance DEC Office, Lake Wheatfield, Kensington DEC.	12-16/2/07 4/12/07 18/12/07
DEC Environmental Management Branch • Branch Manager • Project Officer	4	DEC Kensington Office	12/7/07 19/12/07

The project has also been presented in the local media over a twelve-month period with four articles in the Esperance Express, one article in the Kalgoorlie Minor, one article in the Countryman and three interviews on ABC radio with one interview going state-wide on the country hour.

Rigorous review by Maunsell of scientific journals and conference papers for DEC technical staff and University of Western Australia PhD and Masters Students occurred in addition to public consultation. Appendix K presents the references for the documents.

9.2 Social Issues

Recreation activities at LWWS include nature appreciation, bushwalking, bird watching, picnicking and water based recreation. Implementation of engineering works to the LWWS will directly enhance recreational values. If engineering intervention does not occur, then recreational activities within the system will be restricted or diminished and will decrease the LWWS visual amenity.

A broad and extensive community consultation and awareness raising program has been implemented over an eighteen month period with government agencies, community groups, and schools. The strong level of support is evident in the positive response to the values of the LWWS and need to engineer to save these values. Part of the community identified some concern with the disposal of water into the Esperance bay specifically with the proposed latter phase 2 Lake Warden pumping component which is not part of this referral.

The Esperance Water Ski Club has been a beneficiary of the artificially deeper water depths in the LWWS and their gazetted ski area on Woody Lake is likely to be affected by the Lake Wheatfield phase 1 proposal. DEC has been working with the Esperance Water Ski Association and the Department of Planning and Infrastructure to identify a more suitable land based water ski area west of Esperance. The Esperance Water Ski Club is currently finalising their gazettal proposal for the alternative site with endorsement from DEC and the Esperance Shire Council to the DPI.

Lake Warden forms part of the Esperance Lakes Nature Reserve, which is on the Register of the National Estate and therefore recognized as part of Australia's natural and/or cultural heritage and merits its conservation.

9.3 Historical Site Use

9.3.1 Elevated heavy metal sampling above natural baselines

Sample site WF4 is located near the southern shoreline of Lake Wheatfield. Up until the late 1980's this shoreline traditionally was a popular duck shooting area. The fringing vegetation provided good cover, easy retrieval of birds and reliable local movement of ducks between the Lake Wheatfield channels. The accumulation of lead shot is higher than natural baselines at this site.

Copper and Chromium were recorded in elevated levels at site WF4 which is also adjacent to a Bird Hide and was constructed on-site out of Copper Chrome Arsenic (CCA) treated pine. It is likely that the sampling has detected diffusion of CCA from the bird hide into the lake environment. Also associated with the construction of the bird hide was the use of zincalume materials that are in a highly corrosive environment. The elevated levels of zinc and aluminium may be attributed to these materials, from either the bird hide or historic dumping of old metal items into the lakes.

Sample site BC9 has elevated levels of lead possibly due to illegal disposal of material as the site has easy public access off Frank Freeman drive.

Sample site BC8 is located immediately south of the Bandy Creek Bridge which is also the main road to the Esperance municipal rubbish tip located at Wylie Bay. Samples taken from the site show elevated levels of aluminium, nickel and cadmium above the natural baseline, which indicates the possible disposing of batteries and metal waste off the bridge and concentrating in the deep pool.. There are also granite boulders stabilizing the stream bank adjacent the sample site near the bridge with rocks held in place by a wire mesh that is corroding and appears to be made of a zincalume product.

Sample site BC13 is located on the western boat mooring pens in Bandy Creek Boat Harbour. The recreational yachts and luxury powerboats moored at this facility have elevated levels of copper and zinc, even within ten months of dredging the harbour because of silting from the January 2007 floods experienced in Esperance.

Sample site BH14 located at the mouth of the harbour had one elevated level of cadmium above the natural baseline. This may be attributed to the disposal of batteries by recreational anglers from the adjacent rock groin or by passing boats to and from the Harbour.

Woody Lake Ski Issue

9.3.2 Woody Lake Background Facts

Woody Lake is located 5km north of Esperance on Tranquil Drive, and was vested a Class A Nature reserve for the conservation of flora and fauna in 1978. In 1990 the lake was included in the Ramsar site listing 485 and 1991 as a DPI ski use gazettal 1159.

The available gazetted ski area is about 25 ha, and skiing within 60m of the beach edge, except for the launch area, is prohibited. The legal ski depth outlined in the Department of Planning and Infrastructure (DPI) Gazettal is above 1.8m for the public and Esperance Water Ski Club members and above 1.4m for the Western Australian Water Ski Association (WAWSA) members.
DEC's responsibility is to manage the Lakes natural values and water skiing on Woody Lake has minimal impact on waterbirds as they mainly use the adjoining lakes. DEC has also supported skiing by constructing the recreation facilities at the site with Recreational Boating Facilities funding provided by DPI.

9.3.3 Lake depth versus ski use regulatory depth trigger

Reviewing fortnightly DEC lake depth records collected over the last five years shows that the DPI regulation depth for the public and members of the Esperance club is suitable for only 25% of the time. This is without engineering intervention occurring at Lake Wheatfield.

The Esperance Ski club has a registered membership of 90 people, being 60 Esperance and 30 goldfields and only four boats are safely able to ski on the Lake at one time.

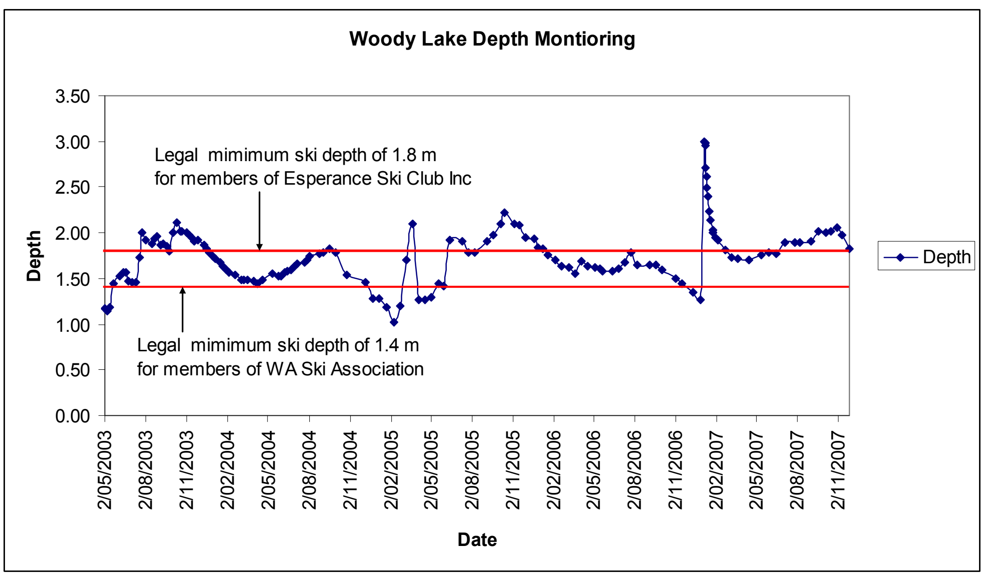


Figure 65 Woody Lake Depth Monitoring from 2003 to 2007 (Courtesy of DEC, 2008)

The number of Esperance and goldfield residents who are a member of WAWSA is yet to be determined. Reviewing lake depth records over the last five years shows that WAWSA members had no skiing for 24% of the time on the Lake.

Modelling indicates that the proposed siphon at the adjoining Lake Wheatfield would affect skiing on Woody Lake for WAWSA members by increasing the current restricted ski period from 24% out to approximately 35-40%. This would be seasonally dependent on climate variability.

9.3.4 Water Ski viability assessment

The 74% of the year that skiing can't take place for the public and Esperance Ski club members (or 24% for WAWSA members), with a limitation of four boats at one time, and a membership of about 100 skiers places in question the current recreational viability for Woody Lake taking into account further population growth and available income for entering the sport.

It is recommended that the DPI and Esperance Water Ski Club review further options for land based water skiing.

9.3.5 Alternative land based water skiing option

Lake Quallilup is located 34km west of Esperance on the coast and is vested as unallocated Crown Land/Water Reserve. It is an end flow point for the Lake Gore Ramsar listed system (Site 1049). It is important to note that Lake Quallilup is not listed under the Ramsar convention as the waterbird values are located to the north on Lake Gore and its associated shallower flow through wetlands.

The approximate potential ski area available is 180 ha, with a perimeter of about 4.0km, width of about 1 km, length of about 1.5km and a depth range between 5 – 7.5m. The salinity is approximately seawater. Access to the lake is off the South Coast Highway via Murrays Road, shire road reserve and then a four-wheel drive track.

There are no existing facilities at the Lake and other uses include Brim fishing and swimming on the eastern shoreline on the granite outcrops. It is the responsibility of the DPI and Esperance Water Ski Club to liaise with local landholders, other user groups, and the Esperance Shire Council to further investigate developing a recreational area and ski gazettal for Quallilup Lake. DEC will be responsible for providing comment on potential biodiversity impacts such as waterbird and vegetation disturbance from such as proposal.

10.0 Discussion and Conclusion

10.1 Key Environmental Risks of Proceeding with the Proposal

Potential risks from the proposal were identified in this Environmental Impact Assessment. The key risk categories are summarized as follows:

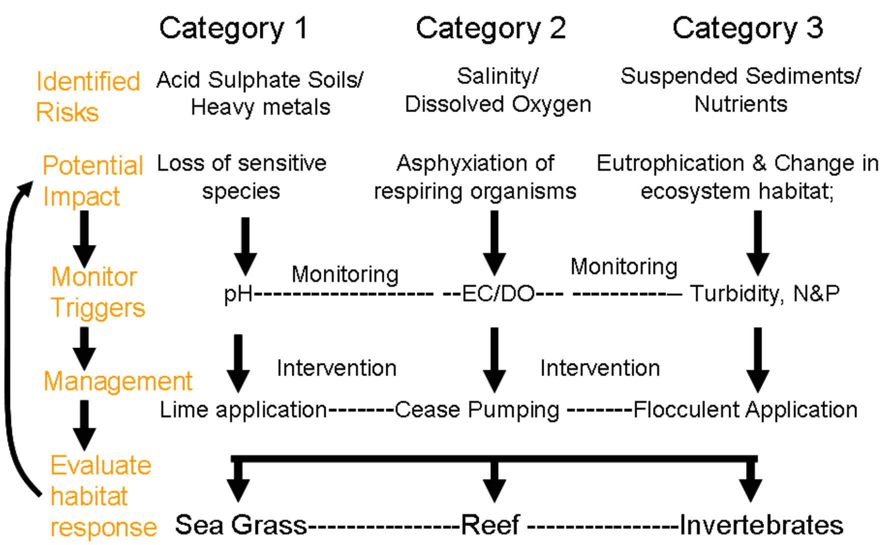


Figure 66 Relationship between Potential Impacts, Triggers and Management Intervention and Evaluation of Habitat to Ensure Key Risk Categories and their Potential Impact are Managed Appropriately.

10.1.1 Acid sulphate soils and heavy metal risk category (1)

The first risk category is acid sulphate soils and heavy metals. Field and laboratory investigations identified areas within the LWWS which have characteristics of acid sulphates, but also a large natural carbonate (historic marine deposits) buffering capacity in the surface and groundwater and sediments. Investigations identified types and levels of heavy metals for the LWWS. Although unlikely due to the existing natural buffering capacity, conditions could occur where the potential acid sulphate soils oxidise, and then acidify the wetland waters. The resulting drop in pH would mobilise and increase bioavailability of specific metals (i.e. Al, Pb, As, Fe). Increased metal bioavailability is responsible for metal toxicity to both plants and animals. The combination of lower pH and increased metal toxicity is a potential wildlife hazard.

10.1.2 Salinity and dissolved oxygen category (2)

The second risk category is salinity and dissolved oxygen. A defined salinity ecotone occurs east to west through the LWWS. Lake Wheatfield at the eastern end is fresh (EC ≈ 12mS/cm) and Lake Warden at the western end is hypersaline (EC ≈ 75mS/cm). Conditions could arise where the discharge of dense hypersaline water into either brackish or marine waters creating a stratified water column. The stratified water column then becomes anoxic, depleting oxygen levels near and at the bottom of the water column. The lack of oxygen results in asphyxiation of respiring organism in the proximal area, in particular benthos.

10.1.3 Nutrient and total suspended solid risk category (3)

The third risk category is nutrients and suspended solids in the wetlands. Field investigation identified that both Lake Wheatfield and Lake Warden have elevated suspended solids. Mass balance calculations revealed that 98% of the nitrogen in Lake Warden is associated to the suspended sediments. Lake Wheatfield mass balance calculations indicated 78% of the phosphorus was bound to the suspended sediments. The discharge of water both high in nutrients and suspended solids could affect receiving waters. Excess nutrients have the potential to create eutrophication. Excess suspended solids change the ecosystems habitat by altering the light penetration through the water column. The decrease in light effects primary production and disrupts predator- prey dynamics.

Table 23 Potential Impacts and Recommendations for LWWS

ENVIRONMENTAL FACTOR	EPA OBJECTIVE	ASPECT / EXISTING ENVIRONMENT	POTENTIAL IMPACT	RECOMMENDED MANAGAMENT ACTIONS
		BIOPHYSICAL		
Flora and Vegetation *(Sections 5.10 and 7.1)*	To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystems levels through the avoidance or management of adverse impacts and improvements in knowledge.	There are 47 Declared Rare or Priority flora species known to occur within the wider Esperance – Lake Warden region. Component 4E is situated along already cleared or developed areas. However, a 60m length of remnant vegetation will need to be cleared immediately east of the Esperance Golf Club as well as some re-generated vegetation. Additionally the pipeline will traverse an existing track line within the A Class Lake Warden Nature Reserve. Previous DEC mapping indicates that a large area of remnant vegetation occurs adjacent to the proposed alignment (Component 1A). Additionally the pipeline will traverse an existing track line within the A Class Woody Lake Nature Reserve. Existing vegetation consists of *Melaleuca cuticularis* woodland over an understorey of rushes and sedges including *Lepidosperma* species and *Ficinia*	Loss of Declared or Priority species and remnant native vegetation.	The DEC should liaise with relevant government authorities with regards to vegetation clearing and clearing permits, especially with Environmentally Sensitive Areas; Clearing of vegetation should be avoided where possible; Where clearing is unavoidable, clearing is to be minimised to reduce the loss of vegetation and not extend beyond the regenerated vegetation zone; Revegetate disturbances with local vegetation; Conduct a detailed clearance flora survey of the specific pipeline route (once alignment is finalised) to accurately determine the presence or absence of flora of conservation significance; Maximise conservation management of remnant native vegetation areas within and adjacent to the pipeline routes;

ENVIRONMENTAL FACTOR	EPA OBJECTIVE	ASPECT / EXISTING ENVIRONMENT	POTENTIAL IMPACT	RECOMMENDED MANAGAMENT ACTIONS
		nodosa. Vegetation fringing Lake Wheatfield in the south also consists of *Banksia speciosa* woodlands. Field investigation identified some areas along Fisheries Road and Bandy Creek Road have previously been cleared and have been subject to heavy disturbance.		
Fauna *(Sections 5.11 and 7.1)*	To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystem levels through the avoidance or management of adverse impacts and improvements in knowledge.	Interrogation of DEC Threatened and priority Fauna Database indicates that there is potential for two threatened fauna species and one specially protected or Priority species to occur within the immediate vicinity of the LWWS. Additionally a search for environmental triggers under the EPBC Act has identified the potential for an additional 63 species to occur in the LWWS.	Disruption to in situ fauna habitats, such as burrows and nests as well as possible loss or reduction of habitat and food source for native fauna.	Clearing of vegetation is avoided where possible; Where clearing is unavoidable, clearing is to be minimised to reduce the loss of vegetation and potential habitat and food source and not extend beyond the regenerated vegetation zone; Excavations of pipe trenches will be done in sections and backfilled as soon as possible to prevent a potential pit trap fall effect on fauna; Install a one in three ramp to provide a means for fauna, especially native mammals to escape.
Conservation Areas *(Sections 5.2.2 and 7.1)*	To protect the environmental values of areas identified as having significant environmental attributes.	Woody Lake A Class Nature Reserve and Lake Warden A Class Nature Reserve are within the study area.	Clearing of vegetation within Conservation significant areas such as Woody Lake A Class Nature Reserve (along the road reserve between Lake Wheatfield and Fisheries Road) as well as some clearing within Lake Warden A Class Nature Reserve.	Liaise with relevant government agencies with regards to vegetation clearing within an Environmentally Sensitive Area; Minimise vegetation clearing as far as practicable; Revegetate disturbances with local vegetation.
Water (Surface and	To ensure that emissions do not adversely affect environment values or the health, welfare and		Loss of seagrass and unknown seafloor habitats	Further video validation will be required to make finer distinctions between substrate and habitat boundaries between Bandy Creek and Wylie Head.

