BEFORE THE COMMISSIONER APPOINTED
BY THE SOUTHLAND REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of resource consents to occupy the Coastal Marine Area with a tide gate and weir and to dam and divert water
AND	
IN THE MATTER	of an application by **SOUTHLAND REGIONAL COUNCIL**

EVIDENCE IN CHIEF OF MATTHEW JAMES GARDNER FOR SOUTHLAND REGIONAL COUNCIL 16/08/2024

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QUALIFICATIONS AND EXPERIENCE

1. My full name is Mathew James Gardner

2. I practice as a consulting engineer specialising in water resources engineering. I am the managing director of Land River Sea Consulting Limited, a Christchurch based engineering consultancy that specialises in flood modelling, geomorphology, river engineering and flood risk management.

3. I hold the degree of Bachelor of Engineering (Hons) in Natural Resources Engineering from the University of Canterbury. I am a Chartered Professional Engineer (CMEngNZ, CPEng). I am also a member of the Engineering New Zealand (EngNZ) Rivers Group (a technical subgroup of EngNZ), the New Zealand Hydrological Society and Water New Zealand (the New Zealand Water and Wastes association).

4. I have been working as a professional engineer in the field of water resources engineering, river modelling and floodplain management since early 2006. Included in this experience is 4 years with Wellington Regional Council where I was employed in the Flood Protection Department. I have further experience on a range of river flood, sediment transport and urban drainage modelling/engineering projects working for URS New Zealand Ltd as well as with River Edge Consulting Limited

EXPERT WITNESS CODE OF CONDUCT

5. I have read the Code of Conduct for Expert Witnesses set out in the Environment Court Practice Note 2014 and agree to comply with it. This evidence has been prepared in accordance with the Code of Conduct. I confirm that the opinions I express in this evidence are within my expertise and represent my true and complete professional opinions. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express. The evidence I am giving is within my area of expertise, except where I state that I am relying on the opinion or evidence of others. I understand it is my duty to assist the Court impartially on relevant matters within my area of expertise.

6. I declare that I have an ongoing contractual relationship with Environment Southland, which relates to ongoing river engineering advice and hydraulic modelling, primarily of their large river systems.

SCOPE OF EVIDENCE

7. Southland Regional Council, known as Environment Southland, has applied for resource consents to re-authorise the location and operation of tide gates and a weir on the Titiroa Stream, 160m upstream of the Tokanui-Gorge Road Bridge on State Highway 92. I understand the application is to replace lapsed coastal permits.

8. My role is to provide expert commentary on the hydraulic impact of the tide gates and weir on the Titiroa Stream drainage network.

9. In preparing this evidence I confirm I have read:

   (a) The parts of the application that are relevant to my professional expertise.

   (b) The evidence of:

      (i) Ian Dave Connor;

      (ii) Colin Shen Young;

   (c) In order get a better understanding of the history and purpose of the scheme;

      (i) MAF Economics Division – Mataura Catchment Scheme Economic Review Internal Paper 6/87 (March 1987)

      (ii) Mataura Catchment Control Scheme Job No 617 - Completion Summary Phase 1 Works – Land Purchase and Willow Control and Channel Restoration

      (iii) Mataura Catchment Control Scheme – Five Year Review Phase 1 Scheme for Floodway Land Purchase and Willow Control and Channel Restoration (Aug 1983)

(iv) Mataura Catchment Control Scheme – Job No 617 Phase 1 Floodway Land Purchase and Willow Control and Channel Restoration (Nov 1976)

(v) Mataura River Catchment Job No 617 – Catchment Management and River Control Plan 1991-1996

BACKGROUND

10. Land River Sea Consulting was contracted by Environment Southland (ES) to build a 2D hydrodynamic model of the Titiroa Stream in order to determine the impact of the Titiroa tide gate on the upstream drainage network.

11. The tide gate operates by opening when there is positive downstream flow and shutting when tidal flow reverses. The primary purpose is to prevent high tides from raising water levels within the drainage system beyond the gate. The tide gate is part of the wider Mataura Catchment Control Scheme designed to reduce flood damage of land.

SITE VISIT

12. A visit to site was conducted on the 2nd of July 2024. The purpose of the visit was to familiarise myself with the site and to better understand how the gate operates as well as view the nature of the surrounding catchment.

13. Whilst on site, I met with local farmer, Les Frisby, who shared his views on the criticality of the gates and explained how the extensive network of 'tile' drains operate.

14. Of note was the fact that he pointed out that every acre of farm has an extensive network of tile drains which he has installed personally since the 1980's. Each drain has been installed with the outlet at the existing water level with the gates in place, indicating that if the water level within the drains was to rise at all, that the drainage from each of the tile drains would be impeded.

15. It was apparent on the site visit that the farmland downstream of the tide gates contains significantly more tussock grasses and appears to be less intensively farmed, and the farmland upstream of the gates appears to be

well maintained pasture with significantly lower water levels within the stream and drainage network.

TILE DRAINS

16. An extensive network of subsurface drains, known as 'Tile Drains' operate in the area. These drains are critical to allowing the surrounding area to be used for productive farming purposes.

17. Tile drainage involves installing sloped, perforated pipes beneath the soil to remove excess water from crop roots, allowing it to enter through the holes and be directed away from the field towards an open drain or channel.

18. Historically, concrete or clay sections known as tiles were commonly used for subsurface drainage pipes. This historic terminology, persists to this day despite the majority of current drainage pipes being made of perforated polyethylene tubing such as NovaFlow pipes currently commonly used in Southland.

19. Subsurface drainage improves the productivity of poorly drained soils by, lowering the water table, providing greater soil aeration, as well as enabling faster soil drying and warming in the spring.

20. It also provides a better environment for crop emergence and early growth, and can reduce soil compaction. Once a crop has been established, subsurface drainage greatly reduces the risk of crop water stress from ill-timed or excessive rainfall.

21. Due to these reasons, subsurface-drained soils are said to represent some of the world's most productive soils. A schematic showing how a tile drain functions is presented in Figure 1.

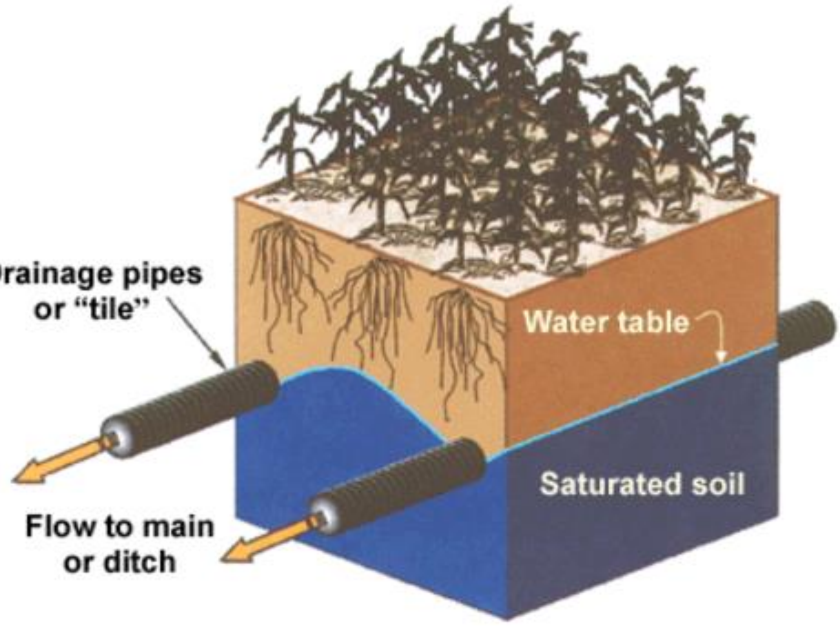

Figure 1: Schematic showing functionality of a tile drain[1]

SURVEY

22. On the 7th of June 2024, at my request, following instructions from Council, staff from True South Survey Services Ltd visited the site and surveyed the current tide cycle, historic high tide water mark as well as the location and invert level of 10 tile drains.

