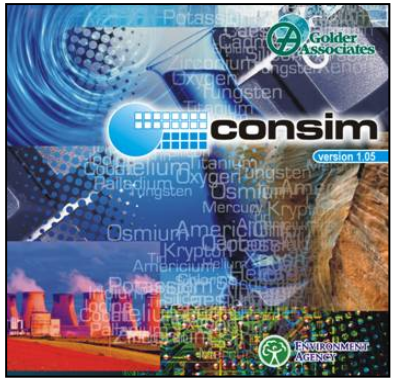


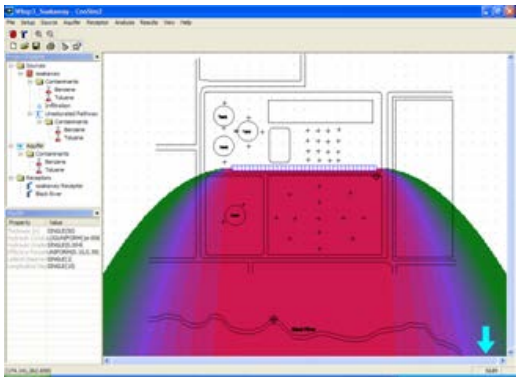

The Environment Agency's probabilistic groundwater risk assessment software: a UK perspective on assessing the risks posed by leaching contaminants

Stephen Barnes and David Hall

Presentation Structure

- **Overview**
  - Software Packages
  - Performance Criteria
- **Operation**
  - Conceptual Model
  - Inputs
  - Why probabilistic?
- **Output**
  - Capability Summary
  - Options
- **Comparison with CCME Tier 2 equations**
- **Summary of Application**

Overview – Software Packages

LAND·SIM

Quantitative assessment of the impact of landfilling on groundwater. First released in 1996 – now v2.5

Quantitative assessment of the impact of contaminated land on groundwater. First released in 1999 – now v2.5

- Output validated during development against ‘measured’ site data from a range of groundwater environments; and since verified by multiple site assessments and users
- Help in decision making, e.g. is there a significant risk to a Domestic Use Aquifer, which of the contaminants should I be worried about?

