Publics Services and
Procurement Canada

Timiskaming Dam-Bridge of Quebec Replacement Project (Quebec)

Environmental Impact Statement
PART E – Other effects
Chapter 15 Effects of Potential Accidents or Malfunctions

TETRA TECH

Project number : 715-32760TT
February 2023

TETRA TECH

PUBLIC SERVICES AND PROCUREMENT CANADA

Environmental Impact Statement Timiskaming Dam-Bridge of Quebec Replacement Project (Quebec)

Our Reference: 32760TT (60ET)

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February 2023
Revision 03

REVISIONS

Revision nº	Description	Date	By
00	Preliminary Report - Version for comments	March 2022	JR
01	Final Draft – Version for comments	June 2022	JR
02	EIS – Version for the Impact Assessment Agency Review	September 2022	JR
03	EIS – Second Version for the Impact Assessment Agency Review	February 2023	JR

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PART E - OTHER EFFECTS

15 EFFECTS OF POTENTIAL ACCIDENTS OR MALFUNCTIONS

The failure of certain infrastructures caused by human error or exceptional natural events (e.g. flooding, earthquake, fire) could cause major environmental effects. To address this, the risks of accidents and malfunctions have been identified to determine their potential magnitude (low, medium or high, based on the professional judgment and experience of the project team). The protective and mitigation measures to be put in place to limit the magnitude and effects of these risks were then identified. Certain design measures to limit these failures were also incorporated into the Project. In the event that these measures are insufficient, an emergency response plan is implemented.

15.1 IDENTIFICATION OF RISKS, THEIR MAGNITUDE AND PROTECTIVE, DESIGN OR MITIGATION MEASURES

Exceptional natural events are those defined in Chapter 16, which covers the effects of the environment on the Project. The risks associated with the work itself or with their operation derive from elements that could fail during construction (including demolition of the existing dam) and the operation of the new facilities. Those risks are considered as the worst-case scenario.

Possible malfunctions or accidents associated with the Project could occur during construction of the new dam, demolition of the existing structure or the operation of the new facility. Table 15.1 describes the risks involved in each phase and the applicable measures.

The sensitive environmental features are the aquatic environment and its shorelines, where wildlife habitats are found. As well, the health and safety of populations along the banks of the river must be protected. Man-made elements—i.e. the dam and various related components, including roads—are also sensitive features, since they are necessary for the proper regulation of water levels and flows or for the safe movement of people.

Various failures may occur during the construction phase. Organizational failures could disrupt the planned work schedule, which could change the duration of the temporary encroachment on the Ottawa River.

At the construction site, errors in the construction of the temporary downstream cofferdam, designed to dewater the work site, could result in water infiltration. This could produce a large amount of pumped water that must be managed, which would increase the possibility of discharging water containing suspended solids (SS) into the Ottawa River.

During construction of the new dam, accidents may occur due to the risk of equipment failures, potentially resulting in hydraulic oil or fuel spills.

All of the potential malfunctions and accidents described have been considered in the effects identified above, for which mitigation measures have been provided (where applicable).

The accidents or malfunctions that could occur during demolition of the dam are mainly related to discharges of SS into the river as a result of improper handling of demolition materials, particularly concrete, or an accidental spill.

The risks associated with the operation phase are related to a failure of the gate lift system used to regulate water levels and flows, as well as events such as fire, earthquake, flooding or accidental spills.

Table 15.1 Identification of Risks, their Magnitude and Protective, Design or Mitigation Measures

Phase	Risk (worst-case credible scenario)	Consequence / Environmental effects	Probability of Occurrence	Magnitude, including the quantity, mechanism, rate, form and characteristics of the contaminants and other materials likely to be released into the environment – credible worst-case scenario	Design Measures	Protective and Mitigation Measures
Construction of the new dam	Larger than anticipated water infiltration through the cofferdam and difficulty dewatering the area.	Increase in SS (water infiltration through the stone filling of the cofferdam) or difficulty treating all of the pumped water. Impacts on water quality, aquatic wildlife and related uses (e.g. fishing).	Medium	Magnitude is hard to quantify. Mainly SS from the water seeping through the non-watertight cofferdam as well as pumped and discharged water not meeting SS criteria.	Drilling prior to construction to estimate the quality and nature of the soil around the cofferdam for the contractor to take into account in the design.	Provide sufficient space at the construction site to treat additional amounts of pumped water. Environmental monitoring during construction.
	Organizational failures that could delay the planned schedule.	Extended duration of temporary encroachment on the Ottawa River. Impacts on fish and aquatic wildlife habitats in connection with longer temporary habitat losses.	Low	Magnitude is equivalent to the area of temporary encroachment. No contaminants, only an extended duration of encroachment.	A realistic schedule that takes into account normal operational difficulties.	Close monitoring of the construction schedule to avoid these situations. Suspension of in-water activities for a certain period to avoid in-water work during sensitive periods.

Phase	Risk (worst-case credible scenario)	Consequence / Environmental effects	Probability of Occurrence	Magnitude, including the quantity, mechanism, rate, form and characteristics of the contaminants and other materials likely to be released into the environment – credible worst-case scenario	Design Measures	Protective and Mitigation Measures
	Flooding that is greater than the design flood of the cofferdam.	Deconstruction of the entire cofferdam and re-opening of the Quebec dam are necessary if the Ontario dam is no longer sufficient. Increase in SS and downstream flows. Risk of flooding. Impacts on water quality, aquatic wildlife and related uses (e.g. fishing). Flood-related impacts on downstream populations.	Low	Magnitude is hard to quantify, depends on the magnitude of flooding. At most, it will be similar to that of an operational dam failure. Mainly SS and cofferdam materials (rocks of assorted sizes).	The rockfill cofferdam was designed to handle a 10-year flood event.	Construction emergency response plan for responding to events within 24 to 48 hours (site evacuation, deconstruction of the cofferdam, and reopening of the Quebec dam). The proposed alert threshold is a water level of the Lake Timiskaming of 179.56 m, which corresponds to the maximum operating level. At this water level, the theoretical flow on the Ontario dam is 1,940 m^3/s. At the alert threshold, the main stakeholders (PSPC, contractor, cities, etc.) and the Indigenous groups will be contacted to determine the actions to be taken based on the flow and water level forecasts established by the Ottawa River Regulation Planning Commission (https://rivieredesoutaouais.ca/location/timiskaming-2/). Monitoring of hydrological forecasts and compliance with the recommendation of the Ottawa River Regulation Planning Board (see Section 16.3.1).

Phase	Risk (worst-case credible scenario)	Consequence / Environmental effects	Probability of Occurrence	Magnitude, including the quantity, mechanism, rate, form and characteristics of the contaminants and other materials likely to be released into the environment – credible worst-case scenario	Design Measures	Protective and Mitigation Measures
Construction of the new dam	Accidental spills during construction	Oil spill into the terrestrial or aquatic environment. Impacts on water quality, aquatic wildlife and related uses (e.g. fishing).	Medium	The quantity will be limited to the amount contained in the faulty equipment. Mainly hydrocarbons.	N/A	Regular inspection of the machinery used. Equipment must be parked as far away from the aquatic environment as possible outside of construction periods. Emergency response plan. Oil recovery kit on site. Decontamination plan. Turbidity curtain and containment boom downstream to limit dispersion in the water. Environmental monitoring during construction.
Demolition of the existing dam	Improper handling of demolition materials, especially concrete	Increase in SS and debris. Impacts on water quality, aquatic wildlife and related uses (e.g. fishing).	Medium	Magnitude is hard to quantify. Mainly material from the existing dam (especially concrete) and SS generated.	Closure of the new dam during demolition of the existing one to limit downstream dispersion of materials.	Use of PSPC-approved work methods that limit risks. Environmental monitoring during construction.
	Accidental spill	Oil spill into the terrestrial or aquatic environment. Impacts on water quality, aquatic wildlife and related uses (e.g. fishing).	Medium	The quantity will be limited to the amount contained in the faulty equipment. Mainly hydrocarbons.	N/A	Regular inspection of the machinery used. Oil recovery kit on site. Containment boom downstream to limit dispersion in the water. Emergency response plan. Decontamination plan. Environmental monitoring during construction.

Phase	Risk (worst-case credible scenario)	Consequence / Environmental effects	Probability of Occurrence	Magnitude, including the quantity, mechanism, rate, form and characteristics of the contaminants and other materials likely to be released into the environment – credible worst-case scenario	Design Measures	Protective and Mitigation Measures
Operation of the new dam	Fire	Operators are unable to access the site, and the opening and closing of the gates cannot be adjusted, as they are operated manually.	Low	Depends on the magnitude of the fire and whether it is possible to continue operations or not. No contaminants	Use of fire-resistant materials (concrete, steel, metal).	Emergency response plan.
	Earthquake	Risk of dam failure if the earthquake is beyond what is addressed by the code. Impacts on water quality, aquatic wildlife and related uses (e.g. fishing). Flood-related impacts on populations.	Low	Depending on the level of dam failure, the magnitude could range from low to high. No contaminants, but could result in erosion (and SS), depending on the flows discharged.	The 2015 National Building Code was taken into account in the design. For the final design, the 2020 version (or the most recent version) will be used.	Emergency response plan.
	Major flooding	Risk of dam failure in the event of exceptional flooding. Impacts on water quality, aquatic wildlife and related uses (e.g. fishing). Flood-related impacts on downstream populations.	Low	Depending on the level of dam failure, the magnitude could range from low to high. No contaminants, but could result in erosion (and SS), depending on the flows discharged.	The design takes into account the 1,000-year flood + 1/3 of the probable maximum flood, which also incorporates the effects of climate change. Operation with gates instead of wooden stop logs, which will provide better responsiveness to particular events.	Emergency response plan.
	Failure of the gate lift system	Impact on the management of water levels and flows	Low	Magnitude is hard to quantify and depends on the time of year when the failure occurs No contaminants	Regular maintenance of the gate lift system	Emergency response plan. Water levels and flows are managed using the gates still in service on the Quebec side and with the assistance of the Ontario dam.

Phase	Risk (worst-case credible scenario)	Consequence / Environmental effects	Probability of Occurrence	Magnitude, including the quantity, mechanism, rate, form and characteristics of the contaminants and other materials likely to be released into the environment – credible worst-case scenario	Design Measures	Protective and Mitigation Measures
Operation of the new dam	Accidental spill during maintenance	Oil spill into the terrestrial or aquatic environment. Impacts on water quality, aquatic wildlife and related uses (e.g. fishing). Impacts on downstream populations related to oil spills in the aquatic environment.	Low	The quantity will be limited to the amount contained in the faulty equipment. Mainly hydrocarbons.	N/A	Regular inspection of the machinery used. Oil recovery kit on site. Emergency response plan. Decontamination plan.

15.2 EMERGENCY RESPONSE PLAN

In addition to the risk of dam failure, other types of hazards affecting human health and safety and the surrounding environment may occur during the dam's normal operations. These hazards are as follows:

- General chemical spill:
    - Chemicals associated with Tenant activities (power generation) are stored on-site;
    - Aboveground Storage Tank (AST) located on-site in the Fuel Shed storage building. Additional fuel containers were also noted at this location.
- Fire/explosion: As a result of spill, leak and/or transport accident;
- Transportation accident (and if vehicle in water):
    - Damage to Structure / Structural Failure;
    - Chemical Spills, including vehicle incident involving transportation of goods/hazardous materials.
- Terrorism/civil disturbance:
    - Damage to Structure / Structural Failure;
    - Service Disruption / Road Closure.
- Vandalism:
    - Damage to Structure / Structural Failure;
    - Service Disruption / Road Closure.
- Dam failure: Catastrophic dam failure caused by seismic activity, flooding, ice jams or accident from boat or vehicle traffic (see Section 15.3).

This Environmental Response Plan (ERP) will aid in PSPC being able to prevent, respond, mitigate and report on emergencies and minimize the environmental impacts of emergencies related to this dam. The basis for the plan development is the Emergency Response Planning Guide, published by the Canadian Centre for Occupational Health and Safety (2004). PSPC is required to have some form of emergency response planning in place for its properties and operations as per the following legislation:

- Emergency Management Act (2007);
- Canadian Environmental Protection Act (1999) and its regulations;
- Transportation of Dangerous Goods Act.

Procedures have been established for each risk. These procedures are based, among other things, on the following documents:

- National Fire Code of Canada;
- Departmental Emergency Book;
- National Fire Protection Association (NFPA);
- PSPC Departmental Policy 001 "Policy for Emergency Preparedness in Public Works and Government Services Canada";
- PSPC Departmental Policy 009 "Critical Incident Reporting Policy" (DP 009);
- Emergency Preparedness Act;
- Canadian Environmental Protection Act.

This emergency response plan is reviewed annually with all stakeholders that may be involved, both internal and external to PSPC, so that each stakeholder is aware of their role and the actions to be taken. Simulations of each emergency scenario (field or desktop exercises) are held regularly to improve response in the event of an emergency. Training sessions are also provided to staff working on site. In the event of a minor spill, spill response equipment located on site can be used to clean up the spill.

15.3 SPECIFIC EMERGENCY RESPONSE PLAN FOR DAM FAILURES

In the event of a dam failure, these are the components that are particularly sensitive: the Quebec dam itself, all infrastructure on the island, the portion of the road across the Quebec dam, conduits in the sidewalk (telephone and power lines), and the Énergir gas pipeline that runs along the downstream edge of the dam. All of the upstream and downstream shorelines and bodies of water, including the populations found there, are elements of the natural and human environments that could be affected in an emergency situation. In extreme cases, dams downstream (managed by Ontario Power Generation or Hydro-Québec) and the Timiskaming Ontario dam could also be affected. Several stakeholders may therefore be involved in the event of an emergency.

15.3.1 Roles and Expected Actions

In the event of an emergency related to the Timiskaming Dam Complex, PSPC will notify the authorities listed below. It is up to those authorities, where applicable and within their mandates, to activate their Emergency Response Plan. The general roles and expected actions of external and internal emergency response officials are outlined below.

15.3.1.1 External Organizations

15.3.1.1.1 Municipalities

The municipal Reeve or Mayor (or delegate such as the Fire Department) is expected to activate the local Emergency Plan in the event of a dam related emergency. The Reeve or Mayor or Delegate may also declare a state of emergency in order to evacuate people from their homes.

15.3.1.1.2 Algonquin Nations

The Chief (or delegate) is expected to activate the local Emergency Plan in the event of a dam related emergency. The Chief (or delegate) may also declare a state of emergency in order to evacuate people from their office on the Island (Algonquin Canoe Company).

15.3.1.1.3 Ontario Provincial Police (OPP)/Fire Department

Generally, the Reeve or Mayor will provide direction to the OPP or Fire Department in order to evacuate Incorporated Municipalities. In the case of Unincorporated Communities, the Local Services Board and/or MNR will assist with the evacuation. It is also expected that the OPP will inform the Ministry of Transportation of Ontario (MTO) to ensure that appropriate road closures are addressed.

15.3.1.1.4 Police Sûreté du Québec (SQ)

Generally, the Mayor (or delegate) will provide direction to the SQ in order to evacuate people from their homes. It is also expected that the SQ will inform the Ministère des Transports du Québec to ensure that appropriate road closures are addressed.

15.3.1.1.5 Ministère des Transports du Québec and Ministry of Transportation Ontario

It is expected that the MTQ and MTO take the necessary measures to ensure safety on both highway 101 and 63 respectively.

15.3.1.1.6 Sécurité Civile (Quebec)

It is expected that the Sécurité Civile (Quebec) supplies Municipalities with the necessary assistance to activate their local Emergency Plan or evacuate people from their homes.

15.3.1.1.7 Emergency Management Ontario (EMO)

It is expected that the EMO supplies Municipalities with the necessary assistance to activate their local Emergency Plan or evacuate people from their homes.

15.3.1.1.8 The Ontario Ministry of Natural Resources

In the event of a dam emergency, PSPC will contact the MNR emergency management. The MNR provincial emergency response coordinator (PERC) will notify the effected MNR district offices of the emergency situation. The MNR districts will activate their emergency response plans as required to ensure that Unincorporated Communities have been notified and appropriate actions are being taken.

15.3.1.1.9 Other Dam Owners

Ontario Power Generation and Hydro-Québec will be informed of the emergency situation. Coordination of operations at different dams may be required to mitigate the emergency.

15.3.1.2 PSPC Personnel

15.3.1.2.1 Dam Foreman

In the event of a dam emergency, if contacted first, it is expected that the Dam Foreman will activate the Emergency Preparedness and Response Plan by contacting the representative of the Water Management group and describing the nature and extent of the emergency. It is expected that the Dam Foreman acts as the PSPC representative on site and direct operations and according to the instructions from the Manager, Marine and Transportation Engineering.

15.3.1.2.2 Water Management Group

It is expected that the representative from Marine and Transportation Engineering (Water Management Group) will put the internal notification plan into action followed by the external notification plan. The first contact should be to the Manager of Marine and Transportation Engineering. In collaboration with the Property and Facility Manager, this person will remain responsible for updating stakeholders (internal and external) throughout the duration of the emergency.

15.3.1.2.3 Manager of Marine and Transportation Engineering

Once notified of the emergency, the Manager of Marine and Transportation Engineering, in consultation with other discipline experts, is responsible for decisions to mitigate the extent and impact of the emergency.

15.3.1.2.4 Property and Facility Manager

The Property and Facility Manager shall maintain regular contact with all key stakeholders throughout the process and this in collaboration with the communications group.

15.3.1.2.5 Regional Manager, Health and Safety

It is expected that the Regional Manager of Health and Safety, or his representative will be available for consultation and to provide advice for employee health and safety during emergency operations.

15.3.1.2.6 Other Discipline Experts

It is expected that the other discipline experts will be available for consultation with the Manager of Marine and Transportation Engineering in order to determine the measures to be taken according to the emergency.

15.3.1.2.7 National Services Call Centre

The NSCC records any emergency requests placed by federal employees, public, municipality’s employees or emergency responders, and dispatches these requests to qualified personnel on location. Operation is available 24 hours a day, 7 days a week, 365 days a year.

15.3.2 Activation Guidelines and Preventative Actions in Case of Dam Failure

The emergency plan includes three emergency levels, which depend on the risks posed by dam failure, and identifies the actions to be taken for each level. These are outlined in Table 15.2 below.

A dam break study for the Timiskaming Dam Complex was completed by the National Research Council (NRC, 2003) for PSPC. The study considered four different scenarios and the full report is attached in Appendix 15.1. The report demonstrates that the critical area (when lake level continues to rise) is located near the East bank of the Ontario dam. There is a formation of an erosion channel across the island at that location. Maps showing the potential flood zones (both upstream and downstream) were produced in the report.

Table 15.2 Emergency Level and Action in Case of Dam Failure

Emergency level	Hydrologic Event	Other Events	Action
1- Non failure emergency	• Unusually large flood (unusual in either magnitude or in timing e.g. spring freshet size flood in summer); Public safety is threatened; however, dam stability does not appear to be in jeopardy. • Maximum water level may be exceeded, and levels are forecast to continue to rise. • Flooding of upstream or downstream communities is imminent.	• Abnormal features observed (leakage, settlement, deflection). • Condition of abnormal features deteriorating. • Act of sabotage threatened. • Inability to operate flow control equipment and it is predicted that the maximum water level may be exceeded. • Earthquake	• Initiate internal and external notification plans to alert organizations of situation (depending on the situation, notification may be limited). • Carry out actions to mitigate emergency. • On site monitoring of dam and flows may be required.
2- Potential failure developing	• All discharge facilities open. • Maximum upstream water level is exceeded and continues to rise.	• Abnormal water level readings. • Condition of abnormal features deteriorating rapidly (e.g. leakage increasing and becoming more turbid, continuous settlement or deflection of dam). • Failure is not imminent but possible.	• Provide external agencies with frequent updates as per notification plan. • Activate entire internal and external notification plans. • Continue actions to mitigate emergency. • Continuous on-site monitoring of dam.
3- Failure is imminent or has occurred	• Dam overtopping is imminent. • Dam failure probably not avoidable or has already occurred.	• Water level increasing or decreasing rapidly. • Abnormal features pose a serious danger to the dam (e.g. large ongoing settlement or deflection, erosion of banks, sabotage).	• External evacuation should be complete. • Evacuate PSPC staff.

A more recent dam break analysis was conducted by KGS Group (KGS, 2022) for PSPC for the Timiskaming Dam Complex as part of a Dam Safety Review for the site. The Canadian Dam Association and provincial regulators require dam owners undertake periodic Dam Safety Reviews. The overall goal of a Dam Safety Review is “to protect people, property and the environment from harmful effects of misoperation or failures of dams and reservoirs”[1]. The HEC-RAS software was used to evaluate the hydraulic conditions that would occur in the river valley and floodplain under various flood and non-flood scenarios, with and without the breach of the Ontario and Quebec dams. The breach of each of the dams was simulated separately in the model to evaluate independently its consequences. The results showed that none of the populated areas identified in the study was identified as flooded in the simulation of a sunny-day failure of the two dams. The increase in water levels at Mattawa was approximately 0.3 m from the normal river level and would not cause flood damages. For the larger floods simulated, the Timiskaming Dams would be overtopped. A dam breach in these conditions would cause flooding on the road along the riverbank and the parking lot at Temiscaming, but the model showed no flooding of the industrial or residential areas near the downstream side of the dams. However, at Mattawa, the model showed that during extreme floods there would be flooding of residential areas on the riverbanks, that would be exacerbated by the flood increase from a failure of any of the dams. For the Otto Holden Dam, this dam has sufficient spill capacity to pass the greatest simulated flows without overtopping, even with dam breaches at the Timiskaming Dams.

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[1] Canadian Dam Association Technical Bulletin: Dam Safety Reviews

Appendix 15.1 Numerical Modelling of Breach Scenarios on the Ottawa River at Témiscamingue

CANADIAN HYDRAULICS CENTRE
CENTRE D'HYDRAULIQUE CANADIEN

Numerical Modelling of Breach Scenarios on the Ottawa River at Témiscamingue

Controlled technical report **CHC-CTR-016**

September 2003

National Research Council Canada
Conseil national de recherches Canada

Numerical Modelling of Breach Scenarios on the Ottawa River at Témiscamingue

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Controlled Technical Report **CHC-CTR-016**

September 2003

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Une version française de ce rapport a aussi été préparée

Summary

As part of its dam safety program, Public Works and Government Services must evaluate the consequences, in case of extreme flood, of equipment failure on the dams at Témiscamingue on the Ottawa River.

A two-dimensional numerical model, based on the Telemac software, has been prepared to simulate the propagation of the spring PMF (maximum discharge 9000 m^3/s).

Four scenarios have been prepared, simulating the island overtopping during the flood:

1. Formation of an erosion channel across the island, no dam failure at Témiscamingue, all gates closed at the downstream Otto Holden dam,

2. Formation of an erosion channel across the island, failure of three gates in the Témiscamingue dams, all gates closed at Otto Holden,

3. Formation of an erosion channel across the island, failure of ten gates in the Témiscamingue dams, all gates closed at Otto Holden,

4. Formation of an erosion channel across the island, failure of ten gates in the Témiscamingue dams, flood gates at Otto Holden 3/4 opened.