ENVIRONMENTAL FACTOR	EPA OBJECTIVE	ASPECT / EXISTING ENVIRONMENT	POTENTIAL IMPACT	RECOMMENDED MANAGAMENT ACTIONS
Ground) *(Sections 6.2, 6.3, 6.4 and 6.5)*	amenity of people and land uses by meeting statutory requirements and acceptable standards.			
		Discharging water from Lake Warden and Lake Wheatfield into Bandy Creek and Esperance Bay	Increased input of water into Bandy Creek via Engineering Alternative 5 (Component 1A and 4E) may ultimately reduce the flow in Bandy Creek due to reduced water levels in Lake Wheatfield.	Modelling of the likely water levels under a range of pumping/flow scenario's will be undertaken
			Loss of waterbird habitat, abundance and diversity.	Dewater Lake Warden according to water balance and waterbird habitat models developed by Massenbauer and Robertson, 2005 and Maunsell, 2007.
Pests and Diseases *(Sections 5.12 and 7.1.5)*	To establish that pests and diseases are effectively contained	Dieback testing conducted by DEC confirmed Dieback occurrences at the northern-most portion of the proposed pipeline (Component 1A); Additionally The Esperance Lakes Nature Reserve Management Plan 1999-2009 identified other areas within LWC that are infected and includes occurrences of *Armillaria luteobubalina* and Dieback within Woodly Lake Nature Reserve, near the Lake Wheatfield car park, in the Coramup Creek area and within Woody Lake Nature Reserve;	The movement of machinery and vehicles throughout the project area during the construction phase has the potential to spread both dieback infection and weeds.	Management of dieback should be carried out in accordance with the Department of Conservation and Land Management (CALM"s) policy Statement No. 3 Threat Abatement for *Phythophthora cinnamomi*; Implement weed control and dieback treatment measures within susceptible areas within and adjacent to the pipeline routes; Develop hygiene strategies and Hygiene Management Plans for construction activities to ensure that uninfected areas free of dieback; Conduct further investigations in the wider Esperance region regarding the potential *Phythophthora megasperma* infestation, particularly along the proposed pipeline routes; Limit development construction and maintenance activities to periods of dry soil conditions; Educate project personnel (both on site and off) via inductions, on-site visual tools and personal reference material; Stockpile soil and vegetative matter only within the area of dieback classification from which it came (i.e. infested or disease free); Minimise soil disturbance and consider mowing, slashing or the use of herbicide, rather than ploughing and grading whenever possible; Complete construction and maintenance activities in uninfected areas then moving to infected areas;

ENVIRONMENTAL FACTOR	EPA OBJECTIVE	ASPECT / EXISTING ENVIRONMENT	POTENTIAL IMPACT	RECOMMENDED MANAGAMENT ACTIONS
				Plan for, construct, manage, supervise and audit high quality clean-down points (Hygiene Stations) where necessary during construction and other similar activities;
		Weeds occur within and adjacent to the pipeline routes.	Increase in weed invasion and edge effects from weeds between infested areas and better quality vegetation.	Clearing of vegetation is avoided where possible; Where clearing is unavoidable, clearing is to be minimised to reduce the potential for weed invasion and edge effects; Conduct detailed clearance surveys of the specific pipeline alignment to accurately determine disturbance opportunist, environmental weeds and Declared Plants; In areas of significant weed invasion, stripped topsoil is to be disposed away from clean stockpiles and away from areas of good quality vegetation;
POLLUTION MANAGEMENT				
Water (Surface and Ground) *(Sections 5.9.5, 6.6, 7.1.5)*	To ensure that emissions do not adversely affect environment values or the health, welfare and amenity of people and land uses by meeting statutory requirements and acceptable standards.	The LWWS has almost doubled in depth since 1979	Increase local groundwater inflow and possibly change lake's chemistry or seasonality	Monitoring of water quality biannually at Lakes high's and low's will occur to determine potential changes in lakes ecology and will be correlated across the wetland suite in comparison to Environmental Water Requirements (EWR); A monitoring program will be required to enable a timely response to falling lake levels. This will occur at monthly intervals and increase to fortnightly once 'monitoring levels' have been reached; Water removal from each lake will be ceased when the lower optimum depth range is reached. For Lake Wheatfield, where water will be siphoned rather than pumped, will be a pre-set response.
			Erosion, sedimentation and potential weed transport	Erosion and sediment control measure requirement should be incorporated into the final design. This can be achieved by using a weir to skim the water from the surface of the lake. A coarse filter will be installed in the pit around the intake pipe to exclude floating debris. The pit will be designed to facilitate the 'mucking out' of sediments that may collect over time and thereby reduce the volume of the pit. Flexmat or other similar erosion mat should be installed along the banks of

ENVIRONMENTAL FACTOR	EPA OBJECTIVE	ASPECT / EXISTING ENVIRONMENT	POTENTIAL IMPACT	RECOMMENDED MANAGAMENT ACTIONS
				Bandy Creek as necessary to avoid erosion in the discharge zone.
			Accumulation of heavy metals in the soil and water.	Consider the development of artificial wetlands in engineering designs for management of the LWWS. This will have potential benefits such as phytoremediation 'green technology' which uses plants to remove or vacuum heavy metals from the soil or water via uptake through their roots and 'digestion' through metabolic processes; Consider the application of Anionic Polyacralymaide (PAM) to improve water quality and remove nutrients and metals from the water.
Acid Sulfate Soils (Land, terrestrial) *(Sections 5.6, 6.2.3, 6.3.3, 6.4.3, 7.2)*	To maintain the integrity, ecological functions and environmental values of the soil and landform.	Subsurface statigraphy encountered throughout Lake Warden consists of mainly an upper organic layer. Underlying materials are primarily light to dark grey siltstone. Four of the samples taken indicated PASS with net acidity values above trigger limit. Subsurface statigraphy encountered throughout Lake Wheatfield consists of mainly an upper organic layer. Soils around Lake Wheatfield were characterised by heavy loam and clay siltstone beneath the organic layer. Three quarters of the samples at Lake Wheatfield exceeded trigger levels for net acidity, and each of the four bores had samples with net acidity above the trigger level.	Exposure of acid sulphate soils to oxygen, production of acid run-off. Possible impact on waterways if not managed.	Further investigation and quantification of the potential acid generation at Lake Warden will be required in order to decide on proper management and the possible application of a neutralising agent. Careful environmental management of the neutralising agent's application, particularly *in situ* is warranted; Further acid sulphate soil analysis will be required in areas identified to be of medium to high risk of PASS where significant disturbance such as dewatering (if at all required) is expected to occur;
Construction and Operational Issues *(Sections 7 and 8)*	To protect the amenity of residents from noise and vibration impacts resulting from	The majority of the pipeline routes are within existing tracks and road reserves. However, some clearing will be required within the A Class Lake Warden Nature Reserve and	Adverse effects on vegetation as a result of leaked flows from pipelines which may result in erosion and/or potential water logging of species not tolerant to prolonged inundation.	Regular inspection and maintenance of pipelines will allow for upgrades and repairs as required;

ENVIRONMENTAL FACTOR	EPA OBJECTIVE	ASPECT / EXISTING ENVIRONMENT	POTENTIAL IMPACT	RECOMMENDED MANAGAMENT ACTIONS
	activities associated with construction of the proposal by ensuring that noise and vibration levels meet statutory requirements and acceptable standards.	the A Class Woody Lake Nature Reserve.		
		Existing vehicle movements in residential areas adjacent to the proposed routes are essentially private and domestic traffic.	Increased heavy vehicle traffic on local roads, giving rise to safety concerns, issues, possible congestion, noise, vibration, spillage of materials and consequent dust.	Ensure compliance with all applicable statutory requirements; Liaise with the Shire of Esperance and other relevant agencies such as Main Roads to minimise disturbance to local residents; Limit operations to normal business hours as practicable; The Shire of Esperance should be advised if significant increases in traffic or minor roads are expected.
		The surrounding land use consists of Crown Reserves, Crown Land, Freehold, Nature Reserves and Other.	Noise levels are expected to increase during construction works. Vibration may also be produced and may be a nuisance to nearby residents.	Implement noise and vibration minimisation techniques during construction; Consultation with community and stakeholders with regards to noise and Contractor environmental management in regards to the *Environmental Protection (Noise) Regulations*; Ensure compliance with all applicable statutory requirements; Limit operations to normal business hours as practicable; Maximise separation between noisy/vibration inducing activities and adjacent residential areas as operationally practicable; Adopt construction techniques that will minimise vibration impacts within nearby residential areas; Pumping station should have a low profile, have acoustic fittings to minimise noise impacts and be surrounded by vegetated earth bunds so as to reduce visual amenity impacts.

ENVIRONMENTAL FACTOR	EPA OBJECTIVE	ASPECT / EXISTING ENVIRONMENT	POTENTIAL IMPACT	RECOMMENDED MANAGAMENT ACTIONS
SOCIAL SURROUNDINGS				
Aboriginal and European Heritage *(Section 8.1)*	To ensure changes in the biophysical environment do not adversely affect historical and cultural associations and comply with relevant heritage legislation.	Eight Aboriginal sites have been identified to occur within the wider Esperance Region. Additionally proposed works will also affect the Esperance Lakes Nature Reserve, which is listed on the Register of the National Estate.	Proposed works will not affect Aboriginal Sites in the Esperance Lakes Nature Reserve.	Liaison with local indigenous groups and the Department of Indigenous Affairs with regards to impacts to areas of Aboriginal significance.

10.2 Management Intervention of Key Environmental Risks

The management strategy for potential marine impacts will incorporate principles of adaptive management and provide decision makers confidence that management options have a high probability of meeting both the LWWS and marine environment outcomes. The strategy involves:

- Categorising the risk;
- Defining the potential impacts;
- Establishing monitoring triggers for when to take action;
- Identifying appropriate management actions associated with triggers;
- Evaluating marine habitat response to management actions and triggers; and
- Feedback to refine the level of risk and uncertainty of potential impacts.

The relationship between each component is illustrated in Figure 66.

1) This work has identified appropriate management activities, which minimises potential damage to the marine environment from the three risk categories. Employing relevant measurement parameters for monitoring allows an appropriate management response. The measurement parameters if effective are diagnostic, reliable and cost effective.
2) Category 1 risk measurement parameters to be monitored are sediment and water pH.
3) Category 2 risk measurement parameters to be monitored are electrical conductivity (EC) and dissolved oxygen (DO).
4) Category 3 risk measurement parameters will be sampling and measuring turbidity, suspended solids, nitrogen and phosphorus.

Monitoring these parameters indicates whether or not the biological values of the receiving waters are at risk and what that risk is and its impact (Figure 66).

These parameters are both diagnostic and responsive, and coupled with information defining the natural conditions, allow managers to effectively intervene to negates or minimise the risks. Category 1 risks only apply to Lake Wheatfield. Category 2 and 3 risks only apply to Lake Warden. Examples of potential trigger management interventions are:

- Category 1 risk intervention: effective liming to neutralise the acid and prevent metals from becoming bioavailable. Action levels. Liming regieme and management options have been described in Dear. *et al*., 2002 and Ahren, *et al*., 1998
- Category 2 risk interventions: A. operation of pumps only during in-coming high tides (switched off during out-going low tides). B. cease pumping operations until water column mixing has occurred and DO is at appropriate levels.
- Category 3 risk interventions: A. operation of pumps only during in-coming high tides (switched off during out-going low tides). B. application of a flocculant to settle suspended solids and attached nutrients to the lake floor. This enhances the water quality discharged into the receiving waters.

10.3 Recommendations for Monitoring Programmes

The following parameters are recommended to be assessed during monitoring programmes implemented to determine the impacts upon the wetland system. These are indicative and a more comprehensive and detailed monitoring program will be required.

Table 24 Recommendation for Monitoring Programmes

Management	Parameters	Timing	Performance Criteria
Hydrology	• Water levels [1] • Water Quality including pH, acidity, and heavy metals; • Outfall monitoring at Bandy Creek	• Ongoing on a fortnightly basis	• Compliance with ANZECC & ANZAME (2000) guidelines for south-west Australia slightly disturbed ecosystems
Flora and vegetation [2]	• Plant density and species diversity[3]; • Trees; • DMSI and Spatial information[4]; • Vegetation health, condition and weeds	• Flora and vegetation monitoring to occur bi annually, once in winter and once in summer • Aerial photography to be taken biannually	• No additional plant deaths;
Fauna monitoring	• Species diversity and abundance[5]; • Targeted bird survey[6]; • Habitat	• Fauna monitoring to be conducted biannually.	• Bird numbers returned to 1980 figures

Table 25 Monitoring Recommendations

Footnote No.	Monitoring Recommendation
1	Water level monitoring, including depth measurements at fixed locations and mapping of lake shorelines, at set seasonal timings, during both wet and dry season.
2	Water quality monitoring at fixed locations varying in distance from shoreline. Parameters to be include pH, Total Nitrogen, Dissolved Oxygen, Total Phosphorous, Turbidity
3	Establish new or additional vegetation monitoring plots around Lake Wheatfield and Lake Warden, extending perpendicular from the current waters edge. Plots will be established and monitored in accordance with methods for the existing State Salinity Strategy Monitoring Program at Lake Wheatfield. Specifically target tree species and other indicator species such as *Melaleuca cuticularis*, *Eucalyptus* and *Banksia* species that are known to be susceptible to excess water loss. Establish monitoring transects adjacent to monitoring bores where possible. Establish control plots away from lakes with the proposed engineering components. Monitoring of Vegetation health, cover diversity, trees, composition and condition changes over time
4	Record aerial photography to identify visual changes in lake water levels and vegetation foliage cover and extent. Photos to be compared for: foliage cover, extent, vegetation composition and health
5	Conduct fauna monitoring program that includes multiple night trapping In various vegetation types to determine changes in fauna habitation over time.
6	Conduct a target Bird survey during at least two varying seasons and including at least one monitoring event during spring. Include nest mapping and spatial assessment of this in relation to a shifting shoreline over time.

The following parameters are to be used to assess Tree health:

- Visual health - to be assessed via established photo points.
- Health ranking - to be derived from visual assessment, ranging from healthy to dead with various degrees of stress as intermediates.
- Alive canopy foliage cover (%) - to be used as a visual measure of tree stress.
- Height (m) - to be used as a measure of growth.
- Diameter at Breast Height (DBH) - to be used as a measure of growth.
- Isotopic analysis - to be used as a quantitative measure of tree stress.

10.4 Conclusions and Recommendations

The waterbird and riparian vegetation values of the LWWS are under immediate threat from rising water tables and excessive inundation. This is a result of broad scale clearing of perennial vegetation in the catchment and subsequent replacement with an agricultural system, based largely on annual crops. Additionally water balance and waterbird habitat models which were developed for individual lakes of the LWWS also indicate that a decline in vegetation condition and loss of waterbird habitat has resulted from hydrological change, particularly prolonged duration and increased volumes of inundation, thus degradation will continue if unmanaged (Massenbauer and Robertson, 2005). Results from the BBN provided by Massenbauer & Vogwill (2007) indicate that only engineering based solutions offer a reasonable prospect for achieving stated management objectives in the LWWS within a 25 year horizon.

The LWWS's international, national, state, regional and locally significant biodiversity values are currently in a state of rapid decline: The identified recreation and conservation values will diminish significantly within the next five years if there is no intervention, to the point where currently the LWWS does not meet its international Ramsar obligations due to extensive loss in waterbird habitat, and abundance. Extensive research has shown that engineered dewatering is required to restore the wetlands. The engineering intervention is a minimal disturbance approach using buried pipe to pump and gravity feed water safely to their disposal sites. The pipe systems allow accurate dewatering to be set at specific lake depths so as not to over dewater the wetlands and can be easily turned off during drought and flood events as a climate change management tool. Environmental risks associated with the dewatering process have been identified and with triggers and on-going monitoring in place, can be managed effectively to minimize potential impacts to the surrounding environment. The recommendations from this for monitoring and management of the LWWS are to achieve effective adaptive management. The primary goal is restoring a RAMSAR site and with minimal to no impact on the surrounding terrestrial, aquatic and marine environments.

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Appendix A Soluble composition and Concentration for Lake Warden Wetlands

Appendix A Soluble composition and Concentration for Lake Warden Wetlands

The expression of solute concentrations as equivalents / liter is due to the type of reactions in which the solutions constituents are involved. The advantage is eqivlent concentrations have as its basis the laws of mass action and an example of this is a charge balance of a solution. The basis for a charge balance is that all solutions must be electrically neutral (Snoeylink & Jenkins, 1980). In a solution the total number of positive charges must equal the total number of negative charges. Since all waters must be electrically neutral we can deduce that a complete water analysis must produce a result in which the total number of positive charges = the total number of negative charges. An acceptable water analysis will have this equation agreeing within ±5%. Larger deviations than this indicate either errors in analysis or an overlooked species (Snoeylink & Jenkins, 1980). .

Example calculation:

Ca = 65 mg/L:(mass/ volume) Ca molecular weight = 40 g/mole, Na = +2 charge/ion

65 mg/L x 1/40 mmole/mg x 2 charge/ion = 3.30 Meq/L (equivalent /volume)

The data displayed below has been converted to Meq/ L the original data is from Marimuthu *et al* (2004 & 2005).

Table No. 1: Summer 2003, Anion-Cation composition and balance of the LWWS lake waters and ground waters

	Ca	Mg	Na	K	Cl	HCO3	SO4	Charge Difference	Percent Difference
	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	%
								[∑(+charge) - ∑(-charge)]	[∑(+charge) - ∑(-charge)] / [∑(total charge]*100
Groundwater(wetlands)									
LW35B (LW 10DB)	32.37	466.44	1948.98	20.67	2416.61	3.22	266.73	-218	-4.23
LW35C (LW 10D)	33.05	440.44	1848.71	19.53	2291.52	3.28	226.79	-180	-3.70
LW40 (LW 13)	21.91	128.60	552.40	6.23	630.06	1.80	67.86	9	0.67
LW45A (LW 18)	6.60	28.59	138.83	2.03	154.09	2.10	17.16	3	0.78
LW45B (LW DW)	14.30	78.01	358.49	4.59	402.00	3.54	46.19	4	0.40
LW49A (LW 15D)	24.26	853.83	3112.01	46.07	3940.49	1.24	453.19	-359	-4.26
LW49B (LW 15DB)	24.64	846.33	3087.22	45.44	4036.01	1.26	445.00	-479	-5.64
LW50 (LW 17)	43.34	302.95	1333.37	15.71	1614.29	1.80	132.96	-54	-1.56
LW54A (LW 8WD)	6.54	56.87	284.11	5.00	325.90	11.80	20.31	-5	-0.77
LW54B (LW 8D)	39.81	252.17	1047.29	13.16	1330.41	3.54	98.06	-80	-2.86
LW55 (LW 20D)	27.10	131.77	449.15	4.45	558.90	2.20	59.45	-8	-0.66
LW39	3.03	15.39	76.25	1.21	95.55	1.32	9.00	-10	-4.95
Lakes									
Wheatfield Lake	5.20	24.82	128.16	2.02	141.42	2.80	13.71	2	0.72
Station Lake	6.74	52.55	286.92	3.99	313.27	2.34	34.70	0	-0.02
Mullet Lake	10.18	119.46	627.42	8.11	718.40	3.32	78.37	-35	-2.23
Ewans Lake	6.04	35.62	176.77	2.41	193.08	1.62	21.89	4	0.97
Woody Lake	5.28	30.56	175.23	2.48	178.37	3.54	17.78	14	3.35
Windabout Lake	9.51	74.39	361.51	5.75	398.97	6.50	39.14	7	0.73
Pink Lake	8.00	1047.16	3626.07	72.98	4558.08	4.39	442.31	-251	-2.57
Lake Warden	20.20	218.78	1270.11	20.81	1526.12	3.68	123.60	-123	-3.88

Table No. 2: Autumn 2003, Anion-Cation composition and balance of the LWWS lake waters and ground waters