23. The location and invert levels of the surveyed Tile Drains in presented in Figure 2.

[1] https://extension.umn.edu/agricultural-drainage/how-agricultural-drainage-works#what-subsurface-drainage-is-1361661

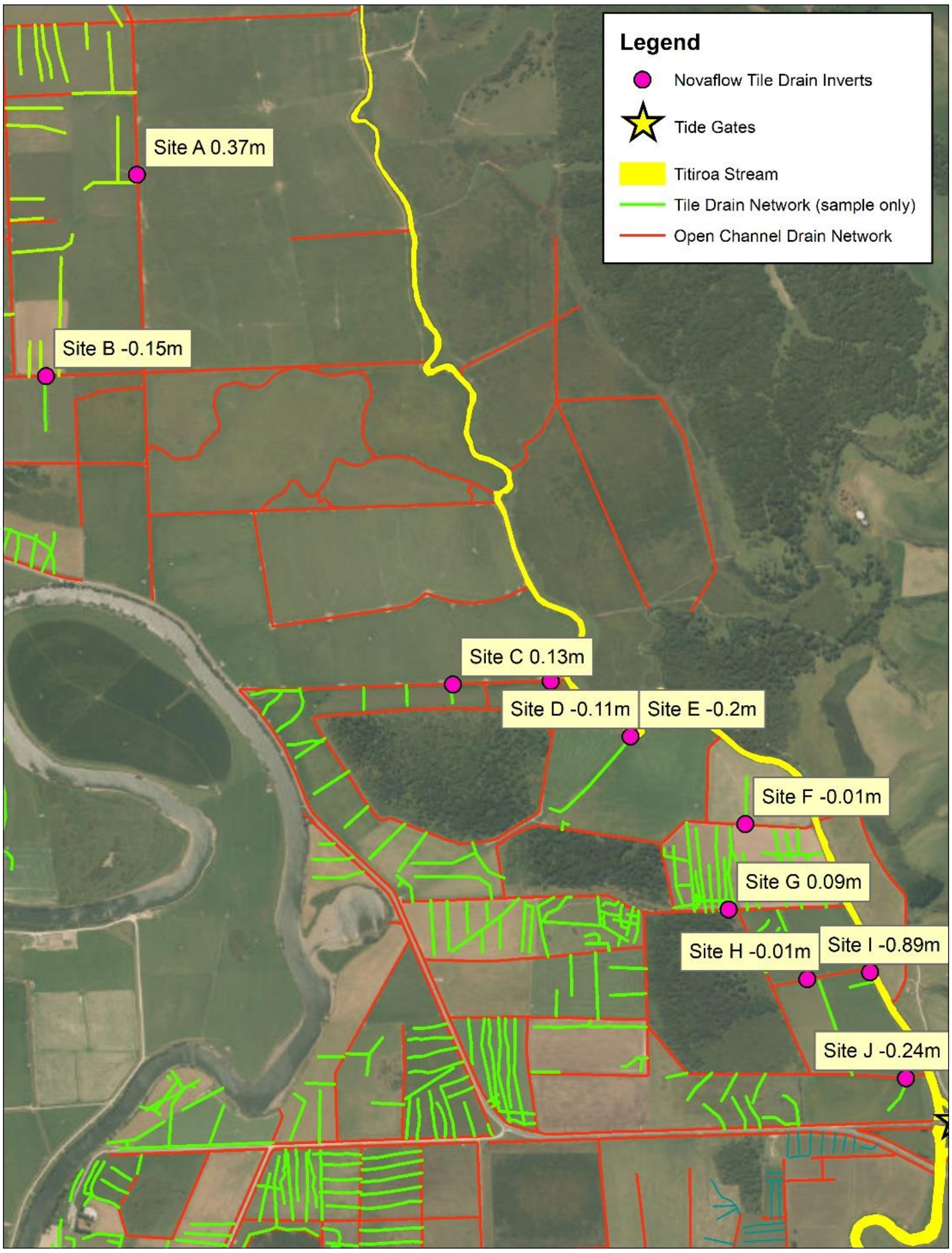

Figure 2: Schematic showing the location and invert levels of the surveyed tile drain outlets

24. The high tide level on the day at the gate was recorded as 1.06 m (NZVD2016) and a recent high tide mark which coincided with a full moon in May was also recorded as 1.3 m. The tide values were surveyed in order to assist with validating the tide levels adopted in the hydraulic model.

MODEL BUILD

25. A detailed 2-dimensional (2D) hydrodynamic model of the area has been built using the Danish Hydraulic Institute (DHI) MIKE21 FM software

package. The model was developed using industry best practice techniques.

26. The model terrain is based on the latest LiDAR data with the stream channel and drainage network being manually delineated and burnt into the terrain by lowering the invert level of the drains within the mesh.

27. The terrain was represented using a flexible mesh, which allows for varying element sizes to represent surface details where needed and increase computational efficiency. The model was built with a 15 m^2 mesh except for the coastal area which is represented by a 200-1000 m^2 mesh.

28. A spatially varying Manning's 'n' roughness values has been applied utilising the LUCAS NZ Land Use Map to classify various areas of land use, which were then assigned representative values for roughness based on standard textbook values.

29. The tide gate has been represented dynamically within the model and opens and closes based on set timings specified by the modellor.

BOUNDARY CONDITIONS

30. Tide levels have been set based on levels in the LINZ Nautical Almanac and converted to the NZVD2016 vertical datum to match the datum of the LiDAR data used in the model. These levels have been verified with on-site survey.

MODEL LIMITATIONS

31. The following key limitations apply to this model;

    (i) Tide levels are based on assumed tidal levels taken from Land Information New Zealand and will vary day to day.

    (ii) No baseflows have been applied to the Titiroa Stream or drainage network (these are expected to be very low)

    (iii) Detailed survey of the drainage network has not been undertaken and this may result in some uncertainty in relation to the exact water levels within the network. The model is intended to show relative water level changes and general trends rather than be considered a precise model of the network.

SIMULATIONS

32. Four simulations have been conducted modelling the existing scenario, removal of tide gate, opening the gate for an additional hour, as well as opening the gate for an additional two hours.

SUMMARY OF RESULTS

33. Model results show that removing the tide gate significantly increases the peak water levels within a large portion of the drainage network.

34. Comparison of the water level at each of the surveyed Tile Drains shows that the majority of the tile drain outlets are either just at, or slightly below the tide level modelled in the existing scenario.

35. Model results show that once the tide gate is removed, the water level at every tile drain significantly exceeds the invert level at each drain location, with each tile drain being completely submerged, in some cases by more than 1 m, indicating that they would be unlikely to function at all.

36. Removing the tide gates, significantly increases the water levels up the entire drainage network, increasing the water level at each of the surveyed tile drains by between 0.77 to 0.87 m.

37. This would very likely make the existing tile drain network completely ineffective and will result in more frequent and longer-lasting ponding of water on the farms during wet weather periods, as well as saltwater intrusion into the soil, which will affect the productivity and quality of the land.

IMPACT OF CHANGING TIDAL GATE OPERATING REGIME

38. Two additional runs have been completed with the opening of the gate extended for an additional hour as well as an additional 2 hours as described in section 4.

39. Results of these scenario show an increase in the order of 0.09 m and 0.021 m respectively at all sites except at Site A and Site B, where a more significant increase is observed as the water was not previously backing up that far.

40. Results show that the increase in water level as a result of increasing the opening time by 2 hours, extends up the network approximately 500 m further than that of a 1 hour increase in opening.

41. A more detailed summary and presentation of the model build and results is presented in the modelling report, which is appended to this document as Appendix 1.

IMPACT OF SEA LEVEL RISE

42. Whilst not directly modelled in the current version of the model, previous iterations of the model have simulated the effects of 0.3 m sea level rise (SLR).

43. Results of that model did show that the gate is providing even more significant benefit with the higher tide levels, as it prevents direct inundation of several of the paddocks immediately upstream of the gate, as well as reducing water levels in an even greater portion of the drainage network.

44. Sea level rise without the gate model results will show that water levels are increased in the entire drainage network, and the increased water levels will extend further upstream within the drainage network than shown in the presented results.

CONCLUSION/SUMMARY

IMPACT OF GATE REMOVAL

45. The key finding of this study is that the removal of the tide gates will significantly increase the water levels within the drainage network so that all of the tile drains are completely submerged. This will therefore impact on the drainage ability of the upstream farmland.

46. This would prevent local runoff from the surrounding farmland from freely draining through the tile drain network, and therefore will likely result in more frequent and longer-lasting ponding of water on farms during wet weather periods as well as saltwater intrusion into the soil, affecting the productivity and quality of the land for agriculture purposes.

IMPACT OF INCREASING GATE OPENING TIME

47. Increasing the opening time by 1 hour and 2 hours has shown to increase water levels within the drainage network in the order of 0.09 m and 0.21 m in the main drainage network respectively.

48. For the tidal levels simulated in these runs, the existing network of Tile Drains is shown to be just below the peak water level in the model and therefore any increase in peak water level, will likely significantly decrease the performance of the drainage network resulting in land which is more water logged and less freely draining.

49. This may result in reduced productivity for agricultural purposes, and if the soil remains in agricultural use, then it is likely that the resulting soil chemistry and stability will change, potentially resulting in increased nutrient runoff due to leaching as well as increased soil erosion.

50. The area most impacted by either the removal of the gate or alteration of the timing is illustrated by the red polygon in the Figure 4 below. This area amounts to approximately 9 ha of farmland that would be at increased risk of ponding and saltwater intrusion, impacting on the soil quality and viability of the land for agricultural use.

