G.0 LANDSIM ASSESSMENT

METHODOLOGY

G.1 The impact of the leachate leakage from the proposed Meenaboll landfill site on groundwater resources and the effectiveness of the proposed engineered containment and leachate management systems of the facility, were examined by a probabilistic risk assessment undertaken using LandSim software. This is a specially designed environmental software package produced by Golder Associates (UK) Ltd under contract from the Environment Agency (England and Wales). LandSim enables the impact of multiple phases of landfill operations to be modelled simultaneously, so that the cumulative impact of the landfill leakage on groundwater resources can be examined at various stages of development.

G.2 The probabilistic risk modelling approach enables uncertainties in input parameters to be represented by specifying maximum/minimum and most likely distribution values, rather than the limited approach of single deterministic input calculations. This facilitates modelling of a range of values to account for variations in incident rainfall, leachate composition, elements of the engineered containment and drainage systems and the prevailing geological and hydrogeological conditions of the site.

G.3 The proposed landfill will comprise of five distinct phases and will be designed as a fully engineered and lined containment site with a full range of leachate management systems designed to meet Landfill Directive requirements. Three of the five phases will be divided internally into two cells each.

LANDSIM MODEL INPUT PARAMETERS

G.4 The distribution input values incorporated in the LandSim analysis for the proposed landfill site are presented in Tables G.1 with the leachate inventory baseline groundwater concentrations and retardation parameters presented in Table G.2. Input parameters used in the simulations were largely based on the engineered design of the landfill and construction specification, and data established during the exploratory site investigations, which included in situ and laboratory tests undertaken to determine the hydraulic properties of the bedrock and drift deposits beneath the site. Where site-specific data was not available conservative software default values or reasoned estimates were used.

Table G.1 LandSim Input Parameters

Model Parameter	Unit	Value			Distribution	Justification
		Minimum	Most Likely	Maximum		
Infiltration						
Uncapped Phase	mm/yr	-	923	-	Normal (SD 10%)	100% Effective Rainfall (Incident rainfall – potential evapotranspiration)
Capped Phase	mm/yr	-	92	-	Normal (SD 10%)	10% Effective Rainfall
Phase Dimensions						
Phase I (Contained phase)						
Top area	Ha	-	0.55	-	Single Value	Phase Dimensions
Base area	Ha	-	0.26	-	Single Value	Phase Dimensions
Base Dimensions	M	-	40x65	-	Single Value	1Nr Cell
Phase II (Contained phase)						
Top area	Ha	-	0.65	-	Single Value	Phase Dimensions
Base area	Ha	-	0.33	-	Single Value	Phase Dimensions
Base Dimensions	M	-	30x110	-	Single Value	1Nr Cell
Phase III (Contained phase)						
Top area	Ha	-	0.80	-	Single Value	Phase Dimensions
Base area	Ha	-	0.46	-	Single Value	Phase Dimensions
Base Dimensions	M	-	30x150	-	Single Value	2Nr Cells each 30x75m
Phase IV (Contained phase)						
Top area	Ha	-	0.98	-	Single Value	Phase Dimensions
Base area	Ha	-	0.57	-	Single Value	Phase Dimensions
Base Dimensions	M	-	30x190	-	Single Value	2Nr Cells each 30x95m
Phase V (Contained phase)						
Top area	Ha	-	1.58	-	Single Value	Phase Dimensions
Base area	Ha	-	0.47	-	Single Value	Phase Dimensions
Base Dimensions	M	-	25x200	-	Single Value	2Nr Cells each 25x100m
Leachate Source						
All Phases						
Final Waste Thickness	M	5.0		18.0	Uniform	Site Capacity between base of landfill and restoration levels
Field Capacity of Waste	Fraction	0.1		0.3	Uniform	LandSim Default Values
Leachate Inventory	mg/l	See Table E.2			Log Triangular	LandSim Default leachate inventory
Drainage Information						
All Phases (Drainage Blanket as Engineered Design Requirement for the proposed site)						
Slope to Sump	Gradient	-	1:25	-	Single Value	Engineered design
Sump Diameter	M	-	3	-	Single Value	Engineered design
Blanket Thickness	M	-	0.5	-	Single Value	Engineered design
Drainage blanket permeability	m/s	1×10^{-3}	-	1×10^{-1}	Log Uniform	CQA specification reduced by 1 order of magnitude to reflect potential clogging
Fixed Head Conditions	M		1.0		Single Value	Assumed maximum operational leachate level

Table G.1 LandSim Input Parameters (continued)

Engineered Barrier System						
All Phases (Composite Lining System)						
BES Construction Thickness	m	-	0.5	-	Single Value	Engineered design
BES Permeability	m/s	$1x10^{-11}$	-	$5x10^{-10}$	Log Uniform	CQA specification
HDPE Membrane Defects						
Pinholes in liner	Nr per Ha	0	5	12	Triangular	Estimated number of defects based on formal CQA with leak detection survey
Holes in liner	Nr per Ha	0	2	2	Triangular	Estimated number of defects based on formal CQA with leak detection survey
Tears in liner	Nr per Ha	0	0.1	2	Triangular	LandSim Default Values
Area of each pinhole	mm^2	0.1	-	5	Uniform	LandSim Default Values
Area of each hole	mm^2	5	-	100	Uniform	LandSim Default Values
Area of each tear	mm^2	100	-	10000	Uniform	LandSim Default Values
Unsaturated Zone (Drift Deposits)						
All Phases						
Hydraulic Conductivity	m/s	$1.0x10^{-8}$		$1.0x10^{-5}$	Log Uniform	Borehole falling head permeability test data
Pathway Length	m	0.1		0.5	Uniform	Estimated from borehole hydrograph data
Pathway Moisture Content	fraction	0.1		0.25	Uniform	Laboratory test data
Pathway Density	kg/l	2.0		2.5	Uniform	Laboratory test data
Longitudinal Dispersivity	m	0.01		0.05	Uniform	10% of vertical pathway length
Aquifer Pathway (Fractured Bedrock)						
Hydraulic Gradient			0.092		Single Value	Hydraulic contours related to borehole monitoring of groundwater level
Hydraulic Conductivity	m/s	$6.4x10^{-7}$		$1.5x10^{-5}$	Log Uniform	Borehole falling head permeability test data
Pathway Porosity		0		0.1	Uniform	LandSim Default Values
Longitudinal Dispersivity	m	5.05		8.95	Uniform	Calculated by LandSim
Transverse Dispersivity	m	1.51		2.68	Uniform	Calculated by LandSim
Mixing Zone Thickness	m	5.0		20.0	Uniform	Assumed Mixing Zone Thickness
Phase I						
Pathway Width	m	-	68	-	Single Value	Dimension of phase measured perpendicular to groundwater flow
Pathway Length	m	22.25	-	77.25	Uniform	Dimension measured between compliance point and phase boundaries parallel to direction of groundwater flow.
Phase II						
Pathway Width	m	-	112	-	Single Value	Dimension of phase measured perpendicular to groundwater flow
Pathway Length	m	77.5	-	122.5	Uniform	Dimension measured between compliance point and phase boundaries parallel to direction of groundwater flow.

Table G.1 LandSim Input Parameters (continued)

Phase III						
Pathway Width	m	-	153	-	Single Value	Dimension of phase measured perpendicular to groundwater flow
Pathway Length	m	125	-	165	Uniform	Dimension measured between compliance point and phase boundaries parallel to direction of groundwater flow.
Phase IV						
Pathway Width	m	-	154	-	Single Value	Dimension of phase measured perpendicular to groundwater flow
Pathway Length	m	170	-	210	Uniform	Dimension measured between compliance point and phase boundaries parallel to direction of groundwater flow.
Phase V						
Pathway Width	m	-	196	-	Single Value	Dimension of phase measured perpendicular to groundwater flow
Pathway Length	m	275	-	215	Uniform	Dimension measured between compliance point and phase boundaries parallel to direction of groundwater flow.

G.5 The proposed Meenaboll landfill was modelled as five phases, referenced as Phase I, II, III, IV and V as illustrated in Figure 11.7. Each phase was modelled as a rectangular area, which were sized to reflect an equivalent area to the physical cell dimensions with phases I and II containing one cell each and phases III – V containing two cells each. Following this the LandSim model was set up to reflect the proposed layout of the five landfill phases, orientated in the direction of groundwater flow. As illustrated in Figure 11.7, the regional groundwater gradient is directed through Phase V toward Phase I of the proposed site.

G.6 LandSim places the landfill model within a domain area that includes a downgradient compliance point that simulates a groundwater abstraction well. This registers the impact of the collective leakage from all landfill phases, which are aligned parallel to the direction of groundwater flow. For the Meenaboll landfill the offsite compliance point was represented by the groundwater monitoring borehole (BH9), which is located approximately 60m downgradient, to the northwest of the Phase I boundary of the proposed landfill site. In the LandSim model each phase of the landfill is also given a dedicated monitoring borehole, which is centred on its downgradient boundary.

G.7 The LandSim models examined two scenarios that are listed below:

Model 1: Unretarded Contaminant Transport Simulation

- Phases I to IV permanently capped (Fixed Head 0.1 to 0.5m)
- Phase V operational (Fixed Head 1m)

Model 2: Retarded Contaminant Transport Simulation

- Phases I to IV permanently capped (Fixed Head 0.1 to 0.5m)
- Phase V operational (Fixed Head 1m)

G.8 The model simulations for all phases included a composite engineered barrier system and a leachate drainage system following the design specifications for the site. The elements of this included a composite lining system (HDPE membrane over 0.5m BES layer) and a 0.5m thick drainage blanket, engineered to meet Landfill Directive and EPA landfill design requirements.

G.9 Leakage of leachate through potential liner defects was calculated by LandSim using in-built equations proposed by Giroud et al, 1992. The model inputs selected were based on the expected size and frequency of defects of various dimensions, given that a formal Construction Quality Assurance (CQA) programme will be implemented. CQA procedures ensure that the placement and welding of the liner is carried out under strict quality control requirements, thereby minimising any potential damage to the liner. In addition to this a leak detection survey will be carried out using electrical resistivity techniques, to detect and enable repair of any pinhole (1mm diameter) size defects in the liner. To account for this high standard of installation, the default number of pinholes and small holes in the liner were reduced, however the number of tears were unchanged. These changes to the input values were agreed with Golder (UK) Associates, the designers of the LandSim software.

G. 10 The quantity and quality of leachate generated within each phase of the landfill operations depends on:

- The incident rainfall;
- The infiltration rate of the landfill surface during various phases of operation;
- The nature and rate of waste input;
- The absorptive capacity of the waste; and
- The effectiveness of the leachate control systems

G.11 The leachate composition at Meenaboll was simulated using LandSim default parameters taken from a database of contaminant concentrations sampled at domestic waste landfills in the United Kingdom and Ireland. As List II substances, chloride and ammoniacal nitrogen represent two major constituents of landfill leachate, they were included in the LandSim simulations as key indicators of groundwater contamination. During the migration of these contaminants through the groundwater system, chloride is not attenuated other than by dilution, while Ammoniacal nitrogen is retarded by ion exchange processes. Mercury was also included to simulate the impact of List I metals, while potassium was included as a metal with reactive potential.

Table G.2 LandSim Default Leachate Inventory

Model Parameter	Unit	Value			Distribution	Justification
		Minimum	Most Likely	Maximum		
Source Concentration of Leachate Contaminants						
Ammonical Nitrogen	mg/kg	4.37	722	3640	Log Triangular	LandSim defaults from leachates sampled at UK and Irish domestic waste landfills
Arsenic	mg/kg	$6.73x10^{-04}$	$4.84x10^{-3}$	1.31	Log Triangular	
Cadmium	mg/kg	$1.90x10^{-03}$	$1.01 x10^{-02}$	$1.05 x10^{-01}$	Log Triangular	
Chloride	mg/kg	36.6	2270	7760	Log Triangular	
Chromium	mg/kg	$8.55 x10^{-03}$	$6.47 x10^{-02}$	1.75	Log Triangular	
Copper	mg/kg	$4.89 x10^{-03}$	$2.43 x10^{-02}$	1.13	Log Triangular	
Lead	mg/kg	$9.57 x10^{-03}$	$1.30 x10^{-01}$	1.02	Log Triangular	
Mercury	mg/kg	$3.94 x10^{-05}$	$8.91 x10^{-05}$	$1.95x10^{-03}$	Log Triangular	
Nickel	mg/kg	$8.83 x10^{-03}$	$1.20 x10^{-01}$	2.21	Log Triangular	
Nitrite	mg/kg	$1.00 x10^{-02}$	$2.70 x10^{-01}$	6.01	Log Triangular	
Phosphate	mg/kg	$1.00 x10^{-02}$	2.54	22.6	Log Triangular	
Potassium	mg/kg	7.55	929	3120	Log Triangular	
Zinc	mg/kg	$2.25 x10^{-03}$	$1.65 x10^{-01}$	208	Log Triangular	
Retardation of Leachate Contaminants for Drift Deposits						
Ammonical Nitrogen	l/kg	0.5		2	Uniform	LandSim defaults
Arsenic	l/kg	25		250	Uniform	
Cadmium	l/kg	1.6		1500	Uniform	
Chloride	l/kg		0		Single Value	
Chromium	l/kg	0		4400	Uniform	
Copper	l/kg	40		27500	Uniform	
Lead	l/kg	27		270000	Uniform	
Mercury	l/kg	450		3835	Uniform	
Nickel	l/kg	20		800	Uniform	
Nitrite	l/kg		0		Single Value	
Phosphate	l/kg		0		Uniform	
Potassium	l/kg		0		Single Value	
Zinc	l/kg	1		600	Uniform	

LANDSIM MODEL RESULTS

G.12 The effectiveness of the engineered containment system and potential impact of the landfill leakage on the groundwater system was quantified using the following LandSim predictions :

- Leakage rate through the liner;
- Contaminant breakthrough concentration at compliance point.

G.13 LandSim model results are plotted statistically as frequency charts, which reflect the probability that an event of a given magnitude will occur. The most likely scenario is reflected by a 50th percentile probability value, whilst the worst case is generally predicted by a 95th percentile value. The results of the leakage and contaminant breakthrough simulations are considered below.

Leakage

G.14 The head of leachate, effectiveness of the leachate control systems and integrity of basal lining and containment systems are the main factors that control the rate of leakage from a landfill site. The leakage from the proposed landfill facility at Meenaboll was calculated for an assumed fixed head of 1m to simulate likely operational conditions, based on a composite lining system, comprising a HDPE membrane over a 0.5m thick BES layer, all installed with full CQA. The results of this analysis are listed in Table E.3.

Table G.3 Leachate Head and Leakage Results (Models 1 and 2)

Landfill Phase	Leachate Head* (m)		Leakage* (litres/day)	
	50%	95%	50%	95%
Phase I (Capped)	0.025	0.109	1.30	13.1
Phase II (Capped)	0.014	0.062	1.58	15.6
Phase III (Capped)	0.007	0.040	1.63	23.1
Phase IV (Capped)	0.008	0.049	2.97	27.6
Phase V (Active)	0.079	0.365	2.20	18.9
Total Leakage from Landfill			**9.68**	**98.3**

Note * Leachate Head calculated from infiltration inputs, Leakage calculated for 1m fixed leachate head

G.15 The tabulated results indicate that the volume of leakage released during the phased landfill development increases in proportion to the basal area of each phase. In accordance with this the smallest amount of leakage occurs from Phase I and the largest from Phase V. Overall the total leakage from the site is calculated to be around 9.68l/day based on the most likely (50th percentile) scenario and around 98.3 l/day following the worst case (95th percentile) prediction. These leakage volumes are not significant given that the total landfill area will cover a total area of approximately 4.5Ha.

G.16 To assess the effectiveness of the leachate drainage and control measures a model was run with the fixed head condition switched off. The leachate head was therefore simulated solely on the basis of the infiltration model input values using the hydraulics only calculation. The results of this leachate head simulation are also listed in Table E.3. The results indicate that the leachate heads generated by rainfall in each phase are small, ranging from 0.007 to 0,079m on the most likely (50th percentile) scenarios and 0.040 to 0.365m following the worst case (95th percentile) prediction.

Contaminant Breakthrough Concentrations

G.17 The contaminant breakthrough concentration at the specified compliance point represents the ultimate determination of the LandSim model and forms the basis for the risk assessment. This calculation takes account of the leachate quality, landfill leakage rate, geosphere travel time, aquifer dilution factor, and biodegradation and retardation effects specific to individual contaminants.

G.18 The compliance point assumed in the LandSim model for Meenaboll landfill was located 60m downgradient (northwest) of the proposed Phase I landfill boundary where groundwater monitoring borehole BH9 is located. In addition to this the maximum contaminant breakthrough concentration was also calculated for each of the phase monitoring boreholes. The predicted maximum concentrations and time of maximum breakthrough at the compliance point and phase monitoring point is listed in Table E.4, as a worst case (95th percentile) and a most likely (50th percentile) values for the selected leachate parameters. To assess the significance of the breakthrough concentration results the Interim Guidance Values (IGV)[1] are listed for each parameter. These values were derived from either the Geological Survey of Ireland regional groundwater quality trigger values or European Community drinking water standards (80/778/EEC).

[1] EPA Interim Report Towards Setting Guideline Values for the Protection of Groundwater in Ireland

G.19 The results demonstrate that the leakage of contaminants produced from the final landfill area is unlikely to cause a significant impact on groundwater quality at the compliance point (BH9). The most likely (50th Percentile) scenario indicates that the maximum contaminant breakthrough concentrations for all simulated contaminants remain significantly below the Interim Guideline Value (IGV). The worst case (95th percentile) scenario indicates that only ammonia (0.354mg/l) slightly exceeds the IGV value (0.15mg/l). This situation occurs for a short period around the 45 year interval for unretarded flow and should not extend significantly downgradient of the landfill beyond the compliance point. On this basis the landfills predicted impact on groundwater resources downgradient of the site would not be considered significant.

Table G.4 Contaminant Breakthrough Concentrations (Models 1 and 2)

Monitoring Location	Ammoniacal Nitrogen (IGV = 0.15mg/l)				Chloride (IGV = 30mg/l)				Mercury (IGV = 0.001mg/l)				Potassium (IGV = 5mg/l)			
	50th Percentile		95th Percentile		50th Percentile		95th Percentile		50th Percentile		95th Percentile		50th Percentile		95th Percentile	
	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)
MODEL 1 Final Phase Landfill Operation - Unretarded Contaminant Transport Simulation																
Phase I (Capped) Monitoring Well	21.5	0.003	9.7	0.092	5.9	0.006	9.9	0.267	10.3	$1.5X10^{-9}$	9.9	$5.1X10^{-8}$	21.9	0.005	9.9	0.132
Phase II (Capped) Monitoring Well	9.4	0.005	9.9	0.068	8	0.01	9.9	0.224	32.4	$1.1X10^{-9}$	10.1	$4.5X10^{-8}$	8.03	0.004	16.1	0.01
Phase III (Capped) Monitoring Well	21.9	0.01	32.2	0.085	21.9	0.02	21.9	0.308	22.2	$2.3X10^{-9}$	31.7	$6.9X10^{-8}$	21.9	0.017	21.9	0.154
Phase IV (Capped) Monitoring Well	45.6	0.003	43.9	0.095	39.8	0.005	31.6	0.37	32.4	$1.6X10^{-9}$	45.3	$8.6X10^{-8}$	32.2	0.003	44	0.131
Phase V (Active) Monitoring Well	44.7	0.003	44.7	0.093	43.8	0.004	44.7	0.18	45.3	$4.7X10^{-10}$	46.2	$2.7X10^{-8}$	44.7	0.002	44.7	0.083
Compliance Point	**45**	**0.024**	**45**	**0.354**	**45**	**0.063**	**31.9**	**0.61**	**45.3**	**$1.3X10^{-8}$**	**44.4**	**$1.2X10^{-7}$**	**45.6**	**0.03**	**43.9**	**0.325**

Table G.4 Contaminant Breakthrough Concentrations (Models 1 and 2) Continued

Monitoring Location	Ammoniacal Nitrogen (IGV = 0.15mg/l)				Chloride (IGV = 30mg/l)				Mercury (IGV = 0.001mg/l)				Potassium (IGV = 5mg/l)			
	50th Percentile		95th Percentile		50th Percentile		95th Percentile		50th Percentile		95th Percentile		50th Percentile		95th Percentile	
	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)	Travel Time (years)	Maximum Concentration (mg/l)
MODEL 2 Final Phase Landfill Operation - Retarded Contaminant Transport Simulation																
Phase I (Capped) Monitoring Well	102.6	$7.2x10^{-4}$	89.5	0.016	7.8	0.016	7.8	0.22	15446	$1.5x10^{-12}$	62846	$5.9x10^{-12}$	6.6	0.003	7.9	0.111
Phase II (Capped) Monitoring Well	87.8	$6.9x10^{-4}$	127.1	0.022	16.1	0.001	16.1	0.155	N/R	N/R	65380	$5.1x10^{-12}$	10.1	0.003	15.7	0.077
Phase III (Capped) Monitoring Well	129.3	0.004	129.3	0.068	21.7	0.015	22.1	0.695	89699	$1.2x10^{-12}$	64101	$2.1x10^{-11}$	30.4	0.009	21.9	0.142
Phase IV (Capped) Monitoring Well	89.5	0.01	89.5	0.031	31.6	0.013	32.2	0.377	89699	$1.4x10^{-12}$	95179	$1.7x10^{-11}$	32.2	0.005	32.2	0.188
Phase V (Active) Monitoring Well	122	0.002	89.5	0.005	44.4	0.016	45.3	0.642	N/R	N/R	89699	$2.2x10^{-12}$	45.6	0.004	44.7	0.169
Compliance Point	**352**	**0.005**	**249.2**	**0.141**	**40.9**	**0.048**	**45**	**1.121**	**N/R**	**N/R**	**250692**	**$1.9x10^{-11}$**	**62.1**	**0.014**	**44.7**	**0.472**

CONCLUSION

G.20 The LandSim models indicate that no significant impact on groundwater quality downgradient of the site is likely to arise following the proposed phased development of the Meenaboll landfill as a fully engineered containment facility. The model indicates that contaminant concentrations will remain below the specified Interim Guidance Values (IGV) at the compliance point, with the exception of possible minor elevations for ammoniacal nitrogen, that is only likely to persist for a short time and is unlikely to exceed the IGV a short distance beyond the compliance point. The time taken to reach the maximum contaminant concentrations of each simulated contaminant varies from decades for unretarded flow conditions to around 200 years for ammonia and thousands of years for the List I metal mercury assuming retarded conditions.

G.21 On the basis of the above it is concluded that the proposed design of the Meenaboll landfill site, would meet the requirements of the EC Landfill Directive and Groundwater Directive with respect to offsite compliance.