	Ca	Mg	Na	K	Cl	HCO3	SO4	Charge Difference	Percent Difference
	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	%
								[∑(+charge) - ∑(-charge)]	[∑(+charge) - ∑(-charge)] / [∑(total charge]*100
Groundwater(wetlands)									
LW35B (LW 10DB)	31.53	452.69	2377.40	20.84	2388.57	2.92	264.16	227	4.10
LW35C (LW 10D)	32.48	466.14	2019.58	16.72	2341.37	3.32	234.41	-44	-0.86
LW40 (LW 13)	19.27	119.46	672.48	4.17	810.93	1.86	63.22	-61	-3.58
LW45A (LW 18)	5.17	28.38	140.29	1.51	170.69	1.58	16.07	-13	-3.57
LW45B (LW DW)	12.89	75.24	385.83	3.34	451.38	3.58	43.72	-21	-2.19
LW49A (LW 15D)	26.45	1268.00	3560.43	38.23	4506.34	1.06	492.88	-107	-1.08
LW49B (LW 15DB)	40.02	675.33	1992.83	19.54	2613.01	1.54	156.04	-43	-0.78
LW50 (LW 17)	41.91	291.75	1403.50	12.14	1797.57	1.04	121.91	-171	-4.67
LW54A (LW 8WD)	8.19	61.64	303.23	4.92	382.58	9.32	24.17	-38	-4.80
LW54B (LW 8D)	42.49	275.87	1198.55	11.19	1465.65	3.42	106.05	-47	-1.52
LW55 (LW 20D)	26.47	137.87	423.91	3.02	582.03	2.82	62.86	-56	-4.55
Lakes									
Wheatfield Lake	3.64	18.62	95.16	1.29	113.88	2.02	10.52	-8	-3.15
Station Lake	8.85	69.80	366.03	3.96	363.69	4.84	43.29	37	4.28
Mullet Lake	8.56	69.53	377.84	3.75	428.43	4.04	44.35	-17	-1.83
Ewans Lake	5.59	35.82	207.88	2.03	216.20	3.12	24.42	8	1.53
Woody Lake	4.12	23.15	115.38	1.35	120.10	2.42	11.62	10	3.54
Windabout Lake	5.40	39.94	189.14	2.40	230.90	4.04	20.59	-19	-3.79
Pink Lake	11.40	1079.62	5279.43	73.21	5111.43	5.36	463.61	863	7.18
Lake Warden	15.35	180.32	1037.46	13.04	1177.66	3.12	95.62	-30	-1.20

Table No. 3: Winter 2003, Anion-Cation composition and balance of the LWWS lake waters and ground waters

	Ca	Mg	Na	K	Cl	HCO3	SO4	Charge Difference	Percent Difference
	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	%
								[∑(+charge) - ∑(-charge)]	[∑(+charge) - ∑(-charge)] / [∑(total charge]*100
Groundwater(wetlands)									
LW35B (LW 10DB)	38.01	558.06	2557.66	19.69	3146.89	3.46	324.02	-301	-4.53
LW35C (LW 10D)	33.32	423.73	1887.90	17.02	2396.71	3.34	201.94	-240	-4.84
LW40 (LW 13)	19.26	116.39	668.48	4.77	807.46	2.02	59.51	-60	-3.58
LW45A (LW 18)	6.40	33.11	159.15	2.03	205.94	1.76	14.98	-22	-5.19
LW45B (LW DW)	13.48	78.65	428.27	3.95	501.69	3.24	43.63	-24	-2.26
LW49A (LW 15D)	24.93	819.29	3101.35	33.53	3986.66	1.78	444.96	-454	-5.40
LW49B (LW 15DB)	43.33	418.90	2438.68	26.58	2408.57	2.32	124.10	392	7.19
LW50 (LW 17)	39.40	260.23	1168.40	11.13	1429.60	0.76	118.27	-69	-2.29
LW54A (LW 8WD)	8.04	65.13	319.11	5.09	398.49	10.36	24.77	-36	-4.36
LW54B (LW 8D)	41.20	275.83	1140.61	10.85	1515.80	4.44	81.16	-133	-4.33
LW55 (LW 20D)	25.87	132.13	430.58	3.88	575.49	2.88	57.36	-43	-3.52
Lakes									
Wheatfield Lake	2.99	16.63	81.21	0.42	80.37	2.10	10.34	8	4.35
Station Lake	4.40	28.17	196.04	1.62	219.63	2.60	14.27	-6	-1.34
Mullet Lake	6.97	56.36	304.39	2.46	349.51	3.12	32.66	-15	-2.00
Ewans Lake	4.06	27.35	153.53	0.82	165.17	2.32	16.66	2	0.44
Woody Lake	3.10	13.75	81.22	0.95	93.06	2.16	8.17	-4	-2.16
Windabout Lake	5.53	38.05	187.09	1.51	231.17	3.46	20.36	-23	-4.68
Pink Lake	6.69	690.31	3499.71	39.62	3869.71	3.64	306.50	56	0.67
Lake Warden	14.86	174.21	1002.78	12.51	1239.26	3.60	90.12	-129	-5.07

Table No. 4: May and November 2003, Weekly Anion-Cation composition and balance of Lake Warden and Lake Wheatfield

Sample	Ca	Mg	Na	K	Cl	HCO3	SO4	Charge Difference	Percent Difference
Id	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	%
								[∑(+charge) - ∑(-charge)]	[∑(+charge) - ∑(-charge)] / [∑(total charge]*100
Lake Warden									
2.5.03	20.23	203.92	1211.08	18.33	1458.73	3.11	111.28	-120	-3.95
6.5.03	19.53	199.68	1196.25	18.39	1509.54	3.00	110.77	-189	-6.20
12.5.03	19.76	200.97	1197.95	18.25	1589.54	3.18	109.79	-266	-8.46
22.5.03	19.03	189.34	1131.74	17.38	1511.18	3.00	103.42	-260	-8.74
5.6.03	19.15	188.27	1111.07	17.10	1358.32	3.11	103.29	-129	-4.61
13.6.03	17.42	165.59	983.14	15.14	1230.92	3.00	90.61	-143	-5.72
17.6.03	18.43	186.37	1108.02	17.04	1251.33	3.18	101.36	-26	-0.97
24.6.03	16.95	167.64	993.26	15.46	1254.21	3.16	90.89	-155	-6.10
3.7.03	16.97	166.69	993.67	15.41	1306.37	3.11	91.30	-208	-8.02
17.7.03	9.83	66.64	420.83	6.81	637.77	3.15	32.45	-169	-14.38
1.8.03	11.81	103.91	629.06	9.23	831.31	3.16	56.19	-137	-8.31
15.8.03	12.82	109.86	657.35	9.80	869.82	3.25	60.43	-144	-8.34
27.8.03	11.87	102.06	596.37	8.91	805.32	3.00	54.57	-144	-9.08
9.9.03	10.16	84.76	492.16	7.34	650.48	3.15	46.82	-106	-8.19
30.9.03	10.81	90.87	537.27	8.10	663.91	3.14	56.20	-76	-5.56
9.10.03	9.75	112.14	647.27	13.37	628.57	3.15	60.16	91	6.15
22.10.03	9.47	99.66	600.07	12.33	591.43	3.15	57.49	69	5.06
7.11.03	9.95	110.82	624.97	13.49	631.43	3.15	60.18	64	4.43
18.11.03	10.43	108.19	603.80	13.79	654.29	3.15	58.86	20	1.37
	14.44	139.86	828.17	13.46	1022.87	3.12	76.64	-107	-5.08

Sample	Ca	Mg	Na	K	Cl	HCO3	SO4	Charge Difference	Percent Difference
Wheatfield									
2.5.03	4.76	23.79	121.28	2.02	136.15	2.50	13.91	-1	-0.23
6.5.03	4.83	24.04	123.47	2.05	76.95	2.62	14.15	61	24.46
12.5.03	4.63	23.20	120.02	1.99	75.42	2.82	13.57	58	24.01
22.5.03	4.05	21.07	105.50	1.77	65.64	2.02	12.59	52	24.52
5.6.03	3.92	21.12	104.73	1.72	73.33	1.76	12.47	44	20.05
13.6.03	3.43	19.40	96.25	1.53	61.99	1.68	11.54	45	23.19
17.6.03	3.55	20.49	98.21	1.61	65.85	1.64	12.12	44	21.75
24.6.03	3.60	21.62	100.53	1.64	67.26	1.62	12.69	46	21.93
3.7.03	3.61	21.76	103.73	1.69	70.05	1.52	12.89	46	21.52
17.7.03	3.51	18.03	82.70	1.38	51.47	1.50	10.66	42	24.81
1.8.03	2.58	17.38	77.81	1.27	48.92	1.34	9.92	39	24.40
15.8.03	2.86	18.88	83.70	1.38	50.59	1.20	10.89	44	26.05
27.8.03	3.96	21.95	99.49	1.53	65.88	1.52	12.36	47	22.82
9.9.03	2.99	19.76	91.65	1.43	149.62	1.48	11.15	-46	-16.69
30.9.03	4.13	15.71	69.37	0.96	95.81	1.24	10.26	-17	-8.68
9.10.03	2.26	14.01	66.31	1.10	73.43	1.25	7.78	1	0.73
22.10.03	2.33	14.30	67.41	1.14	76.57	1.25	7.96	-1	-0.35
7.11.03	2.50	15.14	67.13	1.22	81.43	1.25	8.42	-5	-2.89
18.11.03	2.62	15.90	71.87	1.23	84.00	1.25	8.90	-3	-1.36
	3.48	19.34	92.17	1.51	77.39	1.65	11.28	26	12.66

Table No. 5: 2002, LWWS ground water Anion-Cation composition and balance

	Ca	Mg	Na	K	Cl	HCO3	SO4	Charge Difference	Percent Difference
	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	%
								[∑(+charge) - ∑(-charge)]	[∑(+charge) - ∑(-charge)] / [∑(total charge]*100
	September_2002								
LW35B (LW 10DB)	38.01	558.06	2557.66	19.69	3146.89	3.46	324.02	-301	-4.53
LW35C (LW 10D)	33.32	423.73	1887.90	17.02	2396.71	3.34	201.94	-240	-4.84
LW40 (LW 13)	19.26	116.39	668.48	4.77	807.46	2.02	59.51	-60	-3.58
LW45A (LW 18)	6.40	33.11	159.15	2.03	205.94	1.76	14.98	-22	-5.19
LW45B (LW DW)	13.48	78.65	428.27	3.95	501.69	3.24	43.63	-24	-2.26
LW49A (LW 15D)	24.93	819.29	3101.35	33.53	3986.66	1.78	444.96	-454	-5.40
LW49B (LW 15DB)	43.33	418.90	2438.68	26.58	2408.57	2.32	124.10	392	7.19
LW50 (LW 17)	39.40	260.23	1168.40	11.13	1429.60	0.76	118.27	-69	-2.29
LW54A (LW 8WD)	8.04	65.13	319.11	5.09	398.49	10.36	24.77	-36	-4.36
LW54B (LW 8D)	41.20	275.83	1140.61	10.85	1515.80	4.44	81.16	-133	-4.33
LW55 (LW 20D)	25.87	132.13	430.58	3.88	575.49	2.88	57.36	-43	-3.52
	December_2002								
LW35B (LW 10DB)	32.48	466.14	2019.58	16.72	2341.37	3.32	234.41	-44	-0.86
LW35C (LW 10D)	36.52	554.48	2371.05	18.38	2816.05	2.92	312.91	-151	-2.48
LW40 (LW 13)	19.27	119.46	672.48	4.17	810.93	1.86	63.22	-61	-3.58
LW45A (LW 18)	5.17	28.38	140.29	1.51	170.69	1.58	16.07	-13	-3.57
LW45B (LW DW)	12.89	75.24	385.83	3.34	451.38	3.58	43.72	-21	-2.19
LW49A (LW 15D)	26.45	1268.00	3560.43	38.23	4506.34	1.06	492.88	-107	-1.08

	Ca	Mg	Na	K	Cl	HCO3	SO4	Charge Difference	Percent Difference
	(meq/L)	**(meq/L)**	**(meq/L)**	**(meq/L)**	**(meq/L)**	**(meq/L)**	**(meq/L)**	**(meq/L)**	**%**
								[∑(+charge) - ∑(-charge)]	**[∑(+charge) - ∑(-charge)] / [∑(total charge]*100**
LW49B (LW 15DB)	40.02	675.33	1992.83	19.54	2613.01	1.54	156.04	-43	-0.78
LW50 (LW 17)	41.91	291.75	1403.50	12.14	1797.57	1.04	121.91	-171	-4.67
LW54A (LW 8WD)	42.49	275.87	1198.55	11.19	1465.65	3.42	106.05	-47	-1.52
LW54B (LW 8D)	8.19	61.64	303.23	4.92	382.58	9.32	24.17	-38	-4.80
LW55 (LW 20D)	26.47	137.87	423.91	3.02	582.03	2.82	62.86	-56	-4.55

Table No. 6: 2002, LWWS lake waters Anion-Cation composition and balance

	Ca	Mg	Na	K	Cl	HCO3	SO4	Charge Difference	Percent Difference
	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	(meq/L)	%
								[∑(+charge) - ∑(-charge)]	[∑(+charge) - ∑(-charge)] / [∑(total charge]*100
	September_2002								
Wheatfield Lake	2.99	16.63	81.21	0.42	80.37	2.10	10.34	8	4.35
Station Lake	4.40	28.17	196.04	1.62	219.63	2.60	14.27	-6	-1.34
Mullet Lake	6.97	56.36	304.39	2.46	349.51	3.12	32.66	-15	-2.00
Ewans Lake	4.06	27.35	153.53	0.82	165.17	2.32	16.66	2	0.44
Woody Lake	3.10	13.75	81.22	0.95	93.06	2.16	8.17	-4	-2.16
Windabout Lake	5.53	38.05	187.09	1.51	231.17	3.46	20.36	-23	-4.68
Pink Lake	6.69	690.31	3499.71	39.62	3869.71	3.64	306.50	56	0.67
Lake Warden	14.86	174.21	1002.78	12.51	1239.26	3.60	90.12	-129	-5.07
	December_2002								
Wheatfield Lake	3.64	18.62	95.16	1.29	113.88	2.02	10.52	-8	-3.15
Station Lake	8.85	69.80	366.03	3.96	363.69	4.84	43.29	37	4.28
Mullet Lake	8.56	69.53	377.84	3.75	428.43	4.04	44.35	-17	-1.83
Ewans Lake	5.59	35.82	207.88	2.03	216.20	3.12	24.42	8	1.53
Woody Lake	4.12	23.15	115.38	1.35	120.10	2.42	11.62	10	3.54
Windabout Lake	5.40	39.94	189.14	2.40	230.90	4.04	20.59	-19	-3.79
Pink Lake	11.40	1079.62	5823.52	73.21	6914.29	5.36	547.23	-479	-3.31
Lake Warden	15.35	180.32	1037.46	13.04	1177.66	3.12	95.62	-30	-1.20

Appendix B Definitions of Rare, Priority and Threatened Species

Appendix B Definitions of Rare, Priority and Threatened Species

Table 1: Definition of Rare and Priority Flora Species (Department of Environment and Conservation, 2006a)

Conservation Code	Category
DRF	**Declared Rare Flora – Extant Taxa** "Taxa which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection and have been gazetted as such. "
P1	**Priority One – Poorly Known Taxa** "Taxa which are known from one or a few (generally <5) populations which are under threat, either due to small population size, or being on lands under immediate threat. Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey. "
P2	**Priority Two – Poorly Known Taxa** "Taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat (not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but urgently need further survey. "
P3	**Priority Three – Poorly Known Taxa** "Taxa which are known from several populations, and the taxa are not believed to be under immediate threat (i.e. not currently endangered), either due to the number of known populations (generally >5), or known populations being large, and either widespread or protected. Such taxa are under consideration for declaration as 'rare flora' but need further survey. "
P4	**Priority Four – Rare Taxa** "Taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5-10 years. "

Table 2: Categories of Threatened Flora Species (*Environment Protection and Biodiversity Conservation Act, 1999*)

Conservation Code	Category
Ex	**Extinct** Taxa which at a particular time if, at that time, there is no reasonable doubt that the last member of the species has died.
ExW	**Extinct in the Wild** Taxa which is known only to survive in cultivation, in captivity or as a naturalised population well outside its past range; or it has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.
CE	**Critically Endangered** Taxa which at a particular time if, at that time, it is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria.
E	**Endangered** Taxa which is not critically endangered and it is facing a very high risk of extinction in the wild in the immediate or near future, as determined in accordance with the prescribed criteria.

V	**Vulnerable** Taxa which is not critically endangered or endangered and is facing a high risk of extinction in the wild in the medium-term future, as determined in accordance with the prescribed criteria.
CD	**Conservation Dependent** Taxa which at a particular time if, at that time, the species is the focus of a specific conservation programme, the cessation of which would result in the species becoming vulnerable, endangered or critically endangered within a period of 5 years.

Appendix C Definitions of Threatened and Priority Ecological Communities

Appendix C Definitions of Threatened and Priority Ecological Communities

Definitions for Threatened Ecological Communities in Western Australia (Department of Environment and Conservation, 2006)

Conservation Code	Conservation Category	Definition
PD	Presumed Totally Destroyed	An ecological community that has been adequately searched for but for which no representative occurrences have been located. The community has been found to be destroyed or so extensively modified throughout its range that no occurrence of it is likely to recover its species composition and/or structure in the foreseeable future.
CR	Critically Endangered	An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or that was originally of limited distribution and is facing severe modification or destruction throughout its range in the immediate future, or is already severely degraded throughout its range but capable of being substantially restored or rehabilitated.
EN	Endangered	An ecological community that has been adequately surveyed and found to have been subject to a major contraction in area and/or was originally of limited distribution and is in danger of significant modification throughout its range or severe modification or destruction over most of its range in the future
VU	Vulnerable	An ecological community that has been adequately surveyed and is found to be declining and/or has declined in distribution and/or condition and whose ultimate security has not yet been assured and/or a community that is still widespread but is believed likely to move into a category of higher threat in the near future if threatening processes continues or begin operating throughout its range.

DEFINITIONS AND CRITERIA FOR PRIORITY ECOLOGICAL COMMUNITIES (DEC, 2006)

Possible threatened ecological communities that do not meet survey criteria or that are not adequately defined are added to the Priority Ecological Community Lists under Priorities 1, 2 and 3. These three categories are ranked in order of priority for survey and/or definition of the community, and evaluation of conservation status, so that consideration can be given to their declaration as threatened ecological communities. Ecological Communities that are adequately known, and are rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list, are placed in Priority 4. These ecological communities require regular monitoring. Conservation Dependent ecological communities are placed in Priority 5.

Priority One: Poorly-known ecological communities

Ecological communities with apparently few, small occurrences, all or most not actively managed for conservation (e.g. within agricultural or pastoral lands, urban areas, active mineral leases) and for which current threats exist. Communities may be included if they are comparatively well-known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under immediate threat from known threatening processes across their range.

Priority Two: Poorly-known ecological communities

Communities that are known from few small occurrences, all or most of which are actively managed for conservation (e.g. within national parks, conservation parks, nature reserves, State forest, unallocated Crown land, water reserves, etc.) and not under imminent threat of destruction or degradation. Communities may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements, and/or are not well defined, and appear to be under threat from known threatening processes.

Priority Three: Poorly known ecological communities

(i) Communities that are known from several to many occurrences, a significant number or area of which are not under threat of habitat destruction or degradation or:
(ii) communities known from a few widespread occurrences, which are either large or within significant remaining areas of habitat in which other occurrences may occur, much of it not under imminent threat, or;
(iii) communities made up of large, and/or widespread occurrences, that may or not be represented in the reserve system, but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, and inappropriate fire regimes.

Communities may be included if they are comparatively well known from several localities but do not meet adequacy of survey requirements and/or are not well defined, and known threatening processes exist that could affect them.

Priority Four: Ecological communities that are adequately known, rare but not threatened or meet criteria for Near Threatened, or that have been recently removed from the threatened list. These communities require regular monitoring.

(a) Rare. Ecological communities known from few occurrences that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These communities are usually represented on conservation lands.

