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Modelling Water Restrictions and Nutrient Losses for Horticulture in the TANK Catchment – An Economic Analysis

Prepared for Hawke's Bay Regional Council

Leander Archer & Jonathan Brookes
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1.0 EXECUTIVE SUMMARY

AgFirst has completed an economic analysis of the impacts of changes to flow and allocation restrictions on irrigated horticulture in the TANK Catchments (Tutaekuri, Ahuriri, Ngaruroro and Karamu). The analysis compares the base case, which represents the current irrigation restrictions on horticulture, to three future options.

The irrigation restriction options analysed in this report are:

"Base Case"

- the Ngaruroro River is on ban at 2,400 L/s and this ban affects 21% of irrigated land area
- 100% of land area are subject to a weekly allocation limit but no annual limit

"Future A"

- Habitat Protection (via low flow) increased to 80- 90% on the Ngaruroro and Tutaekuri Rivers, the increased bans affecting 26% of irrigated land area
- The same 26% of land area has an annual allocation with a reliability of 4 years in 5 (one year in five has insufficient water for cropping as 'normal')
- Remaining 74% will move to an annual reliability of 9 in 10 years (one year in ten has insufficient water for cropping as 'normal')

"Future B"

- Habitat Protection (via low flow) increased to 70- 75% on the Ngaruroro and Tutaekuri Rivers, the increased bans affecting 26% of irrigated land area.
- The same 26% of land area has an annual allocation with a reliability of 4 years in 5 (one year in five has insufficient water for cropping as 'normal')
- Remaining 74% will move to an annual reliability of 9 in 10 years (one year in ten has insufficient water for cropping as 'normal')

"Future C"

- Low flow on the Ngaruroro and Tutaekuri are unchanged from Base Case, but now affect 26% of irrigated land area.
- The same 26% of land area is subject to a weekly allocation limit but no annual limit
- Remaining 74% gains an additional annual allocation limit that is either:
    1) enough for the 2013 climate year (similar to a 1-in-20 year drought)
    2) at a 9 in 10 year reliability (one year in ten has insufficient water for cropping as 'normal')

The analysis was undertaken using climate data from years 1998 to 2015 and yield outputs from Plant and Food Research's SPASMO yield modelling software. This analysis also quantifies changes in crop quality by soil-type to determine the impact on earnings before interest and tax (EBIT) on Model Farms developed specifically for the Heretaunga Plains as part of this project.

Table 1- Modelled EBIT earnings for horticultural businesses within the TANK catchment

Scenario	Average model EBIT Earnings (TANK Catchment, Horticulture) Average 1998-2015	Model EBIT Earnings (TANK Catchment, Horticulture) 1998	Model EBIT Earnings (TANK Catchment, Horticulture) 2013
Base Case	$183 million	$202 million	$136 million
Future A	$144 million	($152 million)*	($100 million)*
Future B	$148 million	($157 million)*	($99 million)*
Future C Option 1	$202 million	$54 million	$125 million
Future C Option 2	$124 million	($74 million)*	($77 million)*

* indicates that the value was negative (i.e. cropping returns were lower than costs)

The two driest years in this period were 1998 and 2013. Most irrigation-ban related impacts (major repercussions for the Hawke's Bay economy) are felt in these two dry years with all other years experiencing only minor ban-related issues.

The improved earnings in the Base Case in 1998 can be attributed to minimal ban-dates and favourable heat unit progression.

Future B is a less severe than Future A (low flow) but still requires a severe annual allocation that means our model farm runs out of water in 1 out of 5 years. The 1998 year may seem an odd result, but is due to allocated water running out sooner in that year than the Future A Option. The similar results are showing that in Future A and Future B, crop losses are still severe in the 2 drought years.

Future C Option 1 looks at the use in the 2013 year, that has been calculated by HBRC to be the limit of what the aquifer can handle in terms of extraction. The only impact is for the 1998 year, which was dryer than 2013 climatically. Future C Option 2 impacts 2 out of 18 years significantly, 2013 and 1998.

The downstream impacts of farm EBIT are not included and changes to crop planting and investment decisions are not accounted for at this stage.

A nutrient analysis was also included in this project evaluating:

1. Nutrient loss results
2. Description of mitigation measures available on-farm to reduce nutrient loss (where necessary)
3. Mitigation cost analysis including costs of:
   a. Installing shade over drains and streams adjacent to farm properties
   b. Nutrient and sediment loss risk assessment on farm, and associated costs to implement recommendations on the Model Farm.

- Total nitrogen loss over the Heretaunga Plains is estimated to be 200 tonnes N/year.
- Total phosphorus loss is estimated at 8 tonnes P/year.
- Riparian shade mitigation is expected to cost the TANK catchment's horticultural farms $3.7 million in initial mitigations and then $1.1 Million each year after that in maintenance.
- The nutrient plus the sediment mitigation initial cost totals $2 Million in the first year's initial mitigations, and an additional $1.5 Million each year in maintenance after that.

Nutrient (nitrogen and phosphorus) loss is modelled for each crop and soil type combination. The results show that permanent crops have low nitrogen (N) loss, whilst annual cropping losses are higher due to increased input requirements and high levels of cultivation. Variation by soil-type is dramatic and warrants further consideration (7 kg- 61 kg N /ha/year lost with the exact same inputs)

Phosphorus (P) loss is low in most horticultural crops due to the typically flat terrain, which reduces erosion risk (and therefore P runoff risk). There is still runoff over the surface of the soil occurring on the cultivated land, while the loss as drainage is more significant for permanent crops. Variation by soil type reflects the trends seen within N (0.6 kg- 2.3 kg P/ha/year lost with the same inputs dependent on soil-type)

Table 2- Average Nitrogen and Phosphorus Loss by Crop Type, and Phosphorus as Drainage (1998-2015)

Crop	Nitrogen loss	Total P loss	P as drainage
Kiwifruit	13.4	0.16	65%
Pipfruit	14.6	0.22	55%
Summerfruit	14.1	0.13	73%
Grapes	9.0	0.58	78%
Squash	31.2	0.57	29%
Onions	32.7	1.30	15%
Sweetcorn	28.7	0.61	26%
Peas and beans	28.3	0.62	25%

Note: Each crop type (tree crops, grapes and cropping) is grown across a minimum of 12 different soil-types in the Heretaunga Plains and losses also fluctuate over 18 years climate data.

2.0 REPORT SCOPE AND OBJECTIVES

AgFirst was contracted by **Hawke's Bay Regional Council (HBRC)** and the **TANK** stakeholder group (standing for **Tutaekuri, Ahuriri, Ngaruroro and Karamu catchments**) to assess the economic impact of river flow and irrigation allocation restrictions on farm gate returns for horticultural properties within the TANK catchments.

Figure 1- Area in the TANK Catchments

HBRC and TANK also requested to see nitrate and phosphorus losses from a range of horticultural land use and soil combinations within the catchments and evaluate (and model where possible) mitigation measures.

2.1 Part 1a

The scope of the analysis is to assess the impact of different minimum flow regimes and/or irrigation water allocation rules on current business performance. This provides understanding of the direct economic consequences associated with alternative water take limits and indicators of potential land use change.

The modelling looks at the timing, frequency, magnitude, and severity of irrigation curtailments and their effect on different farm systems 18 climate years (1998-2015). These impacts are reflected in the change in the model farm financial and production results from the current 'No Ban' scenario (scenario 1, see Table 5).

The results compare farm gate financial outputs for irrigated horticultural properties in the TANK area, from the current/base case to 3 future scenarios.

The crop yield modelling was completed using Plant and Food Research's SPASMO software. SPASMO's modelled outputs determine the fresh weight of produce per hectare but does not take crop quality (and associated impacts on price) into account. Once yields are derived for the roughly 12,000 outputs, AgFirst integrated the likely quality impacts on crops into this analysis. The resulting production, packout and price figures were then applied to the farm budgets for each operation to generate an EBIT value (Earnings before interest and Tax).

2.2 Part 1b

Along with the SPASMO model outputting yield impacts of ban scenarios, it also shows the loss of nutrients (nitrogen and phosphorus) from the root zone of the crops.

Using the results from 12 to 14 different soil types per land use, AgFirst calculated the nutrient losses by crop and soil type across the Heretaunga Plains.

From this output, using what is identified as 'current average practice' for the management of each farm, AgFirst identified a range of mitigation measures that are available to farms to reduce the loss of nutrients.

The next phase was the introduction and assessment of additional good management practices and/or mitigation measures into the representative farm systems, however the mitigations that can be modelled through SPASMO are limited and are commonly known as best practice (relating to the type, timing and amount of fertilizer applied).

Mitigations will be different for each farm depending on their crop and soil, but also the catchment they are in, the contours of their land, the waterways on their property and more.

AgFirst has done two mitigations scenarios for the financial budgeting sections of this project:

1) Riparian land management
   Identified the streams, drains and rivers that are adjacent to horticultural land from HBRC maps. From this an estimate can be made of, on average, how many meters of

riparian planting our model farms might require according to their land area. We then costed this and added it into the financial budgets at a level of

    a) Alteration phase (how much will it cost to implement the riparian strategy)
    b) Maintenance phase (what will the longer term annual cost be to the farm)

2) General cost of improvements
   The outcome of this plan may involve some sort of site risk assessment, whether that is internal or external. This could be in the form of a Farm Environment Management Plan, or it could be something else. Either way there will be a cost to business of:
    a) Time taken assessing environmental risks on farm
    b) Decisions on what will mitigation work will need to be done and by when
    c) Carrying out those mitigation measures (such as earthworks, new culverts and track edging or repairs to the irrigation system).
    d) Maintaining mitigation measures

This AgFirst economic model was built for a regional scale economic impact assessment. Model Farms are built for the purpose of regional level information. This work should not be taken down to farm scale.

3.0 METHODOLOGY

3.1 Crops Chosen

The analysis involved the formulation of representative farms for the Heretaunga Plains, which have been determined considering the following factors:

1. Predominance of land use
2. Major revenue generating farm systems
3. Likely relative responses to water irrigation availability (and nutrient leaching)
4. The regional economic impacts (multiplier) of the respective land uses

The representative farms account for the spatial distribution of the land uses across the plains and in relation to soil and climate variables. The crops studied are:

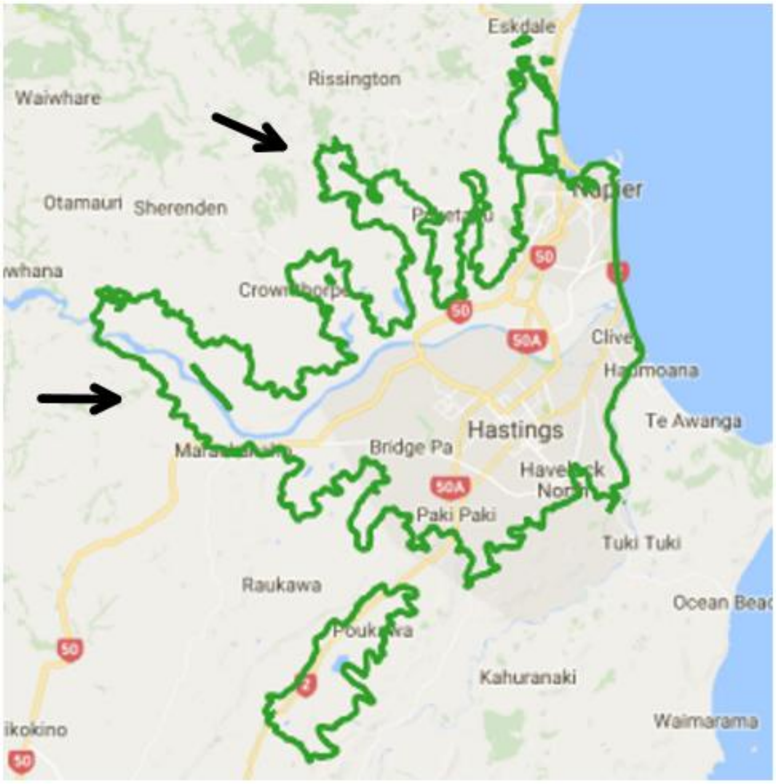
- Grapes
- Pipfruit
- Kiwifruit
- Summerfruit (mostly peaches)
- Squash
- Onions (brown)
- Peas followed by beans
- Sweetcorn
- Pasture- (winter pasture between crop rotation in vegetable models)

All specific model farm information can be found in Appendix 1.

3.2 Climate Data

Climate (ET and rainfall) varies little across the Heretaunga Plains, and in a discussion with Plant and Food Research (Green, 2017) and HBRC it was decided that the VCS 31078 (Hastings-Whakatu) could be used for all modelling on the Heretaunga plains. This includes the river valleys up the Ngaruroro river and Tutaekuri River, though rainfall is slightly higher here.

Figure 2- Map of AgFirst Intensive Area showing extension up river valleys



The climate years 1998 to 2015 were chosen because the HBRC SOURCE model is built around this 18 year period of climate and river flow data. Much of this work needs to be linked beck to findings from the SOURCE model or uses SOURCE model data (see section 3.4). The exception is the first year in this period, 1997/98. This year is not included in the HBRC source model but was included in the AgFirst modelling. The decision was made to include this year due to its importance from both a climatic and economic perspective.

The graph below shows water deficits over 4 climate years, July to June. Each line shows the water deficit (evapotranspiration minus rainfall) by month across the season. The labelled year is the usual 'harvest year' as in the rest of this report, where the 1998 year is depicting the climate in July 1997 to June 1998.

1998 is shown in red as the driest year. 2013 was marginally less dry, shown in orange. While 2013 is less dry on the Heretaunga Plains, it is dryer in the mountains that feed the Ngaruroro and Tutaekuri Rivers. This results in more days on ban due to low river flow rates.

2009 was a moderately dry year, with a moderate number of ban days. 2014 has been added as this is a median deficit year (September- April) out of the 18 climate years studied.

Figure 3- Evapotranspiration minus rainfall (water deficit) monthly for 4 example years

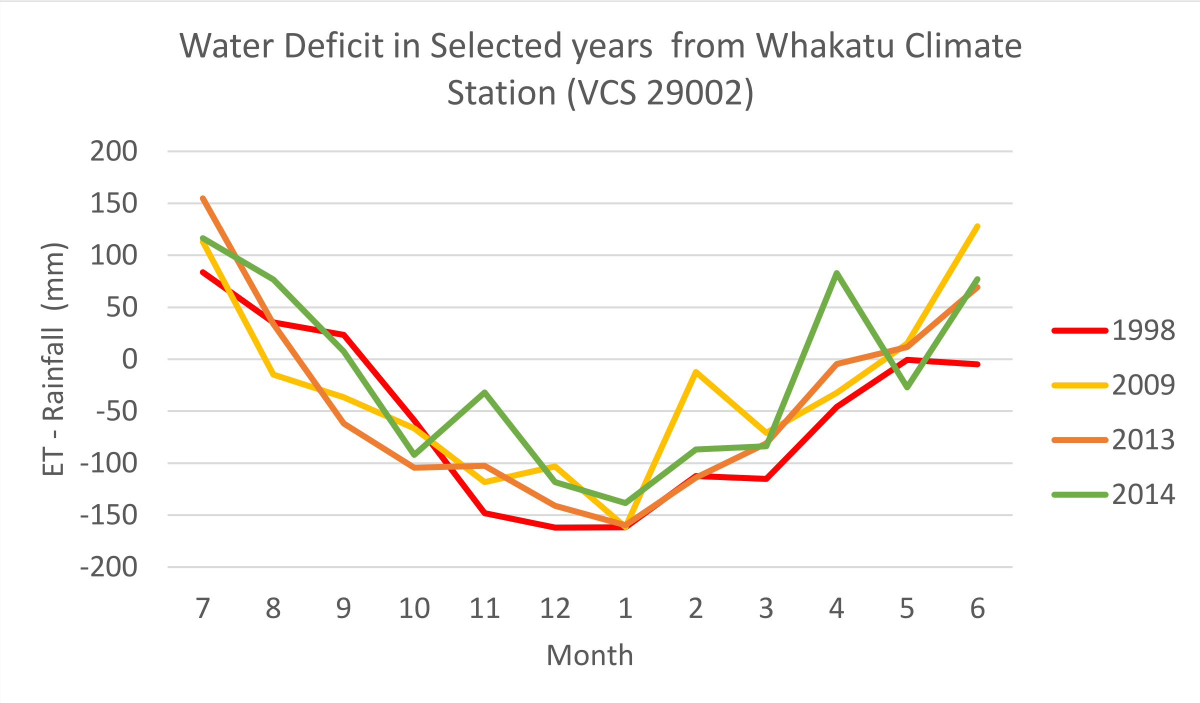


Table 3 shows the water deficit for September to April each year. Colour was applied to specific ranges to visualise severity of water deficit (red highest, orange moderate and green lowest).

Table 3- Deficit (ET- Rainfall) Annually for 1998- 2015

Year	Deficit Sep-Apr
1998	-781
2013	-769
2007	-612
2009	-601
2003	-589
2015	-575
2001	-494
2008	-488
2016	-484
2000	-461
2014	-461
2005	-449
2017	-433
1999	-432
2010	-356
2012	-318
2004	-294
2011	-196
2002	-196
2006	-187
Median	**-461**
Average	**-459**

*Climate data was provided by HBRC

3.3 Soil Types

HBRC provided AgFirst with a list of 12-14 soil types which were commonly found under each of three crop categories- tree crops and kiwifruit, grapes, and vegetables. All were modelled through SPASMO.

