

CHAPTER 1: Introduction to LandSim

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1. INTRODUCTION

About LandSim

Environmental regulators and developers within the UK are using probabilistic risk assessment techniques to assess proposals for waste management facilities with respect to the impact on groundwater. The probabilistic methodology allows improved quantification of uncertainty within the geological environment, the performance of any landfill lining systems and varying leachate chemistry.

One of the many driving forces for the development of this methodology is the difficulty regulators face in assessing any one of the multitude of liner systems and leachate removal systems offered by developers at the permitting stage. Coupled to this is the large variety of geological and hydrogeological regimes beneath and surrounding landfill sites which must, in a proper assessment, be fully considered.

Developed for use by the Environment Agency (the Agency) to provide probabilistic quantitative risk assessments of specific landfill site performance in relation to groundwater protection, LandSim forces uncertainties to be considered and then calculates the confidence in overall landfill performance. This confidence in performance information allows users to better assess the suitability of proposed schemes.

LandSim (Release 1) was developed for the Department of the Environment and NRA under the contract Risk Assessment Methodology for Landfill Engineering EPG 1/7/04 CLO 172. LandSim Release 2 has been developed under Environment Agency Contract CL0294. For those familiar with Release 1, the major changes in this release are set out later in this chapter.

The reference number for this manual is Environment Agency R&D Publication 120.

Program Outline

Because the LandSim model has been encoded using Microsoft's Visual Basic programming language, users with experience of Microsoft Windows will find the program easy to navigate. LandSim follows all Windows conventions in terms of using the mouse, the appearance of input dialogue boxes and results screens.

In short, LandSim enables groundwater risk assessments to be carried out by those without in-depth knowledge of programming.

A cartoon guides you along the path of contaminant transport, from the engineered landfill to a receptor. At each stage along the pathway, you are asked to enter data which enables LandSim to determine the rate of contaminant migration. Parameters are assigned to the model using pop-up dialogue boxes that

are accessed by clicking on active areas of the cartoon or from drop-down menus. To prevent unnecessary data entry the dialogue boxes are customised to the chosen landfill design.

LandSim is a probabilistic model which uses the Monte Carlo simulation technique to select randomly from a pre-defined range of possible input values to create parameters for use in the model calculations. Repeating the process many times gives a range of output values, the distribution of which reflects the uncertainty inherent in the input values and enables you to ascertain the likelihood of the estimated output levels being achieved. Whether you choose to display the LandSim output graphically or in statistical format, report quality printouts can be produced rapidly.

Because LandSim has been written as a modular package it can be upgraded easily and all future releases will be backwardly compatible. This means that landfills modelled with this release can be simulated with future releases using the same LandSim file. Release 1 data files can be read by Release 2 of LandSim, however, entry of a limited amount of additional data may be required.

Changes from Release 1

For those familiar with the operation of Release 1 of LandSim the following section will be a useful starting point in understanding the main changes to the model and the driving forces that dictated that the changes be made.

Multiple Sites

Release 2 allows the modelling of multiple sites. It is quite common that new facilities being authorised will be extensions to existing sites. In order to assess the impact on groundwater, it is desirable to assess the cumulative impact rather than just the impact of the new site. It is possible that the site being assessed is an integral part of a larger site, but each phase may be engineered in a slightly different way. Release 2 allows multiple individual sites and multiple phases to be modelled in a single exercise. The sites can have different infiltration values, different cell geometries, differing liner and engineered barrier systems, and different leachate quality. In addition, the properties of the unsaturated zone (especially the thickness) may also differ. Release 2 allows all of these parameters to be varied between the different phases.

The aquifer pathway must be common to all phases with the only difference being the pathway length and lateral offset to the receptor point.

Biodegradation

Release 2 allows the biodegradation of organic compounds. The decay rate (as a half-life) can be specified for each of the pathways (i.e. unsaturated, vertical saturated and aquifer pathways), and can be enabled for individual pathways if desired. The only restriction is that the rate constants for biodegradation in each selected pathway are

identical for each phase. In other words, you cannot have a different degradation rate in the unsaturated zone beneath each phase. It cannot be over emphasised that the use of the biodegradation function should be used with caution, and a realistic judgement made as to whether the conditions in each of the pathways are likely to be favourable for biodegradation. For a new site it will not be possible to measure the redox conditions that will exist once the site is operational so careful evaluation of the likely redox conditions will need to be made in order to assess the likelihood and efficiency of biodegradation.