(b) Near Threatened. Ecological communities that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable.

(c) Ecological communities that have been removed from the list of threatened communities during the past five years.

Priority Five: Conservation Dependent ecological communities

Ecological communities that are not threatened but are subject to a specific conservation program, the cessation of which would result in the community becoming threatened within five years.

Appendix D Definitions of Threatened and Specially Protected Fauna

Appendix D Definitions of Threatened and Specially Protected Fauna

Western Australian *Wildlife Conservation Act, 1950* Codes for Threatened Fauna

Conservation Code	Conservation Category
Schedule 1	Fauna that are rare or likely to become extinct are declared fauna that is in need of special protection.
Schedule 2	Fauna that are presumed to be extinct are declared fauna that is in need of special protection.
Schedule 3	Birds that are subject to an agreement between the governments of Australia and Japan, relating to the protection of migratory birds and birds in danger of extinction are declared fauna that is in need of special protection.
Schedule 4	Fauna that are in need of special protection other than for the reasons mentioned [in Schedule 1 – 3].

Categories of Specially Protected Fauna Species as Prioritised by DEC

Conservation Code	Conservation Category
P1	**Priority 1 - Taxa with few, poorly known populations on threatened lands.** Taxa which are known from few specimens or sight records from one or a few localities on lands not managed for conservation (e.g. agricultural or pastoral lands, urban areas, active mineral leases). The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.
P2	**Priority 2 - Taxa with few, poorly known populations on conservation lands.** Taxa which are known from few specimens or sight records from one or a few localities on lands not under immediate threat of habitat destruction or degradation (e.g. national parks, conservation parks, nature reserves, State forest, vacant Crown land, water reserves etc). The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.
P3	**Priority 3 - Taxa with several, poorly known populations, some on conservation lands.** Taxa which are known from few specimens or sight records from several localities, some of which are on lands not under immediate threat of habitat destruction or degradation. The taxon needs urgent survey and evaluation of conservation status before consideration can be given to declaration as threatened fauna.
P4	**Priority 4 - Taxa in need of monitoring, considered to be adequately surveyed.** Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands.
P5	**Priority 5 - Taxa in need of monitoring, not considered threatened, but are subject to a specific conservation program.** Taxa which are not considered threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years.

Categories of Threatened Fauna Species (*Environment Protection and Biodiversity Conservation Act, 1999*)

Conservation Code	Category
Ex	**Extinct** Taxa not definitely located in the wild during the past 50 years
ExW	**Extinct in the Wild** Taxa known to survive only in captivity
CE	**Critically Endangered** Taxa facing an extremely high risk of extinction in the wild in the immediate future
E	**Endangered** Taxa facing a very high risk of extinction in the wild in the near future
V	**Vulnerable** Taxa facing a high risk of extinction in the wild in the medium-term
NT	**Near Threatened** Taxa that risk becoming Vulnerable in the wild
CD	**Conservation Dependent** Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classified as Vulnerable or more severely threatened.
DD	**Data Deficient (Insufficiently Known)** Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.

Appendix E Bayesian Belief Network Information

Appendix E Bayesian Belief Network Information

Incorporated within the Bayesian Belief model developed for the LWWS are management strategies and their feasibility. Using a BBN approach allows for dealing with uncertainty and can readily accommodate expert opinion. Updates of the model can readily occur as new information from research and monitoring becomes available and additional experts provide conceptual opinions (CALM, 2006). These graphical models provide a compact and simple representation of probabilistic data. They also depict the relationships among several variables and include conditional probability distributions that allow probabilistic statements about those variables to occur (Lauria, E. & Duchessii, P, 2004). A BBN describes the probability distribution of a set of variables by specifying a set of conditional independence assumptions together with a set of causal relationships among variables and their joint probabilities. Therefore, a BBN is a probabilistic inference engine that can answer queries, or “what-if” questions, about the variables that appear in the network (Lauria, E. & Duchessii, P, 2004).

Conservation management in agricultural landscapes involves the identification and prioritisation of assets based on clear articulation of underpinning values. The LWWS, a Ramsar listed site on the south coast of Western Australia, is threatened by salinity and flooding and the DEC’s management objective for the LWWS is to *“recover the existing (2003) water bird species richness and abundance and its living assemblages, to a near natural condition by the year 2030.”* The Natural condition of the LWWS is benchmarked at early 1980’s waterbird survey counts and hydrology records.

Individual lakes of the LWWS have water balance and waterbird habitat models which have demonstrated that the decline in vegetation condition and loss of waterbird habitat has resulted from hydrological change, particularly prolonged duration and increased volumes of inundation, and that degradation will continue if unmanaged (Massenbauer & Robertson, 2005). Uncertainty and analysis of the model’s components and outcomes give certainty that the hydrological targets are robust (Maunsell, 2007). Using the modelling uncertainty to give upper and lower bounds in the predicted water quantities required to meet hydrological targets enables achievement of the management goal for the LWWS.

Appendix F Lake Warden Wetland System Engineering Scoping Proposal

Lake Warden Wetland System

Engineering Scoping Proposal

Prepared by Tilo Massenbauer and Ryan Vogwill for the Department of Environment and Conservation, March 2007

Draft Version 3.

Reviewed by	Method	Date
Tilo Massenbauer, DEC Esperance	Direct	22/3/07
Ken Wallace, DEC Natural Resource Branch	Email	9/3/07
Ryan Vogwill, DEC Natural Resource Branch	Direct/email	9/3/07
Cliff Lloyd, DEC Natural Resource Branch	Email	2/3/07
Terry Walshe, University of Melbourne	Email/pers com.	15/2/07
Klaus Tiedemann, DEC Esperance District Manager	Email/direct	26/2/07
Alan Danks, DEC South Coast Regional Nat Cons Coord		
Kim Kershaw, DEC Albany Nature Cons Coord		

Government of Western Australia
Department of Environment and Conservation

Stakeholder Consultation and Endorsement

Internal Stakeholders	**Name**	**Outcome**
Catchment Conservation Officer	Tilo Massenbauer	
District Nature Conservation Officer		
Esperance District Manager	Klaus Tiedemann	
Regional Nature Conservation Officer	Alan Danks	
Regional Manager	John Watson	
Natural Resource Branch	Ken Wallace	
Director of Nature Conservation	Gordon Wyre	
External Stakeholders		
Conservation Commission		
Environmental Protection Authority		
Esperance Shire Council	Michael Archer	
Department of Planning and Infrastructure		
Department of Water	Naomi Arrowsmith	
Main Roads Department	Gerome Gohe?	
Department of Agriculture and Food	Brendan Nicholas	
Lake Warden Project Management Committee	Claudia Hadlow	
Quarry Road Flood Group	Eric Temple	
Local Aboriginal Community		
Esperance Regional Forum	Chubb Witham	
South Coast Regional Information Planning Team	Rob Edkins	

Table of Contents

1.0 Aim and Introduction

The aim of this scoping document is to overview the technical, environmental, social and economic issues relevant to the Lake Warden Wetland System (LWWS) engineering proposal. The LWWS is listed as a Wetland of International Importance under the Ramsar Convention, and is located near the coastal town of Esperance on the south coast of Western Australia, approximately 700 km south east of Perth. The Lake Warden Catchment (LWC) was recognised as a Natural Diversity Recovery Catchment in 1996 under the Western Australian Salinity Action Plan.

DEC's management objective for the LWWS is to "recover the existing (2003) water bird species richness and abundance and its living assemblages, to a near natural condition by the year 2030". Natural condition is benchmarked at early 1980's waterbird survey counts and hydrology records. The actions proposed in this document are designed to substantially contribute to achieving this objective.

The waterbird and riparian vegetation values of the LWWS are under immediate threat from rising water tables and excessive inundation. These physical changes result from the broadscale clearing of perennial vegetation in the catchment, and its replacement with an agricultural system based largely on annual plants. Recent efforts have increased the number of perennial crops (blue gums, pines etc) in the catchment but the benefits of these landuse changes will not occur rapidly enough to prevent further, possibly irreparable, degradation of LWWS. Targeted revegetation of the LWC with perennial revegetation and engineering dewatering of the LWWS are needed to ameliorate the impacts of the altered hydrology.

This proposal focuses upon Lakes Wheatfield, Woody, Windabout and Warden (Figure 1). Research, modelling and uncertainty analysis have been undertaken over an eight year period to understand the hydrological system affecting the LWWS and establish priorities for management action. The next section briefly outlines this work, and sets the context for the engineering proposal that follows.

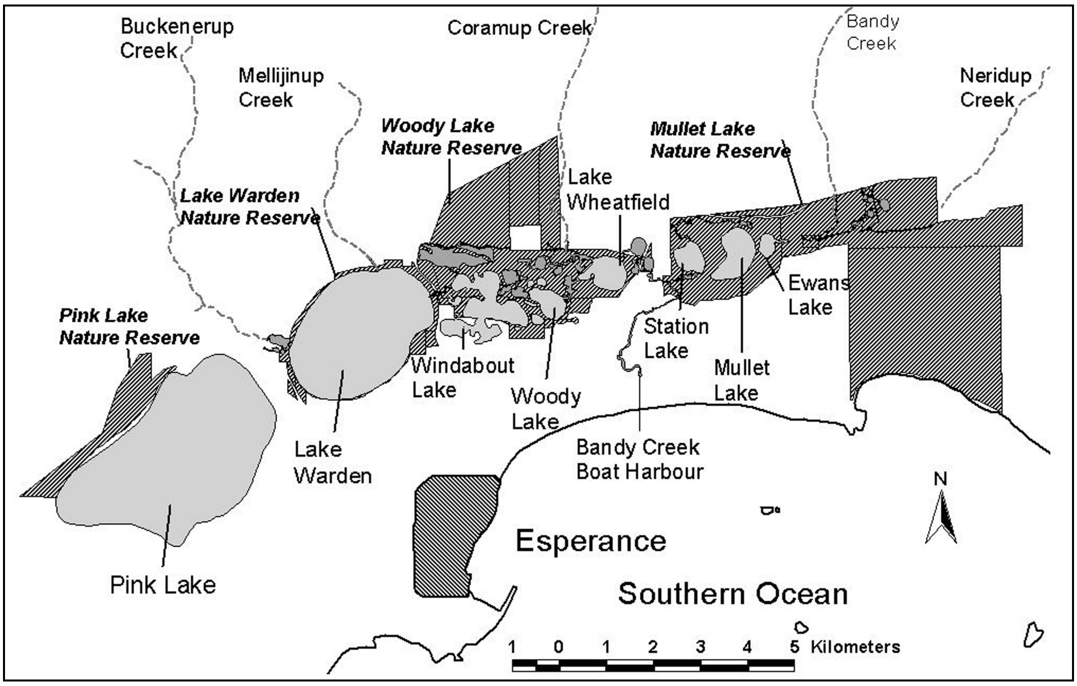

Figure 1. Lake Warden Wetland System

2.0 Background

Water balance and waterbird habitat models have been developed for individual lakes of the LWWS. These models have demonstrated that the loss of vegetation condition and waterbird habitat has resulted from hydrological change, particularly prolonged duration and increased volumes of inundation, and that degradation will continue if unmanaged (Massenbauer and Robertson 2005). Uncertainty and sensitivity analysis of the models' components and outcomes give certainty that the hydrological targets are robust (Maunsell/AECOM 2007). The modelling uncertainty is used to give upper and lower bounds in the predicted water quantities required to meet hydrological targets, and thus achieve the management goal for the LWWS.

Revegetation is an important element of long-term salinity management for the LWWS. However, a Bayesian Belief Network (BBN) (which combines the available scientific analysis and uses expert judgement to define linkages and fill knowledge gaps) prepared for Lake Warden and Lake Wheatfield has been used to assess the probability of meeting biological targets. The outcome of this analysis reinforces that engineering is essential to conserve the biodiversity values of the LWSS (Walshe et al 2007). The results for both the Lake Warden and Wheatfield BBN are given in Appendix 2 and summarised in Table 1 below.

Table 1. Summary of the results from the BBN for both Lakes Warden and Wheatfield

	Probability of meeting Resource Condition Targets			
	Lake Warden		Lake Wheatfield	
	Fringing Veg	Water Birds	Fringing Veg	Water Birds
Target revegetation only	1-4%	2-7%	3-8%	2-9%
Targeted reveg. and Alternative 5	75-79%	69-74%	62-73%	73-79%

3.0 Engineering Proposal

A number of engineering options have been considered to reduce excess water in the lakes system. These options are described in Table 2, and graphically represented in Figure 2. The options include a range of gravity and pumping systems to meet biological water regime targets. These engineering options have been combined into five remediation alternatives (see Tables 2a and 2b and Figure 2). These alternatives have then been evaluated, costed and a preferred option selected.

Selection of the preferred option was based on:

a. determining the minimum volume of water that needed to be removed from the lakes to achieve the management target;
b. minimising the risk of social and environmental impact; and
c. the most cost-effective alternative for achieving (a).

From this analysis, the preferred combination is Alternative 5. For more information on this process or any of the components and alternatives, see Maunsells/AECOM, (2007).

Figure 2. Five Components of Engineering Works Proposed in the LWWS

Table 1. 1a (upper) Components and 1b (lower) alternatives considered for the implementation of Engineering Components

Component	Description	Options
1	**Gravity feed methods for lowering the level of Lake Wheatfield.**	**1A -** The concept of conveying water via a pipeline from the south east corner of Lake Wheatfield along Bandy Creek Road and disposing into Bandy Creek at the Bandy Creek Bridge.
		1B - The concept of conveying water via a constructed waterway from the Lake Wheatfield outflow to the Bandy Creek Boat Harbour.
2	**Spillway structure for installation at the head of the open-channel works (Component 1B) at Lake Wheatfield.**	Concept design for lowering water levels of Lake Wheatfield at 5 to 10 cm increments into the waterway (Component 1B)
3	**Upgrade capacity of the existing Bandy Creek weir structure to manage increased flows and volumes.**	Review the capacity of the Bandy Creek Harbour weir to manage increased disposal flows without causing back flooding into Station Lake.
4	**Pumping methods for lowering the level of Lake Warden.**	**4A** - Pumping main from the north east of Lake Warden, along the Lakes Road (reserve), discharging into the Lake Wheatfield constructed waterway (i.e. Component 1B).
		4B - Pumping main from the south east of Lake Warden, on a route through the Esperance Golf Course, along Windabout Way, Tranquil Drive and Bandy Creek Road, discharging into Bandy Creek at the Bandy Creek Road Bridge.
		4C - Pumping main from the south west of Lake Warden, along the South Coast Highway, Harbour Road, and un-gazetted port roads, discharging via the brine discharge line for the proposed Esperance Desalination Plant.
		4D - Pumping main from the south west of Lake Warden, along the Esperance-Coolgardie Highway, South Coast Highway, Harbour Road, and un-gazetted port roads, discharging via the brine discharge line for the proposed Esperance Desalination Plant.
		4E - Pumping main from the south east of Lake Warden, on a route through the Esperance Golf Course, Claire Road (extension / fire-break), Fisheries Road, Goldfields Road and Daw Drive, discharging into Esperance Bay at the Bandy Creek Boat Harbour.
5	**Flow control system on the culvert structure at the Coolgardie– Esperance Highway.**	In order to achieve hydrological targets for both Lake Warden and Windabout, they need to be temporarily separated using a culvert flow control system.

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Component 1B Component 2 Component 4A Component 5	Component 1A Component 4B Component 5	Component 1A Component 4C Component 5	Component 1A Component 4D Component 5	Component 1A Component 4E Component 5

Note that the colours in Table 1b correspond to those in Figure 1

3.1 Detail of Recommended Option

Details of Alternative 5, the recommended engineering option are outlined below as background to the environmental impact assessment that follows.

Component 1A – Siphon from Lake Wheatfield

At Lake Wheatfield it is recommended that a 900m siphon system be installed to discharge water from Lake Wheatfield at Bandy Creek Bridge at a rate of 80-90 litres per second.

Figure 3. Component 1 Option A – Siphon Pipe Alignment

Component 4E (Pumping Lake Warden)

The component 4E pipeline runs approximately 6.9km from Lake Warden on a route through the Esperance Golf Course, then along Claire Road (extension / fire-break), Fisheries Road, Goldfields Road and Daw Drive, discharging into Esperance Bay at the Bandy Creek Boat Harbour at 125 litres per second.

Figure 4. Component 4 Option E - Pipe Alignment

Component 5 (Coolgardie Esperance Highway culvert flow management)

Installation of a 'stop-logs/gate' system on the Lake Windabout side of the culvert structure that joins the lake with Lake Warden. This is expected to adequately reduce over flows into Lake Warden from the up gradient part of the LWWS. Modifications at the headwalls of the culvert structure are likely to be required to install the 'stop-logs' system. This is an integral component of Alternative 5 and in conjunction with components 1A and 4E will facilitate meeting lake depth targets for Lake Warden.

Plate 1. Existing Culvert Structure on Coolgardie-Esperance Highway

Plate 2. Standing water upstream of the Culvert Structure on Coolgardie-Esperance Highway

3.2 Uncertainty and sensitivity testing

Given the values at risk, and the cost of the proposed engineering, model uncertainty and sensitivity were investigated, and used to optimise scenarios (Massenbauer 2006). The effectiveness of the models used to set hydrological targets for management decision-making purposes is dependent on reliability of input data and sensitivity of simulation results to cumulative and compound effect of errors in the data.

Maunsell applied this methodology to compute upper and lower error bounds for the component input data and then used this to assess uncertainty in the optimal lake level targets. A sensitivity analysis was completed and results plotted to produce overlays of observed, target and modelled (under various management scenarios) lake levels (incorporating upper & lower error bounds) for Lakes Warden, Windabout, Woody and Wheatfield (see Appendix 1 figures 1 to 4).

Predictive simulations were run (incorporating uncertainties) for Alternative 5 and a number of important inferences can be drawn from the modelling to define procedures for the operating the flow control structure (component 5) between the two lakes (Maunsell/AECOM, 2007). These inferences are summarised as follows:

- The sensitivity analysis demonstrates that the models are not sensitive to the effects of cascading or compounding errors in components of the water balance used as inputs. In every case the lower and upper simulation results closely replicate the 'shape of the 'calibrated' model.

- The model effectively simulates seasonal fluctuations in lake level, however extreme events, particularly high magnitude flooding events but also low levels due to drought or extended higher than average evaporation rates. These types of events are in general not well replicated even after taking into account error bounds in the simulation results. This is evident particularly as a result of an intense isolated rainfall/flooding event – such as that which can result from a remnant cyclonic storm. This is not unusual given that these are not able to be incorporated in the water balance model.

- Simulations performed under scenario Alternative 5 produce significantly different positive results to the 'calibrated' model and observed lake levels. In these simulations lake levels in the LWWS can be reduced and/or maintained within the optimal range inside a 3-year period. This is however dependant on no flooding events. Uncertainties in the input data have little impact on outcomes of the simulation under the scenario representative of Alternative 5.

- Appendix 1 figures 3, 4 and 5 suggest that pumping will require careful management to ensure that levels in Lakes Warden, Woody and Wheatfield do no drop below the minimum optimal threshold level at the end of summer.

