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WHAT'S COMING OUT OF TILE DRAINS?

Sarah de Bruin, Carl O'Brien, and Jonanthan Brookes

AgFirst Consultants Hawke's Bay
sarah.debruin@agfirst.co.nz

Abstract

Subsurface "tile drains" are common under high value horticulture crops in the Heretaunga Plains. Drainage systems are becoming increasingly important with the changing climate and increased frequency of extreme rainfall events. Horticultural growers want to proactively understand their impact on waterways, by measuring and mitigating their impact.

The SFFF and AgFirst "What's Coming Out of Tile Drains?" project, is looking at discharge from tile drains under apple, kiwifruit, and cropping sites across the Plains. This project seeks to understand the specific timing, scale and source of the nutrients and sediment when it leaves a cropping or orchard system through tile drains and enters surface water. The project will compare to the receiving water body to understand the catchment context and the relationship between the two.

The project spans three years, taking fortnightly grab samples from the tile drain exit and corresponding receiving water body point, to test for a nutrient suite range. "Event based" grab samples are also taken when a rainfall event greater than 15mm in 24 hours is recorded at a site. Flow meters and proportional samplers have also been installed at selected sites to provide complimentary datasets.

Grower on-farm practice data, local rainfall, soil moisture, soil nutrient content, and site-specific groundwater nutrient content is captured alongside the tile drainage discharge data, to inform the dynamic environment within which subsurface drainage exists.

Findings to date have illustrated the unique state of each tile, with flow behaviour, soil type, and ground water influence, all contributing to the discharge patterns and concentrations. These findings have informed understanding on how tile drainage flow fluctuates across the sites throughout seasons and during weather events, suggesting any mitigation strategies could differ by tile flow behaviour.

Now in the final year of monitoring, work is focussed on understanding whether any discharge seen is related to nutrient loss, and how horticultural land management may influence this.

Introduction & Project Overview

The SFFF and AgFirst "What's Coming Out of Tile Drains?" project seeks to proactively understand any impact that tile drain discharges have on water quality within the receiving environment and how horticultural land management practices influence the discharge parameters. Sites are located across the Heretaunga Plains, Hastings, and include sites within the Ngaruroro, Tukituki, and Karamu catchments.

To achieve this, 16 horticultural sites (8 apple orchards, 4 kiwifruit orchards and 4 cropping farms) are being assessed within a three-year monitoring programme with fortnightly grab samples collected from two tile drain outlets and two receiving water locations within each site.

Monitoring commenced in August 2021 and is scheduled to continue through until August 2024, meaning that two full years of data have now been collected.

The pH, temperature and dissolved oxygen reading of each water sample is recorded. All water samples are also analysed for:

- Total nitrogen,
- Ammonical nitrogen
- Nitrite nitrogen
- Nitrate nitrogen
- Total Kjeldhal nitrogen
- Total phosphorus
- Dissolved reactive phosphorus
- Total suspended solids

In addition, eight sites have flow meters & proportional sampling equipment installed on the tile drain exit, to allow for further data collection and understanding. Soil moisture tubes were also installed above each monitored tile drainage line to help understand movement of water through the profile.

Annual soil tests are also collected from each site to understand any changes over time from horticultural management activities. Soil samples are analysed for a basic soil testing suite, with the addition of nitrogen and organic matter.

Prior to commencement of monitoring, all tile drains were cleared out and mapped to make sure their extent was understood, and they were clear flowing without damage.

Farm Environment Plans (FEPs) were developed through Horticulture's Good Agricultural Practice (NZ GAP) assurance program for all sites, using the NZ GAP Environmental Management System (EMS) add-on, where standards are benchmarked to New Zealand environmental regulation. All monitored sites are at or above good management practice (GMP) level.

