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A model for simulating the dispersal tracks of sand-sized particles in coastal areas – "SandTrack"

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A MODEL FOR SIMULATING THE DISPERSAL TRACKS OF SAND-SIZED PARTICLES IN COASTAL AREAS - “SANDTRACK”

Richard L. Soulsby (1), ***Christopher T. Mead*** (2), ***B. Robert Wild*** (3), ***Matthew J. Wood*** (4)

Summary

A model is described that simulates the paths taken by a large number of identified particles on the seabed in coastal areas in response to waves and currents. A number of practical applications require such a Lagrangian approach, as distinct from the more traditional Eulerian calculations of the transport rates of bulk quantities of identical particles or grains. Such applications include studies of the dispersal of contaminated particulate material, such as may be associated with industrial discharges, and of the dispersal of dredged spoil.

The model algorithm which determines the movement of particles takes account of the following processes:

- burial and re-emergence,
- initiation of motion and entrainment by combined waves and currents,
- bedload transport,
- suspended transport, and
- turbulent diffusion.

A method of simulating these processes has been devised, by formulating functions to parameterise each of them, and then specifying a particle speed as the product of the functions. The functions are:

- F, a “freedom function”, which can take values of zero or one, and represents particle trapping in the seabed,
- P, a “probability of movement function”, which can take values in the range zero to one, and represents the probability that a given particle on the surface of the seabed is mobile, and
- R, a “relative speed function”, which can also take values in the range zero to one, and represents the speed of a particle relative to the near-bottom current speed. R has separate formulations for suspended transport and bedload transport.

The algorithm is implemented within one of HR Wallingford’s PLUME-RW suite of Lagrangian dispersion models, which was originally devised to track the dispersal of muddy sediments. The model includes a random walk representation of turbulent diffusion. Results from TELEMAC, the finite element hydrodynamic model which HR Wallingford uses to

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compute current fields in coastal waters, are used to drive the Lagrangian model. The effects of waves on particle movement are also included. The wave distribution over a study area can be calculated for use in the particle-tracking model by a number of methods, depending on the application. For example, wave information can be derived by hindcasting offshore wave-heights, periods and directions from a long time-series of wind data, and propagating them inshore using a ray model.

A validation exercise for the new particle-tracking model, SandTrack, is described, as is a predictive study. It is shown that SandTrack reproduces the main features and speeds of particle movements observed in the field, and that it constitutes a powerful tool for predicting the movement of contaminated particles.

Keywords

Lagrangian model, contaminated particles, bedload, suspended load

Introduction

Conventional Eulerian transport models predict the bulk flux of sand-sized particles in the sea, ignoring the identity of the particles. However, for certain problems a Lagrangian approach is required, and the identity of the particles is important (that is, we need to simulate the paths taken by "tagged" particles). Such problems include studies of the dispersal of contaminated particulate material, such as may be associated with industrial discharges, and of the dispersal of dredged spoil. Existing Lagrangian models for very fine sediments, such as HR Wallingford's model SEDPLUME-RW (Mead [1], Mead and Rodger [2]), whilst being well-suited to the purpose for which they were designed, do not include particle trapping in the seabed, bedload transport or incipient motion. The objective of the development of the SandTrack model was to devise algorithms to simulate movements of sand-sized particles within a Lagrangian framework.

The processes that must be simulated, which are not included in conventional Lagrangian models are:

- particle trapping in the seabed and re-emergence,
- threshold and mobility of particles on the surface of the seabed, and
- speed variations of mobile particles (moving as bedload and in suspension).

This paper presents the concepts underlying the SandTrack algorithms that determine particle motion in response to wave and current action. The emphasis is on the movement of contaminated, sand-sized particles, but the model is equally applicable to simulation of the movement of natural sand grains (Soulsby et al [3]).

Algorithm formulation

The aim of the model is to simulate the movements of large numbers (typically hundreds or thousands) of tagged particles at each timestep throughout the duration of the required simulation, and over the study area. Tagged particles, or clusters of tagged particles, are represented by the conceptual model particles of the standard Lagrangian approach (Mead [1], Mead and Rodger [2]). In each timestep, Δt, each model particle is moved a two-dimensional (2D), vector horizontal distance, $\underline{\Delta x} = \Delta t.\underline{U}_{tp}$. Here, the velocity of tagged particle movement, $\underline{U}_{tp}$, is different for each model particle, and is represented by:

$$\underline{U}_{tp} = F.P.R.\underline{U}_c + \text{diffusion} \qquad (1)$$

where:
F is a "freedom function" (trapped=0, free=1),
P is a "probability of movement" function ($0 \leq P \leq 1$),
R is a "relative speed" function ($0 \leq R \leq 1$),

$\underline{U}_c$ is the (2D-vector) current velocity averaged over the bottom 1m of the flow, and turbulent diffusion is represented by the well-known random walk process (see, for example, Mead [4]).

