Douglas Shire fertiliser trial and a review of nitrogen fertiliser research in sugarcane cultivation

for the

FNQ NRM LTD

Tully/Murray Water Quality Improvement Plan

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1. Nitrogen fertiliser management in sugar

This report contains a brief review of the current sugarcane industry recommendations for nitrogen (N) fertiliser usage in the Queensland Wet Tropics region in general, and the Tully-Murray catchment in particular; an assessment of N application practices in the Wet Tropics in general, and Tully-Murray in particular, including application rate, placement, timing and choice of N fertiliser; and recommendations for refinement of N management in sugarcane, so that the minimum needed for optimum production is applied.

Nitrogen is an essential element for crop growth, and good returns are made from sugarcane grower's investment in N fertilisation. Management of N on farm is important because monitoring in the Tully River has shown elevated levels of N, particularly nitrate, are of concern, and that this N is more than likely originating from nitrogenous fertiliser use (Mitchell *et al.* 2007).

<u>Review of nitrogen recommendations</u>

Historical N rate recommendations for the sugar industry were established through averaged regional yield response functions (Chapman 1994). The published BSES recommendations for N application to sugarcane in the Wet Tropics, including the Tully-Murray, are shown in Table 1 (Calcino 1994).

Table 1: BSES Recommended Nitrogen application rate (kg/ha)* (Calcino 1994).

	Fallow Plant	Replant and Ratoons
All soil types (except Richland**)	120-150	160-200
Richland** soil	80	120

** Nitrogen rates for plant cane can be reduced by 50-60 kg/ha following a heavy legume crop. Nitrogen rates should be reduced when growing vigorous cane varieties which are prone to lodging.*

*** Richland: Usually recent alluvial or peaty soils. The sugar yield response is cut off sharply at higher nitrogen application rates because lodging and deterioration may cause a decline in ccs and cane yield.*

Recent work by Schroeder *et al* (2005) is establishing a soil specific recommendation for nutrient application to sugarcane, including N. This recommendation has been termed "Six Easy Steps". Recommendations are based on region specific yield potentials, with the amount of N required to achieve the yield potential calculated. Yield potential for ratoons in the Wet Tropics is set at 120 tonnes per hectare, with N requirements calculated to be 160 kg N/ha. Nitrogen application rates are then determined by 'discounting' application from this rate based on a 'soil mineralisation index' which is determined from the soils organic carbon level of the soil. Table 2 presents the N application rates Six Easy Steps is recommending in the Wet Tropics, including Tully-Murray.

Table 2: Recommended Nitrogen application rate in "Six Easy Steps" to Tully-Murray ratoon crops (Schroeder *et al.* 2005).

Organic Carbon (%)	N Mineralisation index	Estimate of easily mineralisable (aerobic) N (kg/ha)	Suggested N rate for ratoons (kg/ha)
<0.4	VL	<20	160
0.41-0.8	L	20-30	150
0.81-1.2	ML	30-40	140
1.21-1.6	M	40-50	130
1.61-2.0	MH	50-60	120
2.01-2.4	H	60-70	110
>2.4	VH	>70	100

Recent research by Thorburn *et al.* (2007) has proposed N application rates to sugarcane could be based on the tonnes of cane harvested in the previous crop. Field trials in the Wet Tropics (Mossman and Innisfail) using N application rates in the order of 1 kg of N per tonne of cane harvested in the previous crop have shown little yield penalty in comparison with the 'normal' farmer application rates. This concept is termed "Nitrogen Replacement". The Nitrogen Replacement concept is still in a research 'proof of concept' stage and is not a current industry recommendation.

Various research by the Sugar Yield Decline Joint Venture (SYDJV) (Garside and Bell, 2001; Garside and Berthelson, 2004) has established the value of growing a legume fallow crop in between sugarcane crop cycles. The SYDJV has established that after a 'good' fallow crop of legumes (soybean, cowpea, peanut), where the grain is not removed (generally the practice in the Wet Tropics), there is no need to apply N fertiliser to the following plant crop of sugarcane.

