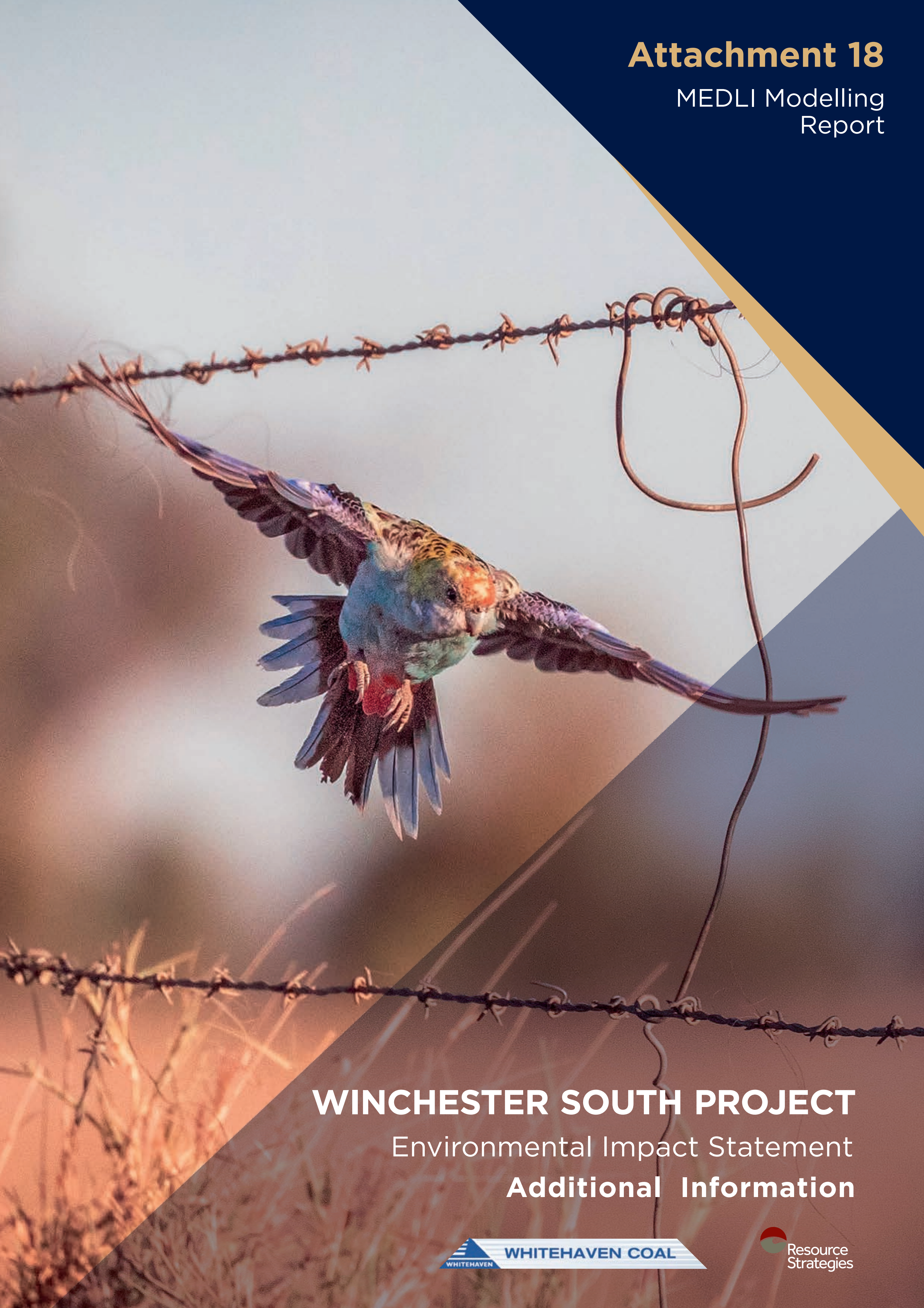

Attachment 18

MEDLI Modelling Report

WINCHESTER SOUTH PROJECT

Environmental Impact Statement

Additional Information

WHITEHAVEN COAL

Resource Strategies

MEDLI Modelling Report
Winchester South Project

Thursday, 17 February 2022

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Quality Assurance

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How to Use This Document

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CAUTION	This symbol includes information and assumptions used in the report that the reader should check for site specific accuracy.

IMPORTANT	This symbol draws attention to information that must be acknowledged and is critical to this report. This includes information which can affect the outcomes of the investigation.

Executive Summary

Project Background & Aim of This Document

The Winchester South Project, being undertaken by Whitehaven Coal Limited, is a project that involves the construction of a new open-cut coal mine, coal processing plant and a rail loop to connect with the existing Bowen Basin coal rail network. Winchester South will produce a primary metallurgical coal product for the steel industry and a secondary thermal coal product for energy generation. Sustainable Solutions International Pty Ltd (SSI) was engaged to assess the impact of the disposal of treated effluent to land through irrigation from the Sewerage Treatment Plant (STP).

This document covers the Model for Effluent Disposal by Land Irrigation (MEDLI) modelling process undertaken in order to determine the optimum operating parameters for the irrigation scheme and to assess the impact on the environment of the treated effluent irrigation scheme from the Winchester South Project.

Site Description

The Winchester South Project is located approximately 30 km south east of Moranbah, with a longitude of 148.2693 and a latitude of -22.1846. Climate data from the SILO Climate Databased provided by the Queensland Government website, indicates that there is an average annual rainfall of 575 mm at this location.

Operating Conditions at Winchester South

The Winchester South project's mining operations are expected to operate on a continuous basis, 24 hours a day, 7 days a week. The population at the Winchester South project site will vary depending on the extent of automation of the mining process. If a fully automated fleet is utilised, there will be 500 personnel at the mine site. If a non-automated fleet is adopted, there will be 750 personnel at the mine site.

Equivalent Person Determination

The Equivalent Persons (EP) for the two different operating conditions were determined using methods stipulated by the QLD government Environmental Protection Regulations 2008 (Reprint 2012). The two methods are based on:

- Daily hydraulic load, where an EP is equal to 200 L/day; and
- Pollutant loading, where an EP is equivalent to 2.5 g phosphorous/day.

The greater of the two EP values will be what the Environmental Licence for the STP will be based on. The EP values determined for each of the different operating conditions are shown in the table below.

Operating Condition	Daily Effluent Volume (kL/day)	EP Value (Hydraulic Loading)	EP Value (Pollutant Loading)
Autonomous Operation (500 personnel)	28.9	144	**224**
Non-autonomous Operation (750 personnel)	43.3	217	**336**

Soil Sampling & Testing

Geotechnical investigation work and soil sampling and testing were conducted in order to identify the soil characteristics at the Winchester South project site. Soil samples were collected from 5 sampling locations at each different horizons to a depth of 2.4 m. A total of 15 soil samples were sent to a NATA accredited laboratory for testing. From the soil testing conducted it was found that the top 2 layers of the soil at the Winchester South project site were classified as clay soil and sandy clay soil.

MEDLI Model Key Input Selection Process

There were a number of key input parameters that needed to be selected during the MEDLI model setup. Through the assessment that was conducted on each of the key input parameters, it was determined that the following inputs were used in the MEDLI model:

- Irrigation field plant parameters for Melaleuca Alternifolia and Kikuyu;
- Average soil characterisation values (otherwise known as Run 2 soil); and
- Total Nitrogen of 20 mg/L, 30 mg/L & 40 mg/L and Total Phosphorous of 15 mg/L & 20mg/L.

MEDLI Modelling Process

MEDLI modelling was conducted for the two different operating scenarios proposed for the Winchester South project in order to determine the optimum operating parameters for the irrigation scheme. A number of different MEDLI modelling scenarios were run in order to determine the optimum operating parameters for each operating condition. The process that was taken to determine the optimum operating parameters for the irrigation scheme were as follows:

1. Identify common MEDLI inputs for the different MEDLI modelling scenarios. The common inputs that were used are shown in the table below.

Description	Set Value
Irrigation Rate (mm/day)	2
Plant Type	Melaleuca Alternifolia Pasture, and Kikuyu Pasture
Soil Type	Run 2 Soil
Treated Effluent – Total Dissolved Salts (mg/L)	1000
Hydraulic Based Equivalent Person volume (L/EP/day)	200
Hydraulic Based Equivalent Persons (EP/day) (autonomous operation – 500 workers)	Average of 144 EP every day
Hydraulic Based Equivalent Persons (EP/day) (non-autonomous operation – 750 workers)	Average of 217 EP every day

2. The baseline performance for the two plant species used in the modelling were then established. This baseline performance was established to determine the baseline effect of rain on the environment at the selected irrigation area.
3. Key performance indicators (KPIs) were then identified and the assessment criteria was defined. KPIs selected focused on the effects of deep drainage, overflows, plant performance and nutrient and salt impacts on the environment and vegitation performance.
4. Scenarios for the MEDLI modelling multi-runs were then defined. There were a total of 12 scenarios for varying nutrient loads in the treated effluent. The different nutrient loads used in the MEDLI model included Total Nitrogen of 20 mg/L, 30 mg/L and 40 mg/L and Total Phosphorous of 15 mg/L and 20 mg/L.
5. The initial MEDLI model was refined after corresponding with the Department of Environment and Science (DES) prior to conducting the MEDLI model multi-runs.

6. A total of 12 MEDLI multi-runs were conducted for both Melaleuca Alternifolia and Kikuyu. Data from each run were assessed and the highest scoring options were identified through the initial assessment.
7. Further assessment of the results was conducted. Through this assessment the ideal plant species was selected along with the optimum operating parameters for the irrigation scheme.
8. Based on the selected optimum operating parameters a MEDLI model investigating the sensitivity of wet weather storage was conducted. The MEDLI model utilised 11 consecutive years of prolonged elevated precipitation as observed for years 2010 to 2020. .

MEDLI Modelling Outcomes

The recommended wet weather storage volume and irrigation area for the two operating conditions are as follows:

⚠ IMPORTANT	• **Autonomous Operation based on 64 years (1958 to 2021) of climate data** – the optimum operating wet weather storage volume was **400 kL** & an optimum effluent irrigation area of **2.0 ha.** • **Autonomous Operation based on 11 consecutive years (2010 to 2020) of high rainfall climate data** – The optimum operating wet weather storage volume was **900kL** and **2.0ha** of irrigation area.

⚠ IMPORTANT	• **Non-Autonomous Operation based on 64 years (1958 to 2021) of climate data** – the optimum operating wet weather storage volume was **550 kL** & an optimum effluent irrigation area of **3.0 ha.** • **Non-Autonomous Operation based on 11 consecutive years (2010 to 2020) of high rainfall climate data** – The optimum operating wet weather storage volume was **1,450kL** and **3.0ha** of irrigation area.

Important points noted for the recommended operating parameters for the effluent irrigation scheme for the two operating conditions included:

- There was no overflow using the recommended wet weather storage volumes and irrigation area for autonomous operation and for non-autonomous operation.
- Increase in deep drainage for both operating conditions was within the DES acceptable limit for deep drainage of 200 mm/year.
- There was minimal leaching of phosphorous into the soil for both operating conditions.
- There was minor leaching of nitrogen into the soil for both operating conditions.
- There was no significant impact on the crop yield for both operating conditions with the high total salt concentration of 1,000mg/L in the treated effluent.

Sensitivity analyses of the nutrient levels in the treated effluent used for irrigation showed:

- When total nitrogen was increased from 20 mg/L to 30 mg/L and then to 40 mg/L for both operating conditions, there was no notable environmental impact at the higher total nitrogen concentrations in the treated effluent.
- When total phosphorous was increased from 10 mg/L to 20 mg/L for both operating conditions, there was no notable environmental impact at the higher total phosphorous concentrations in the treated effluent.

- Crop yield of kikuyu increased by 15% to 20% when the total nitrogen increased, with no significant impact on environment.

Wastewater Treatment Plant Design Considerations

The main wastewater treatment plant design considerations included:

- Due consideration needs to be taken when selecting the appropriate wastewater treatment technology to ensure that the wastewater treatment plant can handle population variation and thus any associated hydraulic loading variation;
- A balance tank needs to be include within the wastewater treatment plant to provide an optimum of 48hours of 80th percentile of daily flow with a no less than 24 hours of storage of the incoming wastewater to provide flow balancing and redundancy;
- As a minimum, the wastewater treatment plant needs to include influent and effluent flow monitoring;
- The wastewater treatment technology that has the ability to remove nitrogen from the wastewater from potential influent concentrations of 120mg/L to levels between 30 to 40 mg/L in the treated effluent.
- The wastewater treatment plant should be able to remove phosphorous from potential influent concentrations of 20 to 30mg/L to levels of 15 mg/L in the treated effluent.
- During the design process of the wastewater treatment plant, influent sampling needs to be conducted to establish the quality of the incoming wastewater. This influent testing is required to determine the level of Oil & Grease (O&G) in the wastewater as well as the level of total petroleum hydrocarbons (TPH) in the wastewater as well as all other pollutant levels crucial for the sizing and design of the wastewater treatment plant. By understanding the composition of the incoming wastewater, it will allow for the design of wastewater treatment plant that is site specific and will comply with its ERA licence conditions under all operating conditions.
- Wastewater treatment plant design will need to include at least 2 points of disinfection (Primary as the treated effluent enters the wet weather storage tank and secondary in the wet weather storage tank recirculation loop) in order to provide Class A water for irrigation.
- The sludge production from the wastewater treatment plant and the sludge management process need to be reviewed during the technology selection and detailed design stage of the wastewater treatment plant.
- Primary screening is required within the wastewater treatment plant design to remove the grit and solids from the incoming wastewater;
- Due to the remoteness of the Winchester South site and the criticality of the wastewater treatment equipment, it is recommended that all critical equipment used at the wastewater treatment plant are operated in duty/standby mode;
- It is preferred for the disinfectant that is used to disinfect the treated effluent to be a non-oxidising disinfectant as the treated effluent will be used for irrigation and oxidising disinfectants, such as chlorine, may cause harm to the soil microbiology, hindering the biological nitrogen removal cycle in the soil;
- Due consideration needs to be taken to ensure that ease of operation and maintenance of the wastewater treatment plant is taken into account during the technology selection and detailed design of the wastewater treatment plant; and
- The control of the wet- weather storage needs to be included within the wastewater treatment plant control panel. Sufficient wet weather storage is required to retain effluent when irrigation is not possible due to wet weather conditions or agronomic practices that prevent irrigation. The recommended wet weather storage tank volumes, determined through the MEDLI modelling, for autonomous operation was 900 kL and for non-autonomous operation was 1,450 kL. This

sizing allows for the management of the wet-weather storage without over flow events for periods of elevated rainfall.
- It is preferred that the wet weather storage is a closed tank system as this will help to minimise algae management requirements.

Effluent Irrigation Field Scheme Design Considerations

The main effluent irrigation field scheme design considerations included:

- For Winchester South, the optimum crop that was selected was Kikuyu Pasture. Due consideration needs to be given when determining the type of irrigation method used to ensure that the Kikuyu Pasture receives the appropriate amount of water, i.e. drip irrigation may not be the most appropriate irrigation method but a spray gun or rain gun irrigation method may be more appropriate.
- It is important to ensure that all fixtures used for the irrigation system are above ground to allow for ease of operation and maintenance.
- Design of the irrigation scheme based on installing irrigation sprinklers on the boundary of the effluent irrigation area to allow for the ease of harvesting the biomass from the effluent irrigation area.
- It is recommended that proper animal-proof fencing (particularly for wild boars) is installed around the irrigation area to ensure that the irrigation field does not get damaged by wild animals.
- Ensure that irrigation meters are installed on the irrigation system and that these irrigation meters have data logging capabilities, which will allow for the irrigation water use to be monitored.
- Soil preparation is required in order to ensure that the proposed irrigation area is appropriate for planting the Kikuyu Pasture. Some soil preparation steps may include adding gypsum to the soil, which will help improve the soil structure, aerating/ deep ripping the soil to create micro passage ways in the soil so that water, air and nutrients can more easily get to the roots.
- The minimum irrigation area determined through MEDLI modelling, for autonomous operation was 2.0 ha and for non-autonomous operation was 3.0 ha.
- Irrigation should occur at a rate of 2 mm/day. Rain sensor should be used to stop ponding in the irrigation area during wet weather periods.

Table of Contents

Quality Assurance i

How to Use This Document ii

Executive Summary iii

1 Introduction 1

1.1 Scope of works for this report 1

1.2 Site Operational Description 1

1.3 Population and Staging 1

2 Site Background 2

2.1 Location and Description of Proposed Irrigation Field 2

2.2 Climate Data 4

2.3 Estimate of Effluent Volume and Nutrient Loading 6

2.3.1 Calculation of EP and Average Dry Weather Flow 6

2.3.2 Calculation of EP of Pollutant Load (Total Phosphorus) 8

2.3.3 Design Capacity of a Proposed STP 10

3 Site & Soil Investigation 12

3.1 Proposed Effluent Irrigation Area Location & Selection 12

3.2 Effluent Area Site Topography 13

3.3 Geotechnical Investigation Scope of works 13

3.4 Site Investigation Findings 14

3.5 Geotechnical Investigation Findings 14

4 Soil Laboratory Work 16

4.1 Description of the Laboratory 16

4.2 Laboratory Scope of Works 16

4.3 Laboratory QA/ QC process 18

4.4 Field Soil Sampling, Soil Processing and Transport 19

4.4.1 Field Soil Sampling Collection for Laboratory Analyses 19

4.4.2 SSI Soil Processing to Prepare Laboratory Samples 19

4.5 Soil Laboratory Results and Description 20

5 MEDLI Model Input 32

5.1 MEDLI Model Software 32

5.2 Selection Process of Key Input Parameters 32

5.2.1 Irrigation Field Plant Selection Criteria 32

5.2.2 Soil Parameter Input Selection 40

5.2.3 MEDLI Inputs for Treated Effluent used for Irrigation Selection Criteria ... 43
6 MEDLI Model Scenarios ... 45
6.1 MEDLI Model Scenario Modelling Approach ... 45
6.2 Baseline Establishment & Baseline Performance ... 46
6.3 Key Performance Indicator Selection & Definition ... 47
6.4 MEDLI Model Scenario Inputs ... 59
6.5 MEDLI Model Scenario Definition ... 61
6.6 MEDLI Model Refinement ... 63
6.7 Melaleuca Alternifolia & Kikuyu MEDLI Model Run Result Summary ... 63
6.7.1 Stage 1 Assessment: Plant Species Selection ... 64
6.7.2 Stage 2 Assessment: Irrigation Area and Wet Weather Storage Tank Volume Selection ... 65
6.8 Summary of Findings from Autonomous Operation MEDLI Modelling ... 69
6.9 Summary of Findings from Non-Autonomous Operation MEDLI Modelling ... 72
7 Sensitivity of Prolonged Elevated Precipitation on Wet-Weather Storage Volume Requirements ... 75
7.1 MEDLI Model Scenario Modelling Approach for Wet Weather Storage Sensitivity Analysis ... 75
7.2 Summary of Findings from Autonomous Operation – Wet Weather Storage Sensitivity Analysis ... 76
7.3 Summary of Findings from Non-Autonomous Operation – Wet Weather Storage Sensitivity Analysis ... 77
8 Summary of MEDLI Modelling Findings ... 80
9 Wastewater Treatment Plant Design Summary ... 99
10 Effluent Irrigation Scheme Design Summary ... 101
11 References ... 102
Appendix A : Geotechnical Investigation Report ... A-1
Appendix B : Soil Sample Photos ... B-1
Appendix C : Chain of Custody ... C-1
Appendix D : Laboratory Soil Sample Results ... D-1
Appendix E : KPI Analysis of all MEDLI Model Runs ... E-1
Appendix F : Kikuyu MEDLI Model Reports – 64 years Climate Data ... F-1
F.1. MEDLI Model Report – Kikuyu – Scenario 1 ... F-1
F.2. MEDLI Model Report – Kikuyu – Scenario 2 ... F-2
F.3. MEDLI Model Report – Kikuyu – Scenario 3 ... F-3
F.4. MEDLI Model Report – Kikuyu – Scenario 4 ... F-4
F.5. MEDLI Model Report – Kikuyu – Scenario 5 ... F-5

F.6. MEDLI Model Report – Kikuyu – Scenario 6 .... F-6
F.7. MEDLI Model Report – Kikuyu – Scenario 7 .... F-7
F.8. MEDLI Model Report – Kikuyu – Scenario 8 .... F-8
F.9. MEDLI Model Report – Kikuyu – Scenario 9 .... F-9
F.10. MEDLI Model Report – Kikuyu – Scenario 10 .... F-10
F.11. MEDLI Model Report – Kikuyu – Scenario 11 .... F-11
F.12. MEDLI Model Report – Kikuyu – Scenario 12 .... F-12
Appendix G : Melaleuca MEDLI Model Reports – 64 years Climate Data G-1
G.1. MEDLI Model Report – Melaleuca – Scenario 1 .... G-1
G.2. MEDLI Model Report – Melaleuca – Scenario 2 .... G-2
G.3. MEDLI Model Report – Melaleuca – Scenario 3 .... G-3
G.4. MEDLI Model Report – Melaleuca – Scenario 4 .... G-4
G.5. MEDLI Model Report – Melaleuca – Scenario 5 .... G-5
G.6. MEDLI Model Report – Melaleuca – Scenario 6 .... G-6
G.7. MEDLI Model Report – Melaleuca – Scenario 7 .... G-7
G.8. MEDLI Model Report – Melaleuca – Scenario 8 .... G-8
G.9. MEDLI Model Report – Melaleuca – Scenario 9 .... G-9
G.10. MEDLI Model Report – Melaleuca – Scenario 10 .... G-10
G.11. MEDLI Model Report – Melaleuca – Scenario 11 .... G-11
G.12. MEDLI Model Report – Melaleuca – Scenario 12 .... G-12
Appendix H : Kikuyu MEDLI Model Reports – 11 years Climate Data H-1
H.1. MEDLI Model Report –Kikuyu– Scenario 1 .... H-1
H.2. MEDLI Model Report –Kikuyu– Scenario 2 .... H-2
H.3. MEDLI Model Report –Kikuyu– Scenario 3 .... H-3
H.4. MEDLI Model Report –Kikuyu– Scenario 4 .... H-4
H.5. MEDLI Model Report –Kikuyu– Scenario 5 .... H-5
H.6. MEDLI Model Report –Kikuyu– Scenario 6 .... H-6
H.7. MEDLI Model Report –Kikuyu– Scenario 7 .... H-7
H.8. MEDLI Model Report –Kikuyu– Scenario 8 .... H-8
H.9. MEDLI Model Report –Kikuyu– Scenario 9 .... H-9
H.10. MEDLI Model Report –Kikuyu– Scenario 10 .... H-10
H.11. MEDLI Model Report –Kikuyu– Scenario 11 .... H-11
H.12. MEDLI Model Report –Kikuyu– Scenario 12 .... H-12
Appendix I : EAL QA/QC Process and QA/QC Results I-1
Appendix J : Correspondence with DES J-1

List of Figures

Figure 2.1 Approximate location of Winchester South Project marked on satellite image (location map provided on Whitehaven Coal Limited Website)....2

Figure 2.2 Map indicating proposed irrigation field location....3

Figure 2.3 Map indicating Irrigation Area Soil Sampling Location....4

Figure 2.4 Averaged Historical Climate Data for Winchester South for 64 years (obtained from the QLD Government's SILO website)....5

Figure 2.5 Averaged Historical Climate Data for Winchester South for 11 years used for wet weather sensitivity analysis (obtained from the QLD Government's SILO website)....5

Figure 3.1 Soil Mapping at Winchester South Site (provided by Whitehaven Coal Limited)....12

Figure 3.2 Soil Sampling of distinct soil layer using Push Tube....14

Figure 3.3 View of typical subsurface soil profile within the proposed irrigation area....14

Figure 6.1 Flow chart of Approach to determine Optimum Operating Conditions of Irrigation Scheme....45

Figure 6.2 Autonomous Operation – Wet Weather Storage Selection Contour Map (Overflow Summary)....66

Figure 6.3 Non-Autonomous Operation – Wet Weather Storage Selection Contour Map (Overflow Summary)....68

Figure 6.4 Salt Balance for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15....71

Figure 6.5 Salt Balance for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20....71

Figure 6.6 Salt Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN20 and TP15....73

Figure 6.7 Salt Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN40 and TP20....74

Figure 8.1 Land Nitrogen Balance for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15....87

Figure 8.2 Land Phosphorous Balance for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15....87

Figure 8.3 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15....87

Figure 8.4 Salt Balance for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15....88

Figure 8.5 Land Nitrogen Balance for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20....88

Figure 8.6 Land Phosphorous Balance for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20....88

Figure 8.7 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20....89

Figure 8.8 Salt Balance for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20 89

Figure 8.9 Land Nitrogen Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN20 and TP15 90

Figure 8.10 Land Phosphorous Balance for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15 90

Figure 8.11 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters for Non-Autonomous Operation at TN20 and TP15 90

Figure 8.12 Salt Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN20 and TP15 90

Figure 8.13 Land Nitrogen Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN40 and TP20 91

Figure 8.14 Land Phosphorous Balance for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20 91

Figure 8.15 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters for Non-Autonomous Operation at TN40 and TP20 91

Figure 8.16 Salt Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN40 and TP20 92

Figure 8.17 Land Nitrogen Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN20 and TP15 92

Figure 8.18 Land Phosphorous Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN20 and TP15 92

Figure 8.19 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN20 and TP15 93

Figure 8.20 Salt Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN20 and TP15 93

Figure 8.21 Land Nitrogen Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN40 and TP20 93

Figure 8.22 Land Phosphorous Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN40 and TP20 94

Figure 8.23 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN40 and TP20 94

Figure 8.24 Salt Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN40 and TP20 94

Figure 8.25 Land Nitrogen Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN20 and TP15 95

Figure 8.26 Land Phosphorous Balance for Recommended Irrigation Parameters for from Wet Weather Sensitivity Analysis Non-Autonomous Operation at TN20 and TP15 95

Figure 8.27 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN20 and TP15 95

Figure 8.28 Salt Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN20 and TP15 96

Figure 8.29 Land Nitrogen Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN40 and TP20 96

Figure 8.30 Land Phosphorous Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN40 and TP20 96

Figure 8.31 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN40 and TP20 97

Figure 8.32 Salt Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN40 and TP20 97

Figure 8.33 Size of Recommended Irrigation Areas in comparison with Proposed Irrigation Area Location 98

List of Tables

Table 2.1 Coordinates of Irrigation Area Soil Sampling Location 3

Table 2.2 Anticipated Daily Workforce 6

Table 2.3 Typical Household (2 – 4 persons) internal water use 7

Table 2.4 Effluent Volume Calculations – Autonomous Operation Peak 7

Table 2.5 Effluent Volume Calculations – Non-Autonomous Operation Peak 8

Table 2.6 EP Calculation for Pollutant Load – Autonomous Operation Peak 9

Table 2.7 EP Calculation for Pollutant Load – Non-Autonomous Operation Peak 9

Table 2.8 Pollution Load per EP/day 9

Table 2.9 Estimated Daily Pollutant Loads – Autonomous Operation Peak 10

Table 2.10 Estimated Daily Pollutant Loads – Non-Autonomous Operation Peak 10

Table 2.11 EP Calculation Summary from Hydraulic and Pollutant Loading Calculations 11

Table 4.1 Soil Testing Parameters, Testing Method and Margin of Error 16

Table 4.2 Grain Size Analysis Results 20

Table 4.3 Atterberg Limits Test Results 21

Table 4.4 MEDLI Phosphorous Adsorption Isotherm Parameter Calculator Results 22

Table 4.5 Soil Hydraulic Properties Test Results 24

Table 4.6 Agricultural Soil Analysis Test Results 27

Table 5.1 Description of the Different Plant Species in the MEDLI Modelling Software Library (References used to compile this table are listed in the references section at the end of this report) 33

Table 5.2 Assessment of Shortlisted Plant Species 38

Table 5.3 MEDLI Planting Parameters for Initial Selected Plant Cover – Melaleuca Alternifolia Pasture 39

Table 5.4 Soil Characterisation Values to be used in MEDLI Model 40

Table 5.5 MEDLI Model Soil Parameters 42

Table 5.6 Soil Parameters for Run-off & Evaporation and Initial Nitrogen used in the MEDLI model. 43

Table 5.7 MEDLI Input of Treated Effluent Quality used for Irrigation 43

Table 6.1 Baseline performance for Melaleuca Alternifolia and Kikuyu with no effluent irrigation occurring. 46

Table 6.2 KPI Scoring Matrix for Melaleuca Alternifolia Multi-run Results Assessment 48

Table 6.3 KPI Scoring Matrix for Kikuyu Multi-run Results Assessment 53

Table 6.4 Common Scenario Settings 59

Table 6.5 MEDLI Planting Parameters for Initial Selected Plant Cover – Melaleuca Alternifolia Pasture 60

Table 6.6 MEDLI Planting Parameters for Selected Plant Cover for MEDLI Model– Kikuyu Pasture 61

Table 6.7 Varied Scenario Settings 62

Table 6.8 Parameters updated in MEDLI Model to Refine Model 63

Table 6.9 Summary of Results for Kikuyu for Scenario 1 to 6 (TN20 to TN40 & TP15 to TP20) – Autonomous Operation (500 personnel) 66

Table 6.10 Summary of Results for Kikuyu for Scenario 7 to 12 (TN20 to TN40 & TP15 to TP20) – Non-Autonomous Operation (750 personnel) 68

Table 7.1 Summary of Inputs and Outcomes for the Preferred Scenarios 82

1 Introduction

Whitehaven Coal Limited is in the process of constructing a new open-cut coal mine, coal processing plant and a rail loop to connect with the existing Bowen Basin coal rail network. This project will be referred to as the Winchester South Project and this project aims to meet the strict environmental guidelines set out by the Queensland (QLD) and Federal Governments. In order to ensure that the project meets these strict environmental guidelines, Sustainable Solutions International Pty Ltd (SSI) was engaged by Whitehaven Coal Limited to assess the impact of the disposal of treated effluent to land through irrigation from the Sewerage Treatment Plant (STP) treating sewerage from the staff and contractors on site. The STP will be built as part of the coal mine development. This assessment included conducting a detailed environmental impact model to determine the effects of long term usage of treated effluent to irrigate a land disposal scheme. The proposed environmental impact model that was used was the QLD Government developed Model for Effluent Disposal by Land Irrigation (MEDLI) Software.

1.1 Scope of works for this report

The scope of works for the Winchester South Project that SSI was engaged to complete are as follows:

- Determine the design capacity of the proposed STP through hydraulic and pollutant loading calculations;
- Conduct modelling for different scenarios of the effluent irrigation on the receiving environment using the MEDLI Software for the site location at the proposed Winchester South Mine;
- Determine the proposed volume of the wet weather storage required based on the MEDLI modelling conducted;
- Determine the size of the proposed effluent disposal area based on the MEDLI modelling conducted; and
- Provide a description of the predicted volumes of effluent to be irrigated to land based on the MEDLI modelling conducted.
- Conduct hydraulic and pollutant load calculations for a population of 500 workers and 750 workers.
- Conduct MEDLI modelling for the treated effluent for a hydraulic load of 500 workers and 750 workers.

1.2 Site Operational Description

The Winchester South project is located approximately 30 km south east of Moranbah. It provides an opportunity to develop an open cut metallurgical coal mine and associated onsite and offsite infrastructure within an existing mine precinct. This open cut mine will produce a mix of products, including metallurgical coal, for use in the steel industry, and thermal coal. This project will comprise of an open cut coal mine and the associated infrastructure corridor, including a raw water supply pipeline, which will connect to the Eungella pipeline network, an electrical transmission line (ETL) and a mine access road. It is estimated that the Winchester South project mine will have a mine life of approximately 30 years.

1.3 Population and Staging

The Winchester South project's mining operations are expected to operate on a continuous basis, i.e. 24 hours a day, 7 days a week. Whitehaven Coal Limited is investigating automation of the fleet to be used for the Winchester South project. The automation of the fleet is expected to improve the safety, efficiency and cost benefits of the project. The population at the Winchester South project site may change depending on the extent of automation of the process. It is anticipated that if the Winchester

South mine is operated with a fully automated fleet, there will be 500 personnel at the mine site. If a non-automated fleet is adopted, the operational workforce would increase to approximately 750 personnel at the mine site.

2 Site Background

2.1 Location and Description of Proposed Irrigation Field

The Winchester South Project is located approximately 30 km south east of Moranbah. The approximate location of the Winchester South Project is shown below in Figure 2.1.

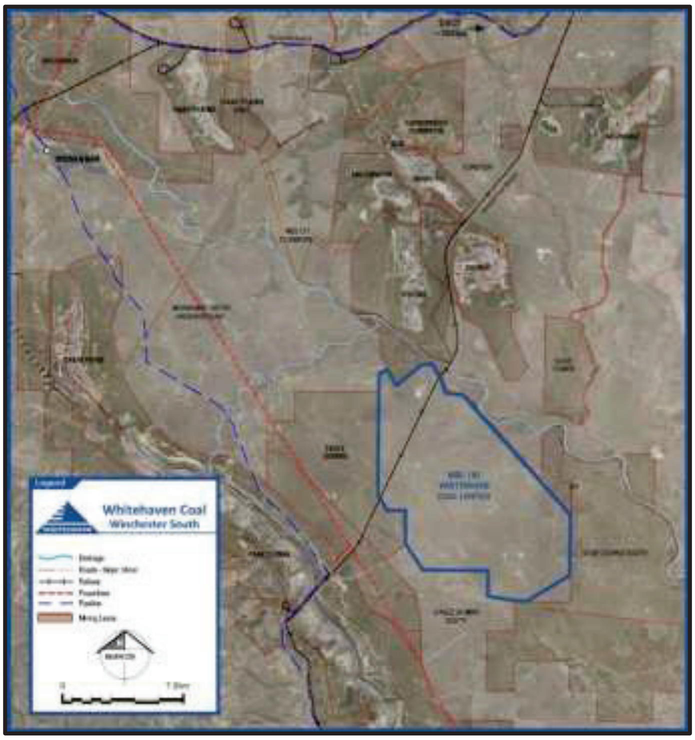


Figure 2.1 Approximate location of Winchester South Project marked on satellite image (location map provided on Whitehaven Coal Limited Website)

The proposed location of the irrigation field at the Winchester South Project mine site is shown as a green square in the site map shown below in Figure 2.2.

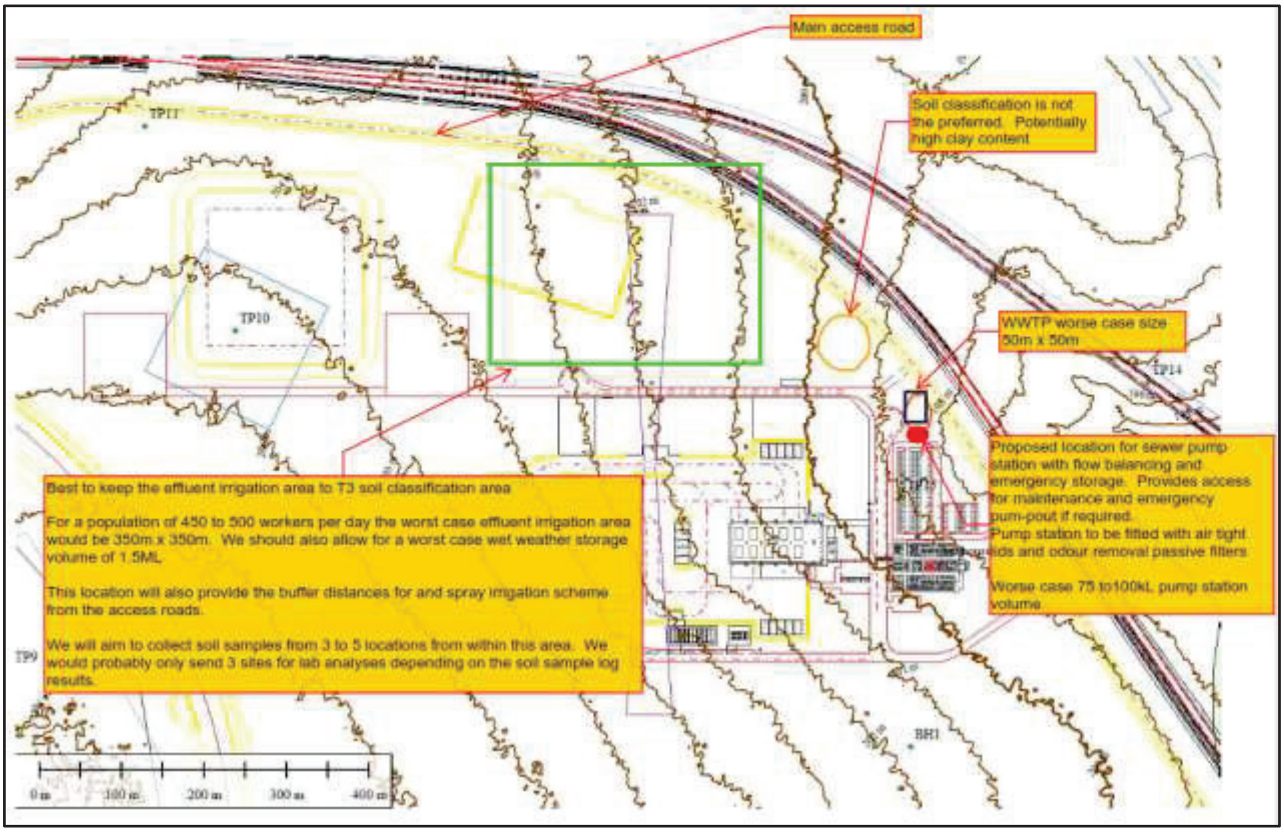


Figure 2.2 Map indicating proposed irrigation field location

In order to conduct the required MEDLI modelling on the Winchester South project site, soil sampling and testing of the soil at the proposed irrigation area was conducted. The coordinates for the soil sampling locations are listed below in Table 2.1.

