Hydraulic and Nutrient Balance Modelling Report

Bindaree Beef Abattoir, Inverell

Prepared For:

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EXECUTIVE SUMMARY

The abattoir operated by Yolarno Pty Ltd (T/A Bindaree Beef), is located on the southern side of the Gwydir Highway, approximately four kilometres west from Inverell, NSW. The existing irrigation areas are located to the south of the abattoir on a different property.

The current abattoir operation generates significant amounts of liquid and solid waste. Currently the liquid waste stream is directed to effluent holding ponds for anaerobic and aerobic breakdown of organic material. The resulting effluent is irrigated on to surrounding agricultural land. Solid waste including paunch and manure from pen cleaning are stored on an impermeable pad and then spread onto agricultural land.

The proposed anaerobic digester plant will utilise the liquid and solid waste streams to generate bio-gas, a low strength effluent and solid fertiliser. This proposed technology will accept all organic waste material from the abattoir, including paunch, which is currently difficult to process. Low strength effluent will be reused for crop production on the existing effluent irrigation areas. The solid fertiliser maybe sold offsite reducing the nutrient loading on the property. The solid fertiliser may also be used over at the farm if permitted by EPA. The proposed development will be a significant improvement to the current land reuse activities currently undertaken on the property.

FSA Consulting was commissioned to undertake hydraulic and nutrient balance modelling of the proposed reuse of low strength effluent via land irrigation. This modelling is required to accompany an Environmental Impact Statement (EIS) and satisfy the regulators that the proposal is sustainable and meets the Environmental Guidelines – Use of Effluent by Irrigation (DEC 2004).

In order to undertake the necessary modelling of the effluent reuse system, climate data for the site was required. Daily data (100 years) for the site was obtained from the Bureau of Meteorology (BOM). The median annual rainfall is 767 mm/year.

To maximise the benefits of the valuable water, nutrient and soil amendment values of the effluent, whilst minimising any adverse impacts upon the environment, land areas used for irrigation must be carefully selected and managed. The sustainable volume of “low strength” effluent that can be reused on the Alsace property has been determined by long-term hydrological modelling using the Model for Effluent Disposal using Land Irrigation (MEDLI).

MEDLI is a Windows™ based daily time step computer model for designing and analysing effluent disposal systems for intensive rural industries, agri-industrial processors (e.g. abattoirs) and sewage treatment plants using land irrigation.

The effluent volume generated by the digester is estimated by Mitchell Hanlon Consulting Pty Ltd to be 1.25 ML/d, five days per week, 52 weeks per year. Therefore, the annual effluent inflow to the ponds was estimated to be approximately 326.6 ML/yr.

The effluent generated from the digester will be stored in a 70.1 ML wet weather dam on the Alsace property, prior to land application. The MEDLI model was calibrated to have nitrogen, phosphorus and salinity concentrations in the irrigated effluent at the maximum concentrations allowable for “low strength” effluent as described in the Environmental Guidelines – Use of Effluent by Irrigation (DEC 2004).

Information supplied by Mitchell Hanlon Consulting Pty Ltd show that dark heavy clay soils dominate the areas proposed for effluent reuse. These soils have moderate to high water holding capacity and are imperfectly drained with low permeability. Therefore, the default 'Black Vertosol' soil in MEDLI was used for the modelling.

The irrigation input data includes the irrigation method, irrigation area size and irrigation scheduling rules. The available effluent irrigation area totals 160 ha and effluent will be applied using spray irrigation, with scheduling was based on a 20 mm soil water deficit. The MEDLI model assumes that all crop material grown is harvested, then removed from the site.

The modelling results show that under the proposed effluent reuse system, overtopping is estimated to be ~2.8 ML/yr or about 0.9% of annual effluent inflow. It is predicted that five overtopping events occur every 10 years, which meets the "uncontrolled releases may be permitted in 50 percent of years" for low strength effluent as outlined in the Environmental Guidelines – Use of Effluent by Irrigation (DEC 2004).

The effluent irrigation volume applied is approximately 200 mm/yr. The predicted deep drainage rate is 41 mm and predicted runoff is estimated to be 20 mm/yr. The nitrogen loading rate is estimated at 101 kg/ha/yr and leached nitrogen is predicted to be <1 kg/ha/yr. The predicted phosphorus loading rate is 20 kg/ha/yr, with approximately 19 kg/ha/yr utilised by cut and cart cropping regime. It is predicted that no phosphorus leaching will occur. The predicted crop yield is 12.2 t DM/ha/yr on average. This is within the yield estimates provided by the agronomist. Although a ryegrass pasture was modelled, a forage corn and winter crop rotation is expected to yield similar (or more) biomass.

The results for the dryland scenario show the predicted deep drainage rate is 21 mm and predicted runoff 27 mm/yr. Therefore, it is predicted that applying 200 mm/yr of effluent will increase deep drainage by 20 mm/yr (~49%) and runoff will actually decrease by 7 mm/yr due to crop growth and improved crop cover.

The modelling of the proposed "low strength" effluent reuse system is considered sustainable because of acceptable pond overtopping frequency (5 events in 10 years), balanced nutrient loading rates causing negligible leaching and minor impacts on deep drainage.

In addition to the modelling of a "low strength" effluent reuse system, several other water balance modelling scenarios were undertaken to determine what irrigation and wet weather pond volume would be acceptable for both "medium" and "high" strength effluent. An additional 10 modelling runs were undertaken. For all scenarios, the inflow (1.25 ML/d (~327 ML/yr), soil types and irrigation scheduling were kept constant.

Modelling runs 1-7 use the existing wet weather storage pond size (70.1 ML) and show the increased land area required for acceptable pond overflows. Modelling runs 8-10 show the wet weather storage volume requirements to achieve the acceptable low, medium and high strength effluent overflow frequency based on the Environmental Guidelines – Use of Effluent by Irrigation (DEC 2004).

If the existing aerobic ponds were decommissioned, Bindaree Beef management estimate this would increase the total wet weather storage capacity to ~200 ML. This increased storage capacity would exceed the requirement for low, medium and high strength effluent overtopping frequency (as per runs 8-10) from a water balance perspective.

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1 BACKGROUND

The project proposes the construction and operation of:

- An anaerobic digester, utilising abattoir wastewater and waste solid products for generation of biogas; and
- A rendering plant for rendering of inedible products for purified fat and protein production.

The proposed facility is to be owned and operated by Bindaree Beef. The proposed biodigester and rendering plant upgrade are part of a larger site development process currently being undertaken by Bindaree Beef.

The current abattoir operation generates significant amounts of liquid and solid waste. The liquid waste (red stream) component is made up of blood; fats, oils and grease; and washdown water from the meat processing plant. The solid waste (green stream) component is made up of paunch and manure. Inedible products are directed to the rendering plant for further processing.

Currently the liquid waste stream is directed to effluent holding ponds for anaerobic and aerobic breakdown of organic material. The resulting effluent is irrigated on to surrounding agricultural land owned by the proponent for crop production. Solid waste including paunch and manure from pen cleaning are stored on an impermeable pad and then spread onto agricultural land. These methods of waste disposal are standard practice for abattoir wastes in NSW.

The proposed anaerobic digester plant will utilise the liquid and solid waste streams to generate bio-gas, low strength effluent and solid fertiliser. This proposed technology will accept all organic waste material from the abattoir, including paunch, which is currently difficult to process.

Low strength effluent will be reused for crop production on the existing effluent irrigation areas. The solid fertiliser maybe sold offsite reducing the nutrient loading on the property. The solid fertiliser may also be used over at the farm if permitted by EPA. The proposed development will be a significant improvement to the current land reuse activities currently undertaken on the property.

FSA Consulting was commissioned to undertake hydraulic and nutrient balance modelling of the proposed reuse of low strength effluent via land irrigation. This modelling is required to accompany an Environmental Impact Statement (EIS) and satisfy the regulators that the proposal is sustainable and meets the Environmental Guidelines – Use of Effluent by Irrigation (DEC 2004).

2 DESCRIPTION OF THE EXISTING ENVIRONMENT

2.1 LOCATION OF SUBJECT PROPERTY

The abattoir operated by Yolarno Pty Ltd (T/A Bindaree Beef), is located on the southern side of the Gwydir Highway, approximately four kilometres west from Inverell, NSW. The existing effluent irrigation areas are located to the south of the abattoir on the Alsace property.

2.2 CLIMATE

In order to undertake the necessary modelling of the effluent irrigation system, climate data for the site was required. The Bureau of Meteorology (BOM) supplied MEDLI-format climate data to enable the necessary modelling. Daily data for the site is summarised in Table 1. It can be seen that the median annual rainfall is 767 mm/year.

