Appendix D

Effluent management study

ASSESSMENT OF TREATED WASTEWATER DISPOSAL

Jilalan Rail Yard,Sarina

FINAL REPORT VERSION 1.1

27 November, 2007

PREPARED FOR

CONNELL WAGNER PTY LTD

BY

BIO-TRACK PTY LTD

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This report has been prepared by Peter Edmiston B.App.Sc.(Hons), M.Phil. for and on behalf of
Bio-Track Pty Ltd (ABN 91 056 237 275).

Peter Edmiston
Director Bio-Track

<u>*Technical Assistance*</u>

The evaluation of technical reports is sometimes difficult. Bio-Track remains available to answer questions regarding this report. Users of this report are encouraged to contact Peter Edmiston on (07) 3289 7179 or fax queries to (07) 3289 7155 to resolve technical issues raised within this report that require clarification.

1 INTRODUCTION

Bio-Track Pty Ltd has been commissioned by Connell Wagner Pty Ltd to prepare a wastewater disposal study for a proposed development at the Jilalan Rail Yard, near Sarina. This report is a specialist component study. It is assumed the reader will have access to other documents describing the project.

This report is based upon site drawings, a description of the proposed treatment system and soil samples provided by the client.

2 DESIGN VALUES AND ASSUMPTIONS

The following design values have been used in this study:

Design Flow of Wastewater	75 kl/day (all days) This is the peak flow that would apply for less than 6 months of the project.
Wastewater Composition	40 mg nitrogen/litre 10 mg phosphorus/litre
Irrigation Area Available	9.6 ha total 8 ha with land lost to marginal buffers
Wet Weather Storage	5 days storage (375 kl)
Irrigation Method	furrow irrigation
Land Use	Grass, harvested (possibly endemic species)

3 IRRIGATION MANAGEMENT

The following management values are relevant to this study:

Project Life	less than 2 years
Crop	priority management for wastewater irrigation, commercial cropping practices are secondary concerns harvesting of crop biomass at 3-6 monthly intervals (more required for access, irrigation management and weed control than for nutrient removal)

4 RE-USE STRATEGY

The following sequence of priority will be used for treated wastewater management:

1. Treated wastewater will be used elsewhere within the construction area as a source of construction water (eg. for soil compaction and dust supression). Up to 2 mega-litres/day (2000 kl/day) will be required for construction. The treated wastewater will be used for construction purposes in preference to irrigation to cane land. A frequency distribution analysis of the daily rainfall total is presented in Appendix 3. On 79% of days the rainfall total is less than 2 mm. It is reasonable to assume that construction water demands can utilise all of the wastewater on days when the rainfall is less than 2 mm.

   Any water held in the wet weather storage will be recovered for construction use in preference to irrigation.

2. On days when construction demand are less than 75 kl water will be irrigated to the crop land except when the following conditions prevail:

   * ponding of rainwater or irrigation water is likely
   * runoff of rainwater or irrigation water is likely

3. During periods when irrigation can not be applied to the crop land it will be directed to the wet weather storage and held for subsequent re-use either as construction water or crop land irrigation water

4. When the wet weather storage is full then the treated wastewater will require alternative disposal (which has not been investigated).

The irrigation strategy has the following objectives:

* minimise the demand for alternative supplies of construction water
* minimise the hydraulic load and nutrient load to the irrigation area
* maximise the opportunity for land disposal when construction requirements are low
* prevent surface movement of treated wastewater away from the crop irrigation area

5 ASSESSMENT OF IRRIGATION PERFORMANCE

A daily time step water balance model has been used to examine the performance of the irrigation area. Two irrigation strategies have been examined.

Standard Irrigation

The "standard" irrigation assessment assumes irrigation can be applied daily to the irrigation area except when the soil moisture in the soil exceeds 80% of field capacity. In this case the wastewater is stored and not irrigated. When the storage is full and can not be irrigated then the surplus water volume is calculated as "surplus". This water requires alternative disposal. This is a standard irrigation management strategy that prevents runoff of irrigation water and minimises deep drainage of irrigation water.

Project Irrigation

The "project" irrigation assessment assumes all of the irrigation water will be consumed by construction demands when rainfall is less than 2 mm and that the storage will be drawn down by 500 if rainfall is less than 2 mm. This is intended to replicate construction demands. Irrigation is then limited to 80% of field capacity as described for standard irrigation.

If no construction water is used then a 3 hectare irrigation area has a 29% surplus. When construction water is used the surplus falls to 8%. The surplus will require irrigation to soil during periods when the soil moisture exceeds 80% of field capacity.

6 ASSESSMENT OF NUTRIENT CONTROL

The mass of nutrient applied is a function of the irrigation rate. When construction water is used the irrigation rate is much lower. Table 1 (following page) provides a summary of the hydraulic and nutrient loads for three model cases. These are:

a) non-irrigated grass
b) irrigated grass, no construction water use
c) irrigated grass, construction water use

When construction water is used the nutrient load is 55 kg N/ha/y and 14 kg P/ha/y. The nitrogen application rate is well below the crop (pasture grass) uptake rate. The phosphorus application rate is close to the crop uptake rate. Provided the irrigation water has sufficient residence time within the crop root zone then very high rates of nutrient attenuation are predicted.

Nitrogen will also be lost as a consequence of soil denitrification. The potential loss rate is approximately 330 kg N/ha/y. This provides a second level of protection for nutrient not utilised by the crop.

Phosphorus will be utilised by the crop as well as being lost through soil phosphate sorption and soil phosphate precipitation. The soil phosphate sorption capacity is being measured and will be reported separately. The sorption capacity is predicted to be adequate for the period of irrigation.