In coastal waters, the tagged particle motion is driven by combined waves and currents, so the formulation must include both. In some cases, the wave motion may be necessary to mobilise the particles, which are then moved by a current that is too weak to mobilise the particles on its own. The model in its present form is designed for relatively deep water; it does not include the detailed processes within the surf-zone.

Although meshed hydrodynamic models are needed to generate distributions of currents and waves, the SandTrack model does not specifically require a mesh, because the position coordinates of each model particle are stored exactly (it can, however, be useful to interpolate particle data to meshes for presentational purposes). The hydrodynamics at the location of each model particle are calculated by interpolation from the mesh of the hydrodynamic model.

Trapping formulation

The tagged particles may be trapped in the seabed to different depths and durations by a number of processes, listed here with their typical depths and timescales of disturbance:

- deposition of natural sediments from suspension (mm, hours),
- migration of natural sand ripples (cm, minutes),
- sandwave migration (m, days to weeks),
- general seabed movement (cm to m, storm to season),
- bioturbation (cm, hours), and
- anthroturbation (cm to m, weeks).

(The term "anthroturbation" was coined originally Soulsby et al [3] to denote disturbance of seabed sediments by human activities, such as trawling, dredging, trenching and anchoring.) Ideally, each of the above processes would be represented by a separate distinctive function. The individual processes are, however, poorly quantified, so an approach is adopted in SandTrack that aggregates together all the trapping processes. It is assumed throughout that the process that caused a given model particle to become trapped can be reversed, so that it becomes free; that is, able to move. Thus, over a given (short) time interval (δt), there is a transition probability, a, that a trapped particle becomes free, and a different transition probability, b, that a free particle becomes trapped. It follows that the probability that a trapped particle remains trapped during the time interval is (1-a), and that a free particle remains free is (1-b). If δt is taken to be "unit time" (for example, 1 second, or 20 minutes or 1 hour), then the probabilities a, b, (1-a) and (1-b) are all probabilities per unit time. This allows a natural time-scale to be introduced.

The residence time of a model particle trapped in the seabed is Poisson-distributed, and the probability that the residence time (T_R) exceeds a chosen value (T) is given by the exponential distribution:

$$P(T_R > T) = e^{-\lambda T} \qquad (2)$$

where $\lambda = a/\delta t$.
If we denote the proportion of model particles that are free by γ, then the long-term equilibrium value of γ is:

$$\gamma_e = a/(a + b) \qquad (3)$$

a and b are the only unknowns in this approach, and these can be determined from Equations (2) and (3) if the equilibrium proportion of model particles free (γ_e) and a target residence-time, T, are specified.

The two-way transitions between the trapped and free states can only take place if the bed is in motion, and transitions are more probable in disturbed conditions. This is represented in the model by allowing the values of a and b to approach their limiting values exponentially as the bed shear stress increases. The functional dependence of the probability is shown in Figure 1 in terms of the maximum Shields parameter, θ_{max}, due to combined waves and currents. θ_{max} is defined as:

$$\theta_{max} = \tau_{max}/g(\rho_s\text{-}\rho)d \qquad (4)$$

where:

τ_{max} is the maximum bed shear stress during a wave period,

g is the acceleration due to gravity,

ρ_s and ρ are the densities of the natural particles and water respectively, and

d is the diameter of the natural particles.

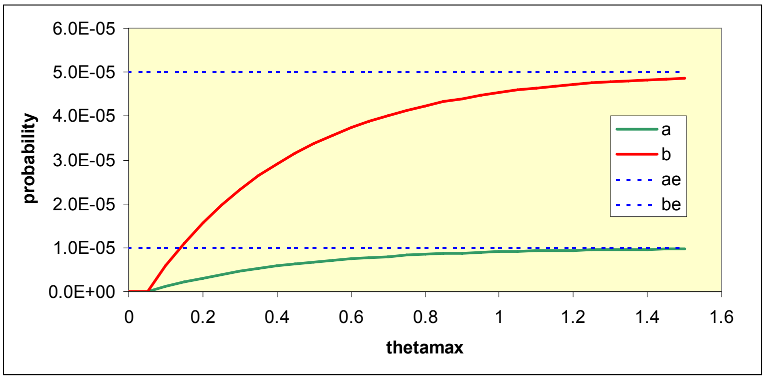

Figure 1 **Dependence of the transition probabilities "a" and "b" on bed stress (reprinted from Wild et al [9], with permission from the Institute of Physics)**

Using the above approach, the value of F can be determined for each model particle in each timestep, based on its value at the previous timestep and the transition probabilities, a and b, using a uniform distribution of random numbers to determine whether a transition occurs.