Findings to Date

As at the completion of year two monitoring, the following key findings have been identified:

- All tiles exhibit independent and unique flow patterns, even within the paired tile programme designed. Tile behaviours have been grouped into four key categories:
    - Dry: none or very few sampling events recorded during sampling runs;
    - Event: only flows following a rainfall event exceeding 15mm;
    - Seasonal: flows during spring, autumn and winter, but dry through summer; and
    - Continuous: continuous flow recorded year round.
- Temperature recorded from all tile drain flows to date has typically ranged from 12 to 20°C, including some sites presenting clear seasonal patterns. Only one sample exceeded 23°C (default guideline value for protection of instream biota) with 25.22°C recorded in January 2022. This matched the receiving water temperature adjacent but was lower than the upstream receiving water sample from the same site.
- All concentrations of nitrite recorded to date are < 1mg/L, the threshold set under Water Services (Drinking Water Standards for New Zealand) Regulations 2022. The highest recorded value at the completion of Year 2 is 0.13 mg/L, and little trend has been

observed in discharge patterns, confirming that Nitrite is not a priority issue within the tile drains assessed in this project.

- Total Suspended Solids (TSS) results have been low, with most samples <20 mg/L. Only four results exceed the threshold used for assessing the efficiency of Erosion and Sediment Control devices (200mg/L) and these are potentially outliers in the data set caused by an issue with the sampling process.
- E.Coli data is limited as only three sites have run stock through the monitoring period, however, from all data collected only 1 result has exceeded the TANK threshold. Therefore, insufficient data is present for determining the percentage of exceedances.

Data Analysis

In accordance with the National Policy Statement for Freshwater Management 2020 (Updated February 2023) (NPS Freshwater), statistical assessment of nutrient data collected up until the end of Year 2, being 31 August 2023, has been completed using descriptive statistical methods. For the purposes of determining whether individual tile discharges may be contributing to environmental impacts within water bodies, a 95% Upper Confidence Limit (UCL) calculation has been undertaken to determine with 95% certainty, what threshold tile drain discharges will not exceed.

The United States of America Environmental Protection Agency (US EPA) software package Pro-UCL was utilised to undertake 95% UCL calculations, including Shapiro-Wilk Normality tests to determine whether data series are normally distributed. While this assessment is not suitable for all analytical parameters, it is relevant for Nitrate, Ammoniacal-Nitrogen, Dissolved Reactive Phosphorous, and dissolved oxygen.

Goodness of Fit

Assessment of the population data series cannot be robustly undertaken at this stage as none of the Tile Drain data series present a statistically significant distribution. Further data will be required to increase the robustness of statistical measures. The following conclusions are reached:

- Several monitored sites have not recorded any appropriate data for assessment;
- No tile drain data series have a statistically significant distribution (either Normal at 1% or Lognormal at 10% that pass all goodness of fit tests);
- Assessment under Pro-UCL has been undertaken using the recommended distribution based on the data set at the time of this report. The majority of sites do not have discernible distribution at this stage, however normal, gamma and log normal have been utilised where recommended by Pro-UCL;
- Manipulation of the data series to remove the ‘0’ values and attribute these to an inconsequential low number cannot be undertaken on nearly all data series, as dry tiles (and hence ‘0’) occurs more than 25% of the time.

Caution must be applied in assessing the data series to date given the duration, goodness of fit results and associated significances.

Analytical Result Assessment

Flow

Flow meter data analysis has identified all sites have different lag times to peak flow, peak flow accumulation, and falling limb times back to base flow. This confirms the finding of the unique behaviour of individual tiles. A selection of Flow Meter data is set out below to demonstrate total accumulated daily flow against rainfall over time for these sites.

A03

This tile is often dry during sampling runs, however the flow meter data shows relatively flashy flow with a short lag time following rainfall over approximately 30mm per day. There are two periods of no flow, from mid October 2022 to late January 2023, and then March to late June 2023.