A map is shown in Figure 4 of these soils (Griffiths, 2001).

For economic modelling, soils were grouped by total available water (TAW) into ‘Low’, ‘Moderate’ and ‘High’. TAW is defined as field capacity (FC) minus wilting point (WP). Data on these values was provided by Plant and Food Research.

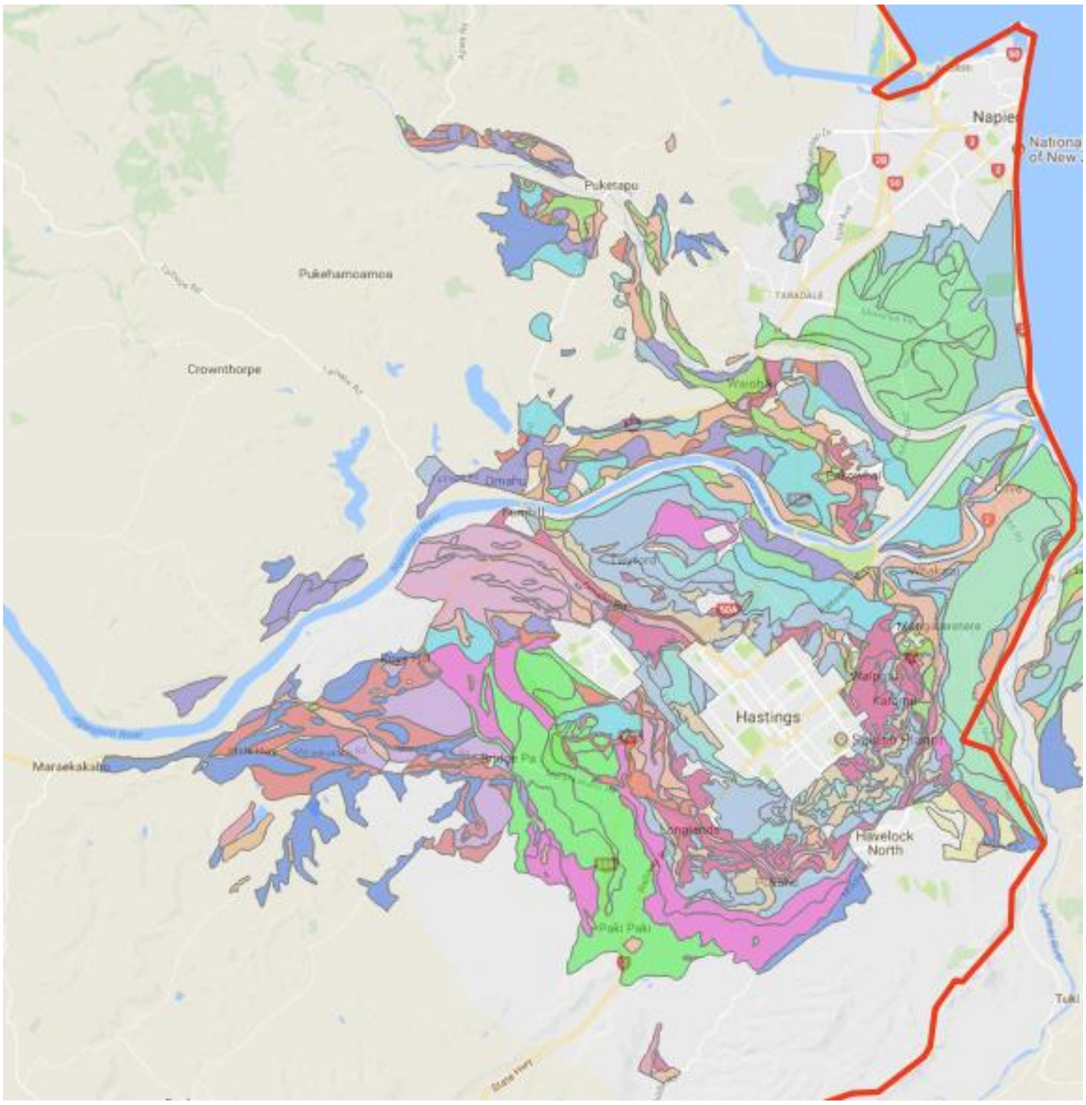
Three soils were chosen for economic modelling. The soils chosen in each situation best represented the TAW of their group and were common soils in terms of area represented on the Heretaunga Plains, according to Griffiths soil maps.

All soils modelled have nutrient loss results for part 1b.

The two areas not covered by the Griffiths soil map are Poukawa, and the Ngaruroro River valley above Maraekakaho. The soils and crops in these areas were looked up using S Maps and identified as high, moderate or low moisture holding capacity soils (S Maps, 2018). They were then added to the modelling using a similar nutrient or economic loss result that was modelled.

There is some area in the Tukituki catchment covered by the soil map, but this area was removed for the modelling.

Figure 4- Map of Griffiths Soils Modelled for at least 1 crop type, and the area they cover



More information on soil types can be found in Appendix 2.

3.4 River Flow Data

In 1998 in the SPASMO model, measured historical flow data was used due to the absence of any modelled flow data from HBRC's SOURCE model.

From 1999-2015 HBRC supplied modelled ban day data generated from the SOURCE model. This is based on the climate years 1999-2015 but re-modelled to take into account abstraction patterns impacting river flows. Re-modelled years in this scenario are treated as future projection for the years 2015-2032.

The number of ban days each year is shown below in Table 4.

Table 4- Ban days under various Ngaruroro and Tutaekuri River Ban Levels (L/s)

Year	Nga 4,000	Nga 3,600	Nga 2,400	Tut 2,000	Tut 2,500	Tut 3,300
1998	65	57	26	0	0	27
1999	0	0	0	0	0	0
2000	11	6	0	0	0	1
2001	1	0	0	0	0	0
2002	0	0	0	0	0	0
2003	21	17	1	0	0	23
2004	0	0	0	0	0	0
2005	17	13	3	0	0	12
2006	0	0	0	0	0	0
2007	19	15	3	0	14	66
2008	30	23	11	0	0	19
2009	28	24	1	0	0	35
2010	7	7	3	0	0	0
2011	0	0	0	0	0	0
2012	0	0	0	0	0	0
2013	67	64	52	0	38	92
2014	25	21	9	0	0	2
2015	38	32	18	0	0	41

More detail on the 1998, 2009 and 2013 years can be found in Appendix 3.

3.5 Options and Ban Scenarios

Regional Council irrigation management options impact on security of irrigation supply, and therefore impact farm production and potential EBIT. The options and scenarios chosen to model through to EBIT are shown in Table 5.

In Table 5, an "option" refers to an option for decision making by the TANK Stakeholder group. Options are made up of one or more "scenarios" combined over different proportions of land area within the TANK Catchments that results in a level of habitat protection for the Ngaruroro and Tutaekuri Rivers.

A "scenario" is one modelling run done by Plant and Food Research, which can be combined to create "options". Plant and Food Research modelled crop yield impacts under 7 different scenarios. Each scenario has a bundle of restrictions to water usage within it.

Table 5- Overview of Option, Scenario modelled, and the definition of each

Option	Scenario	Scenario Detail
Base Case 44% (Ngaruroro) and 60% (Tutaekuri) Habitat Protection	1- No Ban	35mm/week or 14mm for grapes. (Basic SPASMO default included in all scenarios). Represents 'current' as best as possible. No annual allocation restriction Represents Tutaekuri 2,000 L/s (base)
	2- Ngaruroro 2,400 L/s	35mm/week or 14mm for grapes Shuts off irrigation at 2,400 L/s at Fernhill No annual allocation restriction
Future A 80 to 90% Habitat Protection	3- Ngaruroro 4,000 L/s	35mm/week or 14mm for grapes Shuts off irrigation at 4,000 L/s at Fernhill Restricted annually to 4 in 5 year allocations Represents Tutaekuri 3,300 L/s.
Future B 70 to 75% Habitat Protection	4- Tutaekuri 2,500 L/s	35mm/week or 14mm for grapes Shuts off irrigation at 2,500 L/s on the Tutaekuri Restricted annually to 4 in 5 year allocations
	5- Ngaruroro 3,600 L/s	35mm/week or 14mm for grapes Shuts off irrigation at 3,600 L/s at Fernhill Restricted annually to 4 in 5 year allocations
Future C Annual allocation Reductions	6- Groundwater Zone 2-4 2013 allocation	35mm/week or 14mm for grapes No bans Restricted annually to 2013 year allocations
	7- Groundwater Zone 2-4 "9 in 10 year" allocation	35mm/week or 14mm for grapes No bans Restricted annually to "9 in 10 year" allocations

In Table 5 each option lists a level of habitat protection (HP). For the Ngaruroro River, these refer to Torrentfish, while in the Tutaekuri these refer to Trout. Stopping irrigation at these flow thresholds does not stop the river from naturally going below this level of habitat protection.

3.6 Allocations

Allocation limits are applied on a weekly basis for all scenarios, and an additional annual basis for some scenarios. Weekly allocations are based on a fixed 7 day period. All allocations are in mm to the plant-i.e. they represent 100% irrigation efficiency.
Annual allocations are based on the year from July to June and modelled as if water is used to meet the water demands of the plant to the point at which it runs out. At this point modelled irrigation stops. This method allows a simple comparison to 'number of days on ban' statistics provided for river flow related bans.
Note that in a management situation there are ways to better use this annual allocation for an improved crop yield/quality outcome, but they come down to specific individual situations and are not accounted for in these analyses.

3.6.1 Weekly limit

The HBRC's current (since 2015) method of allocation is using an internal version of SPASMO, which calculates allocations for a 28-day period and annual volumes on a "9 in 10 year" basis or a "4 in 5 year" basis. A "9/10 year" allocation means 9 out of 10 years the operation has enough water to cover plant demand. This can also be referred to as "90th percentile" irrigation supply. SPASMO changes allocation depending on crop type, soil type and climate data.

However, it is estimated that 90- 95% of consents are yet to be renewed under the new system. Most existing consents were given on a weekly basis (mm/week), based on the Morgan method, or even earlier, an estimated weekly upper limit set by the land manager (when there were no water meters).

During land sales, these limits can get redistributed or mixed up over different properties.

To account for the variation in allocation method for the current situation, the input to SPASMO for the model farm allocation for the 'base case' was 14mm/week for Grapes and 35mm/week for tree crops, kiwifruit and vegetables. This is a similar limit to what has been set in the past by HBRC, and a SPASMO default figure. In our models, SPASMO provider Plant and Food Research assured that this weekly limit does not impact on modelled crop yields significantly.

These limits apply to scenario 1 to 7.

3.6.2 Annual limits

Annual allocations were provided by Plant and Food Research (PFR) in mm/year to the plant. They were calculated from the first SPASMO output, which was crop + soil + climate years modelled under the 'No Ban' scenario (scenario 1).

For areas linked to the low flows (called surface and surface connected takes based on HBRC new groundwater research), scenarios were linked to an annual limit of a 4 in 5 year allocation. This means that 4 out of 5 years, and 16 out of 20 years, the allocation is enough to provide 100% of plant demand.

For the groundwater 2013 scenario, the TANK group wanted to see what allocation would have been required in the model to get through the 2013 year. The 2013 year is similar to a 1 in 20 year drought in our modelling. Therefore, in the 2013 scenario (scenario 6) over 18 modelled years, EBIT is only impacted in 1998 which was the only year dryer than 2013.

The groundwater "9 in 10 year" scenario (scenario 7) resulted due to a request to see the impact of an annual allocation that was "2013 -15%". This percentage reduction was found to be similar to the "9 in 10 year" allocation level, where plants have enough water to get through 9 in 10 seasons without stress. It is much more equitable allocating on this basis rather than doing a pure 15% drop in each crop × soil allocation.

Table 6 shows the annual allocation imposed on different scenarios and how they compare to the 2013 annual allocation level.

Table 6- Annual allocation limit comparison between 2013, 9 in 10 and 4 in 5 year reliability of supply (mm/year)

Crop	2013	9 in 10	% reduction	4 in 5	% reduction
Pipfruit	480	370	-23%	346	-28%
Stone fruit	489	378	-23%	354	-28%
Kiwifruit	555	483	-13%	444	-20%
Grapes	279	217	-22%	189	-32%
Onions	640	633	-1%	530	-17%
Peas and Beans	618	516	-16%	493	-20%
Squash	515	421	-18%	410	-20%
Sweetcorn	520	417	-20%	403	-22%
Average	**512**	**429**	**-16%**	**396**	**-23%**

*Calculated from the 'No Ban' scenario

Note that these limits relate to a specific crop, planting date, fertiliser regime, rooting depth and more. These therefore are expected to differ from regional water allocation models when targeted at consenting volumes.

3.6.3 Ban equivalents of annual limits

This section describes how the annual allocation limits are impacting on each scenario by cutting off irrigation for a certain number of days (ban equivalents). For each annual allocation, examples are given of the number of days at the end of that season where irrigation is restricted due to the allocation limit. Comparison is made to the 'No ban' scenario. Note that not every 'ban equivalent' day would require irrigation, hence the millimetres of water that is rendered unavailable by the allocation limit is also included.

3.6.3.1 Impact of 2013 allocation limit

Table 7 below shows the difference between the No Ban scenario and the addition of the annual allocation limit for scenario 6- groundwater 2013. Limiting the annual allocation to water required in the 2013 year results in impacts (reduced water availability) in 1998 only. All soils are affected.

Table 7- 1998 year under the groundwater 2013 allocation limit scenario.

Crop	Date of shut off in 1998	Date of 'No Ban' Shut off 1998	Ban equivalents	Irrigation lost in mm (to the plant)
Pipfruit	20th March	20th April	31	80 mm
Grapes	18th April	2nd May	15	30 mm
Squash	9th March	28th March	19	70 mm
Sweetcorn	5th March	17th March	12	45 mm

3.6.3.2 "9 in 10 year" allocation limit

Limiting annual allocation to the 9 in 10 year amount results in irrigation water being shut off early in 1998 and 2013. All soils are affected.

Table 8- 1998 year under the groundwater 9 in 10 year allocation limit scenario

Crop	Date of shut off in 1998	Date of 'No Ban' Shut off 1998	Ban equivalents	Irrigation lost in mm (to the plant)
Pipfruit	17th February	20th April	61	185 mm
Grapes	20th March	2nd May	44	89 mm
Squash	13th February	28th March	43	170 mm
Sweetcorn	12th February	17th March	33	150 mm

Table 9- 2013 year under the groundwater 9 in 10 year allocation limit scenario

Crop	Date of shut off in 2013	Date of 'No Ban' Shut off 2013	Ban equivalents	Irrigation lost in mm (to the plant)
Pipfruit	26th February	2nd April	35	100 mm
Grapes	21st March	18th April	28	56 mm
Squash	22nd February	18th March	24	170 mm
Sweetcorn	15th February	15th March	28	110 mm

3.6.3.3 4 in 5 year allocation limit:

Reducing the annual allocation limit to the 4 in 5 year level affects the years 1998 and 2013, plus minor restrictions in other years (2009, 2003, 2015…)

Table 10- 1998 year under the groundwater 4 in 5 year allocation limit scenario

Crop	Date of shut off in 1998	Date of 'No Ban' Shut off 1998	Ban equivalents	Irrigation lost in mm (to the plant)
Pipfruit	12th February	20th April	66	210 mm
Grapes	11th March	2nd May	53	180 mm
Squash	12th February	28th March	44	180 mm
Sweetcorn	11th February	17th March	34	160 mm

There are increases in ban days in 2013, but we don't have the dates for these due to the overlapping river related bans occurring. Minor restrictions occur 1 to 2 years other than 2013 and 1998 and from the crops assessed (same as above), lost under 1 week of irrigation ability at the end of the season (under 15 mm).

AGFIRST

3.7 Determining Model Farm Data

The model farms were created to represent 'average' inputs, outputs and financials. The core use of the regional scale model was to look at what is current, and then make changes to that going forward. AgFirst used internal knowledge of Hawke's Bay farm systems, as well as external consultants where needed (ELAK Consulting and Vine to Wine to Market). Consultation with industry personnel and companies was also undertaken with particular emphasis towards summerfruit and vegetable cropping. (see section 9- references and acknowledgements).

Where available, data was drawn from industry peak bodies and the Ministry of Primary Industries (MPI), to determine information about each crop type. This included: average size of a business unit, total land area, average production, income and desired produce quality characteristics.

Budget data was collected for the latest 3 seasons on record. It included crop prices received, and expenditure to EBIT level (Earnings before Interest and Tax). This was generally 2014-2016, and sometimes included 2017.

Production data was also for the last 3 years, or a longer-term average if more readily available.

In the model, financial data stays stable throughout the 18-year modelling period. The commercial reality is that prices vary annually and over commodity cycles. The results need to be interpreted with consideration of this.

The model farms are provided in Section 10- Appendix 1.

