Greater Launceston Area Urban Salinity Strategy 2016

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Cover Photograph
View from Seaport across the Tamar River to Trevallyn–West Tamar (A Nicholson)
Executive Summary

The Greater Launceston Area (GLA) has a widespread urban salinity problem that has a broader impact on the community than indicated by previous localised studies. Evidence of salinity damage includes: etching and rotting of brickwork; ‘rising damp’ in masonry walls; fracturing and flaking of pavements and roads; salt efflorescence as a ‘tide mark’ on some brick and concrete walls; blistering of paintwork; formation of scalds in grassy areas; presence of salt tolerant species in water courses; and, acid and saline chemistries in some natural waters.

Informed management of salinised land and water through: skilled urban planning; targeted infrastructure maintenance; use of appropriate construction materials and methods; minimisation of excavation and land-use practices that impact land and water salinity; provision of information to stakeholders; and, other tailored solutions by local councils and water authorities, requires an understanding of how and why salt is manifesting in some parts of the landscape.

Hydrogeological Landscape (HGL) characterisation explains: the configuration of soil, regolith and fractured rock materials in the landscape; the capacity for salt storage and release in different media; how water moves over and through these materials; the mechanisms for salt mobilisation in the landscape; and, the likely origin of the salt. In this study 17 HGL units have been derived from analysis of available map information, collated ‘urban signal’ salinity indication surveys and field observation. These HGL units enable broad discrimination of the way natural and constructed features of the contemporary landscape influence surface and subsurface water flow and salt transport in different parts of the Greater Launceston Area (GLA).

A pivotal aspect of this work was the comprehensive Urban Salinity Signal survey, a street-by-street characterisation of salinity impact in the GLA, conducted by staff of the Launceston Salinity Advisory Group (LSAG) member organisations (Meander Valley Council, West Tamar Council, Launceston City Council, Ben Lomond Water), in collaboration with the University of Canberra, informed by expert advice from the NSW DPI Landscape Management Technical Group.

The LSAG commissioned this research as a 3 Stage project to inform best-practice salinity management in the GLA. The 3 Stages are: Stage 1: HGL Conceptualisation; Stage 2: Detailed HGL characterisation and management framework development; Stage 3: Technical training using the HGL management framework. This report constitutes the findings from Stage 1 and 2 of the GLA Urban Salinity Strategy Project.

The study revealed that, from a salinity perspective, landscape components behaved differently in the GLA. This was dependent on: the underlying rock type, the thickness of regolith (weathered rock and soil) materials and hence the volume of the salt store, the landforms present and the amount of water passing over and through the landscape. Land salinisation typically impacts localised areas on: deeply weathered Jurassic dolerite; moderately to deeply weathered bedded paleo-estuarine sediments of the Paleogene Tamar/Esk River system; some Quaternary terrace deposits along the Tamar and Esk Rivers; and some Holocene estuarine sediment.

Creating a framework of this kind enables authorities to identify relative salinity hazard and risk, and to prioritise works appropriately. Strategic targeting of management actions ensures that the ‘right’ actions take place in the ‘right’ parts of the landscape. Utilising the HGL framework also ensures that natural resource management (NRM) decision-making is grounded in evidence-based science.
Acknowledgements

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- Chris Grose (Snr Land Resource Assessment Officer - Land Conservation Branch, DPIPWE)
- Ian Household (Geoscientist - Water and Marine Resources, DPIPWE)
- Brian Jenkins (Snr Team Leader, Assessment – NSW Office of Environment and Heritage)
- Greg Pinkard (Manager - Land Conservation Branch, DPIPWE – retired).

The LSAG member Councils recognised the value of spatially modelling salinity hazard across the Greater Launceston Area, with a view to implementing management options where warranted. Beyond commissioning the project, they supported the project through staff urban salinity signals surveys and data provision. The enthusiasm of those staff members involved in surveys created a good product on which to base salinity risk modelling. They are:

- City of Launceston: Michael Beg, Chris Boon, Liam Seymour, Mike Wellman, Josh Coates.
- Meander Valley Council: Jayne Jose, Stuart Brownlea, Jacob Zeisel, Natasha Whiteley, Colin Lockhart, Jack McDonald, Andrew Chown.
- West Tamar Council: Brent Thompson, Jenny Stoianou, Ernest Bennett.

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TasWater provided important data on water use distribution across the study area.

NRM North provided support for the rapid catchment assessment and supply of other water data, particularly through the efforts of Toni Furlonge.

The Greater Launceston Area Urban Salinity Strategy Project has been a valuable exercise in regional cooperation. It provides a strong foundation on which to build coordinated and effective salinity management actions, to provide positive outcomes for member organisations and the communities they service.

LAUNCESTON SALINITY ACTION GROUP MEMBERS

(GLA Urban Salinity Strategy Project):

West Tamar Council: Cr. John Watson; Michael Purves
City of Launceston: Leon Murray
Meander Valley Council: Cr. Ian Howard; Stuart Brownlea
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Greater Launceston Area Urban Salinity Strategy

Part A: Hydrogeological Landscape (HGL) Conceptualisation

A1. Dryland Salinity in the Greater Launceston Area (GLA)

A1.1 What is the best approach to studying dryland salinity in the Greater Launceston Area?

If we understand how regolith materials (unconsolidated sediments, soils, weathered rock) are distributed in a landscape we gain an understanding of where most salts are stored in the landscape, and an understanding of how water might move through the landscape. But what is the best way to capture information on the distribution of rock and weathered materials in a catchment, and how water might move through that landscape? And how do we take into consideration the other factors influencing salt distribution and mobilisation (e.g. vegetation cover, landform, soil structures, geology)?

An attempt was made to do this at national scale for the National Land and Water Resources Audit (Coram et al. 2000) based on data that was available from a range of natural resource management (NRM) agencies across the country. This work resulted in development of the Groundwater Flow System (GFS) model, where patterns were recognised in Australian landscapes indicating that some areas behaved similarly with respect to their hydrologic characteristics. Because there was a desire to understand and characterise a range of natural resource management (NRM) issues at regional and local scale, the GFS approach was applied at a range of scales and non-systematically at first, in catchments across Australia. Once practitioners recognised that a resource developed at national scale should be applied at national scale, good sense prevailed, and a number of regional and local agencies used their expertise to develop regional and local scale resources based on the GFS idea.

This work has evolved into the Hydrogeological Landscapes (HGL) approach to characterising landscapes for natural resource management purposes. It involves gathering or acquiring information on as many biophysical parameters as possible for a given landscape, to provide a snapshot of the landscape as it appears now. This also involves gaining an understanding of how this landscape has been modified historically. Once this information is known, parts of catchment/s can be grouped according to hydrogeologic characteristics, and a series of conceptual models are compiled. These models describe how we believe salt is stored in the landscape, water moves through the landscape, geology influences the type of regolith materials produced, structural features like faults enhance or impede water flow, native and exotic vegetation influence the other processes and so on.

Each grouping, or Hydrogeological Landscape (HGL) Unit, can then be described in detail, and the science behind why we see certain processes manifesting in particular landscapes can be explained. The premise is that if we understand the natural processes that result in particular outcomes in a landscape, then strategic decisions about whether to intervene, how to intervene or whether it is worth doing so can be made.

This report details findings from the initial compilation of existing data available for the greater Launceston area (GLA) in central northern Tasmania. The conceptualisation process is undertaken in this stage where preliminary units that appear to have similar hydrogeological landscape (HGL) features are initially described.
A1.2 Dryland salinity: where does the salt come from?

Salt concentrates naturally in the south-eastern Australian landscape. The most important source of salt in Tasmania is natural salt deposition as mist, or aerosols, from the sea. Studies of the flux of these aerosols across the Australian continent indicate that salt derived from the sea can deposit up to a few hundred kilometres from the coast (Keywood, 1995). In Tasmania this process dominates salt accession and forms a constant flux inland from coastal areas. Measured salt (NaCl) deposition from this source in Launceston is approximately 15kg/ha/year (estimate after Keywood, 1997).

In addition some salt is introduced coupled with windblown dust known as parna, via a process termed aeolian accession (Hesse 1993, Gatehouse 2001). This dust originates from areas north-west of Tasmania in inland South Australia, NSW and Victoria, typically from areas that are more arid, and during drier periods. Wind activity mobilises particles from the land surface that may be re-deposited during regional windstorms and with rain. It is now understood that this process has been taking place for millennia and is responsible for an episodic but consistent flux of salt into south-eastern Australian landscapes. Parna has proved to be difficult to study as salt transported with the dust rapidly decouples once deposited. This is partly because the dust grains are aggregate particles which disintegrate into clays and other natural soil forming materials when they are deposited in the soil (Cattle et al. 2005). Despite this, the presence of parna is well known from areas where deposition is thick (e.g. Junee, NSW) or where parna has deposited over a substrate that has a different composition (e.g. quartz-bearing parna in basaltic soils, as basalt does not naturally contain quartz). This is likely to be a less dominant source of salt in Tasmanian landscapes.

Past studies have suggested that fossil ocean water could be preserved in ancient marine sediments forming part of the rock succession in south-eastern Australia (connate waters). Geology in the Launceston area is dominated by Jurassic shallow intrusive rocks (dolerites), Paleogene paleo-estuarine and lacustrine sediments; and Quaternary sediments associated with the Tamar and Esk River systems. These rock types are not formed in an ancient marine environment and do not preserve connate waters in the stratigraphy. Some salt partitioned into the paleo-estuarine sediments at the time of deposition may be preserved, but natural accumulation from the oceanic cyclic salt flux over Launceston since deposition is more likely to account for the accumulation of NaCl salts in these weathered sediments.

A volumetrically small contribution of salts, typically carbonate salts, are mobilised during active rock weathering, particularly of Jurassic dolerites, in this area. Formation of sulphate salts due to oxidation of sulphides in Quaternary estuarine sediments can lead to formation of acid sulphate soils (ASS) on estuarine flood plains along the Tamar River and lower North Esk River systems.

A1.3 Where do salts sit in the landscape?

Salts can be deposited and redeposited as solid grains, they can crystallise in pore spaces in fractured and weathered rock and soil, and they can be adsorbed onto or taken into the structure of weathering products like iron oxides and clay minerals. Salts can be dissolved into surface water and groundwater and mobilised through landscapes in this manner. In the Greater Launceston Area (GLA) the distribution of weathering products and unconsolidated materials is influenced by the structure of the landscape.

It follows that salts introduced to Tasmanian landscapes over the past few hundreds of thousands of years have accumulated and concentrated in a manner that can be understood. To do this we need to understand the processes of salt deposition and mobilisation, and become more knowledgeable about the materials they deposit into, how these materials form and how
they are distributed in the landscape. The movement of water through this landscape is important because: water is a principal weathering agent during the breakdown of rock material to form weathering products, or regolith; and, water mobilises salts through the regolith and fractured rock.

Any factors that influence the deposition of salt, the partitioning of salt, or the mobilisation of salt in the landscape, change the natural system. These factors might include: changes in vegetation cover or type, changes in land-use, urban/peri-urban development, water extraction/addition, soil loss and more. To best understand the impact of factors such as these we need to have an understanding of what is happening in the landscape.

A2. Study Area – the Greater Launceston Area (GLA)

A2.1 Location and extent of study area

The Greater Launceston Area (GLA) study area encompasses the municipalities of Launceston, West Tamar and the western portion of Meander Valley (Figure A1).

Figure A1: Location of the Greater Launceston Area (GLA) study in northern Tasmania
A2.2 Geology, geomorphology and distribution of regolith materials

In the greater Launceston area (GLA) the landscape is dominated by a half graben - a fault-bounded depression (Figure A2). This structure is formed due to NE-SW extension across the Tamar, with dominant NW-SE faults dipping steeply to the west (Longman 1966, McClenaghan and Baillie 1975). These structures cut through the Jurassic dolerite geology, and the underlying Permian sediments (not observed in the study area), and bound the Paleogene sediments that were deposited within the half graben. More recent fluvial and estuarine sediments, associated with the Tamar and Esk Rivers, form the uppermost layers in the half-graben fill sequence.

Deep weathering profiles have developed on fault-step surfaces on the Jurassic dolerite. This rock type is highly reactive and intense weathering has resulted in the formation of clay-rich sequences and bauxites. These regolith materials are preferentially preserved in elongate zones that correspond with fault-parallel depressions and flat surfaces on fault steps. Where these deposits have been stripped due to uplift and erosion, dolerite rock is exposed.

Variably cemented, bedded, Paleogene silt, sand and gravel sediments were deposited during former high-stands of the greater Tamar River system. This created a series of stepped plains surfaces that have been superimposed over the faulted Jurassic landscape, and have been modified by faulting since deposition. This sedimentary sequence has weathered to pallid, bedded loose clays and silts with some gravel intervals, impermeable ferruginous layers sub-parallel to bedding and mottled zones with concentrations of small ferruginous nodules and clay-rich pisolites. There is strong lateral control on subsurface fluid flow in this bedded sequence. In an engineering sense these regolith materials constitute ‘soft weak rock’ and are prone to subsidence, particularly if saturated. To the SW of the study site Paleogene basalt, originally emplaced as lava flows, overlies this sedimentary sequence.
Quaternary deposits are represented by estuarine deposits, flood plains and low terraces of the Tamar River and Esk River systems and their tributaries, and localised areas of wind-blown sand derived from deflation of river sediments (e.g. Hadspen).

**A2.3 Prior mapping of landscape features in the GLA**

Maps detailing biophysical characteristics of the landscape in the GLA have been produced and collated by the Department of Primary Industries, Water and Environment Tasmania and other State and private agencies. Compilation of derivative maps from the metadata provides an overview of this mapping in the study area.

**A2.3.1 Groundwater Flow System (GFS) Salt Storage**

*Figure A3: Groundwater flow system (GFS) Salt Storage in the Greater Launceston Area (GLA)*

Groundwater flow system (GFS) Salt Storage mapping essentially detailed the distribution of the Paleogene geology (sediment deposition and weathering) in the Greater Launceston Area (GLA), recognised as moderate to high salt storage parts of the landscape (Figure A3). Areas of Quaternary to recent sediment deposition and less deeply weathered Jurassic dolerite were recognised as moderate salt storage parts of the landscape. New research suggests that, although this broad pattern is relatively accurate, there is variability in the capacity for salt storage, and the mechanisms of salt storage, depending on the nature and configuration of rock and regolith materials in different hydrogeological landscapes.
A2.3.2 Groundwater Flow Systems Type

Groundwater Flow System (GFS) Type mapping indicated that hydrological and hydrogeological systems in the Greater Launceston Area (GLA) were dominantly local systems, with recharge and discharge occurring in relatively close spatial proximity (Figure 4). Notable exceptions to this were areas of exposed fractured Jurassic dolerite and a more dissected area of colluvial rises and low hills in the north of the study area mapped to indicate they were influenced by intermediate scale hydrologic processes. New research confirms that the hydrological and hydrogeological systems are dominantly local systems, but that the presence of penetrative structures in the sub-surface creates potential pathways for groundwater at intermediate and regional scales.
A2.3.3 Acid Sulphate Soils (ASS) and Potential Acid Sulphate Soils (PASS)

Figure A5: Acid Sulphate Soil (ASS) distribution in the Greater Launceston Area (GLA)

Acid Sulphate Soil (ASS) mapping was conducted at a broad scale but was able to define the general distribution of ASS along the Tamar Estuary and the North Esk River (Figure 5). In the GLA this compilation indicated that there was a higher acid sulphate soil hazard along the axis of the river valleys with less impact further from the main watercourses. New research suggests that the contribution of fresh water along the North Esk River system is influencing the degree of ASS manifestation with less impact along the North Esk River, moderate impact in the mid-west Invermay HGL area and higher impact along the Tamar Estuary (e.g. East Riverside HGL, north Invermay HGL).
A2.3.4 Land Use

Figure A6: Land Use in the Greater Launceston Area (GLA)

*Land Use* in the Greater Launceston Area (GLA) is dominated by the urban/peri-urban development associated with Launceston City, with localised industrial development on the periphery of the urban area (Figure A6). Parts of the landscape with highest relief in the surrounding area are typically forested, or support native grasslands. More open rises, low hills and hills form agricultural landscapes, dominated by grazing on modified pastures, with localised irrigated cropping in the south-east and west.
A2.3.5 Gamma Spectrometry (Radiometrics)

Figure A7: The Gamma Spectrometric (radiometric) image for the Greater Launceston Area (GLA)

The Gamma Spectrometric (radiometric) image for the Greater Launceston Area (GLA) was acquired for interpretation at a much broader scale than the scale of this study (Figure A7). The channel colours for this image are: potassium (K) red, uranium (U) blue and thorium (Th) green. Regolith materials in this area are not typically enriched with respect to K or U, but some scavenging of Th by secondary weathering products (e.g. sesquioxides) may be useful for discrimination of more deeply weathered sequences. Resolution of the derived image, especially over the urban area, is poor. However, use of component extracts of this data may provide information on regolith distribution patterns in a more detailed study.
A2.3.6 Dominant Soil Order

Figure A8: Dominant Soil Order categories in the Greater Launceston Area (GLA)

Dominant Soil Order mapping was conducted at a broad scale and provides only limited detail in the Greater Launceston Area (GLA) (Figure A8). Almost all of the low to moderate relief parts of the landscape have been mapped as supporting Brown Dermosol soils with isolated areas of Brown Chromosol soils in crestal locations in the south-west of the study area, and Brown Kurosols on the forested high relief low hills, hills and mountains to the east. A comprehensive program of soils mapping is currently underway, with a Meander Valley component complete and mapping for the Launceston City area almost finalised. This information should be available to inform more detailed interpretation of the hydrogeological landscape (HGL) units generated in this new research.
A2.3.7 Vegetation

Vegetation mapping was conducted at a broad scale and shows patterns that can generally be related to regolith substrate and aspect, because water is not limiting in this catchment area (Figure A9, Figure A10). Typically the higher relief parts of the landscape preserve Dry Eucalypt Forest and Woodland, with localised areas of Native Grassland in small sub-catchments, and all other areas supporting exotic vegetation (urban/peri-urban and agricultural land). Areas of Saltmarsh and Wetland have been recognised on the flood plains of the North Esk River and the Tamar Estuary. Because of the development of infrastructure, this mapping is of limited use in the urban parts of the Greater Launceston Area (GLA).
A2.3.8 Vegetation Description

Vegetation Description mapping was conducted at a catchment scale and shows more detailed patterns than statewide vegetation mapping (Figure A9, Figure A10). The vegetation distribution can generally be related to regolith substrate and aspect, because water is not limiting in this catchment area. The higher relief parts of the landscape preserve Eucalyptus amygdalina forest and woodland, with pockets of Eucalyptus pauciflora forest or woodland in elevated south facing valleys because of the colder microclimates in this setting. Low hills and hills surrounding higher landscapes preserve Eucalyptus viminalis grassy forest and woodland with some areas of Bursaria – Acacia woodland and scrub. Large areas of rise, low hill and hill country to the south-east and west are used as agricultural land with canopy species in these areas typically Eucalyptus viminalis and some Eucalyptus amygdalina. The urban area is dominated by exotic species but where preserved the canopy species is Eucalyptus viminalis. Areas of Saltmarsh and Wetland have been recognised on the flood plains of the North Esk River and the Tamar Estuary, with localised areas of sedgeland and rushland.
A3.1 Overview of salinity research conducted in the GLA

A great deal of salinity related research has been conducted in the Greater Launceston Area (GLA) by Federal and State agencies and through consultancies. An attempt is made to review these here to indicate the work that has already been undertaken and to contextualise new research.

A Tasmania-wide (1:500 000 scale) assessment of Land Systems containing areas of salinity (Grice, 1992; 1995) defined levels of salinity as nil, moderate (plant and tree vigour reduced, no salt sensitive species, bare patches less than 1m) or severe (extensive areas of bare ground, trees dead or dying, salt tolerant species present) and concluded that there was a moderate amount of salinity in the lower Meander Valley. Noble (1993) identified significant areas of the catchment as ‘marginally suitable for cropping’ and suggested that this area had ‘localised salinity, waterlogging and sodicity on lower-lying alluvial soils’.

Figure A11: Land Systems Containing Areas of Salinity map of Tasmania (Bastick and Walker 2000)
A National Classification of Catchments for land and river salinity control was compiled in the late 1990’s (Coram, 1998) and this formed a precursor document to later groundwater flow systems (GFS) research. As part of the National Land and Water Resources Audit (NLWA) a State-based analysis of the extent and impacts of dryland salinity in Tasmania was conducted by the Department of Primary Industries, Water and Environment (DPIWE), also known as the Land Systems characterisation (Figure A11) (Bastick and Walker 2000; Bastick and Lynch 2003). This research highlighted areas with known salinity expression and ‘land systems containing salinity’ were identified in the Greater Launceston Area (GLA). An estimate of the land area affected by salinity was: 7101 ha for the Tamar Estuary, 7019 ha for the South Esk, 3614 ha for the Meander Valley and 2385 ha for the North Esk subcatchment areas.

The Tasmanian component of the groundwater flow system (GFS) framework within the National Land and Water Resources Audit (NLWA) was based on this research (Latinovic et al. 2003). For the GLA this indicated that most of the area had local groundwater flow systems (GFS) with an intermediate system recognised associated with the Quaternary to recent estuarine landforms. To the south of Launceston a more regional groundwater flow system was identified in Paleogene (Tertiary) sedimentary rocks.

The National Action Plan (NAP) for Dryland Salinity was a Federal and State Government initiative that ran from 2001 to 2008. A number of ‘priority areas’ for detailed research were identified (Figure A12), and in Tasmania the focus was on the Midlands (e.g. Hocking et al. 2005). Although this work did not directly address dryland salinity characterisation in the GLA, the methodologies utilised for this research (e.g. groundwater flow system mapping) informed practice elsewhere.

Figure A12: The National Action Plan for Dryland Salinity and Water Quality Priority Area for Tasmania encompasses the Greater Launceston Area (GLA)
In the north-east of Tasmania, as part of the broader-scale Tasmanian Regional Drought Initiative (TRDI), electromagnetic induction (EM31) surveys were conducted at two sites in the Cressy-Longford area indicating that ‘lateral drainage dissolves soil salts and transports them to lower-lying areas where low flow rates and evaporation reveal salt hazards’ and that ‘ongoing development of widespread irrigation land management practice is both affected by and effecting hazards in the landscape’ illustrating how land salinisation was manifesting in this area (TRDI 2000).

