Transport, fate and management of contaminants in the Mount Lofty Ranges

September 2007 Milestone report.

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Transport, fate and management of contaminants in the Mount Lofty Ranges:
Third Milestone report to the Centre for Natural Resource Management

September 2007

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EXECUTIVE SUMMARY

This is a brief interim report which gives examples of progress to date on the water quality research being done at four sites in the Adelaide hills. A more detailed report will be written by June 2008. This will be the final report to the Centre for Natural Resource Management but will not be the final report for the project. The South Australian Apple and Pear Growers Association is seeking funding to extend the project so that the nutrient transport research runs in parallel for the full length of time of the pesticide transport research being funded by the Australian Centre for International Agricultural Research (ACIAR). The ACIAR project will research the interrelationship between nutrients and pesticides in their generation, transformation and delivery to water bodies. Also, some aspects of the work will continue beyond June 2008 as the South Australian Research and Development Institute and CSIRO Land and Water's contribution to CRC eWater.

The project is designed to research differences in the forms of nutrients generated from texture contrast soils in a Mediterranean climate. This research will help in the design of remedial techniques. Findings from this work and the datasets compiled during this research will help in the refinement of the E2 water quality model. The E2 model is currently being developed as part of an applications project by CRC eWater for the Mt Lofty Ranges.

INTRODUCTION

Background

In the Mount Lofty Ranges, an important environmental concern is the potential for high concentrations of nutrients in westward flowing streams. Some of the activities that can contribute to high nutrient content in surface water include nutrients in runoff from agricultural lands in the peri-urban environment, poorly maintained septic tank systems, allowing livestock access to watercourses, excessive applications of fertiliser, and vegetation clearance. Water quality information has been reported in documents produced by the Catchment Water Management Boards and the EPA (e.g. SA EPA 1998[1]).

An understanding of the impact of control measures (such as riparian vegetation) to reduce the level of these contaminants is an essential prerequisite for policy guidelines. However, the processes and pathways by which nutrients move off catchments into streams must be understood before the impacts of remediation strategies can be assessed. Changing land use within the Mount Lofty Ranges has greatly changed the quality and pattern of stream flow. This has potentially harmful consequences for the ecological values of water-dependent ecosystems. The protection of the health of the streams, ecosystems and public water supply reservoirs from nutrient impacts associated with agricultural development and changes to stream flow regime are key management goals of the EPA and the Interim Integrated Natural Resource Management Group for the Mount Lofty Ranges and Greater Adelaide.

[1] Regional water quality information is also provided in the following reports:
http://www.epa.sa.gov.au/pdfs/wmr_rivers_streams.pdf#search='Myponga%20water%20quality%20monitoring';
http://www.environment.sa.gov.au/reporting/inland/water_quality/exceedriversstreams.html
http://www.epa.sa.gov.au/pdfs/mlrwpo_2003.pdf

Currently there is a lack of clear understanding of the sources, generation process, and forms of nutrients and their pathways through surface water, throughflow or groundwater in the Mt Lofty Ranges. This is a significant shortcoming in our ability to determine the most effective way to manage the nutrients and to determine the true effectiveness of mitigation strategies. These strategies include the minimum width of riparian vegetation strips needed at strategic points along a watercourse to maximise nutrient retention. In addition the nutrient source areas change spatially and temporally. These high risk or "sensitive" areas must be delineated and prioritised to maximise the effectiveness of a mitigation strategy.

Project Description

The overarching research question is: what roles do soil conditions, slope, precipitation frequency and intensity play in the movement and forms (dissolved versus particulate; organic versus inorganic) of nutrients (and thus the effectiveness of on-ground nutrient mitigation measures e.g., riparian vegetation strips).

The first project task was to set up a committee of key research, water management and policy providers with an interest in the western Mount Lofty Ranges. The committee set the research plan, which determined the number, location and design of field experimentation sites. Charleston and Cock Creek catchments contained suitable field experimentation sites. The prevalent land uses chosen were production of apples, cherries and grapes.

OBJECTIVES

- Quantify the timing, quantity and forms of nutrients (P and N) from agricultural activities and their potential impact on downstream ecosystems and reservoirs in the Mt Lofty Ranges;
- Provide advice on restoration techniques to reduce losses of nutrients and minimise negative impacts on downstream ecosystems.

FIELD SITES: EQUIPMENT SETUP AND WATER COLLECTION

Location

The locations of the field sites is shown in Figure 1.

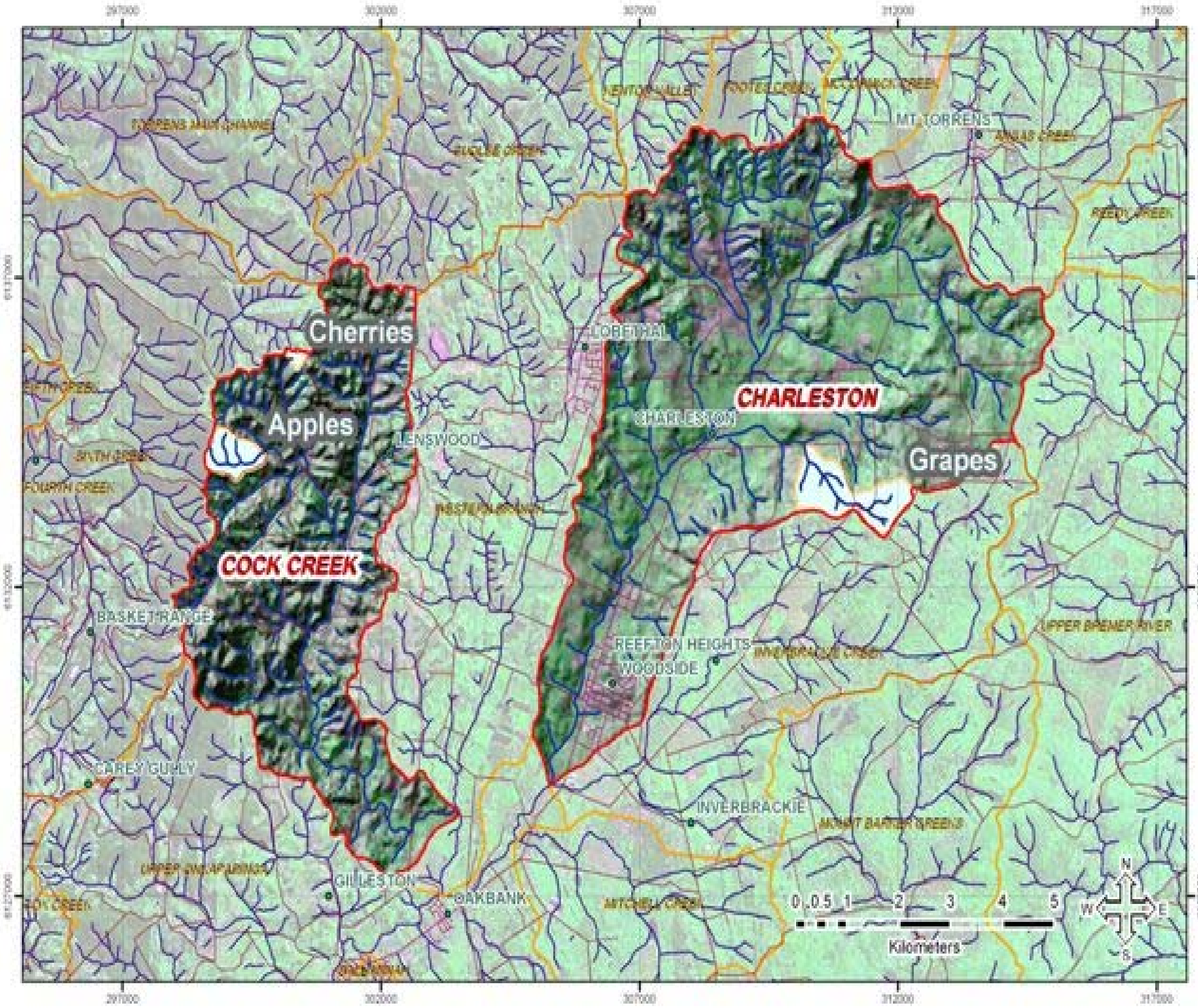

Figure 1. Field site locations.

