Groundwater and salinity study

109 Woodward Street, Parkes NSW

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Executive summary

Background

A residential subdivision is proposed for 109 Woodward Street, Parkes NSW. One dwelling and associated infrastructure are located on the site. Historical land-use is cropping and grazing. Salinity issues have been identified on adjacent land to the east.

Objectives of the investigation

A site and soil investigation was undertaken to assess the existing saline condition of the soil and groundwater to determine the impact of the development on groundwater and salinity.

Investigation

A soil investigation was undertaken of the site. An initial investigation and desktop review was undertaken to collect existing information on groundwater on and around the site and the likelihood of salinity across the site. Boreholes were drilled and soil samples collected on 13 December 2023.

The site investigation included vegetation description, landscape description, soil investigation, laboratory analysis and groundwater investigation. The soil profile investigation was undertaken by drilling boreholes up to 4.5m in depth. A monitoring well was installed in one of the boreholes. Representative soil samples were collected and analysed for pH, electrical conductivity, colour, dispersion, texture, chlorides and exchangeable sodium percentage.

The investigation results and proposed development were evaluated to identify impacts and recommend management outcomes to minimise salinity risk. Water balance was modelled to estimate changes in infiltration following development. Surface water flow containing sediment, nitrogen and phosphorus were modelled.

Conclusions

The site has a historical land-use comprising grazing. Vegetation cover on the site was generally 100% comprising pasture species and broad-leaved weeds. Scattered remnant eucalypts, cypress pine and kurrajong trees were located along the site.

Bare areas were identified on the site and determined to be from soil compaction, vehicle tracks and potentially from stock camp. The dwelling located on-site presented signs of impact by salinity including dampness “tide marks”, white crystals and signs of mechanical breakdown of bricks and mortar. No other indicators of salinity including soil “puffiness”, vegetation dieback or stains were identified during the assessment.

The site is located on a lower slope with gentle to flat inclination of less than 2%. Surface water flows into a drainage line 100m north of the site. The Goobang Creek is located 1km east of the site.

Soils on the site comprised topsoil of brown silty sand to 0.4m. Subsoils comprised brown to dark reddish brown gravelly silty clay over dark yellowish brown sandy clay with fine to medium siltstone and sandstone gravels.

Five boreholes were drilled on-site (MW1, BH1, BH2, BH3 and BH4). Samples from the topsoil of MW1 from 0m to 0.3m were determined to be slightly to moderately saline. Slightly saline subsoils were identified in the samples from MW1 both in the brown gravelly clay layer and the sandy clay layer. Slightly saline soils were identified in the samples collected from BH4 at 1.0m in light clay. Soil samples from the remaining boreholes were non-saline.

Four monitoring bores have been constructed within 1km to the north east of the site to intercept the shallow unconfined aquifer. The monitoring bores have a final depth up to 10.5m. Water bearing zones for the bores ranged from 4.0m to 10m in in silty clay and standing water level (SWL) ranged from 3.9 to 8.7m.

One monitoring well was installed on-site to a depth of 4.25m. The SWL and electrical conductivity were measured. The standing water level (SWL) was 0.79m below ground-level and electrical conductivity was 6.02dS/m. Groundwater in MW1 is classified as unacceptable for use as drinking water and of extremely high salinity for agricultural use based on EC results. Depth of groundwater on-site is expected to range from less than 1m to more than 3m based on site observations.

No visual surface or sub-surface indicators of groundwater discharge areas were identified on the site.

The water balance calculation indicates infiltration will decrease by approximately 13mm/year under the post development scenario as a result of change in land-use and inclusion of hard surfaces and landscaped areas with lower infiltration rates in the proposed lots. The development will not increase recharge of groundwater and groundwater levels over the site are expected to generally decrease if recommendations are implemented.

The risk of groundwater contamination from the proposed land-use is lower than the current land-use. Nitrogen contributions will decrease due to the change in land-use from grazing to landscaped areas and sealed surfaces. A decrease of phosphorus export is predicted. Phosphorous is not expected to move off-site providing vegetation is maintained which will result in slow surface water movement and deposition of sediments. Sediment contributions will also decrease as a result of a reduction of the grazing areas. Other activities which may increase the risk of groundwater contamination including car washing and re-use of greywater. The risk activities are expected to have a minor occurrence or be regulated by Council.

Recommendations

The southern two thirds of the site is suitable for residential development. Due to potential salinity and groundwater risks, the northern third of the site is considered potentially impacted by saline soil and shallow groundwater. The existing dwelling is located in the potential saline area.

The area delineated in the northern section is not expected to impact land rezoning. Additional investigations will provide a more detailed characterisation and guidance for the final development design.

The following are general recommendations to minimise salinity and groundwater risks from developing on the site:

- Undertake plantings of deep-rooted native vegetation to minimise the risk of seepage and improve aquifer drawdown.
- Maintain existing deep-rooted vegetation where possible.
- Piping of surface water off-site.
- Promote water sensitive design of dwellings and gardens.
- Design road levels similar to natural soil levels to minimise excavations.
- Earthworks comprising cut should be minimised.
- Earthworks and design to enable runoff of surface water.
- Consider the use of salt protected materials for services in the saline soil locations, e.g. salt resistant drainage pipes and conduits.

- Determination of the soil electrical conductivity at the design depth in areas to be excavated.
- Determination of the soil electrical conductivity in the proposed road areas.
- Classification of imported material in accordance with NSW EPA Resource Recovery Exemptions to ensure material is non-saline.
- Sediment and erosion control plans during construction.
- Site-specific assessment of building sites and appropriate design in accordance with the *AS2870-2011*.
- Deep excavations should be avoided. If deep excavations are required, the subsurface flows need to be maintained by installation of a drainage blanket.
- Any soil excavated from the site should be tested for salinity and adequately managed.
- Groundwater from the shallow aquifer is considered saline and should not be applied to the site surface.

Specific recommendations for the saline area

Future management of the saline area will include the following recommendations:

- Additional testing should be undertaken to characterise the saline area in the northern third of the site. The additional investigations will assess suitability for residential development.
- Backfilling of trenches should be undertaken keeping the original depths to avoid potential mixing between saline and non-saline soil. Any residual soil should be tested for salinity and transported to landfill if found to be saline.
- Dwellings located in the northern section of the site will be located on potentially saline soils. Soil salinity should be assessed at the time of site classification as part of the footing design. Dwellings of the site should be assessed in accordance with AS 2870 *Residential Slabs and Footings – Construction* to confirm assessment results provided in Section 7.6.2.
- Buildings in the saline area should be constructed in accordance with the BCA exposure conditions (s33.1), AS3700 Mansonry Structures, AS3600 Concrete Structures, AS2870 Restricted Slabs and Footings. The materials must comprise:
  - Salt resistant bricks and mortar
  - Adequate moisture barriers including a damp-proof curse
  - Concrete resistant to salt and water
- Depending on the final design, additional investigation will assist in mitigation measures.
- Installation of surface drains to divert runoff around dwellings.
- Roads to be constructed above a drainage blanket and embankment to avoid impacts of saline soil and maintain subsurface flows.

Contents

1. Introduction

A residential subdivision is proposed for 109 Woodward Street, Parkes NSW. One dwelling and associated infrastructure are located on the site. Historical land-use is expected to be cropping and grazing. Salinity issues have been identified on adjacent land to the east.

An assessment is required to determine salinity and groundwater impact on the site as part of the requirements for council to consider the application.

2. Scope of work

Envirowest Consulting Pty Ltd was commissioned by Stephen and Daniel Mansley to undertake a groundwater investigation and salinity study for 109 Woodward Street, Parkes NSW. The objective was to assess the existing conditions and possible future impact of the proposed development on soil, groundwater and salinity.

3. Site identification

Address	109 Woodward Street Parkes NSW
Client	Stephen and Daniel Mansley c/- Iplan Projects Pty Ltd
Deposited plans	Lot 239 DP750152
Universal grid reference	UTM Zone 55H, 610309mE, 6331776mN
Locality map	Figure 1
Site plan	Figure 2
Photographs	Figure 9
Area	2.43ha
Dates of inspection and assessment	13 December 2024

4. Proposed development

The proposed development is a residential subdivision comprising 24 residential lots ranging in size from 850m^2 to 980m^2, paved areas and road verges (Figure 9). A street will be constructed through the central section of the site and will allow access to all lots from Lee Street. Stormwater on the site will be directed through Woodward Street to the adjacent drainage line to the north east for discharge into Goobang Creek located 1km to the south east of the site. The development will be serviced by reticulated sewer and water. The existing dwelling may be retained at proposed Lot 2 subject to structural integrity assessment.

Irrigation of landscaped areas within residential lots is expected to occur. Large areas of the site will be covered with hard surfaces including roads, dwellings and paved areas.

5. Site condition and surrounding environment

5.1 Land-use

The site is currently rural-residential used for grazing and maintained by slashing. A dwelling, workshop and one shed are existing on the site. The existing dwelling may be retained on-site and remaining structures will be demolished. Historical land-use is grazing and cultivation.

5.2 Vegetation

Vegetation over the site comprises introduced broadleaved weeds and native grasses and herbs. Dominant introduced species included silverleaf nightshade, rabbit foot, clover, horehound, skeleton weed, sandviper gloss, sow thistle, khaki weed, kidney weed, paspalum, windmill grass, crowsfoot, wild oats and African liverseed grass and creeping oxalis. Isolated stands of radiata pine, deodar cedar and London Plane are established as ornamental vegetation surrounding the existing dwelling in the northwestern section of the site.

Dominant native species included tufted bluebell, windmill grass, couch grass, silky bluegrass and yellow burr daisy.

Kurrajong, white cypress and a row of *Eucalypts* individuals were observed amongst ornamental plantings around the dwelling and as paddock trees across the site.

5.3 Topography

The site is located on low slope. Aspect is predominantly north east and the slopes have a very gentle inclination of 0 to 2% to the north. Elevation ranges between 309 and 316 metres above sea level. No evidence of groundwater seepage or discharge areas were observed on the site.

5.4 Soils and geology

The site is within the Parkes Soil Landscape (NSW Government, nd). Soil types comprise shallow to moderately deep, moderately well-drained red earths and red podzolic soils/non-calcic brown soils on side slopes. Lower slopes have moderately deep imperfectly drained red brown earths.

The site is mapped within the Cotton Formation comprising fine-grained siltstone, with isolated calcareous horizons containing a shallow-water coralline assemblage. Lower part of unit has little or no sign of volcanic input (MinView, Geological Survey of NSW).

Soils on the site comprised topsoil of brown silty sand to 0.4m. Subsoils comprised brown to dark reddish brown silty clay with abundant fine to medium gravel over dark yellowish brown sandy clay with fine sandstone and siltstone gravels.

5.5 Surface water

Surface water on the site is expected to flow north east towards adjacent the existing drainage line and discharging into Goobang Creek located approximately 1km south east of the site.

5.6 Groundwater

Four registered water abstraction bores were identified within a 1km radius to the north east of the site on the NSW Government Water NSW website (2024). The bores were monitoring bores installed to intercept the shallow aquifer. The monitoring bores presented water-bearing zones (WBZ's) ranging from 4m to 10m. The standing water levels were from 3.9m to 4.2m. The WBZ's were located in the shallow regolith comprising silty clay soil. No salinity testing was reported for the monitoring wells.