APPENDIX G.1

LANDSIM 2 RESULTS

MODEL 1 FINAL PHASE – UNRETARDED TRANSPORT

PHASE 1 LEAKAGE FROM EBS

PHASE 2 LEAKAGE FROM EBS

PHASE 3 LEAKAGE FROM EBS

PHASE 4 LEAKAGE FROM EBS

PHASE 5 LEAKAGE FROM EBS

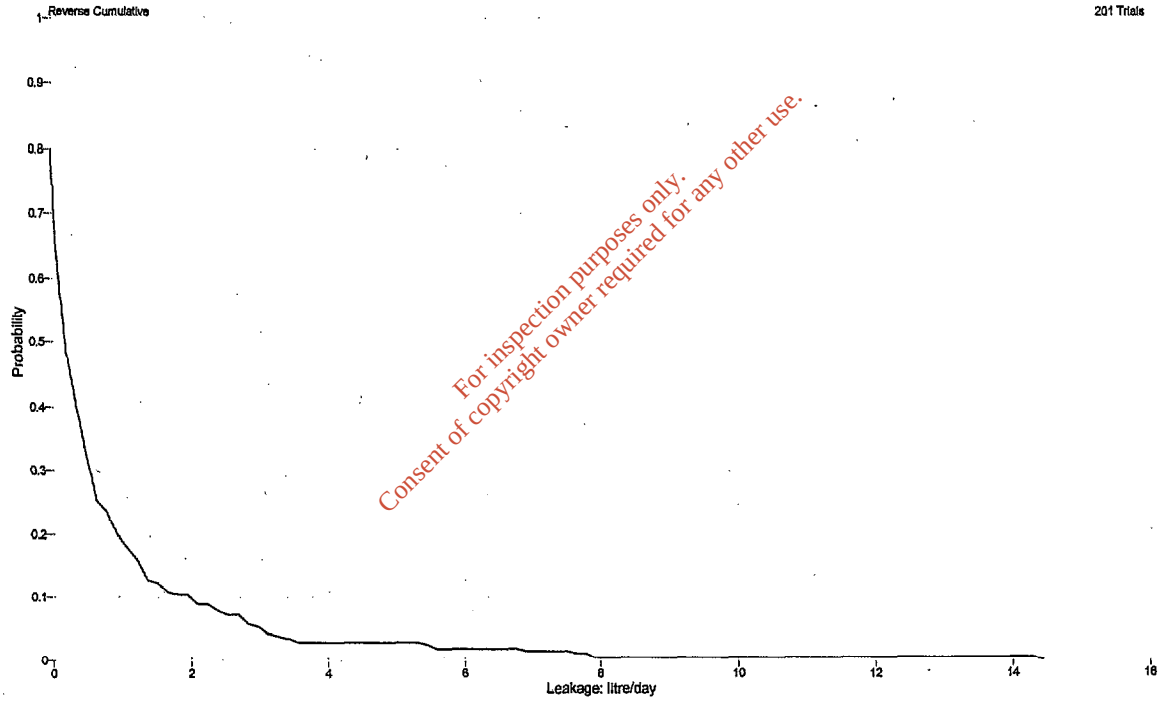
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 1 - Forecast: Leakage from EBS



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

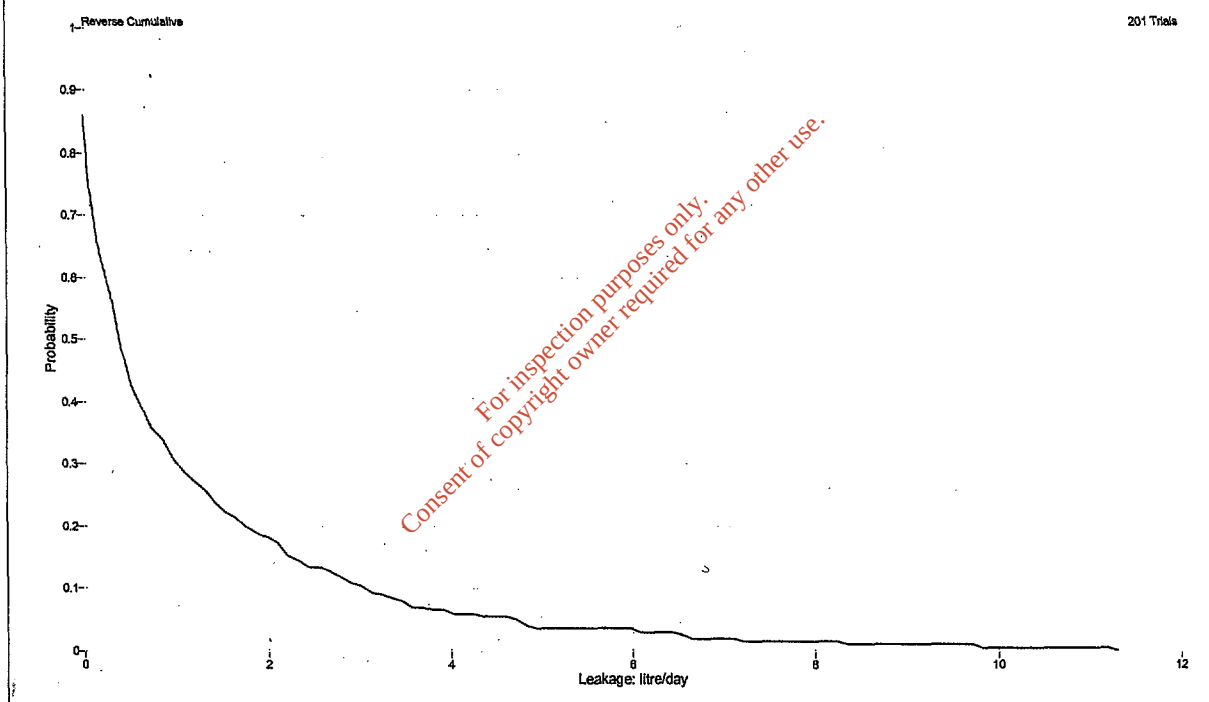
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 2 - Forecast: Leakage from EBS



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

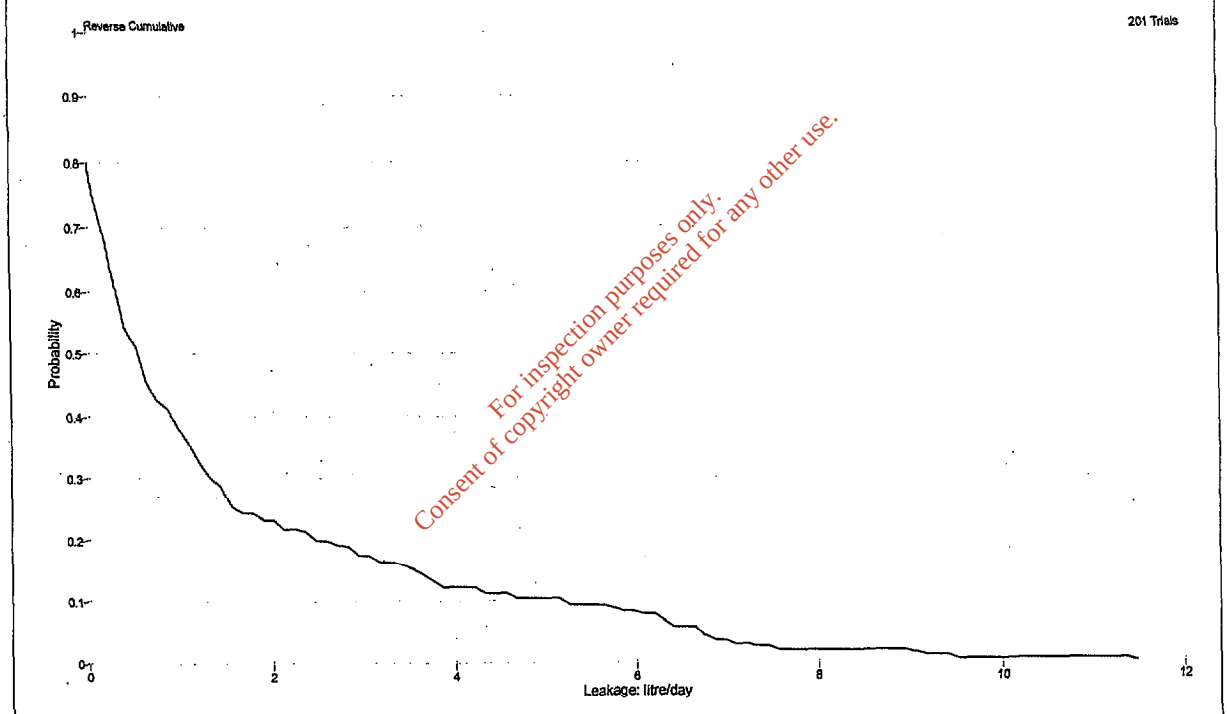
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 3 - Forecast: Leakage from EBS



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

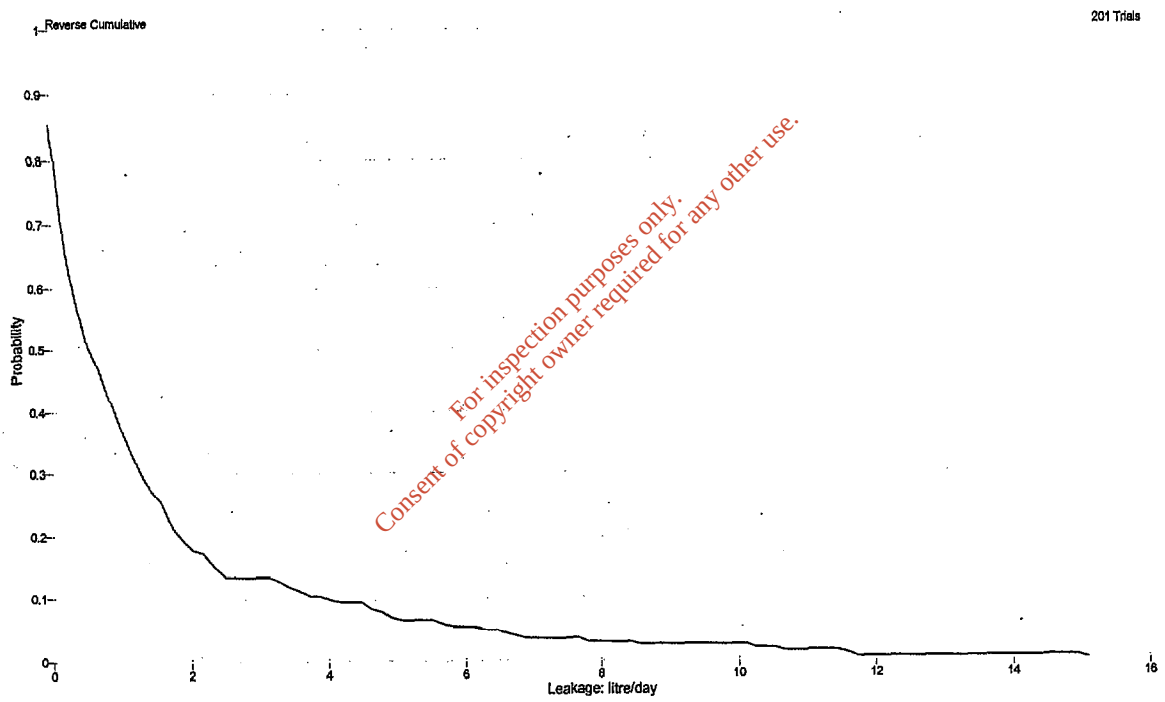
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 4 - Forecast: Leakage from EBS



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

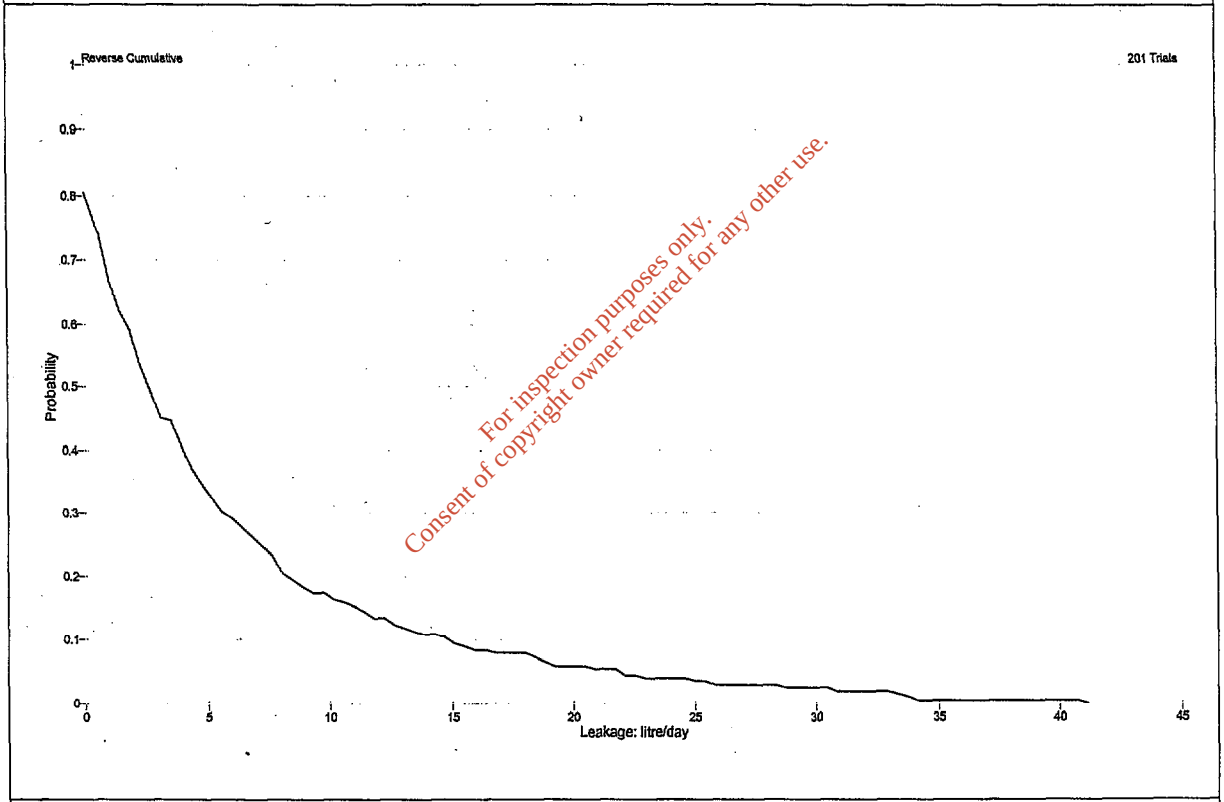
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 5 - Forecast: Leakage from EBS



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

APPENDIX G.2

LANDSIM 2 RESULTS

MODEL 1 FINAL PHASE – UNRETARDED TRANSPORT

AMMONIACAL NITROGEN AT COMPLIANCE POINT

PHASE 1 AMMONIACAL NITROGEN AT MONITOR WELL

PHASE 2 AMMONIACAL NITROGEN AT MONITOR WELL

PHASE 3 AMMONIACAL NITROGEN AT MONITOR WELL

PHASE 4 AMMONIACAL NITROGEN AT MONITOR WELL

PHASE 5 AMMONIACAL NITROGEN AT MONITOR WELL

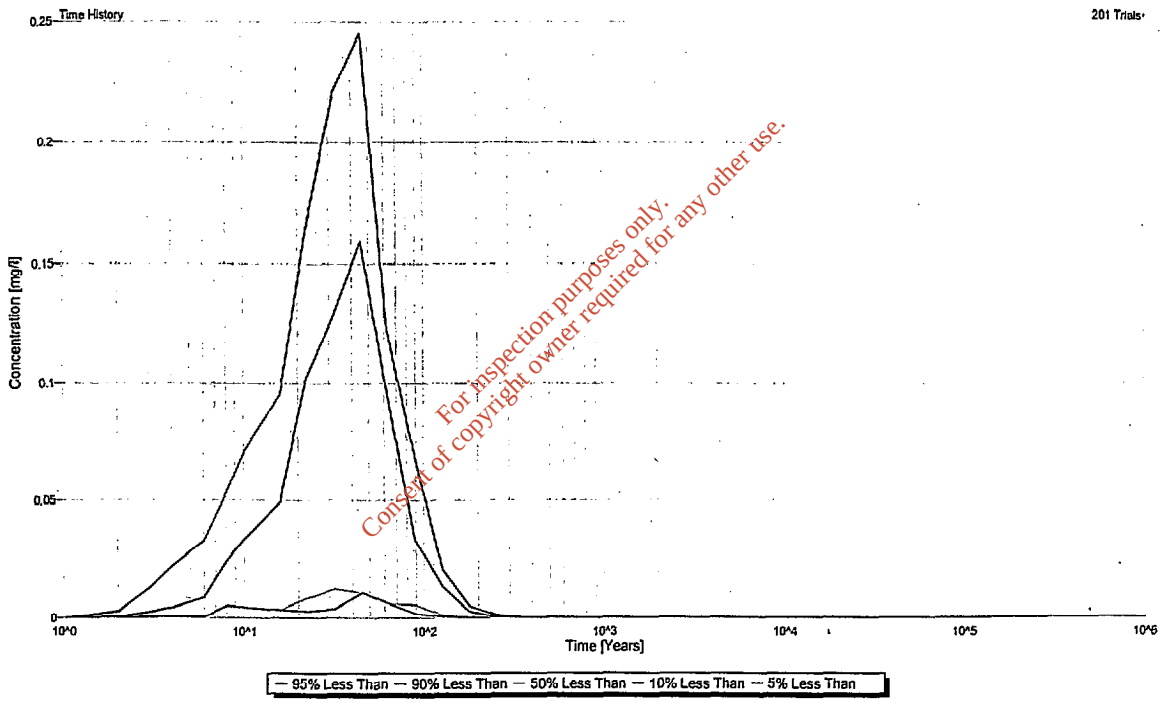
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Ammoniacal_N at Compliance Point



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

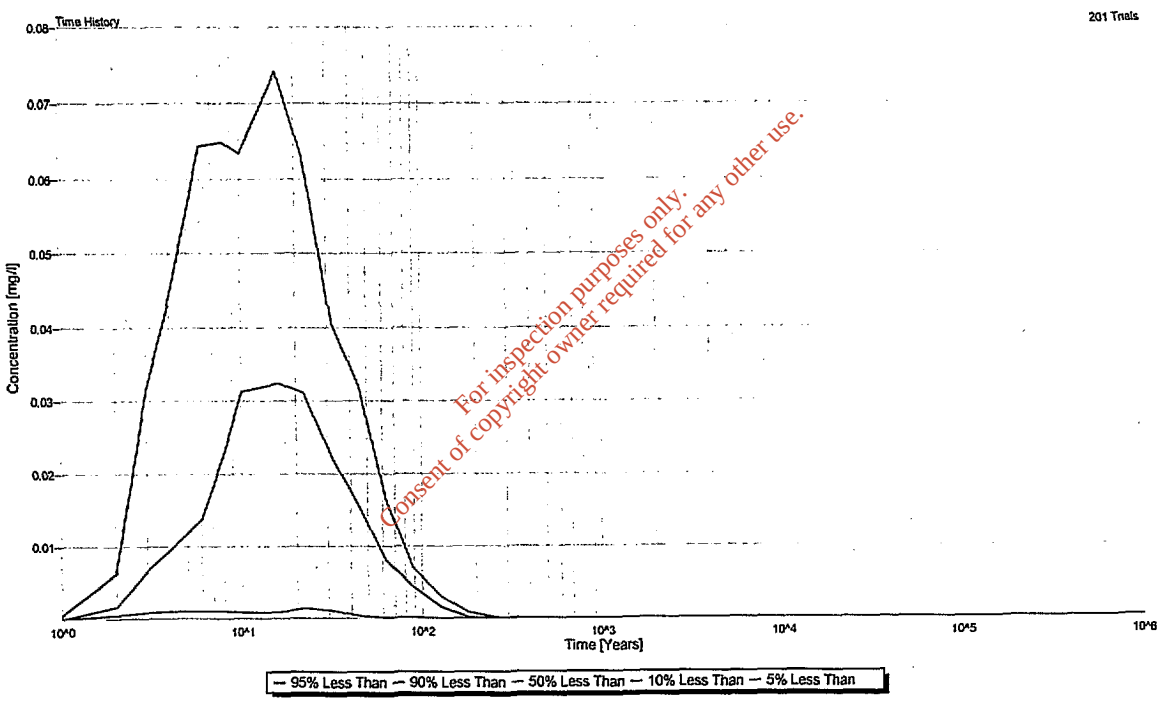
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 1 - Ammoniacal_N at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

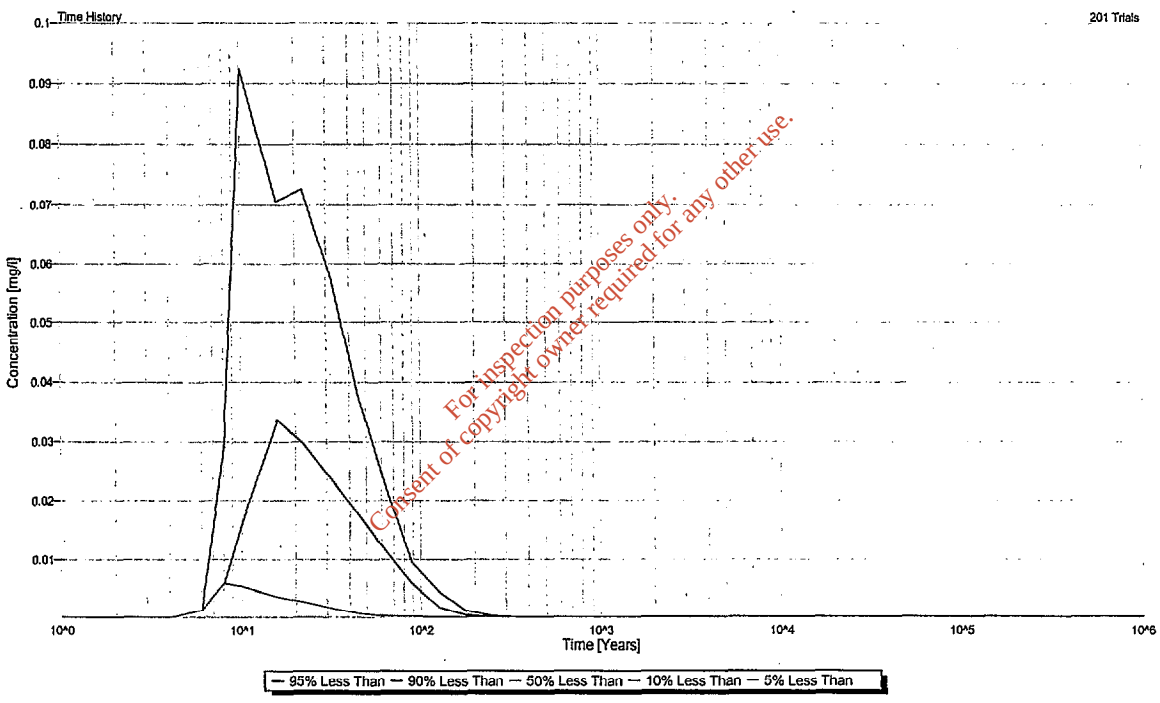
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 2 - Ammoniacal_N at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

