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EXECUTIVE SUMMARY

Lynas Malaysia Sdn. Bhd. (Lynas), intends to operate an Advanced Materials Plant to produce rare earth elements for export market. The plant is located in Gebeng Industrial Estate in Pahang. The plant will be built with an integrated processing system that utilizes physical and chemical treatment processes for production of the rare earth elements with the raw materials (lanthanide concentrates) to be imported from Mount Weld in Western Australia. The plant will process up to 80,000 tonnes per annum (tpa) of lanthanide concentrates (dry weight basis) and produce 22,500 tpa (LnO or lanthanide oxide basis) of high purity lanthanide compounds. The plant has been designed with special allocation reserved for future expansion in anticipation of future increase in product throughputs and product diversification.

The lanthanide concentrates is known to contain naturally occurring radioactive materials (NORM). As the process may disturb the physical and chemical structure of the raw materials and eventually lead to slight enhancement of the original concentration of NORM, thus, the local law requires that operation of such facility should be assessed for any potential radiological impact caused to workers, the general public and the environment. The Company has requested the assistance of Malaysian Nuclear Agency to carry out an updated radiological impact assessment (RIA) of the plant in order to fulfil Atomic Energy Licensing Board (AELB) requirements.

The previous RIA study has been submitted and approved by the AELB in 2008. This updated RIA study includes more site specific data compared to previous study. This is in line with the AELB requirement. The main objectives of this study are to assess potential radiological impact caused by operation of the plant to the workers and the general public living in the surrounding areas of the plant using site specific data and to confirm that such operation will not

cause undue radiological risk beyond what is allowed by the regulatory authority (AELB).

This study covers assessment of radiological safety aspects of the plant to be built by the Company in Gebeng, Pahang. It does not take into consideration non-radiological safety aspects of the project which might also present during operation of the plant, which may have similar impact to the health and safety of the people involved and which may have been covered under different studies sanctioned by the Company. Neither does the study take into consideration the radiological and non-radiological safety aspects of future decommissioning nor the disposal of the plant, after it has been decided to permanently cease operation.

The study covers the radiological safety assessment of exposure scenarios, the critical pathways, the critical radionuclides and the critical groups identified covering both internal and external exposure situations. It covers all anticipated activities that may take place during operation of the plant.

Results of the analysis have indicated that operation of the plant would not caused undue radiological risk to workers and members of the public. The estimated doses to be received by workers and members of the public resulting from operation of the plant are 12.68 mSv/y and 0 mSv/y respectively. These doses are well below the annual dose limits allowed for workers and members of the public by the Radiation Protection (Basic Safety Standard) Regulations of 1989.

The wastes generated from the process, though one of the streams (WLP) appears to be slightly enhanced in term of concentration of NORM, but the method adopted to keep them during the entire operational period of the plant has proved that the resulting doses to workers and members of the public are within the permissible annual dose limit.

Based on the results of the updated RIA, it is concluded and recommended that the operation of the plant would not caused any radiological risk to the workers and members of the public living in the surrounding areas of the site as reported in previous RIA study to be given due consideration by the AELB.

The assessment is to be revised again when more operational data are available to ensure that the estimated doses obtained in this assessment are further refined and the conclusion derived from this assessment is indeed realistic and acceptable.

