RL12/06

Nuclear Site Specific Hydrographic Parameters for use with the WAT/ADO Models

Update V1.3

August 2006

Science commissioned by
Food Standards Agency

CEFAS Contract RB101
Environment Report RL 12/06

Environment Report RL 12/06

Nuclear Site Specific Hydrographic Parameters for use with the WAT/ADO Models

Update V1.3

The Centre for Environment, Fisheries and Aquaculture Science
Lowestoft Laboratory
Pakefield Road
Lowestoft
Suffolk
NR33 0HT

S B Jenkinson and M P Grzechnik

August 2006

The work in this report was completed under contract to
the Radiological Safety Unit of the Food Standards Agency
FSA contract RP0001
CEFAS contract RB101

Table of Contents

1 Introduction

To enable the quantitative assessment of liquid radioactive discharges from the UK's nuclear installations, information concerning the nature of the receiving water body must be known. Collectively this information is termed the hydrographic parameters, and default values of those that are necessary for successful use of Cefas' deterministic aquatic assessment models[1] are presented here.

These parameters, though following a broad pattern according to discharge location, are site-specific; due to the nature of the models they are also mean values, averaged spatially and temporally. Each site is considered individually, and the parameters given are those relevant to the particular model type deemed most applicable to that installation. The parameter values are derived from a number of sources, including hydrographic (Admiralty) charts, historical data, site operators' data and expert elicitation. For a physical description of each parameter and its likely provenance see Grzechnik *et al.* (2006).

Also presented in this report is a brief description of the nuclear activities undertaken at each site, and the current authorised discharge limits. These limits are taken from RIFE-10 (Environment Agency *et al.*, 2005), which also contains details of the actual discharges of liquid radioactive waste made in 2004. Composition of any non-nuclide specific discharges can be estimated from the results of environmental monitoring reports in the region of the site, or obtained from site operators.

It is important to note that the parameters in this report are, by nature, variable and it is thus essential that some perspective is used when seeking to model individual sites' liquid discharges. To fully employ the assessment models, the location of critical groups and the pathways by which they are exposed must also be known – such information is beyond the scope of this report, but can be derived from Cefas' regular habits surveys of nuclear locations.

Each chapter contains a map of the local area, upon which the site location is clearly marked in red. Where the advection-diffusion mode of the WAT model is recommended, an arrow indicates the residual tidal direction as found from the tidal diamond data. This direction is often confined to the local area, and may require modification when critical groups lie outside this area.

Instructions on the use of the WAT/ADO model are given in Grzechnik (2002). Notes on the use of the freshwater discharge model and the lake discharge model can be found in Appendices A and B respectively. A spreadsheet to derive parameter values from Admiralty charts and relevant tidal diamonds, as used in the preparation of this report, is described in Appendix C.

[1] The WAT/ADO suite (Round, 1998*a,b*), as well as two Excel-based models for discharge into freshwater rivers and lakes.

2 Aldermaston

2.1 Aldermaston

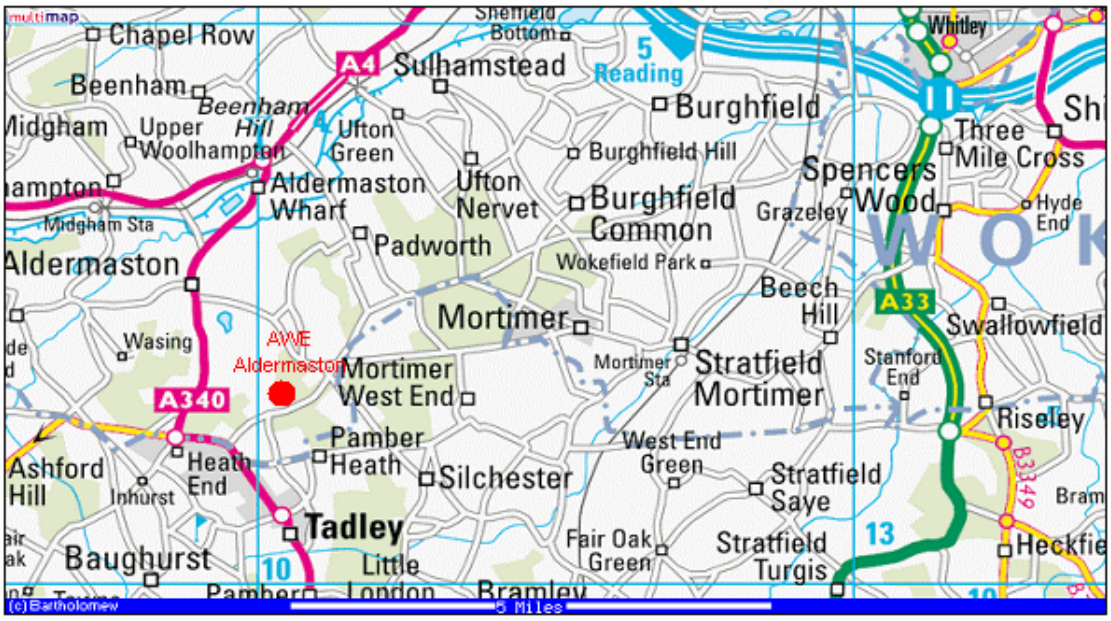
- Owner – MoD
- Operator – AWE Management Ltd
- Date started production – 1950

The Atomic Weapons Establishment (AWE) sites at Aldermaston and Burghfield are involved in processing nuclear material in support of the national defence programme. The Aldermaston site, located approximately two miles southeast of Aldermaston in Berkshire, has two liquid discharge routes. Burghfield, six miles northeast of the Aldermaston site, has not discharged any liquid effluent since 1 April 2000 and is considered unlikely to do so again.

The two liquid discharge routes from Aldermaston are: Aldermaston Stream, which flows from the site through the town of Aldermaston before joining the River Kennet, and via the public sewer to Silchester sewage works, which discharges treated sewage into the Foudry Brook. The Brook confluences with the River Kennet at Reading

Until April 2005 Aldermaston was also authorised to discharge liquid waste via pipeline to the River Thames at Pangbourne, and both Aldermaston and Burghfield are authorised to discharge gaseous radioactive waste via stacks on site. The local area around both sites consists mainly of arable land.

Figure 1 Map of the Aldermaston local area



2.2 Current annual liquid discharge limits for Aldermaston

	Limit (TBq)	
Nuclide	***Silchester (sewer)***	***Aldermaston stream***
Alpha	$4.0\ 10^{-5}$	-
Beta/gamma	$1.2\ 10^{-4}$	-
Tritium	0.05	0.01

2.3 Hydrographic Data

As the site discharges into a non-tidal inland waterway, the WAT and ADO models used to run marine assessments are invalid. An Excel-based freshwater river model has been developed for such discharges; guidance on how to use this model is given in Appendix A. The River Kennet gauging station at Theale is approximately three miles downstream of the confluence with the Aldermaston Stream and a similar distance upstream of the confluence with the Foudry Brook.

Parameter	***Value***
Model	Freshwater
Flow rate ($m^3\ s^{-1}$)	0.072 – Aldermaston Stream 9.49 – River Kennet (at Theale)[a]
Suspended sediment load ($g\ m^{-3}$)	10.0 – Aldermaston Stream 15.0 – River Kennet
Modifying factor	1.0
Dry/Wet mass ratio	1.66
Mud wet density	0.6

a – Environment Agency (2005)

3 Amersham

3.1 Amersham

- Owner – GE Healthcare (formerly Amersham plc)
- Date started production – 1940

GE Healthcare is a pharmaceuticals company manufacturing radioactively labelled materials for use in medicine, research and industry. Their main laboratory in Britain, the Grove Centre, is situated approximately 1 mile east of Amersham, Buckinghamshire.

The site discharges liquid effluent into the local sewers. This is treated at the Maple Lodge sewage works before being released into the Grand Union Canal 500 metres upstream of the confluence with the River Colne. Gaseous discharges are released via stacks at the station. The local area around Amersham is mainly urban industry, housing and some arable fields.

Figure 2 Map of the Amersham local area

3.2 Current liquid discharge limits for Amersham

The nature of the business in which the operators are engaged makes estimates of the isotopic composition of the non-nuclide specific categories difficult. Previous correspondence with the operator indicates that the alpha-emitting nuclides are most likely to be ^{241}Am and the beta-emitting nuclides are likely to be ^{32}P and ^{89}Sr. The 'other radionuclides' category could include

^{57}Co, ^{35}S, ^{201}Tl and ^{65}Zn. There is a general downward trend in the discharge of liquid radioactive waste from this site (OSPAR Commission, 2005).

Nuclide	***Limit (TBq)***
Alpha	$3.0\ 10^{-4}$
Beta (>0.4 MeV)	0.06
Tritium	0.141
Iodine-125	0.004
Caesium-137	0.005
Other radionuclides	0.215

3.3 Hydrographic Data

As the site discharges into a non-tidal inland waterway, the WAT and ADO models used to run marine assessments are invalid. An Excel-based freshwater river model has been developed for such discharges; guidance on how to use this model is given in Appendix A.

Parameter	***Value***
Model	Freshwater
Flow rate ($m^3\ s^{-1}$)	6.8 – Grand Union Canal[a]
Suspended sediment load ($g\ m^{-3}$)	10.0
Modifying factor	0.1 (concrete banks)
Dry/Wet mass ratio	1.66
Mud wet density	0.6

a – Round & Allison (1999)

4 Barrow

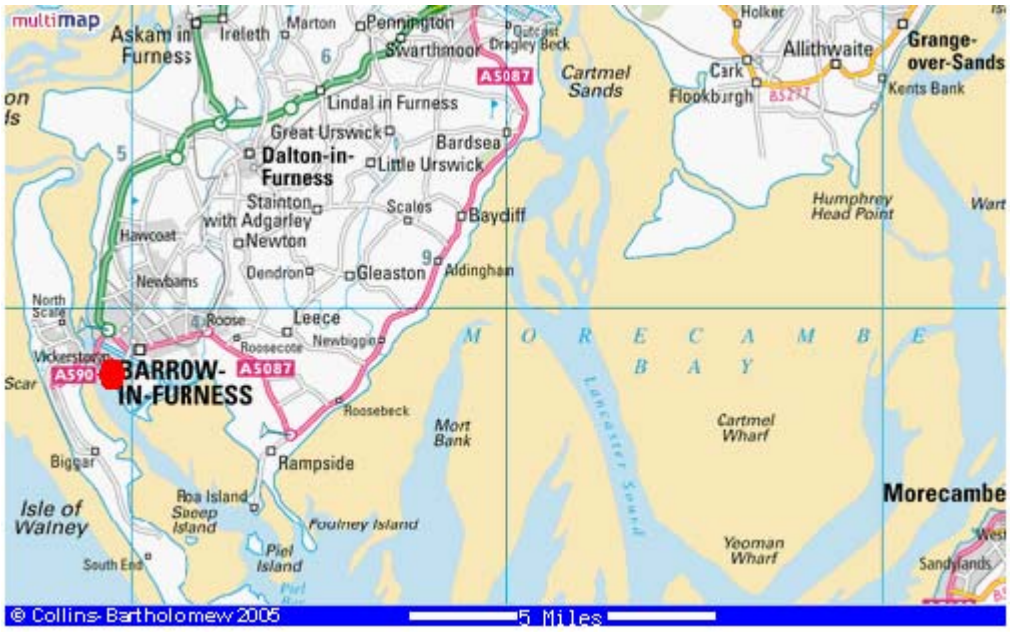
4.1 Barrow

- Owner – BAE Systems Marine Ltd

Barrow Shipyard is situated on the north-western tip of Morecambe Bay in the north of England. It is approximately 25 miles west of Lancaster. The site builds and refits nuclear powered submarines, and is the harbour for the Pacific Nuclear Transport Limited (PNTL) ships.