In 2002 research was commissioned in the lower Meander Valley to assess the variability of soil conductivity using electromagnetic induction (EM31) techniques (Meadows, 2002). This survey identified areas of land saturation and potential land salinisation as more highly conductive than surrounding areas, and hence delineated sites that might be influenced by dryland salinity indicating appropriate locations for subsequent salinity coring. At the Prospect Vale Golf Course there was an elevated signal in small depressions in the bottom of the valley near the water hazard with a surface discharge of salty water (EC max. 13 dS/m) and a parallel moderately saline linear feature also associated with valley floor alluvium. The EMI surveys correlated well with visual signs of land salination, but also picked up zones of saturation (Figure A12). Interpretation of the data together with a local terrain map identified that the profiles were typically more saline with depth and in lower parts of terrain. The observation was that frequent watering, particularly at the Golf Course, potentially flushed surface salts (Meadows, 2002).

Figure A13: Saturated ground and saline scald on the Prospect Vale Golf Course

The Prospect Vale Golf Course became a focus field area for subsequent research commencing with a Salinity Scoping Study (Walker, 2003) that linked the land salinisation with the Land Systems boundaries. The influence of adjacent Land Systems in higher topographic settings on low-lying parts of the landscape was noted. This research recognised the Prospect Vale site as a local groundwater flow system and indicated that systematic reconnaissance in this area might reveal a more widespread salinity signal (Walker 2003).

In 2003 an array of 11 holes was drilled at the Prospect Vale Golf Course. Shallow (6m) and deep (10-15m) holes were drilled at each site, with piezometers inserted for scientific monitoring of saline water (Coffey Geosciences Pty. Ltd 2003). Two holes (at Site 5) were drilled in profiles over dolerite with the balance on Paleogene (Tertiary) sedimentary substrates. Holes were typically drilled through clays and sandy clay sediments. Waters were dominantly sodium.
chloride bearing with a minor magnesium chloride signature. Measured EC values for the water ranged from 9 to 13 dS/m, with pH in the range 5.5 to 7, with two holes at pH8. Preliminary findings from this array were summarised in an investigation into urban salinity and groundwater issues within the Prospect Vale area (Dyson, 2003).

One of the principal findings was that, as suspected, there was shallow saline groundwater present on the Prospect Vale valley floor in the Golf Course area causing damage to urban infrastructure. This was illustrated in the piezometers parallel to the longitudinal axis of the Golf Course greens in the bottom of the valley that show groundwater at or very close to the land surface. Water was observed ponding at the land surface with salt tolerant plant species surrounding scalds (Figure A13, Figure A14). Measured EC values for the holes ranged from 5 to 12dS/m. Groundwater pressures were coincident with land surface or above, indicating an upward discharge of saline groundwater from a deeper aquifer. The substrate is coarse-grained alluvium with preserved paleochannels, and deeper flow likely through underlying fractured dolerite. The implication is that clearing of the southern hills will cause greater recharge to the fractured rock aquifer causing rising water tables at the terminal end of the local flow system on the adjacent plains (Dyson 2003).

**Figure A14:** Buck’s Horn Plantain and Sea Barley Grass are two species of salt tolerant vegetation that are present around scalds at Prospect Vale Golf Course (DPIWE Saltpak)

In order to contextualise a detailed interpretation of the bore and piezometer data, a review of available data for the Prospect Vale location was conducted detailing known geology, land systems, surface waters, groundwater, soil salinity, waste water management and climate data (Coffey Geosciences Pty. Ltd., 2004). A more comprehensive study followed describing the local geology, land systems, surface drainage, and groundwater configuration based on contoured borehole data, in order to provide a context for interpretation of the controls on groundwater and surface water flow (Coffey Geosciences Pty. Ltd. 2005). The main findings were that regionally the geology is very complex with many large-scale structural features (e.g. the Tamar Fault) that influence intermediate and regional hydrogeology. This manifests as a high relief landscape with linked local mass-movement hazard (rock fall, and landslide). The four main rock types, Permian fluvioglacial sedimentary rocks, Jurassic dolerite sills and dykes, Paleogene (Tertiary) gravels and sands and Quaternary sediments associated with modern drainage systems, are variably modified by weathering. Some of the contacts are structural, some are conformable and some are intrusive. Lithological and structural changes across this landscape, in particular the presence of resistant Jurassic rocks and the formation of the Tamar graben, have influenced the broad-scale geomorphology. Contrasts in weathering patterns on the same rock types, and on
adjacent lithologies, introduces an additional layer of geomorphological complexity (Coffey Geosciences Pty. Ltd., 2005).

They observed that weathering influenced how the materials behave hydrogeologically. In summary they describe: Jurassic dolerites with a shallow regolith veneer, commonly in high relief areas; Jurassic dolerites with a thick regolith veneer (Figure A15); bedded Permian sediments with a shallow regolith veneer, commonly in high relief areas; bedded Permian sediments with a thick regolith veneer; semi-consolidated Paleogene (Tertiary) sediments with a thin, possibly eroded, regolith veneer; unconsolidated Paleogene (Tertiary) sediments with a thick regolith veneer; indurated Paleogene (Tertiary) sediment (duricrusts) with a thin regolith veneer; indurated Paleogene (Tertiary) sediment (duricrusts) with a variable thickness regolith veneer depending on configuration of the indurated layers, and whether they are flat-lying, unconsolidated Quaternary sediments with a thick regolith veneer, distal from the River; and, unconsolidated Quaternary sediments with a thin regolith veneer, proximal to the River (Coffey Geosciences Pty. Ltd., 2005). Implicit in this characterisation is the recognition that some understanding of the regolith (weathered soil and rock) configuration in the GLA would be useful to understand where and how salt is stored in this landscape, how much salt there is, and how water moves through and over the landscape mobilising these salts.

Figure A15: An example of Jurassic dolerite with a thick regolith veneer. The dolerite has been weathered along joints to form spheroidal corestones in a clay matrix

A review of GLA salinity by Hocking (2006) confirmed earlier observations that salinity issues in the Prospect Vale area are related to groundwater discharge from fractured dolerite aquifers and that artesian pressure introduces groundwater to sediments nearer the land surface through which saline water discharges (as per Dyson 2003). Hocking (2006) recommended a ‘uniform salinity ranking’ be applied across the entire GLA, and that a salinity monitoring network be established to enable characterisation of a complex system.

In recognition that salinity is ‘an established planning hazard in the GLA’ a Salinity Management Plan for the Greater Launceston Area was established in 2007 (Armstrong 2007). The broad observation was that although the ‘impacts are not widespread…the level of understanding of
drivers of salinity are limited, and hydro-geologists are unable to confidently predict where salinity is a tangible threat to new developments. Given the limited information available and the complexity of the system the conclusion was that for the purposes of the Plan 'salinity is a potential hazard for developments in all areas of the GLA', a view consistent with the earlier evaluation by Hocking (2006). In addition to a framework of planning guidelines the Plan recommended: the distribution of publications describing urban salinity and its management; the monitoring of established groundwater bores for water depth and salinity; monthly monitoring of surface water salinity at sites across the GLA; and, the formation of a Salinity Working Group with representatives from the three (Meander Valley, West Tamar and Launceston City) Councils to implement the other recommendations. In summary the Plan detailed; how planning schemes should address salinity risks; requirements for development applications including assessment and management of salinity risks; how monitoring requirements would be determined; and, mechanisms to initiate future geological investigations in priority areas (Armstrong 2007).

At the same time, a study of salinity hazard in the Meander Valley divided the catchment on the basis of high or low rainfall, identifying that salinity hazards generally only occur below 800 mm annual rainfall. In the <800 mm rainfall zone, groundwater flow systems were identified based on underlying geology and whether the groundwater system was local, intermediate or regional (Lynch, 2007; Bastick et al. 2007a). Although the general classification for the Meander Valley was that it was an area of moderate salinity risk, the higher salinity risk groundwater flow system categories (<800 mm rainfall and local to intermediate GFS) largely coincide with the urban/peri-urban parts of the GLA in the eastern Meander Valley (Bastick et al. 2007a).

Locally, as part of the National Land and Water Resources Audit (NLWRA), an assessment of National Land Salinity Indicators in Tasmania was conducted at Back Creek in the Cressy-Longford area, SW of the GLA (Bastick et al. 2007b). The trial showed that the complexity of the hydrogeological systems and limited access to biophysical data (e.g. for baseflow) or reliable monitoring data (e.g. for salt scald size) limited the indicators that could readily be used in Back Creek and elsewhere in Tasmania. Favoured salinity indicators included: depth to groundwater/groundwater salinity, and surface water salinity (salinity concentration plus flow). The report recommended the establishment of national guidelines for methodology and standards to be used when measuring salinity indicators (Bastick et al. 2007b).

A parallel audit of salinity data for Tasmania (Hocking 2007) identified that although ‘considerable financial and physical investment has been made in salinity monitoring in the NAP region of Tasmania over the past decade, limited coordination…has led to a number of shortfalls in the quantity, location, quality and usefulness of salinity monitoring information’. The recommendation is that there is investment in salinity monitoring infrastructure to determine long-term salinity trends in the region, and achievable (measurable) salinity targets for resource condition management. Hocking (2007) identifies that ‘there is no established framework for monitoring the general status of salinity, nor the status of salinity in response to best practice intervention’ and ‘there is no clearly defined framework which outlines monitoring on the basis of baseline and performance criteria, and that allows these concepts to be adequately viewed in context’. The implication is that a groundwater flow systems-based framework, or adaptation of this approach, might provide this monitoring framework.

In 2007, four shallow groundwater monitoring bores were drilled in the suburbs of Riverside, Mowbray, Kings Meadow and St Leonards in the GLA. The distribution of these sites was designed to complement other sites in South Launceston and at Prospect Vale, in order to establish an urban salinity monitoring network for the GLA (Hocking et al. 2007). Surface water monitoring was also conducted at two locations on Kings Meadow Rivulet, two locations on Jinglers Creek and one location on the North Esk River. Environmental conditions were found to
be highly variable in the area, ‘some have a shallow watertable, some have low salinity surface water and some locations are saline’ (e.g. 5 of 16 bores had mean salinity higher than 2dS/m). The suggestion is that a more sophisticated array of bores and piezometers should be established, and monitored in an ongoing way, in order to identify salinity trends.

The State of the Environment Report for Tasmania (Tasmanian Planning Commission, 2009) has a summary of historical research on ‘Areas Affected by Salinity in Tasmania’. The indicators used for this analysis are: the area affected by salinity, the depth to groundwater (m), the groundwater EC (µS/cm at 25°C) and the surface water salinity (µS/cm at 25°C). The GLA falls within the salt affected area.

Recent studies in the GLA reflect a commitment to ongoing characterisation of the landscape in order to better understand salt mobilisation processes (e.g. this study) and monitoring water across the GLA to ensure that a more continuous record of water quality and salinity data is maintained (e.g. surface water monitoring; Furlonge 2011). Sites in the Furlonge (2011) surface water monitoring program were selected because they had elevated salinity levels. These include Kings Meadow Rivulet (Figure A16), Jinglers Creek and several other sites in the region surrounding the GLA. In most cases data from 2007/8 was compared with data from 2010/11 and apart from one site where a revegetation initiative had been actioned higher in the catchment, the sites showed similar or increased salinity measurements, with some seasonal variation, and increased turbidity over the 4 years. Many of the streams sampled exceeded Australian New Zealand Environment Conservation Council (ANZECC) trigger values for water quality for these two parameters.

Figure A16: Upper Kings Meadow Rivulet with extant native vegetation and water tolerant plant species in the drainage line
A3.2 Significance of the historical context and gaps in the research

National and State salinity programs formed the basis of much of the early targeted salinity research in northern Tasmania, and of later overview and audit reporting (Grice, 1992; 1995; Coram, 1998; Bastick and Walker, 2000; Bastick and Lynch 2003; Latinovic et al. 2003; Hocking 2007; Tasmanian Planning Commission, 2009). A consequence of this is that many of the studies in northern Tasmania were conducted at broad scale, so only generalised characterisations of land and water salinity were made. Detailed studies were conducted in local areas (e.g. Noble 1993; Hocking et al. 2005; TRDI 2000; Meadows, 2002) but studies of this kind were not coordinated across or between regions in a consistent manner. These factors contributed to provision of generic indicator statements rather than detailed process-based characterisations of landscapes and hydrogeological systems. For example salinity manifestation is described as *moderate* on Jurassic dolerites, when commonly salinity is *high* on deeply weathered profiles on Jurassic dolerite, and *low* where there is exposed or subcropping rock. The danger of broad biophysical statements based on hybridised descriptions is the likelihood of underestimating the salinity hazard, and not accurately attributing salinity hazard to appropriate management areas. Scaled groundwater flow system (GFS)-based analyses (e.g. Lynch 2007) started to address this gap using the GFS methodology at more local scales.

The hydrogeological landscapes (HGL) methodology is an adapted and scaled landscape characterisation approach that provides a process-based conceptual framework for interpreting patterns of salinity hazard across catchments. Compilation of HGL units for a region allows schematic conceptual models for salt storage and surface and groundwater flow pathways to be described and the mechanisms for salination of land and water systems to be more clearly understood. It follows that salinity hazard in particular parts of the landscape can be more accurately assessed. In turn this enables more informed strategic management decision-making and planning to take place.

Figure A17: Deeply weathered Paleogene paleo-estuarine and paleo-lacustrine sediments showing secondary weathering features including formation of ferruginised layers (ironstone). These regolith materials have been recognised as one of the major salt stores in the GLA area.
Typically State and local government agencies (e.g. NRM North, city and regional Councils) coordinated research that built on previous work in their area (e.g. for the GLA: Meadows 2002; Walker 2003; Geosciences Pty. Ltd 2003; Dyson 2003; Geosciences Pty. Ltd 2004, 2005; Hocking 2006; Lynch 2007; Bastick et al. 2007a; Bastick et al. 2007b; Hocking et al. 2007; Armstrong 2007; Furlonge 2011), but there was not always ongoing coordinated interaction with agencies from adjacent jurisdictions. The operation of the Launceston Salinity Action Group (LSAG), a collaborative team with representatives from the Meander Valley Council, the West Tamar Council, the Launceston City Council and Ben Lomond Water, is one example of how several agencies with a shared natural resource management (NRM) issue, can sustain a coordinated strategic research program across jurisdictions. Further, the central collation of resources generated for the region, through agencies like NRM North and NRM South, provide access to high quality base-level data for all local and regional studies.

Despite the clear sequence of research commissioned for the GLA over the past decade, consultant scientists focussed on the most apparent manifestation of salinity in the GLA, with a disproportionate amount of work conducted in the Prospect Vale area relative to other areas. This occurred in part because of a significant financial commitment associated with emplacement of the piezometer and bore array at the Prospect Vale Golf Course. This emphasis on understanding what was happening at the Prospect Vale site meant that there may have been less focus on other areas of localised salinity manifestation in Riverside, Kings Meadow, East Launceston, City East and Hadspen, for example, and limited recognition of more cryptic, lower-level salinity manifestation across the GLA. Hydrogeological landscape (HGL) research in this area will provide a basis for analysis of: salinity distribution; the processes causing land and water salinisation; and patterns of urban/peri-urban infrastructure salt damage across the GLA.

A3.3 Identified Gaps in the Research

There a number of notable research gaps that, if addressed, will enable clearer understanding of land and water salinity processes in the GLA. They include:

1. Existing studies are sodium chloride (NaCl) focussed, there is no discussion of carbonate salts developed on more alkaline substrates, and descriptions of sulphate salt distribution are typically restricted to acid sulphate soil (ASS) and potential acid sulphate soil (PASS) reporting instead of being included as part of the hydrogeological overview.

2. Clearer links could be made with aligned research on other hazards relating to salinisation of regolith profiles and/or baseflow, throughflow and surface flow of water, including: soil sodicity and erosion hazard; vegetation health; saturation of shallow regolith systems causing waterlogging; saturation of landslide headscarp sequences due to groundwater perching enhancing rotational slumping; or movement along a bedding-parallel basal décollement formed where saturated clay-rich sediments slide over more coherent materials.

3. There is only limited mention of the influence of extreme relief in some locations, apart from suggesting that this may contribute to hydraulic head in confined groundwater systems.

4. There is limited discussion of the relationship between the high to extremely high rainfall in this area, the seasonality of rainfall and the detailed controls on salt storage in regolith profiles for GLA landscapes.

5. There is limited discussion about the links between the thickness of regolith, the nature of regolith materials (Figure A17), the genetic relationship between regolith materials and the underlying geology, and the volume and location (configuration) of regolith materials in the landscape. Studies to date have recognised broad patterns of salinity hazard over particular rock types, but how this manifests in a landscape depends on how salts are stored and mobilised.
through and over soil and weathered rock. Detailed soil mapping is available for the eastern Meander Valley but the Launceston City mapping is currently being finalised. Access to this information will inform future research.

6. There is limited data and hence limited discussion of structural controls on intermediate to regional groundwater flow systems (GFS). Most salinity ‘case studies’ within the GLA are considered as local systems (e.g. Prospect Vale Golf Course).

7. A commitment to surface and groundwater monitoring is constrained by the expense of emplacing infrastructure and staffing the survey team.

The above were identified in the first stage of the project. The next stage addresses the detailed hydrogeological landscape (HGL) characterisation of the GLA study area, which provides a framework for understanding the landscape processes causing the land and water salinity hazard patterns manifesting in this urban/peri-urban setting.
A4.1 Preliminary Hydrogeological Landscapes (HGL) GLA compilation

Because prior research in the GLA indicated that salinity was preferentially associated with some geological units, geology was used as guide to initially construct boundaries between areas with differing hydrogeological characteristics. Field observations allowed a preliminary description of associated landforms and regolith materials enabling more reliable boundaries to be drawn. This process involved development of an early understanding of where salts might be stored in the landscape and how water might move through and over the landscape, thereby mobilising salts. Coupling this information with the information provided from the Urban Salt Signal survey facilitated preparation of a broad salinity statement for each unit and a preliminary indication of the salinity risk for each unit (Figure A18, Table A1).

Figure A18: Preliminary Hydrogeological Landscape (HGL) units for the GLA

Preliminary Hydrogeological Landscapes (HGL) have been developed based on available biophysical information and field observations. Each HGL has a characteristic configuration of rock and regolith materials, salt storage capacity and surface and groundwater pathways.
Table A1: An overview of biophysical characteristics of the preliminary hydrogeological landscape (HGL) units defined in this study

