Strengthening the Scientific Foundation of Water Quality Programs

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Dissemination Level		
PU	Public	**X**
PP	Restricted to other program participants (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including Commission Services)	

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1. Introduction

Water quality as well as water availability are developing to be major limiting factors for the preservation of good ecological status in many of the Cyprus national water bodies. Larnaca salt lakes, despite their status as Natura 2000 and Ramsar site are no exception to water quality problems. In addition, climate change and urban development, threaten to alter the hydrological balance of the lakes with potentially detrimental impacts on its ecosystem.

Nutrients (nitrogen and phosphorus) are the main causes of water quality impairment in the Larnaca Salt lake. Though various measures have been taken, such as the enforcement of the Good Agricultural Practice Code, these problems still appear whether produced by routine outflows from agricultural areas or from incidental events of accidental or illegal loadings. In addition to nutrients, the lake and incoming stream flows have shown occasional increased levels of BOD and Ammonia which are likely to result from accidental and illegal damping of urban waste. In addition, though no serious issues have been identified regarding F. Coli, their presence in some of the monitoring samples is the cause of concern as to their origin and the risk of a possible future increase. It is noted that dissolved oxygen measurements have shown very low concentrations of oxygen (<3 mg/l) in some instances. These events are considered to be the result of a combination of eutrophic conditions and high temperatures that can develop in the nearly standing and very shallow waters in the streams surrounding the lake. Lastly it is noted that TSS is considered to be an issue of concern. Its impact, however, does not directly concern the ecological status of the lake but rather the long term presence of the lake, as siltation can gradually result in the decrease of the lake’s depth and extent. As it has no immediate impact on ecology, however, there is no basis for producing a TMDL for this parameter.

This report discusses the results of the WATER pilot project pertaining to the modelling of pollutant loads and associated water quality impacts for five parameters, namely NO2-NO3, NH3-NH4, Orthophosphate, BOD and F. Coli. The BASINS modelling system has been used for this purpose and the results include calculations of pollutant loads for three scenarios (1. existing, 2. future land use and 3. climate change) as well as TMDLs for the five selected pollutants. TMDL building scenarios were based on existing meteorological / hydrological conditions. The developed TMDls were assessed over the whole 5-year period for which the model was applied. The TMDls therefore are suited both to the average and extreme case scenarios the occurred over the five year period (2005-2009).

A third meteorological scenario based on future climate change scenarios from General Circulation models was applied. This scenario has been based on the moderate Global Climate Change Scenario that is generally accepted between Competent Authorities as a can be reached regarding which scenario may be realistically applied and considered during the development of Water Quality Management Measures. Results of TMDLs will be reviewed by the Partners and Competent Authorities such that a consensus on suitable TMDLs is reached. The review process foresees the dissemination of results for examination and meetings between all partners.

2. Applicable Water Quality Criteria

Water quality criteria define the maximum levels of pollution that need to be maintained in order to protect and preserve designated uses in the Larnaca Salt Lake. TMDLs are subsequently developed to meet these applicable water quality criteria. In the case of the Larnaca Salt Lake, water quality criteria were based on regulatory standards and additional quality criteria defined by the project team which aimed specifically at maintaining the good ecological status of the area.

2.1 Designated Uses

The Larnaca Salt Lake area is a designated RAMSAR and NATURA 2000 Site, therefore its major designated use is ecological preservation. The Salt Lake is one of the most important natural standing water bodies in Cyprus and is of international ecological significance (Tziortzis, 2008, Christia *et al.*, 2011, Natura 2000 Network).

Larnaca salt lake ecosystem includes the aquatic communities of flora and fauna and the extensive halophytic communities on the shores of the lakes. The lakes of the Larnaca Salt Lake complex are inter-related lakes, which, however, vary significantly among them from an ecological point of view. These lakes were connected to the sea until recent times. The Late Bronze Age anchors found in the main Salt Lake and collections of sea shells found in ancient tombs near the Tekke testify that. These shells could only have originated in coastal lagoons which were connected to the sea. Alyki, the main Salt Lake, has a very high salinity regime, hence its use in the past, for salt collection (Hadjichristophorou, 2008).

The following land uses are also applicable:

- ***Agricultural economic activity.***

The area supports non-irrigated as well as irrigated agriculture while several farm areas are also located within the Kalo Horio catchment.

- ***Non-agricultural economic activity.***

Industrial areas as well as discontinuous housing zones are dispersed to the northwest and northeast of the main salt lake.

- ***Hydrological functions including groundwater recharge and storm water storage***

At around 2m below the sea level the lake is the natural drainage end point of the Kalo Horio catchment.

- ***Non-contact recreation***

The lake offers visual amenity and is a frequent point of visit for walking and bird watching.

2.2 Parameters of Concern

Nutrients (nitrogen and phosphorus) have been identified as the main causes of water quality impairment in the Larnaca Salt lake and surrounding streams. Eutrophication and the associated development of filamentous algae have been a cause of concern in the last few years due to the large expansion of their presence, although some filamental algae are considered beneficial as they offer protection and preserve soil moisture during the dry summer months. In addition, very low dissolved oxygen dissolved oxygen levels (<3 mg/l) have been measured in some instances. These events are considered to be the result of a combination of eutrophic conditions and high temperatures that can develop in the nearly standing and very shallow waters in the streams surrounding the lake. Though various measures have been taken, such as the enforcement of the Good Agricultural Practice Code, these problems still appear whether produced by routine outflows from agricultural areas or from incidental events of accidental or illegal loadings. In particular NO3 has been found to be the main source of impairment.

In addition to nutrients, the lake and incoming stream flows have shown occasional increased levels of BOD and Ammonia levels, which are likely to result from accidental and illegal damping of urban waste. Though no serious issues have been identified regarding F. Coli, their presence in some of the monitoring samples is the cause of concern as to their origin and the risk of presence of other pathogenic organisms. Lastly it is noted that TSS is considered to be an issue of concern. Its impact, however, does not directly concern the ecological status of the lake but rather the long term presence of the lake, as siltation can gradually result in the decrease of the lake's depth and extent. As it has no immediate impact on ecology, however, there is no basis for producing a TMDL for this parameter.

TMDLs to be developed for:

- F-coli,
- Phosphorous
- BOD
- NO2, NO3
- NH3, NH4
- Though DO is not a pollutant and thus Load Capacity is not applicable, the TMDls for the above parameters will be determined such that DO criteria are also met.

Lastly it is noted that Cyprus experiences dry summers while frequent periods of meteorological drought years which in conjunction with the high evapotranspiration rates cause periodic hydrological droughts. This frequent disruption of the hydrological regime results in a wide range of both seasonal and annual water level fluctuations. This cycle can have a significant impact on the ecosystem as it can affect the extent of the salt lake area (thus the size of the wetland ecosystem) and the salinity rages of the lake as well as it can disrupt the biological cycles of several species. The periodicity and extent of flooding are therefore considered as dominant factors for the preservation of the salt lake ecosystem. It is noted, however, that these parameters are weather-driven and human intervention may have minimal impact with the exception of water diversion from the lake. Therefore this parameter is not suitable for a meaningful TMDL

2.3 Numeric Targets

Water quality criteria were determined based on legislative requirements and additional requirements placed by the project team which aimed specifically at preserving good ecological status. The development of these targets concerns only ecological values as no other uses of the salt lake area (pertaining to water quality) were identified. Given the lack of systematic background data regarding pollutant concentrations and their relationship to good ecological status, the selected values were determined from the monitoring undertaken

within the WATER project and were based largely on expert opinion. The following table (Table1) summarises the criteria selected.
It has been decided that the annual average criteria concentration should also be applied as a running three-monthly average limit. Thus the average pollutant concentration of any arbitrarily selected 90-day period should conform to this limit. This additional constraint has been selected on the basis of making the TMDLS more conservative in order to account for the level of uncertainty.
Given the sporadic nature of rainfall and the fact that a significant portion of storm-water runoff is attributed to the occurrence of short-lived extreme rainfall events, it appears impractical and unrealistic to enforce the peak daily limit under all conditions. The limit therefore allows for up to 10% of samples / daily prediction values to exceed this criterion.

TABLE 1: Applicable Water Quality Criteria

Pollutant	Units	Acceptable Limits (legislative)	Additiona comments Comments	Background values based on measurements	Quality criterion (Annual Average)	Quality criterion (daily peak)	Potential Sources
Nitrates	mg/L	2 – 3	Over 10 mg/L can be define as a high level of pollution	0.03-19.2	3	10	Runoff from irrigation basins
Nitrites	mg/L	0.2 – 0.3	Over 0.5 mg/L can be define as a high level of pollution	0-0.18	0.2	0.5	Industrial and/or urban waste
Ammonium	mg/L	≤ 0.5		0.3-12.7	0.5	5	Urban waste and/or fertilization
Phosphates	mg/L	≤ 2		0.02-0.09	1	2	Industrial waste
TOC	mg/L	Examination based on all measurements					Organic and/or industrial pollution
BOD^5	mg/L	≤ 25	Over 40 mg/L can be define as a high level of pollution	16-65	20	40	
DO	μg/L	>5 mg/l.	A concentration of at least 4 mg/l is considered necessary for good ecological status may be acceptable	2.4 - 25.34	4	5	
E. coli	/100 mL	1/100 mL	F. Coli constitutes a part of	$2.42x10^3$			

2.4 Critical Conditions

The Larnaca Salt Lakes are temporary lakes that usually, though not all years, dry out during the late summer period. The surrounding streams feeding into the lake dry out every year with few exceptions at the Kamares area where minor flows (< .5 m^3s^{-1}) may occur throughout the dry season.

Most exceedances of pollutants in the streams occur during high flows which are maintained for short periods during and after intense rainfall. In the Lake, high concentrations of pollutants and salinity occur in the dry summer period when evaporation reduces the water volume and thus concentrates its constituents. The model results show that peak flows is the major contributor to high pollutant concentrations.

3. Water Quality Analysis

3.1 Water Quality Data Availability

In general, water quality data were collected through the water quality monitoring programme undertaken within project WATER during the period of March 2010-Oct 2012. For the period prior to the project data collected by the COMANACY project in 2007 were utilised. Unfortunately, data collected outside the WATER project are not accompanied by water flow or water depth data and are thus of limited value.

3.2 Water Quality

Water quality of the existing situation has been assessed through the available monitoring data while further analysis and interpretation was facilitated through the modelling results.
Through the monitoring it appears that the salt lake area and associated streams are impaired mainly of nitrates. More specific samples were taken from 15 locations and were tested to the above physicochemical parameters (table 1). The table below (table 2) shows the locations and the type of pollution respectively.

TABLE 2: Sampling Locations and level of pollution

Location	Description	Pollution
01	Near Tekkes Mosque	High salinity levels and high conductivity
02	Kamares Area	High nitrates and BOD^5 suggest high levels of pollution due to runoffs from irrigation areas
03	Salt Lake Path Entrance from Artemidos Avenue	High nitrates
04	Kamares Aqueduct	High levels of BOD^5 and nitrites and nitrates suggest industrial and urban waste presence as also irrigation runoffs
05	Kamares Aqueduct - Urban Area Drainage	High levels of nitrates suggest runoff from irrigation areas
06	Old Refinery	Significant levels of phosphates suggesting industrial waste, but also we have high levels of nitrates which show runoffs from irrigation areas.
07	Vergina High School	Significant levels of phosphates suggesting industrial waste, but also we have high levels of nitrates which show runoffs from irrigation areas
08	Vergina Junior School	High levels of nitrates which show runoffs from irrigation areas
09	Faneromeni Roundabout	High levels of nitrates which show runoffs from irrigation areas

10	Old Salt Lake Shooting Centre	High levels of nitrates which show runoffs from irrigation areas, rising of phosphates which suggest possible industrial waste.
11	Kalo Chorio new Industrial Area	High levels of nitrates suggesting runoff from irrigation areas
13	Kalo Chorio Village	-
14	Aradippou Industrial Zone Sewage	High levels of nitrates and phosphates
15	Kamares	High levels of nitrates suggesting runoff from irrigation areas
17	Start of Vergina Urban Area	High levels of nitrates suggesting runoff from irrigation areas, also phosphates are too high and Ammonium is the highest measured level in the total of the basin which suggests urban sewage waste and/or fertilisers

3.3 Pollutant Sources

An assessment of potential pollutant sources was undertaken through the analysis of point and non-point sources in the project area. Point sources were identified through existing data and maps, complemented by field visits. Pollutant loading rates were estimated through available measurements, emission permit data, bibliography and expert opinion. In general point sources are considered to have a minor impact on the Salt Lake water quality since most point sources have been connected to the Larnaca Sewerage System. In addition to point source installations, leaks from the sewerage network are also a contributor of pollution. Though exact numbers are not available, estimates of these loads were made through assumptions regarding a failure rate fo the system. This rate was based on information provided by the Larnaca Sewerage Board. Estimated effluent rates from point sources are provided on Table 1.

Pollutant loadings from non-point sources have been calculated through the BASINS –HSPF modelling system and associated tools (AGCHEM and Fecal Tool). In general, four main land uses constitute the major pollutant loading sources for the area. These are agricultural areas, the farm zone located to the north west of the lake, two industrial areas and the residential areas of western Larnaca.

A summary of pollutant loads for the Salt Lake and the main incoming streams is provided on the following graphs. As can be expected each sub catchment presents a different pattern of pollutant loading, determined by the prevailing land uses in each area.

In order to be able to assess the level of relative impact from each land use type, the pollutant loading rates/per hectare have been calculated for all land uses present within the Kalo Horio catchment. The results are presented in summary form on the following Tables. From examination of the results it is concluded that the impermeable areas, namely urban and industrial areas appear to have the largest impact on the quality of the lake from surface flows. The reason for this is that these areas have the largest and fastest water outflows during rain events which results in very efficient washout of pollutants. In the case of the permeable agricultural areas, storm water runoff is relatively small, which limits the surface washout of pollutants. Thus, surface flows from impermeable surfaces will have a relatively high impact on water quality during and immediately after a storm event, while the slower subsurface flow will have a more even and longer term impact. The total pollutant flux results (Tables 3) illustrate this quite clearly. As can be seen, total flow pollutant fluxes for permeable land uses show that the largest portion of pollutant loads are carried by subsurface flows. For example, surface loads for the period of January-March 2005 appear minimal. 6E-5 kg/ha for land use type 102 (industrial/commercial) while total flows (surface and sub-surface together) are two orders of magnitude larger (.0024 kg / ha).

Table 3- Surface Pollutant Flux

Scenario	KHFL3B - Existing Situation				
Location	P102				
Constituent /haiv	NH3-NH4 (kg)	NO3 (kg)	Ortho-P (kg)	BOD (kg)	F. Coliform (count)
2005/01	0	0.000006	0	0	176
2005/04	0	0	0	0	0
2005/07	0	0	0	0	0
2005/10	0	0.000001	0	0	20.8
2006/01	0	0.000004	0	0	176
2006/04	0	0	0	0	0
2006/07	0	0	0	0	0
2006/10	0	0	0	0	0.1
2007/01	0.000001	0.000011	0	0.000001	326
2007/04	0	0	0	0	0.2
2007/07	0	0	0	0	0
2007/10	0	0	0	0	7.5
2008/01	0	0	0	0	0
2008/04	0	0	0	0	4
2008/07	0	0	0	0	0
2008/10	0	0	0	0	4.9
2009/01	0.000001	0.000015	0	0.000001	365
2009/04	0	0	0	0	0
2009/07	0	0	0	0	0
2009/10	0	0.000003	0	0	133
2010/01	0.000001	0.000012	0	0.000001	426
2010/04	0	0	0	0	0

2010/07	0	0	0	0	0
2010/10	0	0.000004	0	0	184
2011/01	0	0.000002	0	0	85.3
2011/04	0	0	0	0	0
2011/07	0	0	0	0	0

Table 4 (Cont.) - Surface Pollutant Flux

Scenario	KHFL3B														
Location	P104					P105					P110				
Constituent	(NH3-NH4 kg)	NO3 (kg)	Ortho-P (kg	BOD (kg)	F. Coliform (count)	(NH3-NH4 kg)	NO3 (kg)	Ortho-P (kg	BOD (kg)	F. Coliform (count)	NH3-NH4 (kg)	NO3 (kg)	Ortho-P (kg)	BOD (kg)	F. Coliform (count)
2005/01	0.000002	539	3.4E-05	0	2E-06	0	3E-06	0	105	0	1E-06	1.3E-05	0	1E-06	326
2005/04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005/10	0.000001	381	1.7E-05	0	1E-06	0	0	0	5.1	0	0	2E-06	0	0	71.1
2006/01	0.000001	542	2.1E-05	0	1E-06	0	4E-06	0	154	0	0	6E-06	0	0	244
2006/04	0	458	3E-06	0	0	0	0	0	0	0	0	0	0	0	0
2006/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006/10	0.000001	276	0.00001	0	1E-06	0	0	0	0.1	0	0	0	0	0	0.1
2007/01	0.000002	584	2.7E-05	0	2E-06	0	4E-06	0	141	0	1E-06	0.00002	0	1E-06	396
2007/04	0.000002	1690	1.5E-05	0	2E-06	0	0	0	0.2	0	0	0	0	0	0.2
2007/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007/10	0	313	8E-06	0	0	0	0	0	1.8	0	0	1E-06	0	0	26.9
2008/01	0	123	3E-06	0	0	0	0	0	0	0	0	0	0	0	0
2008/04	0.000002	1630	1.5E-05	0	2E-06	0	0	0	4	0	0	0	0	0	4
2008/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008/10	0	309	8E-06	0	0	0	0	0	1.2	0	0	0	0	0	17.9
2009/01	0.000002	1140	3.2E-05	0	2E-06	0	6E-06	0	221	0	1E-06	1.9E-05	0	1E-06	374
2009/04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009/10	0.000002	708	0.00003	0	2E-06	0	1E-06	0	59.6	0	0	8E-06	0	0	295
2010/01	0.000004	979	5.3E-05	0	4E-06	0	4E-06	0	153	0	2E-06	2.9E-05	0	2E-06	719
2010/04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010/10	0.000001	367	1.7E-05	0	1E-06	0	1E-06	0	63.5	0	0	1.1E-05	0	0	338
2011/01	0.000002	945	3.1E-05	0	2E-06	0	0	0	23.1	0	0	6E-06	0	0	231
2011/04	0	163	1E-06	0	0	0	0	0	0	0	0	0	0	0	0

Table 5 (Cont.) - Surface Pollutant Flux

Scenario	KHFL3B														
Location	P102					P113					P115				
Constituent	NH3-NH4 (kg)	NO3 (kg)	Ortho-P (kg)	BOD (kg)	F. Coliform (count)	(NH3-NH4 kg)	NO3 (kg)	Ortho-P (kg	BOD (kg)	F. Coliform (count)	(NH3-NH4 kg)	NO3 (kg)	Ortho-P (kg)	BOD (kg)	F. Coliform (count)
2005/01	0	6E-06	0	0	176	0	468	1E-06	1E-06	2.6E-05	2E-06	3.5E-05	0	2E-06	555
2005/04	0	0	0	0	0	0	0	0	0	0	0	1E-06	0	0	198
2005/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16.5
2005/10	0	1E-06	0	0	20.8	0	209	0	0	7E-06	1E-06	1.7E-05	0	1E-06	421
2006/01	0	4E-06	0	0	176	0	402	1E-06	1E-06	1.1E-05	1E-06	2.2E-05	0	1E-06	593
2006/04	0	0	0	0	0	0	0	0	0	0	0	1E-06	0	0	146
2006/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006/10	0	0	0	0	0.1	0	0.1	0	0	0	0	2E-06	0	0	69.5
2007/01	0.000001	1.1E-05	0	1E-06	326	0	428	1E-06	1E-06	2.2E-05	3E-06	0.00003	0	3E-06	718
2007/04	0	0	0	0	0.2	0	0.2	0	0	0	0	3E-06	0	0	532
2007/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007/10	0	0	0	0	7.5	0	92.8	0	0	2E-06	0	6E-06	0	0	231
2008/01	0	0	0	0	0	0	0	0	0	0	0	3E-06	0	0	111
2008/04	0	0	0	0	4	0	4	0	0	0	1E-06	5E-06	0	1E-06	832
2008/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3
2008/10	0	0	0	0	4.9	0	63.6	0	0	1E-06	0	7E-06	0	0	287
2009/01	0.000001	1.5E-05	0	1E-06	365	0	373	1E-06	1E-06	1.9E-05	2E-06	3.1E-05	0	2E-06	990
2009/04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4
2009/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2009/10	0	3E-06	0	0	133	0	445	1E-06	1E-06	1.7E-05	2E-06	2.6E-05	0	2E-06	612
2010/01	0.000001	1.2E-05	0	1E-06	426	0	869	3E-06	3E-06	4.4E-05	4E-06	5.5E-05	0	4E-06	1030
2010/04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1
2010/07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010/10	0	4E-06	0	0	184	0	368	1E-06	1E-06	1.7E-05	1E-06	1.7E-05	0	1E-06	387
2011/01	0	2E-06	0	0	85.3	0	415	1E-06	1E-06	1.5E-05	2E-06	2.8E-05	0	2E-06	932
2011/04	0	0	0	0	0	0	0	0	0	0	0	3E-06	0	0	417

