University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Maintenance Dredging Sarsfield Lough & Arthurs Quay, Limerick

Dredge Modelling Study

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1. IW TECHNICAL STANDARDS TEMPLATE REVISION 1.0 TEMPLATE NO IW-HSQE-TEM-TEC-05 EFFECTIVE DATE:3/6/2017 ..... **4**

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1 INTRODUCTION

This report outlines the modelling work that was undertaken to examine the impacts of the proposed dredging of the Sarsfield Lough and Arthurs Quay Area in Limerick city docks by Waterways Ireland. The proposed dredging also includes the lock gated area below Honans Quay as shown in figure 1. This modelling activity was commissioned by MWP who are lead consultants on the project.

The modelling approach was to simulate the largest dredging event to take place in one period to assess the impact of the dredging on the downstream benthic environment. The model includes both river flow and tidal forcings to simulate the hydrodynamics responsible for sediment transport in the River Shannon. It should be noted that the model is set up to simulate the transport of finer sediment particles of Clay and silt which represent the greatest threat to smothering of benthic habitat. This however is not expected to have a significant impact on the global sediment transport patterns.

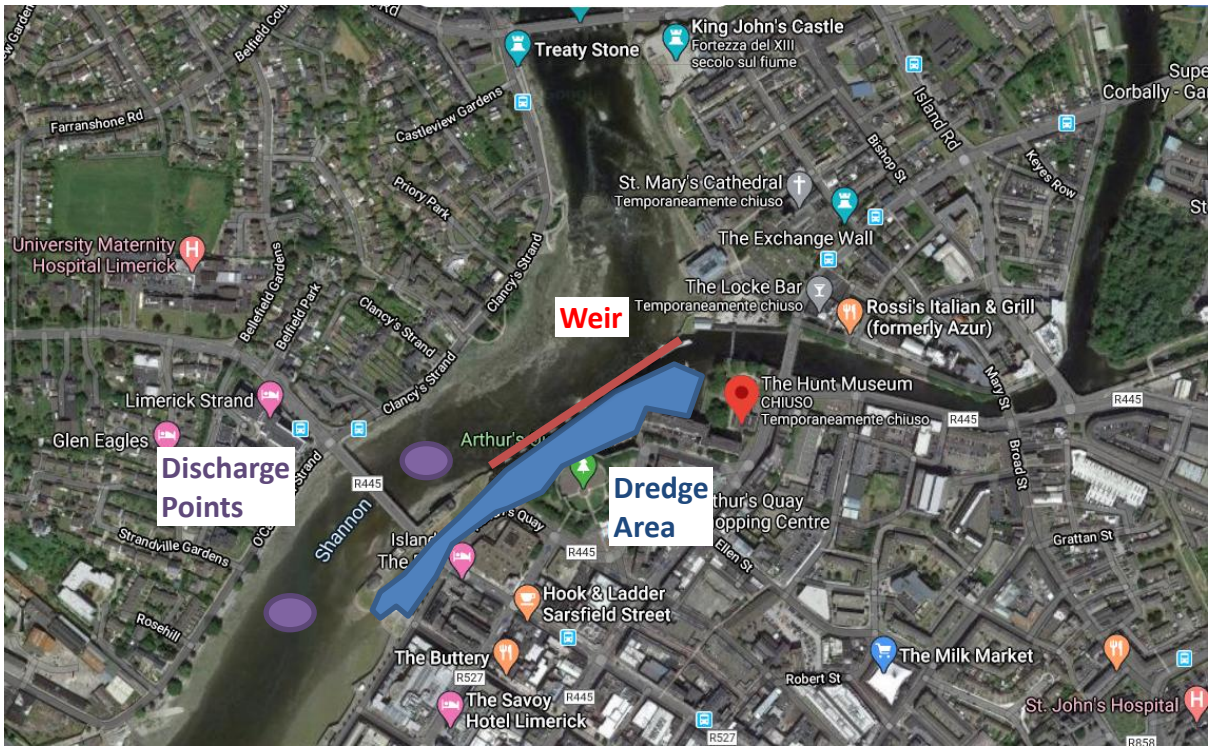

Figure 1 Study Location and Proposed Dredge and Discharge Areas

The proposed dredging is to be undertaken by a DOP pump on a barge. The barge will be moored in the dredge area while the DOP pump will discharge the dredge material into the main channel flow below the weir.

2 RELEVANT SOFTWARE

In this study the MIKE21 suite of software were used, these related to River flow, tidal currents and sediment transport. A brief description of the capability of the software is provided below.

MIKE21 FM HD (Flow Model Hydrodynamic) is used to model River and tidal currents and solves the vertically integrated equations for the conservation of energy, continuity and momentum, i.e. the Saint Venant equations on rectangular, flexible or curvilinear grids covering the area of interest, when provided with the bathymetry, bed resistance coefficients, wind field, hydrographic boundary conditions, etc. The HD (Hydrodynamic) module provides the basis for computations performed in many other modules, but can also be used alone. It simulates the water level variations and flows in response to a variety of forcing functions on flood plains, in lakes, estuaries and coastal areas. Once the model has been validated sediment transport characteristics in the model domain can be examined. The effects of sources and sinks like precipitation and evaporation, river discharge, intakes and outlets from power stations, etc are included in the hydrodynamic equations. The impact of hydraulic structures (bridge piers or piles, weirs, etc) on the flow conditions can also be included. A valuable facility in MIKE 21 is its capability to compute the flow in an area that sometimes floods and dries out such as tidal flats. The US Federal Emergency Management Agency (FEMA) has officially approved MIKE 21 HD for use in national flood insurance program studies (NFIS) for applications in both coastal and riverine environments.

The Mud Transport Module (MIKE21 MT) The intertidal area fronting the embankment comprises mud (silt/clay) . The MT module includes a state of the art mud transport model that simulates the erosion, transport, settling and deposition of cohesive sediment in marine, brackish and freshwater areas. The module also takes into account fine-grained non cohesive material. The model is coupled with the Hydrodynamic solver HD to obtain forcing, the influence of waves on the erosion/ depositions patterns can also be simulated. The model includes a dynamic feedback between update of seabed, and flow. The model calculates the rates of sedimentation/erosion and is mainly used to determine the impact of engineering works on a coastal system.

3 MODEL SETUP

3.1 Model Domain

The model domain as used for the simulation is shown in Figure 2. The domain covers the entire Shannon Estuary from Western coastline of Kilbaha in Co. Clare, eastwards as far as north of Kings Island in Limerick. The domain is converted to a mesh with variable density. It increases in density from the western boundary towards the area of interest in Limerick City. At the Dredge location and discharge area high density mesh aligned with the river channel was used to better represent the behaviour at this location.