<table>
<thead>
<tr>
<th>HGL Unit</th>
<th>Geology</th>
<th>Regolith</th>
<th>Salt Signal</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hadspen</strong></td>
<td>Quaternary alluvium and recent aeolian sediments</td>
<td>Stepped terrace landscape with some aeolian (wind-blown) sands</td>
<td>Salt is abundant on terrace surfaces and in back terrace settings</td>
<td>High</td>
</tr>
<tr>
<td><strong>Prospect Vale</strong></td>
<td>Quaternary alluvium over weathered Jurassic dolerite and possibly over weathered Permian sediment (no outcrop)</td>
<td>Shallow sediment cover, thicker in valley axis, over weathered rock, causes ponding. Up-faulted block to north has formed an enclosed valley</td>
<td>Salt expression is extreme on valley floor, water table is at the land surface. Valley enclosed by higher relief landforms, influences hydraulic head</td>
<td>High; especially on the valley floor</td>
</tr>
<tr>
<td><strong>Reed</strong></td>
<td>Weathered Jurassic dolerite with some exposed corestones</td>
<td>Faulted landscape steps to the east, moderate to deep weathering on surface of steps, especially in back-step settings</td>
<td>Salt expression is more evident on surfaces of steps and in back step settings where regolith is thicker; some discharge associated with step faults</td>
<td>High in discharge areas; high on weathered Jurassic dolerite and on associated colluvial slopes; forms a major salt store in this area</td>
</tr>
<tr>
<td><strong>Trevallyn</strong></td>
<td>Jurassic dolerite, weathered on upper surfaces, with exposed rock on concave faces to east</td>
<td>Incised drainage cuts down into this up-faulted block. The block has moved upward relative to adjacent landscapes to north and south. Weathering preserved on upper surfaces but stripped elsewhere</td>
<td>Moderate to high salt expression corresponding with locally thicker regolith on upper surface of faulted block; partially forested</td>
<td>Moderate, locally high. Removing trees may have significant impact</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>HGL Unit</th>
<th>Geology</th>
<th>Regolith</th>
<th>Salt Signal</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>West Riverside</strong></td>
<td>Weathered Jurassic dolerite with some exposed corestones</td>
<td>Faulted landscape steps to the east, moderate to deep weathering on surface of steps, especially in back step settings</td>
<td>Salt expression more evident on surfaces of steps and in back step settings where regolith is thicker; some discharge associated with step faults</td>
<td>High in discharge areas, high on weathered Jurassic dolerite and on associated colluvial slopes; forms a major salt store in this area</td>
</tr>
<tr>
<td><strong>Legana</strong></td>
<td>Weathered Paleogene sandy paleo-estuarine sediments</td>
<td>Deeply weathered sandy clay sediments forming a flat-topped, terraced peninsula</td>
<td>Moderate to low salt expression on sandy loam soils</td>
<td>Low; locally moderate. Some PASS on the estuarine plain.</td>
</tr>
<tr>
<td><strong>East Riverside</strong></td>
<td>Quaternary alluvium; estuarine sediments (sands, silts and muds)</td>
<td>Potential acid sulphate soils (PASS) and acid sulphate soils (ASS) on estuarine floodplains and low terraces</td>
<td>Parts of this landscape are in the intertidal zone; in general a presence of sulphate salts in oxidised profiles</td>
<td>High PASS/ASS and (NaCl) salt associated with saline estuarine waters</td>
</tr>
<tr>
<td><strong>Alanvale</strong></td>
<td>Weathered Jurassic dolerite, locally draped with Paleogene paleo-estuarine (lacustrine?) sediments (e.g. Mowbray surface). Escarpment adjacent to North Esk River</td>
<td>Faulted landscape steps to the west, landforms cross-cut by creeks, moderate to deep weathering on surface of steps and on colluvial slopes</td>
<td>Salt expression more evident on surfaces of fault steps and on colluvial slopes in weathered dolerite, where regolith is thicker. Some PASS on the estuarine plain.</td>
<td>Moderate on weathered Jurassic dolerite and on associated colluvial slopes; localised highs on deeper profiles. Some PASS on the estuarine plain.</td>
</tr>
<tr>
<td>HGL Unit</td>
<td>Geology</td>
<td>Regolith</td>
<td>Salt Signal</td>
<td>Risk</td>
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<tr>
<td><strong>Ravenswood</strong></td>
<td>Weathered Jurassic dolerite, evidence of Paleogene basalt caps in localised crestal settings. Escarpment adjacent to North Esk River</td>
<td>Dolerite forms an elevated area with cross-cutting incised creeks. Deeper weathering on flatter areas; exposed rock in steeper areas</td>
<td>Salt expression high in flatter elevated areas preserved between stream valleys, and on colluvium; low in steeper areas on exposed rock</td>
<td>Moderate to high</td>
</tr>
<tr>
<td><strong>St Leonards</strong></td>
<td>Weathered Jurassic dolerite</td>
<td>Elevated dolerite area is more dissected by cross-cutting streams in this area; forms conical hills and more undulating landscape</td>
<td>Salt expression is less evident than further north, as deeply weathered profiles not as well preserved; localised salt expression in colluvium</td>
<td>Moderate to low</td>
</tr>
<tr>
<td><strong>Invermay</strong></td>
<td>Quaternary alluvium; estuarine sediments (sands, silts and muds)</td>
<td>An area of low relief typically &lt;10m above River level, flood plain and low terraces</td>
<td>Some ASS and PASS signal as well as salt associated with saline estuarine waters. Terraces store salt, and in city additional salt contribution from higher relief areas to east</td>
<td>High PASS/ASS and (NaCl) salt associated with saline estuarine waters on floodplain. Terraces in city and western Invermay higher salt signal than eastern Invermay plains near the North Esk River</td>
</tr>
<tr>
<td><strong>North Esk</strong></td>
<td>Quaternary alluvium; fluvial sediments (sands, silts and muds)</td>
<td>Flood plains, swampy ground and low terraces showing lower ASS/PASS and salt expression than along the Tamar River</td>
<td>Terraces store some salt, but flushed adjacent to the River. Some ASS/PASS in saturated and drained areas</td>
<td>ASS/PASS and salt moderate; saturation high</td>
</tr>
<tr>
<td>Area</td>
<td>Sediments Description</td>
<td>Hydrological Conditions</td>
<td>Landform Implications</td>
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<tr>
<td>City East</td>
<td>Weathered Paleogene sandy clay and paleo-estuarine sediments</td>
<td>Salt expression is localised near the top and at the toe of the landslide, and on landslide rubble; salt contribution to terrace landforms in the footslope area.</td>
<td>High on deeply weathered sediments; forms a major salt store in this area</td>
<td></td>
</tr>
<tr>
<td>East Launceston</td>
<td>Weathered Paleogene sandy clay and paleo-estuarine sediments</td>
<td>Salt expression present across this landscape but strongly expressed in depressions at the intersection of terrace/fault steps and stream valleys, and behind barriers to flow</td>
<td>High on deeply weathered sediments; forms a major salt store in this area</td>
<td></td>
</tr>
<tr>
<td>West Kings Meadow</td>
<td>Weathered Paleogene sandy clay and paleo-estuarine sediments with adjacent weathered Jurassic dolerite</td>
<td>Localised salt expression in areas of ponded water and local stream salinity levels are high</td>
<td>Moderate land salinity but high potential because of store; high stream salinity</td>
<td></td>
</tr>
<tr>
<td>Youngtown</td>
<td>Weathered Jurassic dolerite</td>
<td>Salt expression concentrated on top of ridge where regolith is thickest; less signal on flanks of ridge</td>
<td>Locally high</td>
<td></td>
</tr>
<tr>
<td>Norwood</td>
<td>Weathered Paleogene sandy clay and paleo-estuarine sediments</td>
<td>Relatively low salinity signal in this area at present but high potential for perchinging of</td>
<td>Low; locally moderate. Potential impact high if land use practice changes,</td>
<td></td>
</tr>
</tbody>
</table>
A4.2 Use of the Greater Launceston Area (GLA) Water Usage data

A preliminary overview of Water Usage Data for the Greater Launceston Area (GLA) did not show evident patterns in water usage at the broad scale. There may also be seasonal variation in water usage that reveals patterns not apparent for the existing data. The data set is detailed and has been interpreted in parallel with detailed characterisation of the Hydrogeological Landscape (HGL) units conducted in Part B (Stage 2) of this study.

A4.3 Use of the Greater Launceston Area (GLA) Urban Salt Signal data

Patterns in the Urban Salt Signal survey data facilitated decision-making about placement of boundaries between preliminary hydrogeological landscape (HGL) units.

A4.3.1 Urban Salt Signal data and Geology

![Figure A19: Urban Salt Signal data overlain on Geology for the Greater Launceston Area (GLA)](image)

When the Urban Salt Signal data, derived from a comprehensive field survey conducted by Launceston Salinity Action Group (LSAG) partner organisation staff, was overlain on the available mapped geology, most salt damage occurred in association with deeply weathered Jurassic dolerite (e.g. West Riverside), deeply weathered Paleogene sediments (e.g. West Launceston), and Quaternary fluvial and estuarine sediments (e.g. Hadspsen) (Figure A19).
A4.3.2 Urban Salt Signal data and preliminary Hydrogeological Landscape units

When the Urban Salt Signal data, derived from a field survey, is overlain on the preliminary hydrogeological landscape (HGL) units, the areas most impacted are Prospect Vale, City East, West Launceston, north Norwood, and West Kings Meadow (Paleogene sediments), localised areas in Youngtown, north Reed, West Riverside, Alanvale, east Ravenswood and northeast St Leonards (deeply weathered Jurassic dolerite), Hadspen and East Riverside (Quaternary fluvial and estuarine sediments) (Figure A20). Although a number of these HGL units are on similar geology each HGL has a characteristic configuration of rock and regolith materials, salt storage capacity and surface and groundwater pathways.

A5.1 Schematic Conceptual Models: 3 Case Studies

Detailed biophysical characterisation of each preliminary hydrogeological landscape (HGL) unit developed for the Greater Launceston Area (GLA) will enable refinement of polygon boundaries, and development of a greater understanding of the hydrogeological and landscape processes taking place in each area. To give an indication of the value of this detailed characterisation, an early overview of observed processes for three preliminary HGL unit areas: West Riverside HGL; City East HGL/East Launceston HGL; and, Hadspen HGL, is provided.
**A5.1.1 West Riverside HGL unit**

In the West Riverside area fault-bounded steps on Jurassic dolerite form a tiered geomorphology that steps toward the valley (Figure A21, Figure A22), and the lower slopes are formed on terrace and floodplain landforms associated with the Tamar River (East Riverside HGL) (Figure A22). Regolith materials on the West Riverside HGL are deeply weathered dolerite commonly preserving joint-controlled spheroidal weathering where relatively resistant dolerite corestones are nested in ‘onion-skins’ of more weathered dolerite wholly enclosed in a red-brown soil-like clay matrix. For some locations these deposits were incorrectly characterised as dolerite conglomerates in previous work (e.g. Longman 1966).

![Figure A21: Schematic Conceptual Model for the preliminary West Riverside HGL](image)

In places this deep weathering process is in its advanced stages with no preserved dolerite corestones and the clay matrix hydrolysed to form bauxite deposits. Deeper weathering profiles are typically found on upper surfaces and in back-fault step settings, and are commonly mapped as Paleogene (Tertiary). Broader studies of the GLA have implied that the principal source of salt in the Launceston landscape are the Paleogene sediments but regolith materials derived from deep weathering of Jurassic dolerite are volumetrically significant and form substantive salt stores in this landscape.
Figure A22: View to the east from an elevated fault-step on the West Riverside HGL across the estuarine plains of the East Riverside HGL looking across the Tamar Estuary to the Alanvale HGL

Because the landscape is faulted there are areas of relatively fresh exposed dolerite near areas with preserved weathering profiles. Groundwater movement is largely controlled by jointing in the Jurassic dolerites, but perching of water over structural features (e.g. faults), behind impediments to flow (e.g. dykes, upfaulted blocks) and over impermeable layers (e.g. saturated clays) influences where solute-laden water discharges. Field observations indicate that salt impact (Figure A23) is most pronounced in back fault step settings with some discharge behind (west of) faults. On the lower colluvial slopes, below West Tamar Road, permeable dolerite colluvium overlies jointed weathered rock so salt impact is more distributed. Quaternary terrace and plain landforms of the East Riverside HGL have been more strongly influenced by interaction with saline fluids of the Tamar Estuary.

Figure A23: Etching of brickwork due to salt damage in the West Riverside HGL area
A5.1.2 City East HGL unit - East Launceston HGL unit

The geology underlying the City East HGL - East Launceston HGL area strongly influences the landscape processes taking place in this part of Launceston City. The most notable geomorphic feature in this area is an elevated N-S oriented lens-shaped ridge, with High Street running along the crest (Figure A24) that is oblique to the dominant NW-SE structural fabric of the Tamar valley. Prior geological mapping has attributed the formation of this elevated ridge to a significant high-stand of the paleo-Tamar River system caused by damming of the valley to the north and deposition of sediments within a lake formed in Paleogene times (Longman 1966, McClenaghan and Baillie 1975). In this model the lens-shaped ridge was formed by subsequent erosion and down-cutting through these lake deposits by the North and South Esk Rivers.

Although this mechanism is not disputed in a general sense, it does not fully explain why the ridge is elevated topographically relative to other clear indicators of Tamar River high-stand (e.g. extensive preserved paleo-floodplain surfaces). The implication is that there is also some structural control on the formation of this ridge, and the geometry of the landscape feature suggests that it might be part of a positive flower structure formed due to oblique transpression across the Tamar Valley in this area.

Figure A24: Schematic Conceptual Model for the preliminary City East HGL and East Launceston HGL

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Regolith materials are deeply weathered bedded Paleogene paleo-estuarine and paleo-lacustrine clayey sands and sandy clays with well-developed bedding-parallel ferruginised (ironstone) layers at approximately metre intervals throughout the stratigraphy (Figure A17). Saturated clay intervals and laterally extensive secondary ironstone layers strongly influence subsurface fluid movement. This results in perching of groundwater at multiple levels throughout the stratigraphy, lateral groundwater flow in the subsurface, emergence of solute-laden water at breaks in slope, and ponding of water in back terrace/fault step areas.

On the western flank, and crestal area on the east, of this ridge there is significant landslide hazard, and evidence of former landslide activity. Landslide impact appears to be more severe on the western side of the ridge implying that there may be some structural and hydrogeological control (e.g. bedding dip to west, saturation due to perching in headscarp area, deeply weathered regolith materials form ‘soft-weak rock’). In the City East HGL area there is greater salt signal in the headscarp and footslope areas where water is emerging at the land surface. The landslide debris is relatively permeable and there is some lateral groundwater flow through these materials. Where the landslide footslope encounters the Quaternary terraces in the city CBD (Invermay HGL) salt is contributed from both landscape components and salinity impact is apparent.
On the eastern flank of the ridge, in the East Launceston HGL, the land surface has a complex geometry formed due to the interaction of (broadly N-S oriented) terrace/fault landforms stepping to the west (Figure A24, Figure A25) and (broadly E-W oriented) stream valleys cross-cutting approximately perpendicular to these features. Salt damage is most apparent in swales formed where stream valleys cut across break-in-slope or back terrace/fault step settings, but is generally present wherever water is perched in the landscape, typically in back terrace/fault step locations (Figure A26). There is localised salt impact in areas where water is ponded west of a low ridge that has Penquite Road constructed on it. The lower slopes in this landscape are formed on terrace landforms associated with the North Esk River (North Esk HGL).

**A5.1.3 Hadspen HGL Unit**

In the Hadspen HGL area the Quaternary terraces associated with landscape evolution in the South Esk River valley (Figure A27, Figure A28), are influencing the *Urban Salt Signal*. Salt presence at the land surface is observed dominantly in break of slope locations and in back terrace settings, but in some cases salt damage is found near the edge of the terrace (Figure A29).
Figure A27: Schematic Conceptual Model for the preliminary Hadspen HGL

Figure A28: View toward the South Esk River showing the terraced landscape of the Hadspen HGL
Regolith materials on the terraces include variably weathered bedded clayey sands and sandy clays with localised bedding-parallel cementation of sediments, forming laterally extensive impediments to flow. There are localised areas of wind-blown (aeolian) sediments, originally derived from deflation of exposed South Esk River sediments, preserved across the terrace landscape, and these are likely to have different hydrological properties to the river (fluvial) sediments they are deposited on.

Figure A29: Etching of brickwork due to salt damage and salt efflorescence in the Hadspen HGL area
Greater Launceston Area Urban Salinity Strategy

Part B. Detailed Hydrogeological Landscape (HGL) characterisation and management framework development

B1. Introduction

Salinity has been recognised in the Launceston area since the early 1990's when considerable salinity mapping was conducted across the area, and a number of salinity investigations were subsequently initiated (Section A3.1). The Hydrogeological Landscapes: Stage 1 Report was completed in 2011 as part of a project with the Dryland Salinity Hazard Mitigation Program (DSHMP) of University of Canberra (Moore et al. 2012). Stage 2 of the project was undertaken to look at finer scale mapping in the urban areas of the Greater Launceston Area (GLA) in line with the methodology used in the previous HGL projects (Moore et al. 2015). This report constitutes a compilation of the findings from Stage 1 (Part A) and Stage 2 (Part B) of the GLA Urban Salinity Strategy Project.

The Hydrogeological Landscape (HGL) concept provides a structure for the understanding of how salinity manifests in the landscape and how differences in salinity are expressed across the landscape. An HGL spatially defines areas of similar salt stores and pathways to salt mobilisation. The process of HGL determination relies on the integration of a number of factors: geology, soils, slope, regolith depth, and climate; an understanding of the differences in salinity development and the impacts (land salinity/salt load/EC) in landscapes. An evaluation of how these factors interact in different parts of the landscape is conducted, resulting in development of a conceptual model to explain: where salt is likely stored in the landscape, how water moves through the landscape; and how these processes interact. Information sources such as soils maps, site characterisation, salinity site maps, hydrogeological data and surface and groundwater data are incorporated into standard templates.

Comprehensive HGL templates for the GLA are presented here to provide a framework that spatially defines management areas and recommends how best to manage and prioritise landscapes. Different HGLs have been defined with unique salinity situations requiring tailored management solutions. Each HGL is defined spatially and urban management actions are assigned to specific management areas in each landscape. The project will enable the community and local government to understand the variability of urban landscapes, and guide approaches to minimise impacts of future developments (both green fill and urban infill) from urban salinity.

Experience gained in project work at various scales in urban situations, has shown that the HGL framework allows the following objectives to be undertaken:

1. Explain how water moves through the landscape
2. Explain where the salt stores are in the landscape
3. Explain and detail the variability in landscapes controlling this movement and storage
4. Management of the landscape based on the understanding of these processes
5. Identify risk and prioritise hazard management in the landscape

The scope of the advice in an urban environment has been to firstly understand how a "landscape works". If you understand the integration of soils, geology, landform, salinity data, regolith and climate (HGL) you can then understand the key criteria needed in new development areas and salinity management in existing landscapes. This has been achieved by use of the
HGL framework (Moore et al. 2016) to identify the appropriate management action in a management area (i.e. “the right action in the right place”).

B2. Background

B2.1 Local Setting

Localised expression of land salinisation, with associated salt load and elevated electrical conductivity levels in streams, is observed in an urban/peri-urban setting in the Greater Launceston Area (GLA)(Figure B30). Evidence for salt presence in parts of the landscape includes: etching and rotting of brickwork; ‘rising damp’ in masonry walls; fracturing and flaking of pavements and roads; salt efflorescence as a ‘tide mark’ on some brick and concrete walls; blistering of paintwork; formation of scalds in grassy areas; presence of salt tolerant species in water courses; and, acid and saline chemistries in some natural waters. Informed management of salinised land and water through: skilled urban planning; targeted infrastructure maintenance; use of appropriate construction materials and methods; minimisation of excavation and land-use practices that impact land and water salinity; provision of information to stakeholders; and, other tailored solutions by local councils and water authorities, requires an understanding of how and why salt is manifesting in some parts of the landscape.

Hydrogeological landscape (HGL) characterisation explains: the configuration of soil, regolith and fractured rock materials in the landscape; the capacity for salt storage and release in different media; how water moves over and through these materials; the mechanisms for salt mobilisation in the landscape; and, the likely provenance of the salt. Preliminary findings indicated that land salinisation typically impacts localised areas on: deeply weathered Jurassic dolerite; moderately to deeply weathered bedded palaeo-estuarine sediments of the Paleogene Tamar/Esk River system; some Late Cenozoic terrace deposits along the Tamar and Esk Rivers; and some Holocene estuarine sediment (Moore 2012). Preliminary hydrogeological landscape (HGL) units have been derived from analysis of available meta-data, collated ‘urban signal’ salinity indication surveys and preliminary field observation. These HGL units enable broad discrimination of the way natural and constructed features of the contemporary landscape influence surface and subsurface water flow and salt transport in different parts of the GLA. The HGL boundaries are further refined based on field observations and measurements.

In Part B an analysis of the HGL units defined in the GLA USS Hydrogeological Landscape Conceptualisation (Moore et al. 2012) is presented. Detailed characterisation of the HGL units is required to: better understand the processes taking place in different areas; explain how the ground saturation and salinity signal manifests differently in different areas; and, support development of targeted management and planning solutions for different parts of the GLA.
Salinity is a symptom of the dynamic way water moves through the landscape. Salinity occurs when salts present in the landscape are mobilised by surface water or groundwater. It is the result of changes in water use by vegetation. If the landscape water balance is altered by natural environmental changes, or human-induced changes in land use, naturally occurring salts are transported and concentrated, and land and water salinity is the result of this change.

Causes of salinity in the wider GLA include:
- Changes in water balance
- Sources of salt and redistribution in the landscape
- Varieties of groundwater processes
- Dry scalds which expose saline soils

Pre European landscapes were characterised by:
- Native vegetation communities which had a high perennial plant component (trees and grasses)
- Native vegetation communities which had a high diversity of species
- Soils which had organic matter layers ($A_0$ horizons).

Post European settlement land use has led to significant changes. In general the landscape has been “annualised” by the farming and grazing systems of the present and the past. Many farming systems, and urban/peri-urban plantings, are now based on annual plants. This has resulted in a simplification of the landscape vegetation. Diverse woodlands and grasslands have
been replaced by mono-cultures of crops, simple mixtures of pasture species or plantings of exotic species. This limits the timing and amount of water used by the vegetation in the landscape across the year and across climate cycles and events. Where pastures are perennial (e.g. perennial ryegrass and some perennial clovers like *Trifolium repens*) species may remain dormant in summer, and as a result use less rainwater compared to native vegetation. In areas of urban/peri-urban development, enhanced runoff and the influence of man-made impediments to flow may augment the salinity impact.

Salt is present naturally in the Australian landscape. Salt is stored within the landscape in soils, regolith materials, groundwater and rock materials. Throughout the GLA an in the surrounding rural areas, stored salts are mobilised through changes in water balance. The original sources of this naturally occurring salt may include:

- Cyclic salt – deposited as sea spray/ atmospheric salt
- Aeolian salt – deposited with dust
- Rock weathering - mineral weathering within rock structures
- Connate salts – salt from sedimentary rocks where the salt stayed within the rock matrix at the time of deposition
- Lacustrine salt - buried lake sediments.

In some landscape settings the soil, regolith and rock material is able to store salt even after a land use change (removal of trees) has occurred, and salt does not cause a salinity impact. Where this balance does not occur salt can express at various points in the landscape, and in waterways. In urban situations, where the landscape shape is modified (for example due to road and building construction, including cut and fill practices), and water movement is impeded and/or water use is increased, salinity may occur.

Saline effects within the Greater Launceston Area occur on a range landforms and geologies. Possible causes of urban salinity in the GLA are shown in the cross-sectional diagrams for each identified landscape (Appendix A).

The increased occurrence of urban salinity may be related to:

- A decrease in deep-rooted perennial vegetation;
- Over-irrigation of private gardens and lawns;
- Alteration of natural drainage patterns by the construction of houses, roads, railways, channels etc.;
- Creation of wet zones of water-logged soil due to impeded drainage;
- Leakage of standing water bodies, pools, lakes and service pipes;
- Exposure of susceptible soils; and
- Irrigation/watering of sports grounds, golf courses, parks and gardens.

Where salinity is likely to occur in areas of urban development, the following overarching principles should apply:

- Land managers should clearly demonstrate what measures will be employed to ensure the salinity hazard does not increase (both on site and on adjoining land) as a result of a development.
- Identify and manage sensitive soils (e.g. sodic soils, reactive soils, type of salts, salt loads)
• New houses, buildings or infrastructure (including roads, pathways, retaining walls and underground services) in current or potentially salt affected areas, may need to be built to withstand the effects of salinity (including the establishment of good drainage prior to construction).

• Employ deficit irrigation/watering principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns, and limit the application of extra salt through water recycling programs or irrigation/watering of saline groundwater.

• Implement a monitoring program (where deemed necessary) including a clear identification of responsibilities.

Salinity processes are driven by the interactions between water-use characteristics of vegetation, physical soil properties and hydrogeological processes. The dynamics of groundwater processes are important to the salt story. There are a variety of systems/scenarios of how water and salt moves through the landscape. These systems need to be understood to best target remediation and to understand the risk and impacts of salinity occurring in the landscape.

**Concentration of salt**

High water tables and the process of capillary rise and evaporation lead to salts concentrating in the surface layers of the soil. This process can be amplified when vegetation and soil cover is lost due to salt and water-logging impacts. This means that quite high levels of salt can be expressed at discharge sites in the landscape, even though the background levels of salt in groundwater and soils can be quite low. The levels of salt expressed in the surface of soils at discharge sites can also vary dramatically over time. Seasonal and longer term climatic influences will flush or concentrate salt over time. Plants have various levels of tolerance or ability to cope with salt concentration in the root zone. The altered urban environment is very effective at concentrating salts.

**Soil Chemistry**

The chemistry of soils can be impacted by the addition of the cations and anions present in the landscape and concentrated by groundwater movement. There is considerable variation in type of salts present on salt sites throughout the GLA. Sites are often dominated by sodium bicarbonate, with sodium chloride, sulfates and carbonates in varying quantities.