TABLE 1: CLIMATIC DATA RECORDED AT INVERELL

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean Rainfall (mm)	97	87	61	41	44	49	50	41	47	69	83	96	767
10 Percentile Rain (mm)													550
90 Percentile Rain (mm)													988
Pan Evap (mm)	220	180	167	116	79	56	62	87	123	163	192	220	1664
Ave Max Temp (DegC)	31	30	28	25	20	17	16	18	21	25	28	30	24
Ave Min Temp (DegC)	16	15	13	9	5	2	1	2	5	9	12	15	8
Radiation (MJ/m2/day)	24	21	20	16	13	11	12	16	19	22	24	25	18

2.3 LAND RESOURCE INFORMATION

Mitchell Hanlon Consulting Pty Ltd has undertaken investigations of the land resources and has provided the following summary.

The existing effluent irrigation area comprises of two distinct land resource areas, black/grey vertosols and red ferrosols. Black and grey vertosols cover the majority of the property over the eastern and northern areas of the effluent irrigation area. They vary in depth between 0.6 m to 1.2 m. The surface soils are characterised by high clay percentage, minimal rock and mottling, and self-mulching properties. At depth clay content decreases, small pieces of decomposed rock are present and slight mottling appears below 0.6 m.

In the surface, the pH of the black vertosols range from 3.97 (strongly acidic) to 6.59 (neutral). The nitrate concentrations range from 17.8 mg/kg (moderate) to 87 mg/kg (high), and total nitrogen ranges from 1500 (medium) to 2600 mg/kg (high). The available phosphorus concentrations range from 62.4 mg/kg to 172.4 mg/kg, high to very high levels.

At depth, the pH ranges from 6.63 (neutral) to 7.58 (alkaline). The nitrate concentrations decrease with depth, ranging from 5.7 mg/kg (low) to 35.4 mg/kg (satisfactory). The total nitrogen concentrations also decrease with depth, ranging from 600 mg/kg (low) to 1200 mg/kg (low). The available phosphorus concentrations decrease with depth, with concentrations ranging from 9.6 mg/kg (low) to 83.2 mg/kg (high).

Red ferrosols extend over the western side of the effluent irrigation area, in a much smaller area than the black vertosols. They are characterised by a deep profile extending over 1 m, clay loam soils, small decomposed rock from 1.0 m and mottling from 0.8 m.

The surface soils have a pH range from 4.46 (strongly acidic) to 5.06 (slightly acidic). The nitrate concentrations range from 49.8 mg/kg (satisfactory) to 71.8 mg/kg (satisfactory). Total nitrogen ranges from 1500 mg/kg (low) to 1800 mg/kg (medium). Surface available phosphorus concentrations range from 40 mg/kg (satisfactory) to 236 mg/kg (very high).

The subsoils of the red ferrosols reflect pH ranges of 6.25 (slightly acidic) to 7.47 (slightly alkaline). The nitrate concentrations decrease with depth, ranging from 2.2 mg/kg (very low) to 38 mg/kg (satisfactory). Total nitrogen also decreases with depth to levels of 500 mg/kg (very low) to 1000 mg/kg (low). Available phosphorus concentrations range from 1.6 mg/kg (very low) to 28 mg/kg (moderate).

2.3.1 Soil Suitability for Effluent Irrigation

When selecting a site for effluent irrigation, it is essential to assess the suitability of the site to minimise environmental impacts. The proposed effluent reuse system was assessed as per the recommendations of the NSW Department of Environment and Conservation (2004) "Environmental Guidelines: Use of Effluent by Irrigation" document. As part of the assessment, the current site physical and chemical properties will be outlined. The landform characteristics of the site will also be discussed. Table 2.1 and Table 2.2 from the NSW Department of Environment and Conservation (2004) document will be used to assess the limitations of the site for effluent irrigation.

Table 2 outlines the landform characteristics of the effluent irrigation area. A field assessment of the site was undertaken on the 9th October 2013 by Mitchel Hanlon Consulting staff.

Table 3 outlines the soil characteristics of the effluent irrigation area. Field data was collected on the 9th October 2013 and where soil analysis was undertaken the results have been included. Literature data has been used for some parameters as part of the assessment, and is considered representative of the site soils.

TABLE 2: LANDFORM CHARACTERISTICS OF THE EFFLUENT IRRIGATION AREA

Landform property	Site characteristic	Potential Limitation	Recommended Mitigation Measure
Slope % - Surface irrigation	2.4-4.8%	Moderate (1-3%) to Severe (>3%)	Effluent irrigation scheduling will be monitored to ensure no runoff and erosion risk
Flooding	None or Rare	Nil or Slight	No recommendation
Landform	Crests, convex slopes and plains	Nil or Slight	No recommendation
Surface rock outcrop %	Nil	Nil or Slight	No recommendation

TABLE 3: SOIL CHARACTERISTICS OF THE EFFLUENT IRRIGATION AREA

Soil property	Site characteristic	Potential Limitation	Recommended Mitigation Measure
Exchangeable Sodium Percentage (0-40 cm) %	1.7-5.9 %[1]	Slight (0-5%) to Moderate (5-10%)	Ongoing soil monitoring of effluent irrigation area
Exchangeable Sodium Percentage (40-100 cm) %	1.27-4.51 %[1]	Nil or Slight (<10%)	No recommendation
Electrical Conductivity (ECe) (dS/m at 0-70 cm)	0.4-1.6 dS/m^2	Nil or Slight (<2 dS/m)	No recommendation
Electrical Conductivity (ECe) (dS/m at 70-100 cm)	0.4-1.84 dS/m^2	Nil or Slight (<4 dS/m)	No recommendation
Depth to top of seasonal high watertable (m)	4.3-15.7 m^3	Nil or Slight (>3m)	No recommendation
Depth to bedrock or hardpan (m)	0.5-1.2 m^4	Moderate (0.5-1m) to Slight (>1m)	Ongoing soil monitoring of effluent irrigation area
Saturated hydraulic conductivity (Ks, mm/hr, 0-100cm)	0.5-1 mm/hr[5]	Severe (<5 mm/hr)	Effluent irrigation scheduling will be monitored to ensure no runoff or waterlogging

Soil property	Site characteristic	Potential Limitation	Recommended Mitigation Measure
Available Water Capacity (mm/m)	150-200 mm/m[5]	Nil or Slight (>100 mm/m)	No recommendation
Soil pH ($CaCl_2$) – Surface layer	3.97-5.72[1]	Moderate (pH 3.5-6.0)	Ongoing soil monitoring of effluent irrigation area and lime application
Effective cation exchange capacity (cmol(+)/kg) (0-40cm)	14.8-76.3[1]	Nil or Slight (>15 cmol(+)/kg) to Moderate (3-15 cmol(+)/kg)	No recommendation
Emerson Aggregate Test (0-100cm)	2(1) – 5	Nil to slight (4, 5, 6, 7, 8) to Moderate (2, 3)	Ongoing soil monitoring of effluent irrigation area
Phosphorus Sorption (kg/ha 0-100cm)	2800-5424 kg/ha[6]	Moderate (2000-6000 kg/ha)	Ongoing soil monitoring of effluent irrigation area

1. Soil analysis results undertaken on the 9th October 2013
2. Converted from EC soil water extract 1:5 method, multiplication factor of 8 for light/medium clay. Soil analysis results undertaken on the 9th October 2013
3. Using historical groundwater monitoring data from 2003-2010
4. Using soil profile pits undertaken on the 9th October 2013
5. Literature data from Peverill et. al. (1999) for Black Vertosols (pg 92)
6. Calculated using bulk density of 1.6 g/cc, PBI results undertaken on the 9th October 2013, and NSW DPI (2004)

Where a soil property is classified as a ‘Slight’ limitation, no soil amelioration is generally necessary. Where a soil property is considered ‘Moderate’, a management response is required to minimise environmental impacts. If a soil property is considered ‘Severe’, the site may be unsuited to effluent irrigation and mitigation measures are recommended to be implemented.

The slope of the effluent irrigation area is potentially a limiting characteristic. It is proposed that effluent irrigation activities are closely monitored to minimise erosion and runoff from the site. The surface exchangeable sodium percentage (ESP) is rated moderate due to the previous effluent irrigation activities on the site. The quality of effluent and the farm management of the proposed development will improve compared to the current practices. Ongoing soil monitoring will be undertaken to identify any trends in ESP.

The depth to bedrock or hard pan is approximately 50 cm in some upslope areas of the effluent irrigation area. Effluent irrigation on these areas will be minimised where possible. Irrigation scheduling will be monitored to prevent waterlogging and runoff from the site.