Equipment setup

Site - Cherries

Runoff from an area of cherries in Cock Creek catchment is being monitored: This is an 8 ha catchment with Broadscale grazing (41%), Stonefruit (34%) and Native vegetation (25%). Water flow is measured over a rectangular weir with end contractions at this site. Flow weighted samples are taken by autosampler at preset flow intervals.

Figure 2. Measurement weir at the cherries site.

Site - Apples

Runoff from an area of apples in Cock Creek catchment is being monitored: A 64 ha catchment with Pomefruit (54%), Exotic vegetation (14%) and native vegetation (13%). Flow is measured through an existing culvert by a Doppler flowmeter with combined depth and velocity sensor.

Figure 3. Velocity and depth sensor of flowmeter at the apples site.

Grapes

Runoff from an area of vines in Charleston catchment is being monitored: A 155 ha catchment with Vines (27%), Broadscale grazing (39%) and Intensive grazing (32%). There are two measurement points at this site - one above and one below a large dam which contains a reed bed. The upper site - Grapes (upper) - measures flow over a rectangular weir with end contractions. The lower site - Grapes (lower) - measures flow over a concrete spillway, using the existing structure as the flow control.

Figure 4. Monitoring equipment at the grapes upper site.

Figure 5. Location of sampling equipment at the grapes lower site.

Surface Runoff Water Collection

The four sites are instrumented with a flowmeter which controls flow-weighted sample collection via an autosampler. Telemetry is fitted to all sites to allow remote download, adjustment and resetting of flow measurement equipment and monitoring of site status. This allows timely and efficient collection of water samples through early notification of sampling activity. All sites have solar panels and batteries and operate independently of 240 volt power. Although the installed power systems are designed to support the higher power requirements of refrigerated autosamplers, the sites are currently fitted with non-refrigerated samplers. South Australian EPA is funding the construction of two refrigerated water samples.

Each site is equipped with an ISCO model 4230 bubble flow meter, ISCO model 3700 autosampler, 60 or 80 watt solar panels and 4 x 65 Ah deep cycle batteries. All sites are also equipped with an Odyssey logging capacitance probe as a backup system for measurement of water flow.

CHEMICAL ANALYSES

Filtered ((<0.45 µm: termed soluble) and unfiltered water samples (total sample composed of "particulate" (>0.45 µm) + "soluble" (<0.45 µm fraction)) were analysed for various elements including nitrate, phosphate, total nitrogen, total phosphate, nonpurgeable organic carbon (NPOC), cations and metals. Each method is taken from the methods manual 'Standard methods for the examination of water and wastewater, 20th ed' published jointly in 1998 by the American Public Health Assoc., the American Water Works Assoc. and the Water Environment Federation is as summarised below for unfiltered and/or filtered samples:

- ***Nitrate (plus nitrite) nitrogen*** [APHA method 4500-NO_3^- F]. In this segmented flow analysis method nitrate is reduced to nitrite in an open tubular cadmium column in an atmosphere of helium then reacted with sulphanilamide and N-(1-naphthyl)-ethylenediamine dihydrochloride (NEDD) in phosphoric acid. The pink colour formed is determined colorimetrically using the automated segmented flow analyser (Alpkem Flow Solution 3) at 540nm. The NO_3-N (also referred to as NO_X-N indicating the sum of nitrite and nitrate nitrogen) concentration is calculated from a set of calibration standards measured at the same time.
  Nitrate can also be determined by ion chromatography but the colorimetric procedure is more sensitive with a lower detection limit than the IC method.

- ***Dissolved reactive phosphorus*** [APHA method 4500-P F]. This is often referred to as molybdate reactive phosphorus. This is also a segmented flow method (Alpkem Flow Solution 3). The sample reacts with ammonium molybdate and potassium antimony tartrate at pH 1 and reduced with ascorbic acid solution then heated to 37°C to produce a blue colour measured at 880nm. The phosphate concentration is calculated from a set of calibration standards measured at the same time.

- ***Total Nitrogen*** [Skalar Analytical (Breda, Netherlands) Formacs HT TOC/TN Analyzer with chemiluminescence detector instruction manual]. Total nitrogen is determined at the same time as total carbon on this dual detector instrument. Combustion occurs at 950°C using a cobalt catalyst and nitrogen is determined by chemiluminescence.

- ***Total phosphorus*** [APHA method 4500-P B4 digestion method]. The sample is digested in a hot block using 10mL sample plus 1mL sulfuric acid with a trace of nitric acid and digest to 0.5mL. Add water, neutralise and determine PO_4-P using method 4500-P F above.

- ***Cations and metals*** [APHA method 3120]. A range of elements are determined by Inductively Coupled Plasma Optical Emission Spectroscopy (ICPOES). The sample is nebulised into the plasma of a Spectroflame Modula (Spectro Analytical Instruments, Kleve, Germany). The emission spectra of the elements of interest are measured simultaneously. This instrument uses nitrogen-filled optics for UV spectral lines and air-filled polychromators for the other spectral lines. This determines the major cations (Ca, K, Mg and Na) along with trace elements (Al, B, Cu, Fe, Mn, Sr and Zn) and the non-metalic elements P, S and Si. Often total S by ICP is compared to SO_4-S by IC to determine if non sulfate sulfur is significant.

- ***Organic carbon*** [APHA method 5310 B]. TOC or DOC (dissolved organic carbon) can be determined directly or by the difference between total carbon and inorganic carbon. Alternatively the organic carbon can be determined directly by acidification of the sample in the sample tube and CO_2 removed by purging with CO_2-free air. The sample is then analysed in the same manner as total carbon and the result reported as nonpurgeable organic carbon (NPOC). Total carbon (or NPOC) is determined by injecting the sample into a high temperature combustion system (Skalar Formacs HT TOC Analyzer). Organic carbon is oxidised to CO_2 and inorganic carbon is decomposed to CO_2 which is measured by a nondispersive infrared detector.

RESULTS

Rainfall

Rainfall figures for Lenswood Research Centre are presented here in relation to the monitoring sites. All sites are within 10 km of the Lenswood centre and are moderately comparable.