6. Groundwater and soil salinity investigation

The soil salinity investigation comprised a desktop study, field assessment and soil analysis. The desktop study included a review of soil landscape maps and groundwater databases. Infiltration modelling was also undertaken.

The field assessment included an initial site investigation and detailed profile descriptions and soil analysis. The soil and landscape information collected provided an adequate description of the physical processes on the site to enable salinity issues to be identified and managed. The frequency of tests undertaken was in accordance with the frequency in Table 1 of Lillicrap and McGhie (2002) for moderately intensive construction.

6.1 Soil landscapes

Soil landscape data was reviewed for information regarding soil types in the locality, occurrence of salinity, erosion and sodic soils.

6.2 Hydrogeological landscapes

No hydrogeological landscape maps were available for the site (NSW Government, nd).

6.3 Groundwater

An investigation of registered bores in the area was undertaken to determine the depth and salinity of the groundwater. Groundwater information was found from a review of the NSW Government Water NSW database.

Two sources of groundwater are present under the site. Deep groundwater is located in river gravels, sands and sandstone at depths greater than 15 metres and shallow groundwater, expected to generally be unconfined in a local aquifer controlled by drainage lines and/or lithological contrasts within the site and occurs intermittently at times of high rainfall.

Water criteria for salinity based on drinking water and agricultural use are presented in Tables 1 to 3. The conversion from EC (dS/m) to total dissolved solids or TDS (mg/L) is undertaken by applying the conversion factor of 640 for an average concentration of salts present (Lillicrap and McGhie 2002).

Table 1. Drinking water criteria for salinity (NHMRC, NRMMC 2011)

Palatability	EC (dS/m)	Total dissolved solids -Salinity (mg/L)
Good	0.94	600
Fair	0.94-1.41	600-900
Poor	1.41-1.88	900-1,200
Unacceptable	>1.88	>1,200

Table 2. Total dissolved solids of water for agricultural use (Reid 1990)

Class	Description	Total dissolved solids -Salinity (mg/L)
1	Low salinity	0-175
2	Medium salinity	175-500
3	High salinity	500-1500
4	Very high salinity	1500-3500
5	Extremely high salinity	>3500

Table 3. Guidelines on salinity class determination (Dubbo City Council Urban Salinity Plan)

Electrical conductivity (dS/m)	Salinity class
0-2	Low
2-6	Moderate
6-15	High
>15	Extreme

6.4 Parkes LEP (2012) groundwater vulnerability map

The Parkes LEP (2012) Groundwater vulnerability map describes the areas within the Parkes Shire Council area where groundwater is considered vulnerable to depletion and contamination as a result of development.

6.5 Infiltration model

A simulation model was developed to predict changes in infiltration pre and post development. The area for each land-use pre and post development was estimated from site walkover, topographical map, aerial photograph, preliminary conceptual site plans and typically scenarios observed in similar developments. Recalculation of the infiltration model will be required upon completion of final concept plans. The site was classified into the different land-use areas pre and post development (Table 4).

Table 4. Land-use areas pre and post development

Land-use	Pre development (ha)	%	Post development (ha)	%	Comments
Pasture	2.110	86.8	0	0	Vacant pasture
Urban	0.240	9.9	1.552	69.2	Existing and proposed landscaped and open space areas
Hard surfaces (buildings, driveway, roads)	0.080	3.3	0.878	30.8	Surface water expected to be piped off-site, bitumen roads
Total	2.430	100	2.430	100	

Groundwater recharge in agricultural pasture areas in the Wagga Wagga area was estimated to be 15mm/year (Cook *et al.* 2001). Wagga Wagga has a similar climate to Parkes and the groundwater recharge data is considered representative of the investigation area.

It is expected overwatering will contribute to recharge however studies have demonstrated the recharge in agricultural grazing land-use of 15mm/year is similar to diffuse urban land-use of 14mm/year (Cook *et al.* 2001).

Infiltration on hard surfaces will be zero with surface water collected and piped off-site.

Leaking pipes can be a source of groundwater recharge however these sources are expected to be negligible in a new development.

6.6 Nutrient model

A simulation model was developed to predict surface runoff, sediment loss, nitrogen and phosphorus export, pre and post development. The area for each land-use pre and post development was estimated from site walkover, topographical map, subdivision plans and an aerial photograph. The site was classified into the different land-use areas pre and post development (Table 5).

Table 5. Land use areas for nutrient model

Land-use areas	Pre-development (ha)	Post development (ha)
Improved pasture	2.070	0
Open space	0	0.075
Roads (sealed)	0	0.080
Urban (landscaped)	0.240	1.605
Roofs	0.080	0.670
Disturbed landscapes	0.040	0
Total	**2.430**	**2.430**

The pre-development land-use is rural-residential including grazing.

- *Improved pasture* is the dominating pre-development land-use.
- *Urban* (landscaped) refers to the built-up area adjacent the dwelling in the north western section of the site.
- *Roofs* refer to rain which fall directly onto roofs of dwellings and infrastructure and discharges into reticulated stormwater system.
- *Disturbed landscapes* refer to the bare areas and areas sparsely vegetated identified on-site.

The post-development land-use is residential.

- *Open space* refers to non-landscaped vegetated areas where the surface water is expected to infiltrate including the road verges.
- *Roads (sealed)* is a calculation of the roads that will be on-site post development.
- *Urban* (landscaped) refers to the landscaped areas within the proposed lots. It is based on typical lots and dwelling size for similar developments with the residual assumed to be the landscaped area.
- *Roofs* based on average sizes determined in similar developments. It is assumed that the average roof size is 250m^2.

Sediment, nitrogen and phosphorus export was estimated for low, median and high scenarios for each land-use class as detailed in Appendix 1 (Chafer 2003).

6.7 Initial site investigation

An initial site investigation was conducted by collecting information on vegetation, slope, bare areas and other indicators of salinity at 8 locations across the site (Figure 7). This density is in accordance with the recommended by Lillicrap and McGhie (2002).

6.8 Detailed profile descriptions and laboratory analysis

Five boreholes were constructed with a EVH truck mounted hydraulic drilling rig with solid auger on 13 December 2023 to provide information on the soil profile and enable sampling. The boreholes were constructed at various locations on the site (Figure 8). The depth of boreholes ranged from 1.5m to 4.5m. A monitoring well was installed in the 4.5m borehole in the northern section of the site as part of the groundwater assessment (Figure 6).

The soil profile was described for colour, texture and moisture. Soil samples were collected from three boreholes at 100mm, 200mm, 300mm, 500mm and 500mm intervals to drilling depth The sampling is expected to provide an adequate description of subsoil salinity conditions. Soil samples were analysed for pH, electrical conductivity and dispersion.

Soil electrical conductivity (EC) results of the 1:5 (soil:water suspension) were converted to saturated extracts (ECe). EC values are converted to ECe by using a multiplier factor (Charman and Murphy, 1991), which is dependent on the soil texture (Table 6). Saline soils are defined as those with an electrical conductivity (ECe) greater than 4 dS/m (Charman and Murphy, 2001). Soil salinity ratings and effects on plant growth are presented in Table 7.

Table 6. ECe texture-based conversion factors (Charman and Murphy 2001)

Soil texture	Conversion factor
Loamy sand, clayey sand, sand	23
Sandy loam, fine sandy loam, light sandy clay loam	14
Loam, loam fine sandy, silt loam, sandy clay loam	9.5
Clay loam, silty clay loam, fine sandy clay loam	8.6
Sandy clay, silty clay, light clay	7.5
Light medium clay, medium clay, heavy clay	5.8

Table 7. Soil salinity ratings based on ECe readings

Salinity rating	ECe (dS/m)*	Effects on Plants
Non saline (NS)	0-2	Salinity effects negligible
Slightly saline (SS)	2-4	Very salt sensitive plant growth restricted
Moderately saline (MS)	4-8	Salt sensitive plant growth restricted
Highly saline (HS)	8-16	Only salt tolerant plants unaffected
Extremely saline (ES)	>16	Only extremely tolerant plants unaffected

*ECe - Electrical conductivity of a saturated extract

Soil with ECe below 2 dS/m will have negligible effects on plant growth and soil stability. Soil with ECe of between 2 and 4 dS/m may restrict very salt sensitive plant growth. Soil with ECe between 4 and 8 dS/m will restrict the growth of salt sensitive plants.

Samples were analysed for dispersion using the Emerson aggregate test. Table 8 details the eight dispersion classes.

Table 8. Emerson dispersion classes

Class	Description
1	Highly dispersive (slakes, complete dispersion)
2	Moderately dispersive, slakes, some dispersion
3	Slightly dispersive, slakes, some dispersion after remoulding
4	Non-dispersive, slakes, carbonate or gypsum present
5	Non-dispersive, slakes, dispersion in shaken suspension
6	Non-dispersive, slakes, flocculates in shaken suspension
7	Non-dispersive, no slaking, swells in water
8	Non-dispersive, no slaking, does not swell in water

Representative soil samples were collected from the topsoil and subsoil and analysed for chloride and sodicity. Chloride criteria for corrosiveness to building material are presented in Table 9 and are an extract from AS2159-1995 Piling – design and installation.

Aggressive soils criteria for salinity and sulfate impacts on building structures are presented in Australia Standard AS2870-2011 (Appendix 2). The AS2870 standard also describes requirements to mitigate salinity and sulphate on footings.

Table 9. Chloride corrosiveness to building materials (AS2159-1995 Piling – design and installation)

Concrete piles		Steel piles	
Chlorides in water (mg/kg)	Soil conditions for low permeability soils or all soils above groundwater	Chlorides in water (mg/kg)	Soil conditions for low permeability soils or all soils above groundwater
<2,000	Non-aggressive	<1,000	Non-aggressive
2,000-6,000	Non-aggressive	1,000-10,000	Non-aggressive
6,000-12,000	Mild	10,000-20,000	Mild
12,000-30,000	Moderate	>20,000	Moderate
>30,000	Severe		

Sodicity is expressed as a percentage of the cation exchange capacity or exchangeable sodium percentage (ESP). Ranking of sodicity is presented in Table 10 (Lillicrap and McGhie 2002). An ESP of less than 5% indicates a non-sodic soil, ESP of between 5 and 15% indicates a sodic soil and an ESP of greater than 15% indicates a highly sodic soil.

Table 10. Ranking of exchangeable sodium percentage

Exchangeable sodium percentage	Ranking
<5%	Non-sodic
5-15%	Sodic
>15%	Highly sodic

7. Results and discussion

7.1 Soil landscape maps

The site is within the Parkes Soil Landscape (NSW Government, nd). Soil types comprise shallow to moderately deep, moderately well-drained red earths and red podzolic soils/non-calcic brown soils on side slopes. Lower slopes have moderately deep imperfectly drained red brown earths.

The Parkes Soil Landscape is underlain by the Cotton Formation, Burrandong Creek Member and Parkes Volcanics. Lithology ranges from sedimentary rocks including siltstones, chert, conglomerates, sandstones, limestones and volcanic rocks including volcanic sandstones and intermediate volcanics.

The site is located in the Cotton Formation comprising fine-grained siltstone, with isolated calcareous horizons comprising a shallow-water coralline assemblage (MinView, Geological Survey of NSW).

Soil salinity is localised. Soil sodicity and dispersibility are considered a soil limitation in the Parkes soil landscape (NSW Government, nd).