The shipyard is authorised to discharge liquid effluent into Morecambe Bay via the public sewer system and the Walney Channel. In the vicinity of the outfall, the bed of the Walney Channel is mainly mud with occasional sandy patches. Gaseous discharges are authorised for release via stacks at the site. The local area around the site at Barrow-in-Furness is mainly marine-based industry.

Figure 3 Map of the Barrow-in-Furness local area



4.2 Current liquid discharge limits for Barrow

Liquid discharges from Barrow shipyard are historically very low, and in 2004 (the last year for which data is currently available) were nil (Environment Agency *et al.*, 2005).

Nuclide	***Limit (TBq)***
Tritium	0.012
Other gamma-emitting radionuclides	$3.5\ 10^{-6}$

4.3 Hydrographic Data

Admiralty chart 3164 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the dockyard's outfall. Tidal diamond C was used, as it is the furthest up the Walney Channel for which tidal data is available. From this data it was possible to estimate the exchange volume and dispersion factor in the area of the outfall. When running the WAT model the single compartment mode should be chosen, as the discharge enters a channel in which conditions are similar to those of an estuary.

Parameter	***Value***
Model	Single compartment
Dispersion factor: changes per day	0.060
Exchange volume (km^3)	0.178
Suspended sediment load (mg l^{-1})	12.5
Sedimentation rate (kg m^{-2} y^{-1})	0.85
Mean depth (m)	20.0
Estuarine silt sedimentation rate (m y^{-1})	0.02

5 Berkeley and Oldbury

5.1 Berkeley

- Owner – Magnox Electric Ltd / NDA
- Date started production – 1962
- Date production ceased – 1989 (defuelled in 1992)

5.2 Oldbury

- Owner – Magnox Electric Ltd / NDA
- Date started production – 1967
- Capacity – 600 MW
- Due to cease production – 2008

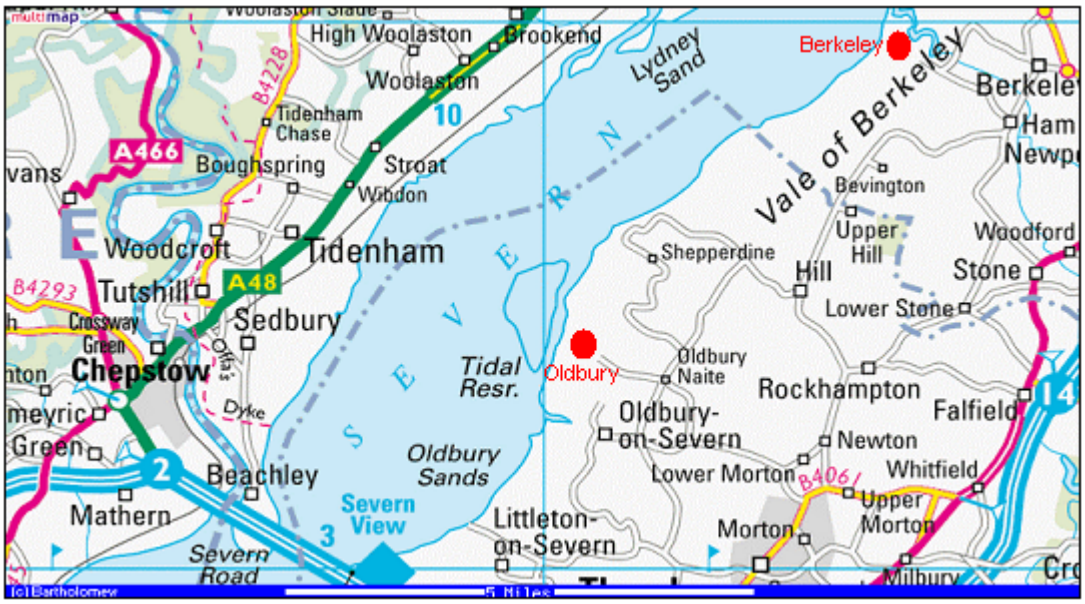
Berkeley and Oldbury are separate sites situated four miles apart on the Severn estuary in the West of England. They are approximately 15 miles north of Bristol and 15 miles south of Gloucester. The power station at Berkeley ceased generating electricity in 1989 although radioactive wastes are still generated and discharged as part of the decommissioning process. Also on the Berkeley site is the Berkeley Technology Centre, which contributes to the discharge authorisation for the site. Oldbury, southwest of Berkeley, continues to generate electricity from twin Magnox reactors.

Each station discharges liquid effluent into the River Severn via separate outfalls, which lie approximately 100 metres offshore. The riverbed in the vicinity of the outfalls is mainly mud with occasional patches of sand. Gaseous discharges are released via stacks at each station. The local area around Berkeley and Oldbury is mainly arable fields. The nearest town to Berkeley is Dursley, 6 miles east of the site, and the nearest to Oldbury is Thornbury, which is 3 miles southeast of the site.

5.3 Current liquid discharge limits for Berkeley and Oldbury

	Limit (TBq)	
Nuclide	***Berkeley***	***Oldbury***
Tritium	2	1
Caesium-137	0.2	0.7
Other radionuclides	0.4	0.7

Figure 4 Map of the Berkeley and Oldbury local area



5.4 Hydrographic Data

Admiralty chart 1166 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond A was used as, although some way downstream of the power stations, it is the furthest point up the estuary for which tidal data is available. From this data it was possible to estimate the exchange volume and dispersion factor for the Berkeley/Oldbury liquid discharge region. When running the WAT model, the single compartment mode should be used as the sites' outfalls are in the Severn Estuary.

Parameter	***Value***
Model	Single compartment
Dispersion factor: changes per day	0.258
Exchange volume (km^3)	0.042
Suspended sediment load (mg l^{-1})	35.87
Sedimentation rate (kg m^{-2} y^{-1})	0.50
Mean depth (m)	5.0
Estuarine silt sedimentation rate (m y^{-1})	0.04

6 Bradwell

6.1 Bradwell

- Owner – Magnox Electric Ltd / NDA
- Date started production – 1962
- Date production ceased – 2002 (defuelled 2005)

Bradwell is situated on the Blackwater estuary on the eastern coast of England approximately 15 miles east of Chelmsford. The power station at Bradwell ceased generating electricity in 2002 although radioactive wastes are still generated and discharged as part of the decommissioning process.

The station discharges liquid effluent into the River Blackwater via a pipeline that extends 200 metres offshore. The riverbed in the vicinity of the pipeline is mainly mud with occasional patches of sand. Gaseous discharges are released via stacks at the station. The local area around Bradwell consists mostly of arable fields, the nearest town to Bradwell being Burnham on Crouch, some 8 miles south of the site.

Figure 5 Map of the Bradwell local area

6.2 Current liquid discharge limits for Bradwell

Nuclide	*Limit (TBq)*
Tritium	7
Caesium-137	0.7
Other radionuclides	0.7

6.3 Hydrographic Data

Admiralty chart 3741 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond A was considered the most appropriate, as it is close to the location of the site's outfall. From this data it was possible to estimate the exchange volume and dispersion factor for the Bradwell liquid discharge region. When running the WAT model, the single compartment mode should be used as the site's outfall is in the Blackwater Estuary.

Parameter	*Value*
Model	Single compartment
Dispersion factor: changes per day	0.160
Exchange volume (km^3)	0.097
Suspended sediment load (mg l^{-1})	27.55
Sedimentation rate (kg m^{-2} y^{-1})	0.95
Mean depth (m)	9.0
Estuarine silt sedimentation rate (m y^{-1})	0.04

7 Capenhurst

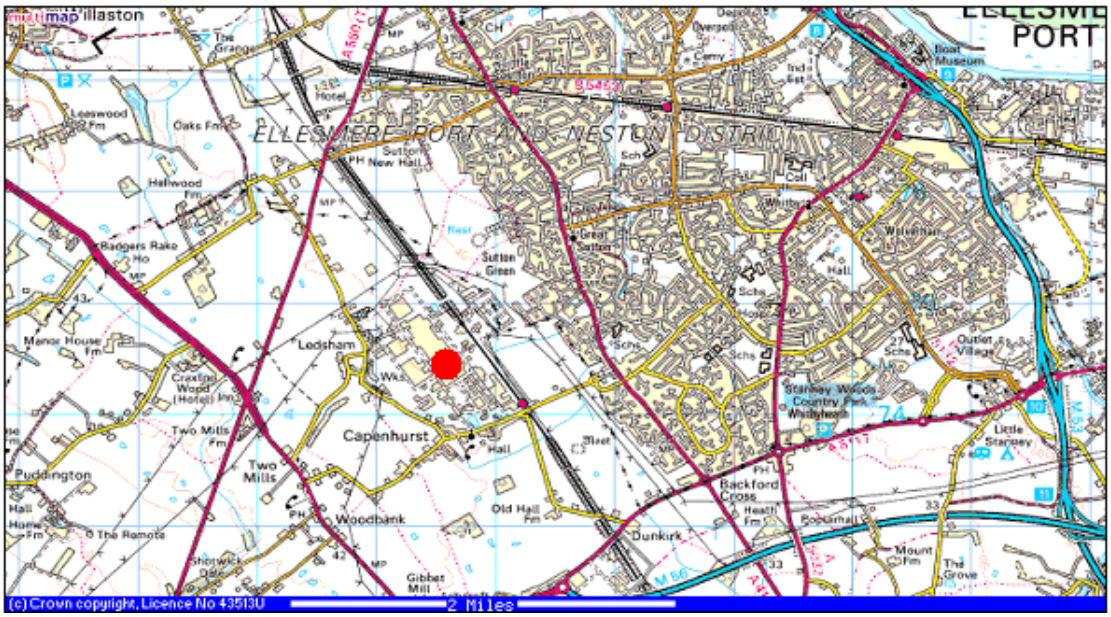
7.1 Capenhurst

- Owner – BNG Sellafield Plc / NDA
- Centrifugal uranium enrichment facility operated by Urenco Ltd
- Ceased gaseous diffusion enrichment operations in 1982
- BNFL uranium storage facility since 1995

Capenhurst is approximately 10 miles north of Chester on the Wirral peninsular in the northwest of England. The site at Capenhurst consists of centrifuge plants and a decommissioned gaseous diffusion plant. Urenco (Capenhurst) Ltd took over the ownership and operations of the centrifuge plants in 1993, whilst BNG decommission the gaseous diffusion plant. The site is also used as a uranic storage service for the nuclear industry.

The site discharges liquid effluent into the River Mersey via the Rivacre brook, a small feeder stream which runs through the site. The riverbed in the vicinity of the discharge point is mainly muddy sand. Gaseous discharges are released via stacks at the site. The local area around Capenhurst is mainly arable farmland, the nearest town to Capenhurst being Ellesmere Port, which is 4 miles to the northeast of the site.

Figure 6 Map of the Capenhurst local area



7.2 Current liquid discharge limits for Capenhurst

Nuclide	*Limit (TBq)*
Uranium	0.02
Uranium daughters	0.02
Non-Uranic alpha	0.003
Technetium-99	0.1
Tritium	78

7.3 Hydrographic Data

As the site discharges into a non-tidal inland waterway the WAT and ADO models used to run marine assessments are invalid. An Excel-based freshwater river model has been developed for such discharges; guidance on how to use this model is given in Appendix A.