The main results of the study are as follow:

- During the four simulated scenarios, flooding extending approximately 100 m from the shore line, occurred on the east bank at Témiscamingue (parking lot and paper mill yard) as well as around Thorne and McDougal creek on the west bank, 1 km downstream.
- The flow through the erosion channel on the island is small compared to the total discharge of the flood. Its creation does not slow down the rise of the water surface, which allows water to overtop the road on the island.
- The breach at the Témiscamingue West dam lowered the water levels upstream of Témiscamingue by 48 cm with 10 sluices removed (scenario 3). In scenario 4 these levels dropped by 78 cm.
- The Témiscamingue dam breach created a local downstream 35 cm super-elevation of the water surface for the breach of 10 sluices. This wave propagated to Otto Holden dam in 55 minutes. Since the dam break does not occur at the peak of the flood, but 76 hours before, this flood wave does not cause the largest inundation downstream of the dam, and water continues to rise after the dam failure. The maximum inundation occurs when the peak of the hydrogram reaches the area.
- All levels downstream of the Témiscamingue dams are controlled by the conditions at Otto Holden dam, irrespective of the breach and bank erosion at Témiscamingue. With all the Otto Holden gates closed (scenario 1, 2, 3) levels

remained very high, (see Figure 8.4 and 8.5). The opening of the flood gates at Otto Holden dropped the downstream levels by 73 cm.

- The opening of all gates and removal of more stop logs in the sluices at Otto Holden would have lowered the levels downstream of Témiscamingue dam even more and minimized the flood extent. This scenario was not simulated. But it is felt that the excess flow (3600 m^3/s) which overtopped the Otto Holden dam in scenario 4 could be handled by all stoplog sluices if one had time, at the beginning of the flood, to remove seven logs in each of them.

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Numerical Modelling of Breach Scenarios

on the Ottawa River at Témiscamingue

1. INTRODUCTION

Two dams across the Ottawa River at Témiscamingue have been built to control the level of the upstream Lake Témiscamingue. They also provide a highway crossing between Ontario and Quebec.

As part of its dam safety program, PWGSC asked the Canadian Hydraulics Centre of the National Research Council of Canada to study the effects of a very large flood as it would propagate down the Ottawa river from Lake Témiscamingue towards the Otto Holden dam further downstream.

As the flood would pass the two dams, it would overtop the bridges and create flooding of the river embankments and of the island located between the two dams.

This overflow could start a bank erosion with the creation of a breach around the dams.

Following the dam overtopping, a structural failure could also occur with the creation of a breach through one of the dams. This sudden failure would create a wave which would propagate downstream, and may cause even more flooding.

To study these scenarios, the CHC has prepared a numerical model, based on the Telemac software, which simulates the various breaches and provide the hydrodynamic characteristics of the resulting inundation flows.

This report describes the preparation of the model and the simulation results in four different breach scenarios.

2. TELEMAC SOFTWARE DESCRIPTION

All simulations were performed with TELEMAC-2D, a two dimensional numerical model. This software was developed by the Laboratoire national d’hydraulique et environnement d'Électricité de France in Chatou.

It has been chosen for its flexibility - special internal or boundary conditions can be programmed in the model using Fortran language, and its robustness in case of extreme flood or dam breach producing both sub- and super-critical flows

TELEMAC-2D, a two dimensional finite element model, has been used very successfully to study the propagation of flood wave following dam break scenarios: The Malpasset dam in France [Hervouet et Rouge, 1996], on the Manicouagan river in Quebec [Faure, 2002], and the Ottawa river downstream of the Carillon dam [Faure, 2001].

In the model, the physical domain is discretized into triangular elements, of varying size, called grid, and the hydrodynamic parameters (velocities and water depth) are calculated at each grid nodes in the triangles.

The Telemac software complies with EDF's Quality Assurance, and has been validated through many test cases and compared with analytical results or site measurements [Cooper A.J., 1996]. These validations have contributed to the reliability of the simulation results.

The model requires many steps for the numerical simulation: preparation of the river bathymetry, topography of the flooded banks, grid preparation, and model application. Each of these steps is described in the following sections of the report.

3. BATHYMETRIC DATA

All bathymetric data were prepared by PWGSC to describe the various regions of the Ottawa river near Témiscamingue. Samples of these data are shown in Figure 3.1 to 3.4.

In Lake Témiscamingue the cross sections were approximately 1 km apart, decreasing to 500 m downstream of the dams. The high density surveys indicate data points at a density in the order of 10 m up to 6.2 km upstream of the dams (prepared by the Canadian Hydrographic Services, see Figure 3.3), and 4 m close to the dam (prepared by PWGSC, see Figure 3.4).

Note: The various data sets coming from different federal departments and provincial ministries (topographic, bathymetric, water contours) were originally defined in different coordinate systems (UTM, MTM, NAD 27- 83). Conversion to the single system used in this study (UTM, NAD83, Zone 17) required manual adjustments which resulted in some minor discrepancies, as seen on Figure 4.2 (small offset of the order of 15 m).

4. TOPOGRAPHIC DATA

The topographic data on both sides of the river (contour vertical spacing: 10 m) was obtained from PWGSC . It originated from the Centre for Topographic Information, Natural Resources, Canada. It was used to get the elevation of the river banks, as shown in Figure 4.1.

The island was surveyed and its ground elevation is shown in Figure 4.2 .

On the east side of the island at Témiscamingue, the road follows the river bank (see

Photo 1), with a relatively wide and flat area extending over a parking lot and the paper mill yard. This area was flooded during the initial simulation runs, but was not described by the topographic DEM data (Figure 4.1). Additional data points were therefore estimated manually in this zone, between levels 180 and 190m to be able to describe the flat zone and Gordon creek (Photo 2) as shown in Figure 4.3 .

Photo 1 - Road on East bank of Ottawa river

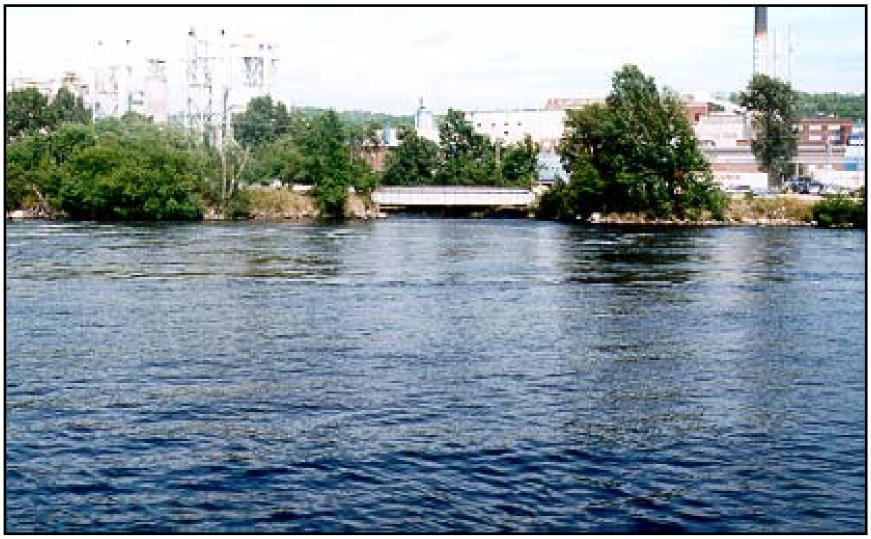

Photo 2 - Bridge over Gordon Creek

5. NUMERICAL MODEL PREPARATION

5.1 Grid Preparation

At the beginning of the project it was proposed to prepare first a one dimensional model along the Ottawa River from Haileybury to the Otto Holden Dam, in order to get a first estimate of the consequences of a flood caused by the failure of the dam or of the embankments. Then a two dimensional model would be used locally in the vicinity of the island in order to get more precise results.

The rational was that a 2D model covering the entire domain (more than 140 km long) would be large, and hence it would take a much longer time to run than a 1D model. However since then, faster new machines and a new version of Telemac have been acquired by the CHC, which have increased the speed of the simulation runs significantly.

Therefore only a 2D model covering the Ottawa river was prepared. This has eliminated the need to calibrate two models and the transfer of boundary conditions from the 1D to the 2D models.

The grid used in the simulations is shown on Figure 5.1, with a more detail grid shown in Figure 5.2. It extends from Haileybury at the north end of the Témiscamingue lake about 95 km upstream of the dams, to the Otto Holden Dam, 49 km downstream. The complete model uses more than 32000 elements ranging in size from 15 m around the island to 500 m in Témiscamingue lake.

5.2 Boundary Conditions

5.2.1 Upstream boundary

At the upstream end near Haileybury, a known discharge hydrogram was specified at the boundary. It corresponded to the spring probable maximum flood. The hydrogram was provided by PWGSC and is shown in Figure 5.3. To save computer time the hydrogram was run only from day 20 to day 44.

5.2.2 Downstream boundary - Otto Holden dam

At the downstream end, to simulate the Otto Holden dam operations (Photo 3), two sets of conditions were prepared:

1. Worst case with sluice gates closed:

   - all 6 sluice gates closed,
   - constant turbine discharge 500 m^3/s,
   - all log sluices positioned with initially one log removed. As level increases, a sluice discharge equivalent to two log removed was assumed, providing a

  maximum equivalent flow of 17.86 m^3/s through each of the 42 sluices (total 750 m^3/s)
  - excess flow evacuated by overtopping the dam (effective length of dam = 765 m, top of dam level= 179.22 m)

2. Sluice gates partially opened:
   - all 6 sluice gates 3/4 open: the sluice rating curve was extended to provide 3300 m^3/s at 181.5 m water level
   - constant turbine discharge 500 m^3/s
   - same as case 1: All log sluices positioned with two log removed when water elevation reaches 178.2 m, providing a maximum flow of 17.86 m^3/s through each of the 42 sluices.
   - excess flow evacuated by overtopping the dam (effective length= 692 m to provide for the opening of the sluice gates, top of dam level= 179.22 m)

Photo 3 - Otto Holden dam with Flood gates and log sluices

5.3 Model Singularities - Bank Erosion and Dam Characteristics

Three types of singularities were programmed inside the model: the creation of the bank erosion on the island, the simulation of the flow through the dams at Témiscamingue and the partial failure during overtopping.

5.3.1 Bank erosion

During the anticipated extreme flows, the banks on each side of the two dams and the island will be flooded and erosion will take place. This erosion was simulated in the model as described below. The location of the erosion was based on observations made during the site survey in August 2003:

- At the north end of the island, there is a concrete wall buried into the ground (Photo 4) . This barrier will slow down local erosion during overflow and the bypassing of the East bridge over the island would be minimal.

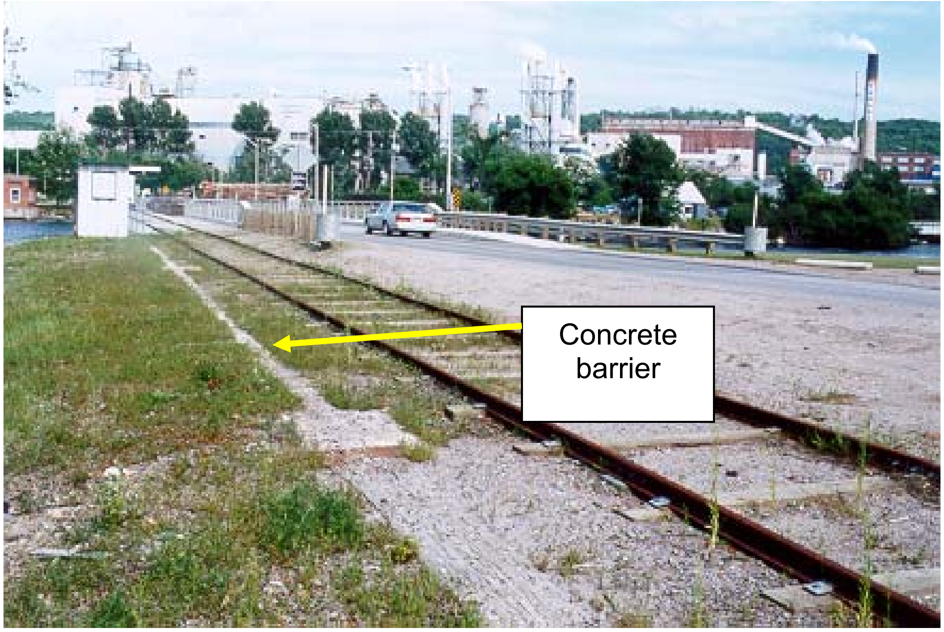

Photo 4 - Erosion protection north end of the island

- The main highway and a paved flat parking lot are located on the East bank of the river, just upstream on the island (Photo 1) . This embankment is at a higher elevation than most of the island itself, and it is felt that this area is less likely to be inundated. In any case, its erosion would be delayed. The overflow would progress towards Gordon creek (Photo 2) over the parking lot and is not expected to produce major damage .
- The road in the middle of the island presents its highest point and will reduce any overflow crossing over from one side of the island to the other.

- The lowest area on the island seemed to be on the South West end, close to the West bridge (see Photos 5 and 6) and it was felt that a deep erosion would take place at that location.

Therefore the model was prepared with the creation of a channel on the south end of the island, bypassing the West dam. This channel, shown in Figure 5.4, was as follows:

- Equivalent width: 20 m
- Maximum depth: 6 m
- Minimum elevation: 175 m
- Duration of breach formation: 30 minutes
- Initial water level for start of erosion: 181.8 m

Note: In the model, the erosion channel was set across the island from the west bank to the east bank, to minimize the grid size and reduce computer time. In fact it is felt that the erosion would take place around the east embankment of the west dam and may not cross over to the east side of the island. It is expected that this change will not affect the global results of the simulations.

Photo 5, 6 - Probable breach location, West side of the island

5.3.2 Sluice gates discharges, dam overtopping

At the beginning of the flood simulations, it was assumed that the flow in the Ottawa river was 500 m^3/s equally divided between the two dams as follows:

- West dam: one sluice fully open (13 logs removed), one sluice with 11 logs removed - 250 m^3/s
- East dam: one sluice fully open (16 logs removed) - 250 m^3/s

As the river discharge increases, it has been assumed that the stop logs in these opened sluices would not be changed, and that no other sluice would be opened; the water level would rise and water would run through the openings above the stop logs, under the road, (visible on Photos 7 and 8). This was modeled with openings of 6.7 m wide and 0.8 m high.

As the level continues to rise, water would run over the road on top of the two dams. This was calculated based on the broad crested weir formula (road elevation: 180.85 m, road width: 10 m)

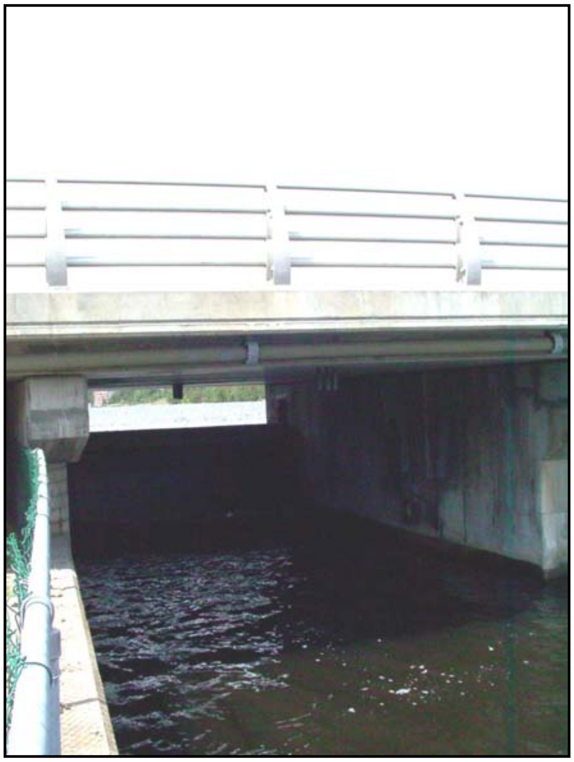

Photo 7, 8 - Openings above the stop logs

5.3.3 West dam breach

During the passage of the flood, both East and West dams would be overtopped, but it was assumed that only the west dam could break since its abutment would be strongly weakened by the erosion of the island. Two types of breach were simulated on the west dam, one corresponding to the failure of 3 gates (opening width 21.9 m) , the other corresponding to the failure of 10 gates (total opening width 68 m).

- Duration of breach formation: 6 minutes
- Upstream water level for initiation of breach: 182.35 m corresponding to a depth of 1.5 m of water over the dam

6. MODEL CALIBRATION

The numerical model was calibrated with the high flows observed in May / June 1995, when 1600 m^3/s was sustained during a two week period. Daily water level measurements during this time were available. During these high flows, water levels were close to 179.13 m and 177.40 m upstream and downstream of the dams respectively, and the Otto Holden level was maintained close to 177.25 m. Head drops of the order of 10 to 20 cm between Haileybury and upstream of the dam, and between downstream of the dam and Otto Holden were recorded during this period.

The bottom friction of the model was adjusted in order to reproduce these conditions, and they corresponded to the following Strickler coefficients:

– Upstream of Témiscamingue:	Strickler: 80
– Downstream of Témiscamingue:	Strickler: 60

These numbers reflect average friction factors for this type of river.

7. FLOOD SIMULATIONS ON THE OTTAWA RIVER

7.1 Flood hydrogram

Three different flood hydrograms were provided by PWGSC, corresponding to:
- Summer probable maximum flood (max flow 6500 m^3/s)
- Spring 100 year return period flood (max flow 7000 m^3/s)
- Spring probable maximum flood (max flow 9000 m^3/s)

All simulations were run with the worst case, the Spring probable maximum flood shown on Figure 5.3.

7.2 Simulated Scenarios

Four scenarios were simulated:

- **Scenario 1**: (run D3)
  - Creation of a 6 m deep channel across the island during its over flowing (see section 5.3.1)
  - No dam failure at Témiscamingue
  - All Otto Holden flood gates closed
- **Scenario 2**: (run C10)
  - Creation of a 6 m deep channel across the island
  - 3 gates failure in the west dam at Témiscamingue
  - All Otto Holden flood gates closed
- **Scenario 3**: (run E1)
  - Creation of a 6 m deep channel across the island
  - 10 gates failure in the west dam at Témiscamingue
  - All Otto Holden flood gates closed
- **Scenario 4:** (run E2)
  - Creation of a 6 m deep channel across the island
  - 10 gates failure in the west dam at Témiscamingue
  - Otto Holden flood gates 3/4 opened

7.3 Initial conditions

At the beginning of the simulations that started at day 20 of the hydrogram (Figure 5.3), the flow condition in the Ottawa river was steady with a 500 m^3/s upstream discharge at Haileybury, and levels were maintained at:

- 179.04 m at Haileybury,
- 179.0 m upstream of the Témiscamingue dams,
- 177.24 m downstream of the Témiscamingue dams,
- 177.2 m at Otto Holden dam.

7.4 Control structures Behaviour

For each scenario, the time at which the control structures started to fail and the discharge through them are shown in table 7.1

Scenario	1	2	3	4
Run number	D3	C10	E1	E2
Time initiation island erosion (day : hour)	34 : 9.5	34 : 8.7	34 : 9.1	34 : 8.8
Time initiation West dam failure (day : hour)	na	35 : 4.3	35 : 4.3	35 : 4.7
Maximum discharge through island erosion channel (m^3/s)	787	724	561	581
Maximum discharge through dam breach (m^3/s)	na	1197	2998	3331
Maximum overtopping discharge, West dam (m^3/s)	1585	1229	650	525
Maximum overtopping discharge, East dam (m^3/s)	1062	998	865	755
Maximum discharge through Otto Holden dam flood gates (m^3/s)	0	0	0	3300
Maximum overtopping discharge at Otto Holden dam (m^3/s)	6386	6364	6333	3542
Hydrogram peak flow (m^3/s)	9034			
Time of Hydrogram peak at Haileybury (day)	37			
Time of peak level at Témiscamingue (day : hour)	38 : 8			

Table 7.1 - Characteristics of control structures during the flood scenarios

7.5 Inundations Maps

Maps showing the maximum water depths observed during the simulations are shown in Figure 7.1 to 7.16 for all four scenarios. These maps cover approximately 2 km upstream, 4 km downstream and 5.5 km downstream of the Témiscamingue island. Digital copies of these maps covering the whole domain were provided to PWGSC .

8. WATER LEVELS DURING THE PROPAGATION OF THE FLOOD

The water level upstream of the East dam during the 24 days of simulation is shown in Figure 8.1 in the case of scenario 3. The general shape of this curve resembles the shape of the upstream hydrograph shown on Figure 5.3.

More detailed water levels are shown in Figure 8.2 to 8.5 for the 4 scenarios at 4 locations (upstream model boundary at Haileybury, upstream of Island, downstream of Island, Otto Holden dam). The effect of the dam failure can readily be seen just upstream of the dam.

Figure 8.6 indicates the detailed water level downstream of the west dam and at Otto Holden during the Témiscamingue dam failure for scenario 3. It shows that the flood wave due to the dam breach creates a super-elevation of the order of 25 cm, and that this wave takes approximately 55 minutes to travel to Otto Holden dam.

Since the dam break does not occur at the peak of the flood but 76 hours before, this flood wave does not cause the largest inundation extent downstream of the dam, and water continues to rise after the dam failure.

9. MAXIMUM VELOCITIES DURING THE PROPAGATION OF THE FLOOD

The maximum velocity maps at the dams are shown in Figure 9.1 to 9.4 for the four scenarios. Table 9.1 indicates the actual velocities in the erosion channel and at the dam break.

In the other portions of the river, the velocities were mostly less that 1 m/s except in a few narrow sections.

Scenario	**1**	**2**	**3**	**4**
Maximum velocity in erosion channel (m/s)	5.1	5.1	5.1	5.9
Maximum velocity in dam break opening (m/s)	na	5.8	4.9	7.5

Table 9.1 - Local maximum velocities during the flood scenarios

10. ANALYSIS OF RESULTS

Several conclusions can be drawn from these flood simulations.

1. During the four simulated scenarios, flooding extending approximately 100 m from the shore line, occurred on the east bank at Témiscamingue (parking lot and paper mill yard) as well as around Thorne and McDougal creek on the west bank, 1 km downstream.
2. The flow through the erosion channel (700 m^3/s) is small compared to the total discharge of the flood, indicating that even after the creation of the channel, the water level will continue to rise to allow water to run across the island over its road.

3. The breach at the Témiscamingue dam lowered the water level upstream of Témiscamingue by 14 cm with 3 sluices removed, and 48 cm with 10 sluices removed. This had the same effect as if more stop logs had been removed from the sluices. In scenario 4, levels upstream of the dam were lowered by 78 cm due to the increase in flow through the breach, because of lower downstream levels.
4. The Témiscamingue dam breach created a local downstream super-elevation of the water surface in the order of 25 cm and 35 cm respectively for the breach of 3 and 10 sluices. This wave would propagate to Otto Holden dam in about 55 minutes. Since the dam break does not occur at the peak of the flood, but 76 hours before, this flood wave does not cause the largest inundation downstream of the dam, and water continues to rise after the dam failure. The maximum inundation occurs when the peak of the hydrogram reaches the area.
5. All levels downstream of the Témiscamingue dams are controlled by the conditions at Otto Holden dam, irrespective of the breach and bank erosion at Témiscamingue. With all the Otto Holden gates closed (scenario 1,2,3) levels remained very high, (see Figure 8.4 and 8.5). The opening of the gates at Otto Holden dropped the downstream levels significantly, by approximately 73 cm.
6. The opening of all gates and removal of more stop logs in the sluices at Otto Holden would have lowered the levels even more and minimized the flood extent. It is felt that the excess flow (3600 m^3/s) which overtopped the Otto Holden dam in scenario 4 could be handled by all stoplog sluices if one had time, at the beginning of the flood, to remove seven logs in each of them.