In Australia there is currently some unpublished work investigating the potential to utilise free living nitrogen fixing bacteria endogenous to sugarcane to supply most of the sugarcane crops N needs. There have also been various, unpublished, attempts to develop 'slow release' N fertilisers for the sugarcane industry (variously via coatings or nitrification inhibitors). While these technologies promise to provide large benefits to the industry, they are at present unproven and therefore not recommended practice for growing sugarcane.

<u>Nitrogen management practices</u>

Nitrogen management practiced by sugarcane growers in the Tully-Murray were surveyed during 2007 (McMahon, 2007). During this survey a total of 48 growers participated, farming a total of 9,189 hectares of sugarcane, which represents approximately 27% of the total sugarcane area of the Tully-Murray. Survey results show that N management, as practiced by growers in the Tully-Murray, can be summarised as:

- Average application rates to ratoon cane is 146 kg N/ha and average application rates to plant cane is 115 kg N/ha;
- 100% of the area is fallowed at the conclusion of each crop cycle. 59% of this is a legume fallow;
- 96% of N to ratoon cane is applied underground in a single application;

- 93% of growers practice Green Cane Trash Blanketing;
- 15% of fallow ground receives an application of mill mud per year at a rate of 100 tonnes/hectare;
- 6% of ratoon crops receive an application of mill mud per year at a rate of 100 tonnes/hectare;
- 78% of growers modify their N management based on soil type and variety.

Average application rates for ratoon and plant crops are both less than the current BSES recommended application rates (Table 1). However when it is considered that 59% of all plant cane follows a legume fallow, N rates to plant cane are probably excessive. SYDJV research recommends 0 kgN/ha be applied to plant crops following a well grown crop of legumes (Garside *et al.* 1997, Bell *et al.* 2003).

Current recommendations in the Tully-Murray for placement of N fertiliser is underground, either stool split or beside the stool (see Roebeling and Webster 2007). Nitrogen fertiliser (particularly urea) applied to the surface is susceptible to significant losses via volatilisation (Denmead *et al.* 1993). Nitrogen fertiliser applied underground reduces this potential for losses and places the N where the plant is better able to utilise it (Chapman and Haysom, 1991). The vast majority (97%) of Tully-Murray growers are applying N fertiliser underground.

The application of N fertiliser in one pass is practiced by the majority of growers (97%). This is standard practice because each additional application costs the grower time and money to drive machinery. Early work reported in Chapman (1994) supports the application of N in one pass. However, modelling work reported in Roebeling *et al.* (2007) suggests that in the Tully-Murray splitting N applications could be an appropriate risk management strategy to reduce average N losses. To be economical split applications either must achieve a higher yield or require less total application of N.

Green cane trash blanketing (GCTB) is practiced by 93% of growers in Tully-Murray. GCTB increases the organic matter content of the soil and returns nutrients, including N, back to the soil (Mitchell *et al.* 2000). Thorburn *et al.* (2000) suggest that after two decades of GCTB growers can reduce the amount of N fertiliser applied without yield penalty.

Mill mud application rates are low across the entire Tully-Murray, however due to the nature of transport efficiencies there are some farms close to the mill where mill mud application is regular and ongoing. Recommendations in Calcino (1994) state a 100 tonne application of mill mud would provide approximately 310 kg N/ha. The N is mostly in an organic form not immediately available to the crop and additional N fertiliser may be required. This is supported by in progress, currently unpublished, work in progress of Sarah Park (CSIRO) who is investigating the C:N ratio of mill mud as a determinant for how much N fertiliser should accompany a mill mud application.

78% of growers in Tully-Murray are varying the amount of N fertiliser they apply based on soil type and variety. This is a recommendation of Calcino (1994), see Table 1. Two principles behind the “Six Easy Steps” are to ‘know your soils’ and to ‘adopt soil/site specific nutrient management guidelines’. As the ‘roll out’ of the “Six Easy Steps” has not occurred yet in Tully, it is promising for adoption that so many growers are already attuned to these principles.

