Sediment model development: Workshop and survey summary

NIWA Client Report: HAM2006-147
December 2006

NIWA Projects: WQQB042 and AQCF042

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NIWA Client Report: HAM2006-147
October 2006

NIWA Projects: WQQB042 and AQCF042

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1. Introduction

This document provides a follow-up to a series of workshops on erosion modelling held in May–June 2006. The workshops worked towards agreement on the types and features of models that can be used by North Island regional councils to help manage on-site erosion and sediment impacts in streams, lakes and coastal areas. This will in turn guide future model development by NIWA, Landcare Research, and Regional Council partners.

Before the workshops, a background discussion report on sediment models was circulated that summarised a range of models, identified the general features of erosion/sediment models, and included blank survey forms on model requirements. The background report is included in this report as an addendum. The reader is referred to the addendum report for general background information on erosion/sediment models, including brief descriptions of models which are referred to in the body of this report.

Two half-day workshops were held; the first at Palmerston North on 25 May; and the second at Hamilton on 2 July 2006. Notes from these meetings are appended to this report (Appendices 1 and 2). Key points from the workshops are summarised in Section 2. Following the workshops, survey responses were collected from the workshop participants. These are collated in Appendix 3, and key points are summarised in Section 3.

With the information from the workshops and survey responses, a meeting was held between Landcare Research and NIWA to plan model development (Section 4). This is the main outcome of the workshop process.

2. Key points from the workshops and surveys

In this section the main points identified in the workshops and surveys are listed. There was no dominant direction or outcome from the workshops and surveys; rather, a range of issues and model requirements was identified. This information is used as a basis to propose a set of models, as outlined in the next section.

2.1 Issues related to sediments and erosion

While regional councils have many sediment-related issues of high importance, there was no overall agreement on a single dominant issue (even within a given region there was often a range of issues). The key issues are listed in Table 1.

Overall, however, the following broad classes of issue had high priority: estuarine infilling and sediment deposition; pasture and soil degradation; sediment-related water quality in streams; and sediment embeddedness (fine sediment filling up voids in gravel rivers) in streams.

Table 1. Key issues, arranged in order from source to sea.

Issue	Areas of the North Island with this issue as a focus
Loss of soil from farm areas, and associated loss of farm production	Erodible lands in eastern and lower parts of the North Island
Erosion from new subdivisions and the effects in the receiving environment (estuaries)	Major urban centres
Environmental effects of sediment from forestry operations	Upper and eastern half of the North Island
River turbidity and water clarity, especially as it relates to aesthetics and public perceptions of water quality	Erodible lands in eastern and lower parts of the North Island
Sediment-related water quality, such as nutrient loads	All areas
Sediment embeddedness (fines in gravel river beds); important for stream biota	All areas with gravel-bed rivers
Accretion of coarse sediment in rivers, particularly the effects on channel flood conveyance	All areas with gravel-bed rivers
Estuarine deposition – both deposition events and long-term accumulation of sediment and changes in sediment texture	Regions with drowned-valley or barrier estuaries (Auckland, Waikato, Bay of Plenty, and to some degree Wellington)

Other issues included: urban stream erosion; effects of sediment on marine systems (not just estuarine); effect of reductions in pest control on sediment loads from bush areas (the relationship of pest control to sedimentation); and sediment deposition at river mouths.

2.2 Roles for and use of models

The workshop identified a number of ways in which models could be used to address sediment-related issues. These uses provide some guidance for model development. A range or suite of models will be needed to provide for the variety of end-uses (it is unlikely that a single model can provide for all these end-uses).

A clear need was seen for models that could be used to **identify soil conservation and erosion controls on farms, forest blocks, or urban sub-divisions**. This is the predominant scale at which erosion control takes place. On farms, this might amount to a tool to identify what soil conservation measures to use, where to implement these measures, and the cost associated with them, all incorporated within a whole-farm plan for soil conservation. Simple models for rapid assessment and for use by land-owners were seen as being particularly appropriate. For forestry sites, models or tools would help plan and manage forest harvesting operations to reduce erosion. Models were seen as useful for quantifying the soil loss from, and the effectiveness of erosion control measures for, urban earthworks, to reduce erosion and as a basis for consent decisions.

Identification of locations and sources of sediment generation within a catchment or region formed another key area for model use. There are two aspects. First, a model can be used to map the spatial distribution of sediment generation in a catchment, to identify critical or cost-effective locations to target mitigation measures, and this in turn could be used to prioritise properties or parts of a catchment for soil conservation. Second, a model could break down the source of sediment into different source types (such as stream-bank erosion, slips, roads/tracks, particular land-uses, sediment from historical land clearance), and this information could be used to target erosion control (such as riparian planting or forest harvesting controls). Reverse modelling could be used to back-calculate from target sediment loads or sediment deposition rates/depths to suitable land or stream treatments.

Erosion models could also serve as a quantitative basis for **prediction and control of environmental effects of sediments.** For example, quantification of sediment loads to an estuary could be linked with an estuarine model to predict sediment accretion or storm deposition depths. Similarly, a model of sediment generation and transport in streams could be used to predict the number of days where turbidity thresholds are exceeded or changes in sediment embeddedness. Such quantitative catchment-scale models could also be used to predict the reduction in environmental effects through various land-use or land-management or mitigation measures (including management policies or programmes). Model predictions can be used to justify erosion control measures, to manage public expectations for the time required for environmental improvements, and to guide policy/rule development.

Models can be used to **guide sediment extraction or dredging activities** to maintain flood conveyance capacity, for example, to assess how much sediment to extract from streams, and where and when to remove it.

Other uses for models were as **communication tools** to the public and to councillors (particularly with map-based outputs), and for refining the **design of monitoring programmes**.

2.3 Model outputs and scales

Identification of model roles drives the types of variable and the temporal and spatial scales of the model.

Variables to be predicted. The following variables were seen as important to the output of model predictions: sediment deposition depth (including spatial distribution); sediment load; soil loss rates; sediment concentrations in streams; and particle-size distributions (insofar as they affect sediment transport and ecological parameters). A breakdown of sediment loads into source areas or types (e.g., sheet erosion versus bank erosion) was also seen as useful, as were maps of relative erosion risk. Not all variables are required for each model use.

Spatial scale and resolution of the catchment model. There was strong support for a catchment-scale model that incorporated subcatchment partitions, which in turn were subdivided according to factors such as land-use or soil type. There was also interest in a separate model to provide predictions at the hillslope or property scale (farm, forestry lot, earthworks site), with sub-property resolution, to be used for the development of local-scale sediment management plans.

Resolution of stream and estuary models. For the stream component, a model providing outputs resolved to the reach scale was seen as suitable in most cases. For the estuary component, either a compartment model or finer spatial resolution (2-D or 3-D grid) was seen as appropriate.

Temporal scale and resolution. There was most interest in models that can provide outputs broken down into storm events over long time periods (decades). This would serve as a suitable basis for assessing environmental effects. It was unclear whether an actual time-series would be required, or whether probabilities of different loads or concentrations would be sufficient. There was also interest in models providing annual average predictions, for example, in highlighting sources of erosion or dominant sources of sediment, and summarising the effectiveness of mitigation measures. There was little interest in model predictions at the sub-event scale.

2.4 Mitigation measures, processes, and other desired model features

A strong desire was expressed for a wide range of mitigation measures to be included in the models, to allow for their comparison and prioritisation. The highest priority mitigation measure able to be evaluated by models was vegetative bank stabilisation, followed by riparian filter strips, ponds and wetlands, track and road erosion, conservation planting, forest harvesting controls, and pasture-cover management. While pasture retirement, streamside stock access, and controlled floodplain deposition were seen as less important for inclusion in the models, they were evaluated as high or medium priority by about half the survey participants.

Farm-scale and other local models need to include the following management practices: stock type, stock rate, riparian practices, wetlands, soil conservation measures, tracks, roads, minimum tillage.

There was strong support for including processes of bank erosion, stream downcutting, and track and road erosion. Raindrop/overland-flow erosion, gully erosion, slips, landslides, bedload transport and deposition, floodplain deposition, and settling in estuaries were of high priority in about half the survey responses. Rilling, debris flows, floodplain deposition, flocculation, re-mobilisation of estuarine deposits, and coastal sediment dispersion were of intermediate importance. Long-term stream shape and landscape evolution, and estuarine hydraulics and wave mechanics were of lowest priority.

If users are to apply models themselves, the models must have a user-friendly interface (graphical or spreadsheet-based), and be GIS-based.

The survey participants considered that the models should be targeted primarily for use by regional council technical staff, rather than by research specialists, planners or the public.

The inclusion of uncertainty estimates of predicted output variables was considered to be desirable.

There was support for erosion models to link to water quality and ecological models (for example, to classify the habitat of stream reaches or to identify impacts of sedimentation on estuarine biota). There was little support for an economic module.

2.5 Summaries developed at the workshops

Model requirements are summarised in Appendices 1 and 2.

The Palmerston North workshop summarised requirements to address a list of 5 key issues (see table in Appendix 1). For each issue, the model variables/outputs, spatial scale, temporal scale, priority, and mitigation measures were identified.

The Hamilton workshop (Appendix 2) developed a list of useful models, incorporating a brief description of each. Four model types were identified and classified according to primary intended use.

The summaries from the two workshops have been used to help develop the list of proposed models presented in the next section.

3. Proposed models

From the workshops and survey, a number of sediment-related issues and model uses were identified, and desirable model features were established. It is clear that no single model would meet all these demands and uses. Rather, a suite of models is required to address the key issues and management applications. Existing models do not address all of these requirements; accordingly, we have identified a set of potential models and their features, to serve as a framework for model development activities (Table 2). The reader is referred to the Addendum Report for general background material on erosion/sediment models.

While the proposed set of models would address the main regional council needs, there is also a need for ongoing research-level modelling and field investigations, to improve understanding of processes and develop the predictive capabilities of the more management-oriented models.

This set of models serves as a desirable end-goal. However, we must be realistic and acknowledge that only some of these needs can be met in the near future. There are limitations in our current ability to characterise the relevant processes adequately, and there are also limitations in the resources available for model development.

In Table 2 we give a broad indication of how the models might be delivered, but have stopped short of laying out the next steps and responsibilities in detail. This task will be addressed in future discussions between research providers, and between research providers and regional councils.

Table 2. Summary of proposed models and their attributes to address key issues and applications.