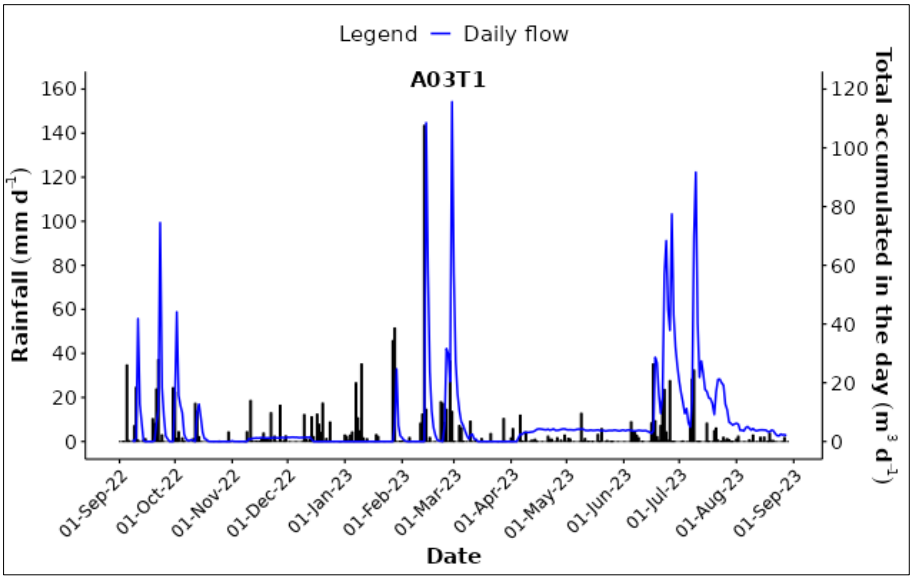

Figure 1: A03T1 Flow Data vs Rainfall

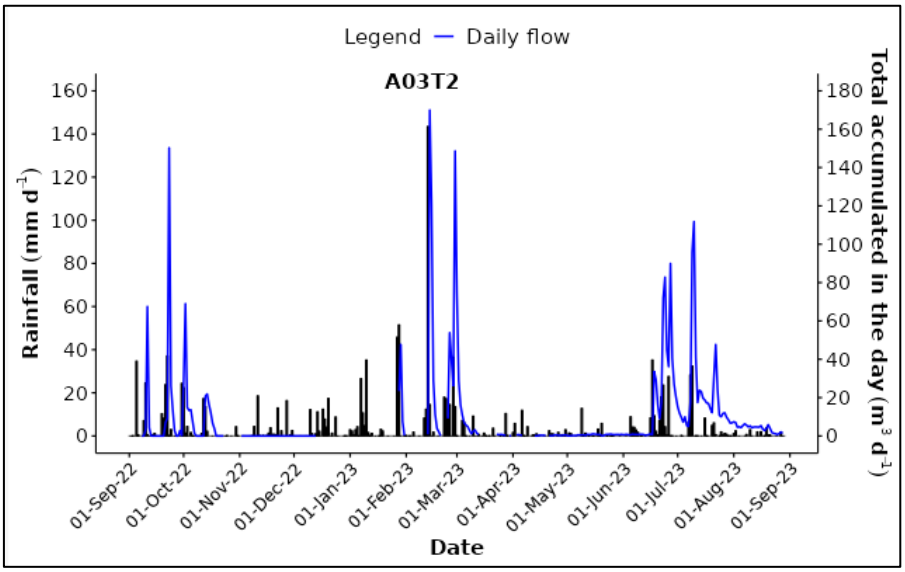

Figure 2: A03T2 Flow Data vs Rainfall

A09

Both Tile 1 and Tile 2 are continuously flowing tiles with high cumulative flow. Both flow meters sustained significant damage during Cyclone Gabrielle and therefore no data could be captured between 14 February and late April 2023 when repairs were completed. While both tiles are continuous, Tile 2 is accumulating much higher flows, up to 480 m^3 / day with even periods of low flow still recording accumulations of 20 – 30 m^3/day.

