New Plymouth WWTP Outfall modelling

Proposal prepared for New Plymouth District Council

April 2022

MetOcean SOLUTIONS

Proposal

Date

Version	Revision Date	Summary	Reviewed by
0.1	28/04/2022	Initial Document	Cussioli
0.2	29/04/2022	Draft for Client Review	Berthot

Proposal summary

Project name: New Plymouth Outfall Modelling

Scope & nature of the Services:

Data review
Hydrodynamic Update and Modelling
Nearfield Modelling
Far Field Particle Tracking Modelling
Reporting

Fees & timing of payments:

- Lump Sum Fee of **NZ$46,000** (ex GST) for the Base case scenario and **NZ$16,000** (ex GST) per additional scenario.
- Delivery: Draft report for client review will be delivered within 10 weeks from engagement
- Invoice submitted monthly

Payment: To be made within 30 days from the day of invoicing

Information or services to be provided by the Client:

- Bathymetry data
- Outfall location, discharge rates including base case to consider and future discharge rates
- Ambient conditions at discharge location (water temperature, salinity, local depth, current measurements if available)
- Number and location of sites for dilution estimates
- Inactivation coefficients to bracket effects to be applied in post-processing

This proposal is valid for 12 weeks from the date of the proposal (delete if not relevant)

1. Introduction

1.1 Background

The New Plymouth District Council (NPDC) is interested in understanding the dilution characteristics of discharged treated wastewater from the New Plymouth Wastewater Treatment Plant.

The plant serves New Plymouth City, Bell Block, Inglewood, Waitara, and Ōākura, receiving about 20,000 m^3 of sewage every day[1]. It uses a biological treatment to produce clean effluent which is discharged to the Tasman Sea via a 480 m ocean outfall, located northeast of the Waiwhakahio River (Figure 1.1).

MetOcean Solutions has previously carried out a dispersal modelling study for NPDC (MetOcean Solutions 2012), applying POM and SELFE as respectively regional and local scale hydrodynamic models, and PartTracker as the particle tracking model. MetOcean Solutions have since updated the modelling approach outlined above, including more scientifically robust particle tracking model.

The council now requires a revision of hydrodynamic modelling to deliver the information on wastewater discharge required for a repeat of the QMRA.

This document presents MetOcean Solutions proposal and fee for this scope of work.

[1] https://www.npdc.govt.nz/home-and-property/water-wastewater-and-stormwater/our-treatment-plants/wastewater-treatment-plant/

Figure 1.1 Location of the New Plymouth wastewater outfall.

2. MetOcean Solutions

2.1 Company background

MetOcean Solutions (MOS) is a science-based consultancy with specialisation in the numerical modelling of estuarine, coastal, ocean and atmospheric processes. Metocean Solutions is a division of the Meteorological Service of New Zealand (MetService). The Metocean Solutions team provides numerical and analytical services worldwide, with clients that include national weather services, navies and maritime industries, ports and harbours, engineering consultants, offshore explorers and operators plus various coastal management agencies.

MOS employs 40 people, including 23 PhD scientists, who cover a range of physical and mathematical disciplines. There are four key science teams (atmospherics, waves, ocean currents and coastal processes). Many of the studies undertaken leverage the expertise from all these teams in developing an understanding of the project environment and the processes therein. A process-based understanding is necessary to identify the best solutions and most practical options for engineering or management outcomes in complex marine environments. The core ethic in the company is maintaining scientific integrity by employing exceptional people and using the latest technology and open-source code to produce robust and defendable outcomes and advice. The company operates several scientific computing facilities, both in-house and externally hosted, which allows computational scalability.

MOS has undertaken an extensive number of harbour and port studies globally, including New Zealand, Australia, Pacific Region, Middle East, Europe, South America. These includes numerical modelling to assess estuarine hydrodynamics, water discharges, plume dispersion and water quality processes.

2.2 Personnel

We have assembled a team with the knowledge and technical skills required to successfully deliver the project. The experience of the project team and key team members is provided below, and CVs can be provided on request:

Dr Brett Beamsley – General Manager

Brett has 25 years' experience in physical oceanography, coastal processes, ocean engineering applications and managing port projects relating to dredging and disposal of dredged material. His professional outputs include more than 30 peer reviewed papers and scientific publications (author and co-author) In addition he has been involved in more than 150 technical reports covering a broad range of topics, including sediment dynamic and transport (including morphological modelling), drill cuttings and dredged sediment disposal characteristics, hydrodynamics and wave processes. Brett has specialist skills in finite-element model establishment and is a long-time user of the SELFE/SCHISM code.