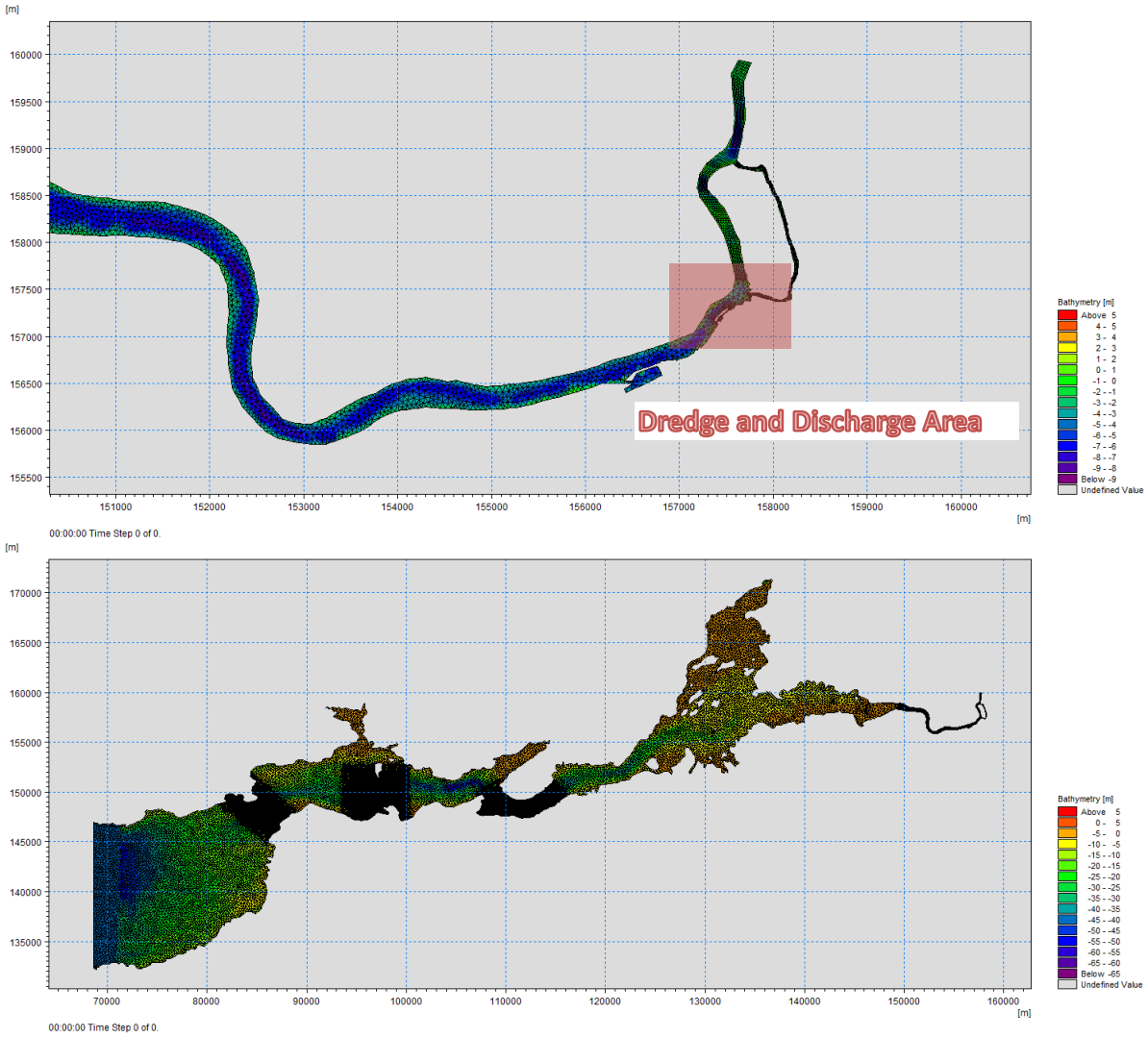

Figure 2 Model Domain

The bathymetric data for the model has been extracted from a range of sources including Infomar data for the outer Estuary and digitised admiralty charts along the Shannon. The bed levels for the approaches to Limerick City was generated from bathymetry supplied by the Limerick Port Company. Waterways Ireland supplied high resolution bathymetry for the dredge area, however, an area which had a paucity of information was the River Shannon from the Thomand weir to the lowest bridge crossing. Limerick City CFRAMs cross sections supplied by the OPW were interpolated to create a bed surface for this area..

3.2 Dredging Areas

The area to be dredged are shown in Figure 3 and comprise 6 separate sections. The breakdown in terms of mass and material type is given in Table 1, provided by MWP. It is intended that only the fine material will be subject to dredging via the DOP pump.

To account for mobilisation, daylight working times, 5 day week and dredging only on an ebbing tide the model simulates a periodic discharge as per Figure 4. This discharge modelled, (orange line) includes 3 types of sediment, Sand Silt and Clay, based on the respective percentage quantities in each dredge section. The model is run with the following conditions:

- 2 week of spring tide
- 4 x 8 hours discharge windows for area 1,2,3,4
- 4 x 8 hours discharge windows for area 5,6
- 1 working day for mobilising equipment to the next area.
- Discharge into the flow starts 30 minutes after peak high tide
- Highly diluted discharged flow – pumped flow density decrease with increase of discharge window.