3.8 Quality Impacts

When the water regime is changed, SPASMO calculates a change in dry matter (DM) created by the plant part to be harvested. It shows a yield change (if any) under water stress but does not indicate whether that volume of DM is of marketable quality. To create accurate farm EBIT results, the impacts on quality need to be factored in. These include:

1- Impact of yield reduction on fruit size (therefore price or packout)
2- Impact of water stress on marketable attributes that year (sunburn, storage disorders, colour, maturity, sugars)
3- Impact of water stress on perennial crops bud formation leading to biennial bearing

AgFirst have done this using a literature survey, their own knowledge and filling knowledge gaps with industry knowledge and known impact years.

1) Yield reduction is fruit size

   Most water restrictions will come on from mid Feb and for most crops this is late season. Once fruit crops get to mid Feb, the fruit number is set. The lowering of dry matter SPASMO shows therefore is 100% fruit size reduction. For example, a 10% drop in dry matter of kiwifruit means the fruit size(grams) drops 10%.

   For each fruit crop that is paid differently for different size fruit (pipfruit, kiwifruit, summerfruit) we begin modelling on industry average fruit size. If the yield decreases, we decrease the fruit weight by the same factor and price it accordingly. For vegetable crops (squash, onion, sweetcorn) the size impact was incorporated in a packout reduction instead. For example, undersized onions will not be picked up by the harvesting machine, and smaller overall onions decrease EBIT, but we assume this is factored in through the packout reduction.

2) Same-year quality impacts

   AgFirst link soil moisture (weekly data) to a % **total available water in the soil (TAW).** The % TAW 'default' stress point is usually 40-50% TAW unless other information is available. Each crop is given a % TAW where they hit 'Low', 'Moderate' or 'Severe' quality impact categories.

   Quality impacts that are seen under drought stress in each crop were determined. Then at a 'low, 'moderate and 'severe' impact level, it was determined how each would reduce the packout % of the crop (i.e. how much makes it to market). Examples of this are an 8% reduced packout due to sunburn at a 'severe' level for pipfruit and kiwifruit. For most vegetables, 'severe' impact levels relate to full crop loss.

3) Biennial bearing

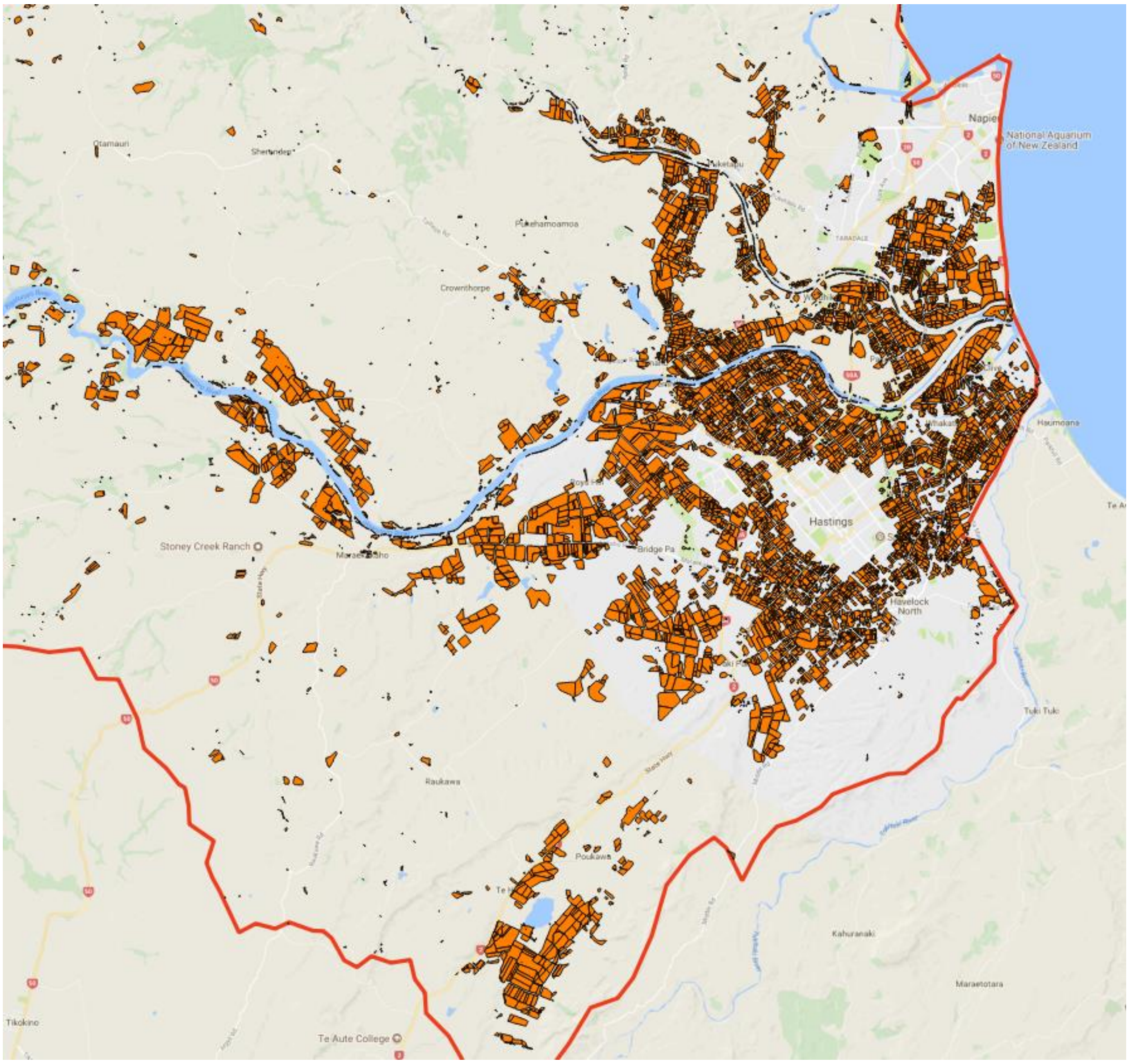
   TAW% data is also linked to a trigger for biennial bearing in crops that experience this issue. If 2013 was a severe impact on pipfruit, this may result in a 50% crop the following year. This we know will only happen to 40% of the varieties. This impact is drawn back into the 2013 year so that when the 2013 impact is quoted, you see the full impact of 2013.

3.9 Land area

There are various ways to estimate land area in each crop, and irrigated land area. One is from consent data that is often outdated (grower hasn't updated their crop from vegetables to pipfruit for example). Another is from aerial maps and unique plant light reflectivity identifiers. Another is simply by asking the large entities and peak industry bodies for area statistics.

Figure 5 shows the irrigated horticultural land estimate from an aerial map.

Figure 5- Image identifying horticultural land use- irrigated and non-irrigated, from HBRC light reflectometry maps



AgFirst used all 3 methods and the overall outcomes (divisions and total areas) were similar. The Aqualinc irrigated area consent data was used unless the data was not backed up by AgFirst 2017 best estimate (from industry). The outcome of this land-area estimation is shown in Tables 11 and 12.

Table 11- Irrigated horticultural land area in each crop in the TANK catchment

Crop	2017 Irrigated Land Area (ha)
Pipfruit	6,006
Grapes	4,347
Summerfruit	500
Kiwifruit	180
Total Vegetables	5817
Total Area	**16,851**

Table 12- Irrigated vegetable land area in the TANK catchment used in this model

Vegetable Crop	2017 Irrigated Land Area (ha)
Onions	873 (15%)
Peas and Beans	873 (15%)
Squash	1745 (30%)
Sweetcorn	873 (15%)
Other vegetables	1454 (25%)

3.9.1 Groundwater (GW) Zone 1

The horticultural land area in **groundwater (GW)** Zone 1 is 2,296 ha (Figure 6). It must be noted that this figure:

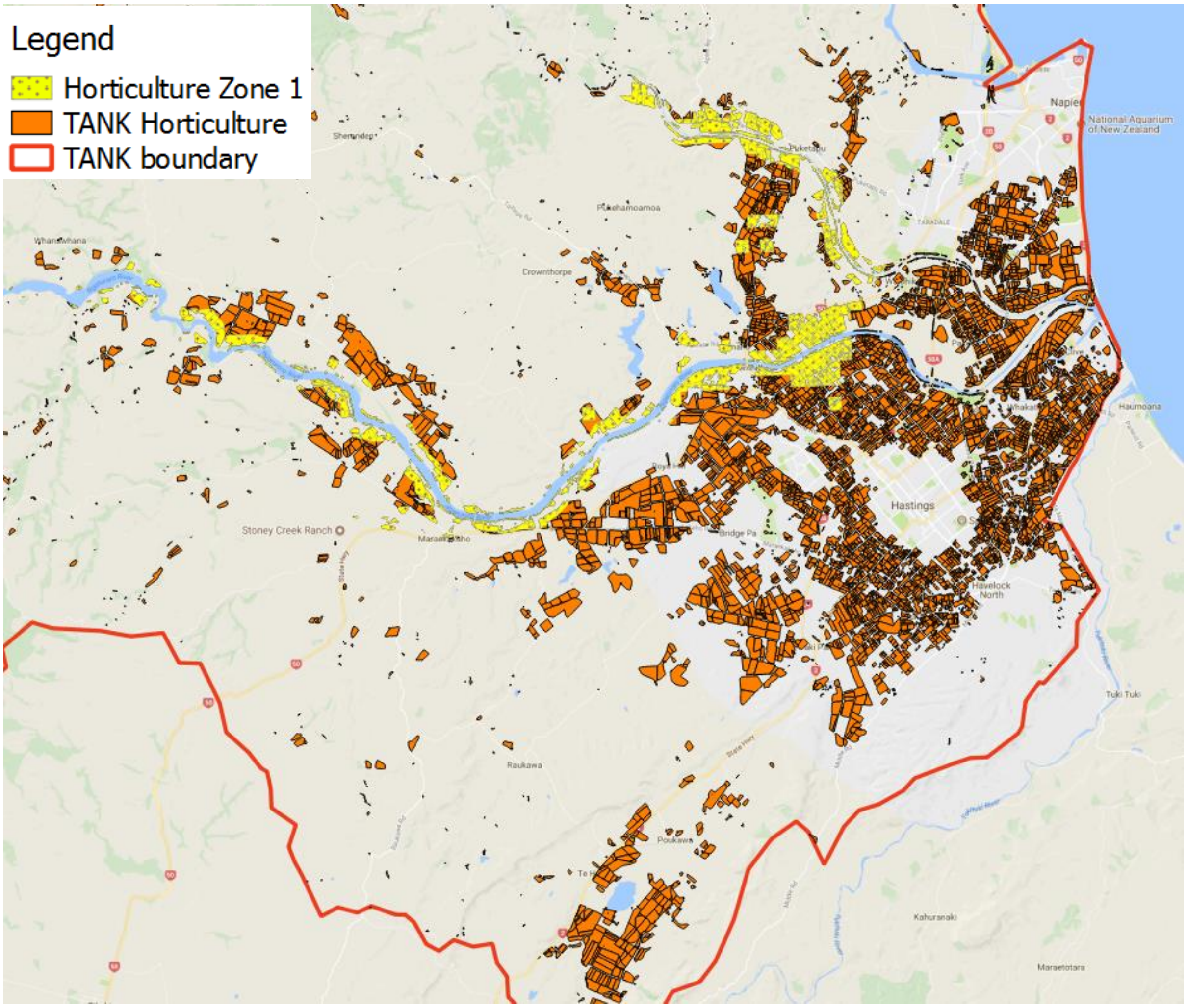
- includes unirrigated land area, as it was derived from the land use map in Figure 6
- is based on exact boundary lines, both 500m from the river mainstems, and around the area of land with a 90% or greater level of effect on the rivers
- is only showing land area that would be affected by bans due to being in the groundwater zone 1, rather than surface takes as well.

HBRC have done an analysis that determined the irrigated land area of properties which would have irrigation water sourced from groundwater Zone 1, or surface water. The results are:

- 74% of land area is in Groundwater Zones 2-4
- 20% of land area is in Groundwater Zone 1 linked to the Ngaruroro River bans
- 6% of land area is in Groundwater Zone 1 linked to the Tutaekuri River bans

For the report below, these are the percentages used.

Figure 6- Map showing the TANK boundary, all Horticultural land and horticultural land in groundwater zone 1. This map cuts across property boundaries so is not the full affected area.



4.0 PART 1A RESULTS- PER HECTARE

Results change depending on

- Climate year
- Ban scenario
- Soil type
- Land area connected to river bans (groundwater zone 1) versus not (Groundwater Zone 2-4)

The land area in each crop in the future will change too, and this alters the totalled EBIT for irrigated horticulture in the TANK catchment, not to mention the prices for crops will fluctuate annually and at times on a commodity cycle.

Results are all reported as **EBIT (Earnings Before Interest and Tax)**, not income, though income was part of the calculations.

Figure 7 below shows a weighted average EBIT of the 5 model farms on a per ha basis. The data is weighted by crop and by soil type. It shows each scenario as defined in Table 5 and gives an overview of how that scenario might impact on horticultural EBIT.

Figure 7- Per hectare impact of water restrictions - weighted average of crop types

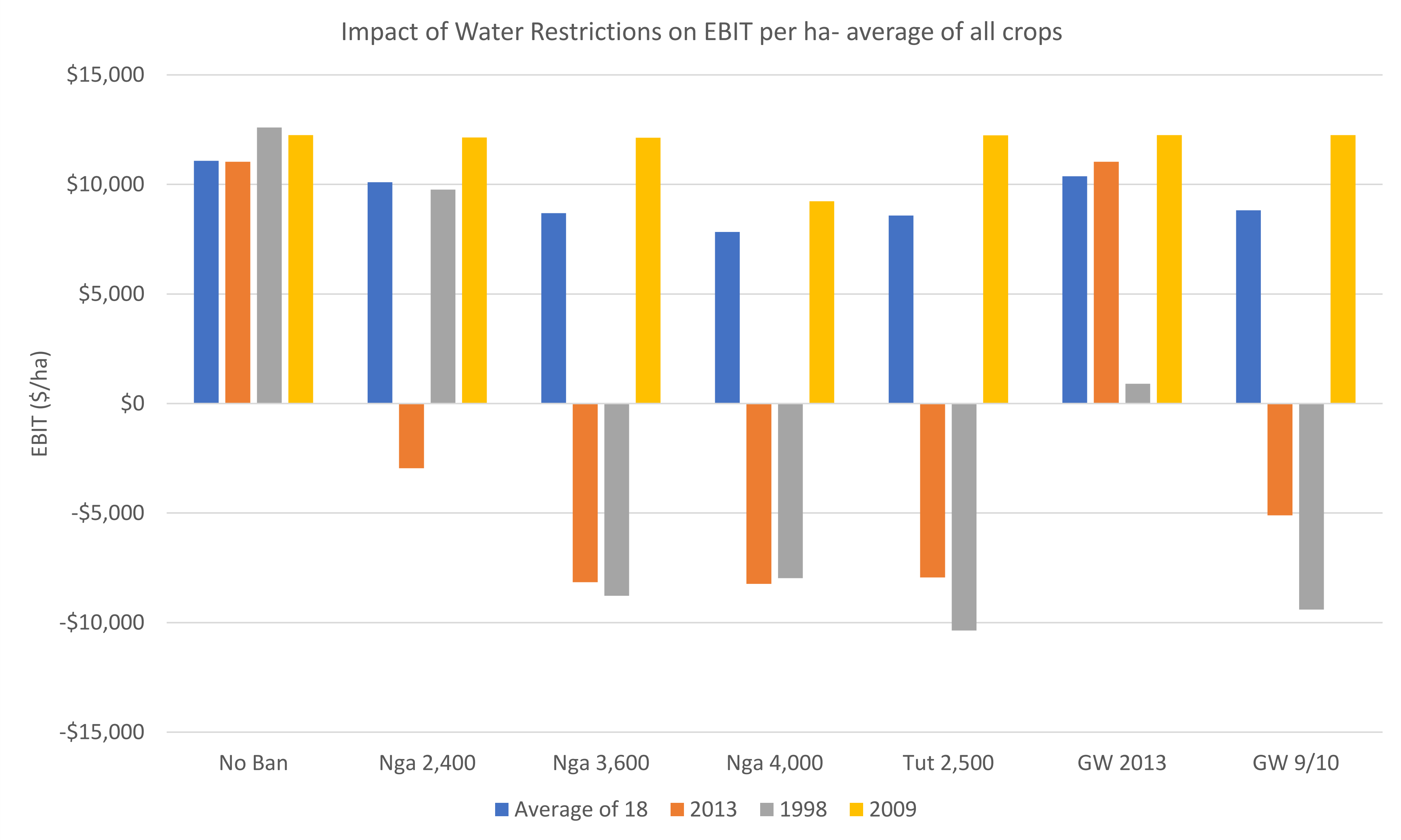


Figure 7 shows the relative change in EBIT on horticulture across all the different scenarios. It shows the average of 18 years as well as the two driest (1998 and 2013), and a moderately dry year (2009). It is made up of weighed averages depending on area in each crop and soil grouping. It shows that in the No Ban scenario the EBIT/ha earns more consistently through dry years. Yield depends on light interception and temperature as well as water availability, hence in dry years, more sunlight results in more yield if water is not limiting.

Note that dry years on the Heretaunga Plains don't necessarily mean dry years in the ranges. 2013 was less dry on the Heretaunga Plains in terms of rainfall, but there wasn't enough rain in the hills to keep river flows up, therefore ban days were severe. 1998 was by far the driest year on the Heretaunga Plains, but experienced fewer ban days, especially at the Ngaruroro 2,400 L/s ban and the Tutaekuri bans at Puketapu.