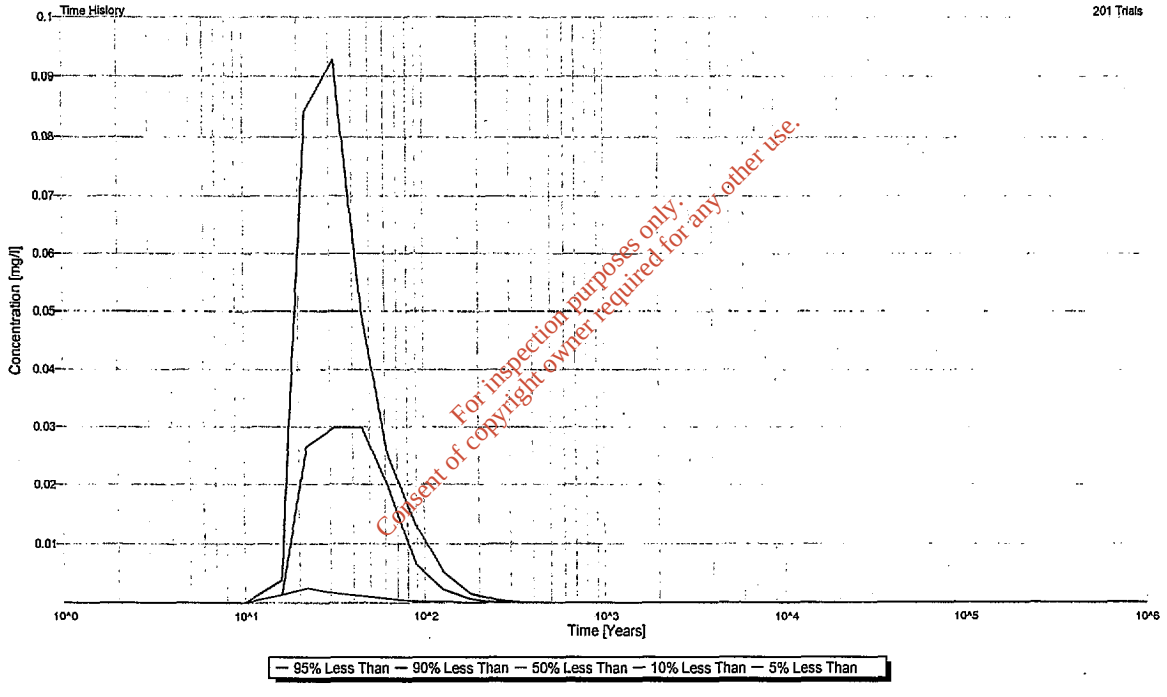
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 3 - Ammoniacál_N at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

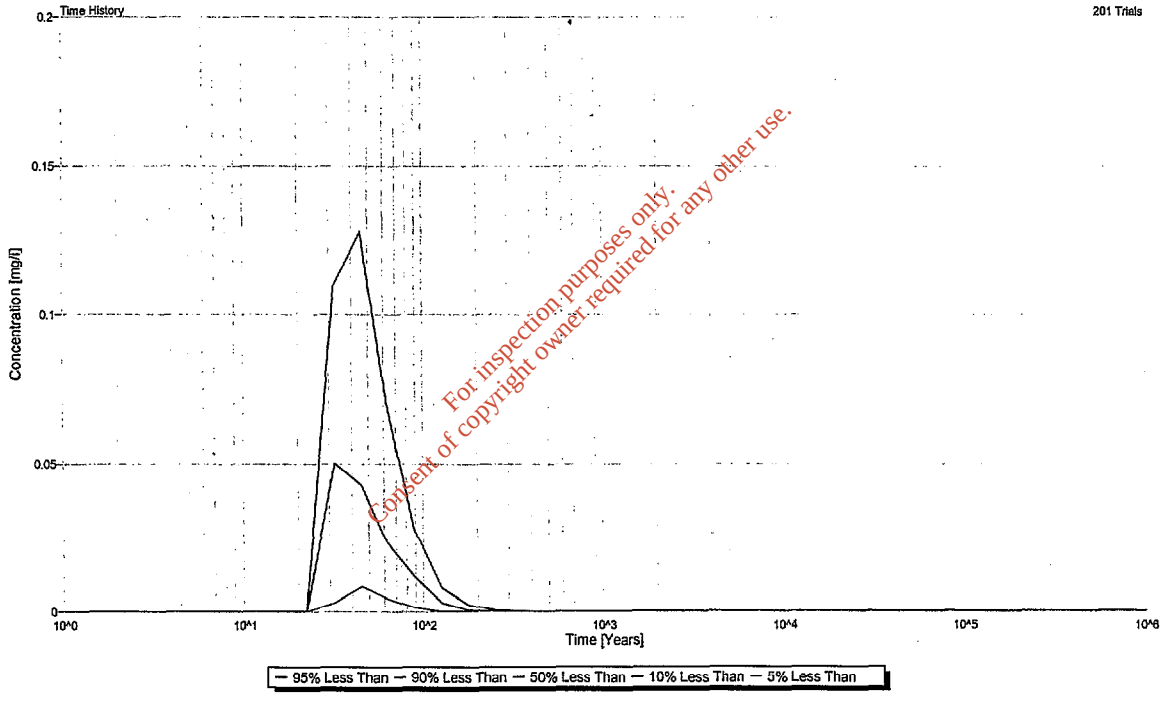
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 4 - Ammoniacal_N at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

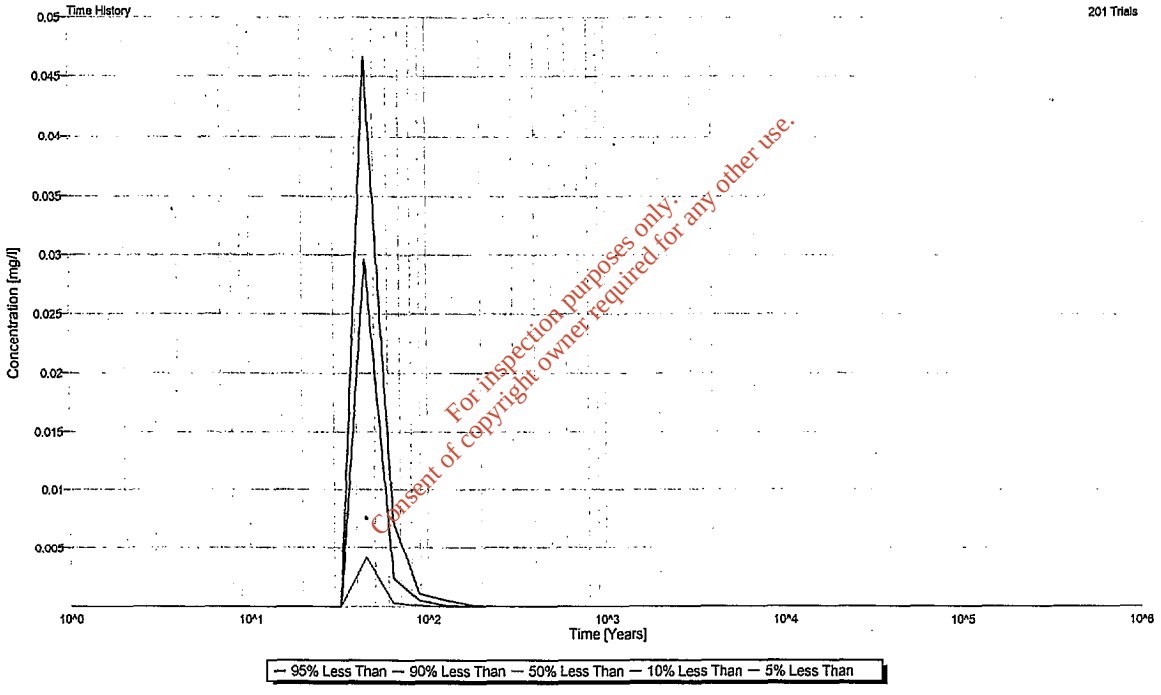
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 5 - Ammoniacal_N at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

APPENDIX G.3

LANDSIM 2 RESULTS

MODEL 1 FINAL PHASE – UNRETARDED TRANSPORT

CHLORIDE AT COMPLIANCE POINT

PHASE 1	CHLORIDE AT MONITOR WELL
PHASE 2	CHLORIDE AT MONITOR WELL
PHASE 3	CHLORIDE AT MONITOR WELL
PHASE 4	CHLORIDE AT MONITOR WELL
PHASE 5	CHLORIDE AT MONITOR WELL

004

G04

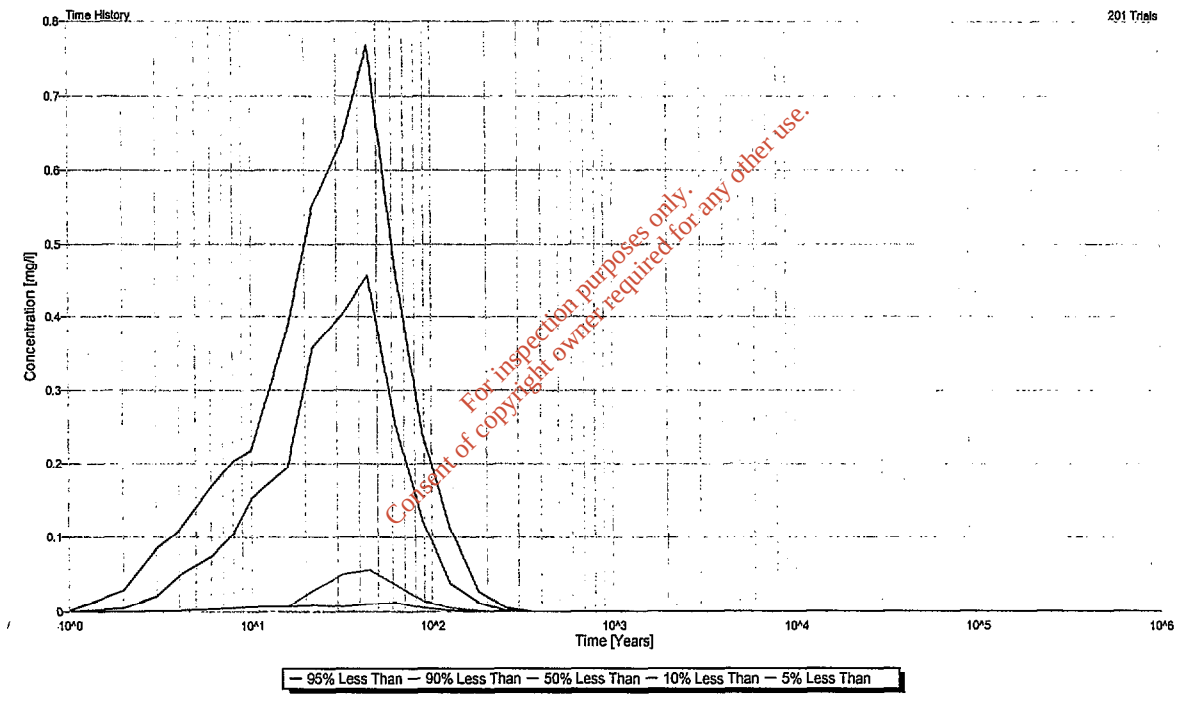
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Chloride at Compliance Point



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

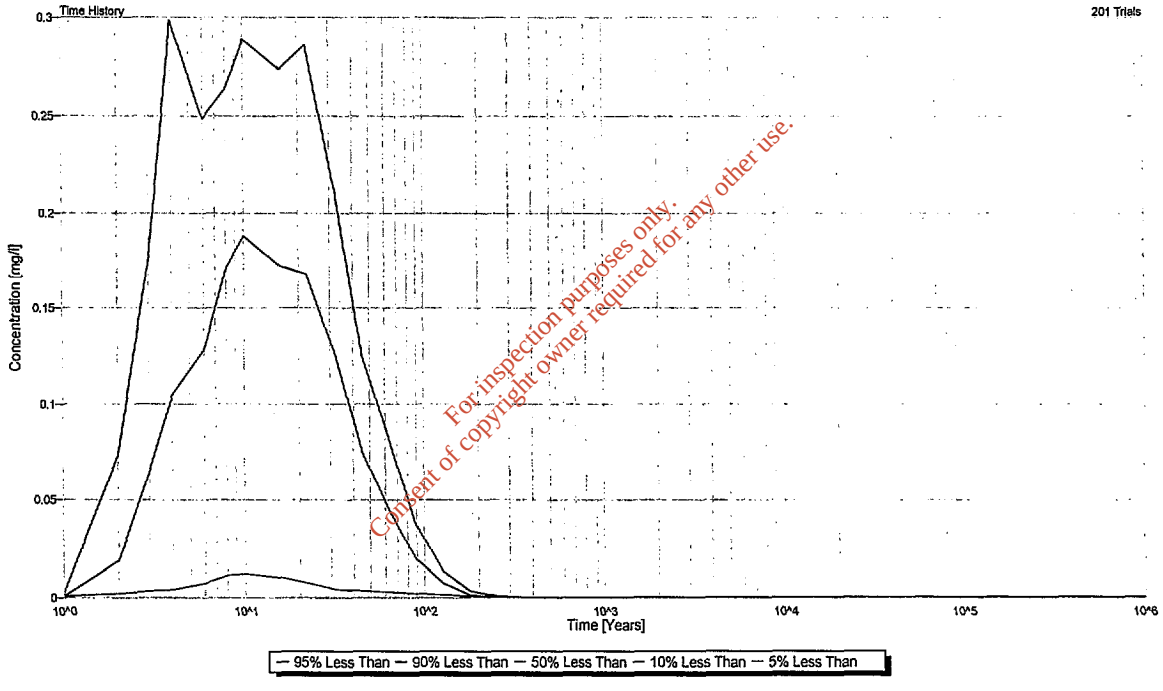
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 1 - Chloride at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

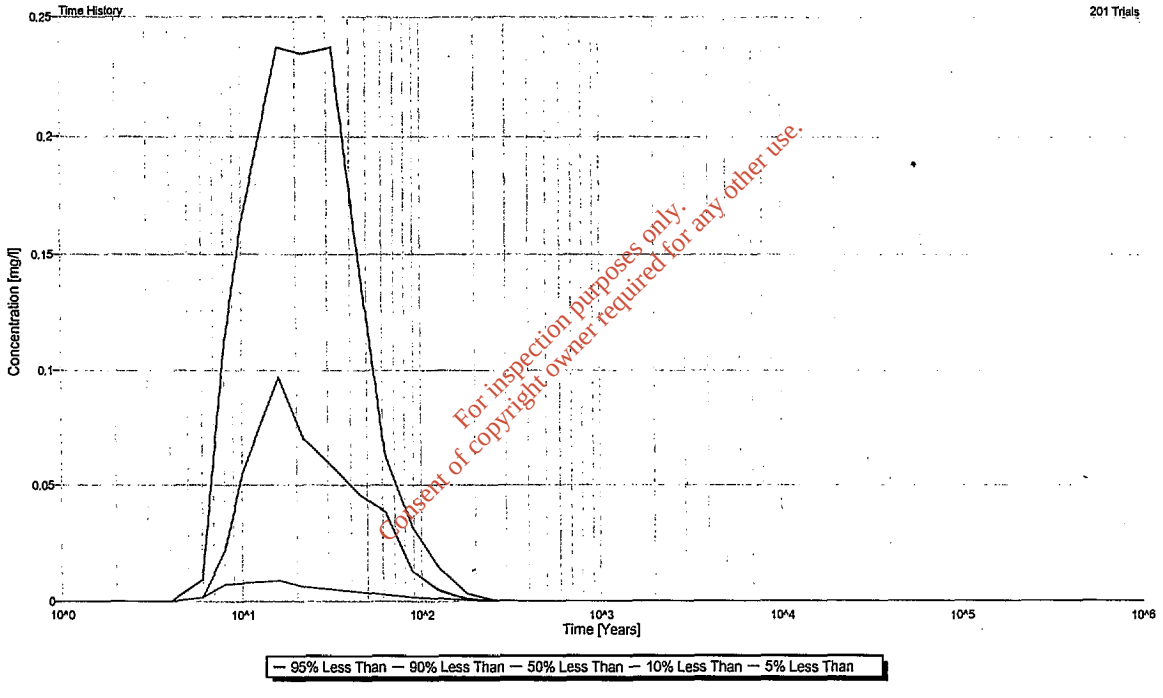
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 2 - Chloride at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

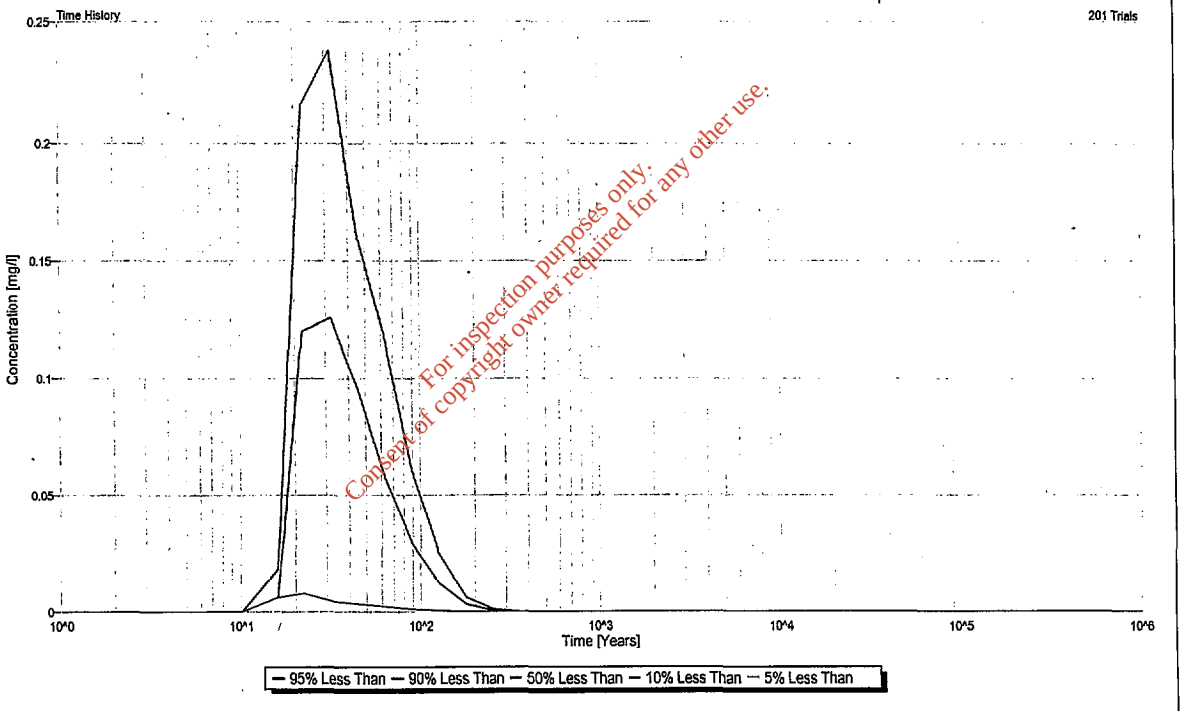
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 3 - Chloride at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

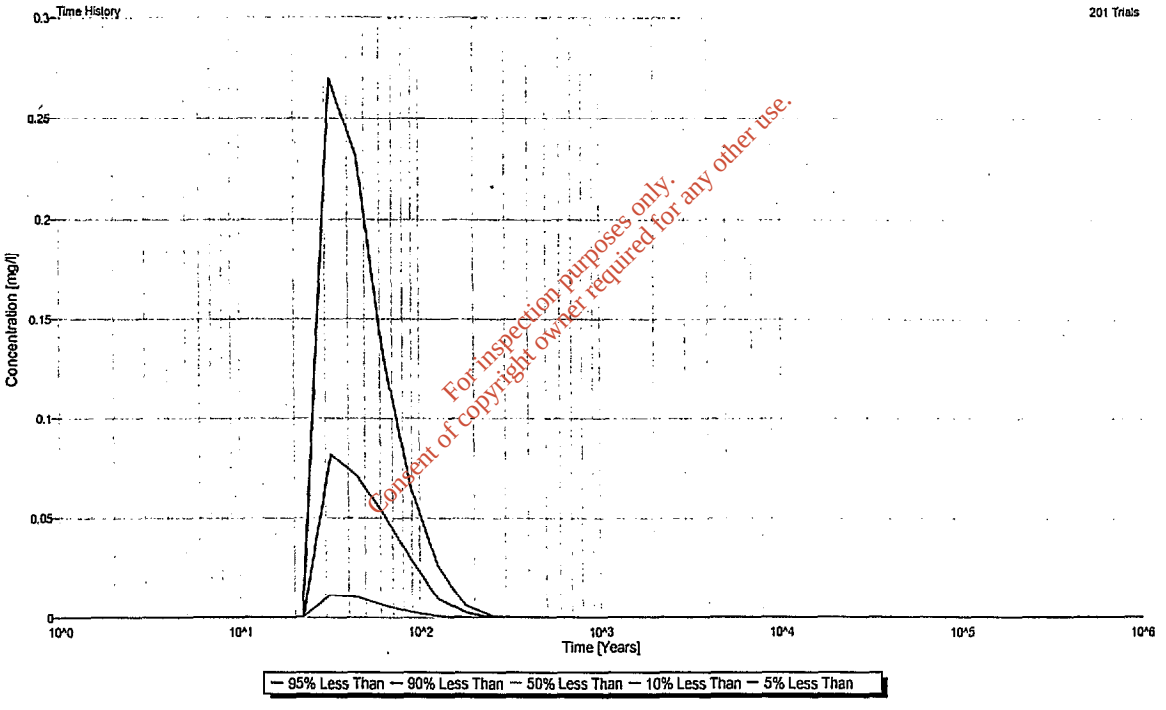
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 4 - Chloride at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

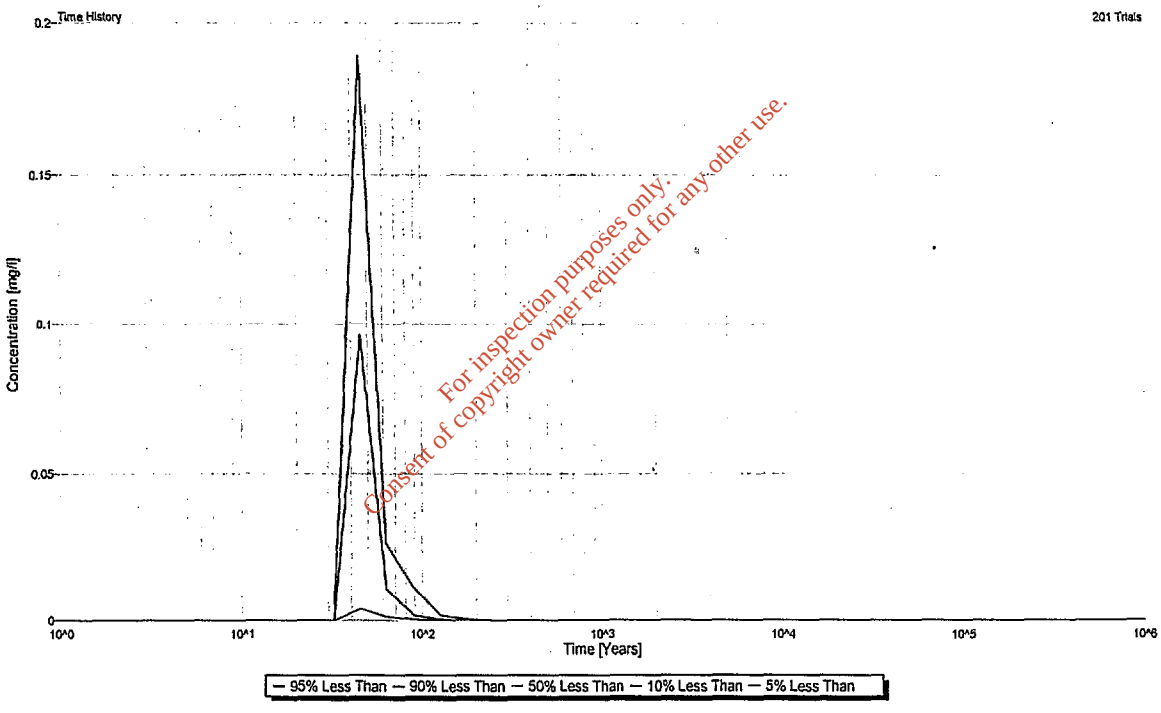
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 5 - Chloride at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