Background Groundwater Quality

It is now possible to include the up-stream groundwater quality within the modelling assessment. This may be important for two reasons. Firstly, the existence of certain species within the background water quality may reduce the margin by which additional contaminant load remains within an acceptable range. For example, if chloride background is 75 mg/l and the maximum acceptable impact is 125 mg/l then the load that can be accepted from the new landfill will be much less than that if the background is assumed to be zero. Secondly, for sites that are located in coastal areas, or regions where groundwater quality may be very poor, it is possible that the concentration of some species (especially chloride) might be higher in the groundwater than in the leachate. In such circumstances, the groundwater quality might actually improve (for certain parameters) as a result of dilution of the groundwater with a lower concentration of leachate leakage. It is likely that this phenomenon will be restricted to chloride, but the ability to model this feature is built into Release 2. When reviewing the graphical output of receptor concentration in a case where the chloride concentration in groundwater is higher than leachate, it should be noted that the highest receptor concentrations result from those realisations where leakage or leachate concentration are lowest and not highest as would normally be the case. This is because the leakage of leachate is diluting the groundwater concentrations.

Retardation

Retardation was included in Release 1, but its functionality has been slightly increased. Organic contaminants are normally modelled using partition coefficients to organic matter (K_{OC}) rather than soils (K_D). The ability to enter K_D or K_{OC} and fraction of organic matter (foc) has been implemented.

Relevant K_D values should normally be derived from site-specific data. Standard testing methods have been investigated and recommendations made as to appropriate test methods (Gillespie et al., 2000). K_{OC} values are specific to the contaminant and not the soil but site-specific values for the fraction of organic carbon should be obtained.

Significant retardation of compounds can result in very long travel times. The dispersion of highly retarded species was not dealt with in a robust way within LandSim Release 1. In Release 1, 1-dimensional (longitudinal) dispersion was only included in the aquifer pathway; for other pathways contaminants essentially moved along a pathway as a slug. If a highly retarded contaminant entered the unsaturated zone during the leachate generating period of a

landfill (say 200 years) and took 50,000 years to reach a receptor; LandSim Release 1 would predict that it would arrive at the receptor as a slug between 50,000 and 50,200 years. Dispersion along the pathway should result in considerable "smearing" of the plume and it is improbable that such a condensed "slug" would appear in this manner. LandSim Release 2 has been developed with an ability to disperse the plume based on the dispersion parameters entered in to the model (or hard coded in the case of diffusion), such that the arrival time and period over which the plume will arrive is more realistically represented. Mass is conserved (unless biodegradation is enabled) but the peak concentrations will be reduced in proportion to the pathway length and the degree of dispersion. For very significantly retarded compounds it is possible that the diffusion processes will dominate during the early arrival of contaminants (i.e. the advective migration is slower). It is, however, unlikely that the diffusion driven contaminant concentrations will be significant in most instances.

The modelling of contaminant movement using the retarded mode will have significant implications when considering the impacts from landfills with respect to the EC Groundwater Directive and its implementation via Regulation 15 of the Waste Management Licensing Regulations 1994 or the Pollution Prevention and Control Regulations 2000. Taking mercury as an example, which is a List 1 substance under the Groundwater Directive, its discharge to groundwater is prohibited. LandSim Release 1 will adequately model the contaminant travel time for mercury through an unsaturated zone, but the concentration of mercury would essentially be unchanged from that in the landfill. Thus, if the concentration exceeded the detection limit in the landfill the concentration at the base of the unsaturated zone would also exceed the detection limit. It is also worth noting that LandSim Release 1 does not have the facility to output concentrations at the base of the unsaturated zone making the assessment of List 1 substance entry concentrations (to the aquifer) practically impossible anyway.

Release 2 of the model will allow dispersion of the plume within the unsaturated zone. If the travel time is very large (i.e. greater than 1000 years) it is likely that the peak leachate concentration would be considerably attenuated by the time that the plume reaches the water table, although the total mass ultimately discharged to the aquifer would remain the same. Resultant concentrations might well be orders of magnitude below initial values. Such results are highly sensitive to the actual K_d value used in the assessment and site-specific data would almost certainly be a requirement.