Additional to the uncertainty analysis the Bayesian Belief Network (BBN) analysis for Lake Warden and Lake Wheatfield was used to determine the probability of meeting biological targets (Walshe *et al.*, 2007). The results for both the Lake Warden and Wheatfield BBN are given in Appendix 2 and summarised in Table 1 above.

The results from both analyses clearly indicate the need to implement engineering option Alternative 5 to meet the LWWS asset objective by the year 2030. The key biological value for Lake Warden is the wader waterbird number targets. The do nothing option of not implementing engineering, whilst undertaking some degree of targeted revegetation for Lake Warden, results in an extremely low likelihood of meeting resource condition targets.

In conclusion, engineering Alternative 5 has the greatest likelihood of achieving and maintaining dewatering targets for Lakes Warden, Windabout, Woody, and Wheatfield based on the modelling uncertainty analysis, and BBN. The alternative is also the most cost effective with minimal risk of offsite impacts. Doing nothing will result in a greater than 90 per cent chance of significant wetland values being lost within the next 25 years.

3.3 Budget Estimate

Budget estimates undertaken for Alternative 5 Engineering Option cost break down by Maunsell are as follows.

Phase 1

Component 1 Option A – Lake Wheatfield to Bandy Creek bridge siphon pipe line

Item		Qty	Rate ($)	Cost ($)
Construction / Installation:				
Priming pumpset system				$80,000
Valves, control & misc. pipe components				$30,000
Inlet / Intake Structure				$50,000
Pipe Supply & Lay 860m DN400 PN12.5 PE100	m	860	280	$240,000
Access Road (80m)				$5,000
OH powerline extension & step down transformer				$50,000
Total C/I:				**$455,000**
Annual Operating & Maintenance				
Total O&M	pa			$5,000
NPV (30 years @ 7.1% discount rate & 2.5% inflation)				-$590,000

Phase 2

Component 4 Option E - Lake Warden to Bandy Harbour pumping pipe line

Item		Qty	Rate ($)	Cost ($)
Construction / Installation:				
Pumpset (e.g. skid-mounted Gorman-Rupp T-Series 10" 75kW, 1450 RPM, in duplex stainless steel) with mesh/acoustic enclosure.				$110,000
Pump installation (basic civil work), enclosures, hoses, controls and cables				$95,000
Intake Structure				$60,000
Total Pump:				$265,000
Pipe Supply & Lay 6900m DN400 PE100 PN10	m	6900	280	$1,932,000
Valves, control & misc. pipe components				$80,000
Total Pipe:				$1,606,000
Access Road (250m)				$15,000
OH powerline 250m extension (for electric drive pumpset) & step-down transformer				$65,000
Total C/I:				**$2,357,000**
Annual Operating & Maintenance				
Total O&M (energy usage: ~12.5c/kWh x 18 hours x 345 days x 75kW)	pa			$70,000
NPV (30 years @ 7.1% discount rate & 2.5% inflation)				-$3,581,000

Construction costs for component 5 is likely to be less than $50,000 with the system being 'retrofitted' to the existing culvert structure without major modification to headwalls or road surface in consultation with the Main Roads Department.

The following budget summary is indicative of upfront capital cost requirements to implement the three components of engineering Alternative 5 and does not include ongoing costs as outlined in the previous tables, which equate to $75,000 per annum.

Table 3. Summary establishment capital costs of Alternative 5

Component Description	Cost Estimate $
Stage 1	
Component 1a – Lake Wheatfield to Bandy Creek bridge siphon pipe line	455,000
Component 5 – Lake Windabout to Warden culvert flow management	50,000
Subtotal	**505,000**
Stage 2	
Component 4e – Lake Warden to Bandy Harbour pumping pipe line	2,357,000
Total for Stage 1 and 2	**2,862,000**

Component 1A and component 5 would require implementation as the first stage of the project. Component 4E would be stage two of the project. These estimates are suitable only for the purpose of broad comparison and preliminary setting of budgets. Construction cannot proceed without an approved Environmental Impact Assessment, further detailed engineering, the production of drawings, tender documents and the appointment of a contractor. An appropriately skilled group/person will be required to oversee construction activities and manage project delivery on the ground. Operationally the systems proposed require specialist skills in terms of inspection, maintenance and repairs.

It is important to contextualise the likelihood of success versus the quantity of investment required to engineer Lakes Warden and Wheatfield. As outlined in the BBN analysis, there is a 62 to 73 per cent likelihood of achieving biodiversity targets for Lake Wheatfield with a siphon system costing approximately $455,000. Also there is a 69 to 74 per cent chance of success resulting from pumping Lake Warden at an estimated establishment cost of $2,400,000. The consequence of not undertaking engineering results in a greater than 90 per cent chance of totally degrading the LWWS's biological and ecosystem service values. It must be noted that a siphon (much lower cost) system is not feasible for Lake Warden due to the topography, physics and distances involved for a disposal site.

3.4 Potential Resource Co investment Opportunities

The large capital investment required to implement the engineering works can be simplified by staging the works and establishing co-investment partnerships with relevant stakeholders. The co-investment of resources may include:

- Internal DEC funding sources such as Salinity Strategy funds, and the Biodiversity Conservation Initiative (Save our Species).
- External State Government funding sources such as flood mitigation grants or environmental schemes.
- External Commonwealth funding relating to the Ramsar Convention and mitigating flood impacts on the Esperance community.
- External regional natural resource management funding from groups such as the South Coast Regional Initiative Planning Team (SCRIPT)
- Private sector investment from local, regional, national and international companies.

4.0 Environmental Impact – Ecosystem Values

The anticipated level of investigation and the potential management issues associated with the project are detailed in Appendix 3, however they can be summarised using the concept of ecosystem values and services, Wallace *et al.*, (2003). Brief definitions of the ecosystem values are given below and the potential changes therein summarised in Table 4. Ecosystem values are a useful framework to look at the various benefits and losses of restoring the ecology of the LWWS to a more natural state.

- *Ecosystem service values*, which contribute to maintaining the catchment and downstream environment. Flood mitigation, nutrient stripping, and salt storage are priority ecosystem services in the catchment.
- *Intrinsic/spiritual/philosophical values* of biodiversity resources are a strong driver for biodiversity conservation at the State and local level. From the perspective of the catchment community, the local desire to maintain local biodiversity for the strong sense of place it provides and its contribution towards people's spiritual and physical well-being were identified as important.

- *Opportunity values* of biodiversity are those that provide a range of potential future opportunities. For example, the potential for future use of genetic resources and opportunities for water use and salt harvesting were identified for BMNDRC.
- *Knowledge and educational values* including a focus on scientific investigations that advance our knowledge of the management of salinity and contribute to education and training.
- *Leisure/recreational values* include opportunities for tourism or recreational use by locals for activities such as bushwalking, picnicking and bird watching.
- *Consumptive use values* are plants and animals harvested for domestic use that do not pass through a market and are not sold or purchased. For example, the use of kangaroos for meat and the use of plants for seed collection and sandalwood.
- *Amenity values* contribute to aesthetics and scenic values. Catchment landholders place a high value on maintaining the biodiversity of the catchment to deliver aesthetic and scenic values. These contribute towards maintaining a sense of place.
- *Productive use values* are commercially harvested plants and animals. For example biodiversity resources in the catchment are used to provide materials such as gypsum, road base gravel and water for stock.

Table 4 - Environmental Impact Assessment of Proposed Engineering – On-site and Downstream Ecosystem Values

Value	**Key elements that may be affected**	**Predicted impacts**
Ecosystem service values	Flood mitigation, nutrient stripping, salt storage	The proposed works will improve the all three values, particularly flood mitigation, an important service for the Esperance township and neighbouring properties to the LWWS. Revegetation in the catchment will deliver greater nutrient stripping and but both revegetation and the proposed engineering will increase safe salt storage.
Intrinsic/spiritual values	A strong driver for biodiversity conservation at the State and local level. From the perspective of the catchment community, the desire to maintain biodiversity for the sense of place it provides and its broader contribution towards people's spiritual and physical well-being were identified by the Catchment Steering Committee as important.	Restoration in condition of fringing vegetation and return of larger bird numbers will contribute strongly to the intrinsic/spiritual values of the area. Further degradation of the system will strongly degrade these values. The impacts to this ecosystem value due to construction of pipelines and out flow structures are anticipated to be minimal. There may be some minor changes in the hydrology of Lower Bandy Creek and the Boat Harbour but given the highly altered nature of these areas it is unlikely to degrade this value.
Knowledge and educational values	LWSS is used extensively as a school education resource, and as a resource for developing and testing salinity management techniques	Continued degradation will damage these values, the proposed engineering will help protect these values. The engineering works will themselves form a useful scientific study that will contribute to salinity management elsewhere.
Leisure values	LWSS provides a valuable local resource for tourism, bushwalking, picnicking, bird watching, canoeing, sailing and windsurfing in designated areas	There will be strong benefits and minor losses in terms of the impact of the proposed engineering works on leisure and recreational values. The reduction in water levels may negatively impact on the ability to use the LWWS for water sports such as water skiing which require deeper water than the natural hydroperiod of the lakes. Maintenance and increase in water bird numbers will positively impact on amateur ornithology, picnicking and bushwalking type activities

		The impacts to this ecosystem value at the out flow are anticipated to be minimal to non existent. Minimisation of impacts to leisure values will be incorporated as part of the detailed design phase. The pipelines will be buried so there should be no impact along their lengths.
Amenity values	Aesthetic (scenic) values of catchment are highly valued, also see sense of place comments under intrinsic/spiritual values. The Esperance Community strongly values the areas visually stunning landscapes which are made up of the Cape Le grand National Park, the Recherché Archipelago, white sandy beaches, turquoise water, granite headlands and the coastal wetland floodplain all visible from local lookouts. The degrading health of the LWWS impacts on these values is amplified by the perceived pristine surrounding landscapes and the close proximity of the LWWS to the Esperance town site.	These values at the LWWS will be strongly positively affected by proposed engineering. Some minor local deterioration in amenity values may occur due to construction of the pipelines and outflow structures but these are anticipated to be minor, reversible and will be minimised.
Consumptive use values	Plants and animals harvested for domestic use that do not pass through a market and are not sold or purchased. For example, the use of kangaroos for meat and the use of plants for seed collection and sandalwood.	Historically the LWW'S was an important game reserve for duck shooting and recreational brim fishing. Both of these activities are no longer deemed compatible with the conservation values of the Nature Reserves. Brim fishing still occurs on the LWWS outside of the Nature Reserve areas. Local fire wood and seed collection of Yates and paper barks on wetlands located on private property still part of the LWWS takes place and would be enhanced by reducing prolonged flooding of these areas.
Productive use values	Commercially harvest of natural resources. Only salt harvesting from Pink Lake comes into this category.	The salt mining in Pink Lake is being impacted by increased fresh groundwater input diluting brines. The reduction in Lake Warden water levels will reduce groundwater throughput into Pink Lake and this will improve productivity for salt mining.
Opportunity values	Conservation of natural resources to provide a range of the above values in the future, but not currently accessed. Maintaining genetic resources for future productive or consumptive benefit are considered to be the primary opportunity values protected by the conservation of LWSS.	Proposed engineering will have a strongly positive impact on these values.

5.0 Project Timeline

Activity	Time Period								
	2007			2008				2009	
	Apr-June	July-Sept	Oct-Dec	Jan-March	Apr-June	July-Sept	Oct-Dec	Jan-March	Apr-June
Internal DEC Review of scoping document									
Stakeholder EIA Liaison for Phase 1 and 2									
Open Community Forum of scoping document									
Identify funding partnerships for phase 1 and 2									
Prepare and award EIA Contract									
Completion of EIA report									
Engage EPA for level of assessment									
Phase 1 Siphon and culvert management									
• Consolidate funding partnerships									
• Contract design and supervision									
• Implement design and supervision									
Monitor and maintain phase 1.									
Phase 2 Lake Warden Pumping									
• Survey in appropriate pipeline route									
• Consolidate funding partnerships									
• Contract design and supervision									
• Implement design and supervision	Undertake prior to June 2010								
Monitor and maintain phase 2.	Undertake on an ongoing basis during and post implementation								

Grey blocks represent anticipated period of implementation of activity.

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Appendix 1 – Engineering scenario hydrograph error ranges

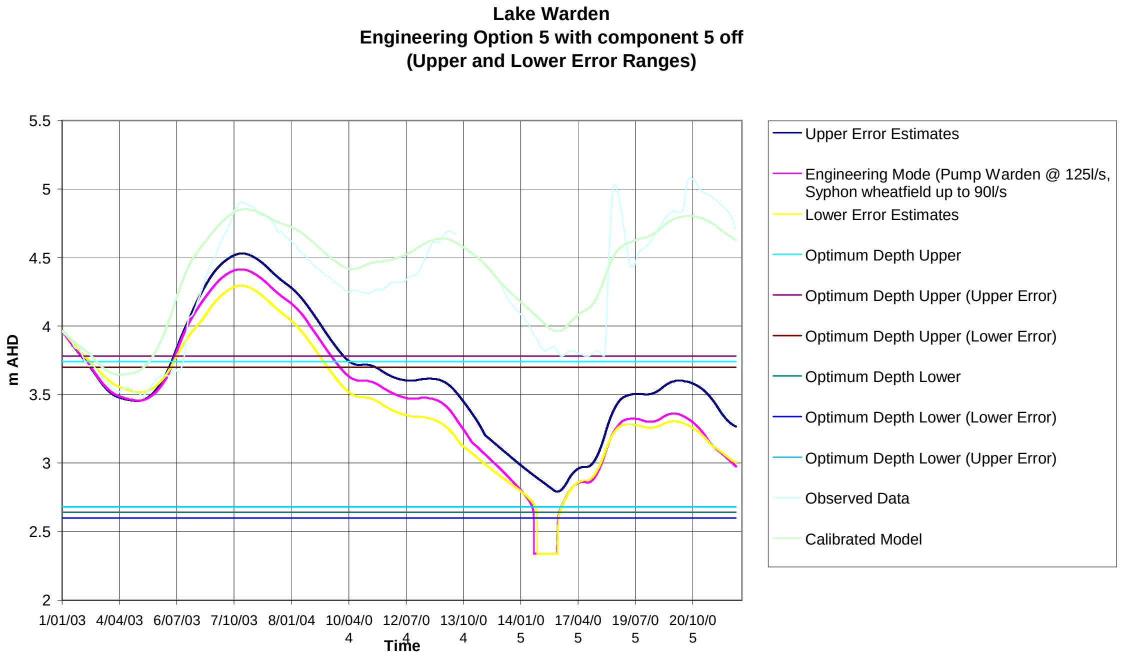


Figure 1 Lake Warden (Engineering Alternative 5 –no simulation of Component 5)

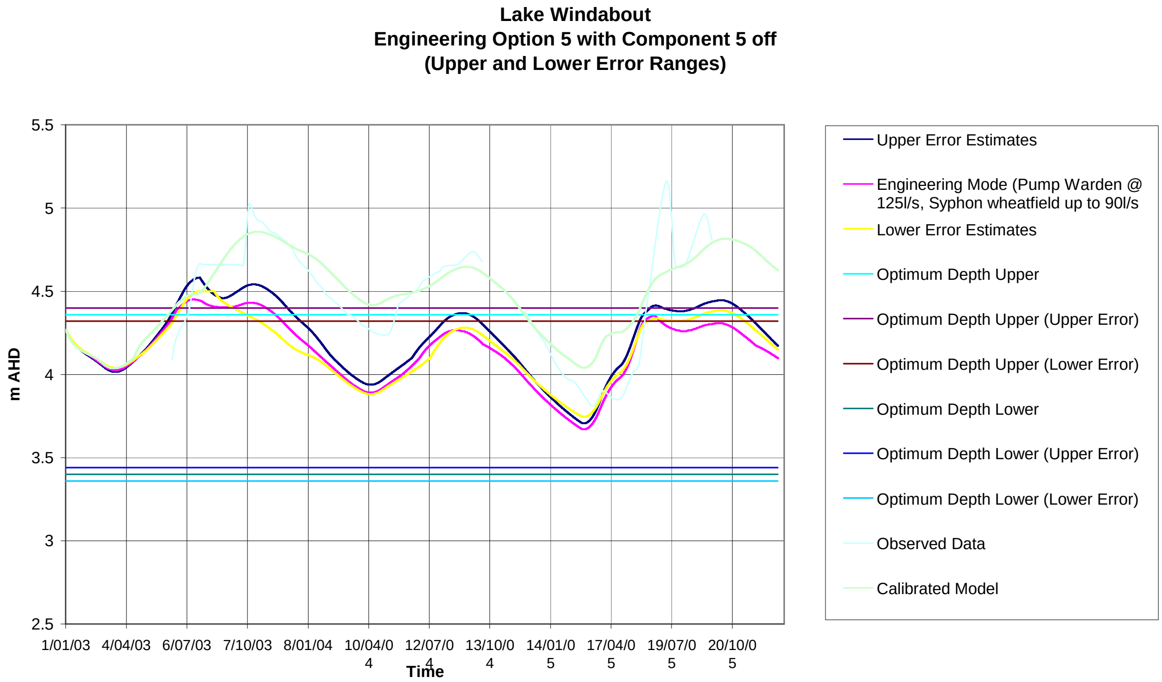


Figure 2 Lake Windabout (Engineering Alternative 5 –no simulation of Component 5)

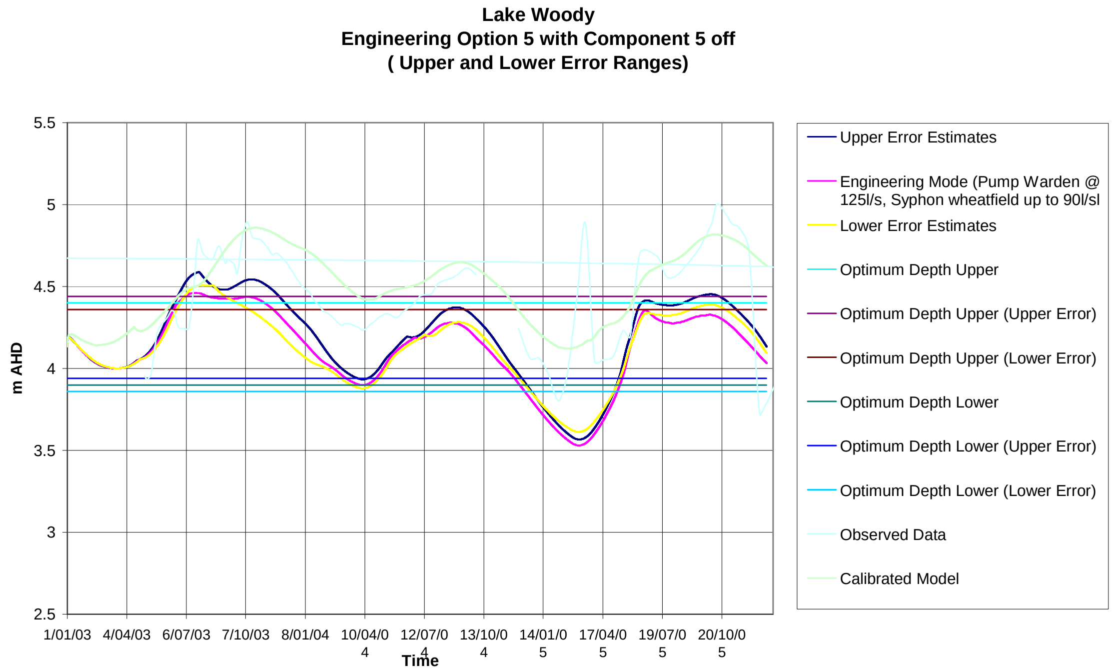


Figure 3 Lake Woody (Engineering Alternative 5 –no simulation of Component 5)