TABLE 1: WATER AND NUTRIENT BALANCE SUMMARY

Component	**Units**			
Irrigation Area	ha	3		
Wet Weather Storage	kL	375		
Storage Depth	mm	2500		
Wastewater Nitrogen	mg/L	40		
Wastewater Phosphorus	mg/L	10		
Water Balance Components				
		No Irrigation	**Irrigated**	**Irrigated**
Construction Use		No	No	**Yes**
ADWF		0	75	75
Net Supply (after recycling)	kl/d	0	75	~12.6
Irrigation	mm/y	0	643	137
Runoff	mm/y	531	562	544
Deep Drainage	mm/y	169	171	171
Transpiration	mm/y	908	1505	1031
Irrigation Frequency	events/year	0	238	44
Surplus for Irrigation	kL/y	0	8000	500
Frequency of Irrigation Surplus	events/y	0	111	7.8
NUTRIENT PATHWAYS				
Wastewater Nitrogen Supply	kg/ha/y	0 *	257	55
Potential Crop Uptake (N)	kg/ha/y	150		
Potential De-Nitrification	kg/ha/y	326	338	330
Phosphorus Supply	kg/ha/y	0*	64	14
Potential Crop Uptake (P)	kg/ha/y	293		
Phosphate Sorption Period (after crop uptake)	years			

* fertiliser application not included

7 SURPLUS WATER MANAGEMENT

There will be periods of wet weather when construction demands for treated wastewater are low and the soil moisture content exceeds 80% of the soil field capacity.

To minimise the risk of runoff it is proposed to incorporate a "dry period" of 12 hours after the last rainfall (event > 10 mm) prior to applying any irrigation. This is intended to allow the surface soil to drain to the point where a further irrigation can be applied without causing runoff.

Irrigation should not be applied under conditions that will result in runoff of wastewater from the study area. A tail water collection drain should be used to collect and re-irrigate water if the irrigation application rates result in flow along the full length of the irrigation furrow.

To minimise the risk of dam surcharge following extreme rainfall events it is proposed to maintain a 500 mm freeboard to the full level

8 PATHOGEN CONTROL

It is believed the water will be treated and disinfected to a Class A standard. This water should be treated to a standard that permits primary contact with an acceptable risk to human health. Routine monitoring of the treatment process (according to the manufacturer specifications) is essential to ensure the treatment process is operating in a satisfactory manner.

The proposed method of irrigation is furrow irrigation so aerosol droplets will not be a management issue.

The most persistent pathogen for wastewater is likely to be a virus. A virus attenuation model has been used to examine the minimum distance required to reduce the virus population by a factor of 10^7.

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THE REQUIRED SETBACK DISTANCE FOR A 10^ 7  REDUCTION OF VIRUSES

REQUIRED SETBACK DISTANCE =   0.8 m   FOR A GRADIENT OF  0.0100 m/m
REQUIRED SETBACK DISTANCE =   1.6 m   FOR A GRADIENT OF  0.0200 m/m
REQUIRED SETBACK DISTANCE =   2.4 m   FOR A GRADIENT OF  0.0300 m/m
REQUIRED SETBACK DISTANCE =   3.2 m   FOR A GRADIENT OF  0.0400 m/m
REQUIRED SETBACK DISTANCE =   4.0 m   FOR A GRADIENT OF  0.0500 m/m
MODEL ASSUMPTIONS

GROUNDWATER TEMPERATURE             25 'C
HYDRAULIC GRADIENT                  0.0500m/m
SATURATED HYDRAULIC CONDUCTIVITY    1.000 m/d
EFFECTIVE POROSITY                  0.25
EXPECTED REDUCTION IN VIRUS DUE TO DIE-OFF ALONE = 10 ^  7
EXPECTED RETENTION PERIOD           19.8 days

METHOD: As per Beavers,P.D; Gardner,E.A.(1993). 15th AWWA Conference, Gold Coast
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The model predicts a minimum distance of 4 metres is required where the hydraulic gradient is 5%. It is understood that bore water is locally used and this water may be used as a domestic water supply. Under these conditions it is recommended a minimum separation distance of 100 metres is maintained between any irrigation area and any bore that may be used as a domestic water supply. The aquifer conditions are unknown but if a steep hydraulic gradient exists through a highly permeable aquifer then a residence period of less than 20 days may not exist, even for a separation distance of

100 metres. If this (probably unlikely) condition applies then a specialist study needs to be undertaken to ensure domestic water supplies are not contaminated.

Irrigation water should not be applied within 30 metres of a dwelling or drainage line to minimise the risk of surface movement of residual pathogens by overland flow.

9 MONITORING

It is assumed routine monitoring of soil and water quality will be required.

This would include routine measurement of the following:

Groundwater	level, nutrients, pH, salinity, major analytes
Soil	nutrient, pH, salinity, chloride, major cations, metals (if the project life exceeds 2 years)
Irrigation Water	nutrient, salinity, pH, acidity/alkalinity, chloride, major anions & cations, trace metals, pathogens, flow rates
Irrigation	records of irrigation application rates
Harvesting	harvest frequency and volume

A generic monitoring schedule has been included in Appendix 4.

10 CONCLUSIONS

The proposed irrigation strategy is not likely to result in an adverse environmental effect provided the management strategies outlined in this report are followed. Care will need to be taken to manage the irrigation area to prevent runoff after a period of wet weather as the wet weather storage volume is small. A prolonged period of wet weather will result in filling of the storage and soil conditions may preclude irrigation. Under these adverse conditions an alternative to irrigation will be required for a small proportion of the total wastewater stream.

The short duration of the project combined with the relatively low rate of irrigation minimise the opportunity for nutrient accumulation. Little or no change in the current rate of nutrient export (eg. that from sugar cane land) is predicted.

Pathogens are not predicted to be a hazard provided adequate separation is maintained between bores and dwelling areas and the irrigation area.