APPENDIX A – LIST OF FIGURES

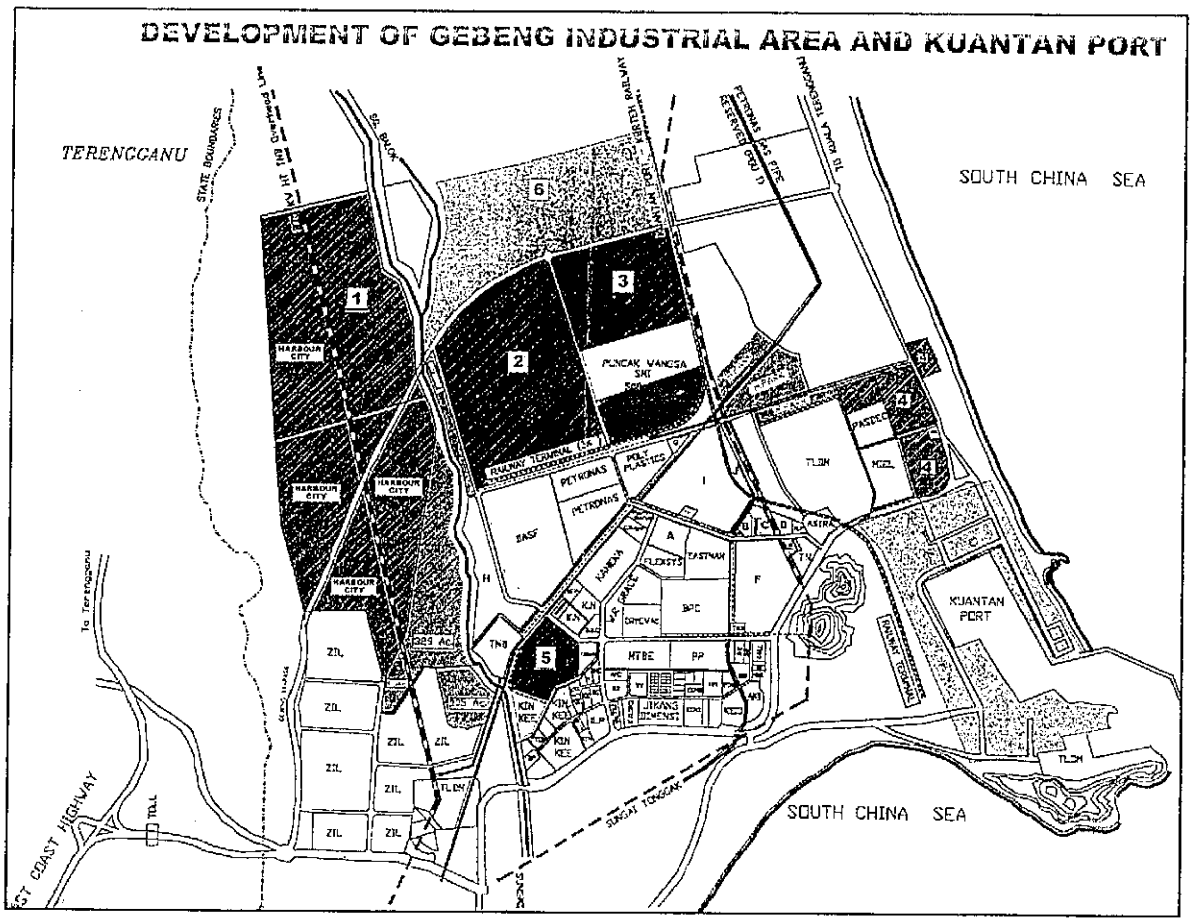

Figure 3.1 Location of the site and its immediate surrounding areas

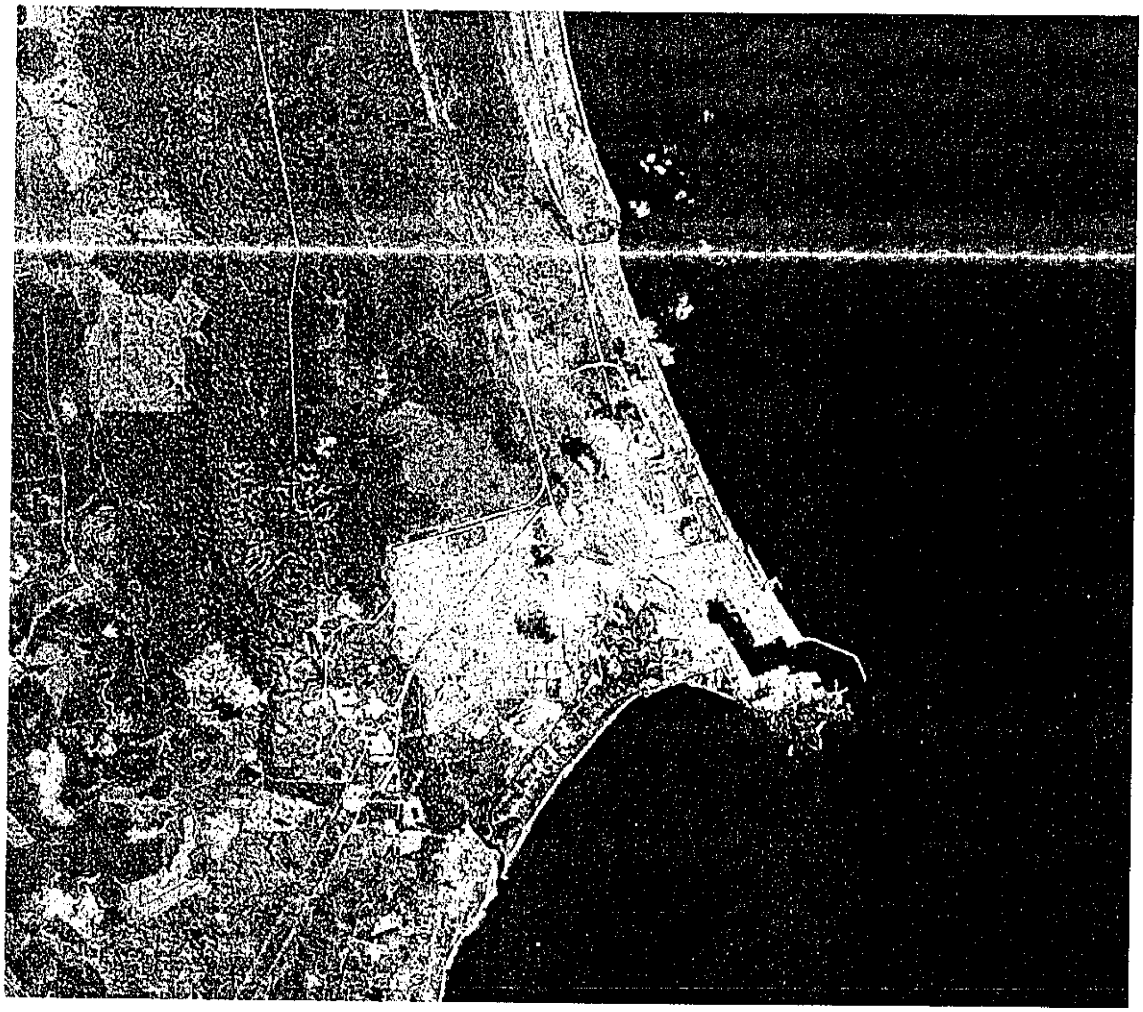

Figure 3.2 Satellite view

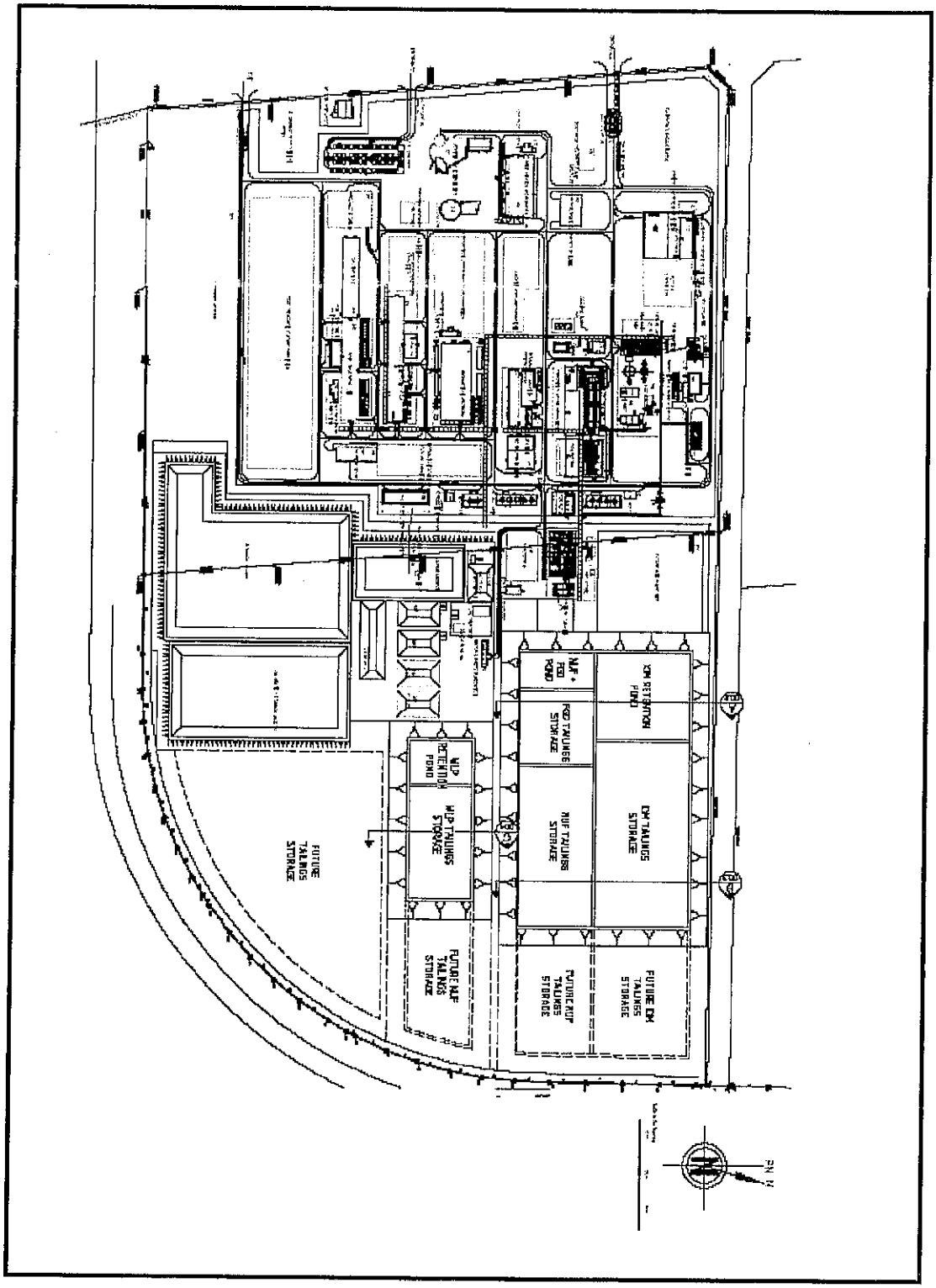

Figure 3.3: A close-up view of the site which indicates location of the proposed plant and its future expansion