The Ngaruroro 2,400 L/s scenario has 52 ban days in 2013, as shown in Table 4. This significantly reduces the earnings in that year and for some crops leaves them making a loss. The only crops that do not make a severe loss in 2013 on the 2,400 L/s ban are peas and grapes. Peas are harvested in December, before the bans take place while according to SPASMO modelling, the grape model farm can sustain the dry period (note that this does not mean vines cannot be impacted by drought. In 2013, vine deaths did occur (HBW, 2018)).

The Ngaruroro 3,600 L/s and 4,000 L/s scenarios are similar, with large crop losses occurring in 1998 and 2013, while small impacts are felt right throughout the 18 year period, pushing the average down. The 4,000 L/s river related ban is worse than the 3,600 L/s, ranging in difference from 0 days to 8 days on ban in a year. Both also have a 4 in 5 year allocation limit annually. Because of the way the allocation has been modelled (using water to plant requirement until it runs out) in some cases the 4,000 L/s ban stops the SPASMO model using water in times of 'low' stress, while the 3,600 keeps irrigating to plant demand. This means that the 4,000 L/s scenario has more allocation leftover in the late season than the 3,600 L/s in some cases. Irrigation is then allowed to carry on for longer late season in the 4,000 L/s scenario. In 2013 this was enough to see the 4,000 L/s kiwifruit model through a particularly late dry spell where the 3,600 L/s ban ran out of water. This is the reason why in Figure 7, 2013 EBIT on the Ngaruroro 4,000 L/s is not as low as than the Ngaruroro 3,600 L/s.

The Tutaekuri 2,500 L/s scenario only experiences ban days in 2007 and 2013 at 14 and 38 days respectively. Notice that in 1998 the Tutaekuri 2,500 L/s scenario uses its annual allocation up earlier than any other scenario (having no bans) and hence runs out sooner, having a greater impact on yield and quality of horticultural crops than other scenarios.

The groundwater 2013 scenario is defined as having enough water for 2013, according to the 'No Ban' scenario. Hence the 2013 year is exactly the same as 'No Ban'. The only year requiring more irrigation water than 2013 is 1998, which was an incredibly dry year, with farmers all over the country suffering. In the 1998 climate year of this model, the allocation runs out early, ranging from 1 to 5 weeks of lost irrigation water at the end of the irrigation season.

The groundwater "9 in 10 year" allocation scenario is one step worse than this, resulting in 2 years out of 20 that don't have enough water to finish the irrigation season. The two years that this occurs in are 1998 and 2013. We see 2013 losing about a month's irrigation and 1998 losing more- 4 to 8 weeks irrigation that couldn't be applied (see section 3.6.3- "Ban equivalents of annual limits").

Figure 8- Reduction in EBIT (%): average over 18 years from 'No Ban' at 0%

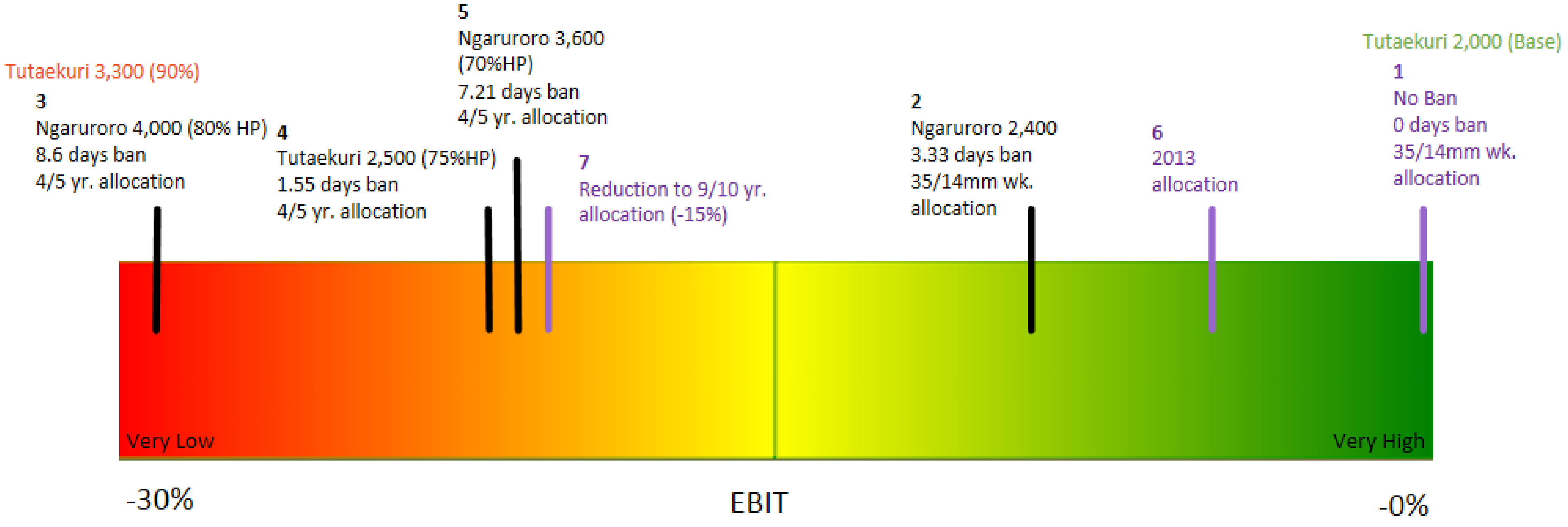


Figure 8 summarises the detail shown in Figure 7. It shows the relative severity of each of the 7 modelled scenarios over a long time period but does not effectively display the yearly variability that can result in extreme financial stressors to businesses (e.g. two particularly bad years in a row).

Each item is labelled with its ban level, level of habitat protection (HP), average number of days on ban per year, and allocation level.

The Ngaruroro 4,000 L/s ban is the worst scenario in terms of economic impact as expected, at 29% reduction on average, while within years it fluctuates down to 175% reduction at its lowest (2013). The Tutaekuri 2,500 L/s, Ngaruroro 3,600 L/s and 9 in 10 year allocation scenarios cluster around the 20% reduction level, while Ngaruroro 2,400 L/s is a 9% reduction and GW 2013 is a 6% reduction in EBIT.

Figure 9- Driest year in 18- impact per hectare for each crop type

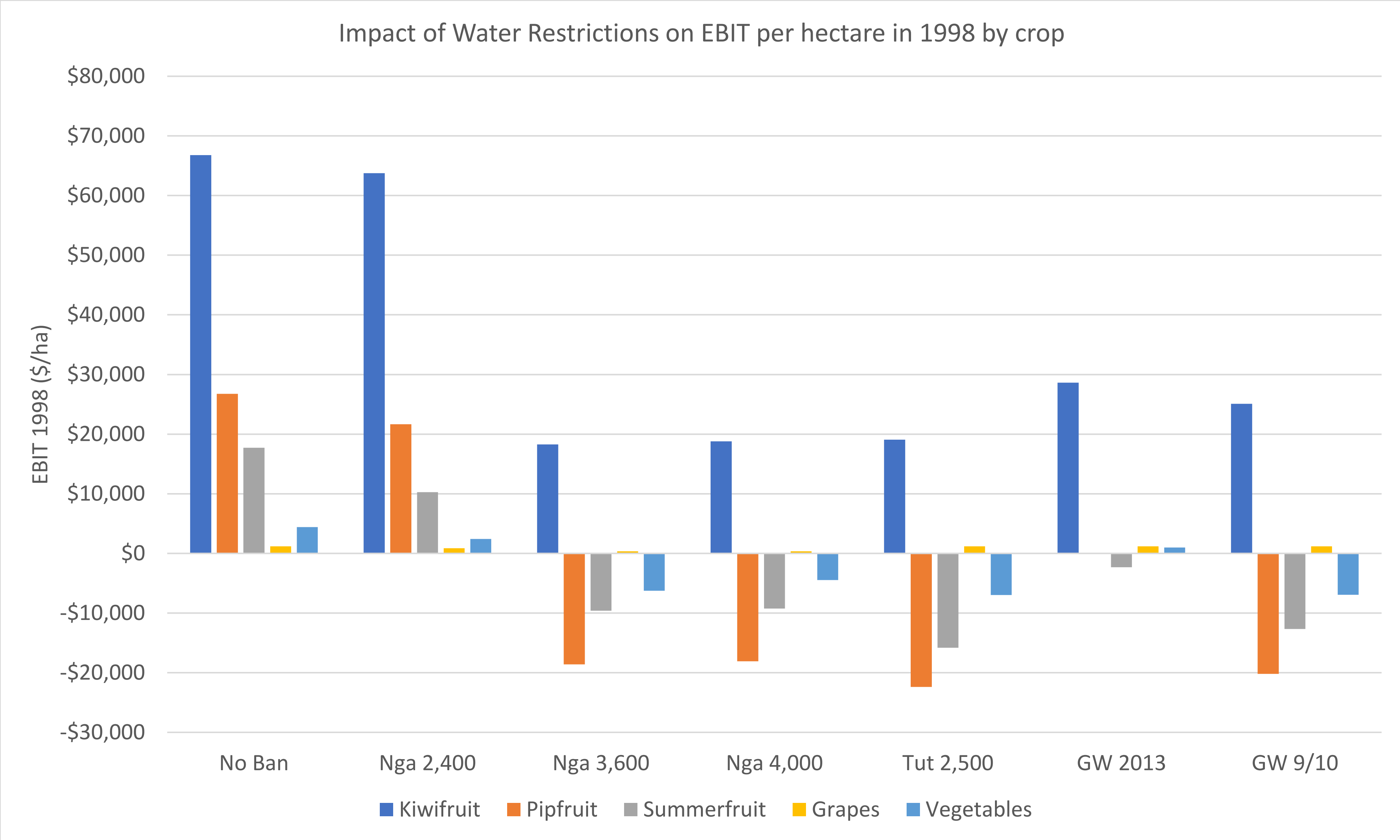


Figure 9 above shows the same EBIT results as Figure 7, narrowed down to one year. 1998 is the driest year in our climatic period, requiring the most water to crops on the Heretaunga Plains. Note that the ban days of the river were lower than in 2013 due to more water in the rivers (falling in the upper catchment). Ban days were more significant on the Ngaruroro River than the Tutaekuri that year (see Table 4).

This shows the extreme year effect on each different crop type. You can see that kiwifruit is impacted massively with over $40,000 reduction in EBIT per hectare in a number of water restriction scenarios. Pipfruit and vegetables already have a lower EBIT and these crops lose money under all scenarios but No Ban, Ngaruroro 2,400 L/s and GW 2013. Summerfruit drops to a near zero EBIT in these same scenarios.

Looking at these crops, it is evident that in 1998 where each is linked to the "4 in 5 year" allocation, it is the allocation that is showing through as the most significant restriction (rather than river flow bans). This results in Ngaruroro 3,600, 4,000 and Tutaekuri 2,500 showing similar outcomes in terms of economic impact due to these allocations. This was the downside of modelling the 4 in 5 year allocation, in conjunction with the bans.

It will be a surprise for some that grape yields did not change significantly under different ban scenarios. AgFirst investigated this and found the following

- The grape model farm is modelled through SPASMO as mature vines, rather than young vines. Mature grape vines are very good at locating water deep within a soil and are reasonably tolerant of drought
- The yields given as 'industry average' are highly managed (around 10 t/ha). Wineries generally determine how many tonnes/ha of fruit they will accept from the vineyard and the grower manages the yield down to this level.

Common horticultural practice during drought situations is to lighten crop load to lower stress on the plant. If this is done regularly no matter the water availability and the vines only have to carry 10 tonnes to harvest rather than their full capacity every year, we would not see the impact in this model.

5.0 PART 1A RESULTS- SCALED TO THE TANK CATCHMENT

From this point in the results section, the per hectare results are scaled up by soil type proportions, and by land area planted in different crops. Hence results are now reported in $M (millions of dollars) and represent the 'within farm gate' EBIT from irrigated horticulture in the TANK catchment.

The 'start point' from which all scenarios are compared is the EBIT from the irrigated horticultural land area in the TANK catchment if the only restriction was a basic weekly allocation as described in section 3.6.1 and Table 5 (No Ban scenario). It uses 3 modelled soil types to group all soils on the Heretaunga Plains into proportions of similar behaviour soils.

The total EBIT in this scenario is $187 million dollars.

5.1 Current (Base Case) Option

The base case is what represents the current situation in the Heretaunga Plains. The No Ban scenario (scenario 1) currently comprises 79% of the irrigated area in the Heretaunga Plains. It's only requirement is a 35mm/week allocation (or 14mm/week for grapes). Other than this restriction, SPASMO irrigates the crops to their water demand.

The other component of the base case is the current irrigation bans people face due to low flows. There are many low flow points across the area, but many only comprise less than 1% of land area. The one major ban that has been curtailing irrigation for growers over the past years has been the Ngaruroro river at Fernhill, limit to 2,400 L/s and below this level of daily mean flow, irrigation is cut off. The remaining 21% of land area in our model is linked to the Ngaruroro at this ban level.

Figure 10- Total EBIT of the No Ban, Ngaruroro 2,400 and Base Case Compared- scaled up by soil type and area in each crop

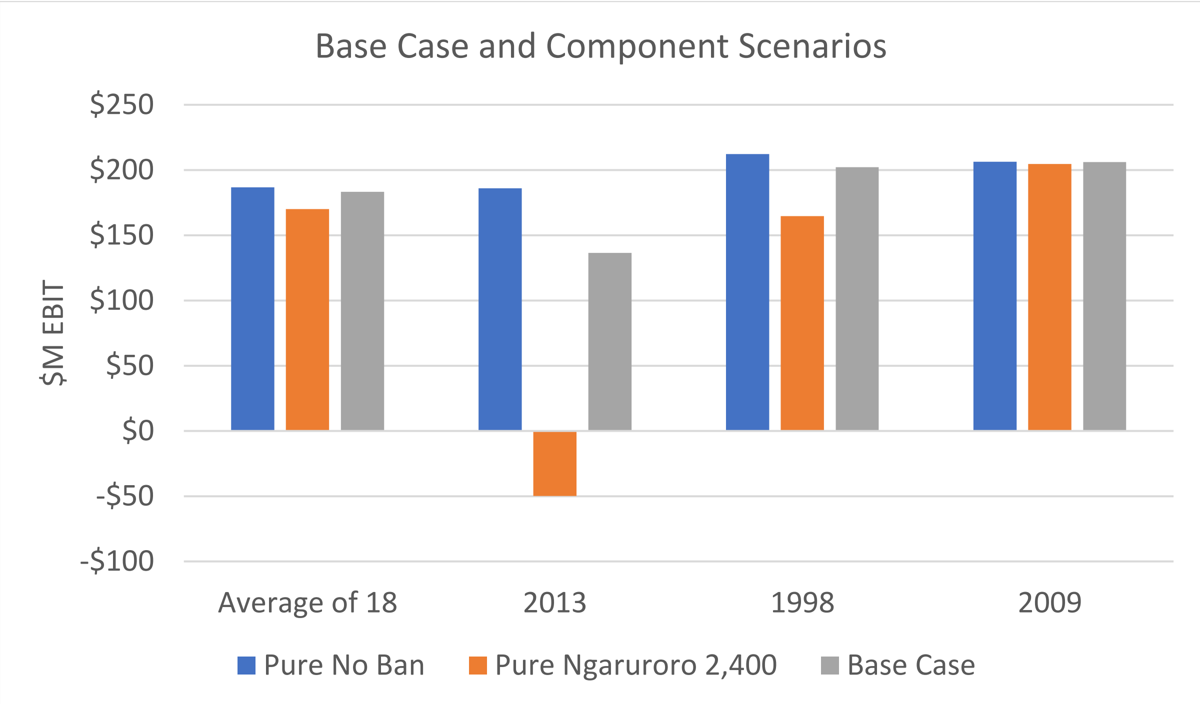


Figure 10 shows three results. The first is 'pure' No Ban. 'Pure' means the entire irrigated horticulture sector is placed on just the scenario in question. The second is 'pure' Ngaruroro 2,400. This shows what the earnings from irrigated horticulture in the TANK catchment would look like, if 100% were on the Ngaruroro 2,400 ban.

The Base Case is a combination of these two scenarios, 21% made up of Ngaruroro 2,400 and 79% made up of 'No Ban'.

The base case overall reduced the average combined Heretaunga Plains EBIT by $3 Million dollars per annum, and $50 Million dollars in the 'hardest hit' year (2013). In 1998 the 2,400 L/s ban was less severe (due to rainfall in the ranges), and there is a loss of $10 Million dollars, while the 2009 year as a 'moderately dry' year was not significantly affected.

5.2 Future Options

In the future options, the land area attached to river flow related irrigation bans changes. The areas proposed for the new 'groundwater zone 1' (connected to river flow related bans) and groundwater zone 2, 3 and 4 (not connected to flow related bans) sis shown below:

- 74% groundwater zones 2-4
- 20% Ngaruroro River connected at Fernhill
- 6% Tutaekuri River connected at Puketapu

5.2.1 Future A

Future scenario A was chosen as an indicator of the potential cost of setting the environmental protection of both major rivers at 80- 90% Habitat Protection for Torrentfish. HBRC have determined that the flows required for this level in the river would be:

- Ngaruroro on ban at 4,000 L/s in GW zone 1.
- Tutaekuri on ban at 3,300 L/s in GW zone 1.