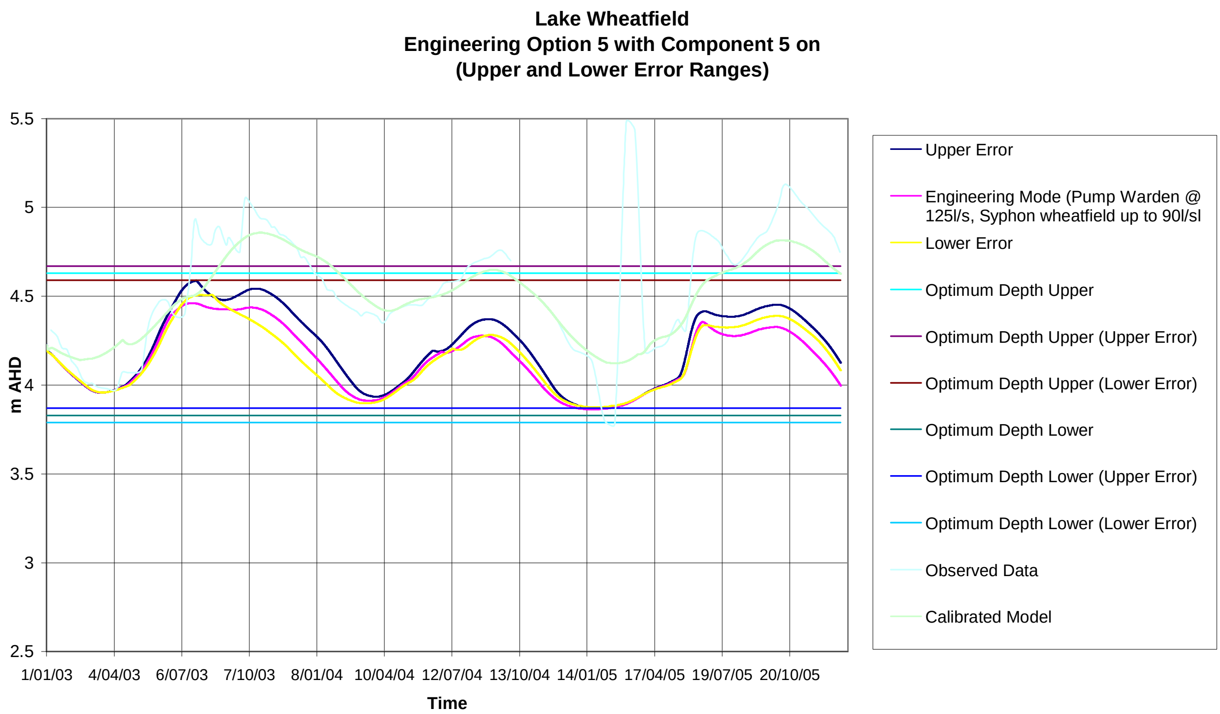


Figure 4 Lake Wheatfield (Engineering Alternative 5 – no simulation of Component 5)

Appendix 2 - Bayesian Belief Network Summary Tables

The management states of the BBN relating to meeting the both Lake Warden and Wheatfield 25 year biodiversity objective are as follows:

- Engineering with or without Alternative 5
- Strategic perennial revegetation of a proportion of the 28,000 ha target landscape:
  - o Low = 0 - 40 per cent
  - o Medium = 40 – 80 per cent
  - o High = > 80 per cent
- Regional Future climate change prediction of a 5 per cent increase in summer rainfall.
- Favourable external pressures assumes little impact from international avian bird flu, culling of wild populations, destruction of migratory habitat and national/state drought

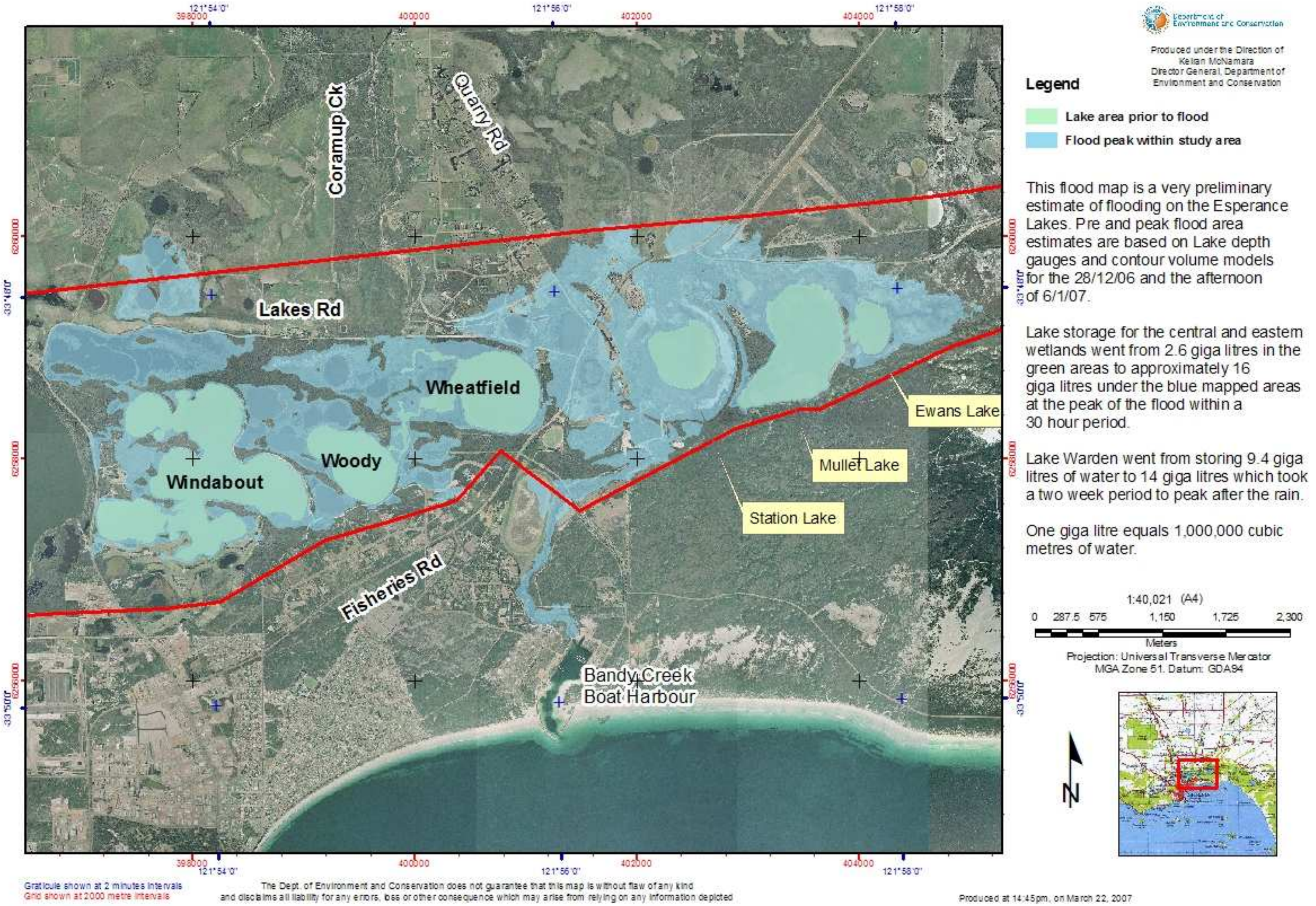
Lake Warden Summary BBN

Management Scenario		Chance of wader abundance			Chance of vegetation shelter	
Engineering Option	**Perennial Cover**	**High >8000**	**Medium 2000 - 5000**	**Low <2000**	**Degraded PFC 0-35%**	**Good PFC >35%**
Without Engineering	Perennials - low	0.8%%	15%	84%	98%	2%
	Perennials - medium	0.9%	16%	83%	97.6%	2.4%
	Perennials - high	4.4%	16.5%	79%	93%	7%
With Engineering	Perennials - low	69%	13%	18%	25%	75%
	Perennials - medium	72%	12%	16%	23%	77%
	Perennials - high	74%	12%	14%	21%	79%

Lake Wheatfield BBN

Management Scenario		Chance of diver abundance			Chance of vegetation shelter	
Engineering Option	**Perennial Cover**	**High >4000**	**Medium 1500 - 4000**	**Low <1500**	**Degraded PFC 0 50%**	**Good PFC > 50%**
Without Engineering	Perennials - low	3%	14%	83%	98%	2%
	Perennials - medium	4%	16%	80%	98%	2%
	Perennials - high	8%	18%	74%	91%	9%
With Engineering	Perennials - low	31%	31%	38%	27%	73%
	Perennials - medium	34%	35%	31%	24%	76%
	Perennials - high	36%	37%	27%	21%	79%

Appendix 3 - Before and after 2007 flood water volume storage comparison as a measure of ecosystem service.



Appendix 4 – Components of Environmental Impact Assessment
Potential Issues at the Lake Warden Wetland System.

Potential Management Issue	Location Specific Comments		Monitoring/Investigation Requirement and/or Performance Measures
	Phase 1 - Wheatfield	Phase 2 - Warden	
Erosion and particulate transport	Siphon inflow needs to be designed to ensure minimum of sediment and particulate transport. This will be more difficult than for a pump as if substantial air is drawn in then siphon will stop and require re-priming. The requirement for some level of filtration needs to be investigated to minimise weeds and sediment from being transported to disposal sites.	Pump inflow needs to be designed to ensure a minimum of sediment and particulate transport. The requirement for some level of filtration should also be investigated to minimise organic weeds and the unlikely issue of unacceptable quantities of fine sediment being transported to disposal sites.	Bathymetric levels in close proximity to the inflow should be measured annually to assess erosion levels. Potential weed transport risk should be assessed prior to project coming online but is considered very low risk.
PASS	Potential Acid Sulphate Soil (PASS) issues could cause ecological harm both in situ (at lakes) and at Bandy Creek disposal site (dealt with below). Due to permanency of water bodies, levels of primary production, increased water levels and changes in hydro-period there is potential for PASS to be present as organic rich sulphide bearing sediments, in the Lake system. When exposed to air oxidation may lower soil/water pH and increase acidity. The area is however also likely to contain abundant buffering material in the form of carbonates. This needs to be investigated, with particular attention paid to those areas of lakes which are <u>above</u> current dewatering target levels but including the core of the lakes where it is more likely PASS has been deposited.		Sediment PASS and buffering potential needs to have a sufficiently detailed investigation. This level will depend on the presence and nature of PASS present in preliminary investigations. Lake water pH, acidity and alkalinity should reported initially monthly then biannually (at water level high and low) for lakes and possibly very shallow groundwater sites (pore water in the lake bed sediments). Ecological water requirements (EWR's) also need to be developed for pH and acidity then compared to monitoring data.

Water Level and Seasonality	Lake levels and hydroperiod's in the LWWS will obviously be altered by this proposal and care must be taken to not dewater the lakes excessively or alter natural seasonal trends to the detriment of the ecology. Some biota could be negatively affected by this directly but it could trigger pH decrease (if PASS is present) or release phosphorous by the disturbance of lakebed sediments if exposed or excessively bioturbated.	Vegetation condition and distribution of aquatic vegetation (including algae) should be monitored and correlated with water levels and bird numbers and compared to EWR's. Lake level should be monitored monthly or more frequently.
Lake Water Quality and Seasonality	Lowering of lake levels will marginally increase local groundwater inflow and possibly change lake chemistry or seasonality (ratios and loading of common anions, cations, nutrients etc) depending on timing of pumping/discharge, rainfall and inflow.	Water quality changes (if detected) correlated with species richness, abundance and distribution of micro and/or macro-invertebrates, water birds, fringing vegetation and aquatic vegetation across wetland suite and compared to EWR's. Changes in operating strategy may be required. Water quality should be reported biannually at lake highs and lows.
Social Issues	Potential social issues associated with returning the LWWS to more natural hydroperiod and water levels will be focused on non-indigenous rather than indigenous issues. The traditional land holders are supportive of returning LWWS to a more undisturbed state. However there may be issues with non-indigenous cultural values (recreational) being effected as lower levels may restrict water skiing, kayaking etc. However eco-tourism activities such as bird watching will be positively influenced.	Social impact study in collaboration with key stakeholders and social water requirements developed.

Potential Issues at the Disposal Sites

Potential Management Issue	Phase 1- Bandy Creek	Phase 2 - Bandy Creek Boat Harbour	Monitoring/Investigation Requirement and/or Performance Measures
Erosion and particulate transport	Discharge into the upper part of Bandy Creek system (up gradient of the weir in the fluvial dominated part of the system) has some limited potential to create negative impacts from erosion, sedimentation and potential weed transport. Erosion and sediment control measures will be required as part of the engineering brief.	Discharge into the Bandy Creek Boat Harbour is not anticipated to create ecological harm. However some erosion and sediment control measures as part of the engineering brief will be required to ensure this.	Erosion and sediment control measures need to be included in the engineering design brief. Undertake a weed risk assessment.
Low pH-high acidity water from PASS oxidation	There is potential for discharge of water rich in ASS oxidation products into the upper Bandy Creek system to negatively impact the ecology. Elevated levels of metals and acidity may cause local (to outflow) and downstream impacts to ecologies and infrastructure. This is not anticipated.	The outflow of this type of water at Bandy Creak Boat Harbour is unlikely to negatively impact due to relative volumes and high amount of flushing in a marine setting. The large amount of carbonate and bicarbonate in sea water and sediments will also provide a high buffering/neutralizing capacity.	Develop pH and metal content based EWR's. Biannual water quality monitoring and ecological condition assessment should be undertaken with monitoring data correlated to EWR's.
Water Level and Seasonality	The increased water input into the upper Bandy Creek System is unlikely to have any impact due to	Not anticipated to be an issue in a tidal dominated system such as Bandy Creak Boat Harbour.	Water level based EWR's developed for the disposal site to weir section of Bandy Creek developed and used as criteria levels. Breaches will trigger

	the volume of siphon discharge verses the volume of water already moving through the system. There may however be some decrease in flow due to reduction in Lake Wheatfield water levels and the potential impact of this should be assessed.		changes in operating strategy or remedial measures. Continuous water level measurements should be undertaken for 2-5 years in proximity of the outflow then reassessed. Modelling of likely water levels under a range of pumping/flow scenarios should also be undertaken for a risk assessment.
Water Quality and Seasonality	There is potential for discharge of water rich in nutrients or contaminants into the upper Bandy Creek system to negatively impact the ecology. Elevated levels of nutrients of contaminants may cause local (to outflow) and downstream impacts to ecologies and infrastructure.	Not anticipated to be an issue in a tidal system such as Bandy Creek Boat Harbour but periodic inspection for iron staining and bio-fouling, nutrient related algal blooms in close proximity of the outflow etc would be prudent. An assessment of the potential for this to negatively impact on the near-shore marine ecology should be completed with a focus on seagrass.	Develop water quality based EWR's and biannual monitoring of water quality for the Bandy Creek disposal site. Ecological condition assessment should be undertaken with water quality monitoring and this data compared with EWR's.
Social Issues	Some water sport activities occur in the section of Bandy Creek downstream of the disposal site and upstream of the weir.	The pipeline disposal site at bandy harbour is not to disturb access to recreational sites.	Social water requirements for the disposal site to weir section of Bandy Creek need to be developed and used as criteria level to trigger changes in operating strategy or remedial measures. Monitoring of water levels and quality should be undertaken at peak and low flows.

Potential Issues with the Pipeline Route and Operations.

Potential Management Issue	Phase 1 - Wheatfield	Phase 2 - Warden	Monitoring/Investigation Requirement
Vegetation Disturbance	Some vegetation disturbance will be necessary, hence a vegetation clearing permit will be required. There is however some scope for variations in pipeline route to reduce any issues which may occur such as encountering DRF and Priority species etc.	Some vegetation disturbance will be necessary, hence a vegetation clearing permit will be required. There is however good scope for variations in pipeline route to reduce any issues which may occur such as encountering Declared Rear Flora (DRF) or Priority species etc.	Standard Department of Environment and Conservation vegetation clearing procedures will apply.
PASS and ASS	Pipeline routes, once finalised should be assessed for Acid Sulphate Soils (ASS) and PASS. If ASS or PASS are detected all material removed must be immediately suitable disposed of as per best practise, i.e. typically in a limestone quarry if available.		
Pathogen Risk	There is potential for machinery used in the construction of pipelines and pumping stations to encounter and spread diseases such as *Phytopthora cinnamomi, P. citricola* and *P. megasperma*.		Departmental best practice wash down and decontamination procedures will be applied.

Social impacts	The level of noise produced for the construction of a siphon priming station and pipeline route needs to be assessed and social acceptability gauged. Once active a siphon system only requires periodic priming to recommence water transport, hence presents a much lower risk of unacceptable social impacts.	The level of noise produced for the construction of a pumping station and pipline route needs to be assessed and social acceptability gauged. The ongoing level of noise due to an operating pump station could present greater social impacts.	Social impact study during pipeline design phase and broad stakeholder consultation to minimize social impacts.