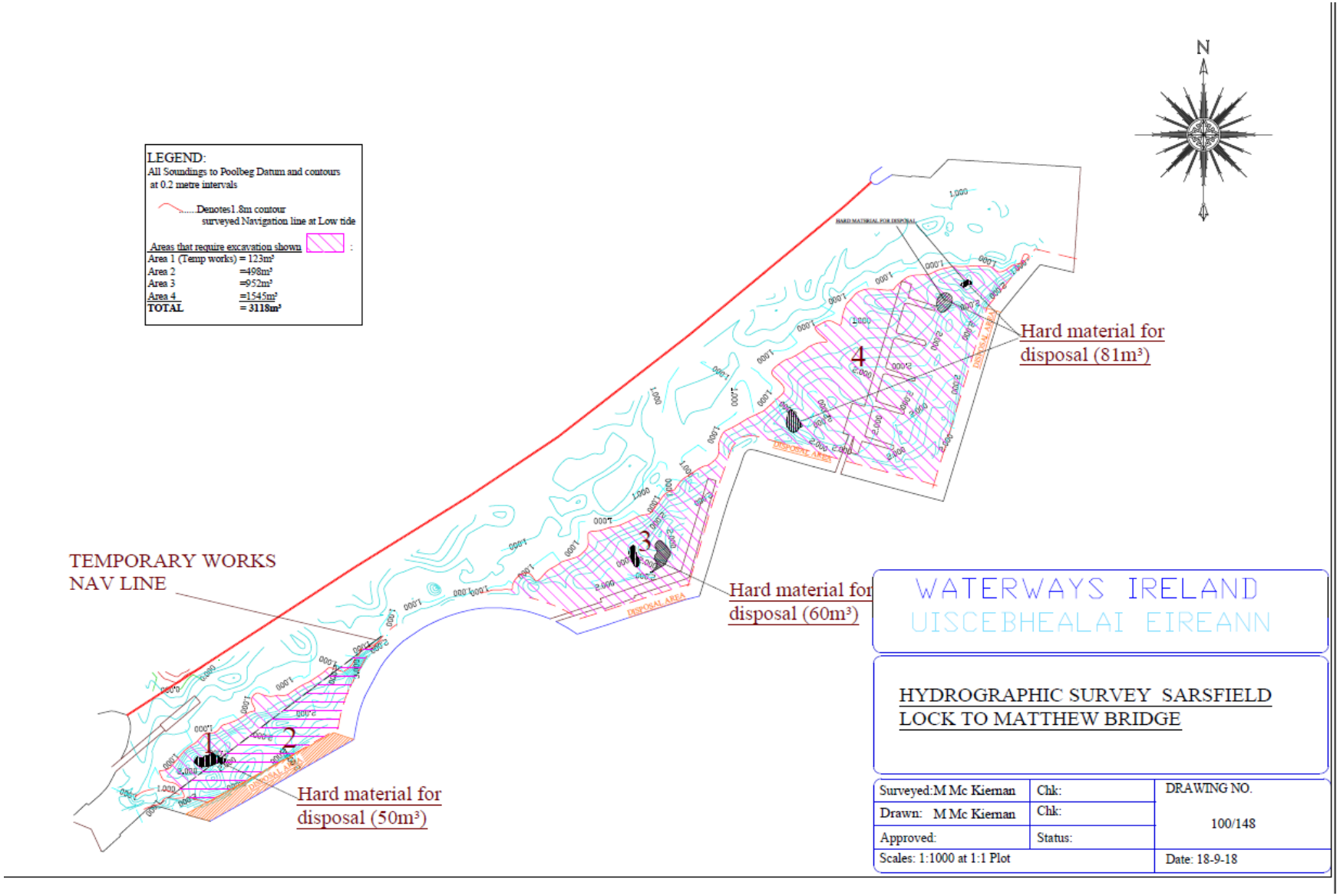

Figure 3 a) Area To be Dredged

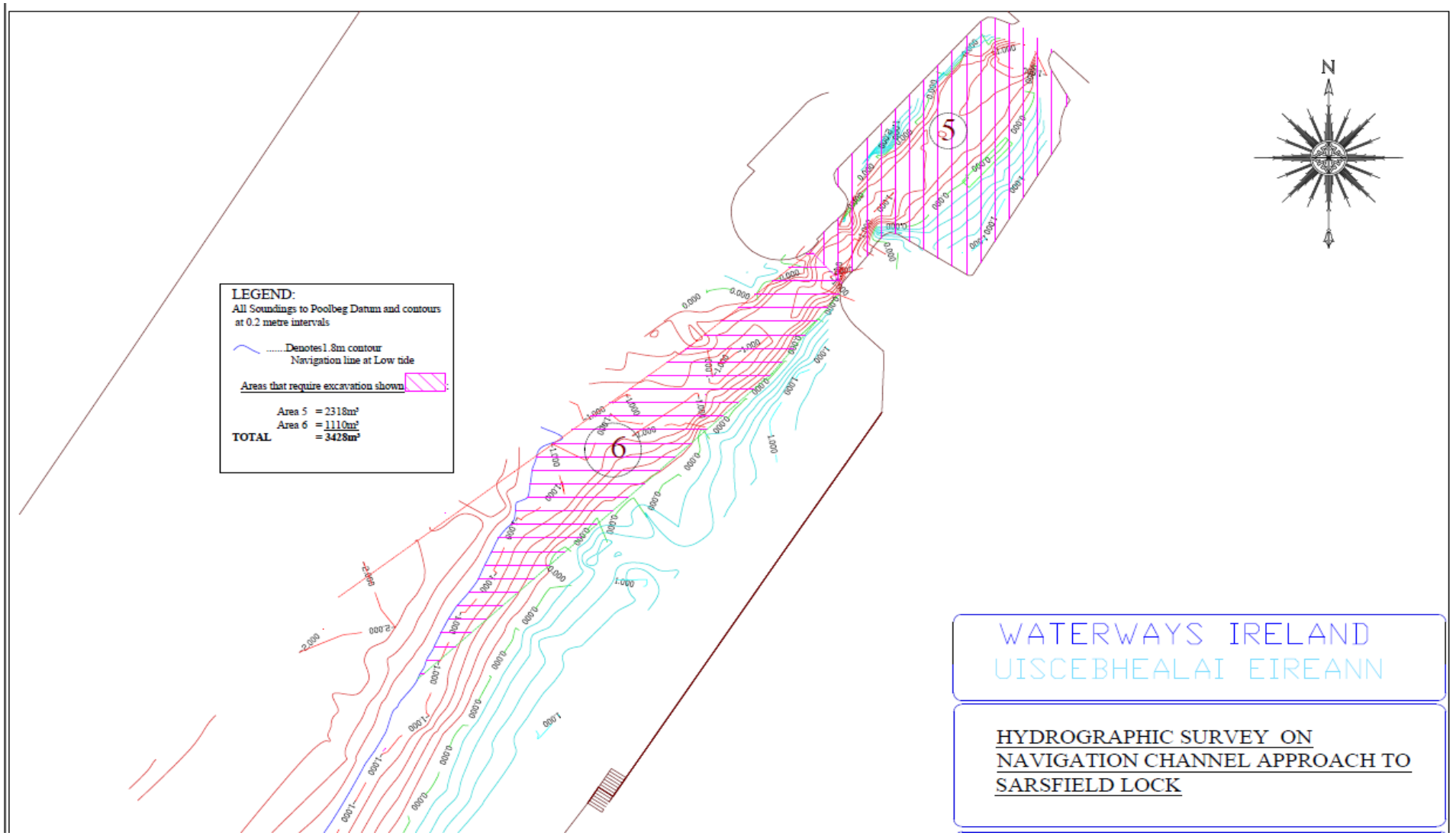

Figure 4 b) Area To be Dredged

Table 1 Dredge Sections and Quantities

Area	Gross (m^3)	Gross (t)	Less Coarse (m3)	Less Coarse (t)	Net (m^3)	Net (t)	Disposal Method
1	123	234	50	95	73	139	Fine material pumped into flow over weir
2	498	946	0	0	498	946	Fine material pumped into flow over weir
3	952	1809	60	114	892	1695	Fine material pumped into flow over weir
4	1545	2936	81	154	1464	2782	Fine material pumped into flow over weir
5	2318	4404	0	0	2318	4404	Fine material pumped into flow over weir
6	1110	2109	0	0	1110	2109	Fine material pumped into flow over weir
TOTAL	**8735**	**12437**	**191**	**363**	**6355**	**12075**	