The saturated hydraulic conductivity of the site has not been measured in the field due to the specific equipment required and high cost of analysis. The literature values for a typical black Vertosol has been used for the assessment. Irrigation scheduling will be monitored to minimise potential impacts from waterlogging and runoff will be minimised due to low applications using spray irrigation.

Surface pH is a moderate limitation. This is due to historic effluent and paunch applications to the site and poor management. It is recommended that amelioration using lime and ongoing soil monitoring be undertaken to monitor improvements in soil acidity.

The phosphorus sorption of the proposed effluent irrigation areas is a moderate limitation. This is due to the fertile nature of black Vertosol soils and the historic effluent application at the site. It is proposed that ongoing soil monitoring be undertaken to identify trends in soil phosphorus sorption.

The proposed effluent irrigation area is suitable for purpose with the proposed mitigation measures in place. The improved irrigation scheduling and agronomic management as part of the development will enhance the nutrient management and environmental outcomes for the site.

3 IRRIGATION DESIGN CONSIDERATIONS

Land application of treated effluent onto areas growing crops or pastures is regarded as the most efficient and beneficial means of utilising the valuable water, nutrient and organic components of this by-product. This practice is consistent with the principles of the internationally accepted waste management hierarchy (i.e. avoidance, recycling, waste to energy, treatment and disposal).

The reuse of effluent through irrigation is aimed at:

- Using crops, pastures and soils to efficiently utilise or sustainably assimilate the nutrients, salts, organic matter and water contained in the effluent; and
- Maximise the utilisation of the fertiliser, water and soil amendment values of the effluent while avoiding adverse environmental impacts.

Effluent irrigation must be managed carefully to ensure that:

- Nutrients are not leached below the active root zone.
- Dissolved and suspended contaminants are not exported from utilisation areas to watercourses.
- Excessive application of effluent does not adversely affect the chemical and physical properties of the soils in the reuse areas.
- The productivity of pasture or cropping land is maintained or enhanced.
- Nearby neighbours do not experience odour or reduce amenity due to poorly timed and managed applications of effluent.

To maximise the benefits of the valuable water, nutrient and soil amendment values of the effluent, whilst minimising any adverse impacts upon the environment, land areas used for irrigation must be carefully selected and managed.

The Environmental Guidelines – Use of Effluent by Irrigation (DEC 2004) classify effluent strength for various environmental management. Table 3.1 of the guidelines (reproduced as Table 4 below) outline the various constituents and concentrations for “low”, “medium” and “high” strength effluents. Classification of effluent as low, medium or high strength is according to its concentrations of nitrogen, phosphorus, BOD_5, TDS, and other potential contaminants. For an effluent to fall within a certain class, all constituents must be within the specified concentration range. However, where an effluent falls into a class by a nominal amount, the design overflow frequency may be interpolated proportionally.

TABLE 4: CLASSIFICATION OF EFFLUENT FOR ENVIRONMENTAL MANAGEMENT (DEC 2004)

Constituent	Strength (average concentration mg/L)[1]		
	Low[2]	Medium	High
Total nitrogen	< 50	50-100	>100
Total phosphorus	< 10	10-20	>20
BOD_5	< 40	40-1500	>1500
TDS[3]	< 600	600-1000	>1000-2500
Other pollutants (e.g. metals, pesticides)	Effluent with more than five times[4] the ANZECC and ARMCANZ (2000) longterm water quality trigger values for irrigation waters must be considered high strength for the purpose of establishing a strength class for runoff and discharge controls and will require close examination to ensure soil is not contaminated.		
Grease & Oil	Effluent with more than 1,500 mg/L of grease and oil must be considered high strength and irrigation rates and practices must be managed to ensure soil and vegetation is not damaged.		

Notes:

1. Average concentrations established from a minimum of 12 representative samples, collected at regular intervals over a year.
2. Effluent generated by municipal sewage treatment plants with secondary treatment will generally be considered to be low strength.
3. Refer to Section 3.7 for relationship of TDS to EC.
4. Criteria of five times the ANZECC and ARMCANZ (2000) long-term irrigation criteria have been selected as nominal criteria at which the level of those contaminants warrants a higher level of management of the reuse system for the following reasons. This criteria when applied to 1 ML/d of effluent irrigated over 100 hectares would take approximately 10 years for soil contaminant levels in the top 15 cm of soil to rise to near the soil contaminant criteria for Cadmium, Chromium and Zinc, which are the most sensitive heavy metal pollutants in this scenario. This criteria is also approximately half the value for Nickel, Mercury, Beryllium and Arsenic at which the effluent would be considered a liquid waste and would need to be managed and disposed of according to the DEC's *Environmental Guidelines for the Assessment, Classification and Management of Liquid and Non-Liquid Waste* (EPA 1999a).

The sustainable volume of low strength effluent that can be reused on the Alsace property has been determined by long-term hydrological modelling using the Model for Effluent Disposal using Land Irrigation (MEDLI).

3.1 PLANT SELECTION & LAND USE

The proposed cropping schedule will be a rotation of high yielding pastures and forages comprising maize and sorghum during summer months followed by winter crops of oats, barley and/or wheat. Discussions have been had with local agronomists and contractors about crop suitability and markets for harvested crops. It is intended to aim for a minimal artificial fertiliser operation, making use of valuable nutrients in the effluent.

4 ANALYSIS OF EFFLUENT IRRIGATION SUSTAINABILITY

4.1 WASTE GENERATION

The current effluent volume generated by the digester is estimated by Mitchell Hanlon Consulting Pty Ltd to be 1.25 ML/d, five days per week, 52 weeks per year. Therefore, the annual effluent production is approximately 326.6 ML/yr. The effluent generated from the digester will be stored in a wet weather dam, prior to land application.

4.2 EFFLUENT IRRIGATION AREAS

Mitchell Hanlon Consulting Pty Ltd advised that approximately 160 hectares of land is available for effluent irrigation. The effluent reuse area will be utilised for the production of permanent pastures and a range of winter/summer forage and grain crops. It is important that crops grown are harvested and removed from the site. Grazing animals recycle the nutrients and very little removal occurs from soil reserves.

4.3 HYDRAULIC AND NUTRIENT MODELLING

4.3.1 MEDLI MODEL INTRODUCTION

This section gives a summary of the MEDLI model and the various modules contained within the model. The following information is contained within the MEDLI Technical Description published by the Department of Natural Resources and Mines.

MEDLI is a Windows based computer model for designing and analysing effluent disposal systems for intensive rural industries, agri-industrial processors (e.g. abattoirs) and sewage treatment plants using land irrigation. It was developed jointly by the CRC for Waste Management and Pollution Control, the Queensland Department of Natural Resources and the Queensland Department of Primary Industries. MEDLI is the model recommended by DAFF and EHP for predicting sustainable effluent reuse systems.

MEDLI requires daily time series climate data for estimating crop water requirements, simulating crop growth and carrying out water balance computations. The data required are rainfall, temperature, Class A pan evaporation and solar radiation. The climatic data used to model the site was supplied by the Bureau of Meteorology (BOM).

The waste estimation component of MEDLI generates, for a given industry, the daily composition and volume of effluent before pre-treatment, storage or irrigation.

The simplest MEDLI waste estimation module uses measured waste stream details. Temporal variation in waste stream characteristics may be assigned monthly or seasonally, or for any other nominated periods, including single days. The user could enter different waste stream details for every day if the data is available. MEDLI assumes these details then apply for every year of the simulation. The model for simulating the effluent re-use system at the site used the effluent quality data measured at the site.

The pond module is a modified version of a design model for treating pig wastes (Casey, 1995). The module consists of mass balances for the hydraulic, nitrogen, phosphorus, potassium and total dissolved salts components. It uses a number of empirically derived relationships. The model allows for up to four effluent ponds in series. Nutrients in the incoming mass are partitioned between the sludge and the supernatant, and a transfer coefficient is used to estimate the nitrogen volatilisation from the pond surface. The pond module's function is to predict water levels and nutrient and salt concentrations. A nominated pond can be used for recycling purposes and the last pond may be used for irrigation.

The soil water movement is simulated as a one-dimensional (vertical) water balance, averaged over a field sized area. The water balance component was taken from PERFECT (Littleboy *et al.,* 1989, 1992) which was based on the Williams and LaSeur (1976) water balance models as used in CREAMS (Knisel, 1980) and similar models.

The soil parameters entered into the MEDLI model are based on the soil physical characteristics observed and those identified in relevant publications. The calculation of plant available water holding capacity (PAWC) is determined as the difference between field capacity and the permanent wilting point. The method is an estimate only and is corrected by assessing restrictions such as potential rooting depth, sodicity, salinity and pH. PAWC values are also compared to those reported for similar soils in various publications.