Table 2.1 Coordinates of Irrigation Area Soil Sampling Location

BORE HOLE LOCATIONS – SOIL SAMPLING FOR MEDLI		
PIT	**EASTING**	**NORTHING**
Irrigation Area Soil Sample 1 (HA1)	631798.0	7551508.0
Irrigation Area Soil Sample 2 (HA2)	631752.0	7551606.0
Irrigation Area Soil Sample 3 (HA3)	631852.0	7551606.0
Irrigation Area Soil Sample 5 (HA5)	631550.0	7551681.0
Irrigation Area Soil Sample 6 (HA6)	631492.0	7551596.0

(Coordinates obtained during geotechnical investigation)

The locations of each of the soil sampling pits in relation to the proposed irrigation area are shown below in Figure 2.3.

⚠ **IMPORTANT**	It is important to note that in the event that the proposed effluent irrigation area location changes, a new geotechnical investigation including new soil sampling and testing will have to be carried out. This new soil data will then need to be used in a new MEDLI model to calculate the required irrigation area and wet weather storage required.

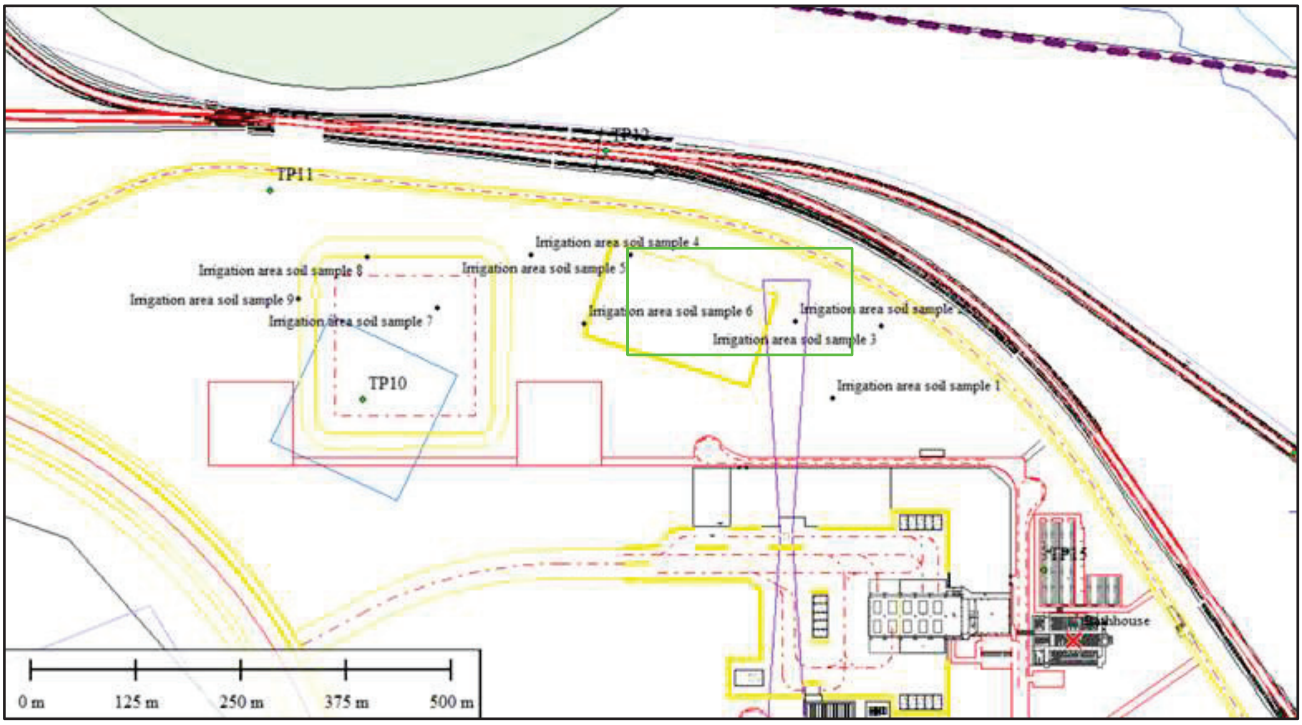


Figure 2.3 Map indicating Irrigation Area Soil Sampling Location

2.2 Climate Data

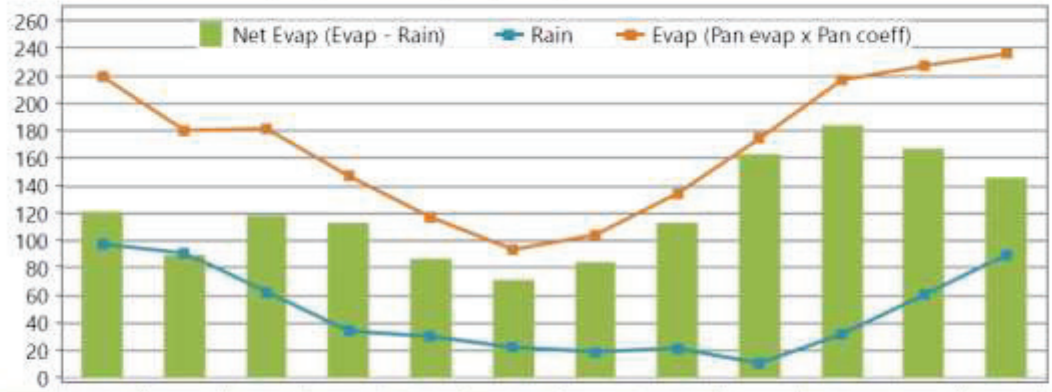
The climate data used in the MEDLI modelling was obtained from the SILO Climate Database provided by the QLD Government website: https://silo.longpaddock.qld.gov.au.

64 years of data, from 1958 to 2021, were located for this location and utilised in the MEDLI models. A secondary MEDLI model of the 11 years of consecutive high rainfall for the period of 2010 to 2020 was also conducted to understand the sensitivity of wet years on the size of the wet weather storage volumes. A summary of the 64years worth of climate data used can be found below in Figure 2.4. A summary of the 11years worth of climate data used to conduct the wet weather sensitivity analysis can be found in Figure 2.5.

Averaged Historical Climate Data Used in Simulation (mm)

Location: Winchester South 1958-2022, -22.2°, 148.25°

Run Period: 01/01/1958 to 31/12/2021 64 years, 0 days



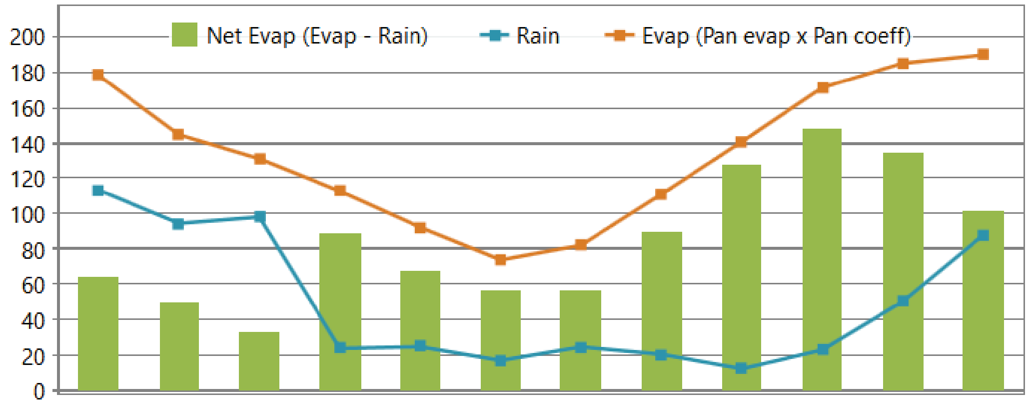
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	97.9	91.1	62.9	34.4	30.6	22.6	19.6	21.9	11.2	32.3	60.6	89.7	574.6
Evap	219.7	180.5	181.6	147.3	117.2	93.8	104.5	134.6	174.6	217.1	227.4	236.0	2034.2
Net Evap	121.8	89.3	118.7	112.8	86.7	71.2	84.9	112.8	163.5	184.8	166.9	146.3	1459.6
Net Evap/day	3.9	3.2	3.8	3.8	2.8	2.4	2.7	3.6	5.4	6.0	5.6	4.7	4.0

Figure 2.4 Averaged Historical Climate Data for Winchester South for 64 years (obtained from the QLD Government's SILO website)

Averaged Historical Climate Data Used in Simulation (mm)

Location: Winchester South -22.20_148.25, -22.2°, 148.25°

Run Period: 01/01/2010 to 31/12/2020 11 years, 0 days



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain	113.4	94.6	98.2	24.1	25.0	17.3	24.9	20.8	12.6	23.2	50.5	88.0	592.8
Evap	178.2	144.6	131.1	112.8	92.4	74.0	82.3	111.1	140.8	171.3	185.0	189.6	1613.2
Net Evap	64.8	50.0	32.9	88.7	67.3	56.7	57.3	90.3	128.2	148.0	134.5	101.6	1020.4
Net Evap/day	2.1	1.8	1.1	3.0	2.2	1.9	1.8	2.9	4.3	4.8	4.5	3.3	2.8

Figure 2.5 Averaged Historical Climate Data for Winchester South for 11 years used for wet weather sensitivity analysis (obtained from the QLD Government's SILO website)

2.3 Estimate of Effluent Volume and Nutrient Loading

The first step to determining the effects of treated effluent irrigation on the environment was to determine the hydraulic load and pollutant load on the STP and thus determine the equivalent persons (EP) of the STP. This section was prepared to provide a summary of the calculations that were done in order to determine the theoretical hydraulic loading and pollutant loading on the wastewater treatment plant along with calculations for the EP based on the hydraulic and pollutant loading for the Environmental Relevant Activity (ERA) licence. For the calculation of daily peak design capacity, there are two methods. These are as follows:

(a) Hydraulically, in which EP = V/200, where V is the volume in litres of the average daily dry weather flow of sewerage that can be treated at the STP per day; and
(b) Based on pollutant load, in which EP = M/2.5g, where M is the mass, in grams, of phosphorous in the influent per day as the inlet load.

The EP that will be used for the environmental licence will be the greater of the two EPs that are calculated based on the hydraulic load and the pollutant load. Furthermore, it is important to note that the environmental licence is based on the peak EP. However, the MEDLI model will take into account the average EP as monthly values which are inputted into the modelling software.

2.3.1 Calculation of EP and Average Dry Weather Flow

This section will provide a summary of the calculations that were done in order to determine the theoretical hydraulic loading for the wastewater treatment plant along with calculations for the equivalent persons based on the hydraulic load. The population at Winchester South, as provided by Whitehaven Coal Limited, is summarised below in Table 2.2.

Table 2.2 Anticipated Daily Workforce

Operation Winchester Staff	Shift Description	Anticipated Daily Workforce – Autonomous Operation Peak				Anticipated Daily Workforce – Non-Autonomous Operation Peak			
		People / Shift	No of Shifts/ Day	People / Day	Total People / Day	People / Shift	No of Shifts/ Day	People / Day	Total People/ Day
Contractor/Admin / Support/ Management	8 hr, 6 day, 1 panel roster	100	1	100	100	150		150	150
Equipment Operators Site Wide Maintenance Coal Processing Plant & TLO Operations	12 hr, 7 day, 4 panel roster	100	2	200	400	150		300	600
Total population per day					**500**				**750**

Each person working on a shift cannot be considered to generate the full amount of wastewater of an Equivalent Person (EP). The average 200 L of effluent per EP per day is based on a person using the facility over a 24 hour period and would include toilet, hand-basin, shower, laundry and kitchen use.

As this mine site will be an open-cut mine and most of the staff are working in an environment that could be considered equivalent to an air-conditioned office, each person would mainly contribute effluent from toilets and hand-basins, with a small percentage also from showers. As the site is intended to be an open-cut mine, it is anticipated that the shower facilities will not be as highly used as it would if the site was an underground mine.

The typical household internal water use, provided by the *Planning Guidelines for Water Supply and Sewerage, April 2010, Chapter 6 amended March 2014, Dept. of Energy and Water Supply* is summarised below in Table 2.3. It was noted that toilet use comes out to being about 26% of the total water use, whilst baths/showers is about 34%.

Table 2.3 Typical Household (2 – 4 persons) internal water use

Water Use Source	House hold Water use Range (L/day)	Typical % of Internal Use	Water use per person per day
Toilets	110 – 180	26%	52 L/day
Baths/Showers	170 – 220	34%	68 L/day
Kitchen	45 – 90	13%	26 L/day
Laundry	100 – 140	22%	44 L/day
Other	15 – 50	5%	10 L/day
Total	**440 to 680**	**100%**	**200L/day**

For this project, it was assumed worst case that only half of the employees will use the showers, which would mean that the baths/showers water usage as a proportion of total water use will decrease from 34% to 17%. This would then result in 26% + 17% = 43% of an Equivalent Person's wastewater production to be considered reasonable for a full 24 hour period.

By taking into account the proportion of an actual work day each employee is present on site, will reduce this EP scaling factor further. For example, 1 x 8 hour shift is 33.3% of a 24 hour day, but can also be considered to be 50% of a daily 16 hour awake period (assuming that 8 hours is the average sleeping period/ person). Similarly, 1 x 12 hour shift is seen as 50% of a 24 hour day, but 75% of a 16 hour awake period. It important to note that for this project, the higher percentage value is selected, as this site differs from a domestic situation, and is operated on a 24 hour basis, with 2 x 12 hour shifts. Table 2.4 and Table 2.5 below provide the hydraulic loading calculations completed in order to determine the equivalent persons for both autonomous operation and non-autonomous operation of the Winchester South mine for the purpose of MEDLI modelling.

Table 2.4 Effluent Volume Calculations – Autonomous Operation Peak

Winchester Staffing Breakdown- Autonomous Operation	Fraction of daily awake hours	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Average
Contractor/Admin/Sup-port/Management	0.5	100	100	100	100	100	0	0	71.4
Equipment Operators Site Wide Maintenance and Coal Processing Plant & TLO Operations	0.75	400	400	400	400	400	400	400	400.0
Total Employees per day		**500**	**500**	**500**	**500**	**500**	**400**	**400**	**471.4**
Estimated Proportion of EP Hydraulic Production (toilets and showers)		43%	43%	43%	43%	43%	43%	43%	43%
Average Daily Staff Presence on site (%)		70%	70%	70%	70%	70%	75%	75%	71.4%

Effective EP Scaling Factor	**0.30**	**0.30**	**0.30**	**0.30**	**0.30**	**0.32**	**0.32**	**0.3**
Daily EP	**150.5**	**150.5**	**150.5**	**150.5**	**150.5**	**129.0**	**129.0**	**144.4**
Volume/EP/day (L)	**200**	**200**	**200**	**200**	**200**	**200**	**200**	**200**
Expected Daily Hydraulic Load (kL/day)	**30.1**	**30.1**	**30.1**	**30.1**	**30.1**	**25.8**	**25.8**	**28.9**

⚠ **IMPORTANT**	**AUTONOMOUS OPERATION:** For the MEDLI modelling process, the EP for average autonomous operation was **144** for an expected daily hydraulic load of **28.9 kL**.

Table 2.5 Effluent Volume Calculations – Non-Autonomous Operation Peak

Winchester Staffing Breakdown Non-Autonomous Operation	Fraction of daily awake hours	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Average
Contractor/Admin/Support/Management	0.5	150	150	150	150	150	0	0	107.1
Equipment Operators, Site Wide Maintenance and Coal Processing Plant & TLO Operations	0.75	600	600	600	600	600	600	600	600.0
Total Employees per day		750	750	750	750	750	600	600	707.1
Estimated Proportion of EP Production (toilets and showers)		43%	43%	43%	43%	43%	43%	43%	43%
Overall Staff Presence Daily (%)		70%	70%	70%	70%	70%	75%	75%	71.4%
Effective EP Scaling Factor		**0.30**	**0.30**	**0.30**	**0.30**	**0.30**	**0.32**	**0.32**	**0.3**
Daily EP		**225.8**	**225.8**	**225.8**	**225.8**	**225.8**	**193.5**	**193.5**	**216.5**
Volume/EP/day (L)		200	200	200	200	200	200	200	**200**
Expected Daily Hydraulic Load (kL)		**45.2**	**45.2**	**45.2**	**45.2**	**45.2**	**38.7**	**38.7**	**43.3**

⚠ **IMPORTANT**	**NON- AUTONOMOUS OPERATION:** For the MEDLI modelling process, the EP for average non-autonomous operation was **217** for an expected daily hydraulic load of **43.3 kL**.

2.3.2 Calculation of EP of Pollutant Load (Total Phosphorus)

This section provides a summary of the calculations that were done in order to determine the theoretical pollutant loading for the wastewater treatment plant along with calculations for the equivalent persons based on the pollutant load. The equivalent persons (EP) calculated for the anticipated pollutant load of phosphorous differs from the EP calculations based on hydraulic loading calculations (shown above) due to the strength of the wastewater being higher in this application compared to a domestic scenario. In this case, the fraction of the day in which each staff member is present on site was taken into consideration as the proportion of an EP contributing to the daily pollutant load. Table 2.6 and Table 2.7 below provide the pollutant loading calculations that were conducted to determine the equivalent persons for autonomous operation and non-autonomous operation at the Winchester mine.

Table 2.6 EP Calculation for Pollutant Load – Autonomous Operation Peak

Winchester Staffing Breakdown- Autonomous Operation	No. Staff/day (averaged over a week)	Time Fraction of 24 hr day spent at the mine site	EP (nutrient load)
Contractor/Admin/Sup-port/Management	71.4	0.33	24
Equipment Operators, Site Wide Maintenance and Coal Processing Plant & TLO Operations	400.0	0.5	200
		Total Daily EP	**224**

Table 2.7 EP Calculation for Pollutant Load – Non-Autonomous Operation Peak

Winchester Staffing Breakdown Non-Autonomous Operation	No. Staff/day (averaged over a week)	Time Fraction of 24 hr day spent at the mine site	EP (nutrient load)
Contractor/Admin/Sup-port/Management	107.1	0.33	36
Equipment Operators, Site Wide Maintenance and Coal Processing Plant & TLO Operations	600.0	0.5	300
		Total Daily EP	**336**

The pollution contributions per EP for the main pollutants in wastewater were obtained from the *QLD Onsite Sewerage Code (2002)*, and these values are summarised below in Table 2.8.

Table 2.8 Pollution Load per EP/day

Pollutant	Value	Unit
Nitrogen	15	g/EP/day
Phosphorous	2.5	g/EP/day
Biochemical Oxygen Demand (BOD)	70	g/EP/day
Suspended Solids (SS)	70	g/EP/day

Using the pollutant contributions per EP values with the EP calculated in Table 2.6 and Table 2.7 along with the estimated hydraulic loading determined in Table 2.4 and Table 2.5, the following estimated pollutant loads, shown below in Table 2.9 and Table 2.10, were calculated.

Table 2.9 Estimated Daily Pollutant Loads – Autonomous Operation Peak

Winchester Staffing Breakdown Autonomous Operation	Nitrogen (g/day)	Phosphorous (g/day)	BOD (g/day)	SS (g/day)
Contractor/Admin/Sup-port/Management	360	60	1,680	1,680
Equipment Operators, Site Wide Maintenance and Coal Processing Plant & TLO Operations	3,000	500	14,000	14,000
Total Mass Load (g/day)	**3,360**	**560**	**15,680**	**15,680**
Concentration in the Influent (mg/L)	**116.3**	**19.4**	**542.6**	**542.6**
EP based on pollutant load (EP)		**224**		

CAUTION	The above pollutant mass and concentration values should only be used as a preliminary value for the purposes of calculating the licence pollutant loads. It should not be used for the design of the wastewater treatment plant.

Table 2.10 Estimated Daily Pollutant Loads – Non-Autonomous Operation Peak

Winchester Staffing Breakdown Non-Autonomous Operation	Nitrogen (g/day)	Phosphorous (g/day)	BOD (g/day)	SS (g/day)
Contractor/Admin/Sup-port/Management.	540	90	2,520	2,520
Equipment Operators, Site Wide Maintenance and Coal Processing Plant & TLO Operations.	4,500	750	21,000	21,000
Total Mass Load (g/day)	**5,040**	**840**	**23,520**	**23,520**
Concentration in the Influent (mg/L)	**116.4**	**19.4**	**543.2**	**543.2**
EP based on pollutant load (EP)		**336**		

CAUTION	The above pollutant mass and concentration values should only be used as a preliminary value for the purposes of calculating the licence pollutant loads. It should not be used for the design of the wastewater treatment plant.

2.3.3 Design Capacity of a Proposed STP

The design capacity for the proposed STP for the Winchester South project was determined by conducting theoretical hydraulic and pollutant load calculations. The equivalent persons for the STP were then determined from these loading calculations. The results from the hydraulic and pollutant loading calculations that were conducted for autonomous and non-autonomous operations can be found below in Table 2.11.

Table 2.11 EP Calculation Summary from Hydraulic and Pollutant Loading Calculations

Parameter	Calculated Value
Autonomous Operation	
Daily expected hydraulic load (kL/day)	28.9
EP based on hydraulic load (EP)	144
EP based on pollutant load (EP)	224
Non-Autonomous Operation	
Daily expected hydraulic load (kL/day)	43.3
EP based on hydraulic load (EP)	217
EP based on pollutant load (EP)	336

The EP that will be used for the Environmental Authority licence will be the greater of the two EPs that are calculated based on the hydraulic load and the pollutant load. For the Winchester South project, the EP that will be used for the Environmental Authority licence for both the autonomous operation and the non-autonomous operation is the EP that was calculated based on the theoretical pollutant load. Therefore the EP that will be used for the environmental licence are as follows:

⚠ **IMPORTANT**	The calculated EP for the Winchester project is: • Autonomous Operation EP = 224; and • Non-autonomous Operation EP = 336.

3 Site & Soil Investigation

In order to gain an understanding of the site conditions at the proposed effluent irrigation area and to utilise the proposed environmental impact model, MEDLI; a geotechnical investigation was conducted. This section of the report provides a description of the proposed effluent irrigation area and the proposed location of the irrigation area along with an explanation into why the proposed effluent irrigation area was selected. This section also provides a summary of the effluent area site topography, a summary of the scope of works for the geotechnical investigation along with a summary of the findings from the site investigation and the geotechnical investigation.

3.1 Proposed Effluent Irrigation Area Location & Selection

Effluent irrigation schemes require suitable land space, appropriate soil types and crop species for it to be viable. The land disposal system needs to be designed and operated carefully to ensure that this practice is fit for purpose and does not cause detrimental impacts to the environment or to human health. A number of factors can contribute to achieving sustainable effluent irrigation for land disposal. One of the most important factors to consider is appropriate site selection as well as the properties of the irrigation area. Some of the properties of the irrigation area that need to be considered include the following:

- Slope, shape, land use and soil type of the selection land space;
- The presence of shallow groundwater tables;
- The likelihood of flooding of the irrigation area and related infrastructure;
- The presence of aquatic environments near the irrigation area; and
- Distance to public amenities or other sensitive receptors.

It is also important to note that the most suitable soils that vegetation thrive on are soils that can absorb phosphorous and lock it in the soil. By taking all of these factors into consideration, the proposed location for the irrigation area was selected as the soil at this location is gradational alkaline silty clay soil on flat plains, as shown in the soil mapping below in Figure 3.1.

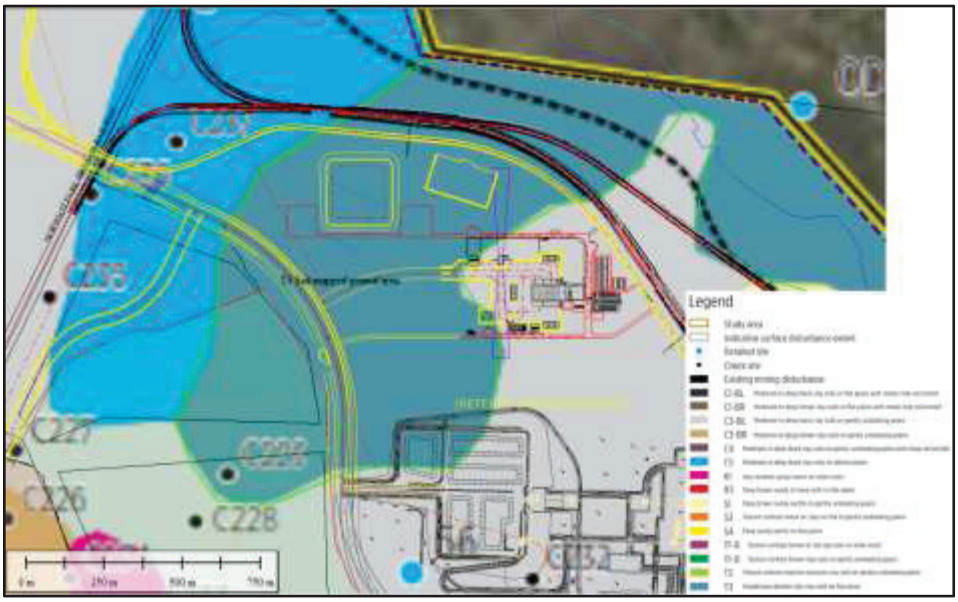


Figure 3.1 Soil Mapping at Winchester South Site (provided by Whitehaven Coal Limited)

Flat plains are the preferred slope profile for an irrigation area as this will minimise effluent run off issues. Furthermore black clay is not the preferred soil type for irrigation as clays can get water logged and the sodium in the treated effluent will also accelerate the water logging process in the soil. It is also important to note that the location of the proposed irrigation area was selected to be close to the access road as this will allow for easier maintenance of the irrigation area. The location of the proposed irrigation area was also chosen at a location where the natural gradient of the site allows for gravity flow towards the irrigation area from the proposed location of the sewerage treatment plant. Finally, it is important to note that the proposed location of the irrigation area is located at an area that provides a buffer distance from the site offices.

3.2 Effluent Area Site Topography

The proposed treated effluent irrigation area is a rectangular site that is approximately 300 m long in an east-west direction and 200 m wide in the north-south direction. The irrigation area is located about 1.5 km to the east of the existing railway line on a flat plateau at about RL (Reduced Level) 200 m relative to Australian Height Datum (AHD). This area is poorly drained with no distinct overland flow paths. The edge of the plateau is to the north-east and the area is assumed to drain to the broad flood plain of the Isaac River.

During the site investigation, it was noted that the irrigation area is currently covered with grasses and low bushes with a few scattered small trees. Variable developed circular and irregular gilgai micro-relief was noted throughout the site. The broad gilgai depressions were typically 0.2 to 0.5 m in depth. No distinct difference in surficial soil between the depressions and the mounds was noted. Approximately a week before the field word was conducted, there was 20 to 50 mm of rain and it was seen that due to the rain, the surface cracks were poorly developed and typically varied between 5 and 20 mm in width.

3.3 Geotechnical Investigation Scope of works

As part of the investigation to determine the long term environmental impact of using treated effluent in a land disposal scheme, a geotechnical site and soil investigation was required. The geotechnical investigation was conducted to provide physical characterisation data of the soil. During the geotechnical investigation, soil samples were also collected. These soil samples were then sent to a soil laboratory to evaluate the chemical parameters of the soil. The physical and chemical soil data was then utilised in the MEDLI model.

The company that carried out the geotechnical investigation work was Jamstone Pty Ltd. The work was carried out by a Principal Engineering Geologist, Josef Major, from Jamstone Pty Ltd. The field work for the geotechnical investigation was carried out between September 9 and 13 2021. The scope of works for the geotechnical investigation included the following:

- Carrying out onsite investigations of the proposed irrigation area and detailing the soil profile and characteristics down to a depth of 2.4m using the below proposed method:
    - The onsite investigations and soil sampling were carried out using a push tube to a depth of 1 – 1.2m and then use a backhoe bucket to expose the remaining soil profile to the depth of 2.4m. This provided the best solution for collecting undisturbed soil samples for the remaining depth from 1 to 2.4m.
- Photos of each step of the process was takes to provide evidence of the site soil and site conditions.
- Soil samples were collected from 5 locations within the proposed irrigation area to a depth of 2.4m.

Photos showing the geotechnical investigation and soil sample collection were provided in Figure 3.2 and Figure 3.3 below.

Figure 3.2 Soil Sampling of distinct soil layer using Push Tube

Figure 3.3 View of typical subsurface soil profile within the proposed irrigation area

The final geotechnical investigation report, prepared by Josef major from Jamstone Pty Ltd, can be found in Appendix A.

3.4 Site Investigation Findings

The development of the open-cut mine for the Winchester South Project will be developed on Mining Lease ML700049 and ML700050 and will be located south-east of the existing Poitrel and Eagle Downs Mines and east of the existing Saraji Mine. The project site is roughly rectangular in shape and is oriented north-north-west to south-south-east and is bisected in the central northern part by the north-east trending Norwich Park Rail Line. The Isaac River is located adjacent and to the east of the project site. An existing hard rock quarry, which is operated by Quarrico, is located in the northern central part of the project site.

The site investigation confirmed the presence of clayey residual soil, including remnant sedimentary rock fragments and petrified wood. The residual soil was underlain in a few test pits by sedimentary rocks consistent with typical coal measures lithology. It was noted that no groundwater was encountered in any of the test pits.

3.5 Geotechnical Investigation Findings

From the geotechnical investigation, it was noted that the proposed irrigation area is underlain by the following geological unit, based on reference to the Department of Natural Resources and Mines online maps:

- Tertiary and Quaternary age residual and colluvial deposits comprising clay, silt, sand and gravel

Other geological units mapped in the adjacent areas, within the Winchester South Project site comprise of the following:

- Holocene age flood-plain alluvium comprising clay, silt, sand and gravel.
- Quaternary age residual and colluvial sediments, commonly basalt derived, comprising black soil, silt and mud.
- Tertiary and Quaternary age high level residual, colluvial and alluvial terrace sediments comprising clay, silt, sand and gravel.

- Early Cretaceous age intrusive rocks comprising gabbro, leuco-diorite, biotite-hornblende granodiorite, microgranite, rhyolite and trachyte.
- Rewan Group - Early to Middle Triassic age sedimentary rocks comprising lithic sandstone, pebbly lithic sandstone, green to reddish-brown mudstone and minor volcanolithic pebble conglomerate.
- Rangal Coal Measures - Late Permian age sedimentary rocks comprising calcareous sandstone, calcareous shale, mudstone, coal and concretionary limestone.
- Fort Cooper Coal Measures - Late Permian age sedimentary rocks comprising lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, tuff and tuffaceous mudstone

Based on the test pit data collected during the geotechnical investigation, the subsurface conditions in the proposed irrigation area are summarised below:

- Topsoil – the topsoil comprised dark grey or dark grey-brown clay or silty clay with trace of sand or gravel size rock fragments. The 0.2 m to 0.3 m thick topsoil is distinguished from the underlying high plasticity clay by the presence of rootlets and its self-mulching, granular structure.
- Clay and Silty Clay – dark grey or dark grey-brown, high plasticity clay with trace of coarse grained sand. The clayey soil underlying the topsoil typically extended to depths of between 1.1 and 1.3 m and contained various amount of 1 mm to 3 mm diameter calcareous concretions. Fissures were commonly observed in this soil layer. In test pits HA2 and HA3 the clay layer was underlain by a similar textured soil with brown grey-brown colour and dark grey mottling, which extended to depths of between 2.0 and 1.7 m respectively. With depth the fissures were typically slickensided.
- Sandy Clay or Clay – high plasticity, brown, pale brown or pale orange-brown colour was encountered from between 1.3 m and 2.0 m depths to the depth of the investigation in all test pits except HA6. The proportion of fine grained quartz-lithic sand varied and the proportion of calcareous concretions was typically abundant.
- Sandstone – highly weathered, very low strength, medium grained sandstone was encountered in test pit HA6 from a depth of 2.1 m. The pale brown rock was friable.

In summary, the subsurface conditions comprised of a dark coloured clayey topsoil underlain by brown and brown-grey subsoil comprising high plasticity, fissured clay, which was in turn underlain by pale coloured clay with variable but elevated proportion of sand.

The full geotechnical investigation report from the geotechnical investigation work that was conducted, prepared by Josef major from Jamstone Pty Ltd, can be found in Appendix A.

4 Soil Laboratory Work

In order to obtain the chemical characteristics of the soil samples collected from the proposed irrigation area for the Winchester South Project, the soil samples collected from the site were sent to a National Association of Testing Authorities (NATA) accredited laboratory for testing. The NATA accredited laboratory that was selected to conduct the testing was the Southern Cross University Environmental Analysis Laboratory (EAL). For the Winchester South Project, there were 5 sampling locations. From the 5 sampling locations, a soil sample was collected from each of the different horizons to a depth of 2.4 m. SSI prepared 2 kg sub samples from each horizon for each of the 5 sample locations for analyses by EAL. In total, there were 15 soil samples sent to EAL for analysis.

4.1 Description of the Laboratory

The Environmental Analysis Laboratory (EAL) has been operating since 1993 and is part of the Southern Cross University Lismore campus. Along with the partner laboratory, the Analytical Research Laboratory (ARL), EAL sits within the Southern Cross Analytical Research Services Unit. EAL specialises in a range of quality analytical services, which include the following:

- Agricultural soil testing;
- Plant testing;
- Acid sulphate soil testing;
- Acid sulphate rock testing;
- Compost testing;
- Potting mix testing;
- Landscape soil testing;
- Contaminant testing;
- Environmental soil testing; and
- Water testing.

EAL holds NATA accreditation, Accreditation no. 14960, for a wide range of tests and are accredited for compliance with ISO/IEC 17025 testing. All analysis conducted by EAL is backed by rigorous quality control procedures, with proven reproducibility through regular proficiency trials.

4.2 Laboratory Scope of Works

The scope of works for EAL was to test the soil samples collected from the proposed irrigation area and determine the chemical characteristics of the soil samples. The chemical characteristics that EAL tested for along with the testing method used and the margin of error on the analyses method can be found below in Table 4.1.

Table 4.1 Soil Testing Parameters, Testing Method and Margin of Error

Soil Testing Parameters	Test Method	Margin of Error
Saturated Hydraulic Conductivity	Rosetta Pedotransfer Functions in RETC	10%
Saturated Water content	Pedotransfer model	10%
Emerson Class Number	AS 1289.3.8.1-2017	10%
Shrink/swell test	AS 1289.1.1 (2009) AS 1289.3.1.2 (2009)	No published value

<table>
<tr><th colspan="3">Soil Testing Parameters</th><th>Test Method</th><th>Margin of Error</th></tr>
<tr><td colspan="3"></td><td>AS 1289.3.2.1 (2009)
AS 1289.3.3.1 (2009)
AS 1289.3.4.1 (2009)</td><td></td></tr>
<tr><td colspan="3">P sorption capacity</td><td>In-house S18b (based on Abbott 1985)</td><td>10%</td></tr>
<tr><td colspan="3">P sorption index</td><td>In-house S18b (based on Abbott 1985)</td><td>10%</td></tr>
<tr><td colspan="3">Sodium</td><td>Base saturation calculations</td><td>10%</td></tr>
<tr><td colspan="3">Cation exchangeable capacity (CEC)</td><td>Calculation: Sum of Ca, Mg, K, Na, Al, H</td><td>10%</td></tr>
<tr><td colspan="3">Exchangeable cations Ca, Mg, K, Na, Al, H</td><td>Rayments & Lyons 2011 – 15D3 (Ammonium Acetate) (for Ca, Mg, K & Na)
In-house S37 (KCl) (for Al)
Rayments & Lyons 2011 – 15G1 (Acidity Titration) (for H)</td><td>10% (20% for Na)</td></tr>
<tr><td colspan="3">Organic N</td><td>Calculation</td><td>10%</td></tr>
<tr><td colspan="3">Nitrate N</td><td>In-house S37 (KCl)</td><td>10%</td></tr>
<tr><td colspan="3">Initial soil solution P</td><td>MEDLI P Adsorption Isotherm Parameter Calculator</td><td>10%</td></tr>
<tr><td colspan="3">Freundlich Isotherm Parameters
• Adsorption exponent
• Adsorption coefficient
• Desorption exponent</td><td>MEDLI P Adsorption Isotherm Parameter Calculator</td><td>10%</td></tr>
<tr><td rowspan="4">1:5 Soil:water ratio</td><td>pH</td><td>pH</td><td>Rayment & Lyons 2011 – 4A1 (1:5 Water)</td><td>10%</td></tr>
<tr><td>EC</td><td>Electrical conductivity</td><td>Rayment & Lyons 2011 – 3A1 (1:5 Water)</td><td>10%</td></tr>
<tr><td>Cl</td><td>Chloride</td><td>Rayment & Lyons 2011 – 5A3a</td><td>10%</td></tr>
<tr><td>NO_3-N</td><td>Nitrate nitrogen</td><td>In-house S37 (KCl)</td><td>10%</td></tr>
<tr><td></td><td>TN</td><td>Total Nitrogen</td><td>In-house S4a (LECO Trumac Analyser)</td><td>10%</td></tr>
<tr><td></td><td>TC</td><td>Total carbon</td><td>In-house S4a (LECO Trumac Analyser)</td><td>10%</td></tr>
<tr><td></td><td>P</td><td>Phosphorus (Colwell)</td><td>Rayment & Lyons 2011 – 9B2 (Colwell)</td><td>10%</td></tr>
</table>

Soil Testing Parameters			Test Method	Margin of Error
	ADMC	Air dry moisture content (40°C)	Pedotransfer model	10%
	1/3 Bar	Field capacity moisture	Pedotransfer model	10%
	15 Bar	Permanent wilting point	Pedotransfer model	10%
Particle Size analysis PSA	Clay	Clay: hydrometer <2 µm	Hydrometer Analysis Method	10%
	Silt	Silt: hydrometer 2 – 20 µm		
	Fine sand	Fine sand: Sieve 0.02 – 0.2 mm		
	Coarse sand	Coarse sand: Sieve 0.2 – 2.0 mm		
	Bulk Density		AS 4419-2003	10%
Phosphorus adsorption curve (isotherm)	Multiple (~5) additions of P to extract solution		MEDLI P Adsorption Isotherm Parameter Calculator	10%

4.3 Laboratory QA/ QC process

The EAL soil testing quality assurance and quality control (QA/QC) process is outlined within this section. For the chemical tests conducted on the soil samples, these tests are run in batches with the test blanks to assess the reagent used in the chemical tests as well as with the laboratory control standard to confirm the test method is performing as they should. A duplicate test was also completed for the chemical tests conducted on the soil samples to assess the repeatability of the chemical tests conducted on the soil samples. The instruments used to conduct the chemical tests are calibrated on a daily basis and instrument check standards are included with each instrument run. It is important to note that the EAL laboratory undertakes proficiency testing and participate in the Global Proficiency ASPAC (Australasian Soil and Plant Analysis Council) program.