Model	Issues addressed and uses	Description	Suggested development path
Urban earthworks site model	Quantification of sediment losses from urban earthworks sites: to identify and assess mitigation options and for consent purposes.	Subdivision scale, broken down into slope and soil classes and sub-areas related to phases of earthworks or ponds. Predicts mean annual load, and load from a design storm. Includes timing/phasing of earthworks, mitigation options such as silt fences and silt ponds, and re-vegetation. Probably incorporate elements of USLE/RUSLE. Probably not a continuous model, but may draw on treatment performance curves derived from continuous simulation.	Probably funded by and driven by regional councils, possibly through Envirolink. A programme of field measurements would be highly desirable to accompany model development.
Farm management plan model	Prioritise erosion control needs on a farm scale, and predict the reduction in erosion risk and sediment delivery: used for farm plan development.	A semi-quantitative farm-scale model, with results expressed as rates of soil loss incorporating spatial variation. Accounts for variation of soils and slope, the climate, farm management practices, e.g., stock type and rate, and mitigation measures. Based on empirical information and expert-type assessment. Includes landslides and bank erosion.	Probably funded by and driven by regional councils, possibly through Envirolink.
Forest block management	Prioritise erosion control needs on a forest block to reduce the sediment loss risk: used to identify and assess mitigation options and for consenting.	A semi-quantitative erosion risk model, with approximate erosion rate and risk in harvesting and establishment phases. Predicts mean annual erosion rate and design storm erosion rate. Takes account of roading, harvest timing and method, topography, slope, soils and climate, post-harvest cover management, sediment interception measures (silt traps in bench drains, silt ponds). Uses expert assessment where necessary.	Probably funded by and driven by regional councils and/or forestry industry.
Catchment and receiving environment model	Quantification of sediment generation rates from catchments, sediment concentrations in streams, and deposition in estuaries, to relate land and stream processes to environmental sedimentation stresses. Integrated view of effectiveness of mitigation measures. Break-down of load into major source categories, and mapping of source distribution: to prioritise interventions in a catchment.	Prediction of sediment load and deposition depths for various event sizes and long-term average load and deposition. Semi-empirical grid-based slips component (slip probabilities as a function of cover, slope, event rainfall, and runout distance). The hydrology and overland flow component will probably be based on process-based, continuous, long-term simulation. Includes surface erosion, slips, bank erosion, estuarine dispersal patterns. Time-stepping model probably required for stream concentrations, but event/probabilistic model may be sufficient for catchment loading and estuarine effects.	FRST. May build on existing models (WAM, SWAT, TopNet, landslide models).

Model	Issues addressed and uses	Description	Suggested development path
Catchment or regional erosion rate models	Sediment loads from catchments. Identification of areas of high delivery of sediment loads. Assessment of effects of land-use and mitigation measures on sediment loads. Long-term catchment planning. Identification of at-risk receiving environments.	An empirically-based model for surface erosion, landslides, bank erosion and stream transport. Use measured data where possible to set yields. Also use expert assessment to assess effect of various driving factors (such as vegetative cover) and effect of mitigation measures.	Build on and combine existing initiatives (Sparrow sediment model, NZEEM, Hicks erosion surface). Bring in elements of SedNet. Collaborative between NIWA and Landcare Research.
Catchment or regional erosion risk maps	Identification of locations of high long-term erosion risk. Maps of relative erosion risk. Use for prioritisation of locations for mitigation measures.	Semi-quantitative or expert-based, map-based assessment of relative risk of erosion as a function of topography, geography, climate, land-cover, land-use.	Build on existing models (e.g., maps of landslide risks based on post-event observations of historical slipping; Dymond et al. landslide susceptibility analysis). Package and distribute these and increase spatial coverage.
Gravel transport / extraction	Bed aggradation in gravel rivers, and associated reductions in channel flood conveyance. Use for planning extraction timing and amounts and flood risks.	Based on river sediment transport model, probably with empirically based lateral source rates. Output resolution to the reach level. Incorporates extraction rates and timing, bed level changes.	FRST gravel-river research programmes? Existing river sediment transport models may be suitable.
Stream-bed fine sediment model	Build-up and flushing of fines in the bed of gravel-bed rivers. Use to identify environmental response to increases or reductions in sediment loads.	Links daily or event catchment model with reach level stream model, including a fine sediment deposition and infiltration model.	New modelling initiative.

4. Current CRI research funding

NIWA

- Raglan Fine Sediment Study (FRST and Environment Waikato). 2006/2007: detailed linked physically-based catchment, stream, and estuarine models. Testing against detailed measurements through a flood. 2007-2009: development of management-level tools. Includes subcontract to Landcare Research for landslide component to SHETRAN (detailed research-level model) and erosion process investigations.

- SPARROW (national empirical model) application for sediments (FRST and Envirolink). Development of a regional/national model using measured river sediment modelling, building on Hicks sediment-yield surface and NZEEM (Landcare Research empirical erosion model).

- Capability funding for initial ‘proof of concept’ for FSIT interactive fine-sediment catchment-estuary tool.

- Auckland Regional Council urban and peri-urban erosion and contaminant (heavy metal) models linked to estuary models.

Landcare Research

- ICM: detailed process modelling and management scale modelling using NZEEM and SedNet (mean annual semi-empirical erosion model).

- Upcoming bidding on long-term landscape evolution erosion processes (currently Land-to-Ocean programme).

- Capability Fund: 50K$ 2006/2007 (review of erosion models and NZ erosion data, preliminary model development for NZEEM and SedNet).

- Sustainable Land Use Research Initiative: $65K project towards depicting erosion and sediment fluxes at various spatial scales.

- A number of Envirolink and commercial projects identifying erosion risk and sediment transfers.

5. Short-term actions

- Circulate report and summarise in NIWA/Landcare Research newsletters.
- Initiate a steering committee including Landcare Research / NIWA / Regional Councils.
- Presentations to individual councils to help promote funding of this area.
- Presentation to Regional Managers Group.
- Possible Envirolink advice: types of data appropriate for modelling.
- Approach Tasman and Marlborough District Councils to see if their interests are sufficiently aligned. Consider extension to cover South Island councils and issues.

6. Appendix 1: Notes on the Palmerston North workshop

Held in Palmerston North, 25th May, 2006.

6.1 Participants

Landcare Research Ltd:	Alison Collins, Anne-Gaelle Ausseil, John Dymond, Les Basher.
NIWA:	Sandy Elliott, Jochen Schmidt, Mal Green.
Horizons RC:	Olivier Ausseil, Jon Roygard, Malcolm Todd.
Hawke's Bay RC:	John Phillips.
Greater Wellington RC:	Paul Denton, Nic Conland, Jeremy Rusbatch.

6.2 Regional Councils issues and expectations

6.2.1 Horizons Regional Council

Key issues and background

- Water clarity, turbidity (from discussions with community), particularly in the main rivers. This affects aesthetic and recreational values.
- Stream bed fines within gravels (embeddedness). This has implications for biota.
- Sediment accumulation in flood protection channels (aggradation).
- Developing a Water Management Framework, with the catchment broken into management zones (subcatchments), a lot of these tied into monitoring sites. The proposed Water Management Framework Management is based around contaminant *load*.
- SLUI (Sustainable Land Use Initiative). The aim of this initiative is to assess economic consequence of erosion, its impact on infrastructure and ecology. An objective is that 50% farms on highly erodible land will be covered by an active 'whole farm business plan' by 2015.

Uses for a model

- Catchment-scale models could provide justification for action, a basis for assessing spatial priorities, and identify the most cost-effective locations for farm purchase and re-forestation.

- Maps of highly erodible land have already been developed for the region and are being used in SLUI to identify areas for action.

- Primary interest is at the catchment scale. Such a model could identify which farms to involve first, and predict whether SLUI would actually help with the environmental goals.

- A farm-scale model could be useful for developing farm action plans, given that this is the scale at which on-the-ground actions are devised. Need a farm-scale tool to identify the most applicable control measures. Actions to be undertaken at farm scale are still unclear. This farm-scale model could be developed after a catchment model.

Key expectations of a model:

- Connect land data to water quality in the rivers.

- Allow an integrated catchment-scale view of the issues in question.

- Need for a management framework: integrated catchment-scale view of problem and sources of sediment.

- Provide a decision-making tool with predictive capability to prioritise intervention locations.

- Serve as a communication tool.

- Use to refine monitoring programme.

'Parameters for success' for model

- Uses regional datasets.

- Adaptable to or can be mapped to the pre-defined spatial units.

- Uses appropriate indicators, e.g., is 'Total Annual Load', good enough, when real interest is in the number of days per year with low clarity?

- Fully tested and reviewed. Limitations known and tested.

- Includes information on particle size distribution, as different sizes have different environmental implications.

- Can be used in 'reverse' mode (a 'reversible' model e.g., can go from the load goals back to the measures needed on land to meet those goals).

- User-friendly interface that can be used by RC technical staff – at least to assess scenarios.

- Used to assess how quickly effects of mitigation would be seen; includes year-to-year progression.

- Daily model not necessary.

- Provides predictions, including probability for design events.

- Predicts effects of sediment on biota.

- Robustness/reliability: from a general orientation to a use in a legal context.

- High resolution.

- Model based on risk assessment.

6.2.2 Greater Wellington Regional Council

- Earthworks erosion is an important issue in the northern part of Wellington.

- At present use the ARC version of the USLE to assess consents. Would like to enhance the defensibility of this type of model.

- Would like a model to feed into assessments of the acceptable degree of earthworks or forestry in a catchment.

- Modelling could lead into policy re land-use.

- Modelling could be used to provide justification for designing and implementing a monitoring system.

6.2.3 Hawke's Bay RC

Points presented by John Pillips.

Key issues

- Stream habitat. Deposition, embeddedness. This is spatially variable, varies from reach to reach, which creates difficulties for modelling, linking to land use.
- Water quality.
- Issues at HBRC are similar to Horizons, and rural Wellington.

Model uses/objectives

- Link environmental effects to causes. As causes are at field scale, and effects at catchment scale, a model is needed to relate causes and effects.
- Scenario assessment: use as a basis for optimising interventions and setting realistic targets.
- Assessment of timeframes for improvement in environmental conditions following intervention, which will provide information for managing public expectations.
- Assessment of risks and probabilities, again to manage public expectations.
- Use models to predict or test the effectiveness of plan management measures.

Some variables for model to predict

- Number of days per year of low clarity.
- Time to return to good clarity after a storm.
- Time to return to normal conditions after a catastrophic flood.
- Timeframes to restore systems (water quality, habitat).

- Percentage of stream length with good/fair/poor habitat (WQ, bed). Corresponding percent of catchment associated with each of these.

- Proportion of fine/coarse sediment (different effects on habitat).

Table 3. Summary of model requirements from the Palmerston North workshop.

Issue	Parameters	Model output	Spatial scale	Temporal scale	Priority (Horizons/ HBRC/ GWRC)	Driver/mitigation
Soil loss	Area affected (mm/y)	Same	- subcatchment - property/forestry unit/subdivision	- Annual (output) - Event (input)	Medium/ Medium/ Medium	Land cover/land use Riparian: - filter stores - bank stabilisation - Stock exclusion - Stock crossing Constructed wetlands Soil conservation measures (incl. sediment traps) Minimum tillage Tracking/roads Seasonal factors, e.g., summer vs winter cultivation Cover crops (incl. grass, growth rates) Stocking rate (incl. seasonal off-wintering) Hard surfaces: changed runoff & channel hydrology
Stream ecological effects	Embeddedness Substrate size class MCI	% each class per reach "Health grading"	Reach	Timeframe to restore, i.e., lag from source through channel to ocean	High/ High/ High	
Water clarity	Black disk Turbidity Sediment concentration	Number of days acceptable How long after x event acceptable	- Catchment - Subcatchment - Reach?	- Day - Seasonal incl. Flow-related	High/ High/ High	
Reduced flood capacity	- Riverbed level - Cross-section area - Size event contained	- $$ to restore capacity - Tonnes of sediment, in reach, flow capacity	Catchment	- Event - Annual	Medium/ ?/ High	
Estuarine effects	- Substrate texture - Rate of infill (depth - Contaminant load in sediment - Clarity/secchi depth	- Area habitat loss - Recreational suitability - Years to exceed critical limit - Same as for freshwater	Subcatchment (input) Estuary (output) For urban areas: subdivision scale	Same as soil loss and flood capacity	Medium/ High/ High	

7. Appendix 2: Notes on the Hamilton workshop

Held at NIWA, Hamilton, 1 June 2006.