Dr Alexis Berthot – Marine Project Consultancy Manager

Alexis has more than 20 years' experience in coastal, ocean and estuarine research and consulting and has provided professional services for a wide range of coastal and ports projects. He has a PhD in Physical Oceanography from the University of Western Australia. His expertise is in numerical modelling and data analysis with particular emphasis in hydrodynamic, wave, sediment transport and morphological modelling. Alexis has extensive experience in undertaking hydrodynamic modelling in support of port operation including the provision of data for ships simulators as well as being involved in ship simulations for port engineering and channel optimisation projects.

Simon Weppe - Physical Oceanographer

Simon is a specialist numerical modeller with expertise in many numerical solutions. His experience extends from wave and hydrodynamics models to sediment transport and coastal system morphodynamics. His MSc in oceanography was from the University of Waikato and his thesis focused on the field monitoring and modelling of oceanographic and morphodynamic processes in the vicinity of a submerged reef. Since joining MSL in 2010, Simon has been involved in a wide range of consultancy projects including large scale dredging and disposal projects at many locations in NZ, as well as wave penetration and agitation in harbours and ports. He is an experienced user of the open source Deflt3D suite as well as nearshore wave models. Simon's modelling expertise extends to Lagrangian modelling applied to dredging and disposal plumes, oil spill tracking and pollution dispersal, and is responsible for open sourcing the Lagrangian particle tracking model.

Dr Mariana Cussioli - Coastal Oceanographer

Mariana is an oceanographer, specialising in coastal oceanography and coastal environments. She has previous experience in consulting and numerical modelling for several projects involving dredging and coastal developments, such as marinas and piers. She has a PhD in Coastal Oceanography from the University of Waikato and her expertise extends from hydrodynamic, wave and sediment transport modelling to modelling and monitoring of dredging plumes and sediment disposal. Mariana is also an experienced user of the Delft3D numerical modelling system for hydrodynamic, wave and sediment transport applications.

Dr Sarah Gardiner - Physical Oceanographer – GIS Specialist

Sarah has 12 years' experience as a physical oceanographer. She holds an MRes degree in Coastal Engineering and a PhD in estuarine hydrodynamics and habitat stability (University of Southampton, UK). She has research interests involving marine geomorphology and coastal habitats and she specialises in the application of GIS, including bathymetry and habitat mapping, data capture, processing & spatial analysis. Sarah has experience in coastal management, policy and spatial planning with reference to shoreline management plans. She is custodian of the company's bathymetry datasets and plays a core role in development of the numerical model domains for structured and unstructured grids used in the forecasting and hindcasting systems.

Dr Gael Arnaud - Physical oceanographer

Gael Arnaud is a physical oceanographer specialized in coastal processes with more than 10 years' experience in hydrodynamic processes such as tide, long wave, tsunamis, wave-current inter-action, wave setup, flooding, morphodynamics and the associated coastal hazards. Gael has a PhD in coastal dynamics from the University of Pau (France). At MetOcean Solutions his work focuses on the development and maintenance of the nearshore flexible mesh operational forecast system (SCHISM model) and the delivery of coastal hydrodynamic hindcasts. Gael is also involved on a range of multidisciplinary consultancy projects for coastal applications including storm surge and tsunami inundation.

Holly Watson – Physical Oceanographer

Holly has five years of industry experience working as a physical oceanographer at coastal engineering consultancies in Australia. Holly has completed a master’s thesis under scholarships where she developed a hydrodynamic model of Tauranga Harbour for port development and environmental assessment purposes. She is a coastal scientist and oceanographer with specialist experience in the fields of coastal and ocean modelling of hydrodynamics, sediment transport and wave conditions. Holly also has experience in statistical modelling and data analysis. Her expertise lies in coastal hydrodynamics with experience in numerical modelling and geographical mapping. Holly has experience working with Delft3D, Delft-FM, SWAN, coupled DFM and SWAN, SWASH, Mike21-FM, Mike21, Global Mapper, QGIS and MATLAB software packages.