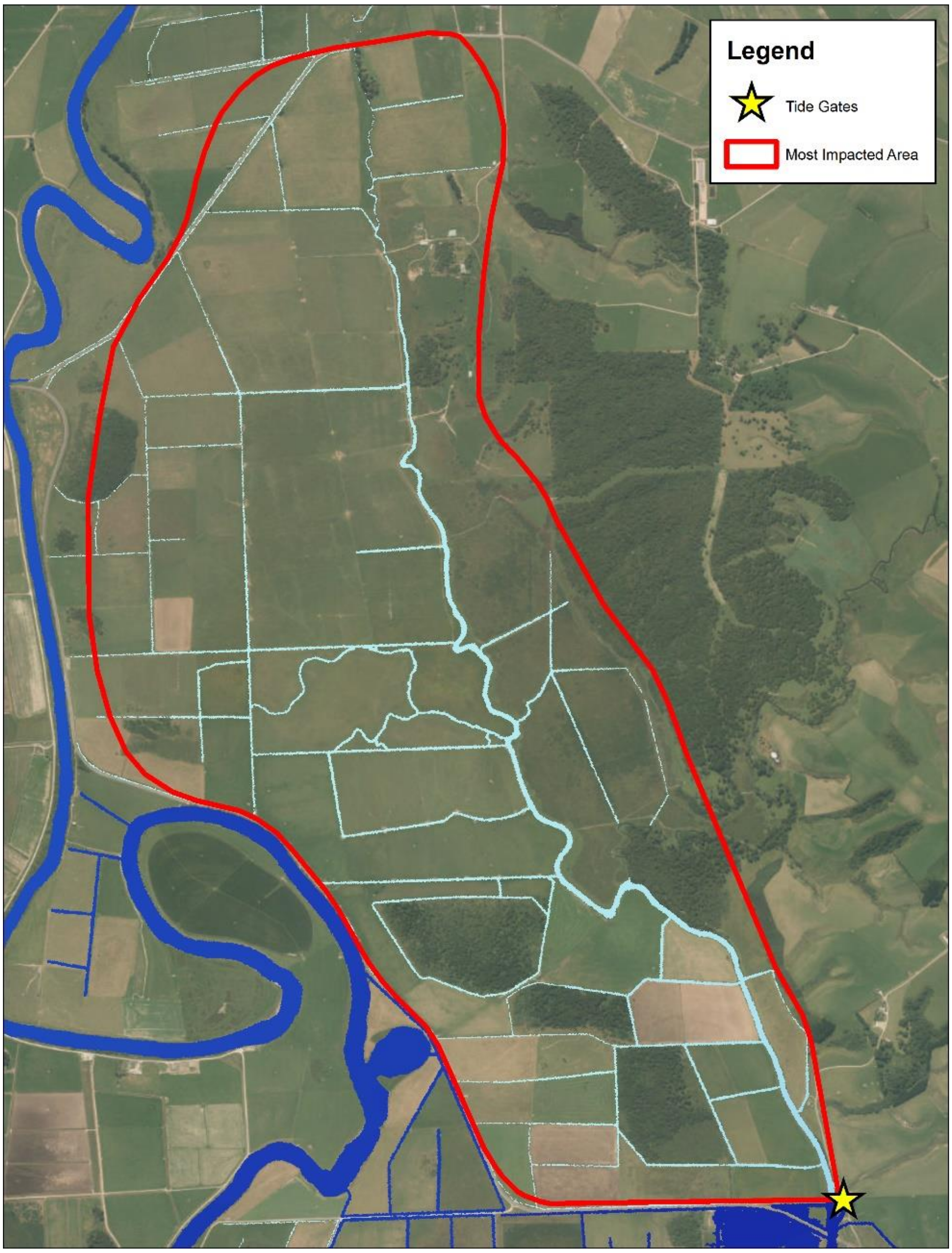

Figure 4: Estimate of area likely to have decreased drainage abilities as a result of removing or altering the timing of the gate opening.

51. Whilst we haven't directly modelled any impacts on the water table, it should be acknowledged that it would not be unreasonable to expect the general water table to rise if the gates were to be removed.

52. A generally higher water table will also likely impact on the drainage abilities on land further upstream from the 9 ha highlighted in Figure 4.

53. The flood extents shown in this model are considered to be a conservative estimate of the impact from removal of the gates. Due to the fact that we

have made assumptions around the depth of the drainage channels and stream based on the surrounding topography due to the lack of available stream survey data, it would not be unforeseeable for the stream to be deeper than we have modelled in the upper reaches.

54. Minor adjustments to the modelled stream channel by further deepening in localised areas will likely result in the impacts from removing the gate extending further upstream, to at least the historic railway embankment, as is believed to be the extent of tidal influence by the local farmers and ES staff and as noted in the evidence of Colin Shen Young.

Matthew James Gardner

16/08/2024

Appendix 1

Model Build Report

Land River Sea Consulting Limited
5/245 St Asaph Street, Christchurch
PO Box 27121, Shirley
Christchurch 8640
http://www.landriversea.com

Memorandum

Recipient Name: Dave Connor / Randal Beal
Recipient Organisation: Environment Southland
Issue Date: 16 August 2024
Author: Matthew Gardner

SUBJECT: TITIROA FLOODGATE MODELLING

1. INTRODUCTION

1.1 Scope

Land River Sea Consulting has been contracted by Environment Southland (ES) to build a 2D hydrodynamic model of the Titiroa Stream to determine the impact of the Titiroa tide gate on the impact of surface water flooding.

Environment Southland's Catchment Management Division has applied for resource consents associated with its existing tide gate in the Titiroa Stream, about 160 metres upstream of the Tokanui Gorge Road Highway bridge (Figure 1-1).

The tide gate operates by opening when there is positive downstream flow and shutting when tidal flow reverses. The primary purpose is to prevent high tides from raising water levels within the stream and drainage network upstream of the gate, which would significantly reduce the ability of the surrounding farmland to be drained and therefore used for agricultural purposes.

Figure 1-1: Titiroa Stream shown in blue, and the tide gate indicated by the yellow dot. The model extent is shown in red.

It is our understanding that Environment Southland has applied for resource consents to re-authorise the location and operation of the tide gates and weir and that this study is to assist with explaining the impact of the gates and weir on the network.

1.2 Site Visit

A visit to site was conducted on the 2nd of July 2024. The purpose of the visit was to familiarise myself with the site and to better understand how the gate operates as well as view the nature of the surrounding catchment.

I met with local farmer, Les Frisby, who shared his views on the criticality of the gates and explained how the extensive network of 'tile' drains operate. Of note was the fact that he pointed out that every acre of farm has an extensive network of tile drains which he has installed personally since the 1980's. Each drain has been installed with the outlet at the existing water level (which is artificially lowered due to the tide gates), indicating that if the water level within the drains was to rise at all, that the drainage from each of the tile drains would be impeded.

A picture of the tide gate is shown in Figure 1-2 below, the difference in water level on each side of the gate can be clearly seen in this image.

Figure 1-2 – Photo of tide gate taken on the 2nd July 2024

Figure 1-3 shows the water levels at the spillway location and clearly shows elevated water levels on the left side of the image where the farm land contains significantly more tussock grasses and appears to be less intensively farmed, and the lower water levels on the right where the farmland appears to be well maintained pasture. The tussock grass cover in the downstream paddocks is highlighted further in Figure 1-4.

Figure 1-3 – Photo of spillway taken on the 2nd July 2024

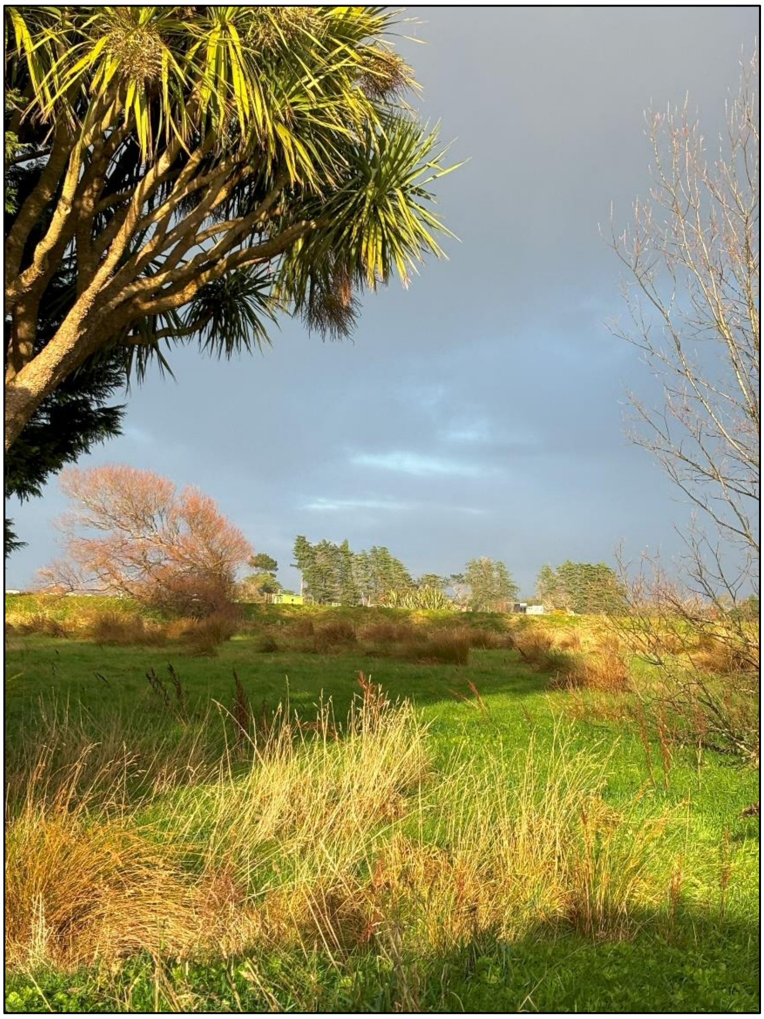

Figure 1-4 – Photo of farmland downstream of the floodgates showing significant tussock grass cover

1.3 Drainage Network

An extensive drainage network consisting of open channel drains as well as subsurface tile drains, feeds into the Titiroa Stream, allowing the entire area to be used for agricultural purposes. The Regional Council holds a record of some of the tile drain network, however local farmers have indicated that the actual network of tile drains is much greater than held on record with virtually every metre of pasture serviced by a tile drain. An example of the network is presented in Figure 1-5, noting that the tile drain network is said to be significantly more extensive than shown in the council records.