APPENDIX 1: IRRIGATION MODELLING PREDICTIONS

IRRIGATION WITH NO CONSTRUCTION WATER DEMAND

Irrigation not applied if rainfall > 25 mm
Maximum irrigation permitted not restricted mm/d
Excess expressed as a percentage of the supply flow

I=irrigation **mm/y**
E=excess water **% of supply**
S=days of storage **days @ supply flow**
A=irrigated area **ha**
W=wastewater supply **kl/d**
SV=storage volume **kl**

I(mm)	E %)	S (d)	A (ha)	W (kl/d)	SV (kl)
1240,	54.60,	5.0,	1.0,	75.00,	375
1143,	37.21,	5.0,	1.5,	75.00,	375
929,	31.95,	5.0,	2.0,	75.00,	375
762,	30.25,	5.0,	2.5,	75.00,	375
643,	**29.34,**	**5.0,**	**3.0,**	**75.00,**	**375**
557,	28.69,	5.0,	3.5,	75.00,	375
490,	28.25,	5.0,	4.0,	75.00,	375
437,	27.94,	5.0,	4.5,	75.00,	375
395,	27.69,	5.0,	5.0,	75.00,	375
360,	27.52,	5.0,	5.5,	75.00,	375
330,	27.44,	5.0,	6.0,	75.00,	375
305,	27.33,	5.0,	6.5,	75.00,	375
284,	27.24,	5.0,	7.0,	75.00,	375
265,	27.16,	5.0,	7.5,	75.00,	375
249,	27.08,	5.0,	8.0,	75.00,	375

IRRIGATION WITH CONSTRUCTION WATER DEMAND

Irrigation not applied if rainfall > 25 mm
Maximum irrigation permitted not restricted mm/d
Excess expressed as a percentage of the supply flow

I=irrigation **mm/y**
E=excess water **% of supply**
S=days of storage **days @ supply flow**
A=irrigated area **ha**
W=wastewater supply **kl/d**
SV=storage volume **kl**

I(mm)	E %)	S (d)	A (ha)	W (kl/d)	SV (kl)
381,	8.61,	23.4,	1.0,	16.05,	375
263,	8.39,	23.4,	1.5,	16.05,	375
201,	8.27,	23.4,	2.0,	16.05,	375
163,	8.21,	23.4,	2.5,	16.05,	375
137,	**8.18,**	**23.4,**	**3.0,**	**16.05,**	**375**
119,	8.17,	23.4,	3.5,	16.05,	375
104,	8.14,	23.4,	4.0,	16.05,	375
93,	8.13,	23.4,	4.5,	16.05,	375
84,	8.12,	23.4,	5.0,	16.05,	375
77,	8.10,	23.4,	5.5,	16.05,	375
70,	8.11,	23.4,	6.0,	16.05,	375
65,	8.10,	23.4,	6.5,	16.05,	375
60,	8.08,	23.4,	7.0,	16.05,	375
56,	8.08,	23.4,	7.5,	16.05,	375
53,	8.06,	23.4,	8.0,	16.05,	375

APPENDIX 2: SELECTED IRRIGATION CASES DETAILED SUMMARY OUTPUT

GQAL CONTROL: NO IRRIGATION

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11-19-2007    19:28:09      E:\POWER\EFFILES\SAR1.SWW
SIMULATION PERIOD  yrs 80
WATER BALANCE INPUTS
RAIN (mm) 1676
IRRIGATION (mm)     0
WATER BALANCE LOSSES
GRASS WATER USE  908
TREE WATER USE    0
RUNOFF 531
DEEP DRAINAGE 169.2
ANNUAL GRASS INTERCEPTION  32
ANNUAL TREEGRASS INTERCEPTION  0
ANNUAL TREE INTERCEPTION  0
SOIL EVAPORATION  32 mm/y
CHANGE TO SOIL WATER      3.7 mm
BALANCE  -0.08 mm
HYDROLOGY

AV. RAINDAYS PER YEAR 128.4
GRASS > F.C. d/y  15  TREE > F.C. d/y   6
GRASS RUNOFF EVENTS>1 mm 18.7  TREE RUNOFF EVENTS>1 mm 14.6
HARD SURFACE RUNOFF EVENTS > 0.00 mm/y 128.4 HARD SURFACE RUNOFF AVERAGE mm/y
= 1676.4 0.00  mm abstraction
BIG RAINFALL (>50 mm) EVENTS  642
Av. water stress days/y (G.S.<10 mm A.W.)169.8   Max. Consec days     190

NUTRIENTS

POTENTIAL DE-NITRIFICATION LOSS (KG/HA/y)  326.87 for a soil depth of  400
mm


SYSTEM VARIABLES

Location ref:  172

SOILS

RUNOFF COEFFICIENT NOMINAL K2              68
SOIL FACTOR CLASS A (program factor)       2
SOIL FACTOR CLASS B (program factor)       3
SOIL FACTOR CLASS C (program factor)       14
GRASS ROOTING DEPTH (m)      .4
MAX EFFECTIVE TREE ROOT DEPTH (m)          1.5
MULCHCOVER (Y/N)            N
TREE ROOTING DEPTH (max m)   1.5
SURFACE HYDRAULIC CONDUCTIVITY IS  150  mm/d
GRASS       Ks mm/d             150
UNDER GRASS Ks mm/d             10
TREE GRASS  Ks mm/d             150
TREE UNDER PASTURE  Ks mm/d     10
PASTURE COMPETITION Ks mm/d     150
UPPER TREE STORE    Ks mm/d     75
LOWER TREE STORE    Ks mm/d     10
BULK DENSITY   0  cm       1.5
BULK DENSITY   50 cm       1.6
BULK DENSITY  100 cm       1.6
BULK DENSITY  200 cm       1.65
SOIL WATER HOLDING CAPACITY (mm/m)         119.8665