Dr. Joao Claudio Albuquerque - Physical Oceanographer and numerical modeller

João comes from the Computer Science field and has a PhD in Physical Oceanography. His research is about the past and projected nearshore wave climate of New Zealand, focussing on the projected changes of New Zealand’s wave characteristics towards the end of this century. João has a BSc and a MSc in Computer Science at Federal University of Paraná, and more than 5 years of lecturing/tutoring experience. He has also worked for 9 years in the environmental science industry with a multidisciplinary team of engineers and meteorologists. By joining our consultancy team, João is bringing on-board his expertise in wave modelling, data analysis, remote sensing, as well as systems design, implementation and troubleshooting.

2.3 Sustainability statement

Since establishment in Raglan and New Plymouth in 2005, MOS has become an important part of the regional and national scientific community. Management and staff actively promote and support a vibrant and strong local economy in both regional centres. MOS staff are actively involved in the local coastguard and community, and the growth of the company has brought talented professionals and their families from around the world to settle in the Waikato and Taranaki region.

The group has consistently supported students and researchers at various universities, including the Waikato University. Through this support, the company has provided tangible benefits to the knowledge economy of New Zealand. Sustainable environmental practices need to be based on robust and unbiased science, and MOS have a decade-long track record in that regard.

With full support from MetService, a zero-harm HSE policy has been adopted, and monthly reporting of the KPIs and performance targets are made to the Board of Directors.

3. Proposed Methodology

3.1 Information required from client

To undertake the modelling, the following data and information will be needed:

- Outfall Time-series of discharge rates including base case to consider and future discharge rates
- Pipe/outflow design (diffuser pipe diameter, number of risers, spacing between the risers, distance along the pipe between the first and last diffuser, depth of the diffusers, orientation of risers, single or double port riser, port diameter
- Location and depth of discharge
- Effluent characteristics (temperature, salinity)
- Ambient conditions at discharge location (water temperature, salinity, local depth, current measurements if available)
- Number and location of sites for dilution estimates
- Inactivation coefficients to bracket effects to be applied in post-processing

3.2 Near-field modelling

Near-field modelling of the initial turbulent mixing will be undertaken using CORMIX[2] CORMIX is a USEPA-supported mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges. The system emphasizes the role of boundary interaction to predict steady-state mixing behaviour and plume geometry.

CORMIX will be used to define the near-field plume characteristics (extent, initial dilution) under a range of representative conditions (water depth, current velocities, discharge characteristics, diffuser configurations) for input into the far-field model (Figure 3.1 and Figure 3.2).

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[2] http://www.cormix.info/

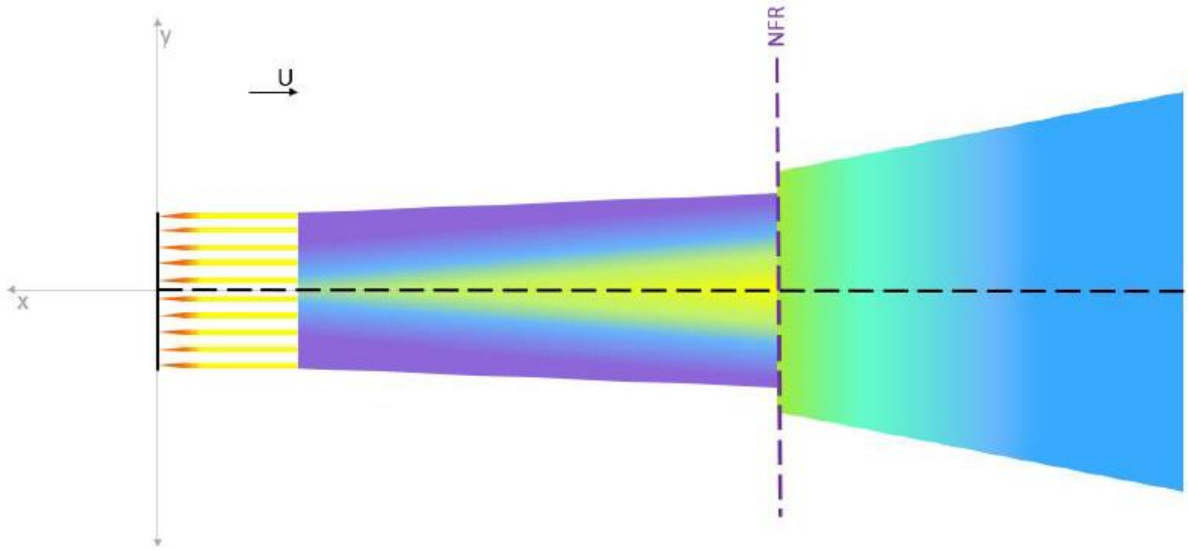

Figure 3.1 Diagram representing the different modules in CORMIX. Beyond the near-field region (NFR) is the far-field region which will be simulated using the particle tracking model (OpenDrift).