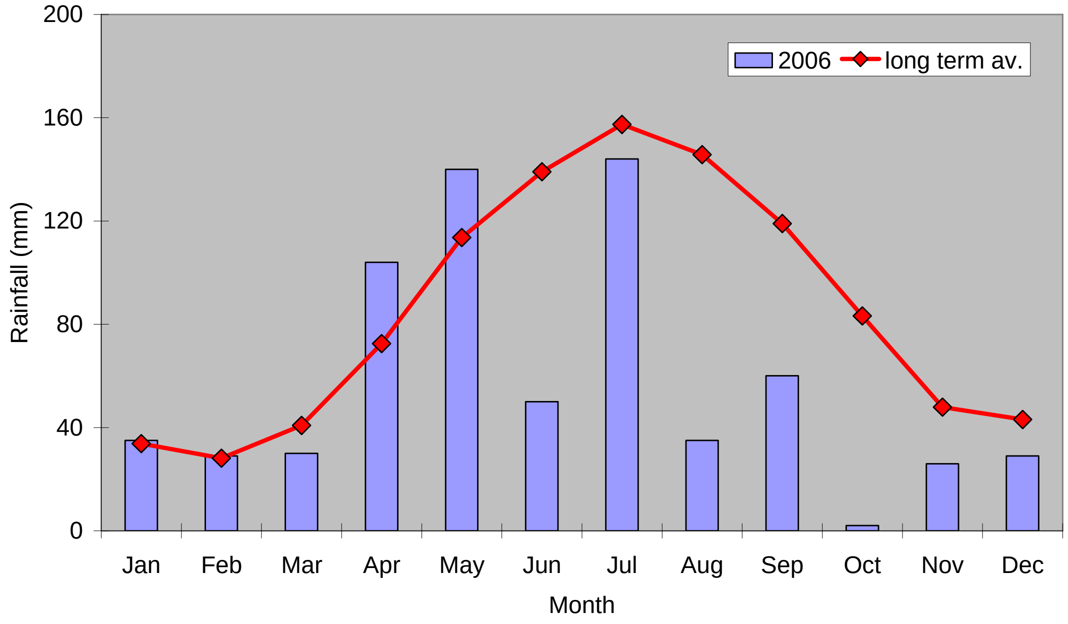

Figure 6. Long term average and 2006 monthly rainfall at Lenswood Research Centre

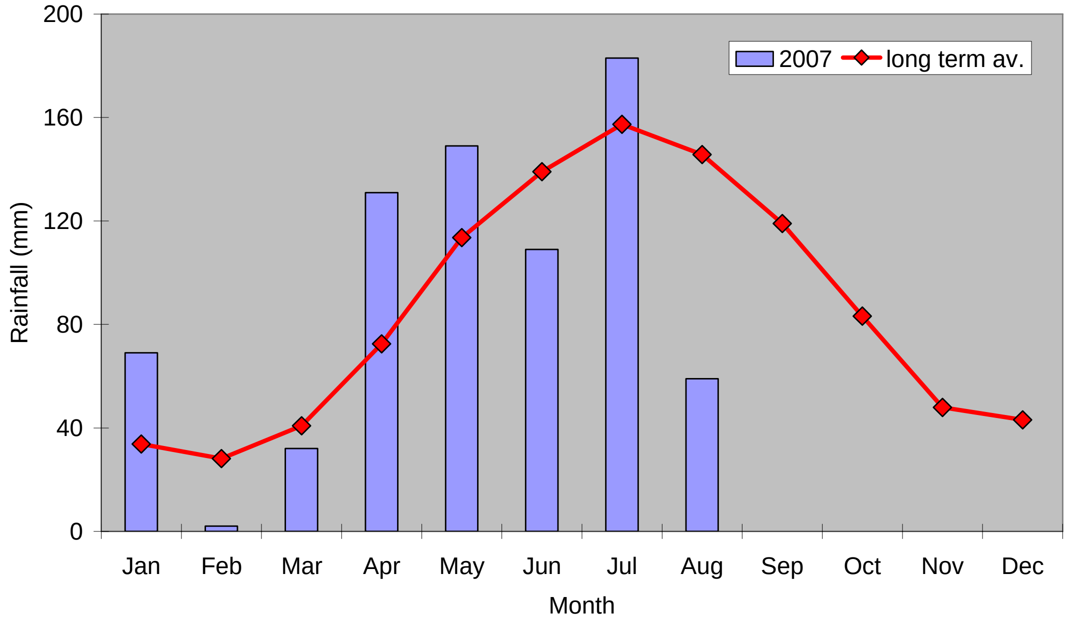

Figure 7. Long term average and 2007 rainfall at Lenswood Research Centre

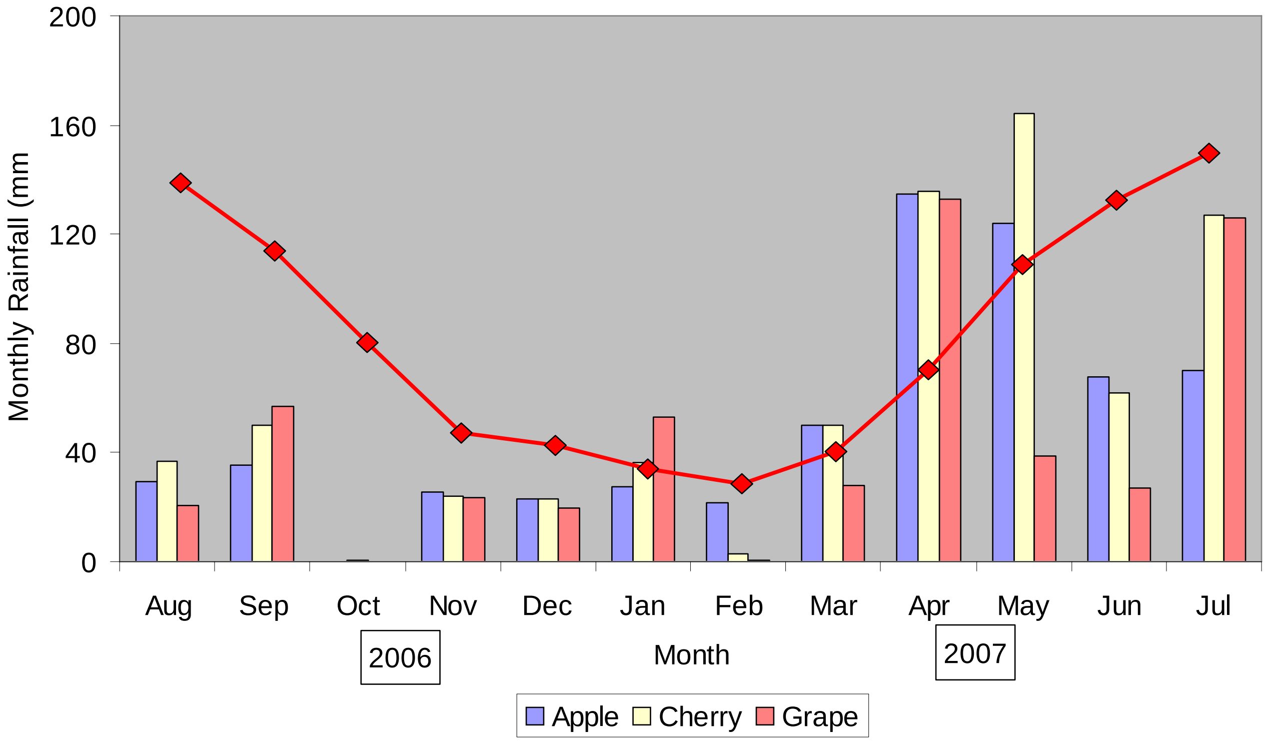

Figure 8. Monthly rainfall at sites during study period and long-term average rainfall

Apples

This 64 ha catchment is instrumented with a Doppler flow meter and autosampler. Around 6% of rainfall was measured as runoff. The following charts show flow weighted sampling during a typical runoff event.