PLANTS

GRASS TRANSPIRATION RATE  .7  OF PAN
TREE TRANSPIRATION RATE  1  OF PAN
TREE COVER  0.01%
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```
GRASS INTERCEPTION (mm)       .25
TREE INTERCEPTION (mm)        .5
AV. MIN. TEMP FOR FROST DAMAGE 0
TREE DENSITY /ha 1
MAXIMUM TREE CANOPY RADIUS (m) .5
THRESHOLD TREE SHADE LEVEL   50  %
SITE GROWTH FACTOR AFFECTING TREE GROWTH   .7
REPLANT STRATEGY IS  EVERY  0  YEARS
```

3 HA IRRIGATION 5 DAYS STORAGE NO CONSTRUCTION WATER USE
IRRIGATION LIMITED TO SOIL WITH <80% FIELD CAPACITY SOIL MOISTURE STORAGE

11-19-2007 19:28:52 E:\POWER\EFFILES\SAR1.SWW
SIMULATION PERIOD yrs 80
WATER BALANCE INPUTS
RAIN (mm) 1676
IRRIGATION (mm) 643
WATER BALANCE LOSSES
GRASS WATER USE 1505
TREE WATER USE 0
RUNOFF 562
DEEP DRAINAGE 171.6
ANNUAL GRASS INTERCEPTION 77
ANNUAL TREEGRASS INTERCEPTION 0
ANNUAL TREE INTERCEPTION 0
SOIL EVAPORATION 0 mm/y
CHANGE TO SOIL WATER 3.7 mm
BALANCE -0.99 mm
HYDROLOGY

AV. RAINDAYS PER YEAR 128.4
GRASS > F.C. d/y 15 TREE > F.C. d/y 6
GRASS RUNOFF EVENTS>1 mm 20.6 TREE RUNOFF EVENTS>1 mm 14.8
HARD SURFACE RUNOFF EVENTS > 0.00 mm/y 128.4 HARD SURFACE RUNOFF AVERAGE mm/y = 1676.4 0.00 mm abstraction
BIG RAINFALL (>50 mm) EVENTS 642
Av. water stress days/y (G.S.<10 mm A.W.) 0.0 Max. Consec days 0

NUTRIENTS

NUTRIENT LOADING (kg/ha/y)
[N] 257.20
[P] 64.30
POTENTIAL DE-NITRIFICATION LOSS (KG/HA/y) 337.91 for a soil depth of 400 mm

IRRIGATION

IGGNAREA 3
IRRIGATION EFFICIENCY FACTOR 1
No. IGGN DAYS 238 IRRIGATION 0
DAILY WASTEWATER LOAD (M3/D) 75
THRESHOLD RAINFALL PREVENTING IRRIGATION 25
DAMLENGTH 30
DAMWIDTH 5
DAMFULL 2500
DAMDEPTH 0
LOW LEVEL SET LEVEL 0
SETLEVEL$ HIGH LEVEL TRIGGER 0
DAM OVERFLOW ML/y 8.0 % OF TOTAL 29.34 OVERFLOW mm/y site 267
AVERAGE DAM OVERFLOW EVENTS/YEAR 111.13

SYSTEM VARIABLES

Location ref: 172

SOILS

RUNOFF COEFFICIENT NOMINAL K2 68
SOIL FACTOR CLASS A (program factor) 2
SOIL FACTOR CLASS B (program factor) 3
SOIL FACTOR CLASS C (program factor) 14
GRASS ROOTING DEPTH (m) .4
MAX EFFECTIVE TREE ROOT DEPTH (m) 1.5
MULCHCOVER (Y/N) N
TREE ROOTING DEPTH (max m) 1.5
SURFACE HYDRAULIC CONDUCTIVITY IS 150 mm/d

```
GRASS       Ks mm/d              150
UNDER GRASS Ks mm/d              10
TREE GRASS  Ks mm/d              150
TREE UNDER PASTURE  Ks mm/d      10
PASTURE COMPETITION Ks mm/d      150
UPPER TREE STORE    Ks mm/d      75
LOWER TREE STORE    Ks mm/d      10
BULK DENSITY   0  cm       1.5
BULK DENSITY   50 cm       1.6
BULK DENSITY  100 cm       1.6
BULK DENSITY  200 cm       1.65
SOIL WATER HOLDING CAPACITY (mm/m)         119.8665
```

PLANTS

```
GRASS TRANSPIRATION RATE  .7  OF PAN
TREE TRANSPIRATION RATE  1  OF PAN
TREE COVER  0.01%
GRASS INTERCEPTION (mm)      .25
TREE INTERCEPTION (mm)       .5
AV. MIN. TEMP FOR FROST DAMAGE 0
TREE DENSITY /ha 1
MAXIMUM TREE CANOPY RADIUS (m) .5
THRESHOLD TREE SHADE LEVEL   50  %
SITE GROWTH FACTOR AFFECTING TREE GROWTH   .7
REPLANT STRATEGY IS  EVERY  0  YEARS
```

3 HA IRRIGATION 5 DAYS STORAGE CONSTRUCTION WATER USE
IRRIGATION LIMITED TO SOIL WITH <80% FIELD CAPACITY SOIL MOISTURE STORAGE

```
11-20-2007    10:46:23      E:\POWER\EFFILES\SAR1.SWW
SIMULATION PERIOD  yrs 80
WATER BALANCE INPUTS
RAIN (mm) 1676
IRRIGATION (mm)   137
WATER BALANCE LOSSES
GRASS WATER USE 1031
TREE WATER USE    0
RUNOFF 544
DEEP DRAINAGE 171.4
ANNUAL GRASS INTERCEPTION  35
ANNUAL TREEGRASS INTERCEPTION  0
ANNUAL TREE INTERCEPTION  0
SOIL EVAPORATION  28 mm/y
CHANGE TO SOIL WATER      3.7 mm
BALANCE  -0.20 mm
HYDROLOGY

AV. RAINDAYS PER YEAR 128.4
GRASS > F.C. d/y  15  TREE > F.C. d/y   6
GRASS RUNOFF EVENTS>1 mm 19.3  TREE RUNOFF EVENTS>1 mm 14.8
HARD SURFACE RUNOFF EVENTS > 0.00 mm/y 128.4 HARD SURFACE RUNOFF AVERAGE mm/y
= 1676.4 0.00  mm abstraction
BIG RAINFALL (>50 mm) EVENTS  642
Av. water stress days/y (G.S.<10 mm A.W.)148.0   Max. Consec days     162

NUTRIENTS

NUTRIENT LOADING (kg/ha/y)
 [N]   54.80
 [P]   13.70
POTENTIAL DE-NITRIFICATION LOSS (KG/HA/y)  331.81 for a soil depth of  400
mm