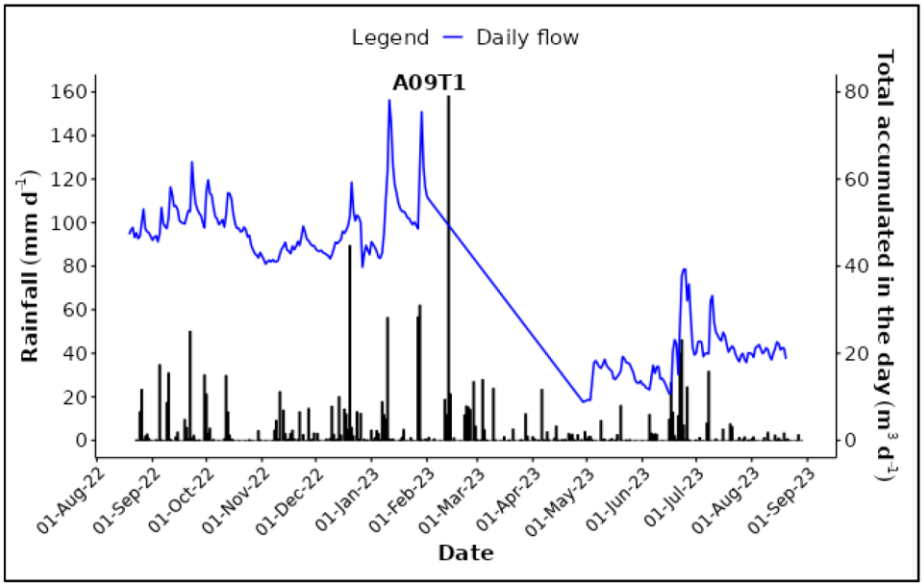

Figure 3: A09T1 Flow Data vs Rainfall

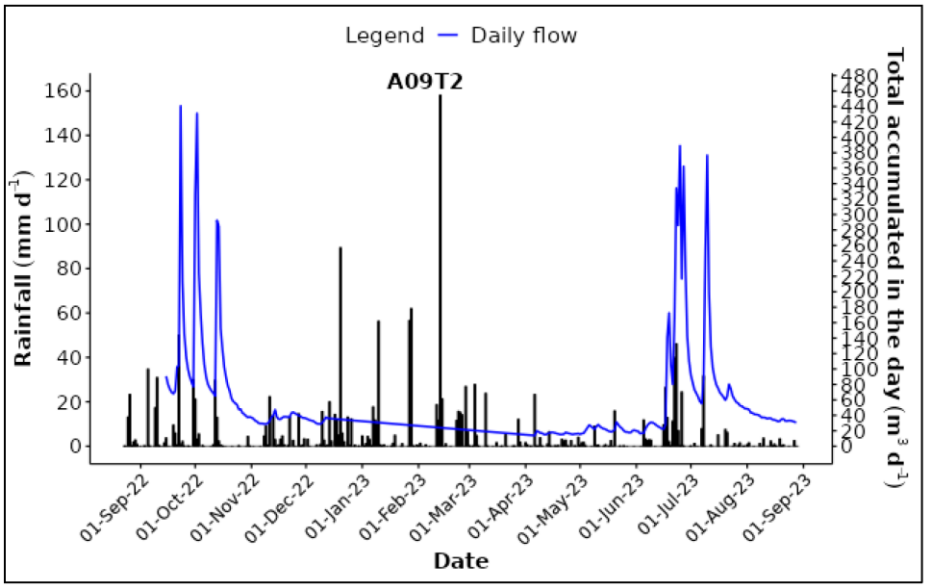

Figure 4: A09T2 Flow Data vs Rainfall

C03

Both tiles at C03 are classified as having event flows, but both present unique behaviours. Tile 2 shows frequent flow following rainfall with a long limb time back to base flow and minimal periods throughout the monitored year of no flow. Comparatively, Tile 1 does not reach as higher peak as Tile 2, nor is the flow as regular following rainfall, and there are more no flow periods.