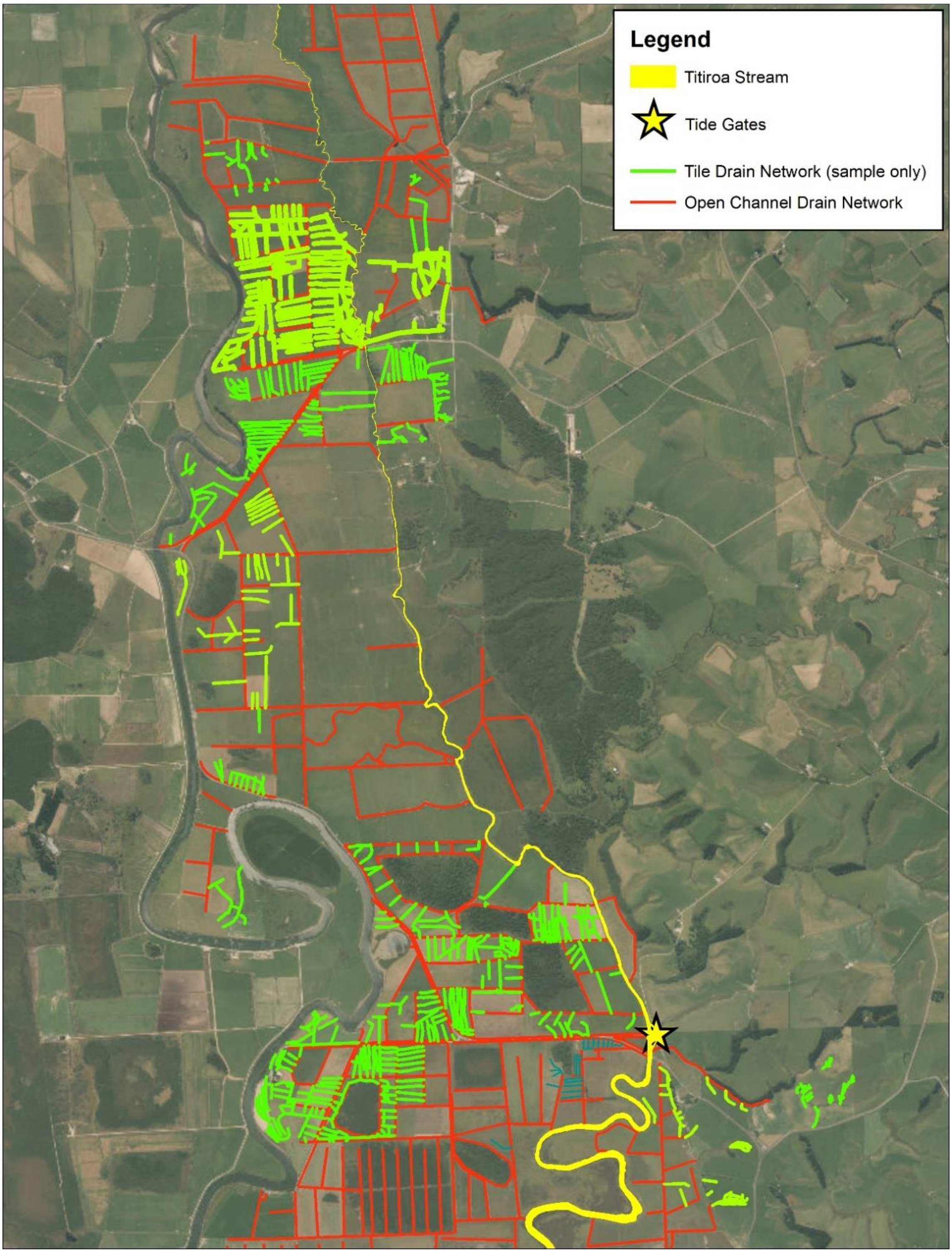

Figure 1-5 – Titiroa Stream Drainage Network

Tile Drains

Tile drainage involves installing sloped, perforated pipes beneath the soil to remove excess water from crop roots, allowing it to enter through the holes and be directed away from the field towards an open drain or channel.

Historically, concrete or clay sections known as tiles were commonly used for subsurface drainage pipes. This historic terminology, persists to this day despite the majority of current drainage pipes being made of perforated polyethylene tubing such as NovaFlow pipes currently commonly used in Southland.

Benefits

According to the University of Minnesota[1], subsurface drainage improves the productivity of poorly drained soils by:

- Lowering the water table (Figure 1-6).
- Providing greater soil aeration.
- Enabling faster soil drying and warming in the spring.

This may allow producers to plant fields earlier, and for other field operations to take place in a timely fashion.

It also provides a better environment for crop emergence and early growth, and can reduce soil compaction. Once a crop has been established, subsurface drainage greatly reduces the risk of crop water stress from ill-timed or excessive rainfall.

For these reasons, subsurface-drained soils represent some of the world's most productive soils.

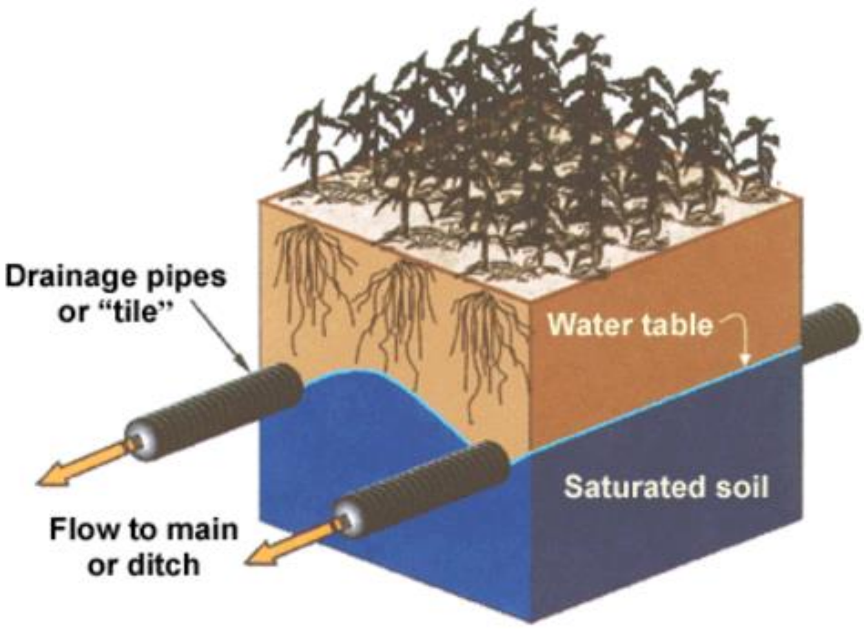

Figure 1-6 – Example of tile Drain[1]

[1] https://extension.umn.edu/agricultural-drainage/how-agricultural-drainage-works#what-subsurface-drainage-is-1361661

2. SURVEY

On the 7th of June 2024, staff from True South Survey Services Ltd visited the site and surveyed the current tide cycle, historic high tide water mark as well as the location and invert level of 10 tile drains. The surveyed invert level of the tile drains is presented in Figure 2-1 below.