MEDLI simulates the movement of phosphorus through a soil profile by modelling adsorption of phosphorus to soil particles, desorption of phosphorus into soil water, and plant uptake of phosphorus. The phosphorus sorption capacity of the soil was not analysed in the laboratory and used the default values for a black vertosol soil contained within MEDLI.

Soil runoff is predicted using the United States Department of Agriculture's Curve Number technique (USDA-SCS, 1972) and is calculated as a function of daily rainfall, soil water deficit and plant total cover. The higher the curve number the higher the runoff. Curves for soils generally range from 60 to 90. Loose sands on flat topography have the lowest runoff rates, while heavy clay soils with slopes greater than 10 degrees have the highest runoff rates. The MEDLI modelling undertaken used a runoff curve of 82, which represents a heavy soil containing considerable clay and colloids, with pastures and a <3% slope. The soil has below-average infiltration after thorough wetting.

The plant growth module in MEDLI predicts the biomass accumulation and the quantities of N and P that are removed from the effluent irrigation site through crop growth and the export of harvested material. Flexibility is gained through the provision of a dynamic pasture growth model and a dynamic crop growth model.

The pasture module is selected if a plant species is grown continuously, allowing regrowth to occur following mowing (rather than re ng the crop as occurs for the dynamic crop module). In this model, plant cover increases with thermal time according to a fixed sine-curve algorithm defined by the total thermal time to reach full cover. Nitrogen stress and low biomass production modify cover development to improve the prediction of cover for stressed pastures. Growth is considered to be a function of solar radiation, plant cover and radiation use efficiency. Radiation use efficiency can be lowered by the highest of any stress due to temperature, water regime and low plant nitrogen. Prediction of daily plant growth allows estimation of the removal of N and P by nutrient uptake and storage in the shoot biomass. It is assumed that when a user-defined yield is reached, the pasture is mowed and the harvested material exported off site.

4.3.2 MEDLI Input Data

The annual effluent inflow to the ponds was estimated to be approximately 326.6 ML/yr based on the number of operating days and the effluent generation data supplied. These are the values entered into MEDLI for analysis.

A 100-year (1913-2012) climate file for Inverell was obtained from the SILO database operated by the Bureau of Meteorology (BOM) that gives daily meteorological data (refer Table 1). The median annual rainfall is 767 mm/year.

The wet weather storage size was based on data supplied by Mitchell Hanlon Consulting Pty Ltd. An existing 70.1 ML dam will be used to store effluent during wet periods. The MEDLI model was calibrated to have nitrogen, phosphorus and salinity concentrations in the irrigated effluent at the maximum concentrations allowable for “low strength” effluent as described in the Environmental Guidelines – Use of Effluent by Irrigation (DEC 2004).

The main soil types on the property range from Ferrosols (krasnosems) to Vertosols (heavy cracking clays). Information supplied by Mitchell Hanlon Consulting Pty Ltd show that dark heavy clay soils dominate the 160 ha area proposed for effluent reuse (see Section 2.3). These soils have moderate to high water holding capacity and are imperfectly drained with low permeability. Therefore, the default ‘Black Vertosol’ soil in MEDLI was used for the modelling.

The irrigation input data includes the irrigation method, irrigation area size and irrigation scheduling rules. The available effluent irrigation area totals 160 ha and effluent will be applied using spray irrigation, with scheduling was based on a 20 mm soil water deficit. The MEDLI model assumes that all biomass grown is harvested, then removed from the site.

4.3.3 MEDLI Modelling Scenarios

The modelling run was setup using the proposed effluent volume, nutrient concentrations, pond details and land area. The irrigation scheduling was based on a 20 mm soil water deficit to assess if the wet weather dam has sufficient volume. To compare this to natural conditions, a dryland modelling run was also undertaken. Therefore, the scenarios modelled were as follows:

- Scenario 1 – Current situation
    - Irrigation Area = 160 ha
    - Effluent Production = 1.25 ML/d (326.6 ML/yr)
    - Effluent Nutrient Concentrations = 50 mg/L N & 10 mg/L P (maximum)
    - Irrigation Scheduling = 20 mm soil water deficit

- Scenario 2 – Dryland Run
    - Irrigated Area = 160 ha
    - Effluent irrigated = 0 ML/yr
    - No irrigation

4.3.4 Modelling Results

Several key results are tabulated below, while the full MEDLI summary outputs are presented in Appendix A. Table 5 summarises the wet weather dam water balance results, while Table 6 shows the water and nutrient balance for the effluent reuse area.

It should be noted that when parameterising models such as MEDLI, certain assumptions have to be made, usually due to a lack of appropriate data. For this reason, the results presented should be viewed in terms of the *relative* sustainability of the different scenarios, rather than any *absolute* differences between them. Monitoring is the only way to ensure that the performance predicted by the modelling is achieved.

TABLE 5: WET WEATHER DAM WATER BALANCE

Water Movement (ML/yr)	Scenario 1	Scenario 2
Effluent inflow	326.6	326.6
Rain	14.3	14.3
TOTAL IN	**340.9**	**340.9**
Evaporation	17.5	27.0
Seepage*	0.4	0.7
Recycling Volume	0	0
Overtopping	2.8	312.5
Irrigation	320.0	0
TOTAL OUT	**340.7**	**340.2**

* seepage estimated at 0.1 mm/d

TABLE 6: EFFLUENT IRRIGATION AREA WATER AND NUTRIENT MASS BALANCE

Parameter	Scenario 1	Scenario 2
Water Balance (mm/yr)		
Rainfall	767	767
Irrigation	200	0
Soil evaporation	69	361
Transpiration	835	359
Runoff	20	27
Drainage	41	21
Nutrient Application and Losses (kg/ha/yr)		
N applied as effluent	101	-
N volatilised	0	-
N removed by crop	121	24
N Leached	<1	-
P applied as effluent	20	-
P removed by crop	19	1
Change in adsorbed P	1	-
P Leached	0	-
Nutrient Concentration in Deep Drainage (mg/L)		
Nitrogen	1	1
Phosphorus	0	0
Crop Yield (t DM/ha/yr)		
Crop Yield	12.2	3.2

NB: All data are means over 100-year simulation period.

The results for Scenario 1 show that under the proposed effluent reuse system, overtopping is estimated to be ~2.8 ML/yr or about 0.9% of annual effluent inflow. The overtopping details show that five overtopping events occur every 10 years, which meets the "uncontrolled releases may be permitted in 50 percent of years" for low strength effluent as outlined in the Environmental Guidelines – Use of Effluent by Irrigation (DEC 2004).

The effluent irrigation volume applied in Scenario 1 is approximately 200 mm/yr. The predicted deep drainage rate is 41 mm and predicted runoff is estimated to be 20 mm/yr.

The nitrogen loading rate is estimated at 101 kg/ha/yr and leached nitrogen is predicted to be <1 kg/ha/yr. The predicted phosphorus loading rate is 20 kg/ha/yr, with approximately 19 kg/ha/yr utilised by cut and cart cropping regime. It is predicted that no phosphorus leaching will occur.

The predicted crop yield is 12.2 t DM/ha/yr on average. This is within the yield estimates provided by the agronomist. Although a ryegrass pasture was modelled, a forage corn and winter crop rotation is expected to yield similar (or more) biomass.

The results for Scenario 2 show the predicted deep drainage and runoff rates if no effluent irrigation occurred. The predicted deep drainage rate is 21 mm and predicted runoff 27 mm/yr. Therefore, it is predicted that applying 200 mm/yr of effluent will increase deep drainage by 20 mm/yr (~49%) and runoff will actually decrease by 7 mm/yr due to crop growth and improved crop cover.

The modelling of the proposed "low strength" effluent reuse system is considered sustainable because of acceptable pond overtopping frequency (5 events in 10 years), balanced nutrient loading rates causing negligible leaching and minor impacts on deep drainage.

4.4 Additional Hydraulic Modelling

In addition to the modelling of a "low strength" effluent reuse system, several other water balance modelling scenarios were undertaken to determine what irrigation and wet weather pond volume would be acceptable for both "medium" and "high" strength effluent.

An additional 10 modelling runs were undertaken. For all scenarios, the inflow (1.25 ML/d (~327 ML/yr), soil types and irrigation scheduling were kept constant.

Modelling runs 1-7 use the existing wet weather storage pond size (70.1 ML) and show the increased land area required for acceptable pond overflows. One problem at the higher land areas is that the irrigation volume maybe too small for successful cropping.