Soils on the site comprised topsoil of brown silty sand to 0.4m. Subsoils comprised brown to dark reddish brown silty clay with abundant gravels over dark yellowish brown sandy clay with fine to medium angular gravel comprising siltstone and sandstone.

7.2 Hydrogeological landscapes

No data available.

7.3 Groundwater

7.3.1 OEH registered bores

Four registered water abstraction bores were identified within a 1km radius of the site on the NSW Government Water NSW website (2023). The bores were monitoring bores installed to intercept the shallow aquifer. The standing water levels were from 3.9m to 8.7m. The monitoring bores presented water-bearing zones (WBZ's) ranging from 4m to 10m. The WBZ's were located in the shallow regolith comprising silty clay soil. No salinity description was available for the monitoring bores. The bores are located on the opposite margin of the unnamed creek to the north of the site and may be subject to different groundwater conditions and therefore considered not representative of groundwater on-site.

7.3.2 Groundwater on-site

A monitoring well was installed at the borehole location MW1 during investigation undertaken on 13 December 2023 (Figure 7). Monitoring well MW1 was drilled to 4.5m, cased to a depth of 4.25m and purged. The monitoring well was installed in accordance with Water NSW guidelines. The field parameters of the groundwater including EC and pH were measured.

The water level and field parameters for the water sample from the well installed on-site are presented on Table 12. Standing water level (SWL) of MW1 was 0.79m below ground level and electrical conductivity was 6.02(dS/m).

Groundwater classified as unacceptable for use as drinking water and of extremely high salinity for agricultural use based on EC and TDS results. The salinity class is considered high. The groundwater salinity levels are potentially due to interaction with saline lithologies occurring at greater depths.

Table 11. Physiochemical parameters of water in monitoring wells on and adjacent the site.

Well	Type	Location (Figure 11)	Date of inspection	Depth bgl(m)^	SWL bgl(m)	EC (dS/m)	TDS (mg/L)*
MW1	Monitoring bore	On-site	13/12/2023	4.25	0.79	6.02	3,852.8

^bgl = below ground level; *Total Dissolved Solids obtained applying a conversion factor of 640

7.4 Parkes LEP (2012) groundwater vulnerability map

The site is not mapped as an area of groundwater vulnerability by Parkes LEP (2012). The groundwater vulnerable area is located approximately 400m east of the site (Figure 4).

7.5 Initial site investigation

The initial site investigation was conducted on an approximately 60m x 60m grid across the site (Figure 7 and Appendix 5).

The site has a historical rural-residential land-use comprising grazing. Land-use in the north western section comprises residential and grazing is identified in the remainder of the site.

Vegetation over the site comprises introduced broadleaved weeds and native grasses and herbs. Dominant introduced species included silverleaf nightshade, rabbit foot, clover, horehound, skeleton weed, sandviper gloss, sow thistle, khaki weed, kidney weed, paspalum, windmill grass, crowsfoot, wild oats, African liverseed grass and creeping oxalis. Dominant native species included tufted bluebell, windmill grass, couch grass, silky bluegrass and yellow burr daisy.

Isolated stands of radiata pine, deodar cedar and London Plane are established as ornamental vegetation surrounding the existing dwelling in the northwestern section of the site. Kurrajong, white cypress and a row of *Eucalypts* individuals were observed amongst ornamental plantings around the dwelling and as paddock trees across the site.

The site is very gently inclined with slopes of 0 to 1% and north eastern aspect.

Bare areas and areas of sparse vegetation ranging from 50 to 70% of soil coverage were identified at the site. The bare areas were attributed to vehicles tracks, areas of stock camp, soil compaction and soil disturbance due to historical land-uses.

A mound containing soil and inert foreign materials was identified in the central section of the site on BH1 location.

7.6 Soil characteristics

Five boreholes were drilled to depths of 4.5m or drill refusal. Drill refusal was encountered at 1.5m in borehole BH1 in the central section of the site due to presence of inert foreign materials including bricks, polystyrene and plastic. Borelogs are presented in Appendix 6.

7.6.1 Texture and colour

Soils on the site comprised topsoil of brown silty clay to silty sand to 0.4m. Subsoils comprised brown to dark reddish brown gravelly silty clay over dark yellowish brown sandy clay with fine to coarse angular gravels comprising sandstone and siltstone.

7.6.2 Salinity (electrical conductivity)

Samples from the topsoil of MW1 were determined to be slightly to moderately saline. The topsoil samples from the remaining boreholes were non-saline (Table 12).

Slightly saline subsoils were identified in the samples from MW1 both in the brown gravelly clay layer and in the sandy clay layer. Slightly saline soils were identified in the samples collected from BH4 located in a bare area from 1.0m in light clay.

All remaining subsoil samples assessed in representative boreholes were determined to be non-saline (Table 12).

Table 12. Soil colour, texture, pH, EC and ECe (detailed profile descriptions)

Borehole No - depth (mm)	Soil colour	Soil texture	pH	EC	ECe (dS/m)	Emerson aggregate test
MW1(100)	Dark brown	Silty clay loam	6.83	0.53	4.56	3
MW1(200)	Strong brown	Gravelly silty clay	7.30	0.39	2.93	2
MW1(300)	Strong brown	Gravelly silty clay	7.40	0.43	3.23	2
MW1(500)	Brown	Light clay	7.76	0.38	2.85	2
MW1(1000)	Brown	Light medium clay	8.08	0.32	1.86	2
MW1(1500)	Pale brown	Gravelly light clay	8.73	0.33	2.48	2
MW1(2000)	Pale brown	Gravelly light clay	9.03	0.29	2.18	3
MW1(2500)	Pale brown	Gravelly light clay	8.97	0.33	2.48	3
MW1(3000)	Pale brown	Sandy clay	9.11	0.33	2.48	3
MW1(3500)	Yellow	Sandy clay	8.74	0.44	3.30	5
MW1(4000)	Yellow	Sandy clay	8.87	0.39	2.93	3
MW1(4500)	Yellow	Sandy clay	8.95	0.31	2.33	3
BH2(100)	Dark brown	Gravelly sandy clay loam	6.59	0.03	0.29	3
BH2(200)	Dark reddish brown	Gravelly sandy clay loam	6.45	0.03	0.29	3
BH2(300)	Dark reddish brown	Gravelly silty clay loam	6.48	0.03	0.26	3
BH2(500)	Dark reddish brown	Light clay	6.48	0.03	0.23	5
BH2(1000)	Dark reddish brown	Light clay	6.59	0.03	0.23	5
BH2(1500)	Brown	Gravelly light clay	7.12	0.05	0.38	5
BH2(2000)	Pale brown	Gravelly light clay	8.01	0.12	0.90	6
BH2(2500)	Pale brown	Gravelly sandy clay	8.52	0.13	0.98	6
BH2(3000)	Pale brown	Gravelly sandy clay	8.68	0.13	0.98	5
BH3(100)	Dark brown	Gravelly fine sandy clay loam	6.66	0.03	0.26	3
BH3(200)	Dark brown	Gravelly fine sandy clay loam	6.48	0.03	0.26	3
BH3(300)	Dark brown	Gravelly fine sandy clay loam	6.66	0.02	0.17	3
BH3(500)	Brown	Gravelly light medium clay	6.86	0.02	0.12	3
BH3(1000)	Brown	Gravelly medium clay	7.58	0.05	0.29	2
BH3(1500)	Dark yellowish brown	Gravelly light clay	8.04	0.11	0.83	1
BH3(2000)	Yellow	Gravelly sandy clay	9.32	0.24	1.80	3
BH3(2500)	Yellow	Gravelly sandy clay	9.57	0.26	1.95	3

Borehole No - depth (mm)	Soil colour	Soil texture	pH	EC	ECe (dS/m)	Emerson aggregate test
BH3(3000)	Yellow	Gravelly sandy clay	9.61	0.19	1.43	5
BH4(100)	Brown	Gravelly fine sandy clay loam	7.28	0.08	0.69	3
BH4(200)	Brown	Gravelly fine sandy clay loam	7.67	0.10	0.86	2
BH4(300)	Dark reddish brown	Light clay	8.14	0.12	0.90	3
BH4(500)	Dark reddish brown	Light clay	8.15	0.13	0.98	3
BH4(1000)	Brown	Light clay	8.25	0.29	2.18	3
BH4(1500)	Brown	Light clay	8.53	0.34	2.55	3

7.6.3 pH
The pH generally increases with depth. The topsoils were generally slightly acidic and the subsoils ranged from slightly acidic to alkaline (Table 12).

7.6.4 Emerson aggregate test
Topsoil on site was generally moderately to slightly dispersive. Subsoil on the site was non-dispersive to highly dispersive (Table 12).

7.6.5 Chlorides
Levels of chlorides in the samples analysed were less than 2,000mg/kg and considered non-aggressive soils for concrete and steel piles (Table 13).

7.6.6 Exchangeable sodium percentage
Two subsoil samples were collected and analysed for exchangeable sodium percentage. The soil samples collected from MW1 from depths of 0.5m and 1.0m presented exchangeable sodium percentages greater than 5% and were determined to be sodic (Table 13).

Table 13. Soil results for chlorides and exchangeable sodium percentage (ESP) (Appendix 7)

Sample ID	Borehole (Figure 8)	Depth (mm)	Chlorides (mg/kg)	Sulfate (mg/kg)	ESP (%)
MW1(500)	MW1	500	450	170	9.02
MW1(1000)	MW1	1,000	310	150	7.04

7.7 Indicators of salinity
7.7.1 Bare soil
The bare areas identified on-site were determined to be from soil compaction, vehicle tracks and stock congregation. Borehole BH4 was drilled in a bare area and did not present shallow saline soils. Slightly saline soils were identified from 1.0m at BH4. No bare soil resulting from sheet erosion or salinity were present on site.

7.7.2 Salt crystals
No salt crystals were present on the site surface.

7.7.3 Vegetation indicators
No highly salt tolerant plant species are present on site.

7.7.4 Die back
No vegetation or tree die back was observed on or surrounding the site.

7.7.5 Effects on buildings
Effects of salinity were identified in the existing dwelling including (Figure 9):

- Tide marks indicating dampness rising through the bricks in the existing dwelling.
- White staining in the dwelling bricks

- Mechanical breakdown of bricks and grout in the dwelling walls and footing potentially due to salt crystals inter-growth.

7.7.6 Conditions of roads

No evidence of surface undulations or break-up of bitumen on the roads surrounding the site.

7.8 Infiltration balance

Infiltration occurs for all permeable areas. Infiltration under a pasture land-use (15mm/year) has been determined to be similar as under an irrigated lawn land-use (14mm/year) (Cook *et al.* 2001). Soil moisture resulting from infiltration not used by vegetation represents potential recharge. Pre-development infiltration will occur across the whole site under the pasture land-use. Post development infiltration will occur on a portion of the site with no infiltration occurring on hard surfaces.

The infiltration balance indicates the development will reduce infiltration by approximately 13mm/year as a result of an increase in hard surfaces and piping of surface water off-site (Table 14).

Table 14. Infiltration from each land-use, pre and post development

Land-use areas	Infiltration (mm/year)	Area pre-development (ha)	Infiltration pre-development (mm/year)	Area post development (ha)	Infiltration post development (mm/year)	Impact (mm/year)
Pasture	15	2.11	31.65	0	0	-31.650
Urban (landscaped)	14	0.24	3.36	1.55	21.728	18.368
Hard surfaces	0	0.08	0	0.88	0	0
Total		**2.43**	**35.01**	**2.43**	**21.73**	**-13.28**

7.9 Nitrogen

Nitrogen soil levels in the grazing system are typically low with concentrated areas around animal wastes. Off-site movement occurs from sediment loss. Water soluble nitrogen has potential to leach into the groundwater.