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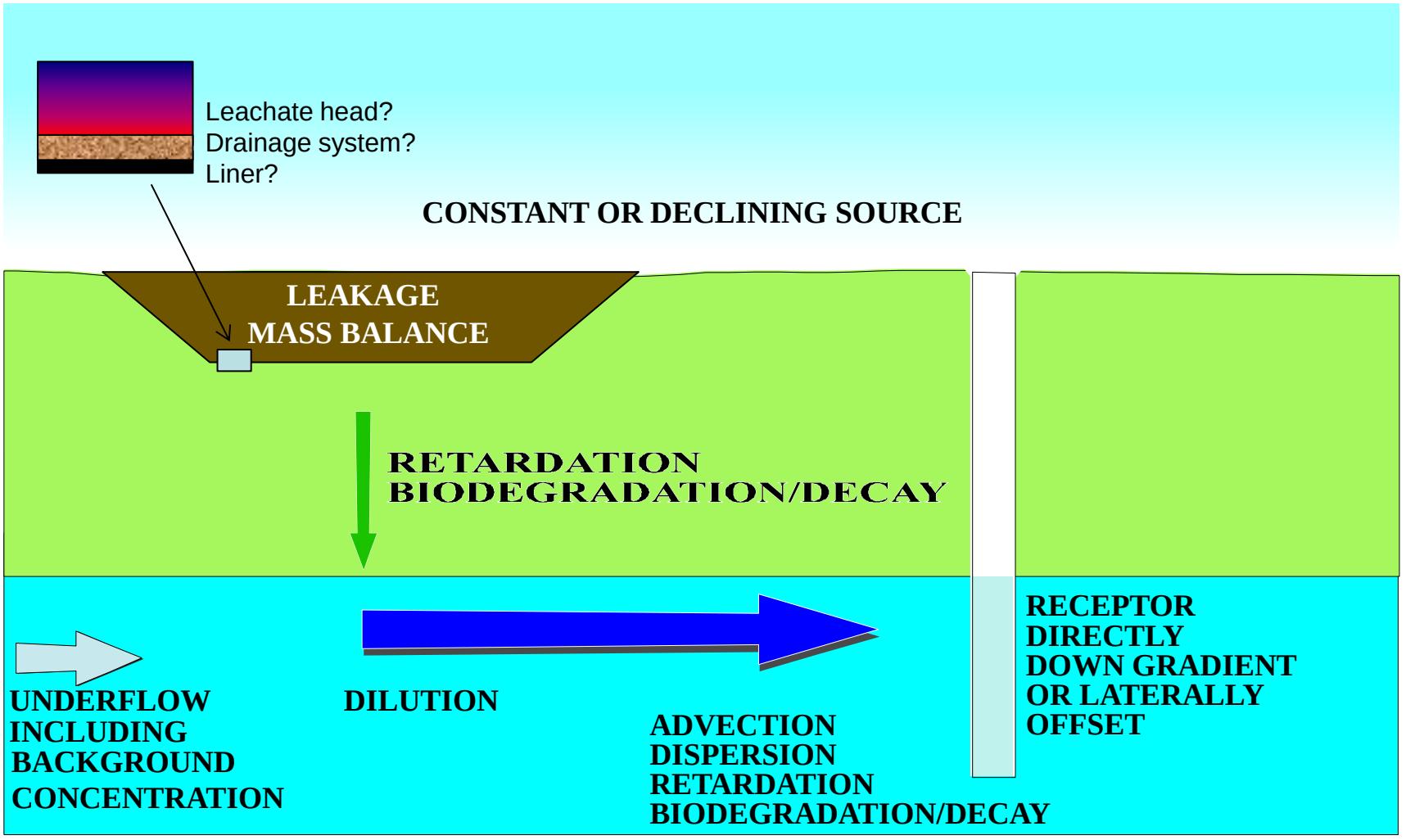
Overview – Performance Criteria

- Predict the fate and transport of contaminants from source concentrations, through the unsaturated zone and within the aquifer/groundwater system
- Calculate travel times and concentrations – likelihood of exceeding Water Quality Guidelines
- Multi-tier assessment approach
- Can be used as screening tools or as more detailed risk assessment tools – depending upon data availability
- Aid in risk estimation (not risk characterization)