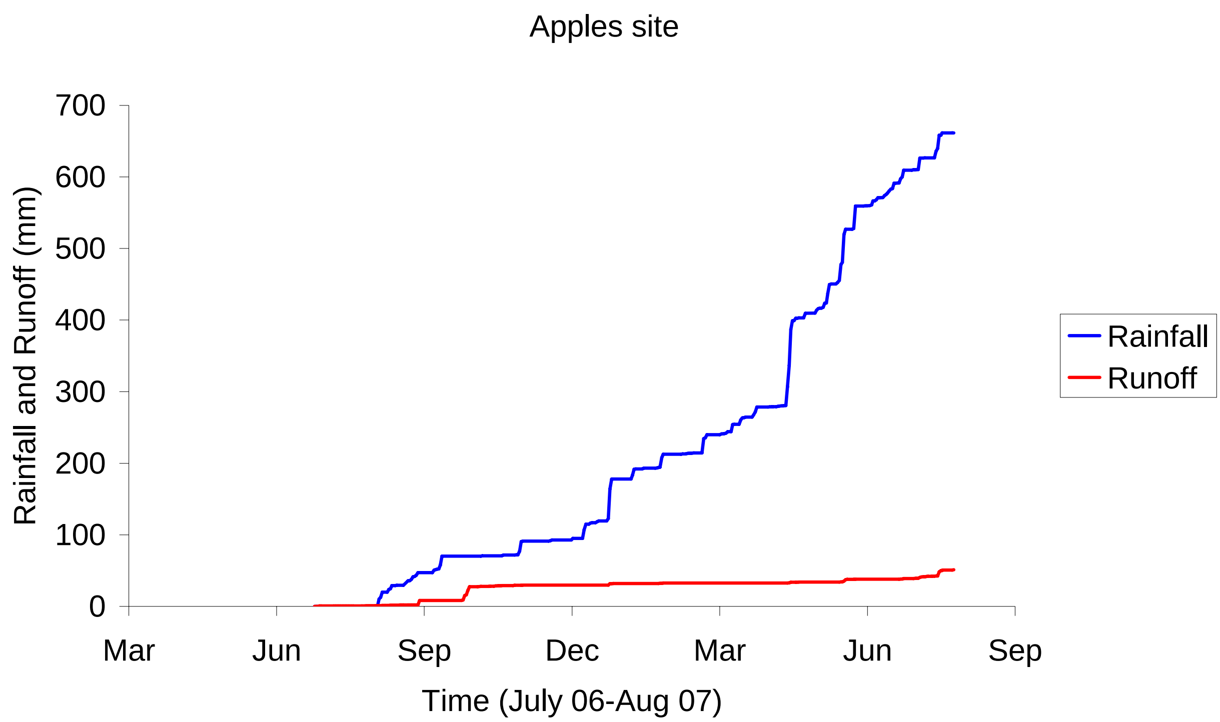

Figure 9. Rainfall and runoff at the apples site (Cock Creek) during the study period.

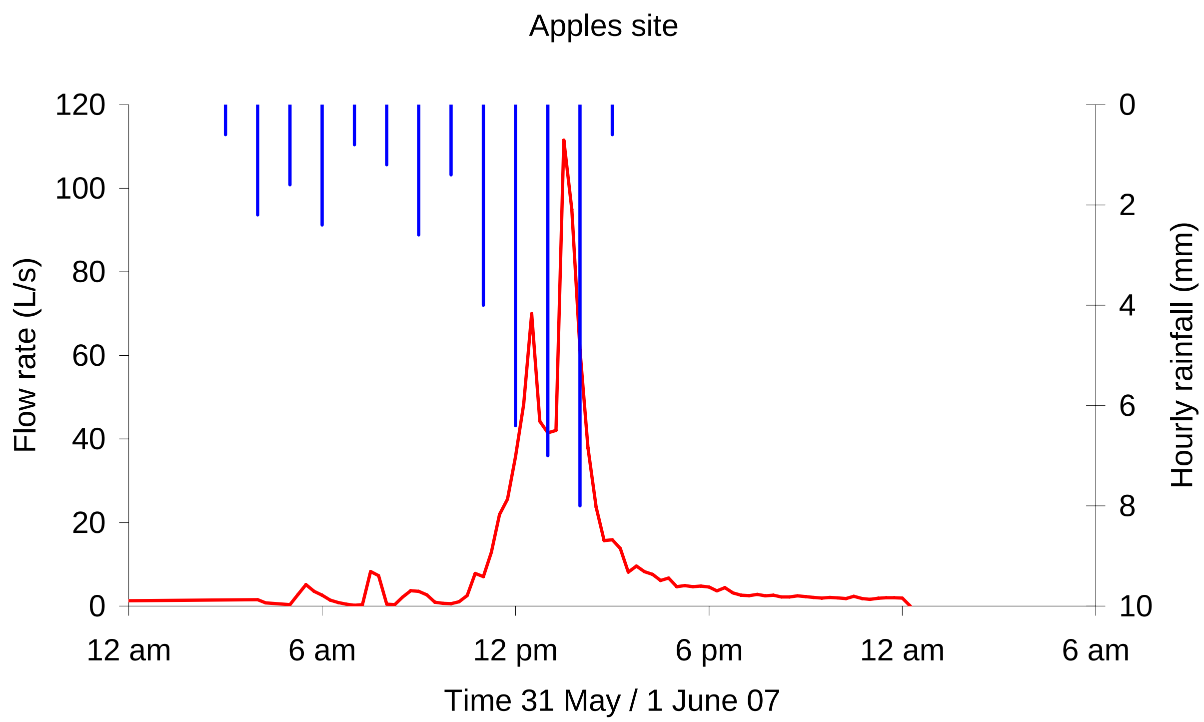

Figure 10. Rainfall and flow rate at the apples site (Cock Creek).

Around 0.82 ML of runoff was generated from the 39 mm of rainfall shown here.

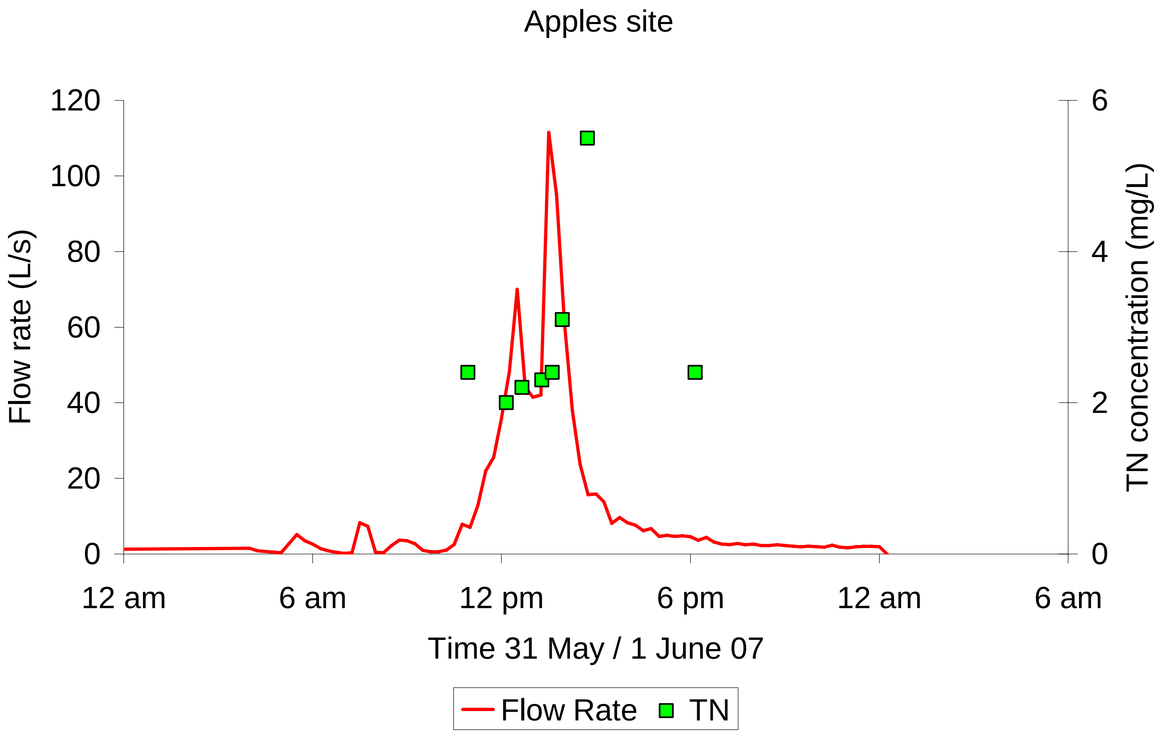

Figure 11. Total nitrogen in unfiltered samples, May 2007.