**Water-logging**

Water-logging means that low levels of oxygen are available in the soil, which impacts on plant growth, health and survival. Plants have various levels of tolerance or ability to cope with water-logging. The combination of water-logging and salinity needs to be taken into account in remediation practices. Over-watering in urban situations exacerbates the water-logging condition.

**Vegetation impacts**

Saline sites are impacted by salt concentration and water-logging. The levels and combination effects of water-logging and salinity will impact on a range of plants. Some plants can cope with high levels of salt. Some plants can cope with high levels of water-logging. Few plants can cope with both salt concentration and water-logging. Common effects on-site include loss of production of agricultural species, decline of exotic pastures and native grasses, tree death and change in pasture health and composition.
Vegetation is a victim and also an indication of salinity processes. Some plants can cope with the conditions on a saline site. These plants commonly fill the vacuum left by original vegetation as it dies. Salt tolerant plants commonly colonise and dominate saline sites. These plants can be very useful to recognise as indicator plants of saline conditions.

In urban situations, a wide range of ornamental and specific vegetation (e.g. turf on playing fields) is used, that is equally impacted by salinity. Vegetation indicators of decline are used in parks, sporting fields and green-space areas.

**Erosion**

Salinity impacts on and is impacted by, gully and sheet erosion in rural landscapes as well as individual urban building blocks. Salinity causes loss of groundcover, amplifying erosion processes. Soils frequently exhibit “puffiness” as a result of salts being concentrated close to the soil surface. This results in the soils becoming more susceptible to erosion. This factor is important in construction of large scale urban development.

**Impacts on infrastructure**

Salinity processes impact on a range of infrastructure in three main ways; water-logging; salinity concentration; and the growth of salt crystals in porous material.

Many infrastructure items are designed and constructed to allow for short term inundation or are waterproof from the top down. Salinity impacts are due to long periods of water-logging and upward pressure from groundwater systems.

Salinity impacts on the strength and longevity of metals used in infrastructure. Salt aids in the rusting process of metals.

Salt is deposited in porous media (bricks and pavers) through capillary rise when water tables are close to the surface. When the moisture is dried during summer or drier times, salt crystals form in the porous media. The crystals exert physical pressure on the media and cause it to fail from the inside out.

In the GLA, salinity impacts are seen in public and urban areas as damage to public and private roads, railways, fencing, recreation areas, houses and public buildings, sewer systems, water delivery systems, gas pipelines, underground cables, car parks and driveways, paving and footpaths, and curbing and guttering. In short, any items placed on or under the surface are impacted by salinity processes.

Some infrastructure items can amplify the local impacts by impeding or redirecting surface and sub-surface water flow.

**Salinity Dynamics**

Changes in vegetation and land use impact on groundwater systems and salinity. The effects of these changes are not always felt where the changes occur. It is common for discharge areas to be impacted by recharge which is occurring over considerable areas which are distant to the site. These changes also take time to be expressed. Increased recharge will impact on a catchment in line with two characteristics:

- The groundwater storage capacity of the catchment
- The porosity of the regolith material and the related rate of groundwater flow within the catchment.

Off-site impacts consist of:
• Sub catchment impacts where cause and effect are separated by distance and time.
• Water quality of streams, rivers and water bodies; which is primarily salinity concentration and salt load which may be redistributed.
• Catchment impact redistribution of load and the issues of water quality vs water quantity are important factors.

Impacts on Water
Salt is mobilised within catchments and impacts on the water quality of streams and rivers. Changes in salinity concentration are related to total amount of mobilised salt, flow in the waterways, and dilution through rainfall. These changes are commonly experienced in two ways:

• As pulses of high concentration water passing down a stream over a comparatively short time – hours or days.
• Streams that have consistent high concentrations which are not impacted greatly by the flow in the streams. They are consistently high with small fluctuations due to flow.

High salinity concentration is of major concern to point source extractors or water for irrigation/watering, industrial and urban use of water. High salinity concentration degrades natural ecosystems particularly within riverine environments and wetland systems.

Salt loads are a measure of the volume of salt. They are expressed as a weight per time (e.g. tonnes per day). High salt loads can be the result of low volumes of water with high concentration of salt or high volumes of water with low concentration of salt. Salt loads are redistributed in the catchment through salinity processes.

In general, salt which has a diffuse expression in upland and slopes areas is transported by streams and rivers to the bottom of catchments. Salt load is also relocated into the soils of irrigation districts, and watered playing fields or gardens, through water pumped from rivers and streams. Salt loads may also be redistributed to wetlands and flood plain areas.

Processes that impact stream and river configurations (such as accelerated incision in urban streams) can influence salt transport pathways. For example, increased flow in urban streams may move salt from upper slope and groundwater stores more rapidly, but there may be an associated increase in stream salt load.

The amount of recharge which occurs, and how this recharge varies or increases due to land management practises is a critical factor in the management of salinity. Salinity processes are driven by the water use characteristics of the vegetation, the climate and hydrogeological characteristics of the landscape. Actions which impact on the way water is used by vegetation or stored in the soil will have impacts on how recharge occurs. The selection of recharge management strategies (such as revegetation and control of applied water) is dependent on the structure of the recharge area (dispersed, linear, point), the landscape processes taking place in that area, and the desired landscape function.

Salinity Management

Salinity processes are usually diffuse within a landscape. Action will need to happen over a large proportion of a regional catchment to have impacts. The design of management actions will also need to allow for both continual and episodic recharge patterns. Like many environmental issues salinity processes are not always linear. Climate cycles within years and decades are linked to patterns of salinity processes. Design of land management actions should consider the extreme events of recharge and discharge.
Regional catchment scale salinity management also needs to consider the surface hydrology of the landscape. Urban catchment management should consider sources and sizes of both saline and fresh inputs in the catchment hydrology.

Actions that impact on the way water is used by urban vegetation or stored in the soil profile will have impacts on recharge. The influence of both continual and episodic recharge and the impacts of extreme weather events need to be considered in deciding on the appropriate management actions, in conjunction with localised urban actions. Short and long-term climate cycles also need to be considered as they will have some bearing on salinity processes, particularly salt load and land salinity.

B3. Urban Salinity Investigation

B3.1 Objectives: Urban project

The objectives of the project are: to understand urban/peri-urban salinity development and its causes, how to manage urban/peri-urban salinity, develop a framework for salinity risk and priority, and inform a process to move forward with salinity management and city planning. The information is captured within Hydrogeological Landscape (HGL) templates which are individual, stand-alone documents that characterise and document the variability and salinity behaviour of a particular landscape. They also guide spatial attribution of urban salinity management actions and relative priorities. A spatial concept (cross-section) of how the “landscape works” in terms of salinity development, is a key component of the HGL template. A standardised landscape attribution process that breaks up the landscape into relative slopes (MA1 Ridges, MA2 Upper Erosional Slope etc.) is used to guide specific management actions. A detailed report, supported by spatial mapping, completes the package.

B3.2 Methodology

The methodology used to arrive at a Hydrogeological Landscape (HGL) involves a structured comparison of salinity characteristics. These include water pathways through the landscape, salt stores, relative mobility of salt within the landscape, salinisation processes, and salt signature within streams (Moore et al. 2016).

Conceptual models are developed to describe unique characteristics within each HGL. A multi-staged approach is used to compile the HGL templates. Firstly, existing information is assessed. The process of HGL determination relies on the integration of a number of factors: geology, soils, geomorphology, regolith depth and climate; an understanding of the differences in salinity development; and the impacts (land salinity/ salt load/ EC) in landscapes. Information sources such as soils maps, geomorphic hazard mapping, site characterisation, salinity site maps, hydrogeological data, surface and groundwater data, are summarised into the HGL templates.

In Stage 1 (Conceptualisation), initial field work was undertaken to verify the applicability of the various datasets to salinity processes and to define the HGLs. Primary datasets used were:

- Geological mapping using the 1:25 000, 1:63 360 and 1:250 000 coverage:
• Geomorphology mapping using the 1:25,000 coverage:

• Soils mapping:

• Radiometrics data (Geoscience Australia 2011, *Australian stratigraphic units database*)
• Cadastre and Topographic data (provided by GLA partner councils)
• Data harvest, field reconnaissance and project derived data - GLA partner councils
  o Urban saline indicator map – 5 class map
  o Stream EC measurements (Furlonge T., 2011)
  o Existing piezometer/bore data (Stage 1 HGL Report)
  o Water use map (derived data – GLA).

Development of local methodology to map salinity indicators in the GLA, based on previous work in NSW (Nicholson et al. 2010; 2011) was undertaken by utilising Stuart Brownlea (NRM Officer, Meander Valley Council) in a “train the trainer” role, together with training and quality assurance between teams from the GLA partner councils. This work proved to be invaluable in determining salinity behaviour in the GLA.

Water use mapping was also conducted by Greater Launceston Area GIS staff by attributing water consumption to individual holdings. An analysis was conducted by commercial and residential water use, as well as block size and annual water consumption. The data was extremely useful.

Multiple GIS compilation techniques (e.g. delineation of boundaries of biophysical parameters including geology, geomorphology, soils and vegetation) were used to define initial concept models and preliminary boundaries.

Hydrogeological Landscapes (HGL) were determined using a range of integrated data (geology, soil landscapes etc.), field work and expert panel assessment. The HGL team consists of geologists, geomorphologists, soil scientists, salinity experts, modellers, vegetation and groundwater experts. Consultation and field trips with Council Staff and other local stakeholders were undertaken and this was an essential step in the process, to gain local perspectives and to validate HGL units and mapping.

In the urban study area, the prime method of HGL concept determination was from lithological (geological) boundaries followed by landform/terrain analysis, weathering intensity evaluation, soils, salinity indications, and water use pattern. Re-interpretation of the soils and geological
information for the study area was conducted for the Launceston urban situation. Integration of this information followed the methodology described in Moore et al. (2016).

The generation of a salt indicator map by GLA staff using visual survey (street survey of salinity indicators) and the generation of water use layer were instrumental in discrimination of salinity impacts.

Vegetation mapping and classification was used to a very minor degree due to the inappropriate scale of local vegetation data. Climate surfaces were also at a very coarse scale.

Once this data was collated the team constructed cross-sections showing how the landscape works, assigning management actions appropriate to that landscape, and assessing likely impact to enable prioritisation. The steps are outlined below:

- Defining management actions for the local urban situation
- Mapping and preparation of data with expert system integration of HGL concepts including a water demand map
- Detailed field work and photography
- Detailed assessment and incorporation of HGL information (soils, vegetation, hydrogeology etc.)
- Cross-section construction
- Assignment of Urban Management Actions
- Risk and priority determination
- Template construction – initial testing and review
- HGL Map boundary checking
- Testing and Quality Assurance step
- Final Report – Maps and templates

A further stage that may be pursued is specific training so that the HGL products can be used strategically, to ensure implementation of the “right action in the right spot” (on ground activity).

**HGL template information**

Each HGL template describes an area of land where salinity manifests in a manner that may be managed relatively uniformly. The salinity response and salinity management options will differ from one HGL to the next. For ease of comparison and consistency each HGL template follows the same structure.

Each HGL template describes:

- How salinity manifests itself in the landscape. It describes salinity in terms of its dryland occurrence, salt export off the HGL and the impact on water quality.
- The amount of salt stored in the landscape and how available it is for export, that is, its mobility.
- The relative hazard as defined by potential impact of salinity and its likelihood of occurrence.
- Lithology, dominant geologies, landforms.
• Soil associations, urban land capability, and key land degradation.
• Vegetation.
• Hydrogeology by quantifying a range of characteristics including aquifer type, catchment size and residence time.
• Function of the HGL in terms of catchment salinity context.
• Specific urban management strategies to improve or maintain function.
• Specific management actions to deliver on appropriate strategies.

Each HGL template provides:
• Cross-sectional diagrams
• Management diagrams
• Characteristic landscape photographs
• References.

B3.3 Results

B3.3.1 Urban Hydrogeological Landscapes for GLA

There are seventeen (17) conceptual models which have been developed for the GLA to describe the unique characteristics and the variability within each HGL (Table B2, Figure B31, Appendix A). A multi-staged approach was used to arrive at the templates. Firstly existing information was assessed. The process of HGL determination relies on the expert system integration of a number of factors: geology, geomorphology, soils, slope, regolith depth and climate; an understanding of the differences in salinity development and the impacts (land salinity/ salt load/ EC) in landscapes (Moore et al. 2016). Information sources such as soils maps, site characterisation, salinity site maps, hydrogeological data, surface and groundwater data are incorporated into standard templates. In the GLA project, geology, soils, radiometric maps, urban salinity indicator maps and water use maps were used to integrate information for interpretation of urban HGLs.
Table B2: Greater Launceston Area HGLs

| 1. | Hadspen HGL          |
| 2. | Prospect Vale HGL    |
| 3. | Reed HGL             |
| 4. | Trevallyn HGL        |
| 5. | West Riverside HGL   |
| 6. | Legana HGL           |
| 7. | East Riverside HGL   |
| 8. | Alanvale HGL         |
| 9. | Ravenswood HGL       |
| 10.| St Leonards HGL      |
| 11.| Invermay HGL         |
| 12.| North Esk HGL        |
| 13.| City East HGL        |
| 14.| East Launceston HGL  |
| 15.| West Kings Meadows HGL|
| 16.| Youngtown HGL        |
| 17.| Norwood HGL          |
B3.3.2 Urban Management Actions

The concept of distinguishing the appropriate strategy objective, then the location and specific nature of the urban management action can be defined at the small scale operational level of an urban environment.

The structure of: Landscape Management Strategy > Urban Management Strategy Objectives > Urban Management Action > Management Area is utilised in each of the HGL templates.

This allows different management to be applied to different landscapes, and different actions within each landscape (Management Area). The management diagrams and associated management information detail these differences.

Management is guided according to broad Landscape Management Strategies, and then to Urban Management Strategies that are more appropriate to specific urban situations, rather than the general natural landscape. Combinations of Urban Management Actions can be tailored to address salinity management issues, in accordance with the Urban Management Strategy Objectives. These management actions can then be applied to differing Management Areas within a structured landform analysis to specifically guide actions to address urban salinity.
B3.3.2.1 Landscape Management Strategy

There are a range of overall landscape strategies that have the high level intent of landscape management. These strategies have been developed for use Australia-wide (Wooldridge et al. 2015).

Table B3: Landscape Management Strategy framework used for salinity landscapes

<table>
<thead>
<tr>
<th>Landscape Management Strategy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy 1</td>
<td>Buffer the salt store</td>
</tr>
<tr>
<td>Strategy 2</td>
<td>Intercept the lateral flow and shallow groundwater</td>
</tr>
<tr>
<td>Strategy 3</td>
<td>Stop discrete landscape recharge</td>
</tr>
<tr>
<td>Strategy 4</td>
<td>Discharge rehabilitation</td>
</tr>
<tr>
<td>Strategy 5</td>
<td>Increase agricultural production to dry out the landscape and reduce recharge</td>
</tr>
<tr>
<td>Strategy 6</td>
<td>Dry out the landscape with diffuse actions over most of the landscape</td>
</tr>
<tr>
<td>Strategy 7</td>
<td>Access and use groundwater to change water balance</td>
</tr>
<tr>
<td>Strategy 8</td>
<td>Maximising recharge to dilute water tables with engineering actions</td>
</tr>
<tr>
<td>Strategy 9</td>
<td>Minimising recharge with engineering actions</td>
</tr>
<tr>
<td>Strategy 10</td>
<td>Maintaining and maximising runoff</td>
</tr>
<tr>
<td>Strategy 11</td>
<td>Manage and avoid acid sulfate hazards</td>
</tr>
</tbody>
</table>

The following list gives examples of Landscape Management Strategies (both rural and urban) that have been used across Australia. A subset of these may form part of a tailored management solution for each HGL unit:

- **Buffer the salt store**: There are stores of salt in the upper and lower terraces in the alluvium, which specialist vegetation can buffer, limiting the salinity impact. Salt stores interact with shallow groundwater through-flow on the edges of the alluvium.

- **Intercept the lateral flow and shallow groundwater**: This HGL can target shallow water tables that exist at edges of the alluvium. Rows of trees (8–30 rows) can be effective in interception of lateral flow.

- **Stop discrete landscape recharge**: There are discrete elements of this landscape where specific recharge occurs, such as the high terraces. Irrigation/watering management can have impacts on very localised recharge.

- **Discharge rehabilitation**: The saline sites are small in size. Discharge management will reduce salt discharge to streams when species salt tolerances are matched to salt site intensity.

- **Increase localised agricultural production to dry out the landscape and reduce recharge**: The area is partly in agricultural production, and an increase in biomass will increase the amount of water utilised.

- **Dry out the landscape with diffuse actions over most of the landscape**: Maximise plant growth and water use by vegetation in order to use excess soil moisture and shallow
groundwater. Healthy, actively growing vegetation will also act as a buffer to groundwater accessions in wet seasonal conditions.

- **Access and use groundwater to change water balance:** The pumping of groundwater from intermediate depth aquifers can alleviate salinity impact, however in this landscape monitoring of landslide hazard is advised.

- **Maximising recharge to dilute water tables with engineering actions:** Stormwater runoff has been diverted and extended to the streamline to aid in dilution of saline surface flow, however in this landscape monitoring of landslide hazard is advised.

- **Minimising recharge with engineering actions:** The gradient of creeks has been steepened, and also re-aligned to limit ponding of saline water that was previously recharging to groundwater.

- **Maintaining and maximising runoff:** This HGL contributes significant fresh water as dilution flow to the system. The fresh runoff mitigates the salt load, stream salinity and EC concentration of the local streams.

- **Manage and avoid acid sulfate hazards.**

### B3.3.2.2 Urban Management Strategy: Objectives

Urban Management Strategy: Objectives are targeted activities in a particular HGL. The actions recognise the need for diffuse and specific activities within the landscape that are required to impact on salinity issues. The priority of objectives will vary both from landscape to landscape, and in respect to each other. They are grouped into six (6) areas of activity:

- **Urban Investigations (UI):** The landscape contains significant salinity, and geological situations that predispose salinity development. Assessment of the location, intensity and scale of salinity is needed. Identification of extreme salinity is needed.

- **Urban Planning (UP):** Planning of sub-division layout and design is required to manage salinity consequences. Development must not increase the salinity hazard of the natural and built environment. Layout and design should consider locations of roads, infrastructure and greenspace as well as building allotments, and water sensitive urban design.

- **Urban Construction (UC):** Construction on saline land will require salt resistant/ resilient materials. The salinities encountered in this HGL require careful consideration of construction method, depth of cut and location of roads, and all infrastructure including underground utilities.

- **Urban Management (UM):** The input of water into the landscape (lawns, gardens, sporting fields) including the management of recycled water, requires careful management.

- **Urban Vegetation (UV):** Maintain and enhance vegetation (including remnant vegetation) for the management of recharge, and as a buffer to excess water input. ‘Waterwise’ gardening should be encouraged in residential areas.

- **Riparian Management (RM):** Vegetation management in riparian areas will assist in minimising salt export to streams.
The Urban Management Strategies will vary in importance across the GLA, indicated by Table 3 below. There are different priorities in HGLs across the urban area. For example, Urban Investigation is a key management strategy for Legana HGL where understanding of the salinity in terrace landforms is important for development. This is usually conducted by Electromagnetic Induction (EM) survey investigatory techniques.

Table B4: Urban management strategy

<table>
<thead>
<tr>
<th>Urban HGLs</th>
<th>Urban management strategy (in priority order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hadspen HGL</td>
<td>UC, UI, UP, UM, UV, RM</td>
</tr>
<tr>
<td>2. Prospect Vale HGL</td>
<td>UI, UC, UM, UP, UV, RM</td>
</tr>
<tr>
<td>3. Reed HGL</td>
<td>UV, UP, UI, UC, UM, RM</td>
</tr>
<tr>
<td>4. Trevallyn HGL</td>
<td>UM, UV, UC, UP, UI, RM</td>
</tr>
<tr>
<td>5. West Riverside HGL</td>
<td>UP, UI, UC, UM, UV, RM</td>
</tr>
<tr>
<td>6. Legana HGL</td>
<td>UI, UP, UM, UV, UC, RM</td>
</tr>
<tr>
<td>7. East Riverside HGL</td>
<td>UP, RM, UC, UI, UV, UM</td>
</tr>
<tr>
<td>8. Alanvale HGL</td>
<td>UM, UC, UI, UP, UV, RM</td>
</tr>
<tr>
<td>9. Ravenswood HGL</td>
<td>UC, UI, UP, UV, UM, RM</td>
</tr>
<tr>
<td>10. St Leonards HGL</td>
<td>UV, UP, RM, UI, UC, UM</td>
</tr>
<tr>
<td>11. Invermay HGL</td>
<td>UC, UP, UI, RM, UM, UV</td>
</tr>
<tr>
<td>12. North Esk HGL</td>
<td>RM, UM, UP</td>
</tr>
<tr>
<td>13. City East HGL</td>
<td>UP, UC, UI, UM, UV, RM</td>
</tr>
<tr>
<td>14. East Launceston HGL</td>
<td>UM, UC, UI, UP, UV, RM</td>
</tr>
<tr>
<td>15. West Kings Meadows HGL</td>
<td>UM, UV, UC, UI, UP, RM</td>
</tr>
<tr>
<td>16. Youngtown HGL</td>
<td>UM, UC, UP, UI, UV, RM</td>
</tr>
<tr>
<td>17. Norwood HGL</td>
<td>UV, UP, RM, UM, UI, UC</td>
</tr>
</tbody>
</table>

Urban Management Strategies are specific actions targeted to elements of the landscape. This is achieved using conceptual landscape profiles where uniform landscape definitions (Management Areas) are applied for each HGL. The standard Management Areas utilised across Australia for landscape definition are defined as:
- MA1 - Ridges
- MA2 - Upper Slopes - Erosional
- MA3 - Upper Slopes - Colluvial
- MA4 - Midslopes
- MA5 - Lower Slopes - Colluvial
- MA6 - Rises
- MA7 - Saline Site
- MA8 - Structural Saline area
- MA9 - Alluvial Plain
- MA10 - Alluvial Channel

NB The salinity management of a saline area is either specifically identified (MA7) or generalised into MA recommendations for that unit.