Operation – Conceptual Model

LAND·SIM



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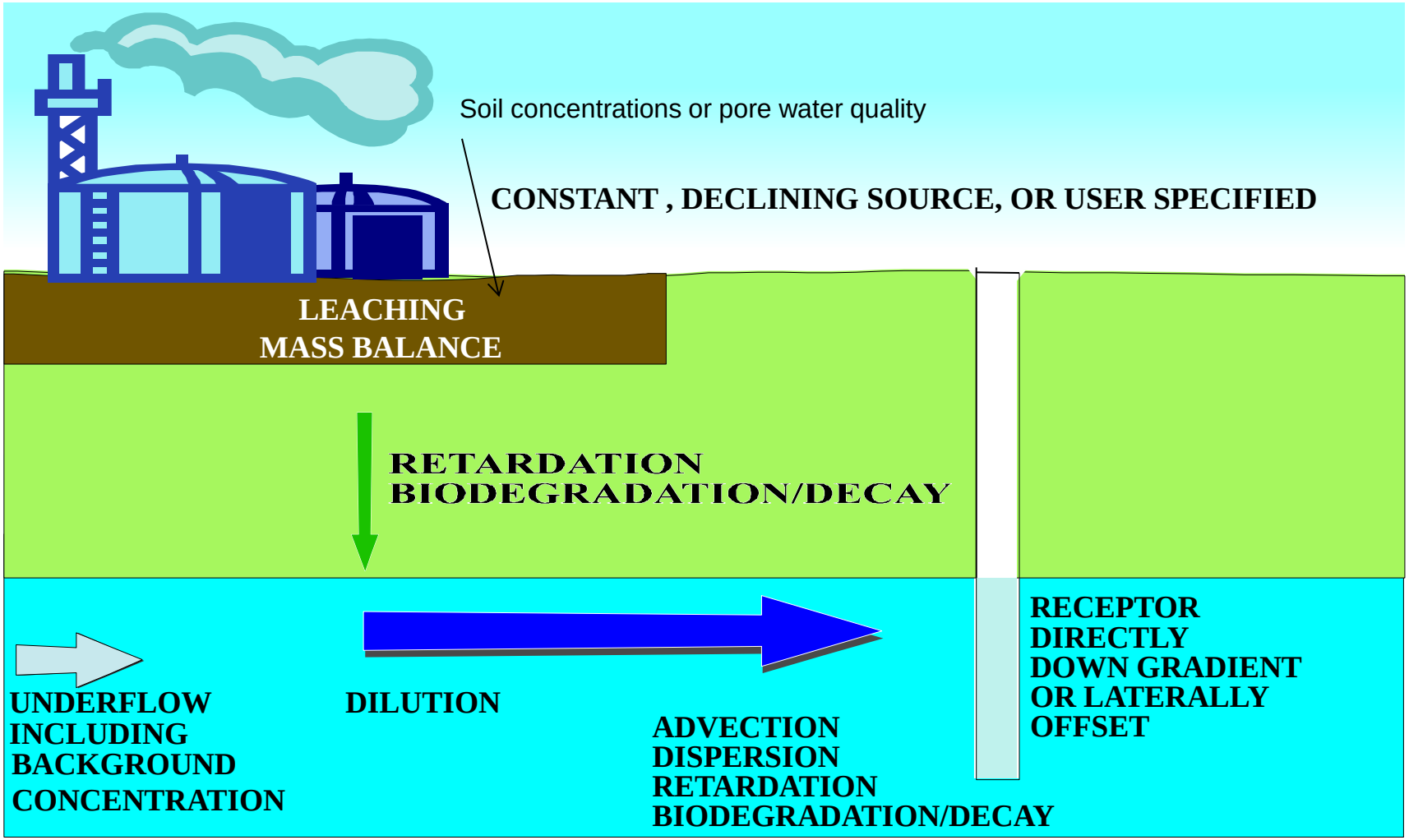
Operation – Conceptual Model

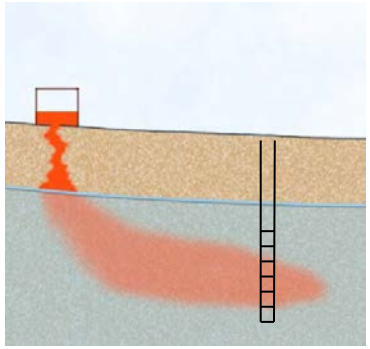


Operation – Inputs (1)

Site specific and/or referenced inputs covering range of values characterizing:

- Infiltration
  - through various phases of landfill life-cycle, to soil surface, or as soakaway/infiltration ditch
- Source term
  - Contaminated soil/waste thickness
  - Bulk density
  - Initial soil concentrations (mg/kg) or leachate concentrations (mg/L)
- Unsaturated zone
  - Thickness/length
  - Moisture content
  - Hydraulic conductivity

Operation – Inputs (2)



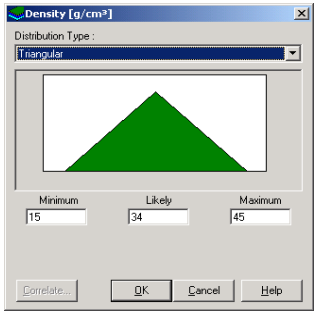
- Aquifer
  - Pathway length
  - Width perpendicular to flow
  - Mixing zone thickness
  - Hydraulic conductivity and gradient
  - Porosity
  - Dispersivity
  - Background concentration range
- Contaminant transport characterization
  - Partition coefficients
  - Fraction of organic carbon
  - Half lives