Parameter	*Value*
Model	Freshwater
Flow rate (m^3 s^{-1})	0.025[a]
Suspended sediment load (g m^{-3})	1.7
Modifying factor	1.0
Dry/Wet mass ratio	1.66
Mud wet density	0.6

a – Environment Agency et al*. (2005)*

8 Cardiff

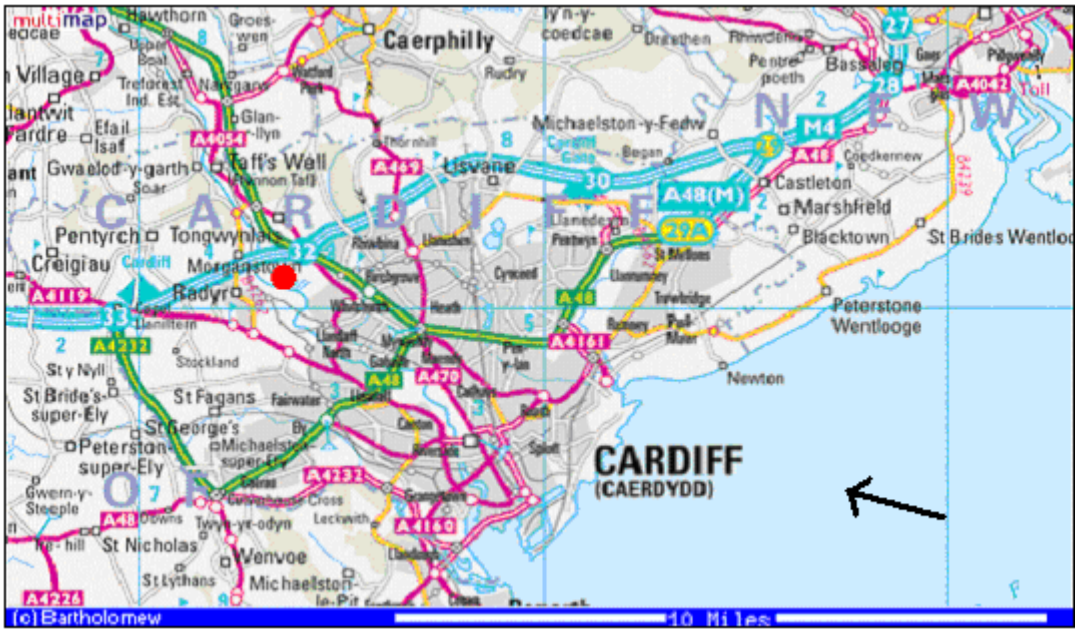
8.1 Cardiff

- Owner – GE Healthcare (formerly Amersham Plc)
- Date started production – 1980

GE Healthcare is a pharmaceuticals company manufacturing radioactively labelled materials for use in medicine, research and industry. The Welsh subsidiary is located in the Maynard Centre, on the north-western outskirts of Cardiff.

The site discharges liquid effluent via the public sewer into the Bristol Channel. Occasionally in periods of heavy rain, storm water containing small amounts of radioactivity may overflow from the sewer into the River Taff. Gaseous discharges are released via stacks at the site. The local area around the site is mainly urban industry and housing and some arable fields.

Figure 7 Map of the Cardiff local area



8.2 Current liquid discharge limits for Cardiff

The Cardiff site is predominantly involved in the manufacture of tritium and ^{14}C. Consequently, these nuclides form the bulk of the radionuclide discharge from this site. In 2004, the non-nuclide specific discharge was nil.

Nuclide	***Limit (TBq)***
Tritium	130
Carbon-14	0.91
Phosphorus-32/33	$8.5\ 10^{-5}$
Iodine-125	$3\ 10^{-4}$
Other radionuclides	$1.2\ 10^{-4}$

8.3 Hydrographic Data

Admiralty chart 1152 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the sewer outfall. Tidal diamond H was used, as it is close to the Orchard Ledges area in which the outfall is situated. When running the WAT model, the advection-diffusion mode should be used as the sewer discharges into the open water of the Bristol Channel.

Parameter	***Value***
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.01
Diffusion coefficient (m^2 s^{-1})	10.0
Tidal excursion (m)	11870
Initial spreading radius (m)	50.0
Start time for discharges	0.08
End time for discharges	0.33
Suspended sediment load (mg l^{-1})	33.93
Sedimentation rate (kg m^{-2} y^{-1})	2.31
Mean depth (m)	5.0
Estuarine silt sedimentation rate (m y^{-1})	0.02

9 Chapelcross

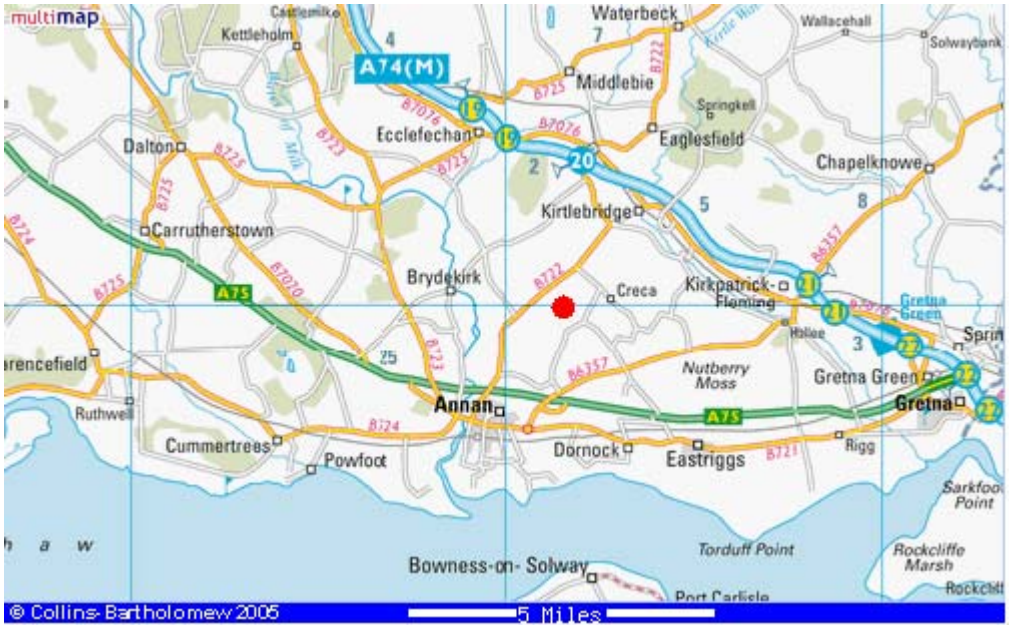
9.1 Chapelcross

- Owner – Magnox Electric Ltd / NDA
- Date started production – 1959
- Date ceased production – 2004

Chapelcross is situated on the northern coast of the Solway Firth in the southwest of Scotland, approximately 15 miles northwest of Carlisle and 15 miles east of Dumfries. The four Magnox type reactors ceased operation in 2004 and are now being prepared for defuelling and decommissioning.

The site continues to discharge liquid effluents via a 5km pipeline into the Solway Firth just south of Annan. The shoreline in the vicinity of the end of the pipeline is mostly sediment flats. Gaseous discharges are released via stacks at the site. The local area around the Chapelcross site consists mainly of arable fields, the nearest town being Annan approximately three miles away.

Figure 8 Map of the Chapelcross local area



9.2 Current liquid discharge limits for Chapelcross

Nuclide	*Limit (TBq)*
Alpha	0.1
Beta (excluding tritium)	25
Tritium	5.5

9.3 Hydrographic Data

Admiralty chart 1346 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond A was considered the most appropriate, as it is the furthest point up the Solway Firth for which tidal data is available. From this data it was possible to estimate the exchange volume and dispersion factor for the Chapelcross liquid discharge area. When running the WAT model, the single compartment mode should be used as the site discharges into the estuarine Solway Firth.

Parameter	*Value*
Model	Single compartment
Dispersion factor: changes per day	0.066
Exchange volume (km^3)	0.023
Suspended sediment load ($mg\ l^{-1}$)	4.09
Sedimentation rate ($kg\ m^{-2}\ y^{-1}$)	0.14
Mean depth (m)	5.0
Estuarine silt sedimentation rate ($m\ y^{-1}$)	0.04

10 Derby

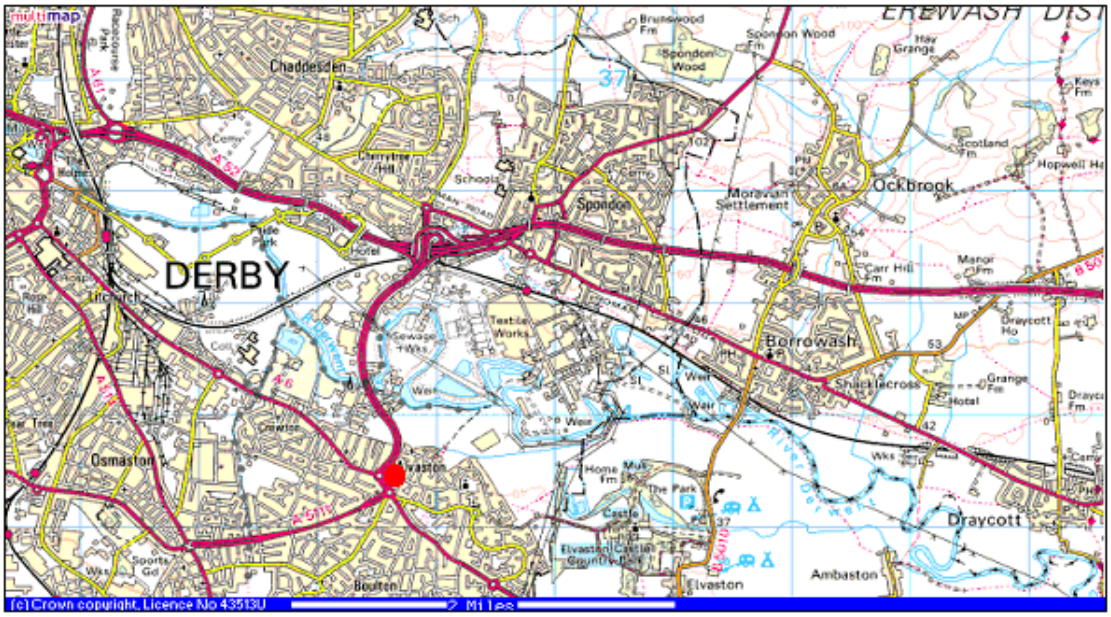
10.1 Derby

- Owner – Rolls-Royce Marine Power Operations Ltd
- Date started production – 1960

Rolls-Royce Derby manufactures fuel for nuclear powered submarines at two adjacent sites: the Nuclear Fuel Production Plant, and the Neptune Reactor and Radioactive Components Facility. These are situated in the Midlands approximately 2 miles east of Derby.

Discharges of liquid effluent are made into the public sewer, which then enters the River Derwent via the Megaloughton Lane sewage works. Gaseous discharges are released via stacks at the site. The local area around the site generally consists of industrial estates.

Figure 9 Map of the Derby local area



10.2 Current liquid discharge limits for Derby

Isotopic composition of the alpha-emitting discharge from both sites is likely to be dominated by ^{235}U, with small amounts of other uranium isotopes. However, for conservative assessments higher levels of ^{234}U may be used. The Neptune reactor's beta-emitting discharge is likely to be made up of ^{60}Co, ^{55}Fe and ^{63}Ni.

Nuclide	Limit (TBq)	
	Fuel production plant	Neptune reactor
Alpha	0.002	$3.0\ 10^{-7}$
Beta	-	$3.0\ 10^{-4}$

10.3 Hydrographic Data

As the site discharges into a non-tidal inland waterway the WAT and ADO models used to run marine assessments are invalid. An Excel-based freshwater river model has been developed for such discharges; guidance on how to use this model is given in Appendix A.