7.1 Participants

Environment Waikato:	Peter Singleton (Chair), Reece Hill
NIWA:	Sandy Elliott, Mal Green, Jochen Schmidt
Landcare Research:	Alison Collins, John Dymond, Les Basher
Environment BOP:	Amy Taylor, Ingrid Pak, Paul Scholes
Gisborne District Council:	Sarah Pitcher-Campbell
Auckland Regional Council:	Grant Barnes, Shane Kelly, Graham Macky, Alex Wilson
Hawke's Bay Regional Council:	Anna Madarasz

7.2 Regional Council issues

Key issues:

- Sedimentation in estuaries.
- Protection of estuaries from sediment deposition in storm events.
- Erosion from building sites (Auckland, Tauranga).
- Urban stream erosion.
- Sediment from forest harvesting (north of Auckland region, Coromandel).
- Soil conservation, gross erosion, keeping the soil on the land (for Gisborne soft rock areas).
- Effects of sediment on marine systems (not just estuarine).

- Contaminants associated with sediments (e.g., zinc from facial eczema treatment).

- Gravel river loads. Build-up of sediment and the associated reduction in river flood conveyance is an issue. River managers want to know when and where to remove sediment. They would like to know the catchment inputs of sediment into the streams, so that not too much sediment is taken out of the system (for BOP and sometimes in Waikato).

- Suspicions that sediment deposition in the marine environment near river-mouth estuaries may be issue (Hawke's Bay).

- Of low importance for ARC: turbidity in streams.

Questions:

- What is the relative contribution from different sources (streambank erosion, slips)?

- Is slow accumulation more important than big dumps of sediment into estuaries?

- Restoration of estuaries: can this be done, for example by dredging?

- What rain intensities cause the damage?

- How fast is the sediment accumulation in estuaries, what is causing it (EBOP, Hawke's Bay)?

- How much of what we see now is due to historical land use? May historical bank/overbank deposits be re-mobilised?

- Is it possible to define/specify a suitable target for sediment loads for estuaries?

- Will riparian retirement hurt or help streambank erosion (see Parkyn's estimates of erosion after retirement). The temporal component is important here.

7.3 Model requirements from Regional Councils

A categorisation of models (see table below) was put forward.

Type 1 Lookup tables, expert systems	Type 2 Effects assessment	Type 3 Budgeting, prioritisation, source allocation	Type 4 Target-based
- Local-scale (urban development, forest lot) - Does not address biological effects	- Risk assessment and receiving environment focus. - Given a certain development, management, or land-use scenario, what is the ecological or system outcome?	- Use to target sediment sources, areas for mitigation, vulnerable habitats	- How can a specified desirable environmental outcome be achieved?

Several model types were also suggested:

1. Simple soil conservation lookup tables

Simple lookup tables, expert-based. Similar to NPLAS. Use for farm plans. Similar in some respects to UCM land component. As an example, would give the reduction in erosion from planting a particular area in poplars, and the associated cost. Provide mean annual soil loss (mm/year) and also loss (extent of slips) in large reference storms.

2. Urban earthworks development-scale model

Risk for different event sizes at development scale. What could be the mitigation measures on a particular site (ponds, etc.), where to place them and how effective would they be. Look-up type model, of similar complexity to the USLE (which is used at the moment). Need to provide some standardised inputs/coefficients, such as rainfall erosivity, hillslope delivery ratio. USLE currently does not provide event runoff or give the effect of ponds for different storm events. The event scale is of interest for deposition probabilities and depths in estuaries, and for providing perspective for monitoring call-outs for earthworks.

3. Model to assess cumulative catchment-scale aggradation in estuaries, change in morphology.

The features of this model were not elaborated upon.

4. Forestry model.

There is a need to assess the loss from forestry as a function of length of road, area of cutover, areas permanently retired, as well as other mitigation measures such as large sediment traps. Sediment size is likely to be important in relation to impacts on estuaries. A risk-based or probability-based model is suitable for assessment of estuarine effects. Model conclusions or summary results could be used for development of rules and for working with the land manager. The rules could run parallel to a farm ‘nutrient management plan’.

5. Farm/rural erosion model

Needs to provide a risk analysis of the relative importance of different sources of sediment; focus on forestry as the source of sediment is not necessarily appropriate. Streambank erosion component needed. Will riparian retirement help or hurt? Should streams be re-graded (enlarged), or should hydrology be modified to address this? The temporal/risk component is important for such a model. For example, are sudden forestry-related impacts more important than ongoing pasture impacts?

6. Gravel river model

Model to assess catchment inputs and aggradation of gravel, to provide information on where and when to extract gravel.

7.4 Funding

This was not addressed in detail. An Envirolink project to package up existing information and models was thought to be suitable. A lookup table approach would work for this purpose.

8. Appendix 3: Summary of survey responses

Nine responses to the survey were obtained. In some cases the participants from a particular institution combined their responses into a single response. The tallies for different responses are shown in the format of the original survey form below, followed by a summary of the responses for each question in turn.

Key points from the survey are:

- Many of the survey participants assigned a high or medium importance to a range of erosion-related issues. The classes of issue with greatest priority were: estuarine infilling and sediment deposition; pasture and soil degradation; and sediment-related water quality in streams.

- There was strong support for a wide range of mitigation measures to be included in the models. The highest priority mitigation measure was vegetative bank stabilisation, followed by riparian filter strips, ponds and wetlands, track and road erosion, conservation planting, stock access to streams, and pasture cover management.

- Nearly all responses included bank erosion and stream downcutting, and track and road erosion, as processes of high priority for inclusion in the model. Raindrop/overland-flow erosion, gully erosion, slips, landslides, bedload transport and deposition, floodplain deposition, and settling in estuaries were of high priority for about half the respondents. Rilling, debris flows, floodplain deposition, flocculation, re-mobilisation of estuarine deposits, and coastal sediment dispersion were of intermediate importance. Long-term stream shape and landscape evolution, and estuarine hydraulics and wave mechanics were of lowest priority.

- Sediment deposition depth, sediment load, and particle-size distribution were seen as important variables for model prediction, with less interest in concentration predictions. The relative risk of erosion was seen as a useful model output in about half the responses. One response noted that the model should predict soil loss (mm/year).

- There was near unanimous support for models that could run over a decade or longer. All the participants thought the model should have a long-term cumulative impact assessment component.

- There was most interest in models that could provide outputs with a daily or storm-event time resolution. Annual average predictions and probabilistic predictions were also of interest. There was little interest in model predictions at the sub-event scale.

- All the respondents wanted a model capable of operating over the catchment scale; with the catchment broken into subcatchments or subdivided subcatchments. There was also interest in a separate model at the hillslope or property scale.

- In terms of the stream component, a model providing outputs resolved to the reach scale was seen as suitable in most cases, although there were some calls for a 2-D or 3-D grid. While a compartment model was generally considered suitable for the estuary component, finer subdivisions (2-D or 3-D grid) were also seen as appropriate in some cases.

- Nearly all respondents thought the model should be GIS-based, and all thought it should have a graphical user or spreadsheet interface.

- The model should be able to be used by skilled-council-staff users; there is also a role for models aimed at more specialist users.

- There was support for a model with links to water quality and ecological models. There was little support for a cost/economic module.

- None of the existing models currently used in New Zealand stood out as being particularly well suited for use by a wide range of the survey respondents.

- One response noted that pest management was of considerable importance.

The responses to each question are tallied below, along with summary text for each question:

Q1. What are the key sediment-related issues in your area?

	H Priority	M	Sum (/9)
Pasture/soil degradation	6	1	6
River turbidity	3	2	5
Channel widening/migration	3	1	4
Estuary turbidity	2.5	2.5	5
Sediment-related nutrients	4	2	6
Sediment-related bacteria	4	2	6
Estuarine deposition events	4	2	6
Estuarine infilling	7.5	0.5	8
Estuarine sediment texture	2.5	3.5	6
Coastal turbidity	2	2	4
Sediment impacts on aquaculture	2	2	4

Other/Comment Gravel management (H+). Estuarine deposition is of most concern. On-site erosion causing loss of 'soft rock' together with the overlying soil (H). Urban sprawl.

A wide range of sediment-related issues was considered to be important (high or medium priority). Each issue was given a high or medium priority in 61% of responses, demonstrating the importance of sediment-related issues.

Estuarine infilling was the issue of highest priority (8 responses out of 9 medium or high priority), followed by pasture/soil degradation (7 responses), estuarine deposition events and sediment texture (6), sediment-related nutrients and bacteria (6), river turbidity (5), estuarine turbidity (5), sediment impacts on aquaculture (4), channel widening/migration (4), and coastal turbidity (4). One participant from Environment BOP noted that gravel extraction was a very high priority issue.

Broadly speaking, the classes of issue with greatest priority were estuarine infilling and deposition events, pasture and soil degradation, and sediment-related water quality in streams.

Q2. What are the key mitigation measures that you would like the model to be able to reflect?

	H Priority	M
Pasture cover management	5	1
Streamside stock access	3.5	2.5
Track and road erosion	6	1
Planting for hillslope stabilisation	5	1
Pasture retirement	3	2
Forest harvesting controls	5	1
Riparian filter strips	7	1
Vegetative bank stabilisation	8	1
Ponds, dams and constructed wetlands	7	
Controlled floodplain deposition	3	2

Other/Comment We would like the model to include all these to prioritise management focus. Pest management (H). Stock type and management; pugging and compaction. Control of urban expansion and associated earthworks. Control of urban sprawl.

There were strong responses in relation to mitigation measures. Items were marked as being of high or medium priority in 72% of the responses and of high priority in 58% of responses. One comment suggested the model should include a wide range of measures, so that the relative importance and effectiveness of various measures could be addressed.

The highest priority was for vegetative bank stabilisation (high priority in nearly all responses), followed by riparian filter strips, ponds and wetlands, track and road erosion, conservation planting, pasture cover management, and forest harvesting controls. Stock access to streams and controlled floodplain deposition were of intermediate interest. The lowest priority was for pasture retirement, but even in that case the item had medium or high priority in about half the responses.

One response noted that pest management was of considerable importance.