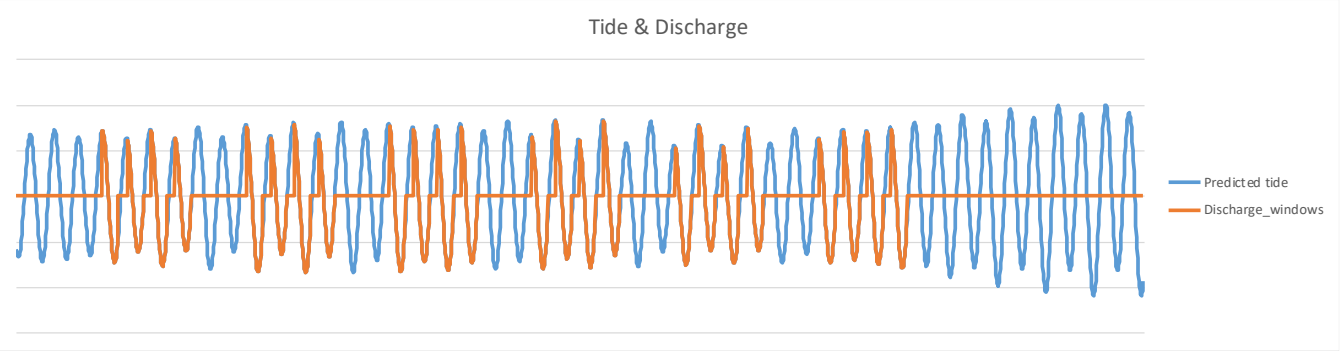

Figure 5 Discharge intervals

The discharge rate is based on a highly diluted flow comprising of both water and dredged material. The density of the discharged is modelled as a flow rate (m3/s) which varies both by material type (sand,silt and clay) and volume to be dredged in specific area and the discharge window, Figure 6.

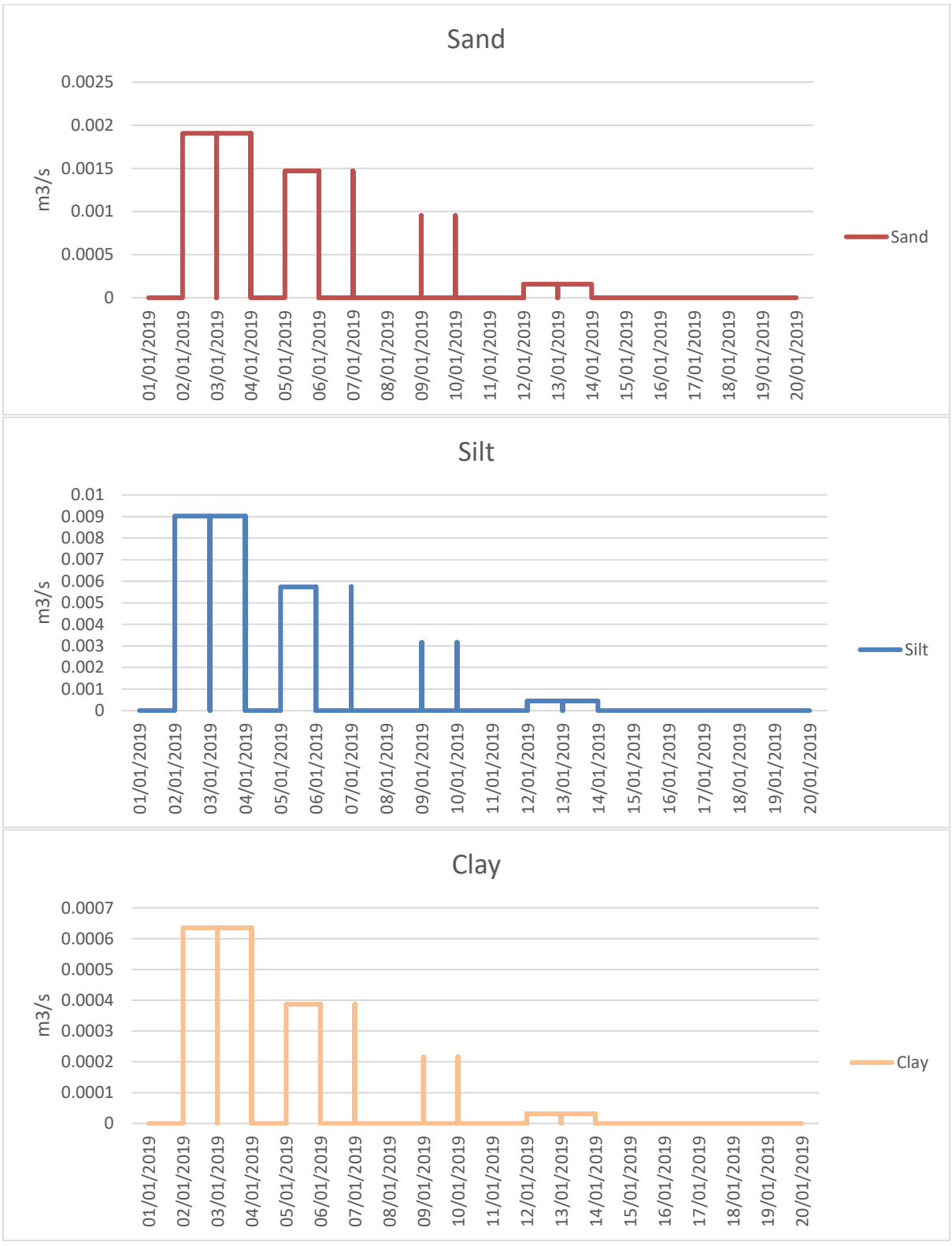

Figure 6 Discharge Rates for Sand, Silt and Clay

3.3 Model Input Conditions

To adequately assess the impact of the proposed dredging activity it is necessary to simulate the most representative hydrodynamic conditions while also being conservative in terms of presenting the worse case scenario impact. An analysis of the winter flows on the Shannon in the area of interest, Figure 5, (2009-2019) provides the following percentile flow:

- Shannon flow 25th %-ile : 176.6 m^3/s
- Shannon flow 50th %-ile : 301.9 m^3/s
- Shannon flow 75th %-ile : 408.4 m^3/s