APPENDIX G.4

LANDSIM 2 RESULTS

MODEL 1 FINAL PHASE – UNRETARDED TRANSPORT

MERCURY AT COMPLIANCE POINT

PHASE 1	MERCURY AT MONITOR WELL
PHASE 2	MERCURY AT MONITOR WELL
PHASE 3	MERCURY AT MONITOR WELL
PHASE 4	MERCURY AT MONITOR WELL
PHASE 5	MERCURY AT MONITOR WELL

004

G04

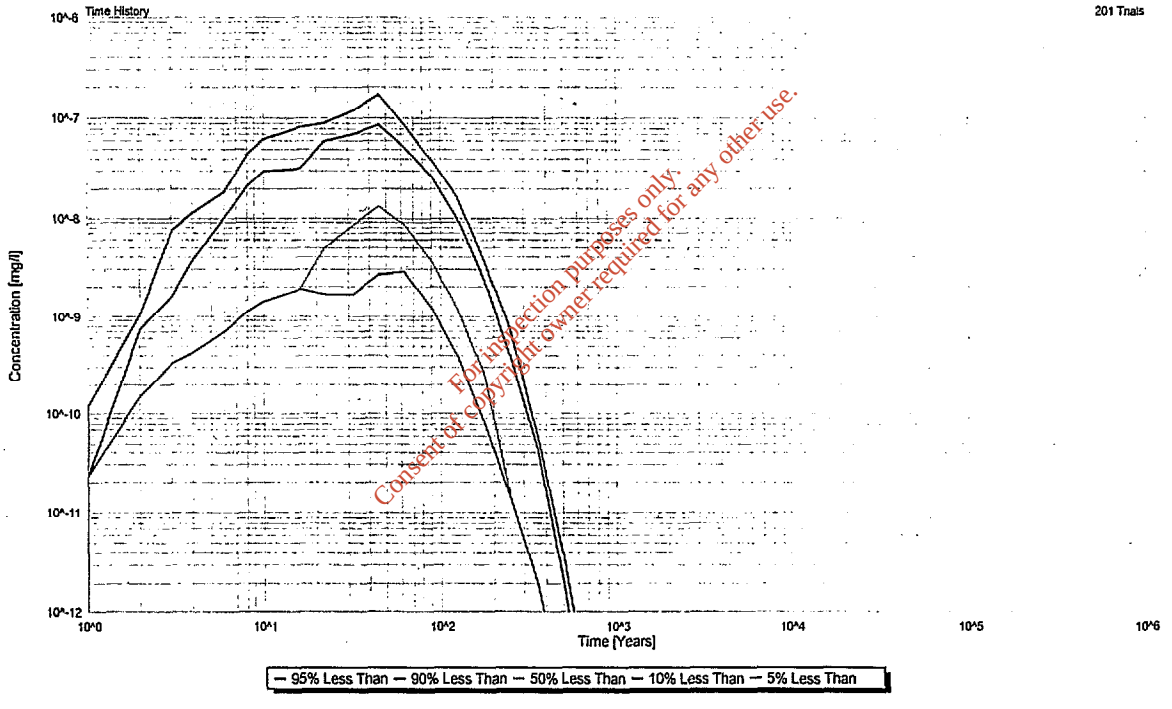
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Mercury at Compliance Point



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

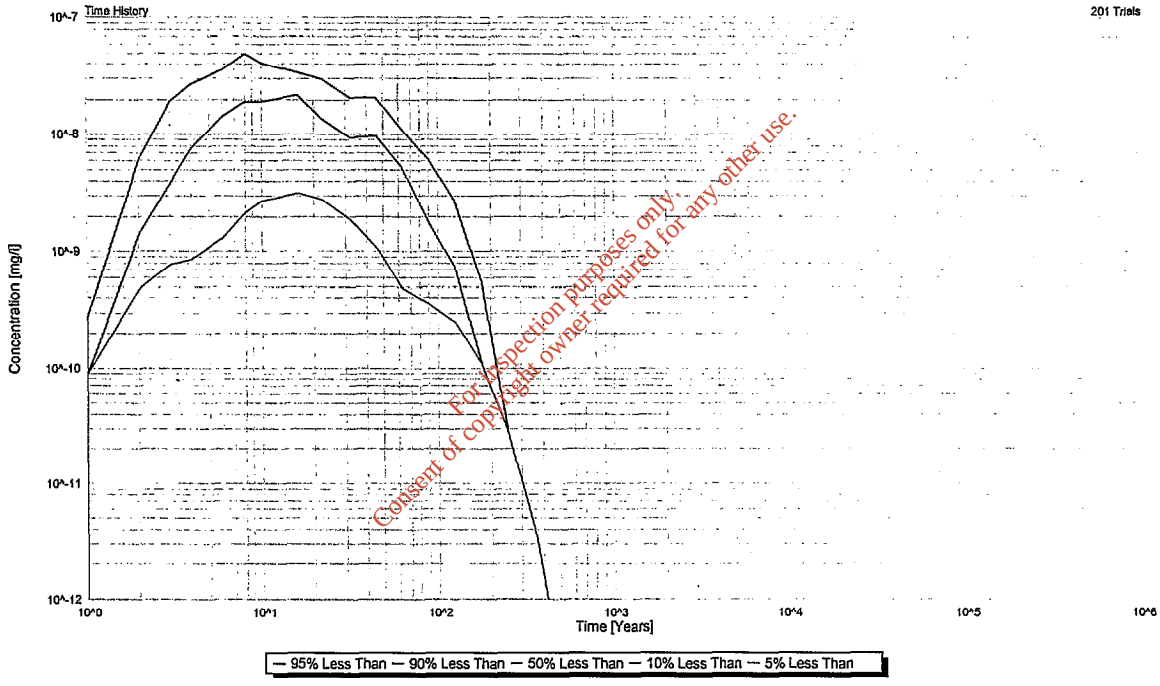
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 1 - Mercury at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

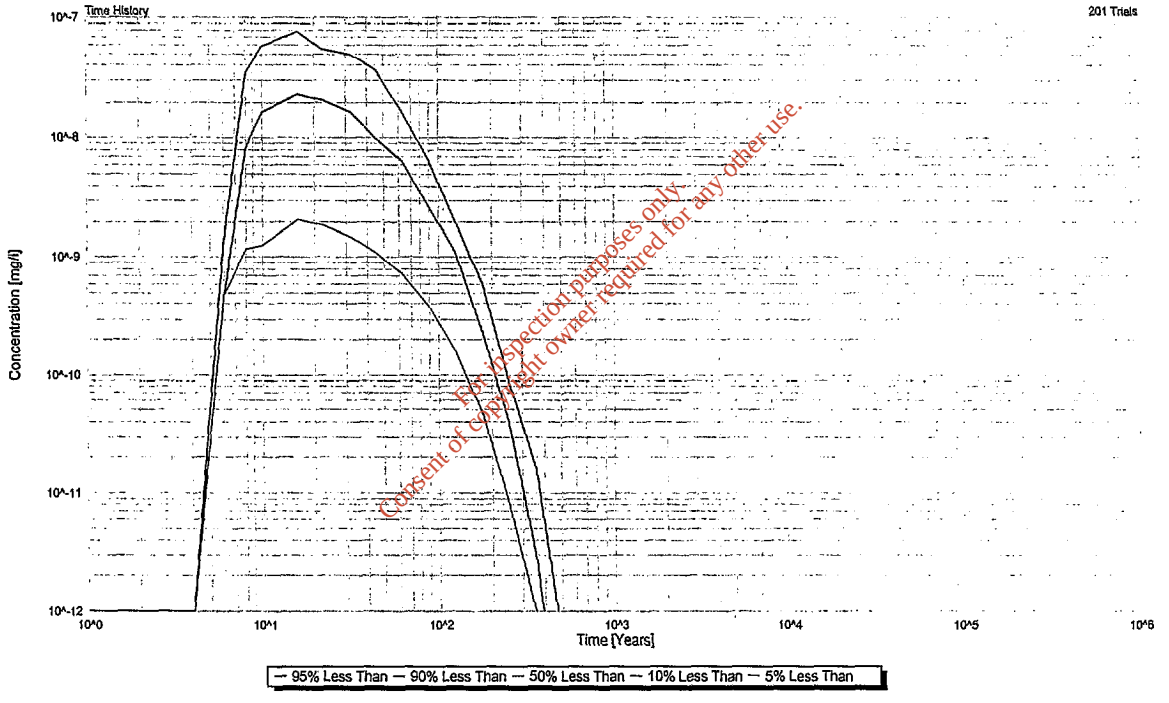
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 2 - Mercury at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

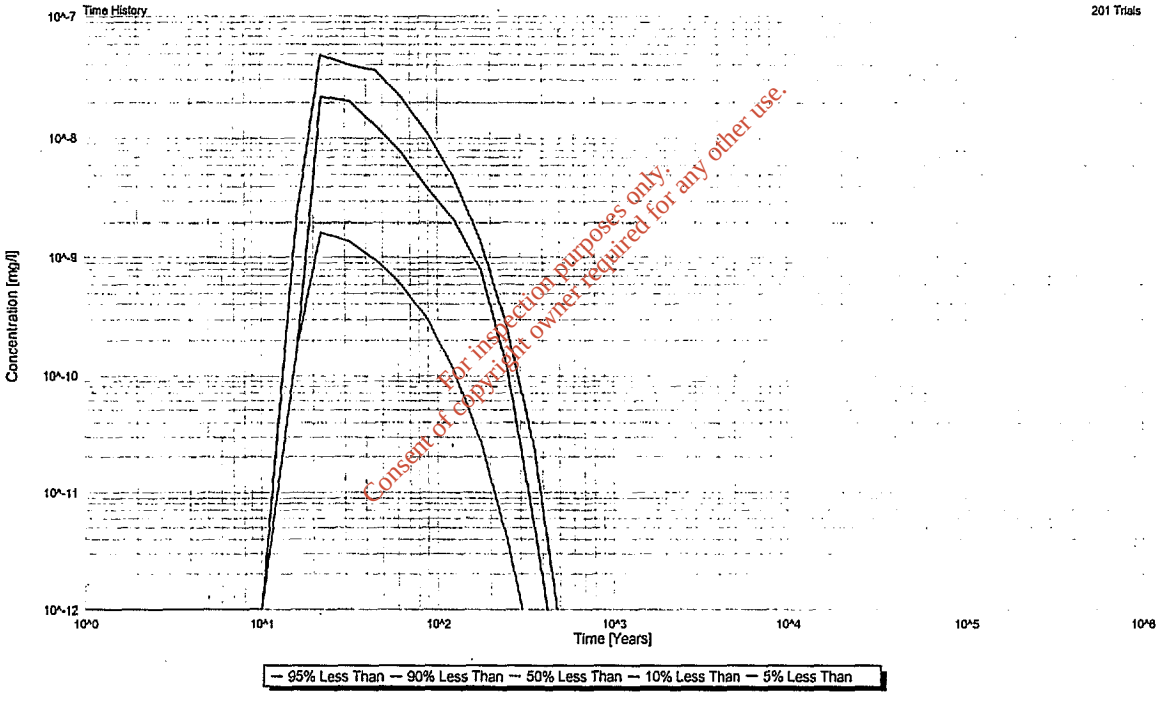
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 3 - Mercury at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

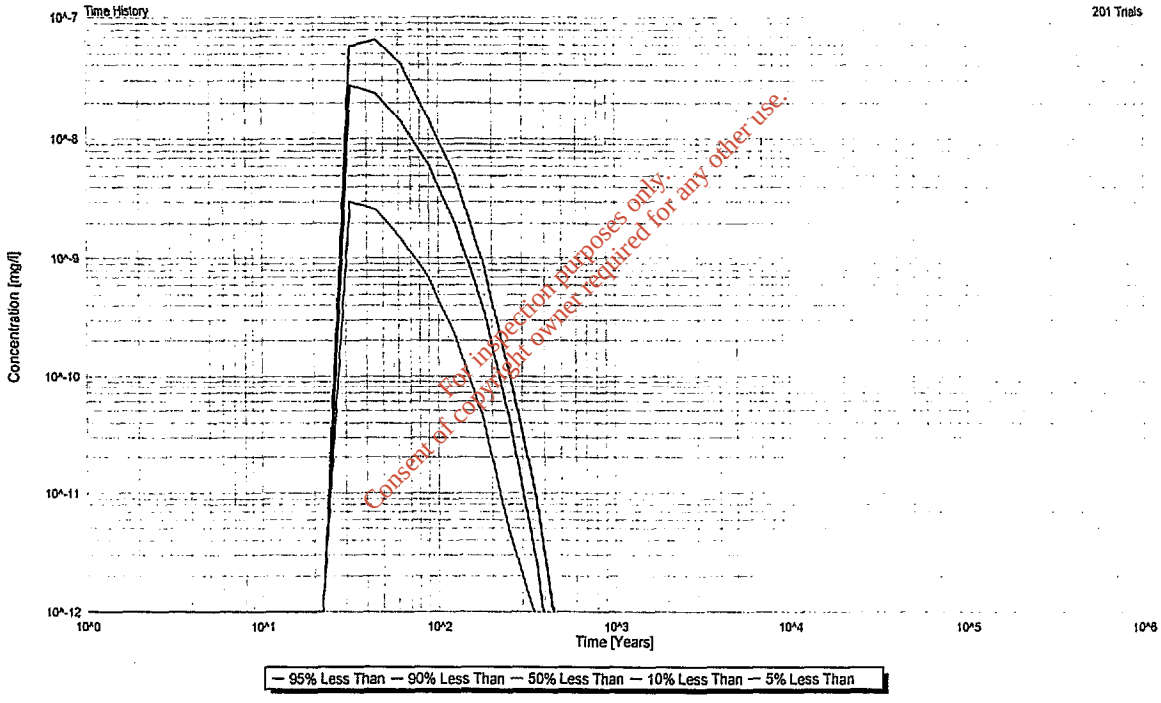
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 4 - Mercury at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

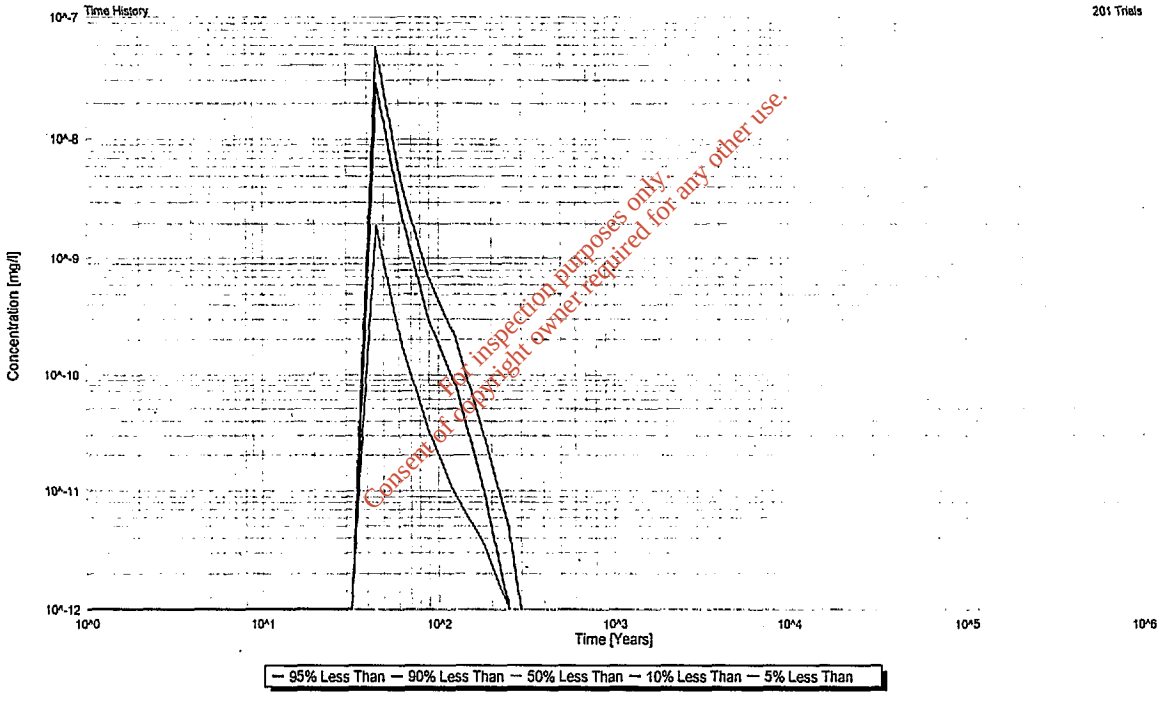
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 5 - Mercury at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

APPENDIX G.5

LANDSIM 2 RESULTS

MODEL 1 FINAL PHASE – UNRETARDED TRANSPORT

POTASSIUM AT COMPLAINCE POINT

PHASE 1	POTASSIUM AT MONITOR WELL
PHASE 2	POTASSIUM AT MONITOR WELL
PHASE 3	POTASSIUM AT MONITOR WELL
PHASE 4	POTASSIUM AT MONITOR WELL
PHASE 5	POTASSIUM AT MONITOR WELL

004

G04

Services Ireland Ltd.

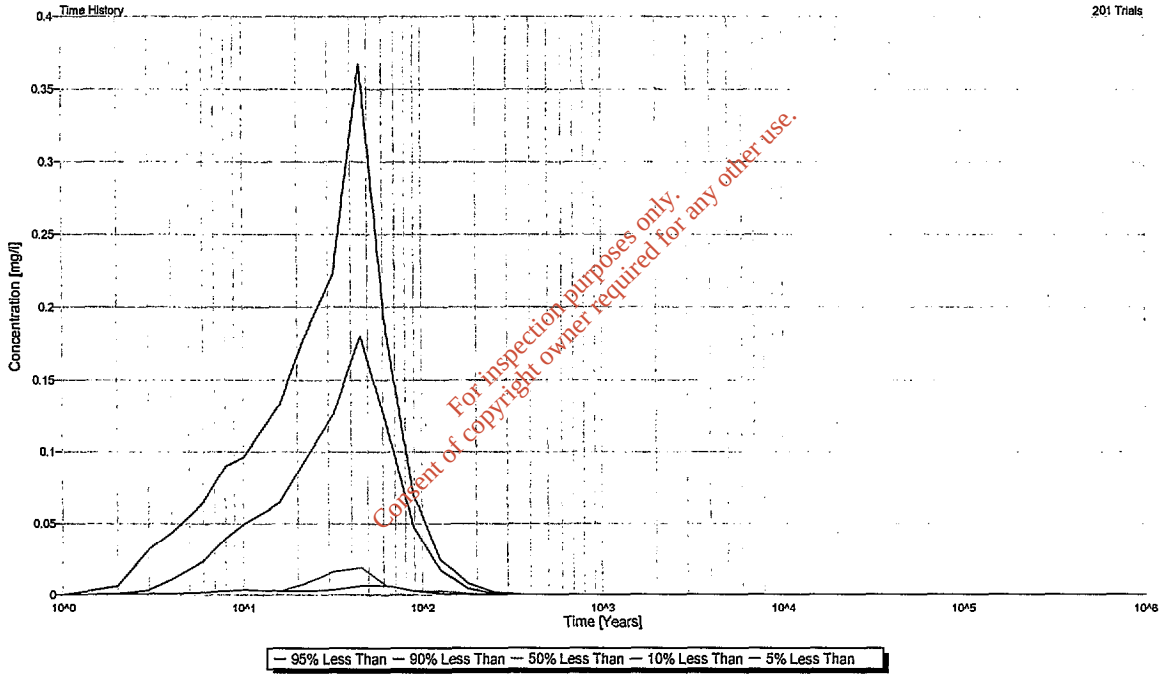
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Potassium at Compliance Point



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

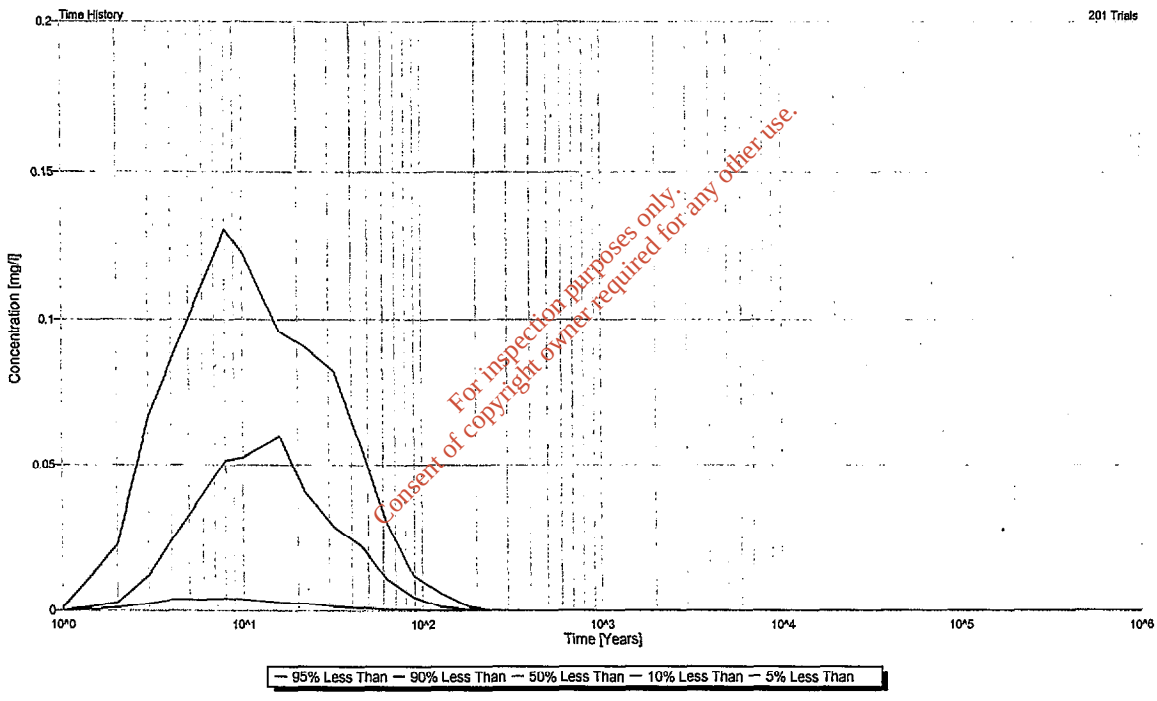
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 1 - Potassium at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