Post development sources of nitrogen are from fertilisers applied to landscaped areas and minor lawns. Post development fertilisation of gardens and lawn areas is only expected to occur in minor landscaped areas. The impact from lawn fertilisers will be less than the impact of animal wastes. The impact of nitrogen fertiliser post development will be reduced.

The nutrient balance indicates the development will reduce nitrogen export by 9.86kg/year under the median scenarios (Table 15). Reduced pasture area and a greater area of hard surfaces has resulted in a decrease in nitrogen loss.

Table 15. Land-use nitrogen export pre and post development (kg/year)

Land-use areas	Pre-development	Post development	Impact
Improved pasture	18.42	0.00	18.42
Open space	0.00	0.24	-0.24
Roads (sealed)	0.00	0.48	-0.48
Urban (landscaped)	1.46	9.79	-8.33
Roofs	0	0	0
Disturbed landscape	0.48	0.00	0.48
Total	**20.37**	**10.51**	**9.86**

7.10 Phosphorus
The main phosphorus sources pre-development are from animal waste and fertilisers. Stock is expected to regularly graze on the site. Off-site movement of phosphorus will occur in sediments and susceptible times are when vegetation cover is low.

Stock numbers will be zero in the post development land-use resulting in a decrease contribution of phosphorus on the site.

Phosphorus binds to soil and the primary method of movement is in sediments. Vegetation cover is expected to be higher post development resulting in filtering of runoff, reduced sediment loads exported and consequently lower phosphorus export.

The nutrient balance indicates a slight decrease in phosphorus export by 0.2kg/year under the median scenarios (Table 16). Reduced pasture area and a greater area of sealed surfaces have resulted in a decrease in the phosphorus loss.

Table 16. Land-use phosphorus exports pre and post development (kg/year)

Land-use areas	Pre-development	Post development	Impact
Improved pasture	2.79	0.00	2.79
Open space	0.00	0.01	-0.01
Roads (sealed)	0.00	0.14	-0.14
Urban (landscaped)	0.44	2.92	-2.48
Roofs	0	0	0
Disturbed landscape	0.05	0.00	0.05
Total	**3.28**	**3.08**	**0.20**

7.11 Sediment
The nutrient balance indicates the development will reduce sediment export by 672kg/year under the median scenario (Table 17). Sediments are reduced due to the decrease in contribution from the pasture area.

Table 17. Land-use sediment export pre and post development (kg/year)

Land-use areas	Pre-development	Post development	Impact
Improved pasture	1,076.40	0.00	1,076.40
Open space	0.00	14.25	-14.25
Roads (sealed)	0.00	15.20	-15.20
Urban (landscaped)	72.00	481.50	-409.50
Roofs	0	0	0
Disturbed landscape	34.80	0.00	34.80
Total	**1,183.20**	**510.95**	**672.25**

8. Soil and water impact assessment
8.1 Soil
Soil depth across the site was generally greater than 3.0m. A mound containing soil and inert foreign materials was identified at BH1 location.

The topsoils and subsoils were identified to be generally non-saline to slightly saline. Moderately saline topsoil was identified in the topsoil at MW1 location. Slightly saline subsoils were identified in MW1 from 0.5m to the drilling depth and in BH4 from 1.0m to the drilling depth. The soil salinity is expected to occur due to influence of saline groundwater.

Sodic subsoils were identified in the samples collected from 0.5m and 1.0m in borehole MW1.

Excavation works are expected for sewer and water services installation. Excavation works for the development adjacent MW1 and the existing dwelling may intercept potentially saline soils (Figure 8). Management will be required to ensure exposure is minimised.

8.2 Water

8.2.1 Surface water

Stormwater on the site will be managed by the reticulated stormwater system to be connected to the site. Stormwater on the site will be directed to the adjacent north eastern drainage line through Woodward Street for discharge into Goobang Creek located to the south east of the site. The development will be serviced by reticulated sewer and water. The majority of rainfall will be piped off-site.

8.2.2 Groundwater

8.2.2.1 Recharge

No recharge areas were identified on the site. The decrease in permeable areas following development will result in a reduction in the amount of infiltration and therefore the recharge potential.

8.2.2.2 Discharge

Discharge areas were not identified on the site from surface and subsurface observations such as ponding water and wet soils.

8.2.2.3 Depth

Shallow groundwater to a depth of 0.8m was identified in the north eastern section of the site. No free water was observed in the remaining boreholes drilled to 3.0m depth on-site.

Groundwater level on-site is expected to range from depths of less than 1.0m to more than 3.0m based on levels observed in the monitoring well on-site and boreholes drilled. The groundwater gradient is expected to flow to the north east towards the drainage line located to the north of the site.

The decrease in recharge rates post development is expected to contribute to increase the depth of the groundwater table on-site.

8.2.2.4 Salinity classification

The groundwater on MW1 presented elevated electrical conductivity and was classified as unacceptable for use as drinking water and of extremely high salinity for agricultural use.

The shallow and saline groundwater has the potential to bring salts from the subsurface to the surface by capillarity.

8.2.2.5 Clause 6.3 of the Parkes LEP 2012

(1) The objectives of this clause are as follows–

- *(a) to maintain the hydrological functions of key groundwater systems, and*
- *(b) to protect vulnerable groundwater resources from depletion and contamination as a result of inappropriate development.*

Response: The development and groundwater at the site are described in the Groundwater and Salinity report prepared by Envirowest Consulting Pty Ltd (Report number R16412s1).

(2) This clause applies to the land identified as "Vulnerable" on the Groundwater Vulnerability Map.

Response: The site is not mapped as a groundwater vulnerable area.

(3) In deciding whether to grant development consent to development on land to which this clause applies, the consent authority must consider-

> *(a) the likelihood of groundwater contamination from the development (including any on-site storage or disposal of solid or liquid waste and chemicals)*
> *(b) any adverse impacts the development may have on groundwater dependent ecosystems,*

Response:
Post development nutrient inputs will only occur in a small proportion of the site that is lawns and gardens. Nitrogen fertiliser will not be required in native gardens. Maintained gardens and lawns will have the capacity to utilise the nitrogen applied. The impact of nitrogen and phosphorous input post development will be reduced and it is not expected to impact the groundwater in the development area. The clay subsoils are expected to have additional capacity to accumulate phosphorus.

Minor usage of herbicides may occur post development on lawns. All fertilisers and agricultural chemicals are not residual and will be utilised by the vegetation or degrade rapidly in the environment. No impact on surface water or groundwater will occur.

NSW Health approves the following methods for greywater reuse:

- Bucketing: Generally only small volumes of greywater are reused and the action is unlikely to occur during wet weather. Risk of overwatering and therefore impact on groundwater is low.
- Greywater diversion devices: Does not require Council approval if conditions relating to installation and use are met. Conditions include undertaking checks and maintenance of the irrigation system, use biodegradable detergents low in phosphorus, sodium, boron and chloride, no irrigation during rain, undertake a water balance prior to installation, monitor soil and plant response to irrigation, do not overwater and notify the local water utility of the device. Notification to the local water utility (Parkes Shire Council) ensures Council is aware the system is in place and can check on compliance. Conditions ensure the water is used sustainably with minimal impact on the groundwater.
- Greywater treatment system: Requires approval from Council. Council can regulate the suitability and number of systems in the locality and check on the satisfactory operation of the system. Regulation of the system ensures minimal impact on groundwater.

Minor washing of cars by householders is expected to be undertaken post development. Most car owners clean cars in commercial washing bays. Small numbers of cars will be washed either on permeable areas resulting in infiltration or non-permeable areas with water moving into the reticulated stormwater system and off-site. Water and detergents infiltrating permeable areas will be utilised by vegetation. Some deeper infiltration may occur but volumes are not expected to be significant. Car washing is not expected to occur during rain.

No industrial activities including bulk storage or use of chemicals will occur in the development.

> *(c) The cumulative impact the development may have on groundwater (including the impacts on nearby groundwater extraction for potable water supply or stock water supply), of the development and any other existing development on groundwater.*

Response:
Impact on groundwater from nitrogen and phosphorus contamination is expected to be less post development compared to pre-development. The site has an agricultural land-use history. Agriculture land-use is not expected post-development. Contribution of nitrogen and phosphorous from stock will cease post development. The cumulative impact of the development on groundwater quality is expected to be negligible.

> *(d) any appropriate measures proposed to avoid, minimise or mitigate the impacts of the development*

Response:
No impacts from the development are expected under the proposed development works and land-use scenario.

(4) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that:

> *(a) The development is designed, sited and will be managed to avoid a significant adverse environmental impact, or*
> *(b) If a significant adverse environmental impact cannot be avoided–the development is designed, sited and will be managed to minimise that impact.*

No impacts from the development are expected under the proposed development works and land-use scenario.

8.3 Vegetation
The site is dominated by shallow rooted perennial grasses and broadleaved weeds. Deep rooted vegetation was observed as scattered remnant trees along the boundaries of the site and in the north western section of the site. No impact from saline soils and groundwater was observed in the vegetation.

Existing trees and pasture grasses will be replaced with introduced or native garden species including deep rooted perennials. Trees will be planted as street trees. The proposed residential development will contain irrigated and unirrigated lawns with plantings of shrubs and trees. Ecowise gardens of native and drought tolerant species will be promoted in the development. Costs associated with irrigation will ensure overwatering and leaching does not occur. On-site shallow groundwater is not expected to be a viable source of irrigation water due to the unreliable shallow groundwater aquifer.

The post development land-use will contain a mix of shallow and deep-rooted vegetation. Species planted in lawns will utilise soil moisture all year round compared to the current pasture species mix which are mostly summer active only. Trees will be planted along roadways and garden areas.

8.4 Infrastructure
The dwelling existing on-site presented signs of impact by salinity. No major earthworks are expected during the development. Excavations of trenches for installation of underground services will be undertaken.

Slightly to moderately saline topsoils were identified in the north eastern section of the site (MW1) from 0 to 0.3m. Shallow and saline groundwater was identified on-site.

Special construction requirements addressing saline soils and groundwater will be required for infrastructure including underground services due to shallow saline groundwater.

The proposed dwelling sites should be individually assessed in accordance with AS 2870 *Residential Slabs and Footings – Construction* to determine the concrete exposure level (Appendix 2) and the use of adequate building materials.

8.5 Pollution risk control

Occasional fertilizer and chemical use are expected from the proposed land-use. Fertilisers will be utilised by plants. All agricultural chemicals degrade rapidly in the environment. No impact on surface water or groundwater will occur.

The site currently has a rural-residential and grazing land-use with historical land-use including grazing. Waste from animals contains significant nutrients and pathogens which have potential to move in surface water flows.

Stock will be excluded in the post development land-use decreasing contribution by animals to nutrients on the site.

Hard surfaces across the site will reduce sediment loads exported. Nutrient impact on surface water will be reduced post development.