Parameter	Value
Model	Freshwater
Flow rate ($m^3\ s^{-1}$)	17.5[a]
Suspended sediment load ($g\ m^{-3}$)	15.2[b]
Modifying factor	1.0
Dry/Wet mass ratio	1.66
Mud wet density	0.6

a – Environment Agency (2005)
b – Winpenny & Allison (2001)

11 Devonport

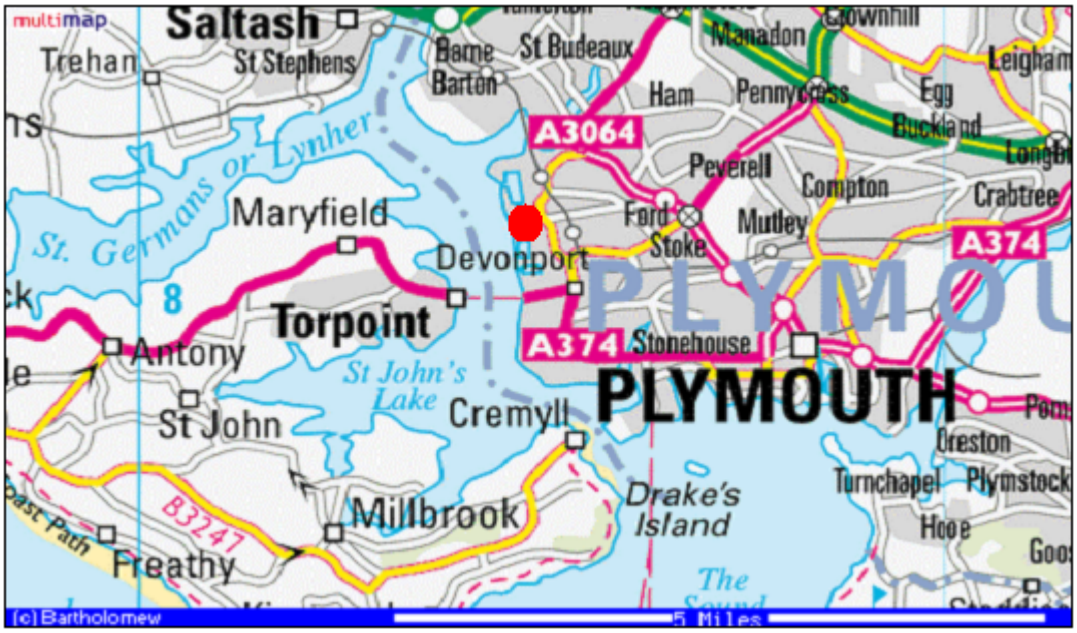
11.1 Devonport

- Owner – MoD / Devonport Management Ltd

Devonport is a nuclear submarine dockyard situated on the River Tamar in Devon, England; it is approximately 1 mile west of Plymouth. As well as being a berthing point for nuclear submarines, the dockyard has the capacity to dismantle the submarines when decommissioned.

The site discharges liquid effluent into the River Tamar via pipeline and sewer. The riverbed in the vicinity of the discharge point is mainly mud with occasional sandy patches. The local area around Devonport is mainly urban housing and local marine-based industry.

Figure 10 Map of the Devonport local area



11.2 Current liquid discharge limits for Devonport

Separate discharge limits are specified for the MoD and Devonport Management Ltd at Devonport. Those shown below are the authorised limits for DML; the MoD limits are expressed as a combination of activity concentration and total activity discharged. The MoD has not discharged any radioactive effluent since 2002.

	Limit (TBq)	
Nuclide	***Pipeline***	***Sewer***
Tritium	0.7	0.002
Carbon-14	0.0017	-
Cobalt-60	$8\ 10^{-4}$	$3.5\ 10^{-4}$
Other radionuclides	$3\ 10^{-4}$	$6.5\ 10^{-4}$

11.3 Hydrographic Data

Admiralty chart 1902 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the dockyard's outfall. Tidal diamond D was used, as it is very close to the location of the outfall. From this data it was possible to estimate the exchange volume and dispersion factor for the Devonport Dockyard liquid discharge region. When running the WAT model, the single compartment mode should be used as the site discharges into the Tamar estuary.

Parameter	***Value***
Model	Single compartment
Dispersion factor: changes per day	0.812
Exchange volume (km^3)	0.041
Suspended sediment load ($mg\ l^{-1}$)	3.37
Sedimentation rate ($kg\ m^{-2}\ y^{-1}$)	0.06
Mean depth (m)	10.0
Estuarine silt sedimentation rate ($m\ y^{-1}$)	0.01

12 Dounreay

12.1 Dounreay

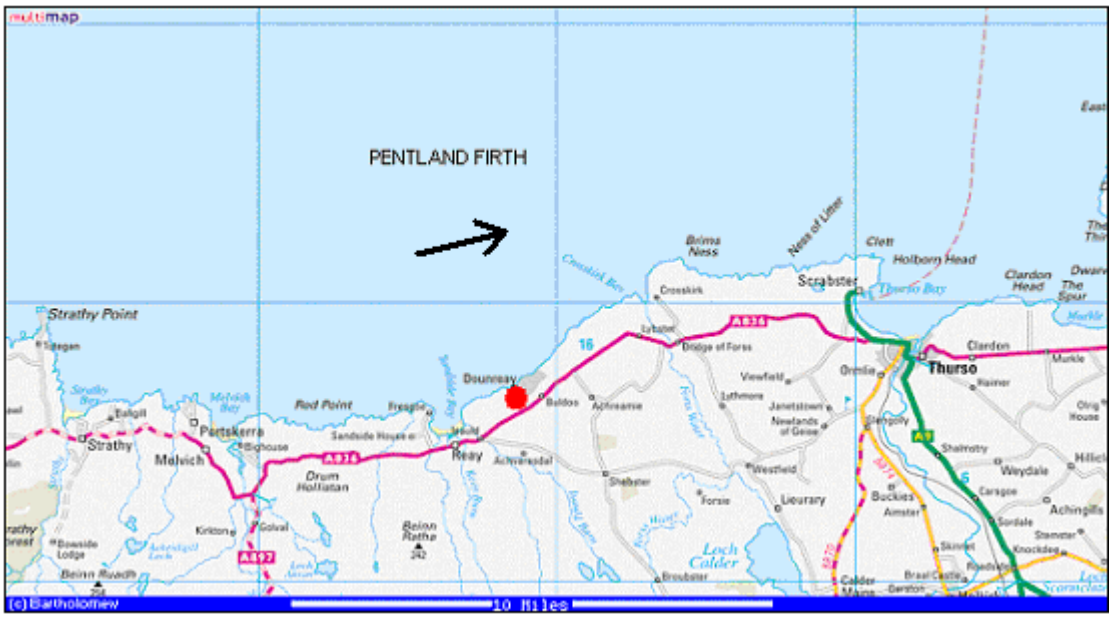
- Owner – UKAEA / NDA
- Date started production – 1955
- Date ceased production – 1998

Dounreay is situated on the northern coast of Scotland approximately 10 miles west of Thurso. The power station at Dounreay ceased generating electricity in 1994, and stopped all commercial operations in 1998 to concentrate on decommissioning. Radioactive wastes are still generated and discharged as part of this process.

The discharge authorisations were revised in 2004, and now prescribe separate limits for the Prototype Fast Reactor liquid metal disposal plant and the site's other facilities. These other facilities include the Ministry of Defence owned Vulcan Naval Reactor Test Establishment, which occupies a small part of the site.

The site discharges liquid effluent into the Pentland Firth area of the North Atlantic Ocean via one main and two subsidiary pipelines. The main pipeline discharges 500 metres offshore at a depth of 21m. The seabed in the vicinity of the outfall is mainly sand with occasional patches of rock. Gaseous discharges are released via stacks at the station. The local area around Dounreay mainly consists of arable fields, the nearest town being Thurso.

Figure 11 Map of the Dounreay local area



12.2 Current liquid discharge limits for Dounreay

The alpha limit for the PFR liquid metal disposal plant excludes the discharge of ^{242}Cm; the beta limit for the PFR liquid metal disposal plant excludes the discharge of tritium.

	Limit (TBq)	
Nuclide	***PFR plant***	***Other facilities***
Alpha	0.02	0.09
Beta	0.11	0.62
Tritium	1.4	5.5
Sodium-22	1.8	0.77
Caesium-137	0.066	1.0

12.3 Hydrographic Data

Admiralty chart 1954 was used to calculate residual velocity, tidal excursion and mean depth in the vicinity of the outfall. However, the relevant tidal diamonds showed the direction of the residual flow to be from east to west, i.e. from the North Sea through the Pentland Firth towards the North Atlantic Ocean. This is at odds with more recent oceanographic data from a Cefas survey of the discharge area in 2001 (Rees, 2001). It was decided to use the Cefas survey data as a basis for the hydrographic parameters rather than the Admiralty chart.

Parameter	***Value***
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.052[a]
Diffusion coefficient (m^2 s^{-1})	10.0
Tidal excursion (m)	6700[a]
Initial spreading radius (m)	50.0
Start time for discharges	0
End time for discharges	1
Suspended sediment load (mg l^{-1})	0.29
Sedimentation rate (kg m^{-2} y^{-1})	0.004
Mean depth (m)	22.9[a]
Estuarine silt sedimentation rate (m y^{-1})	0.02

a – Rees (2001)

13 Dungeness

13.1 Dungeness A

- Owner – Magnox Electric Ltd / NDA
- Date started production – 1966
- Due to cease production – 2006
- Capacity – 450 MW

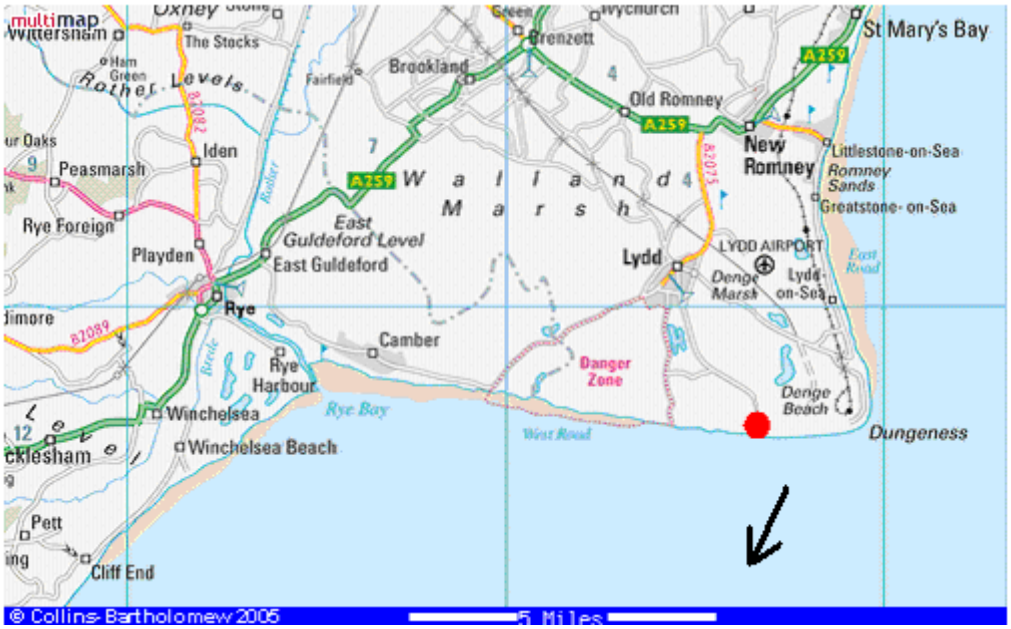
13.2 Dungeness B

- Owner – British Energy Generation (UK) Ltd
- Date started production – 1983
- Capacity – 1110 MW

Dungeness is situated on the southeast coast of England approximately 15 miles southwest of Folkestone. There are two nuclear power stations situated here. The 'A' station is owned by Magnox Electric Ltd and powered by twin Magnox reactors; the 'B' station is owned by BEG (UK) Ltd and is powered by twin advanced gas-cooled reactors (AGR).