Appendix G Acid Sulphate Soil Qualitative and Quantitative Testing Results

Appendix G Acid Sulphate Soil Qualitative and Quantitative Testing Results

Field Observations				Field Test				Lab pH		SPOCAS Suite									Action Criteria	
Sample ID		Soil Description	Depth To Water	pHF	pHFOX	pHF -pHFOX	Reaction Rate	pH KCl	pH OX	TAA	TPA	TSA	S_{POS}	ANC_E	S_p	SKCl	Net Acidity (exl ANC)	Liming Rate (excl ANC)	Net Acidity* (SPOCAS)	Net Acidity* (S_{CR})
Location	Sample Details (Depth in m BGL)																			
	Sample location		mBNS	pH Units	pH Units	pH Units	LMHX	pH Units	pH Units	Moles H+/tonne		%S	%S	Moles H+/tonne	%S	%S	%S	kg CaCO3/t	%S	%S
Assessment Criteria: SANDY LOAM/ PEAT			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV	0.03	0.03
Assessment Criteria SAND			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV		
LW1: 394107.41mE, 6257443.77 mN (MGA94)																				
	0-0.10	Black organic		7.75	6.64	1.11	M	9.6	7.9	<2	<2		0.03	380	0.07	0.04			0.03	
	0.10-0.20	Yellow sand		7.82	2.63	5.19	M	9.2	6.9	<2	<2		0.03	18	0.06	0.03			0.03	
	0.50	Yellow sand		7.61	5.41	2.20	-													
	0.75	Yellow sand with Grey sandy loam in patches		7.61	5.77	1.84	-													
	1.00	Yellow sand		7.42	5.66	1.76	-	8.3	6.4	<2	<2		0.01	<2	0.03	0.02			0.01	

Field Observations				Field Test				Lab pH		SPOCAS Suite									Action Criteria	
Sample ID		Soil Description	Depth To Water	pHF	pHFOX	pHF -pHFOX	Reaction Rate	pH KCl	pH OX	TAA	TPA	TSA	S_{POS}	ANC_E	S_P	SKCl	Net Acidity (exl ANC)	Liming Rate (excl ANC)	Net Acidity* (SPOCAS)	Net Acidity* (S_{CR})
Location	Sample Details (Depth in m BGL)																			
	Median Location of Sample		mBNS	pH Units	pH Units	pH Units	LMHX	pH Units	pH Units	Moles H+/tonne		%S	%S	%S	%S	%S	%S	kg CaCO3/t	%S	%S
Assessment Criteria: SANDY LOAM/ PEAT			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV	0.03	0.03
Assessment Criteria SAND			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV		
LW2: 396241.27 mE, 6256528.64 mN (MGA94)																				
	0.02	Dark organic layer with light grey banding		8.23	6.98	1.25	H	9.5	8.3	<2	<2		0.18	4200	0.29	0.11			0.18	
	0.25	White grey silt stone		7.86	6.55	1.31	M													
	0.50	Darker grey silt stone		7.75	6.31	1.44	H	9.7	8.4	<2	<2		0.20	3500	0.25	0.05			0.20	
	0.75	Darker grey silt stone		7.72	2.13	5.59	X													
	0.90	(Organic/ root material throughout strata)		7.86	1.96	5.90	X	9.1	2.6	<2	260		0.41	<2	0.44	0.03			0.41	

Field Observations				Field Test				Lab pH		SPOCAS Suite									Action Criteria	
Sample ID: Location	Sample Details (Depth in m BGL) / Median Location of Sample	Soil Description	Depth To Water	pHF	pHFOX	pHF -pHFOX	Reaction Rate	pH KCl	pH OX	TAA	TPA	TSA	S_{POS}	ANC_E	S_p	SKCl	Net Acidity (exl ANC)	Liming Rate (excl ANC)	Net Acidity* (SPOCAS)	Net Acidity* (S_{CR})
			mBNS	pH Units	pH Units	pH Units	LMHX	pH Units	pH Units	Moles H+/tonne		%S	%S	Moles H+/tonne	%S	%S	%S	kg CaCO3/t	%S	%S
Assessment Criteria: SANDY LOAM/ PEAT			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV	0.03	0.03
Assessment Criteria SAND			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV		
LW3: 96867.77 mE, 6258167.89 mN (MGA94)																				
	0.10	Dark grey organic layer		8.08	6.71	1.37	M	9.9	7.7	<2	<2		0.02	245	0.05	0.03			0.02	
	0.25	Dark grey organic layer with grey banding		8.20	6.73	1.47	L	9.9	8.5	<2	<2		0.22	490	0.26	0.04			0.22	
	0.50	Light grey marine silt stone		8.25	6.46	1.79	-													
	0.75	Light grey marine silt stone (gastropod shell deposits banded through strata)		8.10	6.33	1.77	-													
	1.0	Light grey marine silt stone		7.95	6.21	1.74	-	9.9	7.5	<2	<2		0.01	128	0.06	0.05			0.01	

Field Observations				Field Test				Lab pH		SPOCAS Suite									Action Criteria	
Sample ID: Location	Sample Details (Depth in m BGL) / Median Location of Sample	Soil Description	Depth To Water	pHF	pHFOX	pHF -pHFOX	Reaction Rate	pH KCl	pH OX	TAA	TPA	TSA	S_{POS}	ANC_E	S_p	SKCl	Net Acidity (exl ANC)	Liming Rate (excl ANC)	Net Acidity* (SPOCAS)	Net Acidity* (S_{CR})
			mBNS	pH Units	pH Units	pH Units	LMHX	pH Units	pH Units	Moles H+/tonne		%S	%S	Moles H+/tonne	%S	%S	%S	kg CaCO3/t	%S	%S
Assessment Criteria: SANDY LOAM/ PEAT			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV	0.03	0.03
Assessment Criteria SAND			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV		
LW4: 396879.76 mE, 6257863.71 mN (MGA94)																				
	0.10	Dark grey upper organic layer		8.25	6.57	1.68	L	9.9	7.9	<2	<2		0.02	304	0.05	0.03			0.02	
	0.25	Grey to light grey silt stone banding		8.47	6.60	1.87	-													
	0.50	Grey to light grey silt stone banding (shell material		8.44	6.46	1.98	-	9.9	7.9	<2	<2		0.02	370	0.07	0.05			0.02	

		distributed throughout strata)																		
	0.75	Grey to light grey silt stone banding		8.30	6.48	1.82	-													
	1.00	Darker grey variable silt stone banding		8.34	6.11	2.23	-	10.0	7.8	<2	<2		0.01	190	0.09	0.08			0.01	

Field Observations				Field Test (Laboratory)				Lab pH		SPOCAS Suite									Action Criteria	
Sample ID		Soil Description	Depth To Water	pHF	pHFOX	pHF -pHFOX	Reaction Rate	pH KCl	pH OX	TAA	TPA	TSA	S_{POS}	ANC_E	S_p	SKCl	Net Acidity (exl ANC)	Liming Rate (excl ANC)	Net Acidity* (SPOCAS)	Net Acidity* (S_{CR})
Location	Sample Details (Depth in m BGL)																			
	Median Location of Sample		mBNS	pH Units	pH Units	pH Units	LMHX	pH Units	pH Units	Moles H+/tonne		%S	%S	Moles H+/tonne	%S	%S	%S	kg CaCO3/t	%S	%S
Assessment Criteria: SANDY LOAM/ PEAT			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV	0.03	0.03
Assessment Criteria SAND			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV		
WF1: 400535.86 mE, 6258313.41 mN (MGA94)																				
	0.05	Dark organic upper layer		7.02	4.67	2.35	H	7.3	4.5	<2	400		0.60	<2	0.65	0.05			0.60	
	0.25	Dark organic upper layer		7.33	7.01	0.32	M													
	0.40	Heavy dark siltstone clay		7.87	7.60	0.27	L													

Field Observations				Field Test (Laboratory)				Lab pH		SPOCAS Suite									Action Criteria	
Sample ID		Soil Description	Depth To Water	pHF	pHFOX	pHF -pHFOX	Reaction Rate	pH KCl	pH OX	TAA	TPA	TSA	S_{POS}	ANC_E	S_p	SKCl	Net Acidity (exl ANC)	Liming Rate (excl ANC)	Net Acidity* (SPOCAS)	Net Acidity* (S_{CR})
Location	Sample Details (Depth in m BGL)																			
	Median Location of Sample		mBNS	pH Units	pH Units	pH Units	LMHX	pH Units	pH Units	Moles H+/tonne		%S	%S	Moles H+/tonne	%S	%S	%S	kg CaCO3/t	%S	%S
Assessment Criteria: SANDY LOAM/ PEAT			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV	0.03	0.03
Assessment Criteria SAND			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV		
WF2: 400311.27 mE, 6258475.7 mN (MGA94)																				
	0.10	Dark organic upper layer		7.27	4.16	3.11	H	7.1	3.2	<2	520		1.36	<2	1.51	0.15			1.36	

	0.25	Dark organic upper layer		8.03	6.44	1.59	H													
	0.50	Light grey banding		8.22	2.32	5.90	M	8.1	4.5	<2	29		0.14	<2	0.15	0.01			0.14	
	0.65	Dark grey silt stone		8.16	7.41	0.75	L													
Field Observations				**Field Test (Laboratory)**				**Lab pH**		**SPOCAS Suite**									Action Criteria	
Sample ID		Soil Description	Depth To Water	pHF	pHFOX	pHF -pHFOX	Reaction Rate	pH KCl	pH OX	TAA	TPA	TSA	S_{POS}	ANC_E	S_P	SKCl	Net Acidity (exl ANC)	Liming Rate (excl ANC)	Net Acidity* (SPOCAS)	Net Acidity* (S_{CR})
Location	Sample Details (Depth in m BGL)																			
	Median Location of Sample		mBNS	pH Units	pH Units	pH Units	LMHX	pH Units	pH Units	Moles H+/tonne		%S	%S	Moles H+/tonne	%S	%S	%S	kg CaCO3/t	%S	%S
Assessment Criteria: SANDY LOAM/ PEAT			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV	0.03	0.03
Assessment Criteria SAND			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	NV	NV	0.03	NV		
WF3: 401126.87 mE, 6258518.81 mN (MGA94)																				
	0.05	Dark grey organic material		7.68	4.55	3.13	H	9.2	6.8	<2	<2		0.03	31	0.04	0.01			0.03	
	0.15	Dark grey organic material		8.05	5.41	2.64	M													
	0.30	shell layer		7.82	7.17	0.65	L													
	0.50	Medium grey silt stone		8.03	7.46	0.57	M	9.3	7.6	<2	<2		0.03	84	0.05	0.02			0.03	
	0.75	Medium grey silt stone		7.89	6.94	0.95	L													
	0.90	Dark grey heavy loam silt stone		7.89	3.45	4.44	H	8.2	4.2	<2	27		0.11	<2	0.13	0.02			0.11	

Field Observations				Field Test (Laboratory)				Lab pH		SPOCAS Suite									Action Criteria	
Sample ID		Soil Description	Depth To Water	pHF	pHFOX	pHF -pHFOX	Reaction Rate	pH KCl	pH OX	TAA	TPA	TSA	S_{POS}	ANC_E	S_p	SKCl	Net Acidity (exl ANC)	Liming Rate (excl ANC)	Net Acidity* (SPOCAS)	Net Acidity* (S_{CR})
Location	Sample Details (Depth in m BGL)																			
	Median Location of Sample		mBNS	pH Units	pH Units	pH Units	LMHX	pH Units	pH Units	Moles H+/tonne		%S	%S	Moles H+/tonne	%S	%S	%S	kg CaCO3/t	%S	%S
Assessment Criteria: SANDY LOAM/ PEAT			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	0.03	NV	0.03	NV	0.03	0.03
Assessment Criteria SAND			-	4	4	1	NV	NV	NV	18.7	18.7	NV	0.03	NV	0.03	NV	0.03	NV		
WF4: 400653.38 mE, 6258262.67 mN (MGA94)																				
	0.10	Dark grey organic layer		7.41	1.85	5.56	H	8.8	8.4	<2	<2		0.20	2800	0.23	0.03			0.20	
	0.20	Light grey heavy clay silt stone with flecks of grey		8.19	7.55	0.64	L													

Appendix H Comprehensive Fauna List of all Species that Occur within the Lake Warden Catchment

Appendix H Comprehensive Fauna List of all Species that Occur within the Lake Warden Catchment

Species	Common Name	WA Conservation Category	*EPBC* Conservation Category	Other Status of Protection Under *EPBC Act*	IUCN Threatened Species Category	Type of Presence
Apus pacificus	Fork - tailed Swift	N/A	N/A	Migratory	Least Concern	Species or species habitat may occur within the area
Ardea alba	Great Egret, White Egret	N/A	N/A	Migratory	Least Concern	Species or species habitat may occur within the area
Ardea ibis	Cattle Egret	N/A	N/A	Migratory	Least Concern	Species or species habitat may occur within the area
Ardeotis australis	Australian Bustard	Priority 4	N/A	N/A	Near Threatened	Species or species habitat may occur within the area
Cacatua leadbeateri	Major Mitchell's Cockatoo	Schedule 4	N/A	N/A	Least Concern	Species or species habitat may occur within the area
Calyptorhynchus latirostris	Carnaby's Black-Cockatoo, Short -billed Black Cockatoo	Schedule 1	Endangered	N/A	Endangered	Species or species habitat may occur within the area
Catharacta skua	Great Skua	N/A	N/A	Marine	Least Concern	Species or species habitat may occur within the area
Cereopsis novaehollandiae grisea	Recherche Cape Barren Goose, Cape Barren Goose (south western)	Schedule 1	Vulnerable	Marine	Least Concern	Species or species habitat may occur within the area
Charadrius rubricollis	Hooded Plover	Priority 4	N/A	N/A	N/A	Species or species habitat may occur within the area
Diomedea amsterdamensis	Amsterdam Albatross	Schedule 1	Endangered	Migratory, Marine	Critically Endangered	Species or species habitat may occur within the area
Diomedea dabbenena	Tristan Albatross	Schedule 1	Endangered	Migratory, Marine	Endangered	Foraging may occur within area
Diomedea exulans	Wandering Albatross	Schedule 1	Vulnerable	Migratory, Marine	Vulnerable	Species or species habitat may occur within the area
Diomedea gibsoni	Gibson's Albatross	Schedule 1	Vulnerable	Migratory, Marine	N/A	Species or species habitat may occur within the area
Falco peregrinus	Peregrine Flacon	Schedule 4	N/A	N/A	Least Concern	Species or species habitat may occur within the area
Haliaeetus leucogaster	White - bellied Sea Eagle	N/A	N/A	Migratory, Marine	Least Concern	Species or species habitat may occur within the area
Halobaena caerulea	Blue Petrel	N/A	Vulnerable	Marine	Least Concern	Species or species habitat may occur within the area
Macronectes giganteus	Southern Giant Petrel	Schedule 1	Endangered	Migratory, Marine	Vulnerable	Species or species habitat

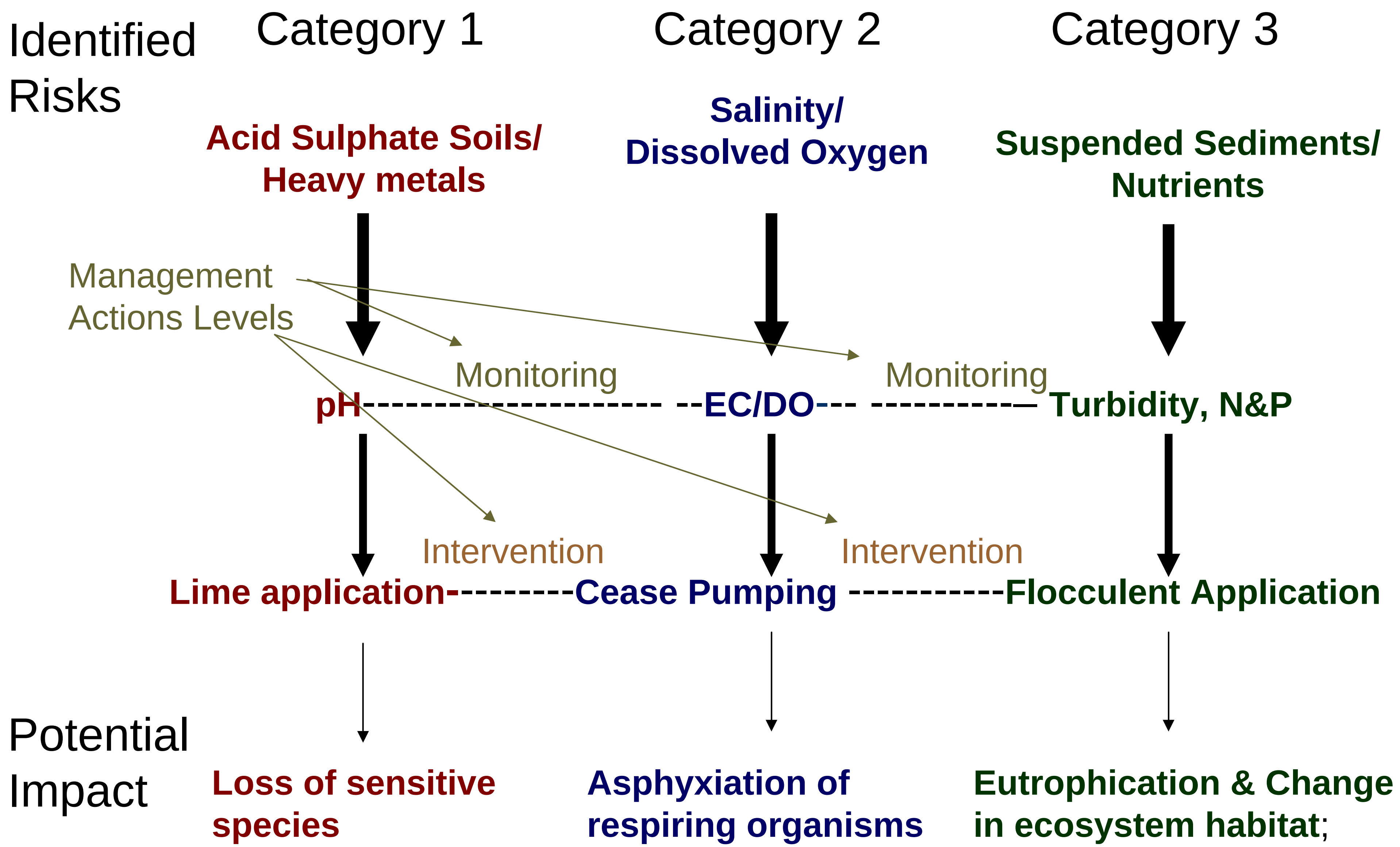
Species	Common Name	WA Conservation Category	*EPBC* Conservation Category	Other Status of Protection Under *EPBC Act*	IUCN Threatened Species Category	Type of Presence
						may occur within the area
Macronectes halli	Northern Giant Petrel	N/A	Vulnerable	Migratory, Marine	Near Threatened	Species or species habitat may occur within the area
Merops ornatus	Rainbow Bee Eater	N/A	N/A	Migratory, Marine	Least Concern	Species or species habitat may occur within the area
Pterodroma mollis	Soft - plumaged Petrel	N/A	Vulnerable	Marine	Least Concern	Species or species habitat may occur within the area
Thalassarche carteri	Indian Yellow - nosed Albatross	Schedule 1	Vulnerable	Migratory, Marine	Endangered	Foraging may occur within area
Thalassarche cauta	Shy Albatross	Schedule 1	Vulnerable	Migratory, Marine	Near Threatened	Species or species habitat may occur within the area
Thalassarche chlororhynchos	Yellow - nosed Albatross, Atlantic Yellow - nosed Albatross	Schedule 1	N/A	Migratory, Marine	Endangered	Species or species habitat may occur within the area
Thalassarche melanophris	Black - browed Albatross	N/A	Vulnerable	Migratory, Marine	Endangered	Species or species habitat may occur within the area
Dasyurus geoffroii	Chuditch, Western Quoll	Schedule 1	Vulnerable	N/A	Vulnerable	Species or species habitat may occur within the area
Parantechinus apicalis	Dibbler	Schedule 1	Endangered	N/A	Endangered	Species or species habitat may occur within the area
Morelia spilota imbricata	Carpet Python	Schedule 4	N/A	N/A	N/A	Species or species habitat may occur within the area
Arctocephalus forsteri	New Zealand Fur Seal	Schedule 4	N/A	Marine	Least Concern	Species or species habitat may occur within the area
Balaenopter acutorostrata	Minke Whale	N/A	N/A	Cetacean	Least Concern	Species or species habitat may occur within the area
Balaenoptera edeni	Bryde's Whale	N/A	N/A	Migratory, Cetacean	Data Deficient	Species or species habitat may occur within the area
Balaenoptera musculus	Blue Whale	Schedule 1	Endangered	Migratory, Cetacean	Endangered	Species or species habitat may occur within the area
Caperea marginata	Pygmy Right Whale	N/A	N/A	Migratory, Cetacean	Least Concern	Species or species habitat may occur within the area
Delphinus delphis	Common Dolphin	N/A	N/A	Cetacean	Least Concern	Species or species habitat may occur within the area
Eubalaena australis	Southern Right Whale	Schedule 1	Endangered	Migratory, Cetacean	Least Concern	Species or species habitat may occur within the area
Grampus griseus	Risso's Dolphin, Grampus	N/A	N/A	Cetacean	Data Deficient	Species or species habitat may occur within the area