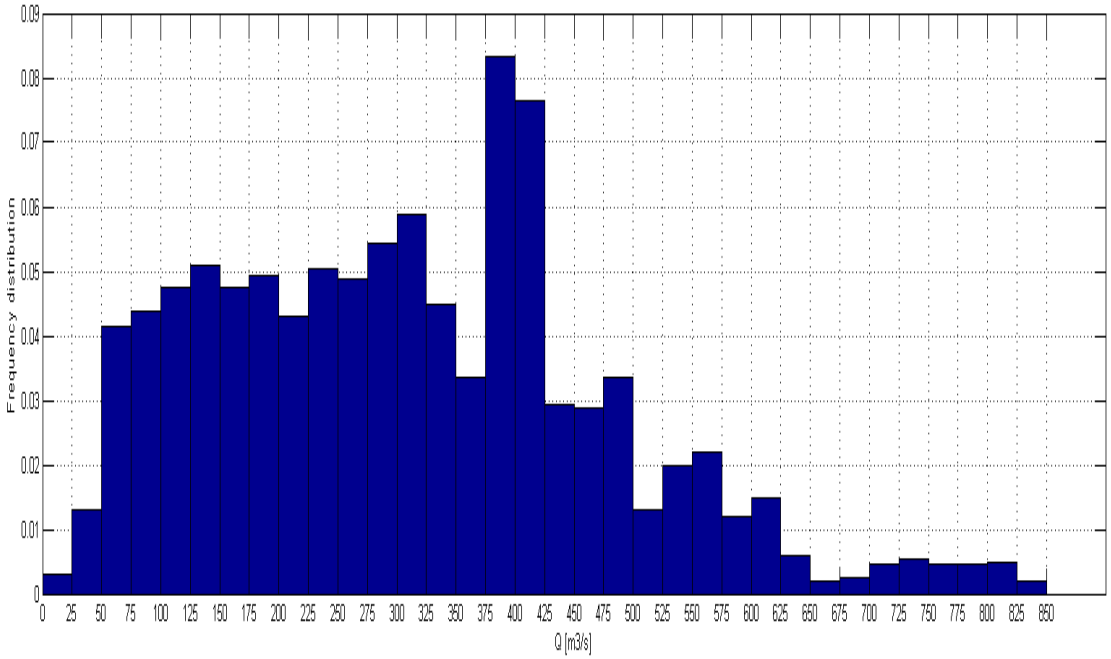

Figure 7 Winter Shannon Flows 2009 - 2019

The model utilises the 25th percentile flow of 176.6m3/s as an input condition.

3.4 Model Calibration

The combined MIKE21 FM HD and MT model was set up and several trial simulations were undertaken to ensure that the hydrodynamic behaviour within the study area as represented by the model was reasonable. During the model setup 5 locations were monitored for water level and velocity, figure 6. While the data was not referenced to a datum the information record was used to check the velocities in the model.

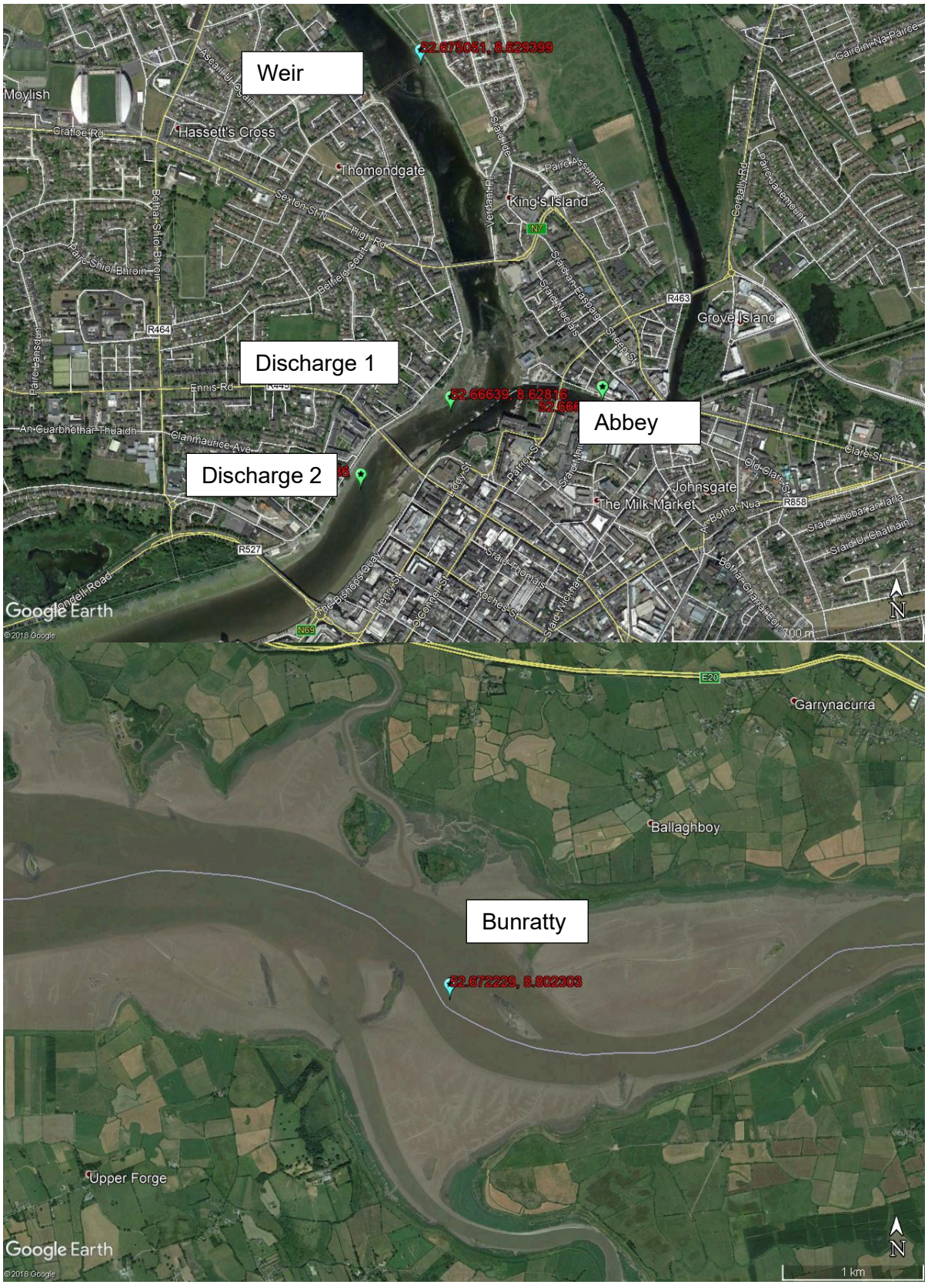

Figure 8 Location of Recording gauges

The model was calibrated for surface water level elevation against Hydrographic data collection undertaken by Aquafact Ltd in September 2019. The data collection included a location in the main Shannon channel at Bunratty and also in the discharge location at Limerick, figure 7 & 8. The

comparison of the simulated and recorded velocities at this location are shown in figure 9. It should be noted that the simulated elevations are within 10% of the recorded high and low tides. This is in line with validation guidelines of Irish Water (Ref 1).