Q3. What are the key processes you think should be included in the model

	H Priority	M
Rain-drop and overland flow erosion	4	1
Rills	1	4
Gully erosion	4	1
Track and road erosion	7	
Shallow slips	4	
Landslides	3	1
Debris flows	2	2
Long-term landscape or land-form evolution		2
Bedload transport and deposition	6	
Bank erosion, stream downcutting	8	1
Floodplain deposition	3	2
Long-term stream shape and flood-plain evolution	2	2
Flocculation	1	4

Estuarine/coastal hydraulics and wave mechanics	2	2
Settling in estuaries	4	2
Re-mobilisation of estuary sediments	2	3
Long-term estuary bathymetry changes	1	3
Coastal sediment dispersion	2	2
Other/Comment General land-use sediment generation based on land-use, grade, land-use capability class, urbanisation process.		

Nearly all responses included bank erosion and stream downcutting, and track and road erosion, as processes of high priority for inclusion in the model. Bedload transport was considered high priority in 6 of the responses. Raindrop/overland-flow erosion, gully erosion, slips, and settling in estuaries were of high priority for about half the responses. Rilling, landslides, debris flows, floodplain deposition, flocculation, floodplain deposition, re-mobilisation of estuarine deposits, and coastal sediment dispersion were of intermediate importance, being considered of high or medium importance in about half the responses. Long-term stream shape and landscape evolution, long-term estuarine bathymetry changes and estuarine hydraulics and wave mechanics were the processes of lowest priority for inclusion in the model.

Q4. What parameters would you like the model to able to predict?

None – just relative risk	4
Load	6
Concentration	4
Deposition depth	7
Particle size distribution	5
Other: Deposition area. Loss of soil.	

Most respondents would like the model to be able to predict the sediment deposition depth. The majority wanted load predictions and particle-size distribution, and concentration predictions. The relative risk of erosion was seen as a useful model output in about half the responses. One response noted that it would be desirable to predict the loss of material (presumably, eroded soil).

Q5. What time-scale would you like the model to be able to operate over?

None – relative risk or probabilistic	2
Century	3
Decade	8
Year	6
Day/event	7
Other/Comment. Relative risk noted to be more important than probabilistic in 2 responses.	

Nearly all respondents would like the model to be able to operate over a decadal period; some would like a model that could operate over a century. Models that run over an event were also of considerable interest. Two responses also considered the relative risk of sediment loss (without a time scale) to be of interest.

Q6. What temporal resolution would you like the model to have?

None – just relative risk or probabilistic	3
Annual average	5
Annual average with flow-based load decomposition	2
Annual	3
Daily or event	7
Sub-event	1
Other/Comment. Risk. Relative risk more important than probabilistic. Two models: risk and time-step.	

There was a wide range of responses in the desired temporal resolution of the model. The most common request was for a model with daily time resolution. The next most popular was annual average predictions. There was only one call for models with sub-event predictions, and there were two calls for annual average models with flow-based decomposition.

Some responses queried the possibility of a two-level model: one assessing relative risk of sediment loss; the other providing a temporally resolved prediction.

A distinction would be necessary between the timestep for which the model provides predictions and the timestep on which the model operates (which, to provide accurate predictions, might be finer than the output timestep). The questionnaire did not make this distinction, but we assume that respondents were primarily responding to the time resolution of the outputs.

Q7. What spatial scale would you like the model to operate over?

Hillslope	3.5
Property	3.5
Small catchment	9
Medium/large catchment	8
Regional	2
National	
Other/Comment. Sometimes want hillslope, otherwise catchment.	

All respondents wanted a model to be able to operate over a small catchment or catchment scale. Three respondents would like to be able to run a model at the hillslope or property scale, at least occasionally. It was noted that there could be separate models for separate occasions. Little need was seen for a model that could run over an entire region or nationally.

Q8. What spatial resolution and element type would you like the model to have?

Catchment:	Grid-based	1
	Sub-hillslope	1
	Hillslope	3
	Subdivided subcatchments	9
	Subcatchment	8

	Lumped	
Stream:	Reach	6
	2-D grid	3
	3-D grid	3
Estuary:	Lumped	1
	Compartment	3
	2-D grid	2
	3-D grid	3

In terms of the spatial resolution of the catchment component of the model, the subcatchment or subdivided subcatchments (subdivision according to land use, for example) level was selected in all the responses. As with the temporal resolution, it is unclear whether this refers to the spatial scale at which the model needs to operate, or to the scale of resolution of the outputs, but it is probably the latter.

Only one respondent was interested in sub-hillslsope predictions.

In terms of the stream component, most responses selected outputs resolved to the reach scale, but some called for a 2-D or 3-D grid. It was unclear whether "reach" meant the stretch of stream between confluences, or whether it referred to a fairly uniform stretch (e.g., 100 m).

There were fewer responses for the estuary component. While there was no interest in a completely lumped estuary model, for finer scales, there was equal interest in compartment models and finer subdivisions (2-D or 3-D grid).

Q9. What type of user-interface features do you think are important?

GIS-based	8
Graphical interface	4
Spreadsheet	7
Text-based	
Don't care	

Nearly all the respondents thought the model should be GIS-based, and all thought the model should have a graphical user interface or a spreadsheet interface.

Q10. What type of user level do you think the model should be aimed at?

Public	1.5
Planner	2.5
Skilled council staff	9
Skilled consultant	4
Researcher/specialist	2
Other/Comment. Used by skilled council staff to help the public 'Resource users'. Planners to use or understand to add policy development.	

All respondents thought the model should be aimed at the skilled-council-staff user level. Some thought the model should also be aimed at skilled consultant, researcher/specialist, or planner levels of use. Only one thought the model should be aimed at public users, and even then the suggestion was that the model should be used by skilled council staff to 'help' the public.

Q11. What other components do you think should be in the model?

Cost component	2
Link to nutrients model	5
Ecological effects component	5
Cumulative effects over time (long-term impacts)	7
Cumulative effects over space (aggregative impacts)	4
Linked into integrated modelling system	3
Other/Comment. Cost/benefit economics for farmers. The need to see our recommendations in $$ terms. Cumulative effects relevant to 10-year plans.	

There were only 7 responses to this question. All thought the model should have long-term impact assessment components. Four thought there should be links to nutrient models and an ecological effects component to the model. Four would like the model to consider aggregated effects over space, and 3 would like the sediment model to be linked into an integrated modelling system. There was some support for a cost component.

Q12. Which of the models that have been applied or are about to be applied in New Zealand is closest to your needs?

GLEAMSHELL and WAM	2
HEM (Hillslope Erosion Model)	1
Landslide Risk Model (Dymond)	1
Morgan-Morgan-Finney	1
NZEEM (New Zealand Empirical Erosion Model)	1
Sednet	0
SHETRAN	0
SPARROW Sediment component and CLUES	2
Suspended Sediment Yield Estimator	1
USLE	0.5
WEPP	0
Catchment to Estuary Sediment Tool	2
DHI Estuary and Coastal models	3
FSIT (Fine Sediment Interactive Tool)	0
RICOM (River and Coastal model)	0
Urban Stormwater Contaminant (USC) model	1

This question was answered in only 5 of the response forms. A range of the existing models was considered to be appropriate, but none were overwhelmingly 'supported'; most were supported in only one or two cases. This suggests there is a need for models more closely targeted to the user needs, or for better communication and training in relation the capabilities of the models.

Q13. What other comments or suggestions do you have for the model?

An area of importance is the role of pest controls in altering catchment condition and its subsequent effects on erosion. At the moment funding for pest control (goats, possums) is largely for TB eradication. Funding will be removed in a couple of years because of TB free areas. The worry is that pests will increase and there is a desperate need for info to demonstrate the benefits for continued pest management for resources other than TB. I think this will be nationally of interest to all regional councils.
Has to provide and output which the user can then use to make recommendations for land use which farmers can understand and robust enough for them to agree and adopt.
End-user: on farm or development.

9. Addendum Report: “Background discussion document on types of sediment models, and description of models used in New Zealand”.

This report was prepared and distributed before the workshops, and is included to serve as a background resource document for future reference.

The original version of this report was titled “Sediment model development: Background discussion document".

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Background discussion document on types of sediment models, and description of models used in New Zealand

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28 April 2006

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1. Purpose of this document

This document serves to provide background information in preparation for a series of workshops on sediment erosion and transport models, to be held in 2006. The workshops are intended to work towards agreement on the type and features of a model that can be used by regional councils to assist with the management of on-site erosion and sediment impacts in streams and coastal areas.

To assist with selection of models, this document provides a brief summary of the features of models that have been applied in New Zealand or about to be applied. This serves to inform the workshop attendees of the existing capability of the research providers. The summary also gives the attendees an idea of the range of models that is available internationally, which will help in selecting a modelling approach for their needs. The models are described in terms of a common set of headings such as the spatial and temporal detail included in the models, the processes represented in the models, user interface, intended users for the models, and overall strengths and weaknesses.

Before the list of models is presented, a brief overview of the range and types of erosion/sedimentation models is given. This will give some conceptual structure to the summary of models, and also serves as a framework for specifying desirable model attributes.

Finally, a list of questions is presents to assist with process of identifying a suitable model. It is intended that this will be used during the workshop to provide a common basis for developing and communicating model specifications.

2. General overview of types and features of erosion and sediment transport models

A wide range of models is available for the prediction for the erosion, transport, and deposition of sediment. The headings below provide some ways to distinguish between the different models. Particular models are discussed in the next section and the Appendix.

Range of environments considered

Some sediment/erosion models are concerned primarily with predicting the amount of sediment delivered into streams, others concentrate only on stream processes, and others are concerned only with estuarine or coastal processes. Few models include all of these three environments in an integrated fashion.

Process included

There is a wide range of erosion and transport processes that can occur, and models usually only consider a limited set of models. The processes are summarised in the table below:

Table 1. Summary of sediment erosion and transport processes.

Hillslope and catchment	- Detachment of sediment by rain on hillslopes. - Runoff generation (with various hydrological sub-models) - Erosion of sediment by overland flow (sheet flow or rills) - Re-deposition of sediment on hillslopes, and delivery processes - Trapping by vegetation, buffer strips, and wetlands - Slips and landslides, and runout of these into streams - Gully erosion - Long-term landscape and land-form evolution
Stream and floodplain	- Stream hydraulics - Deposition and entrainment of sediment on the stream bed - Bank erosion and stream enlargement - Floodplain/overbank deposition - Long-term stream shape and flood-plain evolution - Pond and reservoir trapping
Estuarine and Coastal	- Flocculation - Estuarine/coastal hydraulics and wave mechanics - Dispersion - Settling - Biological filtering and re-mobilisation - Wave and current re-mobilisation - Maturation and digenesis - Long-term estuary form changes

Some models include only a single sediment size class (for example, a single size of gravel in a stream or mud in an estuary) while others cater for a number of different size classes and interactions between particles in different classes (for example, stream bed armouring or estuarine flocculation).

Not only do models differ in relation to the processes that are included, but they may represent the same process in different ways. For example, some models may represent hillslope delivery of sediment using detailed descriptions of erosion and deposition down a hillslope profile, while other models may use an empirical relation or 'black-box' conceptual model to describe the hillslope delivery process.

Temporal resolution and scale

Temporal resolution refers to the underlying time-step or temporal discretisation of the model. Some models are run with a sub-hourly time-step, while others have no time component at all (they may just provide an annual average number or a relative risk estimate). The temporal scale refers to the duration of any simulation. Some models only aim to model a single storm event, while others are intended to be run as a continuous simulation over years or decades. The temporal resolution and scale are related to the computational time required to run simulations. The choice of temporal resolution and scale are also related to the intended purpose of the model application.