N Fertiliser Recommendations

The development of recommendations for refinement of N management in sugarcane in the Tully-Murray is one of continuous improvement. The "Six Easy Steps" recommendations for N fertilisation should be delivered immediately to Tully-Murray growers as the current best management practice recommendation for N management. The development of the "Nitrogen Replacement" concept should be supported with a particular emphasis on the Tully-Murray as it has the potential to be the next step advancing N fertiliser management. Progress needs to be closely monitored over a number of seasons, with support for an implementation program of "Nitrogen Replacement" supported should it prove to be a management practice that can deliver improved downstream benefits while maintaining viable farming enterprises.

Furthermore it is important for the Tully-Murray sugarcane industry to closely monitor progress on "other" N management programs, such as nitrogen fixing bacteria or nitrification inhibiting compounds. Should any "other" management options satisfy the criteria of being beneficial to growers and the downstream environment, then adoption should be supported.

Nitrogen management research into practices other than determination of N rate should be closely observed. This includes work such as the SYDJV, and work on mill mud and splitting of N applications. Interactions between all available N management practices should also be investigated to determine the optimum strategy for sugarcane growers in the Tully-Murray while protecting the downstream environment.

It should also be noted that in the spirit of continuous improvement there are possibly options that become available in the future not mentioned by the authors that will deliver benefits to growers and the environment. These options need to be assessed within a similar framework and if beneficial, implementation supported.

2. Extra data from the Douglas Shire fertiliser trial

Background

In the Douglas Shire Water Quality Improvement Plan (WQIP) development an on-farm trial of different N fertiliser rates on adjacent blocks along with the measurement of loss of surface and drainage nutrients from the blocks were undertaken (Bartley *et al.* 2005). Unfortunately within the life of the Douglas WQIP the results from the trials could not be fully analysed. Funds were then provided from the Tully WQIP process to analyse more of the samples from the Douglas sites and hence better quantify the losses of N under different fertiliser management regimes. The results of the extra analyses in combination with the original results are now being used to provide verification of the water quality benefits expected from fertiliser management systems such as Six Easy Steps and Nitrogen Replacement System at the paddock scale. This information has been and is critical for parametising catchment models to predict discharge of N at the catchment scale in catchments with significant sugarcane areas under different fertiliser management regimes e.g. as in Armour *et al.* (2007) Tully modelling.

Method

Trial site information and setup including water quality monitoring details are described in Barley *et al.* (2005). The trial was established as a replicated N rate trial comparing the farmers usual N rate (N_{farm}) with the "Nitrogen Replacement" rate (N_{rep}). Table 3 presents the N rates used. The trial commenced in 2003 (first trial fertiliser application) and water quality was monitored during the 2003/04, 2004/05 and 2005/06 wet seasons. Harvest data was collected for the 2004, 2005 and 2006 harvests.

Table 3 Fertiliser application rates (kg/ha) to trial. Year represents year of fertiliser application.

Treatment	2003	2004	2005
N_{farm}	186	179	175
N_{rep}	102	86	96

Two plots, one of each treatment, had a cut throat flume installed to automatically sample surface runoff water and lysimeters to sample deep drainage water. N_{farm} is monitored by Flume 2 and N_{rep} is monitored by Flume 1. Surface runoff water samples are analysed for NH4, NO2 and NO3 (disolved inorganic nitrogen – DIN), total nitrogen (TN) and total filterable nitrogen (TFN). The difference between TN and TFN is particulate nitrogen (PN). TN minus DIN and PN equals dissolved organic nitrogen (DON). The data presented here represents the concentrations of each of these forms of nitrogen in μg N/L.