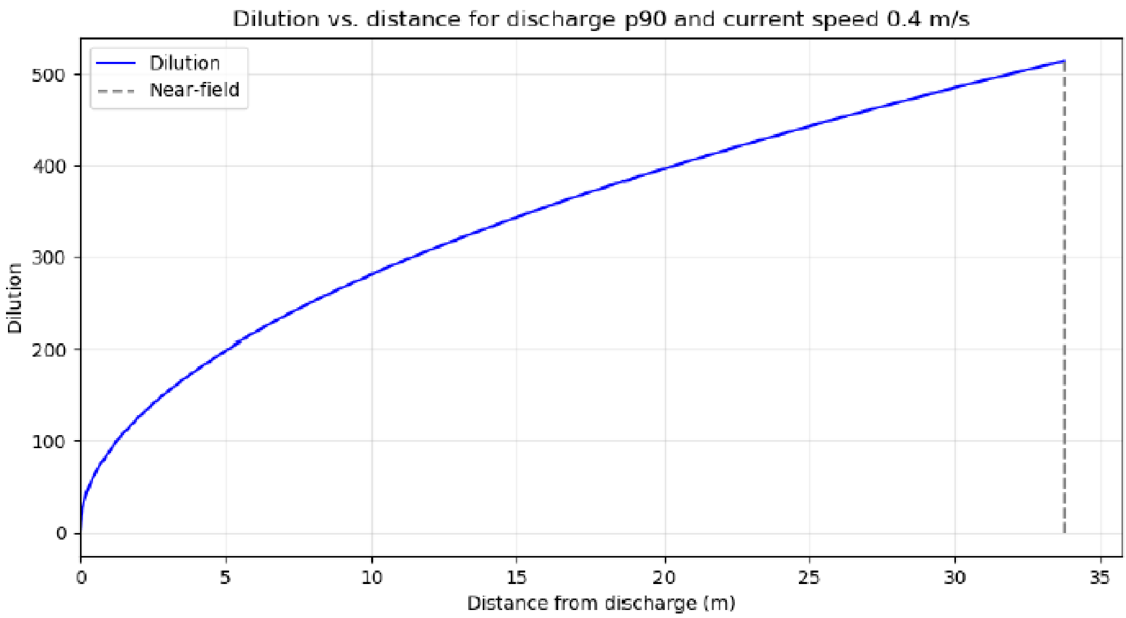

Figure 3.2 Example of results of near-field plume dilution at distances from the discharge source.

3.3 Hydrodynamic model

The simulation of effluent far-field dispersion within a complex coastal system requires high resolution hydrodynamic fields. For the present study, the local hydrodynamic modelling undertaken for the previous study (MetOcean Solutions 2012) will be updated. The update of the hydrodynamic model will include:

- Review of the model mesh
- Upgrade model input: boundary input with recent ROMS hindcast (ROMS Taranaki/Moana Backbone)
- Review wind input CFSR or WRF NZ
- Validation

The updated model will be used to run simulations covering full year simulations of contrasting climatic conditions (i.e., La Niña and El Niño) and provide a sound statistical basis to examine the dispersion of contaminants within the receiving environs.

The simulations are based on the open-source model SCHISM[3][4]. Open-source science models allow full transparency of the code, numerics, boundary conditions and outputs. Further, it allows other consultants and researchers to replicate or enhance any previous modelling efforts for a given environment. The native outputs from SCHISM can be read directly by the WaterRide[5] software (operated by Regional Councils throughout New Zealand).

SCHISM is a prognostic finite-element unstructured-grid model designed to simulate 3D baroclinic, 3D barotropic or 2D barotropic circulation (Figure 3.3). The barotropic mode equations employ a semi-implicit finite-element Eulerian-Lagrangian algorithm to solve the shallow-water equations, forced by relevant physical processes (atmospheric, oceanic and fluvial forcing). A detailed description of the SCHISM model formulation, governing equations and numerics can be found in Zhang and Baptista (2008).