Spatial resolution and scale

The spatial resolution refers to the size of the computational spatial element, while the scale refers to the size of the area that is being modelled.

The catchment may be split into a grid, hillslope elements, hillslopes, or subcatchments, or just a single lumped catchment may be used. The subcatchments may be broken down by land-use, soil, or vegetation type. The stream network may be broken into reaches or a number of smaller computational elements in 1, 2, or 3 dimensions. Estuaries may be treated as a single 'box', compartmentalised into sub-estuaries or zones, or broken into a 2-D or 3-D mesh.

The spatial scale of the model can be a single hillslope or plot or a single stream reach, or the model can extend to a regional or national scale.

User interface and features

Sediment model development efforts have often focused on development of the underlying algorithms to represent the various processes, with relatively little emphasis on graphical user-interface features to facilitate model set-up, scenario management, and visualisation and summarising of results. This is being addressed in some models, as the general user expectations increase (especially for commercial models), as the amount of spatial data to be managed increases, and as resource managers become more involved in the modelling process. Some models now include sophisticated graphical user interfaces and links with GIS, and this is likely to become more commonplace and even expected. Considerable effort is required to develop such links and interfaces, though. This effort may be reduced to some degree with the application of generic model development frameworks that manage some of the interface tasks. For some users, sophisticated interfaces are considered superfluous, so, for example, a simple spreadsheet model would suffice. Some models can be run over the web, so that the user does not need to set up the model on their computer, purchase support software such as GIS, or provide high-speed computer facilities.

Intended users or uses

The intended uses of erosion and sediment models ranges from research models that attempt to test or improve our understanding of erosion and transport process and rates, to management-level models targeted at land management. Some of the research models are difficult and time-consuming to set up and use, and so are not suitable for routine use by land managers. Other models (for example, the USLE), can be used without a computer and are designed for routing application to soil conservation measures. There is a range of intermediate-complexity models which are intended to be used by land managers, but in reality these are too complex for use by land managers themselves and are best suited for use by specialist modellers, which introduces the danger of a disconnect between the modelling process and decision-making process.

3. Summary of models used in New Zealand by NIWA and Landcare Research

A wide range of models has already been used in New Zealand or are being trialled. These are summarised in the table below. Also, each of these models is discussed briefly in the appendix.

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Table 2a. Summary of hillslope and catchment models applied or about to be applied to sediment in New Zealand.

Model Name	Resolution and scale		Modelling approach	NZ application	User features and level	Output type
	Time	Space				
Hillslope and catchment models						
GLEAMSHELL and WAM	Daily, suitable for long-term continuous simulation.	Catchment scale (typically 10 ha–1000 km^2), grid-based.	Daily model combining hydrology, hillslope erosion and stream network routing, including plant growth and nutrients.	Yes (ARC, EW, etc.)	Catchment modelling expertise required. GIS interface for WAM	Maps of sediment load and text output of flow and sediment concentration time series.
HEM (Hillslope Erosion Model)	Storm event based.	Hillslope scale with slope unit elements.	Uses time-averaged solution of flow and sediment down a hillslope profile.	Yes	Specialist expertise not necessary. Web-based version available.	Value of erosion and sediment yield for the event.
Landslide Risk Model (Dymond)	Time independent. Shows relative risk in large magnitude storms.	Covers all NZ on 15 m grid.	Maps land at risk to landsliding based on geology, vegetation and slope thresholds.	Yes (Horizons.MW)	Expertise not necessary	Map based raster GIS file showing landslide (and sediment delivery) risk.
Morgan-Morgan-Finney	Daily	Hillslope to catchment scale.	Predicts annual soil loss from hillslopes using rainfall-runoff model, physically based. Includes P component.	Not used in NZ yet, LCR investigating use here.		Value of daily sediment load
NZEEM (New Zealand Empirical Erosion Model)	Mean annual erosion rates.	Covers all NZ on 15m grid.	Based on SSYE (see below) but with land-use factors applied.	Under development	Expertise not necessary.	Raster GIS file giving mean annual specific sediment yield.
Sednet	Mean annual average load.	Catchment scale, originally developed for large catchments (>1000 km2).	Sediment budget approach, strong spatial component.	LCR currently undertaking trial in the Manawatu. Popular in Australia.	Targeted to management, includes a GIS-like interface	Graphical spatial output of annual average sediment loads.
SHETRAN	Resolution down to seconds. Duration of simulation dependent on computing resource.	User-defined 3D grid cell size. Usually applied to small to medium catchments.	Detailed physically-based 3-D model including stream component. Landslide component added recently.	Yes (Raglan)	Research-level model	Text based input and output, no graphics.

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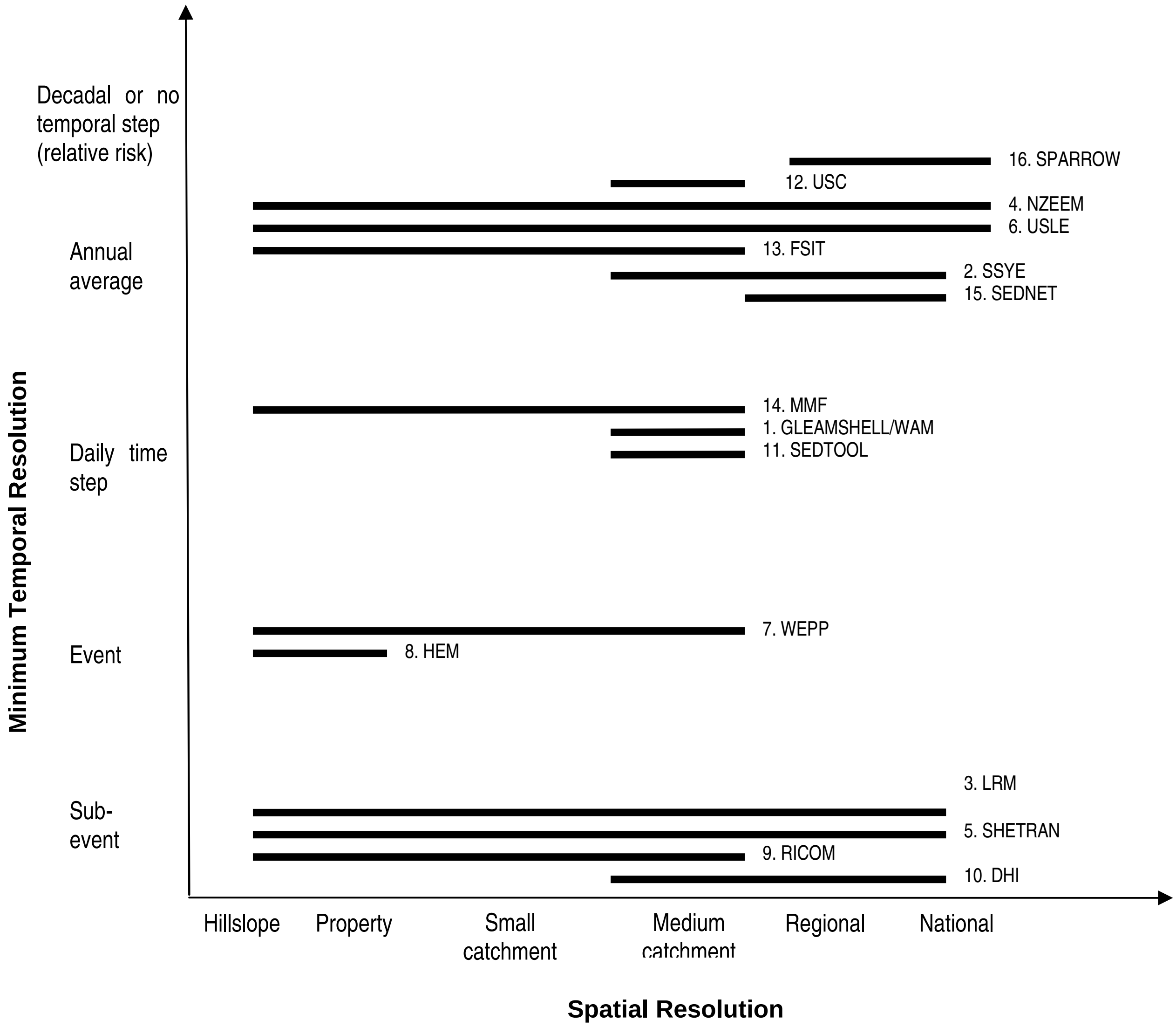
SPARROW Sediment component and CLUES	Mean annual average load.	National/regional scale, based on REC (~0.5 km2 subcatchments).	Sediment yield and stream sources routed down network, calibrated to measured loads. CLUES is a framework linked to other models.	Only to nutrients so far. Application to sediments is in current FRST programme.	Modelling expertise required for calibration. GIS interface for altering land-use and viewing results.	GIS output showing mean annual sediment load from SPARROW and outputs from other models.
Suspended Sediment Yield Estimator (Hicks Erosion Surface)	Mean annual load.	Covers all NZ on 100 m grid.	Empirical model based on gauged sediment yields.	Yes (NIWA and LCR)	Expertise not necessary – although GIS experience useful	Map based raster GIS file giving sediment yields.
USLE	Annual average erosion rate.	Hillslope scale, no spatial subdivision.	Empirical model based on plot study observations. Widely used.	Yes (LCR, consultants)	Specialist expertise not necessary	Spatially and temporally averaged erosion rates.
WEPP	Single storm and daily long-term simulation options.	Hillslope to catchment scale.	Detailed process-based model.	Yes (forestry, urban earthworks, sediment retention)	Catchment modelling expertise required.	Several output options available including annual sediment yield predictions.

Table 2b. Summary of stream, estuary and integrated models applied or about to be applied to sediment in New Zealand.

Model Name	Resolution and scale		Modelling approach	NZ application	User level	Output type
	Time	Space				
Stream, estuary, and integrated models						
Catchment to Estuary Sediment Tool	Probability of critical event load exceedance. Underlying models are more detailed.	Catchment/estuary scale. Underlying models may be more detailed.	Simple GUI to interpret results from detailed sediment generation and deposition models	Yes, single application to an example urban/periurban catchment.	Suitable for use by managers or informed public. Specialist expertise is required for underlying models. Simple graphical interface.	Load probabilities.
DHI Estuary and Coastal models	Resolution down to seconds. Often applied to a few tidal cycles due to computational constraints.	Estuary or coastal embayment scale. Spatial resolution in metres.	Commercial sediment budget type package, comprehensive hydrodynamic model.	Yes, numerous	Catchment/coastal modelling expertise required.	Sophisticated visualisation of dispersion and settling.
FSIT (Fine Sediment Interactive Tool)	Daily (probably)	Catchment and estuary scale, minimal spatial subdivision.	Summarises results of more detailed models within a simple GUI	Model not yet developed	Simple and targeted to management	Not yet determined
RICOM (River and Coastal model)	Fine time resolution. Suitable for long simulations subject to computation constraints.	Reach to catchment scale for streams, small estuary to harbour scale for coastal component.. Fine spatial resolution.	Advanced 3-D finite-element hydrodynamic model.	Yes (Raglan FSS, Kaikoura tsunami modelling).	Hydraulic modelling expertise required.	Graphical and text displays.
Urban Stormwater Contaminant (USC) model	Annual to decadal.	Estuary divided into sub-estuaries based on sediment characteristics.	Predicts accumulation of sediment and contaminants in estuaries over planning timescales	Yes, (ARC,RDC)	Expertise required	Annual sediment and contaminant accumulation

The resolution and operating range of the models presented in the table above are illustrated in the following schematic:

Figure 1. Schematic of spatial and temporal resolution/scale of sediment models that have been or are about to be applied in New Zealand.