This scenario also uses a 4 in 5 year annual allocation for connected groundwater and surface water, (groundwater zone 1) in addition to the base case weekly restrictions.

The groundwater zones 2-4 are shown on "9 in 10 year" annual allocations in addition to the weekly restrictions of the base case.

Figure 11- Total EBIT for Future A, 80 to 90% Habitat Protection, and Constituents

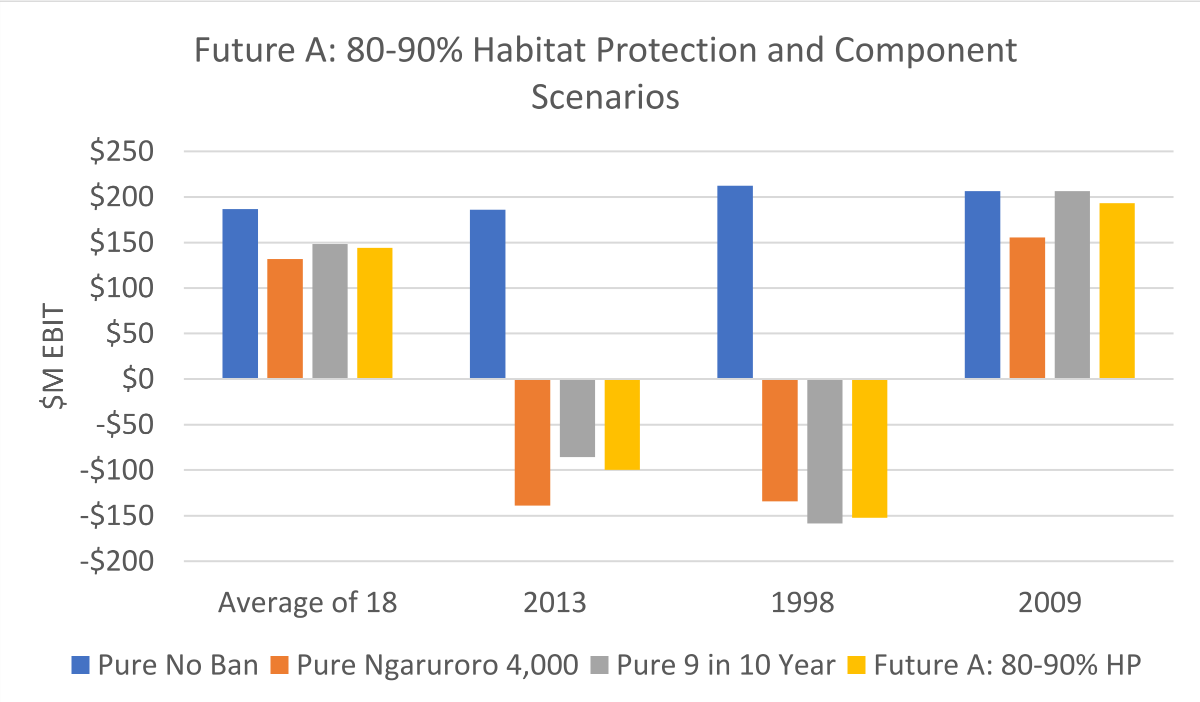


Figure 11 shows the outcome of this scenario at a TANK catchment level in yellow, named 'Future A: 80-90% HP' (habitat protection).

The No Ban scenario is included as a reference point, again being the outcome if the entire area was on No Ban scenario 1. Ngaruroro 4,000 and the "9 in 10 year" scenario are also shown as their individual outcome if everyone was subjected to them. These give reference as to how the Future Option A was created.

Future A is

- 74% land area on "9 in 10 year" scenario
- 26% land area on Ngaruroro 4,000 L/s and 4 in 5 year allocation (which also represents the impact of the Tutaekuri 3,300 L/s scenario).

The result is a reduced EBIT of $43 Million dollars on average per annum. In the harder hit years, the TANK catchment makes large losses, with an EBIT loss of $100 million and $152 million in 2013 and 1998 respectively. Relative to the no ban scenario, the difference is a reduction of $286 Million dollars in the 2013 year and $364 million in 1998. The 2009 year only gets hit on the Ngaruroro 4,000 L/s scenario, so the reduction from No Ban is $13 million in that year.

5.2.2 Future B

Future scenario B was chosen as an indicator of the potential cost of setting the environmental protection of both major rivers at 70- 75% Habitat Protection. HBRC modelers have determined that the flows required for this level in the river would be:

- Ngaruroro goes on ban at 3,600 L/s in GW zone 1.
- Tutaekuri goes on ban at 2,500 L/s in GW zone 1.

This scenario also uses a 4 in 5 year annual allocation for connected groundwater and surface water, (groundwater zone 1) in addition to the base case weekly restrictions.
The groundwater zones 2-4 are shown on 9 in 10 year annual allocations in addition to the weekly restrictions of the base case.

Figure 12- Total EBIT for Future Option B 70 to 75% Habitat Protection, and constituents

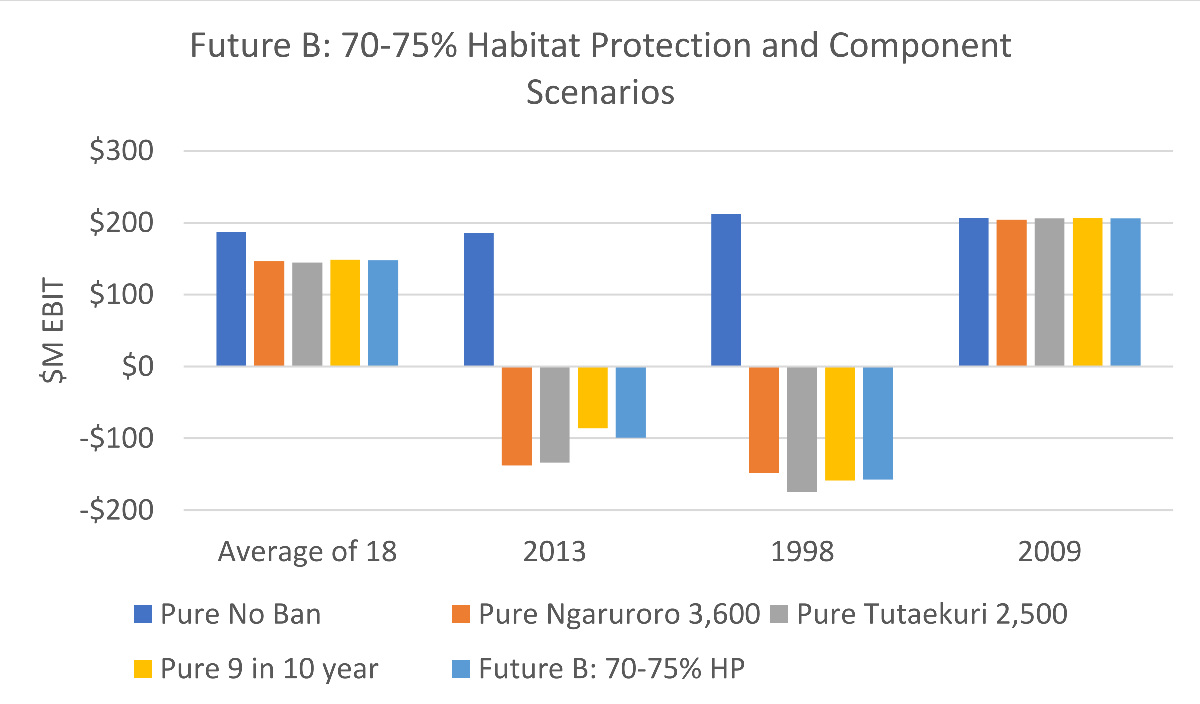


Figure 12 shows the outcome of this scenario at a TANK catchment level in light blue, named 'Future B: 70-75% **habitat protection (HP)**'.

The No Ban scenario, Ngaruroro 3,600, Tutaekuri 2,500 and "9 in 10 year" scenarios are included as references.

Future B is:

- 74% land area on "9 in 10 year" scenario
- 20% land area on Ngaruroro 3,600 L/s and 4 in 5 year allocation
- 6% land area on Tutaekuri 2,500 L/s and 4 in 5 year allocation.

All 3 component scenarios have similar average reductions in EBIT per annum from the No Ban scenario of around $40 million.

The result for Future B is a reduced EBIT of $39 Million dollars on average per annum. In the harder hit years, the loss is similar to that of the 80-90% HP scenario A, mainly due to the fact that all are being heavily impacted by the 4 in 5 year allocation restriction. It is worthwhile to note that the impact of the bans in the Future B option are significantly lower than that of Future A, and there is a 'masking' effect of the 4 in 5 year allocation.

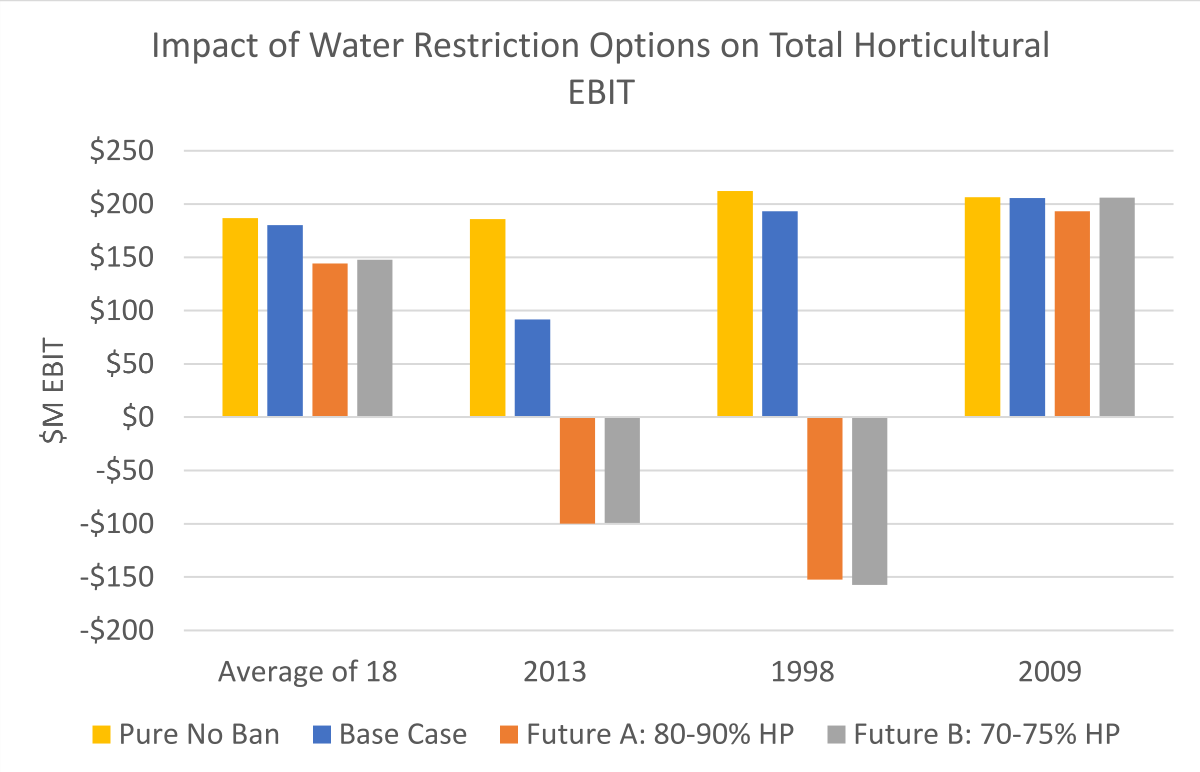
For example, in some crop x soil combinations, the 3,600 L/s scenario is better off than the 4,000 L/s scenario. This is because in the 4,000 L/s ban scenario the crop is banned from irrigating (and using up the annual allocation) for certain periods, while the 3,600 L/s ban scenario may still irrigate. This might alleviate some 'low' stress points in the season, but the 3,600 L/s scenario then runs out of allocation water earlier than the 4,000 L/s scenario. This is often a critical time of year and so the 3,600 L/s comes off worse with a larger soil deficit for longer, late season.

The 2009 year is not impacted by bans in Future B and shows no change in EBIT from the No Ban scenario.

5.2.3 Summary- Base case versus Future A and Future B

Figure 13 below shows a summary of the data presented so far. This is the No Ban scenario compared to each Option- Base Case, Future A and Future B. Note that the average is highly affected in the 2 drought years, and most other years show impacts similar to 2009, or lesser.

Figure 13- Summary of Options



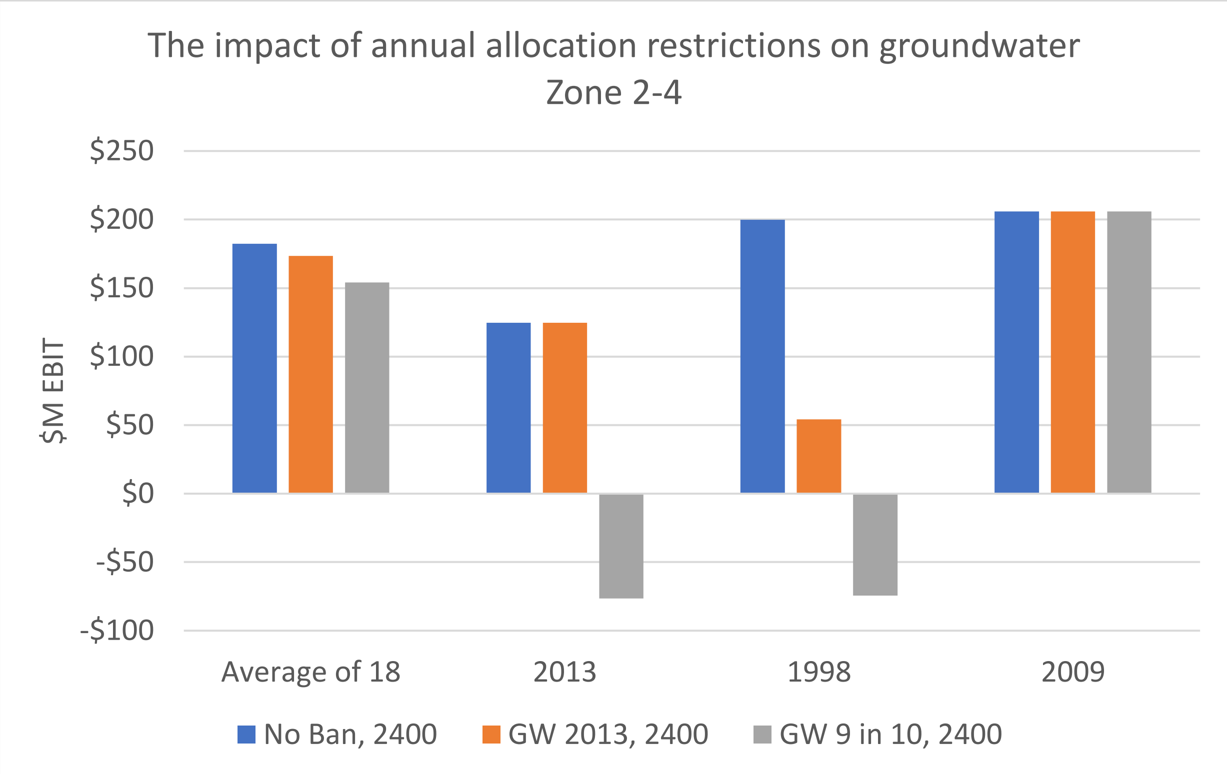
5.2.4 Future Groundwater Zone 2-4

The following data compares 3 allocation options in groundwater zone 2-4. All options are scaled up to the TANK catchment using;

- 74% of area on one of 3 allocation options
- 26% of area on the 2,400 L/s ban

Figure 14 looks at the impact of restricting annual allocations in the groundwater zones 2-4 from No Ban (weekly allocation but no annual allocation) to the amount of water required by the crop in 2013 or the amount required for a "9 in 10 year" security of supply. The 2013 amount is an average of a 16% reduction in allocation from the amount used in the No Ban scenario, while the "9 in 10 year" level is a 23% reduction from No Ban (see Table 6).

Figure 14- Total EBIT for the Future Option C Groundwater Zone 2-4 on 3 different allocation options



GW (meaning groundwater zone 2-4) 2013 has enough water for every year but 1998, where it reduced from a potential $200 million to $54 million total EBIT, a 73% reduction. This scenario results in an annual averaged loss of $9 million, or a 5% reduction every year.

The "9 in 10 year" scenario does not have sufficient water for the two driest years in 20- which are 1998 and 2013. It results in an annual average reduction in EBIT of $28 million, a 16% reduction from the Base Case option. In the two dry years it goes into loss figures, losing $201 million in 2013 and $274 million in 1998 from the Base Case potential.

6.0 PART 1B – NUTRIENT MODELLING

As described throughout the sections above, nutrient modelling results come from the same crops, soils and years as the irrigation restriction modelling, but we have nutrient loss results for all 12-14 soils for each crop.