The ideal irrigation volume based on agronomic advice is around 250-350mm. Therefore, runs 8-10 show the wet weather storage volume requirements to achieve the acceptable low, medium and high strength effluent overflow frequency based on the Environmental Guidelines – Use of Effluent by Irrigation (DEC 2004).

After installation of the anaerobic digester, the existing aerobic ponds will not be required and could be used for wet weather storage. Bindaree Beef management advised that these aerobic ponds, once decommissioned, could increase the total wet weather storage capacity to ~200 ML. This increased storage capacity would exceed the requirement for low, medium and high strength effluent overtopping frequency (as per runs 8-10) from a water balance perspective.

TABLE 7: SUMMARY OF ADDITIONAL WATER BALANCE MODELLING

Run	Irrigation Area (ha)	WWS (ML)	Effluent Application (mm)	Overflow Volume (ML/yr)	Overflow Events (per 10 yrs)
1	80	70.1	382	17.2	34
2	100	70.1	315	8.5	18
3	120	70.1	267	4.1	8
4	140	70.1	229	3.1	6
5	160	70.1	201	2.7	5 (50th percentile)
6	180	70.1	179	2.4	5
7	200	70.1	161	1.8	3.7
8	100	100	319	1.9	4.7 (50th percentile)
9	100	115	319	0.8	1.8 (75th percentile)
10	100	125	319	0.4	0.9 (90th percentile)

Note: The 50th, 75th and 90th percentile are acceptable overflows for low, medium and high strength effluent respectively.

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APPENDIX A: MEDLI OUTPUT FILES

```
*****************************************
         SUMMARY OUTPUT
      MEDLI  Version 1.30

Data Set:   8132 - Bindaree
Run Date: 31/01/14   Time:17:34:26.47
*****************************************

GENERAL INFORMATION
*******************
Title:    Bindaree Beef
Subject:  [no entry]
Client:   [no entry]
User:     JLG
Time:     Fri Jan 31 16:19:52 2014
Comments: 1.25 ML/day


RUN PERIOD
**********

Starting Date  1/ 1/1913
Ending Date   31/12/2012
Run Length    100 years   0 days
_____________________________________________________________________________________

CLIMATE INFORMATION
*******************

Enterprise site: Inverell                           -29.8 deg S  151.1 deg E
Weather station: INVERELL_29.80S_151.10E (Interpo

  ANNUAL TOTALS    10 Percentile  50 percentile  90 Percentile
Rainfall mm/year        550.         760.         988.
Pan Evap mm/year       1537.        1667.        1792.

      MONTHLY       Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec  Year
Rainfall      (mm)   97   87   61   41   44   49   50   41   47   69   83   96   767
Pan Evap      (mm)  220  180  167  116   79   56   62   87  123  163  192  220 1664
Ave Max Temp DegC    31   30   28   25   20   17   16   18   21   25   28   30   24
Ave Min Temp DegC    16   15   13    9    5    2    1    2    5    9   12   15    8
Rad   (MJ/m2/day)    24   21   20   16   13   11   12   16   19   22   24   25   18
-------------------------------------------------------------------------------------
MONTHLY IRRIGATION
******************

Irrigation    (mm)   18   16   18   16   17   14   14   19   17   19   17   17  199
_____________________________________________________________________________________


SOIL PROPERTIES
***************

Soil type: Black Vertosol

SOIL WATER PROPERTIES

                                             Layer 1     Layer 2     Layer 3     Layer 4
Bulk Density                        (g/cm3)     1.0         1.3         1.3         1.3
Porosity                         (mm/layer)    60.4       262.3       298.9       148.3
Saturated Water Content          (mm/layer)    59.6       259.5       297.0       146.7
Drained Upper Limit              (mm/layer)    41.2       232.5       280.2       140.1
Lower Storage Limit              (mm/layer)    25.7       150.5       204.6       115.2
Air Dry Moisture Content         (mm/layer)     3.2
Layer Thickness                        (mm)   100.0       500.0       600.0       300.0

                                             Profile  Max Rootzone
Total Saturated Water Content          (mm)   762.8       418.1
Total Drained Upper Limit              (mm)   694.0       367.1
Total Lower Storage Limit              (mm)   496.0       244.4
Total Air Dry Moisture Content         (mm)     4.6         3.9
Total Depth                            (mm)  1500.0       800.0

Maximum Plant Available Water Capacity        122.7
Saturated Hydraulic Conductivity
                At Surface          (mm/hr)     1.0
                Limiting            (mm/hr)     0.5

RUNOFF

Runoff curve No II                             82.0
```

```
SOIL EVAPORATION

CONA                         (mm/day^0.5)    3.5
URITCH                               (mm)    6.0
___________________________________________________________________________________


AVERAGE WASTE STREAM
********************

Other waste stream
(All values relate to influent after any screening and recycling, if applicable).

Inflow Volume                   (ML/year)  326.6
Nitrogen                     (tonne/year)   19.6
Phosphorus                   (tonne/year)    3.3
Salinity                     (tonne/year)  209.0

Nitrogen Concentration             (mg/L)   60.0
Phosphorus Concentration           (mg/L)   10.0
Salinity                           (mg/L)  640.0
Salinity                           (dS/m)    1.0

WASTE STREAM DETAILS (for last inflow event):
Nitrogen Concentration             (mg/L)   60.0
Phosphorus Concentration           (mg/L)   10.0
TDS Concentration                  (mg/L)  640.0
Salinity                           (dS/m)    1.0
___________________________________________________________________________________


IRRIGATION WATER
****************

Irrigation triggered on a soil water deficit of (mm):   20.0
Irrigating upto upper storage limit +   0 mm

AREA

Total Irrigation Area                (ha)  160.0

VOLUMES

Total Irrigation                (ML/year)  320.0
Minimum Volume Irrigated by Pump (ML/ha/day)    0.0
Maximum Volume Irrigated by Pump (ML/ha/day)    0.1
Maximum Vol. Available For Shandying (ML/yr)    0.0

IRRIGATION CONCENTRATIONS

Average salinity of Irrigation     (dS/m)    1.0
Average salinity of Irrigation     (mg/L)  647.5
Average Nitrogen Conc of Irrigation
                Before ammonia loss   (mg/L)   51.1
                After ammonia loss    (mg/L)   51.1
Average Phosphorus Conc of Irrigation (mg/L)   10.1
___________________________________________________________________________________


FRESH WATER USAGE
*****************

Irrigation (shandying) water        (ML/yr)   0.00

Avg volume of fresh water used      (ML/yr)   0.00

Annual allocation                   (ML/yr)    N/A


POND INFORMATION
****************

POND GEOMETRY
                                            Pond 1

Final pond volume                   (ML)       5.3
Final liquid volume                 (ML)       5.3
Final sludge volume                 (ML)       0.0
Average pond volume                 (ML)      12.2
Average active volume               (ML)      12.2
```

```
Maximum pond volume                  (ML)       70.1
Minimum allowable pond volume        (ML)        5.3
Average pond depth                    (m)        1.1
Pond depth at outlet                  (m)        5.0
Maximum water surface area     (m2 x1000)       18.0
Pond catchment area            (m2 x1000)       18.6
Pond footprint length                 (m)      194.2
Pond footprint width                  (m)       95.7

POND WATER BALANCE

Inflow of Effluent to pond system    (ML/yr)  326.6
Recycle Volume from pond system      (ML/yr)    0.0
Rain water added to pond system      (ML/yr)   14.3
Evaporation loss from pond system    (ML/yr)   17.5
Seepage loss from pond system        (ML/yr)    0.4
Irrigation from last pond            (ML/yr)  320.0
Volume of overtopping                (ML/yr)    2.8
Sludge accumulated                   (ML/yr)    0.0
    Sludge accumulated             (t DM/yr)    0.0
Sludge removed                       (ML/yr)    0.0
No of desludging events every 10 years          0.0
Increase in pond water volume        (ML/yr)    0.1

OVERTOPPING EVENTS

Volume of overtopping                (ML/yr)    2.84
No. of days pond overtops per 10 years         25.10
Average Length of overtopping events  (days)    4.25
% Reuse                                        98.99
No. of overtopping events every 10 years
          >  0.000 ML         5.10
          >  0.009 ML*        5.10
          >  1.000 ML         4.40
          >  2.000 ML         4.00
          >  5.000 ML         3.80
          > 10.000 ML         0.10
          > 20.000 ML         0.00
          > 50.000 ML         0.00
* Volume equivalent to 1 mm depth of water

>>> NO-IRRIGATION EVENTS <<<

%Days rain prevents irrigation                  24.6
%Days water demand too small to trigger irr.    14.2
%Days pond volume below min. vol. for irrig.    16.2
No. periods/year without irrigable effluent     33.2
Average Length of such periods        (days)     1.8

POND NITROGEN BALANCE

Nitrogen Added by Effluent        (tonne/yr)   19.6   Irrig. from pond (ML/yr)  320.0
Nitrogen removed by Irrigation    (tonne/yr)   16.2
Nitrogen removed by Volatilisation(tonne/yr)    3.1
Nitrogen removed by Seepage       (tonne/yr)    0.0
Nitrogen accumulated in Sludge    (tonne/yr)    0.0
Nitrogen lost by Overtopping      (tonne/yr)    0.3
Nitrogen involved in Recycling    (tonne/yr)    0.0
Increase in pond Nitrogen         (tonne/yr)    0.0

POND PHOSPHORUS BALANCE

Phosphorus Added by Effluent      (tonne/yr)    3.3   Irrig. from pond (ML/yr)  320.0
Phosphorus removed by Irrigation  (tonne/yr)    3.2
Phosphorus removed by Seepage     (tonne/yr)    0.0
Phosphorus accumulated in Sludge  (tonne/yr)    0.0
Phosphorus lost by Overtopping    (tonne/yr)    0.1
Phosphorus involved in Recycling  (tonne/yr)    0.0
Increase in pond Phosphorus       (tonne/yr)    0.0

POND SALINITY BALANCE

Salinity Added by Effluent        (tonne/yr)  209.0
Salinity removed by Irrigation    (tonne/yr)  204.6
Salinity removed by Seepage       (tonne/yr)    0.3
Salinity lost by Overtopping      (tonne/yr)    4.1
Salinity involved in Recycling    (tonne/yr)    0.0
Increase in pond Salinity         (tonne/yr)    0.0

POND CONCENTRATIONS
                                              Pond 1
```

```
Average Nitrogen Conc of Pond Liquid  (mg/L)   48.5
Average Phosphorus Conc of Pond Liquid(mg/L)    9.9
Average TDS Conc of Pond Liquid       (mg/L)  632.7
Average Salinity of Pond Liquid       (dS/m)    1.0
Average Potassium Conc of Pond Liquid (mg/L)    0.0

(On final day of simulation)
Nitrogen Conc of Pond Liquid          (mg/L)   44.8
Phosphorus Conc of Pond Liquid        (mg/L)    9.0
TDS Conc of Pond Liquid               (mg/L)  578.6
EC of Pond Liquid                     (dS/m)    0.9
Potassium Conc of Pond Liquid         (mg/L)    0.0

REMOVED SLUDGE - NUTRIENT & SALT CONCENTRATIONS

Nitrogen in removed Sludge (db)   (kg/tonne)    0.0
Phosphorus in removed Sludge (db) (kg/tonne)    0.0
Salt in removed Sludge (db)       (kg/tonne)    0.0
Potassium in removed Sludge (db)  (kg/tonne)    0.0

REMOVED SLUDGE - NUTRIENT & SALT MASSES

Nitrogen in removed Sludge        (tonne/yr)    0.0
Phosphorus in removed Sludge      (tonne/yr)    0.0
Salt in removed Sludge (mass bal.)(tonne/yr)    0.0
Salt in removed Sludge            (tonne/yr)    0.0
Potm. in removed Sludge (mass bal.)(tonne/yr    0.0
Potassium in removed Sludge       (tonne/yr)    0.0
_____________________________________________________________________________________


LAND DISPOSAL AREA
******************

WATER BALANCE
-------------
(Initial soil water assumed to be at field capacity)
(Irrigated up to    8.15% of field capacity)
Rainfall                         (mm/year)    767.4   Irrigation Area     (ha)   160.0
Irrigation                       (mm/year)    199.9
Soil Evaporation                 (mm/year)     69.4
Transpiration                    (mm/year)    834.8
Runoff                           (mm/year)     20.3
Drainage                         (mm/year)     41.2
Change in soil moisture          (mm/year)     -0.9

ANNUAL TOTALS
```