4. Questionnaire on needs for a NZ management-level sediment model

A questionnaire on end-user needs is appended to this document. The questionnaire serves the purpose of prompting end-users for their needs and obtaining responses, and as a basis for comparison of responses in a consistent fashion. It is anticipated that the questionnaires will be completed by attendees before or during the workshops, and that the results of the questionnaire will be summarised during and after the workshops.

A D D E N D U M R E P O R T

5. Appendix A: Description of sediment models used in New Zealand

First the hillslope and catchment models are presented, followed by stream, coastal and integrated models. In each case, the models are discussed in alphabetical order.

5.1 Stream, Coastal, and Integrated models

GLEAMSHELL and WAM

Temporal resolution and scale: Daily, suitable for long-term simulation.

Spatial resolution and scale: Catchment scale. Catchment broken up into square cells (typically 0.1-10 ha). Reach-based flow and sediment routing.

Description: The hydrology and overland-flow erosion components for each cell are based on the field-scale CREAMS model. The hillslope erosion component is similar in some respects to the USLE but includes a runoff component and sediment routing down the hillslope. WAM includes a stream routing component with a deposition velocity and an entrainment velocity for excess shear. Includes buffer-strip and wetland filtering of sediment.

Applications in NZ: Catchment-scale assessment of effects of earthworks associated with urbanisation around Auckland (Okura, Mahurangi, Waitemata Harbour, Whitford); Linked with estuarine models; Applied in a rural setting to Whatawhata; Applied for nutrient modelling to Lake Taupo catchment.

User features and level: GIS-based interface available. Most suitable for experienced catchment modellers.

Strengths and weaknesses: Standard hillslope erosion and hydrology parameters can be used. No slips, bank erosion, gully erosion.. Expensive to set up and run, although it has been used for management purposes.

References:

Stroud, M.J.; Cooper, A.B.; Bottcher, A.B.; Hiscock, J.G.; Pickering, N.B. (1999). Sediment runoff from the catchment of Okura estuary. *ARC90241/1*.

Knisel, W.G. (1980). CREAMS A field scale model for chemicals, runoff and erosion from agricultural management systems. *Conservation Research Report No. 26.*

HEM (HILLSLOPE EROSION MODEL)

Temporal resolution and scale: Storm event based; longer-term erosion rates by simulating many storms individually.

Spatial resolution and scale: Hillslope scale with irregular slopes broken into slope elements.

Description: This model is physics-based, using a time-averaged solution of the coupled kinematic wave equations for overland flow and the sediment continuity equation for sediment transport to provide spatially distributed soil erosion and sediment yield processes averaged over a specified time period. The HEM is used to simulate erosion and sediment yield as a function of position on a hillslope and to simulate the influence of spatial variability in hillslope properties (topography, vegetative canopy cover and surface ground cover) on sediment yield and mean sediment concentration. It requires limited input parameters (slope length, slope steepness, canopy and surface ground cover, soil erodibility (predicted from texture), and runoff volume.

Applications in NZ: Applied to a plot study at Pukekohe (Cogle et al. 2003).

User features and level: Simple interface and data input. Useable with limited expert knowledge. Can be run on the web

Strengths and weaknesses: Only simulates sheet and rill erosion. Easy to set up and run, and suitable for management purposes at the hillslope scale. Requires runoff volume as an input.

References:

Cogle, A.L.; Lane, L.J.; Basher, L.R. (2003). Testing the hillslope erosion model for application in India, New Zealand and Australia. *Environmental Modelling & Software 18*: 825–830.

http://eisnr.tucson.ars.ag.gov/HillslopeErosionModel/

LANDSLIDE RISK MODEL (DYMOND)

Temporal resolution and scale: Time independent. Shows relative risk in large-magnitude storms.

Spatial resolution and scale: Covers all New Zealand on 15m grid.

Description: Maps land at risk to landsliding by identifying all land above slope thresholds (defined by geology) without protective woody vegetation. Slope thresholds are obtained from a 15m grid DTM and woody vegetation is obtained from a 15m grid woody layer (EcoSat). Risk of sediment delivery to stream network is also assessed from DTM analysis.

Applications in NZ: Used by Horizons regional council for identifying highly erodible land and prioritising soil conservation efforts.

User features and level: Raster GIS output.

Strengths and weaknesses: High spatial detail over large areas. Considers delivery to stream network. Not event based as storm rainfall is not considered.

References:

Dymond, J.R.; Jessen, M.R.; Lovell, L.R. (1999). Computer simulation of shallow landsliding in New Zealand hill country. *International Journal of Applied Earth Observation and Geoinformation, 1*: 122-131.

Dymond, J.R.; Ausseil, A.; Shepherd, J.D.; Buettner, J.D. (2006). Validation of a region-wide model of landslide susceptibility in the Manawatu-Wanganui region of New Zealand. *Geomorphology 74*: 70-79.

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MORGAN-MORGAN-FINNEY

Temporal resolution and scale: Daily time step.

Spatial resolution and scale: Hillslope and paddock scale. Hillslope and paddock scale, although contributing areas can be aggregated and coupled with a transport or hydrological routing model to assess transport through a catchment.

Description: The Morgan-Morgan-Finney model predicts annual soil loss from field sized areas on hillslopes. The model consists of a water phase and a sediment phase. The model is more physically based than the USLE and is more flexible than the CREAMS model. Annual rainfall is used to determine the energy of rainfall for splash detachment. Runoff is assumed to occur when a critical amount of (daily) precipitation is exceeded and the corresponding volume is calculated on the basis of annual precipitation. Transport capacity is determined using the runoff volume, slope steepness and crop cover. Current development is focusing on improving the prediction of likely particle size distribution of erosion and sediment to allow more accurate representation of diffuse pollution risk (e.g., phosphorus and pathogens), and on improving the transport model through key landscape features in terms of capacity e.g., transport capacity through riparian strips, topographic depressions and wetlands.

Applications in NZ: Being considered for application by Landcare Research to New Zealand

User features and level: Daily outputs of sediment and phosphorous.

Strengths and weaknesses: By predicting the particle size distribution of sediment generation able to model nutrient and contaminant transport.

Reference:

Morgan, R.P.C. (2001). A simple approach to soil loss prediction: a revised Morgan-Morgan-Finney model. *Catena 44*, 305-322.

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NZEEM (New Zealand Empirical Erosion Model) (under development)

Temporal resolution and scale: Mean annual erosion rates.

Spatial resolution and scale: Covers all New Zealand with 15-m grid.

Description: This model will be based on the “Suspended Sediment Yield Estimator” but will have land-use (on 15m grid) factors applied.

Applications in NZ: Still under development (expect 1st phase by June, 2006).

User features and level: 15m raster GIS file giving specific sediment yield (mean annual rates). Initially the model will run as an improved sediment yield estimator, but when sediment delivery ratios are better understood and able to be modelled, then the model will predict “real” specific sediment yield.

Strengths and weaknesses: Simple calibrated empirical model. Includes land-use effects. Eventually will model sediment yield and “true” specific sediment yield.

SHETRAN (including landslide risk model)

Temporal resolution and scale: Temporal resolution down to seconds. Long-term simulation possible in principle, but duration of simulation may be limited by computation.

Spatial resolution and scale: 3-D grid-based, with a user-defined grid cell size. The size of the catchment is arbitrary, but is likely to be limited by the maximum number of cells (about 300 cells in each direction) and computational constraints. More cells can be used if the catchment is broken into subcatchments.

Description: Detailed physically based model. Integrates overland flow, groundwater, stream flow. Includes hillslope and stream sediment transport components. Recently modified by Landcare Research to incorporate shallow translational slip failures.

Applications in NZ: Modelling runoff and sediment generation under a large rainfall simulator at Whatawhata. Being applied for the 150-km^2 Waitetuna catchment for single events as part of the FRST Raglan Fine Sediment Study.

User features and level: Research-level model. Text-based input and output, no graphics. GIS pre-processing interface developed by NIWA.

Strengths and weaknesses: One of the most comprehensive models available. Can provide intra-event predictions. Difficult to use and many parameters are required for the model, some of which are difficult to assess. Sometimes unstable. Streams flow around cell edges which is awkward for GIS and can introduce artefacts in stream slope. Computationally intensive (at limits for Waitetuna using 20-m cells).

References:

Adams, R.; Elliott A.H. (in press 2006). "Physically-based modelling of sediment generation and transport under a large rainfall simulator" Hydrological Processes. Available online at http://www3.interscience.wiley.com/cgi-bin/abstract/112510807.

Ewen, J.; Parkin, G.; O'Connell, P.E. (2000). SHETRAN: distributed river basin flow and transport modeling system. *ASCE J. Hydrologic Eng. 5*: 250-258.

SUSPENDED SEDIMENT YIELD ESTIMATOR (HICKS EROSION SURFACE)

Temporal resolution and scale: Mean annual load.

Spatial resolution and scale: Covers all New Zealand with 100m grid.

Description: A map of suspended-sediment yield (SSY, t/km^2/y) was developed based on gauged sediment yields at over 200 river stations. The model relates sediment yield per unit area to a power function of mean annual rainfall and to an 'erosion terrain' classification, and has been calibrated to the river-gauging data. The erosion terrains were defined by Landcare Research on the basis of slope, rock type, soils, dominant erosion processes, and expert knowledge. A GIS layer of yields is available.

Applications in NZ: Erosion-carbon project. Used as a base source layer for the SPARROW P model. Used for assessment of sediment loads to coast.

User features and level: Grid file that can be opened in GIS.

Strengths and weaknesses: Simple calibrated empirical model. No land-use effect. Only estimates sediment yield. No information on sediment sources, contributing processes, or inter-annual variation. No explicit consideration of sediment delivery processes. Useful as a first indicator of likely sediment yield.

Reference:

http://www.niwascience.co.nz/ncwr/tools.

USLE

Temporal resolution and scale: Annual average erosion rate.

Spatial resolution and scale: Hillslope scale, no spatial subdivision

Description: An empirical sheet-rill erosion model based primarily on observations from plot studies. Predicts spatially and temporally averaged erosion rates from 5 factors (rainfall erosivity, soil erodibility, slope-length, slope-steepness factor, cover and management, support practices). One of the most widely used soil erosion models and the basis of many other erosion models (e.g., CREAMS, AGNPS). Has been modified to several newer forms to account for limitations in the original USLE (MUSLE, RUSLE, M-USLE).