The cut throat flume concurrently monitors the height of water flowing through it (in mm) and via an algorithm determines the volume of water flowing through it. The height of water flowing through the flume over time is presented as a hydrograph, with the height representing rate of flow. Flow rate can be multiplied by concentrations to give N loads (in kg/ha) moving through the flume via surface runoff water. For the 2003/04 wet season N loads have been calculated as part of the Douglas WQIP. This information is presented in Bartley *et al.* (2005). For the 2004/05 and 2005/06 wet seasons this process is currently being undertaken and written up as a separate activity.

Water samples from 2004/05 and 2005/06 had been previously analysed for DIN, however no TN or TFN analysis was undertaken. This project analysed a selection of samples from each season and each flume for TN and TFN, thus allowing the determination of PN and DON concentrations. This data will be used to calculate TN, PN, DON and DIN runoff loads.

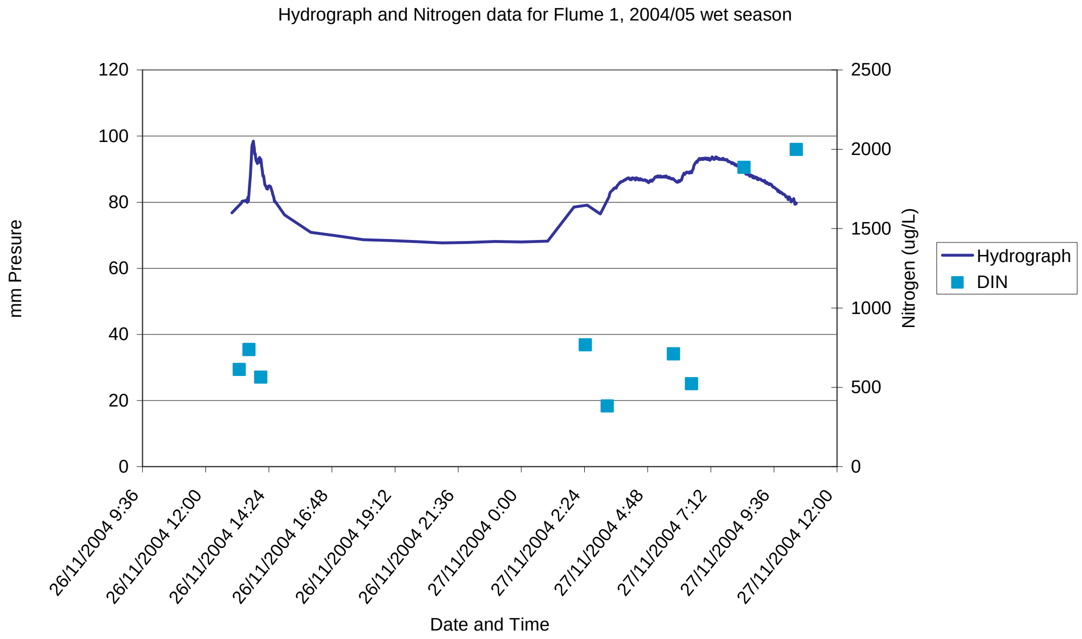
Results

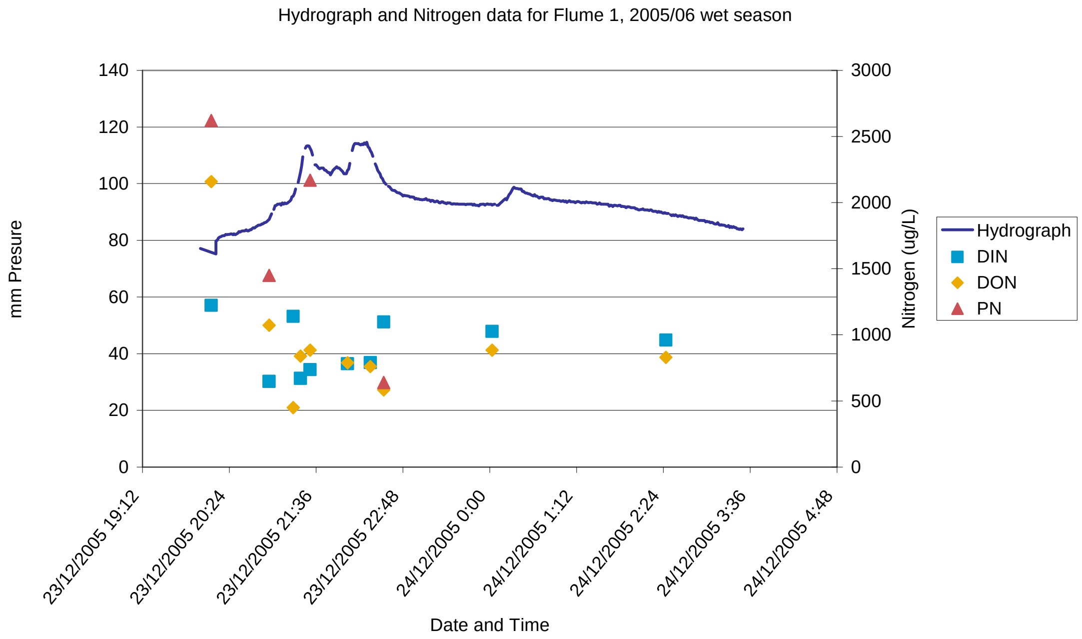
Table 4 is a combination of the results (for NOx and NH4) with the new results (TN and TFN) which allow estimation of TN, PN and DON in most cases.