IRRIGATION

IGGNAREA       3
IRRIGATION EFFICIENCY FACTOR 1
No. IGGN DAYS  44          IRRIGATION     0
DAILY WASTEWATER LOAD (M3/D) 16.04538
THRESHOLD RAINFALL PREVENTING IRRIGATION   25
DAMLENGTH      30
DAMWIDTH       5
DAMFULL        2500
DAMDEPTH       0
LOW LEVEL SET LEVEL          0
SETLEVEL$     HIGH LEVEL TRIGGER            0
DAM OVERFLOW ML/y    0.5  % OF TOTAL   8.18    OVERFLOW  mm/y site   16
AVERAGE DAM OVERFLOW EVENTS/YEAR   7.81


SYSTEM VARIABLES

Location ref:  172

SOILS

RUNOFF COEFFICIENT NOMINAL K2               68
SOIL FACTOR CLASS A (program factor)        2
SOIL FACTOR CLASS B (program factor)        3
SOIL FACTOR CLASS C (program factor)        14
GRASS ROOTING DEPTH (m)       .4
MAX EFFECTIVE TREE ROOT DEPTH (m)           1.5
MULCHCOVER (Y/N)             N
TREE ROOTING DEPTH (max m)   1.5
```

```
SURFACE HYDRAULIC CONDUCTIVITY IS  150  mm/d
GRASS        Ks mm/d            150
UNDER GRASS Ks mm/d             10
TREE GRASS  Ks mm/d             150
TREE UNDER PASTURE  Ks mm/d     10
PASTURE COMPETITION Ks mm/d     150
UPPER TREE STORE    Ks mm/d     75
LOWER TREE STORE    Ks mm/d     10
BULK DENSITY   0  cm       1.5
BULK DENSITY   50 cm       1.6
BULK DENSITY  100 cm       1.6
BULK DENSITY  200 cm       1.65
SOIL WATER HOLDING CAPACITY (mm/m)         119.8665
```

PLANTS