The finite-element grid structure (i.e. triangles) used by SCHISM has resolution and scale benefits over other regular or curvilinear based hydrodynamic models (such as Delft3D). SCHISM is computationally efficiently in the way resolves the shape and complex bathymetry associated with estuaries, while the governing equations are similar to other open-source models such as Delft3D. SCHISM has been used extensively within the

[3] http://ccrm.vims.edu/schism/
[4] http://www.ccrm.vims.edu/w/index.php/Main_Page#SCHISM_WIKI
[5] http://www.waterride.net/

scientific community[6], and forms the backbone to operational systems used to predict nowcast and forecast estuarine water levels, currents, water temperature and salinity[7].

The model resolution will be optimised to ensure the salient hydrodynamic processes are accurately captured, with offshore resolution of the order 100s of metres, and 10 to 50 m nearshore and close to the outfall. The model domain will include all salient river systems which discharge into Tasman Sea.

it is noted that this extent may be useful for other work scopes NPDC may be considering, and as such this work package may provide a price point saving for any additional works.

3.3.1 Boundary conditions

Offshore tidal elevation and velocity data will be prescribed from a NZ scaled tidal model, with offshore residual current velocities, salinity and temperature data sourced from the NZ ROMS implementation. It is expected that discharge flow data at or near the boundary of the salient rivers discharging into Tasman Sea (e.g., Waiwhakahio River, Waitara River) will be supplied by NPDC.

3.3.2 Model calibration and validation

The previous model setup has been calibrated and validated against available measured data. However, it would be useful to validate the model further against site specific data if available.

[6] http://ccrm.vims.edu/schism/schism_pubs.html
[7] https://tidesandcurrents.noaa.gov/ofs/creofs/creofs_info.html