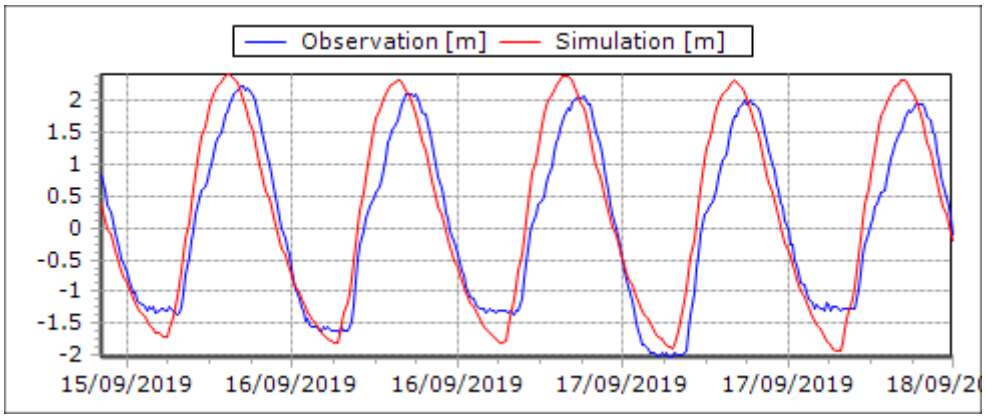

Figure 9 Waterlevel Calibration Bunratty

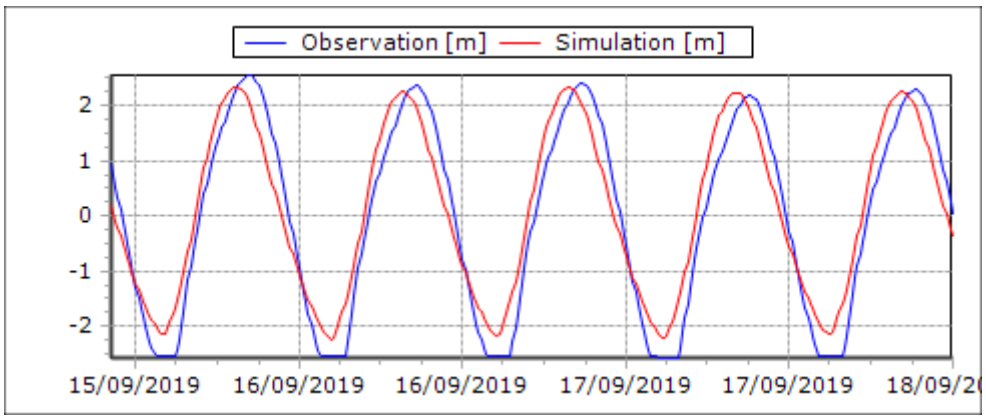

Figure 10 Waterlevel Calibration Limerick

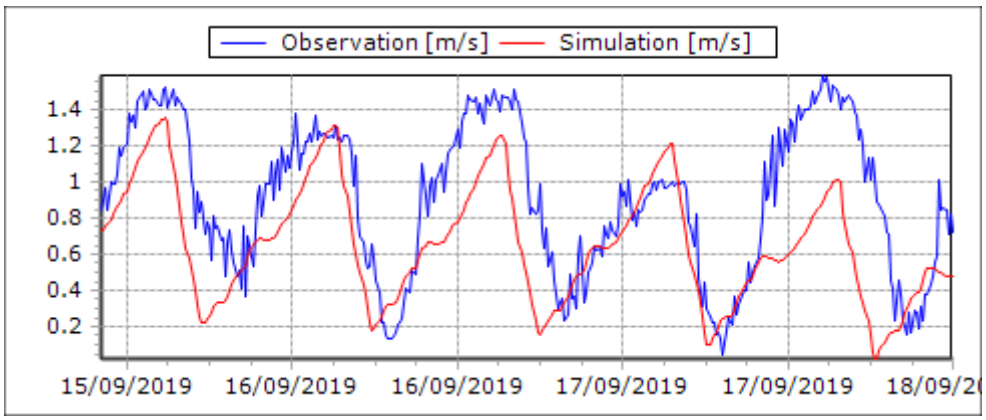

Figure 11 Velocity Calibration Limerick

4 SIMULATION RESULTS

The modelled peak velocities in the study area are shown in Figure 8. In the discharge (the zone in the main channel where dredged material will be pumped) area the peak velocities are in the region of 2m/s.

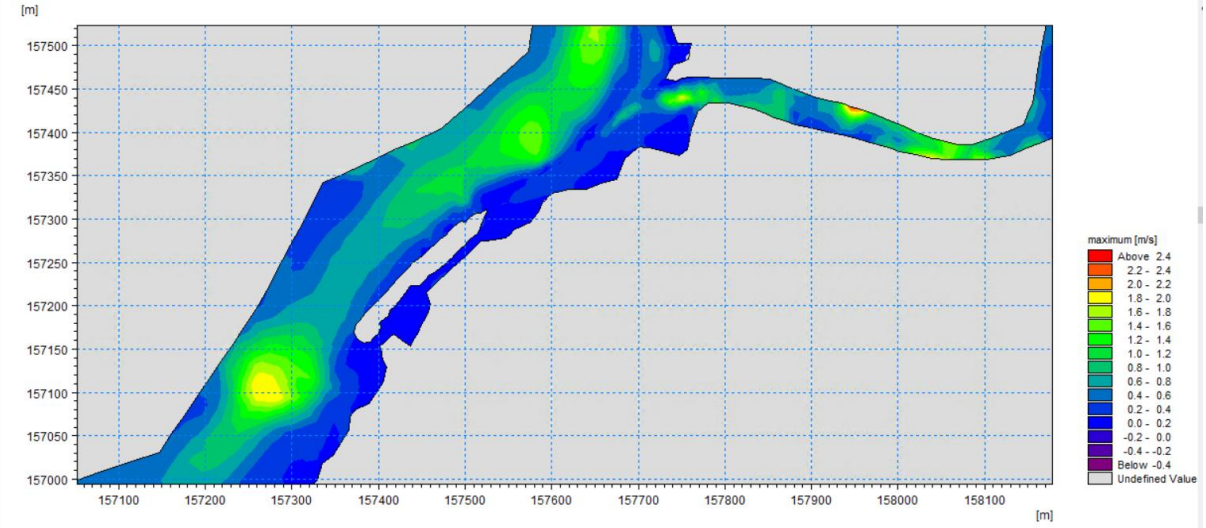

Figure 12 Peak Simulated Velocities Dredging and Discharge areas

The main simulation results are presented in terms of Net bed deposition in grams per m^2 of bed. This gives an overview of the changes in the bed due to the dredging material discharged upstream. The bed level at the end of the model run for the dredging campaign for Clay, Silt and Sand is presented in Figures 11-13.