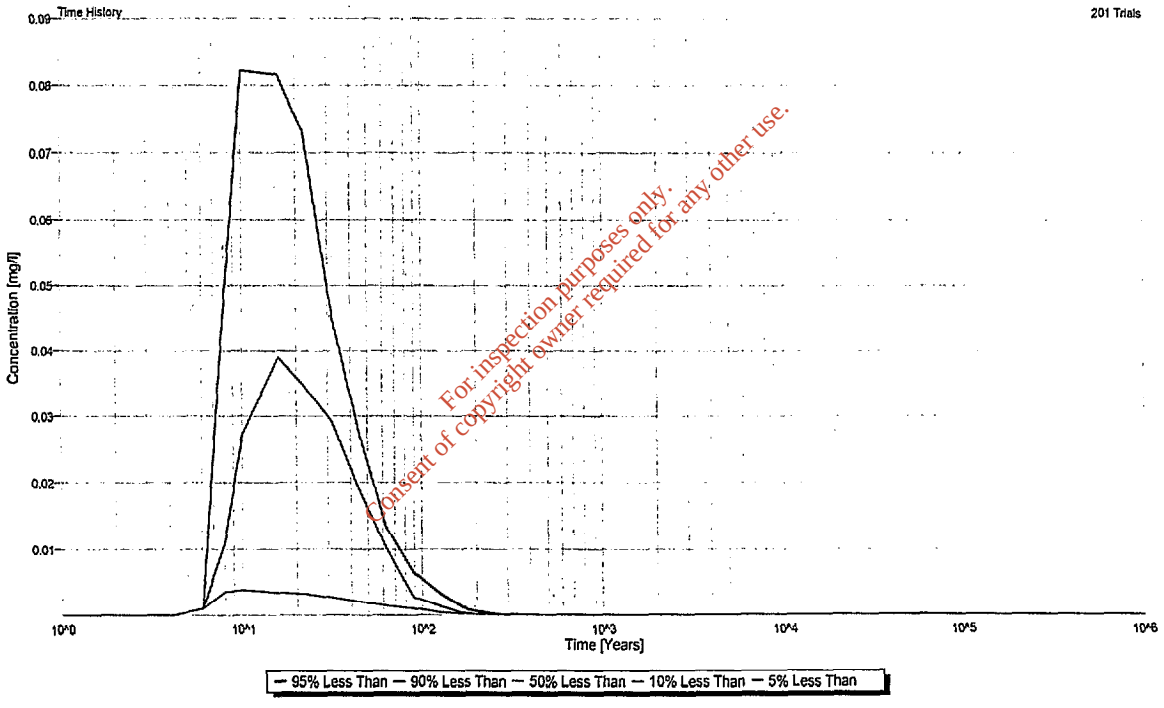
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 2 - Potassium at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

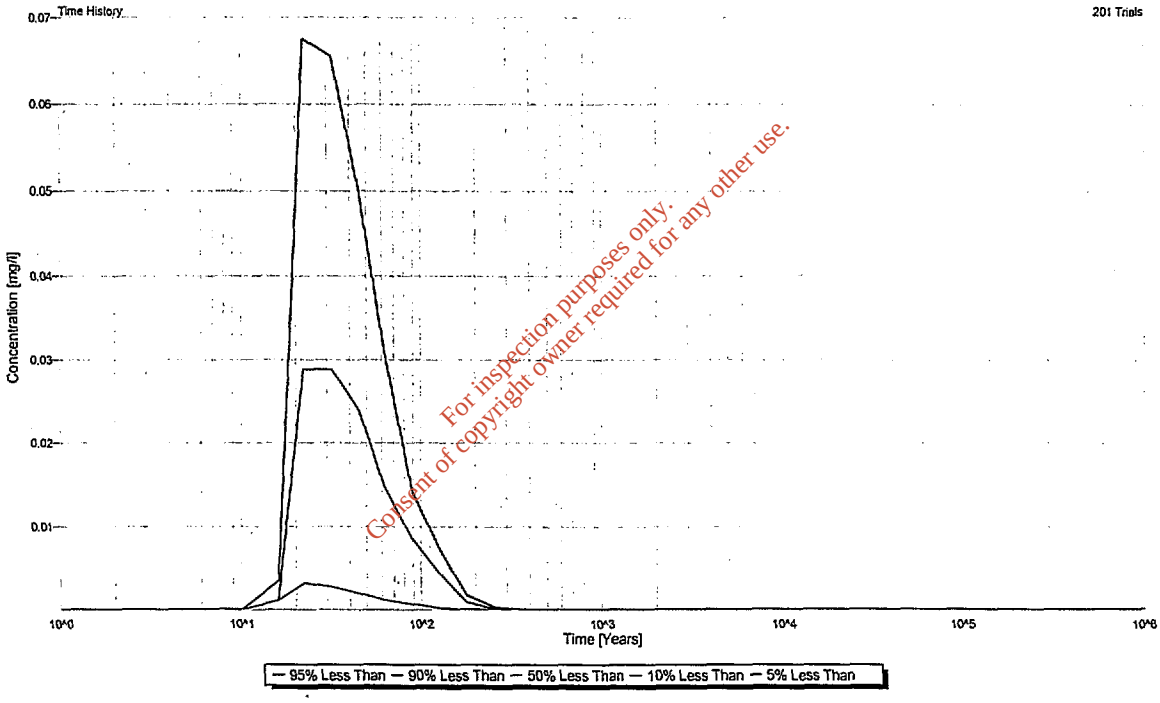
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 3 - Potassium at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

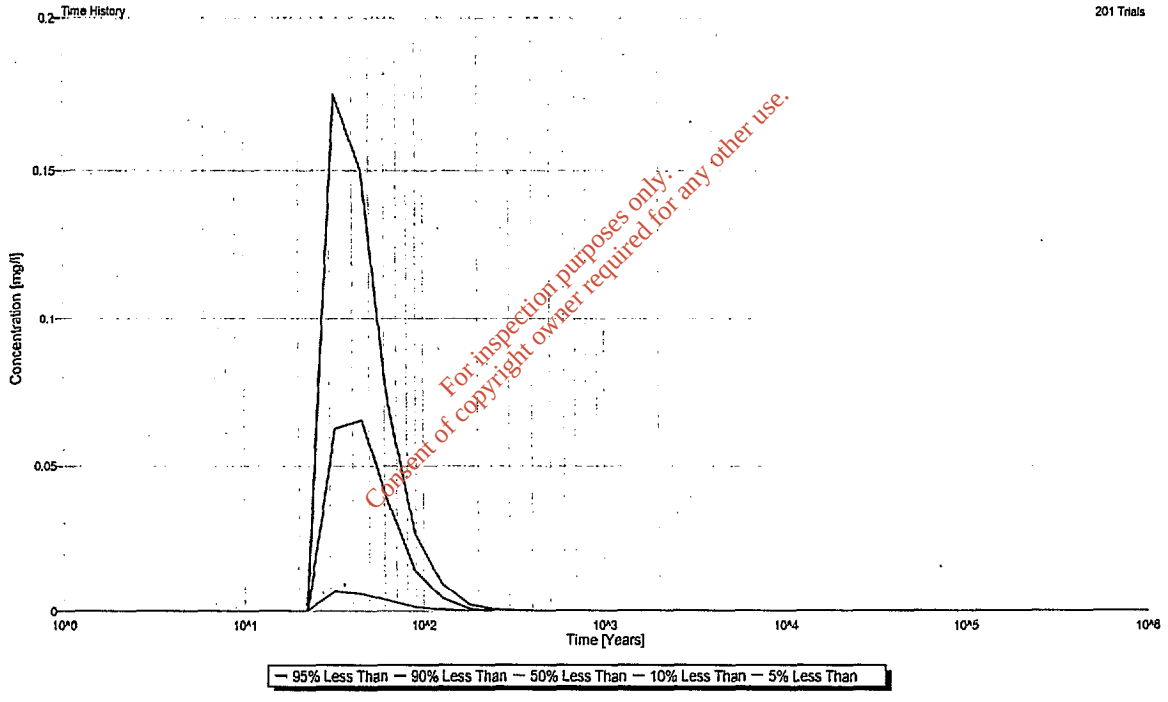
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 4 - Potassium at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

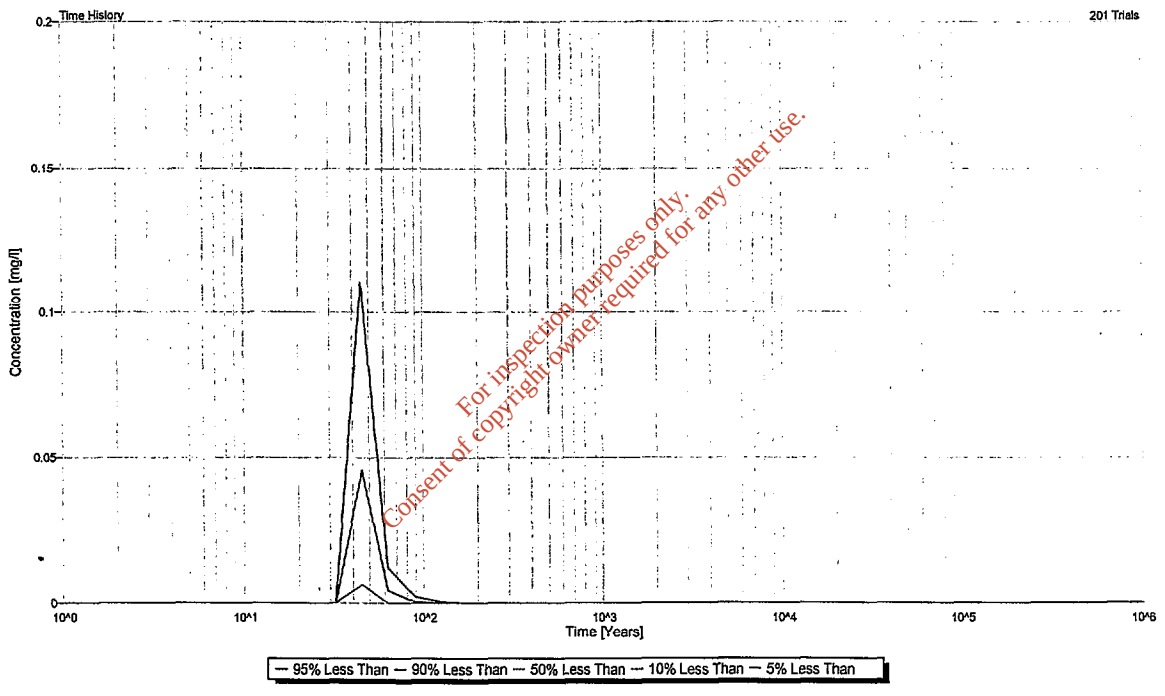
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 1

Client Name : Donegal County Council

Phase 5 - Potassium at Monitor Well



model 1 final phase - unretarded transport.sim 20 September 2004, 2:13 PM

APPENDIX G.6

LANDSIM 2 RESULTS

MODEL 2 FINAL PHASE – RETARDED TRANSPORT

PHASE 1	LEAKAGE FROM EBS
PHASE 2	LEAKAGE FROM EBS
PHASE 3	LEAKAGE FROM EBS
PHASE 4	LEAKAGE FROM EBS
PHASE 5	LEAKAGE FROM EBS

004

G04

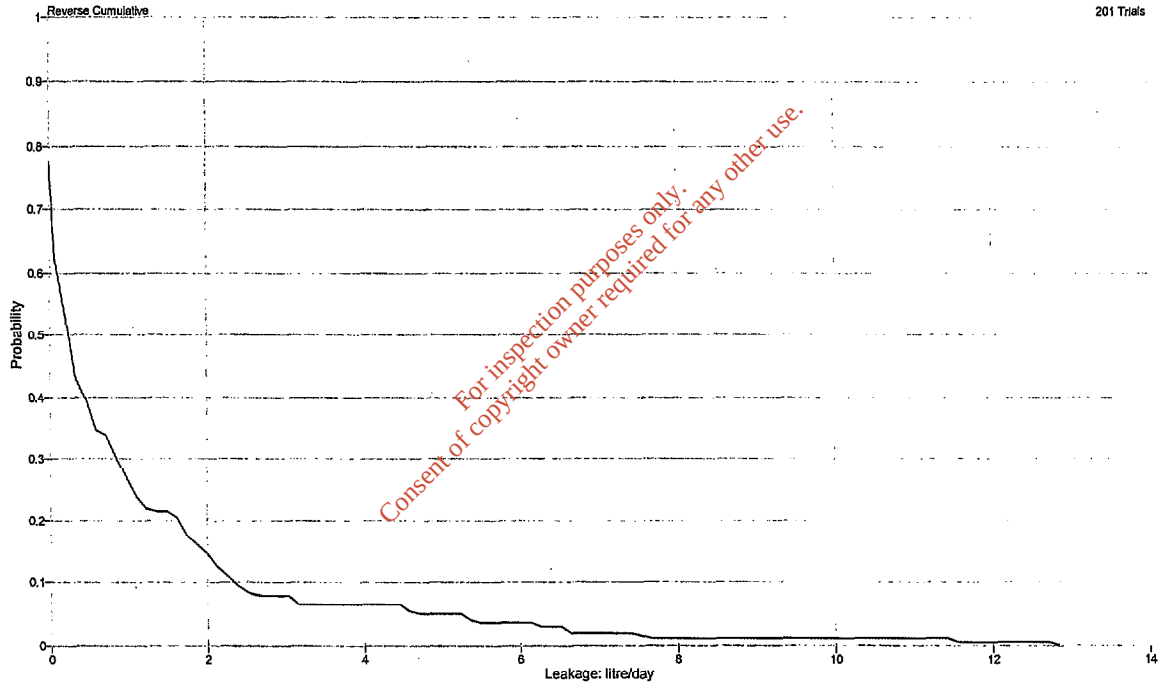
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 1 - Forecast: Leakage from EBS



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

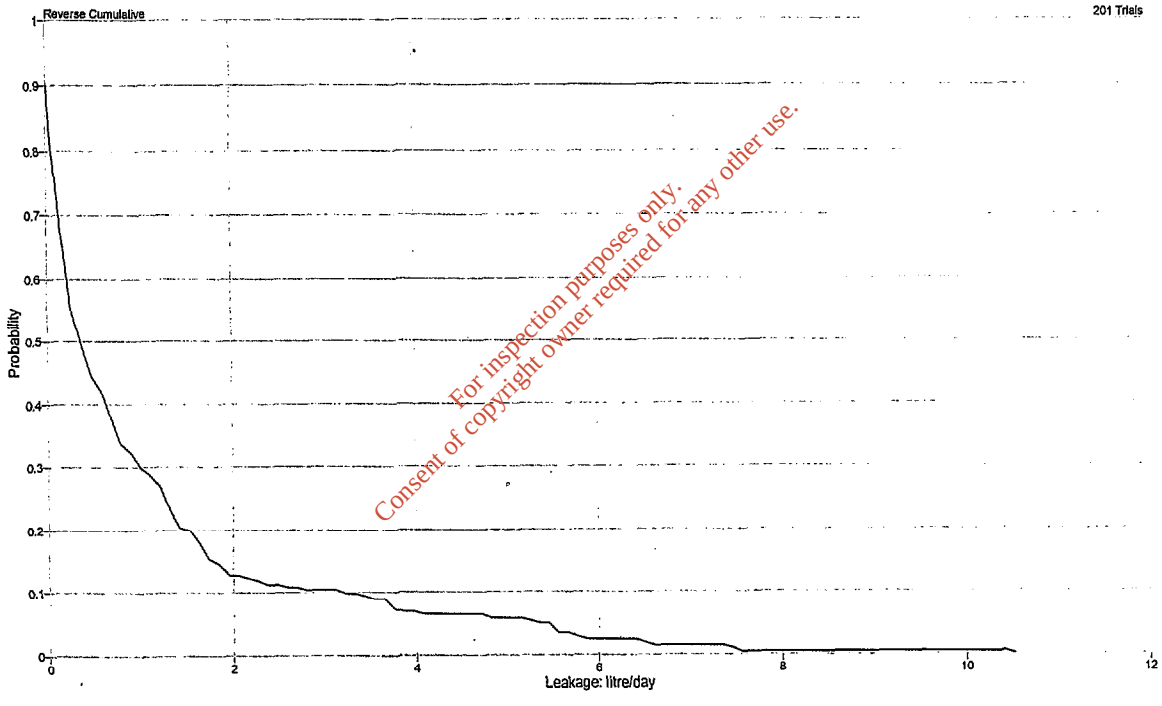
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 2 - Forecast: Leakage from EBS



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

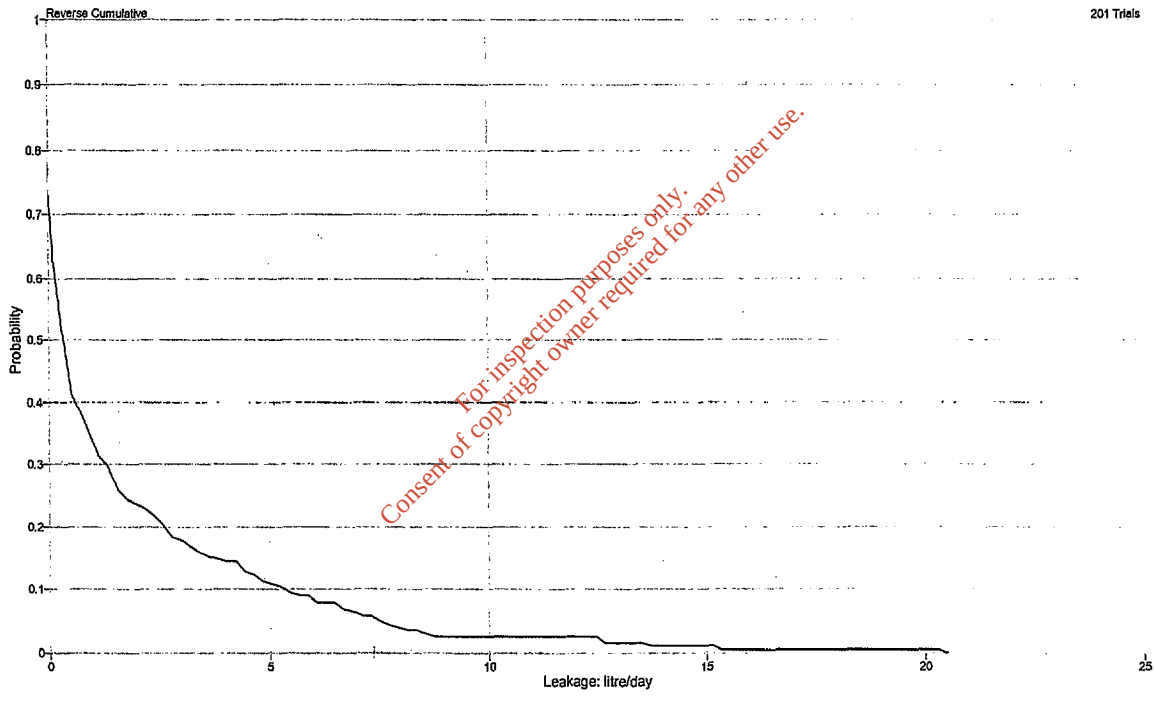
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 3 - Forecast: Leakage from EBS



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

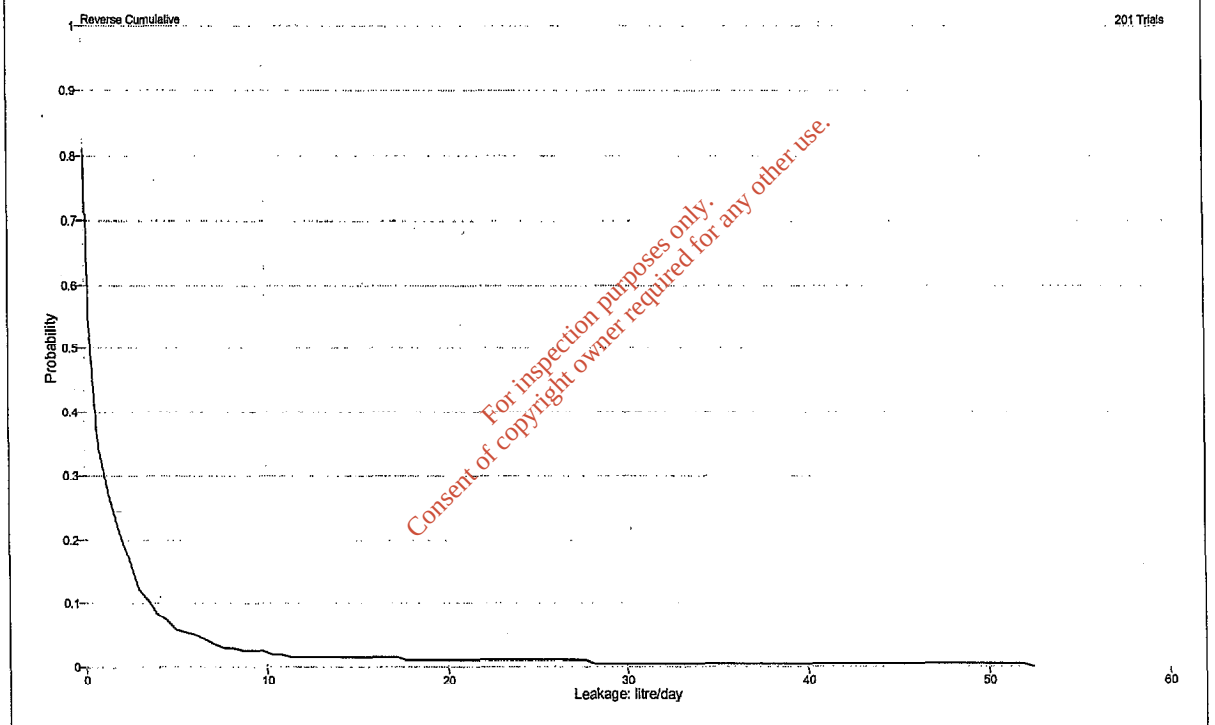
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 4 - Forecast: Leakage from EBS