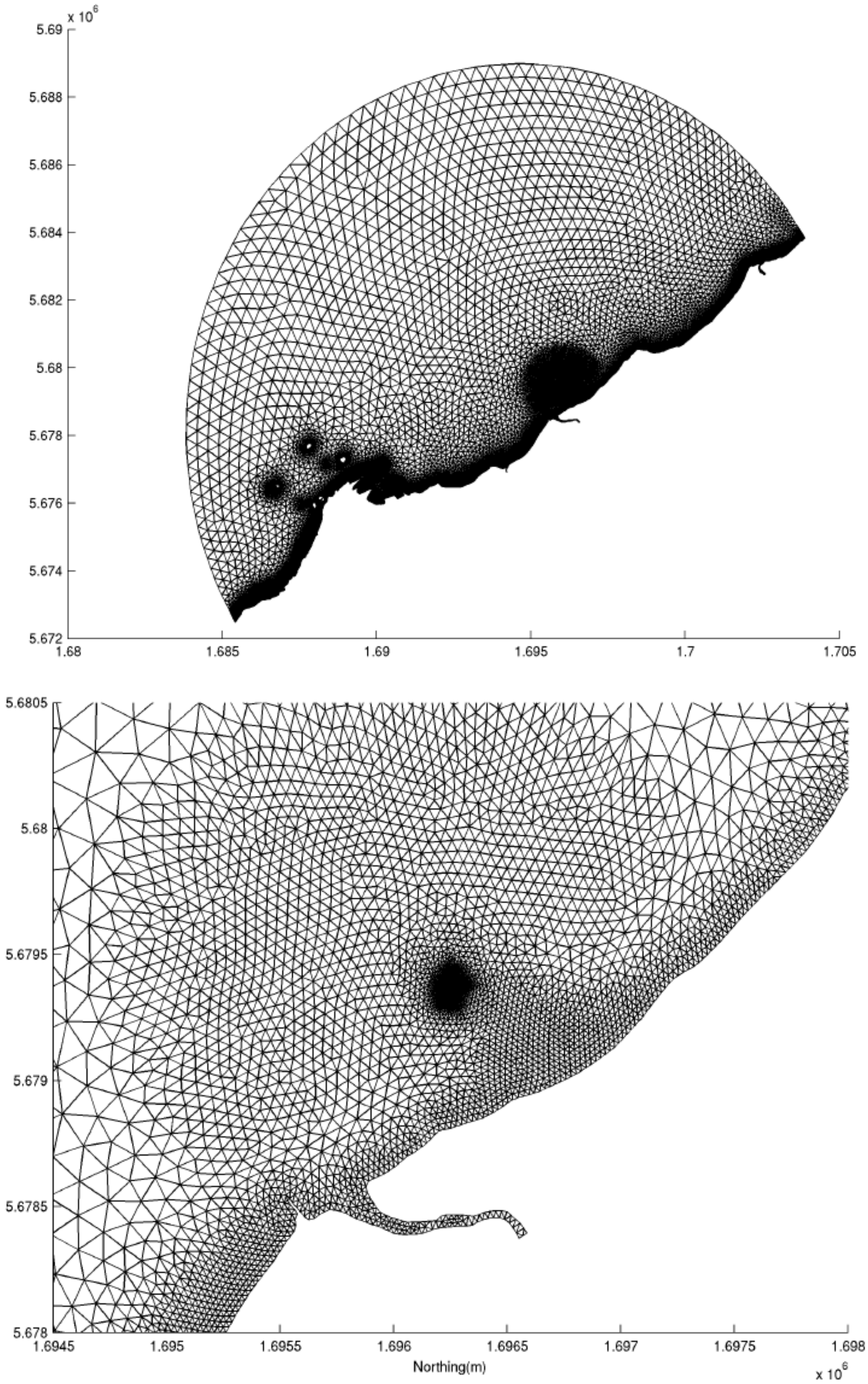

Figure 3.3 *Finite element grid for the local scale hydrodynamic model. The bottom figure is a zoomed in view of the grid in the vicinity of the outfall.*

3.4 Far-field modelling

The far-field dispersal and dilution of wastewater discharged into the marine environment will be treated as a passive tracer and modelled using Lagrangian particle tracking code OpenDrift[8].

Lagrangian particle modelling has been used in numerous trajectory applications, including drilling muds and predictions and persistence of the surface expression of a plume, and work in an offline fashion, with the computationally intensive Lagrangian simulations undertaken within hydrodynamic flow fields.

OpenDrift is an open-source Python-based framework for Lagrangian particle modelling under development at the Norwegian Meteorological Institute with contributions from the wider scientific community. The framework is highly generic and modular and is designed to be used for any type of drift calculations in the ocean or atmosphere. A specific module within the OpenDrift framework corresponds to a Lagrangian particle model in the traditional sense. Several modules have already been developed, including a sediment transport module, an oil drift module, a stochastic search-and-rescue module, and pelagic egg module.

[8] https://github.com/opendrift/opendrift/wiki

Particle tracking modelling will be undertaken for a base case and a future discharge scenario using flow fields based on the SCHISM hindcast (i.e., La Niña and El Niño). A description of both scenarios is presented below.

- Base Case Scenario:
    - Consider proposed consent discharge with passive tracer and simulate for a full El Niño and La Niña year
    - Use of inactivation or 'die-off' coefficient (based on seasonality, instantaneous solar radiation, etc.), A simple high/low inactivation coefficient will be used to bracket effects. This is applied at the post-processing phase of the particle tracking results.
- Projected future scenario:
    - Increase in discharge rate based on population growth projections

If suspended solids/sediments (considering settling velocities and flocculation) also need to be modelled, another particle type with settling properties/resuspension will need to be added in the model and post-processed separately than the neutrally buoyant tracer.

A nominated concentration value (e.g., 1 mg.l^{-1}) will be used for the discharge so that dilution can be calculated at various distances from the source. Specific contaminant levels can then be determined using concentration ratios and the expected or measured discharge value (Figure 3.4).