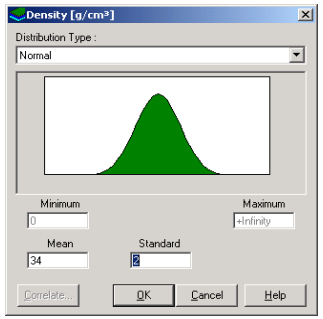
Operation – Why probabilistic? (1)

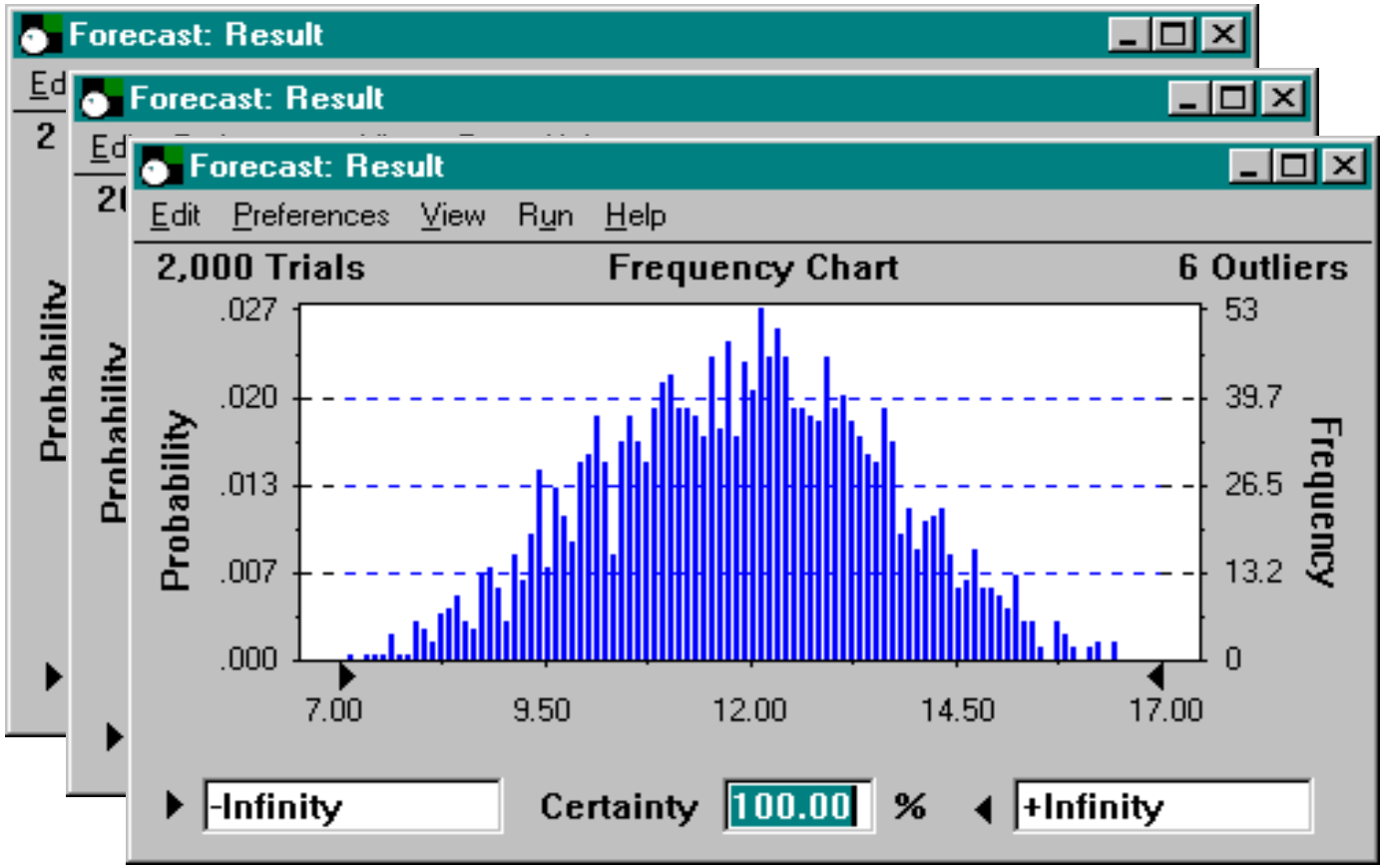
- Uncertainty in the inputs and outputs
- Which input values do we choose?
  - Mean, mode, median, 50th percentile, 95th percentile, single site value, single literature value etc.
- Accounts for parameter uncertainty
  - Because it's there (spatial variability, measurement error etc.)
  - Makes a real difference to the results
  - Should be an unbiased methodology
  - Helps in decision making