Each station discharges liquid effluent into the English Channel via adjacent offshore outfalls. The seabed in the vicinity of the outfalls is mainly stone with occasional patches of sand. Gaseous discharges are released via stacks at each station. The local area around Dungeness is mainly marshland and nature reserves, the nearest town being Lydd, 5 miles from the site.

Figure 12 Map of the Dungeness local area



13.3 Current liquid discharge limits for Dungeness 'A' and 'B'

Recent data suggests that the isotopic composition of the non-nuclide specific category will be dominated by ^{134}Cs at Dungeness 'A', and both ^{134}Cs and ^{137}Cs at Dungeness 'B'.

Nuclide	***Limit (TBq)***	
	Dungeness 'A'	***Dungeness 'B'***
Tritium	8	650
Sulphur-35	-	2
Cobalt-60	-	0.03
Caesium-137	1.1	-
Other radionuclides	0.8	0.25

13.4 Hydrographic Data

Admiralty chart 1892 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the adjacent outfalls. Tidal diamond J was used, as it is the closest to the area in which the outfalls are situated. However, this diamond is not considered to be an ideal indicator of the local hydrographic conditions, and users may wish to consult the data supplied by the site operators in their periodical authorisation applications. When running the WAT model, the advection-diffusion mode should be used as the sites discharge into the open water of the English Channel.

Parameter	***Value***
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.02
Diffusion coefficient (m^2 s^{-1})	5.0
Tidal excursion (m)	10834
Initial spreading radius (m)	50.0
Start time for discharges	0
End time for discharges	1
Suspended sediment load (mg l^{-1})	9.04
Sedimentation rate (kg m^{-2} y^{-1})	0.31
Mean depth (m)	10.0
Estuarine silt sedimentation rate (m y^{-1})	0.02

14 Faslane

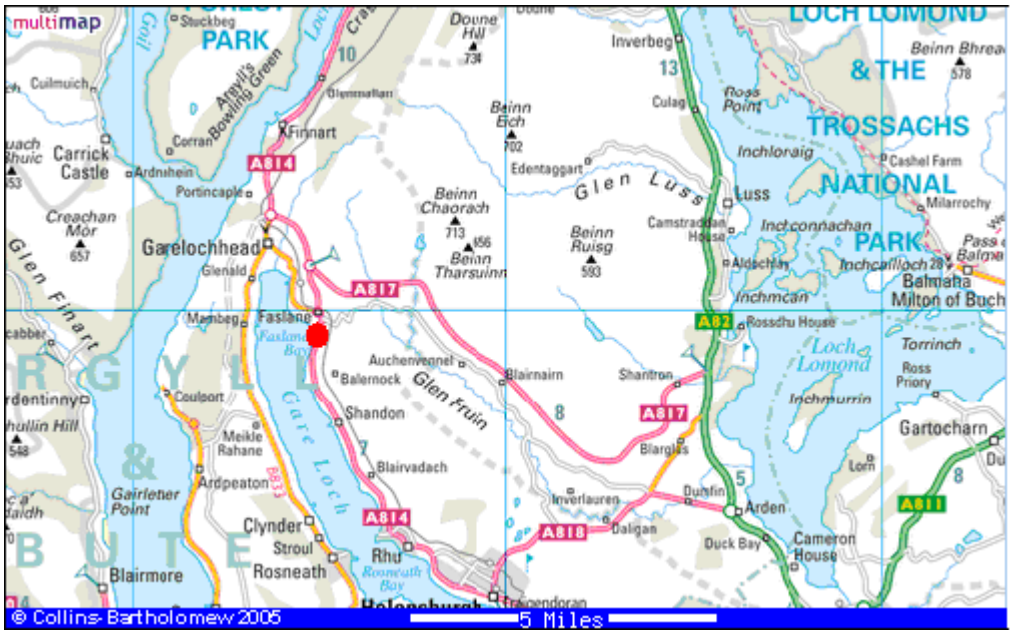
14.1 Faslane

- Owner – MoD (HM Naval Base)
- Date opened - 1967

Faslane, on the shore of Gare Loch in the Strathclyde region of Scotland, is also known as HM Naval Base Clyde. It is situated on the western coast of Scotland approximately 25 miles northwest of Glasgow. The base is home to Swiftsure class nuclear submarines, Trident armed submarines, minesweepers and the Northern Diving group. The Faslane site provides berthing facilities for the submarines and can also undertake out-of-the-water repairs and maintenance.

The site discharges liquid effluent via a short pipeline into the Gare Loch, which feeds into the Firth of Clyde area of the Irish Sea. The seabed in the vicinity of the outfall is mainly small stones with occasional sandy patches. Faslane releases no gaseous discharges. The local area around Faslane is mainly rural countryside and hillside farming areas, the nearest town being Helensburgh, approximately six miles to the south.

Figure 13 Map of the Faslane local area



14.2 Current liquid discharge limits for Faslane

Nuclide	*Limit (TBq)*
Alpha	$2.0\ 10^{-4}$
Beta	$5.0\ 10^{-4}$
Tritium	1.0
Cobalt-60	$5.0\ 10^{-4}$

14.3 Hydrographic Data

Admiralty chart 2000 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond A was used, as it was the only diamond in the vicinity of the Loch. From this data it was possible to estimate the exchange volume and dispersion factor for the Faslane marine discharge area. When running the WAT model, the single compartment mode should be used as the dockyard discharges into a marine Loch displaying estuarine conditions.

Parameter	*Value*
Model	Single compartment
Dispersion factor: changes per day	0.474
Exchange volume (km^3)	0.030
Suspended sediment load ($mg\ l^{-1}$)	4.74
Sedimentation rate ($kg\ m^{-2}\ y^{-1}$)	0.11
Mean depth (m)	30.0
Estuarine silt sedimentation rate ($m\ y^{-1}$)	0.04

15 Hartlepool

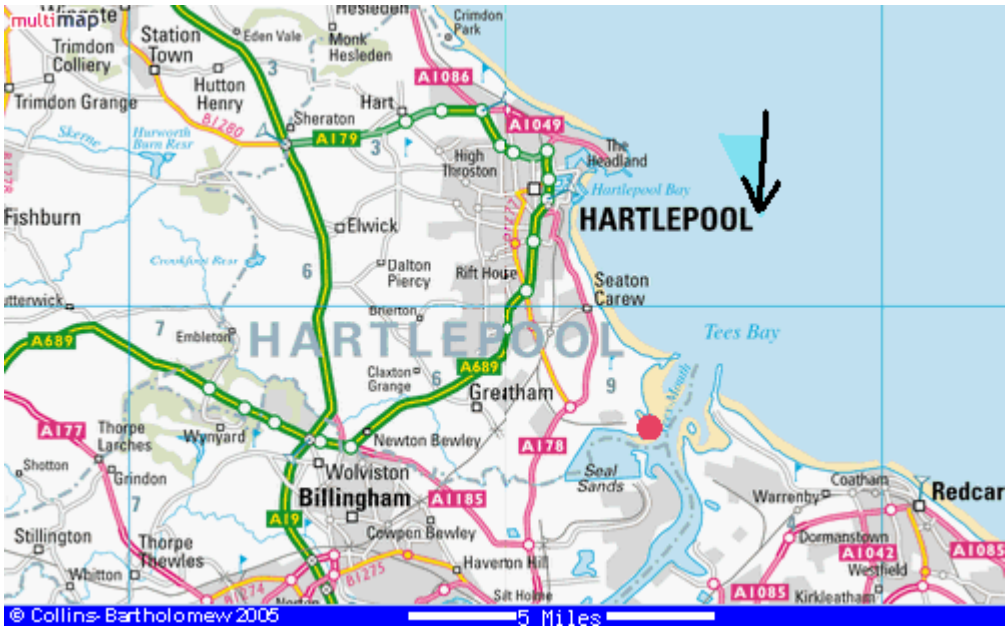
15.1 Hartlepool

- Owner – British Energy Generation (UK) Ltd
- Date started production – 1983
- Capacity – 1210 MW

Hartlepool is situated on the northeast coast of England approximately 10 miles north of Middlesbrough and 20 miles south of Sunderland. There is one nuclear power station situated here owned by BEG (UK) Ltd and powered by twin advanced gas-cooled reactors.

The station discharges liquid effluent into the North Sea via a pipeline, which extends to 200 metres offshore. The seabed in the vicinity of the outfall is mainly sand with occasional patches of gravel. Gaseous discharges are released via stacks at each station. The local area around the site consists of mainly industrial works and nature reserves, the nearest town being Seaton Carew, which is 1 mile from the site.

Figure 14 Map of the Hartlepool local area



15.2 Current liquid discharge limits for Hartlepool

Nuclide	*Limit (TBq)*
Tritium	1200
Sulphur-35	3.0
Cobalt-60	0.03
Other radionuclides	0.3

15.3 Hydrographic Data

Admiralty chart 2567 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond B was used, as it is located in the same Bay as the outfall and is not far offshore. When running the WAT model, the advection-diffusion mode should be used as the site discharges into the open water of the North Sea.

Parameter	*Value*
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.02
Diffusion coefficient (m^2 s^{-1})	5.0
Tidal excursion (m)	4295
Initial spreading radius (m)	50.0
Start time for discharges	0.54
End time for discharges	0.92
Suspended sediment load (mg l^{-1})	2.87
Sedimentation rate (kg m^{-2} y^{-1})	0.10
Mean depth (m)	10.0
Estuarine silt sedimentation rate (m y^{-1})	0.02

16 Harwell

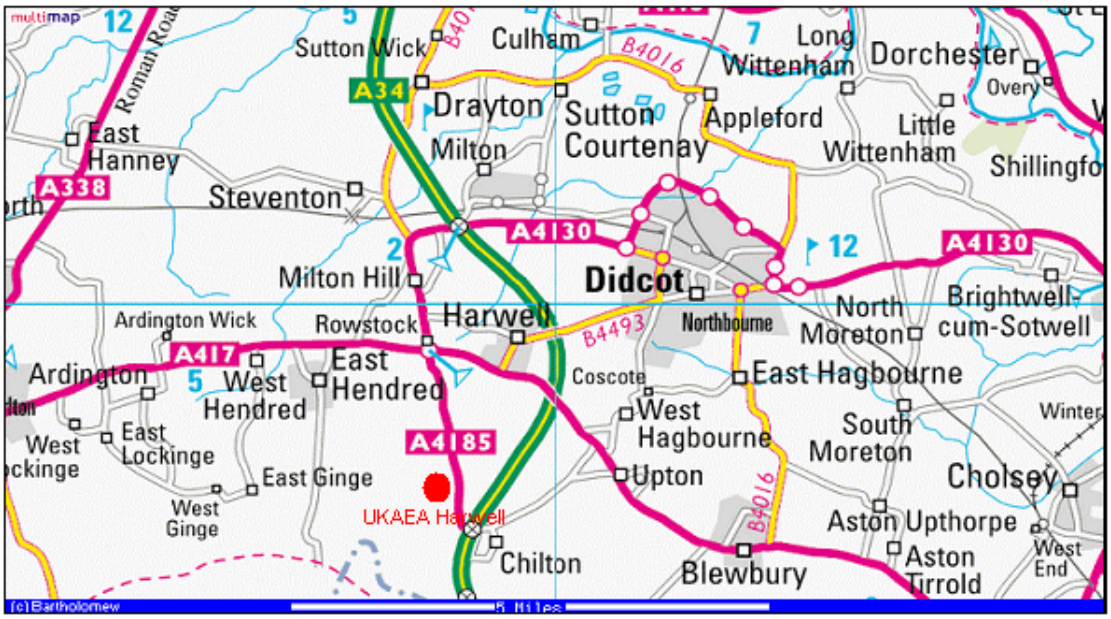
16.1 Harwell

- Owner – UKAEA
- Date started production – 1946
- Date ceased production – 1990

UKAEA Harwell is a complex of radiochemical laboratories and facilities for handling highly active material. Nuclear reactors on the site were shut down in 1990, and their decommissioning continues. Harwell is situated in the Thames valley approximately 20 miles east of Swindon and 15 miles south of Oxford.