Applications in NZ: Used in Landcare Research's erosion-carbon programme to provide national estimates of erosion. Used on urban earthworks to provide estimates of amounts of sediment generated and to evaluate effectiveness of sediment management practices.

User features and level: Simple and easy to use at hillslope scale with limited knowledge. Requires integration into GIS for catchment scale applications.

Strengths and weaknesses: Only simulates sheet and rill erosion. Easy to set up and run, and suitable for management purposes at the hillslope scale. Requires coupling with a transport/routing model in order to predict sediment impacts. Not well representative of volcanic soils.

References:

Wischmeier, W.H.; Smith, D.D. (1978). Predicting rainfall erosion losses a guide to conservation planning. *Agriculture Handbook No. 537*.

Renard, K.G.; Foster, G.R.; Weesies, G.A.; McCool, D.K.; Yoder, D.C. (1997). Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). *Agricultural Handbook 703.*

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WEPP

Temporal resolution and scale: Single storm, daily time-step, and continuous long-term simulation.

Spatial resolution and scale: Hillslope to catchment scale. Breaks landscape into slope and channel segments based on topography and routes sediment between adjacent components.

Description: A detailed process-based model using mainly physics-based equations (kinematic wave equations for overland flow and the sediment continuity equation for sediment transport) to describe hydrologic and sediment generation and transport processes on hillslopes and in streams. A watershed model links the hillslope model to the channel network. WEPP was designed to evaluate management impacts on erosion. The processes represented by WEPP can be broadly characterised as erosional processes, hydrological processes, plant growth and residue processes, water use processes, hydraulic processes and soil processes. The erosion processes represented are sheet and rill erosion, erosion occurring in channels where detachment is due to hydraulic shear, and erosion from ephemeral gullies. It requires a large number of input parameters, many of which are available in databases compiled for the USA and incorporated in the model.

Applications in NZ: Applied to a plot study at Pukekohe (Su, N. et al. 1999), urban earthworks (Winter, E.R., 1998), currently being used in forestry application.

User features and level: Graphical user interface is reasonably user friendly but because of the large data requirements this model is only suitable for experienced modellers, particularly outside of the USA where input parameter databases are not available.

Strengths and weaknesses: Strong process basis but large computational and data requirements limit its applicability. Only suitable for experienced modellers.

References:

Flanagan, D.C.; Nearing, M.A. (1995). USDA - Water Erosion Prediction Project (WEPP). *NSERL Report No. 10.*

Su, N.; Basher, L.; Barringer, J.R.F. & Doscher, C. (1999). Reconstructing the Patterns of Sediment Transport and Related Hydrological Processes Using the WEPP Model, Proceedings MODSIM'99: International Congress on Modelling & Simulation, Hamilton, New Zealand, 6–9 Dec, 1999.

Winter, E.R. (1998). Predicting sediment yield during the earthworks development stage of a subdivision, Auckland, and assessment of the efficiency of a sediment retention pond. M.Sc. thesis, University of Waikato.

SEDNET

Temporal resolution and scale: Mean annual average, although some daily disaggregation routines are being developed.

Spatial resolution and scale: Catchments represented as a grid with subcatchments and links. Originally developed for large catchments (>1000 km^2).

Description: The model is based on an annual average budgeting approach, but with a strong spatial component and some clever methods for assessing some of the budget terms. Budget terms include hillslope erosion (RUSLE with delivery ratio); gully erosion (from measurements); bank erosion (from bank-full stream power and riparian vegetation); bedload deposition (based on flow variability index, mean flow, and slope); overbank deposition based on settling velocity and over-bank flow; reservoir deposition based on settling relation. Now includes a sediment budget model (ANNEX) built around the SedNet concepts but incorporating a baseflow and dissolved component.

Applications in NZ: Landcare Research are currently undertaking a trial application of SedNet to areas in the Motueka and the Manawatu. Popular in Australia.

User features and level: Custom GIS-like user interface. Scenario manager. Mapping of load generated or delivered to outlet, with breakdown by source type. Land-use change tool modifies land uses based on current land use, slope, rain etc. The model is intended to be used by resource managers, but in practice is used by researchers and consultants.

Strengths and weaknesses: Graphical, spatial, simple concepts. Nice interface. No term for slips (although maybe this source could be modelled indirectly using the gully component). Relies on empirical relations that have not been determined for New Zealand.

References:

http://www.toolkit.net.au/sednet

Prosser, I.P.; Rustomji, P.; Young, W.J.; Moran, C.J.; Hughes, A. (2001). Constructing river basin sediment budgets for the National Land and Water Resources Audit. CSIRO Land and Water Technical Report 15/01; 34 pp. Canberra. http://www.clw.csiro.au/publications/technical2001/tr15-01.pdf

SPARROW SEDIMENT COMPONENT AND CLUES

Temporal resolution and scale: Mean annual average load

Spatial resolution and scale: National/regional scale. Spatial framework based on REC (approx 0.5 km^2 subcatchments).

Description: In each subcatchment there are a number of sources, usually characterised by yields for each land-use, and these load are routed through the drainage network with attenuation along the way. The parameters for the model are determined by non-linear calibration to measured loads at gauging stations. This model was developed by the USGS and applied by NIWA in collaboration with the USGS for nutrients for New Zealand. The prediction component of SPARROW (not the calibration component) has been incorporated into the new GIS-based CDRP-funded modelling framework CLUES, which allows the user to change the land-use. That development of that framework is incomplete.

NIWA proposes to apply SPARROW to sediment in the near future, with calibration to the loads determined previously by Murray Hicks. Some applications to sediments have been developed in the USA already. In such applications, stream erosion is treated has been treated as a source term. It is hoped that we will be able to extract the influence of land-use on erosion in this work (as well as precipitation and erosion terrane).

Applications in NZ: Applied to nutrients only so far, plan to apply to sediments.

User features and level: The original USGS model is written in the statistical programme SAS and requires moderate to high modelling skills. The CLUES interface makes it relatively easy to run the model in predictive mode, although this would be best done by someone proficient in GIS.

Strengths and weaknesses: Simple conceptually. Provides uncertainty estimates. Reliance on calibration means that it may be difficult to break the erosion sources down into different components.

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References:

Elliott, A.H.; Alexander, R.B.; Schwarz, G.E.; Shankar, U.; Sukias, J.P.S.; McBride, G.B. (2005). Estimation of Nutrient Sources and Transport for New Zealand using the Hybrid Mechanistic-Statistical Model SPARROW. *Journal of Hydrology (New Zealand) 44(1)*: 1-27

Alexander, R.B.; Smith, R.A.; Schwarz, G.E. (2004). Estimates of diffuse pollution sources in surface waters of the United States using a spatially referenced watershed model. *Water Science and Technology 49(3)*: 1-10.

ADDENDUM REPORT

6. Stream, Coastal, and Integrated models

CATCHMENT TO ESTUARY SEDIMENT TOOL

Temporal resolution and scale: Probabilities of daily loads. Based on long-term daily simulations.

Spatial resolution and scale: Small estuary catchment broken into 3 land-use classes. Estuary broken into 6 segments. The underlying models were much more detailed.

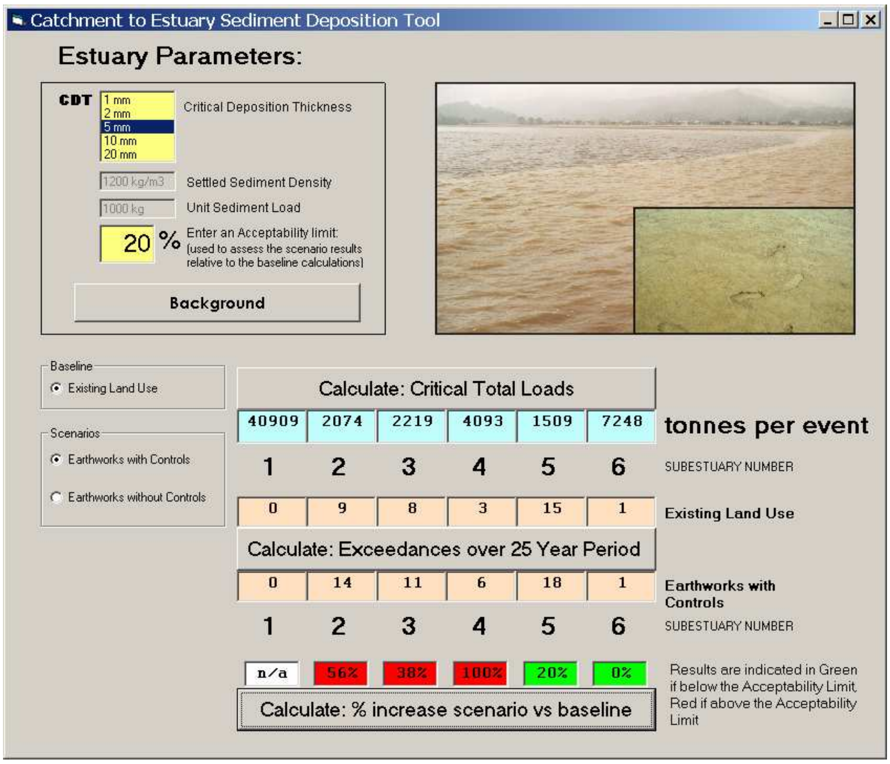
Description: A simple user interface to summarise and interpret the results from detailed simulations in terms of probabilities of exceeding critical event deposition thresholds, with particular relevance to earthworks erosion.

Applications in NZ: Single application to an example urban/peri-urban catchment.

User features and level: The interface for the tool is very simple and could be used by resource managers. The underlying models (WAM, DHI estuary models) require specialist catchment modelling expertise.

Strengths and weaknesses: A simple tool way of summarising key model results. The underlying detailed models need to be set up and run for each new study area.

Reference:
(http://www.niwascience.co.nz/ncwr/tools/sedtool)



DHI ESTUARY AND COASTAL MODELS

Temporal resolution and scale: Typical resolution is minutes to hours, in order to resolve the tidal cycle. Simulation duration typically one week (weather scale) to one month (spring-neap tidal cycle). Longer simulations are possible depending on computing resources and the need to deal with accumulating errors.

Spatial resolution and scale: Typical resolution is metres to tens of metres, which is sufficient in an estuary to capture gross morphology, including sandbanks, channels and sloping intertidal flats. The bathymetry grid typically spans a coastal embayment or an entire estuary.

Description: This is a commercial package, which may include regular or irregular mesh, depth-integrated or 3D. Circulation due to tides, wind stress and the density field (stratified flow) is treated. An evolving (in response to wind and fetch) or static wave field may be superimposed, and wave-orbital motions combined with steady currents in the bottom boundary layer to enhance sediment re-suspension. Non-cohesive sediment transport and cohesive sediment transport may be treated with modules that add-on to the basic hydrodynamic module. Sediment transport includes resuspension from a layered bed (with the cohesive module), flocculation (with the cohesive module) and deposition. External inputs (freshwater, terrestrial sediments) and outputs (loss to the coastal ocean) are treated as sources and sinks in the model.