Figure 3.4. Survey detail

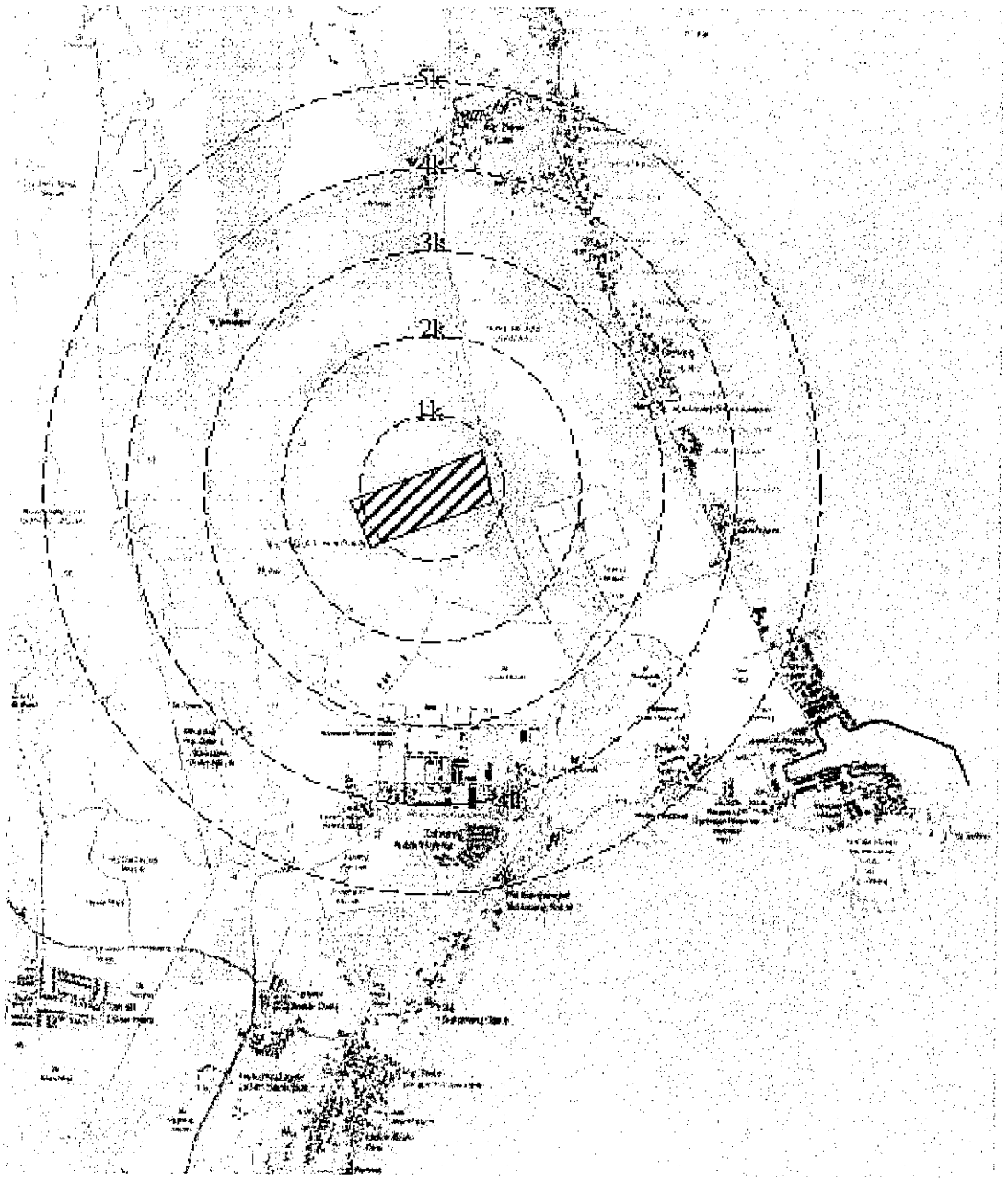

Figure 3.5: Topography of the area

Figure 3.6. Sg. Balok/Sg. Tunggak

Figure 3.7. Geological map

Figure 3.8: Annual wind rose

Figure 3.9: Seasonal wind rose

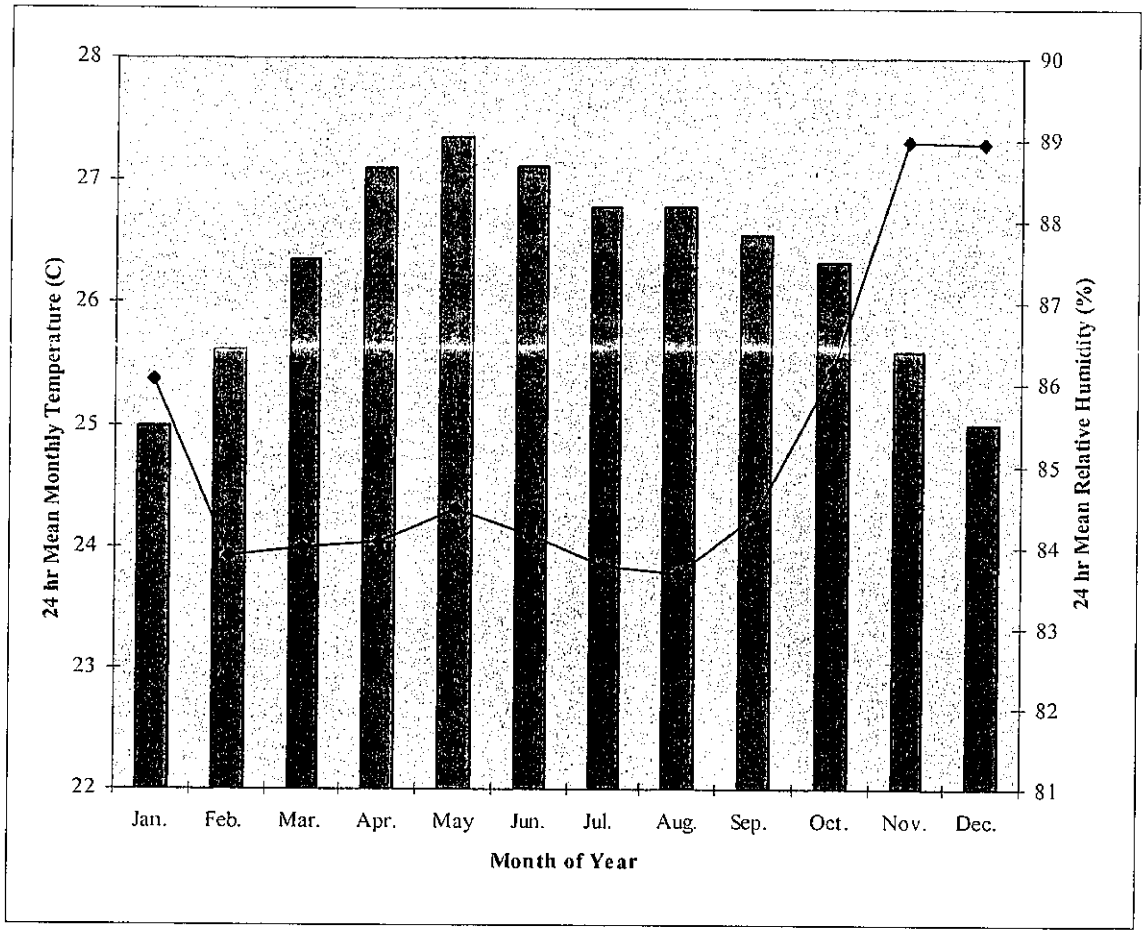

Figure 3.10: Temperature & Relative Humidity Data For The MMS Monitoring Station At Sultan Ahmad Shah Airport, Kuantan, Pahang (Jan 1968 - Oct 2007)

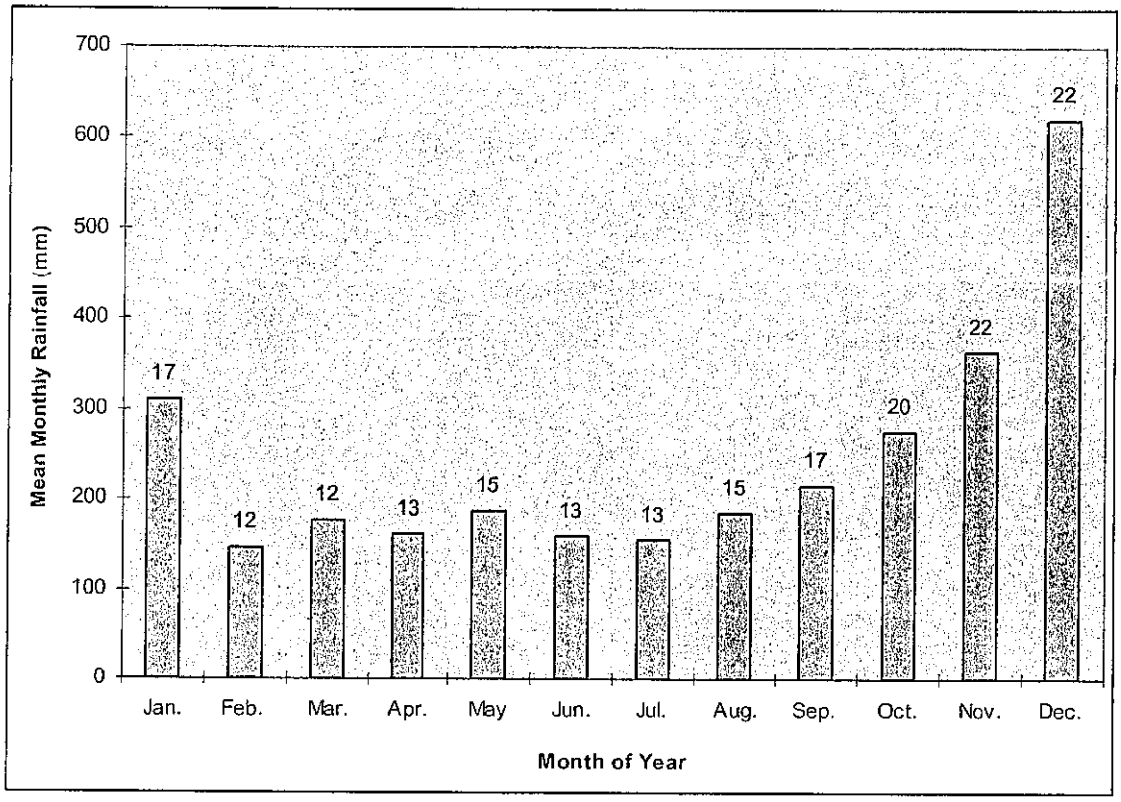

Figure 3.11: Rainfall Data Summary For The MMS Monitoring Station At Sultan Ahmad Shah Airport, Kuantan, Pahang (Jan 1951 - Oct 2007)

Figure 3.12: Land use pattern

Figure 3.13: Process flow (overall)

Figure 3.14: Process flow cracking-separation plant....