```
GRASS TRANSPIRATION RATE  .7  OF PAN
TREE TRANSPIRATION RATE  1  OF PAN
TREE COVER  0.01%
GRASS INTERCEPTION (mm)       .25
TREE INTERCEPTION (mm)        .5
AV. MIN. TEMP FOR FROST DAMAGE 0
TREE DENSITY /ha 1
MAXIMUM TREE CANOPY RADIUS (m) .5
THRESHOLD TREE SHADE LEVEL   50  %
SITE GROWTH FACTOR AFFECTING TREE GROWTH   .7
REPLANT STRATEGY IS  EVERY  0  YEARS
```

APPENDIX 3: RAINFALL FREQUENCY DISTRIBUTION

-------------------- FREQUENCY DISTRIBUTIONS --------------------

NUMBER OF CASES: 29248   NUMBER OF VARIABLES: 1

VARIABLE: 1. mm RAIN

=====CLASS LIMITS====		FREQUENCY	PERCENT	....CUMULATIVE... FREQUENCY	PERCENT
.00 <	2.00	22994	79.16	22994	79.16
2.00 <	4.00	1416	4.87	24410	84.03
4.00 <	6.00	857	2.95	25267	86.98
6.00 <	8.00	629	2.17	25896	89.15
8.00 <	10.00	432	1.49	26328	90.63
10.00 <	12.00	359	1.24	26687	91.87
12.00 <	14.00	258	.89	26945	92.76
14.00 <	16.00	216	.74	27161	93.50
16.00 <	18.00	191	.66	27352	94.16
18.00 <	20.00	165	.57	27517	94.73
20.00 <	22.00	146	.50	27663	95.23
22.00 <	24.00	122	.42	27785	95.65
24.00 <	26.00	99	.34	27884	95.99
26.00 <	28.00	105	.36	27989	96.35
28.00 <	30.00	70	.24	28059	96.59
30.00 <	32.00	87	.30	28146	96.89
32.00 <	34.00	70	.24	28216	97.13
34.00 <	36.00	70	.24	28286	97.37
36.00 <	38.00	54	.19	28340	97.56
38.00 <	40.00	35	.12	28375	97.68
40.00 <	42.00	67	.23	28442	97.91
42.00 <	44.00	49	.17	28491	98.08
44.00 <	46.00	34	.12	28525	98.20
46.00 <	48.00	37	.13	28562	98.32
48.00 <	50.00	38	.13	28600	98.45
50.00 <	52.00	32	.11	28632	98.56
52.00 <	54.00	40	.14	28672	98.70
54.00 <	56.00	27	.09	28699	98.80
56.00 <	58.00	34	.12	28733	98.91
58.00 <	60.00	24	.08	28757	98.99
60.00 <	62.00	23	.08	28780	99.07
62.00 <	64.00	17	.06	28797	99.13
64.00 <	66.00	18	.06	28815	99.19
66.00 <	68.00	15	.05	28830	99.25
68.00 <	70.00	26	.09	28856	99.34
70.00 <	72.00	17	.06	28873	99.39
72.00 <	74.00	18	.06	28891	99.46
74.00 <	76.00	16	.06	28907	99.51
76.00 <	78.00	15	.05	28922	99.56
78.00 <	80.00	14	.05	28936	99.61
80.00 <	82.00	20	.07	28956	99.68
82.00 <	84.00	11	.04	28967	99.72
84.00 <	86.00	16	.06	28983	99.77
86.00 <	88.00	16	.06	28999	99.83
88.00 <	90.00	9	.03	29008	99.86
90.00 <	92.00	7	.02	29015	99.88
92.00 <	94.00	6	.02	29021	99.90
94.00 <	96.00	8	.03	29029	99.93
96.00 <	98.00	8	.03	29037	99.96
98.00 <	100.00	12	.04	29049	100.00
		TOTAL29049	100.00		

Water balance modelling assumes that inputs of water equal losses of water from a field situation. The system inputs are rainfall and irrigation. The losses of water can be partitioned into plant transpiration, plant interception (evaporation of water lying on top of leaf surfaces), soil evaporation, runoff and deep drainage beyond the root zone. It is possible to use recorded rainfall data and expected irrigation inputs to produce a daily estimate of water inputs to a field system. The water losses can also be calculated on a daily basis. The SWAP model uses such a daily water balance model to estimate the likely behaviour of an irrigated area. The model can estimate the likely frequency of events and quantify the water flow through the system.

A computer water balance model (SWAP) has been developed by Bio-Track to model plant growth, plant water usage, runoff and drainage. The package uses a number of integrated sub-models. The sub-models include:

Rainfall Generation (Recorded or synthetic rainfall)
Interception Loss
Runoff
Plant Transpiration
Irrigation Management
Dam Storage Management

<u>Precipitation</u>

Precipitation is defined as the total of rainfall and irrigation.
Daily rainfall data is used. Missing data years and months are eliminated, missing data days are set to zero rain, accumulated rain is averaged across accumulated days.

Irrigation practice will vary according to management strategies and these are built into the program. These include irrigation to a set percentage of field capacity, irrigation of fixed volumes and control over the period between application.

Precipitation is calculated on a daily basis. A range of possibilities are encountered: no precipitation, rainfall only, irrigation only and irrigation plus rainfall.

It is important to examine the irrigation technique used. Up to 30% of applied water can be lost through drift and evaporation under extreme conditions. A more common loss rate would be 5-10% of applied water. Unless specified, the program assumes no evaporation and drift losses from applied irrigation.

When a rainfall event is triggered the following estimations are made:
Interception (evaporation) from leaf surfaces
Runoff
Absorption of water by the soil
Grass Transpiration
Tree Transpiration
Drainage below tree root and grass root zones.

<u>Interception</u>:

An interception loss is calculated as a function of the tree canopy cover, grass cover, temperature, rainfall and pan evaporation. This loss is applied to rainfall and irrigation events or combined precipitation events. Interception for trees is calculated as a power function Y=C+bX^2*E.pan. C=user defined tree interception, a=.08, X=rainfall, b=-.0005. A maximum upper limit is applied. Grass or sward crop interception is fixed at one level.

SOIL EVAPORATION

Soil evaporation estimates are based upon a conservative assessment. If the grass layer has been at wilting point for 10 days then soil evaporation can potentially begin, assuming a minimum vegetative cover of 20%. The vegetative cover is fully restored if soil moisture is present over a 30 day period.

Runoff:

Runoff estimates use antecedent soil moisture conditions, soil drainable porosity, and a modified United States Department of Agriculture runoff model. Natural rainfall data was supplied by the National Climate Centre in Melbourne. Precipitation falling through a tree canopy or a grass surface is reduced by interception losses before soil runoff is calculated.

Runoff is calculated separately for areas covered by grass and trees. This runoff is then totalled to produce a composite runoff for the site.

Runoff is affected by the soil type, soil slope, vegetation cover, canopy interception, amount of rainfall and the antecedent moisture conditions.
Soil moisture is calculated daily and infiltration is limited to a soil absorbance factor driven by soil moisture deficit (available water). The model uses three curves (using the K1,K2,K3 USDA relationship) with the curve/K value selection driven by soil moisture rather than antecedent rainfall.

Soil Infiltration

Infiltration is calculated as precipitation less interception and less runoff. Areas under trees are calculated separately from areas not under tree canopy cover. Drainage is estimated through a number of soil layers and is controlled by saturated and unsaturated flow.

Crop Water Usage:

The SWAP simulation model assumes that a full sward of actively growing crop/pasture will be a direct function of pan evaporation when there is greater than 40% of maximum available water capacity present within the root zone.