There was considerable variability in the total nitrogen concentrations during this event.

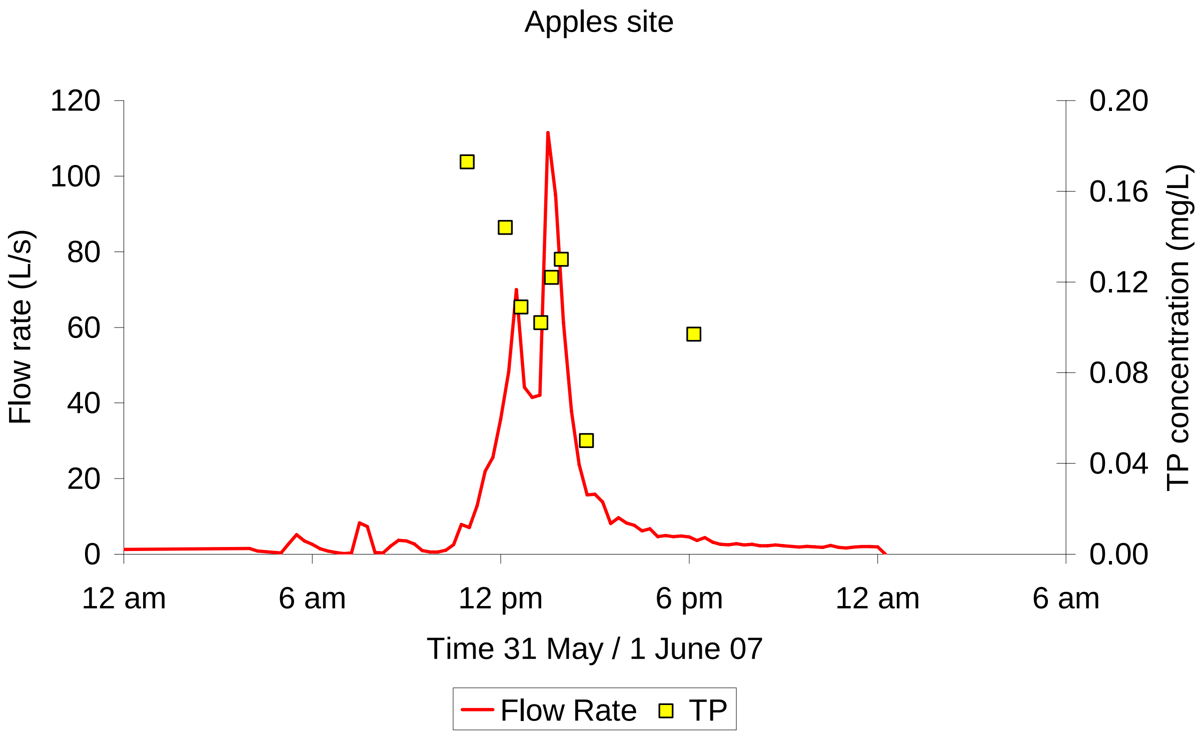

Figure 12. Total phosphorus in unfiltered samples, May 2007.

Total phosphorus concentrations appeared to have a downward trend.

Cherries

This 8 ha catchment is instrumented with an ISCO flow meter and autosampler.

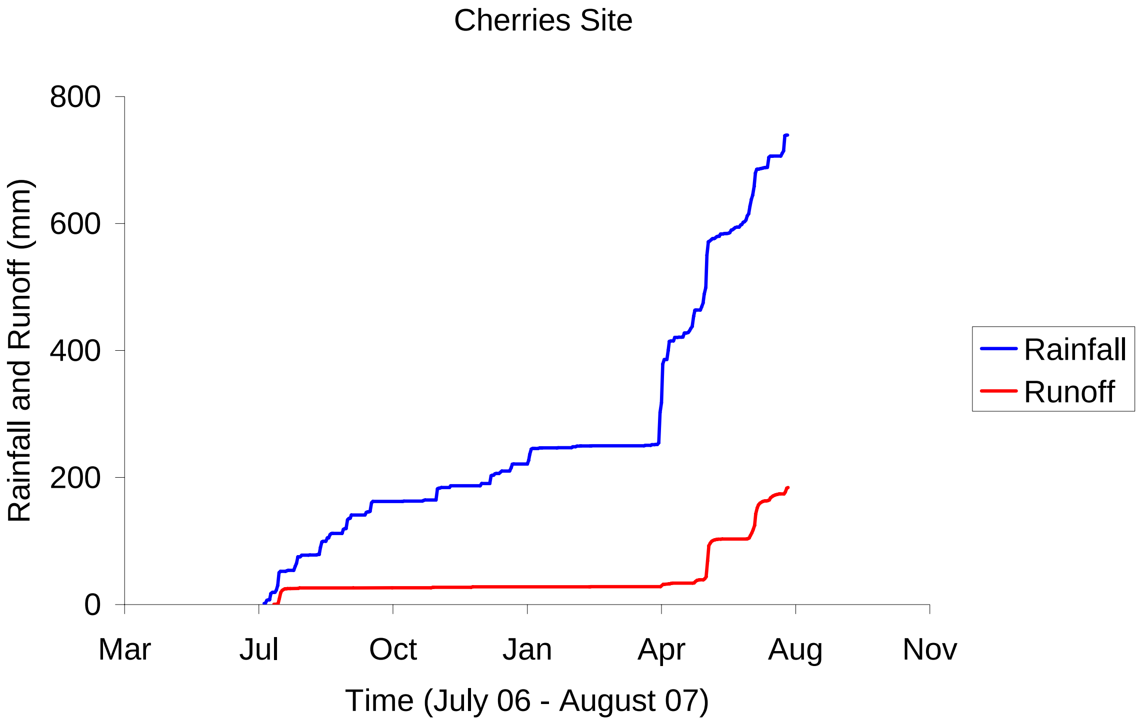

Figure 13. Rainfall and runoff at the cherries site (Cock Creek).

Around 25% of rainfall was measured as runoff. This is a higher runoff proportion than the other sites, although the cherries site is steeper than the grapes site. It also does not have dams or water storages upstream of the measurement point as the other sites do.