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

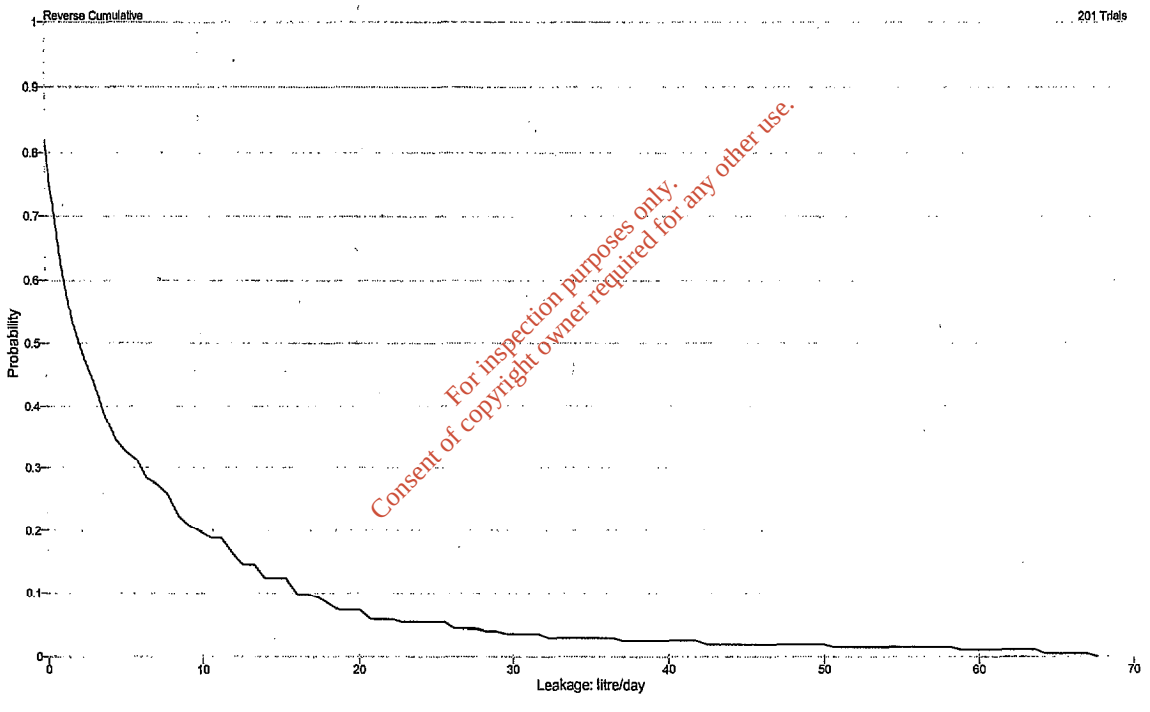
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 5 - Forecast: Leakage from EBS



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

APPENDIX G.7

LANDSIM 2 RESULTS

MODEL 2 FINAL PHASE – RETARDED TRANSPORT

AMMONIACAL NITROGEN AT COMPLIANCE POINT

PHASE 1 AMMONIACAL NITROGEN AT MONITOR WELL

PHASE 2 AMMONIACAL NITROGEN AT MONITOR WELL

PHASE 3 AMMONIACAL NITROGEN AT MONITOR WELL

PHASE 4 AMMONIACAL NITROGEN AT MONITOR WELL

PHASE 5 AMMONIACAL NITROGEN AT MONITOR WELL

004

G04

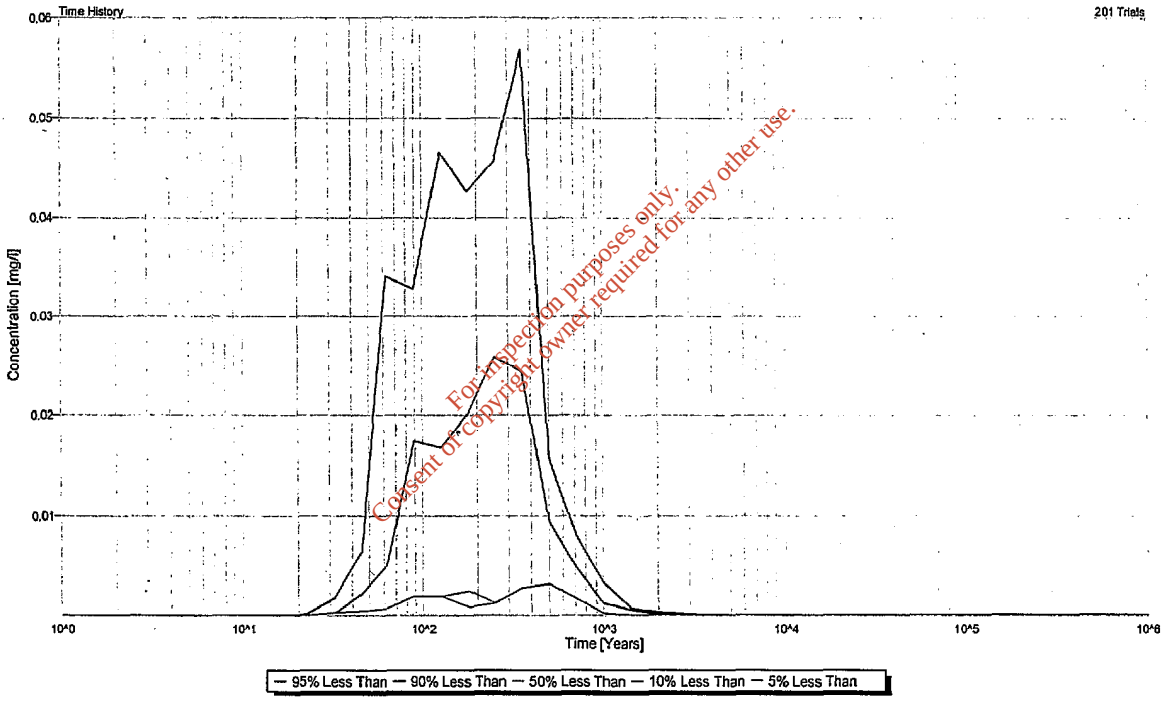
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Ammoniacal_N at Compliance Point



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

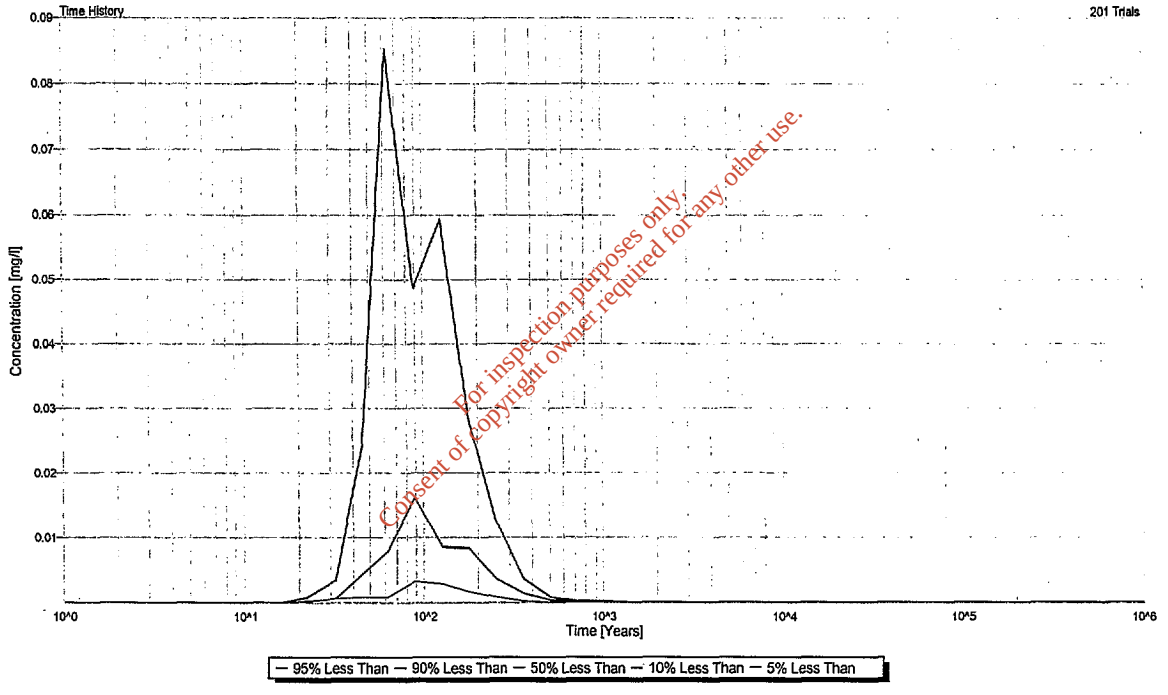
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 1 - Ammoniacal_N at Monitor Well



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

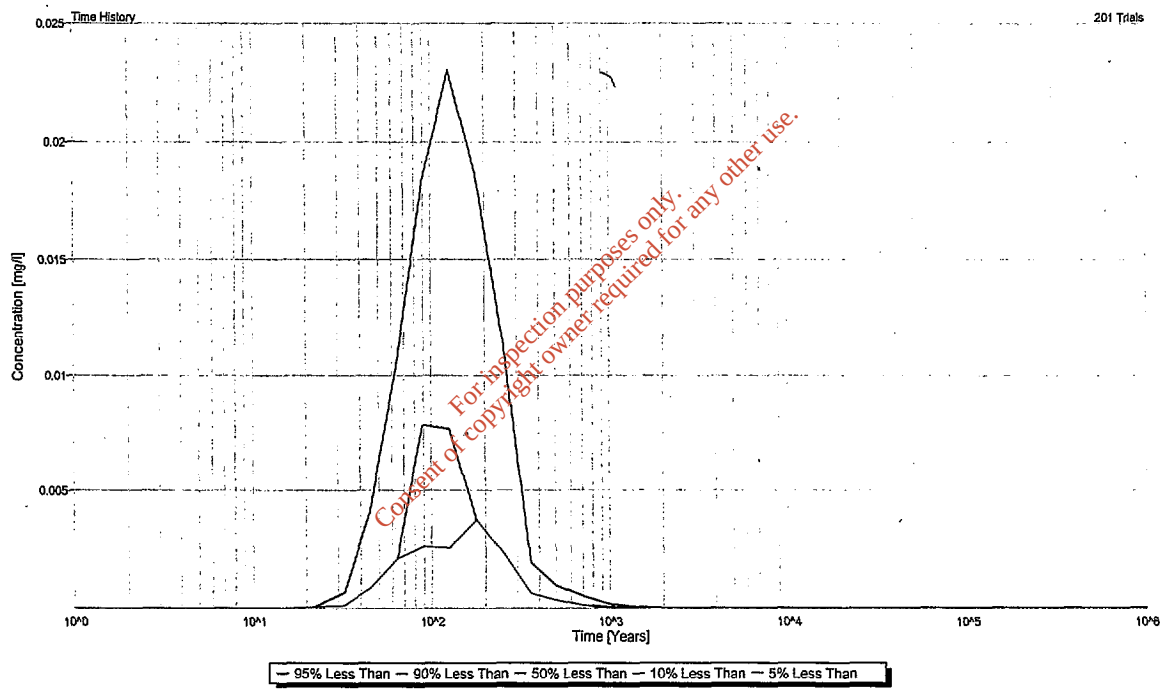
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 2 - Ammoniacal_N at Monitor Well



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

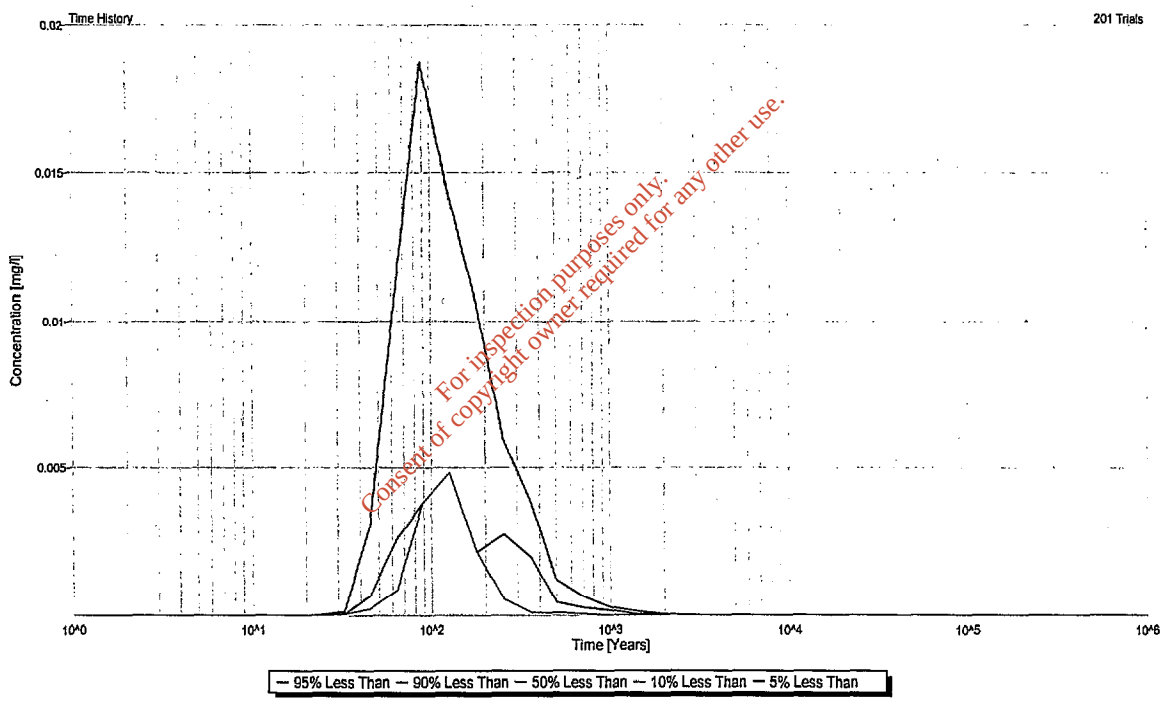
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 3 - Ammoniacal_N at Monitor Well



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

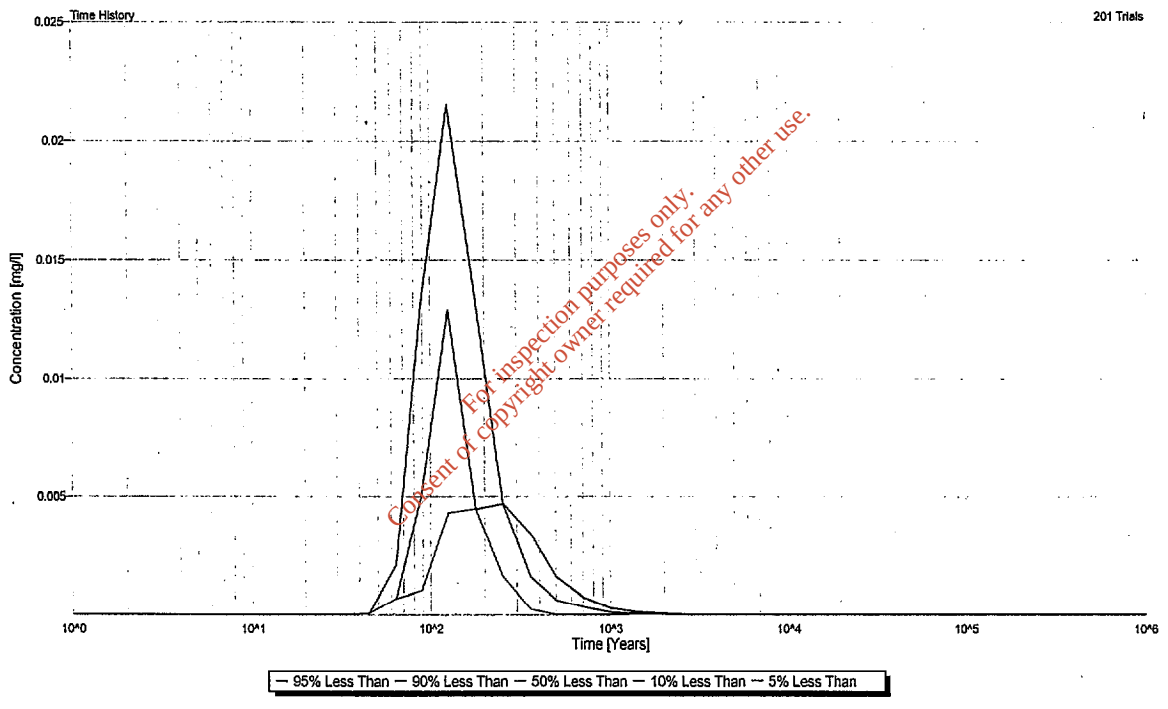
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 4 - Ammoniacal_N at Monitor Well



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

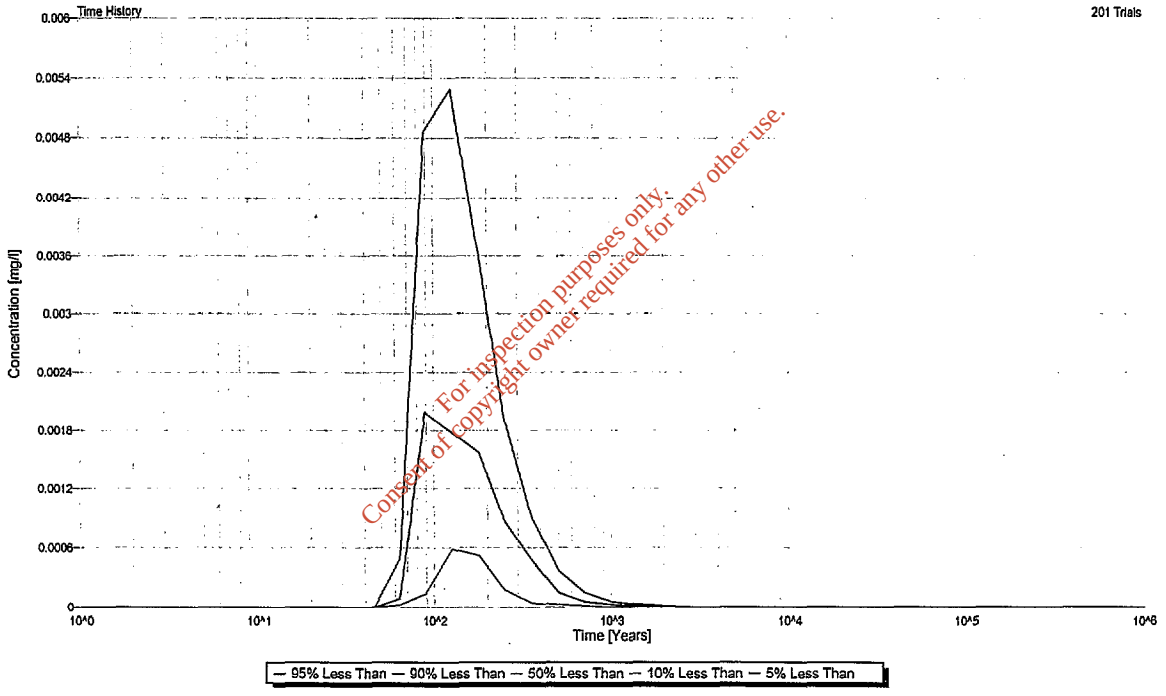
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 5 - Ammoniacal_N at Monitor Well



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

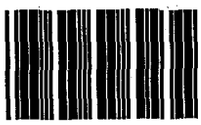
APPENDIX G.8

LANDSIM 2 RESULTS

MODEL 2 FINAL PHASE – RETARDED TRANSPORT

CHLORIDE AT COMPLIANCE POINT

PHASE 1	CHLORIDE AT MONITOR WELL
PHASE 2	CHLORIDE AT MONITOR WELL
PHASE 3	CHLORIDE AT MONITOR WELL
PHASE 4	CHLORIDE AT MONITOR WELL
PHASE 5	CHLORIDE AT MONITOR WELL



004

G04

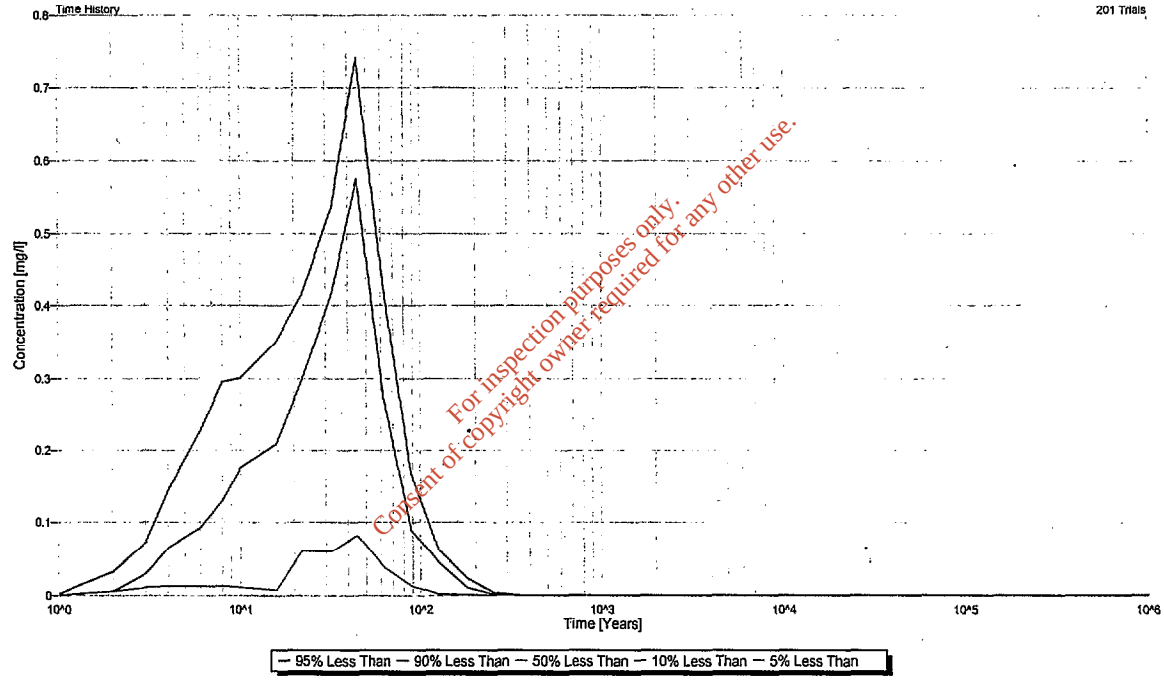
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Chloride at Compliance Point



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

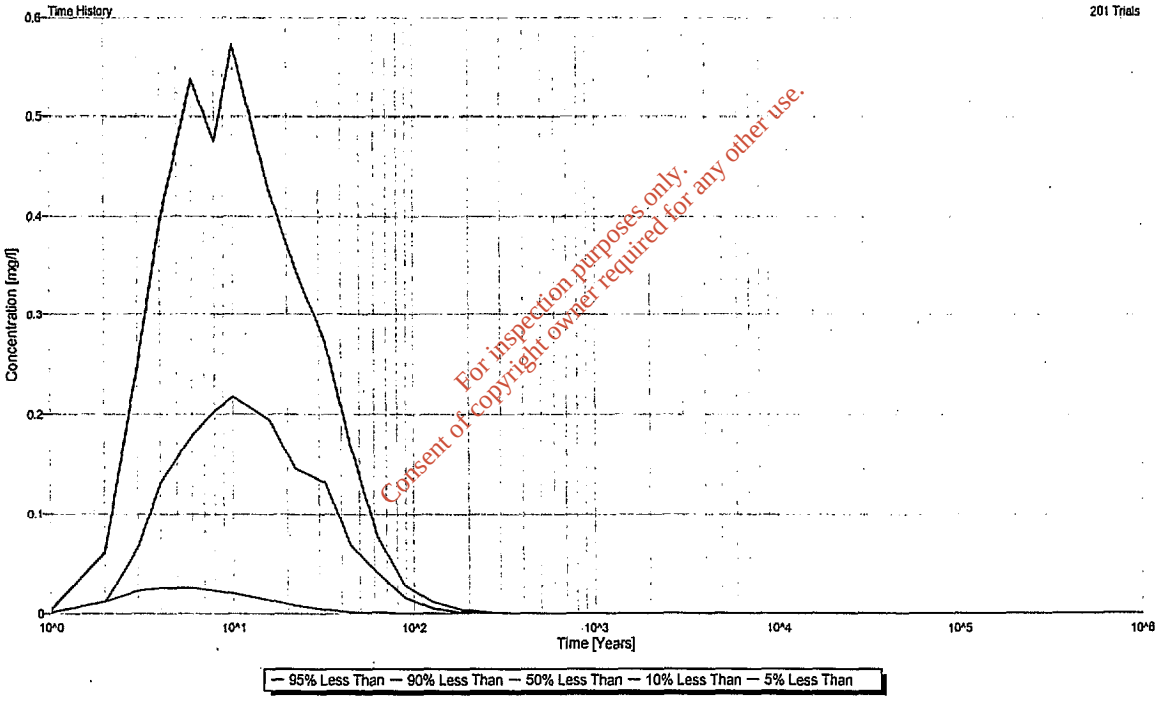
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 1 - Chloride at Monitor Well