In terms of the physical property tests carried out on the soil samples, inter-lab testing was undertaken, particularly for particle size analysis. Duplicate samples for physical property tests are run every 20 samples. In addition to this, the Emerson Aggregate tests are calibrated by laboratory staff through conducting blind tests within the laboratory on a 6 monthly basis.

The Atterberg Limits tests were undertaken by a subcontracted laboratory. The quality assurance procedure followed by the subcontracted laboratory when undertaking Atterberg Limits tests involves evaluating the test results against the acceptance criteria defined in the ASTM (American Society for Testing and Materials) E178-16. A quality control report is then completed for the Atterberg Limits tests conducted to evaluate the testing conducted and to make a note of anything unusual that was detected during the testing. The quality control process for the subcontracted laboratory involves conducting a yearly cycle of in-house proficiency training.

Full details on the EAL QA/QC process, along with the results from the QA/QC process, can be found in Appendix H.

4.4 Field Soil Sampling, Soil Processing and Transport

4.4.1 Field Soil Sampling Collection for Laboratory Analyses

The soil sampling procedure that was utilised to collect the required soil samples from the Winchester South site was to excavate a test pit to the first distinct soil layer and then collect an undisturbed core soil sample by pushing a U50 push tube into the soil layer with a backhoe bucket. The push tube was then retrieved from the soil layer and then the push tube containing the soil sample was sealed using 30 mm Duct Tape. This soil sample collection method using push tubes was repeated for each of the distinct soil layers at the soil sampling location up to a depth of 2.4 m. It is important to note that the test pit was terraced to allow safe access and to allow for a record of the soil profile to be made. These push tubes were then sealed and transported to the SSI Brisbane office in Fortitude Valley.

For soil layers where the push tube could not be used, the soil sample was collected using a backhoe bucket to expose the soil horizons and the soil samples from these layers were transported to the SSI Brisbane Office using bulk soil sampling bags.

4.4.2 SSI Soil Processing to Prepare Laboratory Samples

Once SSI received the soil samples that were collected during the geotechnical investigation, SSI processed the soil samples, using one of the methods outlined below, and prepared 2 kg subsamples for each horizon of each of the 5 soil sample locations for transportation to EAL. A total of 15 samples were prepared and transported to EAL for analyses.

4.4.2.1 Push Tube Samples

For the soil samples that were received in push tubes, the soil processing process involved cutting the push tubes containing the soil samples collected in half using an angle grinder, in order to extract the soil samples from the tubes. Once the soil samples in the push tubes were all extracted, these soil samples were placed into zip-lock bags, which were labelled as per the naming convention outlined in *21028 SOP-T001 Geotechnical Investigation & Soil Sampling*. It is important to note that each of the zip-lock bags were filled with the soil samples from the push tubes to a weight of up to 2 kg.

4.4.2.2 Bulk Soil Sample Bags

For the soil samples that were received in bulk soil sample bags, the soil processing involved mixing the bulk soil sample in each bag and filling zip-lock bags to a weight of up to 2 kg. The zip-lock bags were labelled as per the naming convention outlined in *21028 SOP-T001 Geotechnical Investigation & Soil Sampling*.

Photos of all the soil samples that were sent to EAL can be found in Appendix B.

Once all of the soil samples were processed and packaged into labelled zip-lock bags, the soil samples were then packed into an esky for transport to the soil testing laboratory EAL at the Southern Cross University at Lismore NSW. A signed Chain of Custody was also placed in the esky and was transported to the laboratory along with the soil samples. A copy of the Chain of Custody that was placed in the esky that went to EAL is attached in Appendix C.

4.5 Soil Laboratory Results and Description

The required soil testing for the soil samples collected were conducted by EAL and a summary of the results from the tests conducted are outlined below in Table 4.2,

Table 4.3,

Table 4.4, Table 4.5 and Table 4.6. A copy of the full test results for the soil testing conducted is attached in Appendix D.

Table 4.2 Grain Size Analysis Results

SAMPLE ID	TEXTURE USDA classification	MOISTURE CONTENT (105 °C) (% Moisture)	GRAVEL > 2 mm (%)	SAND > 50 µm USDA (< 2 mm fraction)	SILT 2−50 µm USDA (< 2 mm fraction)	CLAY < 2 µm (< 2 mm fraction)
21028-210910- HA1- H1 (0-0.5m)	Clay	2.9%	15.5%	40.0%	17.9%	42.2%
21028-210910- HA1- H2 (0.6-1.0m)	Clay	3.0%	9.1%	39.4%	18.0%	42.6%
21028-210910- HA1- H3 (1.3-1.6m)	Clay Loam	1.7%	23.6%	39.1%	29.0%	31.9%
21028-210910- HA2- H1 (0-0.5m)	Clay	3.8%	0.8%	16.6%	19.7%	63.6%
21028-210910- HA2- H2 (0.6-1.6m)	Clay	3.7%	0.7%	39.2%	14.3%	46.5%
21028-210910- HA2- H3 (2.1-2.3m)	Clay	2.7%	3.0%	38.8%	15.9%	45.2%
21028-210910- HA3- H1 (0-1.2m)	Sandy Clay	2.8%	2.9%	45.2%	15.2%	39.6%
21028-210910- HA3- H2 (1.3-1.6m)	Clay	2.8%	0.7%	32.6%	18.7%	48.8%
21028-210910- HA3- H3 (2.1-2.2m)	Sandy Clay Loam	1.9%	18.2%	60.0%	9.4%	30.7%
21028-210910- HA5- H1 (0-0.4m)	Clay	3.6%	1.8%	29.6%	16.4%	54.0%

SAMPLE ID	TEXTURE USDA classification	MOISTURE CONTENT (105 °C) (% Moisture)	GRAVEL > 2 mm (%)	SAND > 50 µm USDA (< 2 mm fraction)	SILT 2–50 µm USDA (< 2 mm fraction)	CLAY < 2 µm (< 2 mm fraction)
21028-210910- HA5- H2 (0.7-1.1m)	Clay	3.4%	1.0%	29.4%	18.3%	52.3%
21028-210910- HA5- H3 (1.2-1.6m)	Clay	3.3%	0.4%	29.9%	17.7%	52.4%
21028-210910- HA6- H1 (0-0.5m)	Clay	3.3%	0.2%	38.0%	19.2%	42.8%
21028-210910- HA6- H2 (0.6-1.2m)	Clay	3.3%	0.6%	26.5%	22.0%	51.5%
21028-210910- HA6- H3 (2.1-2.3m)	Sandy Loam	3.0%	6.2%	54.2%	31.0%	14.8%

NOTE:

1. **The Hydrometer Analysis method was used to determine the percentage sand, silt and clay, modified from SOP meth004 (California Dept. of Pesticide Regulation), using method of Gee&Bauder (1986)," & in Methods of Soil Analysis. Part 1 Agron. Monogr. 9 (2nd Ed). Klute, A., American Soc. of Agronomy Inc., Soil Sci. Soc. America Inc., Madison WI: 383-411.**
2. **The texture classification was based on the hydrometer results and the appropriate texture triangle.**

Table 4.3 Atterberg Limits Test Results

SAMPLE ID	Liquid limit (W_L)	Plastic limit (W_P)	Plasticity Index (I_P)	Linear Shrinkage (I_s)
21028-210910- HA1- H1 (0-0.5m)	44%	17%	27%	15.0%
21028-210910- HA1- H2 (0.6-1.0m)	48%	19%	29%	15.0%
21028-210910- HA1- H3 (1.3-1.6m)	28%	12%	16%	11.0%
21028-210910- HA2- H1 (0-0.5m)	56%	20%	36%	16.0%
21028-210910- HA2- H2 (0.6-1.6m)	56%	19%	37%	16.0%
21028-210910- HA2- H3 (2.1-2.3m)	52%	16%	36%	14.0%
21028-210910- HA3- H1 (0-1.2m)	44%	16%	28%	13.0%
21028-210910- HA3- H2 (1.3-1.6m)	50%	17%	33%	15.0%
21028-210910- HA3- H3 (2.1-2.2m)	36%	14%	22%	9.5%
21028-210910- HA5- H1 (0-0.4m)	50%	16%	34%	12.5%

SAMPLE ID	Liquid limit (W_L)	Plastic limit (W_P)	Plasticity Index (I_P)	Linear Shrinkage (I_s)
21028-210910- HA5- H2 (0.7-1.1m)	57%	18%	39%	16.0%
21028-210910- HA5- H3 (1.2-1.6m)	58%	17%	41%	14.5%
21028-210910- HA6- H1 (0-0.5m)	54%	18%	36%	15.0%
21028-210910- HA6- H2 (0.6-1.2m)	64%	18%	46%	14.0%
21028-210910- HA6- H3 (2.1-2.3m)	45%	21%	24%	12.5%

Sub - ASCT Laboratories report # 2440**

Note: N/A - Not obtainable, NP - Non Plastic

NOTES:

1. **AS 1289.1.1: (2001)Preparation of disturbed soil samples for testing**
   AS 1289.3.1.2: (2009)Liquid Limit, One point Casagrande
   AS 1289.3.2.1: (2009)Plastic Limit of a soil
   AS 1289.3.3.1: (2009)Plasticity Index of a soil
   AS 1289.3.4.1: (2008)Linear Shrinkage of a soil

Table 4.4 MEDLI Phosphorous Adsorption Isotherm Parameter Calculator Results

SAMPLE ID	Colwell P (mg/kg solution)	Adsorption Coefficient	Adsorption Exponent	Desorption Exponent
21028-210910- HA1- H1 (0-0.5m)	13.12	15.57	1.1608	1.1027
21028-210910- HA1- H2 (0.6-1.0m)	10.5	32.89	0.8498	0.8073
21028-210910- HA1- H3 (1.3-1.6m)	9.18	27.43	1.0531	1.0005
21028-210910- HA2- H1 (0-0.5m)	13.12	79.65	0.5082	0.4828
21028-210910- HA2- H2 (0.6-1.6m)	10.17	148.72	0.3668	0.3485
21028-210910- HA2- H3 (2.1-2.3m)	11.15	212.86	0.2435	0.2313
21028-210910- HA3- H1 (0-1.2m)	9.84	95.62	0.5128	0.4872
21028-210910- HA3- H2 (1.3-1.6m)	8.86	65.94	0.559	0.531
21028-210910- HA3- H3 (2.1-2.2m)	8.2	8.23	0.9196	0.8736
21028-210910- HA5- H1 (0-0.4m)	10.5	112.47	0.4856	0.4613
21028-210910- HA5- H2 (0.7-1.1m)	9.51	199.84	0.378	0.3591

SAMPLE ID	Colwell P (mg/kg solution)	Adsorption Coefficient	Adsorption Exponent	Desorption Exponent
21028-210910- HA5- H3 (1.2-1.6m)	7.87	181.76	0.3019	0.2868
21028-210910- HA6- H1 (0-0.5m)	11.48	229.19	0.2536	0.241
21028-210910- HA6- H2 (0.6-1.2m)	9.18	197.13	0.2876	0.2732
21028-210910- HA6- H3 (2.1-2.3m)	14.76	298.88	0.1401	0.1331

Table 4.5 Soil Hydraulic Properties Test Results

Client ID	Bulk Density at 10kPa (t DW/m^3)	% Sand > 50 µm	% Silt 2–50 µm	% Clay < 2 µm	van Genuchten parameters					Field capacity (FC)		Permanent wilting point(PWP)	Plant Available Water capacity (PAW)		Air-filled porosity at Field Capacity (cm^3/cm^3)	
					thetaR	thetaS	alpha	n	Ksat (cm/day)	10 kPa or 0.1 Bar	33 kPa or 0.33 Bar	1500 kPa or 15 Bar	assuming FC is at 10 kPa	assuming FC is at 33 kPa	assuming FC is at 10 kPa	assuming FC is at 33 kPa
		from hydrometer determinations			*from Rosetta pedotransfer functions in RETC*											
21028-210910-HA1- H1 (0-0.5m)	1.45	39.96	17.87	42.17	0.0882	0.4409	0.0194	1.2899	12.27	36%	29%	16%	20%	13%	10%	16%
21028-210910-HA1- H2 (0.6-1.0m)	1.45	39.40	18.04	42.56	0.0886	0.4413	0.0194	1.2891	12.15	36%	29%	16%	20%	13%	9%	16%
21028-210910-HA1- H3 (1.3-1.6m)	1.39	39.13	29.01	31.86	0.0804	0.4392	0.0137	1.4151	11.22	35%	26%	12%	23%	15%	12%	21%
21028-210910-HA2- H1 (0-0.5m)	1.45	16.64	19.73	63.63	0.0986	0.4603	0.0187	1.2314	8.65	39%	33%	20%	19%	13%	6%	12%
21028-210910-HA2- H2 (0.6-1.6m)	1.45	39.23	14.25	46.52	0.0916	0.4456	0.0213	1.2590	13.34	36%	30%	17%	19%	13%	9%	15%
21028-210910-HA2- H3 (2.1-2.3m)	1.45	38.84	15.94	45.22	0.0907	0.4443	0.0204	1.2702	12.8	36%	30%	17%	20%	13%	9%	15%

Client ID	Bulk Density at 10kPa (t DW/m^3)	% Sand > 50 µm	% Silt 2–50 µm	% Clay < 2 µm	van Genuchten parameters					Field capacity (FC)		Permanent wilting point(PWP)	Plant Available Water capacity (PAW)		Air-filled porosity at Field Capacity (cm^3/cm^3)	
					thetaR	thetaS	alpha	n	Ksat (cm/day)	10 kPa or 0.1 Bar	33 kPa or 0.33 Bar	1500 kPa or 15 Bar	assuming FC is at 10 kPa	assuming FC is at 33 kPa	assuming FC is at 10 kPa	assuming FC is at 33 kPa
21028-210910-HA3- H1 (0-1.2m)	1.65	45.21	15.17	39.62	0.0759	0.3835	0.0240	1.2049	5.54	32%	27%	17%	15%	11%	6%	11%
21028-210910-HA3- H2 (1.3-1.6m)	1.45	32.57	18.66	48.78	0.0933	0.4481	0.0194	1.2691	11.26	37%	30%	17%	20%	13%	8%	15%
21028-210910-HA3- H3 (2.1-2.2m)	1.60	59.95	9.36	30.69	0.0691	0.3879	0.0252	1.2497	12.99	31%	25%	14%	17%	11%	9%	14%
21028-210910-HA5- H1 (0-0.4m)	1.45	29.59	16.44	53.97	0.0960	0.4524	0.0203	1.2457	11.27	37%	31%	18%	19%	13%	8%	14%
21028-210910-HA5- H2 (0.7-1.1m)	1.45	29.39	18.27	52.35	0.0952	0.4515	0.0196	1.2565	11.1	37%	31%	18%	20%	13%	8%	14%
21028-210910-HA5- H3 (1.2-1.6m)	1.45	29.94	17.70	52.36	0.0952	0.4514	0.0198	1.2545	11.21	37%	31%	18%	19%	13%	8%	14%
21028-210910-HA6- H1 (0-0.5m)	1.45	38.05	19.20	42.75	0.0888	0.4415	0.0189	1.2934	11.56	36%	29%	16%	20%	13%	9%	16%

Client ID	Bulk Density at 10kPa (t DW/m^3)	% Sand > 50 µm	% Silt 2–50 µm	% Clay < 2 µm	van Genuchten parameters					Field capacity (FC)		Permanent wilting point(PWP)	Plant Available Water capacity (PAW)		Air-filled porosity at Field Capacity (cm^3/cm^3)	
					thetaR	thetaS	alpha	n	Ksat (cm/day)	10 kPa or 0.1 Bar	33 kPa or 0.33 Bar	1500 kPa or 15 Bar	assuming FC is at 10 kPa	assuming FC is at 33 kPa	assuming FC is at 10 kPa	assuming FC is at 33 kPa
21028-210910-HA6- H2 (0.6-1.2m)	1.45	26.49	21.99	51.52	0.0948	0.4517	0.0183	1.2717	10.25	37%	31%	17%	20%	14%	8%	14%
21028-210910-HA6- H3 (2.1-2.3m)	1.47	54.22	30.97	14.81	0.0497	0.3857	0.0179	1.4451	24.07	28%	20%	8%	20%	12%	17%	25%

NOTE:

1. **The Hydrometer Analysis method was used to determine the percentage sand, silt and clay under the USDA soil classification, based on SOP meth004 (California Dept of Pesticide Regulation), using hydrometer method of Gee & Bauder. Reference: Gee GW & Bauder JW (1986) Particle-size Analysis. In Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods - Agronomy monograph no. 9 (Second Edition), American Society of Agronomy-Soil Science Society of America, WI.**
2. **Predicted van Genuchten soil water retention curve (SWRC) parameters are derived from Rosetta pedotransfer routines within RETC. References: Rosetta: Schaap MG (2001) 'ROSETTA', Version 1.2, US Salinity Laboratory ARS-USDA, Riverside CA. Rosetta software is incorporated into RETC software: van Genuchten, M. T., Simunek, J., Leij, F. J. & Sejna, M. (2000). RETC ("RETention Curve") - Code for Quantifying the Hydraulic Functions of Unsaturated Soils. Riverside, CA, US Salinity Laboratory, USDA, ARS.**
3. **Plant Available Water Capacity is the difference between Field Capacity and Permanent Wilting Point.**
4. **Accuracy of Field Capacity, Permanent Wilting Point, Plant Available Water and Air-filled Porosity depends on reliable values for Bulk Density, preferably provided by the client. Accuracy of Air-filled Porosity also assumes average Particle Density to be 2.65 g/cm3 which may differ from actual values, especially if heavier minerals are present.**

Table 4.6 Agricultural Soil Analysis Test Results

Sample ID:	21028-210910-HA1- H1 (0-0.5m)	21028-210910-HA1- H2 (0.6-1.0m)	21028-210910-HA1- H3 (1.3-1.6m)	21028-210910-HA2- H1 (0-0.5m)	21028-210910-HA2- H2 (0.6-1.6m)	21028-210910-HA2- H3 (2.1-2.3m)	21028-210910-HA3- H1 (0-1.2m)	21028-210910-HA3- H2 (1.3-1.6m)	21028-210910-HA3- H3 (2.1-2.2m)	21028-210910-HA5- H1 (0-0.4m)	21028-210910-HA5- H2 (0.7-1.1m)	21028-210910-HA5- H3 (1.2-1.6m)	21028-210910-HA6-H1 (0-0.5m)	21028-210910-HA6-H2 (0.6-1.2m)	21028-210910-HA6-H3 (2.1-2.3m)
Parameter															
Soluble Calcium (mg/kg)	10,129	9,227	9,436	3,017	2,349	1,200	4,652	4,827	9,222	3,680	1,818	1,337	2,262	2,369	1,034
Soluble Magnesium (mg/kg)	541	928	732	425	613	485	624	669	613	563	540	458	435	560	417
Soluble Potassium (mg/kg)	45	29	27	39	<25	<25	<25	<25	33	<25	<25	<25	<25	<25	30
Soluble Phosphorus (mg/kg)	2.8	2.1	1.6	1.8	1.3	<1	1.6	1.2	1.4	1.5	1.2	<1	1.0	1.0	<1
Phosphorus (mg/kg P)	4.8	<1	<1	1.3	<1	1.3	<1	<1	<1	<1	1.4	<1	<1	<1	3.0
	13	10	9.2	13	10	11	9.8	8.9	8.2	10	9.5	7.9	11	9.2	15
	36	11	6.0	6.0	6.5	1.9	1.7	3.0	2.2	2.4	2.4	1.2	2.4	3.4	4.4
Nitrate Nitrogen (mg/kg N)	11	1.1	0.81	3.3	1.8	0.86	1.0	0.75	0.93	4.7	1.1	0.88	1.5	1.2	0.85
Ammonium Nitrogen (mg/kg N)	9.0	7.2	7.8	9.3	6.9	9.5	6.2	5.1	5.3	6.4	5.9	5.7	5.7	7.4	6.2
Sulfur (mg/kg S)	54	44	100	12	105	214	44	113	64	7.5	12	47	9.7	65	73
pH	8.64	8.85	8.78	8.20	7.73	5.17	8.65	8.50	9.05	8.82	7.65	6.24	7.39	7.21	5.30

Sample ID:		21028-210910-HA1- H1 (0-0.5m)	21028-210910-HA1- H2 (0.6-1.0m)	21028-210910-HA1- H3 (1.3-1.6m)	21028-210910-HA2- H1 (0-0.5m)	21028-210910-HA2- H2 (0.6-1.6m)	21028-210910-HA2- H3 (2.1-2.3m)	21028-210910-HA3- H1 (0-1.2m)	21028-210910-HA3- H2 (1.3-1.6m)	21028-210910-HA3- H3 (2.1-2.2m)	21028-210910-HA5- H1 (0-0.4m)	21028-210910-HA5- H2 (0.7-1.1m)	21028-210910-HA5- H3 (1.2-1.6m)	21028-210910-HA6-H1 (0-0.5m)	21028-210910-HA6-H2 (0.6-1.2m)	21028-210910-HA6-H3 (2.1-2.3m)
Electrical Conductivity (dS/m)		0.151	0.696	1.045	0.191	1.373	1.638	0.460	1.320	0.814	0.224	1.057	1.307	0.165	1.050	1.090
Estimated Organic Matter (% OM)		4.2	2.9	7.6	2.9	1.4	0.35	1.8	0.65	1.8	1.9	1.3	0.44	1.8	1.4	0.24
Exchangea -ble Calcium	**$cmol_{+}$/ kg**	35	32	28	32	25	14	25	27	24	29	23	17	27	24	15
	kg/ha	15,785	14,418	12,432	14,159	11,352	6,216	11,403	11,957	10,758	12,815	10,104	7,656	11,984	10,671	6,928
	mg/kg	7,047	6,437	5,550	6,321	5,068	2,775	5,091	5,338	4,803	5,721	4,511	3,418	5,350	4,764	3,093
Exchangea -ble Magnesium	**$cmol_{+}$/ kg**	5.4	10	7.0	7.0	11	8.4	7.0	7.7	5.6	7.3	9.1	8.2	7.8	9.5	8.5
	kg/ha	1,480	2,771	1,902	1,909	2,878	2,294	1,894	2,089	1,524	1,977	2,475	2,244	2,120	2,580	2,325
	mg/kg	661	1,237	849	852	1,285	1,024	846	933	680	883	1,105	1,002	946	1,152	1,038
Exchangea -ble Potassium	**$cmol_{+}$/ kg**	0.32	0.23	0.17	0.48	0.23	0.18	0.17	0.18	0.20	0.15	0.17	0.18	0.32	0.27	0.32
	kg/ha	281	205	148	418	204	159	147	162	172	130	146	157	282	233	285
	mg/kg	126	91	66	187	91	71	65	72	77	58	65	70	126	104	127
Exchangea -ble Sodium	**$cmol_{+}$/ kg**	0.58	5.8	5.9	1.2	9.0	8.3	3.8	8.4	6.1	2.6	8.6	8.8	2.1	8.1	11
	kg/ha	301	2,985	3,034	622	4,631	4,284	1,972	4,324	3,132	1,324	4,414	4,557	1,065	4,169	5,540
	mg/kg	134	1,332	1,354	277	2,067	1,912	880	1,930	1,398	591	1,970	2,034	475	1,861	2,473

Sample ID:		21028-210910-HA1- H1 (0-0.5m)	21028-210910-HA1- H2 (0.6-1.0m)	21028-210910-HA1- H3 (1.3-1.6m)	21028-210910-HA2- H1 (0-0.5m)	21028-210910-HA2- H2 (0.6-1.6m)	21028-210910-HA2- H3 (2.1-2.3m)	21028-210910-HA3- H1 (0-1.2m)	21028-210910-HA3- H2 (1.3-1.6m)	21028-210910-HA3- H3 (2.1-2.2m)	21028-210910-HA5- H1 (0-0.4m)	21028-210910-HA5- H2 (0.7-1.1m)	21028-210910-HA5- H3 (1.2-1.6m)	21028-210910-HA6-H1 (0-0.5m)	21028-210910-HA6-H2 (0.6-1.2m)	21028-210910-HA6-H3 (2.1-2.3m)
Exchangeable Aluminium	**cmol$_+$/kg**	<0.01	0.01	<0.01	<0.01	<0.01	0.09	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.92
	kg/ha	1.4	2.4	1.5	<1	<1	18	<1	<1	<1	<1	2.1	2.5	2.1	2.5	186
	mg/kg	<1	1.1	<1	<1	<1	7.9	<1	<1	<1	<1	<1	1.1	<1	1.1	83
Exchangea-ble Hydrogen	**cmol$_+$/kg**	<0.01	<0.01	<0.01	<0.01	<0.01	0.23	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	0.46
	kg/ha	<1	<1	<1	<1	<1	5.2	<1	<1	<1	<1	<1	1.1	<1	<1	10
	mg/kg	<1	<1	<1	<1	<1	2.3	<1	<1	<1	<1	<1	<1	<1	<1	4.6
Effective Cation Exchange Capacity (ECEC) (cmol$_+$/kg)		42	48	41	40	45	31	36	43	36	39	40	34	37	42	36
Calcium (%)		85	66	68	78	56	45	70	62	67	74	56	50	72	57	42
Magnesium (%)		13	21	17	17	23	27	19	18	16	19	23	24	21	23	23
Potassium (%)		0.77	0.48	0.41	1.2	0.52	0.58	0.46	0.43	0.55	0.39	0.41	0.52	0.87	0.64	0.89
Sodium - ESP (%)		1.4	12	14	3.0	20	27	11	20	17	6.7	21	26	5.6	19	30
Aluminium (%)		0.02	0.02	0.02	0.00	0.00	0.28	0.01	0.01	0.01	0.00	0.03	0.04	0.03	0.03	2.5
Hydrogen (%)		0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	1.3
Calcium/Magnesium Ratio		6.5	3.2	4.0	4.5	2.4	1.6	3.7	3.5	4.3	3.9	2.5	2.1	3.4	2.5	1.8
Zinc (mg/kg)		2.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Sample ID:	21028-210910-HA1- H1 (0-0.5m)	21028-210910-HA1- H2 (0.6-1.0m)	21028-210910-HA1- H3 (1.3-1.6m)	21028-210910-HA2- H1 (0-0.5m)	21028-210910-HA2- H2 (0.6-1.6m)	21028-210910-HA2- H3 (2.1-2.3m)	21028-210910-HA3- H1 (0-1.2m)	21028-210910-HA3- H2 (1.3-1.6m)	21028-210910-HA3- H3 (2.1-2.2m)	21028-210910-HA5- H1 (0-0.4m)	21028-210910-HA5- H2 (0.7-1.1m)	21028-210910-HA5- H3 (1.2-1.6m)	21028-210910-HA6-H1 (0-0.5m)	21028-210910-HA6-H2 (0.6-1.2m)	21028-210910-HA6-H3 (2.1-2.3m)
Manganese (mg/kg)	7.2	4.1	17	21	84	18	17	23	1.3	25	66	28	61	51	20
Iron (mg/kg)	19	11	16	27	33	18	19	16	7.0	27	64	109	36	33	18
Copper (mg/kg)	1.2	0.75	0.70	1.4	1.4	0.67	0.96	0.66	0.26	1.1	1.2	1.1	1.8	1.4	0.55
Boron (mg/kg)	0.21	1.9	3.2	0.64	1.6	1.9	1.6	1.8	1.0	0.48	2.1	2.1	0.75	1.6	1.6
Silicon (mg/kg Si)	11	5.4	5.0	20	13	60	5.8	8.0	13	9.1	13	41	19	13	51
Total Carbon (%)	2.4	1.7	4.3	1.7	0.80	0.20	1.0	0.37	1.1	1.1	0.77	0.25	1.1	0.81	0.14
Total Nitrogen (%)	0.07	0.03	<0.02	0.11	0.04	<0.02	0.05	<0.02	<0.02	0.06	0.04	0.02	0.13	0.04	0.04
Carbon/Nitrogen Ratio	33	54	289	15	20	11	22	25	105	19	20	12	8.3	19	3.3
Basic Texture	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay	Clay
Basic Colour	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish
Chloride Estimate (equiv. mg/kg)	97	445	669	122	879	1,048	294	845	521	143	676	836	106	672	698
Chloride (mg/kg)	33	646	879	105	1,310	1,519	315	1,176	613	132	1,005	1,119	50	908	1,148
Phosphorus Buffer Index	113	87	114	67	85	78	106	74	41	107	127	95	80	95	51
Phosphorus Buffer Index - Colwell adj.	116	89	116	70	87	80	108	76	42	109	129	96	82	96	54
Soil Texture	Heavy clay	Medium clay	Light clay	Medium clay	Medium clay	Medium clay	Medium clay	Medium clay	Sandy clay	Medium clay	Medium clay	Medium clay	Medium clay	Medium clay	Medium clay

Sample ID:	21028-210910-HA1- H1 (0-0.5m)	21028-210910-HA1- H2 (0.6-1.0m)	21028-210910-HA1- H3 (1.3-1.6m)	21028-210910-HA2- H1 (0-0.5m)	21028-210910-HA2- H2 (0.6-1.6m)	21028-210910-HA2- H3 (2.1-2.3m)	21028-210910-HA3- H1 (0-1.2m)	21028-210910-HA3- H2 (1.3-1.6m)	21028-210910-HA3- H3 (2.1-2.2m)	21028-210910-HA5- H1 (0-0.4m)	21028-210910-HA5- H2 (0.7-1.1m)	21028-210910-HA5- H3 (1.2-1.6m)	21028-210910-HA6-H1 (0-0.5m)	21028-210910-HA6-H2 (0.6-1.2m)	21028-210910-HA6-H3 (2.1-2.3m)
Phosphorus Sorption (mg P/kg)	400	354	408	352	436	414	436	332	148	446	486	462	382	412	272
Emerson Aggregate Test (EAT)	4	4	4	4	3	4	4	4	4	4	3	3	4	3	3
Moisture Content (%)	13.2	10.9	6.5	16.1	13.5	13.1	10.0	13.1	8.7	12.8	13.1	13.5	14.2	13.5	10.7
Bulk Density (t/m^3)	1.8	1.9	1.5	1.7	1.8	1.4	1.9	1.8	1.3	1.7	1.8	1.8	1.8	1.7	1.4

NOTE:

1. **All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to < 2 mm.**
2. **Methods from Rayment and Lyons, 2011. Soil Chemical Methods - Australasia.CSIRO Publishing: Collingwood.**
3. **Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).**
4. **'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.**
5. **Guidelines for phosphorus have been reduced for Australian soils.**
6. **Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.**
7. **Total Acid Extractable Nutrients indicate a store of nutrients.**
8. **National Environmental Protection (Assessment of Site Contamination) Measure 2013, Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.**
9. **Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.**
10. **Conversions for 1 cmol+/kg = 230 mg/kg Sodium, 390 mg/kg Potassium, 122 mg/kg Magnesium, 200 mg/kg Calcium**
11. **Conversions to kg/ha = mg/kg x 2.24**
12. **The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate**
13. **** NATA accreditation does not cover the performance of this service.**

5 MEDLI Model Input

5.1 MEDLI Model Software

In order to model the proposed irrigation scheme's performance at the Winchester South project site, the QLD Department of Environment and Science's (DES) preferred modelling software, MEDLI, was used. MEDLI has been designed to simulate the operation of land disposal schemes over a 'long' period of time, typically many decades. The model's basis is a 'physical system' comprising of a field of crop or pasture, which is irrigated with water supplied from a tank or pond, known as wet weather storage. The wet weather storage provides buffer storage to hold incoming effluent at times when irrigation is not possible. MEDLI simulates the material balance in the storage systems, in the soil systems and the crop growth. The model provides estimates for the fate of applied effluent, nutrients, salts and pathogenic microorganisms, and their potential impact on the environment. The accuracy of the modelled estimates is reliant on the use of appropriate input data.

5.2 Selection Process of Key Input Parameters

When it came to setting up the MEDLI model, there were a number of key input parameters that needed to be considered and selected. These key input parameters include the following:

- Irrigation field plant selection;
- Soil parameter adjustment, including data analysis of the soil testing results; and
- MEDLI inputs for nutrient concentrations in treated effluent used for irrigation scheme.

This section of the report provides details on the process that was followed in order to determine the aforementioned key input parameters for the MEDLI modelling for the Winchester South project.

5.2.1 Irrigation Field Plant Selection Criteria

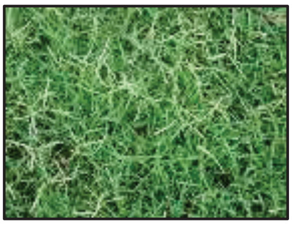
The first of the key input parameters that needed to be considered and selected was the plant species that would be used at the irrigation field. Within the MEDLI modelling software, there are a number of different types of plants that can be selected for the modelling of the irrigation area. In order to select the most appropriate plant type for the irrigation area at the Winchester South site, a number of parameters needed to be considered. These parameters included:

- Salinity tolerance;
- Nitrogen deficiency stress;
- Number of crop deaths per year and number of days without crop on the irrigation field per year;
- Impact of irrigation on deep drainage when compared to the base case scenario with no irrigation;
- Temperature stress;
- Water stress;
- Whether the plant is native or introduced; and
- Harvesting management requirements.

Table 5.1 below provide a brief description for each of the different plant species available in the MEDLI modelling software.

Table 5.1 Description of the Different Plant Species in the MEDLI Modelling Software Library (References used to compile this table are listed in the references section at the end of this report)

Plant Species	Photo of Crop Species	Description	Native/Introduced	Suitability for Winchester South
Banana Pasture		• Banana trees are tropical and originate in rainforests, so they need a lot of water and plenty of moisture in the air. Ensure that soil stays moist but not soggy. Overwatering can cause root rot. • While most banana tree species grow best in warm climates, there are also some cold-hardy banana trees. • Banana trees love organically rich, deep soil with good drainage and a slightly acidic soil pH. They typically have poor tolerance for salt in the soil. • Most types of banana trees prefer to grow in full sun, however, some varieties can scorch easily and will do better in partial shade. • Dead leaves need to be trimmed off banana trees regularly and when harvesting the bananas, pick bananas a hand at a time as they start to ripen faster once picked. Pups or suckers around the stem of the plant need to be pruned off as then can sap energy from the main stem. Leave at least 1 strong sucker per plant as a banana plant will die one it has fruited. The pup that is retained becomes the new plant.	Introduced	Not Suitable • Tropical crop, lots of water required • Poor salt tolerance • Difficult harvesting management
Blady Grass Pasture		• Blady grass is a common grass throughout Australia and other warm climates of the world. It's related to sugar cane and is an extremely tough and hardy species of grass. It is a drought and frost tolerant grass. • Blady grass requires moist well drained soils in moist and healthy woodland and lowland forest and grows well in full sun. • This plant species has many uses such as thatch for roofing,	Native	Not Suitable • Requires moist woodland and lowland environment

Plant Species	Photo of Crop Species	Description	Native/Introduced	Suitability for Winchester South
		ground cover and soil stabilisation to prevent erosion. Dry leaves are used for tinder bundles as it's extremely flammable.		
Coastal Couch Grass (Cynodon dactylon) Pasture		• Coastal Couch is a long-lived (perennial) grass. This type of grass can grow in a wide range of soils from sand to heavy clays. • Coastal Couch prefers moist sites such as stream sides, roadside drains and plains which are occasionally flooded. It is also able to tolerate dry site and forms dense mats in favourable conditions. It is tolerant of slightly to moderately saline soils but more commonly in slightly saline soils. • This grass is widely used as a turf grass species and also provides good grazing.	Introduced	Not Suitable • Prefers moist sites, such as stream sides, roadside drains and plains
Forage Sorghum Pasture		• Forage Sorghum are a group of Sorghum species and hybrids, which have been bred for forage production and are commonly used as annual forage or hay crops. This plant is typically used to provide feed for grazing animals. • Forage Sorghum performs best on heavier soils because of their greater moisture holding capacity. • This plant species is suited to deep, well-drained soils in areas receiving between 900 and 1300 mm annual rainfall. • This plant species is quite drought resistant, though water logging is detrimental to establishment and growth.	Introduced	Not Suitable • Prefers areas that receive between 900 and 1300 mm annual rainfall
Green Panic Pasture		• Green Panic is a tufted summer growing perennial species of guinea grass. It persists best on high fertility, friable, softwood scrub loams and light clays. It dislikes sand, hard setting soils	Introduced	Not Suitable • Prefers lighter soils, does not do well in harder soils

Plant Species	Photo of Crop Species	Description	Native/Introduced	Suitability for Winchester South
		and heavy-cracking black clays and is intolerant of waterlogging. • Green Panic grass needs a minimum of 600 mm annual rainfall. • Having some shad tolerance, it is often found growing under trees and shrubs. It has moderate drought tolerance. • This plant species is typically used for feeding livestock.		
Kikuyu Pasture		• With the ability to perform in most Australian climates, Kikuyu can stand up to a wide range of conditions. • Kikuyu can be a good option for both home lawns and larger spaces and is also used as pasture for livestock grazing. • Kikuyu thrives in a sunny aspect and handles full sun, and its strong, deep root base provides acceptable drought tolerance. • Kikuyu can grow in a wide range of soil types, but performs at its best in fertile, light to medium textured soil with moderate drainage and salinity level. • If irrigation is used, deeply soak the top 100mm of soil. • Frequent mowing throughout the warmer months is required due to its aggressive growth habits.	Introduced	Potentially Suitable • Can grow in full sun, performs in most Australian climates • Moderate salt tolerance • Can grow in a wide range of soil types
Lucerne (Winter Active) Pasture		• Lucerne or alfalfa is a deep-rooted, temperate, perennial pasture legume. • It has the ability to respond quickly to significant summer rainfall (>10 mm) but requires 20 – 25 mm to produce substantial growth. Once established, Lucerne has good drought tolerance and is well suited to irregular rainfall patterns, but it will appear to go	Introduced	Potentially Suitable • Can grow in a wide range of soil types • Moderate salt tolerance

Plant Species	Photo of Crop Species	Description	Native/Introduced	Suitability for Winchester South
		dormant during extended dry periods. • Lucerne can be harvested to provide a high quality feed for livestock and improve animal health. • Lucerne grows well on a wide range of well drained soils including deep loams, deep yellow and brown sands, loamy sands over clay or gravel, deep sandy duplex soils and uniform clays. • Harvesting of Lucerne typically occurs at a cutting interval of 35 – 45 days until the longest day in the year. After the longest day of the year, Lucerne needs to flower to around 50% before going back to the usual cutting interval.		
Melaleuca Alternifolia Pasture		• Melaleuca Alternifolia is a tall shrub that can reach a height of 7 m. • Melaleuca Alternifolia can cope with both moist and dry situations • This plant species is drought tolerant once established and is tolerant of most well-drained soils and situations, including waterlogging and moderate frost. • This plant responds to pruning and the leaves can be used for tea-tree oil extraction.	Native	Potentially Suitable • Can grow in most soil types • Salt Tolerant • Drought tolerant • Can cope with both moist and dry situations
Rhodes Grass Pasture		• Rhodes grass is a summer growing, stoloniferous perennial, whose runners provide good soil cover for erosion control. • Rhodes grass is adapted to a wide range of soils, from infertile sands to fertile Brigalow clays. It is difficult to establish and have it persist on heavy-cracking clay soils. • Rhodes grass does not tolerate drought or flooding well and is best adapted to areas where	Introduced	Not Suitable • Does not grow well in heavy-cracking clay soils • Does not tolerate drought or flooding well

Plant Species	Photo of Crop Species	Description	Native/Introduced	Suitability for Winchester South
		annual rainfall exceeds 600 mm. • This plant species is a valuable pasture grass for horses.		
Ryegrass Pasture		• Ryegrass is a commonly sown pasture grass that grows well in cooler climates around the world and has a great tolerance to shade. • As Ryegrass is a cool season grass it will struggle during warmer months and does get particularly thirsty through spring and summer. A heavy watering schedule over these months is advised. • Regular mowing is required over the fast growing period of spring/early summer, at least on a weekly basis during this period. • Ryegrass is excellent at dealing with harsh winter conditions, with the ability to survive heavy frosts and bleak weather with ease. • Ryegrass prefers fertile, well-drained loam or sandy loam soils, but establishes well on many soil types, including poor or rocky soils. It tolerates clay or poorly-drained soils in a range of climates as well.	Introduced	Not Suitable • Cool climate grass • Prefers to grow in the shade
Vetiver Pasture		• Vetiver is a dense, clumping perennial grass native to India and Ceylon. • It requires a hot and humid climate and is adaptable to a wide range of soil and climatic conditions. It can be established on very acid, sodic, alkaline or saline soils. Due to its extensive and deep root system, vetiver is very tolerant of drought. It can be established in areas with an annual rainfall from 450 mm and higher. • Vetiver grass is widely used in mine rehabilitation and wastewater management	Introduced	Not Suitable • Requires hot and humid conditions

Plant Species	Photo of Crop Species	Description	Native/Introduced	Suitability for Winchester South
		systems. It can also be used to reduce soil erosion and as feed for livestock.		