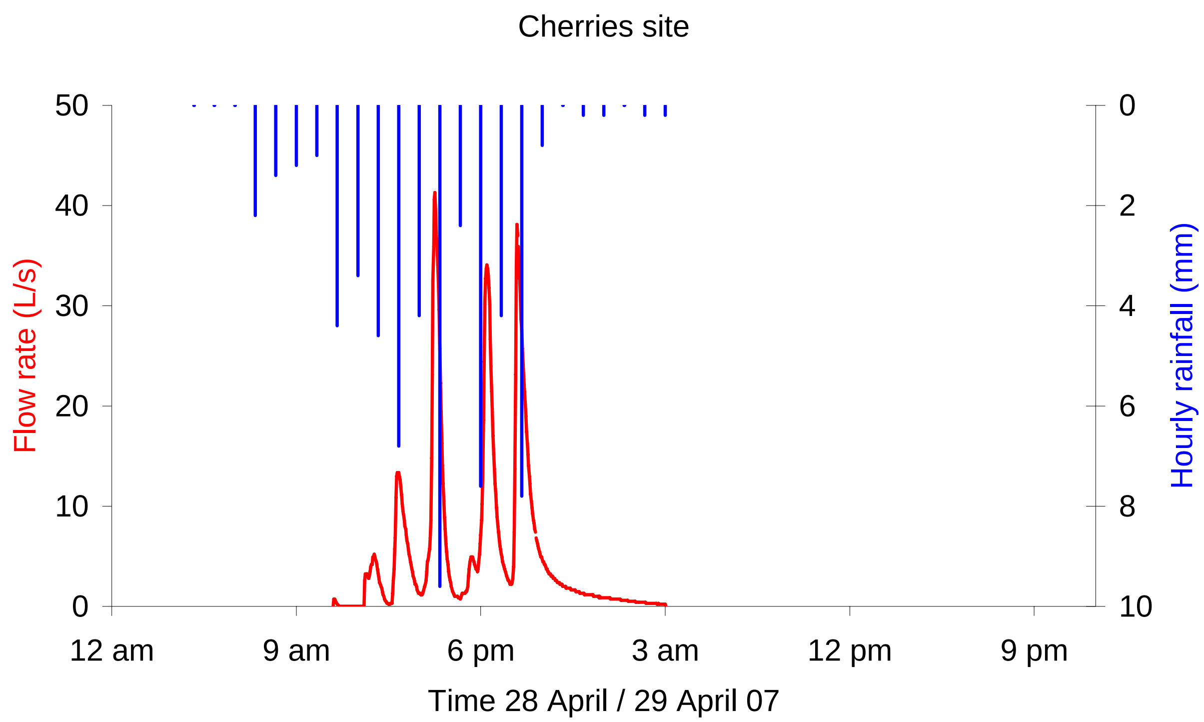

Figure 14. Rainfall and flow rate at the cherries site (Cock Creek).

Around 0.31 ML of runoff was generated from the 62 mm of rainfall shown below.

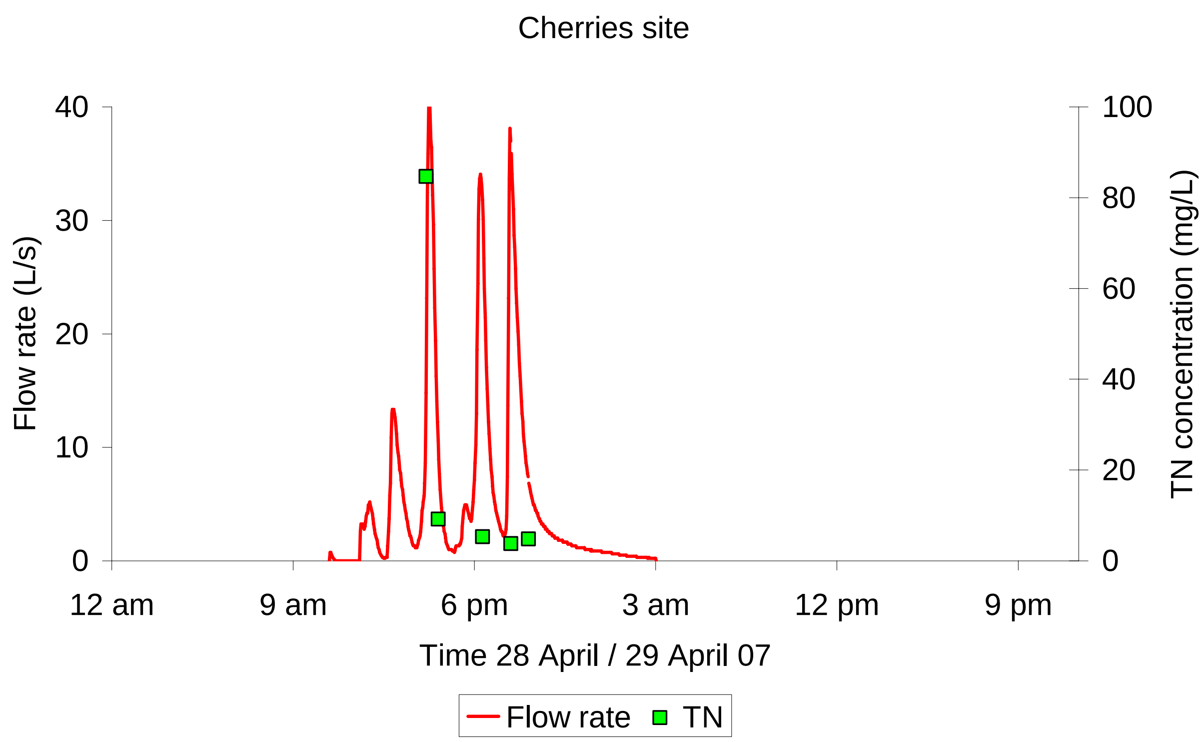

Figure 15. Total nitrogen in unfiltered samples, May 2007.

The first runoff sample showed an elevated total nitrogen concentration compared to the others. This is consistent with a "first flush" following an extended dry period.

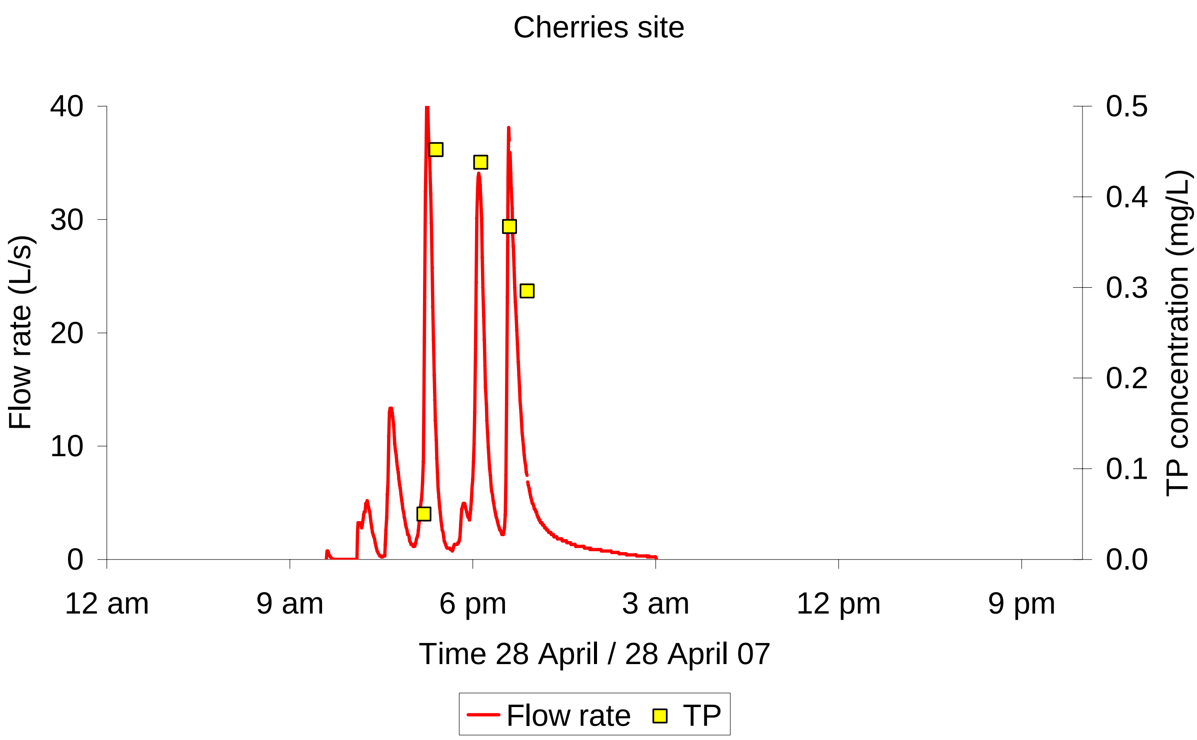

Figure 16. Total phosphorus in unfiltered samples, May 2007.

It is interesting to note that the first sample had a low total phosphorus concentration. This is the opposite of total nitrogen and may reflect different generation and transport processes between the two contaminants.