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

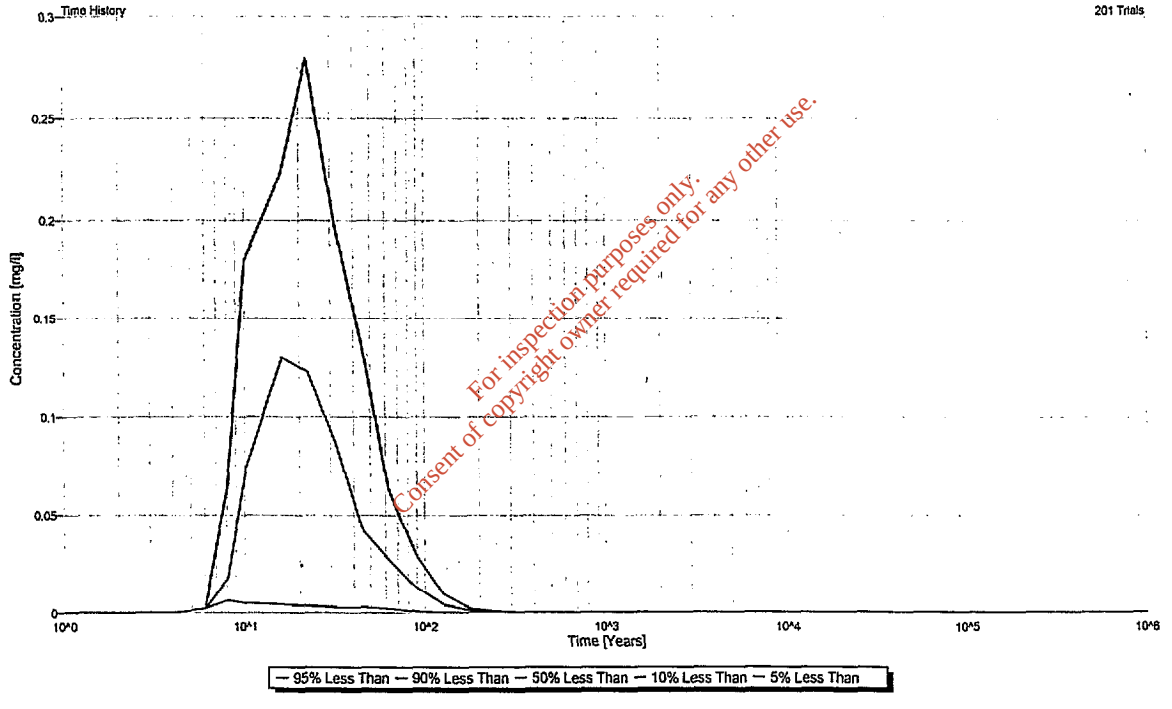
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 2 - Chloride at Monitor Well



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

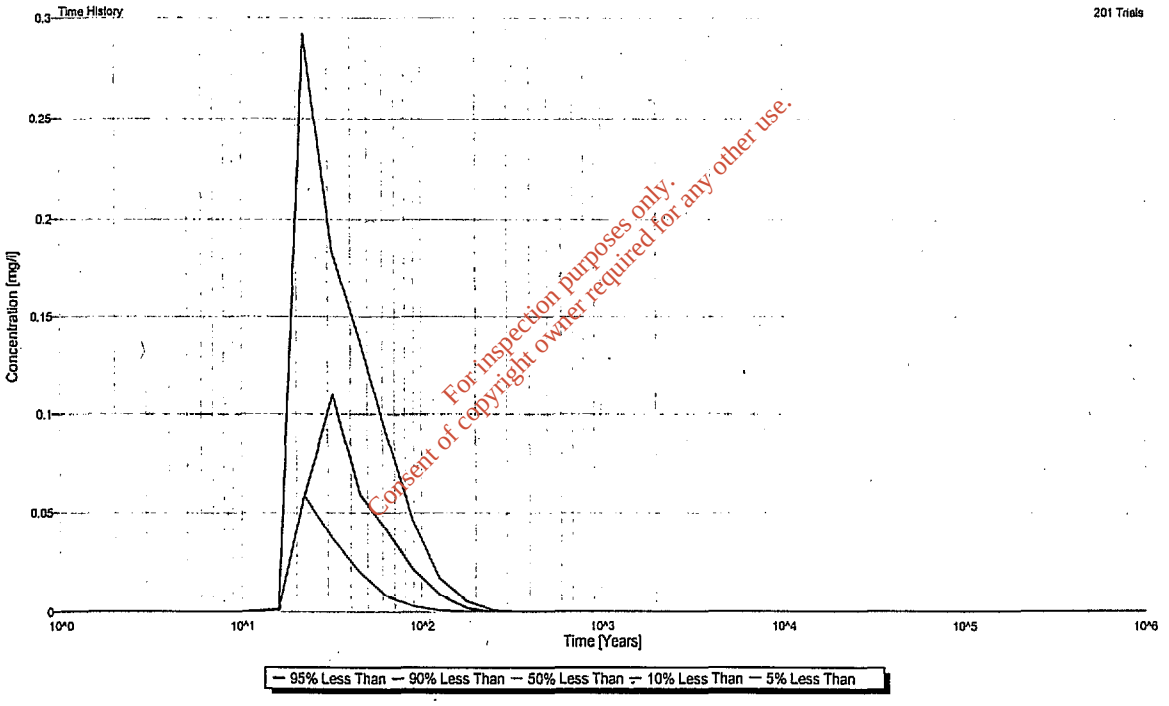
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 3 - Chloride at Monitor Well



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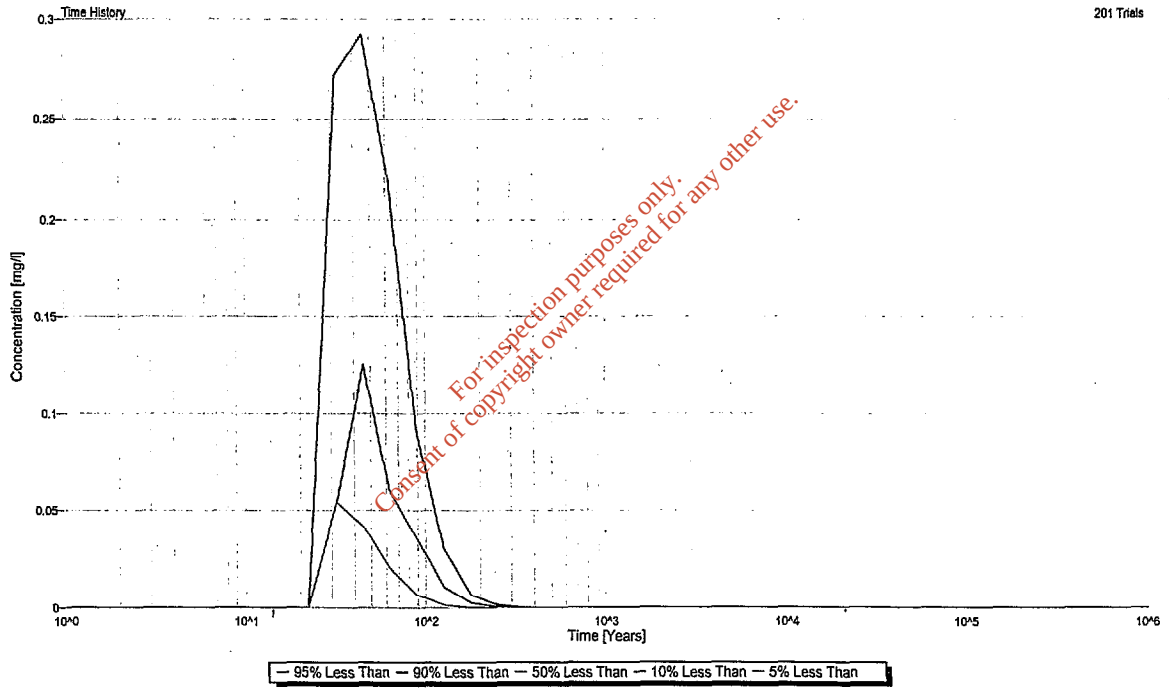
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 4 - Chloride at Monitor Well



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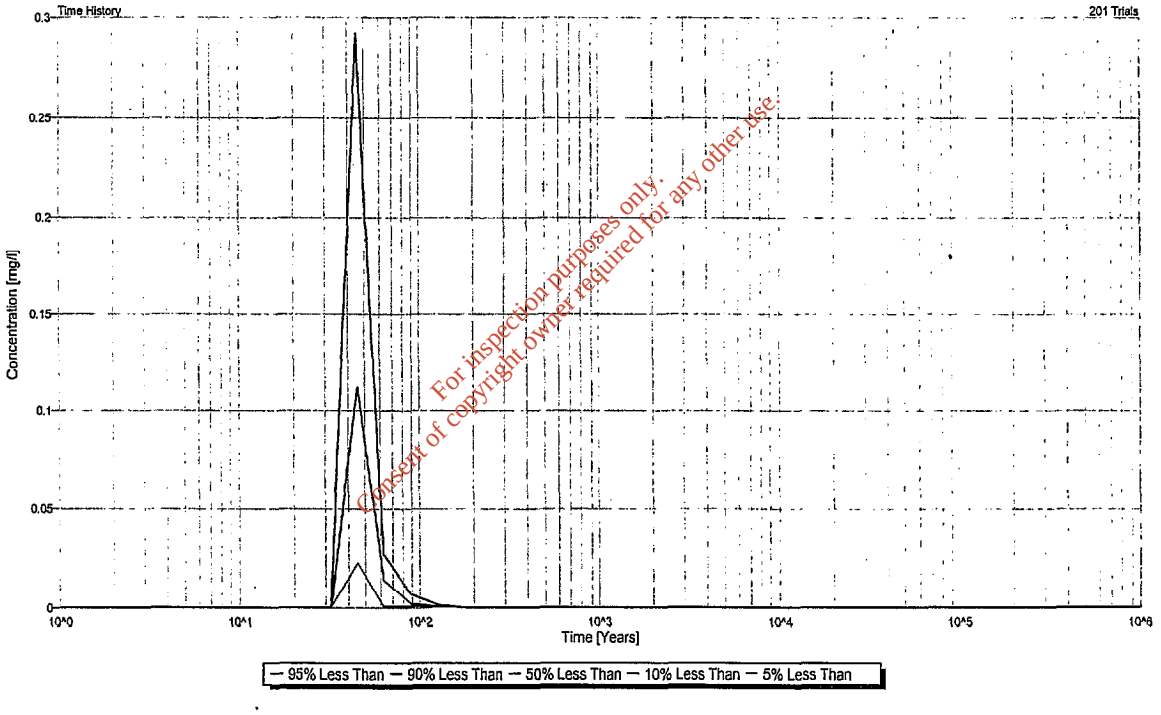
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 5 - Chloride at Monitor Well



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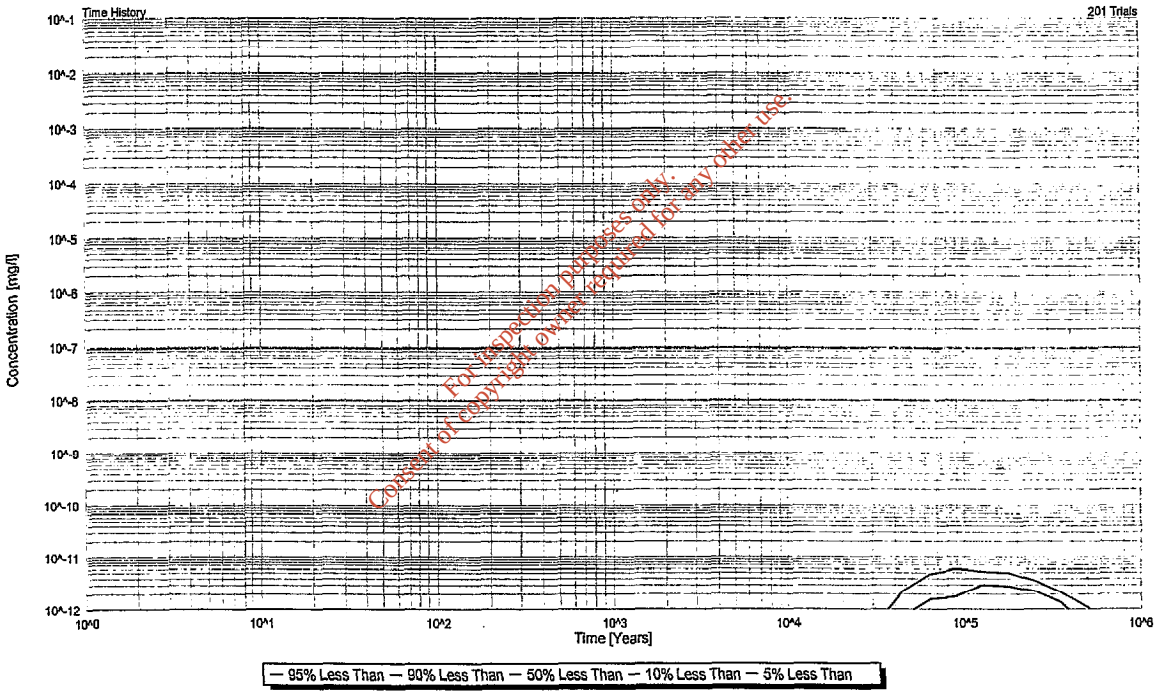
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 2 - Mercury at Monitor Well



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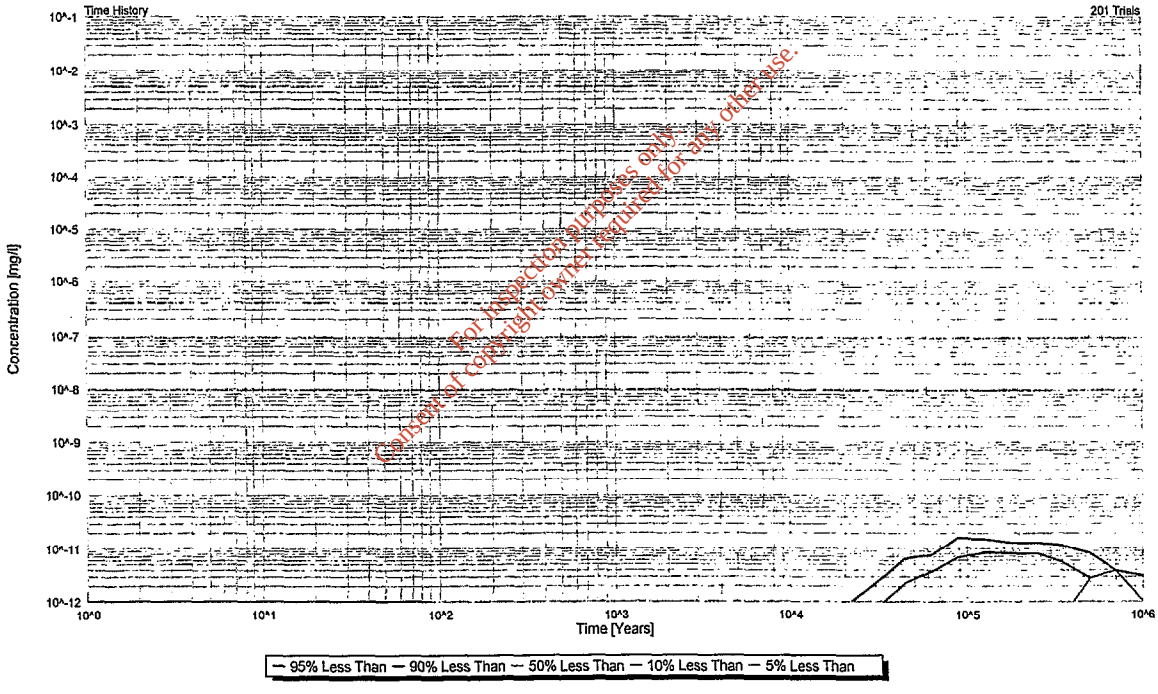
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Mercury at Compliance Point



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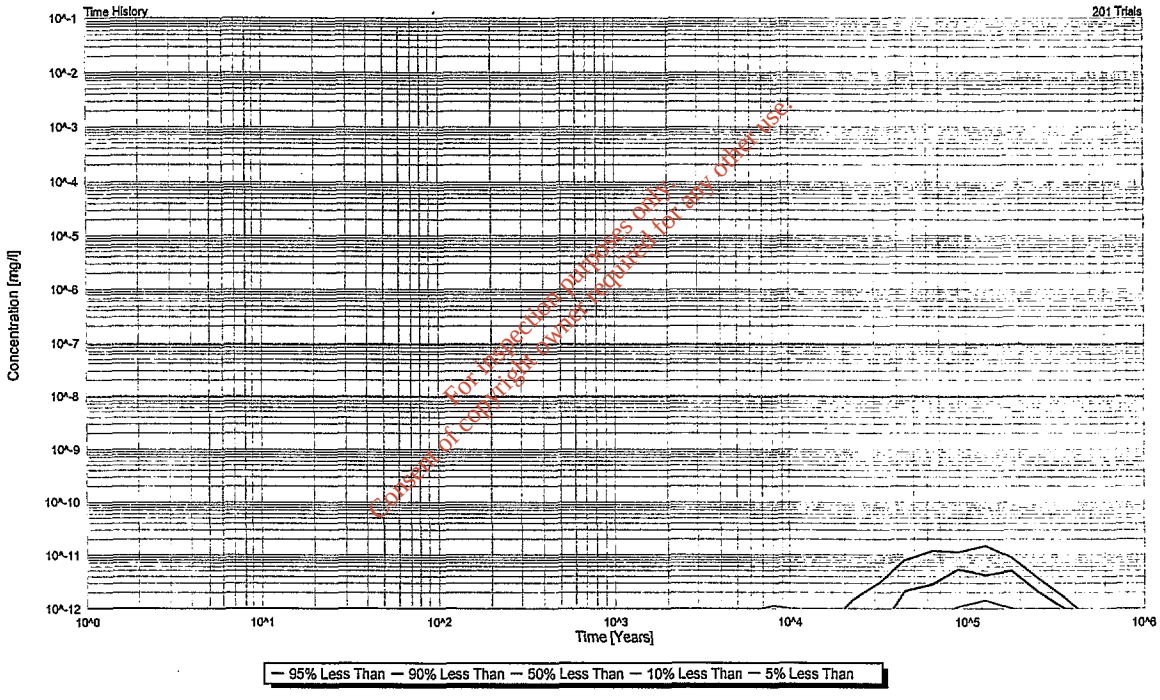
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 1 - Mercury at Monitor Well



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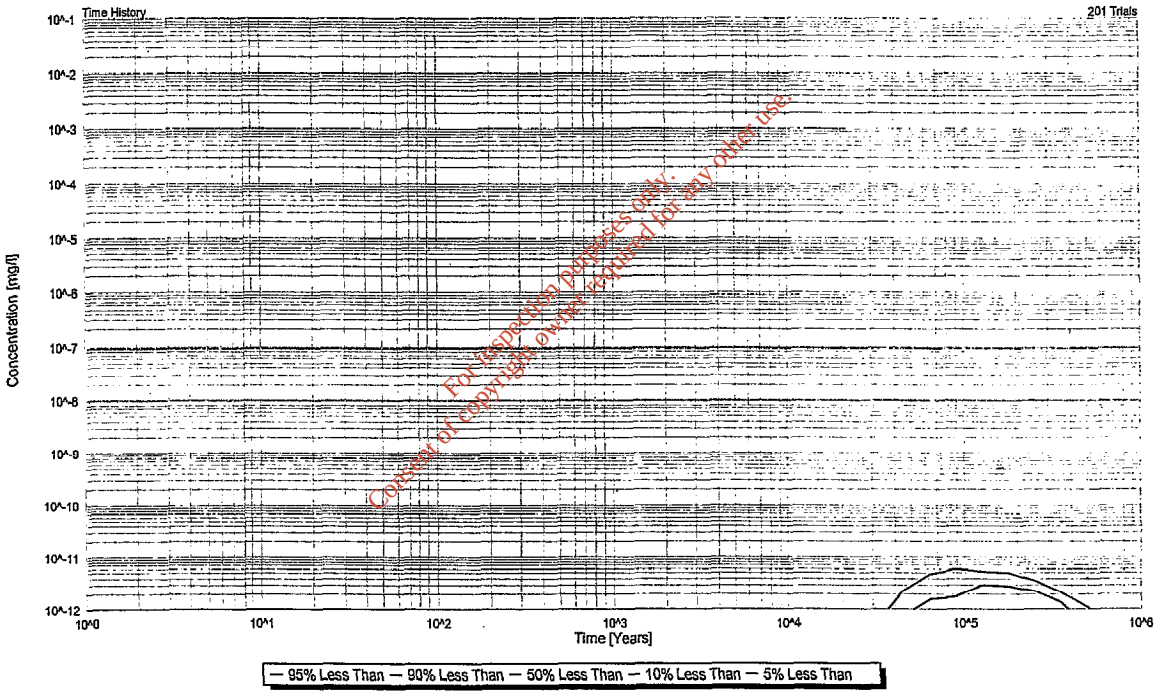
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 2 - Mercury at Monitor Well



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

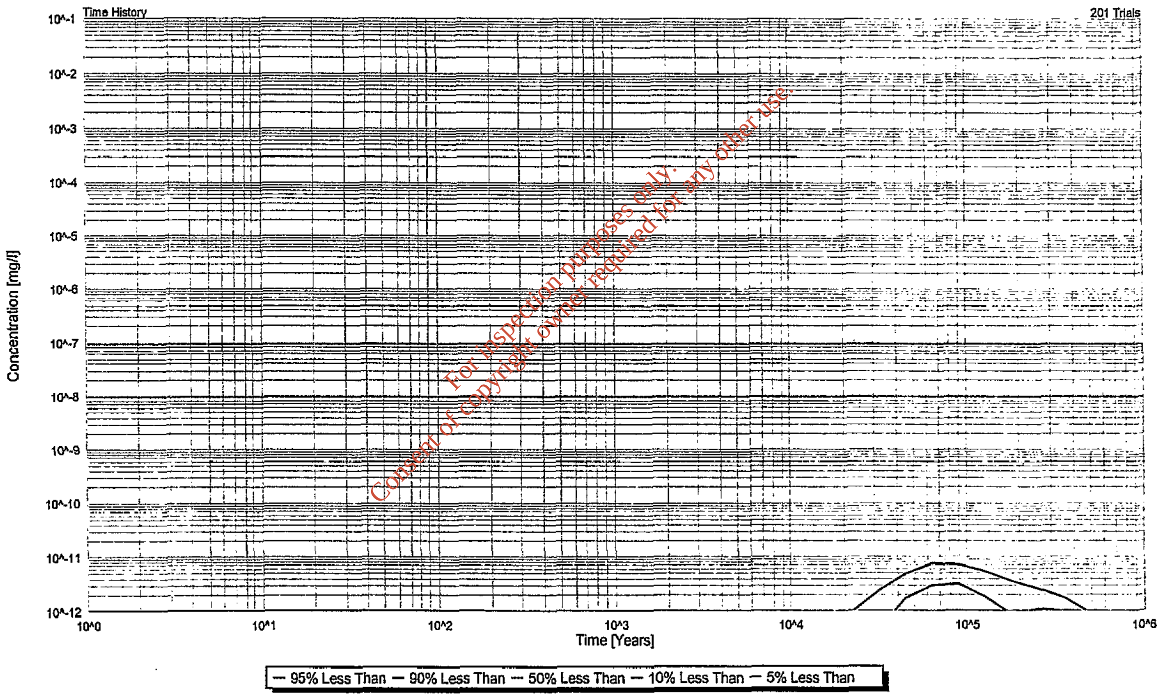
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 3 - Mercury at Monitor Well