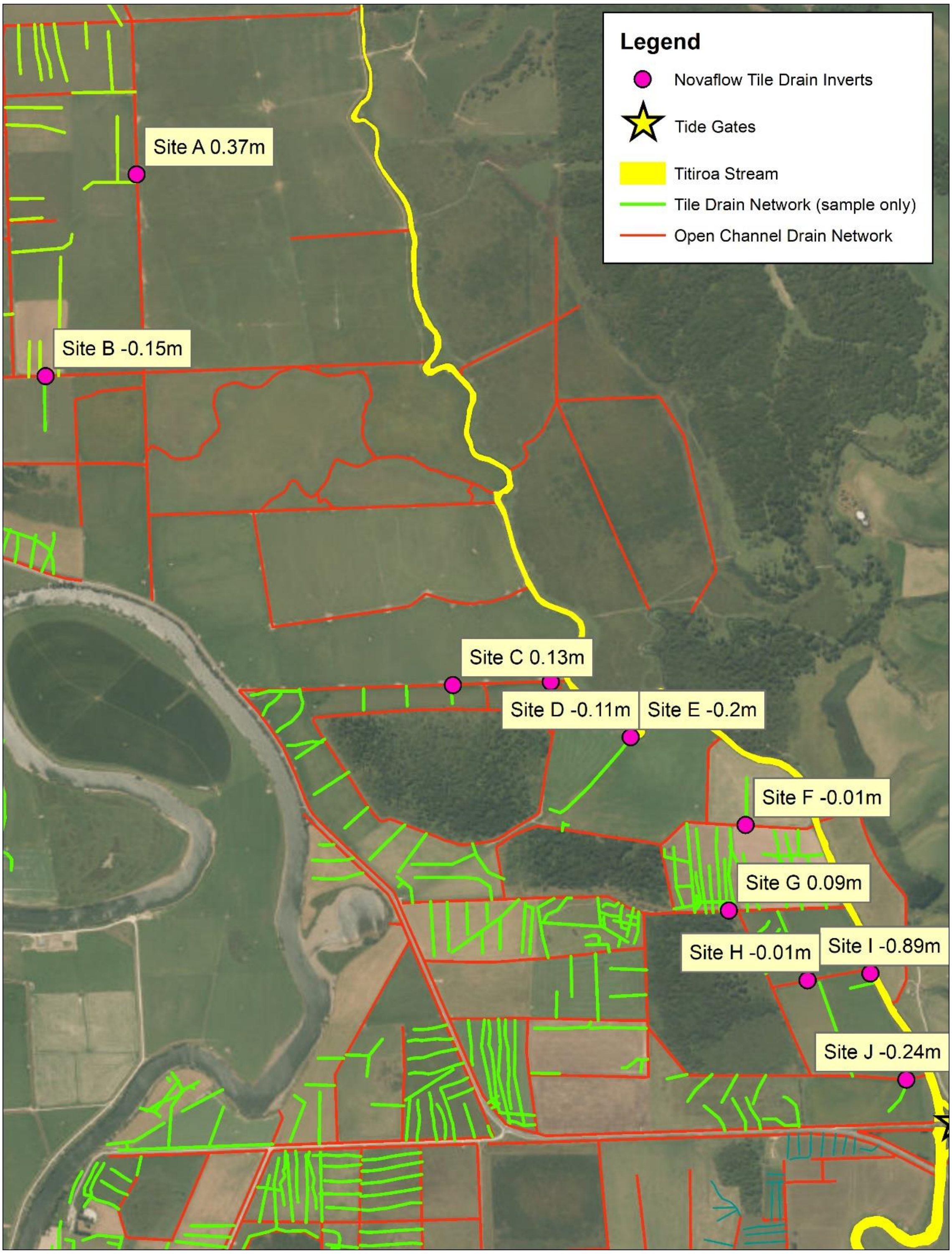

Figure 2-1 – Tile Drain Invert Levels

Tide level

The high tide level at the gate was recorded as 1.06 m (NZVD2016) which matches precisely with the level forecast using the NIWA Tide Forecaster tool. The surveyors have also noted that the general high tide level is in the order of 1.14 m. They also note that the farmer has a photo showing a recent full moon tide being at a level of 1.3 m (ie within 50 mm of the top of the gates).

3. MODEL SETUP

3.1 Mesh Setup

LiDAR data was sourced from LINZ Data Service and the 2022 Landpro bathymetric survey. Invert levels for Titiroa Stream, drainage ditches and the estuary were unavailable due to the LiDAR being unable to penetrate water. Therefore, the Titiroa Stream and farmland drainage were manually delineated and burnt into the model with the farm drains being represented as rectangular channels of 4 m width (to ensure conveyance in the 2D domain), and the estuary/coast bed level inverts were interpolated to ensure that the water would naturally flow in and out of the Titiroa Stream as the tide levels fluctuate.

The terrain was represented using a flexible mesh, which allows for varying element sizes to represent surface details where needed and increase computational efficiency. The model was built with a 15 m^2 mesh except for the coastal area which is represented by a 200-1000 m^2 mesh.

To ensure that the crest levels were accurately captured in the mesh, the crest levels of all key features including roads and stopbanks were extracted from the LiDAR and burnt into the model as dikes using automated techniques (Figure 3-1). These crest levels were extracted from the LINZ LiDAR, and the crest level of the tide gate was surveyed and provided by True South Survey Services Ltd (1.35 m NZVD2016).

Roughness

A spatially varying Manning's 'n' roughness values has been applied utilising the LUCAS NZ Land Use Map to classify various areas of land use, which were then assigned representative values for roughness based on standard textbook values. Due to the nature of coastal inundation being slow flowing water, model results are not particularly sensitive to roughness values, which would otherwise be the case for faster flowing, fluvial systems. Therefore, this basic technique of applying roughness values was considered appropriate for this analysis and no further detail was required.

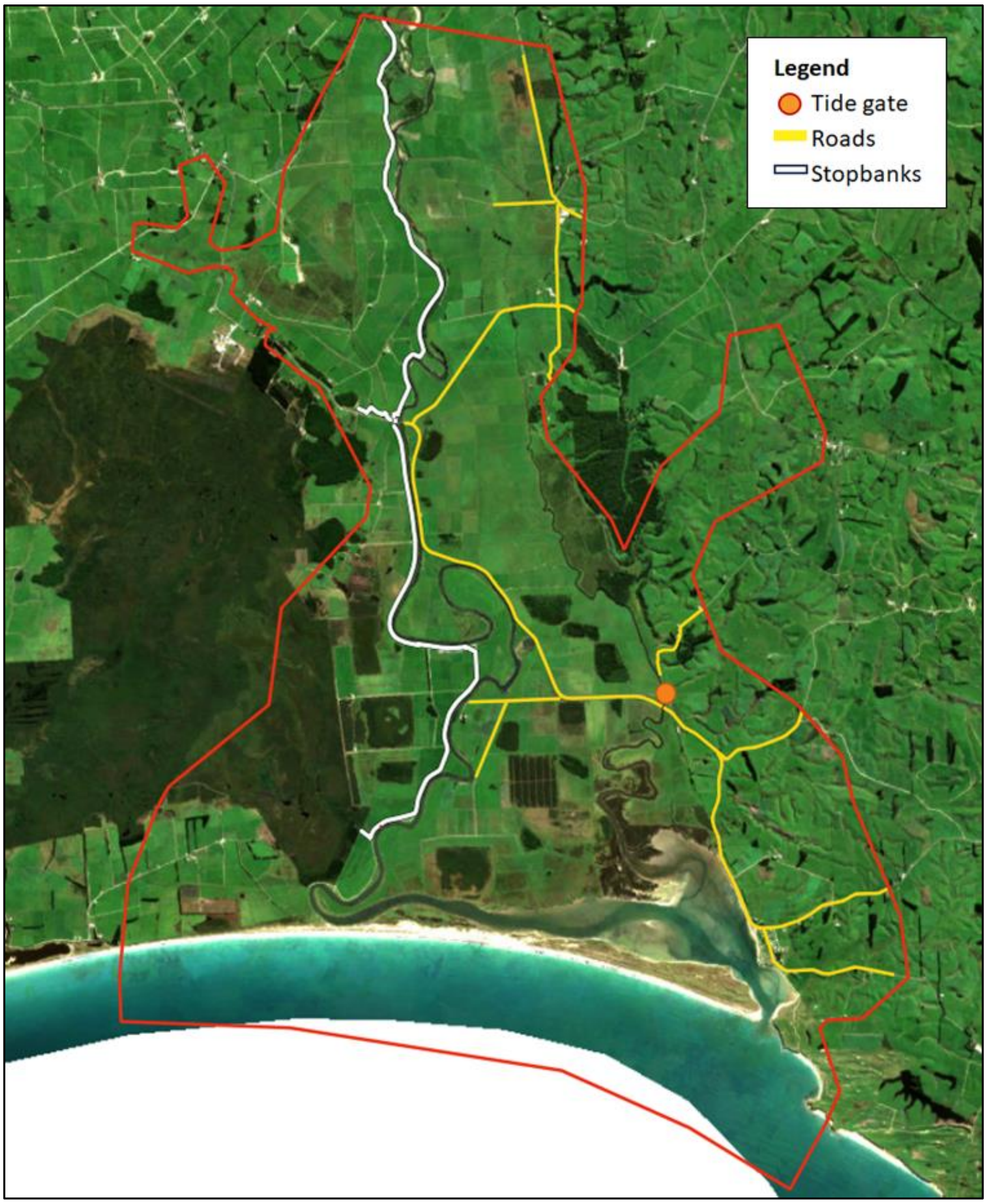

Figure 3-1: Locations of the tide gate, roads and stopbanks within the model extent (red outline).

3.2 Boundary Conditions

Tide levels have been set based on levels in the LINZ Nautical Almanac and converted to the NZVD2016 vertical datum in order to match the LiDAR data used in the model. Tide levels are summarised in Table 3-1 below, with the Mean High Water Spring (MHWS) value used in the calculation for base sea level, as this is when the range of the tide is at its greatest.