For example, the West Riverside HGL has been divided into 4 Management Areas (MA) in order to allow the appropriate action to be targeted to the most appropriate location for the best effect (Figure B32). Specific Urban Management Actions listed in section B3.3.2.3 can be allocated to each Management Area.

[Diagram showing Management Areas for West Riverside and East Riverside HGLs]

Figure B32: An example of Management Areas for West Riverside and East Riverside HGLs
B3.3.2.3 Specific Urban Management Action Priorities

The detailed Management Strategies are outlined below that are incorporated into Management Areas, allowing the variability of landscapes to be accounted for.

The HGL cross-sections use a “visual concept” to represent how the landscape “works”. The report and map products provide the tools and a mechanism to gain a “landscape understanding”, and experience has shown that this is easily translated to local government, agency staff and other stakeholders.

The key to the Urban Management Actions framework is matching the specific actions detailed below into the landscape framework provided by the Management Area approach. As an example, the key Urban Management Action for the Hadspen HGL is Urban Construction, and then specifically UC6 (new houses, buildings or infrastructure (including roads, pathways and retaining walls) in current or potentially salt affected areas may need to be built to withstand the effects of salinity utilising industry accepted standards. In badly affected areas, consideration should be given to rehabilitating salt affected land, building above ground or consideration of open space options.) NB: this list is dynamic and intended to be added to as new concepts come to light.

Management Strategy UI: Urban Investigations

UI1: Investigate concentration and composition of salts in the soil profile, groundwater and surface waters during initial site assessment to determine salinity hazard.

UI2: Use geophysical techniques to define geological contact (EM survey).

UI3: Identify and manage sodic soils.

UI4: Identify and manage acid sulfate soils.

Management Strategy UP: Urban Planning

UP1: Prior to commencement of earthworks, sodic/saline soils should be identified.

UP2: Minimise use of infiltration and detention of stormwater in hazard areas, consider lining of detention systems to prevent infiltration (i.e. reconsider Water Sensitive Urban Design (WSUD) implications in relation to salinity management).

UP3: Identification of discharge sites should influence the size of the area to be developed.

UP4: Maximise the size of impervious surfaces to prevent recharge of (perched) groundwater table. Constructed pervious surfaces may need to be lined and drained to stormwater outlets.

UP5: Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity affects are an issue.

Management Strategy UC: Urban Construction

UC1: Minimise depth of cut and exposure of susceptible soils during development. Ensure fill material interface is not saline.

UC2: Deep drainage should be minimised by maximising surface water runoff and drainage.

UC3: Sub-surface drainage should be incorporated into all infrastructure including roads, pathways, behind cuts and retaining walls and other impervious areas to avoid water-logging.

UC4: Establish good drainage prior to construction in shrink/swell soils.
UC5: Ensure road construction is suitable for conditions.

UC6: New houses, buildings or infrastructure (including roads, pathways and retaining walls) in current or potentially salt affected areas may need to be built to withstand the effects of salinity utilising industry accepted standards. In badly affected areas, consideration should be given to rehabilitating salt affected land, building above ground or consideration of open space options.

UC7: Consider the use of salt protected materials for services (e.g. salt resistant drainage pipes, casing of underground services).

UC8: Minimise the alteration of natural drainage patterns through construction of houses, roads, railways, channels etc.

Management Strategy UM: Urban Management

UM1: Minimise leakage of standing water bodies, pools, lakes and service pipes.

UM2: Employ deficit irrigation principles to prevent over-irrigation of sports grounds, golf courses, parks, private gardens and lawns.

UM3: Manage plant growth to maximise water usage. Consider harvesting mature zones of vegetation and replanting for ongoing water use efficiency.

Management Strategy UV: Urban Vegetation

UV1: Retain or establish areas of deep-rooted salt tolerant indigenous vegetation to manage recharge or discharge site.

UV2: Promote the retention and establishment of deep-rooted vegetation that maximises water use in new urban development areas.

UV3: Develop native landscaping and ‘Waterwise’ gardens to reduce over-irrigation and water usage.

UV4: Establish new vegetation using salt tolerant species.

UV5: Locate strategic plantings of deep-rooted perennial vegetation to manage discharge areas.

Management Strategy RM: Riparian Management

RM1: Retain or re-establish areas of effectively vegetated riparian buffer zones to manage discharge areas (preferably salt tolerant indigenous vegetation).

RM2: Maintain/re-establish effective vegetated riparian buffer zones.

B3.3.3. Salinity Hazard

B3.3.3.1 Salinity Impact

Salinity impact is divided into three components: salt land, salt load (export) and water quality. To understand salinity in a catchment context it is useful to consider the range of processes involved in salinity impacts (Table B4).
Table B5: Catchment scale salinity processes: salt land, salt load export and water quality

<table>
<thead>
<tr>
<th>Process</th>
<th>Salt land</th>
<th>Salt load export</th>
<th>Water quality - salinity concentration in stream</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Land becoming degraded – saline and susceptible to erosion. Slowly spreading areas of degrading land. Infrastructure damage to houses, roads, parks, gardens and underground assets.</td>
<td>Large volume of salt moving down streams and rivers, usually in high volumes of water at low concentration. Salt redistributed in landscape through water flow and irrigation/watering.</td>
<td>High salinity concentration (EC) water moving through rivers and streams.</td>
</tr>
<tr>
<td>Major areas</td>
<td>Low areas, terraces, elevated benches and constricted landforms. High excess water input areas such as Youngtown</td>
<td>Generated from specific geological landscapes. Redistributed in local and riverine ecosystems.</td>
<td>Time based: seen as events or spikes. These last hours or days (e.g. Reed) Area based: certain landscapes express consistently high salinity which are less affected by flow and are reflected in stream hydrographs.</td>
</tr>
<tr>
<td>Management Actions</td>
<td>Rehabilitation of saline discharge sites. Minimise recharge through vegetation and land use in recharge areas.</td>
<td>Minimise recharge through vegetation and land use in recharge areas of salt load generating landscapes. Manage redistribution of salt load to avoid negative impacts.</td>
<td>Minimise recharge through vegetation and land use in high salinity generating landscapes. Maintain and maximise runoff from fresh water generating areas.</td>
</tr>
</tbody>
</table>

The evaluation of salinity hazard and risk is based on the potential impact (low, moderate or high) of salinity for a given HGL and the likelihood of low, moderate or high levels of salinisation occurring. Salinity hazard/risk tables have been prepared for the HGLs and included in the template documents (Appendix A). Each HGL has been assessed for a range of salinity

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characteristics which are detailed in the relevant sections below (Table B6). This table shows the range of salt land, salt load export and water quality hazards each HGL has, as well as an evaluated overall hazard. It is important to note that each of the sub-components do not add to give the overall hazard. For example, there can be an extreme but localised landscape manifestation of salt, but the amount of salt actually being exported may be relatively low, with a variable salt concentration in streams. This may result in a lower overall hazard than the very high land indicator might suggest.

Table B6: Summary of salinity impacts for each HGL

<table>
<thead>
<tr>
<th>HGL</th>
<th>Land Impact</th>
<th>Salt load Export Impact</th>
<th>Impact on water quality</th>
<th>Overall hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hadspen HGL</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>2. Prospect Vale HGL</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Very High</td>
</tr>
<tr>
<td>3. Reed HGL</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>4. Trevallyn HGL</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>5. West Riverside HGL</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>6. Legana HGL</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>7. East Riverside HGL</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>8. Alanvale HGL</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>9. Ravenswood HGL</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Very High</td>
</tr>
<tr>
<td>10. St Leonards HGL</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>11. Invermay HGL</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>12. North Esk HGL</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>13. City East HGL</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>14. East Launceston HGL</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>15. West Kings Meadows HGL</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>16. Youngtown HGL</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>17. Norwood HGL</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Table B7: Grouped HGLs (highest to lowest impact) for salt land, salt load export and water quality

<table>
<thead>
<tr>
<th>Impact Level</th>
<th>Salt land impacts</th>
<th>Salt load export</th>
<th>Impact on water quality – EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Impacts</td>
<td>• Hadspen</td>
<td>• Reed</td>
<td>• Reed</td>
</tr>
<tr>
<td></td>
<td>• Prospect Vale</td>
<td>• West Riverside</td>
<td>• West Riverside</td>
</tr>
<tr>
<td></td>
<td>• West Riverside</td>
<td>• East Riverside</td>
<td>• East Riverside</td>
</tr>
<tr>
<td></td>
<td>• East Riverside</td>
<td>• Invermay</td>
<td>• Invermay</td>
</tr>
<tr>
<td></td>
<td>• Ravenswood</td>
<td>• North Esk</td>
<td>• North Esk</td>
</tr>
<tr>
<td></td>
<td>• Invermay</td>
<td>• City East</td>
<td>• City East</td>
</tr>
<tr>
<td></td>
<td>• North Esk</td>
<td>• East Launceston</td>
<td>• East Launceston</td>
</tr>
<tr>
<td></td>
<td>• City East</td>
<td>• West Kings Meadows</td>
<td>• West Kings Meadows</td>
</tr>
<tr>
<td></td>
<td>• East Launceston</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Impacts</td>
<td>• Reed</td>
<td>• Hadspen</td>
<td>• Prospect Vale</td>
</tr>
<tr>
<td></td>
<td>• Trevallyn</td>
<td>• Prospect Vale</td>
<td>• Legana</td>
</tr>
<tr>
<td></td>
<td>• Legana</td>
<td>• Legana</td>
<td>• Alanvale</td>
</tr>
<tr>
<td></td>
<td>• Alanvale</td>
<td>• Alanvale</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• St Leonards</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• West Kings Meadows</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Youngtown</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Norwood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Impacts</td>
<td>• NIL</td>
<td>• Trevallyn</td>
<td>• Hadsppen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ravenswood</td>
<td>• Trevallyn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• St Leonards</td>
<td>• Ravenswood</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Youngtown</td>
<td>• St Leonards</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Norwood</td>
<td>• Youngtown</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Norwood</td>
</tr>
</tbody>
</table>

This matrix (Table B7) provides a summary of salinity impacts in individual Hydrogeological Landscapes, and is a useful reference for determining the relative impacts affecting a range of HGLs across the GLA. Within each GLA there is a spatial variation in the distribution of each hazard type, and a temporal variation in the manifestation of each hazard.
B3.3.3.2 Salt Land

Salt land occurs as a result of dryland salinity, and locally due to irrigation/watering salinity. It is caused when water tables are high and there is concentration of salt due to evaporation at the soil surface. This process impacts on land-based assets, damages infrastructure, ecosystems, vegetation, soil health and agricultural production. In the GLA the presence of urban salt land is often expressed as salt damage to: parks, roads, bricks, fences, and other infrastructure (Figure B33).

![Figure B33: Land salinity issues impacting on masonry in Hadspen](image)

Nine (9) HGLs have high salt land impacts (Figure B34, Table B7).

<table>
<thead>
<tr>
<th>Hadspen</th>
<th>East Riverside</th>
<th>North Esk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prospect Vale</td>
<td>Ravenswood</td>
<td>City East</td>
</tr>
<tr>
<td>West Riverside</td>
<td>Invermay</td>
<td>East Launceston</td>
</tr>
</tbody>
</table>

There are a wide range of conditions in the GLA that lead to this high land salinity. A number are low-lying landscapes that interact with saline and sulfatic sediments, some are terrace landforms, and others relate to salt store in weathered landscapes on a range of rock types in different landscape positions.

Eight (8) HGLs have moderate land salinity (Figure B34, Table B7).

<table>
<thead>
<tr>
<th>Reed</th>
<th>Alanvale</th>
<th>Youngtown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trevallyn</td>
<td>St Leonards</td>
<td>Norwood</td>
</tr>
<tr>
<td>Legana</td>
<td>West Kings Meadows</td>
<td></td>
</tr>
</tbody>
</table>

There is a predominance of rolling landscapes, with the capacity for high salt storage in the landscape. There are no low land salinity areas in the local landscape. To address salt land issues at a catchment scale, the HGLs with the high and moderate impacts need to be targeted.
Figure B34: Hydrogeological Landscapes (HGL) showing Moderate (yellow) and High (red) land salinity impact in the Greater Launceston Area (GLA)
B3.3.3 Salt Load

Salt load export is the volume of salt moving out of the catchment via shallow groundwater flow, soil throughflow, overland flow and in creeks and rivers. Note that this is different to the concentration of salt in a waterway. A large volume of water may have a low concentration of salt but still maintain a high load of salt. It is the result of salt being mobilised in the landscape and connected with the waterways.

Salt load can be redistributed by surface flow and irrigation/watering. This may result in an increase in salt stored in certain places in the landscape (e.g. irrigation paddocks and wetlands). This redistribution process is long term, slow and invisible.

In an urban situation, significant areas can be “loaded” by the application of irrigation water to household blocks and to parks and gardens. Excessive water use leads to increased load of salt to urban household blocks.

Eight (8) HGLs have high salt load impacts (Figure B35, Table B7).

<table>
<thead>
<tr>
<th>Reed</th>
<th>Invermay</th>
<th>East Launceston</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Riverside</td>
<td>North Esk</td>
<td>West Kings Meadows</td>
</tr>
<tr>
<td>East Riverside</td>
<td>City East</td>
<td></td>
</tr>
</tbody>
</table>

These eight HGLs produce significant load to rivers and streams, or to adjacent HGLs. There are a range of landscapes represented. Some areas are low-lying where salt is stored and delivered to streams in wet times. Other units reflect the huge salt store in the landscape where salt is mobilised by water movement through the landscape. Many units deliver many hundreds of tonnes of salt per day.

Four (4) HGLs have moderate salt load export impacts (Figure B35, Table B7).

<table>
<thead>
<tr>
<th>Hadspen</th>
<th>Prospect Vale</th>
<th>Legana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alanvale</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To address salt load issues at a catchment scale, the HGLs with the high and moderate impacts need to be targeted. Further sampling is required to quantify salt load impacts in the study area.

The moderate salt load export HGLs require specific management actions to balance salt export and water quantity.
Figure B35: Hydrogeological Landscapes (HGL) showing Low (blue), Moderate (yellow) and High (red) stream salt load, in the Greater Launceston Area (GLA)
B3.3.3.4 Water Quality

Water quality in a salinity context is the concentration of salt in water. Stream salinity integrates landscape processes within a catchment and is a primary water quality indicator of dissolved salts. Salinity is expressed by measuring the electrical conductivity (EC) of the water, which results from the concentration of dissolved salts. EC is measured in units of micro-Siemens per centimetre (µS/cm) at 25°C and is easily measured in stream with a conductivity meter. High salinity levels in water systems can be detrimental to ecological values and limit uses for domestic, recreational, industrial and agricultural purposes.

A hydrogeological overview was prepared for each HGL (Appendix A) based on available data and field observation. Stream sampling data was derived from local sampling undertaken over the project timeline, and additional information was provided from a range of sources made available by the three councils in the area, especially data provided by Toni Furlonge with repeated spot sampling.

Eight (8) HGLs have high water quality impacts (Figure B36, Table B7).

<table>
<thead>
<tr>
<th>Reed</th>
<th>Invermay</th>
<th>East Launceston</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Riverside</td>
<td>North Esk</td>
<td>West Kings Meadows</td>
</tr>
<tr>
<td>East Riverside</td>
<td>City East</td>
<td></td>
</tr>
</tbody>
</table>

Three (3) HGLs have moderate water quality impacts (Figure B36, Table B7).

<table>
<thead>
<tr>
<th>Prospect Vale</th>
<th>Legana</th>
<th>Alanvale</th>
</tr>
</thead>
</table>

Actions in these high and moderate water quality landscapes require careful consideration of water quality and quantity.

Six (6) HGLs have low water quality impact.

<table>
<thead>
<tr>
<th>Hadspen</th>
<th>St Leonards</th>
<th>Ravenswood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trevallyn</td>
<td>Youngtown</td>
<td>Norwood</td>
</tr>
</tbody>
</table>

These are important water sources and dilution areas. They have specific management implications at a catchment context to maintain the flow of fresh water:

To address water quality issues at a catchment scale, all HGLs need to be considered. High impact HGLs are sources of high EC water. Moderate water quality impact HGLs can be either a source of high EC water or a potential dilution flow, dependent on rainfall events and catchment context. Low impact HGLs are important water sources and dilution flows, and need to be maintained as such.
Greater Launceston Area
Hydrogeological Landscapes
Stream EC

HGL Number, Name
1. Hadspen
2. Prospect Vale
3. Reed
4. Trevallyn
5. West Riverside
6. Legana
7. East Riverside
8. Alanvale
9. Ravenswood
10. St Leonards
11. Invermay
12. North Esk
13. City East
14. East Launceston
15. West Kings Meadows
16. Youngtown
17. Norwood
100. water

Kilometres

Figure B36: Hydrogeological Landscapes (HGL) showing Low (blue), Moderate (yellow) and High (red) water quality impact, in the Greater Launceston Area (GLA)
B3.3.3.5 Landscape Function

A Landscape Function is the salinity function that a particular landscape provides, for example provision of freshwater runoff, or generation of salt load that enters streams (Table B8). These landscape functions will vary for each HGL. Once the landscape function is recognised, management is guided according to broad Management Strategy Objectives. Landscape Functions are applicable to rural and urban areas, and are used as an overarching framework (Wooldridge 2015).

Table B8: Landscape Function Descriptions

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>The landscape provides fresh water runoff as an important water source</td>
</tr>
<tr>
<td>B</td>
<td>The landscape provides fresh water runoff as an important dilution flow source</td>
</tr>
<tr>
<td>C</td>
<td>The landscape provides important base flow to local streams</td>
</tr>
<tr>
<td>D</td>
<td>The landscape generates salt loads which enter the streams and are redistributed in the catchment</td>
</tr>
<tr>
<td>E</td>
<td>The landscape receives and stores salt load through irrigation/watering or surface flow.</td>
</tr>
<tr>
<td>F</td>
<td>The landscape generates high salinity concentration water</td>
</tr>
<tr>
<td>G</td>
<td>The landscape contains important land based assets which are impacted by salinity processes</td>
</tr>
<tr>
<td>H</td>
<td>The landscape contains high hazard for generating sodic and saline sediment</td>
</tr>
<tr>
<td>I</td>
<td>The landscape contains high hazard for acid sulfate processes</td>
</tr>
</tbody>
</table>

As an example, landscapes with Function A contribute fresh water to catchments, and actions which reduce the flow of water are likely to increase the salinity in streams. For example, complete afforestation of a landscape may reduce volume of water, reducing dilution flow and increasing stream EC.

B3.3.3.6 Salinity Hazard Assessment

Assessment of salinity hazard can be undertaken using a standard risk format, and also by using the landscape function of an HGL referred to in the previous section (B3.3.3.5). For a summary of HGLs and their functions, strategies and hazards see Table B9 below. This table provides a useful summary of the key information relevant to each HGL.
A hazard matrix is a standard way to assess the potential impact and likelihood of occurrence. In relation to urban salinity it allows a framework of risk to be established. A standard hazard matrix is a five class system which integrates the likelihood and consequence of various risks:

Very high (red); High (orange); Medium (yellow); Low (green); Very low (light blue)

Table B9: Function, Strategy and Hazard Analysis (refer Table B5) for the GLA

<table>
<thead>
<tr>
<th>HGL</th>
<th>Function</th>
<th>Strategy</th>
<th>Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hadspen HGL</td>
<td>D, E</td>
<td>2,4</td>
<td>High</td>
</tr>
<tr>
<td>2. Prospect Vale HGL</td>
<td>D, F, H</td>
<td>4, 9</td>
<td>Very High</td>
</tr>
<tr>
<td>3. Reed HGL</td>
<td>B, C, D, E, F</td>
<td>6</td>
<td>Medium</td>
</tr>
<tr>
<td>4. Trevallyn HGL</td>
<td>A, B</td>
<td>10</td>
<td>Low</td>
</tr>
<tr>
<td>5. West Riverside HGL</td>
<td>B, C, E, D</td>
<td>3, 2, 7</td>
<td>Very High</td>
</tr>
<tr>
<td>6. Legana HGL</td>
<td>D, E, F, I</td>
<td>3, 1, 4, 11</td>
<td>High</td>
</tr>
<tr>
<td>7. East Riverside HGL</td>
<td>I</td>
<td>4, 11</td>
<td>Very High</td>
</tr>
<tr>
<td>8. Alanvale HGL</td>
<td>B, D</td>
<td>6, 2</td>
<td>High</td>
</tr>
<tr>
<td>9. Ravenswood HGL</td>
<td>B, D</td>
<td>2, 1, 4</td>
<td>Very High</td>
</tr>
<tr>
<td>10. St Leonards HGL</td>
<td>B, C, D</td>
<td>2, 1, 4</td>
<td>Medium</td>
</tr>
<tr>
<td>11. Invermay HGL</td>
<td>I</td>
<td>4, 11</td>
<td>Very High</td>
</tr>
<tr>
<td>12. North Esk HGL</td>
<td>I, E</td>
<td>4, 11</td>
<td>Very High</td>
</tr>
<tr>
<td>13. City East HGL</td>
<td>D, E, F</td>
<td>3, 4</td>
<td>Very High</td>
</tr>
<tr>
<td>14. East Launceston HGL</td>
<td>D, E, F</td>
<td>3, 4</td>
<td>Very High</td>
</tr>
<tr>
<td>15. West Kings Meadows HGL</td>
<td>D, E, F</td>
<td>3, 4, 6</td>
<td>Medium</td>
</tr>
<tr>
<td>16. Youngtown HGL</td>
<td>D, E</td>
<td>2, 3, 1, 4</td>
<td>Medium</td>
</tr>
<tr>
<td>17. Norwood HGL</td>
<td>B, C, D, E,</td>
<td>6, 2</td>
<td>Medium</td>
</tr>
</tbody>
</table>

The HGLs for Greater Launceston Area have been placed into a salinity hazard matrix below (Table B10). The matrix is represented spatially in Figure B8. There is significant variability across and within the GLA, due to the complexity of the geology, soils and landforms within the area.
Table B10: Summary of Salinity Risk by HGL

<table>
<thead>
<tr>
<th>HAZARD ASSESSMENT</th>
<th>Limited potential impact</th>
<th>Significant potential impact</th>
<th>Severe potential impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>High likelihood of occurrence</td>
<td></td>
<td>Hadspean Legana Alanvale</td>
<td>Prospect Vale East Riverside Ravenswood Invermay North Esk City East East Launceston</td>
</tr>
<tr>
<td>Moderate likelihood of occurrence</td>
<td>Trevallyn</td>
<td>Reed St Leonards West Meadows Youngtown Norwood</td>
<td>Kings</td>
</tr>
<tr>
<td>Low likelihood of occurrence</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The above table conceptually indicates that the GLA has a significant salinity hazard:

- There is high – moderate likelihood of salinity occurrence
- There also is significant to severe potential impact throughout.