Through the research conducted on the different plant species offered in the MEDLI modelling software plant library, a short list of the most suitable plant types were selected. The short list of plant species included Kikuyu Pasture, Lucerne (Winter Active) Pasture and Melaleuca Alternifolia Pasture. An assessment was conducted on the 3 short listed plant species and a summary of the findings from this assessment is provided below in Table 5.2. It is important to note that this assessment was conducted based on results obtained from multi-runs conducted using the MEDLI modelling software.

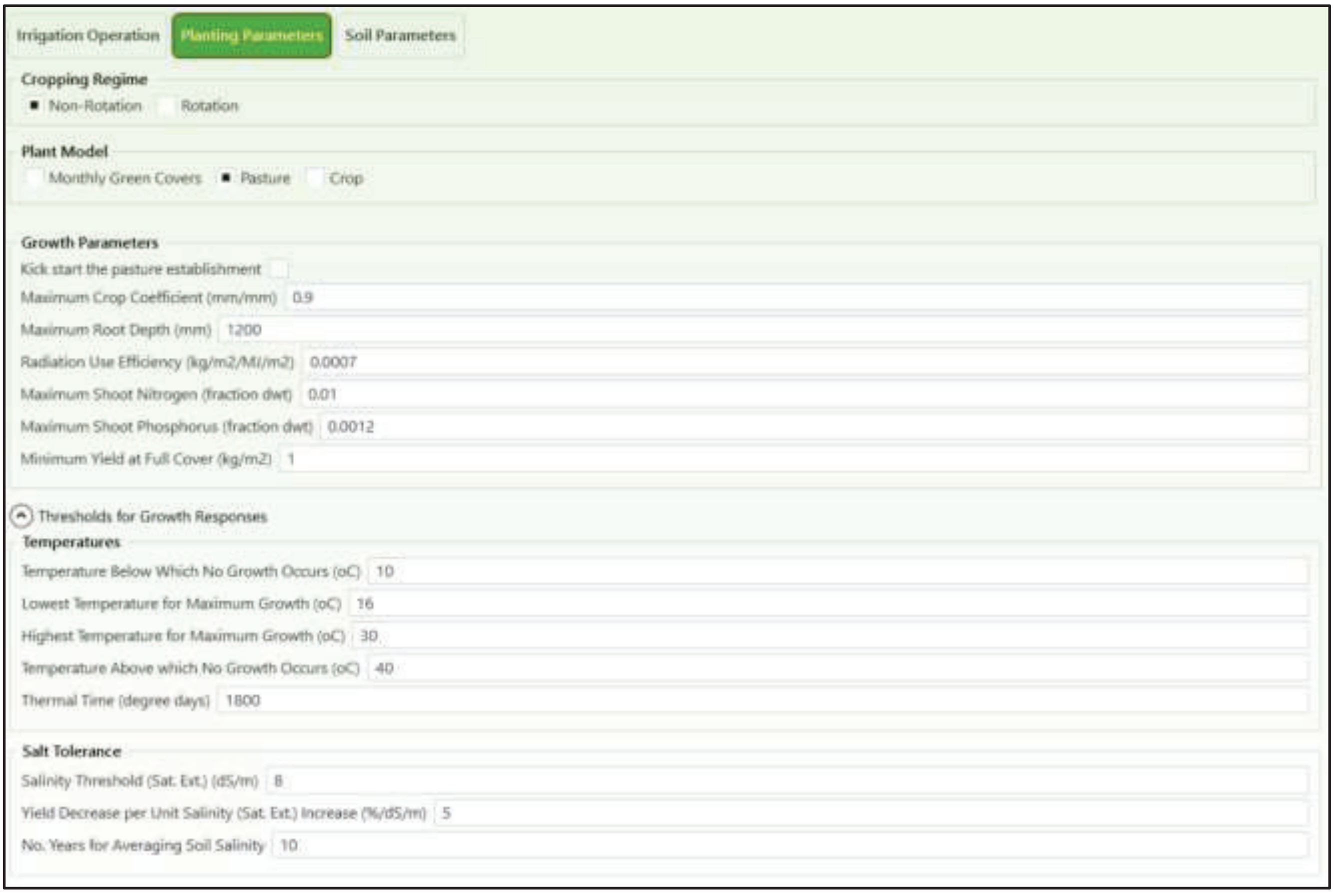
Table 5.2 Assessment of Shortlisted Plant Species

Selection Criteria	Kikuyu Pasture	Lucerne (Winter Active) Pasture	Melaleuca Alternifolia Pasture
Salinity Tolerance	Moderately Tolerant	Moderately Sensitive	Tolerant
Nitrogen Deficiency Stress	0.58 – 0.79	0.42 – 0.55	0 – 0.02
Crop Deaths per year	0	0.09 – 1.18	0.28 – 0.33
Number of days without crop per year	0	1.45 – 45.09	9.84 – 23.02
Percentage increase of deep drainage compared to base case (no irrigation)	100% - 154% increase compared to no irrigation case	250% – 1170% increase compared to no irrigation case	28% – 57% increase compared to no irrigation case
Temperature Stress	0.04 (Jan stress) and 0.46 (Jul stress)	0.04 (Jan stress) and 0.26 (Jul stress)	0.01 (Jan stress) and 0.19 (Jul stress)
Water Stress	0.12 – 0.32	0.17 – 0.26	0.07 – 0.13
Harvesting Requirements (no. of harvests/year)	2 – 3 (average of 2.45)	4 – 11 (average of 7)	0 – 1 (average of 0.45)

Note: Items highlighted in **green** are positive elements of each plant type.

From the assessment that was conducted on the short listed plant species, it was initially determined that the most suitable plant species for the Winchester South site was Melaleuca Alternifolia Pasture. The input parameters in the MEDLI library for Melaleuca Alternifolia Pasture are provided below in Table 5.3. These parameters are the input parameters that were used when completing the MEDLI modelling for the Winchester South project.

Table 5.3 MEDLI Planting Parameters for Initial Selected Plant Cover – Melaleuca Alternifolia Pasture



Irrigation Operation | Planting Parameters | Soil Parameters

Cropping Regime
Non-Rotation   Rotation

Plant Model
Monthly Green Covers   Pasture   Crop

Growth Parameters

Kick start the pasture establishment	
Maximum Crop Coefficient (mm/mm)	0.9
Maximum Root Depth (mm)	1200
Radiation Use Efficiency (kg/m2/MJ/m2)	0.0007
Maximum Shoot Nitrogen (fraction dwt)	0.01
Maximum Shoot Phosphorus (fraction dwt)	0.0012
Minimum Yield at Full Cover (kg/m2)	1

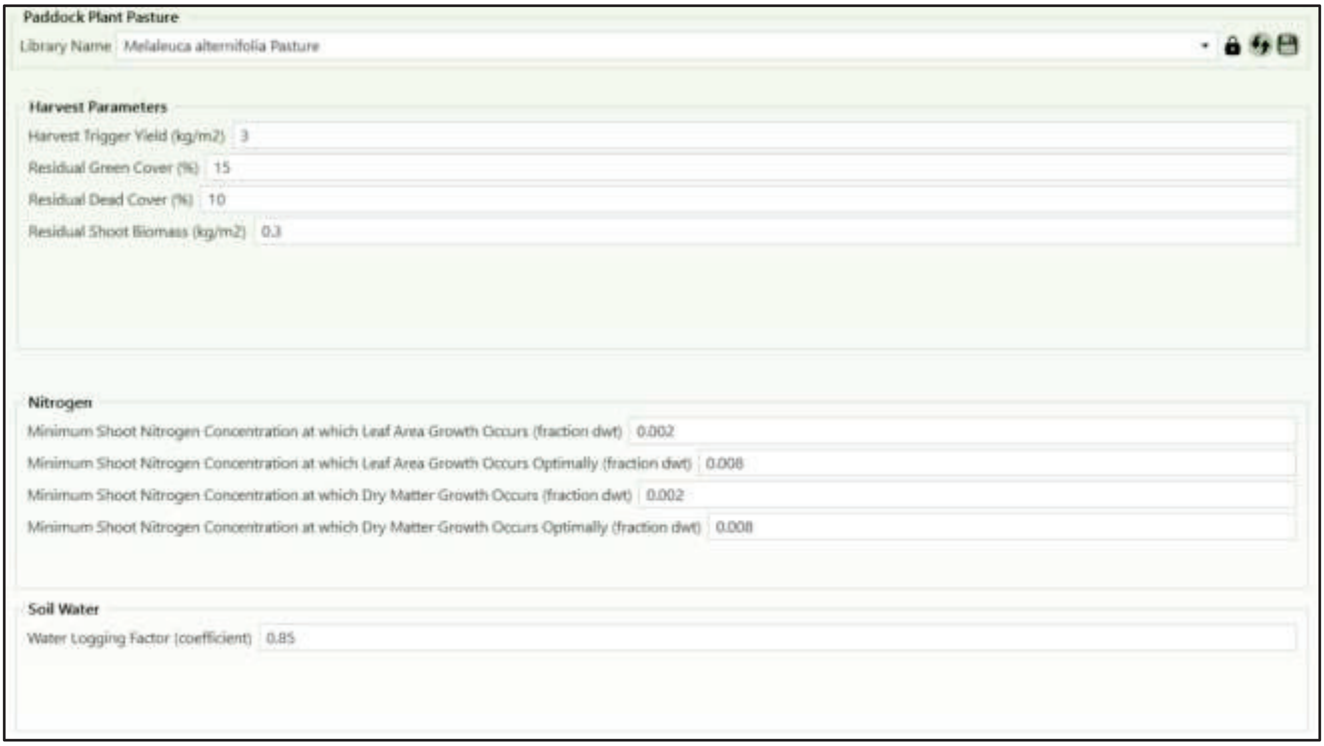
Thresholds for Growth Responses

Temperatures

Temperature Below Which No Growth Occurs (oC)	10
Lowest Temperature for Maximum Growth (oC)	16
Highest Temperature for Maximum Growth (oC)	30
Temperature Above which No Growth Occurs (oC)	40
Thermal Time (degree days)	1800

Salt Tolerance

Salinity Threshold (Sat. Ext.) (dS/m)	8
Yield Decrease per Unit Salinity (Sat. Ext.) Increase (%/dS/m)	5
No. Years for Averaging Soil Salinity	10



Paddock Plant Pasture
Library Name: Melaleuca alternifolia Pasture

Harvest Parameters

Harvest Trigger Yield (kg/m2)	3
Residual Green Cover (%)	15
Residual Dead Cover (%)	10
Residual Shoot Biomass (kg/m2)	0.3

Nitrogen

Minimum Shoot Nitrogen Concentration at which Leaf Area Growth Occurs (fraction dwt)	0.002
Minimum Shoot Nitrogen Concentration at which Leaf Area Growth Occurs Optimally (fraction dwt)	0.008
Minimum Shoot Nitrogen Concentration at which Dry Matter Growth Occurs (fraction dwt)	0.002
Minimum Shoot Nitrogen Concentration at which Dry Matter Growth Occurs Optimally (fraction dwt)	0.008

Soil Water

Water Logging Factor (coefficient)	0.85

5.2.2 Soil Parameter Input Selection

The next parameter that was considered was the soil input parameters. When setting up the MEDLI model to conduct the required modelling, the characteristics of the soil at the Winchester South site need to be defined in the software. The soil characteristics that needed to be defined were determined through the soil testing that was conducted on the soil samples collected. Within MEDLI, soil characterisation can only be defined for 1 soil location for 3 distinct soil layers. For the Winchester South Project, there were a total of 5 soil sampling locations and from the 5 sampling locations a soil sample was collected from each of the different horizons. In total, there were 15 soil samples that were sent to the laboratory for testing.

In order to determine the soil characterisation input values, a statistical analysis of the soil test results was conducted. From this data analysis, it was determined that there were 2 sets of soil characterisation values that could be used for the modelling for the Winchester South project. These two different sets of soil characterisation values are defined below and the associated soil characterisation values are outlined below in Table 5.4.

- Run 1 – combined average and maximum soil characterisation values; and
- Run 2 – only average soil characterisation values.

Table 5.4 Soil Characterisation Values to be used in MEDLI Model

Soil Parameter Description	Run 1 Soil Parameters Average/Maximum Values			Run 2 Soil Parameters Average Values Only		
Soil Hydrologic Layers	Layer 1	Layer 2	Layer 3	Layer 1	Layer 2	Layer 3
Soil layer thickness (mm)[1]	450	1270	740	450	1270	740
Air Dry (% v/v)	4[2]	0.1	0.1	4	0.1	0.1
Lower Storage Limit (%v/v)[3]	17	17	18	17	17	14
Drained Upper Limit (%v/v)[4]	30	30	26	30	30	26
Available Water Capacity (mm)[5]	58.5	165.1	59.2	58.5	165.1	88.8
Saturated Water Content[6]	43.5	45	42	43.5	45	42
Bulk Density[7]	1.49	1.45	1.47	1.49	1.45	1.47
Porosity[8]	43.77	45.28	44.53	43.77	45.28	44.53
Saturated Hydraulic Conductivity[9]	4.11	4.84	10.03	4.11	4.84	6.02
Soil Phosphorous						
Initial Soil Phosphorous (mg/kg)[10]	11.612	9.644	14.760	11.612	9.644	10.232
Adsorption Coefficient[11]	229.19	199.84	298.88	106.5	128.904	145.832

Soil Parameter Description Soil Hydrologic Layers	Run 1 Soil Parameters Average/Maximum Values			Run 2 Soil Parameters Average Values Only		
	Layer 1	Layer 2	Layer 3	Layer 1	Layer 2	Layer 3
Adsorption Exponent[12]	1.1608	0.8498	1.0531	0.5842	0.48824	0.53164
Desorption Exponent[13]	1.1027	0.8073	1.0005	0.555	0.46382	0.50506

Note Items in **Blue** are automatically generated values from MEDLI

[1] Samples were collected from each distinct soil layer at 5 locations. The depths of the layers that were used for the MEDLI model were determined by averaging the depth of each of the layers at the 5 locations.

[2] Air dry percent is located at 100,000 kPa on the soil water retention curve for each of the soil samples tested. However, the van Genuuchten parameters generate a curve with asymptotes that are higher than what is typically found with more extensive physical analysis of the soil. Therefore the EAL laboratory analyst, who is experienced in both modelling and physical soil testing, suggested a value of 4% be assigned for all the samples that were tested.

[3] Lower Storage Limit, also known as Permanent Wilting Point, was determined from the soil retention curve graph at 1,500 kPa for each of the samples and then averaged for each sample location for each distinct soil layer. The maximum Lower Storage Limit was also determined for each sample location for each distinct soil layer.

[4] Drained Upper Limit, also known as Field Capacity, was determined from the soil retention curve graph across the range from 10 kPa to 33 kPa for each of the samples. As the soil samples contained more clay, the EAL laboratory analyst suggests that the Field Capacity at 33 kPa would be more appropriate. The values for the Drained Upper Limit for each of the soil samples at 33 kPa was then averaged for each sample location for each distinct soil layer. The maximum Drained Upper Limit was also determined for each sample location for each distinct soil layer.

[5] Available Water Capacity value was calculated by the MEDLI Modelling Software.

[6] Saturated Water Content was determined from the soil retention curve graph at 0.1 kPa for each of the samples and then averaged for each sample location for each distinct soil layer. The maximum Saturated Water Content was also determined for each sample location for each distinct soil layer. It is also important to note that the Saturated Water Content was set at less than the calculated porosity value.

[7] Average and maximum Bulk density was calculated from the laboratory test results for each sample location for each distinct soil layer.

[8] Porosity value calculated by the MEDLI Modelling software using bulk density and absolute density of 2.65 g/cm^3.

[9] Saturated hydraulic conductivity, or K_{SAT}, is a van Genuchten parameter for each of the soil samples and then the average for each sample location for each distinct soil layer was determined along with the maximum value.

[10] Initial Soil Phosphorous average values for each distinct soil layer was determined from laboratory test results for the 5 soil sample locations.

[11] Adsorption Coefficient average values for each distinct soil layer was from the laboratory test results and were calculated using the P Adsorption Isotherm Parameter Calculator.

[12] Adsorption Exponent average values for each distinct soil layer was from the laboratory test results and were calculated using the P Adsorption Isotherm Parameter Calculator.

[13] Desorption Exponent average values for each distinct soil layer was from the laboratory test results and were calculated using the P Adsorption Isotherm Parameter Calculator.

A number of multi-runs were conducted using the MEDLI modelling software to determine if there were any major differences in the effect that irrigation had on the soil using the 2 different soil characterisation values. From these multi-runs, it was determined that there was no significant difference in the effect that the irrigation had on the soil, in particular when comparing the nutrient leaching rates, when using the 2 different soil characterisation values. Therefore in order to determine the optimal wet weather storage volume and the optimal irrigation area, it was determined that the Run 2 soil characterisation inputs would be used. The soil input parameters that were used when completing the MEDLI modelling for the Winchester South project are outlined below in Table 5.5.

Table 5.5 MEDLI Model Soil Parameters

Soil Parameter Description	Run 2 Soil Parameters Average Values Only		
	Layer 1	Layer 2	Layer 3
Soil Hydrologic Layers			
Soil layer thickness (mm)	450	1270	740
Air Dry (% v/v)	4	0.1	0.1
Lower Storage Limit (%v/v)	17	17	14
Drained Upper Limit (%v/v)	30	30	26
Available Water Capacity (mm)	58.5	165.1	88.8
Saturated Water Content	43.5	45	42
Bulk Density	1.49	1.45	1.47
Porosity	43.77	45.28	44.53
Saturated Hydraulic Conductivity	4.11	4.84	6.02
Soil Phosphorous			
Initial Soil Phosphorous (mg/kg)	11.612	9.644	10.232
Adsorption Coefficient	106.5	128.904	145.832
Adsorption Exponent	0.5842	0.48824	0.53164
Desorption Exponent	0.555	0.46382	0.50506

Note Items in **Blue** are automatically generated values from MEDLI

The soil parameters for runoff and evaporation were adjusted to suit the top layer of soil and the percentage of clay determined by the hydrometer analysis.

The MEDLI Technical Reference Tables 5-1 and 5-6 were used to determine the first 3 values shown in Table 5.6 below.

The value for Initial Nitrate Nitrogen was adjusted to the value obtained from extractable Nitrate testing, and the Initial Organic Nitrogen was calculated based on total nitrogen and the nitrate and ammonia values obtained from the soil testing.

Table 5.6 Soil Parameters for Run-off & Evaporation and Initial Nitrogen used in the MEDLI model

Parameter Description	Run 2 Soil Parameters Average Values only
Runoff & Evaporation Parameters	
Runoff Curve Number (coefficient)	90[1]
Evaporation Stage I Drying Maximum (U) (mm)	9[2]
Slope of Evaporation Stage II Drying (Cona) (mm/sqrt day)	4[3]
Initial Nitrogen in Soil	
Initial Nitrate Nitrogen (average in profile) (mg/kg)	4.4
Initial Organic Nitrogen (Average in Organic Layer) (mg/kg)	808.3
Thickness of Organic Layer (mm)	300
Thickness of Labile Carbon Layer (mm)	150
Soil Temperature Scalars	
Lag Coefficient	0.73
Wet Dry Scaling Factor	0.49
Albedo of Plant Cover (proportion reflectance)	0.23

[1] Runoff Curve Number for hydrologic soil group C from *MEDLI Technical Reference Table 5-1* was used (worst case – highest value in range) to represent clay topsoil.

[2] Clay % = 48% is the average value from the laboratory Grain Size Analysis (hydrometer) testing. This value was then used with the *MEDLI Technical Reference Table 5-6* to estimate value for U.

[3] Clay % = 48% is the average value from the laboratory Grain Size Analysis (hydrometer) testing. This value was then used with the *MEDLI Technical Reference Table 5-6* to estimate value for Cona.

5.2.3 MEDLI Inputs for Treated Effluent used for Irrigation Selection Criteria

The final input parameters that needed to be defined was the water quality of the treated effluent being used for irrigation. The treated effluent quality used for irrigation in the MEDLI model are listed below in Table 5.7.

Table 5.7 MEDLI Input of Treated Effluent Quality used for Irrigation

Treated Effluent Pollutant Loads used in the MEDLI Model	Values (mg/L)
Total Nitrogen	Varied from 20 to 30 to 40
Total Phosphorous	Varied from 15 to 20
Total Dissolved Solids (Salts)	1000

The values for total nitrogen and total phosphorous were selected based on the usual levels of treated effluent required by the Department of Environment and Science (DES) for such an environmentally-relevant activity (ERA) as well as the technical capability of an average on-site wastewater treatment plant. The level of total dissolved solids was selected to allow for a more conservative MEDLI modelling result as there is currently no understanding of the potable water total dissolved solids level. On average there is a 300mg/L of total dissolved solids from the potable water to the wastewater stream.

A sensitivity analysis between 20 mg/L, 30 mg/L and 40 mg/L of total nitrogen in the treated effluent and 15 mg/L and 20 mg/L of total phosphorous in the treated effluent was carried out in the MEDLI modelling to ascertain if there are likely to be any environmental consequences for a higher level of total nitrogen and total phosphorous in the treated effluent.

6 MEDLI Model Scenarios

6.1 MEDLI Model Scenario Modelling Approach

Once the MEDLI model was setup in terms of plant selection, soil parameter input selection and treated effluent inputs, the next step of the process was to determine the optimum operating parameters of the irrigation scheme. These operating parameters include the wet weather storage tank volume and the size of the irrigation area. In order to determine the optimum wet weather storage tank volume and the optimum irrigation area, different MEDLI modelling scenarios were run. The process that was taken in order to determine the optimum operating parameters for the irrigation scheme are provided below in Figure 6.1.

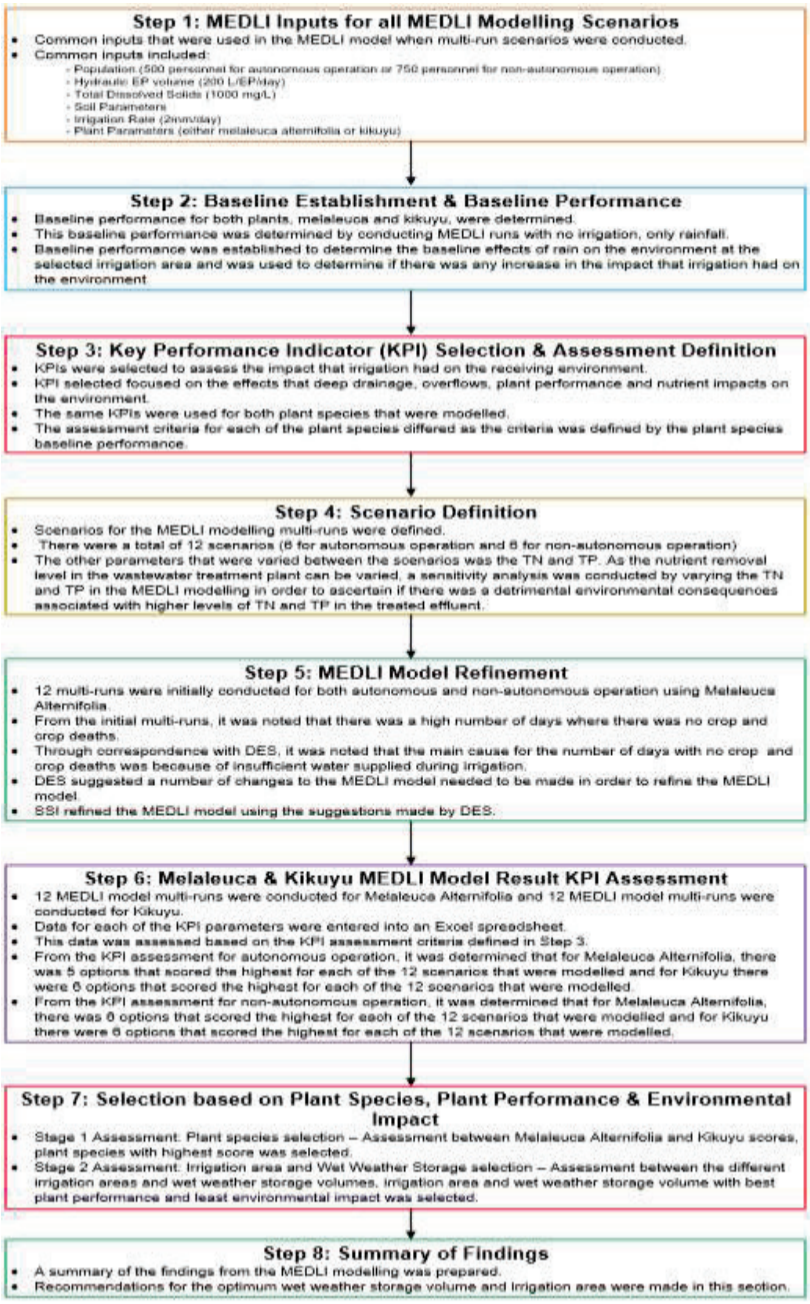


Figure 6.1 Flow chart of Approach to determine Optimum Operating Conditions of Irrigation Scheme

INFORMATION	It is important to note that the MEDLI modelling completed to determine the optimum irrigation scheme operating conditions were completed using both Melaleuca Alternifolia and Kikuyu. This was to allow for a complete comparison of the performance of the two plant species at the Winchester South project site.

6.2 Baseline Establishment & Baseline Performance

In order to determine whether the irrigation using treated effluent caused a detrimental effect on the environment, a baseline for the plant species used on the irrigation field was established first. The baseline performance for the plant species was determined by completing a MEDLI model run with no irrigation using treated effluent. By conducting a MEDLI model with no irrigation establishes the environmental impacts seen on the soil and plants at the irrigation area occurred due only to rainfall.

A baseline establishment MEDLI model run was conducted for Melaleuca Alternifolia and Kikuyu. The results from the baseline establishment runs for Melaleuca Alternifolia and Kikuyu are provided in Table 6.1.

Table 6.1 Baseline performance for Melaleuca Alternifolia and Kikuyu with no effluent irrigation occurring.

Parameter	Melaleuca Alternifolia	Kikuyu
Deep Drainage (mm/year)	88.54	10.68
Nitrogen Uptake (kg/ha/year)	4.09	100
Nitrogen Leach (kg/ha/year)	100	0.843
Phosphorous Uptake (kg/ha/year)	0.498	0.612
Phosphorous Leach (kg/ha/year)	0.00593	0
No. of days without crop per year (days)	65.56	204.41
Average monthly water logging index	0	0
Average monthly water stress index	0.02	0.12
Average no. of crop deaths (no./year)	0.72	2.2
Average Annual Yield (kg/m^2/year)	0.04	0.37
Overflow (m^3/year)	11,148.34	11,148.34
Average N deficiency stress	0.01	0.22

Parameter	Melaleuca Alternifolia	Kikuyu
Average Jan temp. stress	0.01	0.04
Average Jul temp. stress	0.19	0.46
Annual Transpiration (mm/year)	14.85	232.62
Soil Evaporation (mm/year)	401.28	309.25
Design soil profile storage life (years)	∞	∞

Note: ∞ indicates infinity, meaning that the soil has an infinite time for the soil to be saturated with phosphorous. Items highlighted in green indicate better performance.

6.3 Key Performance Indicator Selection & Definition

In order to determine the optimal wet weather storage volume and the optimal irrigation area, multi-runs were completed for a number of scenarios. The following key performance indicator (KPI) parameters were used to assess the results from each of the multi-runs in order to determine the optimal wet weather storage tank volume and the optimal irrigation area. These KPI parameters were also used to determine which operating condition had the best plant performance and the least environmental impact when using the treated effluent for the irrigation of the effluent disposal area over a 64 year period. The key performance indicators that were used to assess the multi-run results different scenarios were following:

- Deep drainage (mm/year);
- Nitrogen Uptake (kg/ha/year);
- Nitrogen Leach (kg/ha/year);
- Phosphorous Uptake (kg/ha/year);
- Phosphorous Leach (kg/ha/year);
- Number of days .without crop per year (days);
- Average Monthly Water Logging Index;
- Average Monthly Water Stress Index;
- Average Number of Crop Deaths (no events./year);
- Average Annual Yield (kg/m^2/year);
- Overflow (m^3/year)
- Average Annual Nitrogen Deficiency Stress;
- Average January Temperature Stress;
- Average July Temperature Stress;
- Annual Transpiration (mm/year);
- Soil Evaporation (mm/year); and
- Design soil profile storage life (years).

The legend for the colour coding system used to assess the multi-run results are outlined below in Table 6.2 for Melaleuca Alternifolia and in Table 6.3 for Kikuyu.

Table 6.2 KPI Scoring Matrix for Melaleuca Alternifolia Multi-run Results Assessment

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Baseline value (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
Deep Drainage (mm/year)	≤106.25	≤200	>200	88.54	The greater of 200 or 25% increase from baseline value	For deep drainage, the criteria was determined using the baseline value for good and the DES defined acceptable limit for deep drainage for acceptable. Therefore the criteria was determined using plus 20% for good, and less than or equal to 200 mm/year for acceptable. It is important to minimise deep drainage due to irrigation as increased deep drainage can lead to contamination of the groundwater table.
Nitrogen Uptake (kg/ha/year)	>6.14	≥4.91	<4.09	4.09		For nitrogen uptake, the criteria was determined using the baseline value for Melaleuca Alternifolia as there was no DES defined acceptable limit for Nitrogen Uptake. Therefore the criteria was determined using plus 50% from the baseline for good and plus 20% for acceptable. It is important to maximise the nitrogen uptake in the plants to maximise the plant yield and to improve the quality of the crop grown. This will also reduce the amount of nitrogen leached to the environment from the treated effluent.
Nitrogen Leach (kg/ha/year)	<4	≤5	>5	100	5	For nitrogen leach, the criteria was determined using the DES defined acceptable limit of 5 kg/ha/year. Therefore the criteria was determined using minus 20% from the DES defined acceptable limit for good and less than or equal to 5 kg/ha/year for acceptable. It is important to minimise nitrogen leaching in the soil as increased nitrogen leaching can lead to contamination of the groundwater table.

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Baseline value (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
Phosphorous Uptake (kg/ha/year)	>0.747	≥0.598	<0.498	0.498		For phosphorous uptake, the criteria was determined using the baseline value for Melaleuca Alternifolia as there was no DES defined acceptable limit for Phosphorous Uptake. Therefore the criteria was determined using plus 50% from the baseline for good and plus 20% for acceptable. It is important to maximise the phosphorous uptake in the plants to maximise the plant yield and to improve the quality of the crop grown. This will also reduce the amount of phosphorous leached in to the environment from the treated effluent.
Phosphorous Leach (kg/ha/year)	<4	≤5	>5	0.00593	5	For phosphorous leach, the criteria was determined using the DES defined acceptable limit of 5 kg/ha/year. Therefore the criteria was determined using minus 20% from the DES defined acceptable limit for good and less than or equal to 5 kg/ha/year for acceptable. It is important to minimise phosphorous leaching in the soil as increased nitrogen leaching can lead to contamination of the groundwater table and will decrease the design soil profile of the soil.
No. of days without crop per year (days)	0	≤3	>3	65.56	0	For number of days without crop, the criteria was determined using the DES defined acceptable limit. Therefore zero days without crops was determined to be good, as ideally there will be no days when there are no crops, and less than or equal to 1% of the year, i.e. 3 days out of 365 days, was determined to be acceptable It is very important to minimise the number of days without crop as an increased number of days without crop indicate that there is less plant cover for more days in the year, which can lead to an increase in soil evaporation and nutrient leaching into the soil, as

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Baseline value (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
						the effluent irrigation scheme fails to be part of the treatment train. High numbers of days without crop may also require increased volume of wet weather storage to store the treated effluent until a crop can be re-established.
Average monthly water logging index	0	≤0.1	>0.1	0		Water logging is a significant issue for plant performance and therefore needs to be minimised. Ideally the water logging stress index would be zero and it was determined to be acceptable to have a water logging stress index of less than or equal to 0.1.
Average monthly water stress index	0	≤0.1	>0.1	0.02		Water stress is a stress index that indicates that there is insufficient water being supplied to the plants via irrigation and therefore needs to be minimised. Ideally the water stress index would be zero and it was determined to be acceptable to have a water stress index of less than or equal to 0.1.
Average no. of crop death events (no./year)	0	≤1	>1	0.72		Crop death events will impact on the plant cover percentage of the irrigation area, which can lead to an increase in soil evaporation and nutrient leaching into the soil. Therefore the crop death events criteria was defined as ideally zero for good and 1 crop death event is acceptable. High numbers of days without crop and high crop death events may also require increased volume of wet weather storage to store the treated effluent until a crop can be re-established.
Average Annual Yield ($kg/m^2/year$)	>1.0	1.0	<1.0	0.04	1.0	For the average annual yield, the criteria was determined using average annual yield greater than the DES defined acceptable limit of 1 $kg/m^2/year$, as this shows that the plants are performing well under the irrigation, climate, soil and nutrient load conditions.

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Baseline value (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
Overflow (m^3/year)	0	≤557.65	>557.65	11,148.34	0m³/ year over flow (or 100% effluent reuse) is preferred, though 95% effluent reuse is acceptable	Overflow needs to be minimised as any overflow from the wet weather storage, results in a point source discharge of treated effluent to the environment. A point source discharge of treated effluent can cause major environmental impact, such as increase nutrient leaching which would lead to contamination of the groundwater table and surface ponding and pooling. Therefore the overflow assessment criteria was determined based on the DES defined acceptable limits of ideally zero m^3/year of overflow. A 5% overflow of treated effluent from the wet weather storage tank, based on a 95% effluent beneficial reuse rate. A 5 % overflow of treated effluent means that with an inflow of 11,153.03 m^3/year, 5% of 11,153.03m^3/year is 557.65 m^3/year of over flow.
Average N deficiency stress	0	≤0.1	>0.1	0.01		Nitrogen deficiency stress is a stress index that indicates that there is insufficient nitrogen being supplied to the plants via effluent irrigation and therefore needs to be minimised. Ideally the nitrogen deficiency stress index would be zero and it was determined to be acceptable to have a water stress index of less than or equal to 0.1.
Average Jan temp. stress	0	≤0.1	>0.1	0.01		January temperature stress is a stress index that indicates that the plant is not performing well due to hot weather and therefore needs to be minimised. Ideally the January temperature stress index would be zero and it was determined to be acceptable to have a water stress index of less than or equal to 0.1. The temperature stress index can only be managed using specific plant species.
Average Jul temp. stress	0	≤0.1	>0.1	0.19		July temperature stress is a stress index that indicates that the plant is not performing well due to cold weather and therefore

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Baseline value (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
						needs to be minimised. Ideally the July temperature stress index would be zero and it was determined to be acceptable to have a water stress index of less than or equal to 0.1. The temperature stress index can only be managed using specific plant species.
Annual Transpiration (mm/year)	≥1000	<1000	≤800	14.85	1000	For the annual transpiration, the criteria was determined using the DES defined acceptable limit of 1000 mm/year. Therefore good transpiration was determined to be greater than the DES defined acceptable limit of 1000 mm/year and 20% less than the DES defined acceptable limit of 1000 mm/year was determined to be when further control measures are required. Annual transpiration indicates evaporation of water/ treated effluent from plants occurring at the leaves. This means that increased transpiration shows that there is a high amount of leaves where the water is being evaporated from. Higher annual transpiration value, indicated a higher uptake of treated effluent by the plant species on the irrigation field.
Soil Evaporation (mm/year)	≤10	≤50	>50	401.28		Soil evaporation provides an indication of the water availability for the plants. I.e. if there is more soil evaporation, this means that there is less water available for the roots of the plants to absorb and use. Therefore soil evaporation needs to be minimised. For soil evaporation, the criteria was determined to be 10 mm/year for good and less than or equal to 50 mm/year for acceptable. High soil evaporation also indicates high accumulation of nutrients in the soil as they are not being utilised by the plants.
Design soil profile storage life based on average infiltrated	>25	25	<25	∞	25	For the design soil profile storage, the criteria was determined using the DES defined acceptable limit of 25 years. The design soil profile indicates the number of years it would take for the soil

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Baseline value (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
water phosphorous concentration of 0 mg/L (years)						to reach its phosphorous storage capacity before it starts to leach from the soil. Therefore the design soil profile design life needs to be maximised.