6.1 Results

The average N loss from different crops is shown below. Within this average, there are a range of different loss figures depending on soil type. Soil type is a large determinant of N losses.

Table 13- Nutrient Loss Summary (average kg/ha/yr)

Crop	Nitrogen loss	Total P loss	P as drainage
Kiwifruit	13.4	0.16	65%
Pipfruit	14.6	0.22	55%
Summerfruit	14.1	0.13	73%
Grapes	9.0	0.58	78%
Squash	31.2	0.57	29%
Onions	32.7	1.30	15%
Sweetcorn	28.7	0.61	26%
Peas and beans	28.3	0.62	25%

*Note that P loss can occur through drainage or runoff, and P as drainage varies a lot by soil type.

Table 14 presents the soil type differences with the same crop and nutrient input level. Interesting here is the grape nitrogen loss result, because grape N inputs are very low, all foliar applied, yet the nitrogen loss value ranges from 1 kg/ha/year on the Omahu to 18 kg/ha/year on the Omarunui soil. This is the opposite relationship to usual thinking. The Omahu soil is very light, and therefore with high N inputs would be most 'leaky'. However, naturally it has very low mineralisation on organic matter in the soil, therefore very little N available to leach. The Omarunui soil, with very low input, still leaches due to higher natural mineralisation.

Where higher nitrogen inputs are applied in vegetable crops, susceptible soils are prone to leaching loss. For both Nitrogen and phosphorus, there are crop type and soil type combinations that are much higher risk than others for nutrient loss.

Note that in Table 14 below, the first soil listed relates to the kiwifruit, pipfruit and summerfruit. The second relates to grapes, and the third relates to the vegetable crops.

Table 14- Minimum, average, and maximum soil type for N leaching- average over 18 years

Nitrogen	Soil		
Crop	Min- Esk/ Omahu/ Pakipaki	Average of all soils (12 to 14)	Max- Farndon/ Omarunui/ Te Awa
Kiwifruit	9	13	23
Pipfruit	9	15	24
Summerfruit	9	14	23
Grapes	1	9	18
Squash	8	31	57
Onions	8	33	61
Sweetcorn	8	29	54
Peas and beans	7	28	55

Table 15 below shows one soil, Hastings Silt loam, and the associated Nitrogen loss under different crops. The grape N input is very low, so we can again see that the natural N loss from this soil is similar to the 14 units of N lost under grapes. The rest of the tree crops don't increase this value significantly. The increase comes when the land is cultivated for cropping.

Table 15- Hastings Silt Loam differences in N loss by crop

Row Labels	Nitrogen Loss (kg/ha/year)
Kiwifruit	14.1
Onions	29.7
Squash	27.8
Pipfruit	14.7
Sweetcorn	24.4
Summerfruit	14.5
Grapes	14.3
Peas and beans	24.8

Figure 15 shows the nitrogen loss per soil type and crop combination. It shows all land uses identified by the aerial reflectometry data, which includes non-irrigated area. However, some soil types are not covered, and the total area used is 16,456 ha, close to the 16,850 ha as derived above. The split of crop type is close to the AgFirst numbers, apart from pipfruit and summerfruit, which are under and over-estimated by the aerial imaging, respectively. Pipfruit and summerfruit N and P loss results are similar, so this 'swap' won't be significant overall.

Figure 15- Map of Horticultural Soil X Crop Combinations and the Related N Loss (kg/ha/year)

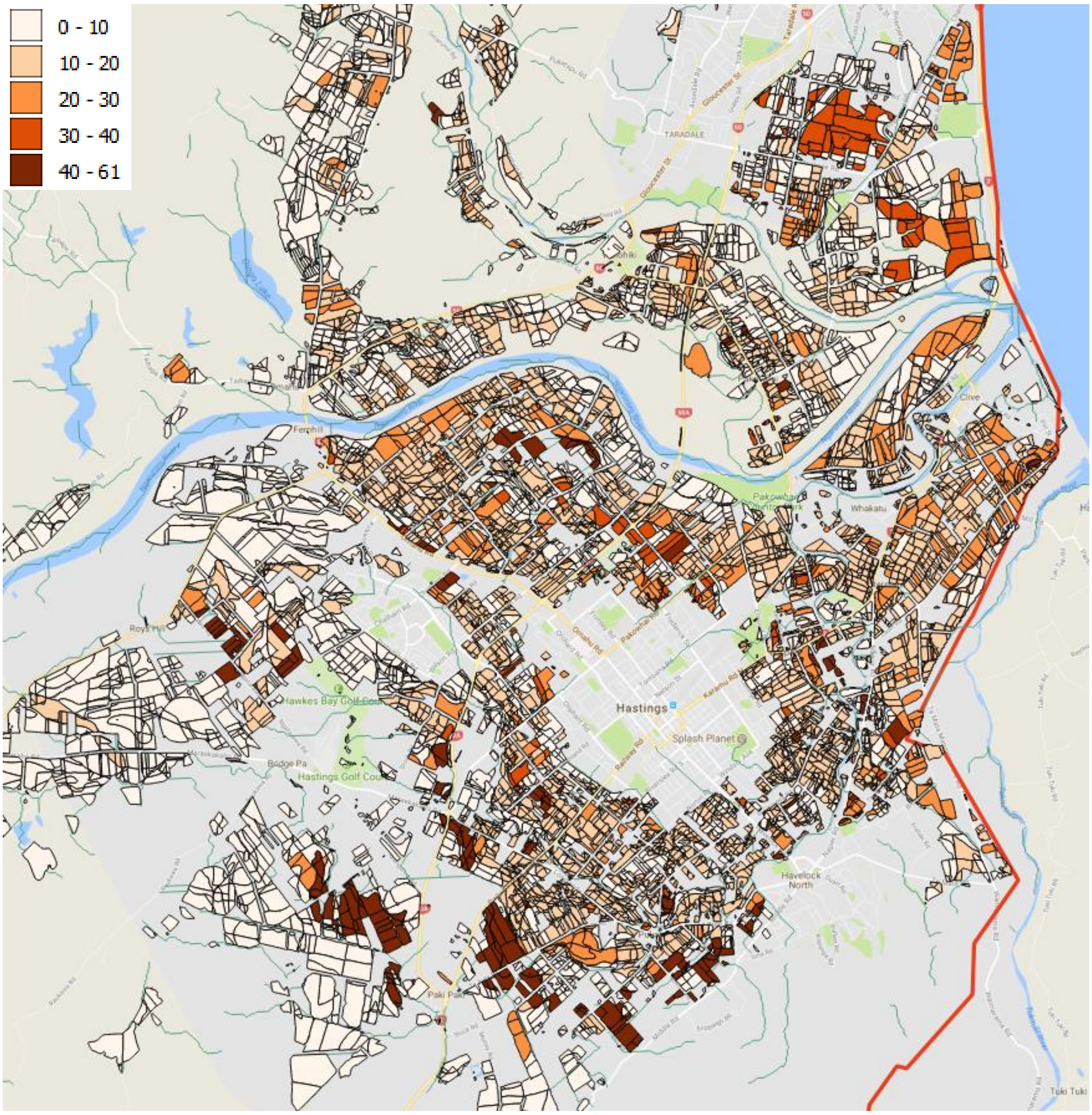
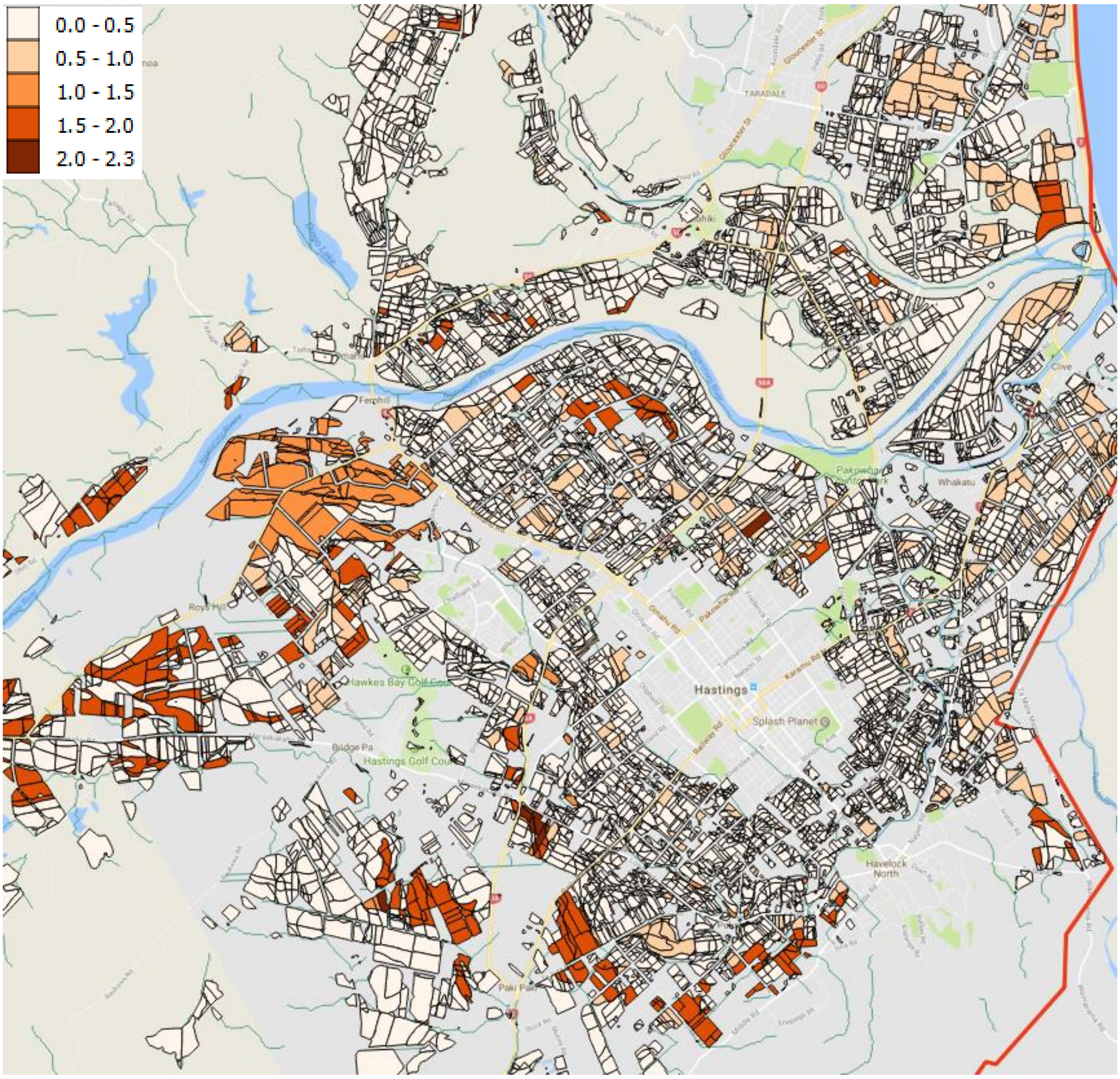


Figure 16 shows a snapshot of the same map but showing total phosphorus loss for each soil type and crop combination.

There are 103 combinations in total for both Figure 15 and 16.

Figure 16- Map of Horticultural Soil X Crop Combinations and the Related P Loss (kg/ha/year)



6.2 Nutrient Results Scaled up

Using the data in the maps above, plus addition of land in Poukawa and the upper Ngaruroro Corridor that is not included in the Griffiths soil maps, a total loss estimate has been calculated.

Table 16- Total Loss of N and P Modelled from Horticulture on the Heretaunga Plains

	Nitrogen	Phosphorus	P as Drainage	P as runoff
Total tonnes	200	8	5	2

Total nitrogen loss from this area was calculated at 200 tonnes per year. The total phosphorus loss calculated is 8 tonnes per year. Interestingly the phosphorus overall lost on the Heretaunga Plains is dominated by drainage losses, rather than runoff as traditionally thought for phosphorus. Drainage accounts for 5 of the 8 tonnes lost annually, while runoff accounts for 2 tonnes. This is because slope is not a large factor in the relatively flat plains.

7.0 MITIGATION OPTIONS

The end goal for nutrient modelling analysis is an outcome that results in the reduction or removal of algal blooms in Waitangi and Ahuriri estuaries and reduced levels of phormidium in the Ngaruroro and Tutaekuri rivers to improve river health, supporting greater fish life and safety to recreational water users.

Once the factors have been identified that contribute to the end goals, along with their level of effect and seasonal timeline, solutions need to be found that based on 'greatest gain, least pain' areas first, and working back toward the goal.

AgFirst were tasked with looking into different mitigation options for the model farms in terms of nutrient and sediment. This enables the TANK group to weigh up the loss data from section 6 above, with the overall estimated cost of mitigations. The following list shows mitigations tools that can be useful for some farms, which were considered for this project.

- Wetlands to filter sediment and nutrient
- Riparian planting
- Fertiliser management –
    - buffer distances
    - timing (month applied, and avoidance of weather events, meeting plant demand)
    - amount applied
    - fertiliser type
    - soil testing, leaf testing
    - Amount/timing with regard to the weather patterns for stream health
    - Method of application (foliar, ground, fertigation)
    - Sprayer calibration
    - Fertiliser placement e.g. banding instead of broadcasting
    - Liming- correct pH for uptake
- Cropping management
    - Contoured headlands
    - contour drains
    - wheel track ripping/diking
    - cover crops
    - silt fences
    - decanting earth bunds
    - Choice of land to grow a crop (soil, slope)
    - Grass filter strips and swales
    - Sediment traps/dams/ponds
    - Reduced tillage
    - Precision farming e.g. permanent GPS wheel tracks
- Reduce runoff via irrigation management
- New technologies- e.g. the bark pit and zeolite filter for nitrogen and phosphorus.

It is difficult for many of these mitigation measures to be blanket applied across the model farms and therefore the region. Every property is different, and some mitigations only apply if there is a particular slope, landform or waterway adjacent to or within the property. Additionally, many mitigations especially within fertiliser management, are already applied as good or average practice in the Hawke's Bay.

Taking these factors into account it was decided to model:

1) Shading of drains and streams
2) A generic sediment and nutrient mitigation cost

Each mitigation incurs a cost in year one, the cost of applying the mitigation, and then an annual maintenance cost from year 2 onwards.

7.1 Mitigation Cost Modelling – Shading of Drains and Streams

Shading of drains and streams links directly back to the goal of reduced algal growth, by cooling water temperatures. Cooler water reduces the growth rate of aquatic plants, reducing their use of oxygen in the water. Cooler temperatures are beneficial for many fish and invertebrate species. Shading using riparian margins also creates a buffer area between any operations (for example fertilising or spraying) and the waterway, and the potential to take up excess N and P.

Riparian planting could be trees, or it could be tall elephant grasses that shade out a small drain quickly and are also highly effective at filtering sediment. This costing relates to a riparian strip, costing $12.50 per meter for installation work and $3.75 per meter for annual maintenance.

AgFirst used the HBRC drain maintenance map to identify the total length of drain potentially needing planting. Some lengths of drain that should be planted have likely been missed by the HBRC network (the property owner does the maintenance) while some length of stream is already planted. It is assumed that these lengths cancel each other out and the total HBRC length was used.

For each model farm of a particular size, an estimate of the metres of waterway boundary edge was made. This was done using about 75% of one edge of a square block, considering that the model farms are likely to be made up of multiple blocks. Only one side of the waterway is planted, while the other is left for drain maintenance. The total metres of edge for each model farm was calculated and multiplied up to a length of stream on the Heretaunga Plains relating to each crop.

Table 17- Model Farm Area and Waterway Edge Assumptions

Cropping	Model Farm Area (ha)	% Edge with Waterway	Model Farm Metres to Plant	Regional Metres to Plant
Pipfruit	40	75% Edge	810	121,584
Grapes	18	50% edge	212	51,230
Summerfruit	18	75% edge	449	12,481
Kiwifruit	5.5	75% edge	248	8,132
Cropping	219	75% edge	3,427	91,027

The initial cost includes an assessment of site need based on metres of water way edge, type of waterway and shade optimisation. It then includes the average cost of installing the riparian mitigation. The model financial calculations are based on planting; however, it could be a range of solutions for different sites. For example, for a kiwifruit grower the cost might relate instead to the installation and maintenance of a shade cloth where there was not space to riparian plant without removing highly valuable rows of kiwifruit or altering the supporting structure.

Maintenance includes weed and pest control.

Table 18- Riparian Mitigation and Maintenance Costs

Crop	Model Farm Assessment and Mitigation ($ year 1)	Regional Mitigation Cost ($ year 1)	Model Farm Maintenance Cost ($/year)	Regional Maintenance Cost ($/year)
Pipfruit	$ 10,122	$ 1,519,803	$ 3,037	$ 455,941
Grapes	$ 2,652	$ 640,374	$ 795	$ 192,112
Summerfruit	$ 5,616	$ 156,008	$ 1,685	$ 46,802
Kiwifruit	$ 3,106	$ 101,655	$ 932	$ 30,496
Combined Vegetable	$ 47,978	$ 1,274,372	$ 12,851	$ 341,350
Total Riparian	**$ 69,474**	**$ 3,692,211**	**$ 19,300**	**$ 1,066,701**

7.2 Mitigation Cost Modelling- Sediment and Nutrient

There are many options for different farms on how best to mitigate against nutrient and sediment losses. There will be a range of risk levels and a range of costs to the farm to implement and maintain mitigations. AgFirst have come up with costs for each model farm of the estimated average requirement.