Table 6 (Cont.) - Surface Pollutant Flux

Scenario	KHFL3B									
Location	I102					I110				
Constituent	NH3-NH4 (kg)	NO3 (kg)	Ortho-P (kg)	BOD (kg)	F. Coliform (count)	NH3-NH4 (kg)	NO3 (kg)	Ortho-P (kg)	BOD (kg)	F. Coliform (count)
2005/01	0.000063	0.00062	0.00005	0.00253	7060000	6.3E-05	0.00062	0.00005	7060000	0.00253
2005/04	0.000038	0.0003	2.2E-05	0.00146	4040000	3.8E-05	0.0003	2.2E-05	4040000	0.00146
2005/07	0.000055	0.00036	2.5E-05	0.00198	5240000	5.5E-05	0.00036	2.5E-05	5240000	0.00198
2005/10	0.000049	0.00043	3.2E-05	0.00195	5490000	4.9E-05	0.00043	3.2E-05	5490000	0.00195
2006/01	0.000062	0.00058	4.4E-05	0.00252	7210000	6.2E-05	0.00058	4.4E-05	7210000	0.00252
2006/04	0.000051	0.00042	3.1E-05	0.00199	5530000	5.1E-05	0.00042	3.1E-05	5530000	0.00199
2006/07	0.000038	0.00034	2.6E-05	0.00153	4380000	3.8E-05	0.00034	2.6E-05	4380000	0.00153
2006/10	0.000058	0.0004	2.9E-05	0.00211	5650000	5.8E-05	0.0004	2.9E-05	5650000	0.00211
2007/01	0.000059	0.00055	4.3E-05	0.00239	6870000	5.9E-05	0.00055	4.3E-05	6870000	0.00239
2007/04	0.000047	0.00038	2.8E-05	0.00179	4990000	4.7E-05	0.00038	2.8E-05	4990000	0.00179
2007/07	0.000016	0.00012	8E-06	0.00063	1690000	1.6E-05	0.00012	8E-06	1690000	0.00063
2007/10	0.00005	0.00033	2.4E-05	0.00177	4660000	0.00005	0.00033	2.4E-05	4660000	0.00177
2008/01	0.000056	0.00043	3.1E-05	0.00215	5920000	5.6E-05	0.00043	3.1E-05	5920000	0.00215
2008/04	0.000045	0.00034	2.4E-05	0.00172	4720000	4.5E-05	0.00034	2.4E-05	4720000	0.00172
2008/07	0.00005	0.00036	2.6E-05	0.00187	5040000	0.00005	0.00036	2.6E-05	5040000	0.00187
2008/10	0.000055	0.00047	3.5E-05	0.00219	6140000	5.5E-05	0.00047	3.5E-05	6140000	0.00219
2009/01	0.00006	0.00061	4.9E-05	0.00249	7330000	0.00006	0.00061	4.9E-05	7330000	0.00249
2009/04	0.00004	0.00033	2.4E-05	0.00156	4390000	0.00004	0.00033	2.4E-05	4390000	0.00156
2009/07	0.00004	0.00023	1.5E-05	0.00135	3410000	0.00004	0.00023	1.5E-05	3410000	0.00135
2009/10	0.000053	0.00045	3.4E-05	0.00206	5750000	5.3E-05	0.00045	3.4E-05	5750000	0.00206
2010/01	0.000056	0.00053	4.1E-05	0.00229	6600000	5.6E-05	0.00053	4.1E-05	6600000	0.00229
2010/04	0.000051	0.00039	2.8E-05	0.00197	5390000	5.1E-05	0.00039	2.8E-05	5390000	0.00197
2010/07	0	0	0	0	0	0	0	0	0	0
2010/10	0.000045	0.00028	0.00002	0.00153	3950000	4.5E-05	0.00028	0.00002	3950000	0.00153
2011/01	0.000056	0.00054	4.3E-05	0.00229	6650000	5.6E-05	0.00054	4.3E-05	6650000	0.00229
2011/04	0.000047	0.00037	2.6E-05	0.00182	5010000	4.7E-05	0.00037	2.6E-05	5010000	0.00182
	0.000043	0.00025	1.7E-05	0.00148	3780000	4.3E-05	0.00025	1.7E-05	3780000	0.00148

Table 7 - Total Fluxes

Scenario	KHFL3B									
Location	P102					P105				
Constituent	NH3-NH4 (kg)	NO3 (kg)	Ortho-P (kg)	BOD (kg)	F. Coliform (count)	(NH3-NH4 kg)	NO3 (kg)	Ortho-P (kg	BOD (kg)	F. Coliform (count)
2005/01	0.000201	0.0024	2.7E-05	0.0052	4.12E+08	0.000201	0.0024	2.7E-05	0.00515	4.12E+08
2005/04	0.000035	0.0004	7E-06	0.0021	1.38E+08	0.000035	0.0004	7E-06	0.0021	1.38E+08
2005/07	0.000001	9E-06	0	5E-05	3030000	0.000001	9E-06	0	0.00005	3030000
2005/10	0.000058	0.0009	7E-06	0.0015	1.26E+08	0.000058	0.0009	7E-06	0.00149	1.26E+08
2006/01	0.000157	0.0019	2.1E-05	0.0043	3.68E+08	0.000157	0.0019	2.1E-05	0.00425	3.68E+08
2006/04	0.000036	0.0004	7E-06	0.0021	1.40E+08	0.000036	0.0004	7E-06	0.00214	1.40E+08
2006/07	0	2E-06	0	1E-05	545000	0	2E-06	0	0.00001	545000
2006/10	0.000052	0.0009	6E-06	0.0013	1.27E+08	0.000052	0.0009	6E-06	0.0013	1.27E+08
2007/01	0.000263	0.0031	3.7E-05	0.0066	4.78E+08	0.000262	0.0031	3.7E-05	0.00661	4.78E+08
2007/04	0.000075	0.0009	1.5E-05	0.0045	2.95E+08	0.000075	0.0009	1.5E-05	0.00451	2.95E+08
2007/07	0.000006	8E-05	1E-06	0.0004	24700000	0.000006	8E-05	1E-06	0.00038	24700000
2007/10	0.000031	0.0005	4E-06	0.0008	67700000	0.000031	0.0005	4E-06	0.00075	67700000
2008/01	0.000056	0.0007	7E-06	0.0015	1.43E+08	0.000056	0.0007	7E-06	0.00153	1.43E+08
2008/04	0.000011	0.0001	2E-06	0.0006	42100000	0.000011	0.0001	2E-06	0.00064	42100000
2008/07	0	0	0	0	29300	0	0	0	0	29300
2008/10	0.00005	0.0008	6E-06	0.0012	1.15E+08	0.00005	0.0008	6E-06	0.00123	1.15E+08
2009/01	0.000307	0.0036	4.2E-05	0.0077	5.82E+08	0.000307	0.0036	4.2E-05	0.00774	5.82E+08
2009/04	0.000058	0.0007	1.2E-05	0.0035	2.28E+08	0.000058	0.0007	1.2E-05	0.00349	2.28E+08
2009/07	0.000001	1E-05	0	5E-05	3040000	0.000001	1E-05	0	0.00005	3040000
2009/10	0.000138	0.002	1.8E-05	0.0032	2.60E+08	0.000138	0.002	1.8E-05	0.00316	2.60E+08
2010/01	0.00041	0.0049	5.6E-05	0.0105	8.09E+08	0.00041	0.0048	5.6E-05	0.0105	8.09E+08
2010/04	0.000059	0.0007	1.2E-05	0.0035	2.29E+08	0.000059	0.0007	1.2E-05	0.00351	2.29E+08
2010/07	0.000001	1E-05	0	6E-05	4170000	0.000001	1E-05	0	0.00006	4170000
2010/10	0.000062	0.0008	8E-06	0.0013	79400000	0.000062	0.0008	8E-06	0.00128	79400000
2011/01	0.000219	0.0027	2.9E-05	0.0059	5.08E+08	0.000218	0.0027	2.9E-05	0.00593	5.08E+08
2011/04	0.000052	0.0006	0.00001	0.0031	2.05E+08	0.000052	0.0006	0.00001	0.00313	2.05E+08
2011/07	0.000001	9E-06	0	5E-05	3000000	0.000001	9E-06	0	0.00005	3000000

Table 8 - Total Fluxes

Scenario	KHFL3B									
Location	P115					P107				
Constituent	NH3-NH4 (kg)	NO3 (kg)	Ortho-P (kg)	ЗOD (kg)	F. Coliform (count)	(NH3-NH4 kg)	NO3 (kg)	)rtho-P (kg	BOD (kg)	F. Coliform (count)
2005/01	0.00027	0.00292	4E-05	0.00556	2.83E+08	0.00021	0.00247	2.9E-05	0.00512	3.79E+08
2005/04	2.5E-05	0.000296	5E-06	0.00147	9.62E+07	3.3E-05	0.00039	7E-06	0.00196	1.28E+08
2005/07	0	0.000004	0	0.00002	1110000	1E-06	8E-06	0	0.00004	2540000
2005/10	6.9E-05	0.00106	9E-06	0.00183	1.04E+08	5.6E-05	0.0009	7E-06	0.00144	1.22E+08
2006/01	0.00017	0.00201	2E-05	0.00412	2.86E+08	0.00015	0.00186	0.00002	0.00411	3.56E+08
2006/04	2.9E-05	0.000355	6E-06	0.00175	1.11E+08	3.5E-05	0.00042	7E-06	0.0021	1.37E+08
2006/07	0	0.000001	0	0	166000	0	2E-06	0	0.00001	491000
2006/10	5.2E-05	0.000837	7E-06	0.00134	1.11E+08	5.3E-05	0.00087	7E-06	0.00131	1.27E+08
2007/01	0.00031	0.00343	4E-05	0.00683	3.82E+08	0.00027	0.00309	3.7E-05	0.00658	4.63E+08
2007/04	6.3E-05	0.000767	1E-05	0.00374	2.31E+08	7.4E-05	0.00089	1.5E-05	0.00442	2.88E+08
2007/07	3E-06	0.000041	1E-06	0.00021	13500000	6E-06	7.3E-05	1E-06	0.00037	23900000
2007/10	3.7E-05	0.000527	5E-06	0.00081	6130000(	2.9E-05	0.00044	4E-06	0.00071	66300000
2008/01	5.2E-05	0.000639	7E-06	0.00137	1.25E+08	5.6E-05	0.0007	7E-06	0.00152	1.42E+08
2008/04	1.3E-05	0.000162	3E-06	0.0007	30400000	1.1E-05	0.00013	2E-06	0.00065	42000000
2008/07	0	0	0	0	42800	0	0	0	0	29300
2008/10	5.7E-05	0.000842	7E-06	0.00132	1.08E+08	4.9E-05	0.00076	6E-06	0.00121	1.14E+08
2009/01	0.00031	0.00362	4E-05	0.00753	5.16E+08	0.00031	0.00362	4.2E-05	0.00774	5.81E+08
2009/04	0.00005	0.000599	1E-05	0.00299	1.95E+08	5.8E-05	0.0007	1.2E-05	0.00349	2.28E+08
2009/07	1E-06	0.000008	0	0.00003	1730000	1E-06	1.1E-05	0	0.00005	3030000
2009/10	0.00022	0.00289	3E-05	0.00424	2.08E+08	0.00015	0.00217	0.00002	0.00336	2.50E+08
2010/01	0.00047	0.00521	7E-05	0.0102	5.78E+08	0.00043	0.00495	5.9E-05	0.0103	7.19E+08
2010/04	3.1E-05	0.000374	6E-06	0.00187	1.22E+08	0.00005	0.0006	0.00001	0.00298	1.94E+08
2010/07	0	0.000001	0	0.00001	396000	1E-06	7E-06	0	0.00003	2260000
2010/10	0.00012	0.00147	2E-05	0.00209	53400000	7.8E-05	0.001	1.1E-05	0.00149	69600000
2011/01	0.00022	0.00257	3E-05	0.00533	3.56E+08	0.00021	0.00257	2.9E-05	0.00564	4.67E+08
2011/04	4.2E-05	0.000497	8E-06	0.00247	1.61E+08	0.00005	0.00061	0.00001	0.00302	1.97E+08
2011/07	0	0.000003	0	0.00002	1110000	1E-06	8E-06	0	0.00004	2650000

Based on the calculated pollutant loads, the following land uses were identified as the main contributors to pollution for each of the five controlled pollutants.

Table 9
Main land use categories contributing to pollutant loads

Parameter	Land use category
NH3-NH4	P105
NO3	P104
Orthophosphate	
BOD	P105
F. Coli	

It is noted that land use category 105 is determined as the major contributor of pollution on account that it has the largest surface area from all land uses, in the order of 3.000 hectares.

3. TMDL Definitions

Development of TMDLs is based on the technical analysis of the watershed such that the dynamics of pollutant loading and their impact on water quality are understood and quantified with a reasonable degree of accuracy. For the purpose, the BASINS modelling system was used through which the impacts of variation in pollutant loads on water quality was analysed. As already discussed, TMDLs are developed for the following parameters

- Phosphorus
- F-coli
- NH3
- TSS
- BOD

The calculation of the pollutant loads are discussed and presented below.

3.1 Existing Load Estimations

Estimates of loads were accomplished through the model results pertaining to water flows and water quality, where total load estimates are calculated as follows:

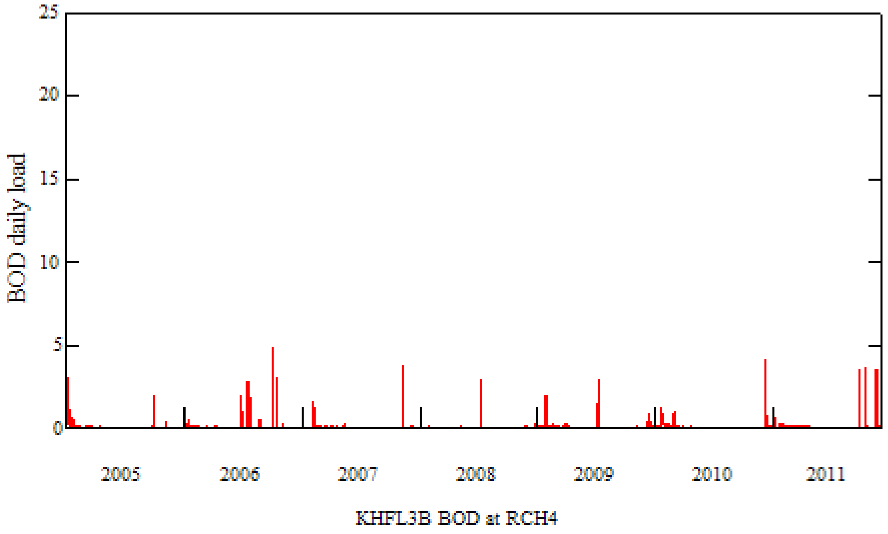
Load = k x ∫flux (t) dt t where

- *k is a constant for converting units,*
- *t is time*
- $Flux_t = Concentration_t \times discharge_t$

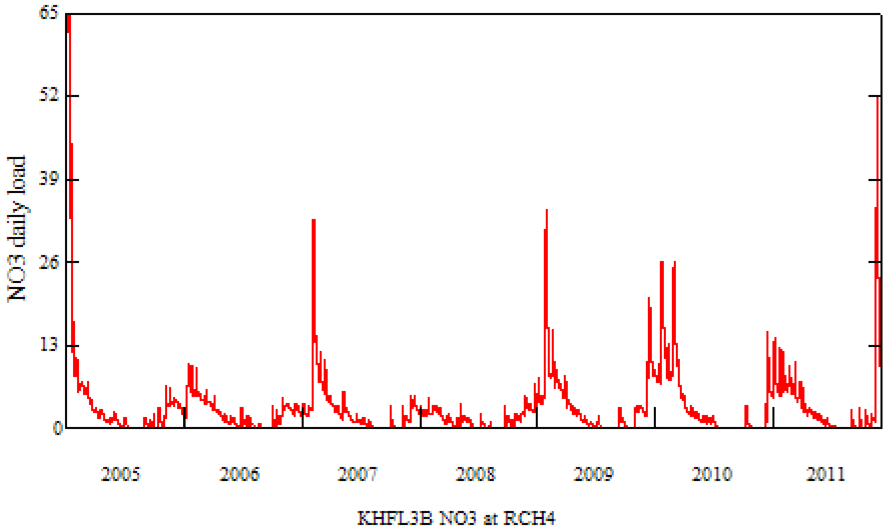
The following Loads were estimated for the existing scenario, the future land use change scenario and the climate change meteorological scenario.