Year	Rain (mm)	Irrig (mm)	Sevap (mm)	Trans (mm)	Runoff (mm)	Drain (mm)	Change (mm)
1913	738.0	196.6	219.2	735.9	19.5	101.8	-141.7
1914	766.0	200.9	208.6	741.9	0.6	0.0	15.8
1915	437.0	197.2	92.6	576.7	0.5	0.0	-35.7
1916	1099.0	174.6	194.3	717.2	76.6	140.7	144.9
1917	942.0	223.9	26.8	961.6	72.1	141.9	-36.4
1918	469.0	198.3	27.3	758.6	1.0	0.0	-119.6
1919	470.0	196.6	37.6	617.1	0.0	0.0	12.0
1920	926.0	184.6	25.2	886.6	23.8	100.0	74.9
1921	1253.0	185.0	31.0	880.6	106.0	265.9	154.6
1922	569.0	205.6	26.5	938.4	4.0	38.8	-233.0
1923	587.0	198.9	36.7	676.7	7.0	0.0	65.5
1924	1015.0	199.4	25.5	1042.6	21.8	83.8	40.7
1925	603.0	199.7	230.4	640.4	2.6	0.0	-70.7
1926	590.0	200.0	22.5	730.9	0.3	0.0	36.3
1927	605.0	200.3	29.0	773.7	3.8	0.0	-1.2
1928	815.0	202.8	28.3	1003.4	16.8	45.9	-76.6
1929	681.0	199.8	123.4	706.8	41.5	0.0	9.1
1930	815.0	195.8	112.4	840.4	13.6	30.7	13.8
1931	886.0	191.9	175.2	763.9	20.4	26.8	91.7
1932	640.0	200.5	161.2	787.3	8.0	0.0	-116.1
1933	955.0	202.0	102.0	838.5	9.2	85.6	121.8
1934	944.0	197.4	29.1	973.8	28.4	34.8	75.4
1935	566.0	206.2	32.8	875.4	8.1	53.9	-198.1
1936	674.0	201.0	258.0	502.7	5.2	0.0	109.1
1937	704.0	200.6	25.6	951.4	23.8	0.0	-96.3
1938	696.0	200.0	39.2	831.1	14.2	0.0	11.5
1939	642.0	199.9	134.7	652.6	12.7	0.0	41.9
1940	545.0	197.0	105.9	603.9	16.4	0.0	15.8
1941	708.0	202.2	32.9	877.8	17.8	63.9	-82.3