Grapes

This catchment is instrumented with an ISCO flow meter and autosampler. Although the full catchment is 155 ha, it is divided at the top of the grape area by a large dam. This dam collects water from the upper catchment and has not overflowed during the study period. Because of this, all runoff measured at the upper grapes site has been generated from the grape area alone. This is an area of around 24 ha.

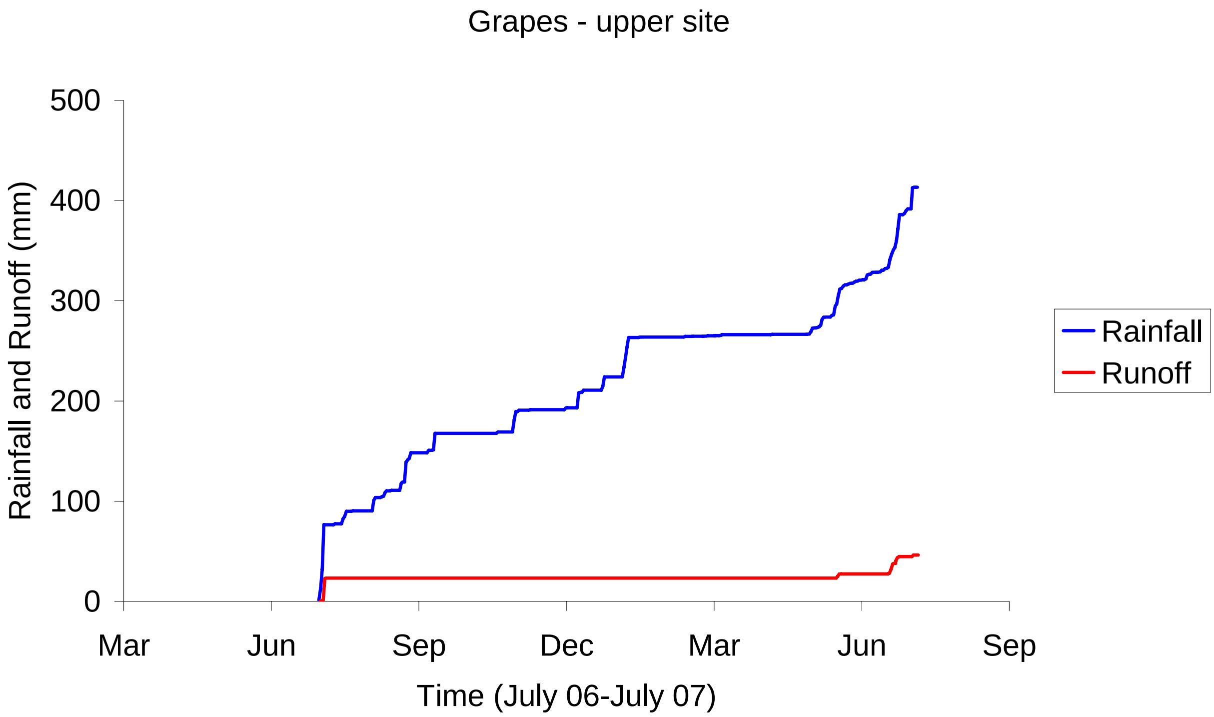

Figure 17. Rainfall and runoff at the grapes upper site (Charleston).

Over the time of the study, 46 mm of water has left as runoff. This is 11% of rainfall during that period.

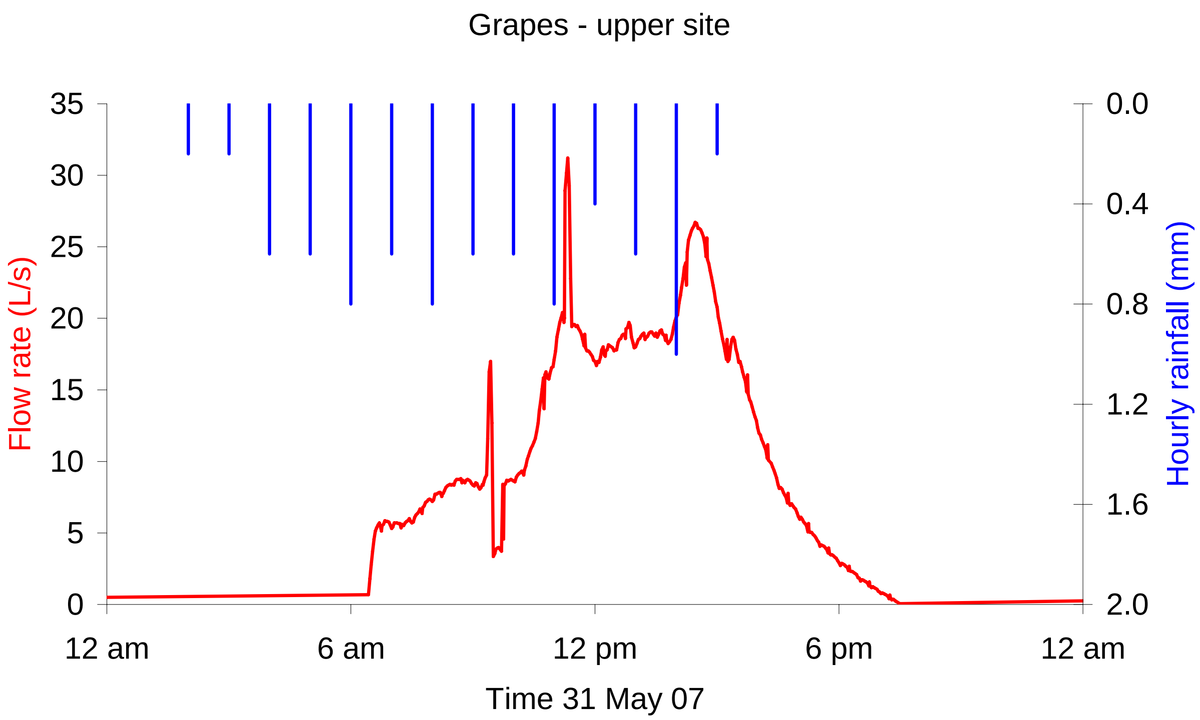

Figure 18. Flow Rate and Rainfall Events at the grapes upper site.

Around 0.54 ML of runoff was generated from the 8 mm of rainfall shown here.