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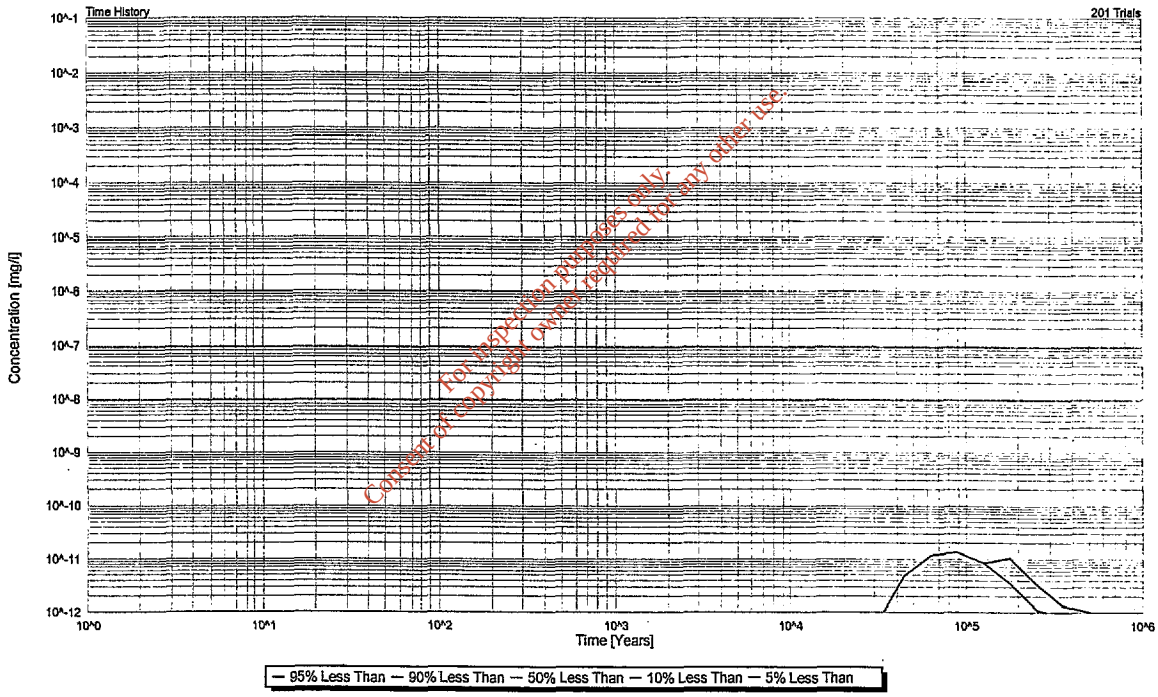
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 4 - Mercury at Monitor Well



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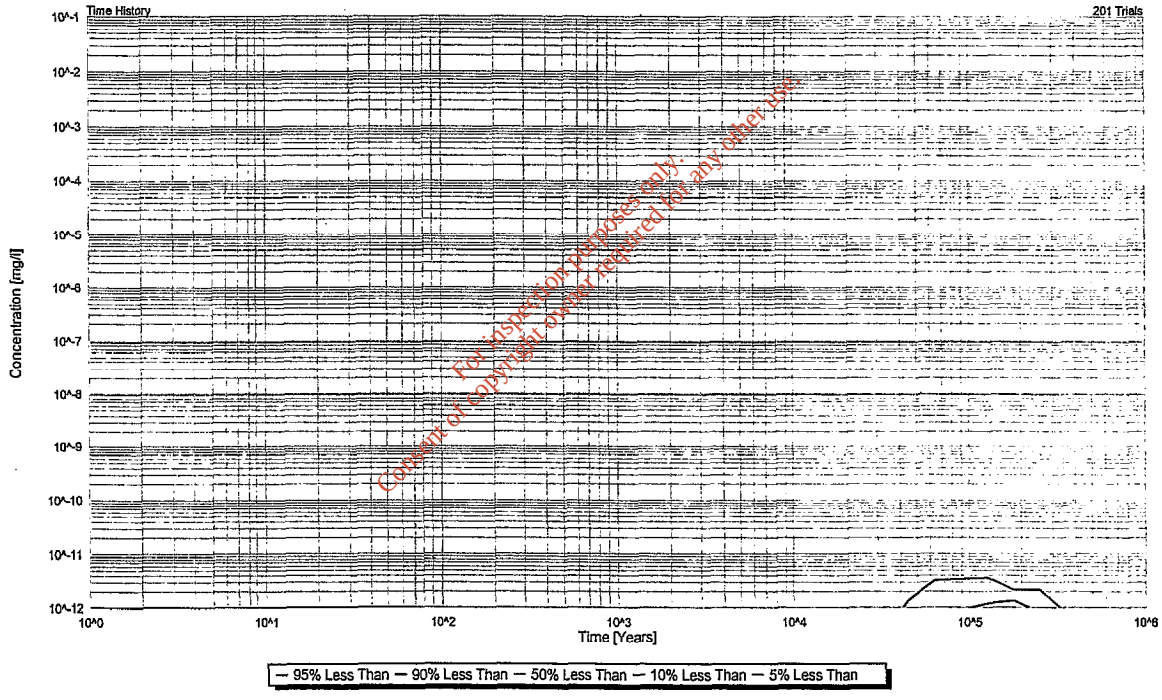
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 5 - Mercury at Monitor Well



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

APPENDIX G.10

LANDSIM 2 RESULTS

MODEL 2 FINAL PHASE – RETARDED TRANSPORT

POTASSIUM AT COMPLAINCE POINT

PHASE 1	POTASSIUM AT MONITOR WELL
PHASE 2	POTASSIUM AT MONITOR WELL
PHASE 3	POTASSIUM AT MONITOR WELL
PHASE 4	POTASSIUM AT MONITOR WELL
PHASE 5	POTASSIUM AT MONITOR WELL

004

G04

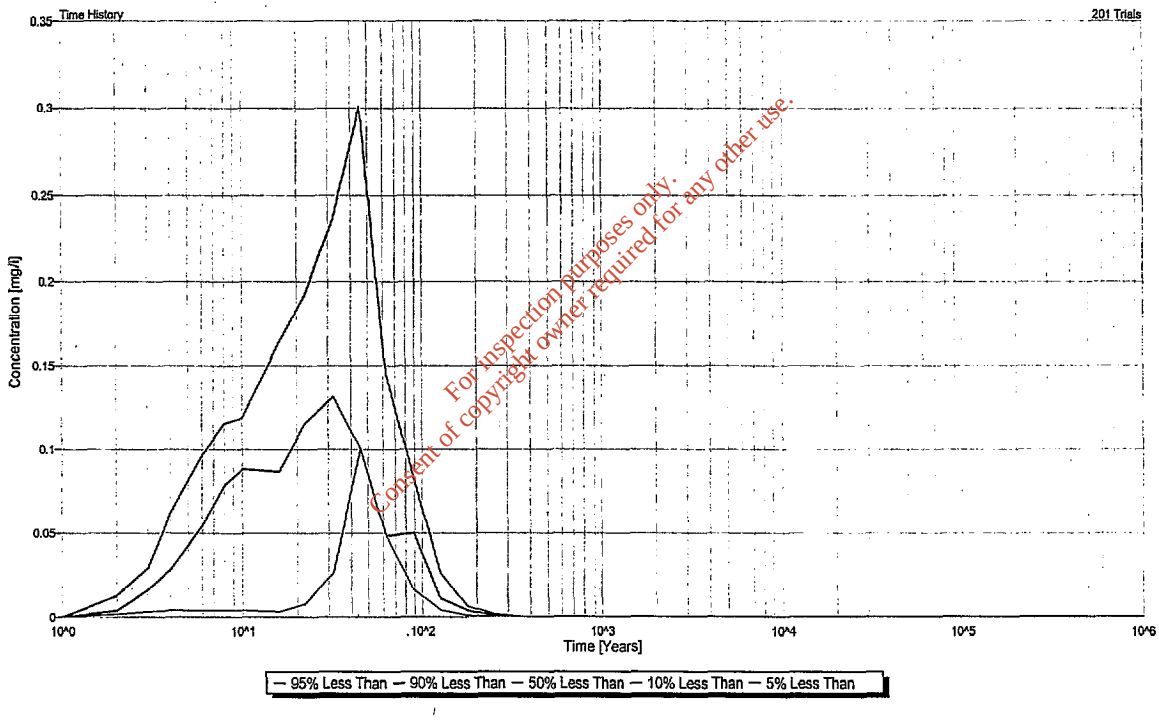
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Potassium at Compliance Point



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

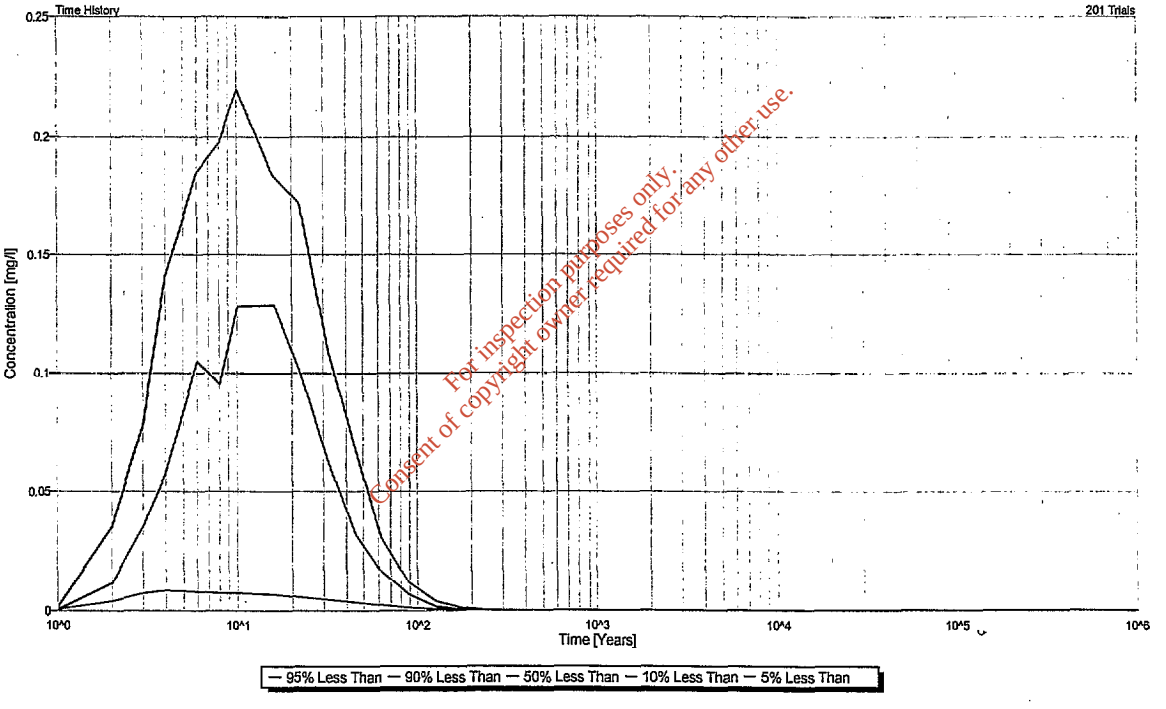
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 1 - Potassium at Monitor Well



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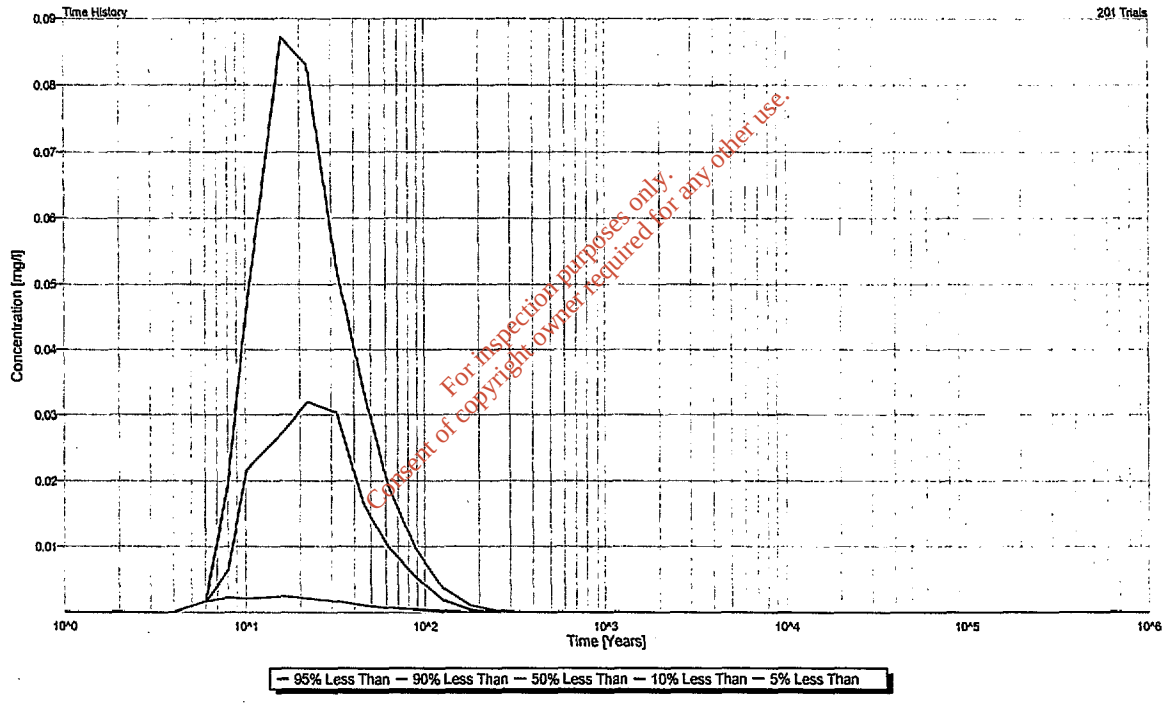
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 2 - Potassium at Monitor Well



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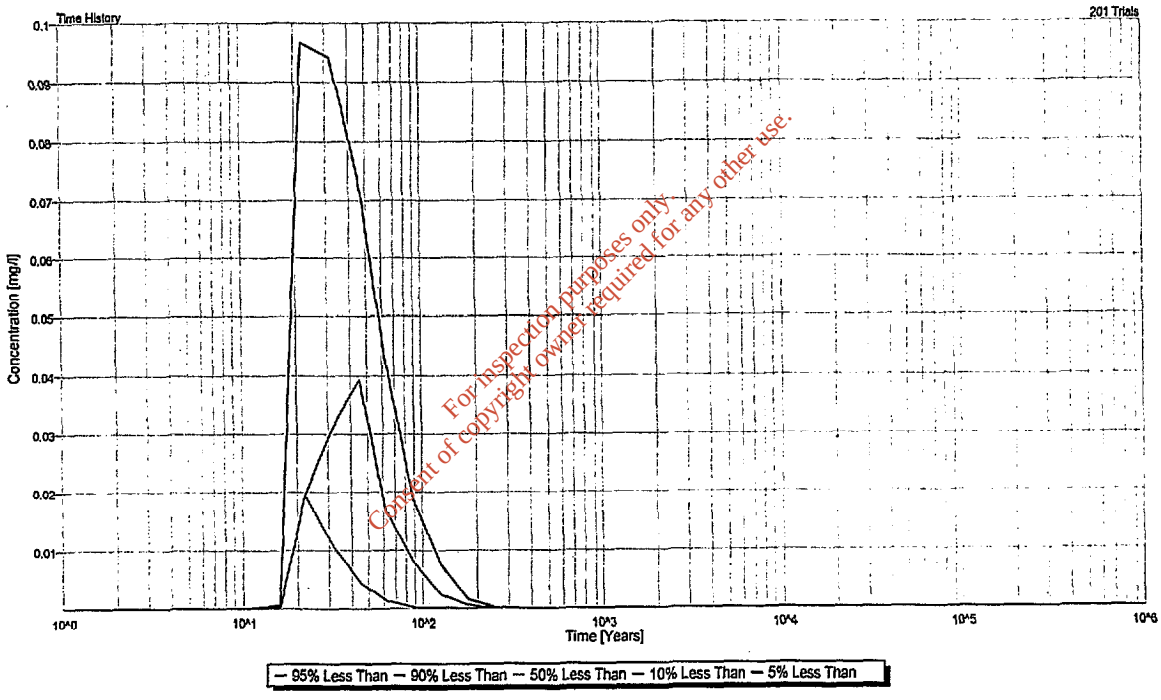
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 3 - Potassium at Monitor Well



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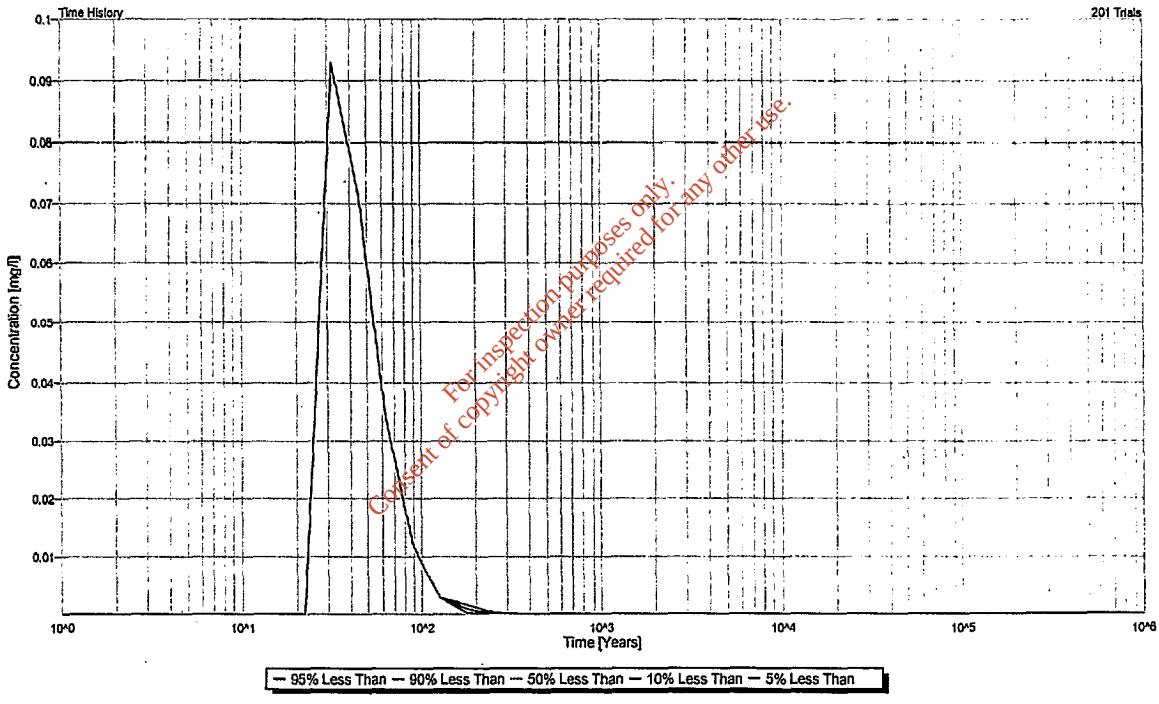
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 4 - Potassium at Monitor Well



model 2 final phase-retarded transport.sim 20 September 2004, 12:59 PM

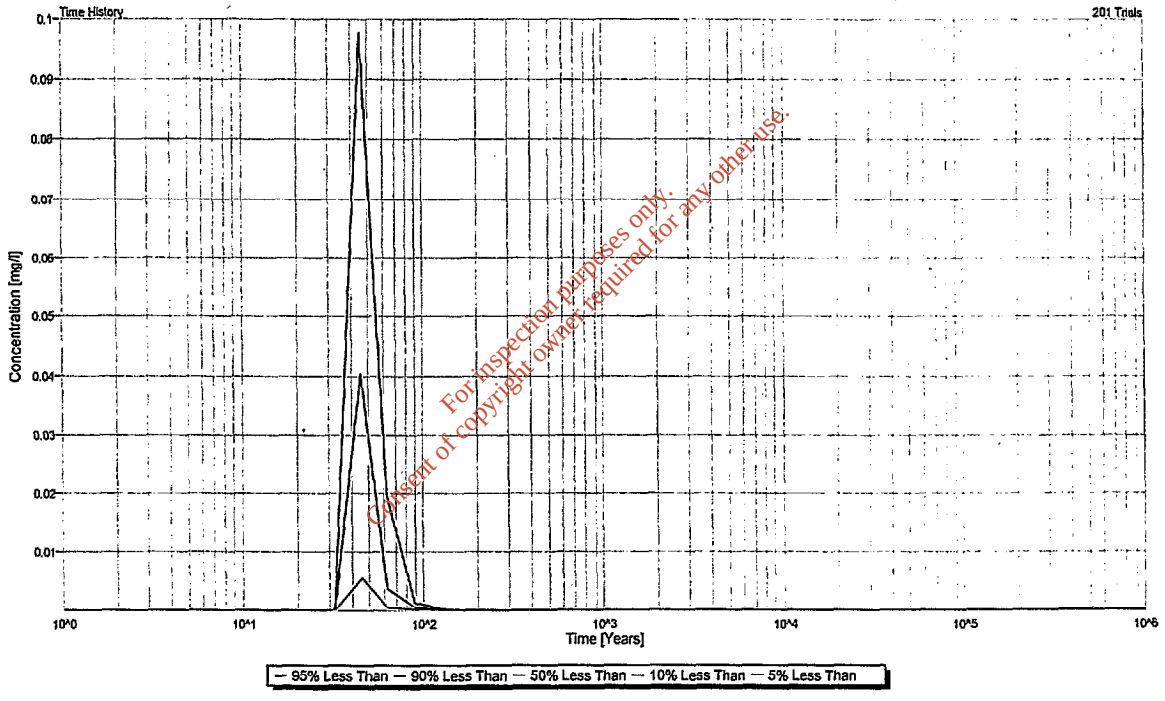
LandSim Version 2.02

Project Name : Meenaboll EIA

Project Number : Model 2

Client Name : Donegal County Council

Phase 5 - Potassium at Monitor Well



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