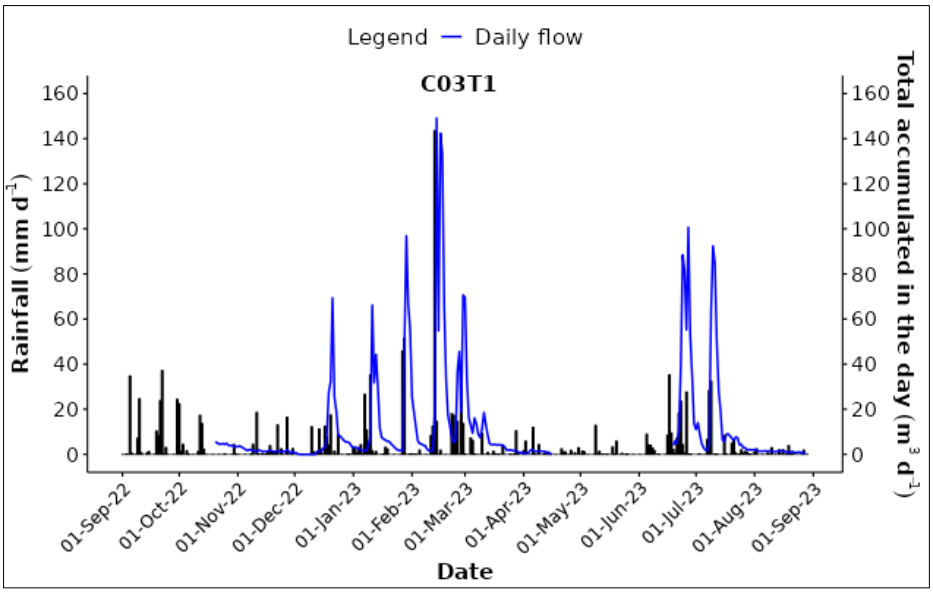

Figure 5: C03T1 Flow Data vs Rainfall

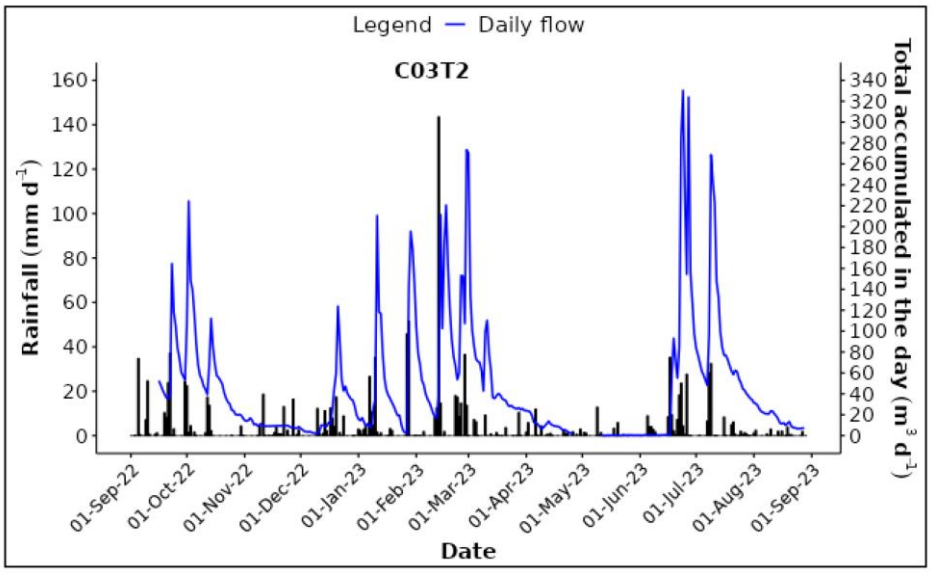

Figure 6: C03T2 Flow Data vs Rainfall.

Physical and Chemical Parameters

At the time of this report, analytical results have shown:

- Ammoniacal Nitrogen tile drain samples are all compliant with the NPS Freshwater National Bottom Line. Values are either within the Attribute A or Attribute B bands, with nearly all receiving water samples higher than those recorded coming from tile drains. Some proportional Ammoniacal Nitrogen samples show higher loadings, however consideration on the integrity of these samples needs to be considered;
- DRP tile drain samples encompass the full range of Attribute Levels from A through to D. Data is split with 15 of 32 data series having receiving water concentrations exceeding the tile drains, 11 data series having tile drain concentrations exceeding the

receiving waters, and the remaining 6 data series having insufficient data for comparison;

- With respect to Nitrate, 18 of the 32 data series show 95% UCL values within the Attribute A level. Of the remaining 14, four series do not have sufficient data for assessment and three exceed the National Bottom Line. Given the prevalence of Attribute A & B concentrations, Nitrate concentrations appear to be a priority issue in localised small catchments;
- Assessment of DIN values against the Default Guideline Values and Proposed TANK threshold for Ngarururoro and Lower Tributaries shows 12 of the 32 tile drain data series are compliant with the 0.444 mg/L threshold while 4 have insufficient data for assessment.
- Receiving water concentrations in most instances exceed the concentrations recorded in tile drains suggesting that tile drains are contributing beneficial dilution to these systems. Observations across the receiving water data series shows that these concentrations appear to flux independently of the tile drains and have more notable impacts during event-based sampling consistent with higher overland flow contributions to these smaller water ways. Further assessment will continue within Year 3 to identify the primary contributing factors.