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Faure, T.; 2001. *Simulation de ruptures du barrage de Carillon, sur la rivière des Outaouais et le fleuve Saint- Laurent à travers la communauté urbaine de Montréal.* Canadian Hydraulics Centre, National Research Council, Ottawa, Ontario. HYD-CTR-111, (Septembre)

Hervouet J-M. and Rouge, D., 1996, *Numerical Simulation of the Malpasset dam–break flood wave*. Rapport Électricité de France-DER, HE-43/96/040/A

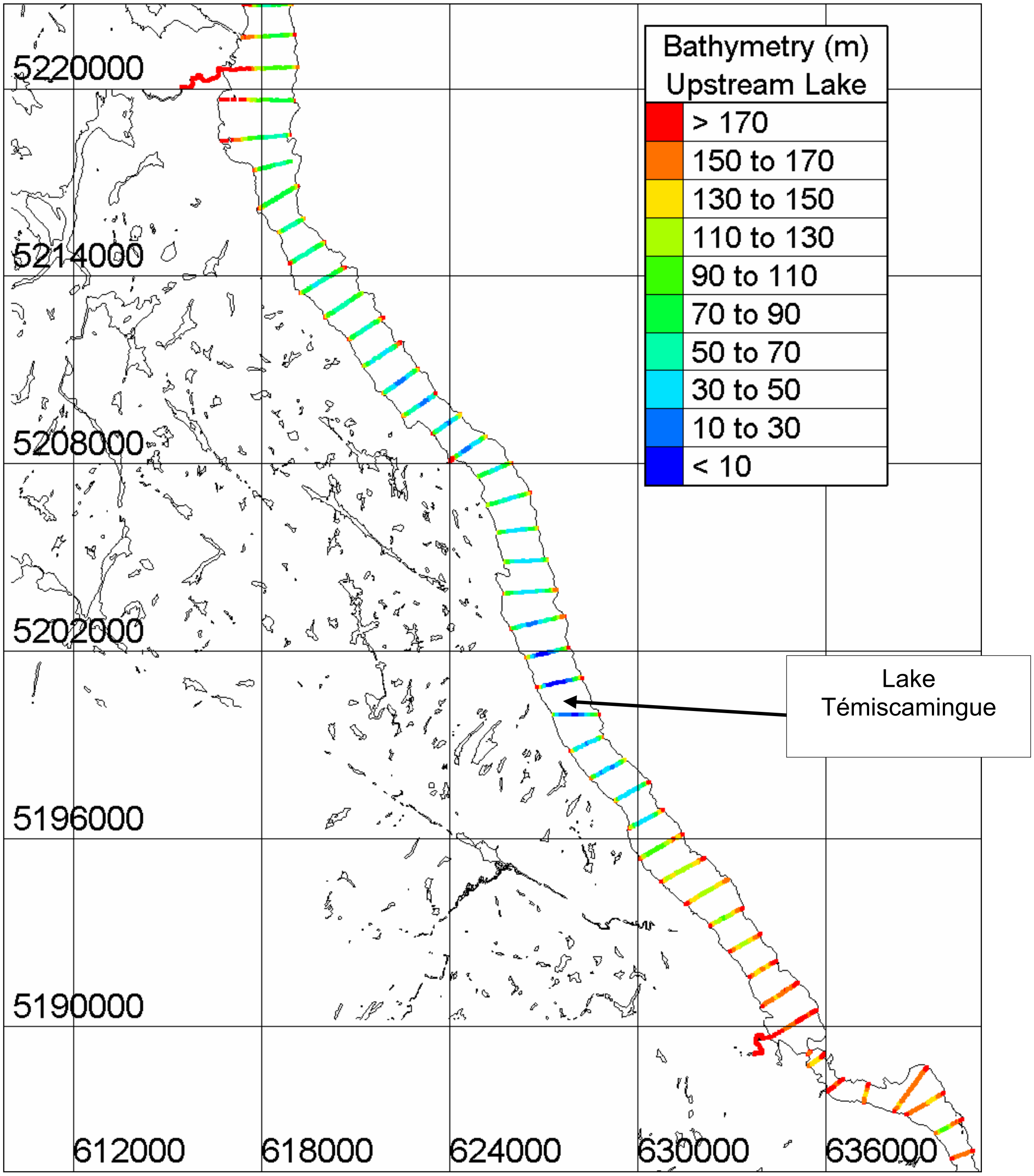

Figure 3.1 - Cross sections in the upstream Lake Témiscamingue

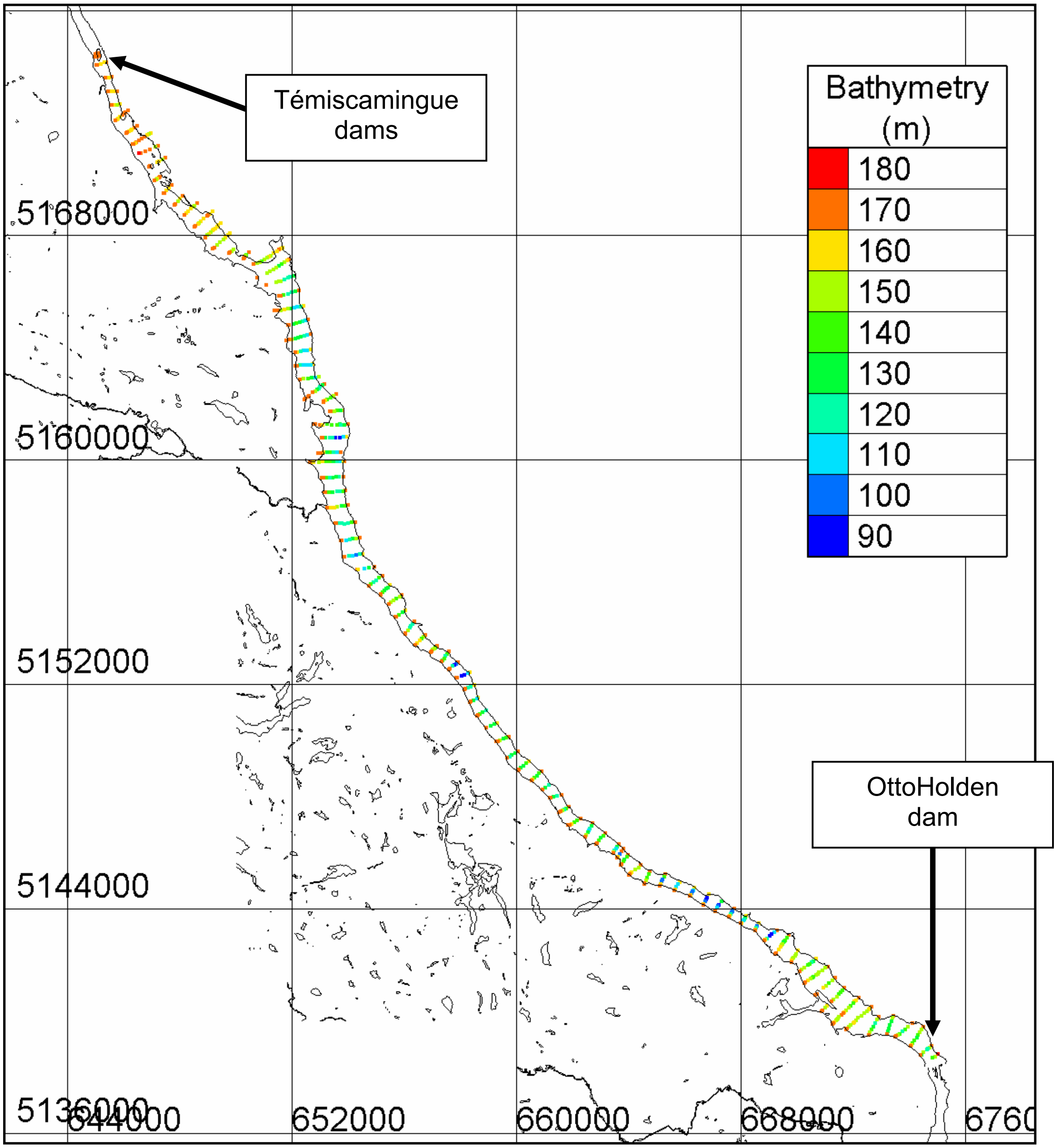

Figure 3.2 - Bathymetric cross sectional data downstream of Témiscamingue

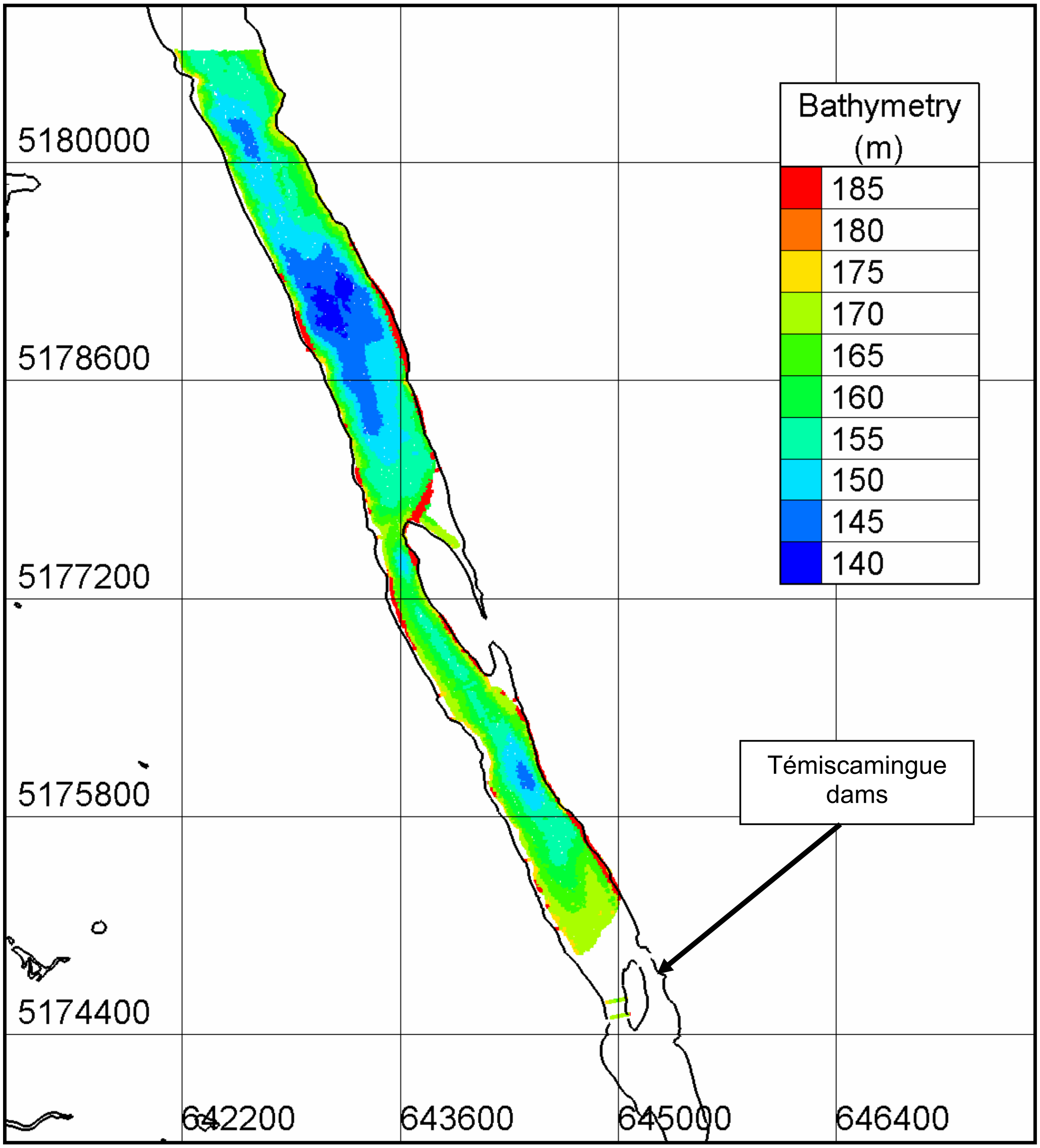