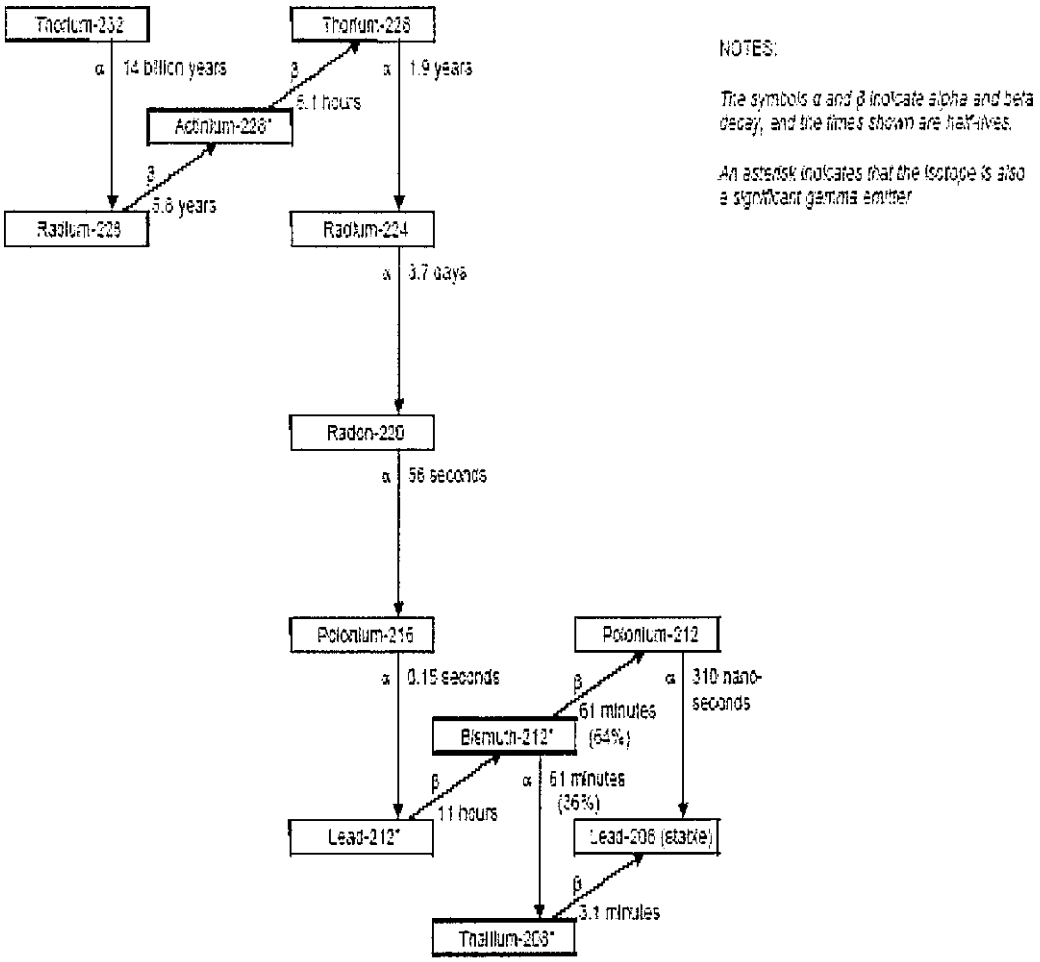

Figure 6.1. Thorium-232 decay series

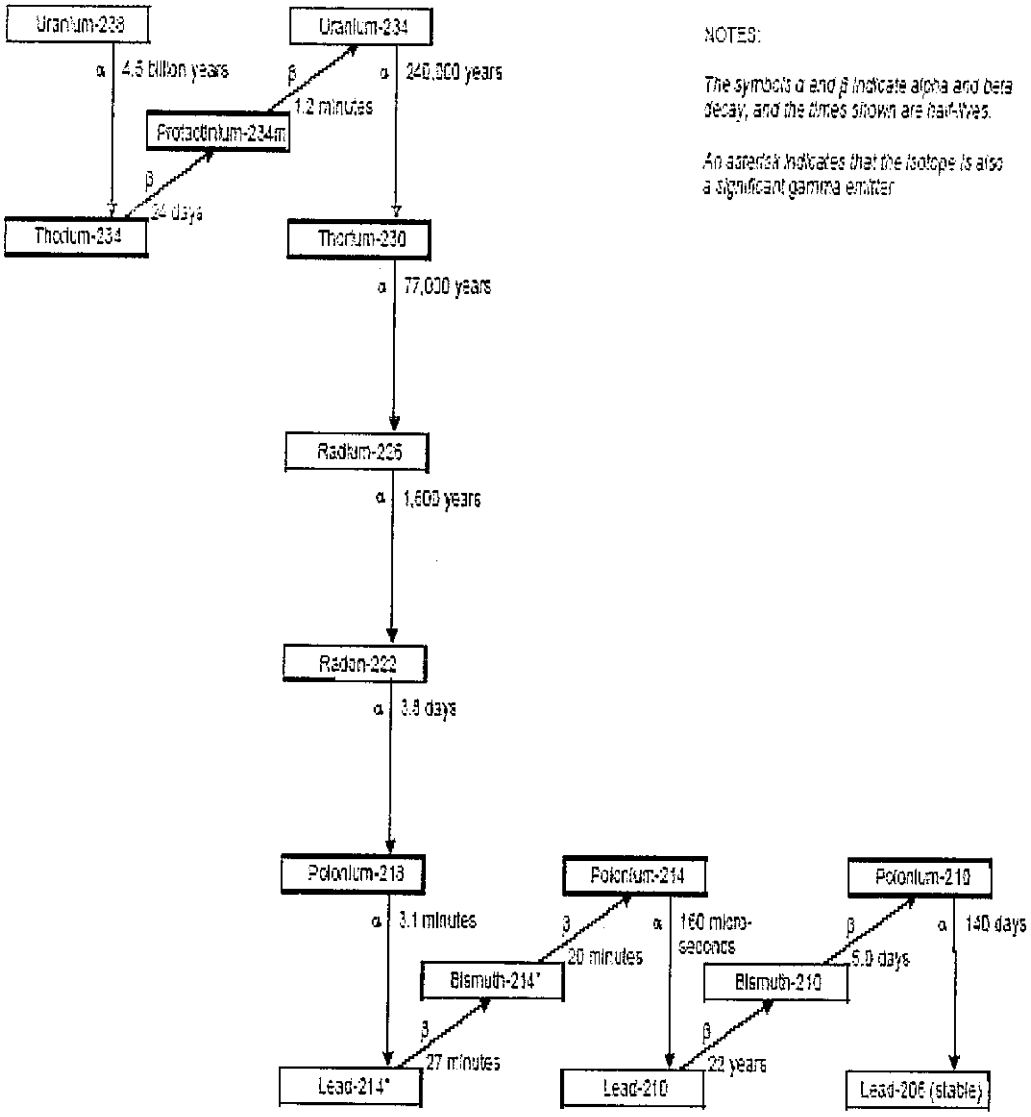

Figure 6.2. Uranium-238 decay series

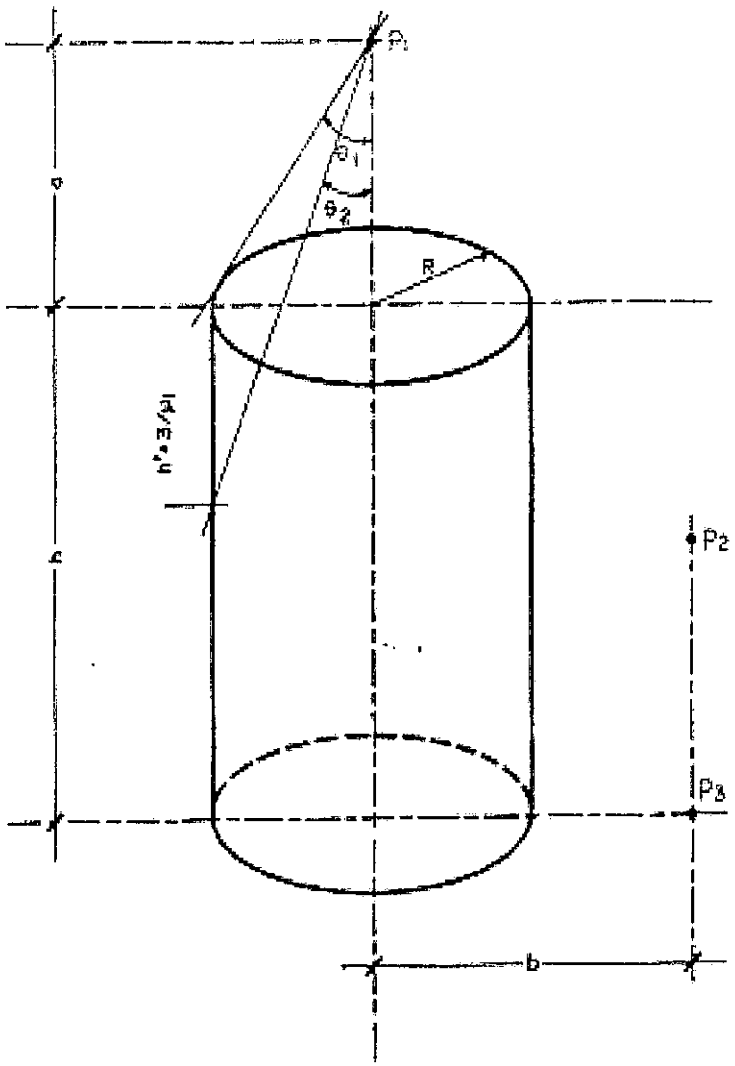

Figure 6.3. Geometry for cylinder source

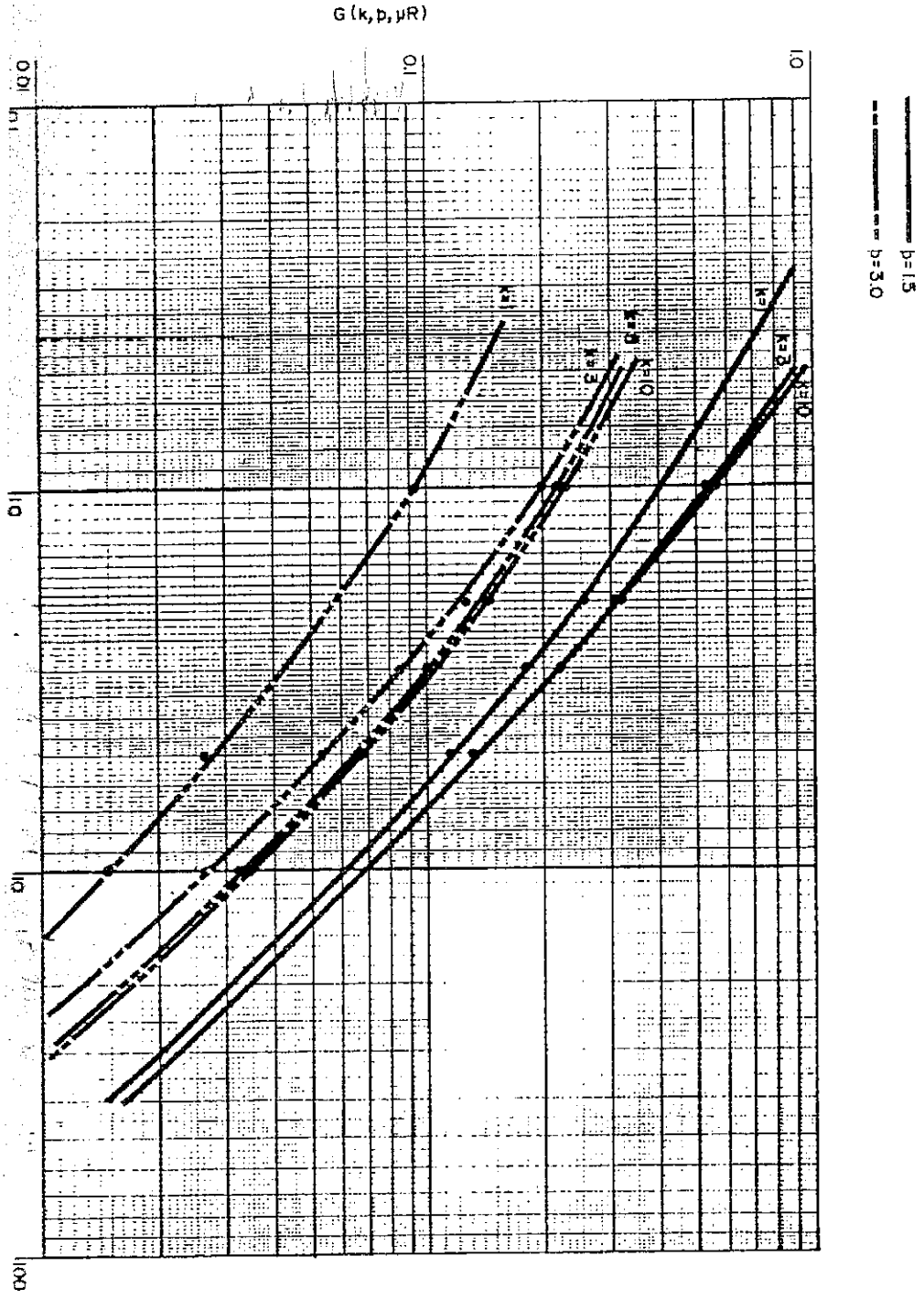

Figure 6.4. The G function for cylindrical volume source calculations

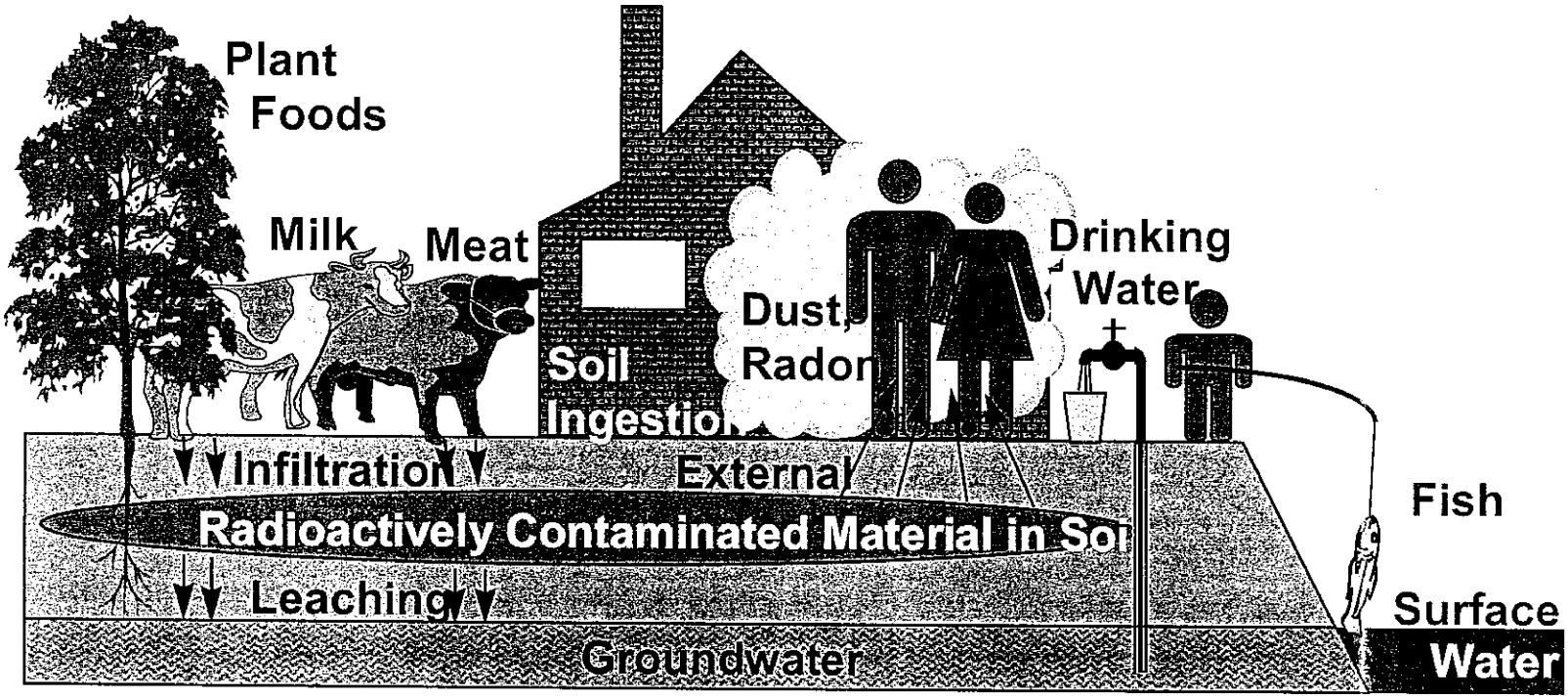

Figure 6.5. Exposure pathways considered in RESRAD

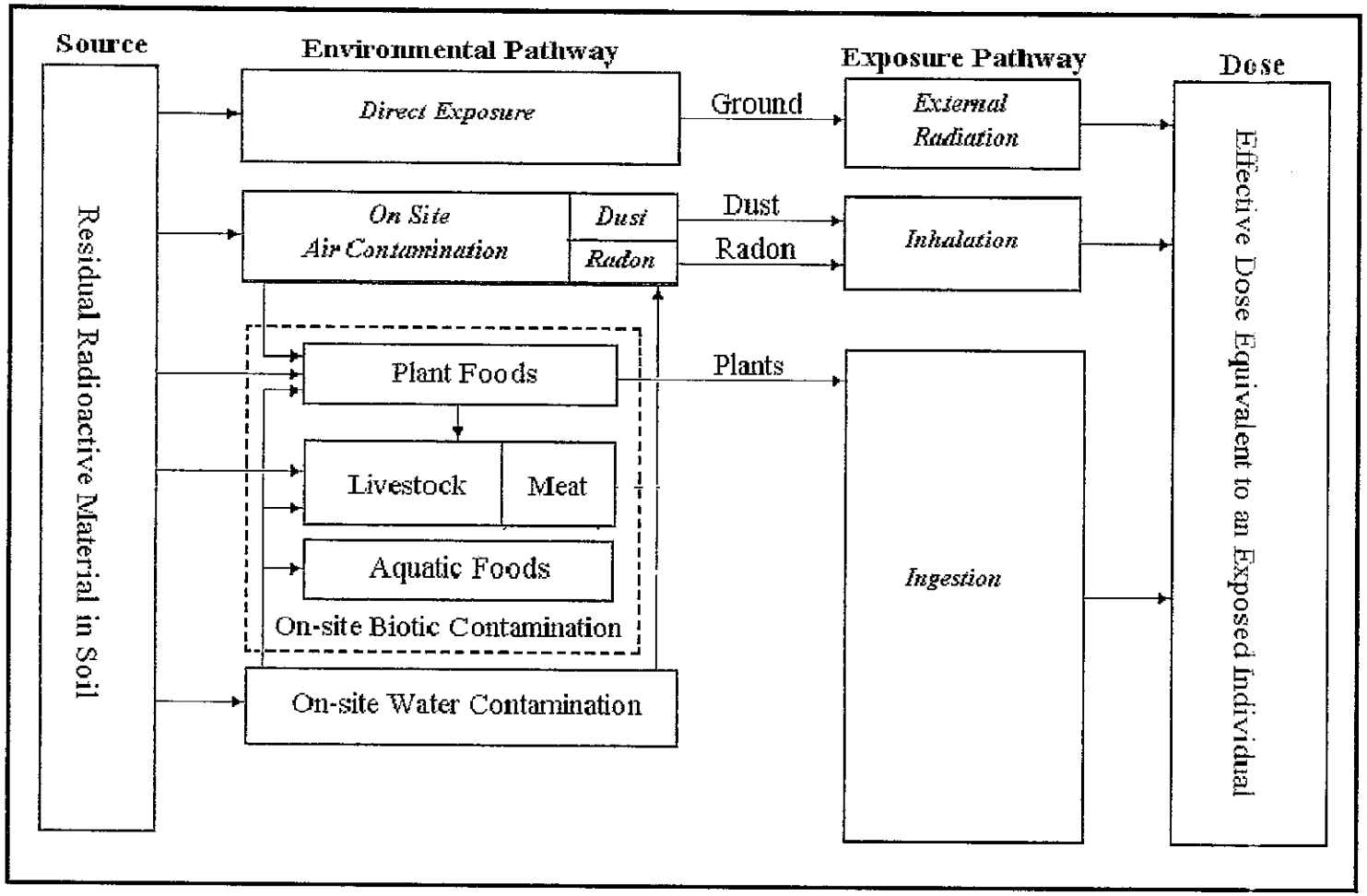

Figure 6.6. Schematic representation of RIA – exposure pathway

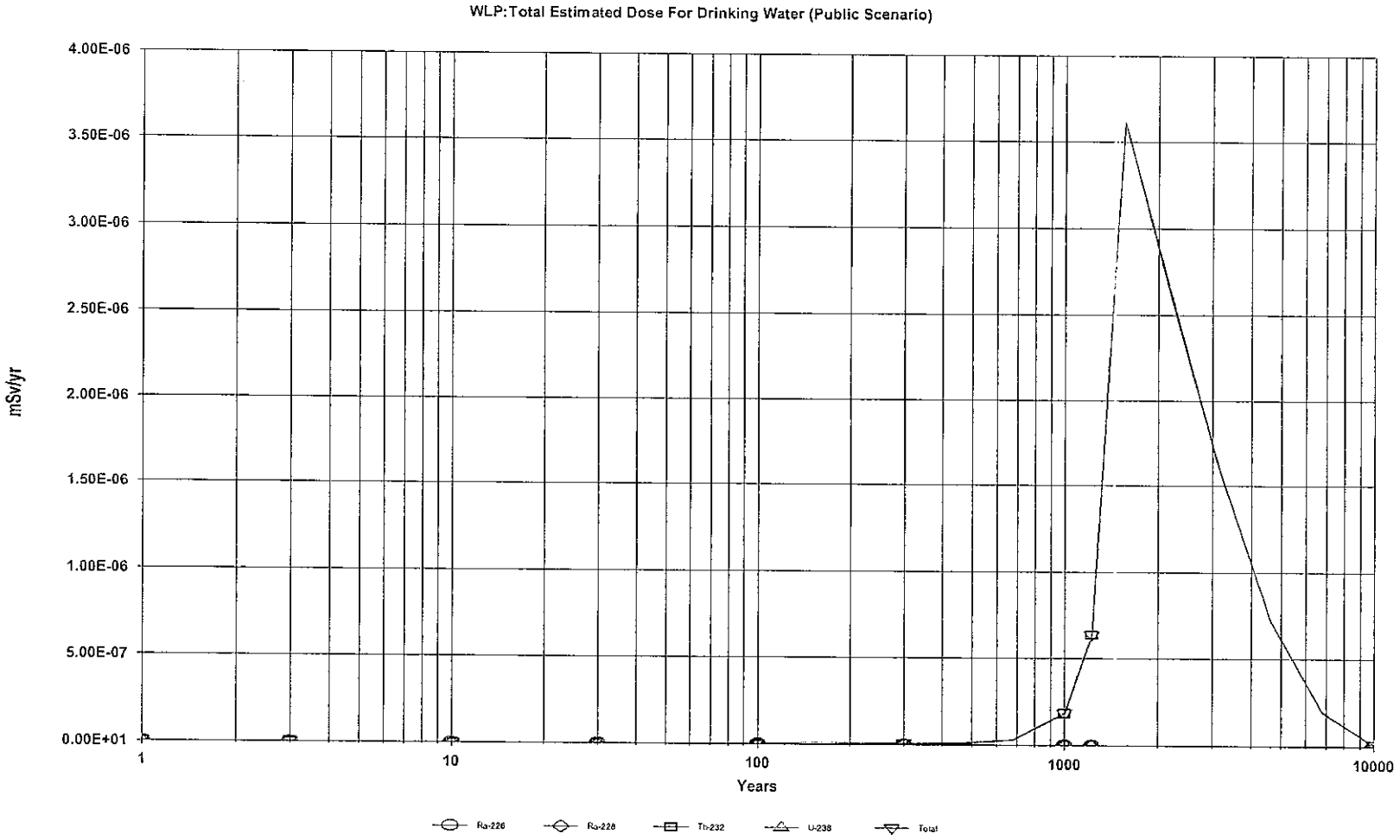

Figure 6.7 : Total estimated dose for drinking water (public scenario)

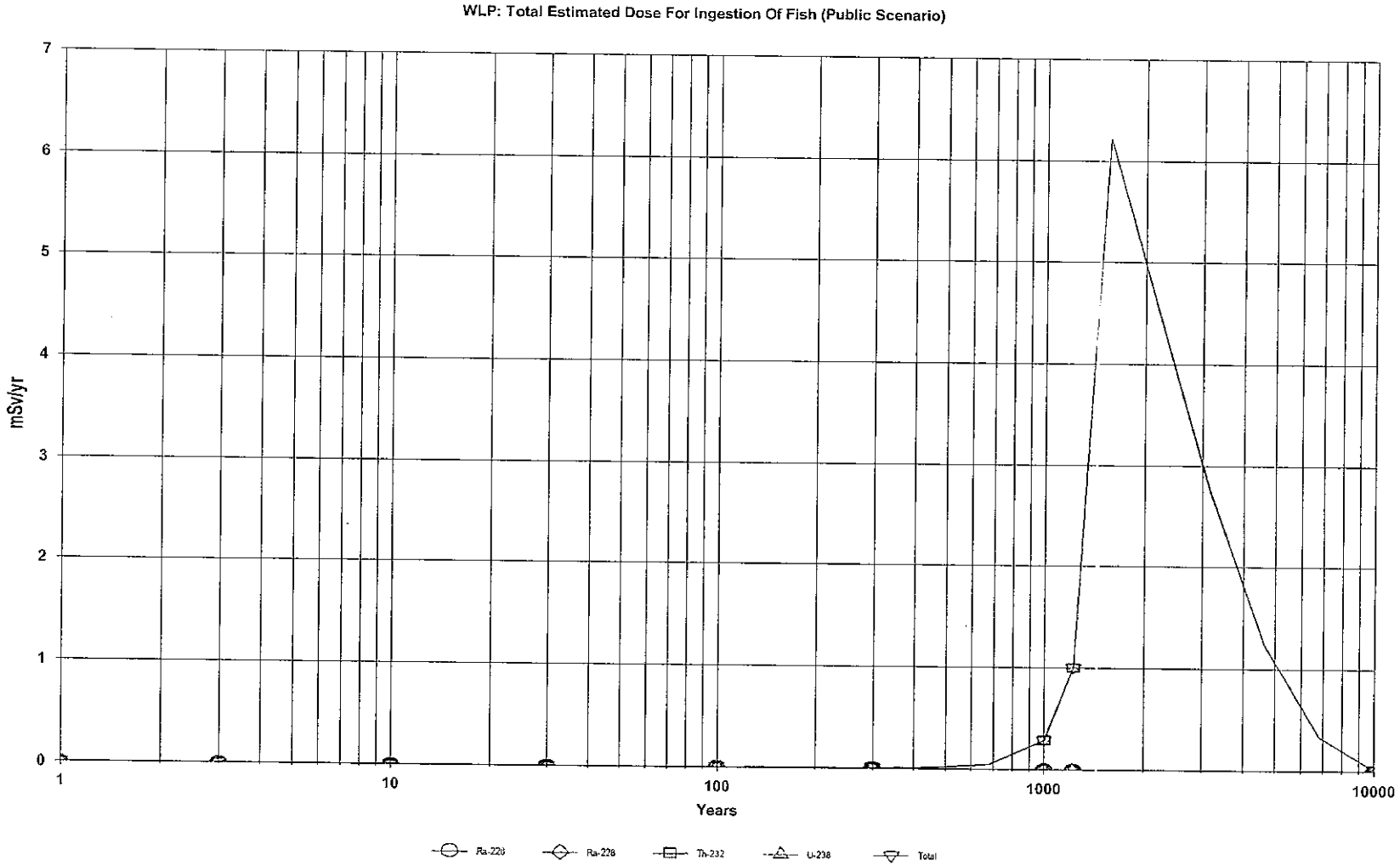

Figure 6.8: Total estimated dose for ingestion of fish (public scenario)

APPENDIX B – LIST OF TABLES

Table 3.1 Summary of Current land uses within the Zone of Impact (ZOI)

Radial Distance from the Centre of the Site	Land Use Types			