Below 40% of available water, transpiration rates diminish to zero (as a linear function of available water between 40% and 0% available water). Once there is no available water in the root zone, transpiration is expected to cease.

Both crop and tree transpiration rates are a user defined function of monthly pan evaporation from the nearest recording station or that most likely to represent the site. Grass water transpiration is a function of available soil moisture, grass cover, tree canopy cover, monthly pan evaporation and monthly temperatures.

Transpiration is reduced directly below a tree canopy to approximately 0.1 of E.pan. Grass/crop transpiration is also reduced after periods of no available water (drought) to account for a reduction in leaf area following a water stress period. The soil zones are a function of the tree size and tree density. These are also limited by external factors eg. soil depth.

Drainage

Water accumulating in a soil layer beyond the field capacity is assumed to enter the next (lower) soil layer. Water entering and leaving each soil layer is calculated on a daily basis. Drainage is set to the saturated infiltration rate for saturated soils. The drainage rate is progressively reduced as soils dry down to field capacity. A small drainage rate is then applied to account for redistribution of soil moisture down to 40% of plant available water. For soil moisture conditions drier than 40% of plant available water drainage is not estimated.

The soil layers exploited by grass roots are assumed to have a constant depth. The soil layers exploited by trees extend as the tree grows (as a direct function of canopy height) until a limit is reached. (User defined limit eg. depth to rock or impermeable layer or a biological limit eg. 10 metres.) The tree growth is a function of age, water availability, site factor and tree type.

Water passing beyond the root zone is

assumed to be lost from the system and be unavailable for subsequent plant uptake. This water is defined as drainage water.

ESTIMATION OF THE EQUILIBRIUM DRAINAGE RATE

A measure of the long term drainage rate can be found by assuming an equilibrium salt balance model (Shaw & Thorburn 1985). In an equilibrium state the quantity of salt entering the soil profile equals the losses of salts.

Salt sources for this study site include:
Rainfall (Assumed E.C. of 0.03 dS/m)

Salt losses for this study site include:
Drainage below the root uptake zone
Runoff Water (Assumed E.C. of 0.03-0.3 dS/m)
Crop Removal (Dependent on crop or grazing practice)

Sub-surface seepage water could also potentially affect this site during periods of prolonged wet weather. The Shaw & Thorburn (1985) model does not include run-off/run-on or seepage effects.

The LR steady state model (Shaw & Thorburn 1985) proposes the following relationship between drainage rates, water supply and solute concentration:

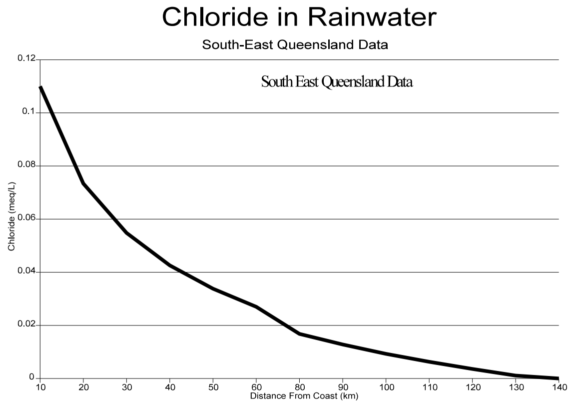
$$I*C_i=L*S_z$$

I= rate of precipitation (rainfall)

C_i= salinity of precipitation (rainfall) = 0.03 dS/cm (Approx.)
L= long term leaching rate
S_z= salinity at depth $_z$ of leaching water

The model is valid for soils where an equilibrium has been established with inputs and losses of solutes from the soil profile. The model does not account for runoff of solutes. To correct for this error runoff needs to be estimated. The model has been adjusted to account for runoff water. A preliminary assessment of the runoff from the site is made using standard runoff estimates. Rainfall is then reduced by the runoff rate (I-Runoff) to estimate the net input of rainwater. No adjustment is made for solute changes in runoff water as run-on water is likely to balance this effect. Rainwater changes in composition according to a wide range of factors. However site data is normally unavailable. A correction for distance from the coast is made to account for coastal influences.

Isbell et al. (1983) cite data that indicate a significant decrease in rainwater salinity with increasing distance from the coast. **Figure 2** illustrates the decrease in chloride concentration in rainwater with distance from the coast in south-east Queensland (from Isbell et al. 1983). Using Australia wide data (presented by Isbell et al. 1983) and assuming a salinity of 0.03 dS/m at a distance of 50 km from the coast, a relationship between rainwater salinity and distance can be approximated. The salinity relationship presented in **Figure 2** estimates the electrical conductivity of rainwater at 100 km from the coast is 0.022 dS/m.



Data from Isbell et al 1983.

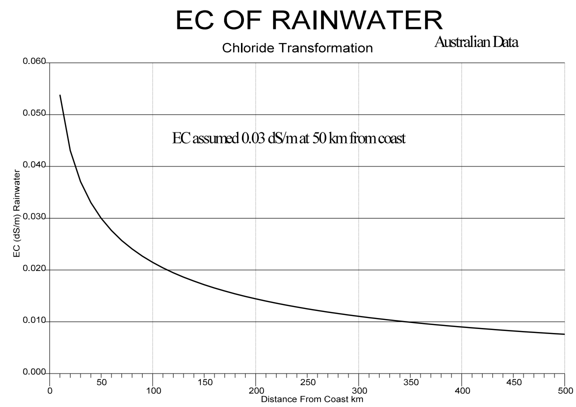


Figure 2: Salinity of Rainwater

De-Nitrification

Under warm, moist soil conditions microbial denitrification of soil nitrate can be expected. The de-nitrification loss is calculated on a daily basis as a function of nitrate levels, soil moisture and temperature in 6 soil layers. This is then used to estimate a long term potential de-nitrification rate over the simulation period using the losses estimated for each soil zone. The potential denitrification rate for a particular soil zone is calculated when the soil moisture is above 60% water filled pore space. This rate can then be compared with nitrogen loads to estimate the risk of transport of nitrate with deep drainage water.

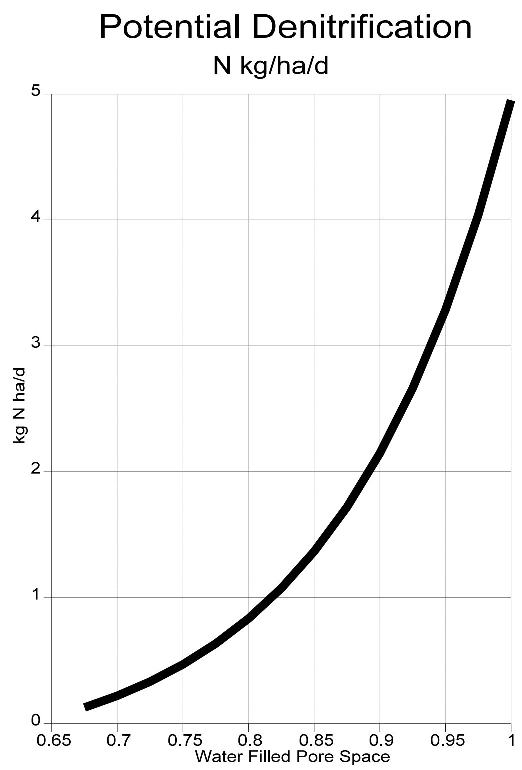


Figure 3: De-nitrification Loss

Ref. Aulakh, M.S. et al.(1992)

Nitrogen Leachate

Nitrogen will readily leach as the nitrate ion and less readily as the ammonium ion. A leachate factor is applied to factor soil nitrogen leaching losses as a function of the drainage rate. Organic nitrogen is assumed not to leach at significant rates.

Irrigation Management

Irrigation can be scheduled using a wide variety of parameters and restraints. These include:

Time Schedule (eg. irrigation every 7 days),
Soil Moisture (eg. irrigation volumes and times according to soil moisture status) and
Rainfall Events (eg. irrigation ceases if rainfall is greater than a threshold event).

Restraints can include:
Antecedent Rainfall,
Antecedent Soil Moisture,
Availability of Stored Water,
Storage Dam Levels,
Temperature and
Pan Evaporation.

Dam Storage

Storage dams can be incorporated into the irrigation management as water storage (to supply water in dry weather) or as wet weather withholding devices. Dams can be allocated in series or parallel. Runoff from a modelled catchment or waste water can be diverted to a dam. Water stored in the dam is then subject to surface evaporation, rainfall and drawoff for irrigation. Dam storage volume, depth and overflow is calculated on a daily basis. Overflow or discharge can be compared with stream flow data to predict dilution effects and loading rates.

12 APPENDIX 5: MONITORING SCHEDULE

A number of conditions require routine measurement for effective irrigation management and nutrient control.

12.1 Hydraulic Flow

The use of water should be recorded using a water meter. The meter should be read monthly.