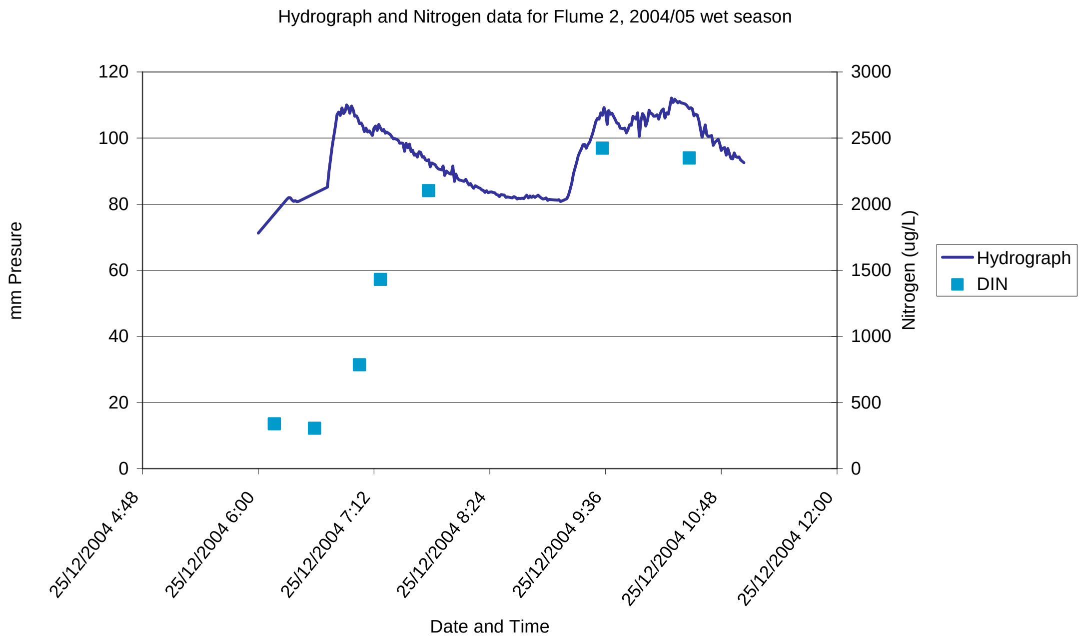
Flume	Date	Time	Hydrograph Position	TN	PN	NO_x	NH_4	(DIN)	DON
2004/2005 Wet Season									
1	26/11/04	13:17	Rising	2720		173	440	613	
1	26/11/04	13:39	Rising	1580		128	610	738	
1	26/11/04	14:06	Falling	1520		113	451	564	
1	27/11/04	02:26	Rising	1240		104	663	767	
1	27/11/04	03:16	Rising	1110		96	286	382	
1	27/11/04	05:47	Peak	1740		532	178	710	
1	27/11/04	06:28	Peak	1750		408	114	522	
1	27/11/04	08:28	Falling	3270		1795	91	1886	
1	27/11/04	10:27	Falling	3640		1889	110	1999	
2004/2005 Wet Season									
2	25/12/04	06:10	Rising	2030		271	68	339	
2	25/12/04	06:35	Rising	1670		247	58	305	
2	25/12/04	07:03	Peak	1850		733	53	786	
2	25/12/04	07:16	Peak	2540		1388	42	1430	
2	25/12/04	07:46	Falling	3210		2066	36	2102	
2	25/12/04	09:34	Peak	3000		2418	6	2424	
2	25/12/04	10:28	Peak	3100		2346	4	2350	
2005/2006 Wet Season									
1	23/12/05	20:09	Rising	6000	2620	98	1124	1222	2158
1	23/12/05	20:57	Rising	3170	1450	57	590	647	1073
1	23/12/05	21:17	Rising			1122	18	1140	450
1	23/12/05	21:23	Rising			669	2	671	839