Operation – Why probabilistic? (2)

- Characterize inputs as Probability Density Functions



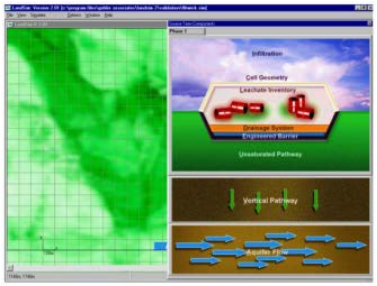


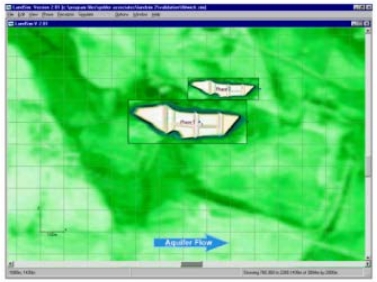


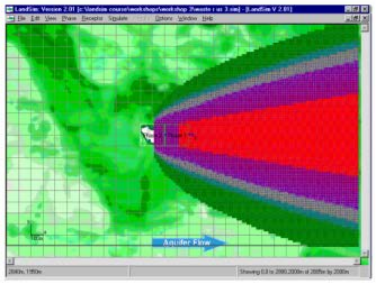
- Monte Carlo Analysis used for sampling PDFs

Output – Capability Summary (1)

LAND·SIM







- ‘Hydraulics’ includes predictions of:
  - Leachate head and leakage rates for large variety of liner types (incorporating liner degradation through time as applicable)
  - Flow to the leachate treatment plant
  - Dilution factors
  - Surface breakout
  - Flow volumes in the aquifer
  - Times to peak concentrations at the groundwater table and in the aquifer

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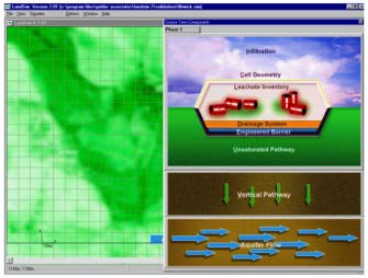
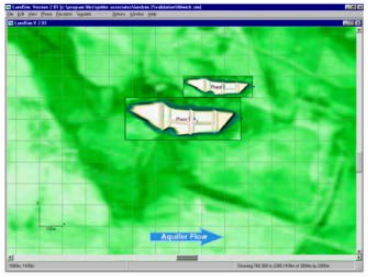
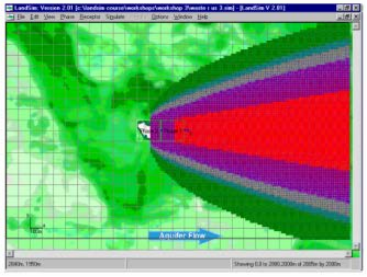
Output – Capability Summary (2)