If a model particle is free (F=1), it lies on the surface of the seabed until moved by the waves and currents as described in the following sections.

Mobility formulation

A free model particle lies on the surface of the seabed until it is moved by the waves and currents represented in the model. The P function represents the probability (or equivalently, percent of time) that a given tagged particle (on the surface of the seabed) is mobile. It is a function of the tagged particle properties and τ_{max}. If the shear-stress is less than the threshold value, τ_{cr}, for movement of the tagged particles (taking into account that they might be a different size to the grains of ambient seabed sediment on which they lie), then the probability of movement is taken to be zero. For larger shear-stresses there is an increasing probability that an individual grain will move during a time-step of the model. This is formulated as:

$P = 0, \text{ if } \tau_{max} < \tau_{cr}$ (5a)

P increases with τ_{max} to 1, if $\tau_{max} > \tau_{cr}$ (5b)

The functional dependence of the probability (Figure 2) is written in terms of θ_{max}. The function is based on an expression given by Fredsøe and Deigaard [5], which in turn is based on the work presented by Engelund and Fredsøe [6] as part of a bedload transport theory for sand grains in steady flows. Here, we have adapted it to combined waves and currents by replacing the original authors' steady shear-stress with τ_{max}. The maximum bed shear-stress, τ_{max}, is calculated from the current speed and wave orbital velocity using the method presented by Soulsby [7]. The wave orbital velocity at the seabed is calculated from the significant wave-height, peak-period and water depth by transforming all the frequencies in an assumed JONSWAP spectrum using linear wave theory by the method of Soulsby [7].

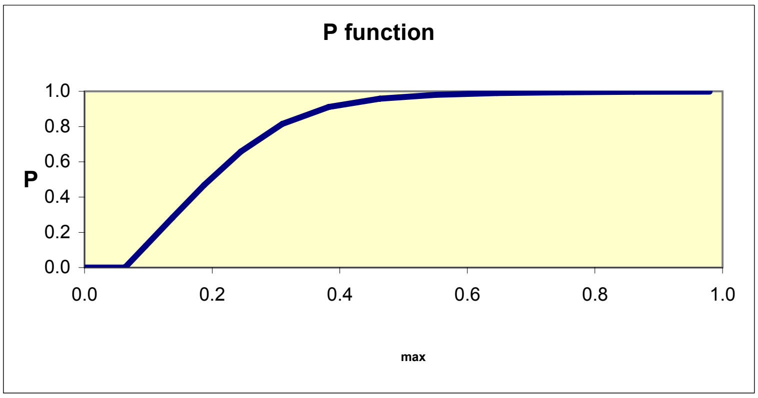

Figure 2 **Dependence of the probability of motion “P” on bed stress (reprinted from Wild et al [9], with permission from the Institute of Physics)**

The possible difference in size of the tagged particles and the grains of ambient seabed sediment is accounted for by using a “hiding and exposure” function when calculating the threshold bed shear-stress. A range of sizes of the tagged particles is dealt with by performing separate runs of SandTrack for a number of different sizes. The degree of grading of the ambient sediment is not accounted for, nor is the possibility that the tagged particles might carpet the ambient sediment at the point of release. Thus, it is assumed that the quantity of tagged particles is very small compared with the quantity of ambient grains, and that the tagged particles do not affect the ambient grain movement, which will generally be true some time after the release.

Relative speed formulation

Once a model particle is mobile (P>0), it will move either as bedload or in suspension. Its speed of movement will be some fraction of the current speed near the bed (usually taken to be the lowest 1m, although this can be varied). The function, R, represents the speed of a given mobile tagged particle relative to the near-bottom current speed. It is a function of the grain properties, τ_{max} and the mean bed shear-stress in combined waves and current, τ_{mean}. It is formulated as:

For bedload, R increases with τ_{max} to about 0.3 - 0.5 (6a)

For suspended load, R increases with τ_{max} (and with decreasing settling velocity) to 1 (6b)

The expression for bedload speed, R_b, is based on the same work (Fredsøe and Deigaard [5]) as the P function, and hence is compatible with it. It is adapted from steady flow to waves-plus-currents by assuming that the particle mobility depends on τ_{max}, while the speed is scaled by the mean friction velocity, $u_{*mean} = (\tau_{mean}/\rho)^{1/2}$, where τ_{mean} is the mean bed shear-stress. The expression for speed in suspension, R_s, is based on the concentration-weighted average speed in the bottom layer, assuming a power-law concentration profile (see, for example, Soulsby [7]). A power-law concentration profile corresponds to an eddy diffusivity that increases linearly with height above the seabed. No account is taken of density stratification by suspended sediment. R_s is taken for R if a criterion for the threshold of suspension is exceeded, otherwise R_b is taken. The value of R only approaches 1 for cases with very fine tagged particles, very fast currents, or large wave orbital velocities. Figure 3 shows a site-specific example of the behaviour of the R-function. In this example, the threshold of motion is exceeded for θ_{max}=0.063, and the threshold of suspension for θ_{max}=0.129.