Probability Density Functions

Release 1 allowed uncertainty to be represented by Probability Density Functions (PDFs) but the type of distribution was predefined. Release 2 allows greater flexibility in the type of distribution used for most input parameters. The only exceptions are those used for defining membrane defect rates and leachate concentrations. The latter remain with a choice of either a log triangular or linear triangular distribution. This restriction is needed to retain the functionality of the leachate database in-built into LandSim. The means of entering PDFs into Release 2 is dealt with in the section on 'Entering PDFs in Chapter 3.

Export of Results

Release 2 allows the export of some model results. Leakage values and concentrations at the base of the liner system, base of the unsaturated zone and receptor can be output to a text file in comma separated value format (that can be read by most commercial spreadsheets). The combination of leakage volume and concentration (either beneath the liner or at the base of the unsaturated zone) will allow the flux of contaminants to be calculated and if necessary entered into a different hydrogeological model for assessing more complex hydrogeological regimes.

Results Saving and Reloading

Release 2 can require a significant run time depending upon the complexity of the system being modelled and the run options selected. For this reason an option to save the results of a model run and the option to reload these at a later date has been provided.

Plan View Plume Generator

It is now possible to view the expected values of contaminant concentrations within the aquifer at any user specified time. A colour coded contour plan of the total modelled area or domain is produced along with the site boundaries of the phases being modelled. This option is only available for the expected values and cannot be used to indicate concentrations at other confidence limits.

How this Manual is Organised

This section presents a brief description of LandSim and of working in Windows.

Chapter 2 gives a complete guide to installing LandSim and describes the main LandSim toolbar items that need to be used to get started. The chapter also provides some background to the initial dialogue boxes, probabilistic risk assessment with LandSim, and quality assurance issues.

Chapter 3 shows how to enter parameters in order to set up and run a model, looks at issues for landfill risk assessment (for groundwater receptors) and details the options for running a simulation. The chapter also highlights assumptions that must be borne in mind when assigning values and ranges to input parameters.

Chapter 4 describes what LandSim predicts, how the prediction graphs can be customised and how to interpret the statistics generated by the model. The chapter also describes the important elements of a performance assessment and how to deal with modelling errors.

Chapter 5 contains suggested ranges of input parameters such as permeability, porosity and cation exchange capacities for a range of rock types. In addition, ranges of initial leachate concentration and partition coefficients are suggested for individual contaminants.

Chapter 6, which describes the theory behind LandSim, is a reference chapter and you will probably not need to consult it. However, if you do, you might like to have a hydrogeology text available. Freeze & Cherry (1979), the source of many of the equations used to describe contaminant migration, is recommended.

Chapter 7 presents a brief description of the validation of the LandSim model. The lessons we learnt might help you in assessing your own input parameters.

Your Experience

Don't let LandSim's ease of use deceive you. This program is intended solely for use by experienced professionals with a good background in landfill engineering, hydrogeology and risk assessment.

Your approach will be the key to obtaining useful results. Crucial to their validity will be your thoroughness when developing models and working out uncertainties in the system. LandSim requires that you justify all expressed uncertainties and the output and printed record are locked together with a filename/timestamp system. Your justifications are held in these records for subsequent audit.

What You Will Need

To run LandSim Release 2 you will need an IBM compatible PC with a Pentium Processor with a speed of at least 200 MHz with 32 bytes of RAM. The software has been developed to run under Windows 95/98. It is unlikely that NT users will have difficulty installing and using the Software, but LandSim has not been specifically developed for NT and installation problems are not supported. Users will need 15 Mbytes of hard disk space for installation. Hard disk space required for temporary files during simulation may vary from 10 Mbytes upwards depending on the complexity of the simulation. Complex multi-phase, multiple contaminant simulations may need in excess of 100 Mbytes.

Technical Support

Golder Associates (UK) Limited offers full technical support for LandSim. If you have problems installing the program or getting the code running on your computer, please call the Help Desk (available from 9.30 to 5.00 Mondays to Fridays) or contact us by fax or electronic mail.

LandSim Help

Golder Associates

Tel: (0115) 9456544

Fax: (0115) 9456540

or e-mail us on landsim@golder.com

For problems running the program, or for technical enquiries, Help files are available within LandSim either from the Main Menu or through buttons in each input window.