	North	**South**	**East**	**West**
< 1 km	This area is within site boundary.	This area is within site boundary.	This area is within the site boundary.	This area is within the site boundary.
1 km – 3 km	Swamp forests which are undeveloped industrial plots (part of the GIE). The Gebeng By-pass (Jabur-Cherating Link) is located to the north of the undeveloped plot.	Polyplastics Asia Pacific Sdn Bhd is located about 50m across the railway line from the southern boundary of the site. Undeveloped industrial plot (part of the GIE) to the northeastern boundary of Polyplastics.	Kuantan Port-Kerteh railway line runs along the eastern boundary of the site. Petronas gas pipe runs on the east side of the site.	Kuantan Port – Kerteh railway line runs along the railway terminal to the west of the site. Utlities pipe reserve runs along the railway line. Gebeng Railway Yard is located to the west of the site.
1 km – 3 km	To the noth-east of the site runs the Kuantan Port – Kerteh railway line.	Secondary forests on undeveloped industrial plot (part of the GIE) to the south of Polyplastics. Other industries located to the south of the site, south of Polyplastics are a Biodiesel Plant, Erupee Sugar, Kaneka, Flexsys, Eastman, WR, Cryovac, BP Chemicals and MTBE. Kuantan Port – Kerteh railway line runs along the southern boundary	Secondary forests on undivided plots of land with the GIE on the eastern side of the site, across the railway line. Undeveloped plots of land with the GIE on the southeast side of the site. East-Coast Highway runs about 4km from the eastern boundary of the site.	Swamp forests on undeveloped industrial plots (part of the GIE). To the south-west of the site is a Petronas Emergency Response Centre. Surrounding that centre is secondary forests on undeveloped Petronas land. To the west of the Petronas land is the BASF plant. Sungai Balok meanders along