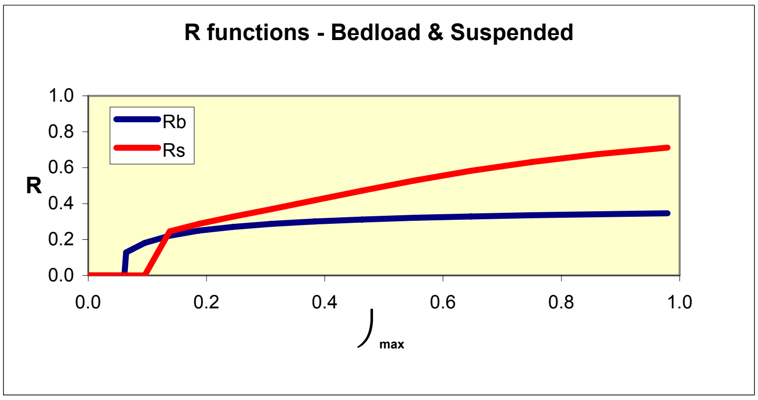

Figure 3 **Dependence of the relative speed factor "R" on bed stress (reprinted from Wild et al [9], with permission from the Institute of Physics)**

Turbulent diffusion formulation

As well as responding to the deterministic forcing by the mean currents and waves, mobile tagged particles will be affected by the turbulent fluctuations in the near-bed velocities. It is standard practice in Lagrangian models to cater for diffusion of dissolved pollutants or fine suspended particles by adding a random vector step of length/direction $\underline{\Delta}_t$ (see, for example, Mead [1], Mead and Rodger [2], Mead [4]).

In SandTrack, a representation of horizontal diffusion is required, but vertical diffusion is included in the formulation for suspension of tagged particles. As in other Lagrangian models, the horizontal eddy diffusivity is given a constant value, typical of coastal flows. However, in SandTrack, this is adapted by multiplying the step $\underline{\Delta}_t$ by the product of the F, P and R functions, and adding this to the deterministic step-length $\underline{\Delta}$. In practice, it is found that diffusion by large-scale, slowly varying processes (for example, waves and wind) is much greater than the small-scale turbulent diffusion. This is consistent with the known characteristics of turbulent diffusion. The randomness applied to individual model particles in SandTrack in both the F function and the diffusion term ensures that particles released simultaneously from the same point follow different, diverging paths, as would separate tagged particles in nature.

Wind-driven dispersion formulation

SandTrack includes wind-driven velocity components in its tagged particle movements. Constant or time-varying wind speeds and directions can be specified as input data and, in each model timestep, these are resolved into long-shore and cross-shore components. Model particles are allocated long- and cross-shore velocity increments which have both ordered and random components. The ordered components are 0.0014 and –0.001 times the wind velocity components in the long- and cross-shore directions respectively, these coefficients being based on correlations between measured winds and near-bed currents derived from both observations and 3D hydrodynamic modelling. In the long-shore case, this gives movement in the direction of the wind, whilst in the cross-shore case, the movement is in the opposite direction to the wind; effectively representing overturning flows in near-shore waters, with downwind flow at the sea surface, vertical motion near the shore and up-wind flow near the seabed. Additionally, SandTrack allows the amplitudes of random wind-driven dispersion components to be applied. In the long- and cross-shore directions, velocity increments are selected from uniformly distributed random numbers in the ranges $\pm\Delta w_l$ and $\pm\Delta w_c$ respectively. Δw_l and Δw_c are site-specific. On the basis of analyses of current meter data, values of Δw_l=0.022ms^{-1} and Δw_c=0.014ms^{-1} are reasonably typical values, which have been used in some previous studies.

Wave asymmetry formulation

To a first approximation, the orbital velocity at the seabed caused by surface waves can be represented by a sinusoidal oscillation. Because the oscillation is symmetrical, a particle is carried just as far backward under a wave trough as it is carried forward under a wave crest, so there is no net movement over a wave cycle. Nonetheless, the wave motion can mobilise particles which are then carried by simultaneous tidal or wind-induced currents. Wave-induced velocities are not, however, completely symmetrical; the forward velocity under the wave crest is larger than the backward velocity under the trough, although it lasts for a shorter time, so that there is no net transport of water. Because sediment transport depends on higher powers of velocity, this wave asymmetry can cause a net movement of particles in the direction of wave travel. The effect is strongest under large, steep waves, and hence major storms can produce a significant onshore movement of particles, which counters the offshore transport produced by onshore winds according to the discussion of the preceding section.