Table 3-1 – Tide values from the LINZ nautical almanac including mean high/low water springs (MHWS and MLWS), mean high/low water neaps (MHWN and MLWN), and mean sea level (MSL).

	MHWS	MHWN	MLWN	MLWS	MSL
Chart Datum	2.86	2.3	1.1	0.66	1.76
NZVD2016	0.93	0.37	-0.83	-1.27	-0.17

As the effects on drainage will be most pronounced during a low-pressure weather system when sea levels are naturally elevated, the model has been run allowing for 0.3 m of sea level rise due to barometric pressure and an additional storm surge component of approximately 0.3 m which is in line with reported historic storm surges in the area.

Thus, we have used added the barometric pressure and storm surge allowance (0.6 m) to the MHWS tide value (0.93 m) to get a base sea level of 1.5 m for the simulations.

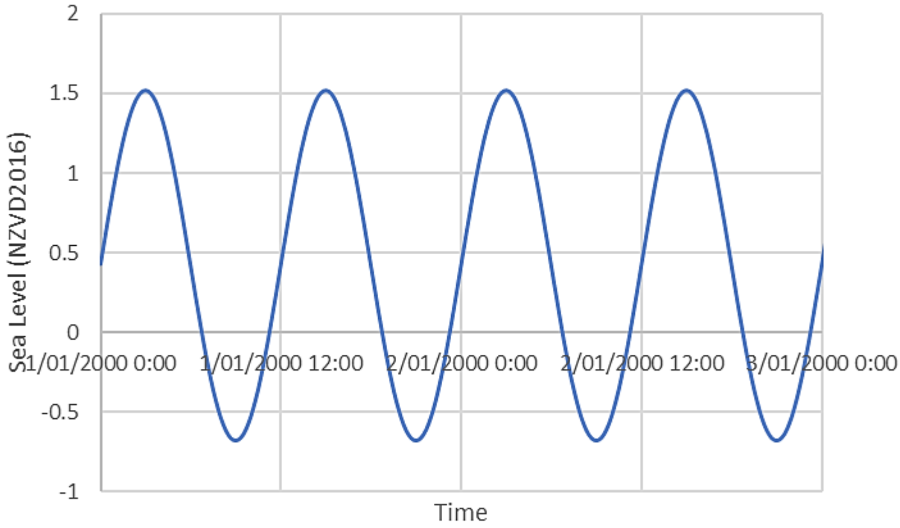

Figure 3-2 – Design tide for the existing sea level scenario (01 and 02).

3.3 Tide Gate

The model has been run with and without the existing tide gate in place. The tide gate has been modelled so that it open and closes dynamically with the tide cycle. We have assumed that it is open for 6 hours and then closed for 6 hours, with the closed portion of the cycle coinciding with the highest water levels (Figure 3-3).

Further runs have also been carried out to timing of the opening and closing of the gates.

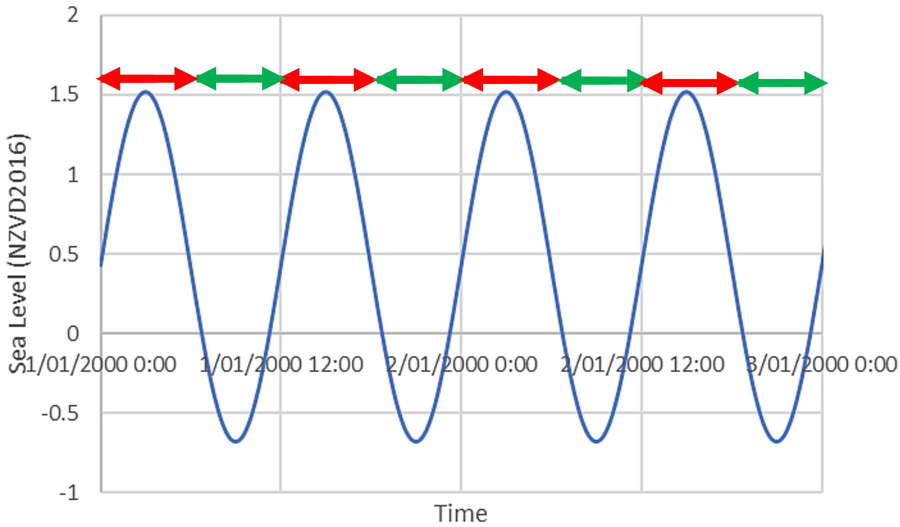

Figure 3-3 – Design tide showing opening and closing timing of the tide cycle (red indicates gate closed and green indicates gate open)

3.4 Model Validation

Whilst a detailed model calibration has not been undertaken due to a lack of data, the peak water level at the tide gates in the design runs has been compared with surveyed water levels collected in June 2024 and found to give a very close match indicating that the model is providing an accurate representation of reality. The modelled water level in the base run is 1.27 m at the gate, compared to 1.3 m which was recorded as occurring in May 2024. We have not spent additional time running various tide scenarios, considering the tide level varies day to day based on a wide range of factors and we are simply demonstrating the trends within the system.

3.5 Model limitations

The following key limitations apply to this model;

- Tide levels are based on assumed tidal levels taken from Land Information New Zealand and will vary day to day.
- No baseflows have been applied to the Titiroa Stream or drainage network (these are expected to be very low)
- Detailed survey of the drainage network has not been undertaken and this may result in some uncertainty in relation to the exact water levels within the network. The model is intended to show relative water level changes and general trends rather than be considered a precise model of the network.

4. SIMULATIONS

Four simulations have been conducted, simulating the existing scenario, a scenario with no gate at all, and then two scenarios with different gate opening configurations as summarised in Table 4-1.

Table 4-1 – Summary of modelled scenarios

Scenario Name
01 – Existing Scenario (with gate)
02 – No Gate
03 – Gate open for an additional 1 hour
04 – Gate open for an additional 2 hours

4.1 Summary of results

Scenario 01 and 02

The results of the modelling scenarios show that removing the tide gate for the existing sea level increases peak water levels within a large portion of the drainage network. Figure 4-1 on the following page shows the total network area expected to get a significant increase in water depth as a result of removing the gate.

Impact on Tile Drains from removing the gate

The peak water level recorded in the open channel drain adjacent to the surveyed Tile Drain outlets is summarised in Table 4-2 below.

Table 4-2 – Peak water level at tile drain outlets

	Pipe Invert (NZVD2016)	Peak WL (Existing)	Peak WL (No Gate)	Increase in depth (m)
Site A	0.37	No Water*	0.82	>1
Site B	-0.15	No Water*	0.83	>1
Site C	0.13	0.15	0.92	0.77
Site D	-0.11	0.15	0.92	0.77
Site E	-0.2	0.15	0.93	0.78
Site F	-0.01	0.15	0.96	0.81
Site G	0.09	0.15	0.97	0.82
Site H	-0.01	0.16	1.00	0.85
Site I	-0.09	0.16	1.01	0.86
Site J	-0.24	0.16	1.02	0.87

** Site A and Site B show no water in the existing scenario due to the fact that no base drainage flow is simulated, in reality all drains will likely always have a small volume of water. The increase in flood depth shown, indicates that tidal waters will reach the site if the gate is removed.*

These results show that the majority of the tile drain outlets are either just at, or slightly below the tide level modelled in the existing scenario.

Results show that once the tide gate is removed, the water level at every tile drain significantly exceeds the invert level at each drain location, with each tile drain being completely submerged, in some cases by more than 1 m, indicating that they would be unlikely to function at all.

Removing the tide gates, significantly increases the water levels up the entire drainage network, increasing the water level at each of the surveyed tile drains by between 0.77 to 0.87 m.

This would very likely make the existing tile drain network completely ineffective and will result in more frequent and longer-lasting ponding of water on the farms during wet weather periods, as well as saltwater intrusion into the soil, which will affect the productivity and quality of the land.