Figure 3.3 - Bathymetric high density data upstream of Témiscamingue dams

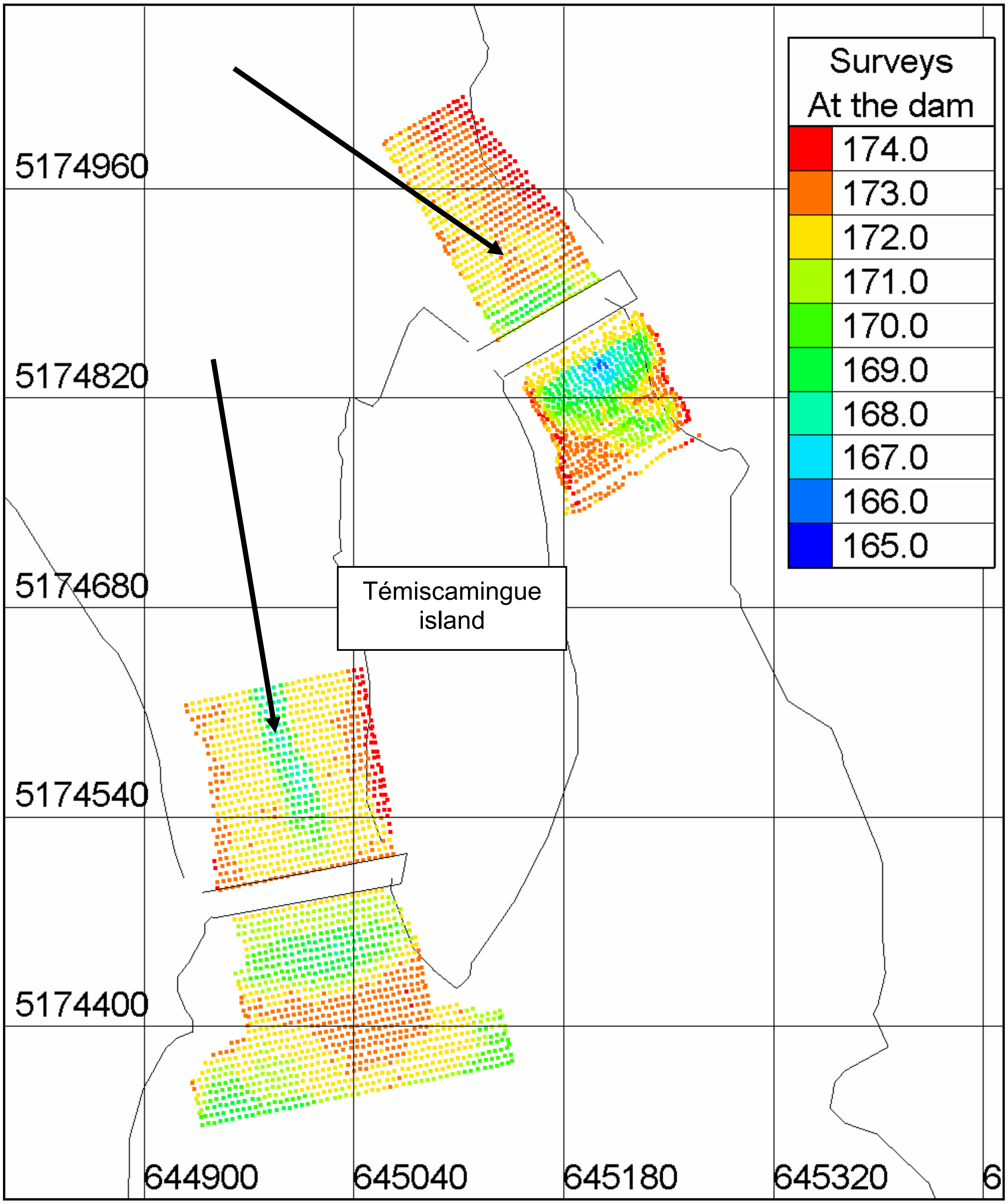

Figure 3.4 - Bathymetric surveys close to the Témiscamingue dams

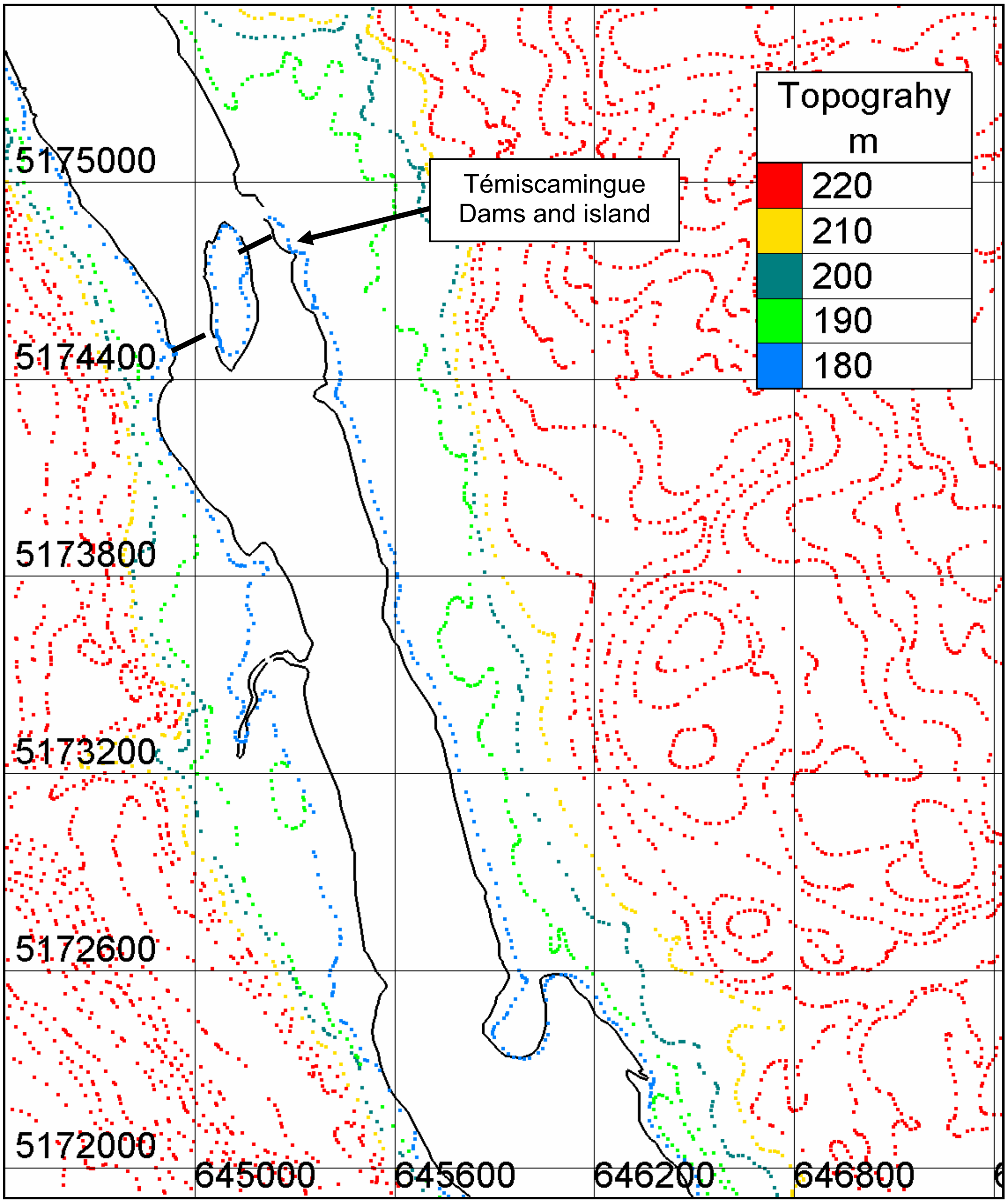

Figure 4.1 - Topographic contour data

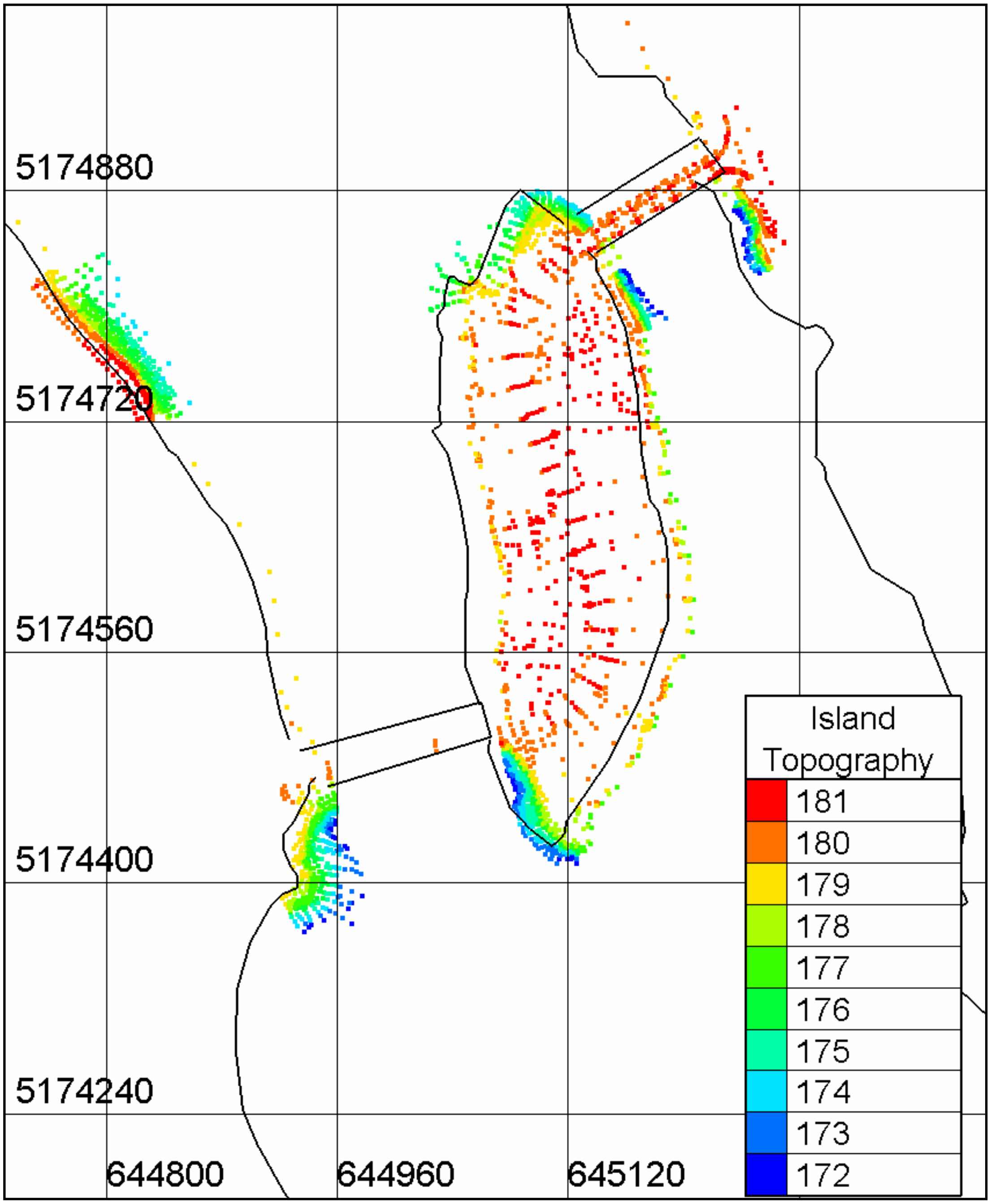

Figure 4.2- Detail topographic survey of the island

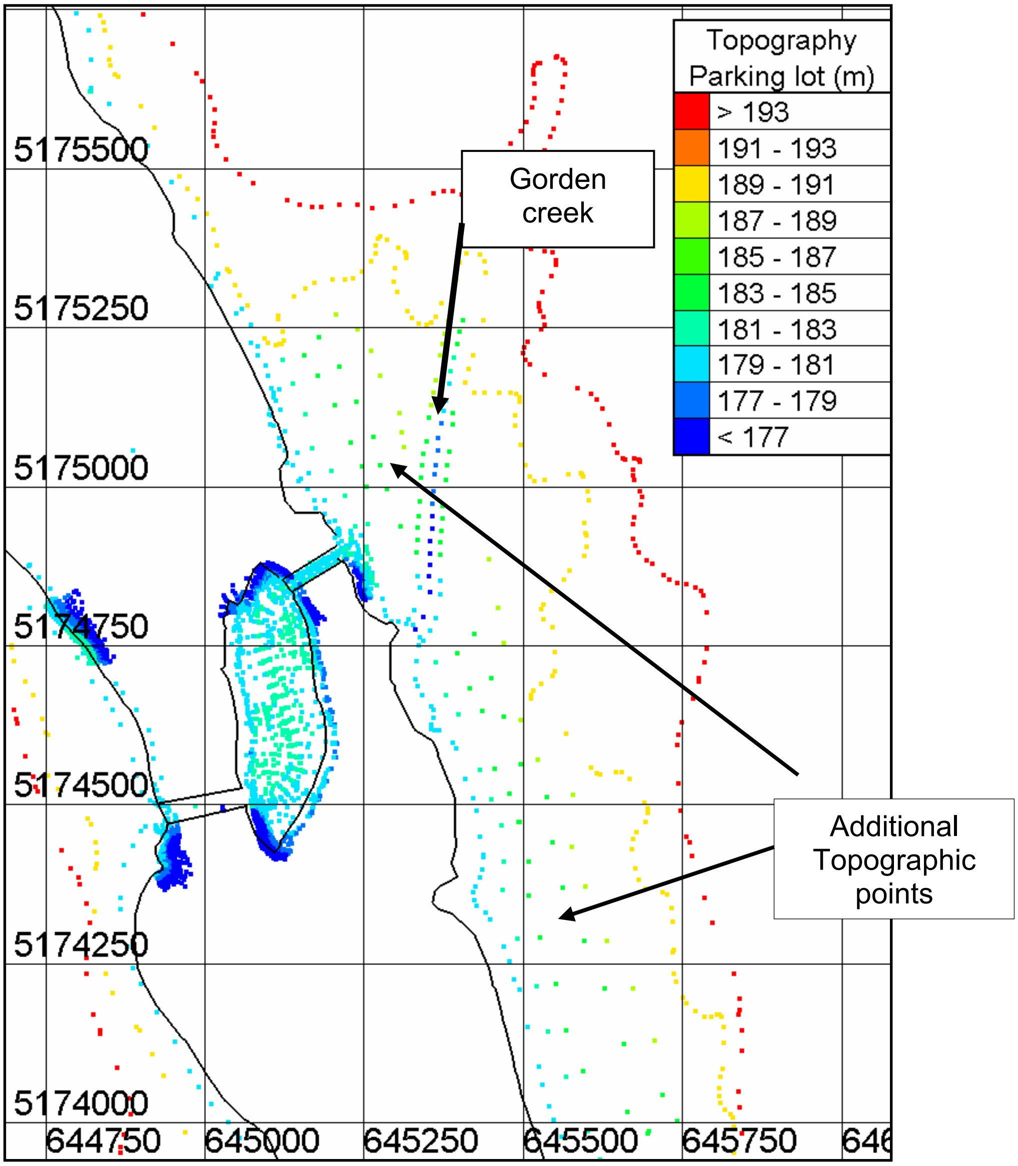

Figure 4.3 - Additional topographic data points

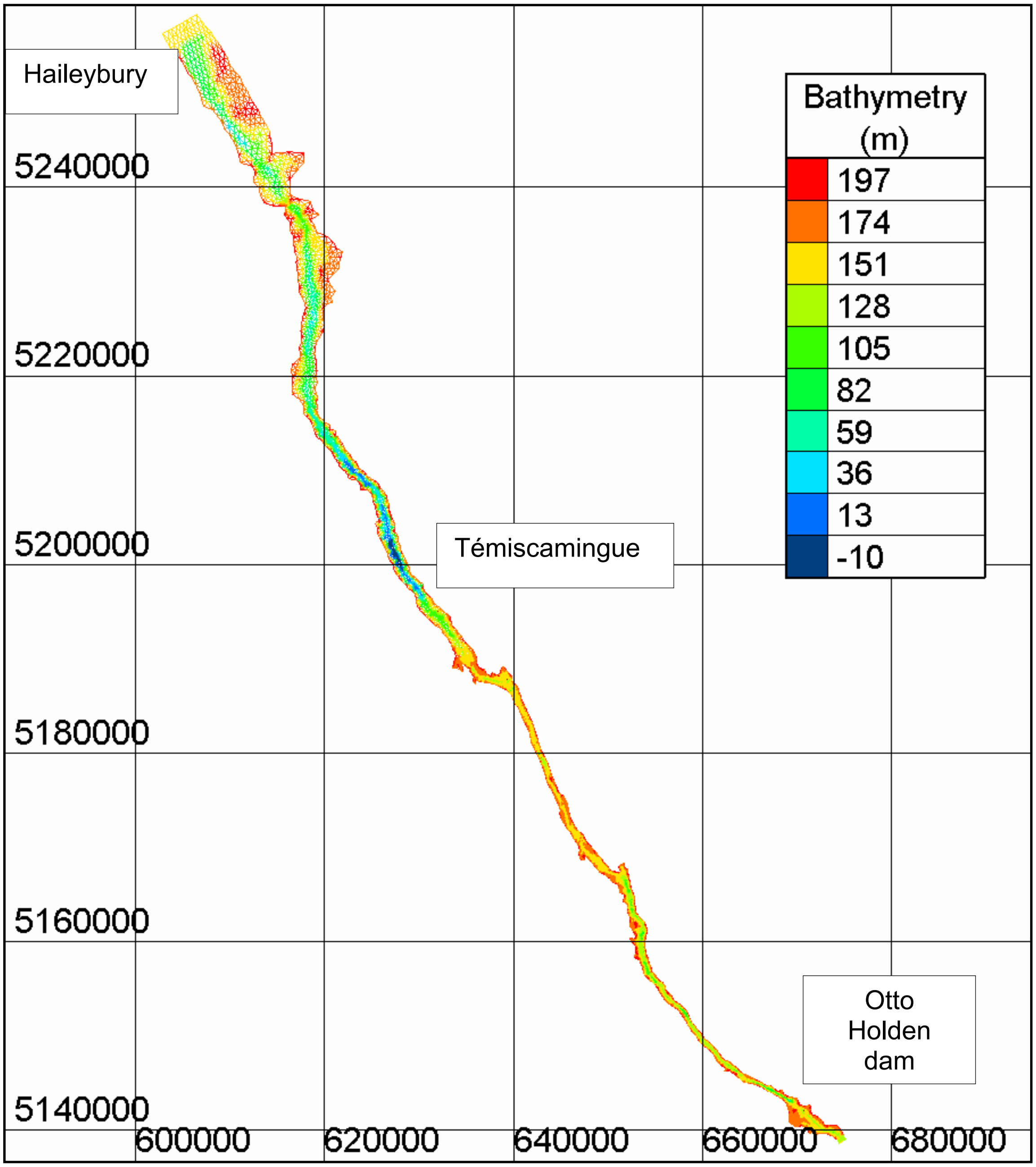

Figure 5.1 - General grid used in the simulations

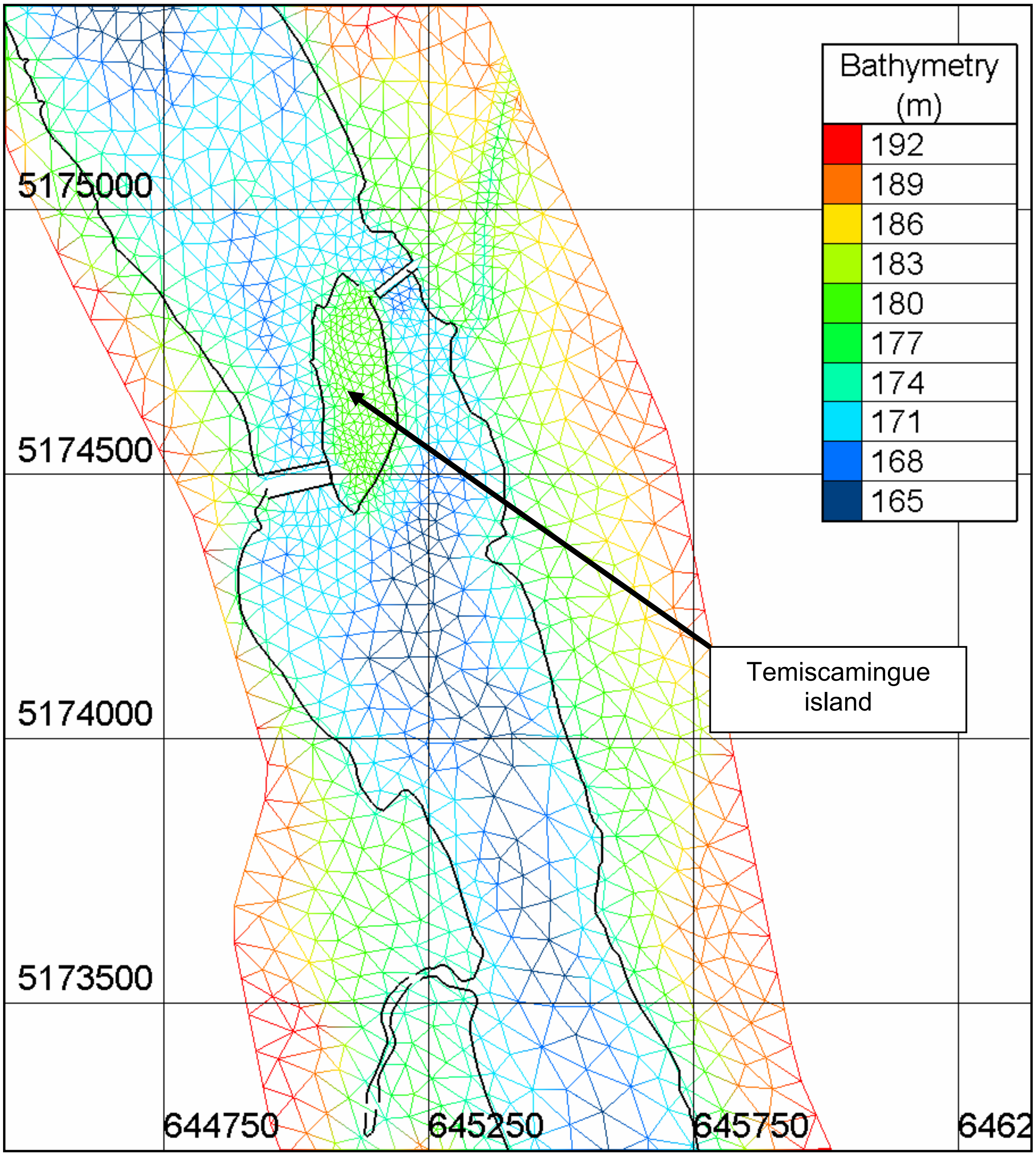

Figure 5.2 - Detail grid around Témiscamingue

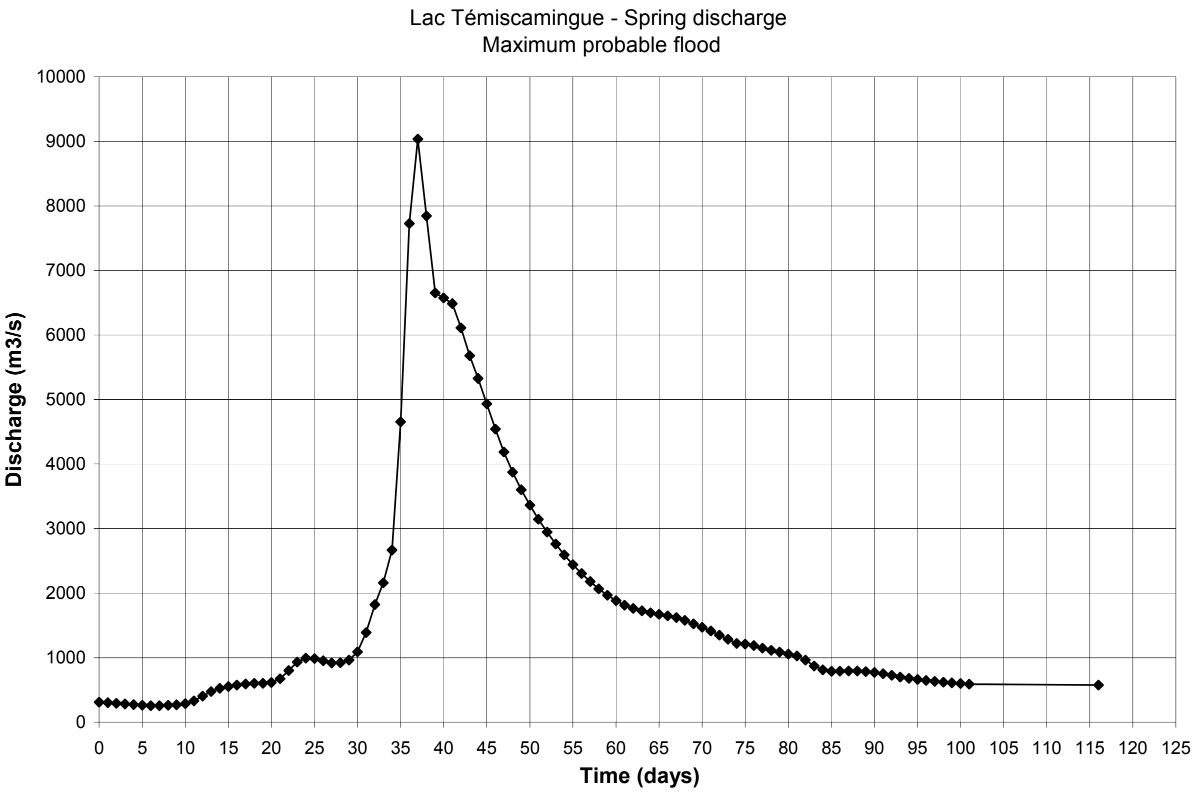