The movement of water through weathered dolerites and Paleogene sediments hosting the salt store, and the interaction with saline and sulfatic sediments lower in the landscape, predispose the area to salinity.

High and very high salinity hazard HGLs require the greatest degree of management response. In general the moderate salinity hazard HGLs require salinity to be considered as part of an overall management strategy where salinity is but a component.

Eight (8) HGLs have a Very High hazard rating (Figure B37, Table B10).

<table>
<thead>
<tr>
<th>Prospect Vale</th>
<th>Invermay</th>
<th>East Launceston</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Riverside</td>
<td>North Esk</td>
<td>Invermay</td>
</tr>
<tr>
<td>East Riverside</td>
<td>City East</td>
<td></td>
</tr>
</tbody>
</table>

The Very High hazard HGLs encompass a wide range of landscapes and geological settings.
Three (3) HGLs have a High Hazard rating (Figure B37, Table B10).

<table>
<thead>
<tr>
<th>Hadspen</th>
<th>Legana</th>
<th>Alanvale</th>
</tr>
</thead>
</table>

These are high hazard because they have demonstrated on-site and off-site impacts but of a lesser severity to the Very High hazard grouping. These HGLs tend to be in the terrace landforms of the GLA.

Five (5) HGLs have a Moderate hazard rating (Figure B37, Table B10).

<table>
<thead>
<tr>
<th>Reed</th>
<th>St Leonards</th>
<th>West Kings Meadows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Youngtown</td>
<td>Norwood</td>
<td></td>
</tr>
</tbody>
</table>

These are Moderate hazard HGLs because they have some component of increased salt store, on-site impacts and/or off-site impacts. They are across a wide range of geologies and landforms, and tend to have more vegetation and are less developed.

One (1) HGL has a Low hazard rating (Figure B37, Table B10).

<table>
<thead>
<tr>
<th>Trevallyn</th>
<th></th>
</tr>
</thead>
</table>

This area is Low hazard due to the steep rocky slopes and the high level of existing vegetation. There are no areas of very low salinity hazard.

Very High and High hazard HGLs account for the majority of salt in the landscape, and areas which require the greatest degree of management action. The Moderate hazard HGLs need salinity management to be site assessed, to gauge the most appropriate management responses.
Figure B37: Hydrogeological Landscapes (HGL) showing Low (blue), Moderate (yellow), High (orange) and Very High (red) salinity hazard in the Greater Launceston Area (GLA)
B3.3.3.7 Derived Salinity Mapping

There were two derived products instrumental in providing information for understanding salinity behaviour in the urban area of the GLA: salinity indicator mapping (Figure B38) and water use mapping (Figures B39; B40; B41).

Figure B38: Salinity Indicator Mapping

The partner councils in the GLA generated a salinity indicator map for the urban. The purpose of the mapping was to provide indications of salinity behaviour in an urban area, where the landscape indicators such as bare ground or vegetation change are not as easy to discriminate.

Common urban indicators include damage to bricks, mortar, walls, wet zones, cracking, paint, increased vents, road pavement, kerb and guttering, vents in walls, precipitate, garden damage, change of salt tolerant, wet and water-logged sites. The normal process is to drive and record on maps (or real time GPS equipment) signals such as those listed above.

A series of colour coded dots were used to provide a graduated scale of visual assessment (severe / moderate/ minor) with relation to the following:

- Brick and house damage
- Road damage
- Land indicators
The data (Figure B38) shows:

- Clusters of severe impact in the GLA, particularly in low-lying areas
- Moderate damage in localised areas of landscapes
- Widespread low-level indicators across the urban area in wide range of geologies and landscapes.

There is some “white precipitate” staining on housing, which is also a common occurrence due to the high carbonate levels in the surface water that is used for reticulation purposes.

**Water Use Mapping**

City of Launceston GIS staff conducted a series of mapping exercises to graphically demonstrate the total water consumption of individual holdings across the urban area of the GLA (Figure B39; B40; B41). Comparison was made between commercial and domestic water application, consumption per area, and with different ranges to graphically highlight the spatial impact of water use.

![Figure B39: Water Consumption in the Central Launceston area](image)

(High and moderate high usage = red/orange; moderate to low usage = dark to light green)

This information was integrated into the HGL framework for the urban area (Central Launceston; Figure B39). In most cases the water use mapping did not correlate with increased urban signals. The total water use is notably low in comparison to other areas of investigation across Australia. Salinity in the GLA is linked to salt store in the landscape and, not applied water. Information from Meander Valley and West Tamar indicates a similar situation (Figures B40; B41).
Figure B40: Water consumption in the north-east Meander Valley area
(High and moderate high usage = red/orange; moderate to low usage = dark to light green)

Figure B41: Water consumption in the West Tamar area
(High and moderate high usage = red/orange; moderate to low usage = dark to light green)
B4. Discussion

Urban salinity is a “real issue” within the Greater Launceston Area. The scale, intensity and the infrastructure damage to domestic, commercial and heritage buildings, as well as to community and individual assets is considerable.

The GLA urban landscape is old and has had many periods of growth (and is still rapidly growing). The local environmental setting has contributed to the development of urban salinity.

- Locations adjacent to the Tamar and North Esk Rivers are saline, estuarine and have sulfatic sediments
- Jurassic dolerite weathering profiles have developed on stepped neotectonic erosion surfaces where intense weathering has resulted in the formation of clay rich sequences that have high propensity to store salt.
- Paleogene sediments have been uplifted and weathered to pallid, loosely bedded clays and silts. These landscapes are also a high salt store environment
- Landform situations that predispose salinity development are present.
- Geology, soils and regolith that predispose salinity development are present.

The HGL project has attempted to understand the dynamics and variability of landscapes; guide works and actions both broadly and specifically; and also look at the risk and priority in the urban landscape. The following objectives have been undertaken in the project, and delivered within the individual Urban HGL templates and associated mapping:

1. Explain how water moves through the landscape
2. Explain where the salt stores are in the landscape
3. Explain and detail the variability in landscapes controlling this movement and storage
4. Management of the landscape based on the understanding of these processes
5. Identify risk and prioritise hazard management in the landscape

B4.1 Impacts

There is a full spectrum of urban salinity impacts throughout the urban area of Launceston, with strong concentrations in clusters throughout the areas. Damage to brickwork, walls, foundations and other infrastructure is readily visible. Buildings with increased numbers of vents to dry out the underfloor cavity also predominate in some areas. A street-by-street visual survey was conducted to use as a qualifier in the development of urban HGLs. The salinity indicator map (Figure B38) details the scale and extent of salinity damage that was detected.

In the GLA, salinity impacts are seen in public and urban areas as damage to:

- public and private roads
- fencing (particularly brick)
- recreation areas, sporting fields and public parks
- houses (walls, footings, slabs, brickwork)
- public and heritage buildings
- sewer systems
Greater Launceston Area Urban Salinity Strategy 2016

- water delivery systems
- gas pipelines
- car parks and driveways
- paving and footpaths
- curbing and guttering.

In short any items placed on or under the surface are impacted by salinity processes.

Salt is deposited in porous media (bricks and pavers) through capillary rise when water tables are close to the surface. When the moisture is dried during summer or drier times, salt crystals form in the porous media. The crystals exert physical pressure on the media and cause it to fail from the inside out (Figure B42).

![Figure B42: Brick degradation in East Launceston showing bricks in a wall that have failed due to salinisation processes.](image)
Damage to pavers and to brick walls is evident in commercial and public buildings (Figure B43). Private dwellings are also impacted. Damage to residential buildings is evident across the urban area, with most damage to brickwork on homes. This impact varies depending on the quality of brick and other building materials used. Damp patches, missing mortar, brick loss, erosion and face degradation indicators are readily observable.

There is a tendency for damage to 1970s age buildings, older heritage buildings and older homes across Launceston.

The HGL areas of City East and East Launceston have significant urban salinity in older homes, and at all points in the landscape.

In Ravenswood the scale of damage to public housing is high.

The terrace landforms of Hadspen show damage at specific locations.

The development area of West Riverside shows significant damage with a high potential in new development areas. In summary there are a wide range of urban salinity indicators in many locations throughout the wide ranging landforms of Launceston.

Figure B43: Damage to brick walls in City East HGL
There has been significant damage to road surfaces in salinity impact areas, for example in low-lying areas of the Prospect Vale HGL (Figure B44).

Figure B44: Road damage to residential streets in Prospect Vale

An increase in the number of vents is an indicator of wetness in the sub-floor space. The retrofitting of vents is noted in the older areas of Launceston (Figure B45).

Figure B45: Vents under homes in Launceston installed in an attempt to dry out the sub-floor space. Note the re-rendering of walls below vents and on balcony.
Extensive damage may occur 1-2 metres above ground when local groundwater pressure combines with a matrix that allows capillary action to rise up a wall. There has been significant damage to brickwork due to high groundwater pressure in the West Riverside area (Figure B46).

Figure B46: Significant damage above new render due to high groundwater pressure in the West Riverside area
B4.2 Building and Construction

In the GLA the local situation with construction needs to take into account salt store issues, water movement pathways, and landform considerations including constrictions and building technique and practice. Urban Construction is a major concern for 10 of the 17 HGLs described from the GLA (Table B11).

Table B11: Urban management strategy – Urban Construction considerations

<table>
<thead>
<tr>
<th>Urban HGLs</th>
<th>Urban management strategy (in priority order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hadspen HGL</td>
<td>UC, UI, UP, UM, UV, RM</td>
</tr>
<tr>
<td>2. Prospect Vale HGL</td>
<td>UI, UC, UM, UP, UV, RM</td>
</tr>
<tr>
<td>5. West Riverside HGL</td>
<td>UP, UI, UC, UM, UV, RM</td>
</tr>
<tr>
<td>7. East Riverside HGL</td>
<td>UP, RM, UC, UI, UV, UM</td>
</tr>
<tr>
<td>8. Alanvale HGL</td>
<td>UM, UC, UI, UP, UV, RM</td>
</tr>
<tr>
<td>9. Ravenswood HGL</td>
<td>UC, UI, UP, UV, UM, RM</td>
</tr>
<tr>
<td>11. Invermay HGL</td>
<td>UC, UP, UI, RM, UM, UV</td>
</tr>
<tr>
<td>13. City East HGL</td>
<td>UP, UC, UI, UM, UV, RM</td>
</tr>
<tr>
<td>14. East Launceston HGL</td>
<td>UM, UC, UI, UP, UV, RM</td>
</tr>
<tr>
<td>16. Youngtown HGL</td>
<td>UM, UC, UP, UI, UV, RM</td>
</tr>
</tbody>
</table>

On an individual house lot scale, a number of construction and maintenance decisions affect the potential for water movement and the related salinity damage. These include:

- whether to cut or fill the site
- whether the ground is reshaped to slope away from the building
- how the site is landscaped
- how the landscaping is watered
- how much of the site is hard surfaces vs pervious surfaces
- whether a path is provided around the perimeter of the house and sloping away from the building
- what stormwater drainage is provided
- whether pools, taps, and downpipes are regularly checked for leaks

A builder does not have control over many of these factors so needs to design and construct for the most likely scenario and the salinity risk of the area. There are seven simple solutions that will reduce the impact of urban salinity by sound construction.
**Solution 1:** The placement of a layer of sand under the slab to improve drainage and minimise capillary rise from the subsoil.

**Solution 2:** The placement of a high impact damp proof membrane under the slab to protect the concrete.

As of the 1st of May 2004, variations to Volume 2 of the Building Code of Australia (BCA) requires that the membranes installed beneath slab-on-ground construction for new Class 1 buildings (houses) be **high impact resistant** in NSW in accordance with clause 5.3.3.2 (c) of AS 2870 - 1996. This is a NSW variation to the national BCA.

**Solution 3:** The use of a higher MPa concrete that will be more durable, less permeable and that will minimise potential capillary rise through the slab.

**Solution 4:** Use exposure class bricks below the damp proof course.

The Building Code of Australia (BCA), Part 3.3.1, requires masonry units to be classified and used in the exposure conditions appropriate to their classification. Table 3.3.1.1 of the BCA states exposure grade is:

“Suitable for use in all classifications including severe local conditions such as:

a) below the damp-proof course in areas where walls are expected to be attacked by salts in the groundwater or brickwork itself (salt attack or salt damp) ……

b) in retaining walls.”

c) in retaining walls.”

**Solution 5:** Install a damp proof course under all masonry walls to stop the rise of moisture.

**Solution 6:** Install and maintain good drainage systems on the site.

The Building Code of Australia Part 3.1.2.3 requires:

- Surface water to drain away from the building (50mm over the first 1m)
- Slab on ground heights to be 150mm above finished external ground and 50mm above concrete and paved areas
- When there is a raised floor, the fall of the natural ground under the house should prevent ponding under the building.

**Solution 7:** Avoid practices that will negate the effects of previous solutions.

The ‘Building Code of Australia’ is a performance based code that sets out the objectives and outcomes required for different classes of buildings. It guides the construction of buildings. The two diagrams below indicate building construction that will cause problems, as well as one which is more sympathetic to an urban environment (Figure B47).
B4.3 Development

In the GLA areas, development needs to be undertaken in a salinity sensitive manner. Residential, rural residential, commercial, industrial, recreational and other urban land uses may result in salinity issues in areas with even a low salinity hazard. This is because urban land uses can have a large impact on salinity processes. For example:

- exposure of saline subsoils through deep site cuts and earthworks
- changes to the water cycle linked to potable water, stormwater and sewerage systems
- changes to surface and subsurface natural drainage patterns.

Urban Planning is a major concern for 9 of the 17 HGLs described from the GLA (Table B12).

Table B12: Urban management strategy – Urban Planning considerations

<table>
<thead>
<tr>
<th>Urban HGLs</th>
<th>Urban management strategy (in priority order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hads pen HGL</td>
<td>UC, UI, UP, UM, UV, RM</td>
</tr>
<tr>
<td>3. Reed HGL</td>
<td>UV, UP, UI, UC, UM, RM</td>
</tr>
<tr>
<td>5. West Riverside HGL</td>
<td>UP, UI, UC, UM, UV, RM</td>
</tr>
<tr>
<td>6. Legana HGL</td>
<td>UI, UP, UM, UV, UC, RM</td>
</tr>
<tr>
<td>7. East Riverside HGL</td>
<td>UP, RM, UC, UI, UV, UM</td>
</tr>
<tr>
<td>10. St Leonards HGL</td>
<td>UV, UP, RM, UI, UC, UM</td>
</tr>
<tr>
<td>11. Invermay HGL</td>
<td>UC, UP, UI, RM, UM, UV</td>
</tr>
<tr>
<td>13. City East HGL</td>
<td>UP, UC, UI, UM, UV, RM</td>
</tr>
<tr>
<td>17. Norwood HGL</td>
<td>UV, UP, RM, UM, UI, UC</td>
</tr>
</tbody>
</table>
Understanding the HGL will guide investigations and planning decisions. The expansion of residential development is planned in the following areas and HGL understanding will guide planning.

Hadspen Expansion
The green belt surrounding the development would provide a buffer to the rural environment. Specifically in the Hadspen HGL, road construction in the terrace landforms of Hadspen Village will need to be carefully managed, as the natural landscape coupled with constriction to groundwater flow caused by road construction will initiate urban salinity. The existing urban damage is indicative of this situation. New road construction should avoid higher risk areas of the terrace, and should be a planning consideration in development. Building construction will need to be conscious of the higher salinities on elements of the terraces. The area may require a series of tree belts to be placed on the terrace landform, with trees on the upstream side and services on the other side of the road in planning layouts.

Reed Development
There is significant push for development in Reed and the area contributes high salinity water to the landscape. There is the opportunity to incorporate existing vegetation in this landscape planning for salinity control. Groundwater emerges high in the landscape of the Reed HGL, impacting a newly constructed road in a new development (Figure B48).

Figure B48: A view of groundwater expression high in the landscape of the Reed HGL, impacting infrastructure in a new development
West Riverside Development and Infill
The West Riverside area is very saline particularly in upland valleys which have very high salinity groundwater discharging to the surface. The level of salinity and salt stores necessitate construction methods (houses/ roads/ utilities) that will need to consider extreme salinity, and planning controls will need to detail this risk. Redevelopment and repair will also need to consider extreme salinity. Urban water management in the upper landscape is imperative to limit recharge to the upper valleys and lower colluvial landscape. Planning layout will need to reflect landform to limit development in upland valley, and consider urban greenspace as an alternative (Figure B49).

Figure B49: A view of urban development in West Riverside that will need to be carefully planned

Legana Development
Legana will potentially be extensively developed on the terraced landform with loamy former orchard soils over saline, acidic and sulfatic sediments. The most important planning issue is the need to limit the interaction of applied water to limit the recharge to the very high risk lower landform units. The lower units are at higher risk to development, and road layout will need to not impede surface flow. Stormwater management that recharges the local landscape needs to be avoided. The level of salinity, acid sulfate soils, acid discharge and salt stores necessitate construction methods (roads/ utilities) that consider these extreme conditions.

East Riverside
The landscape situation in East Riverside is an alluvial plain formed on both older and more recent estuarine environments on the edge of the Tamar River. Housing development is very high risk with playing fields, recreation and conservation areas more conducive to the landscape situation. The level of salinity, salt stores and acid sulfate soils necessitate construction methods (roads/ utilities) that consider extreme salinity, a reducing environment and low pH.

Invermay
Industrial and urban development on the Invermay HGL is on low alluvial terrace landforms that have naturally occurring alluvial materials preserved from older and more recent estuarine
processes at the edge of the Tamar River, and man-made materials from estuarine deposits that have been dredged for infill. These estuarine sediments are significantly saline with large acid sulfate signatures and high hazard. The level of salinity, salt stores and acid sulfate soils necessitate construction methods (buildings, roads/ utilities) that consider extreme salinity, a reducing environment and low pH. The area already has considerable pile construction that deals with the severe environment. Housing expansion and re-development has a high risk in this landscape setting.

City East Infill

The planning issues in City East relate to the temptation to utilise previously identified high risk landslip areas for infill development. Salt within the soils, above and below the slip predispose the area to structural instability, and these are also areas of preferred flow for water movement. The areas become wet, and slip under gravity in wet times. Water application to the landscape is a salinity issue and a structural soils issue. The area is and has high hazard for both soil stability and salinity, due to these landscape situations. Planning should consider leaving these areas undeveloped.

St Leonards and Norwood Development

These two areas are potential development areas, which are mostly undeveloped at this stage. In the St Leonards area the landscape has minor salinity where soil depth occurs, but the vegetated upper landscape, lack of rural development and shallow, rocky soils contribute to a relatively low risk landscape. Development of the area will require monitoring of potential urban salinity impact.

In the Norwood area, there is also the opportunity to develop the area to lessen the impact of urban salinity. The midslope areas have small scale peri-urban development with little indication of salinity damage. There are sites in the upper landform below the basalt cap that have initial planning concerns. An increase to density of housing will increase the stream salinity lower in the catchment and locally at mid-slope locations.

Australian Standards (for Development)

The following excerpt is from LGSI Booklet - Book 6: Building in a Saline Environment - gives guidance to the Australian Standards for development and also examples of where NSW provides additional information, which may be appropriate to the Launceston situation.

Australian Standards are created by groups of interested stakeholders donating their time and expertise to follow a prescribed process and format to create a reference document. The BCA “deemed to satisfy provisions” refers to over 100 Standards thus these standards become part of the legislative framework of the building industry. Several provide requirements for construction in saline soils.

‘AS 2159 Piling Design and Installation (1995)’ provides table (6.1) Exposure Classification for Concrete Piles. Soil conditions are listed as non-aggressive, mild, moderate, severe or very severe, based on test results for pH, chlorides, sulfates and soil resistivity, for permeable soils which are below the groundwater table and for low permeability soils or all soils above the groundwater table. Various notes of caution are attached to the table such as the impact of magnesium or ammonium ions, in the presence of sulfates, increases the aggressiveness of the soil on concrete. This standard also recommends site specific design of concrete for sulfate attack noting that dense, well compacted, low permeable concrete of the correct type is more important than a high characteristic strength. Extracts from this standard are provided in the Local Government Salinity Initiative booklet ‘Site Investigations for Urban Salinity’.

‘AS 2870 Residential Slabs and Footings (1996)’ requires:
• a design life of 50 years (clause 1.4.2)
• drainage to be designed and constructed to avoid the ponding of water against or near footings. A graded fall of 50mm minimum away from the footing over a distance of 1m is required even on the ground uphill from the slab on cut and fill sites (clause 5.2.1)
• 40mm cover to reinforcement
• concrete to be vibrated and cured for at least three days in known salt damp areas (clause 6.4.8)
• careful detailing of DPC in high salt damp areas (clause 5.3.4)
• damp proof membranes to be extended under the edge beam to ground level (clause 5.3.3.3)

It also provides an advisory note to use damp proof membranes in South Australia and areas prone to rising damp and salt attack (clause 5.3.2).

Building Codes

The ‘Building Code of Australia’ is a performance based code that sets out the objectives and outcomes required for different classes of buildings. Acceptable building solutions (also called “deemed to satisfy provisions”) are listed to show how to achieve these requirements. However, a builder may choose other construction materials and practices provided it can be demonstrated that all the required outcomes of the BCA are met.

The Damp and Weatherproofing provisions require the following:

• F2.2.2 A building is to be constructed to provide resistance to moisture from the outside and moisture rising from the ground.
• P2.2.3 Moisture from the ground must be prevented from causing -
  o unhealthy or dangerous conditions, or loss of amenity for occupants; and
  o undue dampness or deterioration of building elements.
    and NSW adds
  o Barriers installed beneath slab on ground construction for the purposes above must have a high resistance to damage during construction.