Radial Distance from the Centre of the Site	Land Use Types			
	North	**South**	**East**	**West**
		of the site. Utlities pipe reserve runs along the southern boundary of the site along the railway line. Petronas gas pipe runs along the southern boundary of the Polyplastics site. Sungai Tonggok is located about 5km south of the site. Kuantan-Pelabuhan By-pass is located about 4km from the site southern boundary.		about 3km along the western side of the site flowing in the southerly direction..
1 km – 3 km		Across the road from the Kuantan-Pelabuhan By-pass are two residential settlements, namely Taman Balok Perdana and Taman Balok Makmur.		
3 km – 5 km	Secondary forests to the north and northwest of the site. Sparse residential and commercial properties in the north-easterly direction along the coastal road leading to Kuala Terengganu.	Sparse residential and commercial properties along the coastal road leading from Kuantan to the Port.	Kuantan Port facilities lie about 4.5km to the south-east direction from the site. The initial parts of Cherating Beach is about 5km from the eastern boundary of the site.	Swamp forest on undeveloped plots of land with the GIE on the western side of the site.

Radial Distance from the Centre of the Site	Land Use Types			
	North	South	East	West

Table 6.1. Summary of exposure scenarios data for individual/critical groups

Exposed Individual/ Critical Groups	Mode of Exposure	Remarks
Truck Driver (1 person)	External radiation from loads of lanthanide concentrates	Occupational exposure during transportation
Excavator driver (1 person)	External radiation from lanthanide concentrates and inhalation of airborne dust and resuspension of contaminants	Occupational exposure during loading at Kuantan Port – Lynas godown site
Process operator- lanthanide concentrates handling (1 person)	External radiation from - stockpile - FEL - Feed bin	Occupational exposure during work at Lynas site
Process operator - kiln feed (1 person)	External radiation from concentrate in bins and feeders before fed into the kiln	Occupational exposure during work at Lynas site cracking separation plant kiln feed section
Process operator – Oversize calcine handle (1 person)	External radiation from concentrate at - filter press - pushcart - stockpile	Occupational exposure during work at Lynas site cracking separation plant preliminary leaching section
Process operator – WLP solids filtration (1 person)	External radiation from WLP wastes at - filter presses - filter cake	Occupational exposure at Lynas site cracking separation plant water leach purification section
Machine operator- waste solids handling (1 person)	External radiation from WLP wastes - truck stockpile - FEL	Occupational exposure at Lynas site TSF cells and waste sites

Table 6.2: Exposure scenario data for individual

Exposed and no. of individual/ Critical group	**Mode/type of exposure**	**Description**	**Model for external exposure**
Truck Driver (1 person) P1 point from truck	External radiation from loads of lanthanide concentration	Truck load 20 tons, 5 hr/day loaded per shift, 6 trips/day 1666 hrs/yr	Half cylinder Radius=60 cm Length=900 cm Distance=100 cm Density=1.2 g/cm^3
Excavator driver (1 person loader) P2 point from wall of excavator	External radiation from ores and inhalation of airborne dust and resuspension of contaminants	Working hours 3.5 hr/day 15.2 shift/month 637 hrs/yr Inhalation 637 hrs/yr	Full cylinder Radius = 40 cm Length =280 cm Distance =200 cm Density =1.2 g/cm^3
Process operator –concentrate handling (1 person) P3 point from wall of feed bin	External radiation from stockpile concentrate, concentrate feed bin	Working hours Stockpile: 4hr/shift, 15.2 shift/month 728 hrs/yr FEL 4hr/shift, 15.2 shift/month 728 hrs/yr Feed bin 2hr/shift, 15.2 shift/month 364 hrs/yr	Full cylinder (Feed bin) Radius= 113 cm Length= 300 cm Distance= 100 cm Density=1.8 g/cm^3 (Stockpile) Semi infinite space infinite source (Loader) Full cylinder Radius = 40 cm Length =280 cm Distance =200 cm Density =1.2 g/cm^3
Process operator - kiln feed (1 person)	External radiation from concentrate in bins and feeders before fed into the kiln	Working hours 4 hr/shift 4 shift/month 192 hr/yr	Full cylinder Radius = 104 cm Length =250 cm Distance =100 cm Density =1.8 g/cm^3

Exposed and no. of individual/ Critical group	Mode/type of exposure	Description	Model for external exposure
Process operator – Oversize calcine handle (1 person)	External radiation from concentrate at - pushcart - filter presses - stockpile	Working hours Pushcart: 4 hr/shift, 4 shift/month 196 hr/yr Filter press 4 hr/shift, 2 shift/month 96 hr/yr Stockpile: 4 hr/shift, 2 shift/month 96 hr/yr	Full cylinder (Filter press) Radius = 62.5 cm Length =125 cm Distance =100 cm (Pushcart) Radius = 36 cm Length = 40 cm Distance =100 cm Stockpile: Semi infinite space infinite source Density =1.2 g/cm^3
Process operator – WLP solids filtration (1 person)	External radiation from WLP wastes - filter presses - filter cake	Working hours Filter press: 4 hr/shift, 4 shift/month 196 hr/yr Filter cake: 4 hr/shift, 2 shift/month, 96 hr/yr	Full cylinder (Filter presses) Radius =62.5 cm Length = 125 cm Distance=100 cm (Filter cake) Radius =138 cm Length = 150 cm Distance=100 cm Density=1.43 g/cm^3
Machine operator- WLP solids handling	External radiation from WLP wastes - truck - FEL - stockpile	Working hours Truck: 4 hr/shift, 12 shift/month, 576 hr/yr FEL: 4 hr/shift, 12 shift/month, 576 hr/yr Stockpile: 4 hr/shift, 12 shift/month, 576 hr/yr	Half cylinder (Truck) Radius =60 cm Length=900 cm Distance=100 cm Full cylinder (loader) Radius =40 cm Length=280 cm Distance=200 cm Stockpile WLP wastes: Semi infinite space infinite source Density=1.2 g/cm^3

Table 6.3: Parameters Used in the RESRAD Code for the drinking water and fish pathways for public scenario

Parameters	Unit	Value	References
		WLP Public Scenario	
Area of contaminated zone	m^2	24000	Lynas
Thickness of contaminated zone	m	9	Lynas
Length parallel to aquifer flow	m	155	estimated
Initial principal radionuclide: Uranium-238 Thorium-232 Radium-226 Radium-228	Bq/g	 2.76E-01 6.62E+00 2.76E-01 6.62E+00	Lynas
Dose limit	mSv/y	0.3	AELB
Fish consumption	kg/y	50	estimated
Other seafood consumption	kg/y	10	estimated
Drinking water intake	L/y	700	estimated
Drinking water contaminated fraction		1	(30)
Aquatic food contaminated fraction		0.5	(30)
Groundwater fractional usage for drinking water		1	(30)

Table 6.4: Committed effective dose per unit intake (Sv/Bq) via inhalation for workers

Nuclide	Type	Inhalation (5 μm)
Pb-210	F	1.1×10^{-6}
Pb-212	F	3.3×10^{-8}
Pb-214	F	4.8×10^{-9}
Bi-210	M	6.0×10^{-8}
Bi-212	M	3.9×10^{-8}
Bi-214	M	2.1×10^{-8}
Po-210	M	2.2×10^{-6}
Ra-224	S	2.4×10^{-6}
Ra-226	M	2.2×10^{-6}
Ra-228	M	1.7×10^{-6}
Ac-228	F	2.9×10^{-8}
	M	1.2×10^{-8}
	S	1.2×10^{-8}
Th-228	M	3.2×10^{-5}
	S	4.0×10^{-5}
Th-230	M	4.3×10^{-5}
	S	1.4×10^{-5}
Th-232	M	2.9×10^{-5}
	S	1.2×10^{-5}
Th-234	M	5.3×10^{-9}
	S	5.8×10^{-9}
U-234	F	6.4×10^{-7}
	M	2.1×10^{-6}
	S	6.8×10^{-6}
U-238	F	5.8×10^{-7}
	M	1.6×10^{-6}
	S	5.7×10^{-6}
Pa-234	M	5.5×10^{-10}
	S	5.8×10^{-10}

Table 6.5: Parameters Used in the RESRAD Code for the Analysis of the tailings wastes for TSF.