Figure 5.3 - Probable maximum flood (PMF) discharge at Haileybury

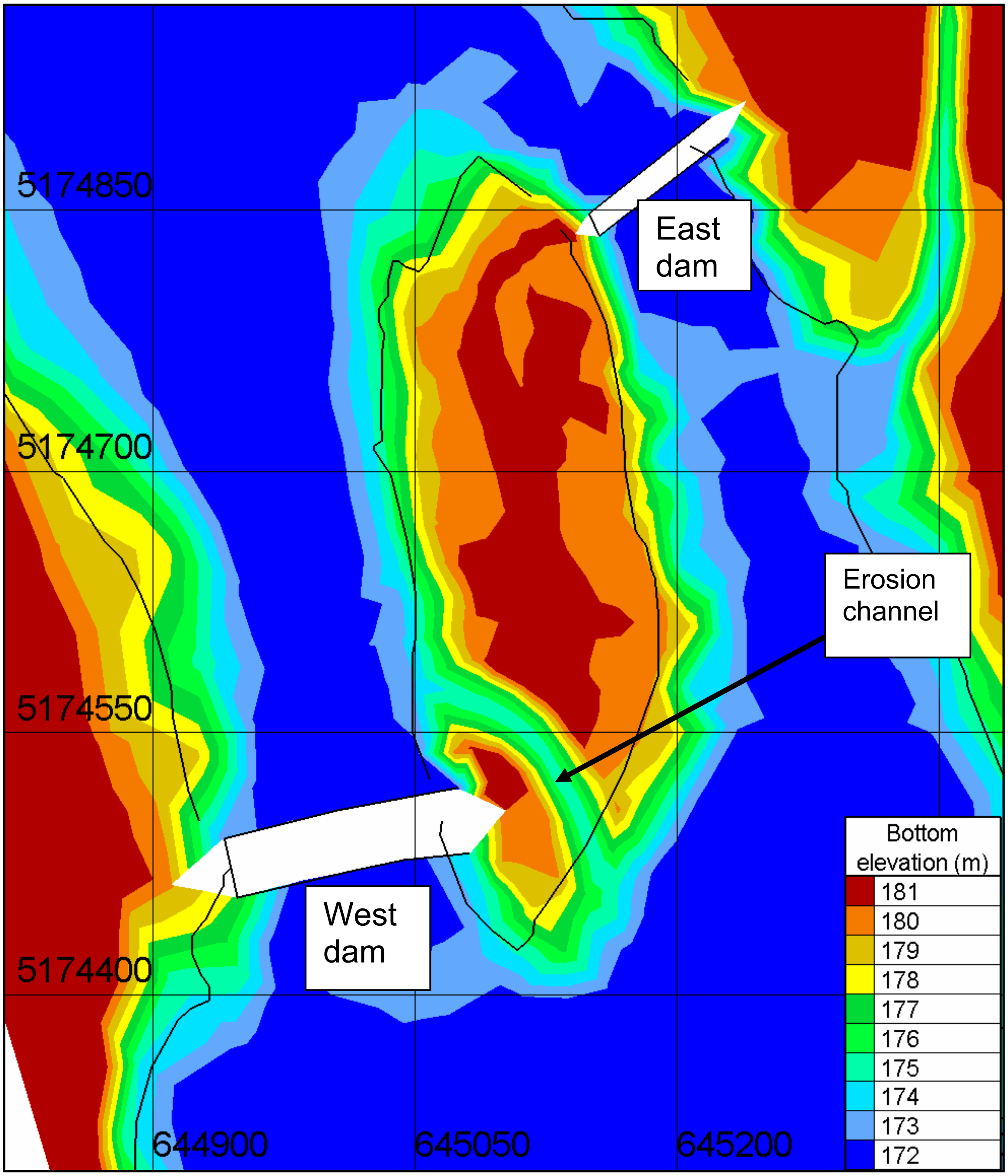

Figure 5.4 - Erosion channel across the island

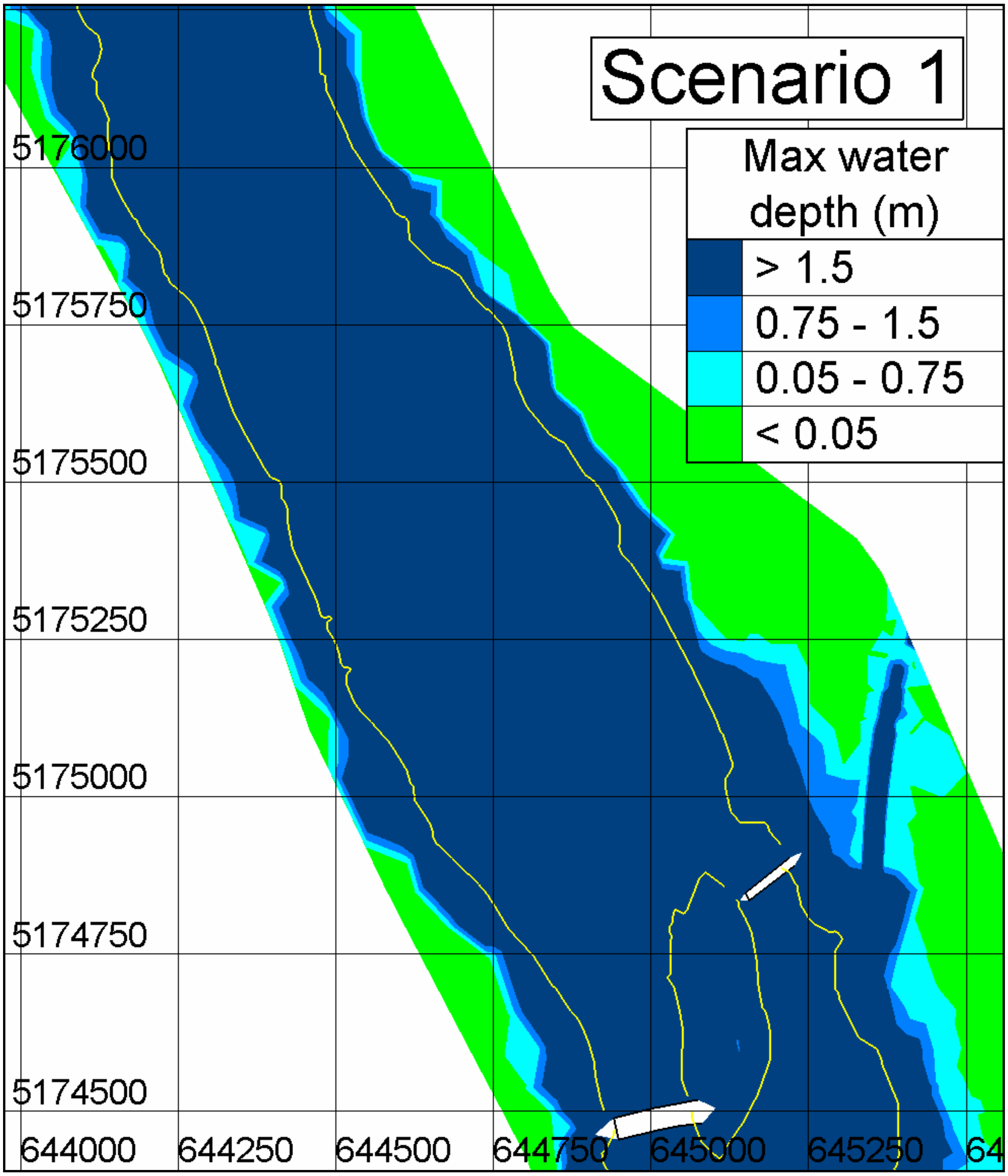

Figure 7.1 - Scenario 1- inundation upstream of island

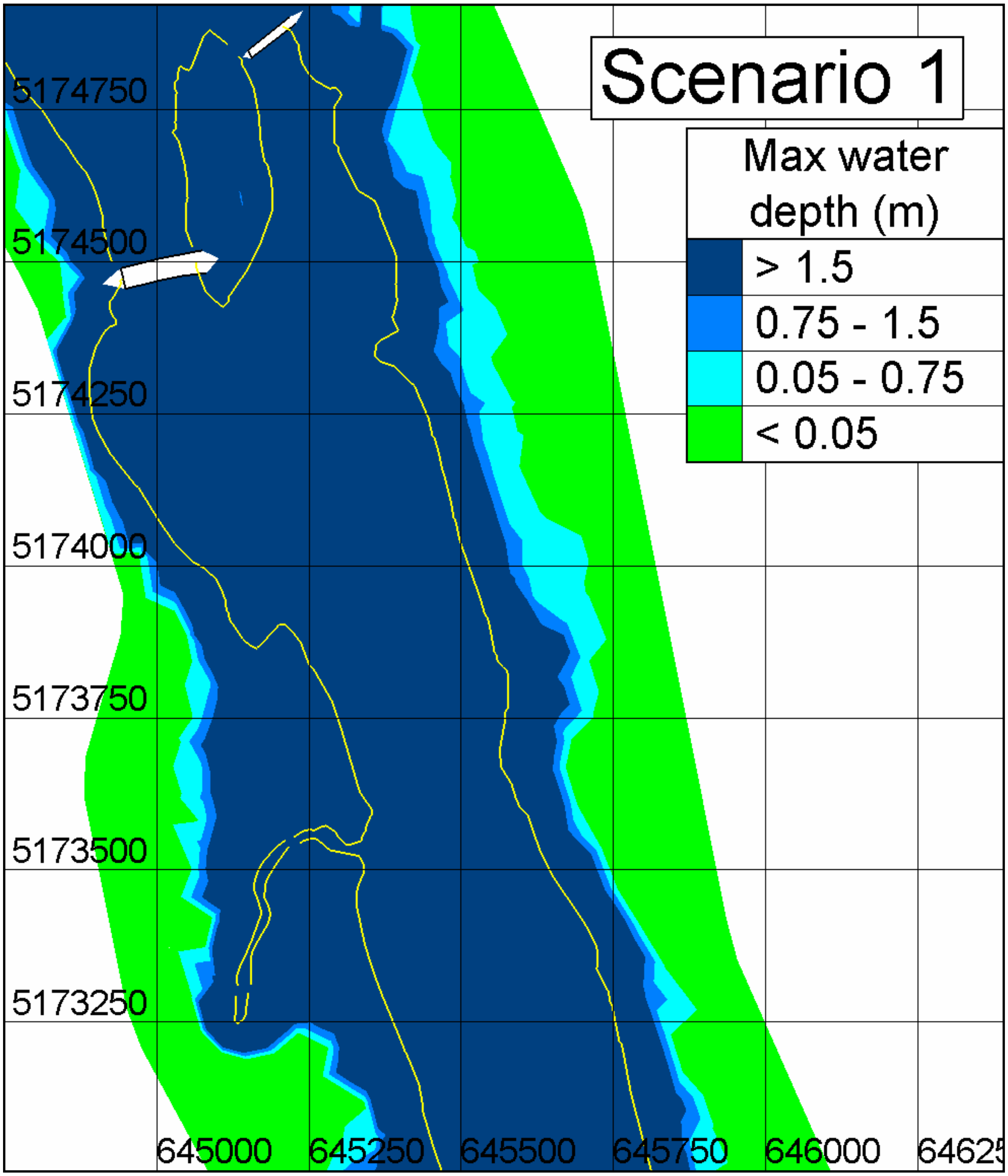

Figure 7.2 - Scenario 1- inundation downstream of island

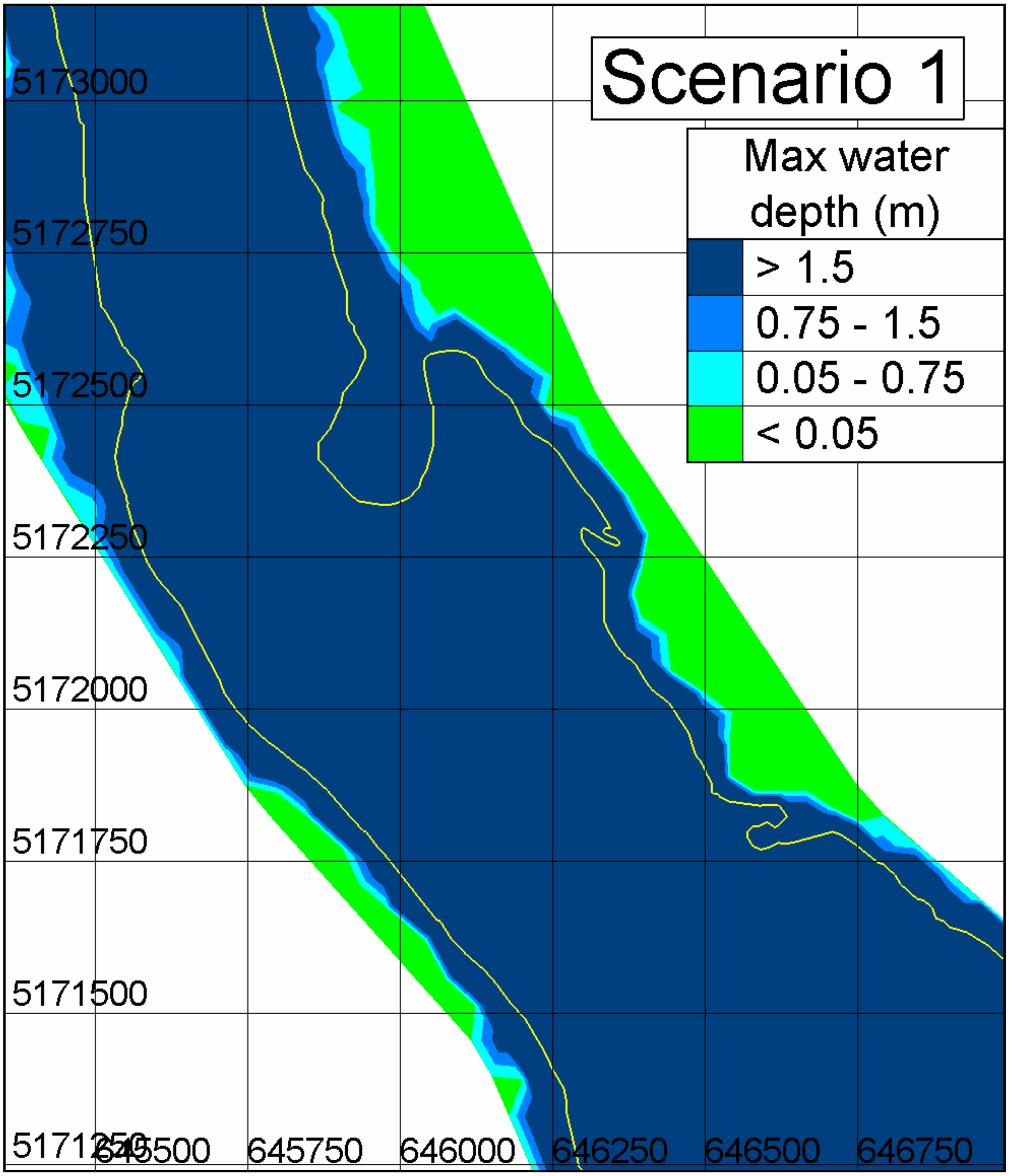

Figure 7.3 - Scenario 1- inundation 2 km downstream of island

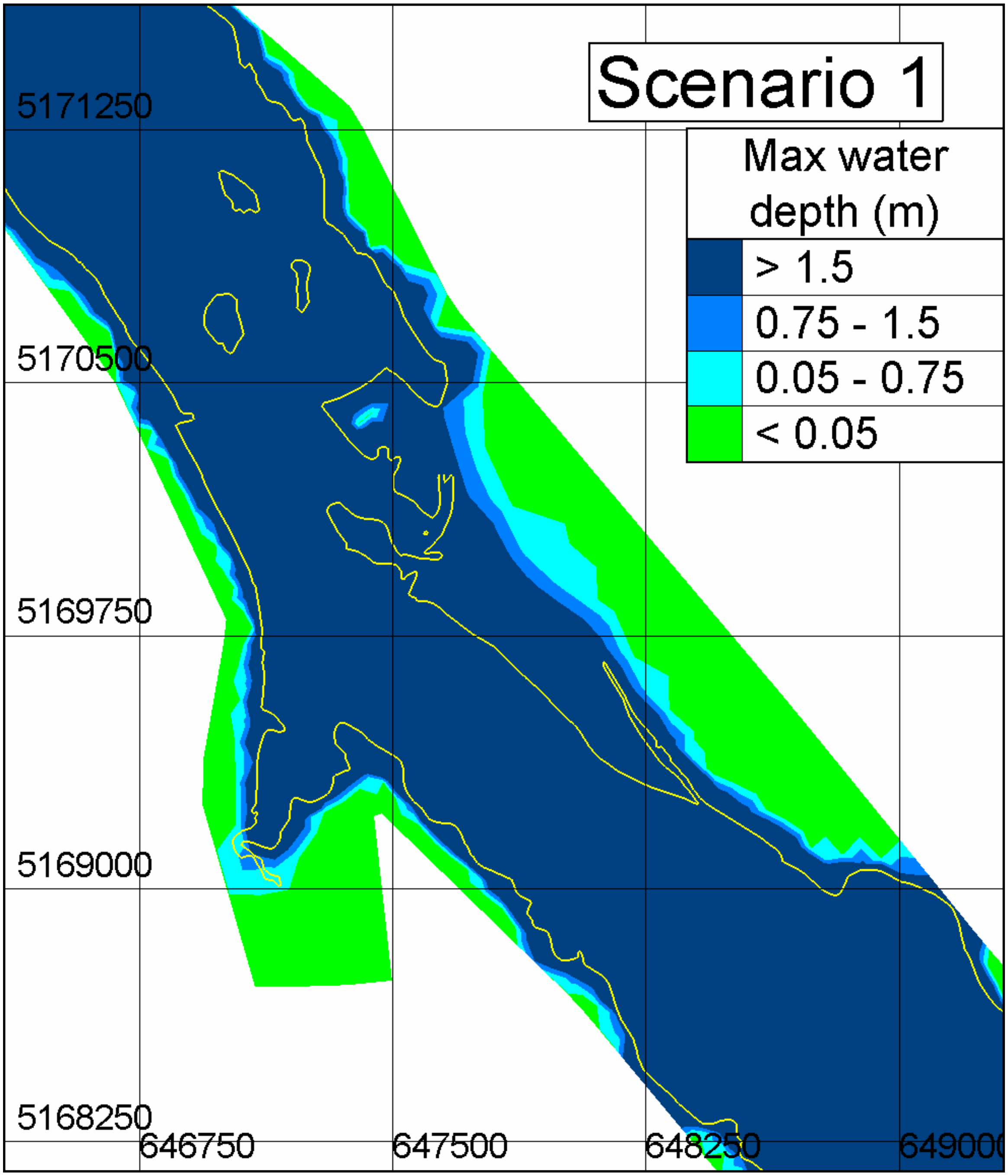

Figure 7.4 - Scenario 1- inundation 5 km downstream of island

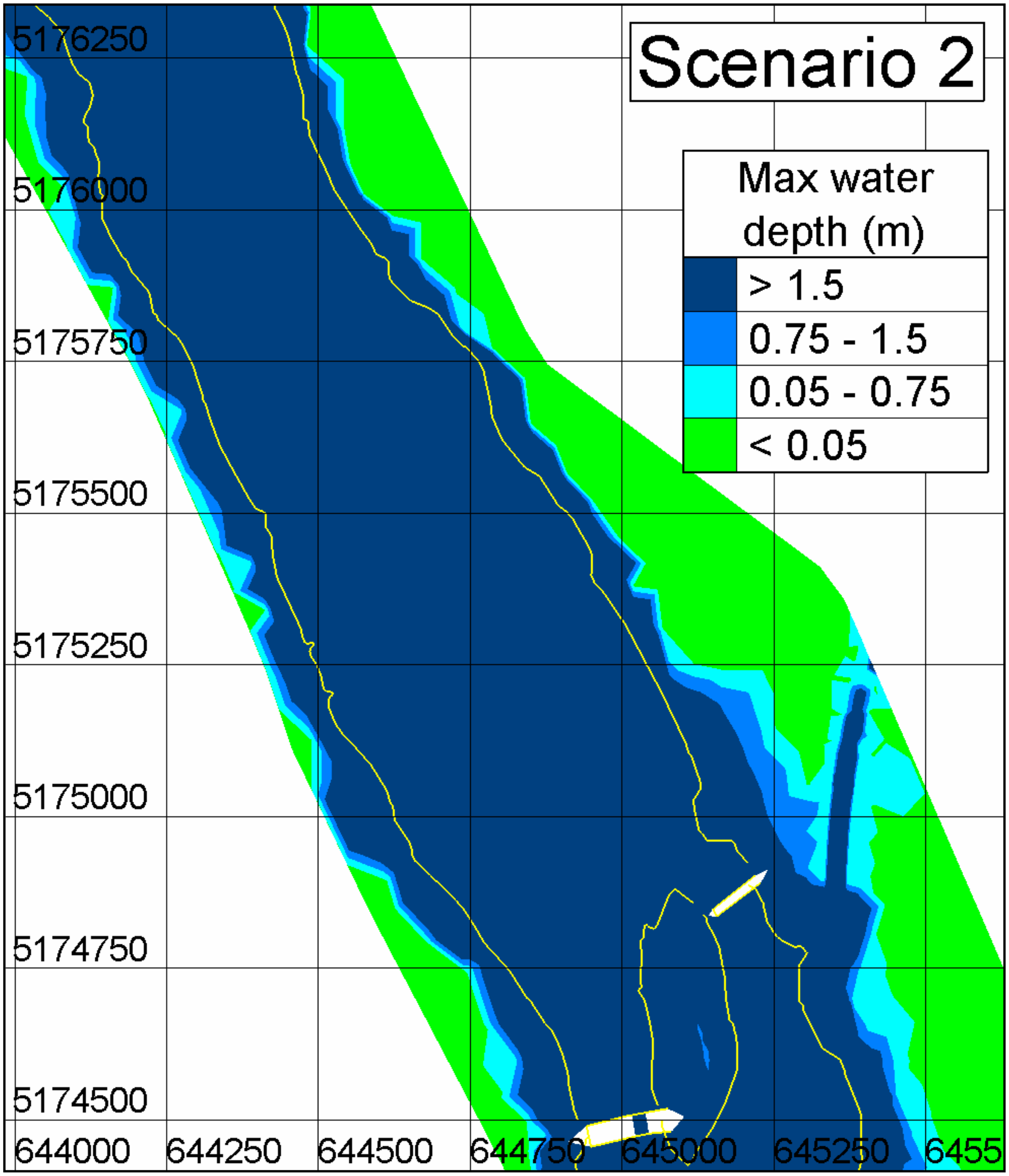

Figure 7.5 - Scenario 2- inundation upstream of island

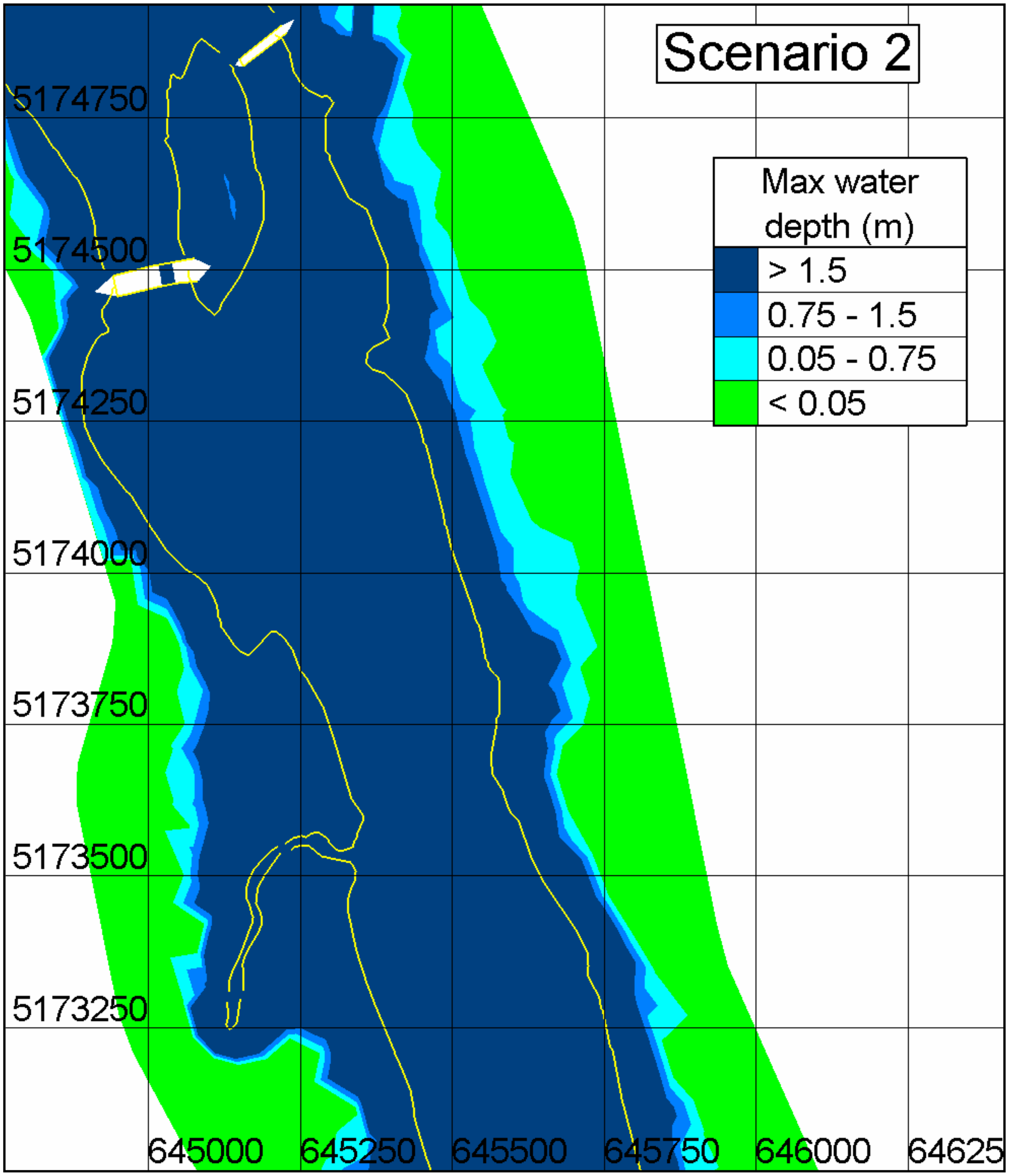