The Australian Building Code Board has been reviewing the issue of urban salinity/salt attack for a number of years. One of the outcomes of this process may be to improve the clarity of these performance requirements by including a reference to salt as well as water. Another may be modification of the deemed to satisfy provisions. In NSW, the Building Code of Australia becomes legislation through the Environmental Planning and Assessment Act. The Building Systems Unit within the Department of Planning, consults with the NSW construction industry and stakeholders via the Building Regulation Advisory Council to consider national proposals in terms of their suitability for NSW. The State variation to the BCA implemented in 2004 and still current today, relating to use of high impact damp proof membranes under house slabs was introduced as an interim measure while national debate regarding salt attack continues.

In NSW, local government may also introduce building policies above and beyond the BCA although they cannot water down or make any BCA provisions not apply. Several councils have or are currently reviewing the necessity of this option for building in saline environments. The existing NSW local government policies generally require:

• 50mm of sand under the building slab
• 32MPa concrete  
• seven days curing time for concrete, and  
• reinforce the NSW BCA requirement of a high impact resistant damp proof membrane.

References to urban salinity are also being made in Council Engineering Guidelines and one council is considering the introduction of a higher minimum construction standard for domestic pools. Leakage from pools not only wastes water but adds to the salinity potential of the area. The NSW Office of Fair Trading requires all builders and tradesperson who undertake work in the home building industry (for jobs over $1000 including labour and materials) to be licensed. License holders must regularly update their knowledge by undertaking continuing professional development. Sydney Metropolitan Catchment Management Authority, the Department of Environment and Climate Change, and TAFE NSW, have developed a four hour course for builders, building inspectors and certifiers to increase their awareness and understanding of urban salinity and its management. The course is called ‘Building in a Saline Environment – An Awareness Course for NSW.’

B4.4 Vegetation

Vegetation plays an important role in urban salinity management and the following excerpt from LGSI Booklet - Book 7: ‘Waterwise’ Parks and Gardens - gives example to the potential tools for vegetation management.

‘Local government has a number of tools that provide opportunities for promoting appropriate vegetation management. These include:

• Local environmental plans that determine land use within an area. For example, a plan could identify areas of existing native vegetation on hilltops and in drainage corridors that are set aside for recreational or environmental protection purposes.

• Development control plans that establish landscaping requirements and tree cover requirements, or determine the size of allotments, buildings and house set backs, etc. For example, in Wagga Wagga, DCP11 sets tree cover percentages based on land capability for new rural residential development. If this tree cover is not present at the time of development, steps are put in place for revegetation using specified tree and shrub species at a rate of one tree per four shrubs.

• Development approval conditions allow development to take place provided certain conditions are met. These could include a requirement for the submission and approval of a landscaping plan with ‘Waterwise’ gardening design criteria.

• Plans of management for community land are required under the Local Government Act (1993) for all council-owned and managed land, including public reserves and parks. These plans could include short- and long-term goals to increase perennial vegetation cover, remEDIATE salt-affected areas, mulch garden beds and upgrade watering systems to minimise waste water and leakage into groundwater systems.

• Council management plans are the annual organisational plans for a council’s activities. They identify the priority activities, budget, fees and charges of the council. The plan should take into account the effect of salinity on council activities and assets as well as how the council is managing salinity. Matters that could be considered include:
  
  o water usage charges (where appropriate);
• expenditure on reserves or landscape maintenance (e.g. watering and lawn mowing);

• programs to improve irrigation efficiencies;

• the planting of water efficient landscaping; and

• the provision of a salinity education program.

- Council policies and practices are often less formal measures that influence salinity management. These include how a council enforces a Tree Preservation Order, or supports vegetation and salinity management committees, Landcare or bush regeneration groups and whether the council has a tree nursery and sells to the public, encourages mulching and composting, manages road corridors or integrates natural resource management into everyday decision-making. These all influence salinity processes as well as public responsiveness to good salinity management practices.

Local government policies and investment on public land should ultimately reflect community expectations. However, community education may be required to increase awareness and understanding of salinity in order to gain acceptance and support in some salinity management decisions and actions. For example, the community may assist in planting or managing areas vegetated to control groundwater levels, once there is an understanding that excess water infiltration can exacerbate salinity and in turn increase the repair and maintenance costs for roads, buildings and other infrastructure.

As well as public land, large proportions of our urban areas are occupied and managed by private landholders. The majority of water used around the home is utilised in outdoor activities such as watering lawns and gardens.

Private property can contribute significant amounts of both water and fertilisers to groundwater systems. Again, education may change people’s attitudes and behaviour, resulting in better management of salinity on private land.”

Urban Vegetation is of specific concern in 5 of the 17 HGLs described from the GLA (Table B13). The locations essentially are areas where vegetation remains in an urban area, or the area is undergoing new development.

Table B13: Urban management strategy - urban vegetation considerations

<table>
<thead>
<tr>
<th>Urban HGLs</th>
<th>Urban management strategy (in priority order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Reed HGL</td>
<td>UV, UP, UI, UC, UM, RM</td>
</tr>
<tr>
<td>4. Trevallyn HGL</td>
<td>UM, UV, UC, UP, UI, RM</td>
</tr>
<tr>
<td>10. St Leonards HGL</td>
<td>UV, UP, RM, UI, UC, UM</td>
</tr>
<tr>
<td>15. West Kings Meadows HGL</td>
<td>UM, UV, UC, UI, UP, RM</td>
</tr>
<tr>
<td>17. Norwood HGL</td>
<td>UV, UP, RM, UM, UI, UC</td>
</tr>
</tbody>
</table>

Greater Launceston Area Urban Salinity Strategy 2016
B4.5 Water Management

Water management is of specific concern in 8 of the 17 HGLs described from the GLA (Table B14). In these areas water use and the over-application of water to the landscape has interacted with the large salt store to create and enhance urban salinity issues.

Table B14: GLA HGLs with Urban Management as the priority urban strategy

<table>
<thead>
<tr>
<th>Urban HGLs</th>
<th>Urban management strategy (in priority order)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Prospect Vale HGL</td>
<td>UI, UC, UM, UP, UV, RM</td>
</tr>
<tr>
<td>4. Trevallyn HGL</td>
<td>UM, UV, UC, UP, UI, RM</td>
</tr>
<tr>
<td>5. West Riverside HGL</td>
<td>UP, UI, UC, UM, UV, RM</td>
</tr>
<tr>
<td>6. Legana HGL</td>
<td>UI, UP, UM, UV, UC, RM</td>
</tr>
<tr>
<td>8. Alanvale HGL</td>
<td>UM, UC, UI, UP, UV, RM</td>
</tr>
<tr>
<td>14. East Launceston HGL</td>
<td>UM, UC, UI, UP, UV, RM</td>
</tr>
<tr>
<td>15. West Kings Meadows HGL</td>
<td>UM, UV, UC, UI, UP, RM</td>
</tr>
<tr>
<td>16. Youngtown HGL</td>
<td>UM, UC, UP, UI, UV, RM</td>
</tr>
</tbody>
</table>

B4.5.1 Water use

The main cause of urban salinity is over-watering of gardens, sporting fields and parks. There are impacts from individual usage, cumulative impacts on an area from widespread usage and impacts on adjoining areas due to increase in hydraulic loading on groundwater. In Launceston the additional issue relates to salt store and recharge to that saline environment. As shown in section 3.3.3.7, City of Launceston GIS staff conducted a series of mapping exercises to graphically demonstrate the total water consumption of individual holdings across the urban area. The analysis highlighted a number of factors:

- In general the level of water use was much, much lower than encountered in previous urban investigations elsewhere
- There were some correlations to salinity damage, but not as closely linked as in other urban investigations.

Water consumption in the GLA is relatively low and it is the interaction with the salt store that is the key issue. For example, Ravenswood has a low water use, but very high salinity signature. The risk to overwatering causing salinity damage is real in these high salt store environments. At present low water application is limiting damage.

The common methods of application of water via automatic systems, rose-head sprinklers and soaker hoses, makes it very easy to over-water. Modifying community watering behaviour would prove beneficial. In other urban centres a combination of techniques has been employed and these options might be considered for application in the GLA.

Demand management

- Pricing policy on a sliding scale so that the more water used attracts higher costs.
• Physical restriction of water supply by pipe sizing and storage restrictions in new developments.

• Regulation on operation of automatic sprinkler systems.

Community education

• Conduct ‘Waterwise’ program, targeted at urban water use. Being ‘Waterwise’ requires the incorporation of three principles in the design, implementation and maintenance of landscapes:
  1. minimising the application of water;
  2. incorporating vegetation that uses rainfall efficiently; and
  3. reducing direct evaporation from the soil surface.

• By adopting ‘Waterwise’ practices and education programs, we may decrease the incidence and severity of urban salinity. Savings can be made through:
  o reduced irrigation/watering costs;
  o reduced costs associated with the repair and maintenance of infrastructure affected by salinity;
  o improved water quality; and
  o improved biodiversity.

• Use of native gardens and native plants with low water use characteristics.

• Plant types selection for lower water use, and drought tolerance. Subsidy programs have been employed for changing or establishing more appropriate species. Salt tolerance of plant selection is also an issue in saline areas.

• Older people as educators in the community.

• School education programs.

• Urban Landcare Group establishment.

• Water use education programs targeted at conveying how much water is needed for a plant type for a particular soil type.

B4.5.2 Stormwater

The stormwater contribution to the issue is part of the water management issue. Excessive stormwater infiltration causes localised groundwater rise, localised wetting of soil and increases in mobilisation of salt store, that flow on to cause urban salinity damage. Both impacts (groundwater and salt store) are also cumulative.

Sources of excess groundwater recharge include:

• Discharge of roof water directly to the ground adjacent to buildings that recirculates carrying salts with it to continually cause damage to buildings.

• Stormwater where no stormwater system established.

• Leaky stormwater reticulation systems.

• Drainage systems that both recharge and discharge.
• Clusters of rubble pits where increases in recharge of groundwater occurs.
• Unlined detention and storage basins adding to increases in recharge of groundwater.

There needs to be a balance in both recharge and discharge. Urbanisation perturbs this balance. The natural landscape is displaced by hard structures (roads etc.), homes and gardens. The natural landscape is also perturbed by infrastructure, construction practices (cut and fill), drainage systems and constrictions in the landscape.

Water Sensitive Urban Design (WSUD) methodology and principles play a role in urban salinity management, but understanding the urban landscape dynamics is critical. The positioning of WSUD actions can be a huge benefit, or a cause of salinity damage. This is brought out in the Urban Salinity Management Actions applied to Management Areas. Each relevant HGL has detailed actions applied to urban management areas to guide urban salinity management (listed below).

Management Strategy UP: Urban Planning

UP1: Prior to commencement of earthworks sodic/saline soils should be identified.

UP2: Minimise use of infiltration and detention of stormwater in hazard areas, consider lining of detention systems to prevent infiltration (i.e. reconsider WSUD implications in relation to salinity management).

UP3: Identification of discharge sites should influence the size of the area to be developed.

UP4: Maximise the size of impervious surfaces to prevent recharge of (perched) groundwater table. Constructed pervious surfaces may need to be lined and drained to stormwater outlets.

UP5: Implementation of WSUD techniques considers the potential impact on the local salinity hazard. Revise principles of WSUD where salinity affects are an issue.

Management Strategy UM: Urban Management

UM1: Minimise leakage of standing water bodies, pools, lakes and service pipes.

Care should be taken with WSUD actions in the following situations so as to not increase the impact of urban salinity in areas that may be at risk, such as:
• Identified high groundwater conditions
• High groundwater salinity conditions
• High salt store areas
• Landscape positions where accumulation of surface and groundwater occurs
• Geological structures, e.g. faults and fractures, contacts of geological systems
• Above locations where high groundwater salinity seeps into water bodies and streams.

Additionally, the installation of WSUD technology, such as the installation of rain gardens or infiltration trenches, will need to consider the following so as not to re-wet local shallow groundwater and mobilise salt:
• Clay content of soil – clay soils once wet require very little water to re-wet them and hence re-mobilisation of salts can occur which could cause damage to buildings and infrastructure. Small rainfall events could have significant impacts once the clay soil is wet.
• **Salt** – high salt store in profiles will be impacted by the CEC of soils and associated salt store. A high CEC soil (usually a clay soil) has a high salt storage and also a threshold value over which salts are not bound to clays. Accumulation of salts in the soil profile will breach this threshold, hence mobilising salt to profile.

• **Free draining** – the ability of a soil to drain (which is impacted by clay content, pore size, groundwater level, bedrock etc.) will determine if a soil is likely to re-mobilise salts.

• **Shallow grades** - low slope (or no slope) gradients on trenches will increase the potential of water to be available to re-mobilise salt.

Bio-retention systems will need to be lined with “geotextile” to operate effectively (design of these systems should be closely aligned to soil type and salt store), and there will be an effective “lifespan” of these systems until they become “clogged” with silts and other materials. Lot size of developments is also an issue. Smaller lot sizes will add a cumulative impact where this development occurs, as opposed to larger lots where there is more capacity to dissipate excess water.

In stormwater management systems, rubble pits and detention basins are commonly used to reduce the design capacity of drainage infrastructure and to increase stormwater retention time.

**Rubble pits**

In an urban environment a significant source of concentrated recharge occurs through rubble pits. Rubble pits are usually installed:

- Where drainage to the street is not possible
- In older developments (especially in housing commission areas) where there is a need to reduce the design capacity of drainage infrastructure
- To increase stormwater retention time.

The level of rubble pit operation in the GLA is not well documented.

**Detention basins**

Detention basins are installed to change the time of concentration of surface flows, as flood detention storages, and as primary nutrient/sediment traps in stormwater systems. From an urban salinity viewpoint, it is essential that the detention storages do not leak and hence raise the local groundwater conditions or place a hydraulic head on other groundwater systems causing salinity.

**Salt store accession**

Stormwater systems also need to take into account the salt store in the medium through which they are constructed. If the area has a high salt store, the local system is at high risk to have impacts within the system itself. A classic example of this is in the St Clair area of Western Sydney where the construction of a stormwater system through high salt stores has instigated salinity damage, particularly to the vegetation and pipe work that lines the channels. Reference should be made to the Local Government Salinity Initiative Booklets, especially Book 3: Site Investigations for Urban Salinity for soil tests and assessment of salt store in these areas prior to WSUD planning and design in new areas.

**Water Audit**

A water audit that fully apportions all aspects of the urban water cycle may be able to attribute the specific contribution of stormwater to urban salinity development.
B4.5.3 Water supply and delivery

Losses in water supply and delivery systems are often a significant contributor to urban salinity. Old galvanised pipes corrode and leak, and joints/connections degrade with wear. In previous work in other urban investigations, the following have shown to be major issues:

- Leaky reservoirs
- Leaky pipes (both council supply and internal household)
- Leaky swimming pools and ponds
- Areas where old reticulation systems have been replaced with new supply systems, but the old systems have not been disconnected and continually recharge groundwater
- “Grey water” reticulation systems.

The GLA has a reticulation network that has been constructed through time. It is unknown as to the level of leakage in the operation of this network in the GLA.

B4.6 Heritage Issues

Launceston has a wealth of heritage buildings because it was one of Australia’s early settlements.

There is urban salinity damage to heritage structures throughout the GLA. The salinity indicator mapping conducted within this project (Figure 9) noted a tendency for salinity impacts in older homes and buildings to have significantly more salinity damage. This effect may be due to:

- Age of structures and the accumulation of salts around the buildings through time
- Construction method of the period that did not have damp proof coursing etc.
- Long term water application
- Deterioration and lack of maintenance
- Building materials with a high proportion of salts (e.g. mortars)

From heritage information contained within the “*Technical Guide: Salt attack and rising damp – A guide to salt damp in historic and older buildings* - by David Young” it outlines seven key steps to successfully dealing with salt damp.

1. **Accurate diagnosis of the cause**
   - is it rising damp? or is it falling damp? or a combination? or
   - is the damp penetrating sideways from a localised source, or
   - is it condensation on internal surfaces?
   - is there an existing DPC that is buried or otherwise bridged?
   - how bad is the problem — does it really need major works?
   - is there a lot of salt? what is its source?

2. **Good housekeeping is fundamental**
   - ensure gutters and downpipes are working
   - ensure rainwater is carried well away from base of walls
• ensure site is well drained — no ponding against walls
• minimise splash from hard pavements into walls
• maintain about 200 mm between DPCs and ground level
• check for and fix any plumbing leaks, including sewers
• check for fungal rot, borers and termites in damp floor timbers
• ensure adequate (but not too much) underfloor ventilation
• monitor changes, for these may be sufficient.

3. Treat mild damp sacrificially
• use weak mortars in eroding joints, or
• weak plasters and renders to control damage
• monitor changes before considering further treatment
• ongoing sacrificial treatments may be sufficient.

4. Remove excessive salts
• remove surface salt deposits by dry vacuuming, then
• use captive-head washing for near-surface salts
• use poultices of absorbent clay and/or paper pulp
• use sacrificial plasters, renders and mortars.
• monitor effectiveness — re-treat if necessary
• periodic maintenance treatments as required.

5. Review results before proceeding
• allow at least one year of monitoring
• account for unusual events — storms, floods, drought, etc.
• routine maintenance activities may be sufficient.

6. Inserting damp-proof courses
• undersetting with mechanical DPC, and/or
• slot sawing with mechanical DPC, and/or
• impregnation of chemical DPC, and/or
• active electro-osmotic damp-proofing.
• install DPCs at a level that will also protect floor timbers
• monitor for ‘leaks’.

7. Desalinating walls
• when salts abound, do not just insert DPC
• also remove excessive salts from above DPC
• use poulticing, captive-head washing and sacrificial treatments
• monitor annually for further salt attack
• re-treat if necessary until salts are reduced to a less harmful level."

B4.7 Monitoring

Unfortunately once salts are *in situ* in a wall, slab, brick or footing they are almost impossible to remove. The management of urban salinity then lies entirely with management of water. Additionally once salts are embedded, very small quantities of water remobilise salts to cause problems. Prevention of salinity damage is the preferred practise.

**Water Monitoring**

There are a number of standard approaches to monitoring water in an urban salinity situation:

- Installation of peizometers that allow assessment of groundwater height, pressure and groundwater quality
- Soil moisture probes and capacitance probes that monitor soil moisture
- Flow monitors (e.g. “Mag flow sensors”) that can be used to determine flow in large pipes, or flows in toilet systems and taps at the fine scale
- Weather stations and automatic systems that can be used to control the application of water
- Moisture meters used to sample moisture in walls on a point basis.
- Sampling stream EC and salt load by use of hand sampling equipment at regular intervals or automatic stream gauging stations.

Responsiveness to change in urban areas relates to the ability of water to flow through a system. A sandy soil has the potential to respond quicker to reductions in applied water. In the soils of the Launceston area with increased clay levels the responsiveness would be slower. Climatic impacts such as drought and associated water restrictions may have greater impacts than demand management. HGLs in the GLA would all respond differently to changes in water application. Some areas such as the Ravenswood HGL may take decades to respond to local changes, whilst steep, shallow landscape HGLs, such as Trevallyn HGL, may respond within a season.

**Additional risks**

There may be some additional risks due to urban salinity that council may need to monitor.

- Brick walls and retaining walls if impacted by salinity, or poorly constructed, may pose a threat to residents (e.g. recent court case of retaining wall falling and killing a child).
- Concrete paths which degrade pose increased trip hazards.
- Road damage causing decline in council asset and increasing costs of repair.
- Loss of vegetation in parks, sporting fields and public space due to the impacts of salinity.
B4.8 Costs

Costs of urban salinity are hard to determine but the following excerpt from LGSI Booklet - Book 10: Costs of Urban Salinity - attempts to ascribe costs.

"Where urban salinity impacts are experienced, costs are incurred by households, businesses, local government and state government agencies and utilities. Avoidance of these costs through the implementation of an urban salinity management strategy will result in benefits to these stakeholders and a reduction of offsite impacts. Valuation of these costs and the portion of the costs that will be avoided, is required to perform a financial evaluation of the strategy.

The presence of salty mains water supply can result in costs to water users. For households, these include increased pipe corrosion, shorter lifespan of hot water systems and increased consumption of bottled water, domestic filters, rainwater tanks and water softeners. Commercial water users may experience increased operating and maintenance costs for cooling towers, boiler operation and industrial water treatment (Wilson 1999).

High saline water tables can result in costs in both urban and rural areas. For households and businesses, such costs arise from damage to, and shortened lifespan of, buildings and other concrete structures (retaining walls, paths, and driveways) and from impact on lawns and gardens. Local government incurs additional costs in maintaining infrastructure, including roads and bridges, footpaths and concrete pavements, stormwater and sewerage systems, sports ovals, parks and gardens and council-owned buildings. State government agencies and utilities also incur additional costs in managing their infrastructure, including railways, roads and bridges, water storage facilities, concrete power poles and steel towers and underground gas and power supply lines (Wilson 1999).