Table 6.3 KPI Scoring Matrix for Kikuyu Multi-run Results Assessment

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Base Case (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
Deep Drainage (mm/year)	≤12.82	≤200	>200	10.68	The greater of 200 or 25% increase from baseline value	For deep drainage, the criteria was determined using the baseline value for good and the DES defined acceptable limit for deep drainage for acceptable. Therefore the criteria was determined using plus 20% for good, and less than or equal to 200 mm/year for acceptable. It is important to minimise deep drainage due to irrigation as increased deep drainage can lead to contamination of the groundwater table.
Nitrogen Uptake (kg/ha/year)	>150	≥120	<100	100		For nitrogen uptake, the criteria was determined using the baseline value for Kikuyu as there was no DES defined acceptable limit for Nitrogen Uptake. Therefore the criteria was determined using plus 50% from the baseline for good and plus 20% for acceptable. It is important to maximise the nitrogen uptake in the plants to maximise the plant yield and to improve the quality of the crop grown. This will also reduce the amount of

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Base Case (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
						nitrogen leached to the environment from the treated effluent.
Nitrogen Leach (kg/ha/year)	<4	≤5	>5	0.843	5	For nitrogen leach, the criteria was determined using the DES defined acceptable limit of 5 kg/ha/year. Therefore the criteria was determined using minus 20% from the DES defined acceptable limit for good and less than or equal to 5 kg/ha/year for acceptable. It is important to minimise nitrogen leaching in the soil as increased nitrogen leaching can lead to contamination of the groundwater table.
Phosphorous Uptake (kg/ha/year)	>0.918	≥0.734	<0.612	0.612		For phosphorous uptake, the criteria was determined using the baseline value for Kikuyu as there was no DES defined acceptable limit for Phosphorous Uptake. Therefore the criteria was determined using plus 50% from the baseline for good and plus 20% for acceptable. It is important to maximise the phosphorous uptake in the plants to maximise the plant yield and to improve the quality of the crop grown. This will also reduce the amounphosphorous leached to the environment from the treated effluent.
Phosphorous Leach (kg/ha/year)	<4	≤5	>5	0	5	For phosphorous leach, the criteria was determined using the DES defined acceptable limit of 5 kg/ha/year. Therefore the criteria was determined using minus 20% from the DES defined acceptable limit for good and less than or equal to 5 kg/ha/year for acceptable. It is important to minimise phosphorous leaching in the soil as increased nitrogen leaching can lead to contamination

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Base Case (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
						of the groundwater table and will decrease the design soil profile of the soil.
No. of days without crop per year (days)	0	≤3	>3	204.41	0	For number of days without crop, the criteria was determined using the DES defined acceptable limit. Therefore zero days without crops was determined to be good, as ideally there will be no days when there are no crops, and less than or equal to 1% of the year, i.e. 3 days out of 365 days, was determined to be acceptable It is very important to minimise the number of days without crop as an increased number of days without crop indicate that there is less plant cover for more days in the year, which can lead to an increase in soil evaporation and nutrient leaching into the soil, as the effluent irrigation scheme fails to be part of the treatment train. High numbers of days without crop may also require increased volume of wet weather storage to store the treated effluent until a crop can be re-established.
Average monthly water logging index	0	≤0.1	>0.1	0		Water logging is a significant issue for plant performance and therefore needs to be minimised. Ideally the water logging stress index would be zero and it was determined to be acceptable to have a water logging stress index of less than or equal to 0.1.
Average monthly water stress index	0	≤0.1	>0.1	0.12		Water stress is a stress index that indicates that there is insufficient water being supplied to the plants via irrigation and therefore needs to be minimised. Ideally the water stress index would be zero and it was determined to be acceptable to have a water stress index of less than or equal to 0.1.

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Base Case (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
Average no. of crop death events (no./year)	0	≤1	>1	2.2		Crop death events will impact on the plant cover percentage of the irrigation area, which can lead to an increase in soil evaporation and nutrient leaching into the soil. Therefore the crop death events criteria was defined as ideally zero for good and 1 crop death event is acceptable. High numbers of days without crop and high crop death events may also require increased volume of wet weather storage to store the treated effluent until a crop can be re-established.
Average Annual Yield (kg/m^2/year)	>1.0	1.0	<1.0	0.37	1.0	For the average annual yield, the criteria was determined using average annual yield greater than the DES defined acceptable limit of 1 kg/m^2/year, as this shows that the plants are performing well under the irrigation, climate, soil and nutrient load conditions.
Overflow (m^3/year)	0	≤557.65	>557.65	11,148.34	0 (or 100% effluent reuse) is preferred, though 95% effluent reuse is acceptable	Overflow needs to be minimised because if there is any overflow from the wet weather storage tank, this means that there is a point source discharge of treated effluent. A point source discharge of treated effluent can cause major environmental impact, such as increase nutrient leaching which would lead to contamination of the groundwater table. Therefore the overflow assessment criteria was determined based on the DES defined acceptable limits of ideally zero m^3/year of overflow and 5% overflow of treated effluent from the wet weather storage tank, based on a 95% effluent reuse rate. A 5 % overflow of treated effluent

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Base Case (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
						means that with an inflow of 11,153.03 m^3/year, 5% of 11,153.03 m^3/year is 557.65 m^3/year.
Average N deficiency stress	0	≤0.1	>0.1	0.22		Nitrogen deficiency stress is a stress index that indicates that there is insufficient nitrogen being supplied to the plants via irrigation and therefore needs to be minimised. Ideally the nitrogen deficiency stress index would be zero and it was determined to be acceptable to have a water stress index of less than or equal to 0.1.
Average Jan temp. stress	0	≤0.1	>0.1	0.04		January temperature stress is a stress index that indicates that the plant is not performing well due to hot weather and therefore needs to be minimised. Ideally the January temperature stress index would be zero and it was determined to be acceptable to have a water stress index of less than or equal to 0.1. The temperature stress index can only be managed using specific plant species.
Average Jul temp. stress	0	≤0.1	>0.1	0.46		July temperature stress is a stress index that indicates that the plant is not performing well due to cold weather and therefore needs to be minimised. Ideally the July temperature stress index would be zero and it was determined to be acceptable to have a water stress index of less than or equal to 0.1. The temperature stress index can only be managed using specific plant species.
Annual Transpiration (mm/year)	≥1000	<1000	≤800	232.62	1000	For the annual transpiration, the criteria was determined using the DES defined acceptable limit of 1000 mm/year. Therefore good transpiration was determined to be greater than the DES defined acceptable limit of 1000 mm/year and 20% less than the DES defined acceptable limit of

Parameter	Good Score = 2	Acceptable Score = 1	Further Control measures required Score = 0	Base Case (No irrigation)	Department or Environment & Science (DES) Defined Acceptable Limits	Comments
						1000 mm/year was determined to be when further control measures are required. Annual transpiration indicates evaporation of water/ treated effluent from plants occurring at the leaves. This means that increased transpiration shows that there is a high amount of leaves where the water is being evaporated from. Higher annual transpiration value, indicated a higher uptake of treated effluent by the plant species on the irrigation field.
Soil Evaporation (mm/year)	≤10	≤50	>50	309.25		Soil evaporation provides an indication of the water availability for the plants, i.e. if there is more soil evaporation, this means that there will be less water available for the roots of the plants to absorb and use. Therefore soil evaporation needs to be minimised. For soil evaporation, the criteria was determined to be 10 mm/year for good and less than or equal to 50 mm/year for acceptable. High soil evaporation also indicates high accumulation of nutrients in the soil as they are not being utilised by the plants.
Design soil profile storage life based on average infiltrated water phosphorous concentration of 0 mg/L (years)	>25	25	<25	∞	25	For the design soil profile storage, the criteria was determined using the DES defined acceptable limit of 25 years. The design soil profile indicates the number of years it would take for the soil to reach its phosphorous storage capacity before it starts to leach from the soil. Therefore the design soil profile design life needs to be maximised.

6.4 MEDLI Model Scenario Inputs

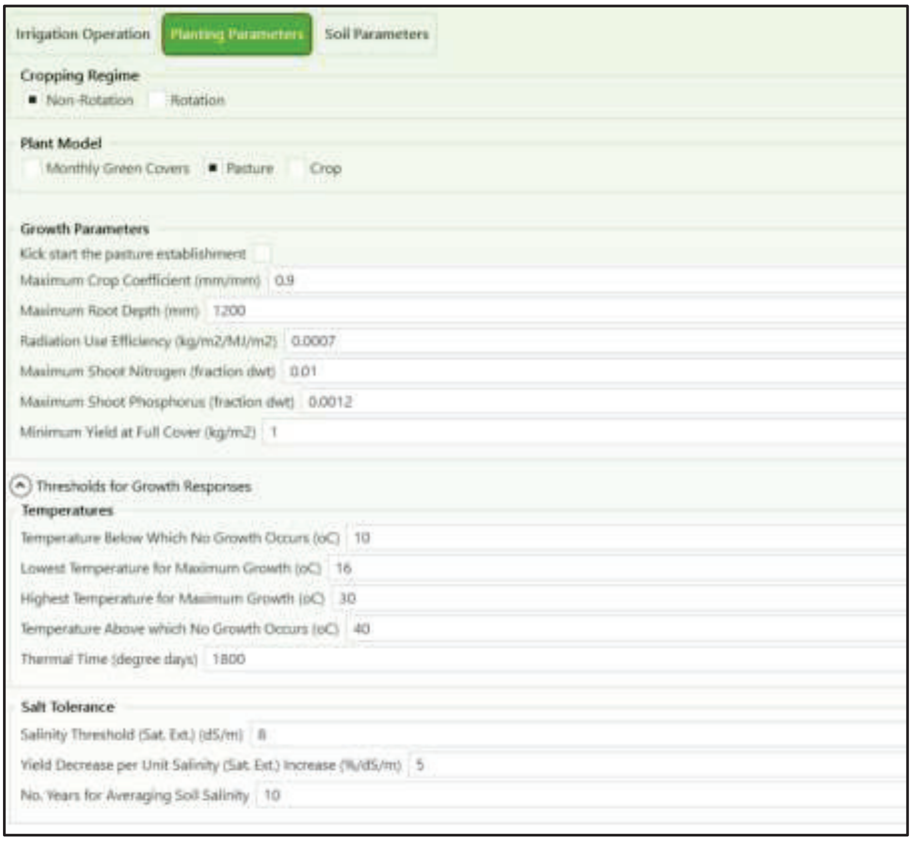
In order to determine the optimum wet weather storage volume and irrigation area, a number of MEDLI modelling scenarios were conducted. For the Winchester South Project, there were two different operating conditions that resulted in two different site populations that needed to be considered; autonomous operation and non-autonomous operation. As the site population was dependent on the type of operating condition used, two sets of MEDLI modelling scenarios were conducted, one for autonomous operation with an estimated population of 500 workers and one for non-autonomous operation with an estimated population of 750 workers. When conducting the MEDLI modelling for each of these operating conditions for the different nutrient scenarios, the common scenario settings that were used in the MEDLI models are outlined below in Table 6.4.

Table 6.4 Common Scenario Settings

Description	Set Value
Irrigation Rate (mm/day)	2
Plant Type	Melaleuca Alternifolia Pasture, or Kikuyu Pasture
Soil Type	Run 2 Soil
Treated Effluent – Total Dissolved Solids (Salts) (mg/L)	1000
Hydraulic Based Equivalent Person volume (L/EP/day)	200
Hydraulic Based Equivalent Persons (EP/day) (autonomous operation – 500 workers)	Average of 144 EP every day
Hydraulic Based Equivalent Persons (EP/day) (non-autonomous operation – 750 workers)	Average of 217 EP every day

The input parameters for the two plant species that were used in the MEDLI scenario modelling are provided below in Table 6.5 for Melaleuca Alternifolia and Table 6.6 for Kikuyu.

Table 6.5 MEDLI Planting Parameters for Initial Selected Plant Cover – Melaleuca Alternifolia Pasture



Irrigation Operation | Planting Parameters | Soil Parameters

Cropping Regime

Non-Rotation | Rotation

Plant Model

Monthly Green Covers | Pasture | Crop

Growth Parameters

Kick start the pasture establishment	
Maximum Crop Coefficient (mm/mm)	0.9
Maximum Root Depth (mm)	1200
Radiation Use Efficiency (kg/m2/MJ/m2)	0.0007
Maximum Shoot Nitrogen (fraction dwt)	0.01
Maximum Shoot Phosphorus (fraction dwt)	0.0012
Minimum Yield at Full Cover (kg/m2)	1

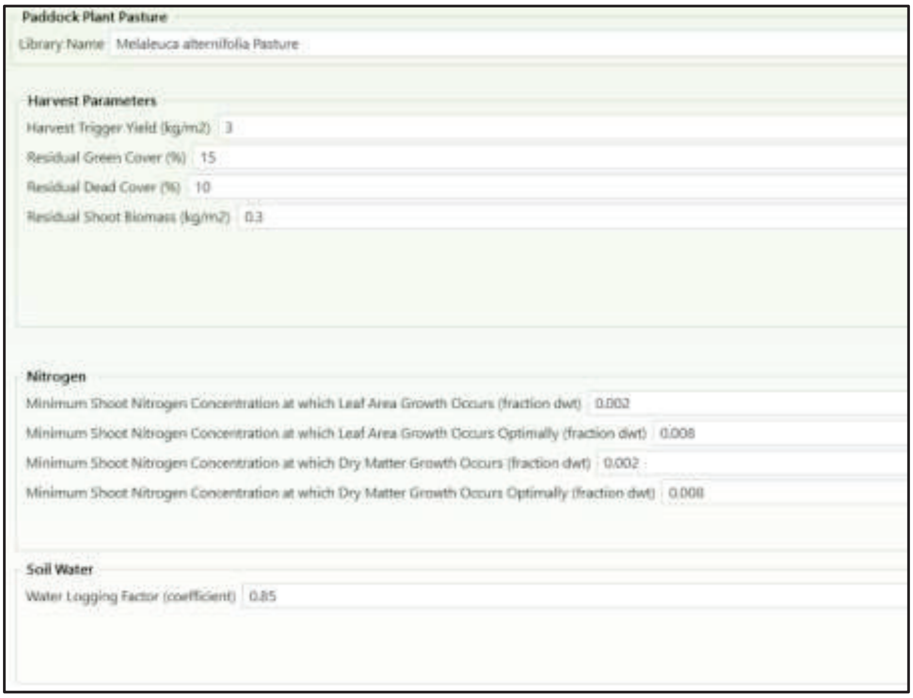
Thresholds for Growth Responses

Temperatures

Temperature Below Which No Growth Occurs (oC)	10
Lowest Temperature for Maximum Growth (oC)	16
Highest Temperature for Maximum Growth (oC)	30
Temperature Above which No Growth Occurs (oC)	40
Thermal Time (degree days)	1800

Salt Tolerance

Salinity Threshold (Sat. Ext.) (dS/m)	8
Yield Decrease per Unit Salinity (Sat. Ext.) Increase (%/dS/m)	5
No. Years for Averaging Soil Salinity	10



Paddock Plant Pasture

Library Name: Melaleuca alternifolia Pasture

Harvest Parameters

Harvest Trigger Yield (kg/m2)	3
Residual Green Cover (%)	15
Residual Dead Cover (%)	10
Residual Shoot Biomass (kg/m2)	0.3

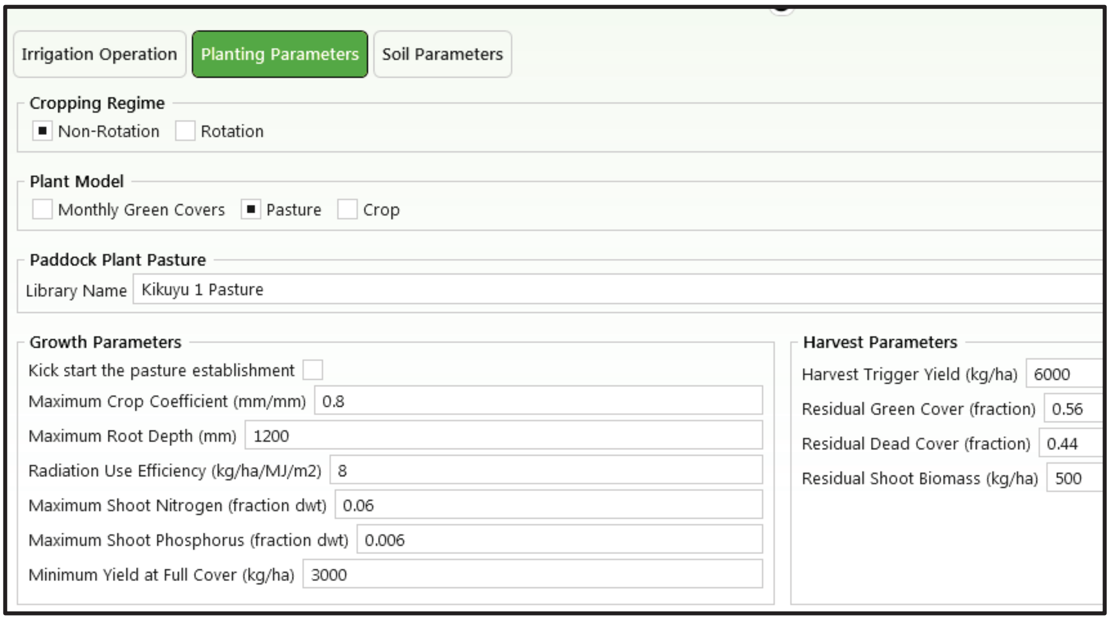
Nitrogen

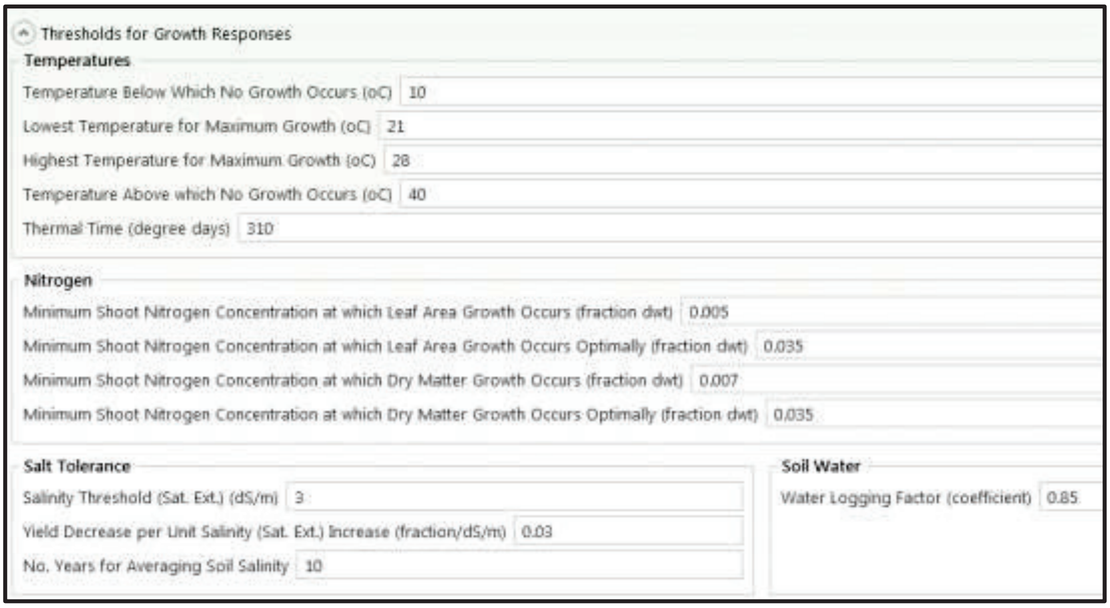
Minimum Shoot Nitrogen Concentration at which Leaf Area Growth Occurs (fraction dwt)	0.002
Minimum Shoot Nitrogen Concentration at which Leaf Area Growth Occurs Optimally (fraction dwt)	0.008
Minimum Shoot Nitrogen Concentration at which Dry Matter Growth Occurs (fraction dwt)	0.002
Minimum Shoot Nitrogen Concentration at which Dry Matter Growth Occurs Optimally (fraction dwt)	0.008

Soil Water

Water Logging Factor (coefficient)	0.85

Table 6.6 MEDLI Planting Parameters for Selected Plant Cover for MEDLI Model– Kikuyu Pasture





6.5 MEDLI Model Scenario Definition

A number of different scenarios were used in the MEDLI modelling when determining the optimum wet weather storage volume and irrigation area. This was because there were two different operating conditions that needed to be modelled and because nutrient removal levels in the treated effluent from the STP can be varied. Therefore a sensitivity analysis was conducted by varying the total nitrogen and total phosphorous in the MEDLI modelling in order to ascertain if there was a detrimental environmental consequences associated with higher levels of total nitrogen and total phosphorous.

The multi-run settings and the different discharge nutrient level settings for each of the scenarios that were modelled are outlined below in Table 6.7.

Table 6.7 Varied Scenario Settings

Scenario No.	EP/day	Wet weather Storage volume (kL)	Irrigation Area (ha)	Total N (mg/L)	Total P (mg/L)
Scenario 1 (500 personnel) Multi-run	144	200 – 900 in 100 kL increments	0.5 – 3.0 ha in 0.5 ha increments	20	15
Scenario 2 (500 personnel) Multi-run		200 – 900 in 100 kL increments	0.5 – 3.0 ha in 0.5 ha increments	20	20
Scenario 3 (500 personnel) Multi-run		200 – 900 in 100 kL increments	0.5 – 3.0 ha in 0.5 ha increments	30	15
Scenario 4 (500 personnel) Multi-run		200 – 900 in 100 kL increments	0.5 – 3.0 ha in 0.5 ha increments	30	20
Scenario 5 (500 personnel) Multi-run		200 – 900 in 100 kL increments	0.5 – 3.0 ha in 0.5 ha increments	40	15
Scenario 6 (500 personnel) Multi-run		200 – 900 in 100 kL increments	0.5 – 3.0 ha in 0.5 ha increments	40	20
Scenario 7 (750 personnel) Multi-run	217	350 – 1450 in 200 kL increments	1.0 – 4.5 ha in 0.5 ha increments	20	15
Scenario 8 (750 personnel) Multi-run		350 – 1450 in 200 kL increments	1.0 – 4.5 ha in 0.5 ha increments	20	20
Scenario 9 (750 personnel) Multi-run		350 – 1450 in 200 kL increments	1.0 – 4.5 ha in 0.5 ha increments	30	15
Scenario 10 (750 personnel) Multi-run		350 – 1450 in 200 kL increments	1.0 – 4.5 ha in 0.5 ha increments	30	20
Scenario 11 (750 personnel) Multi-run		350 – 1450 in 200 kL increments	1.0 – 4.5 ha in 0.5 ha increments	40	15
Scenario 12 (750 personnel) Multi-run		350 – 1450 in 200 kL increments	1.0 – 4.5 ha in 0.5 ha increments	40	20

6.6 MEDLI Model Refinement

Through the initial plant selection process that was conducted, the plant type that was selected was Melaleuca Alternifolia Pasture. From the initial MEDLI results obtained through the initial multi-runs conducted for scenarios 1 to 12 using Melaleuca Alternifolia Pasture, it was noted that with the current setup of the MEDLI model, there was a high number of days without crop. It is important to note that crop deaths and number of days without crop needs to be minimised as much as possible. This was because when there are a high number of crop deaths or number of days without crop, this will result in higher adverse effects on the environment. The environmental impacts include: increased deep drainage, increased nutrient leaching and increased soil evaporation. Through correspondence with the Department of Environment and Sciences (DES), it was noted that the main cause for the high number of days without crop is due to insufficient water supply with low levels of nutrients for the Melaleuca Alternifolia Crop. Full details from the correspondence with DES can be found Appendix I.

The cause for the high number of days without crop was confirmed to be insufficient water supply by conducting a MEDLI model run by increasing the amount of irrigation from 2 mm/day to 7 mm/day. From this increased irrigation run, it was seen that there was zero days of crop death and the percentage of crop cover increased, however, there was a significant increase in the deep drainage and nutrient leaching. It was also seen that with the increase in the irrigation, there was also an increase in the soil evaporation.

From the outcomes of the initial MEDLI modelling that was conducted for the two operating scenarios, it was seen that Melaleuca Alternifolia Pasture was not as ideal as initially expected. This was reflected in the MEDLI modelling that was conducted using Melaleuca Alternifolia Pasture. The following effects were seen when using Melaleuca Alternifolia Pasture with the current MEDLI model setup of irrigating with 2 mm/day:

- Crop deaths due to water stress cause by insufficient water supply;
- Low crop cover percentage due to crop deaths; and
- High soil evaporation due to low crop cover percentage.

This therefore meant that if Melaleuca Alternifolia Pasture was used as the plant cover for the effluent irrigation area, more water needs to be supplied for irrigation. However, if more water is supplied for irrigation, this will cause other environmental impacts, such as increased deep drainage and increased nutrient leaching.

Therefore, the MEDLI model was refined based on discussions with the DES MEDLI technical support team. Table 6.8 below provides a list of the parameters that were updated, as per the suggestions made by DES:

Table 6.8 Parameters updated in MEDLI Model to Refine Model

Parameter	Original Model Input	Updated Model Input
Pan Coefficient	0.8	1.0
Pumping Limits	As Scheduled	Rate per Area (min. = 0 L/day/m^2, max. = 100 L/day/m^2)
Runoff Curve Number	90	83
Nitrogen Transfer Coefficient	0.1 m/day	0 m/day

6.7 Melaleuca Alternifolia & Kikuyu MEDLI Model Run Result Summary

The MEDLI modelling for the defined scenarios were conducted for both Melaleuca Alternifolia and Kikuyu. The data that was obtained from these MEDLI model runs were assessed using the KPI assessment criteria defined in Section 6.3. From the KPI assessment conducted, the highest scoring options were determined. The highest scoring options were then assessed to determine the most suitable plant species along with the optimum irrigation area and wet weather storage volume for Winchester South.

6.7.1 Stage 1 Assessment: Plant Species Selection

From the initial KPI assessment that was conducted on the data obtained from the MEDLI model runs, the highest scoring options for each of the plant species that were modelled for the two different operating conditions was determined.

It was noted that for autonomous operation, there were 12 options. The highest scores and the highest scoring options for each of the plant species were determined to be the following:

- Melaleuca Alternifolia: 6 options with the highest score of 20:
  - 300 kL, 1.5 ha;
  - 300 kL, 2.0 ha;
  - 600 kL, 1.5 ha;
  - 600 kL, 2.0 ha;
  - 900kL, 1.5 ha; and
  - 900 kL, 2.0 ha.
- Kikuyu: 6 options with the highest score of 27:
  - 300 kL, 1.5 ha;
  - 300 kL, 2.0 ha;
  - 600 kL, 1.5 ha;
  - 600 kL, 2.0 ha;
  - 900 kL, 1.5 ha; and
  - 900 kL, 2.0 ha.

By assessing the highest scores between the two plant species modelled for autonomous operation, it was determined that Kikuyu was the more suitable plant species for Winchester South, as it had a higher score compared to Melaleuca Alternifolia. With Kikuyu selected as the most suitable plant species, this brought the number of options to consider down to 6 options for autonomous operation.

A similar process was followed when assessing the highest scoring options determined from the MEDLI modelling conducted for the non-autonomous operation. It was noted that for non-autonomous operation, there were 11 options with the highest scores and the highest scoring options for each of the plant species were determined to be the following:

- Melaleuca Alternifolia: 5 options with the highest score of 21:
  - 450 kL, 2.5 ha;
  - 950 kL, 2.5 ha;
  - 950 kL, 3.0 ha;
  - 1050 kL, 2.5 ha; and
  - 1450 kL, 3.0 ha.
- Kikuyu: 6 options with the highest score of 27:
  - 450 kL, 3.0 ha;
  - 950 kL, .2.5 ha;
  - 950 kL, 3.0 ha;
  - 1050 kL, 2.5 ha;
  - 1450 kL, 2.5 ha; and
  - 1450 kL, 3.0 ha.

By assessing the highest scores between the two plant species modelled for non-autonomous operation, it was determined that Kikuyu was the more suitable plant species for Winchester South, as it had a higher score compared to Melaleuca Alternifolia. With Kikuyu selected as the most suitable plant species, this brought the number of options to consider down to 6 options for non-autonomous operation.

6.7.2 Stage 2 Assessment: Irrigation Area and Wet Weather Storage Tank Volume Selection

Another assessment was conducted on the 6 remaining options for the autonomous operation and the 6 remaining options for the non-autonomous operation. This assessment was conducted in order to determine the optimum irrigation area and wet weather storage volume for each of the operating conditions. This assessment was conducted by first comparing each of the remaining options to determine the optimum irrigation area for each of the operating conditions. The optimum irrigation area was determined by assessing each of the options and comparing the plant performance and environmental effects. The optimum irrigation area was selected to be the option that had better plant performance and the smaller environmental impact. Once this was determined, the optimum wet weather storage volume was selected by using the contour map produced from each of the MEDLI runs that were completed.

For the remaining 6 options for autonomous operation, it was determined that the 3 options with 1.5 ha of irrigation were not suitable when compared to the options with 2.0 ha of irrigation area. This is because the options that had 1.5 ha of irrigation area had overflow of treated effluent from the wet weather storage tank. Furthermore the options with 2.0 ha of irrigation area had a lower nutrient leaching rate compared to the options with 1.5 ha of irrigation area.

The optimum wet weather storage volume for autonomous operation was then selected by using the contour map produced from MEDLI. Figure 6.2 below shows the contour map that was produced from MEDLI for autonomous operation along with the optimum wet weather storage volume for an irrigation area of 2.0 ha.

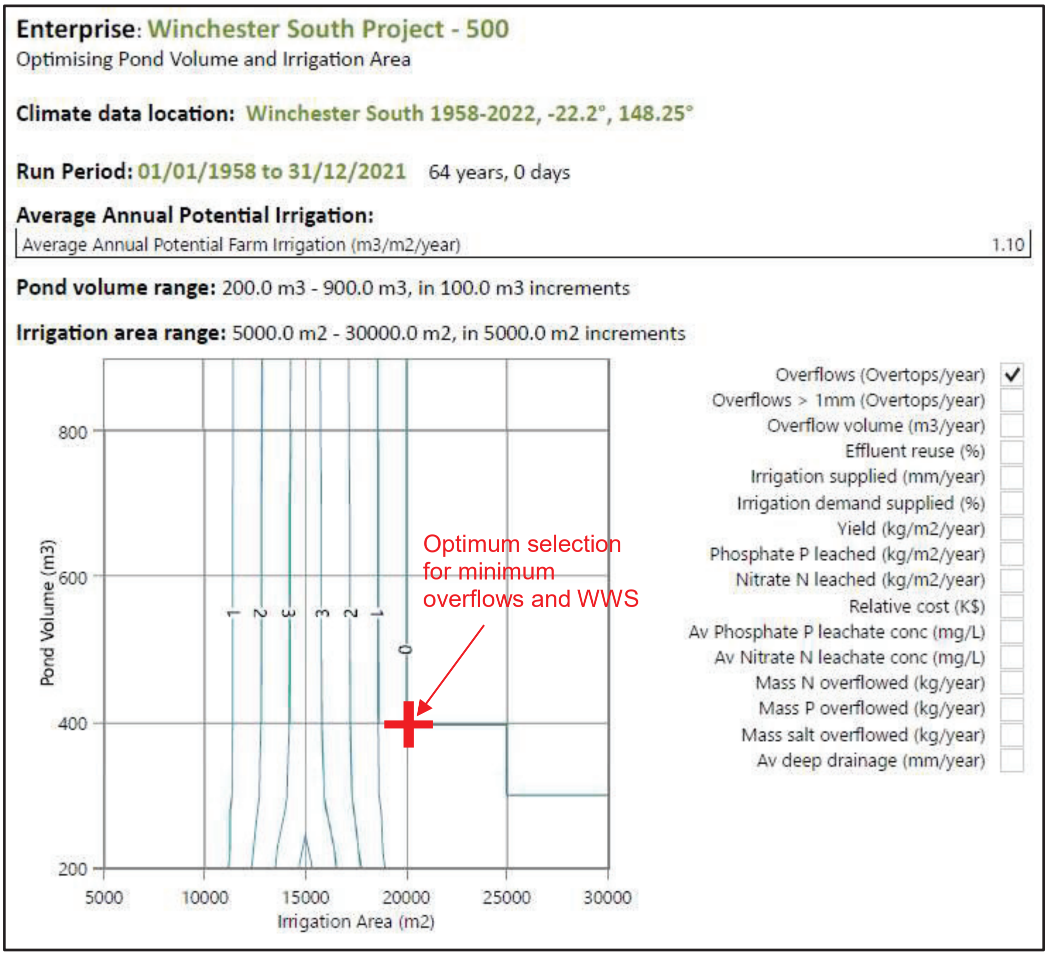


Figure 6.2 Autonomous Operation – Wet Weather Storage Selection Contour Map (Overflow Summary)

From the contour map shown in Figure 6.2, it was seen that the optimum wet weather storage volume for autonomous operation was 400 kL.

A summary of the results for the most suitable irrigation area and wet weather storage volume for autonomous operation along with the baseline results for kikuyu were provided below in Table 6.9.

Table 6.9 Summary of Results for Kikuyu for Scenario 1 to 6 (TN20 to TN40 & TP15 to TP20) – Autonomous Operation (500 personnel)

Autonomous Operation (500 personnel) – Kikuyu		
Parameters	**Kikuyu – 400 kL, 2.0ha**	**Kikuyu – Baseline**
Deep Drainage (mm/year)	49.91 – 50.87	**10.68**
Nitrogen Uptake (kg/ha/year)	200 – 300	**100**
Nitrogen Leach (kg/ha/year)	0.912 – 0.914	**0.843**
Phosphorous Uptake (kg/ha/year)	39.6 – 100	**0.612**
Phosphorous Leach (kg/ha/year)	0.0046 – 0.00557	**0**
No. of days without crop per year (days)	0	**204.41**
Average monthly water logging index (Scale of 0 to 1)	0	**0**
Average monthly water stress index (Scale of 0 to 1)	0.21	**0.12**

Autonomous Operation (500 personnel) – Kikuyu		
Parameters	**Kikuyu – 400 kL, 2.0ha**	**Kikuyu – Baseline**
Average no. of crop deaths (no./year)	0	**2.2**
Average Annual Yield (kg/m^2/year)	1.2 – 1.65	**0.37**
Overflow (m^3/year)	0	**11,148.34**
Average Nitrogen deficiency stress (Scale of 0 to 1)	0.64 – 0.75	**0.22**
Average January temp. stress (Scale of 0 to 1)	0.04	**0.04**
Average. July temp. stress (Scale of 0 to 1)	0.46	**0.46**
Transpiration (mm/year)	1067.78 – 1069.37	**232.62**
Soil Evaporation (mm/year	1.3	**309.25**
Design Soil Profile (years)	139.18 – 159.54	∞
Score	**27**	

From the short listed 6 options for non-autonomous operation, when the options with 2.5 ha of irrigation area were compared with the options with 3.0 ha of irrigation area, it was determined that the options with 2.5 ha of irrigation area were not suitable. This is because the options with 2.5 ha of irrigation area had a higher deep drainage rate. The options with an irrigation area of 3.0 ha was also determined to be more suitable because there was less nutrient leaching when an irrigation area of 3.0 ha is used compared to an irrigation area of 2.5 ha.

The optimum wet weather storage volume for non-autonomous operation was then selected by using the contour map produced from MEDLI. Figure 6.3 below shows the contour map that was produced from MEDLI for non-autonomous operation along with the optimum wet weather storage volume for an irrigation area of 3.0 ha.