Graph 1: Daily Load Allcoations for the existing scenario

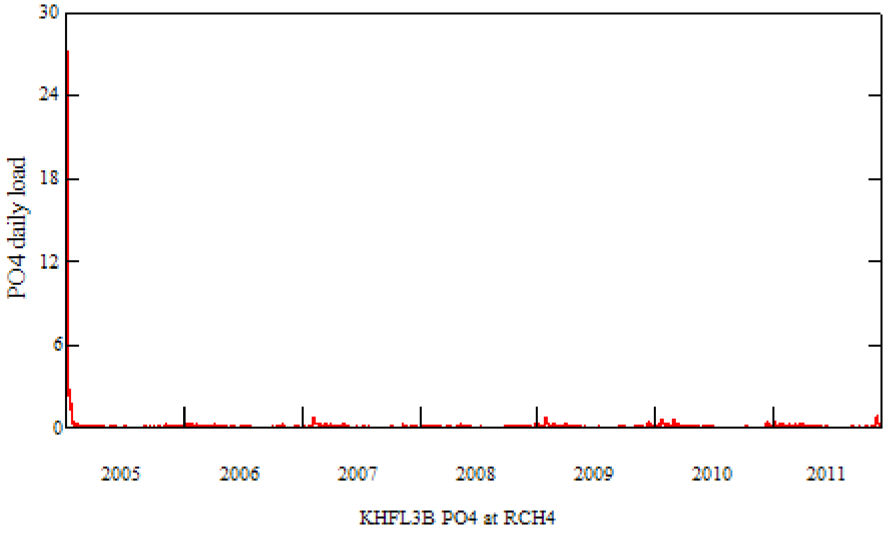
Graph 1a BOD



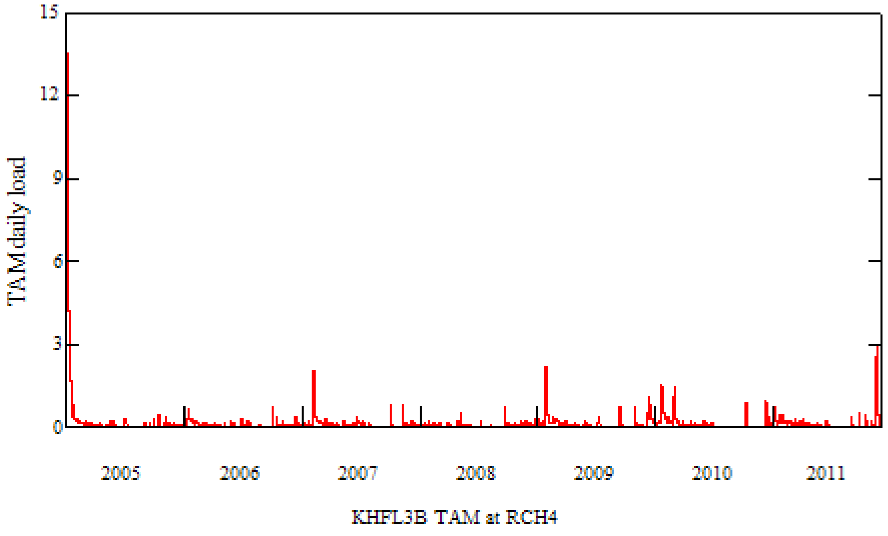
Graph 1b NO3



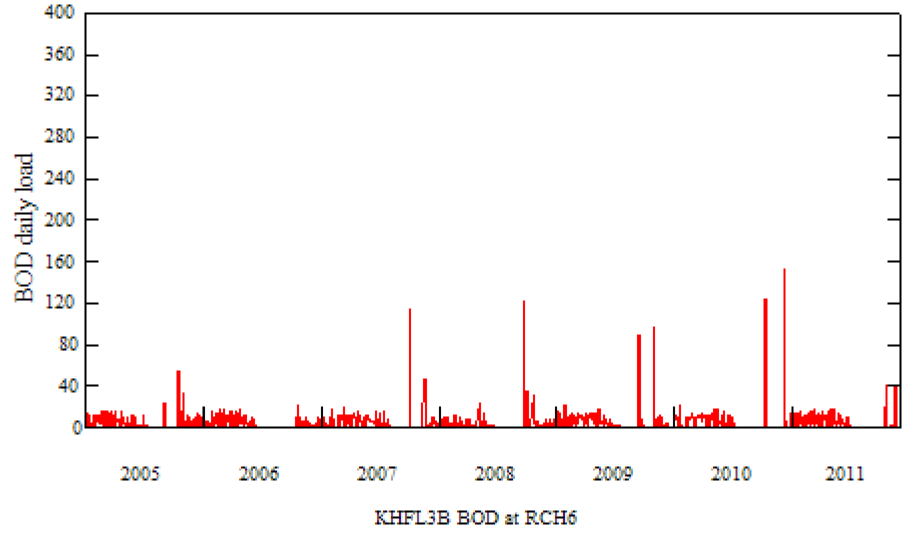
Graph 1c PO4



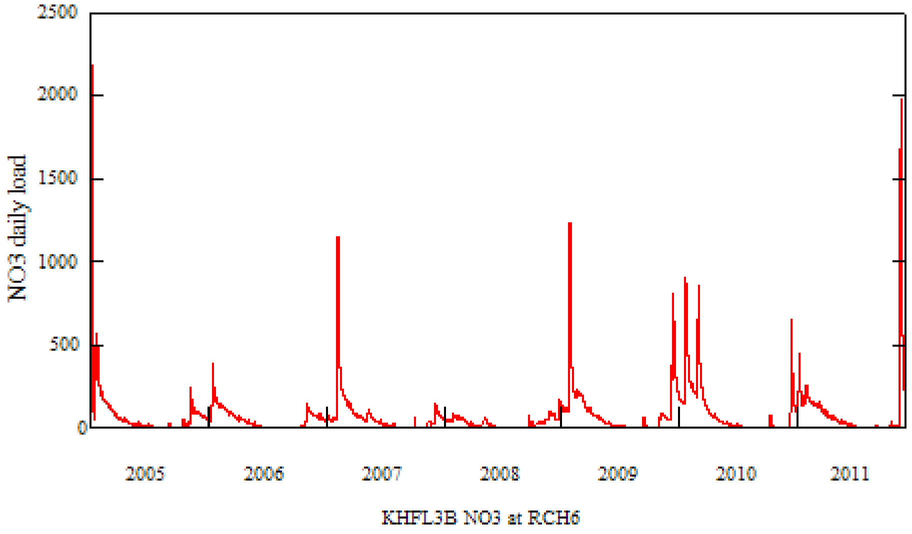
Graph 1d TAM



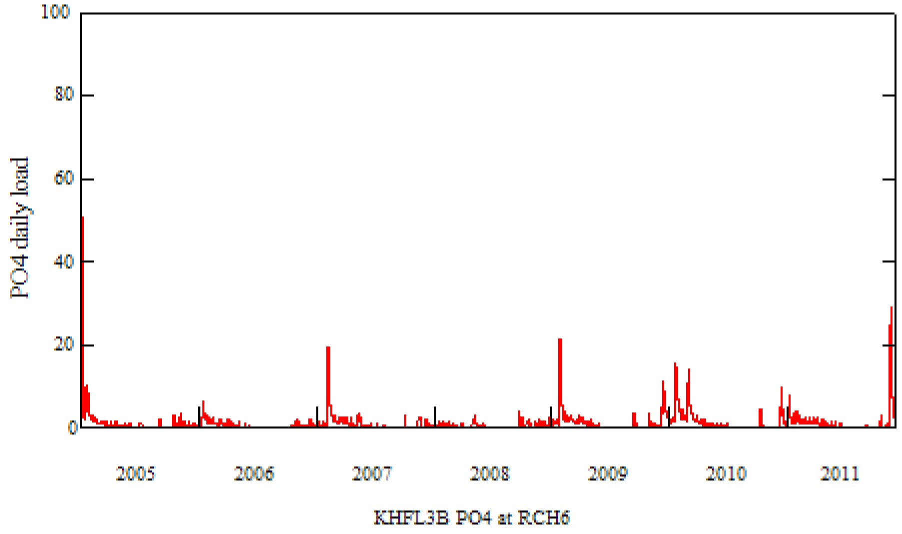
Graph 1e BOD



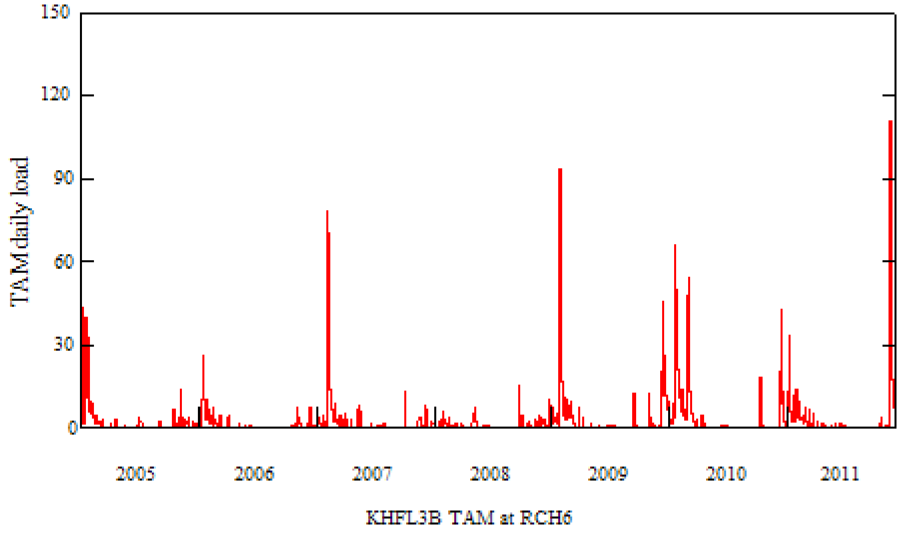
Graph 1f NO3



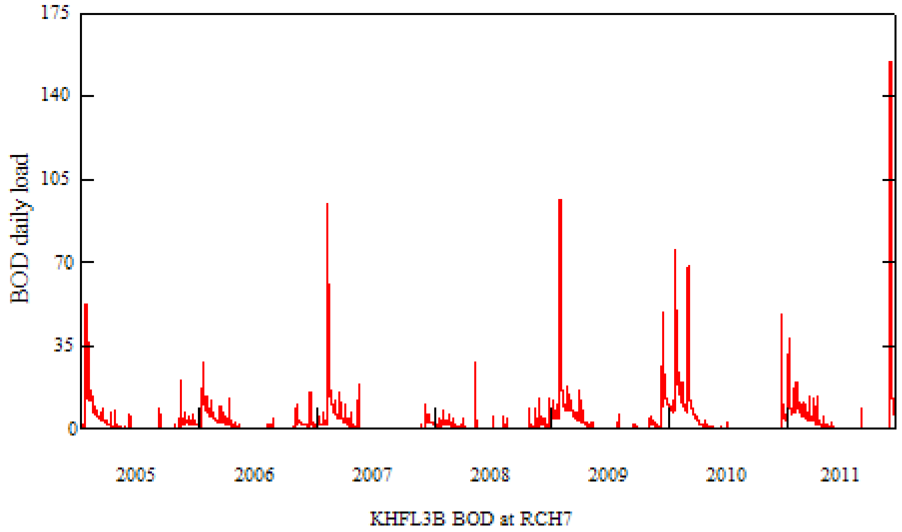
Graph 1g PO4



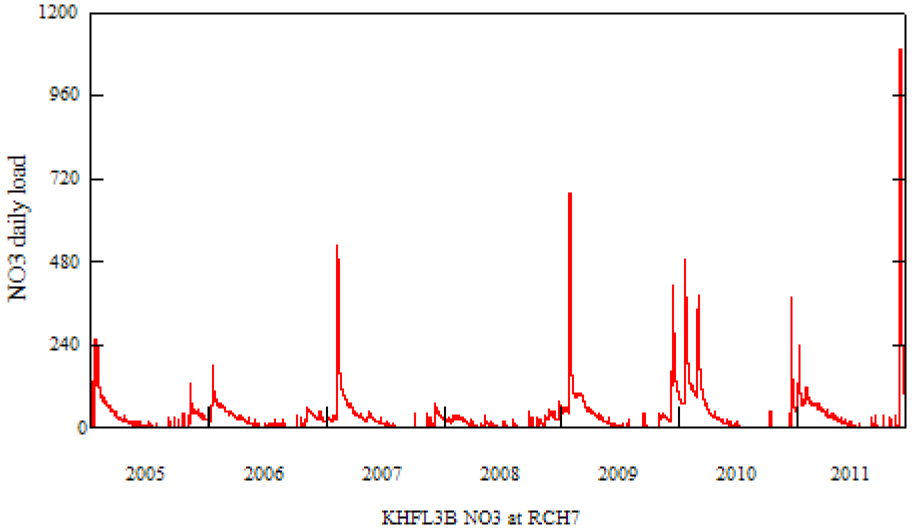
Graph 1h TAM



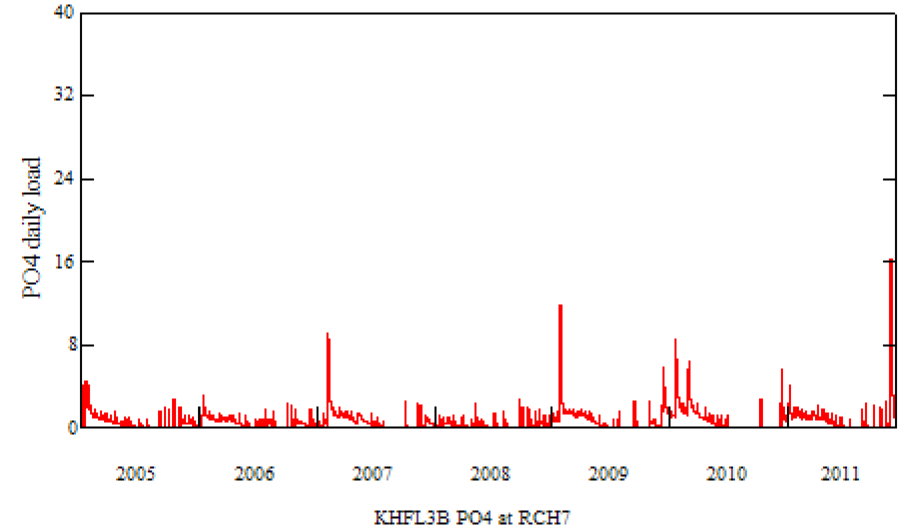
Graph 1i BOD



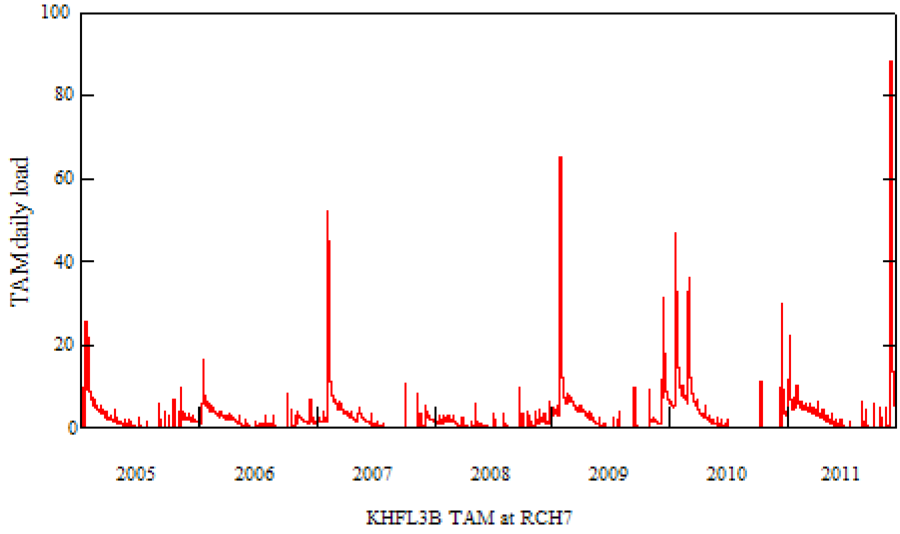
Graph 1j NO3



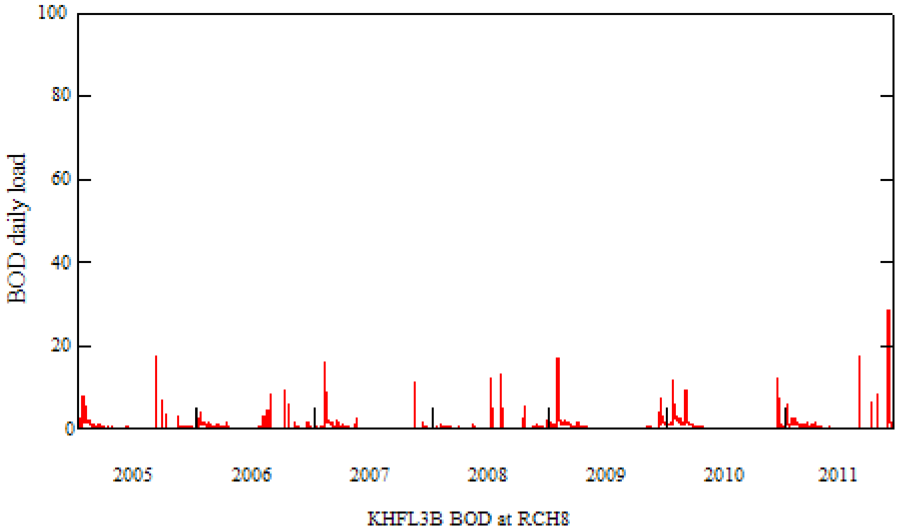
Graph 1k PO4



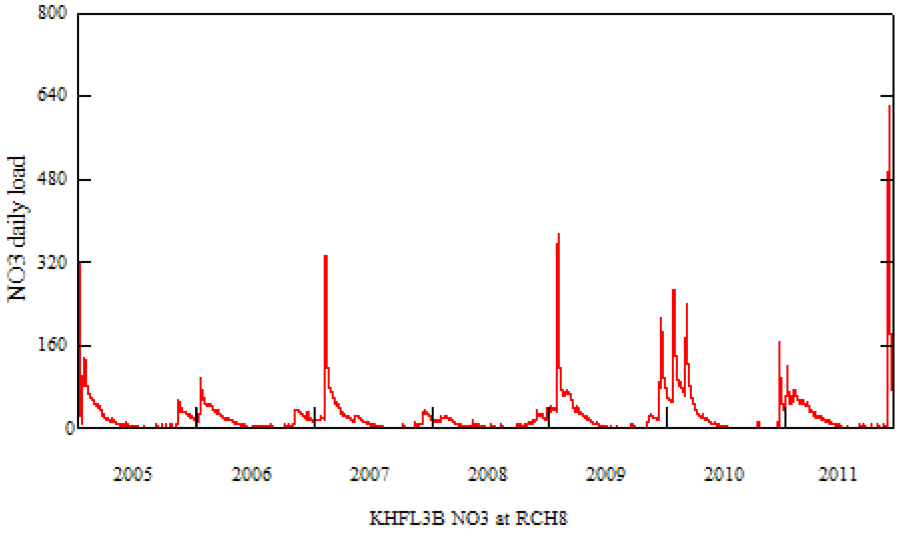
Graph 1l TAM



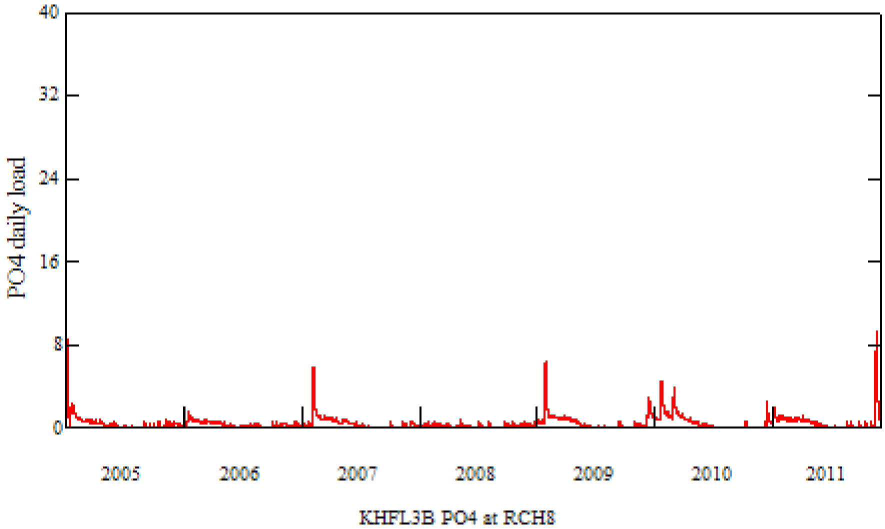
Graph 1m BOD



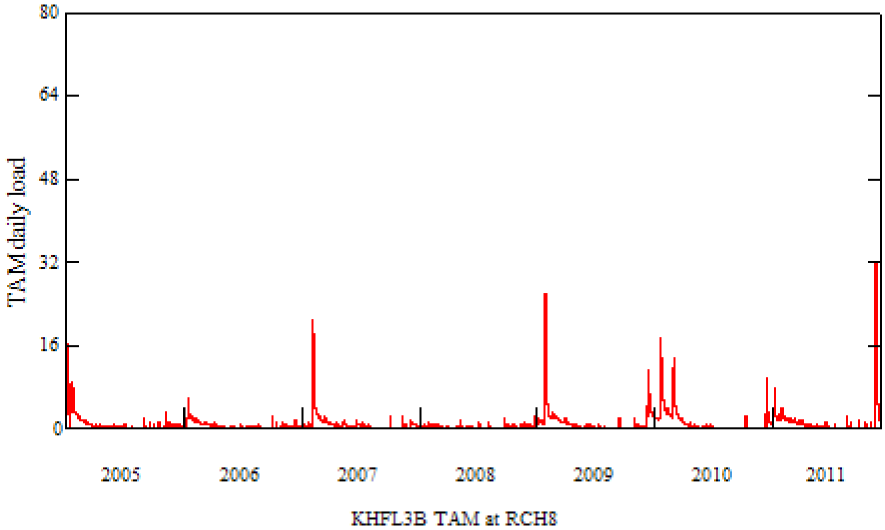
Graph 1n NO3



Graph 1p PO4

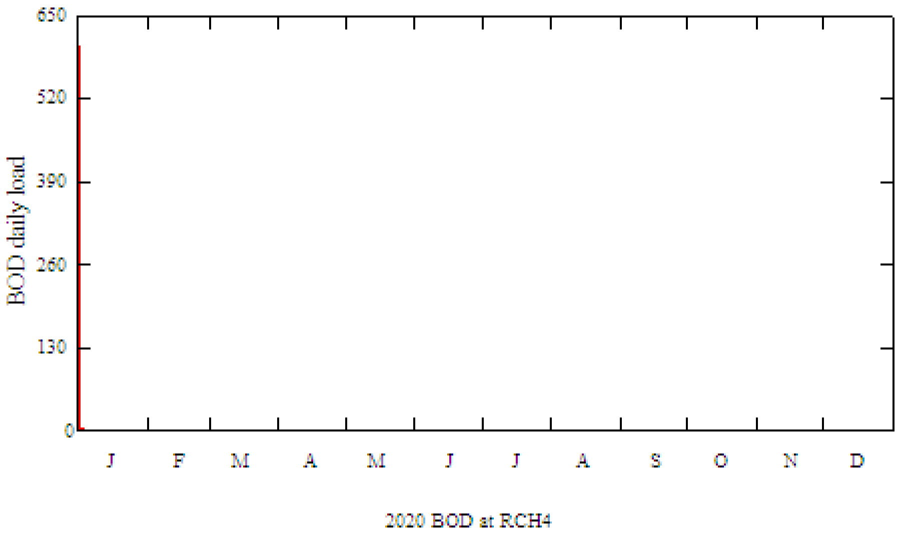


Graph 1q TAM

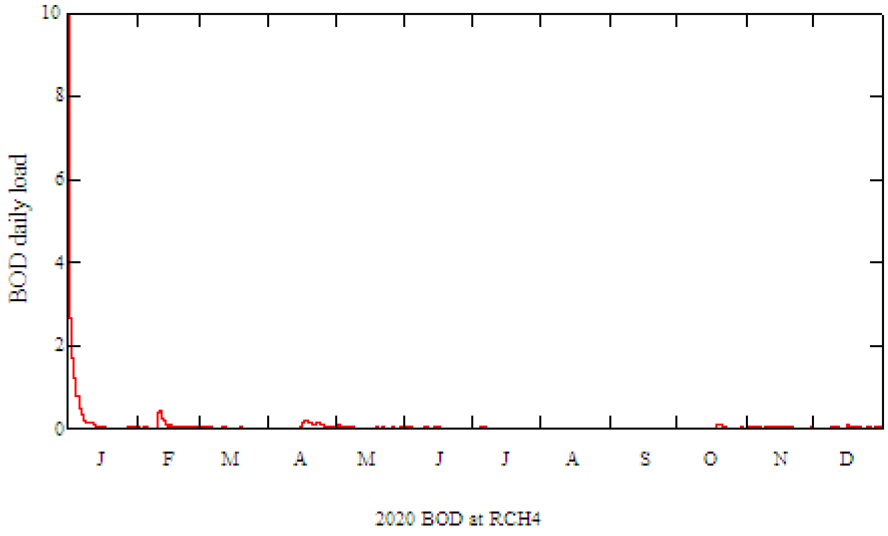


Graph 2: Daily pollutant Loads for the climate Change Scenario (PRECIS Driven 2020)