1	23/12/05	21:31	Peak	3790	2170	709	27	736	884
1	23/12/05	22:02	Peak	NS		776	6	782	788
1	23/12/05	22:21	Peak	NS		790	0	790	760
1	23/12/05	22:32	Falling	2320	640	1097	0	1097	583
1	24/12/05	00:02	Falling	NS		942	84	1026	884
1	24/12/05	02:26	Falling	NS		657	304	961	829
2005/2006 Wet Season									
2	24/12/05	11:55	Rising	3230	1630	15	6	21	1579
2	24/12/05	11:58	Rising	1910	660	43	41	84	1166
2	24/12/05	14:25	Peak	1930	630	41	68	109	1191
2	24/12/05	15:10	Falling	1910	700	19	28	47	1163
2	25/12/05	09:17	Ring	1990	500	23	197	220	1270
2	25/12/05	09:27	Peak	2270	870	37	173	210	1190
2	25/12/05	09:31	Falling	NS		19	157	176	1194
2	25/12/05	09:38	Falling	2360	730	58	284	342	1288
2	15/1/06	01:38	Rising	1980	230	733	97	830	920
2	15/1/06	02:21	Peak	1740	100	868	19	887	753
2	25/1/06	12:44	Rising	1380	360	87	42	129	891

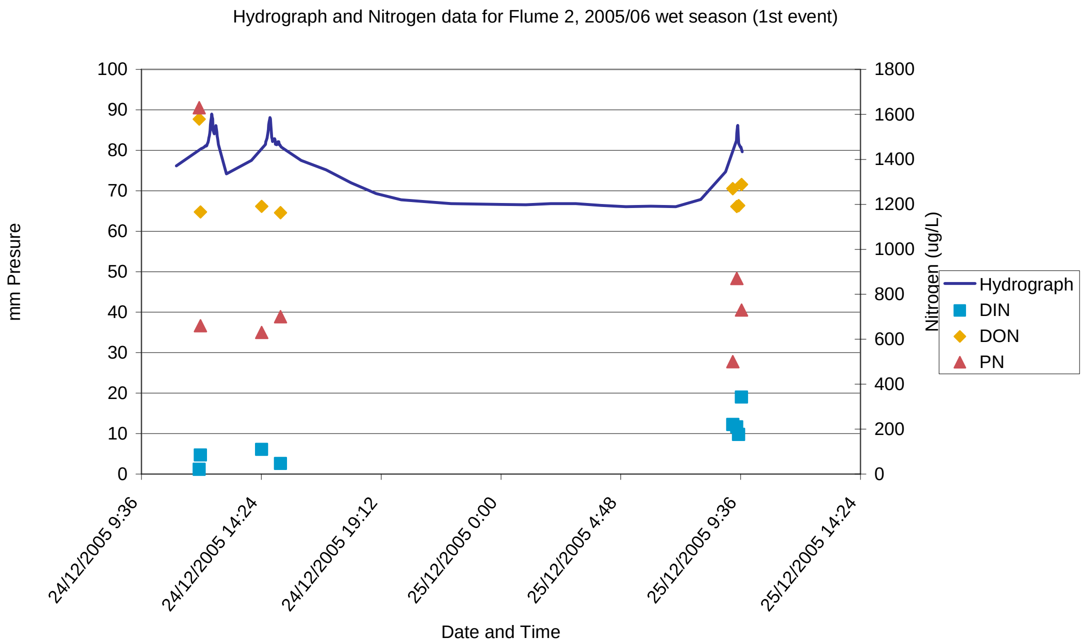
2	25/1/06	12:58	Rising	1180	389	100	36	136	655
2	25/1/06	13:03	Rising	1230	429	107	44	151	650
2	25/1/06	13:09	Peak	751	244	119	38	157	350
2	25/1/06	13:40	Peak	744	159	72	0	72	513