The site discharges liquid effluent via pipeline to the River Thames, and also to the Lydebank Brook north of the site. Both discharge routes eventually join the River Thames at Sutton Courtenay. Gaseous discharges are released via stacks at the site. The local area around Harwell consists mainly of arable fields, the nearest town being Didcot, which is 3 miles from the site.

Figure 15 Map of the Harwell local area



16.2 Current liquid discharge limits for Harwell

Nuclide	*Limit (TBq)*	
	Pipeline	*Lydebank brook*
Alpha	$5\ 10^{-5}$	$1.04\ 10^{-4}$
Beta	0.0033	$6\ 10^{-4}$
Tritium	0.3	0.08
Cobalt-60	$1.2\ 10^{-4}$	-
Caesium-137	$5.4\ 10^{-4}$	-

16.3 Hydrographic Data

As the site discharges into a non-tidal inland waterway then the WAT and ADO models used to run marine assessments are invalid. An Excel-based freshwater river model has been developed for such discharges; guidance on how to use this model is given in Appendix A.

Parameter	*Value*
Model	Freshwater
Flow rate ($m^3\ s^{-1}$)	4.75 – River Thames[a]
	0.1 – Lydebank Brook[a]
Suspended sediment load ($g\ m^{-3}$)	10.0 (both discharge routes)
Modifying factor	1.0 (both discharge routes)
Dry/Wet mass ratio	1.66
Mud wet density	0.6

a – Round et al. *(1999)*

17 Heysham

17.1 Heysham 1

- Owner - British Energy Generation (UK) Ltd
- Date started production – 1983
- Capacity – 1150 MW

17.2 Heysham 2

- Owner – British Energy Generation (UK) Ltd
- Date started production – 1988
- Capacity – 1250 MW

Heysham is situated on the north-western coast of England approximately 10 miles north of Blackpool. There are two operational nuclear power stations situated here, both powered by twin Advanced Gas-cooled reactors (AGRs).

Each station discharges liquid effluent into Morecambe Bay via pipeline to a combined outfall, which is approximately 500 metres offshore. The seabed in the vicinity of the outfall is mainly mud with occasional sandy patches. Gaseous discharges are released via stacks at each station. The local area around Heysham is mainly light industrial use, the nearest town being Heysham, which is 1 mile from the site.

Figure 16 Map of the Heysham local area

17.3 Current liquid discharge limits for Heysham

Based on previous years' discharge data, the isotopic composition of the non-nuclide specific category is likely to be dominated by ^{54}Mn and ^{137}Cs at Heysham '1', and ^{45}Ca and ^{137}Cs at Heysham '2'.

Nuclide	***Limit (TBq)***	
	Heysham '1'	***Heysham '2'***
Tritium	1200	1200
Sulphur-35	2.8	2.3
Cobalt-60	0.03	0.03
Other radionuclides	0.3	0.3

17.4 Hydrographic Data

Admiralty chart 1552 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond A was used, which is slightly south of the outfall but not too far offshore. When running the WAT model, the advection-diffusion mode should be used as the site's discharge into the non-estuarine open water of Morecambe Bay.

Parameter	***Value***
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.01
Diffusion coefficient (m^2 s^{-1})	5.0
Tidal excursion (m)	8200
Initial spreading radius (m)	50.0
Start time for discharges	0
End time for discharges	1
Suspended sediment load (mg l^{-1})	9.53
Sedimentation rate (kg m^{-2} y^{-1})	0.65
Mean depth (m)	7.0
Estuarine silt sedimentation rate (m y^{-1})	0.04

18 Hinkley Point

18.1 Hinkley Point A

- Owner – Magnox Electric Ltd / NDA
- Date started production – 1964
- Date ceased production – 2000 (defuelling completed 2004)

18.2 Hinkley Point B

- Owner – British Energy Generation (UK) Ltd
- Date started production – 1976
- Capacity – 1220 MW

Hinkley Point is situated on the northern coast of Somerset approximately 10 miles northwest of Bridgwater. There are two nuclear power stations situated here. Hinkley Point 'A' ceased production in 2000 and is in the process of decommissioning, whilst the 'B' station, powered by an advanced gas-cooled reactor (AGR) remains operational.

Each station discharges liquid effluent into the English Channel via a combined outfall, which lies 500 metres offshore. The seabed in the vicinity of the outfalls is mainly rock with occasional sandy patches. Gaseous discharges are released via stacks at each station. The local area around Hinkley Point is mainly arable fields and nature reserves, the nearest town being Nether Stowey, which is 5 miles from the site.

Figure 17 Map of the Hinkley Point local area

18.3 Current liquid discharge limits for Hinkley Point 'A' and 'B'

Based on previous years discharge data, the isotopic composition of the non-nuclide specific category is likely to be dominated by ^{90}Sr and ^{134}Cs at Hinkley 'A', and ^{54}Mn and ^{137}Cs at Hinkley 'B'.

Nuclide	***Limit (TBq)***	
	Hinkley Point 'A'	***Hinkley Point 'B'***
Tritium	1.8	620
Sulphur-35	-	5
Cobalt-60	-	0.033
Caesium-137	1	-
Other radionuclides	0.7	0.235

18.4 Hydrographic Data

Admiralty chart 1152 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond E was used, as it was judged to give the most reliable data of the diamonds located near to the outfall. When running the WAT model, the advection-diffusion mode should be used as the site's discharge into the open water of the Bristol Channel.

Parameter	***Value***
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.02
Diffusion coefficient (m^2 s^{-1})	5.0
Tidal excursion (m)	21680
Initial spreading radius (m)	50.0
Start time for discharges	0.08
End time for discharges	0.33
Suspended sediment load (mg l^{-1})	35.24
Sedimentation rate (kg m^{-2} y^{-1})	1.21
Mean depth (m)	5.0
Estuarine silt sedimentation rate (m y^{-1})	0.04

19 Hunterston

19.1 Hunterston 'A'

- Owner – Magnox Electric Ltd / NDA
- Date started production – 1964
- Date ceased production – 1990 (defuelling completed 1995)

19.2 Hunterston 'B'

- Owner – British Energy Generation (UK) Ltd
- Date started production – 1976
- Capacity – 1190 MW

Hunterston is situated on the western coast of Scotland approximately 6 miles south of Largs. There are two separate power stations here – Hunterston 'A', which ceased generating electricity in 1990 although radioactive wastes are still generated and discharged as part of the decommissioning process, and the operational Hunterston 'B', powered by a pair of advanced gas cooled reactors.

The site discharges liquid effluent into the Firth of Clyde area of the Irish Sea via a shared outfall. The seabed in the vicinity of the outfall is mainly sand with occasional patches of mud. Gaseous discharges are released via stacks at the station. The local area around Hunterston is mainly arable fields and light industrial areas, the nearest town being West Kilbride.

Figure 18 Map of the Hunterston local area

19.3 Current liquid discharge limits for Hunterston

Nuclide	*Limit (TBq)*	
	Hunterston 'A'	*Hunterston 'B'*
Alpha	0.04	0.001
Beta	0.6	0.45
Tritium	0.7	800
Sulphur-35	-	10
Cobalt-60	-	0.03
Plutonium-241	1.0	-

19.4 Hydrographic Data

Admiralty chart 1907 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond A was used as it lies in the Hunterston Channel, in which the outfall is situated. When running the WAT model, the advection-diffusion mode is recommended as the site discharges into open water at the juncture of the Irish Sea and the Firth of Clyde. The single compartment mode could also be used if it was felt that the Isles of Cumbrae combined to form a sufficiently enclosed environment.

Parameter	*Value*
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.01
Diffusion coefficient (m^2 s^{-1})	5.0
Tidal excursion (m)	2562
Initial spreading radius (m)	50.0
Start time for discharges	0.08
End time for discharges	0.33
Suspended sediment load (mg l^{-1})	4.74
Sedimentation rate (kg m^{-2} y^{-1})	0.11
Mean depth (m)	5.0
Estuarine silt sedimentation rate (m y^{-1})	0.01

20 Rosyth

20.1 Rosyth

- Owner – Babcock Rosyth Defence Ltd (BRDL) / MoD

Rosyth Royal Dockyard is a nuclear submarine berth situated on the Firth of Forth in Scotland, approximately 10 miles northwest of Edinburgh. The site is preparing for decommissioning following the decision to move submarine refit work to Devonport.

Radioactive waste, both operational and decommissioning, is discharged into the Firth of Forth via a low active effluent discharge line. The riverbed in the vicinity of the outfall is mainly mud. Gaseous discharges are released via stacks at the site. The local area around Rosyth consists mainly of urban housing and local industry, the nearest town to Rosyth being Dunfermline which is 2 miles to the north of the site.

Figure 19 Map of the Rosyth local area

20.2 Current liquid discharge limits for Rosyth

Nuclide	*Limit (TBq)*
Alpha	$1\ 10^{-6}$
Beta	$5.0\ 10^{-4}$
Tritium	0.04
Cobalt-60	0.005

20.3 Hydrographic Data

Admiralty chart 736 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond A was used, as it is in close proximity to the dockyard. From this data it was possible to estimate the exchange volume and dispersion factor for the Rosyth Dockyard marine discharge area. When running the WAT model, the single compartment model should be used as the dockyard discharges into the Firth of Forth.

Parameter	*Value*
Model	Single compartment
Dispersion factor: changes per day	0.638
Exchange volume (km^3)	0.355
Suspended sediment load (mg l^{-1})	6.83
Sedimentation rate (kg m^{-2} y^{-1})	0.07
Mean depth (m)	20.0
Estuarine silt sedimentation rate (m y^{-1})	0.04

21 Sellafield

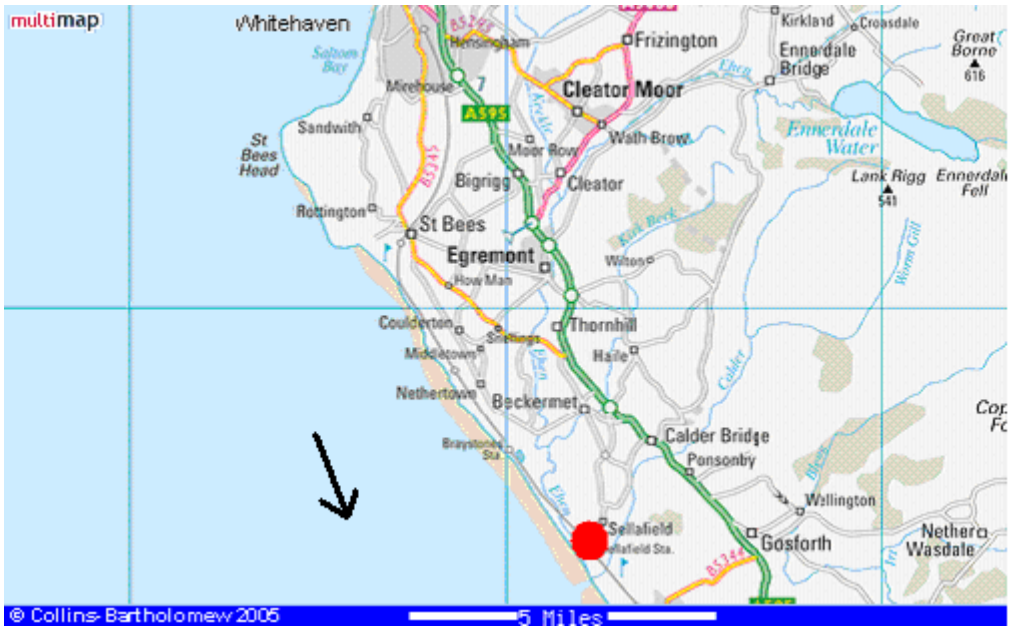
21.1 Sellafield

- Owner – BNFL / UKAEA / NDA
- Date started production – 1947 (Windscale)
- Calder Hall power station ceased production – 2003

Sellafield is situated on the west coast of northern England approximately 10 miles south of Whitehaven and 15 miles north of Barrow-in-Furness. A range of nuclear activities are encompassed on the site: (re)processing of spent nuclear fuel from around the world, management and storage of high-level radioactive waste, fuel fabrication, and the decommissioning of the Calder Hall power station. The Windscale laboratories of UKAEA, also situated on the site, are in the process of decommissioning.