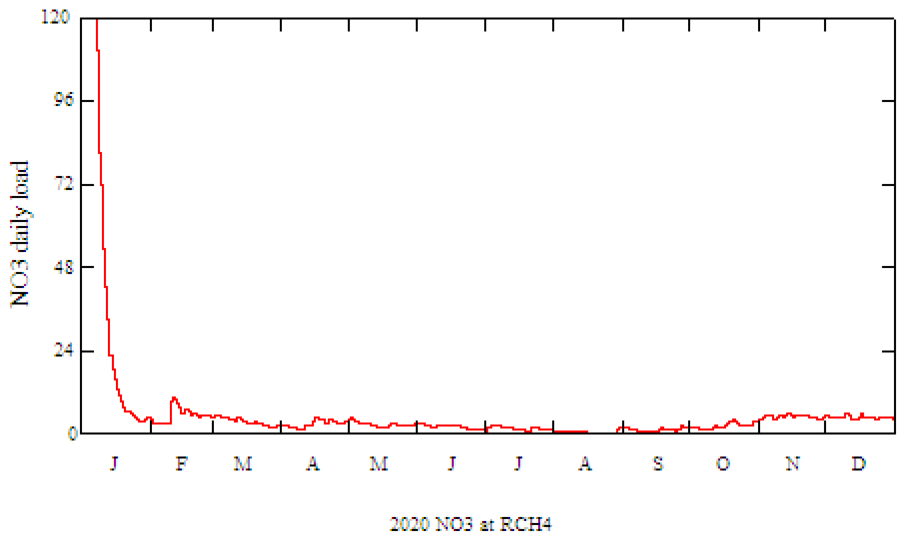
Graph 2a BOD



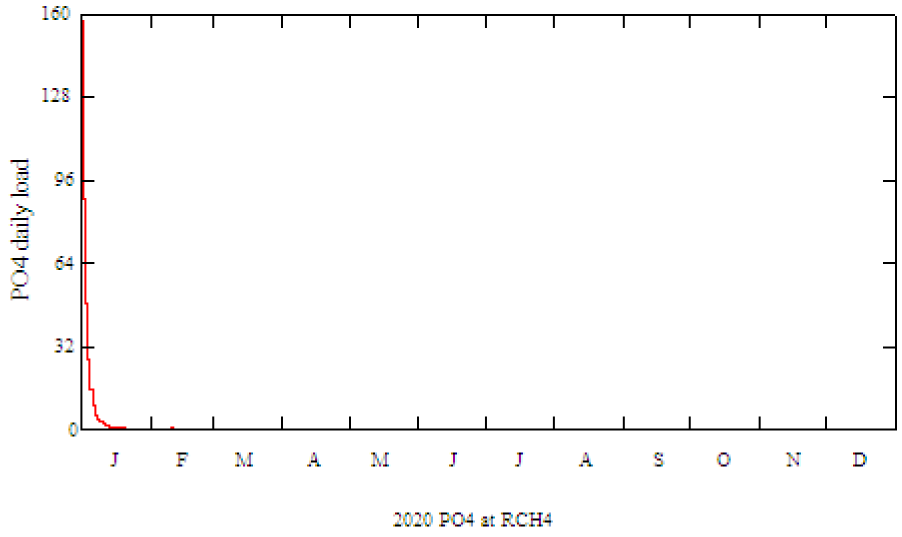
Graph 2a BOD



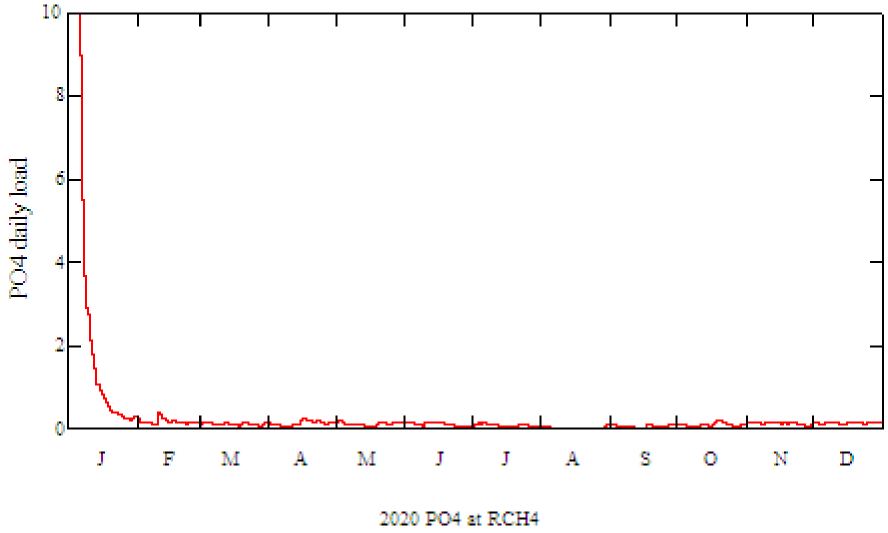
Graph 2b NO3



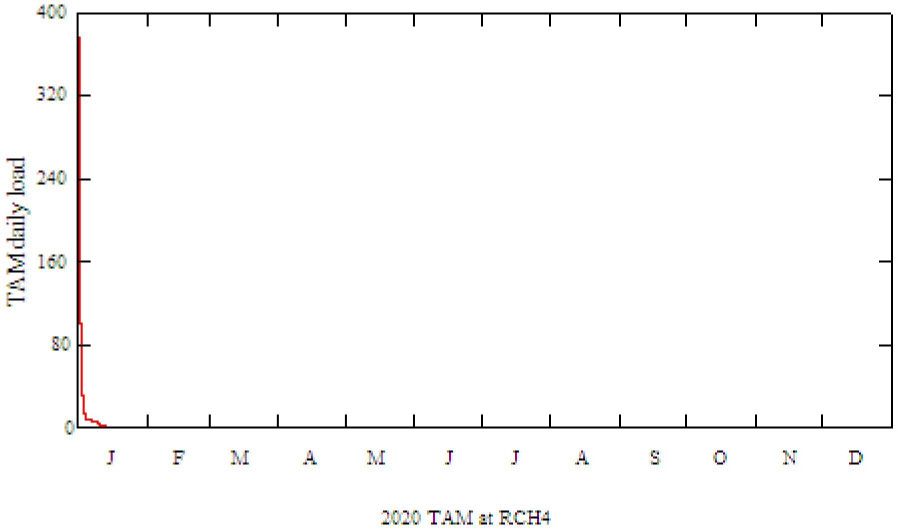
Graph 2c PO4



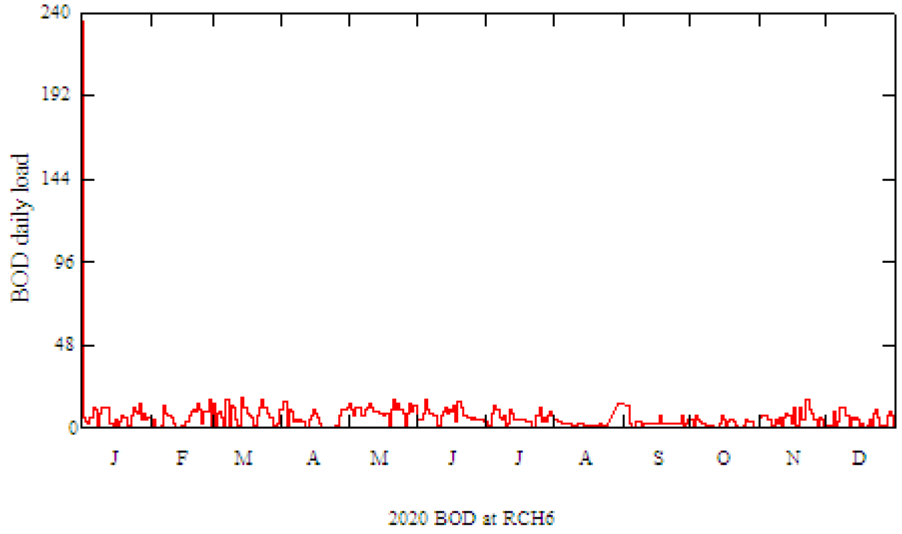
Graph 2c PO4



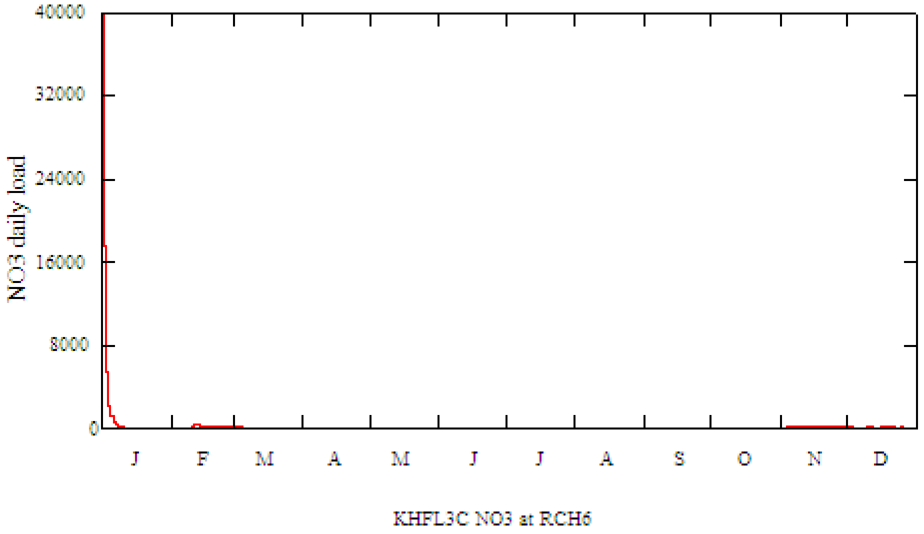
Graph 2d TAM



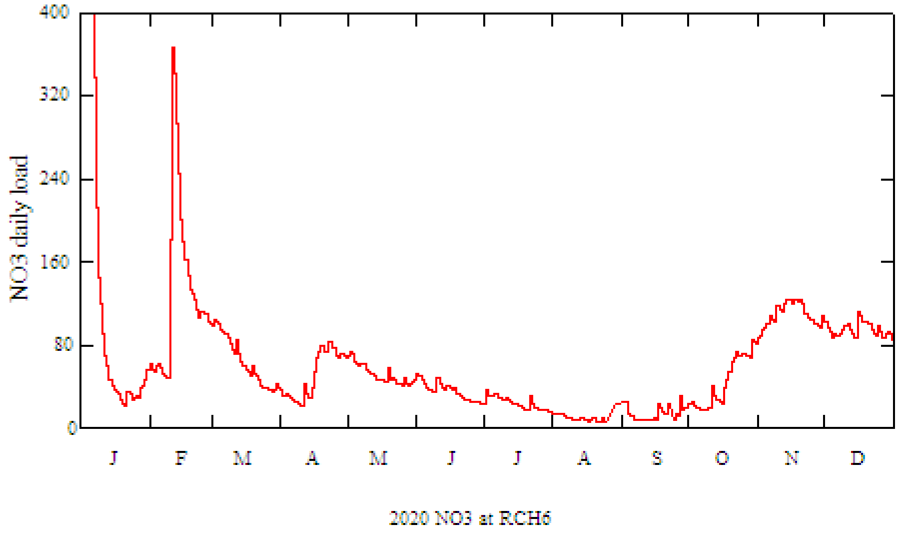
Graph 2f TAM



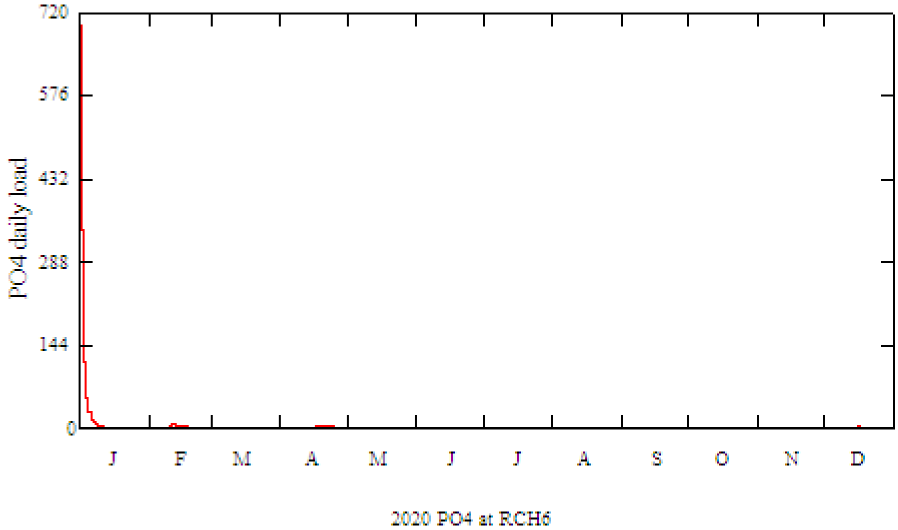
Graph 2g NO3



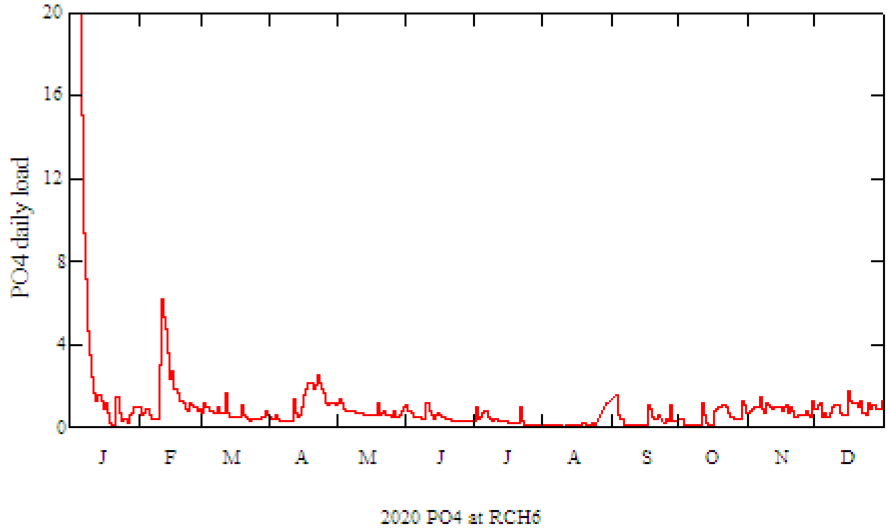
Graph 2g NO3



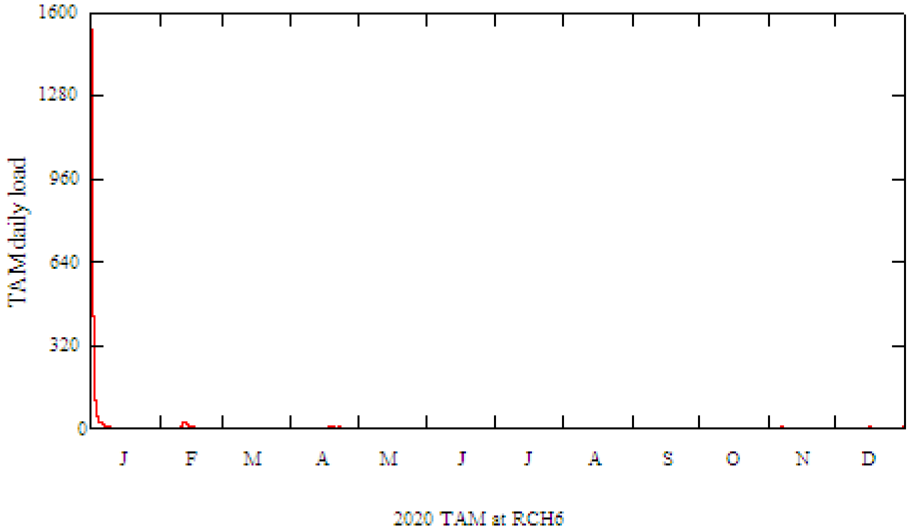
Graph 2h PO4



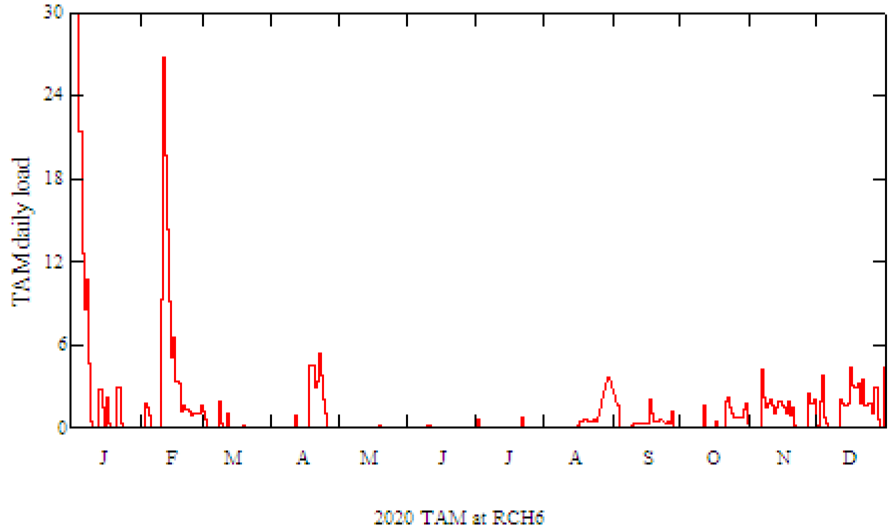
Graph 2h PO4



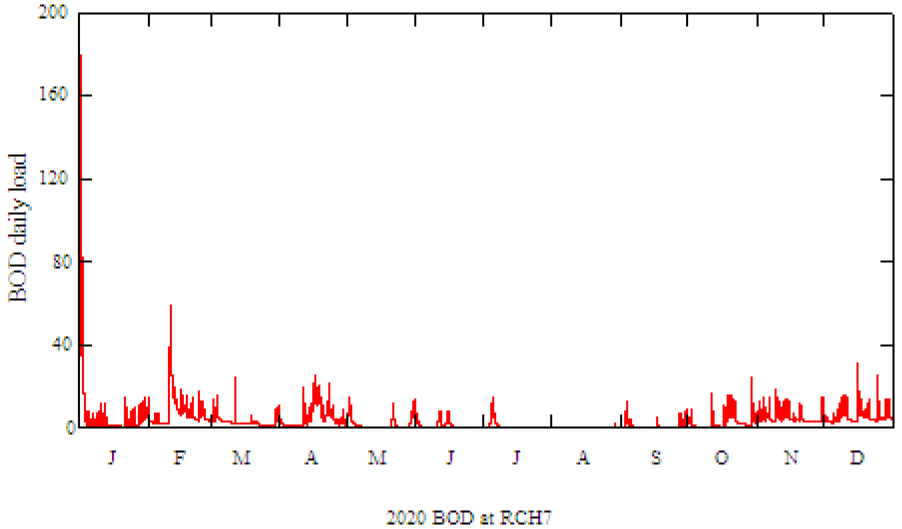
Graph 2i TAM



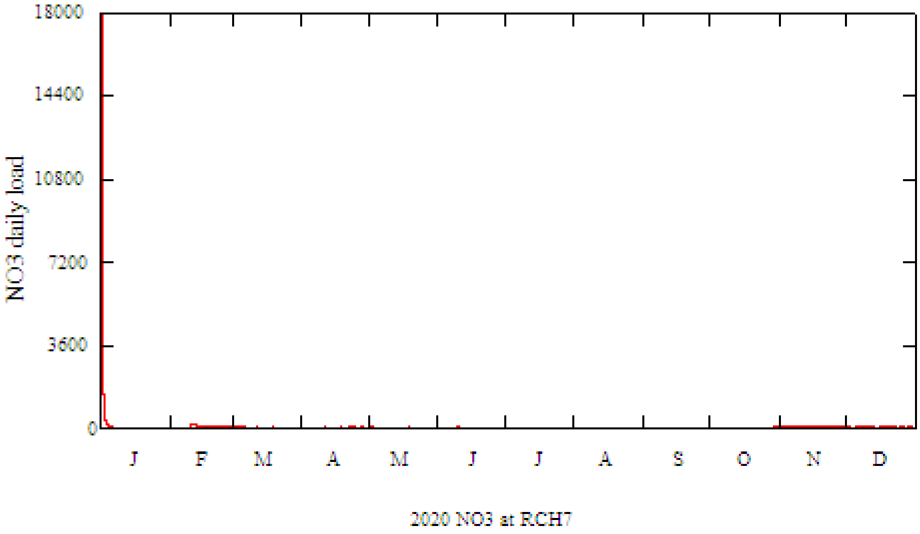
Graph 2i TAM



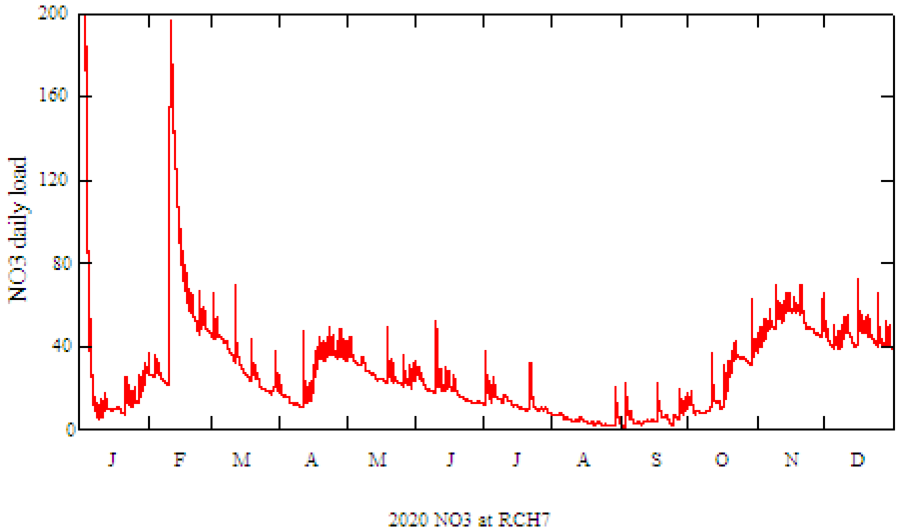
Graph 2j BOD



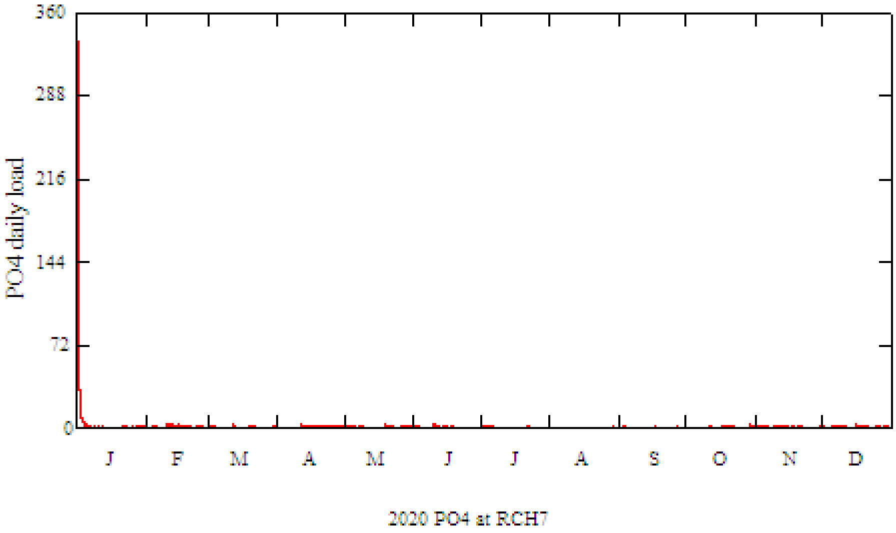
Graph 2k NO3



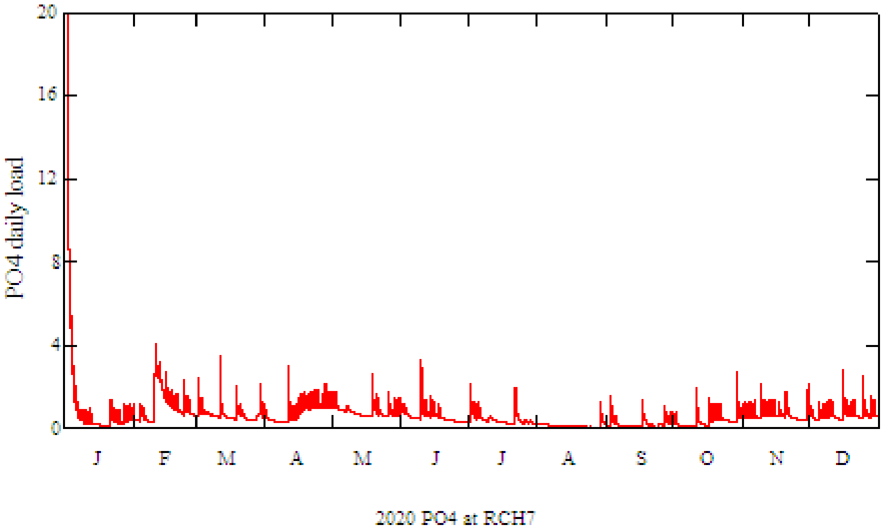
Graph 2k NO3



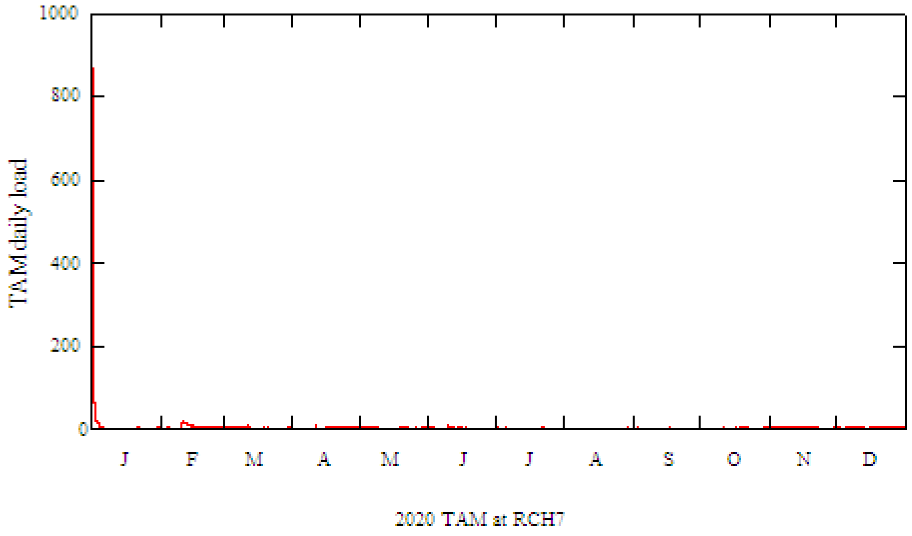
Graph 2l PO4



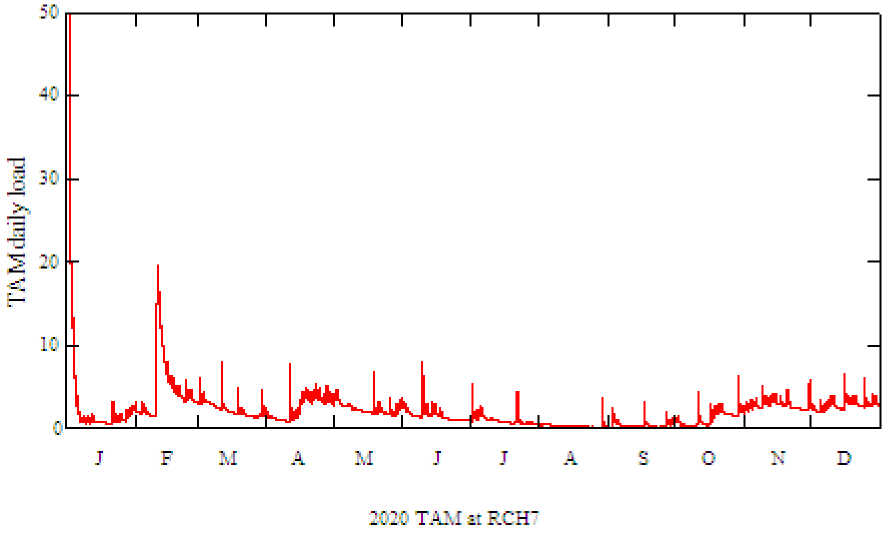
Graph 2l PO4



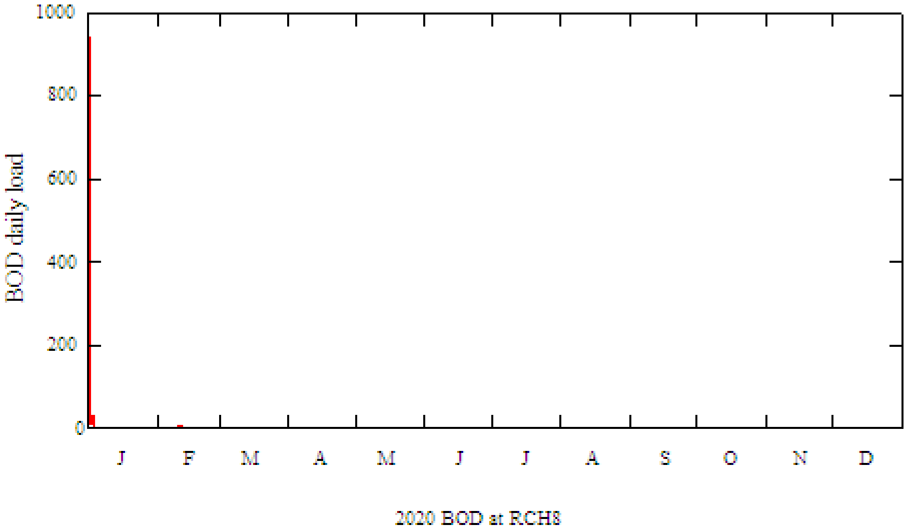
Graph 2m TAM



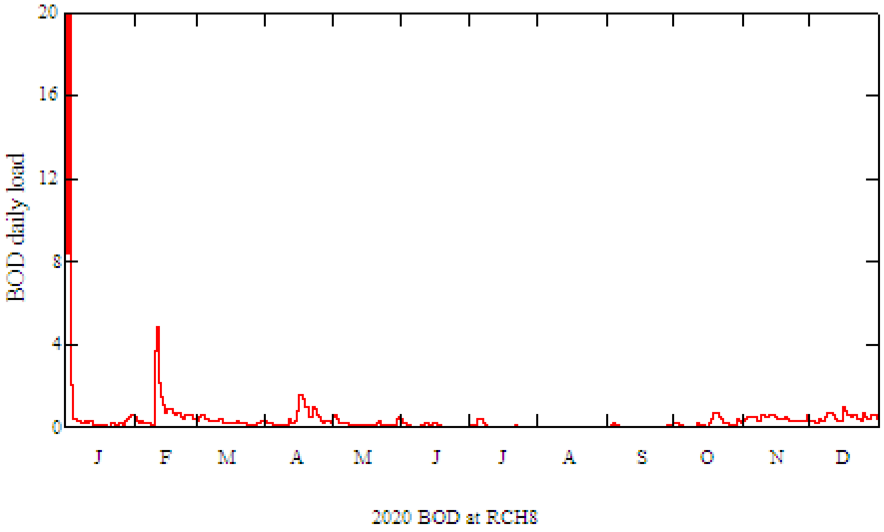
Graph 2m TAM



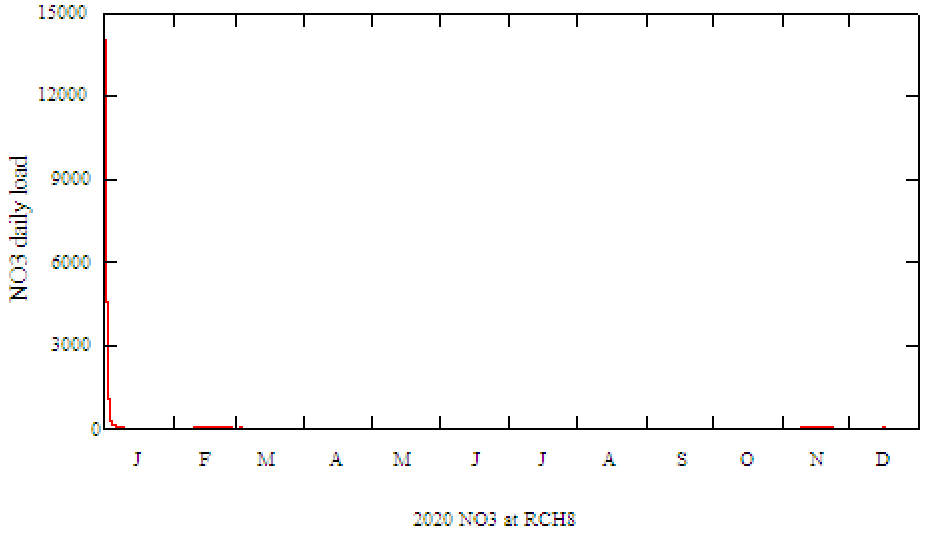
Graph 2n BOD



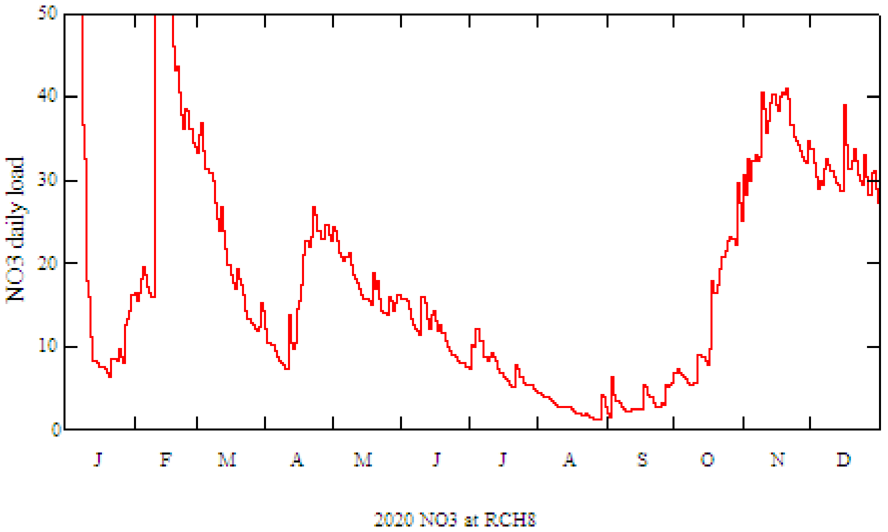
Graph 2n BOD



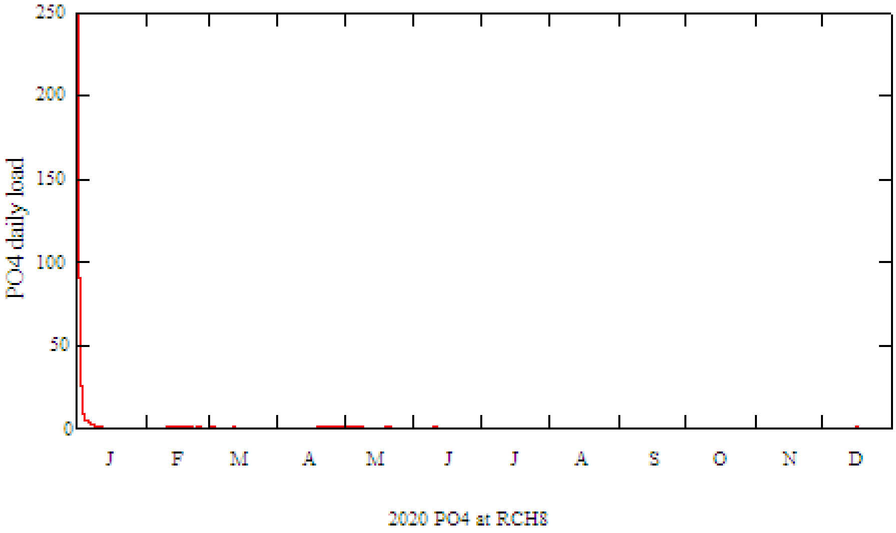
Graph 2p NO3