The site area is considered important as it forms part of the Lachlan River catchment. ANZECC (2000) has determined water quality indicators for river systems in regard to various environmental values (Table 18). The environmental values relate to the protection of:

- aquatic ecosystems
- aquatic foods
- primary contact recreation
- secondary contact recreation
- drinking water
- visual amenity
- irrigation water supplies
- homestead water supplies
- livestock water supplies
- human consumption of fish

The irrigation water quality indicators are considered appropriate for the catchment. The potential impact of the development on each water quality indicator has been assessed (Table 18). Potential issues relate to current and future land-use and management of the site.

Table 18. Impacts of development on water quality (Environmental objectives)

Indicator	Objective	Impact of development
Nitrogen	5 mg/L	Nitrogen may be applied to areas of the site as fertilisers. Nitrogen will be used by plants, digested by microbes or volatilised into the atmosphere. Infiltration for nitrogen into the subsoil and impact on groundwater systems will not occur. Maintenance of groundcover by minimal cultivation and no grazing are important factors in reducing nitrogen export. Nutrient modelling indicates nitrogen will decrease on site.

Indicator	Objective	Impact of development
Faecal coliform	<10 cfu/100mL to 10,000cfu/100mL	The site will be serviced by town sewer. No impact on faecal coliform levels is expected to result from the development.
Aluminium	5 mg/L	No impact.
Iron	0.2 mg/L	No impact.
Manganese	0.2 mg/L	No impact.
Dissolved oxygen	>6.5 mg/L	No effluent applied to the site. Vegetated areas are expected to be managed. No impact.
Phosphorus	0.05mg/L	Phosphorus may be applied to small areas of the site as fertilisers Phosphorus will be used by plants and absorbed in the soil. Groundcover will be enhanced in the development resulting in reduced sediment and phosphorus export. Post development fertiliser application rates will be reduced and the effect on phosphorus less. Nutrient modelling indicates phosphorous will decrease on site post development.
pH	between 6.0 and 8.5	Fertilisers have a declining influence on pH and effects off-site will be negligible.
Cyanobacteria	-	Cyanobacteria are dependent on the levels of nitrogen, phosphorus and water temperature. The development will not increase nitrogen and phosphorus therefore will have negligible impact. No cyanobacteria are present in fertilisers.
Conductivity	-	Exposure of saline soils and off-site movement will be minimised by adoption of recommendations including minimising depth of cut and implementation of erosion and sediment control plans. No impact expected.
Turbidity	-	Negligible impact due to small size of the development and the absence of any disturbed areas on site.

The impact of the development on each water quality indicators will be negligible.

8.6 Earthworks

Earthworks for roads and underground services will be undertaken.
The site is very gently to gently sloped and significant landform excavation is not expected. Minimal cut and fill may occur to realign the slopes.

Trenches are expected to be generally up to 3.0m deep. Soil electrical conductivity testing is recommended at the design depth for excavations deeper than 3.0m.

The earthworks in the northern section will intercept moderately saline topsoils. Backfilling procedures should maintain soils at the depths encountered at excavation and avoid potential mixing between saline and non-saline soil.

Imported fill should be non-saline. Any residual soil should be assessed for salinity to determine suitability for reuse on-site or requirements for disposal to landfill.

8.7 Other impacts of the development

Nil

9. Management recommendation

The southern two thirds of the site is suitable for residential development. Due to potential salinity and groundwater risks, the northern third of the site is considered potentially impacted by saline soil and shallow groundwater. The existing dwelling is located in the potential saline area.

The area delineated in the northern section is not expected to impact land rezoning. Additional investigations will provide a more detailed characterisation and guidance for the final development design.

The following are general recommendations to minimise salinity and groundwater risks from developing on the site:

- Undertake plantings of deep-rooted native vegetation to minimise the risk of seepage and improve aquifer drawdown.
- Maintain existing deep-rooted vegetation where possible.
- Piping of surface water off-site.
- Promote water sensitive design of dwellings and gardens.
- Design road levels similar to natural soil levels to minimise excavations.
- Earthworks comprising cut should be minimised.
- Earthworks and design to enable runoff of surface water.
- Consider the use of salt protected materials for services in the saline soil locations, e.g. salt resistant drainage pipes and conduits.
- Determination of the soil electrical conductivity at the design depth in areas to be excavated.
- Determination of the soil electrical conductivity in the proposed road areas.
- Classification of imported material in accordance with NSW EPA Resource Recovery Exemptions to ensure material is non-saline.
- Sediment and erosion control plans during construction.
- Site-specific assessment of building sites and appropriate design in accordance with the *AS2870-2011*.
- Deep excavations should be avoided. If deep excavations are required, the subsurface flows need to be maintained by installation of a drainage blanket.
- Any soil excavated from the site should be tested for salinity and adequately managed.
- Groundwater from the shallow aquifer is considered saline and should not be applied to the site surface.

Specific recommendations for the saline area

Future management of the saline area will include the following recommendations:

- Additional testing should be undertaken to characterise the saline area in the northern third of the site. The additional investigations will assess suitability for residential development.
- Backfilling of trenches should be undertaken keeping the original depths to avoid potential mixing between saline and non-saline soil. Any residual soil should be tested for salinity and transported to landfill if found to be saline.
- Dwellings located in the northern section of the site will be located on potentially saline soils. Soil salinity should be assessed at the time of site classification as part of the footing design. Dwellings of the site should be assessed in accordance with AS 2870 *Residential Slabs and Footings – Construction* to confirm assessment results provided in Section 7.6.2.
- Buildings in the saline area should be constructed in accordance with the BCA exposure conditions (s33.1), AS3700 Mansonry Structures, AS3600 Concrete Structures, AS2870 Restricted Slabs and Footings. The materials must comprise:
    - Salt resistant bricks and mortar
    - Adequate moisture barriers including a damp-proof curse

  - Concrete resistant to salt and water
- Depending on the final design, additional investigation will assist in mitigation measures.
- Installation of surface drains to divert runoff around dwellings.
- Roads to be constructed above a drainage blanket and embankment to avoid impacts of saline soil and maintain subsurface flows.
- Roads to be constructed above a drainage blanket and embankment to avoid impacts of saline soil and maintain subsurface flows.

10. Conclusions

The site has a historical land-use comprising grazing. Vegetation cover on the site was generally 100% comprising pasture species and broad-leaved weeds. Scattered remnant eucalypts, cypress pine and kurrajong trees were located along the site.

Bare areas were identified on the site and determined to be from soil compaction, vehicle tracks and potentially from stock camp. The dwelling located on-site presented signs of impact by salinity including dampness “tide marks”, white crystals and signs of mechanical breakdown of bricks and mortar. No other indicators of salinity including soil “puffiness”, vegetation dieback or stains were identified during the assessment.

The site is located on a lower slope with gentle to flat inclination of less than 2%. Surface water flows into a drainage line 100m north of the site. The Goobang Creek is located 1km east of the site.

Soils on the site comprised topsoil of brown silty sand to 0.4m. Subsoils comprised brown to dark reddish brown gravelly silty clay over dark yellowish brown sandy clay with fine to medium siltstone and sandstone gravels.

Five boreholes were drilled on-site (MW1, BH1, BH2, BH3 and BH4). Samples from the topsoil of MW1 from 0m to 0.3m were determined to be slightly to moderately saline. Slightly saline subsoils were identified in the samples from MW1 both in the brown gravelly clay layer and the sandy clay layer. Slightly saline soils were identified in the samples collected from BH4 at 1.0m in light clay. Soil samples from the remaining boreholes were non-saline.

Four monitoring bores have been constructed within 1km to the north east of the site to intercept the shallow unconfined aquifer. The monitoring bores have a final depth up to 10.5m. Water bearing zones for the bores ranged from 4.0m to 10m in in silty clay and standing water level (SWL) ranged from 3.9 to 8.7m.

One monitoring well was installed on-site to a depth of 4.25m. The SWL and electrical conductivity were measured. The standing water level (SWL) was 0.79m below ground-level and electrical conductivity was 6.02dS/m. Groundwater in MW1 is classified as unacceptable for use as drinking water and of extremely high salinity for agricultural use based on EC results. Depth of groundwater on-site is expected to range from less than 1m to more than 3m based on site observations.

No visual surface or sub-surface indicators of groundwater discharge areas were identified on the site.

The water balance calculation indicates infiltration will decrease by approximately 13mm/year under the post development scenario as a result of change in land-use and inclusion of hard surfaces and landscaped areas with lower infiltration rates in the proposed lots. The development will not increase recharge of groundwater if recommendations are implemented.

The risk of groundwater contamination from the proposed land-use is lower than the current land-use. Nitrogen contributions will decrease due to the change in land-use from grazing to landscaped areas and sealed surfaces. A decrease of phosphorus export is predicted. Phosphorous is not expected to move off-site providing vegetation is maintained which will result in slow surface water movement and deposition of sediments. Sediment contributions will also decrease as a result of a reduction of the grazing areas. Other activities which may increase the risk of groundwater contamination including car washing and re-use of greywater. The risk activities are expected to have a minor occurrence or be regulated by Council.

11. Recommendations

The southern two thirds of the site is suitable for residential development. Due to potential salinity and groundwater risks, the northern third of the site is considered potentially impacted by saline soil and shallow groundwater. The existing dwelling is located in the potential saline area.

The area delineated in the northern section is not expected to impact land rezoning. Additional investigations will provide a more detailed characterisation and guidance for the final development design.

The following are general recommendations to minimise salinity and groundwater risks from developing on the site:

- Undertake plantings of deep-rooted native vegetation to minimise the risk of seepage and improve aquifer drawdown.
- Maintain existing deep-rooted vegetation where possible.
- Piping of surface water off-site.
- Promote water sensitive design of dwellings and gardens.
- Design road levels similar to natural soil levels to minimise excavations.
- Earthworks comprising cut should be minimised.
- Earthworks and design to enable runoff of surface water.
- Consider the use of salt protected materials for services in the saline soil locations, e.g. salt resistant drainage pipes and conduits.
- Determination of the soil electrical conductivity at the design depth in areas to be excavated.
- Determination of the soil electrical conductivity in the proposed road areas.
- Classification of imported material in accordance with NSW EPA Resource Recovery Exemptions to ensure material is non-saline.
- Sediment and erosion control plans during construction.
- Site-specific assessment of building sites and appropriate design in accordance with the *AS2870-2011*.
- Deep excavations should be avoided. If deep excavations are required, the subsurface flows need to be maintained by installation of a drainage blanket.
- Any soil excavated from the site should be tested for salinity and adequately managed.
- Groundwater from the shallow aquifer is considered saline and should not be applied to the site surface.

Specific recommendations for the saline area

Future management of the saline area will include the following recommendations:

- Additional testing should be undertaken to characterise the saline area in the northern third of the site. The additional investigations will assess suitability for residential development.
- Backfilling of trenches should be undertaken keeping the original depths to avoid potential mixing between saline and non-saline soil. Any residual soil should be tested for salinity and transported to landfill if found to be saline.
- Dwellings located in the northern section of the site will be located on potentially saline soils. Soil salinity should be assessed at the time of site classification as part of the footing design. Dwellings of the site should be assessed in accordance with AS 2870 *Residential Slabs and Footings – Construction* to confirm assessment results provided in Section 7.6.2.
- Buildings in the saline area should be constructed in accordance with the BCA exposure conditions (s33.1), AS3700 Mansonry Structures, AS3600 Concrete Structures, AS2870 Restricted Slabs and Footings. The materials must comprise:
    - Salt resistant bricks and mortar
    - Adequate moisture barriers including a damp-proof curse
    - Concrete resistant to salt and water
- Depending on the final design, additional investigation will assist in mitigation measures.
- Installation of surface drains to divert runoff around dwellings.
- Roads to be constructed above a drainage blanket and embankment to avoid impacts of saline soil and maintain subsurface flows.

