6. Project Overview and Conclusions

In the course of this project, the potential impacts of tsunamis from three different sources on Northland Region were considered. Detailed predictions of maximum onshore inundation and current speed for each event, at two different sea level heights, have been made for 32 locations in Northland. The modelling was performed using the general hydrodynamic model RiCOM.

Overall, the relatively likely, but smaller, South American event caused the least inundation, the M_w8.5 event slightly more, and the M_w9.0 event had much more severe impacts. Tsunamis originating from South American subduction earthquakes have a return period of about 50-100 years. In contrast, the return period of large events from the Tonga-Kermadec subduction zone is estimated at about 500-2000 years (Lane et al., 2007; Goff, 2008), but the resulting impacts of these less frequent events are potentially much greater. The simulation results presented here cover the likely range of tsunami that might be expected in Northland.

All the modelled events have the largest impacts on the communities and shoreline along the east coast of Northland. Resonance in bays can lead to greatly enlarged waves and increased inundation at the coast. Predicted wave heights at the coast from the South American tsunami reach up to about 3 m, whereas for the Tonga-Kermadec events wave heights reach up to about 5 m and 9 m respectively for the M_w8.5 and M_w9.0 earthquakes. In some localised areas, these values could be exceeded.

Arrival times of the first wave for the east Northland coast are 70-90 minutes for tsunamis from the Tonga_Kermadec trench, and about 15 hours for the South American event. The first wave may not necessarily be the largest; usually there is a series of large waves that arrive over the course of the next few hours. The maximum wave height can occur at any time during this period. Waves from both events wrap around Cape Reinga and propagate down the west coast of Northland. Arrival times for the west coast are correspondingly longer than those for the east coast, typically arriving 1-2 hours after arrival at the east coast, and wave heights are also much smaller.

Predicted onshore inundation is highly variable between the 32 modelled locations, depending critically on the topography of local area. Waves typically propagate up streams and creeks that discharged into the sea, and could therefore penetrate considerable distances inland along these waterways. Settlements on tombolos and along the shores of estuaries are also typically at risk of flooding. Coastal roads may be inundated by these events, cutting off escape routes and inhibiting subsequent access.

6.1 Uncertainty of the Modelling Results

The physics of wave propagation are well understood, and the numerical treatment of the problem by RiCOM has been carefully developed over a number of years to ensure efficient and accurate simulation. However, the modelling performed here is dependent on, and therefore limited by, a number of other factors. In particular, the generation processes and initialisation of the tsunami for each earthquake source is based on theoretical analysis and is difficult to establish by observation. Also, the simulation of inundation is strongly dependent on the quality of the LiDAR topographic data and the bathymetric data in inshore waters. Bathymetric data are often relatively sparse, and of indeterminate quality, which will influence the accuracy of the water depths and speeds presented here.

The greatest uncertainty in modelling tsunami impacts arises from the representation of the wave generation process. Regional source tsunamis arise from earthquakes along subsea faults, which are transformed into tsunamis using the elastic dislocation model of Okada (1985). Details of the rupture (e.g. fault rupture length, angle, movement etc) are entered into the model to derive a displacement of the sea surface. This displacement acts as the initial conditions to RiCOM simulations. Inevitably, however, there is considerable uncertainty over both the accuracy of the predicted seabed movement and the validity of the assumption that the seabed displacement translates directly to the sea surface. Nevertheless, the model of Okada (1985) is widely used by tsunami modellers and remains an established tool.

Remote tsunamis generated in the Pacific to the west of South America are simulated as a series of solitary waves entering the eastern boundary of the model. The amplitude and period of the waves have been fitted against data from Lyttelton Harbour to produce the best fit against sea level data collected following the 1960 Chilean earthquake and, as such, have been qualitatively validated. Nevertheless, an improvement to the model predictions could be achieved by modelling the propagation of the tsunami from source to inundation on a single continuous trans-Pacific computational grid, and research effort is currently focussed on achieving that goal.

Other uncertainties in the modelling study include sparse bathymetry data, particularly in the nearshore region, and the gridded representation of a continuous coastline, which can deform the shape of bays and estuaries. The effects of building and land features on wave drag are largely unknown, but could substantially modify the onshore propagation of tsunamis. Improving the drag representation remains a goal of current research. Eradication of the other errors is constrained by limitations of data quality and the practicalities of grid resolution; models always represent an approximation of reality.

Model uncertainty can be quantified by running multiple simulations with small variations in key parameters, an approach known as ensemble prediction or sensitivity analysis. Such an approach would provide an envelope of predicted solutions, rather than single “worst-case” or “scenario-type” predictions, on which to base emergency response procedures. However, running many simulations increases the computational and research costs, and, in any event, model forecasts can never be certain, because our knowledge of all the geophysical processes involved in tsunami generation, propagation and inundation remains incomplete.

Quantitative calibration of the tsunami inundation model against real measurements is difficult due to the uncertain nature of tsunami impact data from New Zealand and the consequent difficulty in identifying tsunami events from the past. Nevertheless, the RiCOM model has been continuously validated against standard analytical test cases (e.g. Walters and Casulli 1998; Walters 2005), and model predictions of run-up height have compared well to palaeotsunami data in the Bay of Plenty (Walters et al. 2006c) and along the Otago coastline (unpublished data).

Despite the inherent uncertainties in numerical modelling of tsunami impacts on New Zealand, we believe that the current modelling exercise provides the best possible estimate of inundation in Northland from remote and regionally sourced tsunamis available to date.