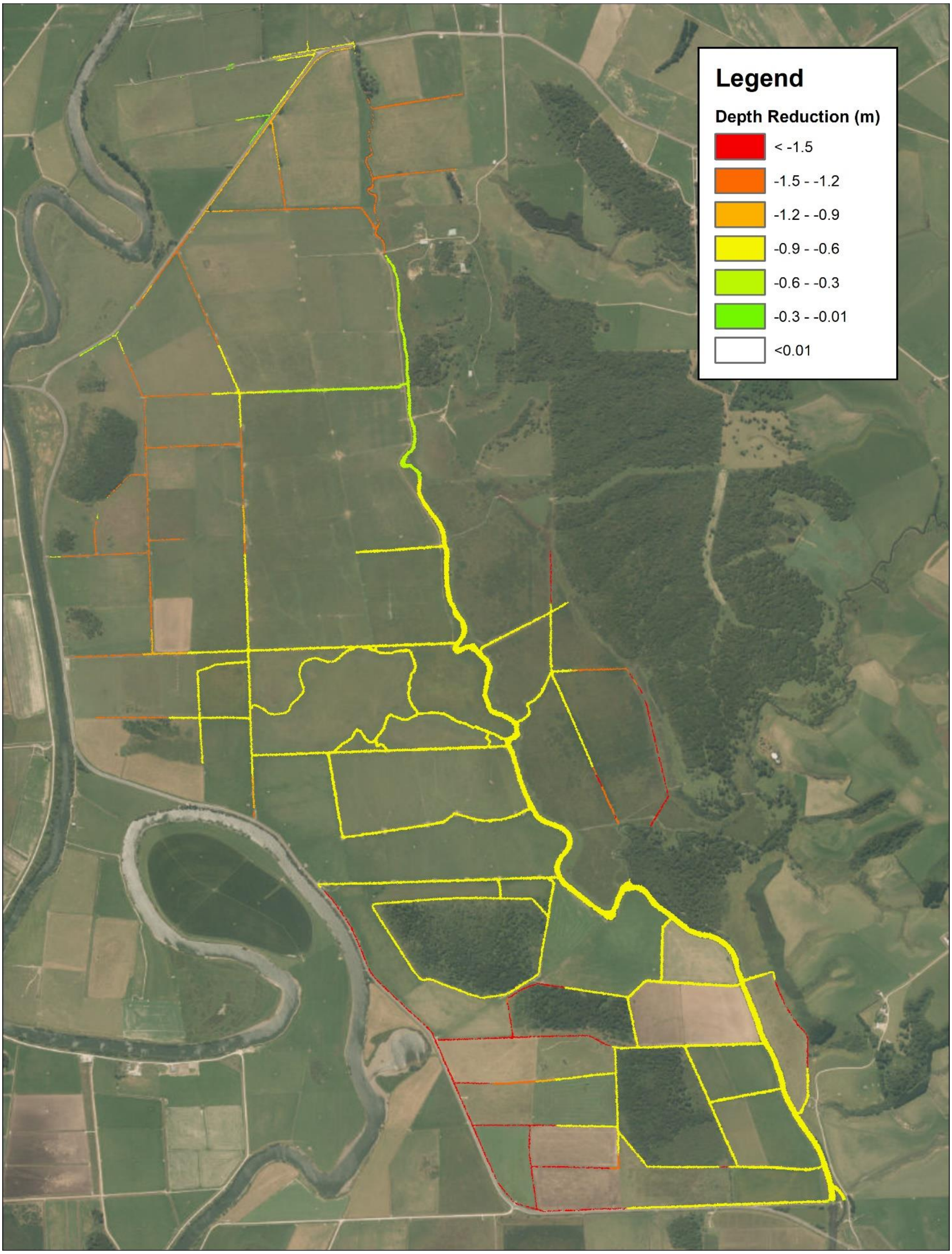

Figure 4-1 - Depth difference map showing the decrease in water levels within the drainage network as a result of the flood gate.

The results shown in Figure 4-1 are considered to be a conservative estimate of the impacts on the flood extents. Due to the fact that we have made assumptions around the depth of the drainage channels and stream based on the surrounding topography due to the lack of available stream survey data, it would not be unforeseeable for the stream to be deeper than we have modelled in the upper reaches Minor adjustments to the modelled stream channel by further deepening in localised areas will likely result in the impacts from removing the gate extending further upstream,, to at least the historic railway embankment, as is believed to be the extent of tidal influence by the local farmers and ES staff.

4.2 Impact of changing tidal gate opening regime

Two additional runs have been completed with the opening of the gate extended for an additional hour as well as an additional 2 hours as described in section 4. Results show an increase in the order of 0.09 m and 0.021 m respectively at all sites except at Site A and Site B, where a more significant increase is observed as the water was not previously backing up that far. These results are summarised in Table 4-3.

Table 4-3 - Increase in water level at tile drains due to changes in opening time at Tide Gate

Tile Drain Location	Open for extra 1hr	Open for extra 2hr
Site A	0.80	0.99
Site B	0.80	1.00
Site C	0.10	0.22
Site D	0.09	0.21
Site E	0.09	0.21
Site F	0.09	0.21
Site G	0.09	0.21
Site H	0.09	0.21
Site I	0.09	0.21
Site J	0.09	0.21

Depth difference maps, showing the increase in water level as a result of the change in operating regime are presented in Figure 4-2 and Figure 4-3.

Results show that the increase in water level as a result of increasing the opening time by 2 hours, extends up the network further than that of a 1 hour increase in opening. The drains coloured in orange and red indicate a significant increase in water level, and are a result of water having more time to backflow up the drains, are receiving tidal water which they wouldn't otherwise receive.

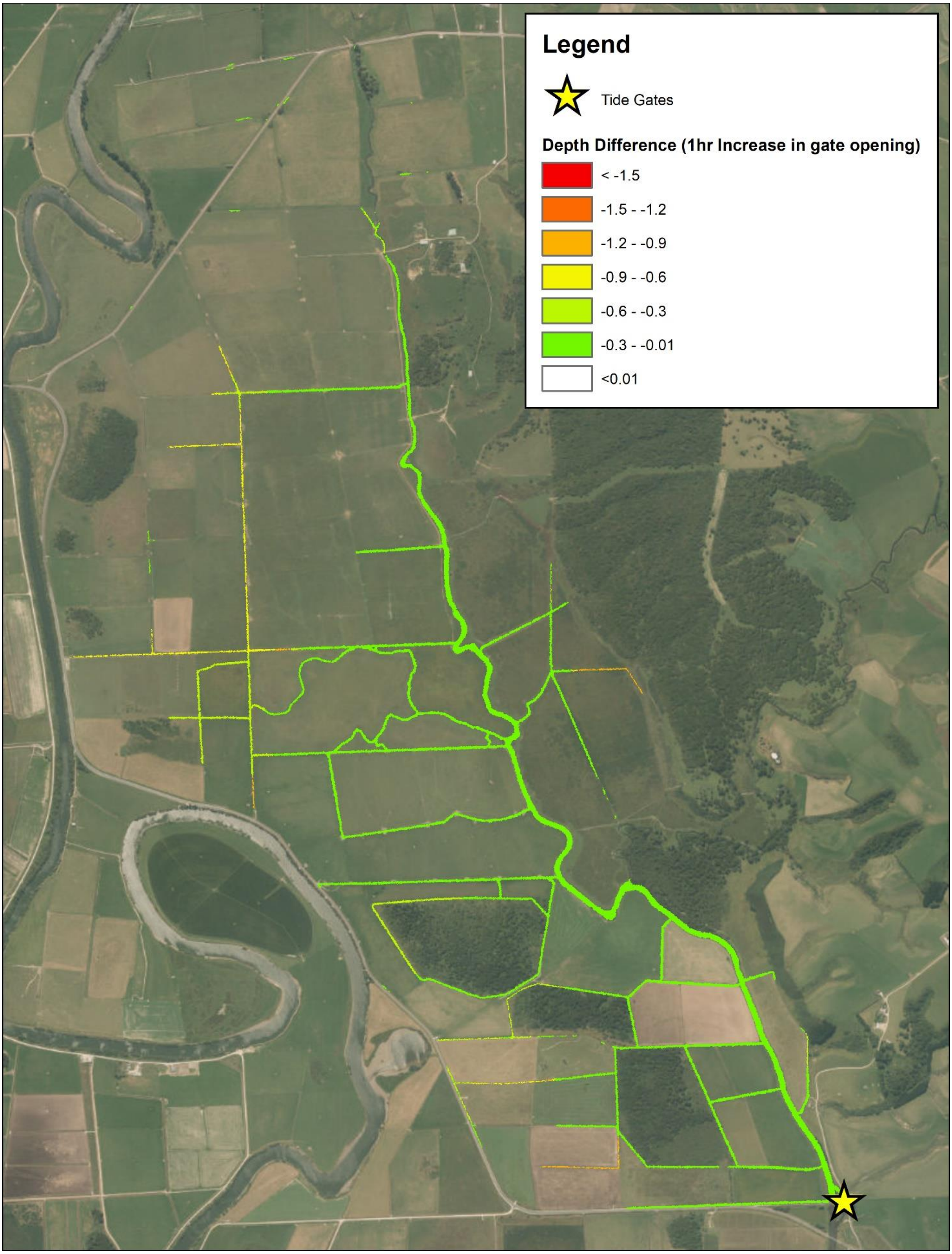

Figure 4-2 – Depth difference as a result of opening the gates for an additional hour (30 min increase either side of high tide)