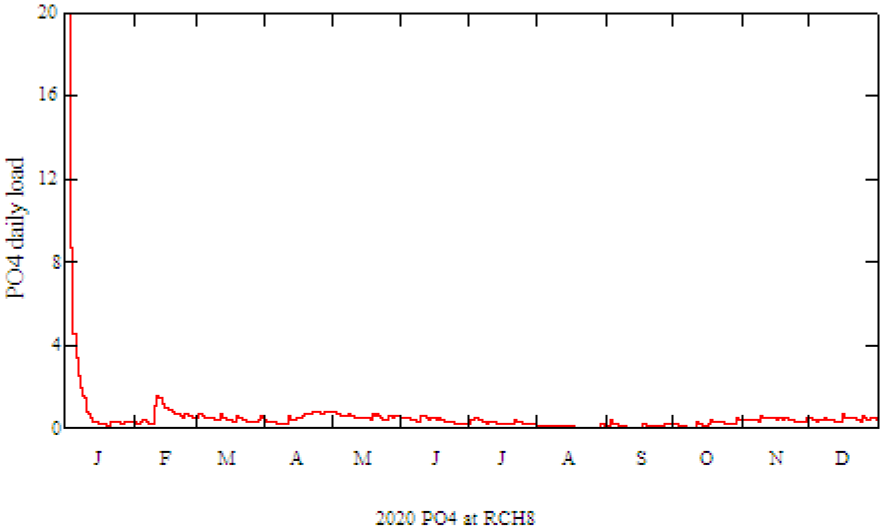
Graph 2p NO3



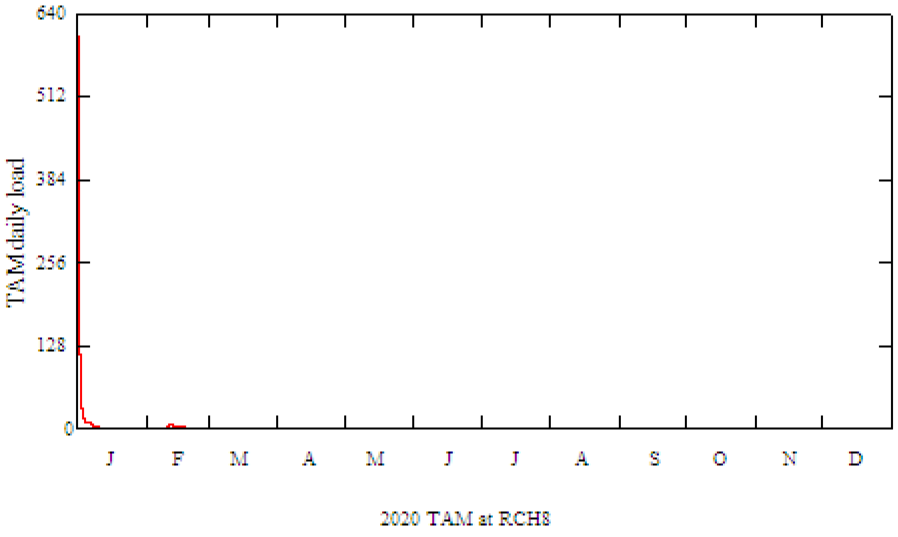
Graph 2q PO4



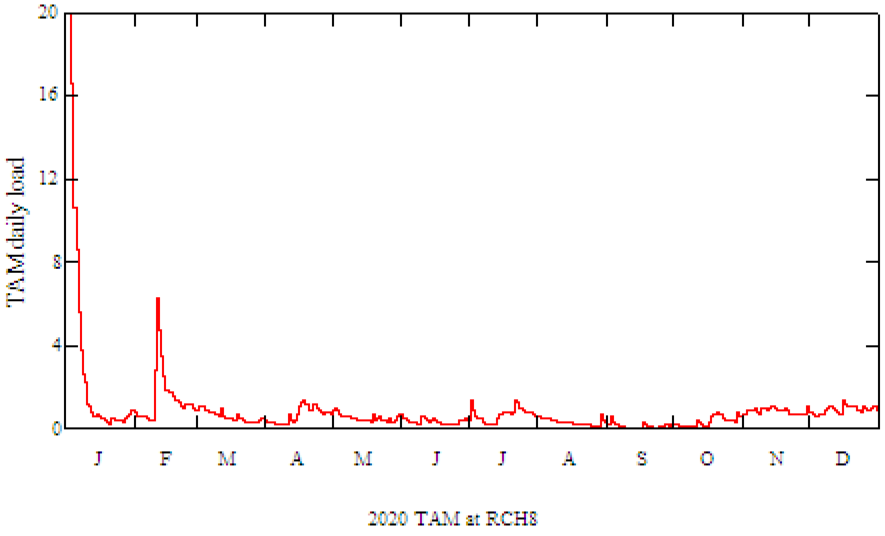
Graph 2q PO4



Graph 2r TAM

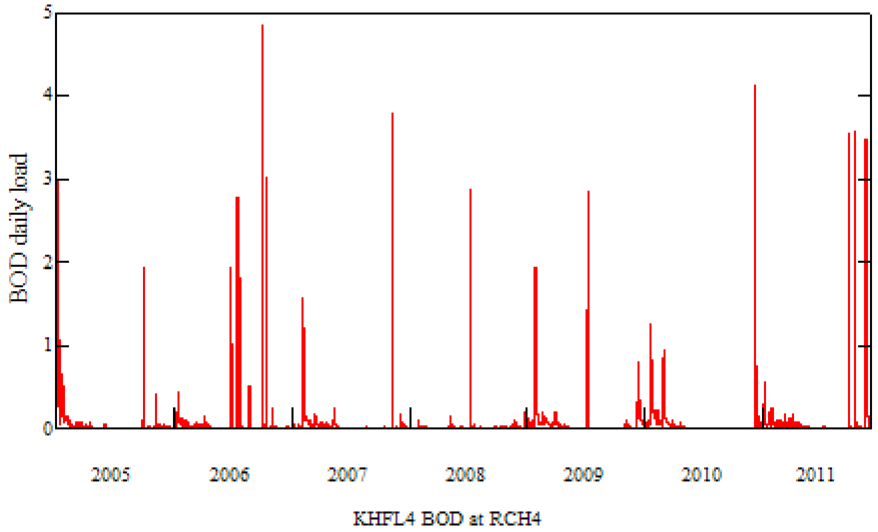


Graph 2r TAM

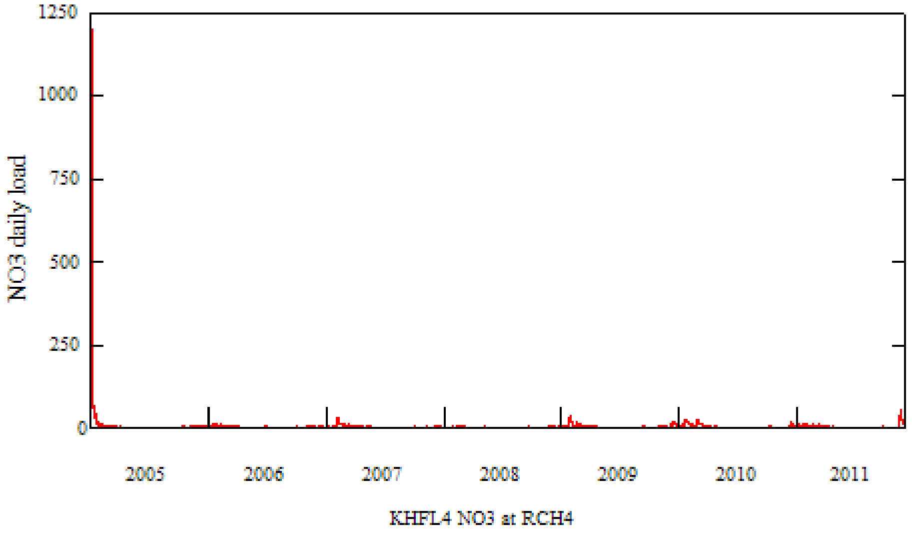


Graph 3: Pollutant load Allocations for the future land-use scenario

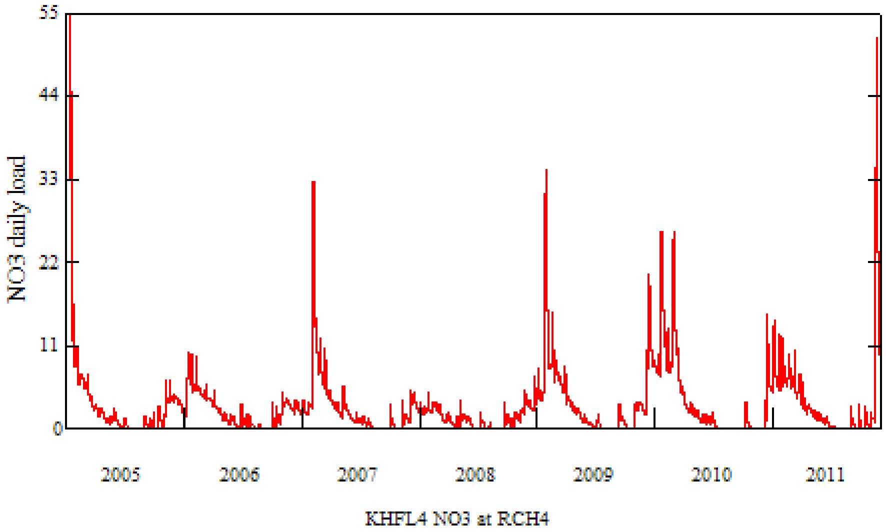
Graph 3a BOD



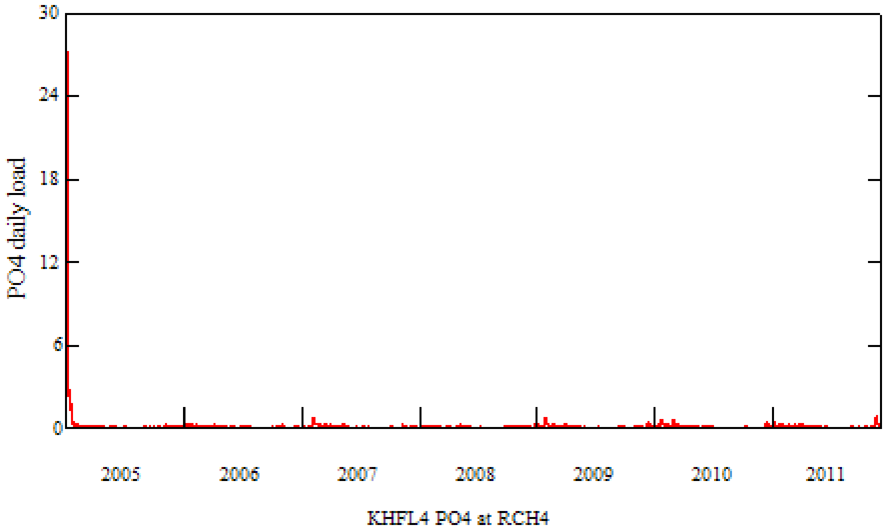
Graph 3b NO3



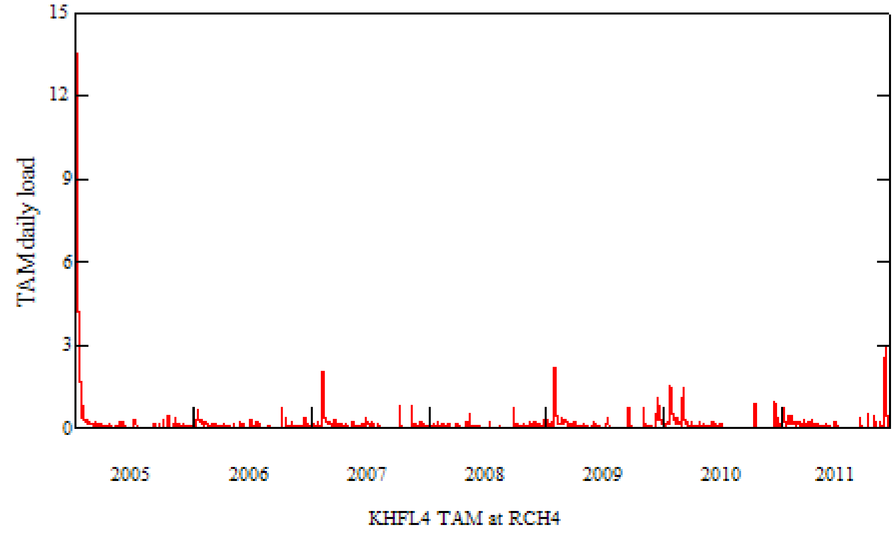
Graph 3b NO3



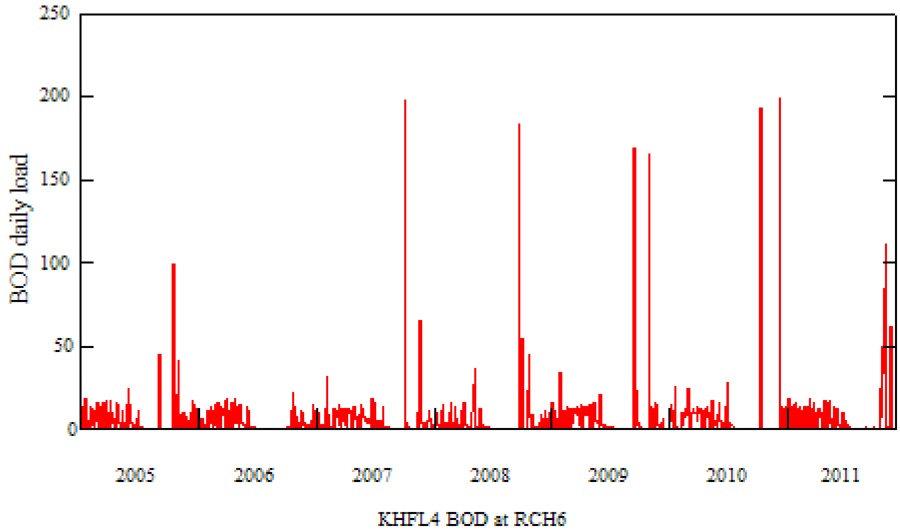
Graph 3c PO4



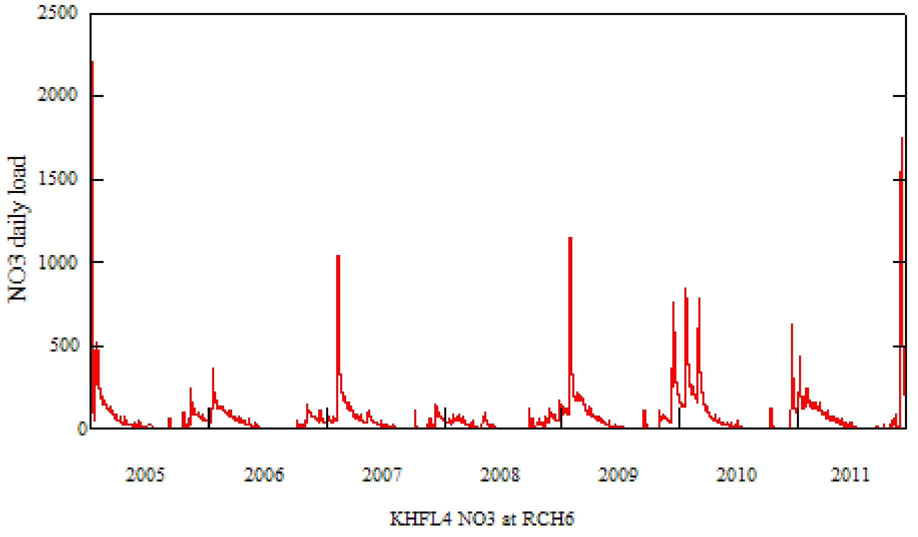
Graph 3d TAM



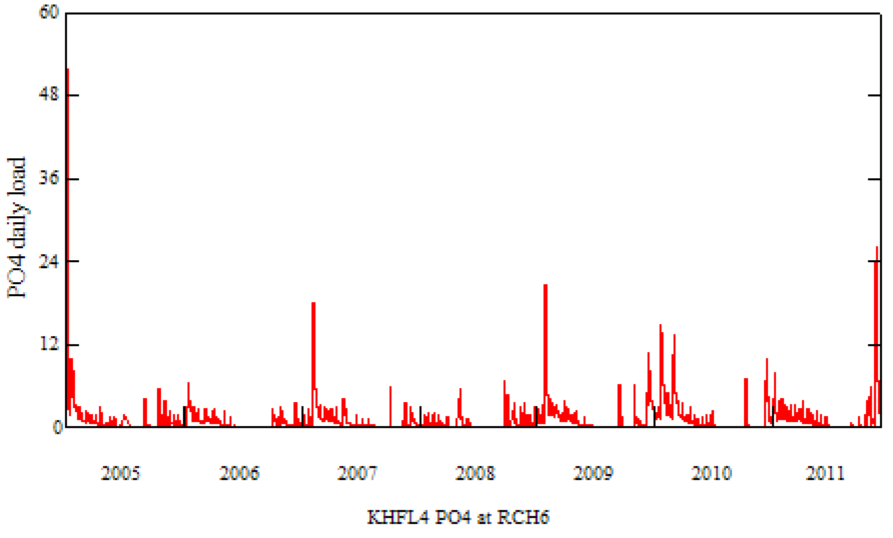
Graph 3f BOD



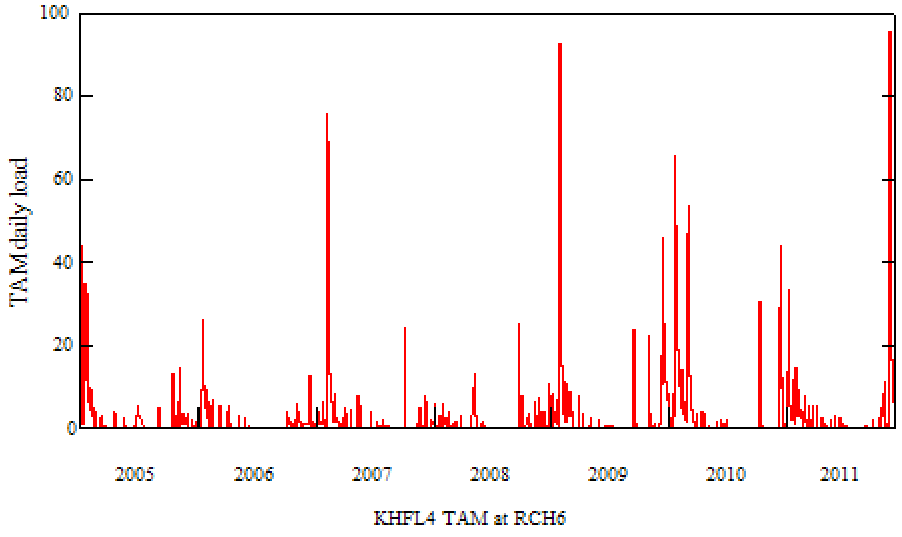
Graph 3g NO3



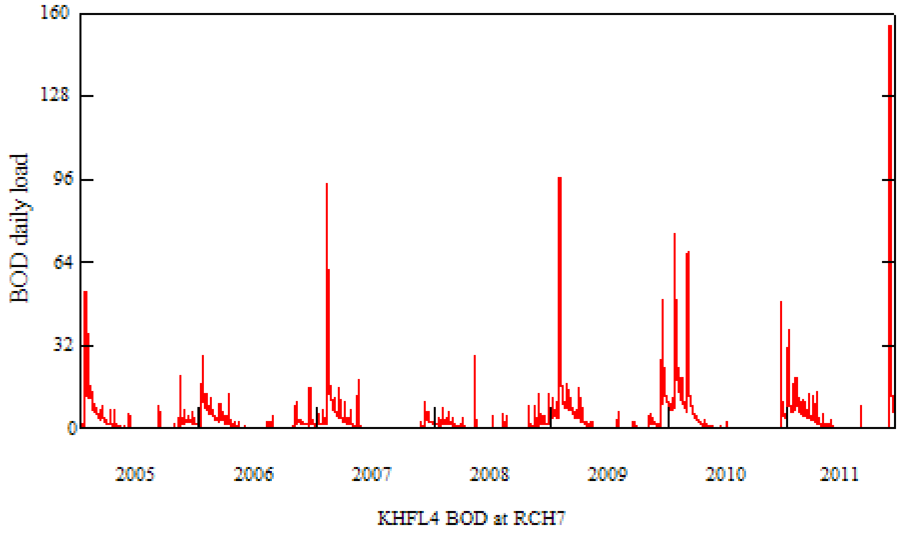
Graph 3h PO4



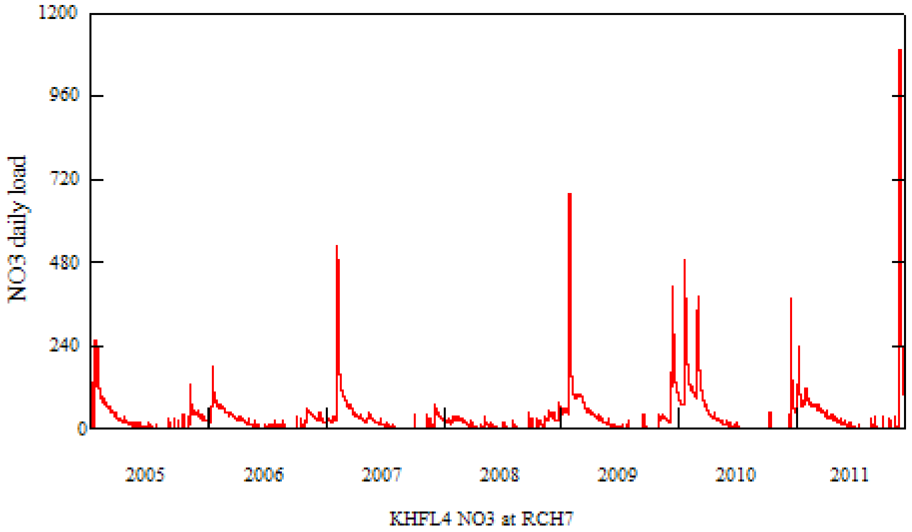
Graph 3i TAM



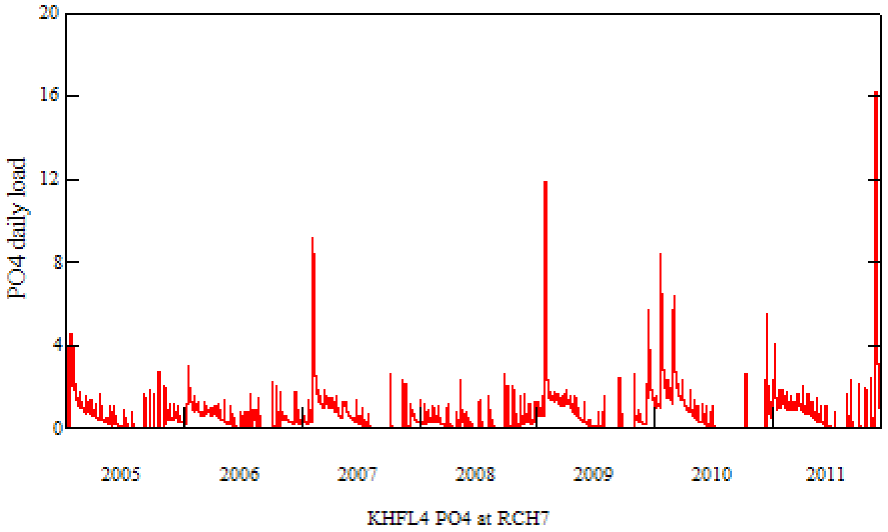
Graph 3g BOD



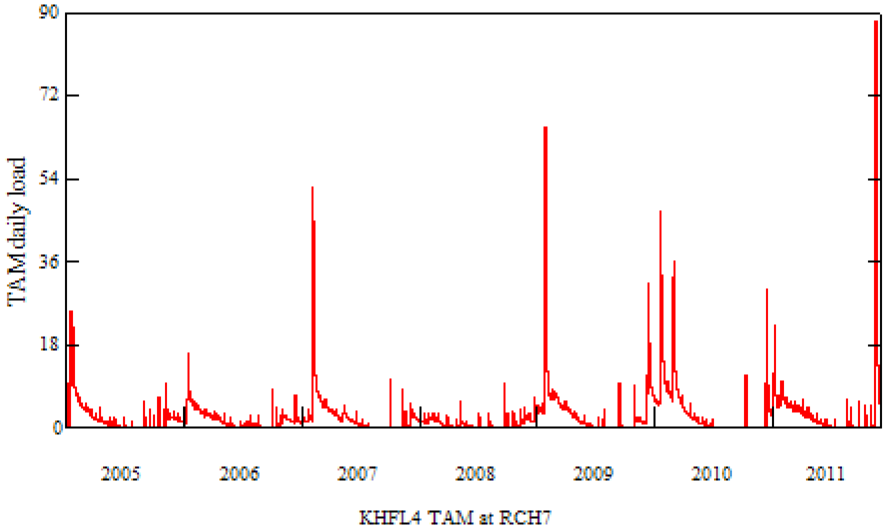
Graph 3k NO3



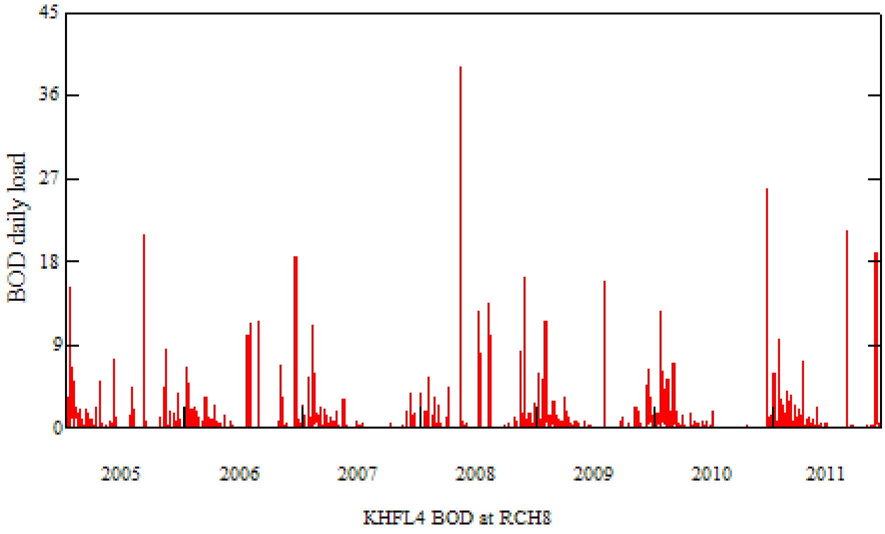
Graph 3l PO4



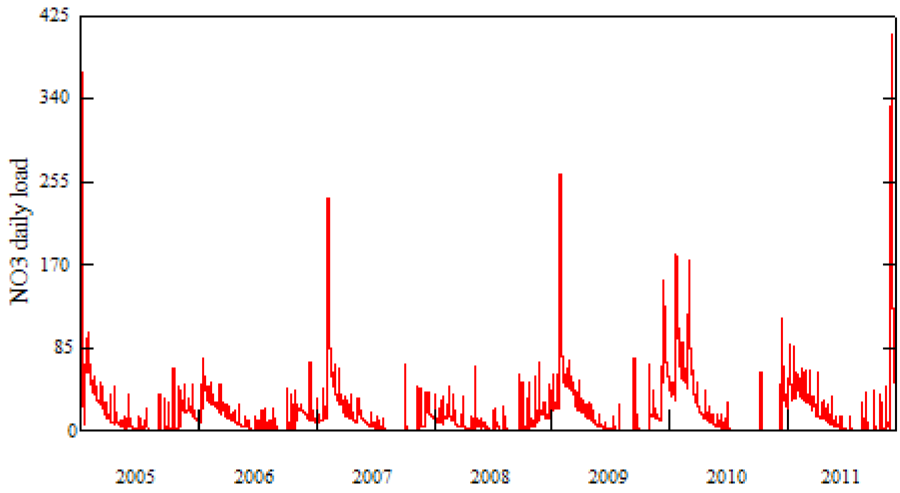
Graph 3m TAM



Graph 3n BOD

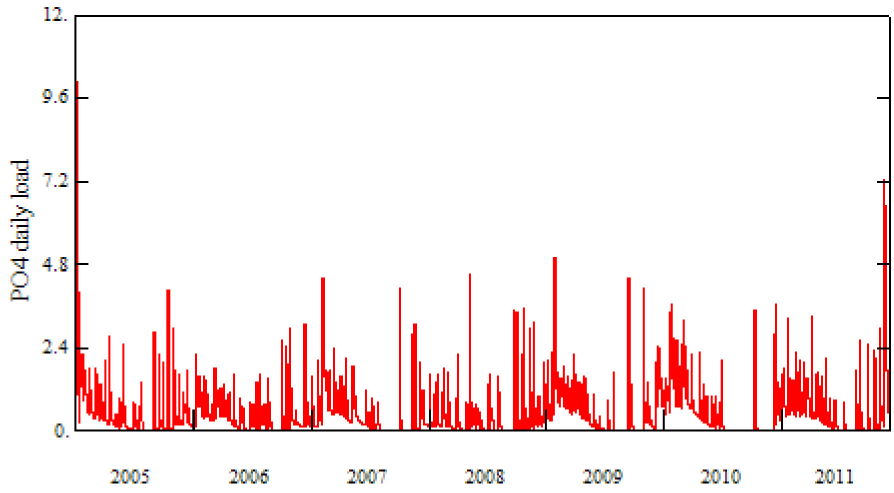


Graph 3n NO3



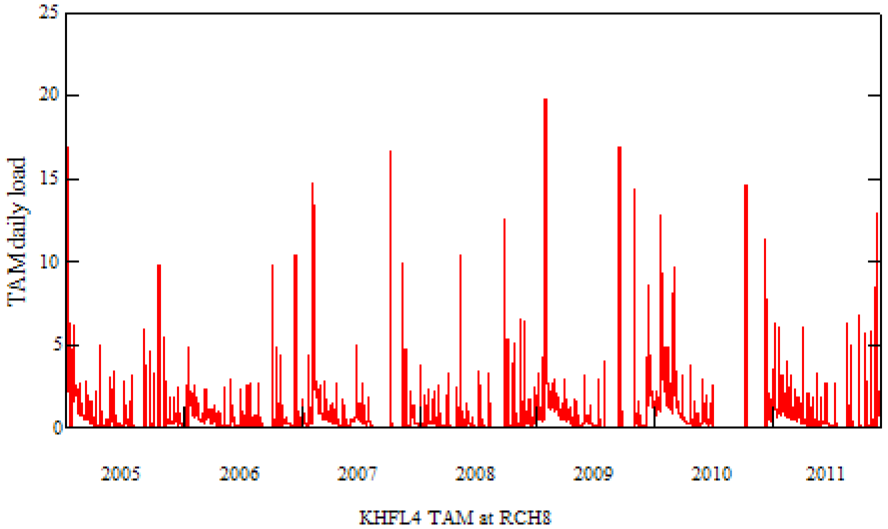
KHFL4 NO3 at RCH8

Graph 3p PO4



KHFL4 PO4 at RCH8

Graph 3q TAM



25
20
15
10
5
0
TAM daily load
2005
2006
2007
2008
2009