It can be seen that there is no significant deposition on the bed level change for Clay, Figure 9. Any slight differences are localised variations in the bed layer development. The Silt component of the discharge travels in low concentrations as far as Bunratty at approximately 4kg/m2. Closer to the discharge location the Silt settles in two distinct areas at a density of 17kg/m2. The sand fraction displays a similar deposition pattern as the silt and in similar quantities. However it doesn't travel down stream as far as the silts. The maximum deposition is in the region of 18kg/m2 of bed.

These results have also been interpolated to represent Bed level thickness in mm. However it should be noted that while representative, several significant assumptions have been made to compile the bed thickness plots including bulk density and settling characteristics which are not directly modelled, Figures 14-17. Thicknesses of less than 1mm for Clay, 20mm for Silt and 60mm for sand are recorded. There is an accumulation of sand over 150mm at the discharge location, however in operation this would be dispersed due to action of pipe and river velocity.

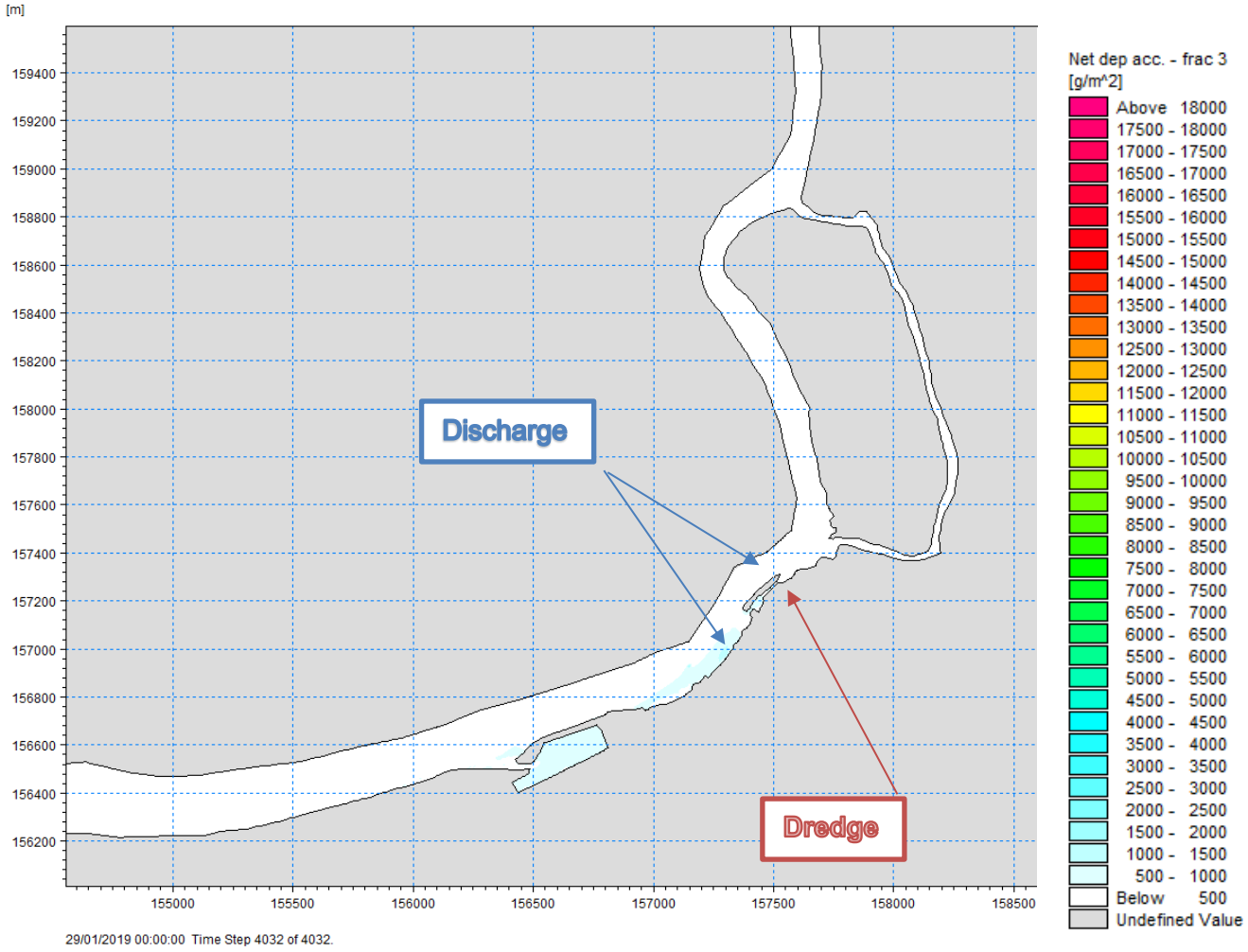

Figure 13 Clay Net Deposition

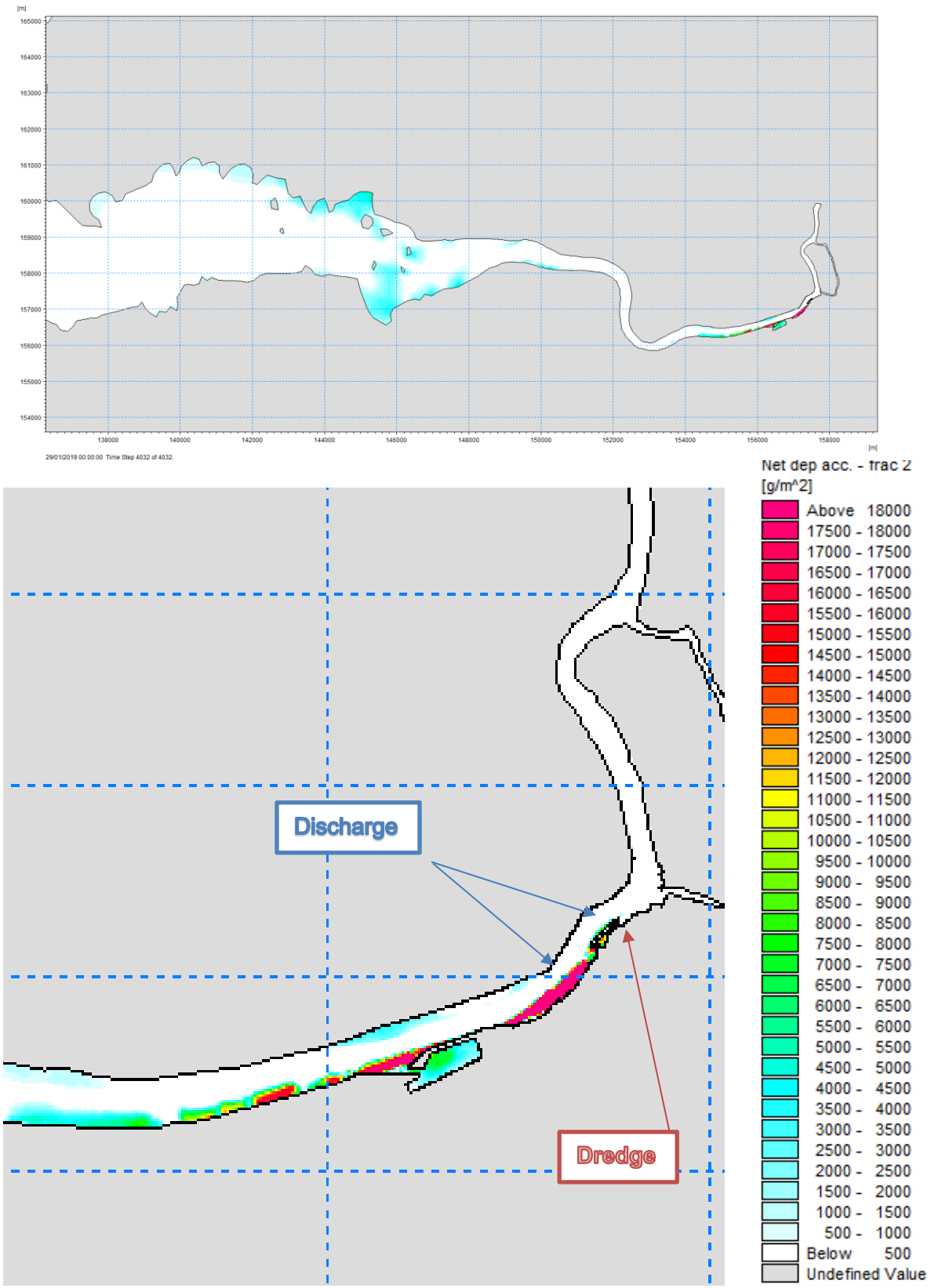

Figure 14 Silt net deposition

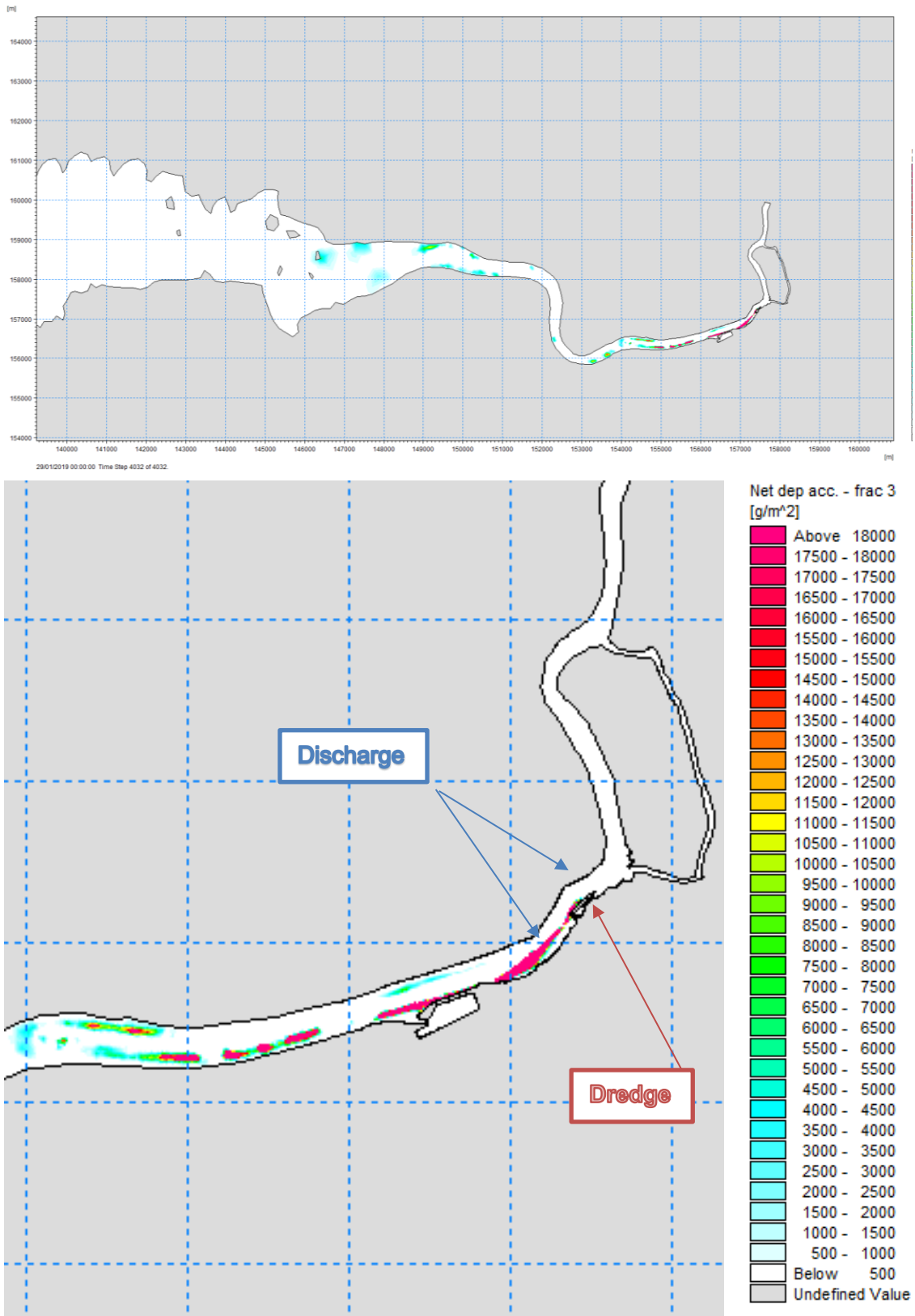

Figure 15 Sand net deposition

5 CONCLUSION

The numerical modelling carried out in this study provided an assessment of the discharge behaviour resulting from the proposed dredging Sarsfield Lock and Arthurs Quay . The modelling indicates that the proposed discharge methods and rates does not have a significant impact on the morphodynamics of the river bed. The modelling indicates that there may be some slight changes in intertidal bed levels in localised areas adjacent.

6 REFERENCES

1. IW Technical Standards Template Revision 1.0 Template No IW-HSQE-TEM-TEC-05 Effective Date:3/6/2017