1942	901.0	199.9	307.5	582.9	38.2	0.0	172.3
1943	706.0	204.8	27.2	961.1	10.3	28.2	-116.1
1944	493.0	198.7	86.7	663.1	0.4	0.0	-58.4
1945	781.0	201.6	103.9	863.1	13.5	0.0	2.1
1946	639.0	199.7	123.7	639.4	74.1	0.0	1.5
1947	963.0	185.6	32.2	893.6	26.8	33.6	162.4
1948	726.0	218.5	31.4	1009.1	8.4	36.7	-141.1
1949	952.0	205.1	22.9	1006.3	25.1	71.9	30.9
1950	987.0	180.5	25.9	901.3	23.8	228.9	-12.4
1951	466.0	197.5	30.6	672.3	0.0	0.0	-39.4
1952	795.0	200.8	171.3	740.2	22.8	46.2	15.3
1953	553.0	200.8	30.1	733.6	6.8	0.0	-16.7
1954	878.0	199.3	25.3	861.2	22.9	35.8	132.1
1955	877.0	206.2	29.1	985.2	73.4	51.3	-56.0
1956	1083.0	178.9	28.6	975.5	95.1	227.8	-65.1
1957	580.0	197.8	181.5	600.8	7.2	0.0	-11.7
1958	877.0	198.5	130.5	865.8	10.9	0.0	68.3
1959	1081.0	194.0	28.8	1061.0	29.0	52.8	103.5
1960	638.0	217.4	27.9	972.7	1.1	4.7	-151.0
1961	678.0	200.1	25.1	823.6	0.0	0.0	29.4
1962	922.0	202.8	28.3	1012.7	11.1	22.0	50.7
1963	754.0	202.1	28.6	963.6	17.9	3.7	-57.7
1964	791.0	202.8	112.5	876.7	5.3	40.8	-41.4
1965	411.0	196.7	34.9	524.2	1.0	0.0	47.6
1966	773.0	201.0	185.2	707.0	37.6	26.7	17.5
1967	520.0	199.7	26.5	731.2	6.0	0.0	-44.0
1968	662.0	201.5	92.5	775.9	13.0	0.0	-17.9
1969	829.0	202.6	74.6	833.3	18.2	13.6	91.8
1970	980.0	188.5	28.6	847.7	45.1	137.2	109.8
1971	920.0	219.1	27.0	993.7	36.7	171.4	-89.7
1972	734.0	200.6	29.5	903.0	4.1	0.0	-2.0
1973	885.0	195.2	23.5	934.9	39.8	13.9	68.1
1974	602.0	210.3	25.9	902.5	17.1	41.7	-174.9
1975	989.0	203.5	23.3	874.5	41.3	166.4	87.0
1976	891.0	204.1	26.0	1023.6	90.6	48.7	-93.8
1977	744.0	201.2	24.8	843.3	15.8	61.9	-0.6
1978	1043.0	174.6	26.1	885.2	6.5	130.0	169.8
1979	622.0	205.3	105.1	888.7	3.4	0.0	-169.9
1980	504.0	196.1	39.9	615.3	0.0	0.0	44.9
1981	593.0	201.1	78.6	675.8	5.6	1.0	33.0
1982	578.0	198.3	81.1	710.4	11.9	0.0	-27.0
1983	1084.0	110.3	115.9	788.6	22.3	189.3	78.3
1984	969.0	198.3	24.6	963.0	48.9	143.3	-12.5
1985	730.0	203.2	25.4	920.4	7.0	0.0	-19.6
1986	525.0	198.6	26.2	794.6	0.0	0.0	-97.2
1987	922.0	203.8	26.1	1000.2	8.5	0.0	91.0
1988	901.0	181.9	27.7	1013.0	16.8	89.5	-64.2
1989	784.0	176.1	23.6	822.7	1.7	25.0	87.0
1990	738.0	185.5	146.5	809.0	19.3	23.6	-75.0
1991	801.0	201.5	116.6	791.1	50.7	0.0	44.1
1992	772.0	204.7	29.1	955.0	4.1	0.0	-11.5
1993	680.0	200.6	28.4	910.9	0.7	0.0	-59.5
1994	578.0	198.6	148.9	558.1	24.3	0.0	45.3
1995	906.0	195.7	124.1	900.5	7.1	0.0	69.9
1996	890.0	210.3	27.6	995.2	19.2	105.2	-47.0
1997	727.0	202.9	29.2	888.5	3.0	0.0	9.2
1998	1000.0	173.6	23.1	884.9	27.6	181.8	56.2
1999	924.0	166.4	24.1	979.0	44.5	30.2	12.5
2000	854.0	208.1	26.8	952.3	23.1	54.7	5.3
2001	832.0	231.2	28.1	1027.6	26.3	7.9	-26.7
2002	631.0	199.9	29.3	837.4	12.2	0.0	-48.0
2003	754.0	201.6	122.0	871.4	32.2	0.0	-70.0
2004	854.0	201.7	114.6	814.9	17.3	0.0	108.9
2005	686.0	202.6	27.7	937.7	6.8	0.0	-83.6
2006	631.0	200.4	133.4	738.0	3.9	0.0	-43.9
2007	874.0	195.3	27.2	897.5	12.3	0.0	132.4
2008	799.0	211.2	26.1	972.0	17.8	22.5	-28.4
2009	547.0	196.1	97.6	668.3	5.3	0.0	-28.2
2010	842.0	125.8	91.2	701.7	5.8	86.2	82.9
2011	1055.0	173.6	29.5	924.2	58.6	226.8	-10.5
2012	706.0	240.8	29.0	944.1	12.3	24.5	-63.1

NUTRIENT BALANCE

NITROGEN

```
Total N irrigated from ponds  (kg/ha/year)     101.0   % of Total as ammonium      0.0
Nitrogn lost by ammonia volat.(kg/ha/year)       0.0   Deep Drainage (mm/year)    41.2
```

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Nitrogen added in irrigation  (kg/ha/year)     101.0
Nitrogen added in seed        (kg/ha/year)       0.6
Nitrogen removed by crop      (kg/ha/year)     121.3
Denitrification               (kg/ha/year)       0.2
Leached NO3-N                 (kg/ha/year)       0.3
Change in soil organic-N      (kg/ha/year)     -18.3
Change in soil solution NH4-N (kg/ha/year)       0.0
Change in soil solution NO3-N (kg/ha/year)      -1.9
Change in adsorbed NH4-N      (kg/ha/year)       0.0
Initial soil organic-N             (kg/ha)    1963.5
Final soil organic-N               (kg/ha)     131.0
Initial soil inorganic-N           (kg/ha)     193.5
Final soil inorganic-N             (kg/ha)       0.0
Average N03-N conc in the root zone (mg/L)       0.1
Average N03-N conc below root zone  (mg/L)       0.3
Average N03-N conc of deep drainage (mg/L)       0.7

PHOSPHORUS

Phosphorus added in irrigatn  (kg/ha/year)      20.0   % of Total as phosphate   100.0
Phosphorus added in seed      (kg/ha/year)       0.1
Phosphorus removed by crop    (kg/ha/year)      18.9
Leached PO4-P                 (kg/ha/year)       0.0
Change in dissolved PO4-P     (kg/ha/year)       0.0
Change in adsorbed PO4-P      (kg/ha/year)       1.2
Average P04-P conc in the root zone (mg/L)       0.0
Average P04-P conc below root zone  (mg/L)       0.0

SOIL P STORAGE LIFE
```

Year	YearNo.	Tot P stored kg/ha	P leached in year kg/ha
1913	1	2009.4	0.0
1914	2	2029.2	0.0
1915	3	2046.6	0.0
1916	4	2066.8	0.0
1917	5	2073.2	0.0
1918	6	2083.0	0.0
1919	7	2091.5	0.0
1920	8	2102.2	0.0
1921	9	2098.7	0.0
1922	10	2102.3	0.0
1923	11	2105.9	0.0
1924	12	2112.4	0.0
1925	13	2110.9	0.0
1926	14	2112.9	0.0
1927	15	2112.8	0.0
1928	16	2117.3	0.0
1929	17	2113.5	0.0
1930	18	2114.0	0.0
1931	19	2113.9	0.0
1932	20	2121.1	0.0
1933	21	2116.1	0.0
1934	22	2115.3	0.0
1935	23	2114.5	0.0
1936	24	2124.5	0.0
1937	25	2118.7	0.0
1938	26	2117.2	0.0
1939	27	2119.5	0.0
1940	28	2127.7	0.0
1941	29	2119.0	0.0
1942	30	2124.1	0.0
1943	31	2122.2	0.0
1944	32	2126.0	0.0
1945	33	2120.8	0.0
1946	34	2122.3	0.0
1947	35	2120.4	0.0
1948	36	2123.1	0.0
1949	37	2116.4	0.0
1950	38	2113.9	0.0
1951	39	2114.4	0.0
1952	40	2123.7	0.0
1953	41	2118.2	0.0
1954	42	2118.7	0.0
1955	43	2117.1	0.0
1956	44	2119.8	0.0
1957	45	2117.0	0.0
1958	46	2119.9	0.0
1959	47	2117.7	0.0
1960	48	2122.8	0.0

1961	49	2117.4	0.0
1962	50	2115.9	0.0
1963	51	2115.7	0.0
1964	52	2123.4	0.0
1965	53	2119.8	0.0
1966	54	2123.7	0.0
1967	55	2122.1	0.0
1968	56	2126.7	0.0
1969	57	2121.9	0.0
1970	58	2120.3	0.0
1971	59	2117.9	0.0
1972	60	2124.0	0.0
1973	61	2117.9	0.0
1974	62	2117.0	0.0
1975	63	2116.1	0.0
1976	64	2121.4	0.0
1977	65	2116.5	0.0
1978	66	2115.8	0.0
1979	67	2117.6	0.0
1980	68	2125.4	0.0
1981	69	2121.2	0.0
1982	70	2123.3	0.0
1983	71	2120.0	0.0
1984	72	2119.0	0.0
1985	73	2116.2	0.0
1986	74	2117.8	0.0
1987	75	2117.7	0.0
1988	76	2121.0	0.0
1989	77	2115.2	0.0
1990	78	2116.3	0.0
1991	79	2119.3	0.0
1992	80	2125.7	0.0
1993	81	2119.7	0.0
1994	82	2121.9	0.0
1995	83	2123.5	0.0
1996	84	2127.4	0.0
1997	85	2121.8	0.0
1998	86	2120.1	0.0
1999	87	2118.0	0.0
2000	88	2123.2	0.0
2001	89	2117.8	0.0
2002	90	2118.9	0.0
2003	91	2120.5	0.0
2004	92	2128.2	0.0
2005	93	2122.0	0.0
2006	94	2122.5	0.0
2007	95	2121.7	0.0
2008	96	2125.4	0.0
2009	97	2119.4	0.0
2010	98	2121.0	0.0
2011	99	2114.9	0.0
2012	100	2121.8	0.0

PLANT

Plant species: Ryegrass pasture

PLANT WATER USE