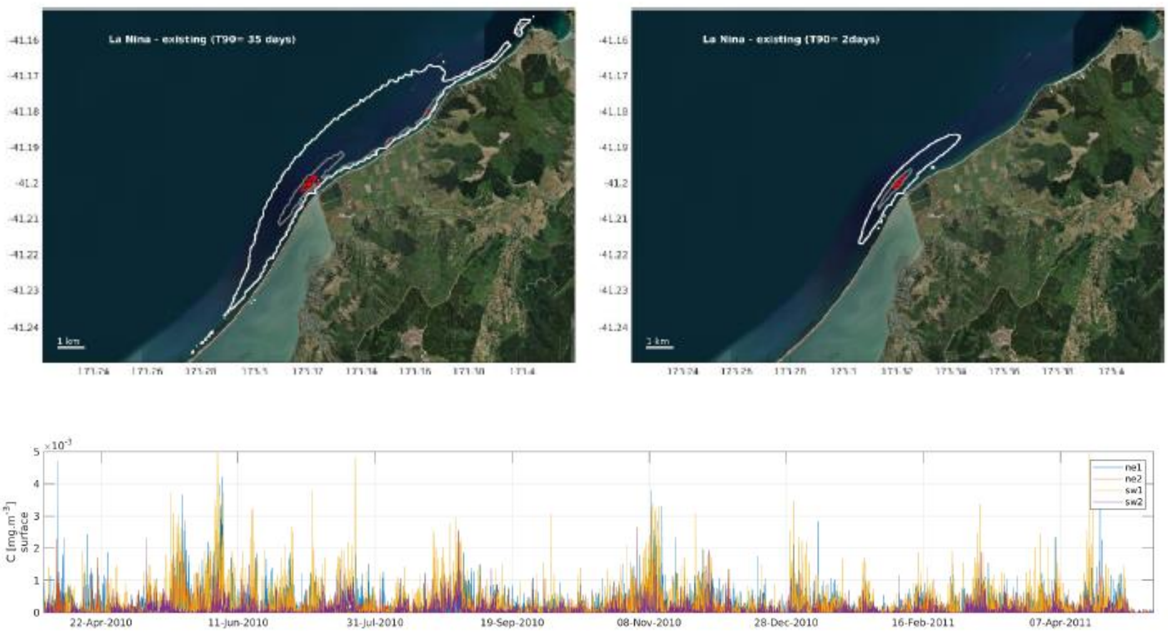

Figure 3.4 Example of dilution contours maps (top) and timeseries at a site (bottom) representing results of the particle tracking modelling in the far-field.

4. Deliverables

A short concise report will be prepared, presenting the methodology, assumptions and results of the modelling.

Annual time-series of contaminant levels (including potentially die-off) will be supplied at key locations specified within the model domain by client (not shallower than 2-3 m water depth). Results will be supplied in a format suitable to undertake a QMRA.

Provision of timeseries data to generate animations of the plume over selected periods (e.g., over three-day periods) to aid community to visualise where plume of wastewater is likely to travel.

5. Timing and cost

Our fee for the scope presented in this proposal is **NZ$46,000** (ex GST) for the Base Case and **NZ$16,000** (ex GST) per additional scenario. Details of the fee is presented in Table 1.

The estimated time frame for the delivery of the entire work scope is approximately 10 weeks from engagement. It is anticipated that some part of the scope can be delivered earlier as preliminary results if needed.

Table 1: Fee Breakdown

Items	Description	Details	Fee (NZ$ - ex GST)
1	Hydrodynamic Modelling update and simulations	Update model, boundary conditions, and validation of a hydrodynamic model and provide appropriate flow fields to undertake far-field Lagrangian particle tracking modelling.	$12,000
2	Nearfield Modelling	Modelling of Nearfield dilution for proposed outfall diffuser	$8,000
3	Particle Tracking Modelling (Base Case)	Lagrangian particle tracking model initialised by the near-field model, including appropriate die-off rates (depending on client requirements) for two complete years that represent the expected climatic variability. Process and supply time-series of dilutions for a range of contaminants (initial concentrations/dilutions to be supplied by clients)	$18,000
		Consideration for Suspended Solids Sediment	$8,000
Total (Base Case)			**$46,000**
Additional Scenarios	Future discharge rate scenario or other scenarios	Particle Tracking for Contaminants	$10,000 / Per Scenario
		Consideration for Suspended Solids Sediment	$6,000 / Per Scenario
Total (Additional Scenarios)			**$16,000 (Per Scenario)**

The timing and cost consider the retrieval of existing hydrodynamic models and update of bathymetry. However, timeframe for the liaison with NPDC and confirmation of assumptions, sign off on dredge plume modelling assumption etc is not included in the timing estimate.

Additional project support, such as evidence preparation and presentation, can be supplied on day rate terms (NZ$1800 ex GST).

6. References

Metocean Solution 2012. New Plymouth Wastewater Outfall. Virus dispersal modelling. Report n. P0106-01, Prepared for the New Plymouth District Council.

Zhang, Yinglong, and António M. Baptista. 2008. "SELFE: A Semi-Implicit Eulerian-Lagrangian Finite-Element Model for Cross-Scale Ocean Circulation." *Ocean Modelling* 21 (3–4): 71–96. https://doi.org/10.1016/j.ocemod.2007.11.005.

Zhang, Yinglong J., Fei Ye, Emil V. Stanev, and Sebastian Grashorn. 2016. "Seamless Cross-Scale Modeling with SCHISM." *Ocean Modelling* 102: 64–81. https://doi.org/10.1016/j.ocemod.2016.05.002.

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