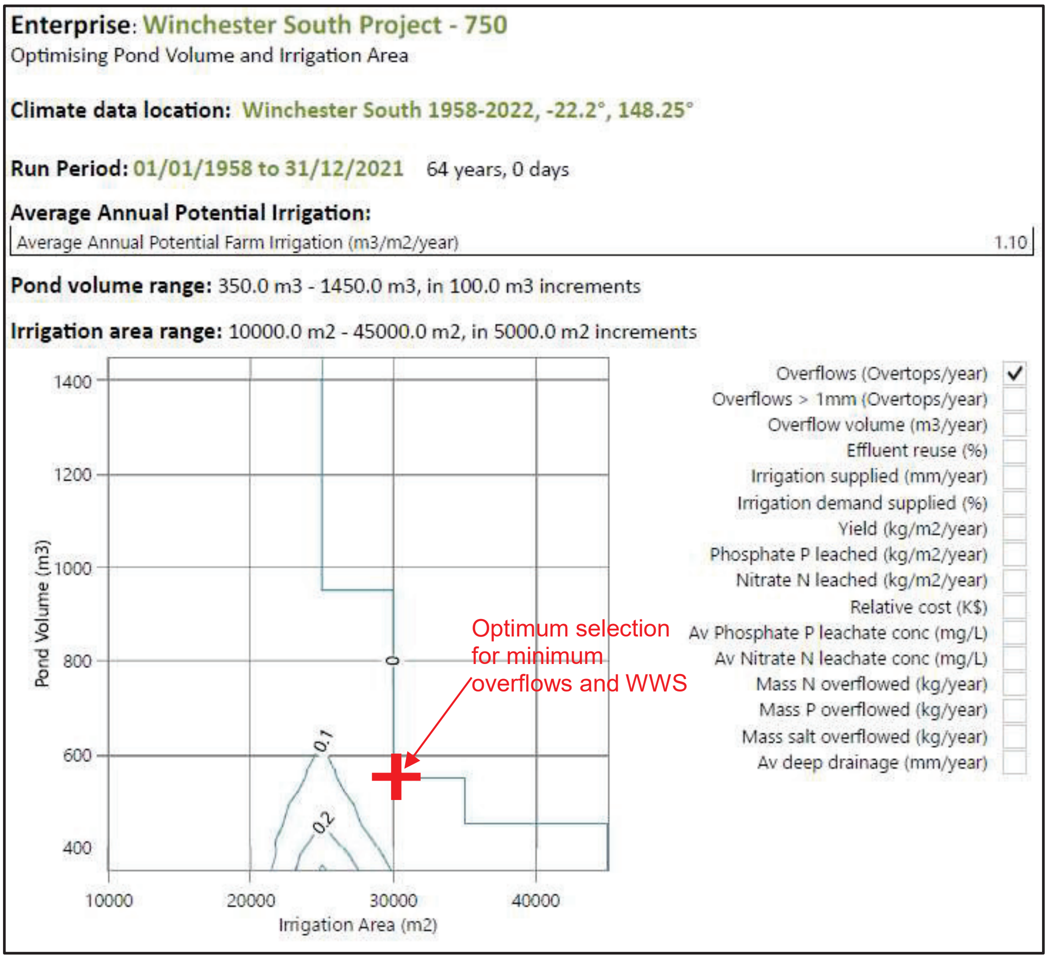


Figure 6.3 Non-Autonomous Operation – Wet Weather Storage Selection Contour Map (Overflow Summary)

From the contour map shown in Figure 6.3, it was seen that the optimum wet weather storage volume for non-autonomous operation was 550 kL.

A summary of the results for the most suitable irrigation area and wet weather storage volume for non-autonomous operation along with the baseline results for kikuyu were provided below in Table 6.10.

Table 6.10 Summary of Results for Kikuyu for Scenario 7 to 12 (TN20 to TN40 & TP15 to TP20) – Non-Autonomous Operation (750 personnel)

Non-Autonomous Operation (750 personnel)-Kikuyu		
Parameters	**Kikuyu – 550 kL, 3.0ha**	**Kikuyu – Baseline**
Deep Drainage (mm/year)	50.67 – 51.33	**10.68**
Nitrogen Uptake (kg/ha/year)	200 – 300	**100**
Nitrogen Leach (kg/ha/year)	0.912 – 0.914	**0.843**
Phosphorous Uptake (kg/ha/year)	39.7 – 100	**0.612**
Phosphorous Leach (kg/ha/year)	0.00475 – 0.00558	**0**
No. of days without crop per year (days)	0	**204.41**
Average monthly water logging index (Scale of 0 to 1)	0	**0**

Non-Autonomous Operation (750 personnel)-Kikuyu		
Parameters	**Kikuyu – 550 kL, 3.0ha**	**Kikuyu – Baseline**
Average monthly water stress index (Scale of 0 to 1)	0.2 – 0.21	**0.12**
Average no. of crop deaths (no./year)	0	**2.2**
Average Annual Yield (kg/m²/year)	1.2 – 1.66	**0.37**
Overflow (m³/year)	0	**11,148.34**
Average Nitrogen deficiency stress (Scale of 0 to 1)	0.64 – 0.75	**0.22**
Average January temp. stress (Scale of 0 to 1)	0.04	**0.04**
Average. July temp. stress (Scale of 0 to 1)	0.46	**0.46**
Transpiration (mm/year)	1070.08 – 1071.01	**232.62**
Soil Evaporation (mm/year)	1.31	**309.25**
Design Soil Profile	138.76 – 159.11	**∞**
Score	**27**	

The full KPI assessment that was completed for all of the results for all of the scenarios can be found in Appendix E. The full results from all of the multi-runs that were conducted for scenarios 1 to 12 for Kikuyu can be found in Appendix F. The full results from all of the multi-runs that were conducted for scenarios 1 to 12 for Melaleuca Alternifolia can be found in Appendix G.

6.8 Summary of Findings from Autonomous Operation MEDLI Modelling

From the assessment that was conducted on the results from the MEDLI modelling for autonomous operation, it was determined that the optimal plant species to use was Kikuyu, the optimal wet weather storage volume was 400 kL and the optimal irrigation area was 2.0 ha.

⚠ **IMPORTANT**	The preferred effluent irrigation scheme for autonomous operation is: • Plant species for the effluent irrigation area is Kikuyu • Effluent irrigation land area of 2.0 ha • Wet weather storage of 400 kL • Total nitrogen in the treated effluent of 30 to 40 mg/L. • Total phosphorous in the treated effluent of 15 mg/L

In terms of the environmental impacts of operating the irrigation scheme with the recommended wet weather storage volume and irrigation field area, there were a number of environmental impacts to be considered. The environmental impacts that need to be considered, along with an explanation on how to manage the environmental impact, are provided below:

- **Deep Drainage:** From the multi-run that was conducted, it was seen that at the recommended wet weather storage volume of 400 kL and the recommended irrigation area of 2.0 ha, the deep drainage increased by more than 20% when compared to the base case deep drainage, with no irrigation occurring. It should be noted that the deep drainage at the recommended storage volume and irrigation area is still within the acceptable DES deep drainage limit of 200 mm/year. Deep drainage impacts can be further mitigated by not irrigating during periods of prolonged rain events. The 400kL wet weather storage tank allows for this.
- **Water Stress:** It is important to note that from the MEDLI model, it was seen that when Kikuyu is used as the plant crop for the irrigation area, there was minor water stress on the Kikuyu. This is most likely because Kikuyu grows best in areas where there is an annual average

rainfall of 1000 to 1500 mm, (Sprivulis, 1978). From the climate data, it was seen that Winchester South has an average annual rainfall of 574.6 mm, which means that in order to use Kikuyu on the irrigation field, irrigation is essential.
Kikuyu was the plant that was selected for the Winchester South project as this plant has the best performance out of the 3 shortlisted crop types. In particular, when Kikuyu is used, there are zero days when there are no crops and there are zero crop deaths. It is also important to note that when Kikuyu is used there is less nitrogen leaching when compared to Melaleuca Alternifolia and there is less water stress on the crops. Kikuyu is also an ideal plant to use for the irrigation area as this crop is fairly easy to manage, as Kikuyu only requires regular mowing during the peak Kikuyu growing season.

- **Nitrogen Deficiency stress:** It is important to note that when the irrigation area is irrigated with treated effluent that has a total nitrogen concentration of 20 mg/L, there is nitrogen deficiency stress on the Kikuyu. This is because Kikuyu is typically fertilised with between 50 and 100 kg/ha of nitrogen on a 6 weekly basis between October and March, which is equivalent to approximately 217.5 to 435 kg/ha/year of nitrogen. From the MEDLI model, it was noted for scenario 1, there was 200 kg/ha/year of nitrogen applied to the irrigation field through irrigation. This indicates that there approximately half the average typical amount of nitrogen applied to the Kikuyu through the effluent irrigation scheme. In order to reduce the nitrogen stress on the Kikuyu, pasture management techniques can be used to reduce this stress, including applying fertiliser to the irrigation field or the preferred is to allowing the clippings to be returned to the soil every few months to reduce soil fertility rundown.

It was seen from the multi-runs that were conducted for scenario 1 to 6 that when the total nitrogen (TN) was increased from 20 mg/L to 30 mg/L and then up to 40 mg/L that there was only a 0.1 % increase in the amount of nitrogen leaching into the soil compared to 20mg/L of TN. Therefore this indicated that there was no significant increase in the impact on the soil if the total nitrogen in the treated effluent used to irrigate the irrigation area is increased. Similarly, it was seen that when the total phosphorous was increased from 15 mg/L to 20 mg/L there was a 25% increase in the amount of phosphorous leach into the soil.

ⓘ INFORMATION	It is important to note that though the increase in the amount of phosphorous leaching appears to be quite significant when the total phosphorous was increased from 15 mg/L to 20 mg/L, this was not considered to be a significant increase as the amounts of phosphorous leaching into the soil was very low.

It was also seen from the multi-runs that were conducted for scenario 1 to 6 that when total nitrogen was increased from 20 mg/L to 30 mg/L, there was an increase of 20% in the crop yield and when the total nitrogen was increased from 30 mg/L to 40 mg/L, there was an increase of 15% in the crop yield. This therefore showed that with an increase in the nitrogen level in the treated effluent used to irrigate, there was an increase in the crop yield without causing a significant impact on the environment. It was noted that increasing the total phosphorous in the treated effluent had no effect on the crop yield.

Therefore as long as the STP is operated to ensure that the total nitrogen level in the treated effluent is maintained between 30 to 40 mg/L and the total phosphorous level in the treated effluent is maintained between 15 to 20 mg/L, there will be minimal environmental impacts when the treated effluent is used for irrigation. Though it is important to note that the nitrogen deficiency stress on the Kikuyu decreases when the total nitrogen is increased from 20 mg/L to 30 mg/L and then up to 40 mg/L.

ⓘ INFORMATION	It is important to note that due consideration needs to be taken in regards to the energy consumption, greenhouse gas emission and chemical consumption when designing the STP, particularly when it comes to the level

	of nutrient removal required. These considerations will be analysed in more detail during the detailed design phase for the STP and will also require the influent characteristics to be considered.

Through the MEDLI modelling process, a worst case total dissolved solids concentration of 1000 mg/L was assumed and used for each of the MEDLI model runs completed. The salt balance for each of the multi-runs that were conducted for scenario 1 to 6 was reviewed to determine if the high salt concentration in the treated effluent had a significant impact of the plant performance. From the salt balance, shown below in Figure 6.4 and Figure 6.5, it was seen that even with a total dissolved solids concentration of 1000 mg/L in the treated effluent used to irrigate, these was no significant impact on the yield of the Kikuyu.

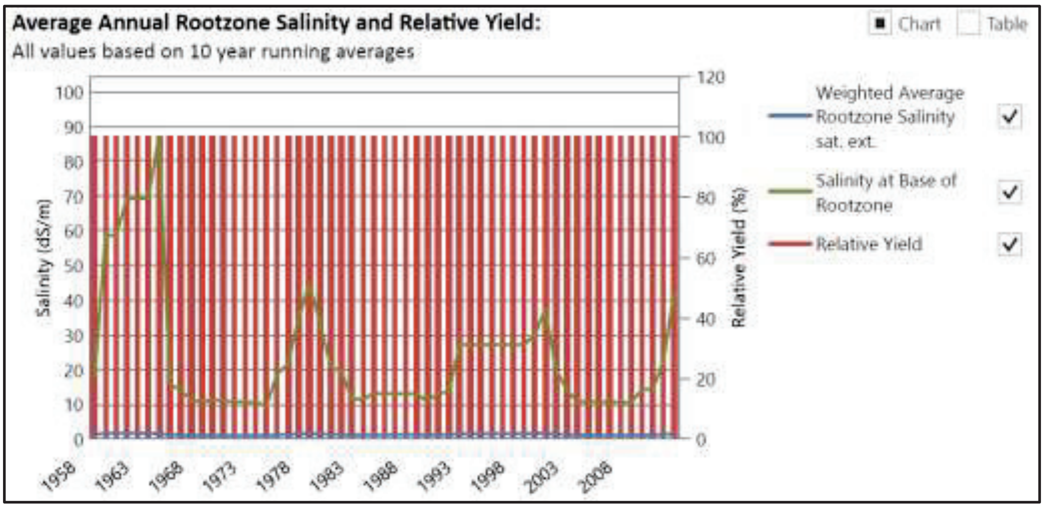


Figure 6.4 Salt Balance for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15

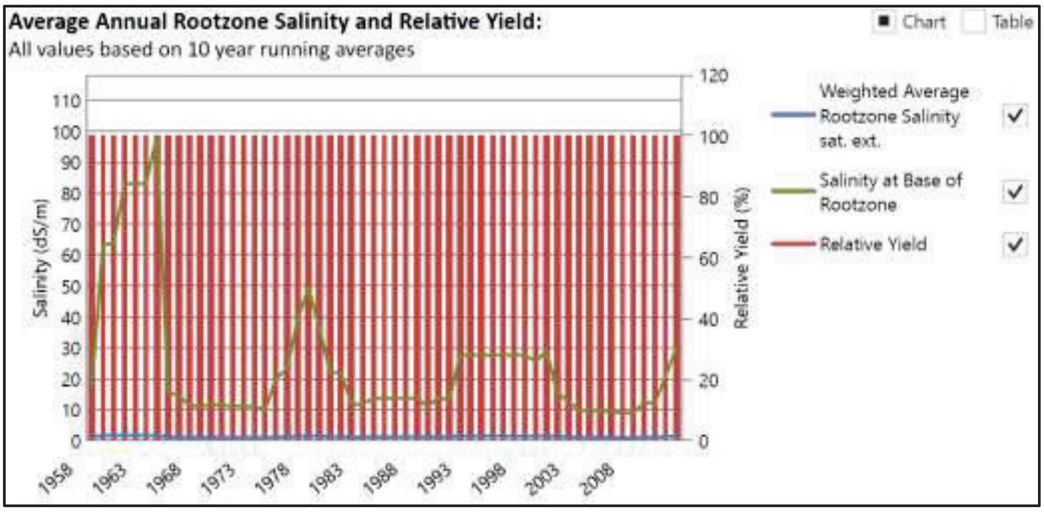


Figure 6.5 Salt Balance for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20

6.9 Summary of Findings from Non-Autonomous Operation MEDLI Modelling

The assessment of the MEDLI modelling results for non-autonomous operation, concluded that the optimal plant species to use was Kikuyu. The optimal wet weather storage volume was 550 kL and the optimal irrigation area was 3.0 ha.

⚠ IMPORTANT	The preferred effluent irrigation scheme for non-autonomous operation is: • Plant species for the effluent irrigation area is Kikuyu • Effluent irrigation land area of 3.0 ha • Wet weather storage of 550 kL • Total nitrogen in the treated effluent of 30 to 40 mg/L. • Total phosphorous in the treated effluent of 15 mg/L

The environmental impacts of operating the irrigation scheme with the recommended wet weather storage volume and irrigation field area, there were a number of environmental impacts to be considered. The environmental impacts that need to be considered, along with an explanation on how to manage the environmental impact, are provided below:

- **Deep Drainage:** From the multi-run that was conducted, it was seen that at the recommended wet weather storage volume of 550 kL and the recommended irrigation area of 3.0 ha, the deep drainage increased by more than 20% when compared to the base case deep drainage, where no irrigation occurred. It should be noted that the deep drainage at the recommended storage volume and irrigation area is still within the acceptable DES deep drainage limit of 200 mm/year. Deep drainage impacts can be further mitigated by not irrigating during periods of prolonged rain events. The 550 kL wet weather storage tank allows for this.
- **Nitrogen Deficiency stress:** It is important to note that when the irrigation area is irrigated with treated effluent that has a total nitrogen concentration of 20 mg/L, there is nitrogen deficiency stress on the Kikuyu. Kikuyu is typically fertilised at a rate of 50 to 100 kg/ha of nitrogen on a 6 weekly basis between October and March. This is equivalent to approximately 217.5 to 435 kg/ha/year of nitrogen. From the MEDLI model, it was noted for scenario 7, there was 200 kg/ha/year of nitrogen applied to the irrigation field through irrigation. There is approximately half the average typical amount of nitrogen applied to the Kikuyu through irrigation. In order to reduce the nitrogen stress on the Kikuyu, pasture management techniques can be used to reduce this stress, including applying fertiliser to the irrigation field or the preferred approach of returning the clippings to the soil every few months to reduce soil fertility rundown.
- **Water Stress:** It is important to note that from the MEDLI model, it was seen that when Kikuyu is used as the plant crop for the effluent irrigation area, there was minor water stress on the Kikuyu. Kikuyu grows best in areas where there is an annual average rainfall of 1000 to 1500 mm (Sprivulis, 1978). From the climate data, it was seen that Winchester South has an average annual rainfall of 574.6 mm, which means that in order to use Kikuyu on the effluent irrigation field, additional irrigation is essential.

  Kikuyu was the plant that was selected for the Winchester South project as this plant has the best performance out of the 3 shortlisted crop types. In particular, when Kikuyu is used, there are zero days when there are no crops and there are zero crop deaths. It is also important to note that when Kikuyu is used there is less nitrogen leaching when compared to Melaleuca Alternifolia and there is less water stress on the crops. Kikuyu is also an ideal plant to use for the irrigation area as this crop is fairly easy to manage, as Kikuyu only requires regular mowing during the peak Kikuyu growing season.

It was seen from the multi-runs conducted for scenario 7 to 12 that when the total nitrogen was increased from 20 mg/L to 30 mg/L and then up to 40 mg/L that there was only a 0.1% increase in the amount of nitrogen leach into the soil. Therefore this shows that there is no significant increase in the impact on the soil if the total nitrogen in the treated effluent used to irrigate the effluent irrigation area increased up to 40 mg/L. Similarly, it was seen that when the total phosphorous was increased from 15 mg/L to 20 mg/L there was a 25% increase in the amount of phosphorous leach into the soil compared to 15 mg/L.

INFORMATION	It is important to note that though the percentage increase in the amount of phosphorous leaching appears to be quite significant at 25% when the total phosphorous was increased from 15 mg/L to 20 mg/L, this was not considered to be a significant increase as a mass load on the environment as the amounts of phosphorous leaching into the soil was very low.

It was also seen from the multi-runs that were conducted for scenario 7 to 12 that when total nitrogen was increased from 20 mg/L to 30 mg/L, there was an increase of 20% in the crop yield and when the total nitrogen was increased from 30 mg/L to 40 mg/L, there was an increase of 15% in the crop yield. This therefore showed that with an increase in the nitrogen level in the treated effluent used to irrigate, there was an increase in the crop yield without causing a significant impact on the environment. It was noted that increasing the total phosphorous in the treated effluent had no effect on the crop yield.

Through the MEDLI modelling process, a worst case total dissolved solids concentration of 1000 mg/L was assumed and used for each of the MEDLI model runs completed. The salt balance for each of the multi-runs that were conducted for scenario 7 to 12 was reviewed to determine if the high salt concentration in the treated effluent had a significant impact of the plant performance. From the salt balance, shown below in Figure 6.6 and Figure 6.7, it was seen that even with a total dissolved salt concentration of 1000 mg/L in the treated effluent used to irrigate, these was no significant impact on the yield of the Kikuyu.

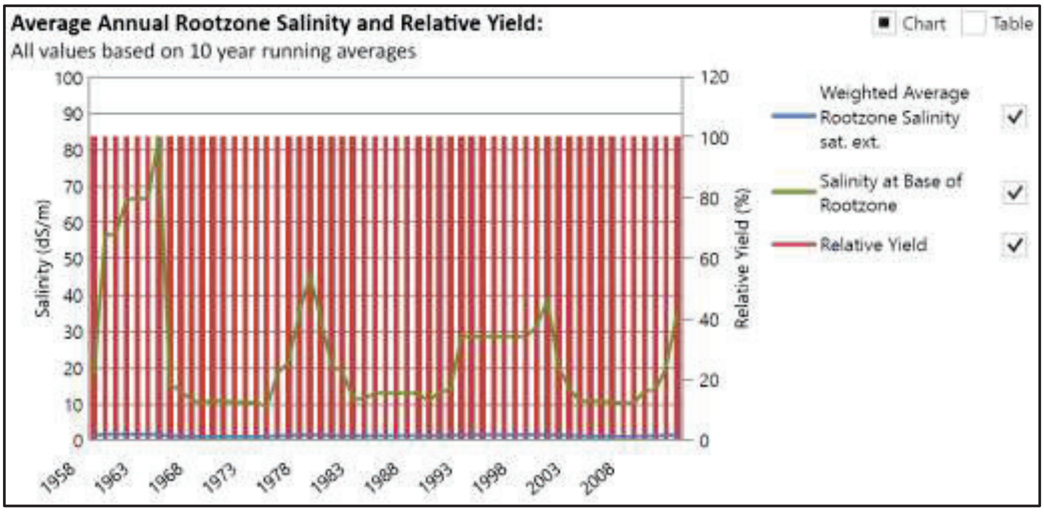


Figure 6.6 Salt Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN20 and TP15

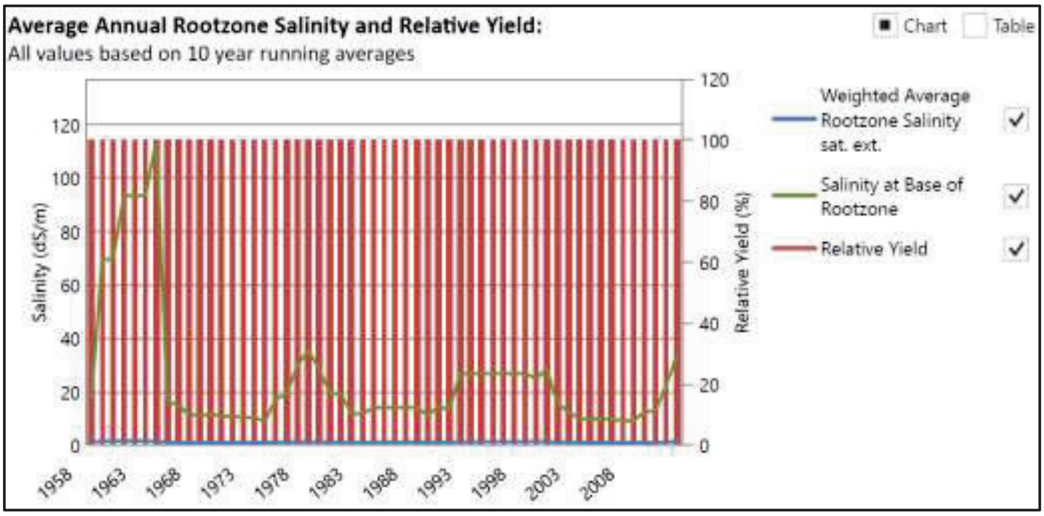


Figure 6.7 Salt Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN40 and TP20

7 Sensitivity of Prolonged Elevated Precipitation on Wet-Weather Storage Volume Requirements

Based on the selected optimum operating parameters, a MEDLI model investigating the sensitivity of wet weather storage was conducted. The model utilised 11 consecutive years of prolonged elevated precipitation as observed for years 2010 to 2020. The MEDLI modelling process and outcomes are discussed further in the sections below.

7.1 MEDLI Model Scenario Modelling Approach for Wet Weather Storage Sensitivity Analysis

The wet weather storage sensitivity analysis MEDLI modelling that was completed utilising the 11 consecutive years of prolonged precipitation as observed for years 2010 to 2020 was conducted using a similar approach to the one that was utilised in the initial MEDL modelling investigation, outlined in Section 6.1. It is important to note that for the wet weather storage sensitivity analysis MEDLI modelling, the only plant species that was modelled was Kikuyu. A summary of the steps that were undertaken is outlined below.

1. Common MEDLI model inputs that were used in the wet weather storage sensitivity analysis MEDLI model when the multi-runs were conducted were identified and these common inputs included the following:
    a. Population (500 personnel for autonomous operation or 750 for non-autonomous operation);
    b. Hydraulic EP volume (200 L/EP/day);
    c. Total dissolved solids (1000 mg/L);
    d. Soil parameters;
    e. Irrigation Rate (2 mm/day); and
    f. Plant parameters (Kikuyu).
2. The baseline performance for Kikuyu based on MEDLI utilising 11 consecutive years of prolonged elevated precipitation as observed for years 2010 to 2020 was established. This baseline performance was determined by conducting a MEDLI run for Kikuyu with no irrigation. The baseline performance was established in order to determine the baseline effects that rain had on the environment at the selected irrigation area and was used to determine if there were any increases in the impact that irrigation had on the environment.
3. Key Performance Indicators were selected to assess the impact that irrigation had on the environment. The KPI that were selected focused on the effects that deep drainage, overflows, plant performance and nutrient impacts on the environment. The assessment criteria for each KPI was also determined for Kikuyu.
4. The scenarios for the wet weather sensitivity analysis MEDLI modelling multi-runs were defined. There were a total of 12 scenarios with varying nutrient levels. These scenarios were used in order to determine the effects that different nutrient levels in the treated effluent had on the environment.
5. A total of 12 MEDLI model multi-runs were conducted for Kikuyu utilising 11 consecutive years of prolonged elevated precipitation as observed for years 2010 to 2020. Data from each of these MEDLI multi-runs were entered into an Excel spreadsheet and the results were assessed based on the KPI assessment criteria that was defined in Step 3 of the process. From this initial assessment of the MEDLI model multi-run results, the highest scoring options were determined.
6. Further assessment of the MEDLI model multi-run results was conducted. This assessment involved the selection of the optimum irrigation area. The optimum irrigation area was the option with the best plant performance and the least environmental impact.

The full KPI assessment that was completed for all of the results for all of the scenarios for the wet weather sensitivity analysis can be found in Appendix E. The full results from all of the multi-runs that were conducted for scenarios 1 to 12 for Kikuyu for the wet weather sensitivity analysis can be found in Appendix H.

7.2 Summary of Findings from Autonomous Operation – Wet Weather Storage Sensitivity Analysis

From the assessment that was conducted on the results from the MEDLI modelling that was conducted for the wet weather storage sensitivity analysis for autonomous operation, it was determined that the optimal wet weather storage volume was between 300 kL and 900 kL and the optimal irrigation area was 2.0 ha.

It is recommended that for the wet weather storage tank, a storage volume of 900 kL should be used. Using a 900 kL tank will provide 30 days of wet-weather storage of the treated effluent, which would provide redundancy in the treated effluent supply in the event that the irrigation area needs to be shut down for maintenance or if there were crop losses in the irrigation field. Based on SSI experience, it is expected that there will not be a significant cost difference between a 300 kL tank and a 900 kL tank as part of the overall cost of the project.

⚠ **IMPORTANT**	The preferred effluent irrigation scheme for autonomous operation, based on the wet weather storage sensitivity analysis MEDLI modelling, is: • Effluent irrigation land area of 2.0 ha • Wet weather storage of 900 kL • Total nitrogen in the treated effluent of 30 to 40 mg/L. • Total phosphorous in the treated effluent of 15 mg/L

In terms of the environmental impacts of operating the irrigation scheme with the recommended wet weather storage volume and irrigation field area, there are a number of environmental impacts to be considered. The environmental impacts that need to be considered, along with an explanation on how to manage the environmental impact, are provided below:

- **Deep Drainage:** From the multi-run that was conducted, it was seen that at the recommended wet weather storage volume of 900 kL and the recommended irrigation area of 2.0 ha, the deep drainage increased by more than 20% when compared to the base case deep drainage, with no irrigation occurring. It should be noted that the deep drainage at the recommended storage volume and irrigation area is still within the acceptable DES deep drainage limit of 200 mm/year. Deep drainage impacts can be further mitigated by not irrigating during periods of prolonged rain events. The 900kL wet weather storage tank allows for this.
- **Nitrogen Leaching:** The nitrogen leaching for the recommended wet weather storage volume of 900 kL and the recommended irrigation area of 2.0 ha, is just above the acceptable DES nitrogen leaching limit of 5 kg/ha/year. However, after speaking with DES it was noted that any native nitrate-nitrogen will be flushed out of the soil profile in the first year or so of irrigation. This nitrate-nitrogen flush out is dependent on the initial soil nitrate concentration, and the increased amount of water percolating through the soil profile due to the commencement of irrigation. DES notes that due to the flushing out of nitrate-nitrogen from the soil profile due to the irrigation, the nitrogen leaching will hopefully diminish over time. Full details from the correspondence with DES can be found Appendix I.
- **Water Stress:** It is important to note that from the MEDLI model, it was seen that when kikuyu is used as the plant crop for the irrigation area, there was minor water stress on the kikuyu. This is most likely because kikuyu grows best in areas where there is an annual average rainfall of 1000 to 1500 mm, (Sprivulis, 1978). From the climate data, it was seen that Winchester

South has an average annual rainfall of 592.8 mm, which means that in order to use kikuyu on the irrigation field, irrigation is essential.

Kikuyu was the plant that was selected for the Winchester South project as this plant has the best performance out of the 3 shortlisted crop types. In particular, when kikuyu is used, there are zero days when there are no crops and there are zero crop deaths. It is also important to note that when kikuyu is used there is less nitrogen leaching when compared to melaleuca and there is less water stress on the crops. Kikuyu is also an ideal plant to use for the irrigation area as this crop is fairly easy to manage, as kikuyu only requires regular mowing during the peak kikuyu growing season.

- **Nitrogen Deficiency stress:** It is important to note that when the irrigation area is irrigated with treated effluent that has a total nitrogen concentration of 20 mg/L, there is nitrogen deficiency stress on the kikuyu. This is because kikuyu is typically fertilised with between 50 and 100 kg/ha of nitrogen on a 6 weekly basis between October and March, which is equivalent to approximately 217.5 to 435 kg/ha/year of nitrogen. From the MEDLI model, it was noted for scenario 1, there was 100 kg/ha/year of nitrogen applied to the irrigation field through irrigation. This indicates that there is less than half the typical amount of nitrogen applied to the kikuyu through the effluent irrigation scheme. In order to reduce the nitrogen stress on the kikuyu, pasture management techniques can be used to reduce this stress, including applying fertiliser to the irrigation field or the preferred is to allowing the clippings to be returned to the soil every few months to reduce soil fertility rundown.

It was seen from the multi-runs that were conducted for scenario 1 to 6 that when the total nitrogen was increased from 20 mg/L to 30 mg/L and then up to 40 mg/L that there was only a 0.7% increase in the amount of nitrogen leaching into the soil compared to 20mg/L of TN. Therefore this indicates that there is no significant increase in the impact on the soil if the total nitrogen in the treated effluent used to irrigate the irrigation area is increased. Similarly, it was seen that when the total phosphorous was increased from 15 mg/L to 20 mg/L there was a 5.5% increase in the amount of phosphorous leach into the soil.

Therefore as long as the STP is operated to ensure that the total nitrogen level in the treated effluent is maintained between 20 to 40 mg/L and the total phosphorous level in the treated effluent is maintained between 15 to 20 mg/L, there will be minimal environmental impacts when the treated effluent is used for irrigation. Though it is important to note that the nitrogen deficiency stress on the kikuyu decreases when the total nitrogen is increased from 20 mg/L to 30 mg/L and then up to 40 mg/L.

ⓘ INFORMATION	It is important to note that due consideration needs to be taken in regards to the energy consumption, greenhouse gas emission and chemical consumption when designing the STP, particularly when it comes to the level of nutrient removal required. These considerations will be analysed in more detail during the detailed design phase for the STP and will also require the influent characteristics to be considered.

7.3 Summary of Findings from Non-Autonomous Operation – Wet Weather Storage Sensitivity Analysis

The assessment of the MEDLI modelling results from the modelling that was conducted for the wet weather storage sensitivity analysis for non-autonomous operation, concluded that the optimal wet weather storage volume was between 450 kL and 1,450 kL and the optimal irrigation area was 3.0 ha.

It is recommended that for the wet weather storage tank, a storage volume of 1450 kL should be used. The use of a 1,450 kL wet weather storage tank will provide 30 days of storage of the treated effluent.

This would provide redundancy for the treated effluent supply in the event that the effluent irrigation area was to be shut down for maintenance or if there was a crop loss situation. Based on SSI experience, it is expected that there will not be a significant cost difference between a 950 kL tank and a 1,450 kL tank as part of the overall cost of the project.

⚠ **IMPORTANT**	The preferred effluent irrigation scheme for non-autonomous operation, based on the wet weather storage sensitivity analysis MEDLI modelling, is: • Effluent irrigation land area of 3.0 ha • Wet weather storage of 1,450 kL • Total nitrogen in the treated effluent of 30 to 40 mg/L. • Total phosphorous in the treated effluent of 15 mg/L

The environmental impacts of operating the irrigation scheme with the recommended wet weather storage volume and irrigation field area, there are a number of environmental impacts to be considered. The environmental impacts that need to be considered, along with an explanation on how to manage the environmental impact, are provided below:

- **Deep Drainage:** From the multi-run that was conducted, it was seen that at the recommended wet weather storage volume of 1,450 kL and the recommended irrigation area of 3.0 ha, the deep drainage increased by more than 20% when compared to the base case deep drainage, where no irrigation occurred. It should be noted that the deep drainage at the recommended storage volume and irrigation area is still within the acceptable DES deep drainage limit of 200 mm/year. Deep drainage impacts can be further mitigated by not irrigating during periods of prolonged rain events. The 1,450kL wet weather storage tank allows for this.
- **Nitrogen Leaching:** The nitrogen leaching for the recommended wet weather storage volume of 1,450 kL and the recommended irrigation area of 3.0 ha, is above the acceptable DES nitrogen leaching limit of 5 kg/ha/year. However, after speaking with DES it was noted that any native nitrate-nitrogen will be flushed out of the soil profile in the first year or so of irrigation. This nitrate-nitrogen flush out is dependent on the initial soil nitrate concentration, and the increased amount of water percolating through the soil profile due to the commencement of irrigation. DES notes that due to the flushing out of nitrate-nitrogen from the soil profile due to the irrigation, hopefully the nitrogen leaching will diminish over time. Full details from the correspondence with DES can be found Appendix I.
- **Nitrogen Deficiency stress:** It is important to note that when the irrigation area is irrigated with treated effluent that has a total nitrogen concentration of 20 mg/L, there is nitrogen deficiency stress on the kikuyu. Kikuyu is typically fertilised at a rate of 50 to 100 kg/ha of nitrogen on a 6 weekly basis between October and March. This is equivalent to approximately 217.5 to 435 kg/ha/year of nitrogen. From the MEDLI model, it was noted for scenario 7, there was 100 kg/ha/year of nitrogen applied to the irrigation field through irrigation. There is less than half the typical amount of nitrogen applied to the kikuyu through irrigation. In order to reduce the nitrogen stress on the kikuyu, pasture management techniques can be used to reduce this stress, including applying fertiliser to the irrigation field or the preferred approach of returning the clippings to the soil every few months to reduce soil fertility rundown.
- **Water Stress:** It is important to note that from the MEDLI model, it was seen that when kikuyu is used as the plant crop for the effluent irrigation area, there was minor water stress on the kikuyu. Kikuyu grows best in areas where there is an annual average rainfall of 1000 to 1500 mm (Sprivulis, 1978). From the climate data, it was seen that Winchester South has an average annual rainfall of 592.8 mm, which means that in order to use kikuyu on the effluent irrigation field, additional irrigation is essential.
  Kikuyu was the plant that was selected for the Winchester South project as this plant has the best performance out of the 3 shortlisted crop types. In particular, when kikuyu is used, there

are zero days when there are no crops and there are zero crop deaths. It is also important to note that when kikuyu is used there is less nitrogen leaching when compared to melaleuca and there is less water stress on the crops. Kikuyu is also an ideal plant to use for the irrigation area as this crop is fairly easy to manage, as kikuyu only requires regular mowing during the peak kikuyu growing season.

It was seen from the multi-runs conducted for scenario 7 to 12 that when the total nitrogen was increased from 20 mg/L to 30 mg/L and then up to 40 mg/L that there was only a 0.7% increase in the amount of nitrogen leach into the soil. Therefore this shows that there is no significant increase in the impact on the soil if the total nitrogen in the treated effluent used to irrigate the effluent irrigation area increased up to 40 mg/L. Similarly, it was seen that when the total phosphorous was increased from 15 mg/L to 20 mg/L there was a 4.3% increase in the amount of phosphorous leach into the soil.

8 Summary of MEDLI Modelling Findings

For the Winchester South Project, in order to determine the optimal wet weather storage volume and irrigation area for the two operating conditions, autonomous operation and non-autonomous operation, a number of MEDLI model multi-runs were completed for a total of 12 scenarios with varying nutrient levels. The full MEDLI modelling process that was undertaken in order to determine the optimum irrigation area and wet weather storage volume was summarised below:

7. Common MEDLI model inputs that were used in the MEDLI model when the multi-runs were conducted were identified and these common inputs included the following:
    a. Population (500 personnel for autonomous operation or 750 for non-autonomous operation);
    b. Hydraulic EP volume (200 L/EP/day);
    c. Total dissolved solids (1000 mg/L);
    d. Soil parameters;
    e. Irrigation Rate (2 mm/day); and
    f. Plant parameters (either Melaleuca Alternifolia or Kikuyu).
8. The baseline performance for each of the plant species that were modelled were established. This baseline performance was determined by conducting MEDLI runs for both Kikuyu and Melaleuca Alternifolia with no irrigation. The baseline performance was established in order to determine the baseline effects that rain had on the environment at the selected irrigation area and was used to determine if there were any increases in the impact that irrigation had on the environment.
9. Key Performance Indicators were selected to assess the impact that irrigation had on the environment. The KPI that were selected focused on the effects that deep drainage, overflows, plant performance and nutrient impacts on the environment. The assessment criteria for each KPI was also determined for each of the plant species that were modelled.
10. The scenarios for the MEDLI modelling multi-runs were defined. There were a total of 12 scenarios with varying nutrient levels. These scenarios were used in order to determine the effects that different nutrient levels in the treated effluent had on the environment.
11. The initial MEDLI model that was setup was refined after corresponding with DES.
12. A total of 12 MEDLI model multi-runs were conducted for both Melaleuca Alternifolia and Kikuyu. Data from each of these MEDLI multi-runs were entered into an Excel spreadsheet and the results were assessed based on the KPI assessment criteria that was defined in Step 3 of the process. From this initial assessment of the MEDLI model multi-run results, the highest scoring options for each of the plant species was determined.
13. Further assessment of the MEDLI model multi-run results was conducted. Stage 1 of the assessment involved the selection of the ideal plant species. The plant species that had the highest score was selected. Stage 2 of the assessment involved the selection of the irrigation area. The optimum irrigation area was the option with the best plant performance and the least environmental impact whilst the optimum wet weather storage volume was selected by reviewing the contour map produced from the MEDLI model multi-runs.
14. Based on the selected optimum operating parameters a MEDLI model investigating the sensitivity of wet weather storage was conducted. The model utilised 11 consecutive years of prolonged elevated precipitation as observed for years 2010 to 2020. The MEDLI modelling conducted for the wet weather sensitivity analysis was only conducted using Kikuyu.