Parameters	Unit	Value	References
		WLP Scenario	
Area of contaminated zone	m^2	24000	Lynas
Thickness of contaminated zone	m	9	Lynas
Length parallel to aquifer flow	m	155	estimated
Initial principal radionuclide: Uranium-238 Thorium-232 Radium-226 Radium-228	Bq/g	 2.76E-01 6.62E+00 2.76E-01 6.62E+00	Lynas
Dose limit	mSv/y	20	AELB
Cover depth	m	0	
Density of cover depth	g/cm^3	NA	
Cover depth erosion rate	m/y	NA	
Density of contaminated zone	g/cm^3	0.7	Lynas
Contaminated zone erosion rate	m/y	0.001	(30)
Contaminated zone total porosity	-	0.4	(30)
Contaminated zone field capacity	-	0.2	(30)
Contaminated zone hydraulic conductivity	m/y	0.177	Lynas
Contaminated zone b -parameter	-	5.3	(30)
Evapotranspiration coefficient	-	0.5	(30)
Wind speed	m/s	3.3	site specific
Precipitation	m/y	2.96	site specific
Irrigation	m/y	0.2	(30)
Irrigation mode	-	overhead	(30)
Runoff coefficient	-	0.2	(30)
Watershed area for nearby pond	m^2	1000000	(30)

NA= Non Applicable

Table 6.5 (continue): Parameters Used in the RESRAD Code for the Analysis of the tailings wastes for TSF

Parameters	Unit	Value	References
		WLP Scenario	
Density of saturated zone	g/cm^3	0.187	Lynas
Saturated zone total porosity	-	0.40	(30)
Saturated zone effective porosity	-	0.06	(30)
Saturated zone field capacity	-	0.20	(30)
Saturated zone hydraulic conductivity	m/y	0.442	Lynas
Saturated zone hydraulic gradient	-	0.02	(30)
Saturated zone b parameter	-	5.3	(30)
Water table drop rate	m/y	0.001	(30)
Well pump intake depth (below water table)	m	0.00001	(30)
Model for water transportation parameter:	-	Non-dispersion (ND)	
Number of unsaturated zone strata	-	2	Lynas
Unsaturated zone 1, thickness	m	0.3	Lynas
Unsaturated zone 1, soil density	g/cm^3	1.80	Lynas
Unsaturated zone 1, total porosity	-	0.40	(30)
Unsaturated zone 1, field capacity	-	0.20	(30)
Unsaturated zone 1, effective porosity.	-	0.06	(30)
Unsaturated zone 1, soil-specific b parameter.	-	5.3	(30)
Unsaturated zone 1, hydraulic conductivity.	m/y	0.315	Lynas
Unsaturated zone 2, thickness	m	3	Lynas
Unsaturated zone 2, soil density	g/cm^3	1.80	Lynas
Unsaturated zone 2, total porosity	-	0.40	(30)
Unsaturated zone 2, field capacity	-	0.20	(30)
Unsaturated zone 2, effective porosity.	-	0.33	(30)
Unsaturated zone 2, soil-specific b parameter.	-	5.3	(30)
Unsaturated zone 2, hydraulic conductivity.	m/y	0.2	Lynas

NA= Non Applicable

Table 6.5 (continue): Parameters Used in the RESRAD Code for the Analysis of the tailings wastes for RSF

Parameters	Unit	Value	References
		WLP Scenario	
Distribution coefficient	ml/g		
Contaminated zone			
Uranium-238		67	
Thorium-232		530	Lynas
Radium-226		9100	
Radium-228		9100	
Unsaturated zone 1			
Uranium-238			
Thorium-232		38	
Radium-226		399	Nuclear
Radium-228		18	Malaysia
		18	
Unsaturated zone 2			
Uranium-238			
Thorium-232		39	
Radium-226		441	Nuclear
Radium-228		19	Malaysia
		19	
Saturated zone			
Uranium-238		1859	
Thorium-232		10907	Nuclear
Radium-226		34	Malaysia
Radium-228		34	
Inhalation rate	m^3/y	8,400	
Mass Loading for inhalation	g/m^3	0.0001	
Dilution length for airborne dust, inhalation	m	3	(30)
Exposure Duration	year	30	
Inhalation shielding factor	-	0.4	(30)
External gamma shielding factor	-	0.7	(30)
Indoor time fraction	-	0.33	assumed
Outdoor time fraction	-	0	assumed

NA= Non Applicable

Table 6.5 (continue): Parameters Used in the RESRAD Code for the Analysis of the tailings wastes for TSF

Parameters	Unit	Value	References
		WLP Scenario	
Shape of contaminated zone		circular	(30)
Cover total porosity	-	NA	(30)
Cover volumetric water content		NA	(30)
Building foundation: volumetric water content thickness density	 - m g/cm^3	 NA 0 NA	(30)
Diffusion coefficient for radon gas:- in cover material in foundation material in contaminated zone soil	m^2/s	 NA NA 2.00E+06	(30)
Radon vertical dimension of mixing	-	2	(30)
Average building air exchange rate	l/h	3	(30)
Height of the building (room)	m	12	estimated
Building indoor area factor		0.7	(30)
Foundation depth below ground surface	m	0	(30)
Rn-222 emanation coefficient		0.25	(30)
Rn-220 emanation coefficient		0.15	(30)

NA= Non Applicable

Table 6.6: Results of Assessment on Dose Received By Workers (Sv/yr)

Scenario	Dose (mSv/y)		
	Uranium series	**Thorium series**	**Total**
Driver (Kuantan Port to Lynas site and Lynas stockpile site)	8.84E-04	2.95E-02	3.04E-02
FEL (Kuantan Port and Lynas site) :			
External	4.10E-02	2.80E+00	2.84E+00
Dust (Inhalation)	3.12E-02	4.87E-02	7.99E-02
Process Operator – Concentrate handling:			
Stockpile	4.40E-01	8.56E+00	9.00E+00
FEL	3.26E-02	2.24E+00	2.27E+00
Feed bin	3.62E-01	1.05E+00	1.41E+00
Process Operator - Kiln feed	1.94E-01	2.03E+00	2.22E+00
Process Operator – oversize calcine:			
Pushcart	5.47E-03	2.47E-01	2.53E-01
Filter press	2.90E-02	1.37E-01	1.40E-01
Stockpile	1.17E-01	2.26E+00	2.38E+00
Process Operator – WLP solid filtration:			
Filter press	3.32E-01	4.98E-03	3.37E-01
Filter cake	5.93E-01	8.84E-01	6.02E-01
Machine Operator – WLP solid handling:			
Truck	2.42E-04	1.10E-01	1.10E-01
FEL	2.00E-02	1.83E+00	1.85E+00
Stockpile	2.72E-01	6.99E+00	7.27E+00

Table 6.7: Summary of dose for individual/critical groups

Exposed Individual	**Individual dose (mSv/yr)**	**Collective dose (man.Sv)**	**Maximum (exposure pathway)**
Truck Driver (1 person)	3.04E-02	3.04E -05	External
FEL (1 person)	2.92E+00	2.92E -03	External
Process operator-concentrate handling (1 person)	12.68E+00	12.68E -03	External
Process operator – kiln feed (1 person)	2.22E+00	2.22E -03	External
Process operator - oversize calcine (1 person)	2.77E+00	2.77E-03	External
Process operator – WLP Solid Filtration (1 person)	9.39E-01	9.39E -04	External
Machine operator – WLP solids handling (1 person)	9.23E+00	9.23E -03	External

Table 6.8: Total Dose Contributions, TDOSE (mSv/y) For Individual Radionuclides and Pathways at t= 1 year

WLP Contaminated Zone Dimensions
Area: 24000 square metres
Thickness: 9 metres
Cover Depth: 0 metre

Initial WLP Concentrations, Bq/g
U-238 = 2.760E-01
Th-232 = 6.62E+00
Ra-226 = 2.760E-01
Ra-228 = 6.62E+00

Radionuclide	External		Inhalation		Radon		All Pathways	
	mSv/y	fraction	mSv/y	fraction	mSv/y	fraction	mSv/y	fraction
Uranium-238	2.48E-03	0.00	1.40E-04	0.00	1.58E-16	0.00	2.62E-03	0.00
Thorium-232	5.47E-01	0.13	4.72E-02	0.01	5.74E-02	0.00	5.99E-01	0.14
Radium-226	1.83E-01	0.04	1.15E-05	0.00	2.30E-02	0.01	2.06E-01	0.05
Radium-228	3.47E-00	0.80	3.83E-03	0.00	5.44E-01	0.01	3.53E+00	0.81
TDOSE	4.21E+00	0.97	5.12E-02	0.01	8.31E-02	0.02	4.34E+00	1.00

6.9: Total Dose Contributions, TDOSE (mSv/y) For Individual Radionuclides and Pathways at t=1558 year

WLP Contaminated Zone Dimensions
Area: 24000 square metres
Thickness: 9 metres
Cover Depth: 0 metre

Initial WLP Concentrations, Bq/g
U-238 = 2.70E-01
Th-232 = 6.62E+00
Ra-226 = 2.70E-01
Ra-228 = 6.62E+00

Radionuclide	Ingestion of Fish		Drinking Water		All Pathways	
	mSv/y	fraction	mSv/y	fraction	mSv/y	fraction
Uranium-238	1.00E-04	0.00	1.49E-10	0.00	1.00E-04	0.00
Thorium-232	6.23E+00	1.00	3.62E-06	0.00	6.23E+00	1.00
Radium-226	1.01E-03	0.00	3.18E-10	0.00	1.01E-03	0.00
Radium-228	0.00E+00	0.00	0.00E+00	0.00	0.00E+00	0.00
TDOSE	6.23E+00	1.00	3.62E-06	0.00	6.23E+00	1.00