There are two liquid effluent disposal pathways at the site. The main pipeline discharges approximately 2 kilometres offshore into the Irish Sea, and the Seaburn sewer, essentially a surface water drain, discharges into the confluence of the Rivers Calder and Ehen. The seabed in the vicinity of both the sewer outfall and the pipeline is mainly mud. Gaseous discharges are released via stacks at the station. The local area around Sellafield consists of mainly arable fields, the nearest town being Whitehaven.

Figure 20 Map of the Sellafield local area



21.2 Current liquid discharge limits for Sellafield

Nuclide	*Limit (TBq)*	
	Pipeline	*Sewer*
Alpha	1	0.0033
Beta	400	0.0135
Tritium	$2.5\ 10^4$	0.132
Carbon-14	20.8	-
Cobalt-60	13	-
Strontium-90	48	-
Zirconium-95 + Niobium-95	9	-
Technetium-99	90	-
Ruthenium-106	63	-
Iodine-129	1.6	-
Caesium-134	6.6	-
Caesium-137	75	-
Cerium-144	8	-
Plutonium alpha	0.7	-
Plutonium-241	27	-
Americium-241	0.3	-
Uranium[a]	2040	-

a – *Discharge limit is expressed in kg*.

21.3 Hydrographic Data

Admiralty chart 1346 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond E was considered the most appropriate to use as it is in the region of the outfall and only slightly further offshore. When running the WAT model, the advection-diffusion mode should be used, as the outfall lies in the open water of the Irish Sea. However, due to the complexity of circulation patterns in the Irish Sea it is recognised that more sophisticated modelling techniques, such as the CSERAM model (Aldridge, 1998) of the Irish Sea region, or normalised activity concentrations, may be more applicable to this site.

Parameter	*Value*
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.03
Diffusion coefficient (m^2 s^{-1})	5.0
Tidal excursion (m)	5371
Initial spreading radius (m)	50.0
Start time for discharges	0.08
End time for discharges	0.33
Suspended sediment load (mg l^{-1})	4.24
Sedimentation rate (kg m^{-2} y^{-1})	0.10
Mean depth (m)	15.0
Estuarine silt sedimentation rate (m y^{-1})	0.04

22 Sizewell

22.1 Sizewell A

- Owner – Magnox Electric Ltd / NDA
- Date started production – 1965
- Due to cease production – end of 2006
- Capacity – 420 MW

22.2 Sizewell B

- Owner – British Energy Generation (UK) Ltd
- Date started production – 1995
- Capacity – 1188 MW

Sizewell is situated on the east coast of England approximately 20 miles north of Ipswich and 25 miles south of Lowestoft. There are two nuclear power stations situated here. The 'A' station, powered by twin Magnox reactors, is due to cease production in 2006; the 'B' station is the most modern nuclear power station in the UK, and the only one to be powered by a Pressurised Water Reactor.

Each station discharges liquid effluent into the North Sea via adjacent offshore outfalls. The seabed in the vicinity of the outfalls is mainly sand with occasional patches of gravel. Gaseous discharges are released via stacks at each station. The local area around Sizewell is mainly arable fields and heathland, the nearest town being Leiston, which is 2 miles from the site.

Figure 21 Map of the Sizewell local area

22.3 Current liquid discharge limits for Sizewell 'A' and 'B'

Recent data shows that the predominant nuclides discharged under the 'other radionuclides' limit are ^{134}Cs and ^{90}Sr at Sizewell 'A', and ^{134}Cs, ^{137}Cs and ^{55}Fe at Sizewell 'B'.

	Limit (TBq)	
Nuclide	***Sizewell 'A'***	***Sizewell 'B'***
Tritium	11	80
Caesium-137	1.0	-
Other radionuclides	0.7	0.2

22.4 Hydrographic Data

Admiralty chart 1543 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond S was considered the most appropriate, as it is close to the shore and not too far north of the outfall. When running the WAT model the advection-diffusion mode should be used, as the site discharges into the open water of the North Sea.

Parameter	***Value***
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.02
Diffusion coefficient (m^2 s^{-1})	1.0
Tidal excursion (m)	10945
Initial spreading radius (m)	50.0
Start time for discharges	0.54
End time for discharges	0.92
Suspended sediment load (mg l^{-1})	12.89
Sedimentation rate (kg m^{-2} y^{-1})	0.44
Mean depth (m)	10.0
Estuarine silt sedimentation rate (m y^{-1})	0.02

23 Springfields

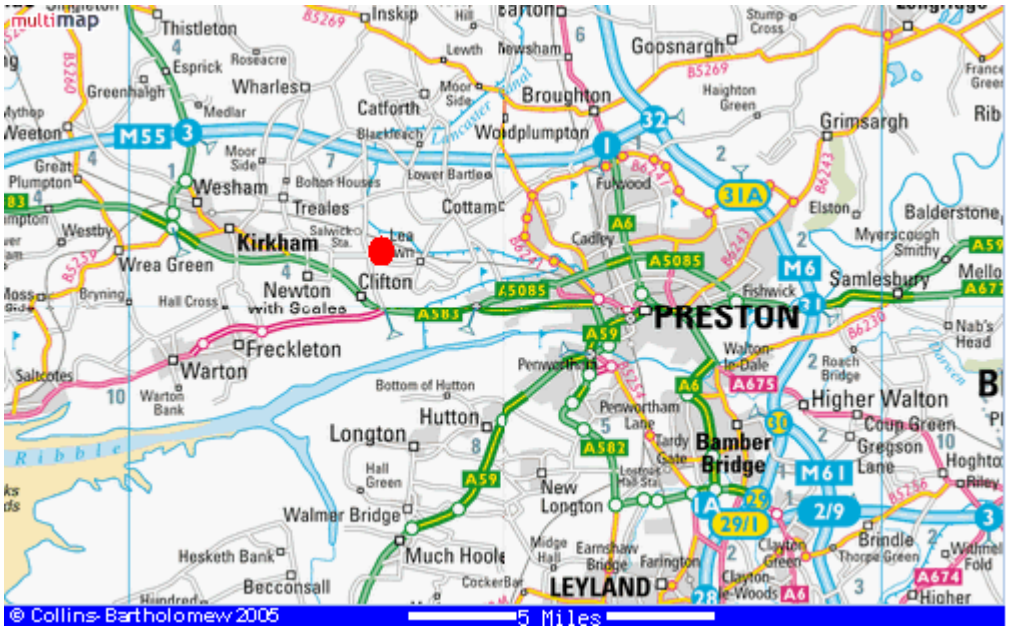
23.1 Springfields

- Owner – Springfields Fuels Ltd / NDA
- Date started production – 1946

Springfields lies approximately 4 miles west of Preston in the northwest of England. The site is the main supplier of fuel and intermediate fuel products for the nuclear industry in the UK and abroad. Uranium hexafluoride is converted on site to provide oxide fuel for use in Advanced Gas-cooled reactors (AGRs) and Light Water reactors (LWRs). Decommissioning work on old plants and redundant buildings is also being undertaken.

Springfields is authorised to discharge liquid effluent into the River Ribble via pipeline. The riverbed in the vicinity of the discharge point is mainly muddy sand. Gaseous discharges are released via stacks at the site. The local area around Springfields is mainly arable farmland, the nearest town being Preston.

Figure 22 Map of the Springfields local area



23.2 Current liquid discharge limits for Springfields

Nuclide	*Limit (TBq)*
Alpha	4.0
Beta	240
Technetium-99	0.6
Thorium-230	2.0
Thorium-232	0.2
Neptunium-237	0.04
Uranium	0.15

23.3 Hydrographic Data

Admiralty chart 1981 maps the upper reaches of the Ribble Estuary, as far as Preston docks. There is, however, little hydrographic detail in the vicinity of the outfall. As a result, the residual velocity and tidal excursion calculated from tidal diamond D have been modified in an attempt to model the likely conditions at the outfall. When running the WAT model, the single compartment model is recommended, as effluent is discharged into the Ribble Estuary.

Parameter	*Value*
Model	Single Compartment
Dispersion factor: changes per day	0.744
Exchange volume (km^3)	0.005
Suspended sediment load (mg l^{-1})	208.34
Sedimentation rate (kg m^{-2} y^{-1})	14.16
Mean depth (m)	2.0
Estuarine silt sedimentation rate (m y^{-1})	0.06

24 Torness

24.1 Torness

- Owner – British Energy Generation (UK) Ltd
- Date started production – 1988
- Capacity – 1250 MW

Torness is situated on the east coast of Scotland, approximately 5 miles southeast of Dunbar. The nuclear power station situated here is owned and operated by BEG (UK) Ltd, and powered by twin advanced gas-cooled reactors.

The station discharges liquid effluent into the North Sea via an outfall on the shoreline. The seabed in the vicinity of the outfall is mainly rock with occasional sandy patches. Gaseous discharges are released via stacks at the station. The local area around Torness consists of mainly arable fields, the nearest town being Dunbar.

Figure 23 Map of the Torness local area

24.2 Current liquid discharge limits for Torness

Nuclide	*Limit (TBq)*
Alpha	0.001
Beta	0.45
Tritium	800
Sulphur-35	10
Cobalt-60	0.03

24.3 Hydrographic Data

Admiralty chart 1192 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Although the site location is not covered by this chart, tidal diamond A was judged to be sufficiently close, and located off a stretch of coastline similar to that at the point of discharge, as to give reliable results. When running the WAT model the advection-diffusion mode should be used, as the site discharges into the open water of the North Sea.

Parameter	*Value*
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.03
Diffusion coefficient (m^2 s^{-1})	5.0
Tidal excursion (m)	3374
Initial spreading radius (m)	50.0
Start time for discharges	0
End time for discharges	1
Suspended sediment load (mg l^{-1})	10.0
Sedimentation rate (kg m^{-2} y^{-1})	0.23
Mean depth (m)	10.0
Estuarine silt sedimentation rate (m y^{-1})	0.02

25 Trawsfynydd

25.1 Trawsfynydd

- Owner – Magnox Electric Ltd / NDA
- Date started production – 1965
- Date ceased production – 1991 (defuelled 1993)

Trawsfynydd is situated on Lake Trawsfynydd in the Snowdonia National Park, Wales, approximately 6 miles east of Porthmadog. The only UK nuclear power station to have been built inland, Trawsfynydd ceased generating electricity in 1991 although radioactive wastes are still generated and discharged as part of the decommissioning process.

The site discharges liquid effluent into Lake Trawsfynydd via a pipeline, and gaseous discharges are released via stacks at the station. The local area around Trawsfynydd is mainly arable land.

Figure 24 Map of the Trawsfynydd local area

25.2 Current liquid discharge limits for Trawsfynydd

The discharge limit for ^{90}Sr represents a sub-limit within the non-nuclide specific category.