By following the process summarised above, the recommended wet weather storage volume and irrigation area for the two operating conditions are as follows:

- **Autonomous Operation based on 64 years (1958 to 2021) of climate data** – the optimum operating wet weather storage volume was **400 kL** & an optimum effluent irrigation area of **2.0 ha.**

- **Autonomous Operation based on 11 consecutive years (2010 to 2020) of high rainfall climate data** – The optimum operating wet weather storage volume was **900 kL** and **2.0 ha** of irrigation area.
- **Non-Autonomous Operation based on 64 years (1958 to 2021) of climate data** – the optimum operating wet weather storage volume was **550 kL** & an optimum effluent irrigation area of **3.0 ha.**
- **Non-Autonomous Operation based on 11 consecutive years (2010 to 2020) of high rainfall climate data** – The optimum operating wet weather storage volume was **1,450 kL** and **3.0 ha** of irrigation area.

Points to note for the recommended wet weather storage volume and irrigation area for the two operating conditions are as follows:

- There is no overflow using the recommended wet weather storage volume and irrigation area for ***autonomous operation*** and more than 20% increase in the deep drainage compared to the base case with no irrigation, though the increase in the deep drainage is within the DES acceptable limit for deep drainage of 200 mm/year.
- There is no overflow when using the recommended wet weather storage volume and irrigation area for ***non-autonomous operation*** and an increase in deep drainage of more than 20% when compared to the base case with no irrigation, though the increase in the deep drainage is within the DES acceptable limit for deep drainage of 200 mm/year.
- Minimal leaching of phosphorous into the soil occurred for both operating conditions;
- Minor leaching of nitrogen into the soil occurred for both operating conditions.

Table 8.1 provides a summary of the inputs and the outcomes for the recommended scenarios for the two different operating conditions.

Table 8.1 Summary of Inputs and Outcomes for the Preferred Scenarios

	Effluent Irrigation Scheme Items	Autonomous – 64yrs climate data	Non-Autonomous – 64yrs climate data	Autonomous – 11yrs climate data	Non-Autonomous – 11yrs climate data
MEDLI calculated parameter	**Wet Weather Storage Volume based on 64 years of climate data (1958 to 2021):**	400 kL	550 kL		
	Wet Weather Storage Volume based on 11 years of climate data with elevated precipitation (2010 to 2020):			900 kL	1,450 kL
	Treated effluent volume:	28.9 m^3/day	43.3 m^3/day	28.9 m^3/day	43.3 m^3/day
	Irrigation Area:	2.0 ha	3.0 ha	2.0 ha	3.0 ha
	Total Nitrogen in irrigated effluent	20 to 40 mg/L	20 to 40 mg/L	20 to 40 mg/L	20 to 40 mg/L
	Total Phosphorous in irrigated effluent	15 to 20 mg/L	15 to 20 mg/L	15 to 20 mg/L	15 to 20 mg/L
	Maximum salt (TDS) concentration in the treated effluent used for effluent irrigation.	1,000 mg/L	1,000 mg/L	1,000 mg/L	1,000 mg/L
Pond					
Rain	kL/year	0	0	0	0
Inflow	kL/year	11,153.03	16,807.00	11,172.76	16,836.72
Recycling	kL/year	0	0	0	0
Evaporation	kL/year	0	0	0	0
Overflow	kL/year	0	0	0	0
Irrigation	kL/year	11,152.88	16806.78	11,170.29	16,832.74
Land					
Rain	mm/year	574.64	574.64	592.75	592.75
Irrigation	mm/year	557.64	560.23	558.51	561.09
Soil Evaporation	mm/year	1.30	1.31	7.79	7.80

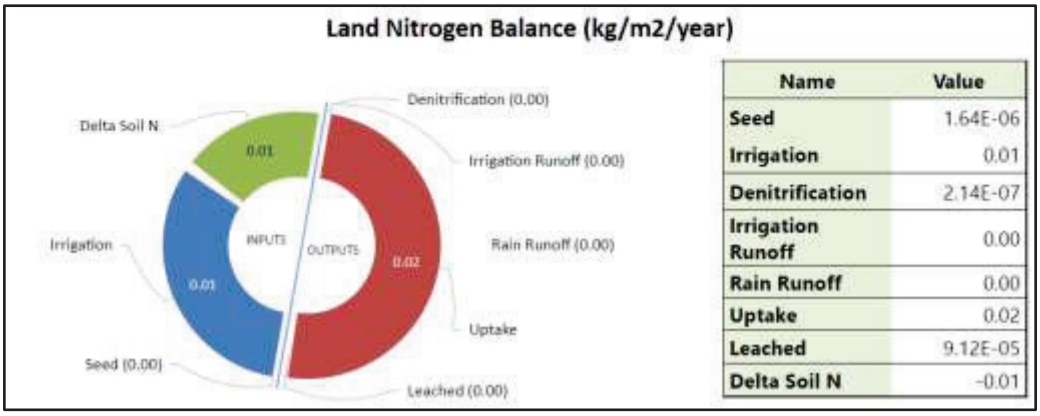
MEDLI calculated parameter	Effluent Irrigation Scheme Items	Autonomous – 64yrs climate data	Non-Autonomous – 64yrs climate data	Autonomous – 11yrs climate data	Non-Autonomous – 11yrs climate data
	Wet Weather Storage Volume based on 64 years of climate data (1958 to 2021):	400 kL	550 kL		
	Wet Weather Storage Volume based on 11 years of climate data with elevated precipitation (2010 to 2020):			900 kL	1,450 kL
	Treated effluent volume:	28.9 m³/day	43.3 m³/day	28.9 m³/day	43.3 m³/day
	Irrigation Area:	2.0 ha	3.0 ha	2.0 ha	3.0 ha
	Total Nitrogen in irrigated effluent	20 to 40 mg/L	20 to 40 mg/L	20 to 40 mg/L	20 to 40 mg/L
	Total Phosphorous in irrigated effluent	15 to 20 mg/L	15 to 20 mg/L	15 to 20 mg/L	15 to 20 mg/L
	Maximum salt (TDS) concentration in the treated effluent used for effluent irrigation.	1,000 mg/L	1,000 mg/L	1,000 mg/L	1,000 mg/L
Transpiration	mm/year	1067.78 – 1069.37	1070.08 – 1071.01	1069.11 – 1064.25	1065.58 – 1071.13
Rain Runoff	mm/year	14.37 – 14.47	14.48 – 14.55	15.81 – 15.85	15.82 – 15.88
Irrigation Runoff	mm/year	0	0	0	0
Deep Drainage	mm/year	49.91 – 50.87	50.67 – 51.33	71.27 – 74.61	71.80 – 76.04
Soil Nitrogen Balance					
Average annual effluent nitrogen added	(kg/ha/year)	100 – 200	100 – 200	100 – 200	100 – 200
Average annual soil nitrogen removed by plant uptake	(kg/ha/year)	200 – 300	200 – 300	300 – 400	300 – 400
Average annual soil nitrogen removed by denitrification	(kg/ha/year)	0.0021 – 0.0034	0.0022 – 0.0034	0.0075 – 0.0096	0.0075 – 0.0097
Average annual soil nitrogen leached	(kg/ha/year)	0.912 – 0.914	0.912 – 0.914	5.41 – 5.46	5.42 – 5.46

	Effluent Irrigation Scheme Items	Autonomous – 64yrs climate data	Non-Autonomous – 64yrs climate data	Autonomous – 11yrs climate data	Non-Autonomous – 11yrs climate data
MEDLI calculated parameter	**Wet Weather Storage Volume based on 64 years of climate data (1958 to 2021):**	400 kL	550 kL		
	Wet Weather Storage Volume based on 11 years of climate data with elevated precipitation (2010 to 2020):			900 kL	1,450 kL
	Treated effluent volume:	28.9 m^3/day	43.3 m^3/day	28.9 m^3/day	43.3 m^3/day
	Irrigation Area:	2.0 ha	3.0 ha	2.0 ha	3.0 ha
	Total Nitrogen in irrigated effluent	20 to 40 mg/L	20 to 40 mg/L	20 to 40 mg/L	20 to 40 mg/L
	Total Phosphorous in irrigated effluent	15 to 20 mg/L	15 to 20 mg/L	15 to 20 mg/L	15 to 20 mg/L
	Maximum salt (TDS) concentration in the treated effluent used for effluent irrigation.	1,000 mg/L	1,000 mg/L	1,000 mg/L	1,000 mg/L
Average annual nitrate-N loading to groundwater	(kg/ha/year)	0.912 – 0.914	0.912 – 0.914	5.41 – 5.46	5.42 – 5.46
Soil organic-N (initial-Final)	(kg/ha)	3600 – 2000	3600 – 2000	3600 – 2100	3600 – 2100
Average nitrate-N concentration of deep drainage	mg/L	1.80 – 1.83	1.78 – 1.80	7.26 – 7.66	7.13 – 7.61
Max. annual nitrate-N concentration of deep drainage (mg/L)	mg/L	11.53 – 11.57	11.52 – 11.57	12.16 – 12.67	12.11 – 12.63
Soil Phosphorus Balance					
Average annual effluent phosphorus added (kg/ha/year)	(kg/ha/year)	100	100	100	100
Average annual soil phosphorus removed by plant uptake	(kg/ha/year)	39.6 – 100	39.7 – 100	41.60 – 100	41.70
Average annual soil phosphorus leached	(kg/ha/year)	0.0046 – 0.0056	0.0048 – 0.0056	0.0048 – 0.0050	0.0049 – 0.0051

MEDLI calculated parameter	Effluent Irrigation Scheme Items	Autonomous – 64yrs climate data	Non-Autonomous – 64yrs climate data	Autonomous – 11yrs climate data	Non-Autonomous – 11yrs climate data
	Wet Weather Storage Volume based on 64 years of climate data (1958 to 2021):	400 kL	550 kL		
	Wet Weather Storage Volume based on 11 years of climate data with elevated precipitation (2010 to 2020):			900 kL	1,450 kL
	Treated effluent volume:	28.9 m^3/day	43.3 m^3/day	28.9 m^3/day	43.3 m^3/day
	Irrigation Area:	2.0 ha	3.0 ha	2.0 ha	3.0 ha
	Total Nitrogen in irrigated effluent	20 to 40 mg/L	20 to 40 mg/L	20 to 40 mg/L	20 to 40 mg/L
	Total Phosphorous in irrigated effluent	15 to 20 mg/L	15 to 20 mg/L	15 to 20 mg/L	15 to 20 mg/L
	Maximum salt (TDS) concentration in the treated effluent used for effluent irrigation.	1,000 mg/L	1,000 mg/L	1,000 mg/L	1,000 mg/L
Dissolved phosphorus (Initial – Final)	(kg/ha)	0.062 – 12	0.062 – 12	0.062 – 1.10	0.062 – 1.11
Adsorbed phosphorus (Initial – Final)	(kg/ha)	400 – 3600	400 – 3600	400 – 900	400 – 900
Average phosphate-P concentration in root zone	mg/L	1.18 – 1.80	1.19 – 1.81	0.06 – 0.10	0.06 – 0.10
Average phosphate-P concentration of deep drainage	mg/L	0.01	0.01	0.01	0.01
Max. annual phosphate-P concentration of deep drainage	mg/L	0.02 – 0.03	0.02 – 0.03	0.01	0.01
Design soil profile storage life	years	139.18 – 159.54	138.76 – 159.11	139.44 – 157.76	139.03 – 157.39
		Based on avg. infiltrated water phosphorous conc. of 7.06 – 9.41 mg/L	Based on average infiltrated water phosphorous conc. of 7.07 – 9.43 mg/L	Based on average infiltrated water phosphorous conc. of 6.95 – 9.26 mg/L	Based on average infiltrated water phosphorous conc. of 6.96 – 9.29mg/L

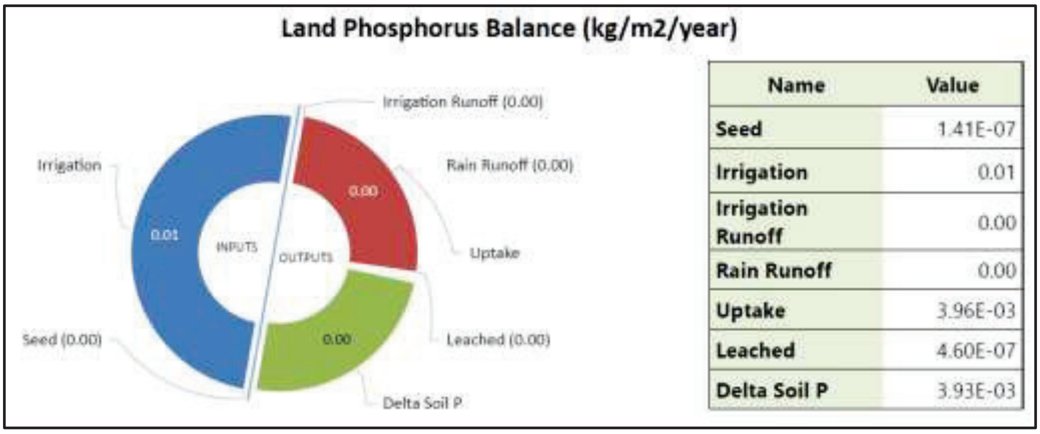
	Effluent Irrigation Scheme Items	Autonomous – 64yrs climate data	Non-Autonomous – 64yrs climate data	Autonomous – 11yrs climate data	Non-Autonomous – 11yrs climate data
MEDLI calculated parameter	**Wet Weather Storage Volume based on 64 years of climate data (1958 to 2021):**	400 kL	550 kL		
	Wet Weather Storage Volume based on 11 years of climate data with elevated precipitation (2010 to 2020):			900 kL	1,450 kL
	Treated effluent volume:	28.9 m^3/day	43.3 m^3/day	28.9 m^3/day	43.3 m^3/day
	Irrigation Area:	2.0 ha	3.0 ha	2.0 ha	3.0 ha
	Total Nitrogen in irrigated effluent	20 to 40 mg/L	20 to 40 mg/L	20 to 40 mg/L	20 to 40 mg/L
	Total Phosphorous in irrigated effluent	15 to 20 mg/L	15 to 20 mg/L	15 to 20 mg/L	15 to 20 mg/L
	Maximum salt (TDS) concentration in the treated effluent used for effluent irrigation.	1,000 mg/L	1,000 mg/L	1,000 mg/L	1,000 mg/L
Average Plant Performance					
Average annual shoot dry matter yield	kg/ha/year	12,000 – 16,500	12,000 – 16,600	16,100 – 19,600	16,200 – 19,600
Average number of crop deaths per year	no./year	0	0	0	0
No. of days without crop/year	days	0	0	0	0

The land nitrogen balance chart, land phosphorous balance chart, the plant stresses chart and salt balance chart for the recommended wet weather storage volume of 400 kL and recommended irrigation area of 2.0 ha for autonomous operation with total nitrogen at 20 mg/L and total phosphorous at 15 mg/L are shown below in Figure 8.1, Figure 8.3, Figure 8.3 and Figure 8.4.



Name	Value
Seed	1.64E-06
Irrigation	0.01
Denitrification	2.14E-07
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	0.02
Leached	9.12E-05
Delta Soil N	-0.01

Figure 8.1 Land Nitrogen Balance for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15



Name	Value
Seed	1.41E-07
Irrigation	0.01
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	3.96E-03
Leached	4.60E-07
Delta Soil P	3.93E-03

Figure 8.2 Land Phosphorous Balance for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15

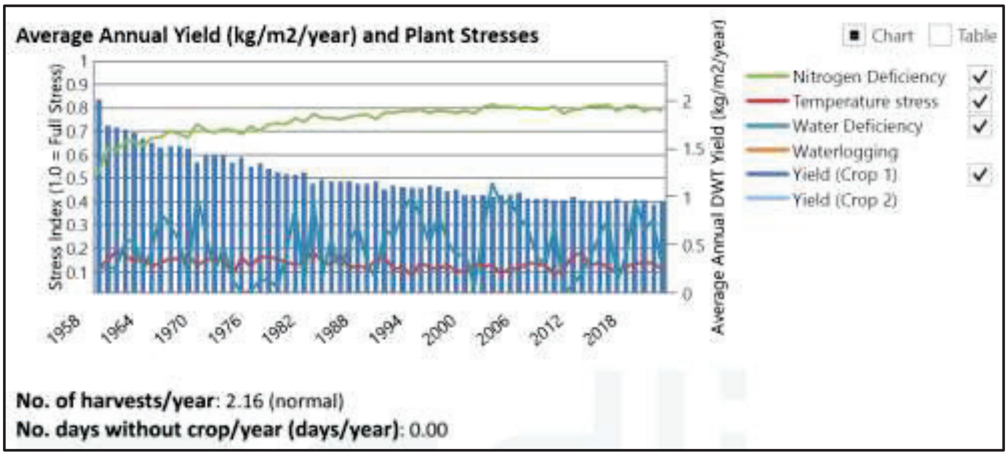


Figure 8.3 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15

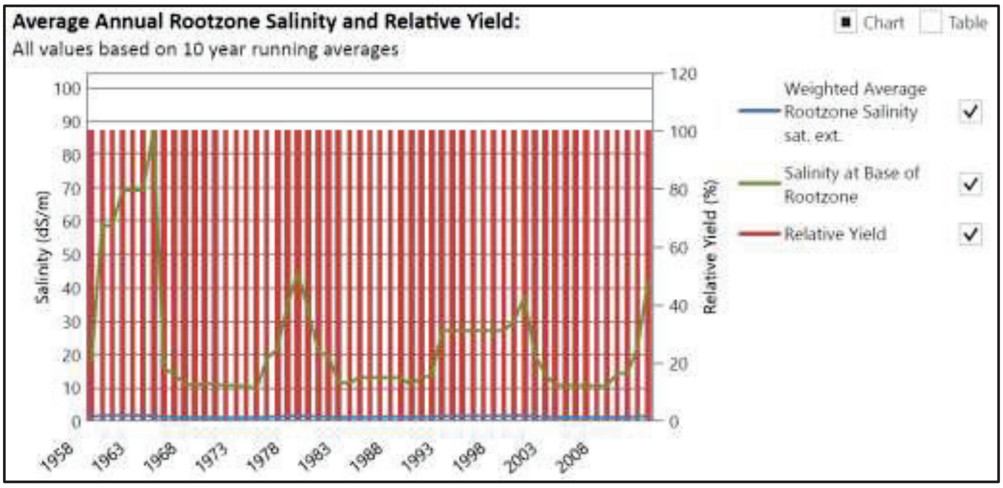


Figure 8.4 Salt Balance for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15

The land nitrogen balance chart, land phosphorous balance chart, the plant stresses chart and the salt balance chart for the recommended wet weather storage volume of 400 kL and recommended irrigation area of 2.0 ha for autonomous operation with total nitrogen at 40 mg/L and total phosphorous at 20 mg/L are shown below in Figure 8.5, Figure 8.6, Figure 8.7 and Figure 8.8.

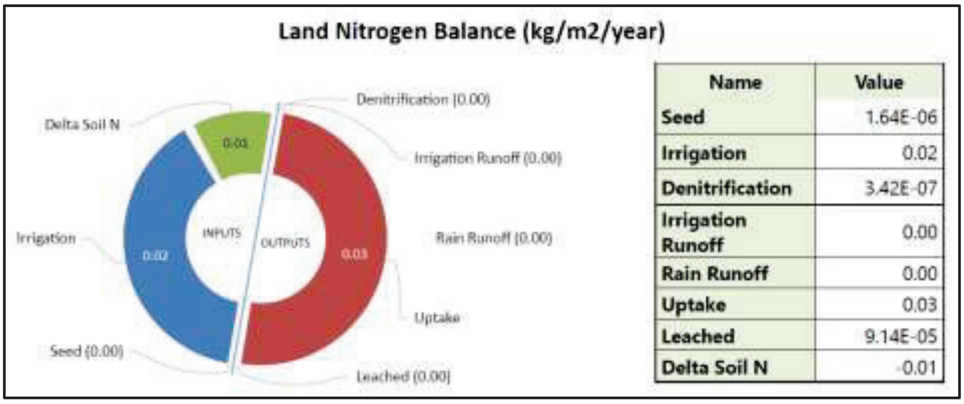


Figure 8.5 Land Nitrogen Balance for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20

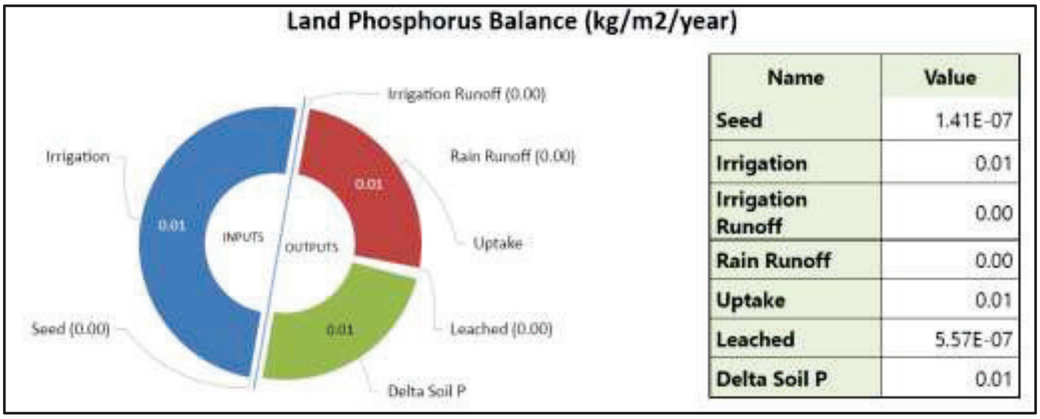


Figure 8.6 Land Phosphorous Balance for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20

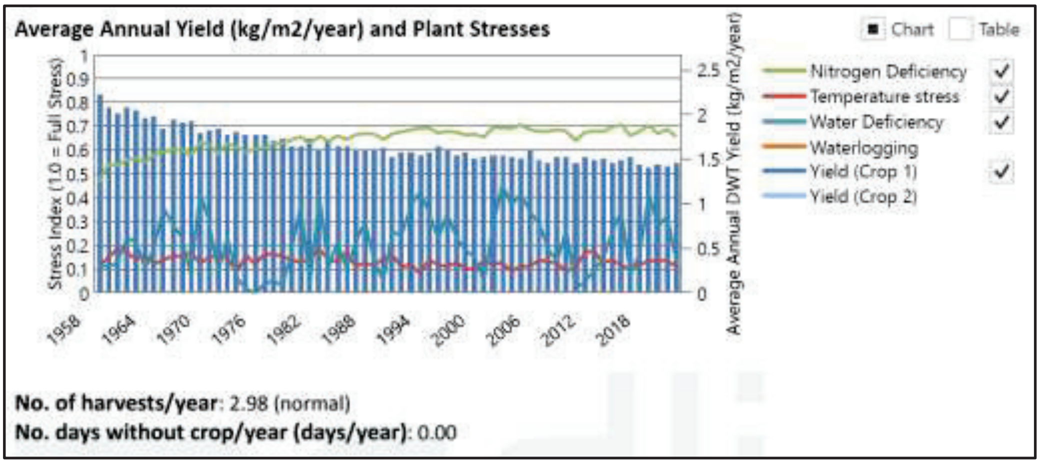


Figure 8.7 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20

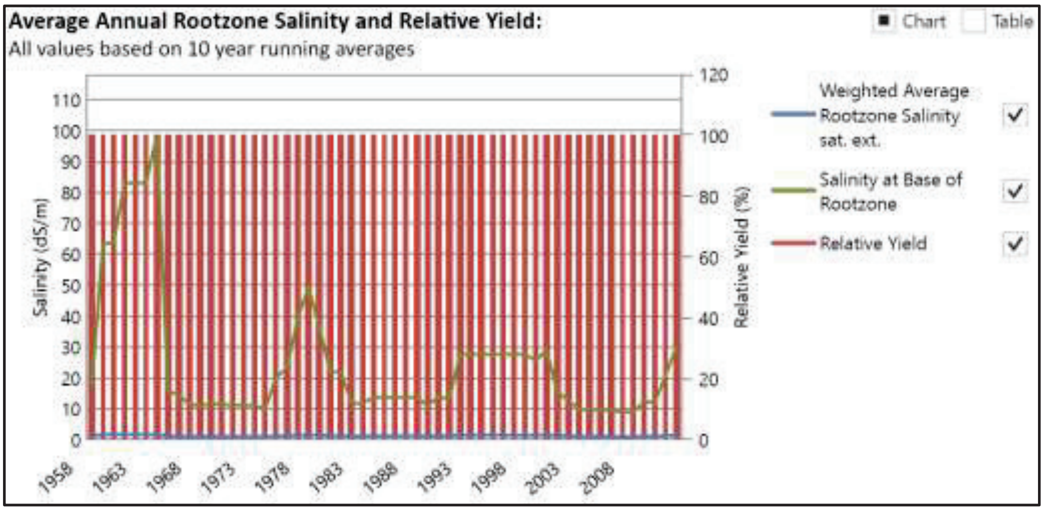
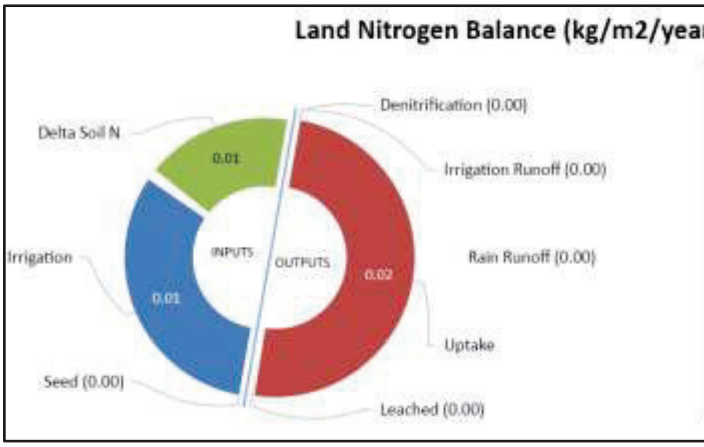


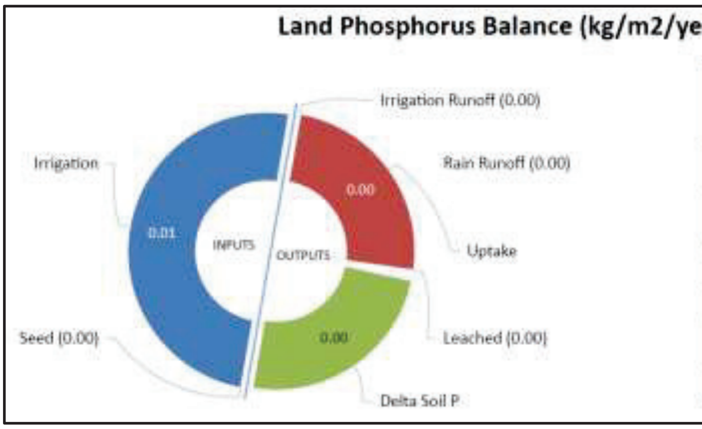
Figure 8.8 Salt Balance for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20

The land nitrogen balance chart, land phosphorous balance chart, the plant stresses chart and the salt balance chart for the recommended wet weather storage volume of 550 kL and recommended irrigation area of 3.0 ha for autonomous operation with total nitrogen at 20 mg/L and total phosphorous at 15 mg/L are shown below in Figure 8.9, Figure 8.10, Figure 8.11 and Figure 8.12.



Name	Value
Seed	1.64E-06
Irrigation	0.01
Denitrification	2.15E-07
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	0.02
Leached	9.12E-05
Delta Soil N	-0.01

Figure 8.9 Land Nitrogen Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN20 and TP15



Name	Value
Seed	1.41E-07
Irrigation	0.01
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	3.97E-03
Leached	4.75E-07
Delta Soil P	3.96E-03

Figure 8.10 Land Phosphorous Balance for Recommended Irrigation Parameters for Autonomous Operation at TN20 and TP15

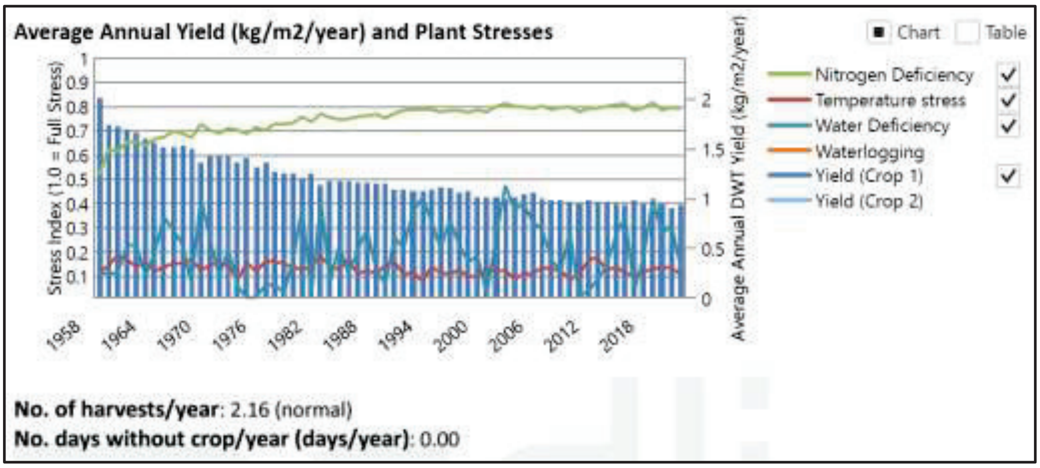


Figure 8.11 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters for Non-Autonomous Operation at TN20 and TP15

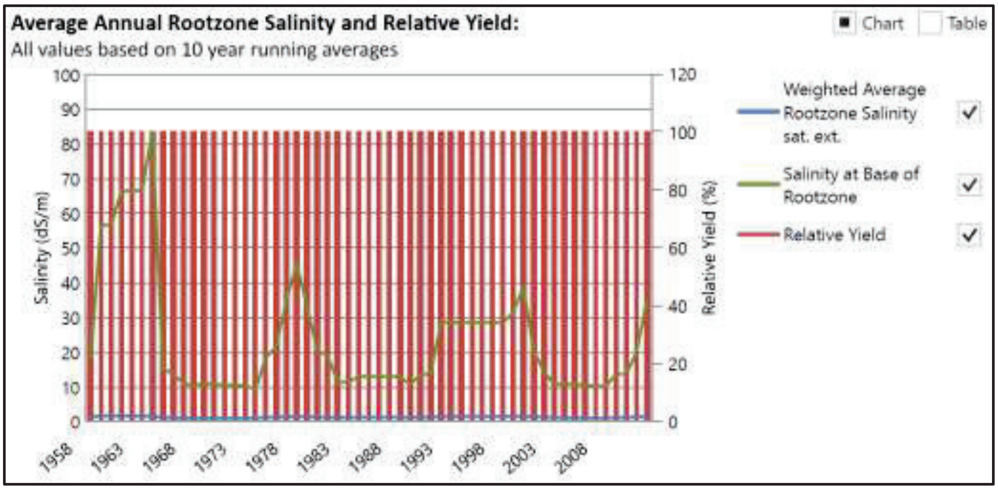
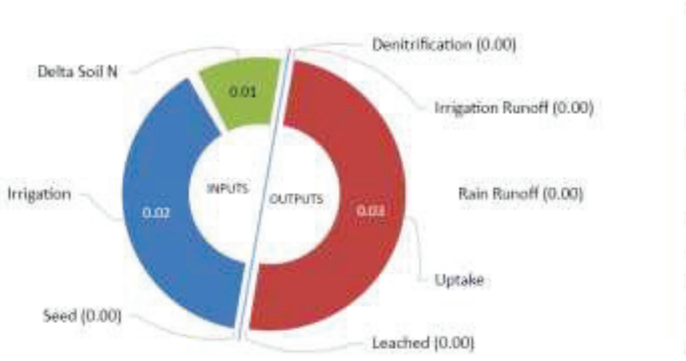


Figure 8.12 Salt Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN20 and TP15

The land nitrogen balance chart, land phosphorous balance chart, the plant stresses chart and the salt balance chart for the recommended wet weather storage volume of 550 kL and recommended irrigation area of 3.0 ha for autonomous operation with total nitrogen at 40 mg/L and total phosphorous at 20 mg/L are shown below in Figure 8.13, Figure 8.14, Figure 8.15 and Figure 8.16.

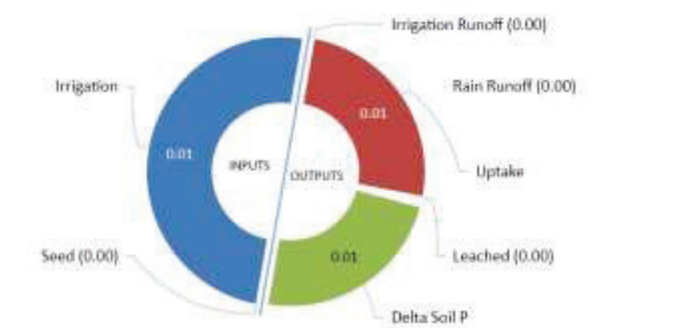
Land Nitrogen Balance (kg/m2/year)



Name	Value
Seed	1.64E-06
Irrigation	0.02
Denitrification	3.43E-07
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	0.03
Leached	9.14E-05
Delta Soil N	-0.01

Figure 8.13 Land Nitrogen Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN40 and TP20

Land Phosphorus Balance (kg/m2/year)



Name	Value
Seed	1.41E-07
Irrigation	0.01
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	0.01
Leached	5.58E-07
Delta Soil P	0.01

Figure 8.14 Land Phosphorous Balance for Recommended Irrigation Parameters for Autonomous Operation at TN40 and TP20

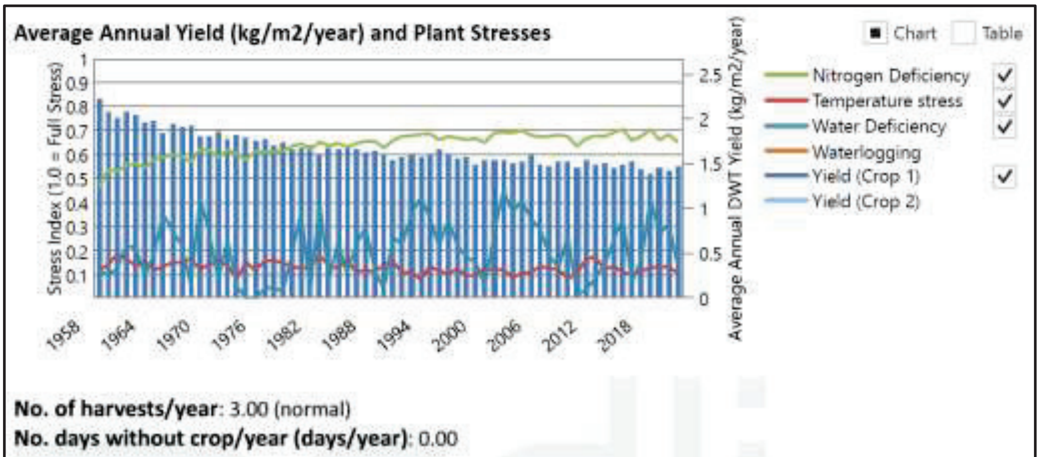


Figure 8.15 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters for Non-Autonomous Operation at TN40 and TP20

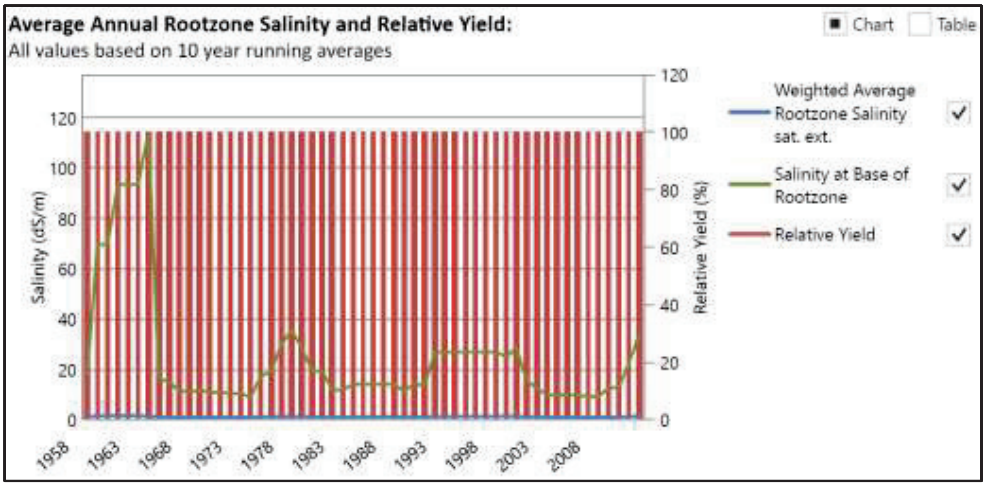
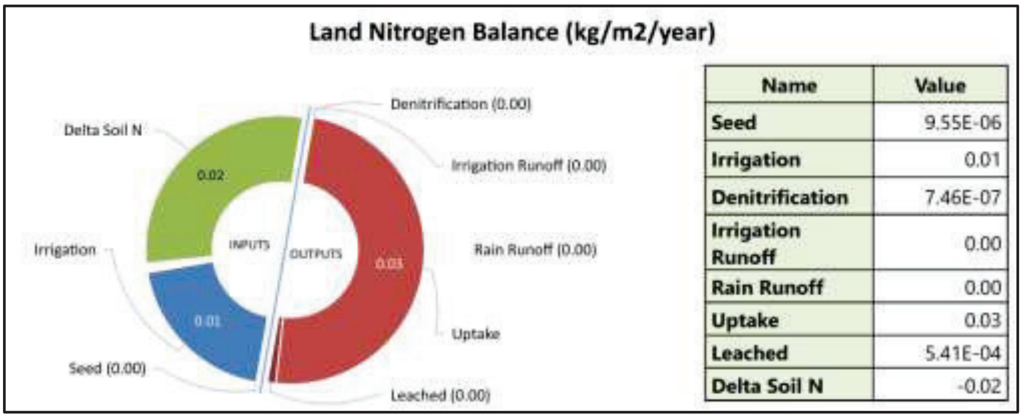


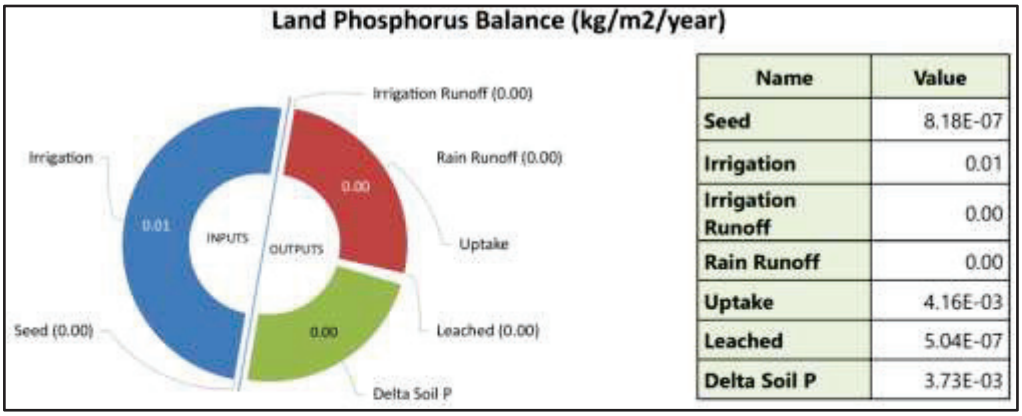
Figure 8.16 Salt Balance for Recommended Irrigation Parameters for Non-Autonomous Operation at TN40 and TP20

The land nitrogen balance chart, land phosphorous balance chart, the plant stresses chart and the salt balance chart for the recommended wet weather storage volume of 900 kL and recommended irrigation area of 2.0 ha from the wet weather storage sensitivity analysis for autonomous operation with total nitrogen at 20 mg/L and total phosphorous at 15 mg/L are shown below in Figure 8.17, Figure 8.18, Figure 8.19 and Figure 8.20.