A thorough investigation and valuation of all of the costs arising from urban salinity can be both difficult and expensive. Sample cost functions (Table B14; Table B15) give an indication of the cost borne by each stakeholder at different salinity severities. The severity represents the level of salinity determined by the presence and magnitude of observable salinity outbreaks."
### Table B15: Sample Cost Functions for Various Stakeholders and Levels of Salinity Impact

<table>
<thead>
<tr>
<th></th>
<th>Very Slight Impact</th>
<th>Slight Impact</th>
<th>Moderate Impact</th>
<th>Severe Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Households</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$/household/yr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Industrial/Commercial/retail buildings</strong></td>
<td>$/household/yr</td>
<td>$75</td>
<td>$250</td>
<td>$2,135</td>
</tr>
<tr>
<td><strong>Moderate Impact</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Severe Impact</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Local councils</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased repair and maintenance</td>
<td>Rural minor sealed roads $/km/yr</td>
<td>$100</td>
<td>$300</td>
<td>$700</td>
</tr>
<tr>
<td></td>
<td>Rural non-sealed roads $/km/yr</td>
<td>$75</td>
<td>$200</td>
<td>$500</td>
</tr>
<tr>
<td></td>
<td>Urban sealed roads $/km/yr</td>
<td>$150</td>
<td>$375</td>
<td>$1,150</td>
</tr>
<tr>
<td><strong>Cost of shortened lifespan</strong></td>
<td>Rural minor sealed roads $/km/yr</td>
<td>$296</td>
<td></td>
<td>$1,333</td>
</tr>
<tr>
<td></td>
<td>Rural non-sealed roads $/km/yr</td>
<td>$222</td>
<td></td>
<td>$1,000</td>
</tr>
<tr>
<td></td>
<td>Urban sealed roads $/km/yr</td>
<td>$407</td>
<td></td>
<td>$1,833</td>
</tr>
<tr>
<td><strong>State government agencies and utilities</strong></td>
<td>National and state highways $/km/yr</td>
<td>$2,000</td>
<td>$6,930</td>
<td>$17,325</td>
</tr>
<tr>
<td></td>
<td>Major sealed roads $/km/yr</td>
<td>$200</td>
<td>$450</td>
<td>$1,600</td>
</tr>
<tr>
<td>Railway infrastructure $/km single track/yr</td>
<td>$11,723</td>
<td>$24,971</td>
<td>$59,465</td>
<td></td>
</tr>
<tr>
<td><strong>Cost of shortened lifespan</strong></td>
<td>National and state highways $/km/yr</td>
<td>$2,407</td>
<td></td>
<td>$10,833</td>
</tr>
<tr>
<td></td>
<td>Major sealed roads $/km/yr</td>
<td>$481</td>
<td></td>
<td>$2,167</td>
</tr>
</tbody>
</table>

Reproduced from Wilson and Laurie (2001)
Table B16: Damage Costs per Item for Common Categories of Infrastructure

<table>
<thead>
<tr>
<th>Item</th>
<th>Depth to groundwater</th>
<th>Cost ($)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>House: brick on ground</td>
<td>1.5 m</td>
<td>Nil</td>
<td>House: brick on ground</td>
</tr>
<tr>
<td></td>
<td>0.5 m</td>
<td>$6,000/house in 3rd year after groundwater reaches 0.5m</td>
<td>Construction of perimeter drains around each house block, with slotted pipe and granular fill, to promote discharge of groundwater to surface runoff, such as natural channel, or exiting kerbside drain, with a sump serving the whole street and a pump to surface channel/disposal route if required.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$2,000/house in 1st year after groundwater reaches 0.5m</td>
<td>Repair of fretting brickwork, crumbling mortar; assumed to be a once-off expenditure, due to assumed installation of perimeter drains (see above), which would prevent recurrence.</td>
</tr>
<tr>
<td>House on stumps</td>
<td>1.5 m</td>
<td>Nil</td>
<td>House on stumps</td>
</tr>
<tr>
<td></td>
<td>0.5 m</td>
<td>$1,000/house every five years.</td>
<td>Jacking and re-stumping where necessary, starting in the first year the groundwater reaches 0.5 m.</td>
</tr>
<tr>
<td>Main road</td>
<td>1.5 m</td>
<td>$145,000/km every seven years</td>
<td>Costs apply to 0.3 of the length of road in the zone every seven years.</td>
</tr>
<tr>
<td></td>
<td>0.5 m</td>
<td>$195,000 / km every three years</td>
<td>Costs apply to 0.3 of the length of road in the zone every three years.</td>
</tr>
<tr>
<td>Local road</td>
<td>1.5 m</td>
<td>$70,000/km every seven years</td>
<td>As above, but with lower level of costs due to reduced traffic carried on local roads</td>
</tr>
<tr>
<td></td>
<td>0.5 m</td>
<td>$100,000/km every three years</td>
<td></td>
</tr>
</tbody>
</table>

Source: Dames and Moore (2001)

Note the above tables use costing generated in 2000, so are dated; but provide a relative idea of costs.
B5. Conclusions

The detailed HGL study facilitates understanding of how the landscape works, and the variability across the landscape. The detailed HGL characterisation (Stage 2) has provided a comprehensive overview of salinity hazard across the GLA and enables governance and planning organisations to evaluate ‘risk’, prioritise works and gauge the impact of salinity hazard in the GLA. Put simply, it allows natural resource managers to take appropriate management actions in the right parts of the landscape for defensible reasons. Scenario-based planning for potential futures is possible once this information is known, and the influence of modified land use practice and changes in environmental systems (e.g. climate change influences) can be evaluated within the HGL framework.

The Greater Launceston Area Urban Salinity Strategy project work, has shown that the HGL framework allows the following objectives to be undertaken:

1. Explain how water moves through the landscape
2. Explain where the salt stores are in the landscape
3. Explain and detail the variability in landscapes controlling this movement and storage
4. Management of the landscape based on the understanding of these processes
5. Identify risk and prioritise hazard management in the landscape

The scope of the advice in an urban environment has been to firstly understand how a “landscape works”. If you understand the integration of soils, geology, landform, salinity data, regolith and climate (HGL) you can then understand the key criteria needed in new development areas and the salinity management required in existing landscapes.

This documentation, coupled with appropriate training, will provide a resource to manage salinity across the GLA. Our understanding of salinity process in the GLA has been markedly improved, and also informs natural resource management (NRM) principles that may apply in this urban/peri-urban environment.

The overall recommendations listed below (section B6) detail appropriate actions to take salinity management forward. They are categorised in two sub-sections:

B6.1 Urban Recommendations.
B6.2 Landscape Technical Recommendations.
B6. Overall Recommendations
The GLA is a complex environment of geology, soils, regolith, landforms, climate and salinity impacts. There is huge variability in the behaviour and management of Hydrogeological Landscapes (HGLs) that can be prescribed to urban areas.

B6.1 Urban recommendations
There are a range of short term actions that can be taken.

B6.1.1 Training
Training is required to convey the importance of urban salinity. Although there is some specialist expertise in agencies, in general there is a very low level of salinity awareness throughout the community with regard to salinity in the GLA. Training can be conducted via:

Community awareness and training
A range of programs could be effectively implemented:

- Awareness walks - simple activities where the community is shown the impacts of urban salinity and the damage that results.
- Media program – a communication strategy targeted at raising the awareness of water use, urban salinity and simple building techniques to limit the impact of salinity.
- ‘Waterwise’ programs - Conduct ‘Waterwise’ program, targeted at urban water use. Being ‘Waterwise’ requires the incorporation of three principles in the design, implementation and maintenance of landscapes:
  1. Minimising the application of water;
  2. Incorporating vegetation that uses rainfall efficiently; and
  3. Reducing direct evaporation from the soil surface.
- Water use demonstrations - water use education programs targeted at conveying how much water is needed for a plant type for a particular soil type. This can be as simple as timing of rose sprinkler head run time or the use of neutron probes and/or capacitance probes to gain very detailed information.
- Vegetation - use of native gardens and native plants with low water use characteristics, along with plant type selection for lower water use, and drought tolerance. Subsidy programs have been employed for changing or establishing more appropriate species. Salt tolerance of plant selection is also an issue in saline areas.
- Education programs:
  o Older people as educators in the community (e.g. Wagga salinity program)
  o School education programs
  o Urban Landcare Group establishment
  o Heritage education programs.
**Staff training and awareness**

Programs that give staff information for incorporation of salinity information into their day to day business can be helpful. For example, a planner may require information on development and the principles of HGLs, a road engineer may require information on landscape position impacts of road design etc.

As part of a “Stage 3: Training and Awareness” component of the current HGL project, there are two programs that could be rolled out to Greater Launceston Area staff:

- HGL training – a one day course outlining the principles of HGLs, aiming at giving an understanding of the variation of salinity throughout the area.
- Day to day business – a program targeted at how GLA staff can incorporate salinity information into day to day business. This will use a facilitator in day long sessions.

**Building and construction training**

A very successful “Building in a Saline Environment (BIASE)” course has been implemented across NSW targeted at builders, plumbers, construction companies, certifiers, local government staff and regulators. Also as a part of “Stage 3: Training and Awareness” component of the HGL program this could be rolled out to the above groups in a series of 4 hour sessions. The sessions attract 4 CPD points (NSW) and provide simple steps to limit the impact of salinity in building and construction.

**B6.1.2 Policy**

A number of agencies and local councils have developed policies to deal with the impacts of urban salinity. These can be used as guides for implementation, or as statutory regulations which need to be implemented.

There are a number of key short term policy documents and instruments that could influence salinity management in urban areas.

**Salinity policy**

Emerging State government policy on risk management suggests that private risk associated with natural hazards ought to be managed by the affected property owners.

Planning policies need to establish the requirement to consider salinity within the review or changing of the zone that applies to land. This would be achieved through implementation of a State Planning Policy under the State Policies and Projects Act 1993 and would need to be completed by the State Government.

Urban salinity would then be considered on a consistent basis, with other natural hazards. Thresholds could be set where interventions required specific planning controls within a planning scheme.

A number of mainland agencies and local councils have developed policies to deal with the impacts of urban salinity. These can be used as guides for implementation. Camden Council implemented a salinity policy “Building in a Saline Prone Environment – Policy 1.15” in 2004 (updated 2009). This forms a guide for implementation of local salinity policy and is widely adopted by many councils, and could be readily adopted by the GLA Councils.

**Local government policy**

Local government policy would allow for detailed management of urban salinity risk through both of the planning and building approval processes.
Local planning policy would be based on the identification of specific risk areas that are already, or are available for, development. The Tasmanian Government established Planning Directive No. 1 – the Format and Structure of Planning Schemes (the PD1 template) as the basis for all new planning schemes. Under the PD1 template, natural hazards are managed through a combination of mapping as an overlay, which is regulated through a Code. These can be used for existing and new development areas. These tools equate to the Local Environmental Plans and the Development Control Plans within the New South Wales system.

Where significant salinity problems exist, it may be appropriate to manage such an area through a Specific Area Plan under the PD1 template.

**Urban Salinity Management Plan**

Urban Salinity Management Plans can provide an effective mechanism to define problem areas, establish particular responses that are required and provide a basis for intervention through planning and building controls.

Dubbo Council has adopted an “Urban Salinity Management Plan” in 2008 to provide directions and actions to council’s actions with regard to urban salinity. The document can be referenced on [www.dubbo.nsw.gov.au](http://www.dubbo.nsw.gov.au)

The Dubbo City Council approach provided a structured framework for actions into the future for a local council to address urban salinity. It provides information on current programs and actions, and proposed programs for the future. Dubbo City Council has also undertaken a HGL project which has actively informed actions in all areas of council, and staff have undergone training in HGLs of the Dubbo Urban area. In a recent innovation the HGL structure has been incorporated into an “Urban Salinity Plan “…that directs actions in each HGL. Urban Salinity Management Plans of this style and HGL structures should be part of the response to more problematic areas of urban salinity and inform preparation of specific town planning controls for each overlay or specific area plan (Nicholson et al. 2010).

**Building and Construction Policy**

There are a range of policies (Australian Standards / Building Codes of Australia) referred to in Sections 3.4.5 and 3.4.7 that address factors relevant to buildings within the urban salinity environment:

- AS 2870 Residential Slabs and Footings (1996)
- Building Code of Australia (BCA) provisions
  - High impact membranes
  - Exposure class bricks
  - Drainage of surface water
  - The damp and weatherproofing provisions

These matters are regulated through the National Construction Code and the Building Act 2000 (within Tasmania). They relate to the technical construction requirements for buildings and infrastructure to improve their resilience to salinity.

**Other Responses**

The policy response is limited within Tasmania. There are a range of other mechanisms that could assist with salinity management. The State government has not implemented a policy-
Based response to salinity issues. Until this work is completed by the State, Councils should carefully consider local policy responses.

**B6.1.3 Planning**

The following excerpt is from LGSI Booklet - Book 1: Land Use Planning and Urban Salinity, which can be used when considering salinity in the Tasmanian context:

“When addressing urban salinity in land use planning it is useful to differentiate between the three land use planning phases, namely the:

1. **Strategic or plan making phase**
2. **Development or plan implementation phase**
3. **Management or post construction phase.**

The opportunities to address urban salinity are different at each of these phases, reflecting the differences in the scale of the area being considered, as well as the investment and approval decisions required.

The strategic and development phases (i.e. the first two phases) are the most important in determining the ongoing land use and the likely changes to landscape processes. However the management phase is also very important in determining what the long-term impacts of these changes will be.

It is important to think about salinity throughout the land use planning and development process, and at all relevant phases. Ignoring salinity at any one phase may limit the ability to successfully implement initial measures or to include other appropriate measures at later stages of development.

Salinity cannot be managed effectively by responses limited to any one stage; it requires an integrated approach throughout the life and the scope of land use planning and development for an area.

Salinity is a relevant matter of consideration under Section 79C of the Environmental Planning and Assessment Act 1979 (NSW). Under this section councils need to consider if the development is suitable for the proposed location and the likely impacts of development. However, plans with clear urban salinity objectives facilitate integration of salinity considerations into planning processes. For example, objectives based on the following points can be incorporated in local environmental plans to integrate salinity management into strategic planning:

- Minimise disturbance to natural hydrological systems as a result of development and appropriately manage land uses affecting land salinisation and/or those affected by salinity.
- Ensure that land is used and developed in a manner that does not significantly increase water infiltration to groundwater systems and does not significantly increase salt loads in waterways, wetlands, drainage lines, or soils.

As well as more specific objectives where appropriate, such as:

- Minimise damage to buildings and infrastructure in urban areas caused by salinity.
- Regulate and provide guidelines for appropriate land uses and management practices on urban zoned land affected by and affecting salinity, (e.g. groundwater recharge and discharge areas).
• Ensure that the off-site impacts of any development on groundwater and salinity are recognised and assessed.

• Recognise environmental values that are affected by salinity, and specify targets for these values, e.g. tree cover based on land class.

• Retain or restore native vegetation on sites with high groundwater recharge potential, or where protecting salt affected land.

In making a decision in an area with salinity potential it is important to address not only the impact that salinity may have on the development proposed, but also whether the proposed development is likely to contribute to local or regional salinity processes. This could include likely salinity impacts on the site itself or on other sites because of changes to the landscape processes and water balance.

Another important part of the development assessment process is considering the need for conditions of consent, which may require certain actions to be undertaken or certain standards achieved. These could include:

• Requirements for salt resistant building materials and techniques.

• Limitations to the types of wastewater treatment or re-use on-site due to the potential for these processes to bring additional salt onto the site.

• Limitations on the types of on-site stormwater management techniques in order to minimise the amounts of groundwater recharge occurring.

• Controls on the depth of cut and fill or areas of excavation allowed on the site to avoid disturbing areas of saline sub-soils.

• Requirements for vegetation retention or restoration.

• Requirements for remediation of salt affected areas or ongoing monitoring.

Urban salinity is a complex issue that results from the interaction between natural processes and urban development processes. Considering salinity in urban land use planning and development assessment decisions needs to become normal practice in many parts of NSW.

Planners in local government and in state government agencies will need to:

• Consider the need to incorporate suitable provisions in LEPs and other planning documents to allow salinity to be properly considered in decision-making.

• Recognise the range of planning tools that exist and look at the opportunities to use these effectively to address urban salinity.

• Access the range of information available about urban salinity to improve the way in which it is addressed in the planning process.”

B6.1.4 Resources

There are a range of resources that were developed in NSW for Urban Salinity Management that have been utilised across Australia.

Local Government Salinity Initiative – Booklet series

Under the NSW Salinity Strategy, a project under the Local Government Salinity Initiative developed a series of booklets to provide specific advice on urban salinity. They form a substantial body of reference work to aid councils in dealing with urban salinity. They are
available on the internet at the NSW Office of Environment and Heritage website www.environment.nsw.gov.au. These booklets are generally transferrable to the Tasmanian context.

Book 1  Indicators of Urban Salinity
Book 2  Broad Scale Resources for Urban Salinity Assessment
Book 3  Site Investigations for Urban Salinity
Book 4  Roads and Salinity
Book 5  Introduction to Urban Salinity
Book 6  Building in a Saline Environment
Book 7  ‘Waterwise’ Parks and Gardens
Book 8  Salinity Indicator Plants
Book 9  Groundwater Basics for Understanding Urban Salinity
Book 10  Costs of Urban Salinity
Book 11  Land Use Planning and Urban Salinity
Book 12  Repairing and Maintaining Salinity Affected Houses

Urban salinity networks and other councils (NSW centric)
There are a number of salinity networks that may provide information and experience in dealing with urban salinity:

- Central West Councils - Salinity and Water Quality Alliance
- Western Sydney Urban Salinity Working Party - WSROC

Other Councils have had extensive experience dealing with urban salinity:

- Dubbo City Council
- Wagga Wagga City Council
- Camden Council
- Fairfield Council
- Hawkesbury Council
- Blacktown Council
- The Hills Council
- Bathurst Regional Council

It is recommended that GLA partner in implementation and education programs conducted by other Local Government organisations to gain and share ideas, approaches and experiences.

B6.1.5 Investigations
There are a number of urban related investigations which could be undertaken to provide information for decision-making.
Water Audit

A water audit to determine inputs and losses of the whole water reticulation system, both supply and drainage, is needed to understand and identify losses that cause urban salinity damage. Components may include:

- Leaky pipes including clay pipes that use natural clay as a collar
- Leaky reservoirs
- Stormwater systems including rubble pits concentration etc.
- Flow monitors (e.g. “Mag flow sensors”) that can be used to determine flow in large pipes, or flows in toilet systems and taps at the fine scale.

Water Use Mapping

City of Launceston GIS staff conducted a series of mapping exercises to graphically demonstrate the total water consumption of individual holdings across the urban area of the GLA. Comparison could be made between commercial and domestic water application, consumption per area, and with different ranges to graphically highlight the spatial impact of water use.

This technique could be continued to identify seasonal and/or annual water use, and “hot spots” identification of water use.

Water Requirement

The use of soil moisture probes and capacitance probes that monitor soil moisture can be used to determine water requirement for areas such as gardens and parks that vary in different soil types and landform units. Linkage to weather stations and automatic systems that can be used to control the application of water can be installed as demonstrations to accurately determine water requirement.

This technique has been used in Victoria Park in Dubbo NSW to determine water use in a range of land uses (croquet lawn, rose garden, oval, skate park, swimming pool, general park). Forbes Council conducted a similar exercise in Victoria Park and sporting ovals. The technique has been used as an education tool for the general community, as well as parks and gardens staff.

Water Monitoring

There are a number of standard approaches to monitoring water in an urban salinity situation that will allow an understanding of groundwater and salinity.

- Installation of peizometers that allow assessment of groundwater height, pressure and groundwater quality. Within the GLA it is suggested that a gridded network of shallow peizometers be installed where it is suspected that groundwater conditions have a local store. Processes such as groundwater contouring can then be used to determine where impacts are greatest, and will guide the understanding of water source. Peizometers can also be installed in new development prior to construction to determine the impact of urbanisation.
- Sampling stream EC and salt load by use of hand sampling equipment (EC snapshots) at regular intervals or automatic stream gauging stations will guide understanding of salinity. Community monitoring is a dynamic way of gaining both information and education outcomes.
**Assets Monitoring (Roads and Infrastructure)**

A GIS system coupled with data from repair sites of roads and pipe networks may allow identification of problem areas that are caused by salinity. It is common that repairs need to be made more frequently in areas affected by salinity. Annual repair and maintenance schedules can be then targeted at specific areas and catchment based solutions applied as well as local repair. This information would be very pertinent for council staff, as well as road and water engineers.

**Heritage Mapping**

A GIS process that overlays heritage value of buildings with the scale of urban damage, may provide a useful layer to rank heritage actions, and possibly provide a mechanism, by use of photo record, to assess damage through time. This information can be recorded in a GIS system attribute table, and then displayed using a number of methods.

**Land Use and Known Salinity Mapping**

Local Government is increasingly being asked to undertake benchmarking and monitoring programs. Land use is often mapped and the change in land use can act as a guide to salinity situation. Periodic updates of “salinity indicator mapping” could be conducted and provide a monitoring mechanism for the impact of land use, and more recently the impacts of climate change. Data can be used to graphically highlight the spatial impact of change via GIS systems. Council may be able to provide information to these data sources. These techniques could be utilised to identify seasonal/annual changes and “hot spot” identification.

**B6.2 Landscape Technical Recommendations**

There are a range of activities that could be undertaken to provide better information about the landscape.

**B6.2.1 Landform interpretation**

The utilisation of Digital Elevation Models (DEM) and surfaces derived from LIDAR mapping have enabled other HGL projects to accurately map the location of the Management Areas in a conceptual cross-section to spatially explicit areas. This is exceptionally useful as a mechanism to guide on ground actions, i.e. “the right action in the right place”. The GIS process revolves around landform modelling and terrain assessment.

**B6.2.2 Soil landscape mapping**

Detailed soil mapping in a landscape situation would allow the attribution of soil characteristics to a landscape. Coupled to a Management Area conceptualisation, it has proven useful for spatial attribution of a range of soil factors:

- Soil erosion
- Land capability (and urban capability)
- Regolith stability
- Chemical factors including: Soil carbon, nutrient status, acidity, sodicity, etc.

There is currently a soils mapping program underway in Tasmania that may add value.
B6.2.3 Salt sources and accumulation processes

The accumulation of salts in the dolerite and Paleogene sediments is an interesting technical area. The source and weathering processes appear to be different to other studied areas. This is currently an area of investigation by a PhD candidate from the University of Canberra (Sweeney et al. 2016).

B6.2.4 Detailed regolith mapping / geological investigation

A detailed regolith map of the GLA may be of assistance, as would further detailed geological investigation.

B6.2.5 Landscape and groundwater modelling

The utilisation of data sets from further investigations would allow a range of landscape and groundwater models to be undertaken and assumptions confirmed. There are a number of standard approaches to monitoring the salinity situation that will allow an understanding of groundwater and salinity processes, and also act as monitoring mechanisms:

- **Bores and peizometers** - assessment of groundwater height, pressure and groundwater quality could be determined using the existing bore network across the GLA. It is noted that there is not an extensive network at present. A regular sampling regime could be put in place to determine groundwater condition from bores in the area, already in use. Processes such as groundwater contouring can then be used to determine where impacts are greatest, and will guide the understanding of salinity management.

- **Installation of peizometers** that allow assessment of groundwater height, pressure and groundwater quality. Within the GLA it is suggested that a gridded network of shallow peizometers be installed in the high potential impact areas. Peizometers can also be installed in new development prior to construction to determine the impact of urbanisation over time.

- **Sampling stream EC and salt load** by use of hand sampling equipment (EC snapshots) at regular intervals or automatic stream gauging stations will guide understanding of salinity. Identification of springs in the landscape would form a useful aspect of this work. Community monitoring is a dynamic way of gaining both information and education outcomes. It is suggested that consideration be given to installation of gauging stations and a snapshot program of EC reading is maintained.
B7. References