In SandTrack, wave asymmetry is implemented through the inclusion of "asymmetry" step-lengths added (vectorially) to the model particle step-lengths in each timestep calculated as described in the previous sections. These additional step-lengths are based on a simple expression derived to predict the magnitude of the velocity asymmetry as a function of significant wave height, H_s, the equivalent monochromatic wave period, T, and depth.

Wave-induced mass transport formulation

Waves drive sediment in the direction of wave travel by two mechanisms:

- wave asymmetry (see the preceding section), and
- mass transport, otherwise known as boundary-layer streaming, in which the vertical orbital wave motions near the seabed carry sediment up into strong onshore velocities in the upper part of the wave boundary layer, and down into weak offshore movements nearer the seabed.

Myrhaug et al [8] consider the relative magnitudes of the above two effects, and provide a plot of their ratio, R_9 (Figure 4). This is solely a function of $\bar{k}h$, where the wavenumber $\bar{k} = 2\pi /$ (mean wavelength of waves) and h is the water depth. SandTrack utilises an approximation formula fitted to the solid curve in Figure 4, which gives R as a function of $\bar{k}h$. The total bedload transport rate due to both of the above mechanisms is thus equal to that for wave asymmetry alone multiplied by a factor of (1 + 1/R).

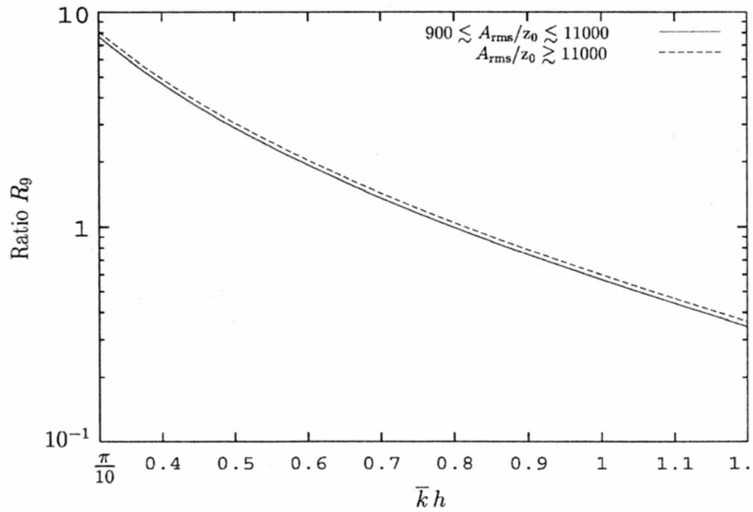

Figure 4 The ratio R_9 versus the product of wave number, k, and water depth, h (reprinted from Myrhaug et al [8] with permission from Elsevier)

The factor (1 + 1/R) ranges from 1.1 in shallow (≤5m) water to 3.5 in deep (≥50m) water (however, both the asymmetry and the streaming effects are very weak in the deeper water).

Implementation of the SandTrack algorithms

The SandTrack algorithms have been incorporated into one of HR Wallingford’s PLUME-RW suite of Lagrangian models. The model is driven non-interactively by water levels, currents and waves, computed over study areas on unstructured finite element meshes, by modules from the TELEMAC system (http://www.telemacsystem.com/gb/default.html). TELEMAC was developed originally by Laboratoire National d’Hydraulique of Electricité de France, and has been extensively calibrated and applied by HR Wallingford in coastal hydraulic studies throughout the world. The wave distribution over the study area can be calculated by a number of methods, depending on the application. For example, by hindcasting offshore wave heights, periods and directions from long time-series of wind, and propagating them inshore using ray models. For simple bathymetries, it is sometimes adequate to hold wave heights constant until the water is so shallow that they break, and inshore of the break-point make wave height proportional to water depth.

Once a set of hydrodynamic inputs has been computed, SandTrack can be run for various tagged particle sizes, release points and scenarios (for example, instantaneous or continuous sources of tagged particles, different times of release). The model particles are transported through the study area according to the algorithm for their individual step lengths at each timestep, as described in the previous sections. The model can be driven by simple repeating tides or by longer time-series of currents and waves. Timesteps from 3 minutes to 20 minutes, numbers of model particles from 800 to 12,000, and durations of simulation from 6 weeks to 60 years have been run for different applications.

Validation exercise, Morecambe Bay

This section presents a validation exercise for SandTrack, undertaken using observations of dispersal of radioactive and fluorescent sand tracers from an experiment in 1968 in connection with a proposed barrage in Morecambe Bay, United Kingdom. The sediment was fine sand, which was suspended by strong tidal currents of up to 1.8ms^{-1}, but with negligible waves. The distribution of the tracer was measured at intervals over six weeks following release. The experiment was simulated using SandTrack, with synthesised currents, a timestep of 20 minutes, and 12,000 model particles representing sand grains of 0.12mm diameter all released at the same point but over several tidal cycles.