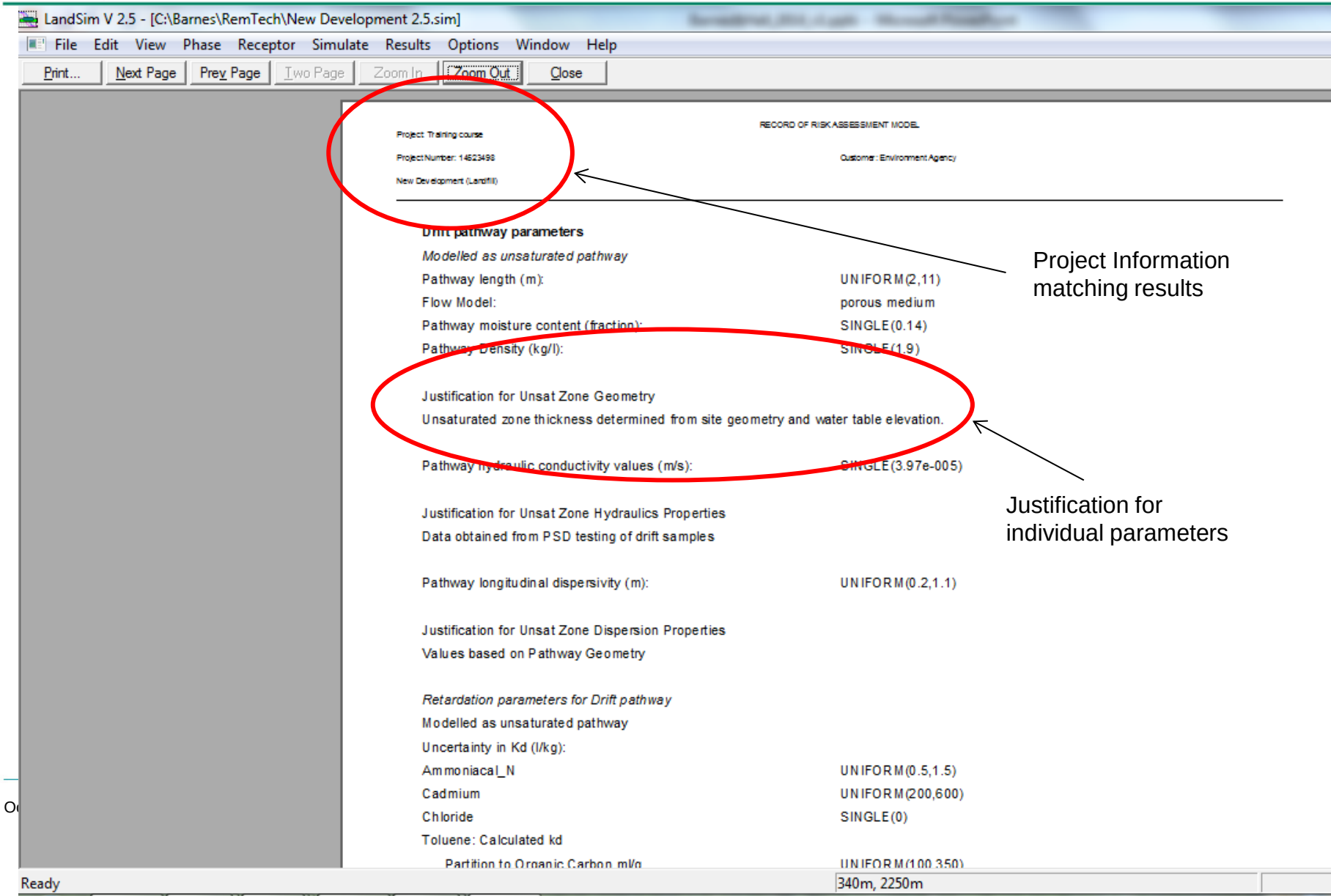






- ‘Contaminant concentrations’ includes predictions of:
  - Source
  - Base of liner (if present)
  - Base of the unsaturated zone
  - Base of vertical pathway (if present)
  - In aquifer – at the edge of the landfill (impact of individual cell) or a down gradient receptor (cumulative impact)

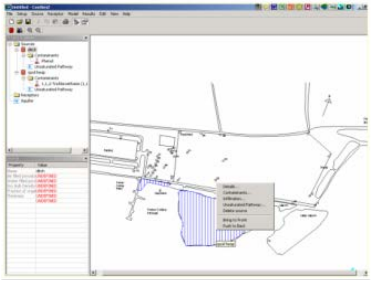
Output – Options (1)