Name	Value
Seed	9.55E-06
Irrigation	0.01
Denitrification	7.46E-07
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	0.03
Leached	5.41E-04
Delta Soil N	-0.02

Figure 8.17 Land Nitrogen Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN20 and TP15



Name	Value
Seed	8.18E-07
Irrigation	0.01
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	4.16E-03
Leached	5.04E-07
Delta Soil P	3.73E-03

Figure 8.18 Land Phosphorous Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN20 and TP15

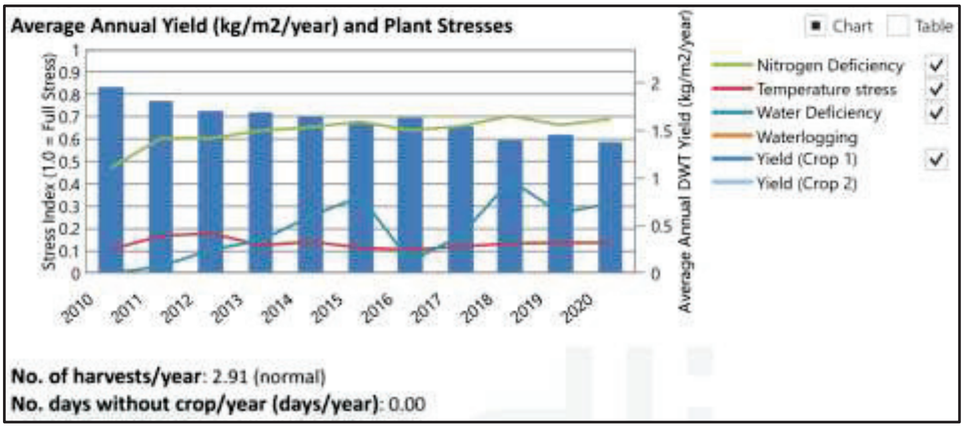


Figure 8.19 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN20 and TP15

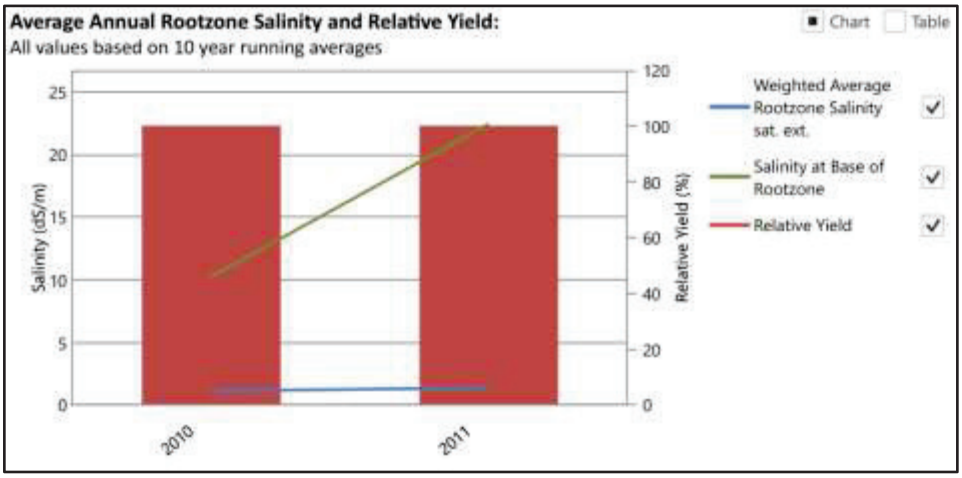
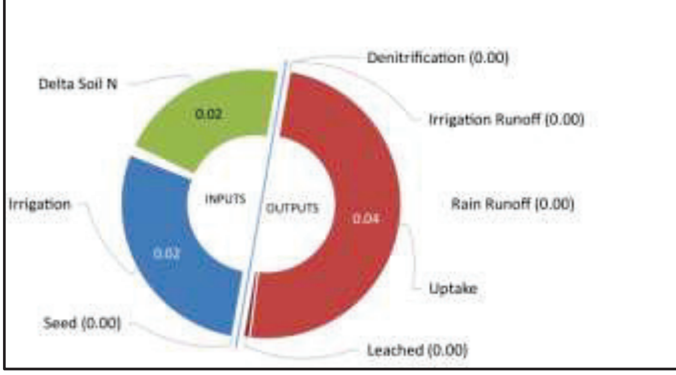


Figure 8.20 Salt Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN20 and TP15

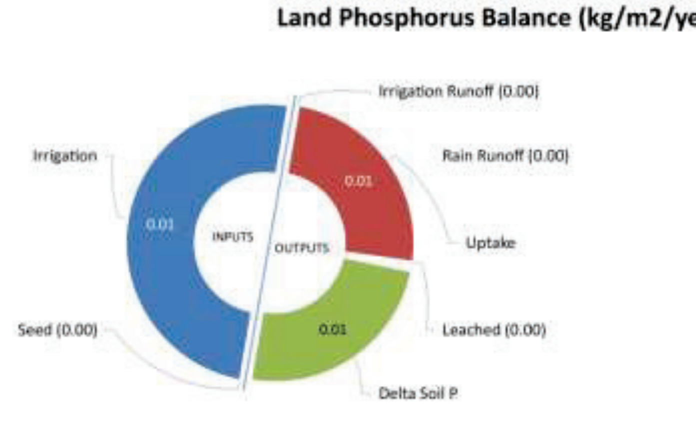
The land nitrogen balance chart, land phosphorous balance chart, the plant stresses chart and the salt balance chart for the recommended wet weather storage volume of 900 kL and recommended irrigation area of 2.0 ha from the wet weather storage sensitivity analysis for autonomous operation with total nitrogen at 40 mg/L and total phosphorous at 20 mg/L are shown below in Figure 8.21, Figure 8.22, Figure 8.23 and Figure 8.24.

Land Nitrogen Balance (kg/m2/year)



Name	Value
Seed	9.55E-06
Irrigation	0.02
Denitrification	9.64E-07
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	0.04
Leached	5.46E-04
Delta Soil N	-0.02

Figure 8.21 Land Nitrogen Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN40 and TP20



Name	Value
Seed	8.18E-07
Irrigation	0.01
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	0.01
Leached	4.83E-07
Delta Soil P	0.01

Figure 8.22 Land Phosphorous Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN40 and TP20

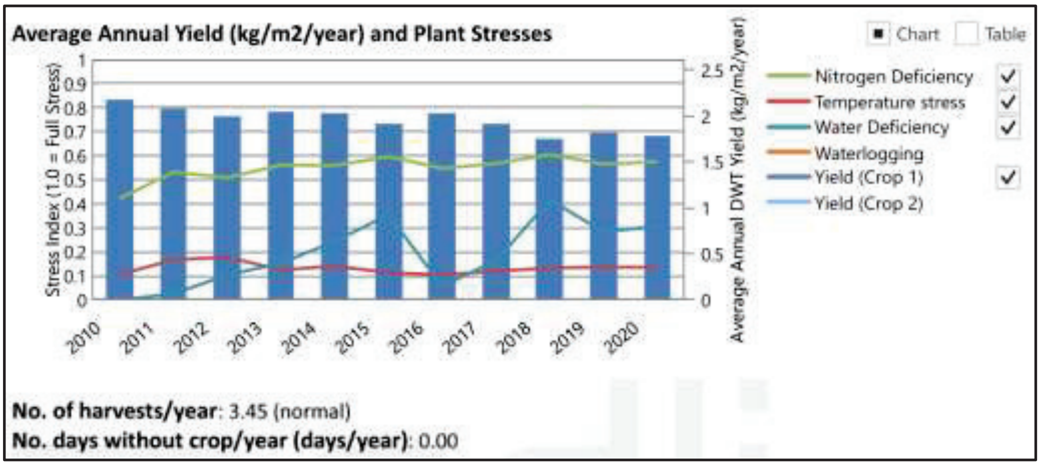


Figure 8.23 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN40 and TP20

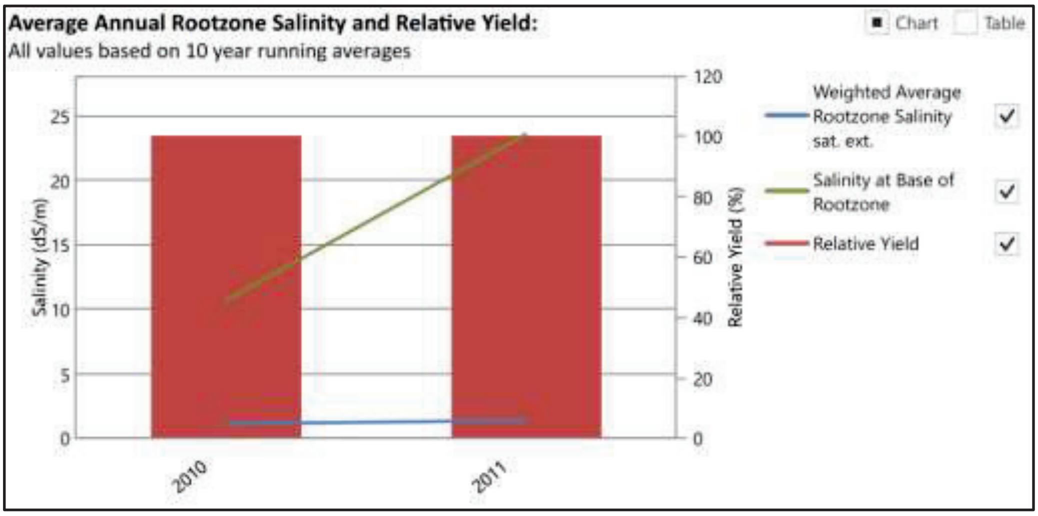
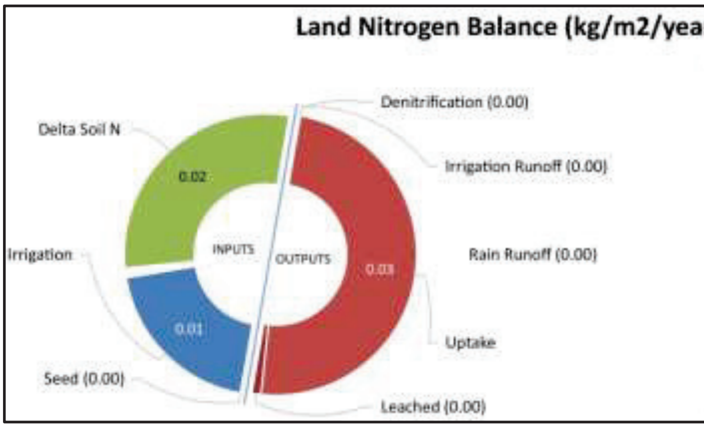


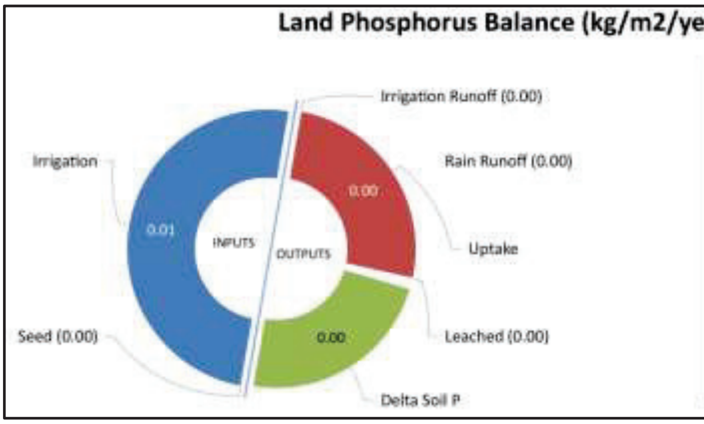
Figure 8.24 Salt Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN40 and TP20

The land nitrogen balance chart, land phosphorous balance chart, the plant stresses chart and the salt balance chart for the recommended wet weather storage volume of 1,450 kL and recommended irrigation area of 3.0 ha from the wet weather storage sensitivity analysis for non-autonomous operation with total nitrogen at 20 mg/L and total phosphorous at 15 mg/L are shown below in Figure 8.25, Figure 8.26, Figure 8.27 and Figure 8.28.



Name	Value
Seed	9.55E-06
Irrigation	0.01
Denitrification	7.49E-07
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	0.03
Leached	5.42E-04
Delta Soil N	-0.02

Figure 8.25 Land Nitrogen Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN20 and TP15



Name	Value
Seed	8.18E-07
Irrigation	0.01
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	4.17E-03
Leached	5.14E-07
Delta Soil P	3.76E-03

Figure 8.26 Land Phosphorous Balance for Recommended Irrigation Parameters for from Wet Weather Sensitivity Analysis Non-Autonomous Operation at TN20 and TP15

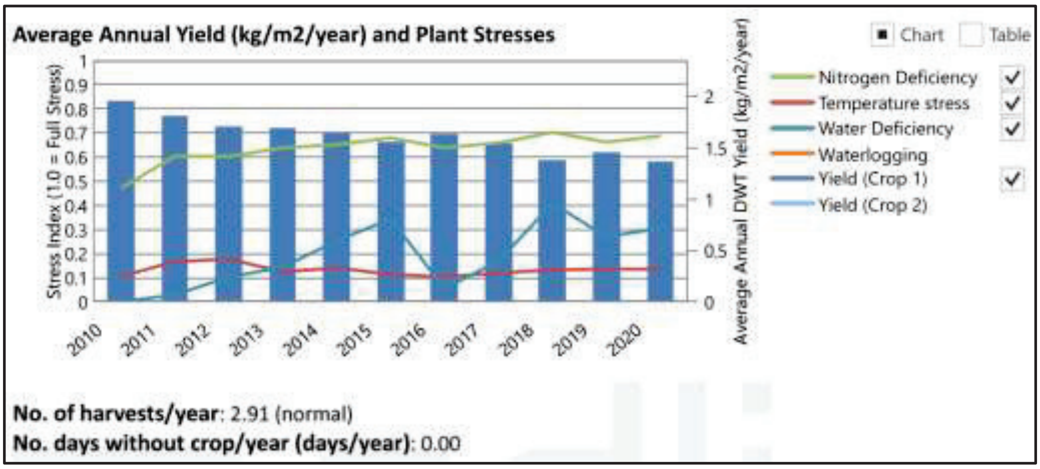


Figure 8.27 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN20 and TP15

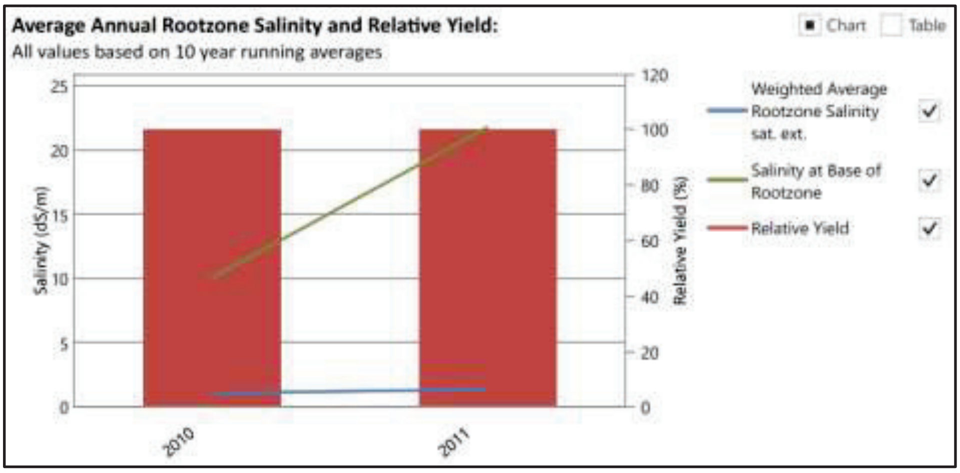
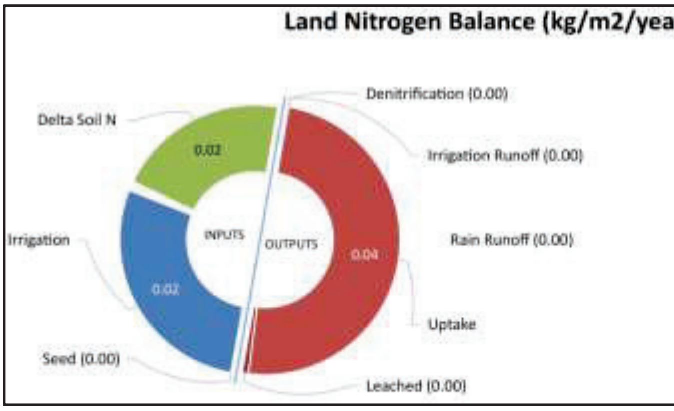


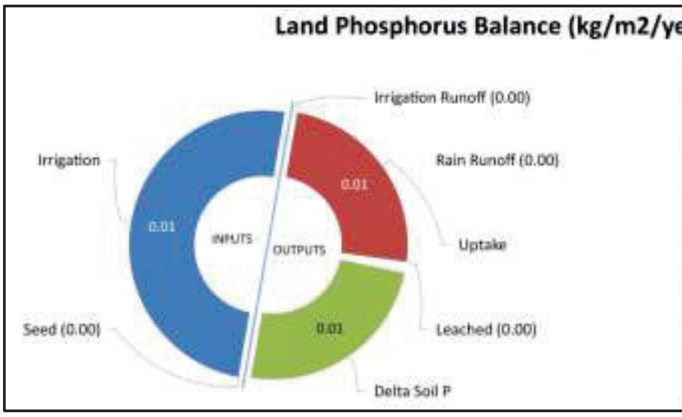
Figure 8.28 Salt Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN20 and TP15

The land nitrogen balance chart, land phosphorous balance chart, the plant stresses chart and the salt balance chart for the recommended wet weather storage volume of 1,450 kL and recommended irrigation area of 3.0 ha from the wet weather storage sensitivity analysis for non-autonomous operation with total nitrogen at 40 mg/L and total phosphorous at 20 mg/L are shown below in Figure 8.29, Figure 8.30, Figure 8.31 and Figure 8.32.



Name	Value
Seed	9.55E-06
Irrigation	0.02
Denitrification	9.68E-07
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	0.04
Leached	5.46E-04
Delta Soil N	-0.02

Figure 8.29 Land Nitrogen Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN40 and TP20



Name	Value
Seed	8.18E-07
Irrigation	0.01
Irrigation Runoff	0.00
Rain Runoff	0.00
Uptake	0.01
Leached	4.87E-07
Delta Soil P	0.01

Figure 8.30 Land Phosphorous Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Autonomous Operation at TN40 and TP20

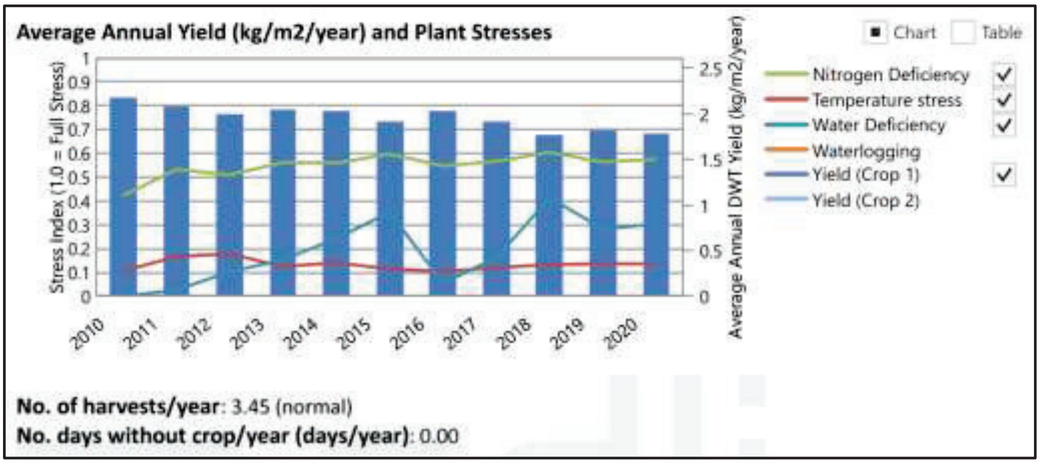


Figure 8.31 Crop Yield and Plant Stresses Chart for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN40 and TP20

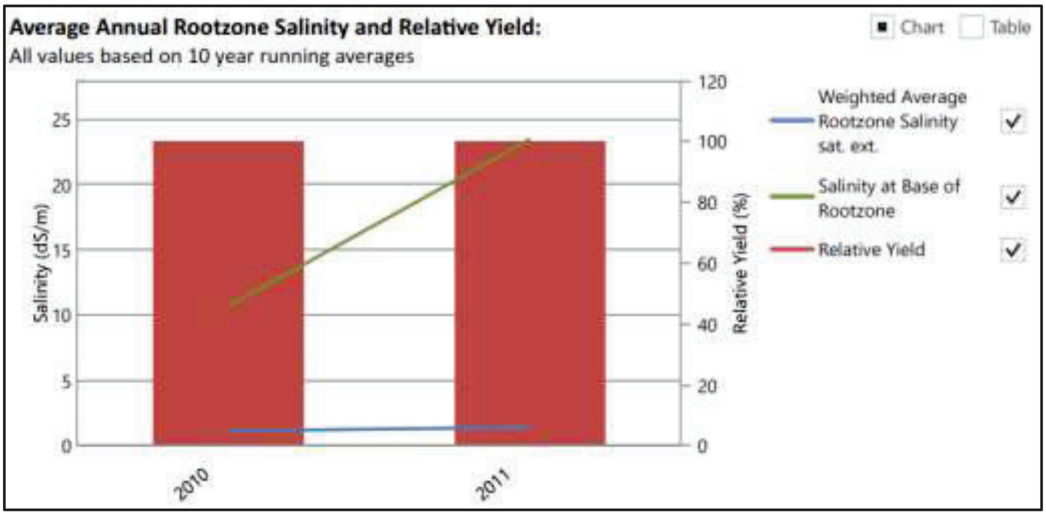


Figure 8.32 Salt Balance for Recommended Irrigation Parameters from Wet Weather Sensitivity Analysis for Non-Autonomous Operation at TN40 and TP20

The recommended irrigation field area size for the two different operating conditions can be seen below in Figure 8.33. From Figure 8.33, it can be seen that the recommended irrigation field area size will fit within the proposed location for the irrigation area.

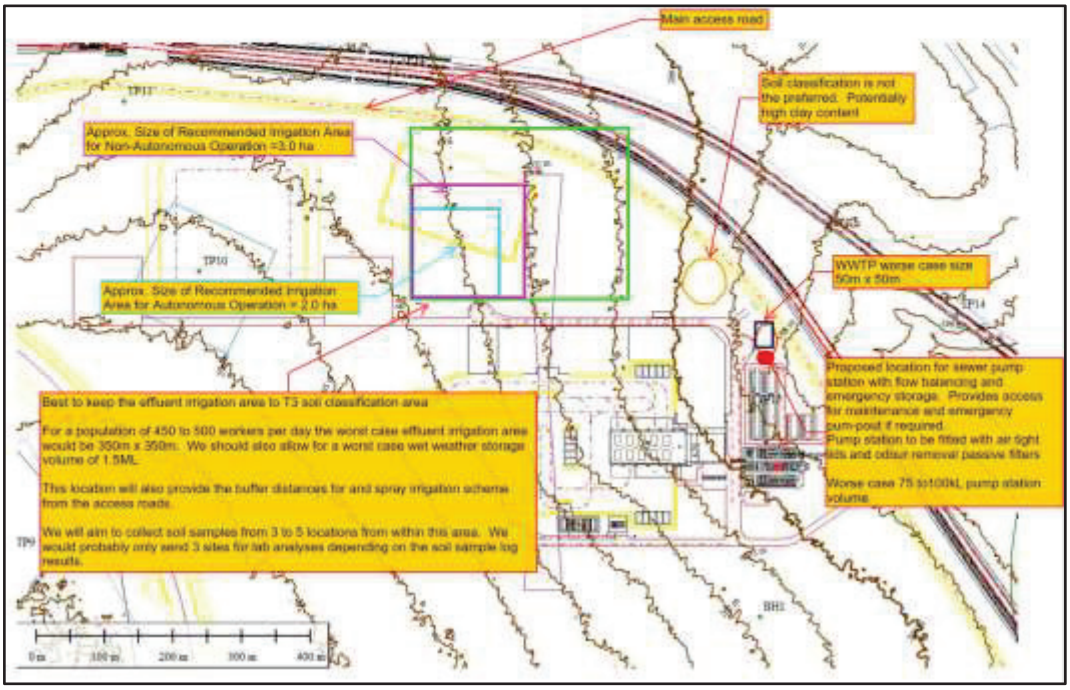


Figure 8.33 Size of Recommended Irrigation Areas in comparison with Proposed Irrigation Area Location

9 Wastewater Treatment Plant Design Summary

This section provides a summary of the design principles that need to be taken into consideration when designing the wastewater treatment plant for the Winchester South site. These design principles include the following:

- Due consideration needs to be taken when selecting the appropriate wastewater treatment technology to ensure that the wastewater treatment plant can handle population variation and thus any associated hydraulic loading variation;
- A balance tank needs to be include within the wastewater treatment plant to provide an optimum of 48hours of 80th percentile of daily flow with a no less than 24 hours of storage of the incoming wastewater to provide flow balancing and redundancy;
- As a minimum, the wastewater treatment plant needs to include influent and effluent flow monitoring;
- The wastewater treatment technology that has the ability to remove nitrogen from the wastewater from potential influent concentrations of 120mg/L to levels between 30 to 40 mg/L in the treated effluent.
- The wastewater treatment plant should be able to remove phosphorous from potential influent concentrations of 20 to 30mg/L to levels of 15 mg/L in the treated effluent.
- During the design process of the wastewater treatment plant, influent sampling needs to be conducted to establish the quality of the incoming wastewater. This influent testing is required to determine the level of Oil & Grease (O&G) in the wastewater as well as the level of total petroleum hydrocarbons (TPH) in the wastewater as well as all other pollutant levels crucial for the sizing and design of the wastewater treatment plant. By understanding the composition of the incoming wastewater, it will allow for the design of wastewater treatment plant that is site specific and will comply with its ERA licence conditions under all operating conditions.
- Wastewater treatment plant design will need to include at least 2 points of disinfection (Primary as the treated effluent enters the wet weather storage tank and secondary in the wet weather storage tank recirculation loop) in order to provide Class A water for irrigation.
- The sludge production from the wastewater treatment plant and the sludge management process need to be reviewed during the technology selection and detailed design stage of the wastewater treatment plant.
- Primary screening is required within the wastewater treatment plant design to remove the grit and solids from the incoming wastewater;
- Due to the remoteness of the Winchester South site and the criticality of the wastewater treatment equipment, it is recommended that all critical equipment used at the wastewater treatment plant are operated in duty/standby mode;
- It is preferred for the disinfectant that is used to disinfect the treated effluent to be a non-oxidising disinfectant as the treated effluent will be used for irrigation and oxidising disinfectants, such as chlorine, may cause harm to the soil microbiology, hindering the biological nitrogen removal cycle in the soil;
- Due consideration needs to be taken to ensure that ease of operation and maintenance of the wastewater treatment plant is taken into account during the technology selection and detailed design of the wastewater treatment plant; and
- The control of the wet- weather storage needs to be included within the wastewater treatment plant control panel. Sufficient wet weather storage is required to retain effluent when irrigation is not possible due to wet weather conditions or agronomic practices that prevent irrigation. The recommended wet weather storage tank volumes, determined through the MEDLI modelling, for autonomous operation was 900 kL and for non-autonomous operation was 1,450 kL. This sizing allows for the management of the wet-weather storage without over flow events for periods of elevated rainfall.

- It is preferred that the wet weather storage is a closed tank system as this will help to minimise algae management requirements.

10 Effluent Irrigation Scheme Design Summary

This section provides a summary of the design principles that need to be taken into consideration when designing the effluent irrigation scheme for the Winchester South site. These design principles include the following:

- For Winchester South, the optimum crop that was selected was Kikuyu Pasture. Due consideration needs to be given when determining the type of irrigation method used to ensure that the Kikuyu Pasture receives the appropriate amount of water, i.e. drip irrigation may not be the most appropriate irrigation method but a spray gun or rain gun irrigation method may be more appropriate.
- It is important to ensure that all fixtures used for the irrigation system are above ground to allow for ease of operation and maintenance.
- Design of the irrigation scheme based on installing irrigation sprinklers on the boundary of the effluent irrigation area to allow for the ease of harvesting the biomass from the effluent irrigation area.
- It is recommended that proper animal-proof fencing (particularly for wild boars) is installed around the irrigation area to ensure that the irrigation field does not get damaged by wild animals.
- Ensure that irrigation meters are installed on the irrigation system and that these irrigation meters have data logging capabilities, which will allow for the irrigation water use to be monitored.
- Soil preparation is required in order to ensure that the proposed irrigation area is appropriate for planting the Kikuyu Pasture. Some soil preparation steps may include adding gypsum to the soil, which will help improve the soil structure, aerating/ deep ripping the soil to create micro passage ways in the soil so that water, air and nutrients can more easily get to the roots.
- The minimum irrigation area determined through MEDLI modelling, for autonomous operation was 2.0 ha and for non-autonomous operation was 3.0 ha.
- Irrigation should occur at a rate of 2 mm/day. Rain sensor should be used to stop ponding in the irrigation area during wet weather periods.

11 References

Australian Native Plants, n.d. *Melaleuca Alternifolia.* [Online] Available at: https://www.australianplants.com/plants.aspx?id=1373 [Accessed 25 November 2021].

AusWest Seeds and Stephen Pasture Seeds, n.d. *Forage Sorghum.* [Online] Available at: https://www.austweststephenseeds.com.au/advice/pasture-establishment/forage-sorghum [Accessed 25 November 2021].

Barenbrug, n.d. *Green Panic.* [Online] Available at: https://barenbrug.com.au/international/international-products/tropical-grasses/green-panic.htm [Accessed 25 November 2021].

Cameron, A. G., 2006. *Forage Sorghum.* [Online] Available at: https://industry.nt.gov.au/__data/assets/pdf_file/0006/232953/514.pdf [Accessed 25 November 2021].

Johnson, B. & Lloyd, D., 2008. *Panics.* [Online] Available at: https://keys.lucidcentral.org/keys/v3/pastures/Html/Panics.htm [Accessed 25 November 2021].

Lawn Solutions Australia, n.d. *Kikuyu Grass in Focus.* [Online] Available at: https://lawnsolutionsaustralia.com.au/turf-supplies/best-lawn-for-me/kikuyu-grass/ [Accessed 25 November 2021].

Lusweti, A., Wabuyele, E., Ssegawa, P. & Mauremootoo, J., n.d. *Cynodon Dactylon (Couch Grass).* [Online] Available at: https://keys.lucidcentral.org/keys/v3/eafrinet/weeds/key/weeds/Media/Html/Cynodon_dactylon_(Couch_Grass).htm [Accessed 25 November 2021].

Mckays Grass Seeds, 2016. *A Quick Guide to Perennial Ryegrass.* [Online] Available at: https://www.mckaysgrassseeds.com.au/quick-guide-perennial-ryegrass/ [Accessed 25 November 2021].

Michaels, F., n.d. *Vetiver Grass Growing Information.* [Online] Available at: https://greenharvest.com.au/Plants/Information/Vetiver.html [Accessed 25 November 2021].

Myers, V. R., 2021. *How to Grow and Care for a Banana Tree.* [Online] Available at: https://www.thespruce.com/banana-tree-growing-profile-3269353 [Accessed 25 November 2021].

NSW Department of Primary Industries, n.d. *Green Panic.* [Online] Available at: https://www.dpi.nsw.gov.au/agriculture/pastures-and-rangelands/species-varieties/green-panic [Accessed 25 November 2021].

Pioneer, 2017. *Crop Goals Key to Determining Lucerne Harvesting Schedule.* [Online] Available at: https://www.pioneer.co.nz/news/crop-goals-key-to-determining-lucerne-harvest-schedule.html [Accessed 25 November 2021].

Project Noah, n.d. *Blady Grass.* [Online]
Available at: https://www.projectnoah.org/spottings/1540591617
[Accessed 25 November 2021].

QLD Department of Agriculture and Fisheries , 2013. *Rhodes Grass.* [Online]
Available at: https://www.daf.qld.gov.au/business-priorities/agriculture/plants/crops-pastures/pastures/rhodes-grass
[Accessed 25 November 2021].

QLD Department of Agriculture and Fisheries, 2013. *Green Panic.* [Online]
Available at: https://www.daf.qld.gov.au/business-priorities/agriculture/plants/crops-pastures/pastures/green-panic
[Accessed 25 November 2021].

Sheather, W. & Sheather, G., 2020. *Melaleuca Alternifolia Snow-in-Summer.* [Online]
Available at: https://resources.austplants.com.au/plant/melaleuca-alternifolia/
[Accessed 25 November 2021].

Sprivulis, R., 1978. *Kikuyu Grass: Establishment, Management and Utilisation in the South West.* Department of Primary Industries and Regional Development, Western Australia, Perth. Bulletin.

Vetiver Australia, 2020. *About Vetriver Grass.* [Online]
Available at: https://vetiver-australia.com/about-vetiver-grass/
[Accessed 25 November 2021].

WA Department of Primary Industries and Regional Development, 2018. *Lucerne - the Plant and its Establishment.* [Online]
Available at: https://www.agric.wa.gov.au/pasture-establishment/lucerne-plant-and-its-establishment
[Accessed 25 November 2021].

Whitehaven Coal Limited, n.d. *Winchester South Project.* [Online]
Available at: https://whitehavencoal.com.au/our-business/our-assets/winchester-south/
[Accessed 12 October 2021].

Whitehaven Coal Limited, n.d. *Winchester South Project Environmental Impact Statement - Section 2 Project Description.* [Online]
Available at: https://whitehavencoal.com.au/wp-content/uploads/2021/08/04.-Section-2-Project-Description.pdf
[Accessed 12 October 2021].

Williamson , L., 2020. *How to Grow Bananaas and Care for Banana Plants.* [Online]
Available at: https://www.bhg.com.au/banana-plants-how-to-grow-bananas
[Accessed 25 November 2021].

Email dated 13 July 2021 from Robert Simpson, Whitehaven Coal Limited.

Email dated 10 August 2021 from Robert Simpson, Whitehaven Coal Limited – Sample Locations.

Email dated 16 August 2021 from Robert Simpson, Whitehaven Coal Limited – Effluent Irrigation Area 02.

Environmental Protection Regulation 2008, Reprinted as in force on 9 November 2012, Queensland Government.

Excel spreadsheet: *Data for STP MEDLI Modelling for issue*, Whitehaven Coal Limited, 13/07/2021.

Google Images

Map: *Potential Effluent Irrigation Area*, Whitehaven Coal Limited, 16/08/2021.

MEDLI Model for Effluent Disposal using Land Irrigation Version 2 Technical Reference, Rev: 13 September 2016, Department of Information Technology and Innovation, State of QLD.

On-Site Sewerage Code, QLD (2002), Department of Natural Resources and Mines.

Planning Guidelines for Water Supply and Sewerage, April 2010, Chapter 6 amended March 2014, Department of Energy and Water Supply (QLD Govt.).

Presentation: *STP Irrigation Area Preliminary Assessment*, Whitehaven Coal Limited, 10/08/2021.

Tennakoon. S, and Ramsay. I, 2020. *Disposal of effluent using Irrigation Technical Guideline*. Brisbane: Queensland Department of Environment and Science, Queensland Government.

The following sample results from Environmental Analysis Laboratory (EAL), Southern Cross University, East Lismore:

- SLR002 – Atterberg – M2040;
- SUS003 – MEDLI – M2040;
- SUS003 – PSA – M2040;
- SUS003 – RA – M2040; and
- SUS003 – SWRC – M2040.