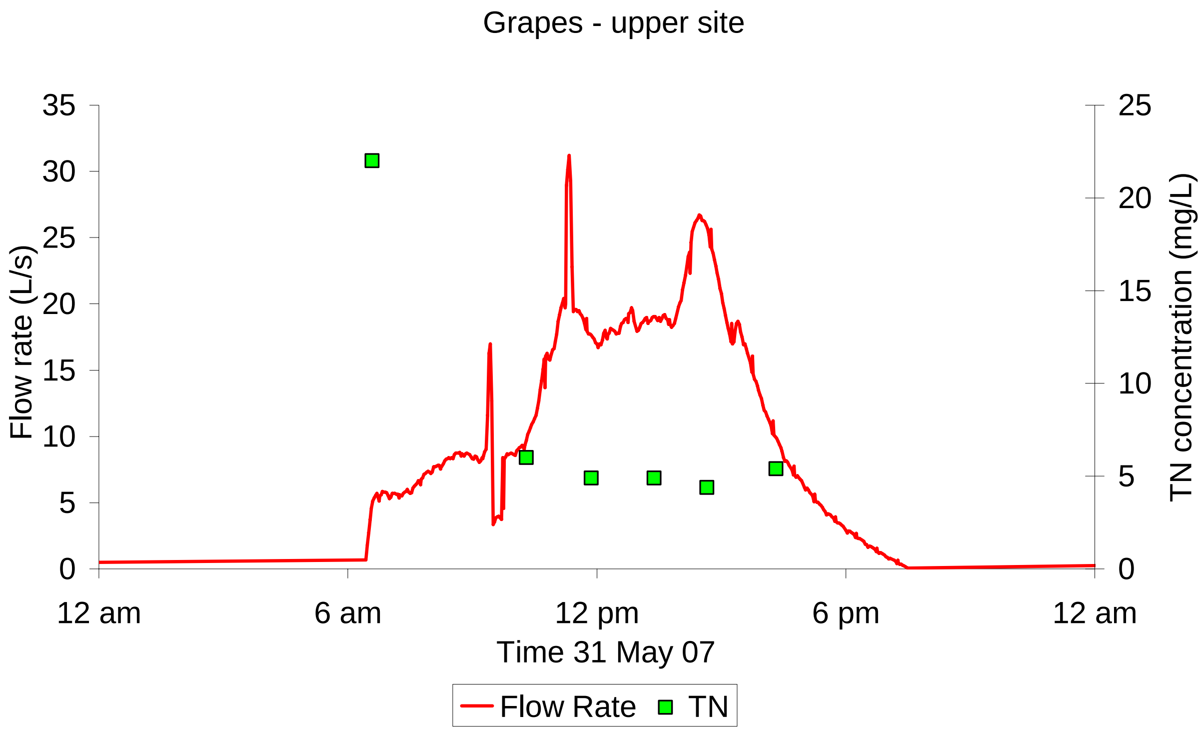

Figure 19. Total nitrogen in unfiltered samples, May 2007.

The first sample showed an elevated total nitrogen concentration, similar to the pattern at the cherries site.

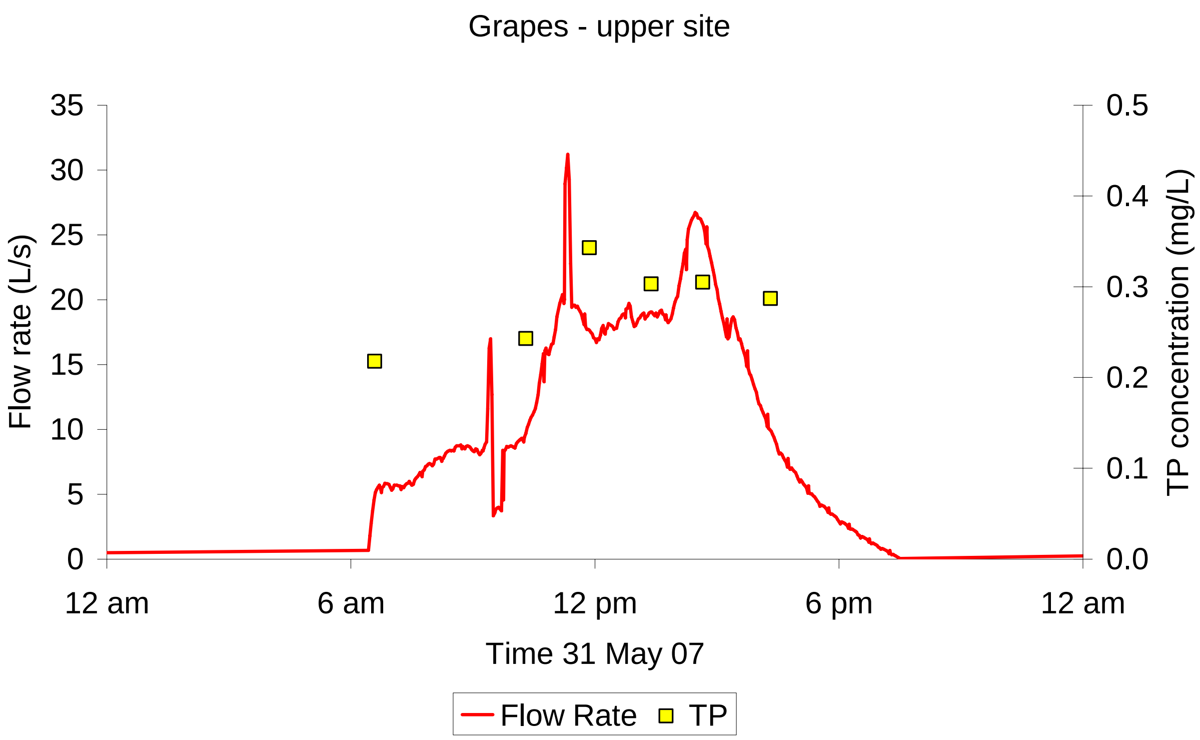

Figure 20. Total phosphorus in unfiltered samples, May 2007.

There was no obvious change in total phosphorus concentration during this flow event.

Summary data for the apple, cherry and grape sites

Table 1. Rainfall and runoff at the four sites (July 06-July 07)

Site	Rainfall (mm)	Runoff	
		(mm)	(%)
Apples	609	38	6
Cherries	739	184	25
Grapes (upper)	413	46	11
Grapes (lower)	413	26	6

Runoff ranged from 6% to 25% of incident rainfall. There was less runoff from the lower grapes site than the upper grapes one due to the amount required to fill the dam between the sites before it overflowed and runoff was measured at the lower site.

Table 2. Concentrations of total N, P and TOC at the four sites (July 06-July 07).

Site	TN (mg/L)	sd	TP (mg/L)	sd	TOC (mg/L)	sd
Apples	1.4	1.1	0.07	0.04	4.6	2.0
Cherries	10.2	16.0	0.11	0.13	18.6	42.7
Grapes (upper)	5.3	3.2	0.29	0.10	23.9	14.6
Grapes (lower)	3.5	5.1	0.15	0.06	15.2	11.8

Table 3. Loads of total N, P and TOC at the four sites (July 06-July 07).

Site	TN (kg/ha)	TP (kg/ha)	TOC (kg/ha)
Apples	0.65	0.03	1.61
Cherries	11.0	0.12	21.5
Grapes (upper)	21.7	1.19	111
Grapes (lower)	8.1	0.41	36.8

These measured loads are within a factor of two or three of those measured by Wood (1986) in the Mount Lofty Ranges, albeit at larger scale and under wetter conditions. These are shown in Table 4.

Table 4. Loads of total N and P in Mount Lofty Ranges catchment study by Wood (1986).

Land Use	TN load (kg/ha)	TP load (kg/ha)	Annual rainfall (mm)	Catchment Area (ha)
Urban with septic tanks	5.3	0.39	1100	830
Native Vegetation	1.5	0.10	1100	850
Grazing (small % forest)	4.6	0.20	750	500
Orchards (small % forest)	4.5	0.22	1050	1700
Market Gardening (small % forest)	26	2.7	1100	410

CONCLUSIONS

This interim data suggests that there will be differences in the timing of the generation and transformation and forms of nutrients from the different landuses.

Runoff monitoring sites are operating effectively for flow measurement and sampling and analysis of runoff for nutrient concentration and load. Closer examination of the analytical data (for example, comparison of the proportion of dissolved vs particulate phosphorus during events) will deliver information on the likely processes of nutrient movement at these sites. The effect of residence in, and movement from, a farm dam can be investigated by closer examination of results from samples above and below the dam.

Establishment of a robust group of monitoring sites such as this is an excellent basis for further process studies. These would potentially include upscaling (to existent catchment-level monitoring sites), downscaling (plot or lab studies) and hydrological work. Possibilities for hydrological work include installation of piezometers, investigation of groundwater pathways, and the interactions of surface and ground water at different scales.

REFERENCES

Wood G (1986) The Mount Lofty Ranges Watershed - Impact of land use on water quality and implications for reservoir water quality management. EWS 3319/86, Adelaide.

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