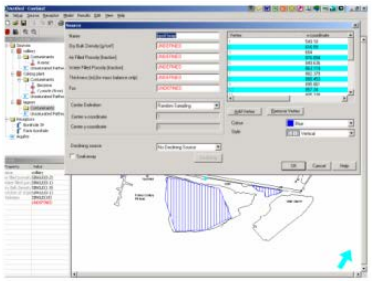


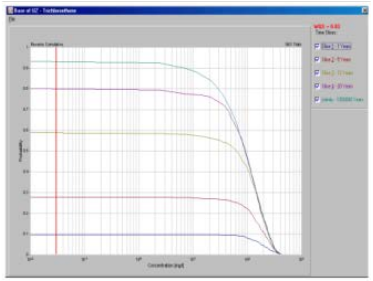
Project Information matching results

Justification for individual parameters

Output – Capability Summary (3)







- Source

  Level 1 deals with the source only
  - limited site investigation, limited cost
  - highly conservative

- Source
  Pathway

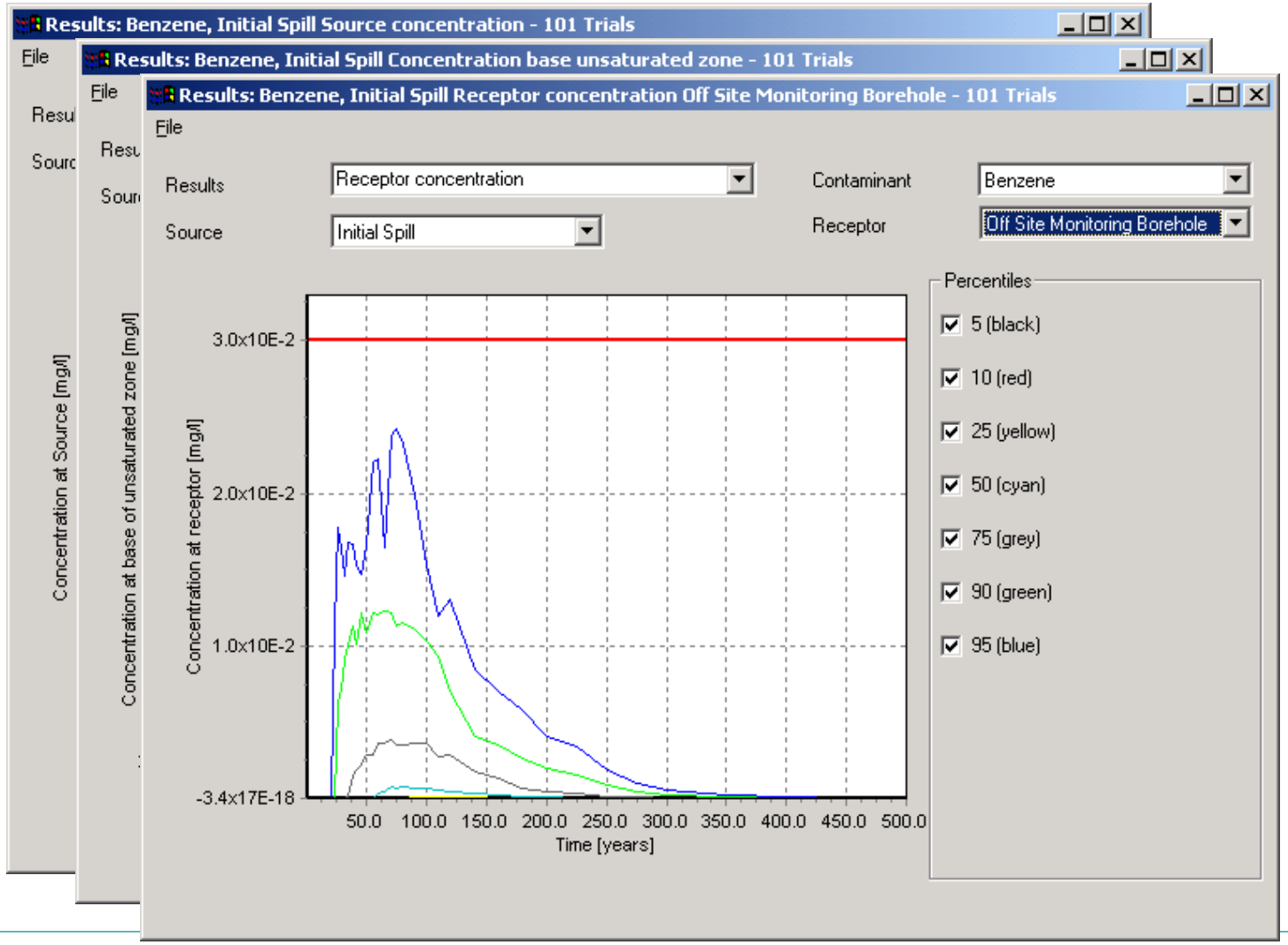
  Level 2 deals with the Unsaturated zone
  - more intensive SI
  - higher cost
  - less conservative