This includes a site-specific assessment of some kind. This could be internal or external and looks at where the risk of loss is coming from on the property. For permanent crops, the risk of sediment loss is mostly very low, and it is expected that on average, the assessment will be done and no further mitigations will need to be applied and maintained. Some properties might be an exception, with an area of heavy traffic on a slope near a waterway or other risky landforms. In this case they would follow the assessment with a management strategy, potential solutions and maintenance or ongoing monitoring.

The cropping model farm has the highest risk of sediment loss and mitigations are expected to be required for the average cropping block. The cost for a cropping farm includes a site specific sediment loss risk assessment. It develops a management strategy according to best practice guidelines that includes potential solutions such as sediment traps and grass filter strips. The maintenance cost includes maintenance of these additions, plus an ongoing sediment loss monitoring program. It is expected that best practice guidelines will change over time and the model farm will have to keep up with best practice guidelines.

Costs are shown in Table 19 below. These show the cost of the mitigation implementation in year 1, and then the maintenance of those mitigations annually thereafter.

Table 19- Sediment Mitigation and Maintenance Costs

Crop	Model Farm Assessment and Mitigation ($ year 1)	Regional Mitigation Cost ($ year 1)	Model Farm Maintenance Cost ($/year)	Regional Maintenance Cost ($/year)
Pipfruit	$ 200	$ 30,030	$ 0	$ 0
Grapes	$ 50	$ 12,075	$ 0	$ 0
Summerfruit	$ 100	$ 2,778	$ 0	$ 0
Kiwifruit	$ 50	$ 1,636	$ 0	$ 0
Combined Vegetable	$ 27,000	$ 717,164	$ 9,000	$ 239,055
Total Sediment	**$ 27,400**	**$ 763,684**	**$ 9,000**	**$ 239,055**

In the same way as for sediment, the nutrient management risk is assumed to require some form of site assessment. Permanent crops have a low expected nutrient loss as described in section 6. The initial mitigations expected therefore are minor, including upskilling on best practice and carrying out baseline monitoring of nutrient loss from the farm system (e.g. practical measurements from tile drains). The ongoing cost for permanent crops are then similar each year going forward, carrying out best practice such as soil and leaf tests, ongoing loss monitoring and nutrient reconciliations, using this information to better assess nutrient requirements.

The cropping farm is estimated on average to require a more in depth nutrient loss risk and fertiliser use assessment, adding some initial mitigation actions, examples of which are listed at the start of this section. More specifically the budget was calculated on potential mitigations including grass buffer or riparian margin widening, fertiliser application technique or product choice changes, and monitoring of drainage water in 'at risk' blocks. Where grazing is taking place, a specific nutrient risk focus may be required.

Table 20- Nutrient Mitigation and Maintenance Costs

Crop	Model Farm Assessment and Mitigation ($ year 1)	Regional Mitigation Cost ($ year 1)	Model Farm Maintenance Cost ($/year)	Regional Maintenance Cost ($/year)
Pipfruit	$ 3,000	$ 450,450	$ 3,000	$ 450,450
Grapes	$ 1,250	$ 301,875	$ 1,000	$ 241,500
Summerfruit	$ 2,000	$ 55,556	$ 1,500	$ 41,667
Kiwifruit	$ 1,500	$ 49,091	$ 1,000	$ 32,727
Combined Vegetable	$ 16,000	$ 424,986	$ 17,000	$ 451,548
Total Nutrient	**$ 23,750**	**$ 1,281,958**	**$ 23,500**	**$ 1,217,892**

8.0 ASSUMPTIONS AND LIMITATIONS

This report was created for the purposes of determining the economic and environmental impact of TANK catchment water allocation/ restriction options on the Hawke's Bay Region. Farm models were created to represent wider impacts on the region, NOT to represent individual farms.

8.1 Current Situation

Assessment of crops to model was done on the current situation in terms of planted area, value, market, etc. This changes over time and the vegetable model especially is volatile. This report should not be taken out of context through time.

Budget prices are the most recent 3 year averages and should represent 'average' or the current situation out in the TANK catchment as 2014 to 2016 (and where available, 2017).

8.2 Soil Related

Fertiliser applications were not specified by soil type.

Not all soil types are modelled through SPASMO. From SPASMO results, only 3 soil types per crop were taken to an EBIT result. These 3 soils were used to represent the rest of the modelled soils (by grouping them into low, moderate and high TAW). The proportion of modelled soils that were low, moderate or high TAW was used to scale up. For example, 27% of summerfruit was planted on soil types grouped into the 'low' category (5 soil types). 44% are on 'Moderate' soil types (another 5 soils) and 29% were on the 2 'high' TAW soil types. It was then assumed that any soil types under summerfruit that were not captured conform to this ratio.

For each soil grouping above, one soil was used as the 'representative EBIT result' of that soil group under each scenario and year. Continuing the example, the soil representing the 5 'low' TAW summerfruit soils is Karamu 13s. Karamu 13s is the only 'low' TAW soil for summerfruit that has an EBIT result calculated.

8.3 Land Area

We used industry knowledge and combined this with Aqualinc's irrigation consent data, where it made sense. AgFirst had come up with a 2017 best estimate of land area in each crop that came from industry- e.g. Apples and Pears NZ, Summerfruit NZ, HB Winegrowers, Heinz Watties, Zespri, Bostock, Apatu, McCain Foods, other consulting companies, other growers.

AgFirst understands roughly the amount of each crop that is going to be unirrigated, and Aqualinc consent data agreed with this for all but 2 crops- summerfruit and kiwifruit. For these crops we used AgFirst figures.

8.4 Climate

Climate data for Whakatu is used to represent the entire horticultural area in TANK. In reality, there is slightly higher rainfall up the river valleys and down in Poukawa, however this was not deemed to be significant enough to warrant inclusion in the scope of this project given time and financial limitations.

8.5 Water Management

It is assumed that when a ban or restriction on water comes into play, it is 100% adhered to.

It is assumed that there is no 'panic irrigating' prior to an irrigation ban, and that water is used to plant requirement. In reality, growers can let their crops go into small deficits at certain times of the year, sometimes to their benefit, and there are also equipment limitations that stop the plant receiving its full requirement 100% of the time. Conversely, some people over water at times of the year, whether a mistake or through lack of understanding.

Another key limitation of this model is that in reality, a lot of land under such severe water restrictions, would be used for alternative crops (i.e. dryland crops). There would be behaviour change relative to the risk imposed on the business. The EBIT results of this report assume there is no behaviour change and the same crops keep getting grown even under the severe restrictions.

Annual allocations are used to full plant demand through the season until they run out of water. When they run out, there is effectively a 100% ban put in place suddenly. In reality this would be managed. Growers might run crops at slight deficits at particular times to conserve water if they know they have an annual allocation to abide by. They might use 'sacrifice crops' where they are getting low on allocation and can't continue full plant requirement on every hectare.

Annual allocations are also *model specific*. In reality, we cannot allocate an exact 9 in 10 year such as this (further work to check our limits in relation to SPAMSO or Irricalc allocation limits).

8.6 Young Trees and Vines

Young trees and vines aren't accounted for through SPASMO or financial data. Grape vines and other crops are assumed to be mature in terms of drought response. The economic impact of young plant loss is not considered in this analysis. Where a severe impact on kiwifruit in the model might reduce income for that year, it bounces back the next year. Young trees under a severe deficit will die, and when establishment costs are $100,000 plus, and land value is the same, it can easily mean life or death for a business.

8.7 Grape Model

Because the grape model EBIT is low, the 'noise' in the modelling data from Plant and Food Research (in yields), looks as if it increases and reduces EBIT by a large percentage. We have noise in which yields increase or reduce in different scenarios by a maximum of 4% (not statistically significant). Therefore, the yield increases have been removed. There is no physiological reason for grape vines receiving the right amount of water, to increase yield under ban (as outlined earlier many wineries mandate the amount of production they will accept from a given planted area and growers match a yield to this value). AgFirst and Plant and Food Research has worked together to thoroughly check that this anomaly has no basis and should be removed.

8.8 Quality

Impacts of biennial bearing on the subsequent year are included in the instigating year. In reality, these impacts are spread over multiple years (at least two) and may extend for numerous years following their induction.

The amount of TAW in the root zone and how it links to plant stress and therefore quality change, and what type of quality change, is not an exact science. It took

1) Finding the best scientific indicators available
2) Filling the gaps with practical knowledge
3) Determining what industry would see as 'severe' impacts on their crop out of a drought
4) Matching TAW to categories of impact
5) Checking that known 'severe' years in known 'severe' scenarios triggered the 'severe' category, and same for other categories.
6) Making alterations to the TAW% to remove the error (usually the issue was soil moisture content reporting depth limitation of SPASMO).

8.9 Financials

Prices for crops are static over the years where in reality they are ever changing.

AgFirst realises that the modelling at this point has a fixed expenditure amount, and that in reality, with lower yields come lower postharvest costs, and lower packouts can mean higher postharvest costs. This is an accepted limitation of the model due to funding limitations.

8.10 SPASMO

Each crop requires one harvest date for all scenarios and years. This is not what occurs in reality, especially with cropping. Summerfruit was difficult having both process and fresh as part of the model. We chose to use the process harvest date.

SPASMO output information for soil water content, weekly, was one of 2 options- to 50cm or 1 m depth. Therefore TAW% had to be calculated off one of these options.

SPASMO assumptions and limitations. A Plant and Food Research summary report is to be added in at a later stage.

9.0 REFERENCES AND ACKNOWLEDGEMENTS

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- Apatu Group
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- Drumpeel Farms
- Lawson's True Earth
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- Alan Kale (ELAK Consulting)

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10.0 APPENDIX 1- THE MODEL FARMS

This appendix summarises the model farms AgFirst have created. They are meant to represent an industry average situation in the Hawke's Bay, more specifically the TANK catchment. The document also includes SPASMO input parameters of interest.
Note that these have not yet been updated to the latest of PFR outputs, so some things may change.

10.1 Pipfruit

Table 21- Farm information

Crop/s	Pipfruit
Farm area	40
Owned	60%
Leased	40%
Market	Export, local and process
Orchard varieties	As in MPI Farm Monitoring 2016
Orchard age	Mixture as represents industry from MPI farm monitoring
Total area in TANK	6,000 ha

Table 22- Annual N and P application to Pipfruit

Nutrient	(Kg/Ha)	Month applied	Application method
Nitrogen	40	April/May	Ground/Foliar
	2	Oct	Foliar
	2	Nov	Foliar
	2	Dec	Foliar
	2	Jan	Foliar
Total N	48		
Phosphorous	15	September	Ground

Table 23- Production and Returns for Pipfruit

Crop	Gross production (Kg/Ha)	Export production (Kg/Ha)	Local/process production (Kg/Ha)	Export (%)	Local (%)	Export return ($/Kg)	Local return ($/Kg)	Gross income ($/Ha)
Pipfruit	60,878	43,733	17,145	72%	28%	$1.54	$0.19	$70,606

*Export return changes depending on fruit size

Table 24- Pipfruit model income and expenditure 2014- 2016 average

Item	$/ha
TOTAL INCOME	70,606
Total postharvest expenses	26,133
FARM GATE INCOME	44,473
Total labour expenses	18,826
Total working expenses	6,583
Total overhead expenses	1,662
TOTAL ORCHARD WORKING EXPENDITURE	27,070
CASH OPERATING SURPLUS	17,403
Depreciation	1,375
Lease	1,875
EBIT	14,153

Table 25- SPASMO model parameters of interest

Input	Value
Canopy height	4m
Rooting Depth	1m
Drought tolerance	0.4 then 0.5
Harvest date	31st March
Grazing	None
Clover content of grass sward (for N fixation)	5%
% Crop harvested (Pickout)	90%
Crop factor (Kc) at full canopy	0.75 (Includes grass sward)

Drought tolerance is a scale of 0 being low and 1 being high tolerance.

10.2 Kiwifruit

Table 26- Farm information

Crop/s	Kiwifruit
Farm area (Ha)	5.5ha (1.5 Hayward, 4 Gold3)
Owned	100%
Leased	0%
Market	Export
Orchard varieties	G3, Hayward
Orchard age	Hayward mostly mature, and a mix of mature and young G3
Total area in TANK	180 ha

Table 27- Annual N and P application to Kiwifruit

Nutrient	Kg/ha	Month	Ground/foliar
Nitrogen	70	Sept	Ground
	50	Oct	Ground
	20	Nov	Ground
Total N	140		
Phosphorus	20	Aug	Ground

Table 28- Production and Returns for Kiwifruit

Variety/Crop	Area	Gross production (Kg/Ha)	Export production (Kg/Ha)	Export (%)	Export return ($/Kg)	Gross income ($)
Gold 3	4	39,401	37,401	95%	$3.53	$528,701
Green	1.5	27,549	25,549	93%	$2.29	$87,608
Total	5.5	36,169	34,169	94%	$3.19	$616,308

Table 29- Kiwifruit model income and expenditure

Item	$/ha
TOTAL INCOME	112,056
Total postharvest expenses	37,225
FARM GATE INCOME	74,831
Total labour expenses	29,955
Total working expenses	9,917
Total overhead expenses	1,570
TOTAL ORCHARD WORKING EXPENDITURE	41,442
CASH OPERATING SURPLUS (per Ha)	33,389
Depreciation	0
Lease	0
EBIT	33,389

*Depreciation was not included in this budget, provided to AgFirst from a grower source. Rather the known income and expenditure items were added until total orchard working expenditure and the EBIT matched what was known as the average situation for the 3 recent years.

Table 30- SPASMO model parameters of interest

Input	Value
Canopy height	2m
Rooting Depth	1m
Drought tolerance (0-1)	0.35
Harvest date	15th May
Clover content of grass sward (for N fixation)	5%
% Crop harvested (Pickout)	90%
Crop factor (Kc) at full canopy	1

10.3 Summerfruit

Table 31- Farm information

Crop/s	Fresh & process Summerfruit
Producing area	18
Owned	60%
Leased	40%
Market	Fresh summerfruit goes to local market
Orchard varieties	Fresh: A mixture of nectarines and peaches. Process: Tatura and Golden Queen peaches.
Orchard age	Fresh: 10% young (50% production). Process: An average of ages 3 to 15
Total area in TANK	500 ha, 70% fresh, 30% process

Table 32- Annual N and P application to Summerfruit

Product	Kg/ha	Month	Ground/foliar
Nitrogen	25	Sept	Ground
	1	Oct	Foliar
	1	Nov	Foliar
	1	Dec	Foliar
	20	Jan	Ground
	20	Feb	Ground
Total N	68		
Phosphorus	8	Sept	Ground

Table 33- Production and Returns for Fresh Summerfruit

Crop	Gross production (Kg/Ha)	Local market production (Kg/Ha)	Local (%)	Local return ($/Kg)	Gross income ($/Ha)
Fresh Summerfruit	21,291	21,291	100%	$2.98	$63,420

*Average 15 to 17

*Local return changes depending on fruit size

Table 34- Production and Returns for Process Peaches

Crop	Gross production (Kg/Ha)	Process production (Kg/Ha)	Process (%)	Process return ($/Kg)	Gross income ($/Ha)
Process Peaches	33,350	33,350	100%	$0.71	$23,679

*Process return changes depending on fruit size

Combined production and income for an orchard with 30% process and 70% fresh local crops was 25,000 kg/ha and $51,498 respectively.

Table 35- Fresh Summerfruit model expenditure

Item	$/ha
TOTAL INCOME	61,850
Total postharvest expenses	16,549
FARM GATE INCOME	45,301
Total labour expenses	21,029
Total working expenses	7,422
Total overhead expenses	667
TOTAL ORCHARD WORKING EXPENDITURE	29,118
Depreciation	1,000
Lease	1,800
EBIT	13,384

Table 36- Process Summerfruit model expenditure

Item	$/ha
TOTAL INCOME	23,679
Total postharvest expenses	948
FARM GATE INCOME	22,730
Total labour expenses	12,043
Total working expenses	4,219
Total overhead expenses	1,015
TOTAL ORCHARD WORKING EXPENDITURE	17,276
CASH OPERATING SURPLUS (per Ha)	5,454
Depreciation	1,406
Lease	1,000
EBIT	3,048

Combined expenses for an orchard with 30% process and 70% fresh local crops were $28,247.

Table 37- SPASMO model parameters of interest

Input	Value
Canopy height	4m
Rooting Depth	1m
Drought tolerance (0-1)	0.5
Harvest date	25th March
Grazing	None
Clover content of grass sward (for N fixation)	Zero
% Crop harvested (Pickout)	90%
Crop factor (Kc) at full canopy	0.9

Important:
When modelling summerfruit in SPASMO, we had to choose a harvest date to model from. We decided to use the golden queen peach harvest date of late March, because otherwise we would not be able to see impacts of the bans (that are mostly Feb- March). Many fresh stonefruit are harvested by mid-January.

Hence yield impacts are derived from a late march harvest. For fresh summerfruit, this will over estimate impacts because ban days before mid-Jan are very uncommon.