```
Irrigation                          (mm/year)   199.   Totl Irrigation Area(ha)   160.0
Pan coefficient                           (%)     1.0
Maximum crop coefficient                  (%)     0.8
Average Plant Cover                       (%)    79.
Average Plant Total Cover                 (%)    94.
Average Plant Rootdepth                  (mm)   763.
Average Plant Available Water Capacity   (mm)   121.
Average Plant Available Water            (mm)    68.
Yield produced per unit transp.    (kg/ha/mm)    15.
```

PLANT NUTRIENT UPTAKE

```
Dry Matter Yield (Shoots)          (kg/ha/yr) 12270.
Net nitrogen removed by plant      (kg/ha/yr)   121.   Shoot Concn         (%DM)    0.98
Net phosphorus removed by plant    (kg/ha/yr)    19.   Shoot Concn         (%DM)    0.15
```

AVERAGE MONTHLY GROWTH STRESS (0=no stress, 1=full stress)

Month	Yield kg/ha	Nitr	Temp	Water Defic	Water Logging
1	1194.	0.6	0.4	0.2	0.0
2	1041.	0.5	0.3	0.2	0.0
3	1134.	0.6	0.2	0.2	0.0
4	982.	0.6	0.0	0.3	0.0
5	806.	0.6	0.1	0.2	0.0
6	695.	0.6	0.3	0.1	0.0
7	785.	0.6	0.4	0.1	0.0
8	965.	0.6	0.3	0.1	0.0
9	1040.	0.7	0.1	0.1	0.0
10	1176.	0.7	0.0	0.1	0.0
11	1211.	0.7	0.2	0.2	0.0
12	1240.	0.6	0.3	0.2	0.0

>>> NO-PLANT EVENTS <<<

%Days due to temperature stress	0.2
%Days due to scorching	0.2
%Days due to water stress	0.9
%Days due to nitrogen stress	0.1
No. of forced harvests per year	0.5
No. of normal harvests per year	1.9

SALINITY

Salt tolerance - plant species: tolerant

Average EC of Irrigation Water	(dS/m)	1.0	Irrigation	(mm/year)	199.9
Average EC of Rainwater	(dS/m x10)	0.3	Rainfall	(mm/year)	767.4
Average EC of Infiltrated water	(dS/m)	0.2			
Av. water-upt-weightd rootzone EC	(dS/m s.e.)	0.5			
EC soil soln (FC) at base of rootzone	(dS/m)	7.8	Deep Drainage	(mm/year)	41.2
Reduction in Crop yield due to Salinity	(%)	0.0			
Percentage of yrs that crop yld falls below 90% of potential because of soil salinity		0.0			

Period	ECrootzone sat ext (dS/m)	ECbase in situ (dS/m)	Rel Yield (%)
1913 - 1922	0.39	2.80	100.
1914 - 1923	0.41	3.22	100.
1915 - 1924	0.37	2.87	100.
1916 - 1925	0.37	2.88	100.
1917 - 1926	0.42	3.55	100.
1918 - 1927	0.47	4.52	100.
1919 - 1928	0.43	4.15	100.
1920 - 1929	0.43	4.16	100.
1921 - 1930	0.45	4.80	100.
1922 - 1931	0.55	10.18	100.
1923 - 1932	0.56	11.92	100.
1924 - 1933	0.49	8.22	100.
1925 - 1934	0.51	9.71	100.
1926 - 1935	0.50	8.08	100.
1927 - 1936	0.50	8.08	100.
1928 - 1937	0.50	8.09	100.
1929 - 1938	0.52	9.68	100.
1930 - 1939	0.52	9.68	100.
1931 - 1940	0.56	11.14	100.
1932 - 1941	0.56	9.43	100.
1933 - 1942	0.54	9.44	100.
1934 - 1943	0.59	12.42	100.
1935 - 1944	0.68	16.06	100.
1936 - 1945	0.67	24.31	100.
1937 - 1946	0.68	24.26	100.
1938 - 1947	0.60	17.68	100.
1939 - 1948	0.60	13.81	100.
1940 - 1949	0.53	9.61	100.
1941 - 1950	0.43	4.84	100.
1942 - 1951	0.46	5.60	100.
1943 - 1952	0.46	5.02	100.
1944 - 1953	0.47	5.34	100.
1945 - 1954	0.44	4.94	100.
1946 - 1955	0.43	4.44	100.
1947 - 1956	0.36	3.04	100.

```
   1948 - 1957      0.39      3.20      100.
   1949 - 1958      0.39      3.35      100.
   1950 - 1959      0.38      3.42      100.
   1951 - 1960      0.45      5.35      100.
   1952 - 1961      0.44      5.36      100.
   1953 - 1962      0.44      5.70      100.
   1954 - 1963      0.43      5.66      100.
   1955 - 1964      0.43      5.60      100.
   1956 - 1965      0.46      6.37      100.
   1957 - 1966      0.56     14.99      100.
   1958 - 1967      0.55     14.99      100.
   1959 - 1968      0.56     14.97      100.
   1960 - 1969      0.62     21.07      100.
   1961 - 1970      0.50      8.93      100.
   1962 - 1971      0.45      5.44      100.
   1963 - 1972      0.46      5.73      100.
   1964 - 1973      0.45      5.57      100.
   1965 - 1974      0.47      5.56      100.
   1966 - 1975      0.41      3.97      100.
   1967 - 1976      0.39      3.83      100.
   1968 - 1977      0.38      3.47      100.
   1969 - 1978      0.34      2.88      100.
   1970 - 1979      0.35      2.93      100.
   1971 - 1980      0.39      3.60      100.
   1972 - 1981      0.43      4.82      100.
   1973 - 1982      0.44      4.81      100.
   1974 - 1983      0.39      3.37      100.
   1975 - 1984      0.35      2.90      100.
   1976 - 1985      0.39      3.74      100.
   1977 - 1986      0.42      4.07      100.
   1978 - 1987      0.42      4.62      100.
   1979 - 1988      0.45      5.07      100.
   1980 - 1989      0.42      4.73      100.
   1981 - 1990      0.40      4.48      100.
   1982 - 1991      0.40      4.50      100.
   1983 - 1992      0.38      4.52      100.
   1984 - 1993      0.46      7.84      100.
   1985 - 1994      0.55     15.92      100.
   1986 - 1995      0.54     15.89      100.
   1987 - 1996      0.47      9.09      100.
   1988 - 1997      0.48      9.07      100.
   1989 - 1998      0.44      6.56      100.
   1990 - 1999      0.43      6.43      100.
   1991 - 2000      0.42      5.96      100.
   1992 - 2001      0.42      5.91      100.
   1993 - 2002      0.44      5.90      100.
   1994 - 2003      0.43      5.90      100.
   1995 - 2004      0.42      5.92      100.
   1996 - 2005      0.43      5.93      100.
   1997 - 2006      0.47      8.15      100.
   1998 - 2007      0.46      8.13      100.
   1999 - 2008      0.54     19.64      100.
   2000 - 2009      0.61     26.91      100.
   2001 - 2010      0.56     18.91      100.
   2002 - 2011      0.45      6.43      100.
   2003 - 2012      0.45      6.10      100.
_____________________________________________________________________________________

GROUNDWATER
************

Average Groundwater Recharge        (m3/day)   180.6
Average Nitrate-N Conc of Recharge    (mg/L)     0.7

Thickness of the Aquifer                   (m)    10.0
Distance (m) from Irrigation Area to where
Nitrate-N Conc in Groundwater is Calculated  1000.0

Concentration of NITRATE-N in Groundwater (mg/L)
---------------------------------------------

       Year     Depth Below Water Table Surface
                   0.0 m      5.0 m      9.0 m
____________________________________________
       1917        0.1        0.1        0.1
       1922        0.2        0.2        0.2
       1927        0.3        0.3        0.3
       1932        0.3        0.3        0.3
       1937        0.4        0.4        0.4
       1942        0.4        0.4        0.4
       1947        0.4        0.4        0.4
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       1952        0.4       0.4       0.4
       1957        0.4       0.4       0.4
       1962        0.4       0.4       0.4
       1967        0.4       0.4       0.4
       1972        0.4       0.4       0.4
       1977        0.4       0.4       0.4
       1982        0.4       0.4       0.4
       1987        0.4       0.4       0.4
       1992        0.4       0.4       0.4
       1997        0.4       0.4       0.4
       2002        0.4       0.4       0.4
       2007        0.4       0.4       0.4
       2012        0.4       0.4       0.4
Last   2012        0.4       0.4       0.4
_____________________________________________________________________________________

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