Species	**Common Name**	**WA Conservation Category**	***EPBC* Conservation Category**	**Other Status of Protection Under *EPBC Act***	**IUCN Threatened Species Category**	**Type of Presence**
Lagenorhynchus obscurus	Dusky Dolphin	N/A	N/A	Migratory, Cetacean	Data Deficient	Species or species habitat may occur within the area
Megaptera novaeangliae	Humpback Whale	Schedule 1	Vulnerable	Migratory, Cetacean	Vulnerable	Species or species habitat may occur within the area
Neophoca conerea	Australian Sea Lion	Schedule 4	Vulnerable	Marine	Least Concern	Species or species habitat may occur within the area
Orcinus orca	Killer Whale, Orca	N/A	N/A	Migratory, Cetacean	Least Concern	Species or species habitat may occur within the area
Tursiops aduncus	Spotted Bottlenose Dolphin	N/A	N/A	Cetacean	Data Deficient	Species or species habitat may occur within the area
Tursiops truncatus	Bottlenose Dolphin	N/A	N/A	Cetacean	Data Deficient	Species or species habitat may occur within the area
Carcharias taurus (west coast population)	Grey Nurse Shark (west coast population)	Schedule 1	Vulnerable	N/A	Vulnerable	Species or species habitat may occur within the area
Carcharodon carcharias	Great White Shark	Schedule 1	Vulnerable	Migratory	Vulnerable	Species or species habitat may occur within the area
Rhincodon typus	Whale Shark	N/A	Vulnerable	Migratory	Vulnerable	Species or species habitat may occur within the area
Acentronura australe	Southern Pygmy Pipehorse	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Campichthys galei	Gale's Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Galaxias truttaceus hesperius	Western Trout Minnow	Schedule 1	Critically Endangered	N/A	N/A	Species or species habitat may occur within the area
Heraldia nocturna	Upside down Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Hippocampus breviceps	Short - head Seahorse, Short - snouted Seahorse	N/A	N/A	Marine	Data Deficient	Species or species habitat may occur within the area
Histiogamphelus cristatus	Rhino Pipefish, Macleay's Crested Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Leptoichthys fistularius	Brushtail Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Lissocampus caudalis	Australian Smooth Pipefish, Smooth Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Lissocampus runa	Javelin Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Maroubra perserrata	Sawtooth Pipefish	N/A	N/A	Marine	N/A	Species or species habitat

Species	Common Name	WA Conservation Category	*EPBC* Conservation Category	Other Status of Protection Under *EPBC Act*	IUCN Threatened Species Category	Type of Presence
						may occur within the area
Nannocampus subosseus	Bony - headed Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Notiocampus ruber	Red Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Phycodurus eques	Leafy Seadragon	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Phyllopteryx taeniolatus	Weedy Seadragon	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Pugnaso curtirostris	Pug - nosed Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Solegnathus lettiensis	Indonesian Pipefish, Gunther's Pipehorse	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Stigmatopora argus	Spotted Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Stigmatopora nigra	Wide - bodied Pipefish, Black Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Urocampus carinirostris	Hairy Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Vanacampus margaritifer	Mother of Pearl Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Vanacampus phillipi	Port Phillip Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area
Vanacampus poecilolaemus	Australian Long - snout Pipefish, Long - snouted Pipefish	N/A	N/A	Marine	N/A	Species or species habitat may occur within the area

Appendix I Marine Habitat Survey Using Sidescan Sonar and Video - Bandy Creek to Wylie Head, Esperance

Marine Impact: Risk Management



Appendix J Results of Open Public Forum Consultation

Appendix J Results of Open Public Forum Consultation

REPORT OF THE

LAKE WARDEN WETANDS COMMUNITY CONSULTATION FORUM

DETAILS

Date: Sunday 16 December 2007

Time: 5 – 7pm

Venue: Esperance Golf Club
Esperance

Items Discussed

1. **Opening of meeting**

The meeting was opened at about 5.10 pm by Mr. Garry English, Chair of the South Coast Natural Resource Management Inc. and a committee member of the South Coast Regional Forum. Mr. English extended a welcome to all participants.

The Community noted the following points made by Mr. English:

i. Acknowledged the Noongar traditional owners of these wetlands.
ii. the Lake Warden Wetlands system is of international, regional and state importance
iii. it was important to acknowledge and thank the strategic partners who had been involved in this exercise and in particular the management and staff of the Department of Environment and Conservation, Esperance Office [Klaus Tiedemann, Tilo Massenbauer and Nikki Cowcher], the Farmers who had participated in this project, the Lake Warden Project Management Team, the SLOG, the Esperance Small Landowners Group and the Natural Resource Management Team of the Department of Agriculture and Food.
iv. Special thanks to Josette O' Donnell for organising the meeting
v. Welcomed Michael Jackson as facilitator of the Forum, mentioning that Michael had been Esperance Response Coordinator, following the lead contamination of Esperance.

2. **Community and Historical Perspective – Mr. Barry Stearne Community member**

The Community noted the following points made by Mr. Stearne:

- Mr. Stearne had been observing Lake Warden since the 1930's. His father owned a property on Lake Warden and in the 1930's had built a jetty out onto the lake for tourists to use canoes.
- The normal system for the Lake was a series of cycles between full then dry. Examples of particular dates recorded by Mr. Stearne were in 1941, Lake Warden had dried right up, but it had been dry before that too.
- The original road into Esperance from Noresman was down Six Mile Hill and the road went over the lake area.
- In 1968 there was a 40mm rainfall event which washed the Gun Club away. After this event the road was rebuilt and the culverts were built higher. This interfered with the natural drainage.

- The last time Lake Warden had been dry was in 1988 and it had not been dry since that time.
- The number of birds had changed too. In the early days there were 5-6 acres of banded stilts and thousands of swans and mountain ducks on the lakes. The numbers of birds were at their highest when the lakes were dry. Now the lakes are too full and the wading birds cannot feed [on small molluscs etc], as the water is too deep and the shoreline areas have been lost to the rising water levels.
- The fish numbers in the lakes had also been affected. Both he and his father had caught many fish in the lakes in the early days, but since the weir had been constructed there were no fish and no fishing in the lakes.
- All of the lakes in this system are connected
- That he considered that the water levels in Lake Windabout should be reduced in the first instance rather than draining from Lake Warden as to do so would impact on the Golf Club environs.
- The wet dry cycle was not regular, for example in 1950 the lakes were dry for 4 to 5 years then refilled after heavy rain of 5 to 6 inches in November of that year.

The Community thanked Mr. Stearne for his presentation.

3. Community Views and Values

A series of short presentations were given on the various community views and values of the lakes as set out below:

i. Indigenous Values of the Lakes – Mr. Henry Daub

The Community noted the following points from Mr. Henry Daub, one of the traditional owners of the land.

- Doc Reynolds had sent his apologies for not being able to attend the meeting.
- The Lake system was of great value to the Aboriginal people who had fished and caught marron in these lakes.
- Aboriginal people wanted to see the lakes cleaned up and restored to their previous condition for the wildlife.
- Expressed support for the proposal to manage the water levels in the Lakes
- Expressed strong support for the points made by Mr. Stearne, and thanked the community for their attention.

ii. Value of the Lake system to Bird life – Mr. Mike Gibbs, Esperance Bird Observers Group.

The Community noted the following points by Mr. Mike Gibbs from the Esperance Bird Observers Group:

- Mr. Gibbs had lived on Six Mile Hill since 1983 and prior to this had spent considerable time in the Lake area.
- Hooded plovers used to be plentiful on the north eastern section of Lake Warden as there used to be a large beach shoreline in that area. In addition, the small red capped plovers were found in that area. The rising water levels have now resumed this beach and the hooded and red capped plovers are not seen there anymore.

- Another site where hooded plovers were spotted was along the shore line of Mullet Lake. However these too have disappeared.
- Large numbers of these species were present in the area but these have now disappeared. The rising water levels have resulted in reduced shorelines and the water is now too deep for the wading bird species.
- The Bird Observers Group has also noted that the paperbark trees have died in many of the shoreline areas and this has reduced the bird habitat area.

iii. Impact of the High Lake Water Levels on Local Residents - Mr. Eric Temple, Quarry Road Flood Group

The Community noted the following points by Mr. Eric Temple from the Quarry Road Flood Group. [Mr. Eric Temple replaced Mr. Tom Parkins at the meeting, as Mr. Parsons was involved in fighting a fire.]

- Mr. Temple had come to Esperance in the 1960's. At that time the Bandy Creek weir did not exist and the water would move through the lake system in periods of high rainfall and floods.
- Following a very wet year in 1979, building a weir was considered. At first a sleuth gate was installed but this was vandalized. The weir was opened in 1998
- The installation of the weir caused objectionable odours because the water drained to the racecourse.
- The weir was closed and never reopened again and it was washed away with the floods in January 2007.
- The natural cycle of filling and drying of the lakes did not happen after the weir was put in.
- When the lakes flood, all the people on Quarry Road and east of town are cut off from town, and there are enormous costs. Quarry Road Residents would like to see the levels of the lakes go back to pre-weir days, and let the natural drainage of the lakes occur. This meant that during the flood it was necessary to drive through about ¾ of a metre of water.
- Quarry Road residents would like to see the water levels in the lake system go back to their normal/natural levels.

iv. Views of the Esperance Water Ski Club- Mr. Nigel Walker

The Community noted the following points by Mr. Nigel Walker President of the Esperance Water Ski Club:

- The Esperance Water Ski Club, which uses Woody Lake, has about 100 members including members from Kalgoorlie. There are approximately 30 boats in the club and this number is expected to increase with members having more disposable income.
- Water levels in excess of 1.4m are necessary for water skiing. If the water levels are reduced below this levels water skiing in the lake would not be possible.
- Mr. Walker recognised the importance for the bird feeding areas to be restored, and recommended that Woody Lake be dredged to enable water skiing all year round.

v. DEC Obligations in Managing the Wetlands Wildlife – Klaus Tiedemann, District Manager, DEC

The Community noted the following points made by Mr. Klaus Tidemann, District Manager of DEC:

- Mr. Tidemann had visited Esperance in the 1970's and became a resident in 1984.

- The Lake Warden Wetlands system is an A Class Reserve and is therefore the responsibility of the DEC. The reserve includes the following lakes – Mullet, Woody, Wheatfield, Windabout and Lake Warden. It also includes the western fringe of Pink Lake.
- In 1984 there were large stretches of shoreline along Lake Warden. A survey in 1984 estimated the bird population to be over 20,000.
- In the 1980's, the wetlands were classified as a game reserve under the management of the Fisheries Department. However, the Department of Conservation and Land Management took over responsibility for management of the wetlands in 1985 following the definition of a 'nature reserve'.
- In the late 1980's, Lake Warden was classified as an internationally significant Ramsar Wetland. This followed work by the Local Environmental Action Forum [LEAF]. As such, Lake Warden was one of only nine wetlands in WA to be recognised as such at the time and even now there are only 13 Ramsar sites in WA.
- In the late 1990's Lake Warden was registered as a Natural Diversity Recovery Catchment under threat from salinity. This registration was under the State Salinity Strategy.
- The Esperance Lakes Management Plan was published in 1999.
- There are 59 species of water birds recorded on the Lake Warden wetlands system. 17 of these species are protected under agreements with Japan and China.
- Approximately 60 species of aquatic invertebrates have been recorded. The area is also an important habitat for paperbarks and banksia woodlands.
- The lakes are therefore an important habitat for the region.
- The DEC is most concerned that these wetlands on the outskirts of Esperance are managed appropriately. In view of the current high water levels in the wetlands system, the option of doing nothing is not a viable option for the DEC in managing these wetlands.

4. The Problem-Causes of Excess Catchment Water and how it interacts with the Esperance Coastal Floodplain Mr. John Simons, Department of Agriculture and Food.

The Community noted the following points by Mr. John Simons, Department of Agriculture and Food:

- He had come to Esperance in 1994 and stayed ever since.
- The hydrology of the Lake Warden wetlands system is a catchment water balance between inputs such as rainfall and ground water and outputs such as discharge and evaporation. The ground water entering the system either must go out or is stored.
- Monitoring of a series of groundwater bores throughout the catchment area had shown there to be an average 25cm per year rise in ground water levels
- Ninety percent of the flow into the Lake Warden wetlands system is from Bandy and Coramup Creeks. However approximately 50 to 70percent of this total is actually ground water recharge.
- The only outlet to the Lake Warden Wetlands system is through Bandy Creek.
- Agricultural practices have impacted on the wetland system, especially with the removal of most of the native vegetation surrounding the wetlands system. The symptoms being – the water in the wetlands system has become more saline, water logging, inundation, erosion and flooding have increased.
- Increased urbanisation has also affected the input to the wetlands system with greater runoff from roads, roofs and buildings.
- Unless there is some form of water management of the wetlands system, the water levels in the system will continue to increase.

- The Pink Lake is based on a shallow bedrock base similar to the headlands around Esperance. The source of ground water is localised-this is a saline aquifer.

5. **How does the hydrology affect the wildlife of the Lake Warden Wetlands System? The options for solving the problem and the recommended solution pros and cons. - Mr. Tilo Massenbauer, Catchment Conservation Officer Department of Environment and Conservation.**

The Community noted the following points by Mr. Tilo Massenbauer, Catchment Conservation Officer, Department of Environment and conservation:

- Tilo had gown up in Esperance and his grandfather used to shoot ducks on the Lake Warden wetlands.
- The catchment area is 212,000 hectares, 75% of the area has been cleared of native remnant vegetation, there are 4 sub catchments, the lakes are surrounded by 148,000ha of farmland, of which 85% has been cleared of native vegetation.
- The values of the Lake Warden Wetlands System are
  - biological values to migratory waterbirds,
  - water quality ecosystem functions and infrastructure protection values provided by the LWWWS during flood events,
  - production values –salt mining on Pink Lake,
  - Indigenous and European heritage,
  - recreational and tourism values such as walk trails, bird watching and water sports,
  - educational values such as interpretational trails, and
  - aesthetic landscape values
- The management objective for the Lake Warden Wetland System is to recover the existing waterbird species richness and abundance and living assemblages to a near natural state by the year 2030.
- Vegetation decline is evidenced by the drowning or waterlogging of paper barks. These trees can cope with ‘wet feet’ for periods of between 18 months and 3 years, but periods longer than this cause tree death.
- Under normal conditions of wet and dry cycles, the paper barks can regenerate with seedlings re-establishing during the drying cycle. Under the current conditions, paperbarks are only re-establishing at higher elevations on the banks of the system.
- Mapping of the vegetation over the period 2004 to 2007 has shown a significant proportion to be already dead and a large proportion to be degrading.
- The targets for the Lake Warden Wetlands System are:
  - To have a carrying capacity for greater than 10,000 waterbirds
  - To recover the habitat from 3ha to 200ha
  - To dewater 6 to 9Gigga litres to recover the habitat
  - To set an annual maintenance target of 3Gigga litres
  - To have a target landscape area of 28,000ha
- Lake Warden is the lowest lake in the system. However there is a significant drop between the lake system and sea level.
- Management options include-to drain, surface water management, deep drain and siphon.
- The option of a surface drain is not recommended as this would have high maintenance costs, would require vegetation clearing and would cause disturbance of Aboriginal sites.
- The option of a deep drain would also cause major disturbance to vegetation especially with machinery in the wetlands environment, and such a proposal would inevitably be rejected by the Environmental Protection Authority.

- Assessment of all options has led to the conclusion that the preferred option is to reduce the water levels in the lake using a piping system. It is proposed to use a 40cm pipe submerged at a specified depth in Lake Wheatfield and siphoning to Bandy Creek. This would take about 2.4Gigga litres per year and cost about $550k. It is also proposed to pump water fro Lake Warden which would de-water about 3 Gigga litres per year and cost about $3.5m.
- As part of the assessment of these proposals issues such as impact on water quality [pH, salinity, nutrients and heavy metals], the potential for acid sulphate soils, water skiing and depth target management, have been evaluated.
- A further advantage of these proposals is that they can be regulated. For example, in a period of flooding the pump and siphon can be turned off.
- The proposal has to be submitted and approved by the Environmental Protection Authority [EPA].

It was questioned if the pipeline route can avoid the golf club and be imbedded in the lakes. However, Mr. Massenbauer assured the community that the greens would not be disturbed.

It was also questioned what would happen if nothing was to be done. What would the lake system look like in say, 60years. Mr. Massenbauer responded that the lakes would be like a 'soup' and gave an example of Lake Gore.

6. Summary and Closure

Mr. Jackson summarised the meeting with the following points:

- The observations of the earlier speakers had been supported by the scientific work of Mr. Massenbauer and Mr. Simons,
- The presentations have demonstrated that there is an urgent need to address the degrading of the vegetation and the loss of the wildlife in the Lake Warden Wetlands system
- The preferred option of engineering proposals will provide 'management' of the system, it can be regulated according to prevailing conditions,
- Approval by the EPA is yet to be obtained and it will take some time before the engineering solutions/proposals can be in place, and
- The proposal provides for protection and conservation of the lakes and the marine environments.

Community participants were thanked for their attendance and requested to complete the Community Feedback Form on the proposed Lake Wheatfield siphon and the Lake Warden pump proposal, and to provide additional comments if desired.

Closure

Meeting closed at 7.10pm

Appendix K Review of Reference Documents by DEC Technical Staff and UWA PhD and Master Students

Appendix K Review of Reference Documents by DEC Technical Staff and UWA PhD and Master Students

CALM (1999), *Esperance Lakes Nature Reserves Management Plan 1999-2009, Management Plan Number 39,* National Parks and Nature Conservation Authority, Perth WA.

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Street, G. and Abbott, S. (2004). *Interpretation of airborne electromagnetic survey over the Lake Warden Catchment Esperance, Western Australia*. Department of Conservation and Land Management.

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