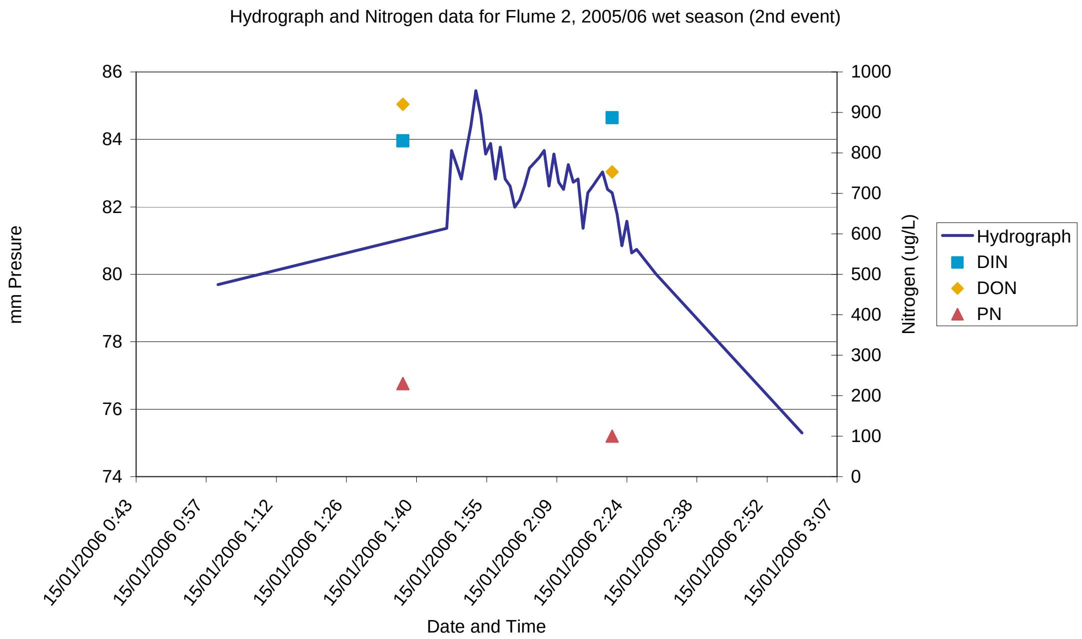
Results against the hydrograph

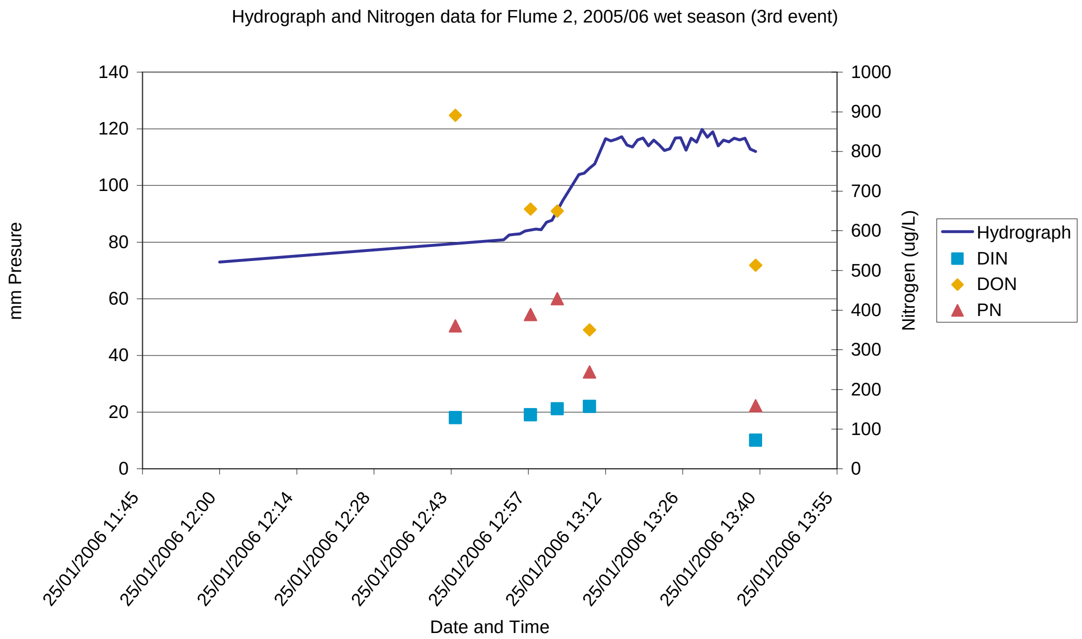





Hydrograph and Nitrogen data for Flume 2, 2004/05 wet season
mm Presure
Nitrogen (ug/L)
Hydrograph
DIN
120
100
80
60
40
20
0
3000
2500
2000
1500
1000
500
0
25/12/2004 4:48
25/12/2004 6:00
25/12/2004 7:12
25/12/2004 8:24
25/12/2004 9:36
25/12/2004 10:48
25/12/2004 12:00
Date and Time


Hydrograph and Nitrogen data for Flume 2, 2005/06 wet season (1st event)
mm Presure
Nitrogen (ug/L)
Hydrograph
DIN
DON
PN
100
90
80
70
60
50
40
30
20
10
0
1800
1600
1400
1200
1000
800
600
400
200
0
24/12/2005 9:36
24/12/2005 14:24
24/12/2005 19:12
25/12/2005 0:00
25/12/2005 4:48
25/12/2005 9:36
25/12/2005 14:24
Date and Time


Hydrograph and Nitrogen data for Flume 2, 2005/06 wet season (2nd event)
mm Presure
86
84
82
80
78
76
74
Nitrogen (ug/L)
1000
900
800
700
600
500
400
300
200
100
0
15/01/2006 0:43
15/01/2006 0:57
15/01/2006 1:12
15/01/2006 1:26
15/01/2006 1:40
15/01/2006 1:55
15/01/2006 2:09
15/01/2006 2:24
15/01/2006 2:38
15/01/2006 2:52
15/01/2006 3:07
Date and Time
Hydrograph
DIN
DON
PN


Hydrograph and Nitrogen data for Flume 2, 2005/06 wet season (3rd event)
mm Presure
140
120
100
80
60
40
20
0
Nitrogen (ug/L)
1000
900
800
700
600
500
400
300
200
100
0
25/01/2006 11:45
25/01/2006 12:00
25/01/2006 12:14
25/01/2006 12:28
25/01/2006 12:43
25/01/2006 12:57
25/01/2006 13:12
25/01/2006 13:26
25/01/2006 13:40
25/01/2006 13:55
Date and Time
Hydrograph
DIN
DON
PN

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