The simulated tagged particles spread both longitudinally and laterally relative to the axis of the tidal current, and drifted slowly southwest in response to the ebb-dominant tidal current. Figure 5 shows that the modelled movement of the centroid of the cloud of simulated grains over 50 tides was an accurate representation of the observed movement, in that it moved in the correct direction at the about the correct speed, both initially and subsequently. The longitudinal and lateral spreads were also seen by eye to be similar to the measured contours of radioactivity.

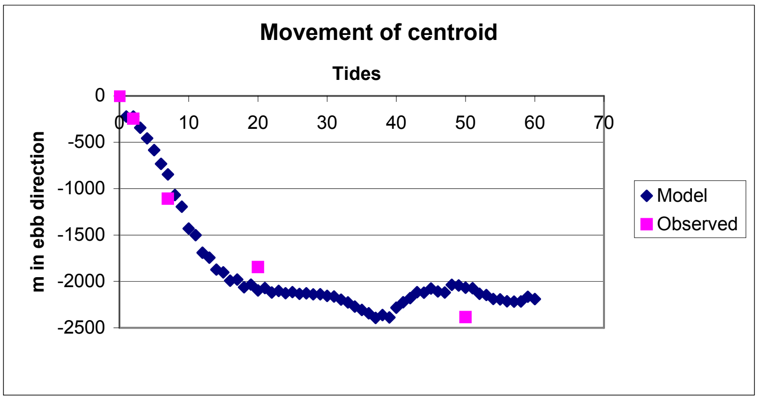

Figure 5 **Movement of centroid of released tracer at Morecambe Bay (reprinted from Wild et al [9], with permission from the Institute of Physics)**

Overall, it was considered that these results indicated a highly satisfactory validation of the SandTrack model, which correctly simulated:

- the rapid initial spread and slower subsequent spread and redistribution of tracer,
- the rate and direction of movement of the centroid of the tracer patch,
- the amplitude of the initial spread, and
- the development of the longitudinal profile.

Validation exercise and predictive simulation, Dounreay

Originally, the motivation for the development of SandTrack was the need to develop a predictive tool for simulating the movement of sand-sized industrial particles released into the sea near Dounreay, United Kingdom, over a number of years. The United Kingdom Atomic Energy Authority (UKAEA) required such a tool to assist the planning of its particle clearing operations. This section summarises briefly results discussed in more detail by Wild et al [9].

A validation exercise for SandTrack in the Dounreay application used the results of a number of particle surveys carried out by UKAEA between August 2000 and May 2003 on four specific "repopulation areas", in which located particles were recorded and removed (more areas were surveyed, but particle recoveries were low, and the results were not used in the model validation). These areas were then re-surveyed at intervals and the newly accumulated particles removed again. The repopulation surveys covered inner circles with 28.2m radii and, for two periods, also covered outer annuli extending for a further 21.8m.

For each repopulation area, a simple-geometry SandTrack model was set up, centred on the middle of the area, and covering a total area of 0.25km^2 (approximately 100 times that covered by each inner repopulation area). Each model was assigned a constant sea bed depth, characteristic of the depth at the centre of its repopulation area. Time series of wave and current conditions corresponding to the three-year survey period were applied to the models. Each model was initialised with model particles distributed at random over its full area, with an average particle distribution density equal to that in the associated repopulation area during the initial survey period in August 2000.

The models were run for the period of the repopulation surveys. Following the initial survey, there were a possible six further survey periods. At times corresponding to these periods, the models counted and removed any model particles that lay within the repopulation areas. Figure 6 shows representative results from the validation exercise, in the form of the numbers of actual and simulated particles recovered for the inner and outer portions of one of the four repopulation areas. This was the area for which the most data were available. The model was generally in good agreement with the data, although it overestimated the number of particles that repopulated the inner area for the last two re-surveys.