Figure 7.6 - Scenario 2- inundation downstream of island

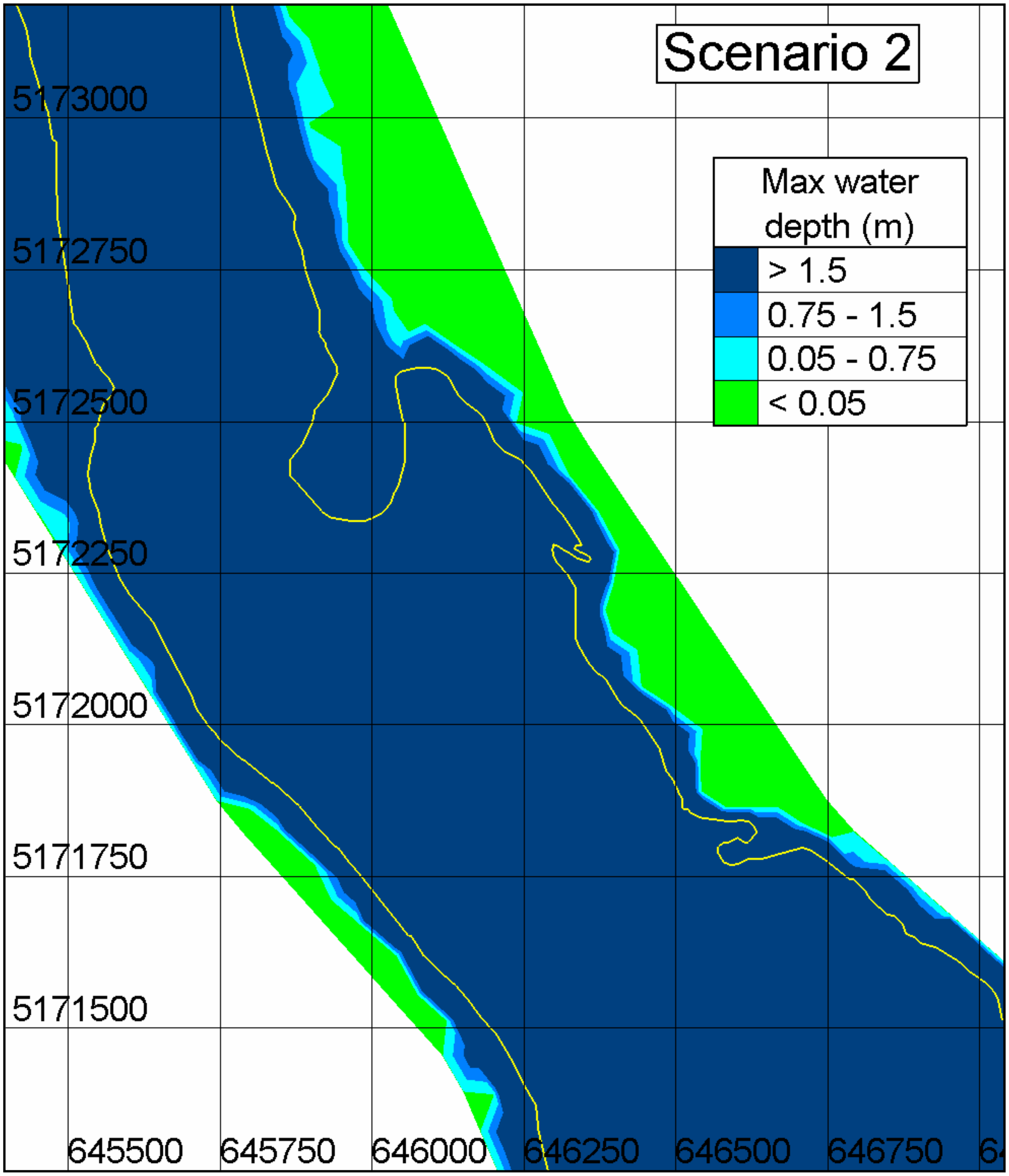

Figure 7.7 - Scenario 2- inundation 2 km downstream of island

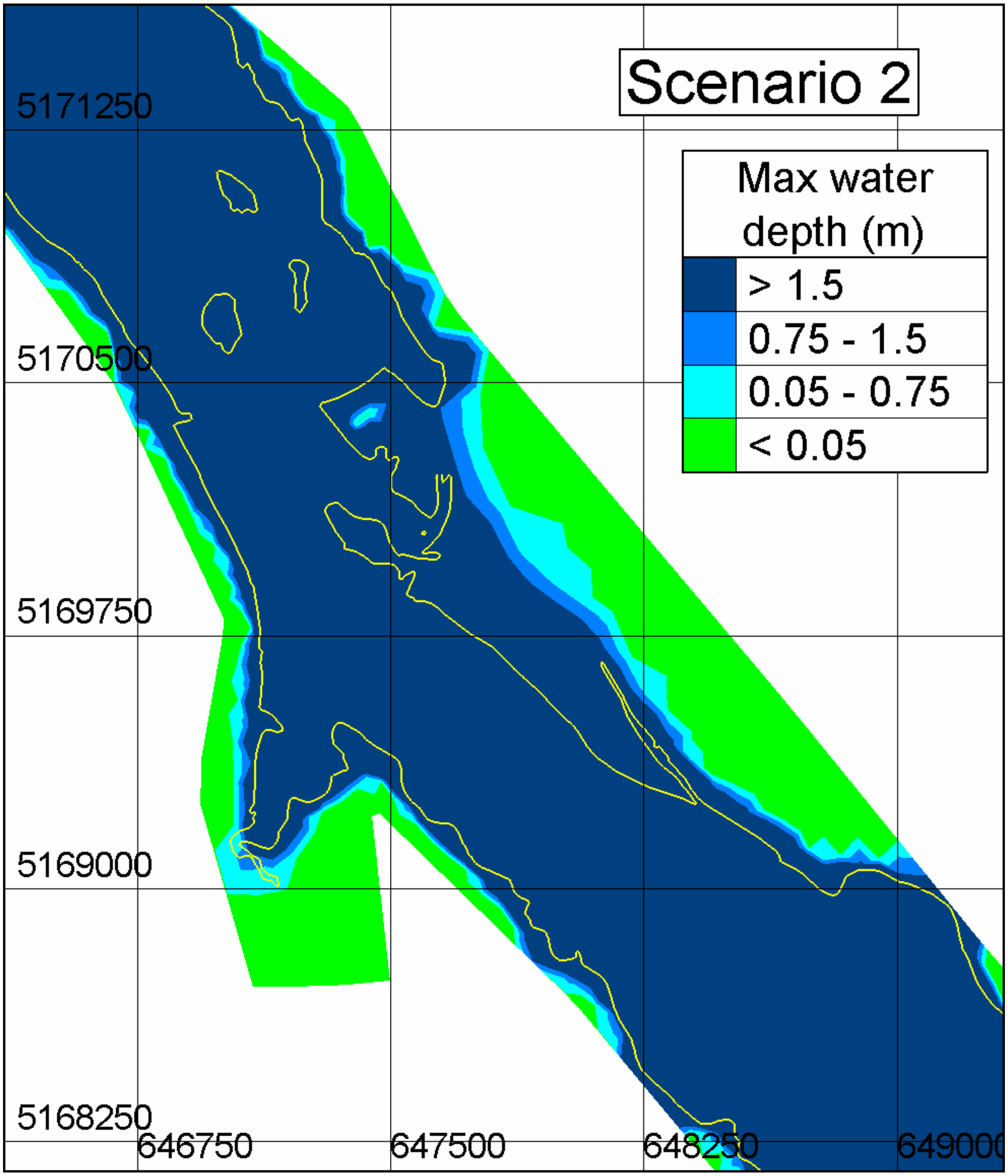

Figure 7.8 - Scenario 2- inundation 5 km downstream of island

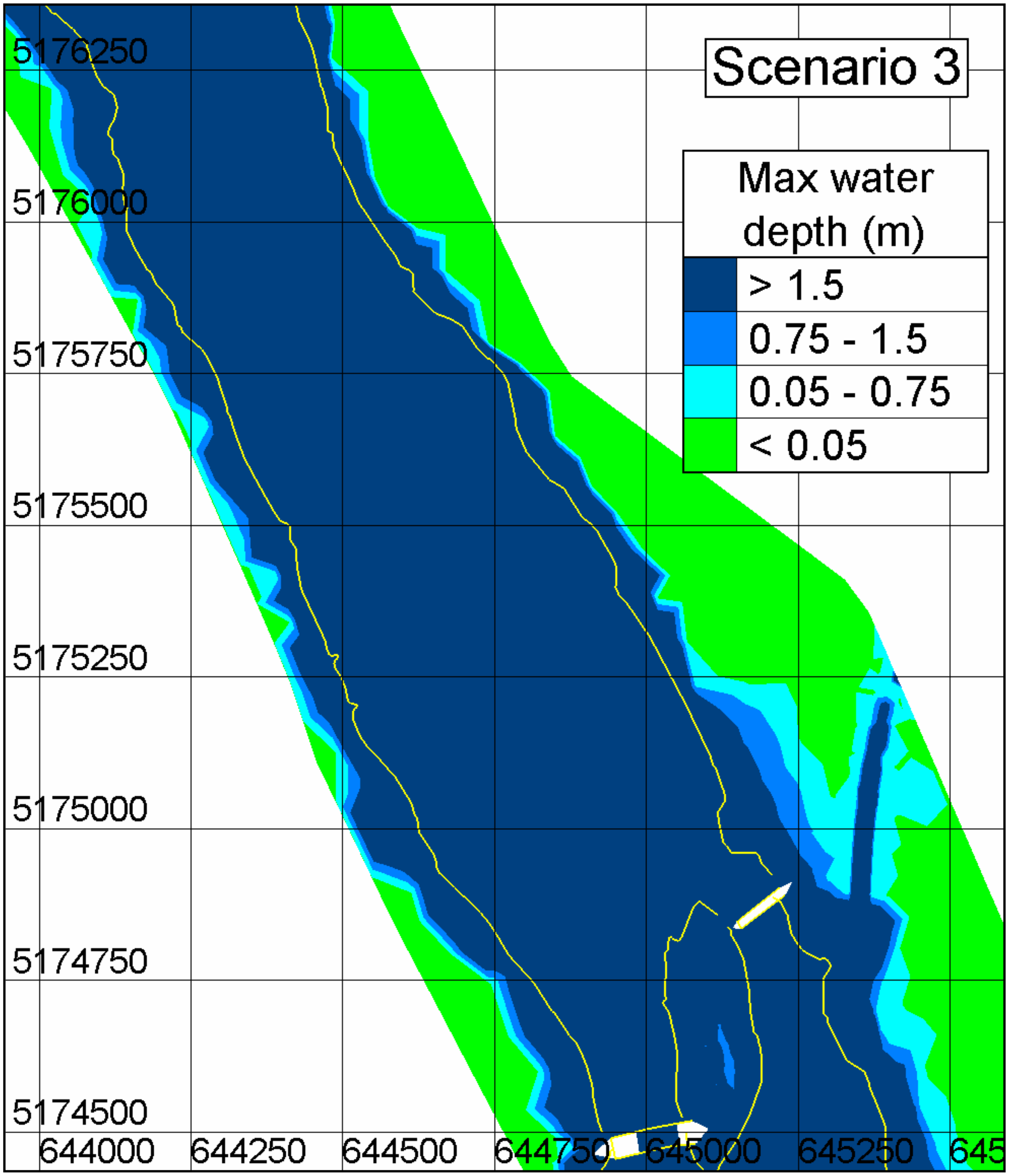

Figure 7.9 - Scenario 3- inundation upstream of island

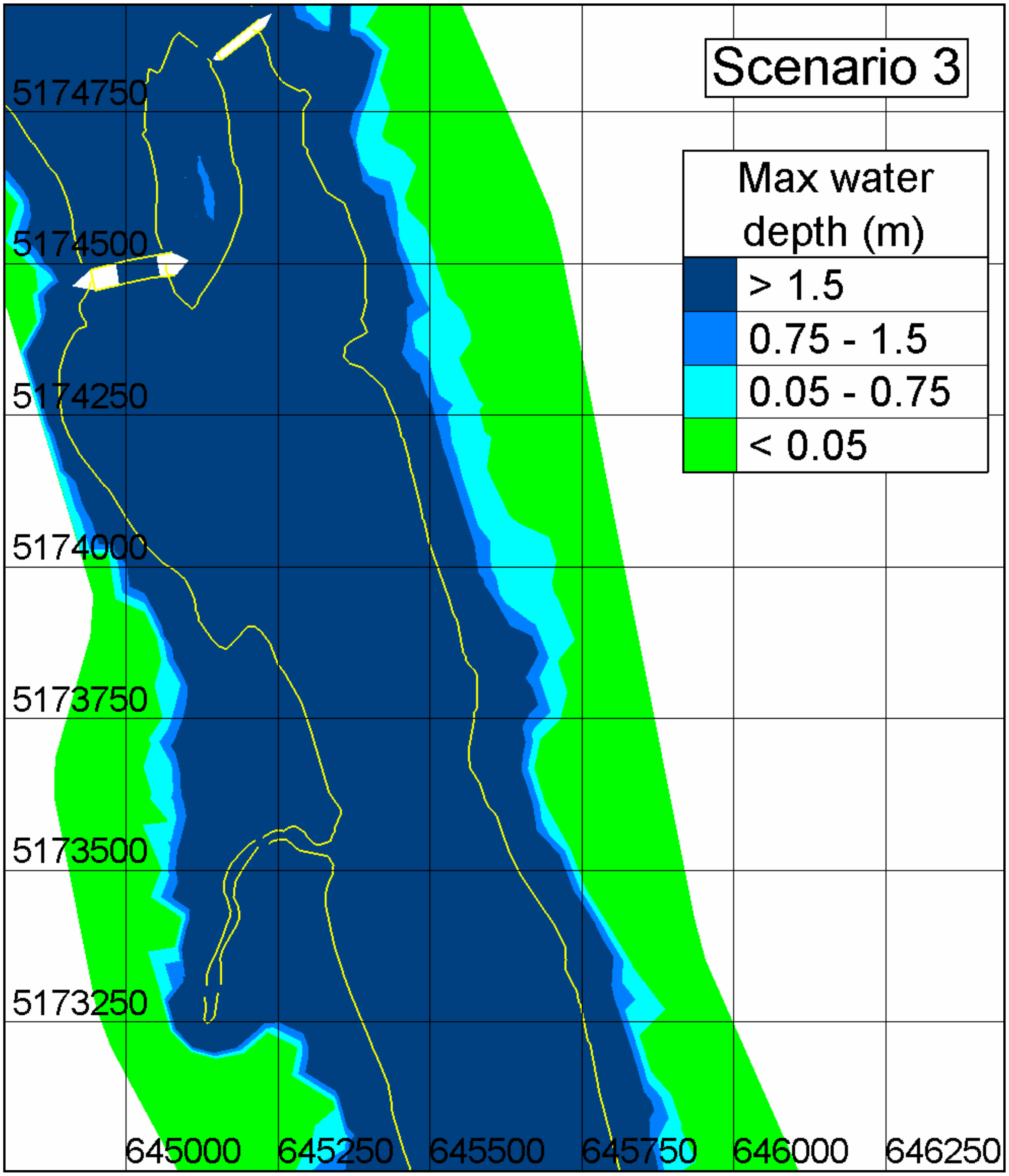

Figure 7.10 - Scenario 3- inundation downstream of island

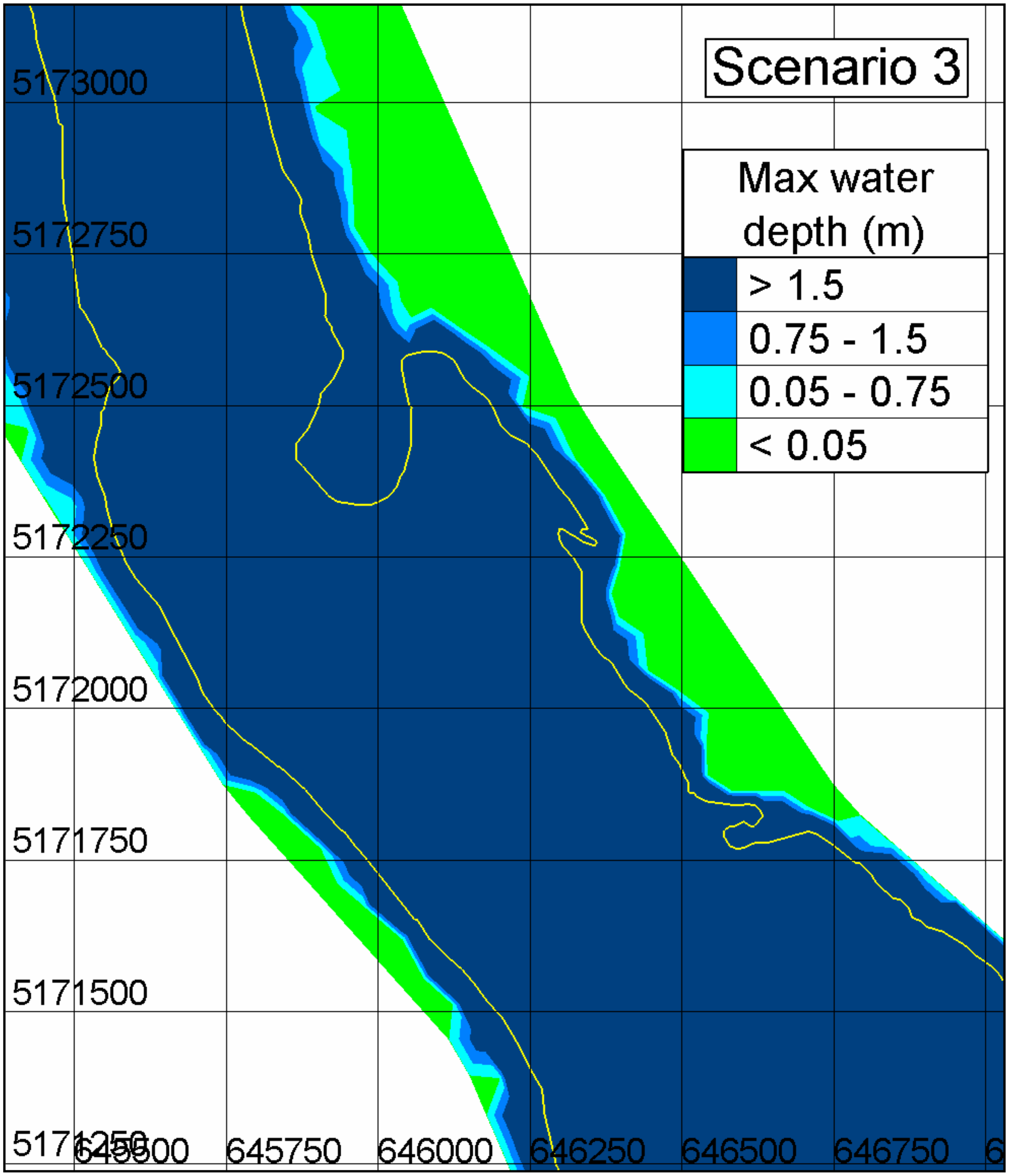

Figure 7.11 - Scenario 3- inundation 2 km downstream of island

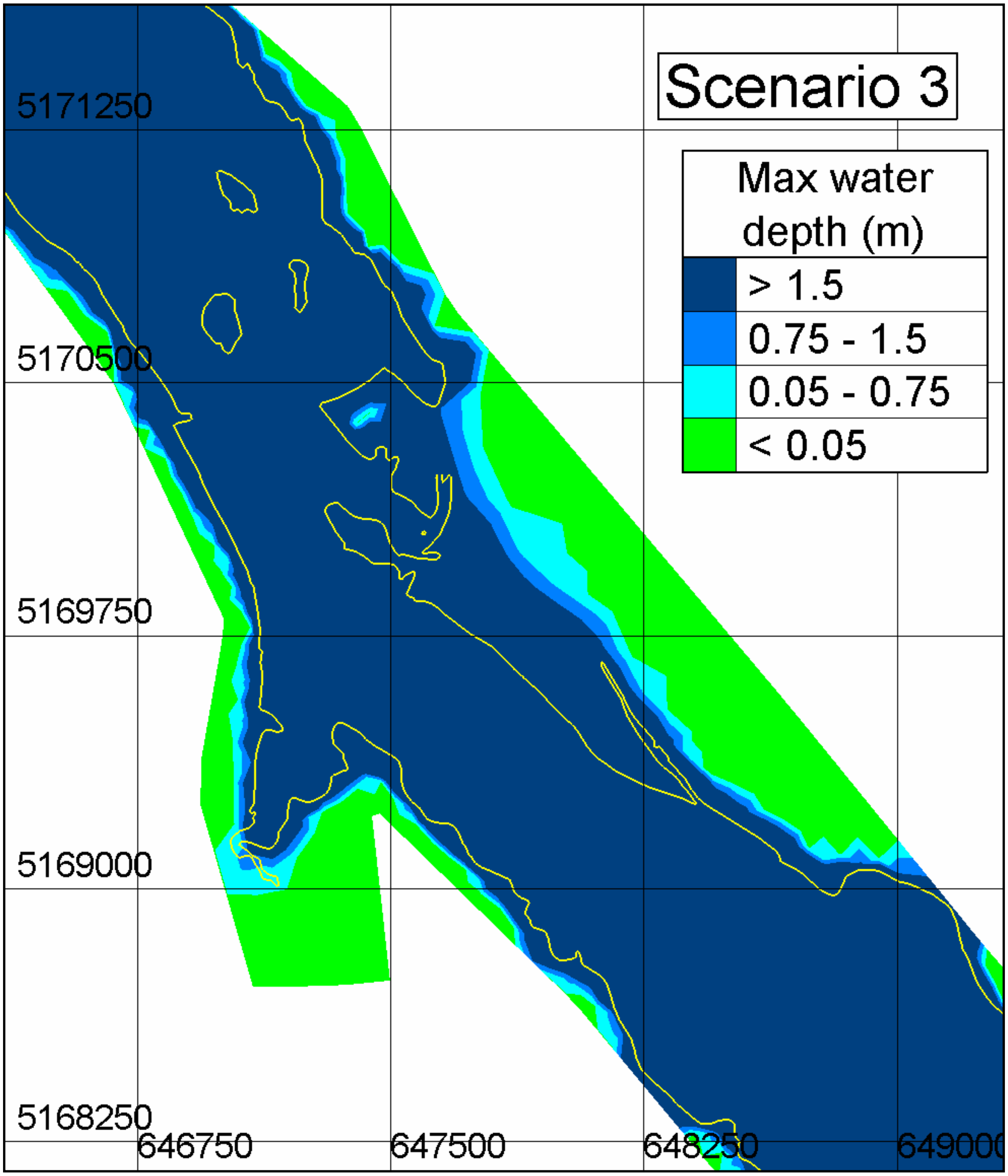

Figure 7.12 - Scenario 3- inundation 5 km downstream of island

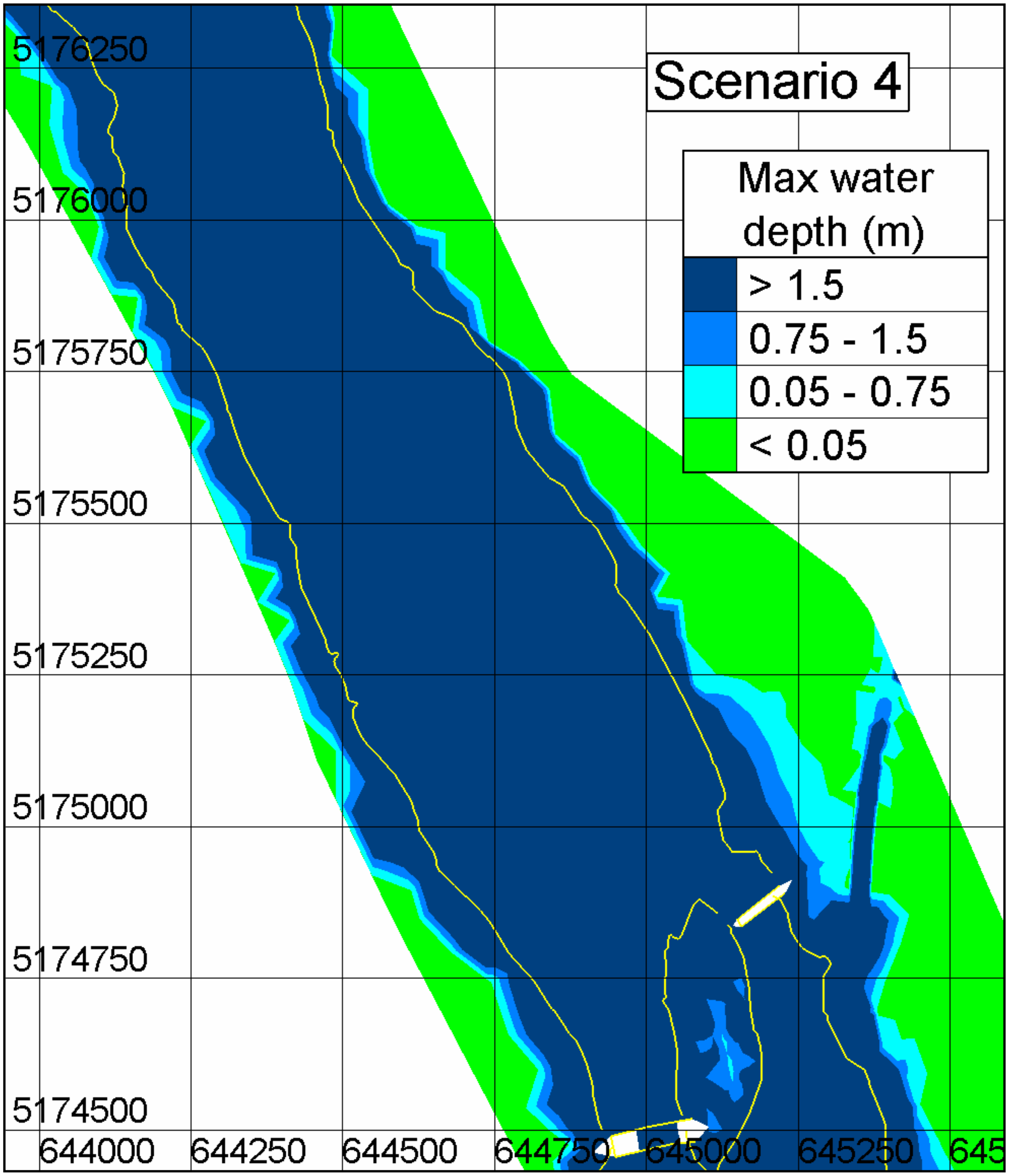