12.2 Wastewater Composition

Wastewater should be routinely tested for pathogens, pH, salinity, nutrients and metals. The following list is recommended assuming the treatment system is performing according to specifications and no abnormal wastewater loads occur and industrial loads are low:

Analyte	Test Frequency
Disinfection (free chlorine)	Daily
pH, Electrical Conductivity	Weekly
Indicator Organism (eg. faecal coliform)	Monthly
Total N, Total P	3 Months
Na,K,Ca,Mg,S,Mn,Fe,Cl,Cu,Zn,B	3 Months
Toxic Metals: Cd,Hg,As,Pb	6 Months

The test frequency should be increased for large scale projects (eg. > 1 Ml/d irrigation).

12.3 Groundwater

Groundwater level is probably the most significant irrigation control parameter. Excessive irrigation leading to groundwater rises must be prevented as this typically results in a broad spectrum of environmental problems. Small diameter (50-100 mm) groundwater observation bores should be located at representative locations within and down gradient (hydraulic gradient if this is known) of the irrigation area. A minimum of six bores is recommended as groundwater in perched aquifers is frequently difficult to detect on a small scale. At least two background bores should also be installed. Levels should be observed every two months during wet weather and every month during wet weather. The level should be graphed. A rise trend against background levels should trigger an immediate review of irrigation practices.
Groundwater nitrate nitrogen is the key control issue. If funds are limited then measurement could be limited to measurement of nitrate nitrogen in observation bores every 3 months. At least two background bores should also be used. Samples should be preserved prior to transport as nitrate nitrogen can be lost from samples. Additional analytes are less likely to be of concern. The measurement of faecal coliforms is recommended as a public health check but complete annenuation in the soil is expected over a distance of a few metres in the absence of preferential flow lines. The following parameters are desirable but are likely to be of less significance. These could be measured every 6-12 months depending on funding limitations:

* pH
* electrical conductivity
* ammonium nitrogen and total nitrogen
* ortho-phosphate and total phosphorus
* sulfate
* chloride

12.4 Uniformity of Irrigation

Irrespective of the care taken with irrigation design it is highly likely that significant variation in irrigation application rates and/or soil moisture will develop. Field observations are required and periodic adjustment of application rates will be necessary. This particularly applies to the first years of operation. Provision for this labour cost needs to be made.

12.5 Irrigation Maintenance

Irrigation pipework will be damaged and sprinklers/emmitters will become blocked. The inclusion of adequate filtration, good quality components and a high standard of construction will make the difference between a high and low maintenance operation. Even a high standard of system will require routine maintenance.

If the supply water has a tendency to form scale (as a consequence of poorly soluble calcium or sodium salts) or block due to the presence of iron or bacterial growth then steps should be taken at the design stage to minimise these potential problems. Treatment of irrigation water using pH control, aeration and disinfection may be required. The use of fine orifice emmitters (eg. drippers and micro-sprays) should be avoided.

Irrigation lines should be fitted with filters, scour valves and possibly air relief valves to handle sediment and air pockets.

12.6 Soil Monitoring

Soils have the potential to accumulate then release nutrient. Soils can also accumulate salinity and heavy metals. In some cases extreme levels of pH or sulphur can develop. Soils will accumulate sorbed or poorly soluble material at the surface with mobile elements passing through with drainage water. Testing of the soil profile is regarded as essential to measure the response to irrigation water.

The number of sample sites should be adequate to describe the site. At least one site per major soil group, one site per 10 hectares and a minimum of two (for sites less than 10 hectares) should be planned.

One profile measurement per site should be undertaken prior to irrigation as a control sample.

Testing every two years is recommended as the minimum frequency. The frequency should be increased if the scale of the project is large or the surrounding environmental sensitivity is high. Samples should be obtained at fixed sample points and the same time of the year. Ideally this should be towards the end of the dry season when accumulation of irrigation sulutes will be highest.

Care should be taken to standardise the sampling and analytical procedures to ensure test results are comparable. As a generalisation testing every 200 mm from the surface down to 1000 mm or refusal is adequate.

The following list of test elements is recommended assuming the treatment system is performing according to specifications and no abnormal wastewater loads occur and industrial loads are low:

pH,Electrical Conductivity,Cl	1 soil:5 water
Na,K,Ca,Mg,Al	1 soil:20 soil ammonium chloride
Mn,Fe,Cu,Zn	1 soil:10 DTPA
B	1:2 $CaCl_2$
P,NO^3	1 soil:5 water
P	1 soil:100 $NaHCO_3$
P	1 soil:200 0.01 N H_2SO_4
N	Kjeldal

Kjeldal nitrogen tests are expensive and one sample for the range 0-300 mm per test location is regarded as adequate if funds are limited.

If analysis of the wastewater indicates a significant level of heavy metals then testing for these should also be undertaken. This should include both "total" and "soluble" extract procedures.

12.7 Crop Nutrients

A healthy crop is required to effectively utilise water and nutrients. Plant tissue analysis at 12 monthly intervals is recommended. Sampling protocols are specific for each crop. This needs to be established after crop selection. Plant tissue is typically analysed for N,P,K,Ca,Mg,S,Cu,Zn,Mn,Fe,B and possibly Mo. This information (particularly total N and P) will provide valuable information regarding harvest rates for nutrient removal. The information will also be useful in the detection of trace element or phosphorus deficiency as a consequence of the high soil pH. Should poor plant growth be observed or suspected additional tissue analysis will be useful.

12.8 Harvest Bio-Mass

The mass of harvested material should be recorded. Ideally the harvested material should be weighed (eg. using a weigh bridge). If the site is used as a mown grass surface and lawn clippings are harvested then this becomes difficult. It would be possible to compost the clippings or harvested material to reduce the volume prior to trucking off-site. Compost heaps should be covered to minimise drainage losses of nutrient. If weighing is not practical then some record of harvest rates should still be maintained.