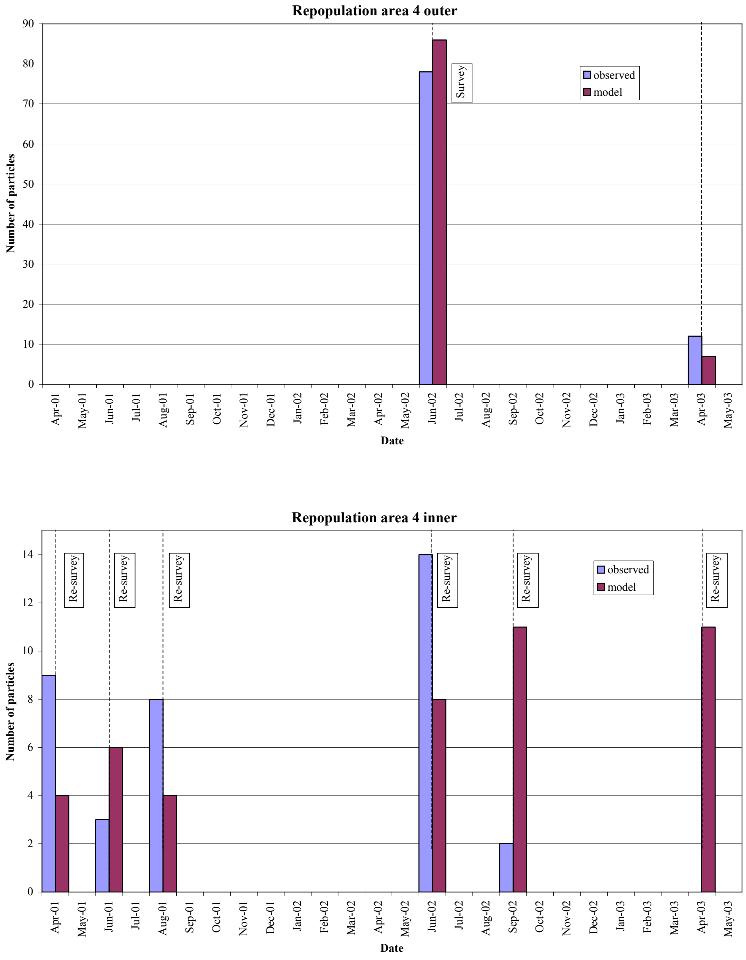

Figure 6 Comparison of model and actual particle recoveries in the Dounreay repopulation areas (reprinted from Wild et al [9], with permission from the Institute of Physics)

Both the model predictions and the natural processes are essentially stochastic in nature, so some variability in the level of agreement between the model and the observed data is to be expected, particularly where the numbers of particles under consideration are small. Overall, for the four repopulation areas, the model predictions were approximately evenly distributed between over- and under-estimation. We conclude that the results of this SandTrack validation exercise were satisfactory, given the expected stochastic variability for small samples.

An example set of results from a series of SandTrack simulations of the movement of the Dounreay particles is shown in Figure 7. In these simulations, particle release took place over a period of a few days at a point source in the late 1960s. The simulated distributions of particles after 30 years are shown for four particle sizes.