Figure 7.13 - Scenario 4- inundation upstream of island

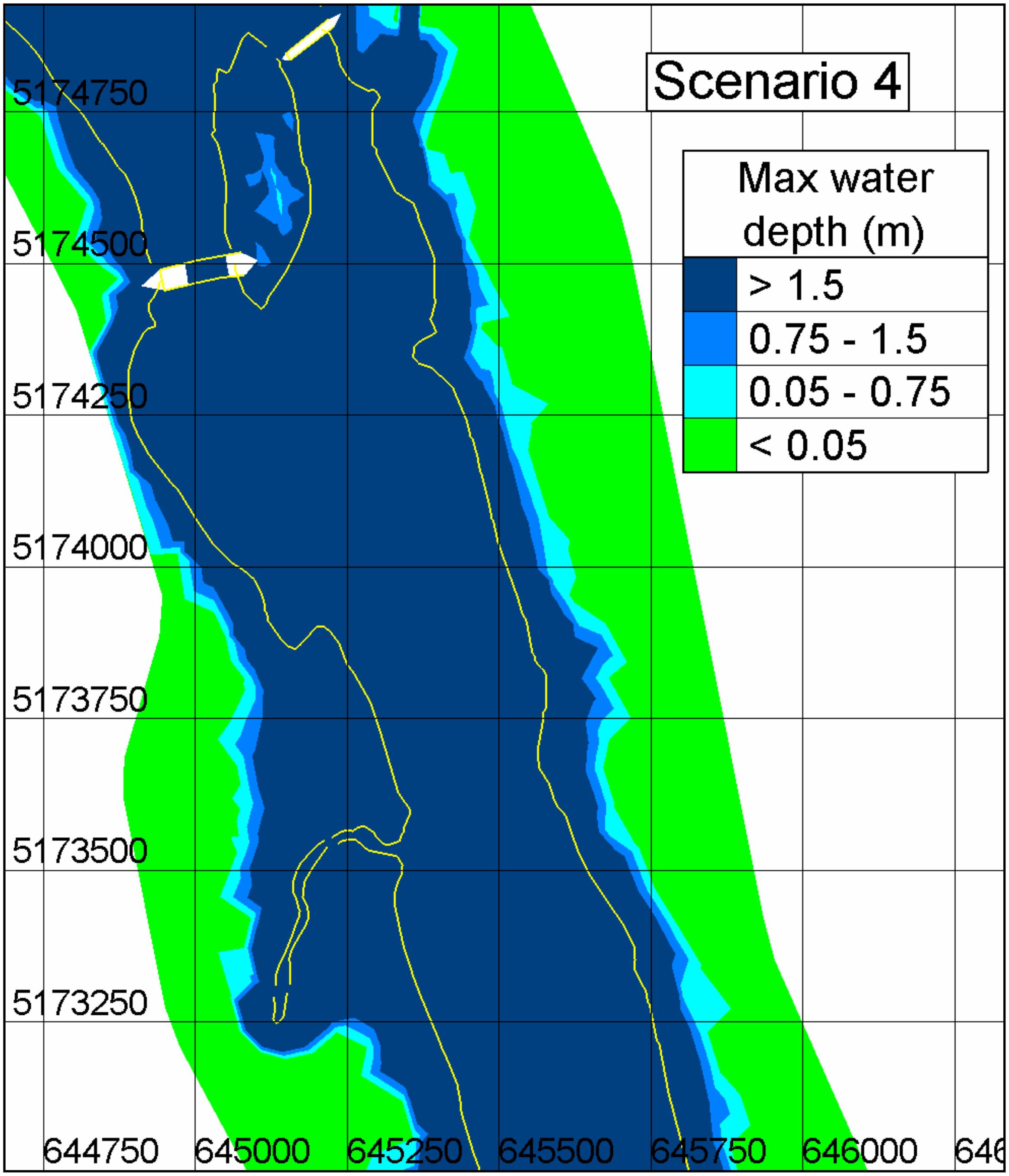

Figure 7.14 - Scenario 4- inundation downstream of island

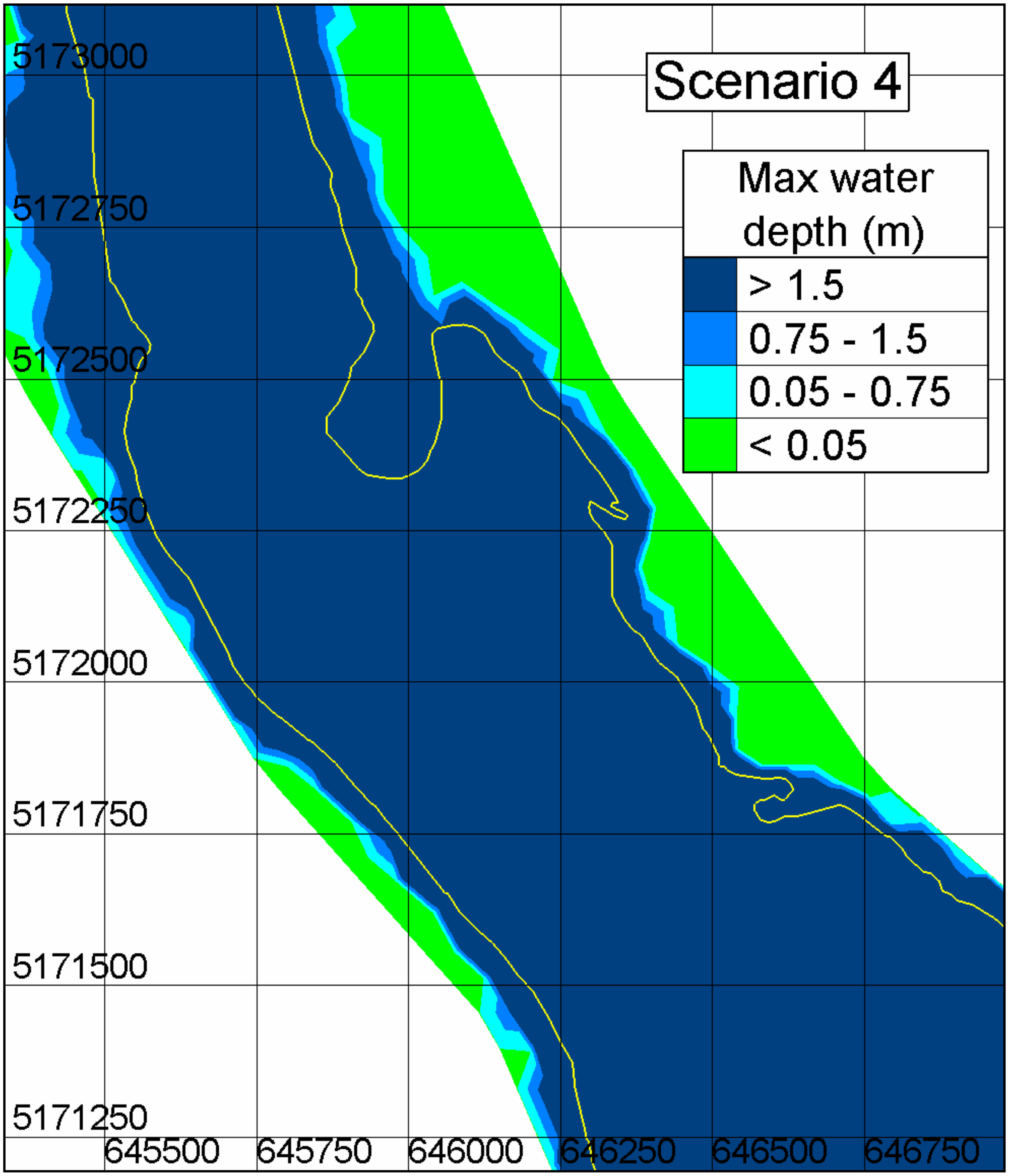

Figure 7.15 - Scenario 4- inundation 2 km downstream of island

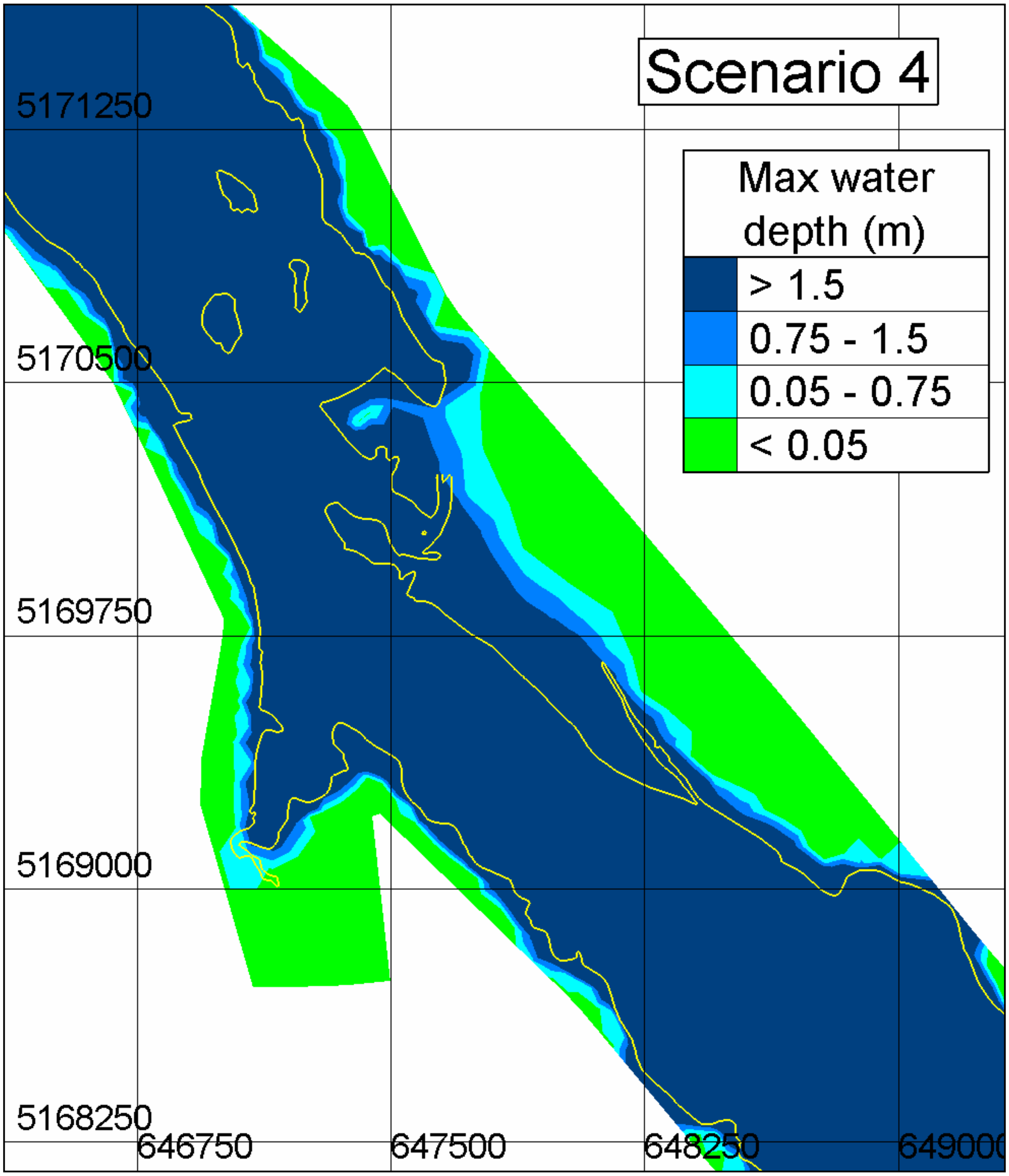

Figure 7.16 - Scenario 4- inundation 5 km downstream of island

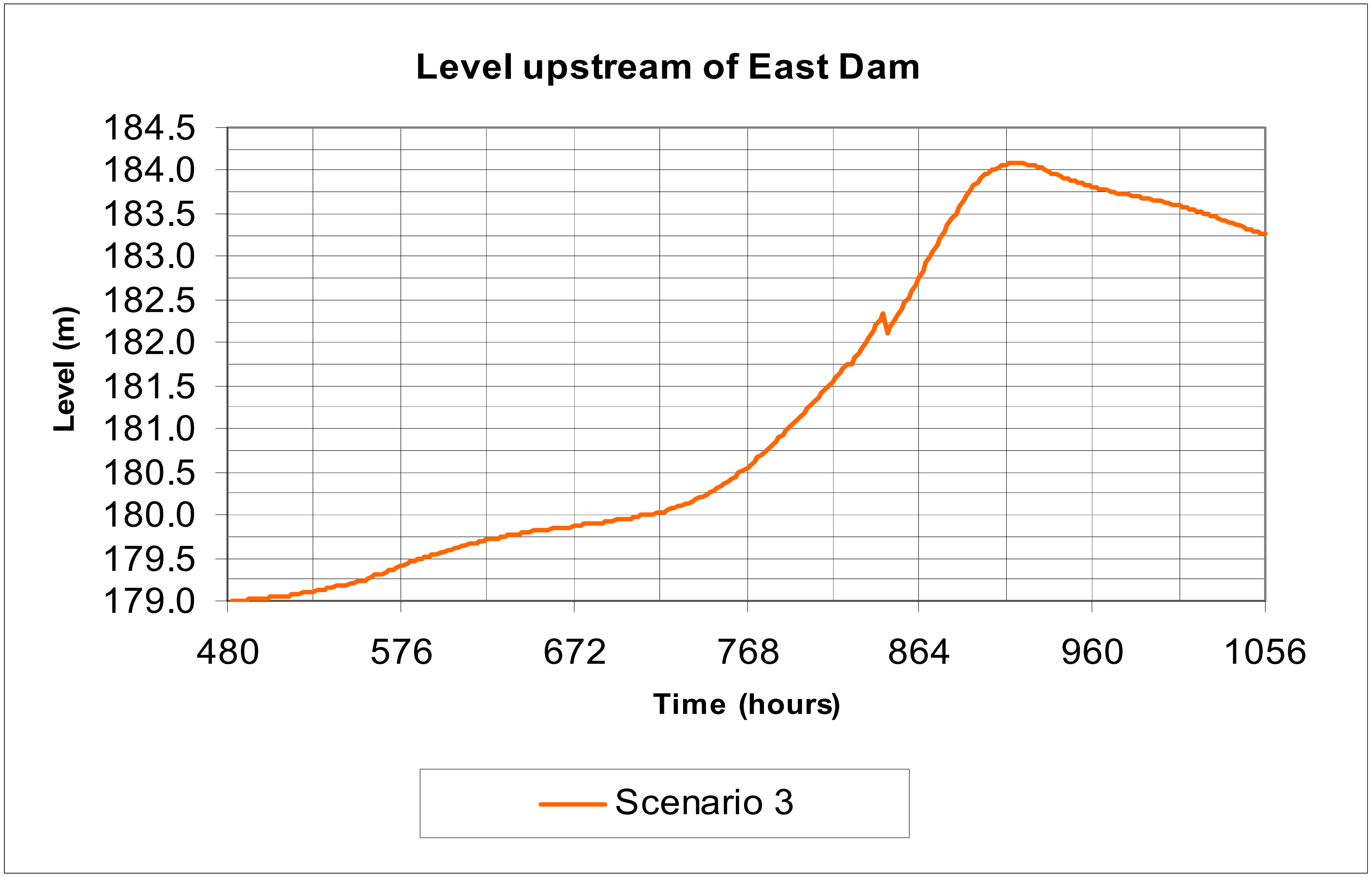

Figure 8.1 - Typical limnigram upstream of the dam from day 20 till day 44

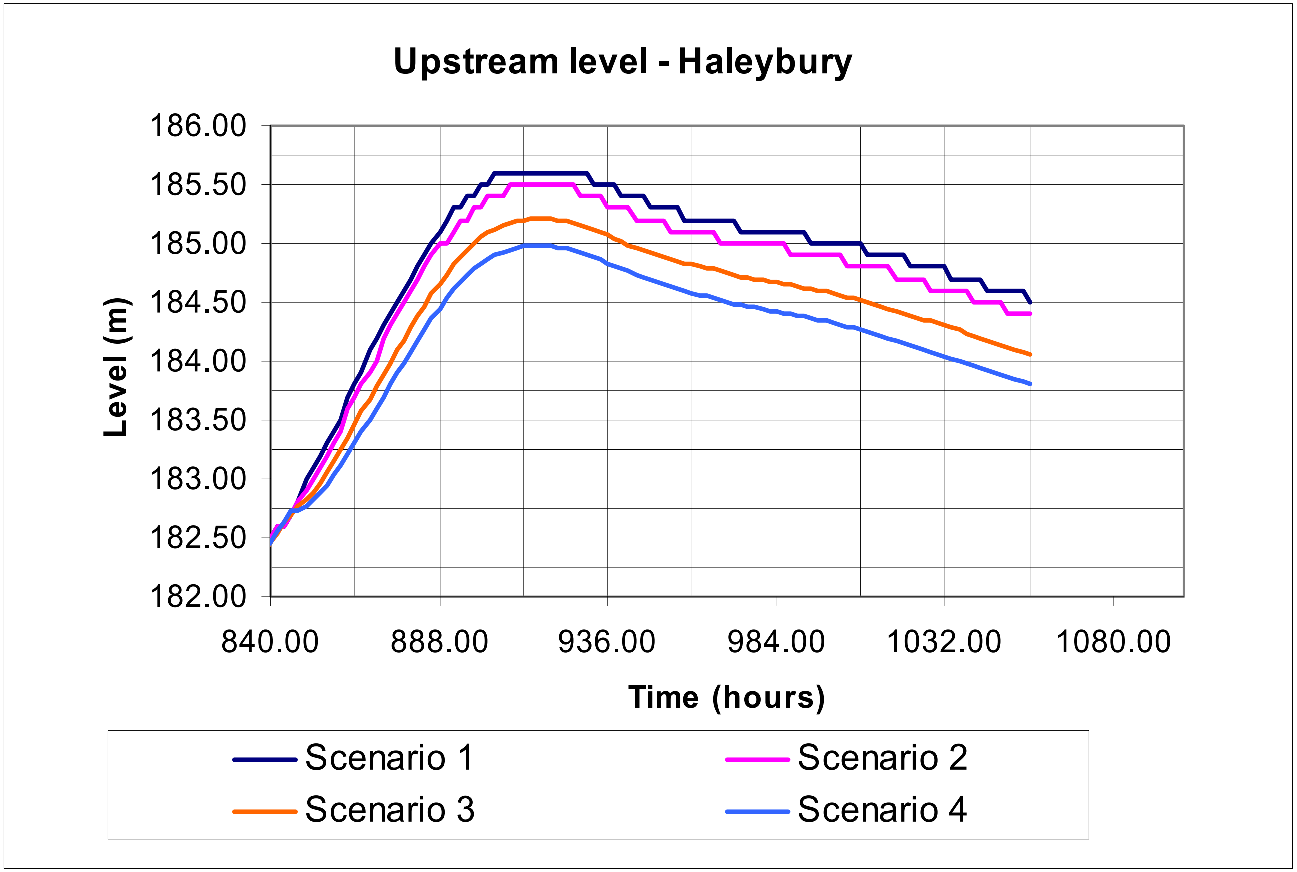

Figure 8.2 - Water levels at the upstream boundary

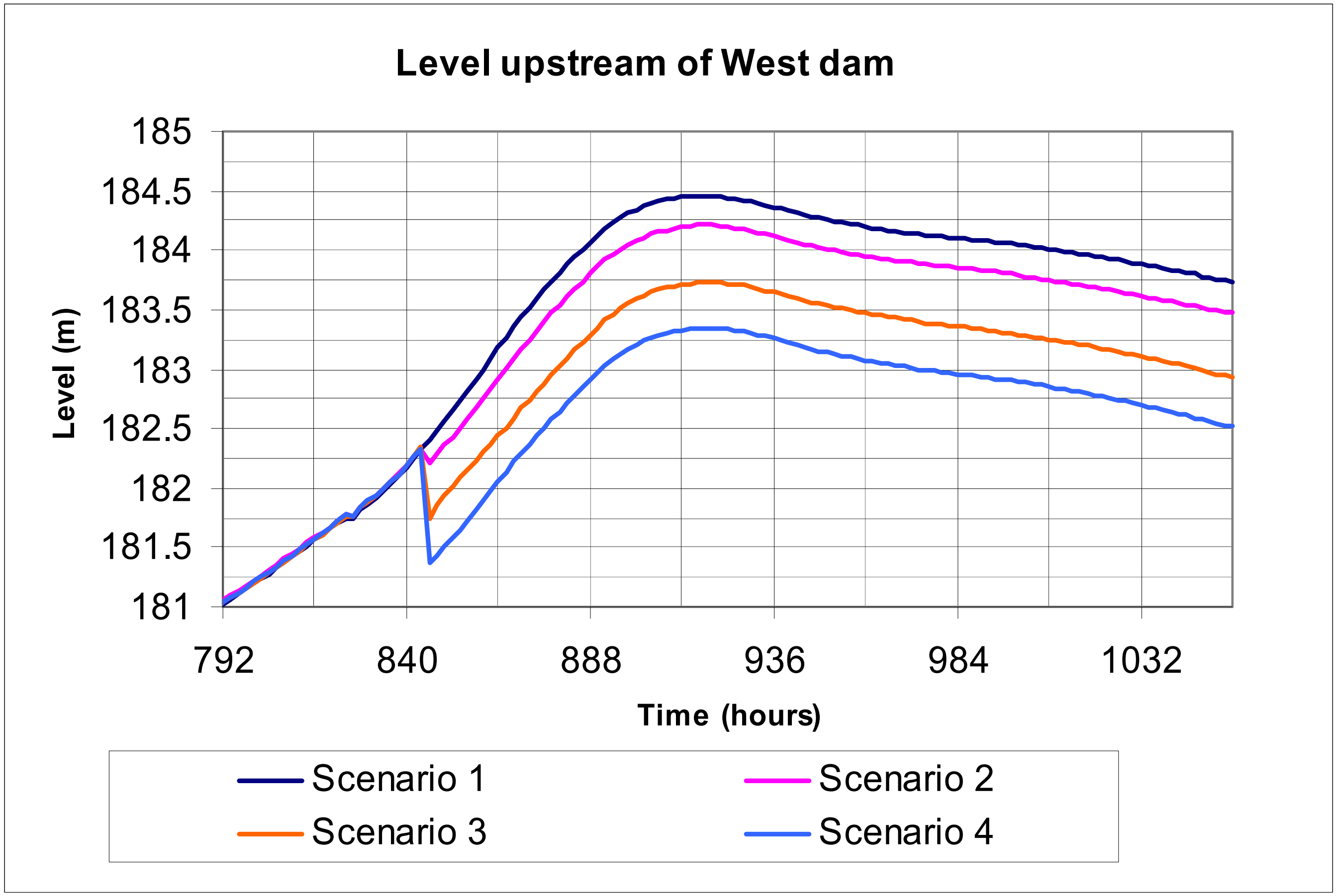

Figure 8.3 - Water levels upstream of the Témiscamingue dam

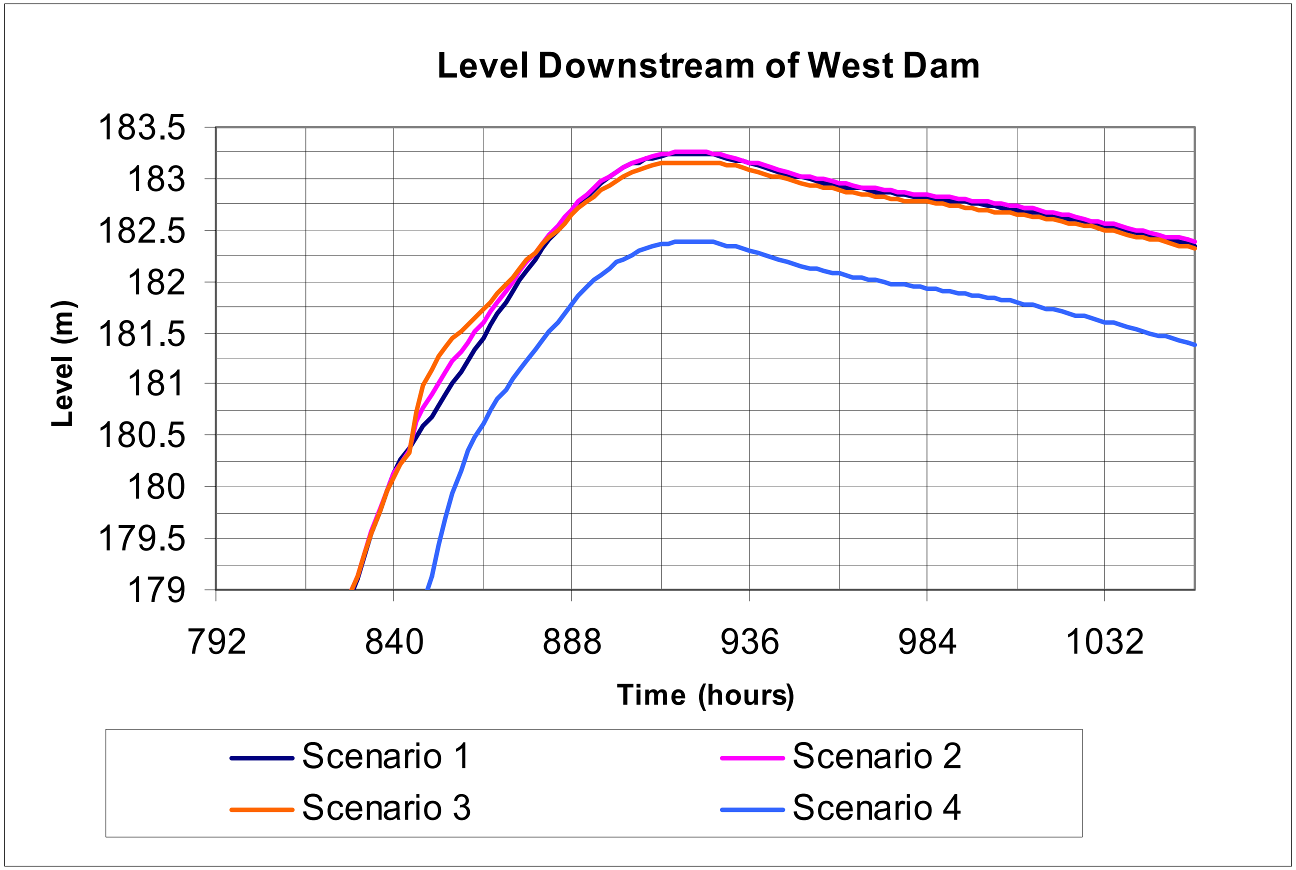