12. Report limitations and intellectual property

This report has been prepared for the use of the client to achieve the objectives given the clients requirements. The level of confidence of the conclusion reached is governed by the scope of the investigation and the availability and quality of existing data. Where limitations or uncertainties are known, they are identified in the report. No liability can be accepted for failure to identify conditions or issues which arise in the future and which could not reasonably have been predicted using the scope of the investigation and the information obtained.

The investigation identifies the actual subsurface conditions only at those points where samples are taken, when they are taken. Data derived through sampling and subsequent laboratory testing is interpreted by geologists, engineers or scientists who then render an opinion about overall conditions, the nature and extent of likely impacts of the proposed development, and appropriate remediation measures. Actual conditions may differ from those inferred to exist, because no professional, no matter how well qualified, and no sub surface exploration program, no matter how comprehensive, can reveal what is hidden by earth, rock or time. The actual interface between materials may be far more gradual or abrupt than a report indicates. Actual conditions in areas not sampled may differ from predictions. It is thus import to understand the limitations of the investigation and recognise that we are not responsible for these limitations.

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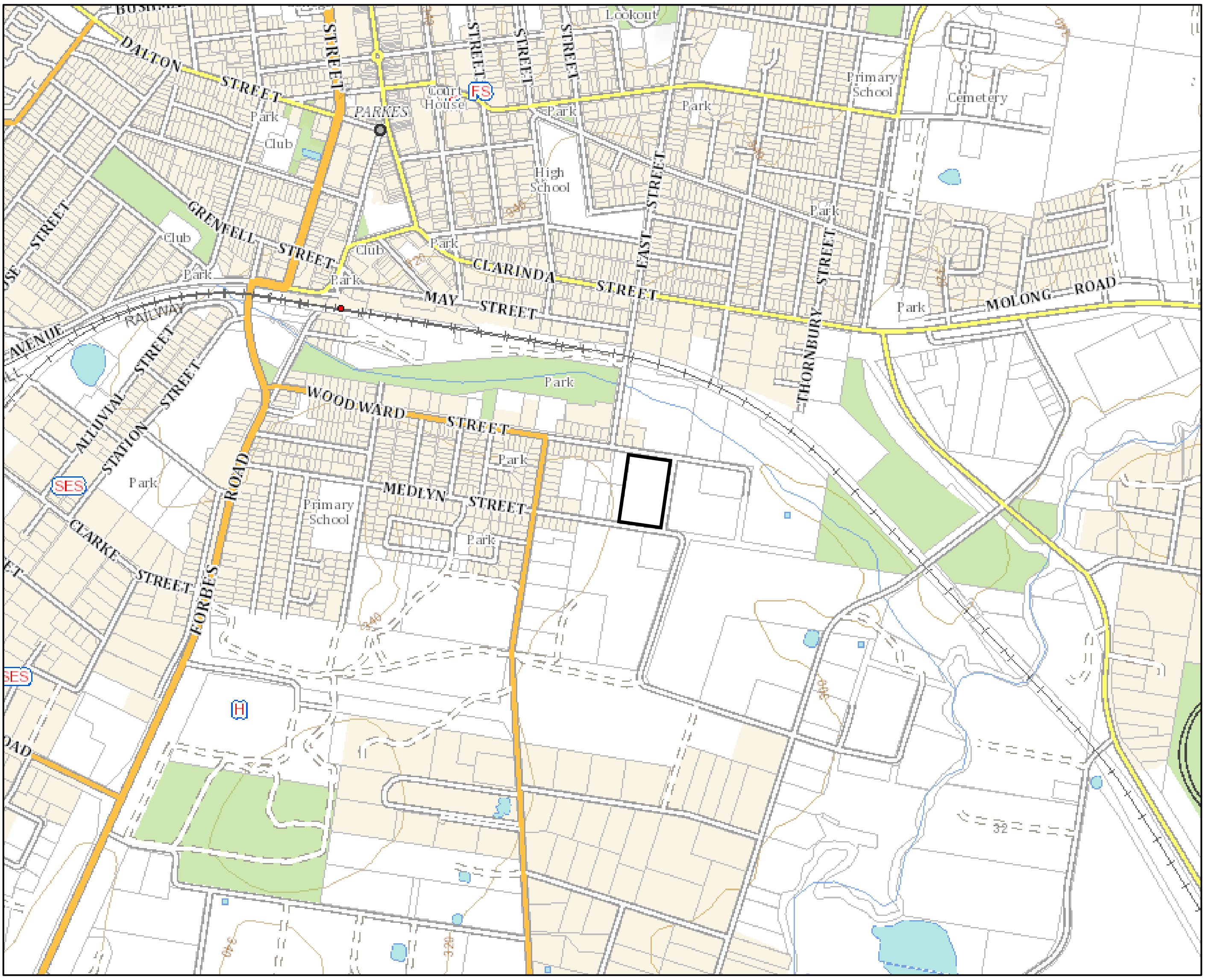
Figures



Legend

Investigation area

Figure 1. Locality plan		
109 Woodward Street, Parkes NSW		
	Envirowest Consulting Pty Ltd	
Job: R16412s1	Drawn by: FC	Date: 05/01/2023

Legend

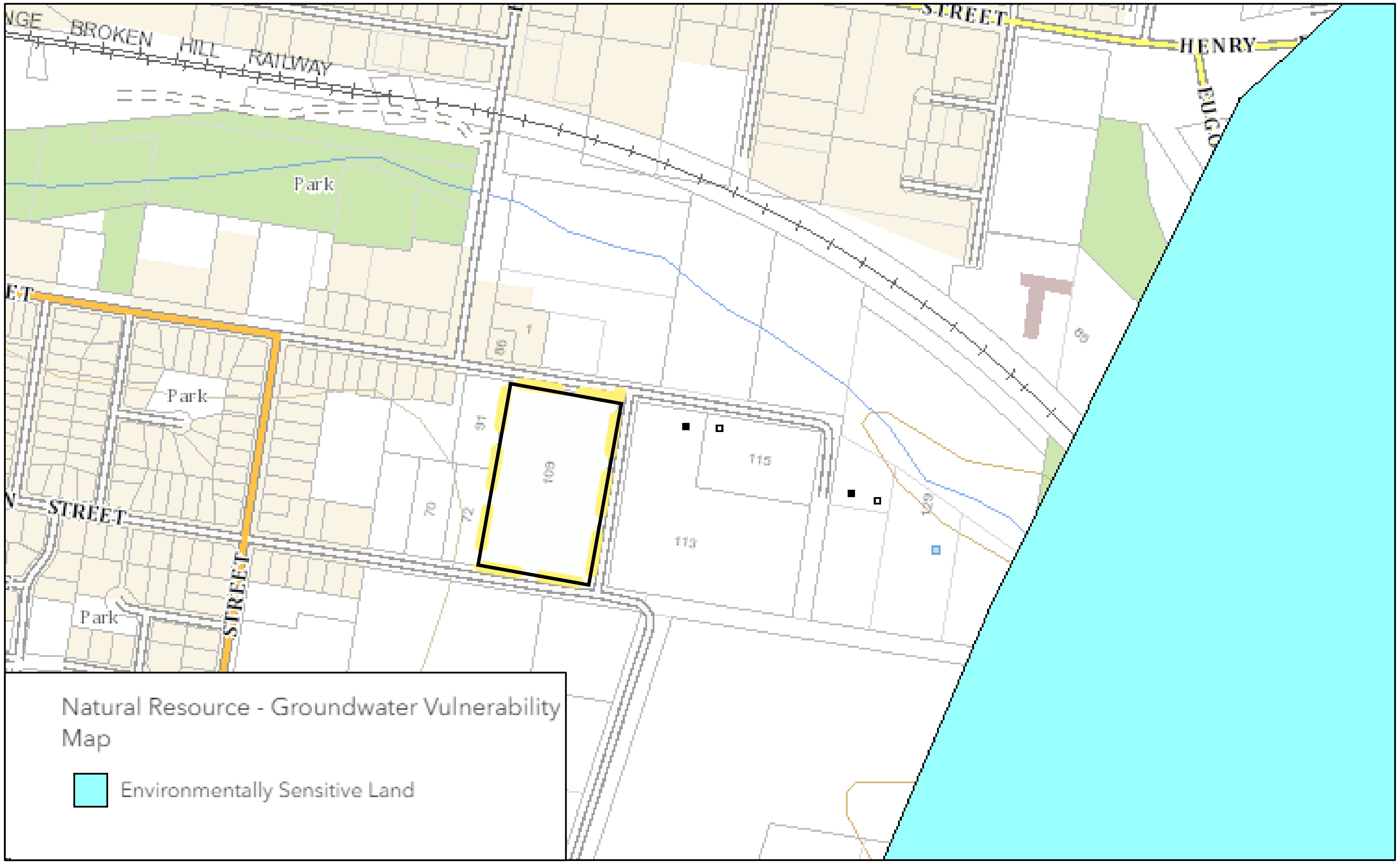
(solid line)	Investigation area
(dashed arrow)	Slope
(hatched oval)	Bare area/disturbed soil
(dashed oval)	Mound containing foreign materials

Approximate Scale 1:1,400

0 14 28 56m

Figure 2. Site layout and aerial photograph (Google Earth 2021)		
109 Woodward Street, Parkes NSW		
	Envirowest Consulting Pty Ltd	
Job: R16412s1	Drawn by: FC	Date: 05/01/2023