10.4 Grapes

Table 38- Farm information

Crop/s	Grapes
Planted area	18
Owned	100%
Leased	0%
Market	Winemaking
Orchard varieties	Merlot, Chardonnay, Sauvignon blanc, Pinot Gris, Syrah
Orchard age	Mature
Total area in TANK	4347ha

Table 39- Annual N and P application to Grapes

Nutrient	Kg/ha	Month	Ground/foliar
Nitrogen	7.3	Nov	Foliar
	5.6	Dec	Foliar
	4.5	Jan	Foliar
	3.3	Feb	Foliar
Total N	20.7		
Phosphorus	3	Nov	Foliar
	1.7	Dec	Foliar
	0.1	Jan	Foliar
	0.6	Feb	Foliar
	5	May	Ground
Total P	10.4		

Table 40- Production and Returns for Grapes

Crop	Gross production (Kg/Ha)	Grape Sales %	Return ($/Kg)	Gross income ($/Ha)
Grapes	9,266	100%	$1.65	$15,289

Table 41- Grape model farm expenditure

Item	$/ha
TOTAL INCOME	15,289
Total postharvest expenses	103
FARM GATE INCOME	15,186
Total labour expenses	9,593
Total working expenses	3,030
Total overhead expenses	917
TOTAL ORCHARD WORKING EXPENDITURE	13,540
CASH OPERATING SURPLUS (per Ha)	1,646
Depreciation	1,430
Lease	0
EBIT	216

With such a low EBIT currently, it raised the question- why are people still growing grapes to sell to wineries? The answer to this is to remember for small growers, the EBIT already has manager wages of about $60,000 removed. The other answer is that in all horticultural businesses there is a long-term fluctuation in market prices, and this budget will change as time goes on.

Table 42- SPASMO Model Parameters of Interest

Input	Value
Canopy height	2m
Rooting Depth	1m
Drought tolerance (0-1)	0.45
Harvest date	25th March
Grazing	None
Clover content of grass sward (for N fixation)	None
% Crop harvested (Pickout)	90%
Crop factor (Kc) at full canopy	0.45 (includes grass sward)

10.5 Vegetables

Table 43- Farm information

Crop/s	Onions, squash, peas & beans, sweetcorn
Farm area (ha)	219
Planted area (ha)	210
Owned	10%
Leased	90%
Market	Process, export
Total vegetable area in TANK	2017 season: 5,217 (AgFirst). 2015 season: 7,800 (Land Use Map HBRC). Area includes beetroot, tomato, and market garden, but not grains. Final irrigated: 5817 ha.

Crops listed above in the title are the crops going to be modelled through SPASMO.

Table 44- Model vegetable farm areas in ha and %

Model Farm	ha	%
Onions	31.5	15%
Squash	63.0	30%
Peas & Beans	31.5	15%
Sweet Corn	31.5	15%
Other	52.5	25%
Total effective	210.0	100%
Headlands & infrastructure	9	5%
Total Land area	**219**	

Table 45- Rotation dates for crops and pasture

Crop	Planting	Harvest	Grazed Pasture
Onions	23rd Aug (DOY 235) Leaf showing DOY 265	20th March (DOY 80) Ploughed DOY 90	95 to 260
Squash	27th Oct (DOY 300) Leaf showing DOY 310	31st Mar (DOY 90) Ploughed DOY 215	95 to 295
Peas	2nd Sept (DOY 245) Leaf showing DOY 255	16th Dec (DOY 350) Ploughed DOY 360	7th Sept pasture out (DOY 250)
Beans	1st Jan (DOY 1) Leaf showing DOY 11	10th April (DOY 100) Ploughed DOY 105	20th April pasture in (DOY 110)
Sweet Corn	7th Oct (DOY 280) Leaf showing DOY 295	21st March (DOY 80) Ploughed DOY 85	95 to 275

Table 46- Nutrient applied to vegetable crops

	Sept-Feb		Oct- Jan		Sep - Dec		Nov- March		Dec- Feb		Nov planting		Dec planting	
Crop	Onions		Squash		Peas		Sweetcorn		Beans		Tomatoes		Beetroot	
Kg/ha	N	P	N	P	N	P	N	P	N	P	N	P	N	P
Sep	32	35												
Oct	32	10	20	28										
Nov	32	10	42		0	0	44	45			32	58		
Dec	32	10					110		30	13	37	16	45	43
Jan									24	10			92	
Feb											31	13	69	
Total	128	65	62	28	0	0	154	45	54	23	100	87	206	43

Table 47- Vegetable Production and Returns

TANK Vegetable Base Model - Cropping Gross Margins					
	Ave Yield/ ha	**$/T**	**Return/ ha**	**Cost/ha**	**Margin/ ha**
Peas	6.7	$ 366.55	$ 2,448	$ 1,354	$ 1,094
Beans	14.1	$ 366.36	$ 5,161	$ 2,525	$ 2,636
Sweet Corn	20.7	$ 202.07	$ 4,186	$ 2,116	$ 2,070
Squash	22.5	$ 435.00	$ 9,780	$ 8,534	$ 1,246
Onions	63.0	$ 456.00	$ 28,728	$ 20,790	$ 7,938
TANK Other	68.0	$ 189.00	$ 12,393	$ 9,671	$ 2,722

*Other= beetroot, tomato and carrot

Table 48- Cropping Revenue and Area

TANK Vegetable Base Model - Cropping Revenue			
Crop	**$/ha**	**area (Ha)**	**$/model**
Peas	$ 2,448	31.5	$ 77,097
Beans*	$ 5,161	27	$ 138,175
Sweet Corn	$ 4,186	31.5	$ 131,859
Squash	$ 9,780	63	$ 616,152
Onions	$ 28,728	31.5	$ 904,932
TANK Other	$ 12,393	52.5	$ 650,623
Total Cropping Revenue		**210**	**$ 2,518,838**

Table 49- Whole Farm Financial Model

Tank Vegetable Base Model - Profit and Loss				
			$ Total	$/ha
Revenue	Sheep Revenue	Sales - Purchases	237,300	1,130
		Wool	24,990	119
		Total Sheep	262,290	1,249
	Cropping Revenue	Cash Crops	2,602,355	12,392
	Total Revenue		$2,864,645	$13,641
Expenses	Wages	Wages	23,940	114
		Wages of Management	80,000	381
	Stock	Animal Health	3,780	18
		Shearing	16,380	78
	Cropping expenses	Direct Crop Expenses	1,653,825	9,932
		Re-grassing	73,500	350
		Nitrogen	18,480	88
		Irrigation Charges	630	3
	Other Farm Working	Weed and Pest Control	2,730	13
		Vehicle Expenses	7,980	38
		Fuel	10,080	48
		Repairs & Maintenance	7,350	35
		Freight & Cartage	3,780	18
		Electricity	26,250	125
	Standing Charges	Administration Expenses	13,230	63
		Insurance	10,080	48
		ACC Levies	1,260	6
		Rates	56,367	436
	Total Farm Working Expense			2,009,642
	Depreciation		100,700	480
	Total Farm Expenses		$2,110,342	$10,049
Economic Farm Surplus (EBIT)			**$754,303**	**$3,592**

Table 50- SPASMO input parameters of interest

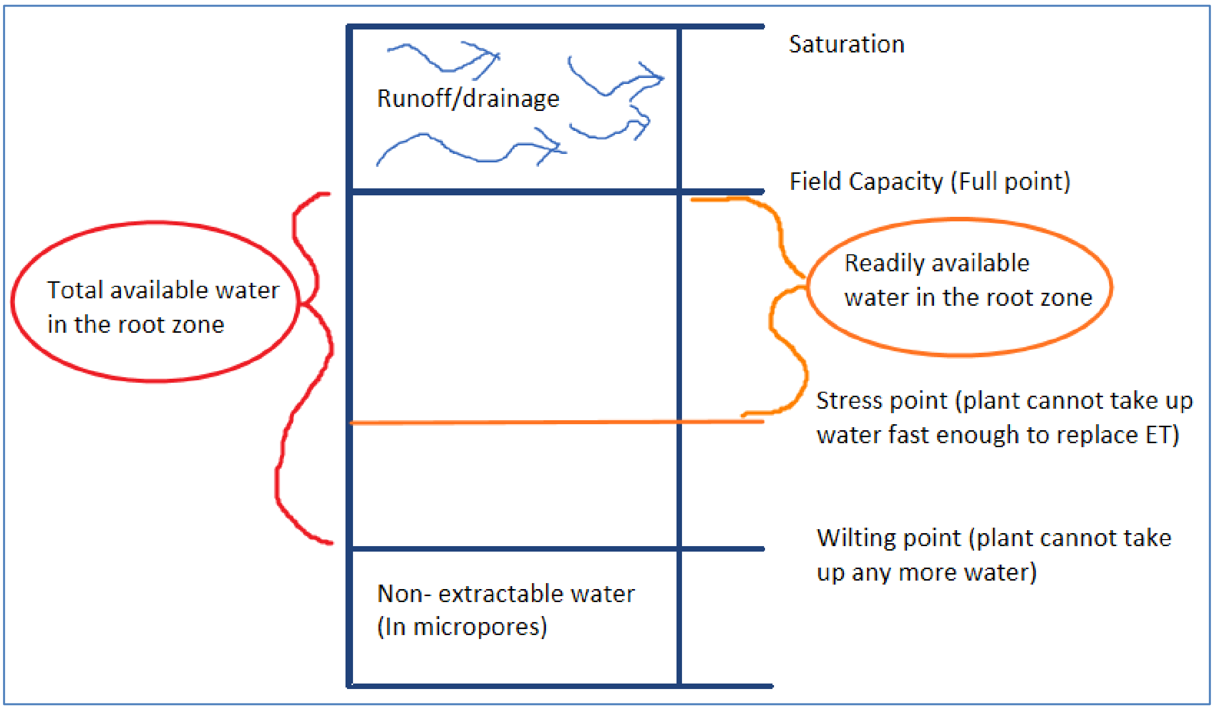
Input		Value
Pasture		
	Farm size	200 ha
	Sheep no.	4,000
	Clover content of grass sward (for N fixation)	5%
	Pasture root depth (m)	0.7
	Ploughing in	None- model is evergreen
Onion		
	Root depth	0.1 then 0.5
	Drought tolerance	0.35
	Flowering date	315
	Harvest index	90%
Squash		
	Root depth	0.1 then 0.7
	Drought tolerance	0.5
	Flowering date	360
	Harvest index	90%
Sweetcorn		
	Root depth	0.1 then 1
	Drought tolerance	0.55
	Flowering date	360
	Harvest index	90%
Peas		
	Root depth	0.1 then 0.6
	Drought tolerance	0.35
	Flowering date	295
	N Fixation	0.25
	Harvest index	90%
Beans		
	Root depth	0.1 then 0.5
	Drought tolerance	0.45
	Flowering date	35
	N fixation	0.25
	Harvest index	90%

Note that one pasture model was created, and then merged by date with the correct crop rotation. For example, onions are planted on August 23rd, harvested on the 20st March and ploughed in 10 days later. Then we cut to the outputs of the pasture model from the 5th of April to the 17th September.

11.0 APPENDIX 2- SOIL TYPES

For economic modelling, soils were grouped by total available water (TAW), which is defined as field capacity (FC) minus wilting point (WP) all values in mm. Different soils have different capacities in each section of the schematic below. Good soils have plenty of available water, and not too much clay- which is the usual reason for non-extractable water locked in tiny micropores.

Figure 17- Soil Water Schematic



The 3 soils chosen in each situation best represented the TAW of their group and were common soils in terms of area represented on the plains. The tables below show the soil types that were modelled through SPASMO, and highlighted soils (3) which were taken further through the AgFirst quality matrix.

Table 51- Tree crops and Kiwifruit soils and 3 highlighted soils chosen to represent the Low, Mod and High TAW groupings

Soil ID	Soil Name	TAW (mm)	Group
1	Soil-HawkesBay-Farndon_23s.csv	212.5	Mod
2	Soil-HawkesBay-Farndon_silt_loam.csv	280	High
3	Soil-HawkesBay-Hastings_silt_loam.csv	230.2	Mod
4	Soil-HawkesBay-Hastings_silty_clay_loam.csv	187	Low
5	Soil-HawkesBay-Karamu_13.csv	195.8	Low
6	Soil-HawkesBay-Karamu_13s.csv	190.2	Low
7	Soil-HawkesBay-Mangateretere_71.csv	159.6	Low
8	Soil-HawkesBay-Pakowai_silt_loam_17.csv	272.7	High
9	Soil-HawkesBay-TeAute_fine_sandy_silt_loam.csv	187.4	Low
10	Soil-HawkesBay-Twyford_sandy_loam.csv	202.2	Mod
11	Soil-HawkesBay-Twyford_silt_loam.csv	233.3	Mod
12	Soil-HawkesBay-Twyford_silty_clay_loam.csv	230.5	Mod
13	Soil-HawkesBay-Esk_sandxx.csv	175.5	Low
14	Soil-HawkesBay-Omaranui_4.csv	210.4	Mod

Table 52- Grapes soils and 3 highlighted soils chosen to represent the Low, Mod and High TAW groupings

Soil ID	Soil Name	TAW (mm)	Group
1	Soil-HawkesBay-Hastings_silt_loam.csv	230.2	High
2	Soil-HawkesBay-Irongate_21.csv	170.8	High
3	Soil-HawkesBay-Matapiro_silt_loam_28.csv	108.2	Low
4	Soil-HawkesBay-Ngatarawa_sandy_loam_10.csv	99.8	Low
5	Soil-HawkesBay-Omaranui_4.csv	210.4	High
6	Soil-HawkesBay-Otane_11.csv	124.4	Mod
7	Soil-HawkesBay-Poporangi_32.csv	127.5	Mod
8	Soil-HawkesBay-Takapau_sandy_loam_39.csv	129.3	Mod
9	Soil-HawkesBay-TeAwa_9axx.csv	157.3	High
10	Soil-HawkesBay-Tikokino_74x.csv	116.6	Mod
11	Soil-HawkesBay-Waipukurau_30.csv	183	High
12	Soil-HawkesBay-Flaxmere_2xx.csv	117.8	Mod
13	Soil-HawkesBay-Omahu_1xx.csv	79.3	Low

Table 53- Vegetable soils and 3 highlighted soils chosen to represent the Low, Mod and High TAW groupings

Soil ID	Soil Name	TAW (mm)	Group
1	Soil-HawkesBay-Farndon_24.csv	192.4	Low
2	Soil-HawkesBay-Hastings_silt_loam.csv	230.2	Mod
3	Soil-HawkesBay-Hastings_silty_clay_loam.csv	187	Low
4	Soil-HawkesBay-Kaiapo_silty_clay_loam_19.csv	165.3	Low
5	Soil-HawkesBay-Mangateretere_71.csv	159.6	Low
6	Soil-HawkesBay-Meeanee_26.csv	243.9	High
7	Soil-HawkesBay-Pakipaki_sandy_loam_8.csv	360	High
8	Soil-HawkesBay-Pakowai_silt_loam_17.csv	272.7	High
9	Soil-HawkesBay-TeAwa_9a.csv	157.3	Low
10	Soil-HawkesBay-Twyford_sandy_loam.csv	202.2	Mod
11	Soil-HawkesBay-Twyford_silt_loam.csv	233.3	Mod
12	Soil-HawkesBay-Twyford_silty_clay_loam.csv	230.5	Mod

12.0 APPENDIX 3- RIVER RELATED BAN DAYS

In Table 4, the total ban days each year caused by the flow in the Ngaruroro or Tutaekuri Rivers reducing below a certain L/s rate are shown. This section expands the data to show what ban days look like per month in selected years.

Table 54- River related ban days in 1998 (L/s)

Ban days in 1997/98	Nga 4000	Nga 3600	Nga 2400	Tut 2000	Tut 2500	Tut 3300
Dec	0	0	0	0	0	0
Jan	17	16	7	0	0	0
Feb	17	16	7	0	0	1
Mar	22	20	12	0	0	20
Apr	10	5	0	0	0	6
May	0	0	0	0	0	0
Total	65	57	26	0	0	27

Table 55- River related ban days in 2009 (L/s)

Ban days in 2008/09	Nga 4000	Nga 3600	Nga 2400	Tut 2000	Tut 2500	Tut 3300
Dec	0	0	0	0	0	0
Jan	0	0	0	0	0	0
Feb	9	8	0	0	0	1
Mar	6	3	0	0	0	12
Apr	13	13	1	0	0	21
May	0	0	0	0	0	1
Total	28	24	1	0	0	35

Table 56- River related ban days in 2013 (L/s)

Ban days in 2012/13	Nga 4000	Nga 3600	Nga 2400	Tut 2000	Tut 2500	Tut 3300
Dec	0	0	0	0	0	0
Jan	2	1	0	0	0	0
Feb	16	14	9	0	0	13
Mar	26	26	25	0	11	27
Apr	15	15	15	0	11	19
May	7	7	3	0	11	16
Jun	0	0	0	0	5	10
Jul	1	1	0	0	0	7
Total	67	64	52	0	38	92

Contact

Leander Archer

Horticultural and Environmental Consultant
06 872 7082
leander.archer@agfirst.co.nz

201B Warren Street North
PO Box 1261, Hastings 4156, New Zealand
06 872 7080
hawkesbay@agfirst.co.nz
www.agfirst.co.nz