Regression Assessments

Data assessment at the completion of Year 2 has not identified any clear correlating factors for on farm actions and associated discharges. Focussing on Nitrate and DRP as the two key contaminants of concern, regression analysis notes:

- No clear relationship between DRP concentrations in Tile Drains and Olsen-P concentrations in soil ($R^2 = 0.0437$, polynomial relationship);
- Assessment of total phosphorous application (kg/ha) against Tile Drain DRP concentrations shows no discernible correlation ($R^2 = 0.0198$);
- No correlation between Tile Drain DRP concentrations and total base saturation or Cation Exchange Capacity exists (R^2 values of 0.0409 and 0.0637 respectively);
- Assessment of Tile Drain Concentrations against all assessed soil parameters did not identify any correlation of note with all R^2 values <0.1; and
- A weak correlation between mineralizable N (kg/ha) and Tile Drain nitrate concentrations is observed ($R^2 = 0.1375$).

Confidence

Current data assessed only represents a snapshot of benchmarking data against a dynamic environment. Although the fortnightly grab samples and rainfall triggered event samples is considered to align with best practice for establishing a baseline data set, the three-year length of the project presents a shortfall in being able to implement and actively monitor improvements from mitigation actions. This is particularly notable against the NPS Freshwater which recommends compliance against National Bottom Lines and Attribute Levels be based on:

> *a monthly monitoring regime where sites are visited on a regular basis regardless of weather and flow conditions. Record length for grading a site based on 5 years.*

Mitigation

At this stage, no practicable mitigation options have been identified for installation and monitoring within the project extent. To effectively mitigate, a baseline data set is required to confirm what degradation is present, the scope and scale of any issues and how these may vary over time to ensure that mitigation is targeted. At the completion of Year 2 monitoring, mitigation is currently considered premature given the uncertainties in data.

Grower project participants already undertake a range of land management mitigation options including split fertiliser dressing, fertigation, variable rate irrigation and reduction / tailored fertiliser budgets. These measures are all set out within their FEP's as part of GMP and BMP. At this stage, no further improvements have been identified for implementation.

Edge of field treatment of discharges needs to be tailored to the level of flow associated with specific tile behaviours, while ensuring drainage is not compromised. Installed flow meters have recorded variable flow, ranging from an annual cumulative flow of 2,557 m^3 to 15,543 m^3. This variance means a bespoke solution for each drain will be required to ensure flow volumes are adequately treated.

Many edge of field mitigation strategies (i.e. bio-reactors and constructed wetlands) require large installation surface area for treatment to be successful. None of the trial sites have sufficient area available within their outlet configuration, without compromising the receiving water area. Installation of systems where a sump and pump were installed, would restrict the productive area as well as require significant capital investment.

A range of trial sites discharge into the Hawke's Bay Regional Council (HBRC) drainage network, an asset owned and maintained by HBRC to mitigate flood risk to the region. Activities within the drainage network need to account for its purpose of flood mitigation and ensure mitigation systems do not obstruct or exacerbate flood flows.

For these reasons, a key requirement is to first understand the contribution of the farming system to water quality, before determining what mitigation may be required.

Year 3

Analysis of Year 1 and 2 data has confirmed the relationships governing tile drain outflows are complex and deeper understanding of dynamic drivers will be required. To further develop this understanding and investigate potential correlating factors, Year 3 will be undertaking:

- Further environmental data collection to help understand the dynamic environment including groundwater profile testing and rainfall nutrient quantities to understand the extent of influence each of these may have in a nutrient budget.
- Assessment of Olsen-P soil concentrations within differing soil horizons to look at any variation with depth, and its potential relationship to DRP concentrations in tile flow;
- Slake, Slump, and Visual Soil Health Assessments of sites where concentrations are notably different to expected trends based on farm management actions and associated management strategies;
- Alternative mitigation options available and the practicability of implementing these within the dynamic drainage network; and
- Determination of the confidence of the data set and what, if any, further information may be necessary to formulate appropriate conclusions.