2010
2011
KHFL4 TAM at RCH8

3.2 Loading Capacity

One of the essential components of a TMDL is identifying and representing the relationship between the desired condition of the stream (expressed as the water quality standard) and pollutant loadings.

Based on the monitoring results and on the results of the modelling of the existing, future and climate change scenarios, it was concluded that the Salt Lake showed impairments mainly with respect to the presence of Nitrates. In addition, though it does not present a high risk, it is considered prudent that F. Coli pollution is reduced. Minor localised issues pertaining to BOD should also be addressed through specific load reduction measures.

The above section presents the loads pertaining to each sub-catchment which resulted in the predicted pollutants concentrations. The examination of those results can provide guidance as to the level of loading reductions that are required in order to achieve the needed improvements in water quality. The above loading reduction measures were deemed useful and practical. The respective Load Allocations were calculated through the BASINS models and are presented below.
In particular, based on the Daily load results, it is apparent that Reach 7 dominates loadings of NO3 while Reach 8 also has a significant contribution. Developing a TMDL for NO3 should therefore concentrate on the potential loading reductions that can be achieved in these two Reaches.

- **Wasteload Allocation**

Because the point sources are already under the pollution control strategies of the competent authorities and because it was found that point sources have a relatively minimal contribution to impairment of the lake, waste load allocation reductions are not at present considered necessary. It is noted, however, that this does not exclude the possibility that wasteload reductions are prescribed during the preparation of the programme of measures that will follow.

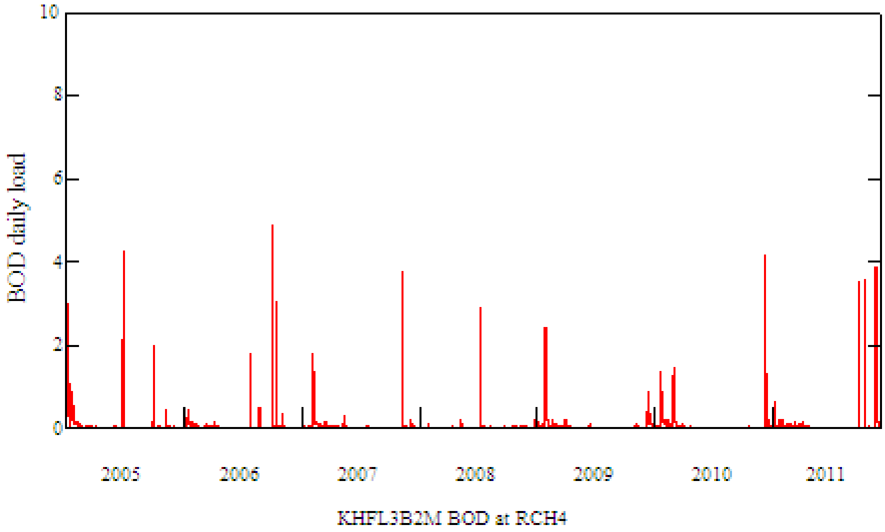
- **Load Allocation**

Load allocations were determined via a set of realistic measures (BMPs) for the existing scenario. These measures include the following:

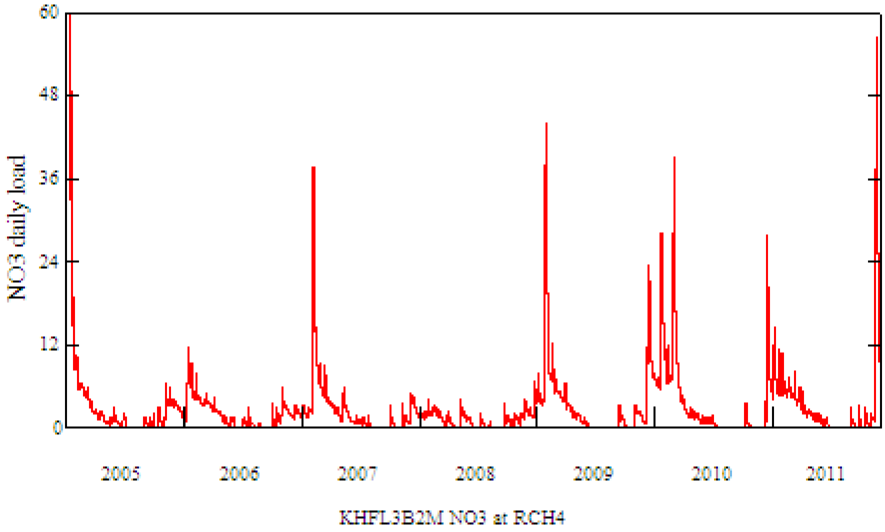
- Relocation of farms outside of the Kalo Horio catchment
- Installation of water retention measures in developed areas (affects residential and industrial areas in Reaches 5 and 9)
- Agricultural Activity in the Vicinity of the Lake (affects 1500 hectares).

The new pollutant loads by Reach (subcatchment) are provided in the Graphs below.
Examples of the new water quality predictions resulting from the new pollutant loads are given in Graphs 4.