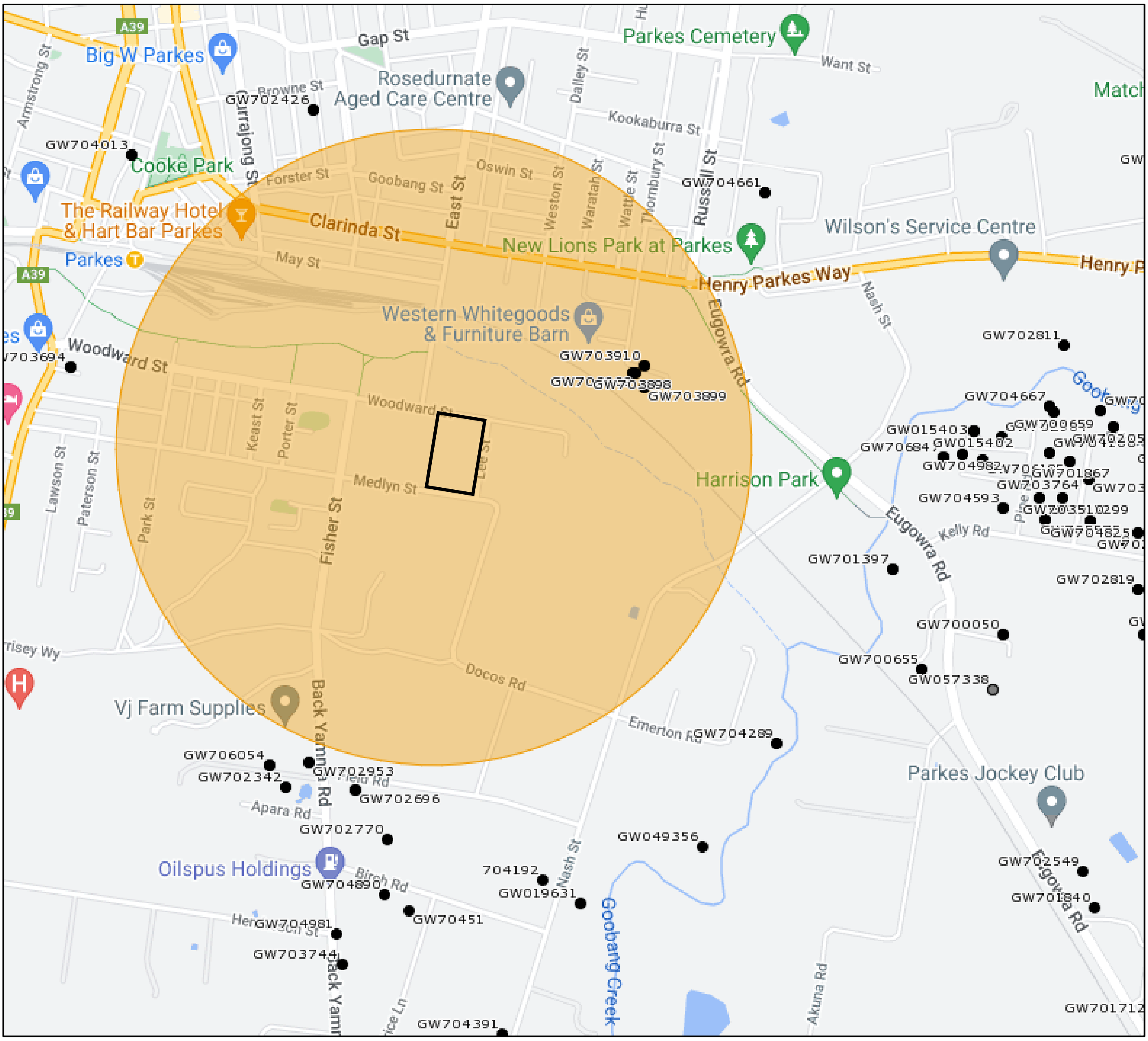
Figure 3. Soil landscapes (NSW Government nd)		
109 Woodward Street, Parkes NSW		
	Envirowest Consulting Pty Ltd	
Job: R16412s1	Drawn by: -	Date: 05/01/2024



Legend

Investigation area

Figure 4. Groundwater vulnerability map		
109 Woodward Street, Parkes NSW		
	Envirowest Consulting Pty Ltd	
Job: R16412s1	Drawn by: -	Date: 05/01/2024



Legend

—— Investigation area

Approximate Scale 1: 11,000

0 110 220 440m

Figure 5. Location of groundwater bores within 1km of the site		
109 Woodward Street, Parkes NSW		
	Envirowest Consulting Pty Ltd	
Job: R16412s1	Drawn by: -	Date: 08/01/2024

Legend

Investigation area

⊗ Initial site investigation

Approximate Scale 1: 1,400

0 14 28 56m

Figure 6. Initial site investigations		
109 Woodward Street, Parkes NSW		
	Envirowest Consulting Pty Ltd	
Job: R16412s1	Drawn by: FC	Date: 08/01/2024

Legend

Investigation area

⊗ Borehole location

Approximate Scale 1:1,400

0 14 28 56m

Figure 7. Borehole locations		
109 Woodward Street, Parkes NSW		
	Envirowest Consulting Pty Ltd	
Job: R16412s1	Drawn by: FC	Date: 08/01/2024

Legend

- Investigation area
- ⊗ Initial site investigation
- Moderately saline topsoil
- Area potentially impacted by saline topsoils

Approximate Scale 1:1,400

0 14 28 56m

Figure 8. Salinity detections		
109 Woodward Street, Parkes NSW		
	Envirowest Consulting Pty Ltd	
Job: R16412s1	Drawn by: FC	Date: 08/01/2024

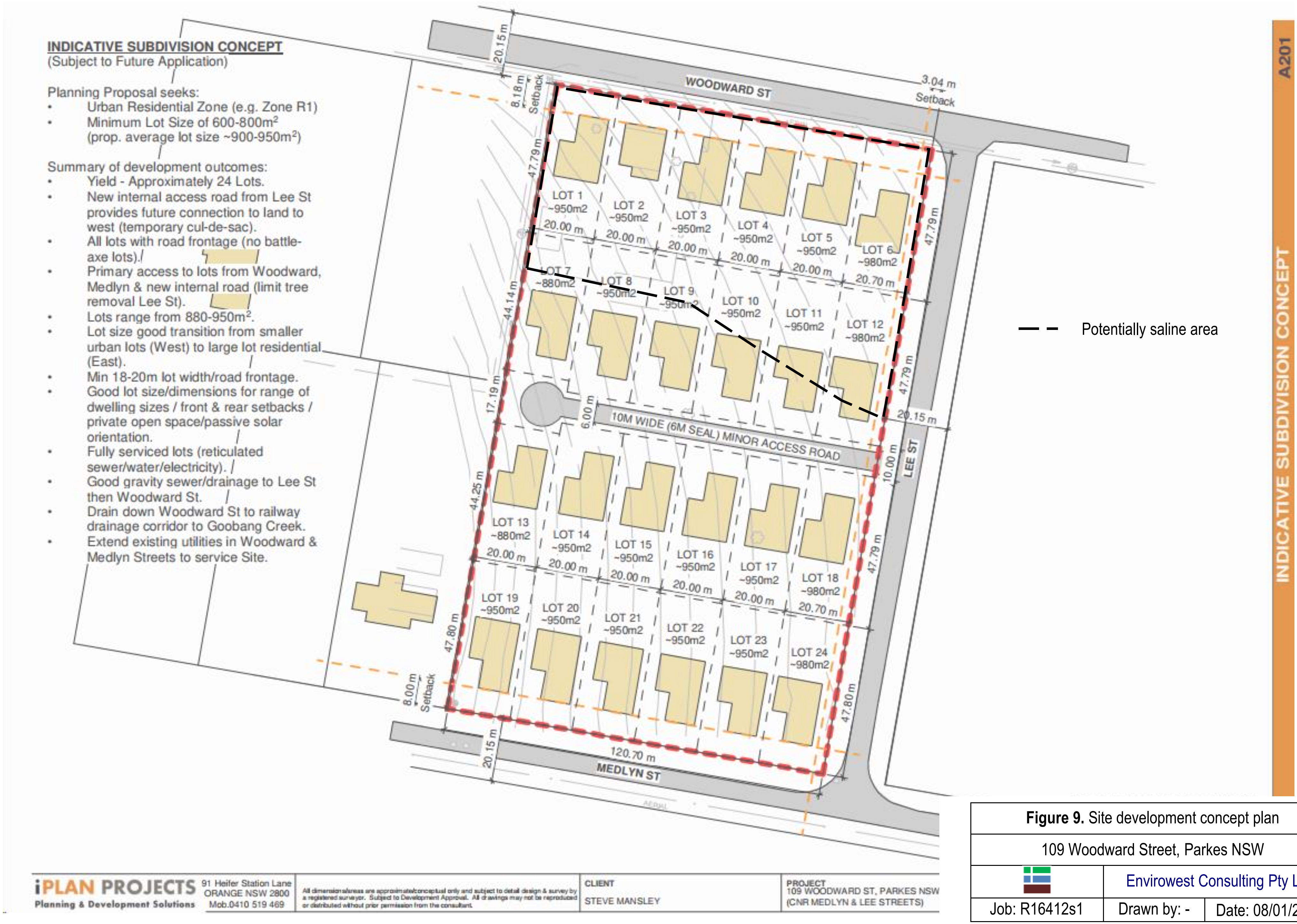


Figure 9. Site development concept plan

109 Woodward Street, Parkes NSW		
	Envirowest Consulting Pty Ltd	
Job: R16412s1	Drawn by: -	Date: 08/01/2024

Figure 10. Photographs of the site

Looking west through the eastern section of the site

Looking south through the southern section of the site

Looking north through the southern section of the site

Bare areas caused potentially due to stock camp and compacted soil

Existing dwelling

Base of dwelling presenting dampness “tide marks” and signs of mechanical breakdown due to salt crystals


White staining at the base of the dwelling


Brickwork presenting white staining and signs of mechanical breakdown due to salt crystals


White staining due to salt crystals at the base of the dwelling


Footings presenting signs of mechanical breakdown


Footings presenting signs of mechanical breakdown

Appendices

Appendix 1. Nutrient and sediment modelling

Land-use export rates for sediments, nitrogen and phosphorus mg/kg/year (Chafer 2003)

Sediment export kg/yr

LOW	**PRE**	**POST**	**IMPACT**
Native bushland	0.00	0.00	0.00
Disturbed landscapes	13.20	0.00	13.20
Remediated gullies	0.00	0.00	0.00
Cropped	0.00	0.00	0.00
Pine plantations	0.00	0.00	0.00
Improved pasture	289.80	0.00	289.80
Open area	0.00	10.50	-10.50
Roads (sealed)	0.00	11.20	-11.20
Roads (earth)	0.00	0.00	0.00
Urban	7.20	48.15	-40.95
Urban (open space)	0.00	0.00	0.00
Rural residential	0.00	0.00	0.00
Industrial	0.00	0.00	0.00
Commercial	0.00	0.00	0.00
Golf course	0.00	0.00	0.00
Orchard	0.00	0.00	0.00
TOTAL	**310.20**	**69.85**	**240.35**

MEDIAN	**PRE**	**POST**	**IMPACT**
Native bushland	0.00	0.00	0.00
Disturbed landscapes	34.80	0.00	34.80
Remediated gullies	0.00	0.00	0.00
Cropped	0.00	0.00	0.00
Pine plantations	0.00	0.00	0.00
Improved pasture	1076.40	0.00	1076.40
Open area	0.00	14.25	-14.25
Roads (sealed)	0.00	15.20	-15.20
Roads (earth)	0.00	0.00	0.00
Urban	72.00	481.50	-409.50
Urban (open space)	0.00	0.00	0.00
Rural residential	0.00	0.00	0.00
Industrial	0.00	0.00	0.00
Commercial	0.00	0.00	0.00
Golf course	0.00	0.00	0.00
Orchard	0.00	0.00	0.00
TOTAL	**1183.20**	**510.95**	**672.25**

HIGH	**PRE**	**POST**	**IMPACT**
Native bushland	0.00	0.00	0.00
Disturbed landscapes	91.60	0.00	91.60
Remediated gullies	0.00	0.00	0.00
Cropped	0.00	0.00	0.00
Pine plantations	0.00	0.00	0.00
Improved pasture	1800.90	0.00	1800.90
Open area	0.00	17.25	-17.25
Roads (sealed)	0.00	18.40	-18.40
Roads (earth)	0.00	0.00	0.00
Urban	288.00	1926.00	-1638.00
Urban (open space)	0.00	0.00	0.00
Rural residential	0.00	0.00	0.00
Industrial	0.00	0.00	0.00
Commercial	0.00	0.00	0.00
Golf course	0.00	0.00	0.00
Orchard	0.00	0.00	0.00
TOTAL	**2180.50**	**1961.65**	**218.85**