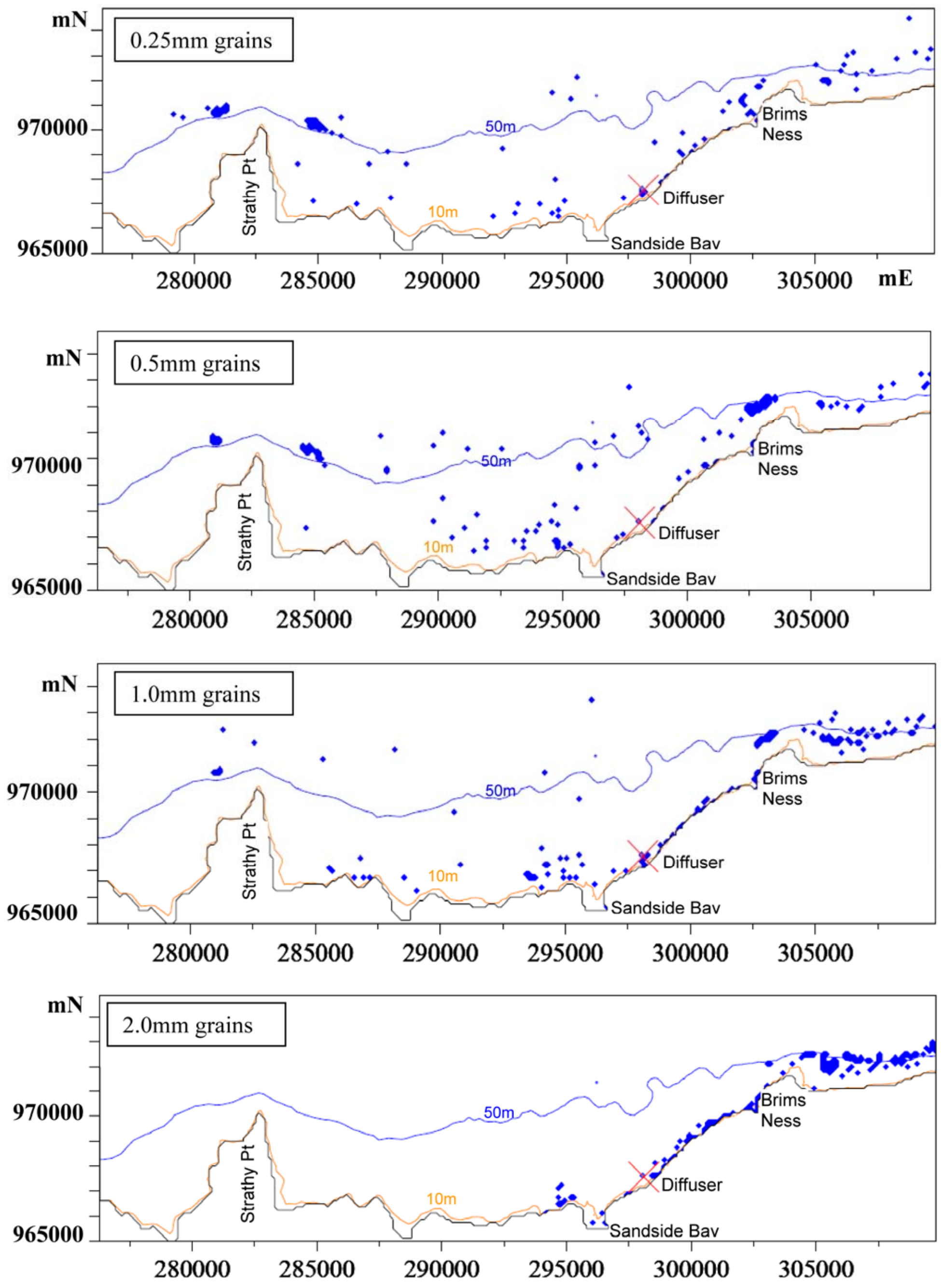

Figure 7 **Simulated particle positions near Dounreay after 30 years (reprinted from Wild et al [9], with permission from the Institute of Physics)**

The results shown in Figure 7 are largely consistent with actual particle recoveries, in that most particles remain close to the coastline, the majority of particles move to the northeast, and some particles enter Sandside Bay. However, the balance of eastward and westward particle movement by size differs from recoveries, and large particles are not found as far from the release point as the model suggests. In addition, recent particle mapping work by UKAEA did not find industrial particles in some of the more widespread locations which had been predicted by the model. The reasons for these inconsistencies are, as yet, not fully understood, but could be due in part to the particle trapping algorithm not dealing effectively with deeply buried particles, releasing them too readily from the bed. However, the quality of the overall comparison with actual particle recoveries is considered to be encouraging.

Conclusions

SandTrack fills a gap in previous modelling capabilities: it can be used to predict the long-term paths of sand-sized particles released into the sea. As well as being a useful predictive tool for assessing the dispersal of industrial particles, it can be used to predict the dispersal of sandy dredged spoil. The model uses an algorithm based on a product of functions describing burial, mobility and speed of individual grains.

Validation exercises for SandTrack based on measurements in Morecambe Bay and at Dounreay reproduced the main features and speeds of tagged particle dispersal. The model has also been applied in simulations of the 30-year movement of released particles at Dounreay, in which application it reproduced some of the main features of the distributions of actual particle recoveries. It is evident that SandTrack constitutes a powerful tool for predicting the movement of contaminated particles.

Acknowledgements

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References

[1] Mead,CT: “Random walk simulations of the dispersal of sewage effluent and dredged spoil”. Proceedings of the 10th Australasian Conference on Coastal and Ocean Engineering, Auckland, New Zealand, pp477-480. 1991.

[2] Mead,CT-Rodger,JG: “Random walk simulations of the dispersal of dredged spoil”. Environmental Hydraulics (eds Lee,JHW-Cheung,YK), pp783-788, Balkema, Rotterdam. 1991.

[3] Soulsby,RL-Mead,CT-Wild,BR: “A model for simulating the dispersal tracks of sand grains in coastal areas – ‘SandTrack’”. Geological Society Special Publication on Coastal and Shelf Sediment Transport. In press.

[4] Mead,CT: “Realisation of the potential of Lagrangian models in aquatic dispersion studies”. Proceedings of the 3rd International Conference on Marine Waste Water Disposal and Marine Environment, Catania, Italy, Paper E18. 2004.

[5] Fredsøe,J-Deigaard,R: “Mechanics of sediment transport”. ISBN: 981-02-0840-5, World Scientific Publishing, Singapore, 369pp. 1992.

[6] Engelund,F-Fredsøe,J: “A sediment transport model for straight alluvial channels”. Nordic Hydrology, 7, 293-306. 1976.

[7] Soulsby,RL: “Dynamics of marine sands”. ISBN: 0 7277 2584 X, Thomas Telford Publications, London, UK, 249pp. 1997.

[8] Myrhaug,D-Holmedal,LE-Rue,H: “Bottom friction and bedload sediment transport caused by boundary layer streaming beneath random waves”. Applied Ocean Research, 26, 183-197. 2004.

[9] Wild,BR-Mead,CT-Soulsby,RL-Wood,MJ: “Sediment tracking – modelling the movement of sand-size particles on the sea bed”. Journal of Radiological Protection. In press.

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