- Source
  Pathway
  Receptor

  Level 3 deals with the aquifer
  - full hydrogeological study needed
  - least conservative

Level 3a does not fit into this structure and is included to allow increased functionality only

Output – Options (2)



Comparison with CCME Tier 2 Equations (1)

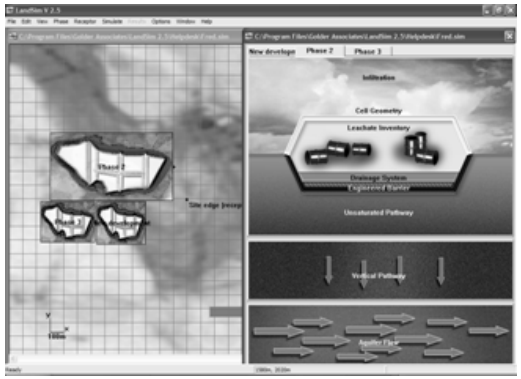
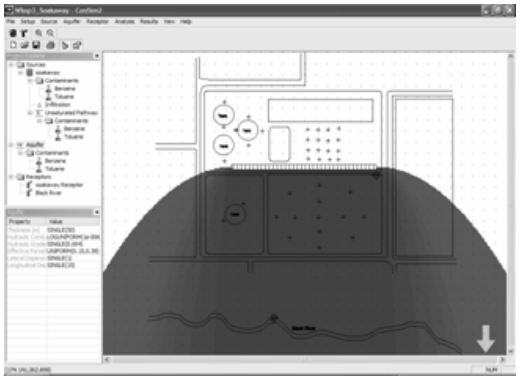
- Similarities include:
  - Conceptual model;
  - Initial partitioning between soil and groundwater concentrations in source;
  - Immiscible phase contaminant not considered;
  - Unsaturated zone plug flow driven by infiltration rate and moisture displacement;
  - Output options for concentrations just above the groundwater table and downstream in the aquifer;
  - Mixing of leachate and groundwater assumed to occur through mixing of mass fluxes; and
  - Consideration of dispersion, retardation and degradation.

Comparison with CCME Tier 2 Equations (2)

- Differences are that LandSim/ConSim include:
  - Range of input values and a probabilistic analysis
  - Impact assessments that do not specifically back calculate remedial targets
  - Source term degradation
  - Cumulative impact from various cells or areas of concern
  - A confined aquifer option (vertical pathway)
  - Vertical dispersivity input is possible to constrain mixing zone thickness in aquifer
  - Option to include up gradient or background groundwater quality data characterization
  - Sensitivity analysis output option (ConSim only)
  - Time series data can be exported to EXCEL

Summary of Application

- Output helps communicate the real risks
- Helps direct effort regarding site investigation
- Helps in the decision making process around the containment of contaminated water and/or in the management of contaminated land
- Helps demonstrate compliance through prior investigation
- Typically 95th percentile concentrations used for regulation purposes – 50th percentile (most likely) output used to calibrate against site data
- Used to derive groundwater monitoring ‘trigger’ concentrations to provide on-going validation of model output – i.e. reduces emphasis on performance assessment through statistics/trend analysis

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