Figure 8.4 - Water levels downstream of the Témiscamingue dam

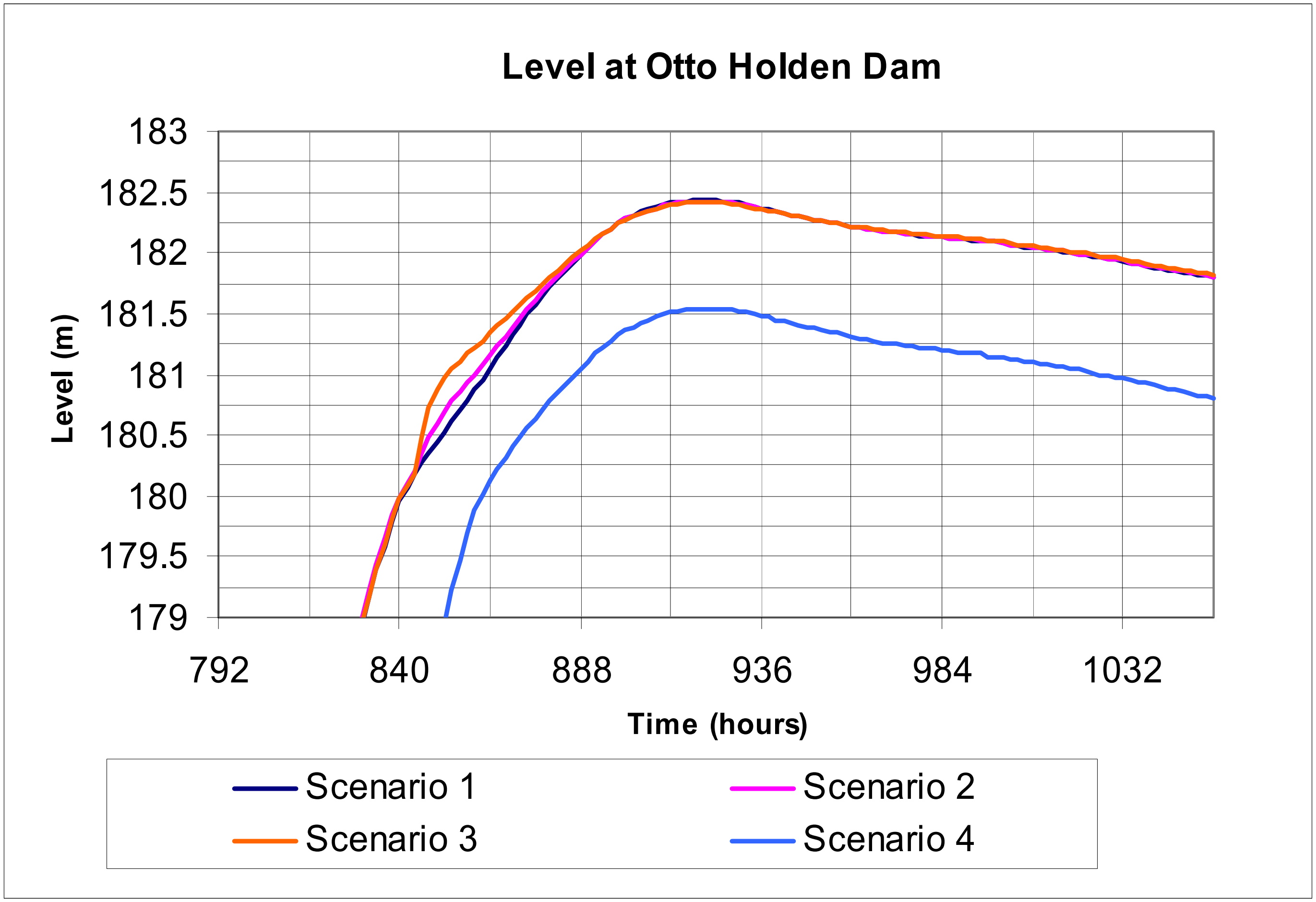

Figure 8.5 - Water levels at the Otto Holden downstream boundary

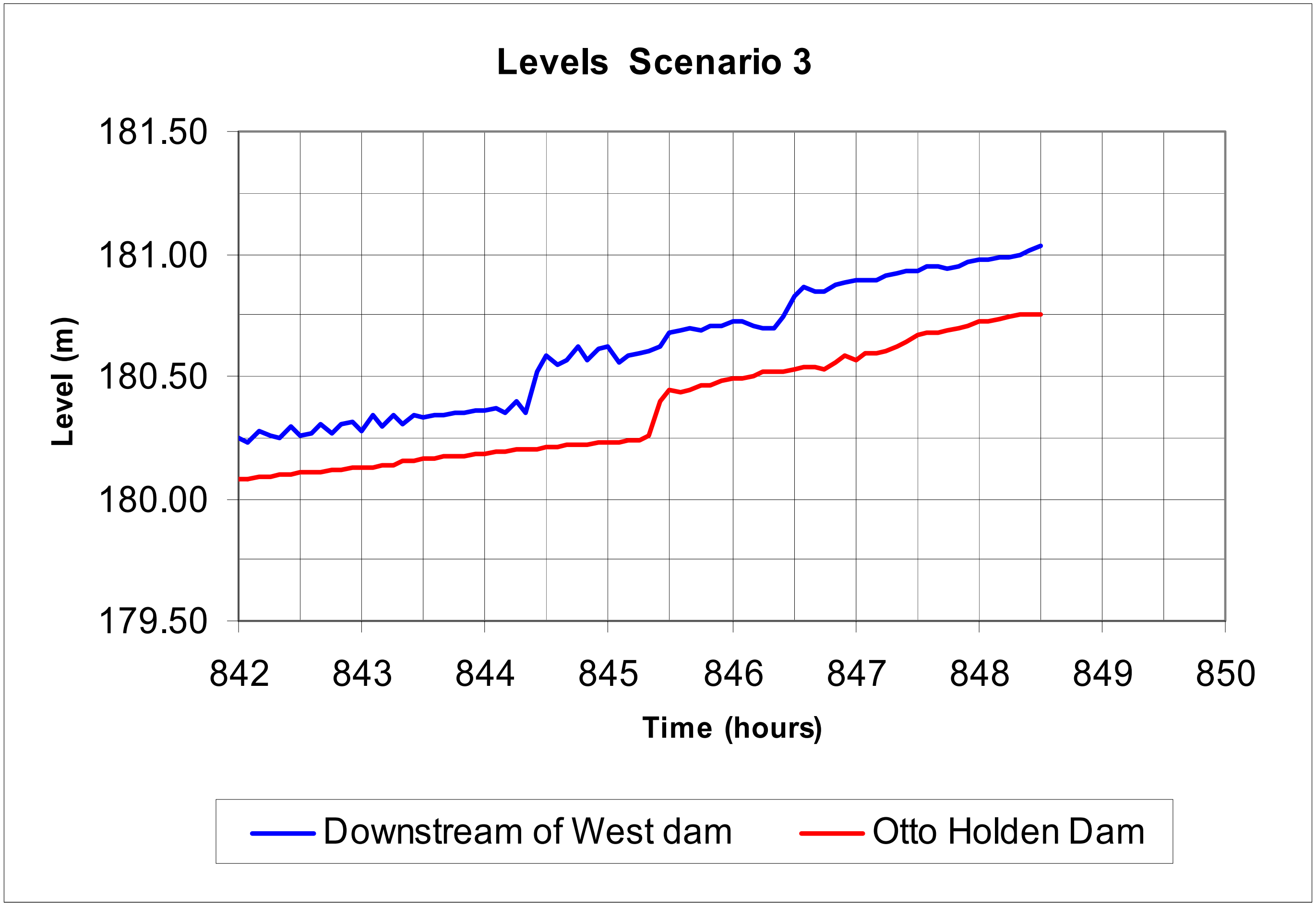

Figure 8.6 - Detail water levels after the dam failure

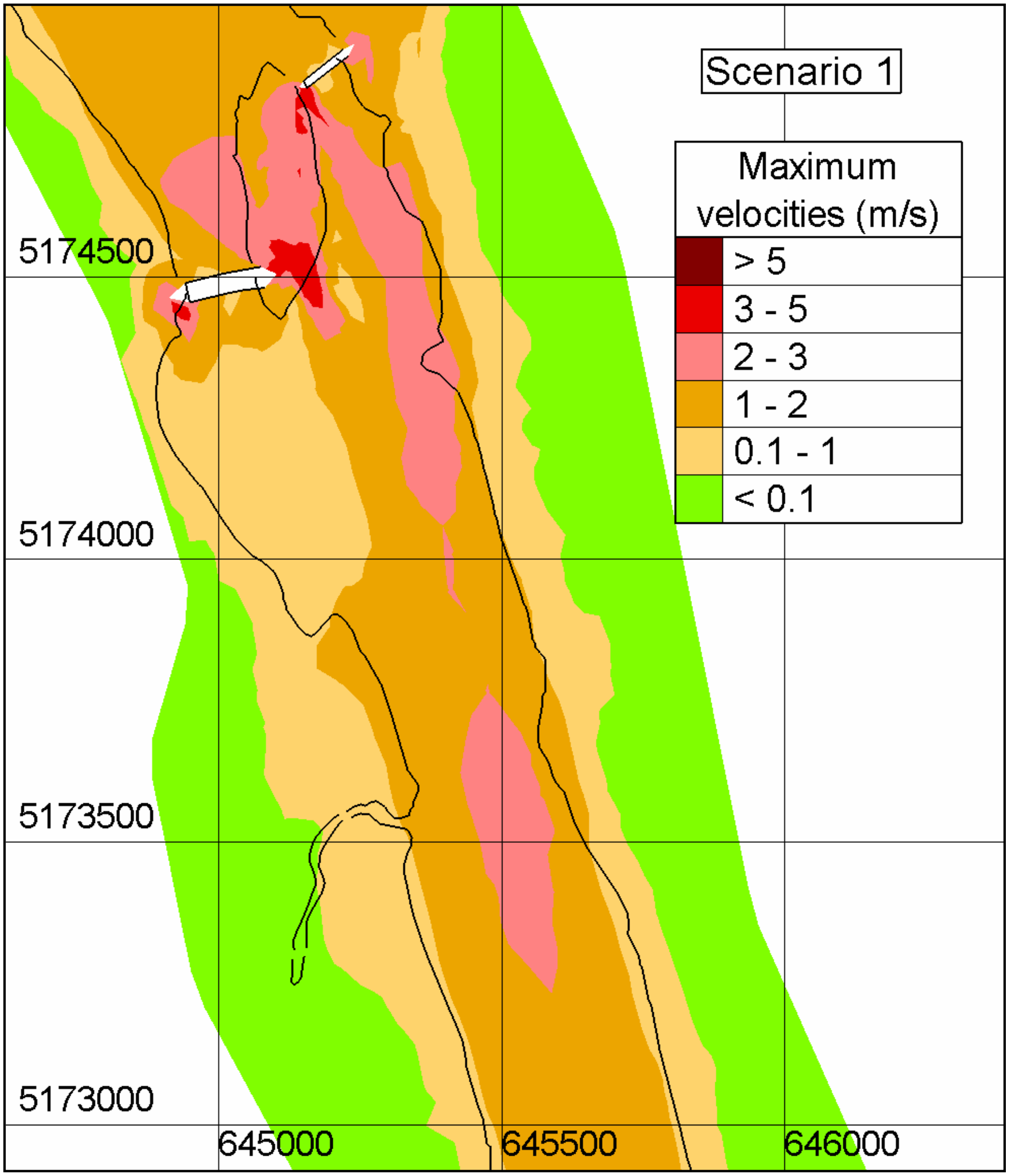

Figure 9.1 - Maximum velocities downstream of the dams - Scenario 1

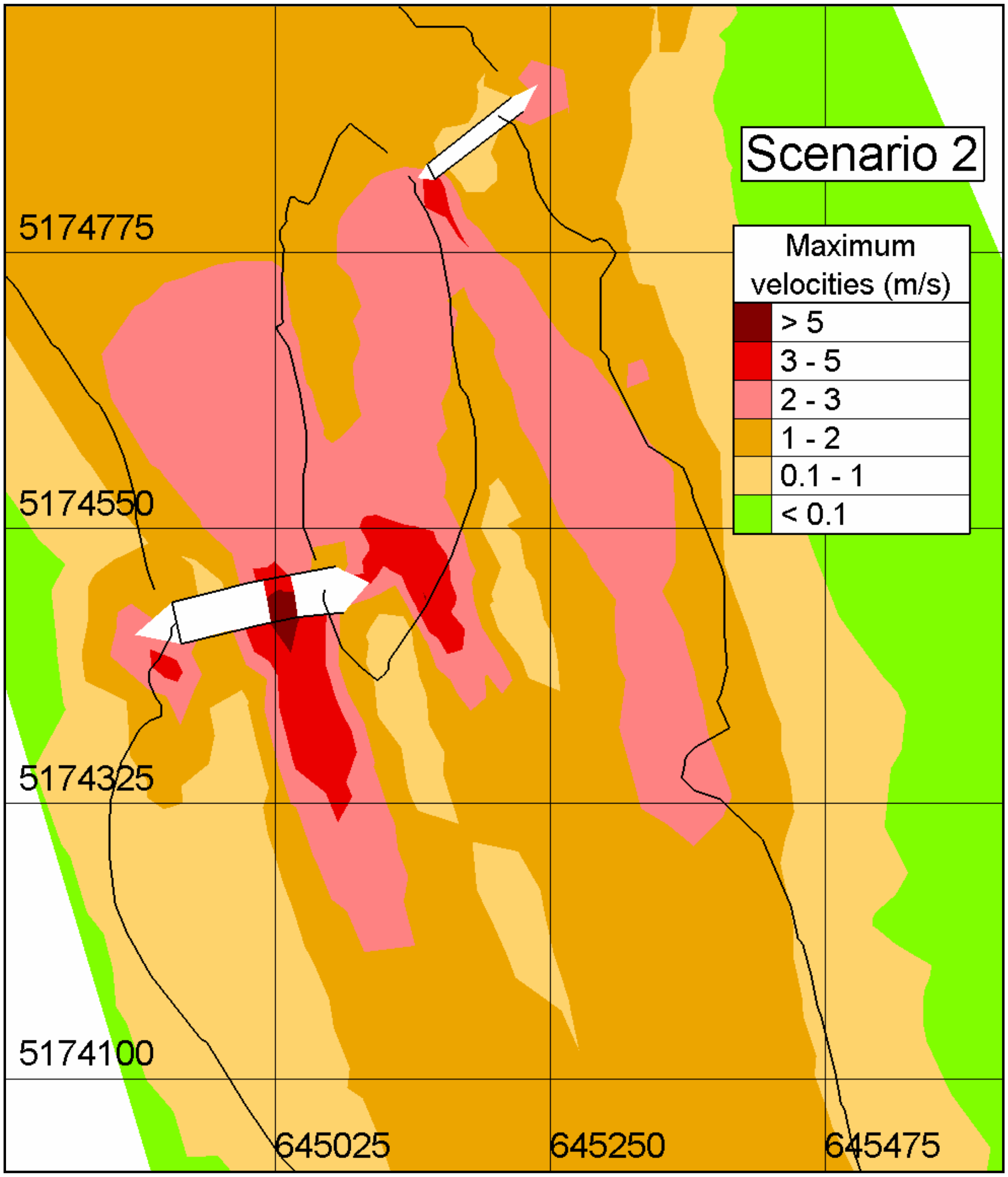

Figure 9.2- Maximum velocities downstream of the dams - Scenario 2

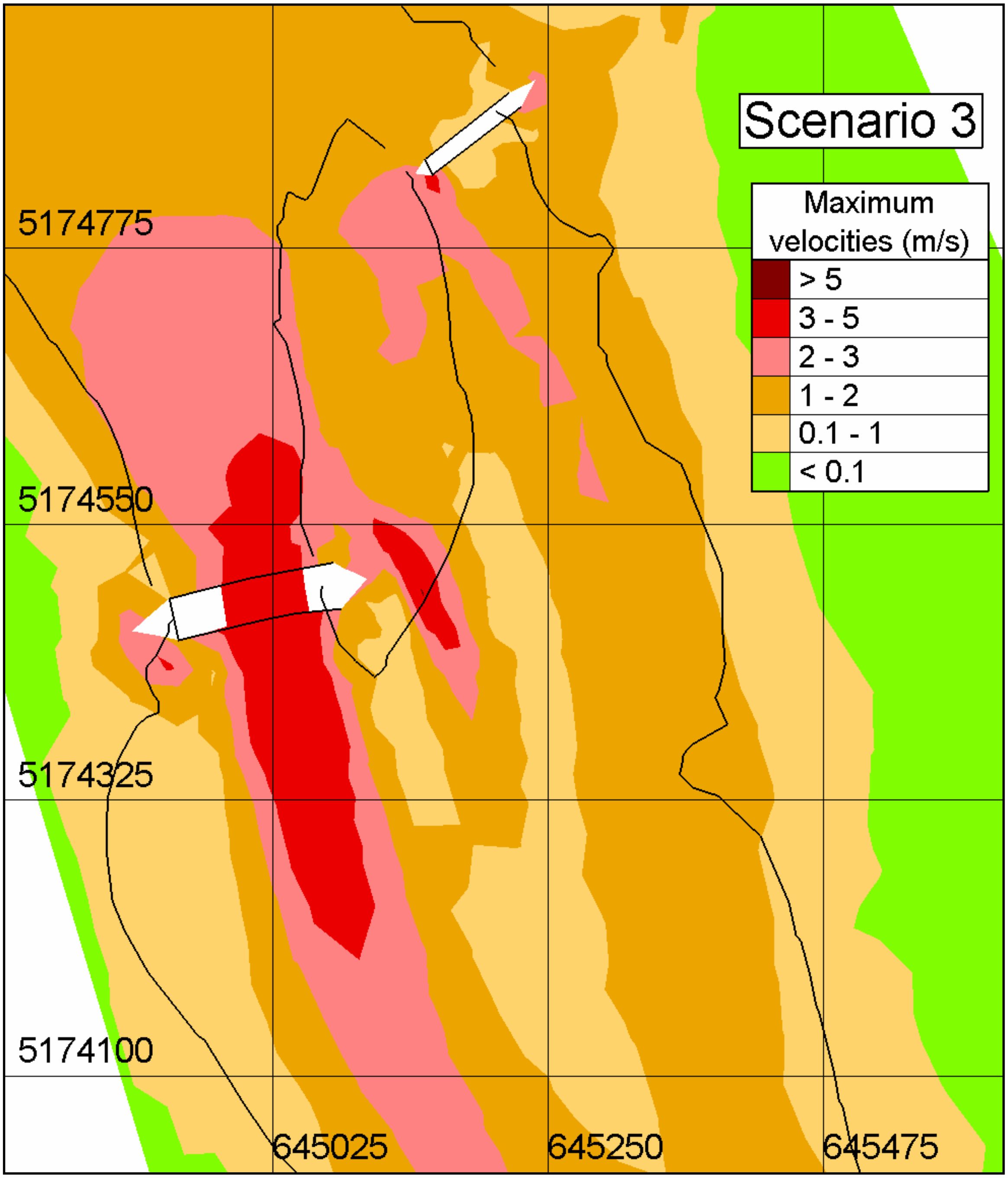

Figure 9.3 - Maximum velocities downstream of the dams - Scenario 3

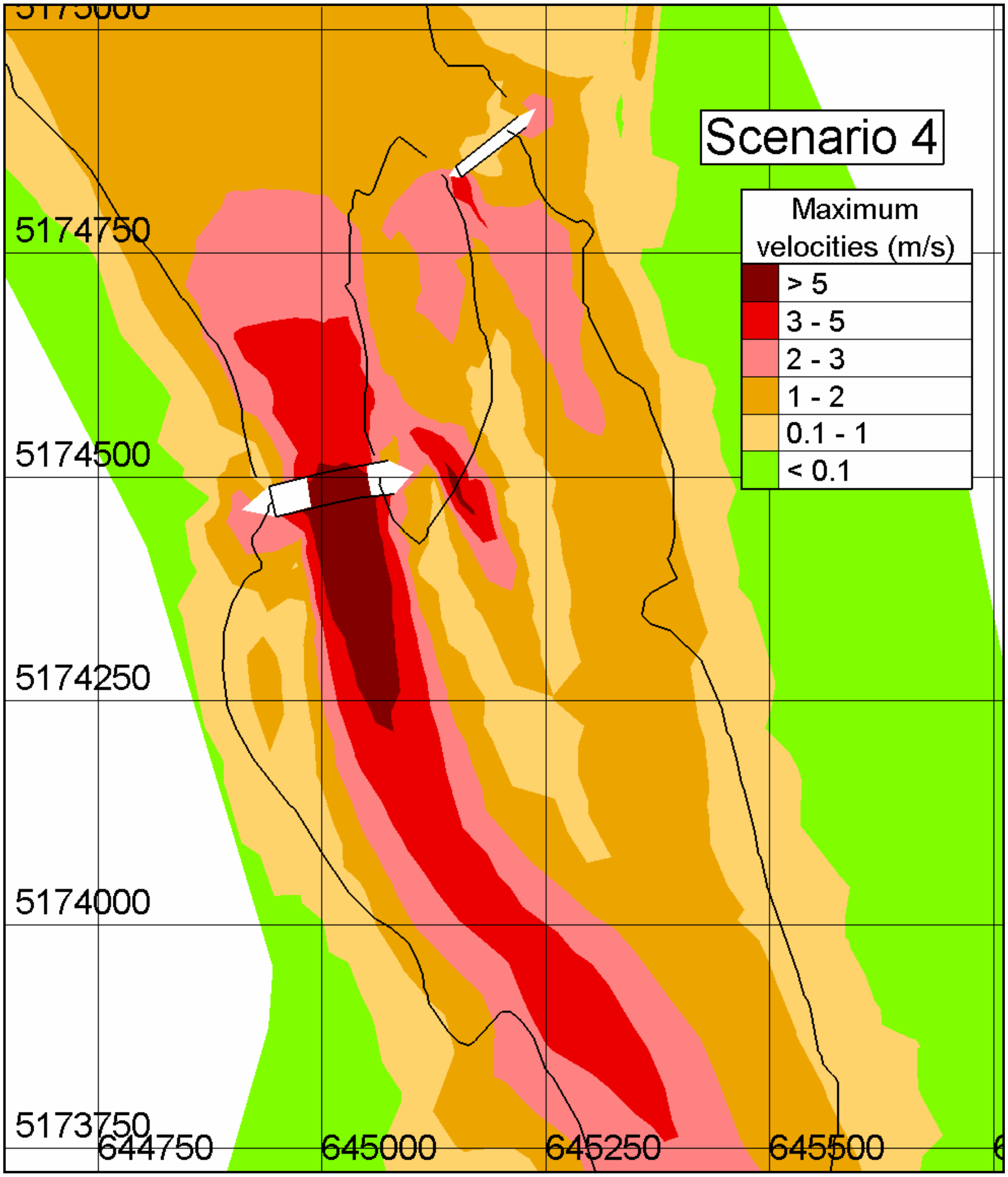

Figure 9.4 - Maximum velocities downstream of the dams - Scenario 4