Applications in NZ: There have been numerous applications in estuaries and on the coast including sewage outflows, stormwater overflows, contaminant dispersal, sedimentation, fate of sediment derived from urban earthworks, and larval dispersal. This model is currently being applied to the Raglan Fine Sediment Study.

User features and level: Although there is no access to the core code, the ECOLAB module allows the user to design and add modules, for example, flocculation. Good pre-processing and graphical post-processing features are standard, including routines for grid generation. Suitable for specialist coastal modellers.

Strengths and weaknesses: De facto industry standard, but lags behind latest developments in research models. Very easy to quickly implement an exploratory model, if needed. Requires considerable work to set up and calibrate a full model. Does not account for evolving morphology.

ADDENDUM REPORT

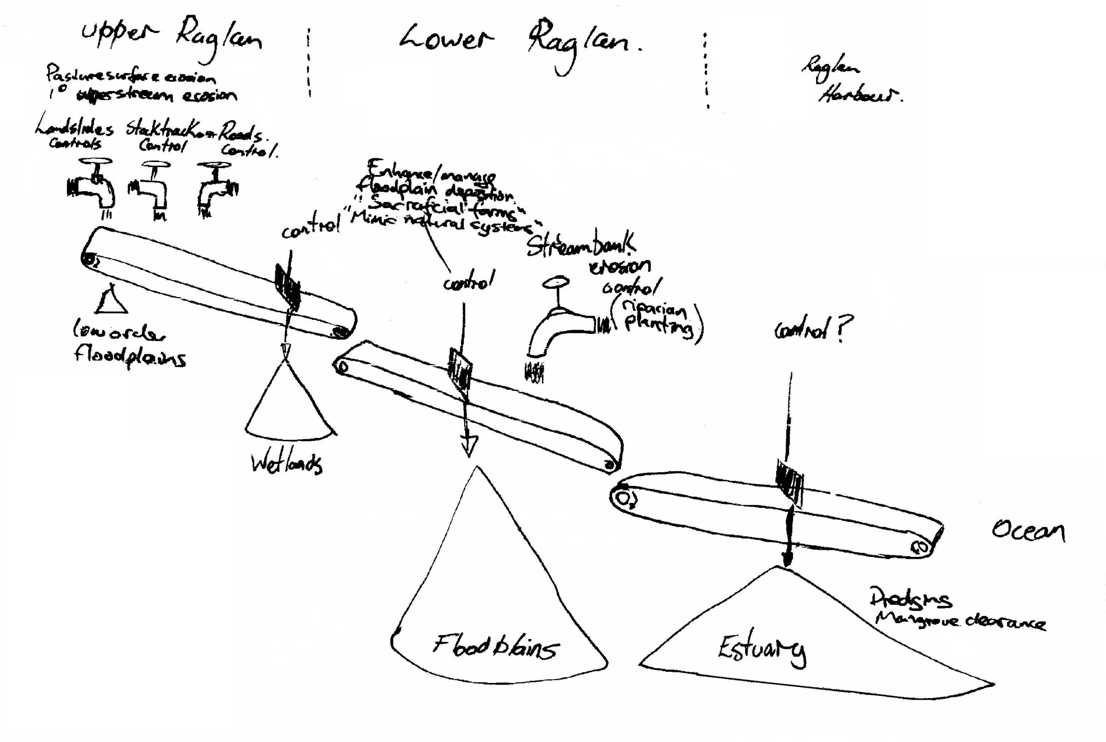
FSIT (FINE SEDIMENT INTERACTIVE TOOL) (PROPOSED)

Description: This model concept was proposed by Peter Hairsine from the CSIRO during a recent research workshop on fine sediments.

The concept is to summarise or capture the results of a more detailed models within a simple graphical user interface that: emphasises the management 'levers' on sources and stores of sediment at various levels in the catchment (for example, km of riparian planting); their effects on key environmental indicators (e.g., rate of estuary deposition); and the associated costs.

It is anticipated that the model would be applied to catchments such as the Raglan catchment and the Murrimbidgee. Funding is being sought for this proposed collaborative project.

User features and level: This model is intended to be simple and targeted on management measures so that it can be used in participatory decision-making. More detailed models would underlie FSIT.



RICOM (RIVER AND COASTAL MODEL)

Temporal resolution and scale: Fine Temporal resolution. Suitable for long simulations subject to computation constraints.

Spatial resolution and scale: Reach to catchment scale for streams, small estuary to harbour scale for coastal component. Fine spatial resolution possible.

Description: This is an advanced 3-D finite-element hydrodynamic model for streams and estuaries, and it includes a sediment transport component. The model was developed by Roy Walters (NIWA). The model contains novel numerical algorithms that stress numerical stability and accuracy.

Applications in NZ: The model is being applied to the main-stem streams (and possibly the estuary) of the Waitetuna catchment in the Raglan fine sediment study. The hydrodynamic component has been applied to tsunami modelling at Kaikoura. The model has been applied in several studies in the USA.

User features and level: Largely used in-house for research and high-level applied studies. Pre-processing and graphical post-processing features are available.

Strengths and weaknesses: Advanced numerical algorithms. Can require large amounts of topographic input data.

References:

Walters, R.A.; Casulli, V. (1998). A robust, finite element model for hydrostatic surface water flows. *Communications in Numerical Methods in Engineering 14*: 931-940.

Walters, R.A. (2005). Coastal Ocean models: Two useful finite element methods. *Continental Shelf Research 25*: 775-793.

URBAN STORMWATER CONTAMINANT (USC) MODEL

Temporal resolution and scale: Annual to decadal.

Spatial resolution and scale: Estuary divided into sub-estuaries based on sediment characteristics.

Description: The USC model predicts accumulation of sediment and sediment-related contaminants in estuaries over planning (years, decades) timescales. This is a "composite model" that combines predictions of catchment sediment runoff and generation of urban contaminants (sediments, heavy metals, PAHs) with predictions of estuarine sediment-transport patterns, all of which are done with underlying, much more sophisticated models.

Applications in NZ: Used in large studies of the Upper Waitemata Harbour and the Middle Waitemata Harbour for the ARC. A simplified version of the model has been applied in the Orewa estuary and the Weiti estuary for Rodney District Council.

User features and level: A user-friendly interface to the model is currently being developed which will allow resource managers to make "what if" explorations without re-running the underlying models. Simplified methods for implementing the underlying models were developed in the RDC project (above) which may greatly reduce cost.

Strengths and weaknesses: Specifically designed as a planning model for investigating possible development scenarios. Provides explicit predictions. The underlying models may be as complicated or simple as desired.

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Appendix B. Questionnaire: End-user needs for a sediment model

Completed by: ______________________________________

Note: If there is a distinct need for more than one model, then it would be appropriate to complete more than once copy of the questionnaire.

Q1. What are the key sediment-related issues in your area?
Mark items that are high or medium priority with and H or M.

Pasture/soil degradation	________
River turbidity	________
Channel widening/migration	________
Estuary turbidity	________
Sediment-related nutrients	________
Sediment-related bacteria	________
Estuarine deposition events	________
Estuarine infilling	________
Estuarine sediment texture	________
Coastal turbidity	________
Sediment impacts on aquaculture	________
Other/Comment ___________________________	________

Q2. What are the key mitigation measures that you would like the model to be able to reflect?
Mark items that are high or medium priority with and H or M.

Pasture cover management	________
Streamside stock access	________
Track and road erosion	________
Planting for hillslope stabilisation	________
Pasture retirement	________
Pasture retirement	________
Forest harvesting controls	________
Riparian filter strips	________
Vegetative bank stabilisation	________
Ponds, dams and constructed wetlands	________
Controlled floodplain deposition	________
Other/Comment ____________________________	________

Q3. What are the key processes you think should be included in the model

Mark items that are high or medium priority with and H or M.

Rain-drop and overland flow erosion _________
Rills _________
Gully erosion _________
Track and road erosion _________
Shallow slips _________
Landslides _________
Debris flows _________
Long-term landscape or land-form evolution _________

Bedload transport and deposition _________
Bank erosion, stream downcutting _________
Floodplain deposition _________
Long-term stream shape and flood-plain evolution _________
Flocculation _________
Estuarine/coastal hydraulics and wave mechanics _________
Settling in estuaries _________
Re-mobilisation of estuary sediments _________
Long-term estuary bathymetry changes _________
Coastal sediment dispersion _________
Other/Comment ______________________________ _________

Q4. What parameters would you like the model to able to predict?

Tick relevant items.

None- just relative risk _________
Load _________
Concentration _________
Deposition depth _________
Particle size distribution _________

Q5. What time-scale would you like the model to be able to operate over?

Tick relevant items.

None – relative risk or probabilistic _________
Century _________
Decade _________

Year _________
Day/event _________
Other/Comment ______________________________ _________

Q6. What temporal resolution would you like the model to have?
Tick relevant items.

None – just relative risk or probabilistic ________
Annual average ________
Annual average with flow-based load decomposition ________
Annual ________
Daily or event ________
Sub-event ________
Other/Comment ____________________________ ________

Q7. What spatial scale would you like the model to operate over?
Tick relevant items.

Hillslope ________
Property ________
Small catchment ________
Medium/large catchment ________
Regional ________
National ________
Other/Comment ____________________________ ________

Q8. What spatial resolution and element type would you like the model to have?
Tick relevant items.

Catchment: Grid-based ________
Sub-hillslope ________
Hillslope ________
Subdivided subcatchments ________
Subcatchment ________
Lumped ________
Stream: Reach ________
2-D grid ________
3-D grid ________
Estuary: Lumped ________
Compartment ________
2-D grid ________
3-D grid ________
Other/Comment ____________________________ ________

Q9. What type of user-interface features do you think are important?
Tick relevant items.

GIS-based ________
Graphical interface ________
Spreadsheet ________
Text-based ________
Don't care ________
Other/Comment ____________________________ ________

Q10. What type of user level do you think the model should be aimed at?
Tick relevant items.
Public ________
Planner ________
Skilled council staff ________
Skilled consultant ________
Researcher/specialist ________
Other/Comment ____________________________ ________

Q11. What other components do you think should be in the model?
Tick relevant items.
Cost component ________
Link to nutrients model ________
Ecological effects component ________
Cumulative effects over time (long-term impacts) ________
Cumulative effects over space (aggregative impacts) ________
Linked into integrated modelling system ________
Other/Comment ____________________________ ________

Q12. Which of the models that have been applied or are about to be applied in New Zealand is closest to your needs?
Tick relevant items.
GLEAMSHELL and WAM ________
HEM (Hillslope Erosion Model) ________
Landslide Risk Model (Dymond) ________
Morgan-Morgan-Finney ________
NZEEM (New Zealand Empirical Erosion Model) ________
Sednet ________
SHETRAN ________
SPARROW Sediment component and CLUES ________
Suspended Sediment Yield Estimator ________
USLE ________
WEPP ________

Catchment to Estuary Sediment Tool ________
DHI Estuary and Coastal models ________
FSIT (Fine Sediment Interactive Tool) ________
RICOM (River and Coastal model) ________
Urban Stormwater Contaminant (USC) model ________
Other/Comment ____________________________ ________

Q13. What other comments or suggestions do you have for the model?

____
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