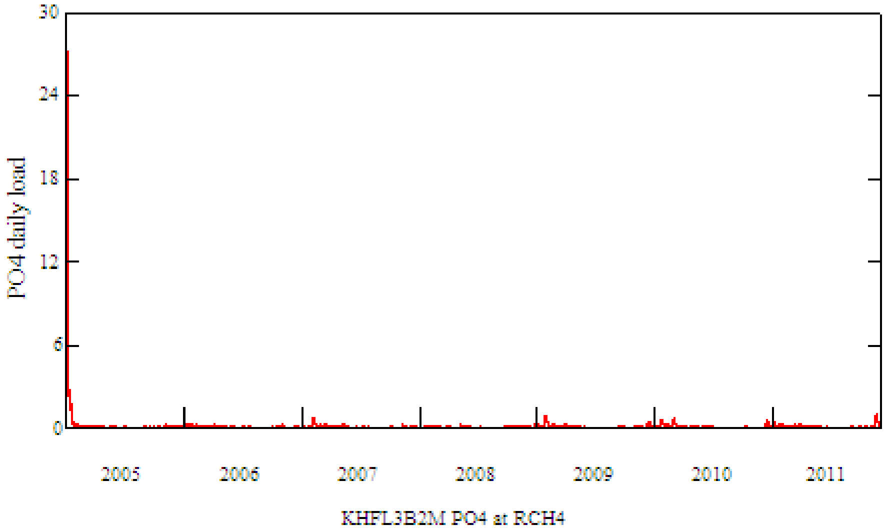
Graph 4a BOD



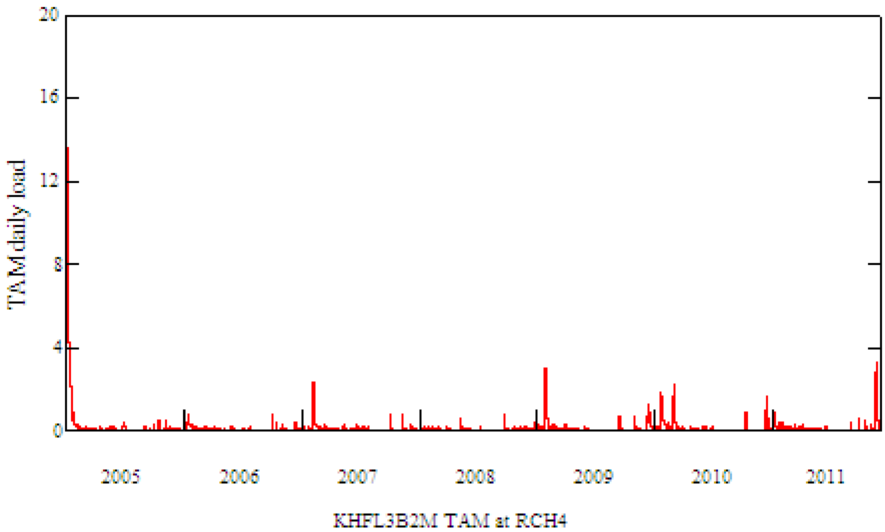
Graph 4b NO3



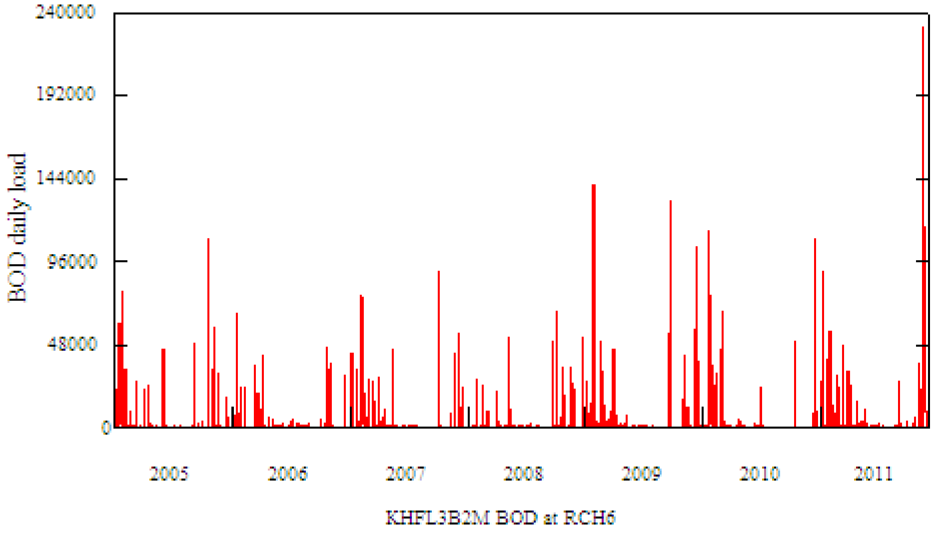
Graph 4c PO4



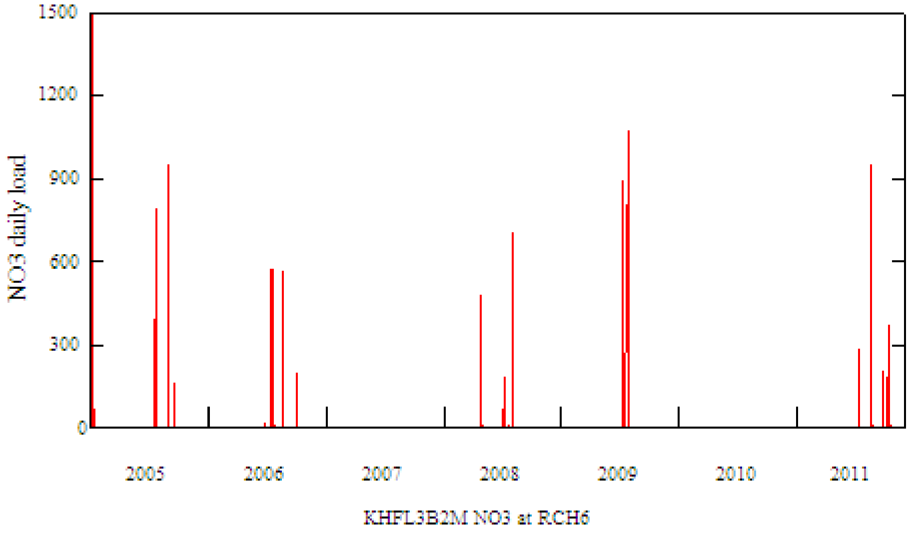
Graph 4d TAM



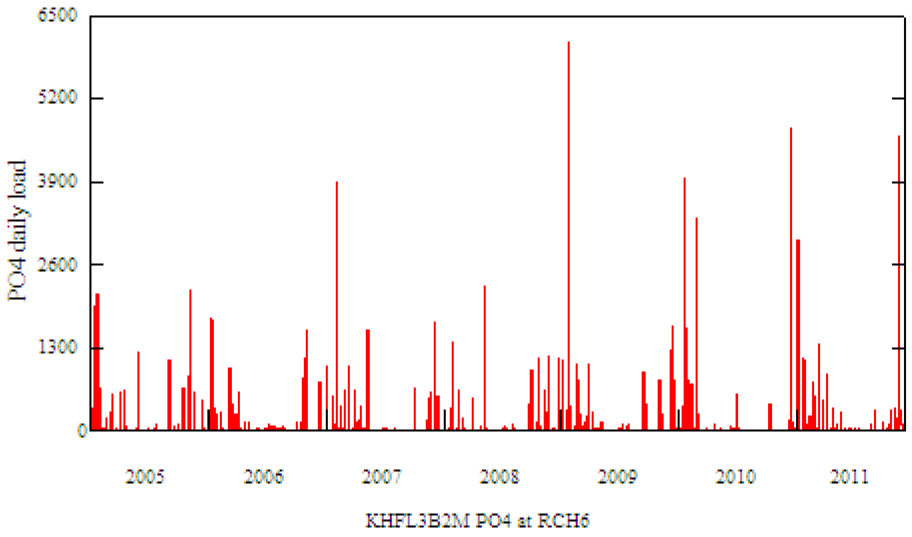
Graph 4f BOD



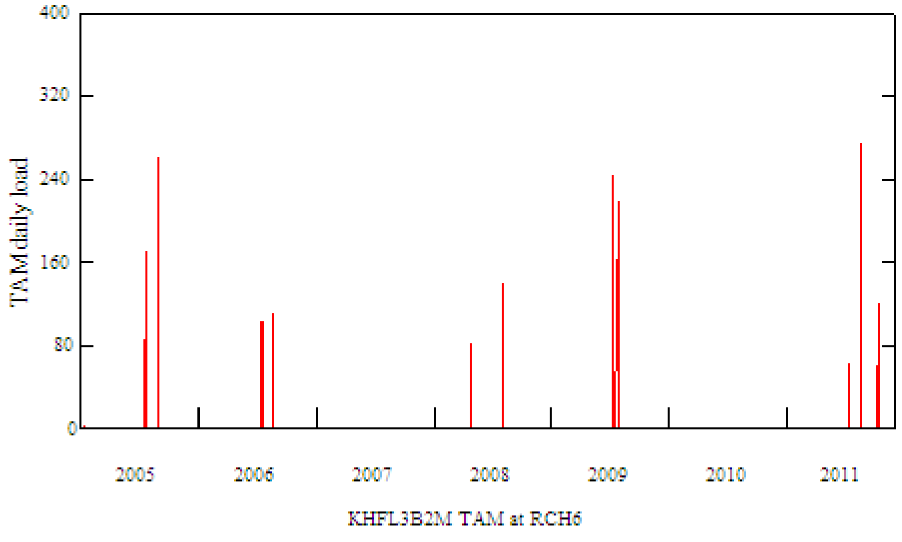
Graph 4g NO3



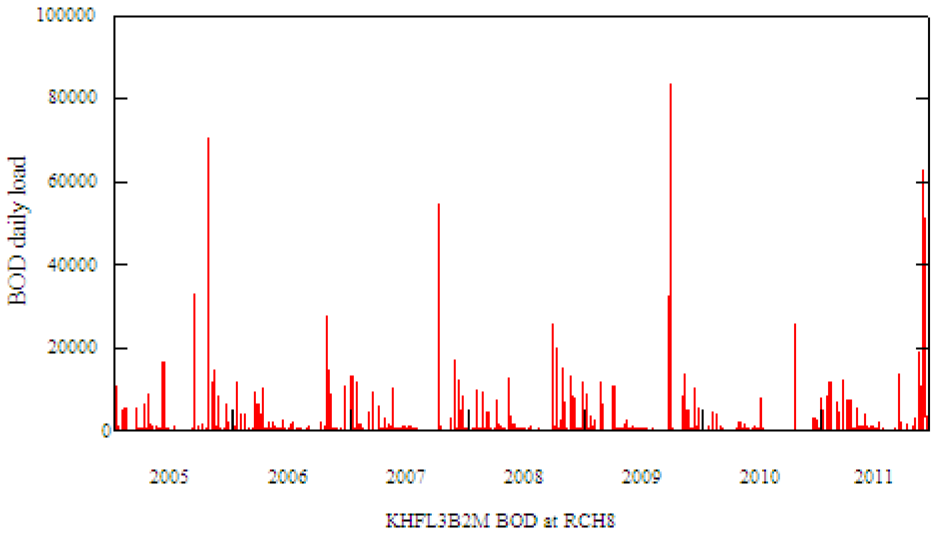
Graph 4h PO4



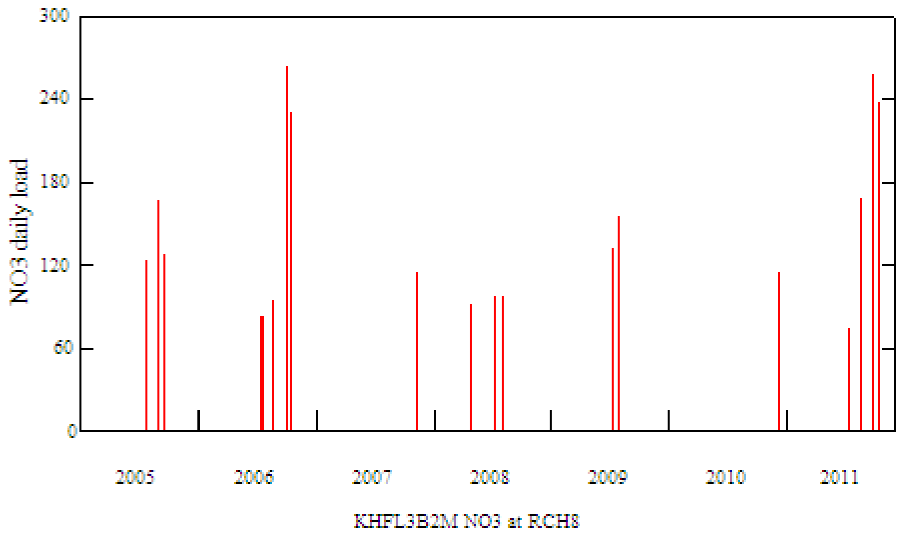
Graph 4i TAM



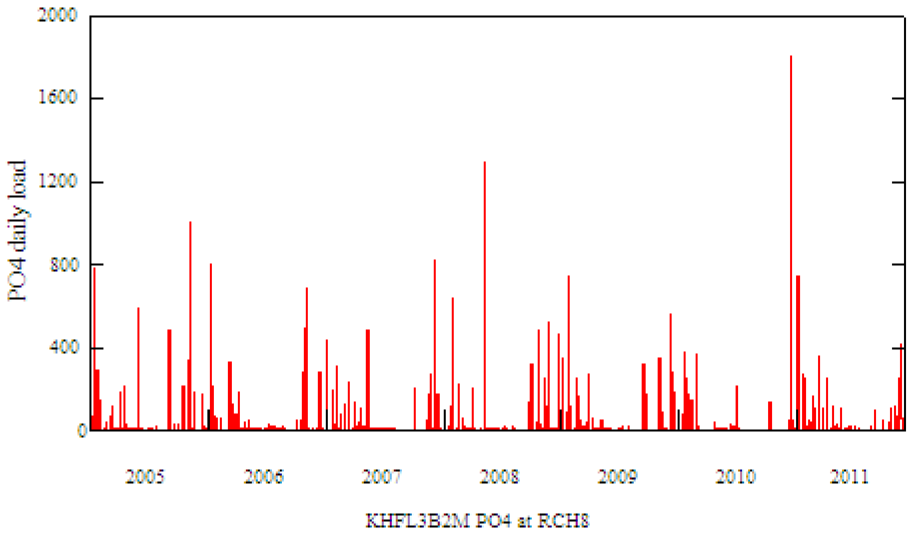
Graph 4j BOD



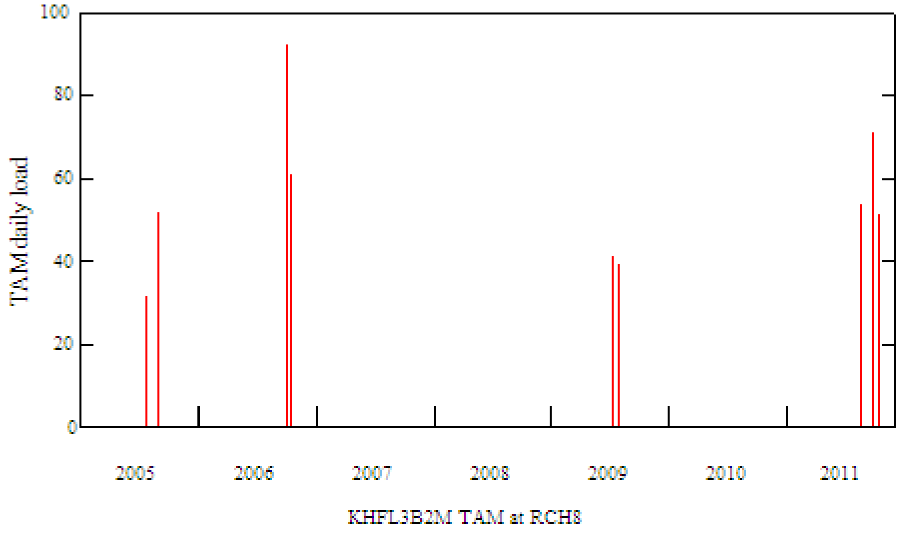
Graph 4k NO3



Graph 4l PO4



Graph 4m TAM



- **Margin of Safety**

This section addresses the incorporation of a margin of safety (MOS) into the TMDL analysis. The MOS is used to counteract against various levels of uncertainty that arise from the lack of data, assumptions used in the model and uncertainties regarding the effectiveness of proposed measures. In order to account for this uncertainty the following were undertaken

- Conservative model assumptions which
- Conservative assumptions regarding pollutant loads. For example a 10% failure rate was assumed for the sewerage system, while model inputs that influenced pollutant build up and removal rates were also set to conservative values. Thus linear build up rates were selected while no maximum values are placed on F. Coli.

- **Seasonal Variation**

Seasonal variations were incorporated in the case of agricultural activities, such as for the use of fertiliser. For other loads including F. coli, no seasonal variations were assumed. This decision was based on the fact that the remaining loadings are for the most part relatively constant. In some instances small variations may occur. These, however, are expected to be relatively small and the available data are not in a position to differentiate these load factors seasonally. More importantly, however, it is believed that such variations will have not only minimal but also an erratic effect due to the fact that the large seasonal variability of rainfall and the fact that the catchment is characterised by long periods of no or minimal water flows.

4. CONCLUSIONS

TMDL Summary and discussion

In order to facilitate pollutant allocations and the detailed design of measures, the contribution of pollutant loads of each land use category in each sub catchment has also been calculated on the above tables. These will be utilised in the next stages of the project for the detailed definition of measures.

It is noted that TMDL reduction targets, and consequently the resulting pollutant allocations, can have a profound impact on permitting and land use development policies. It is therefore important that practically achievable targets are set.
By definition, the TMDL should be an expression of the maximum daily load value which represents the allowable upper limit of pollutant loads entering a water body that adequately protects the water body in the long term. Selecting a constant daily average value can thus constitute an overburden as the daily peak may require unpopular or costly measures or may even be practically impossible. Several methods may be applied to overcome this problem.

For example an appropriate maximum load from the daily load dataset could be a percentile load value that will account for high-flow events while not relying too heavily on potential outlier values. Setting a daily value on this basis (e.g., 90th, 95th, or 99th percentile) requires high confidence in the original analysis and data representing the initial conditions. A lower percentile is appropriate if there is concern that the model could over-predict loads on individual days.

Since TMDL analyses is highly dependent on the data on which they are built and since a theoretical percentile value can again be subject to issues of representativeness and the selection of the right percentile, the project team has opted to adopt the TMDLs time series distribution that is produced from the large-scale utilization of selected BMPS, provided of course that the annual / seasonal average criterion is achieved. Thus it is possible that in the next stages of the project the daily peak criterion is readjusted. In any case, the resulting final pollutant loads will justify the selected pollutant concentration criteria.

In conclusion, the above Total Maximum Daily Loads will constitute key components of the Watershed Management Program. The five-year cycle of the period 2005-2009 provides o reliable basis for assessing water impairments and developing TMDLs. It is noted, however, that the lack of systematic long term monitoring data, was a limiting factor which required the adoption of conservative assumptions during model calibration. This may be a point of conflict in the next phases as some measures may be characterized as excessive. The management measures that will be produced in the next phases of the project will therefore need to consider these underlying assumptions. It is also important that the measures are well defined and explained during the next phase of consultations such that an achievable, consensus driven program of measures is produced.

5. References

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- **Urban storm water pollutant sources.** Per-Ame Malmquist and Gilbert Svensson, 200
- TMDL Report
- Nutrient, Un-ionized Ammonia, and DO TMDLs for Lake Trafford (WBID 3259W) Woo-Jun Kang, Ph.D. and Douglas Gilbert. June 2008
- WATER project, DELIVERABLE 3: LIST OF ECOLOGY- DRIVEN WATER QUALITY INDICATORS AND CRITERIA VALUES

Annex I – Land Use Code Definitions

Source ID	Source Description	Target ID	Area (Hectares)
PERLND 108	Sclerophylous vegeta	RCHRES 1	188.5
PERLND 102	Industrial or commer	RCHRES 1	72.7
IMPLND 102	Industrial or commer	RCHRES 1	218.1
PERLND 110	Discontinuous urban	RCHRES 1	32.5
IMPLND 110	Discontinuous urban	RCHRES 1	32.5
PERLND 112	Land principally occ	RCHRES 1	99.5
PERLND 115	Complex cultivation	RCHRES 1	155.1
PERLND 105	Non-irrigated arable	RCHRES 1	18.6
PERLND 102	Industrial or commer	RCHRES 2	49.9
IMPLND 102	Industrial or commer	RCHRES 2	149.7
PERLND 112	Land principally occ	RCHRES 2	26
PERLND 115	Complex cultivation	RCHRES 2	8.7
PERLND 105	Non-irrigated arable	RCHRES 2	131.3
PERLND 102	Industrial or commer	RCHRES 9	21.3
IMPLND 102	Industrial or commer	RCHRES 9	63.9
PERLND 105	Non-irrigated arable	RCHRES 9	687.2
PERLND 110	Discontinuous urban	RCHRES 10	84.7
IMPLND 110	Discontinuous urban	RCHRES 10	84.7
PERLND 103	Green urban areas	RCHRES 10	41.3
IMPLND 103	Green urban areas	RCHRES 10	13.8
PERLND 104	Salt marshes	RCHRES 10	0
PERLND 115	Complex cultivation	RCHRES 10	228.1
PERLND 105	Non-irrigated arable	RCHRES 10	363.8
PERLND 102	Industrial or commer	RCHRES 5	34.1
IMPLND 102	Industrial or commer	RCHRES 5	102.4
PERLND 105	Non-irrigated arable	RCHRES 5	1511.2
PERLND 102	Industrial or commer	RCHRES 8	77.8
IMPLND 102	Industrial or commer	RCHRES 8	233.3
PERLND 110	Discontinuous urban	RCHRES 8	84.7
IMPLND 110	Discontinuous urban	RCHRES 8	84.7
PERLND 103	Green urban areas	RCHRES 8	13.6
IMPLND 103	Green urban areas	RCHRES 8	4.5
PERLND 104	Salt marshes	RCHRES 8	0.8
PERLND 115	Complex cultivation	RCHRES 8	134
PERLND 105	Non-irrigated arable	RCHRES 8	1352.7
PERLND 102	Industrial or commer	RCHRES 11	37.8
IMPLND 102	Industrial or commer	RCHRES 11	113.5
PERLND 110	Discontinuous urban	RCHRES 11	0.9
IMPLND 110	Discontinuous urban	RCHRES 11	0.9
PERLND 115	Complex cultivation	RCHRES 11	13.8
PERLND 102	Industrial or commer	RCHRES 4	10.1
IMPLND 102	Industrial or commer	RCHRES 4	30.3

PERLND 110	Discontinuous urban	RCHRES 4	147.2
IMPLND 110	Discontinuous urban	RCHRES 4	147.2
PERLND 103	Green urban areas	RCHRES 4	166.8
IMPLND 103	Green urban areas	RCHRES 4	55.6
PERLND 104	Salt marshes	RCHRES 4	0
PERLND 113	Continuous Urban Fab	RCHRES 4	24.4
IMPLND 113	Continuous Urban Fab	RCHRES 4	73.2
PERLND 114	Sport and leisure fa	RCHRES 4	25.7
IMPLND 114	Sport and leisure fa	RCHRES 4	2.9
PERLND 102	Industrial or commer	RCHRES 3	10.3
IMPLND 102	Industrial or commer	RCHRES 3	30.9
PERLND 110	Discontinuous urban	RCHRES 3	4.3
IMPLND 110	Discontinuous urban	RCHRES 3	4.3
PERLND 105	Non-irrigated arable	RCHRES 3	841.6
PERLND 106	Transitional woodlan	RCHRES 7	112.2
PERLND 107	Annual crops associa	RCHRES 7	218.7
PERLND 108	Sclerophylous vegeta	RCHRES 7	100.6
PERLND 102	Industrial or commer	RCHRES 7	52.8
IMPLND 102	Industrial or commer	RCHRES 7	158.5
PERLND 109	Sparsely vegetated a	RCHRES 7	561.6
PERLND 110	Discontinuous urban	RCHRES 7	303.2
IMPLND 110	Discontinuous urban	RCHRES 7	303.2
PERLND 103	Green urban areas	RCHRES 7	30.4
IMPLND 103	Green urban areas	RCHRES 7	10.1
PERLND 111	Bare rocks	RCHRES 7	17.4
IMPLND 111	Bare rocks	RCHRES 7	52.1
PERLND 104	Salt marshes	RCHRES 7	0
PERLND 112	Land principally occ	RCHRES 7	143.5
PERLND 105	Non-irrigated arable	RCHRES 7	2548.6
PERLND 101	Airports	RCHRES 6	73
IMPLND 101	Airports	RCHRES 6	73
PERLND 102	Industrial or commer	RCHRES 6	5.2
IMPLND 102	Industrial or commer	RCHRES 6	15.6
PERLND 103	Green urban areas	RCHRES 6	83.8
IMPLND 103	Green urban areas	RCHRES 6	27.9
PERLND 104	Salt marshes	RCHRES 6	1259.7
PERLND 105	Non-irrigated arable	RCHRES 6	1.1