Total Nitrogen kg/yr

LOW	PRE	POST	IMPACT
Native bushland	0.00	0.00	0.00
Disturbed landscapes	0.17	0.00	0.17
Remediated gullies	0.00	0.00	0.00
Cropped	0.00	0.00	0.00
Pine plantations	0.00	0.00	0.00
Improved pasture	8.69	0.00	8.69
Open area	0.00	0.10	-0.10
Roads (sealed)	0.00	0.16	-0.16
Roads (earth)	0.00	0.00	0.00
Urban	0.53	3.53	-3.00
Urban (open space)	0.00	0.00	0.00
Rural residential	0.00	0.00	0.00
Industrial	0.00	0.00	0.00
Commercial	0.00	0.00	0.00
Golf course	0.00	0.00	0.00
Orchard	0.00	0.00	0.00
TOTAL	**9.39**	**3.79**	**5.60**

MEDIAN	PRE	POST	IMPACT
Native bushland	0.00	0.00	0.00
Disturbed landscapes	0.48	0.00	0.48
Remediated gullies	0.00	0.00	0.00
Cropped	0.00	0.00	0.00
Pine plantations	0.00	0.00	0.00
Improved pasture	18.42	0.00	18.42
Open area	0.00	0.24	-0.24
Roads (sealed)	0.00	0.48	-0.48
Roads (earth)	0.00	0.00	0.00
Urban	1.46	9.79	-8.33
Urban (open space)	0.00	0.00	0.00
Rural residential	0.00	0.00	0.00
Industrial	0.00	0.00	0.00
Commercial	0.00	0.00	0.00
Golf course	0.00	0.00	0.00
Orchard	0.00	0.00	0.00
TOTAL	**20.37**	**10.51**	**9.86**

HIGH	PRE	POST	IMPACT
Native bushland	0.00	0.00	0.00
Disturbed landscapes	0.80	0.00	0.80
Remediated gullies	0.00	0.00	0.00
Cropped	0.00	0.00	0.00
Pine plantations	0.00	0.00	0.00
Improved pasture	27.95	0.00	27.95
Open area	0.00	0.38	-0.38
Roads (sealed)	0.00	0.80	-0.80
Roads (earth)	0.00	0.00	0.00
Urban	2.40	16.05	-13.65
Urban (open space)	0.00	0.00	0.00
Rural residential	0.00	0.00	0.00
Industrial	0.00	0.00	0.00
Commercial	0.00	0.00	0.00
Golf course	0.00	0.00	0.00
Orchard	0.00	0.00	0.00
TOTAL	**31.15**	**17.23**	**13.91**

Total Phosphorus kg/yr

LOW	PRE	POST	IMPACT
Native bushland	0.00	0.00	0.00
Disturbed landscapes	0.01	0.00	0.01
Remediated gullies	0.00	0.00	0.00
Cropped	0.00	0.00	0.00
Pine plantations	0.00	0.00	0.00
Improved pasture	1.04	0.00	1.04
Open area	0.00	0.01	-0.01
Roads (sealed)	0.00	0.02	-0.02
Roads (earth)	0.00	0.00	0.00
Urban	0.05	0.32	-0.27
Urban (open space)	0.00	0.00	0.00
Rural residential	0.00	0.00	0.00
Industrial	0.00	0.00	0.00
Commercial	0.00	0.00	0.00
Golf course	0.00	0.00	0.00
Orchard	0.00	0.00	0.00
TOTAL	**1.10**	**0.35**	**0.74**

MEDIAN	PRE	POST	IMPACT
Native bushland	0.00	0.00	0.00
Disturbed landscapes	0.05	0.00	0.05
Remediated gullies	0.00	0.00	0.00
Cropped	0.00	0.00	0.00
Pine plantations	0.00	0.00	0.00
Improved pasture	2.79	0.00	2.79
Open area	0.00	0.01	-0.01
Roads (sealed)	0.00	0.14	-0.14
Roads (earth)	0.00	0.00	0.00
Urban	0.44	2.92	-2.48
Urban (open space)	0.00	0.00	0.00
Rural residential	0.00	0.00	0.00
Industrial	0.00	0.00	0.00
Commercial	0.00	0.00	0.00
Golf course	0.00	0.00	0.00
Orchard	0.00	0.00	0.00
TOTAL	**3.28**	**3.08**	**0.20**

HIGH	PRE	POST	IMPACT
Native bushland	0.00	0.00	0.00
Disturbed landscapes	0.09	0.00	0.09
Remediated gullies	0.00	0.00	0.00
Cropped	0.00	0.00	0.00
Pine plantations	0.00	0.00	0.00
Improved pasture	4.55	0.00	4.55
Open area	0.00	0.02	-0.02
Roads (sealed)	0.00	0.27	-0.27
Roads (earth)	0.00	0.00	0.00
Urban	0.86	5.78	-4.91
Urban (open space)	0.00	0.00	0.00
Rural residential	0.00	0.00	0.00
Industrial	0.00	0.00	0.00
Commercial	0.00	0.00	0.00
Golf course	0.00	0.00	0.00
Orchard	0.00	0.00	0.00
TOTAL	**5.51**	**6.07**	**-0.56**

Appendix 2. Aggressive soils, extract from Australian Standards, *AS 2870-2011*, 2011

Exposure classification for concrete in saline soils

Saturated extract electrical conductivity (EC_e), *dS/m*	Exposure classification
<4	A1
4-8	A2
8-16	B1
>16	B2

Notes:

1. Guidance on concrete in saline soils can be found in CCAA T56
2. Exposure classifications are from AS 3600
3. The currently accepted method of determining the salinity level of the soil is by measuring the extract electrical conductivity (*EC*) of a soil and water mixture in deciSiemens per metre (dS/m) and using conversion factors that allow for the soil texture, to determine the saturated extract electrical conductivity (EC_e)
4. The division between a non-saline and saline soil is generally regarded as an EC_e value of 4dS/m, therefore no increase in the minimum concrete strength is required below this value

Exposure classification for concrete in sulfate soils

Exposure conditions			Exposure classification	
Sulfates (expressed as SO_4)*		pH	Soil conditions A**	Soil conditions B†
In soil (ppm)	In groundwater (ppm)			
<5,000	<1,000	>5.5	A2	A1
5,000-10,000	1,000-3,000	4.5-5.5	B1	A2
10,000-20,000	3,000-10,000	4-4.5	B2	B1
>20,000	>10,000	<4	C2	B2

* Approximately 100ppm SO_4 = 80ppm SO_3

** Soil conditions A – high permeability soils (e.g. sands and gravels) that are in groundwater

† Soil conditions B – low permeability soils (e.g. silts and clays) or all soils above groundwater

Minimum design characteristic strength (f_c') and curing requirements for concrete

Exposure classification	Minimum f_c' MPa	Minimum initial curing requirement
A1	20	Cure continuously for at least 3 days
A2	25	
B1	32	Cure continuously for at least 7 days
B2	40	
C1	≥50	
C2	≥50	

Minimum reinforcement cover for concrete

Exposure classification	Minimum cover in saline soils * mm	Minimum cover in sulfate soils ** (mm)
A1	See Clause 5.3.2	40
A2	45	50
B1	50	60
B2	55	65
C1	†	70
C2	†	85

* Where a damp-proofing membrane is installed, the minimum reinforcement cover in saline soils may be reduced to 30mm.

** Where a damp-proofing membrane is installed, the minimum reinforcement cover in sulfate soils may be reduced by 10mm.

† Saline soils have a maximum exposure classification of B2.

Appendix 3. Details of registered bores within 1km of the site – Water NSW

Bore record No. (Figure 6)	Eastings	Northings	Drilled / Completed depth (m)	Salinity description	Water bearing zones (m)	Standing water level (m)	Date drilled and or tested	Purpose
GW703898	610801	6332004	9.0	-	9.0-10.0	3.9	2009	Monitoring bore
GW703909	610812	6332007	7.5	-	4.0-7.5	6.1	2009	Monitoring bore
GW703910	610833	6332026	10.5	-	4.0-10.0	8.7	2009	Monitoring bore
GW703899	610833	6331967	9.0	-	8.0-10.0	4.19	2009	Monitoring bore

Appendix 4. Initial site investigation characteristics

Location (Figure 6)	Vegetation	Slope (%)	Bare areas	Indicators of salinity	Surface rocks	Trees (within 50m)
1	Tufted bluebell, sow thistle, khaki weed	0-1 NE	Approximately 70% soil coverage, bare areas due to stock congregation	Nil	Nil	Eucalypts and wattles along boundary
2	Oats, silverleaf nightshade windmill grass, khaki weed, thistle, sandvipers gloss	0-1 NE	Bare areas likely from gate movement	Nil	Nil	Cypress pine
3	Rabbit foot, clover, tufted bluebell, yellow burr, daisy, horehound, skeleton weed, windmill grass, oats	0-1 NE	Minimal, due to vehicle movement	Nil	Nil	Eucalypts, kurrajongs, cypress pine
4	Kikuyu, crowsfoot grass, kakhi weed, creeping oxalis,	0-1 NE	Approximately 60% soil coverage	Base of dwelling presenting dampness, mechanical breakdown of brickwork and grout and white staining in the bricks.	Nil	Eucalypts, kurrajongs, cypress pine
5	Sow thistle, oats, thistle, sandviper glass, paspalum	0-1 NE	Nil	Nil	Nil	Eucalypts, kurrajongs, peppercorn tree
6	Sow thistle, paspalum	0-1 NE	Nil	Nil	Nil	Nil
7	Tufted bluebell, windmill grass, African linseed grass, skeleton weed, African daisy	0-1 NE	Nil	Nil	Nil	Eucalypts
8	Tufted bluebell, windmill grass, silverleaf nightshade, rabbit foot, clover.	0-1 NE	Minimal	Nil	Nil	Eucalypts

Appendix 5. Field sampling log

Client	Steve and Daniel Mansley c/- Iplan Projects
Contact	Andrew Napier
Job number	16412
Location	109 Woodward Street Parkes NSW 2870
Date	13 December 2023
Investigator	Felipe Canavez
Weather conditions	Fine and warm

Sample ID	Matrix	Date	Analysis required	Observations/comments
MW1(500)	Soil	13/12/2023	Chloride, sulfate, calcium (Ca), magnesium (Mg), sodium (Na), potassium (K)	
MW1(1000)	Soil	13/12/2023	Chloride, sulfate, Ca, Mg, Na, K	

Appendix 6. Borelogs

Appendix 7. Reference methods for soil testing

Colour: Munsell (2000) In 'Munsell Soil Colour Charts' (Gretag Macbeth: NY)

Field texture: McDonald RC, Isbell RF, Speight JG, Walker, Hopkins MS (1990) Australian Soil and Land Survey Field Handbook pp.115-124 (Inkata Press: Melbourne)

PH: HB160-2006 Soils testing –Determination of pH using indicator papers

Salinity: Rayment GE and Higginson FR (1992) Australian Laboratory Handbook of Soil and Water Chemical Methods (Method 3A1, pp.15-16) (Inkata Press Melbourne) Electrical conductivity of saturated extract is based on conversions of EC (1:5) and soil texture class, to give a more accurate assessment of soil salinity hazard (Salavich PG and Peterson GH (1993) Estimating the electrical conductivity of soil paste extracts from 1:5 soil water suspensions and texture. Australian Journal of Soil Research 31, 3-81)

Appendix 8. SGS laboratory report SE258256 and chain of custody form