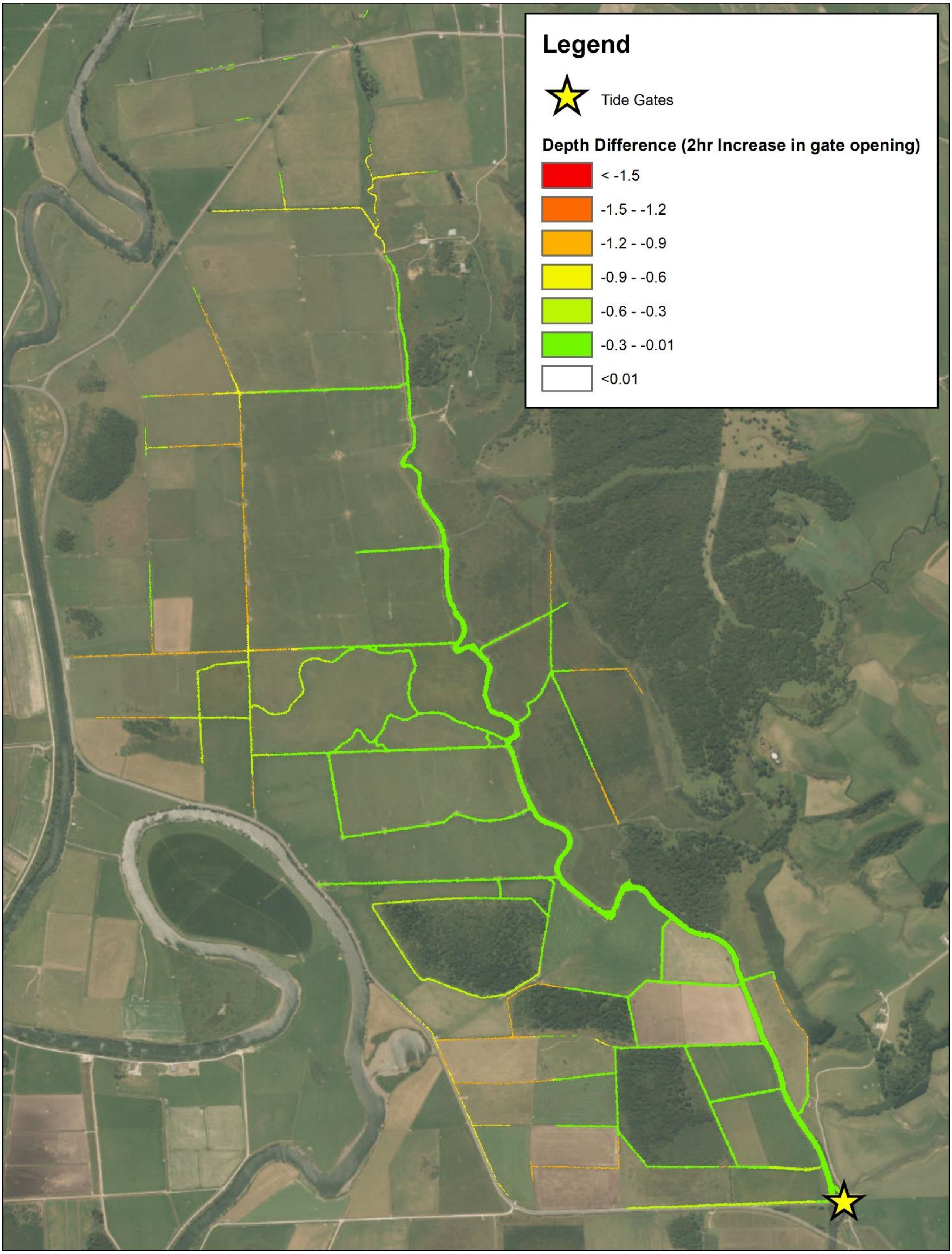

Figure 4-3 – Depth difference as a result of opening the gates for an additional 2 hours (1 hour increase either side of high tide)

4.3 Impact of future sea level rise

Whilst not directly modelled in the current version of the model, previous iterations of the model have simulated the effects of 0.3m sea level rise (SLR). Results of that model did show that the gate is providing even more significant benefit with the higher tide levels, preventing direct inundation of several of the paddocks immediately upstream of the gate, as well as reducing water levels in an even greater portion of the drainage network. Water levels will be increased in the entire drainage network, and the increased water levels will extend further upstream.

5. CONCLUSION

A hydrodynamic model of the Titiroa Stream has been used to assess the impact of the Titiroa tide gate on surface water flooding across the upstream farmland.

5.1 Impact of gate removal

The key finding of this study is that the removal of the tide gates will significantly increase the water levels within the drainage network so that all of the tile drains are completely submerged. This will therefore impact on the drainage abilities across the upstream farmland.

This would prevent local runoff from the surrounding farmland from freely draining through the tile drain network, and therefore will likely result in more frequent and longer-lasting ponding of water on farms during wet weather periods as well as saltwater intrusion into the soil, affecting the productivity and quality of the land for agriculture purposes.

The area most impacted is illustrated by the red polygon in the figure below. This area amounts to approximately 9 ha of farmland that would be at increased risk of ponding and saltwater intrusion, impacting on the soil quality and viability of the land for agricultural use.

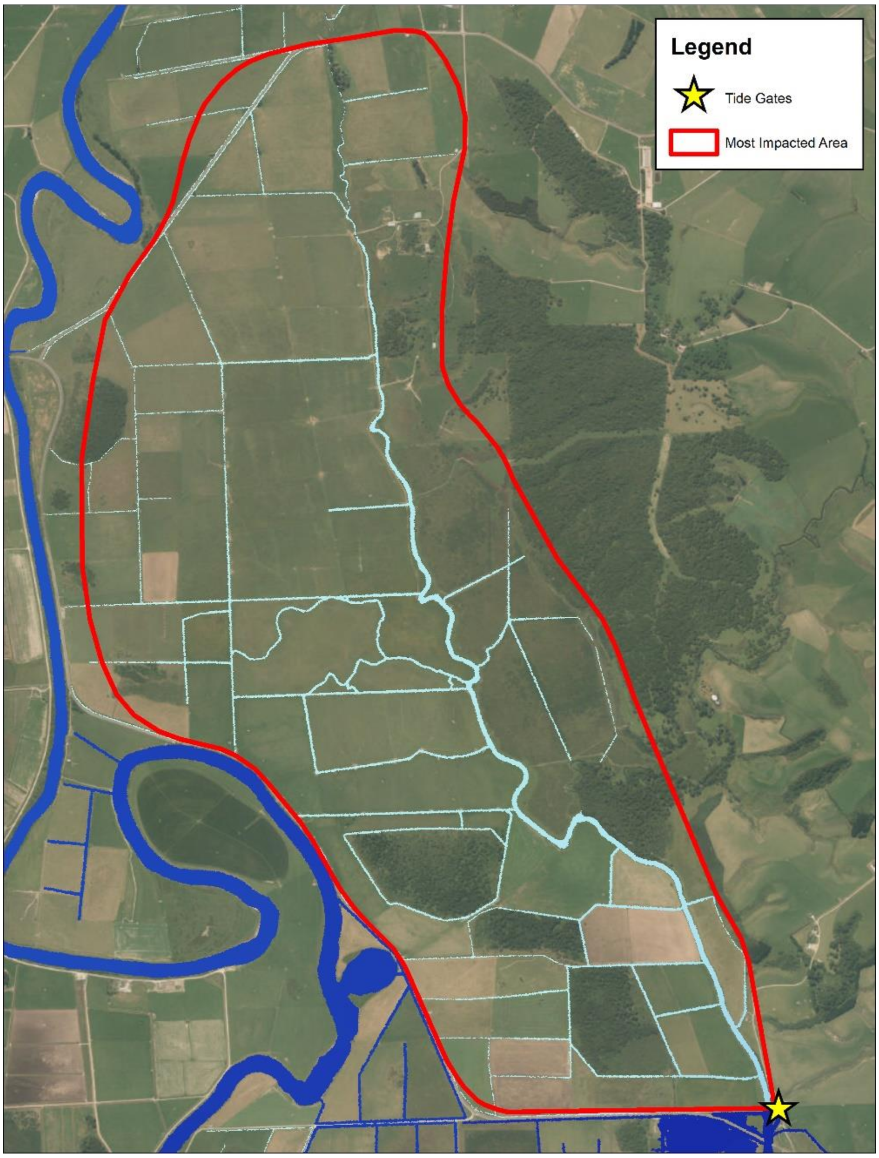

Figure 5-1 – Approximate area likely to have decreased drainage abilities.

Whilst we haven't directly modelled any impacts on the water table, it should be acknowledged that it would not be unreasonable to expect the general water table to rise if the gates were to be removed. A generally higher water table will also likely impact on the drainage abilities on land further upstream from the 9ha highlighted in Figure 5-1.

5.2 Impact of increasing gate opening time

Increasing the opening time by 1 hour and 2 hours has shown to increase water levels within the drainage network in the order of 0.09 m and 0.21 m in the main drainage network respectively. The extent of drainage network which is impacted by tidal waters is also increased as highlighted in Figure 4-2 and Figure 4-3 in section 4.

For the tidal levels simulated in these runs, the existing network of Tile Drains is shown to be just below the peak water level in the model and therefore any increase in peak water level, will likely significantly decrease the performance of the drainage network resulting in land which is more waterlogged and less freely draining. This may result in reduced productivity for agricultural purposes, and if the soil remains in agricultural use, then it is likely that the resulting soil chemistry and stability will change, potentially resulting in increased nutrient runoff due to leaching as well as increased soil erosion.

Please contact me if you need further clarification.

Kind regards,

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