Nuclide	*Limit (TBq)*
Tritium	0.5
Strontium-90	0.05
Caesium-137	0.03
Other radionuclides	0.17

25.3 Hydrographic Data

As the site discharges into a non-tidal inland waterway then the WAT and ADO models used to run marine assessments are invalid. An Excel-based model for discharge into a lake has been developed; guidance on how to use this model is given in Appendix B. The volume of the lake is held constant by the operation of the Maentwrog hydroelectric power station at the northwest corner of the lake. The station is required to maintain the lake level to avoid exposing the contaminated sediments on the bed to the atmosphere.

Parameter	*Value*
Model	Lake
Volume (m^3)	$3.00\ 10^{10}$
Flushing rate ($m^3\ y^{-1}$)	$1.50\ 10^{11}$
Modifying factor	1.0
Dry/Wet mass ratio	1.66
Mud wet density	0.6

26 Winfrith

26.1 Winfrith

- Owner – UKAEA
- Date started production – 1958
- Date ceased production – 1995

UKAEA Winfrith is situated in Dorset on the south coast of England, approximately 15 miles east of Weymouth. It is a former civil nuclear research site, which operated some eight reactors, manufactured nuclear fuel, and housed a range of laboratories and workshops. It is now in the process of decommissioning the final two reactors, one of which is the steam generated heavy water reactor (SGHWR).

The site discharges liquid effluent into Weymouth Bay via a double pipeline – the outer pipeline carries mainly trade wastes and discharges just beyond the foreshore, the inner pipeline carries the more active effluents and discharges 4km out to sea. The seabed in the vicinity of the outfall mainly consists of rock with occasional sandy patches. Gaseous discharges are released via stacks at the station. The local area around Winfrith consists of mainly arable fields, the nearest town being Wareham, which is 5 miles from the site.

Figure 25 Map of the Winfrith local area

26.2 Current liquid discharge limits for Winfrith

	Limit (TBq)	
Nuclide	***Inner pipeline***	***Outer pipeline***
Alpha	0.3	0.004
Tritium	650	1.0
Cobalt-60	10	-
Zinc-65	6.0	-
Other Radionuclides	80	0.01

26.3 Hydrographic Data

Admiralty chart 2610 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the outfall. Tidal diamond R was used, as it is located in the same Bay as the outfall of the inner pipeline. When running the WAT model the advection-diffusion mode should be used, as the inner pipeline discharges into non-estuarine open water.

Parameter	***Value***
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.07
Diffusion coefficient (m^2 s^{-1})	5.0
Tidal excursion (m)	8123
Initial spreading radius (m)	50.0
Start time for discharges	0
End time for discharges	1
Suspended sediment load (mg l^{-1})	5.12
Sedimentation rate (kg m^{-2} y^{-1})	0.05
Mean depth (m)	25.0
Estuarine silt sedimentation rate (m y^{-1})	0.02

27 Wylfa

27.1 Wylfa

- Owner – Magnox Electric Ltd / NDA
- Date started production – 1971
- Capacity – 980 MW

Wylfa is situated on the northwest coast of Anglesey approximately 15 miles northeast of Holyhead. There is one nuclear power station situated here, powered by twin Magnox reactors. It is due to cease operation in 2010.

The station discharges liquid effluent into the Irish Sea via an offshore outfall. The seabed in the vicinity of the outfall is mainly rock with occasional sandy patches. Gaseous discharges are released via stacks at the station. The local area around Wylfa consists of mainly arable fields, the nearest town being Amlwch, approximately 5 miles east of the site.

Figure 26 Map of the Wylfa local area

27.2 Current liquid discharge limits for Wylfa

Recent data suggests that the nuclides discharged under the non-nuclide specific category are mainly ^{60}Co, ^{134}Cs and ^{137}Cs.

Nuclide	***Limit (TBq)***
Tritium	15
Other radionuclides	0.11

27.3 Hydrographic Data

Admiralty chart 1413 was used to calculate the residual velocity, tidal excursion and mean depth in the vicinity of the adjacent outfalls. Tidal diamond A was used, as it is the closest to the area in which the outfall is situated. However, this diamond is not considered to be a good indication of the local hydrographic conditions, as it is some distance northwest of the site and describes a strong residual flow perpendicular to the coastline in the area of the outfall. Consequently, users may wish to consult the data supplied by the site operators in their periodical authorisation applications. When running the WAT model, the advection-diffusion mode should be used as the site discharges into the open water of the Irish Sea.

Parameter	***Value***
Model	Advection-diffusion
Residual Velocity (m s^{-1})	0.29
Diffusion coefficient (m^2 s^{-1})	5.0
Tidal excursion (m)	32772
Initial spreading radius (m)	50.0
Start time for discharges	0
End time for discharges	1
Suspended sediment load (mg l^{-1})	3.73
Sedimentation rate (kg m^{-2} y^{-1})	0.009
Mean depth (m)	25.0
Estuarine silt sedimentation rate (m y^{-1})	0.02

28 References

Aldridge, J. N. (1998), *CSERAM: a model for prediction of marine radionuclide transport in both particulate and dissolved phases*, Radiat. Prot. Dosim. **75**.

Environment Agency (2005), *Water situation report – monthly bulletin for England and Wales [various months]*, www.environment-agency.gov.uk

Environment Agency, Environment & Heritage Service, Food Standards Agency and Scottish Environment Protection Agency (2005), *Radioactivity in Food and the Environment, 2004* **(RIFE-10)**, Bristol, Belfast, London and Stirling.

Grzechnik, M.P. (2002), *A User Guide for Radiological Assessments, PC Version 1.0*, Cefas, Lowestoft.

Grzechnik, M. P., Jenkinson, S. B. & Pidcock, A. J. (2006), *User Guide for PRAME,* Cefas Env. Rep. **RL09/06**, Lowestoft.

Hydrographer of the Navy, *Admiralty charts [various numbers]*, Taunton.

OSPAR Commission (2005), *The application of BAT in UK nuclear facilities report*, Radioactive Substances Ser. Rep. No. **241**, London.

Rees, J. (2001), *Minipod deployment 2 at Dounreay, Dec 2001*. Cefas Rep. **C1214**, Lowestoft.

Round, G. D. (1998*a*), *Individual doses from discharges of liquid effluents to the sea: water concentration model – WAT.* Cefas Env. Rep. **RL 2/98**, Lowestoft.

Round, G. D. (1998*b*), *Individual doses from discharges of liquid effluents to the aquatic environment: dosimetric model – ADO.* Cefas Env. Rep. **RL 8/98**, Lowestoft.

Round, G. D. & Allison, M. R. (1999), *Nycomed Amersham plc, Amersham laboratory authorisation applications 1998: radiological assessment of liquid discharges*. Cefas Env. Rep. **RL 5/99**, Lowestoft.

Round, G. D., Allison, M. R. & Winpenny, K. (1999), *UKAEA Harwell, authorisation application 1999: radiological assessment of liquid discharges.* Cefas Env. Rep. **RL6/99**, Lowestoft.

Winpenny, K. & Allison, M. R. (2001), *Rolls-Royce Marine Power Operations Limited, Nuclear Fuel Production Plant Site and Neptune Nuclear Licensed Site Authorisation Applications 2000: Radiological Assessment of Liquid Discharges*. Cefas Env. Rep. **RL 25/00**, Lowestoft.

Acronyms

BAE – British Aerospace

BEG – British Energy Generation

BNFL – British Nuclear Fuels Limited

BNG – British Nuclear Group

Cefas – Centre for Environment, Fisheries and Aquaculture Science

MoD – Ministry of Defence

NDA – Nuclear Decommissioning Authority

UKAEA – United Kingdom Atomic Energy Authority

Appendix A – Excel River Assessments (Freshwater) Model

(Freshwater_Master.xls)

A simple Excel spreadsheet has been developed to model the effects of radionuclide discharge into a freshwater river environment in which the WAT/ADO suite is invalid. Within the spreadsheet are individual sheets to calculate water concentrations and effective doses to specified groups.

The model requires the input of the site-specific hydrographic parameters, discharge data and details of the consumption/occupancy of the specified groups. The spreadsheet has been designed such that only the areas shaded yellow, which pertain to the user-input data, can be modified, in order to prevent the accidental alteration of cells intrinsic to the working of the freshwater model.

The data is entered on the following sheets*: Water concs, Dosimetry (fish)*, *and Dosimetry (ext).* The doses are then calculated and automatically transferred to the *Summary sheet* where the dose data is presented in a tabular format. The *Summary sheet* is pre-formatted so that once the relevant parameters are entered the sheet can be printed directly.

Screen captures of the three entry sheets within *Freshwater_master.xls* are shown below. Areas available to user-input are shaded yellow.

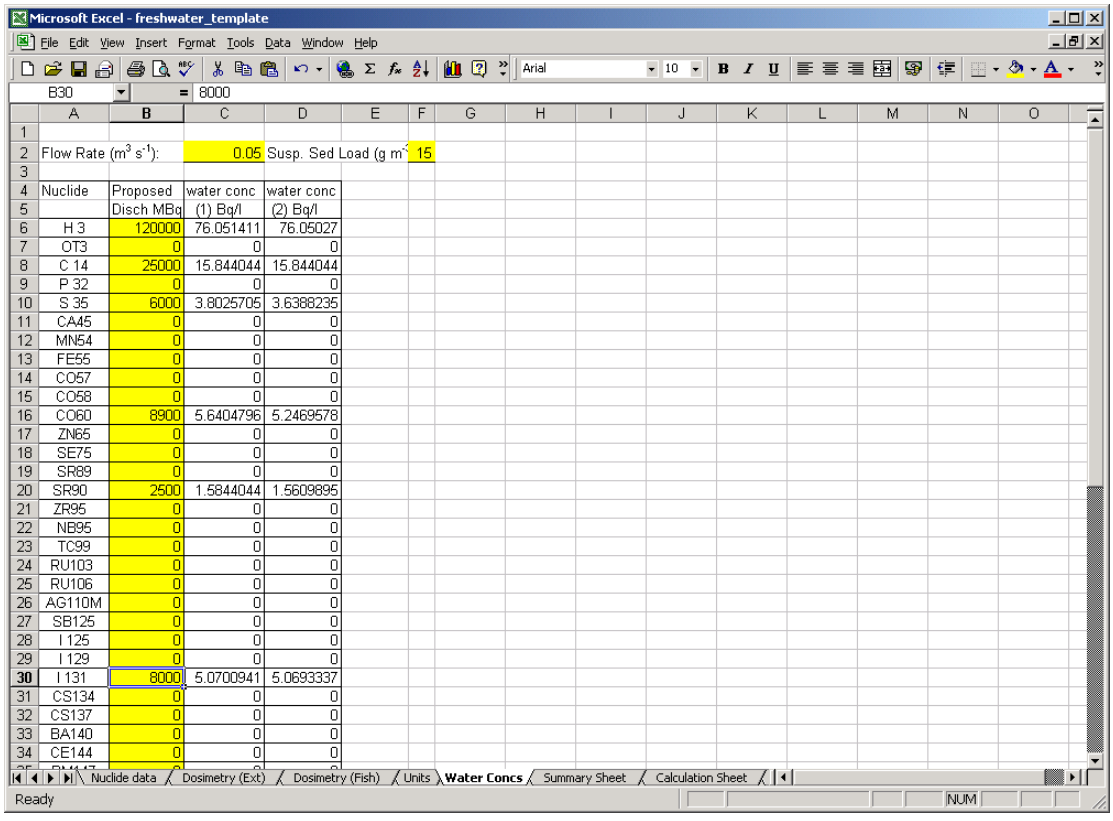


Figure 27: Water concentrations, in Bq/l, are calculated from the annual discharge rates, flow rate and sediment load

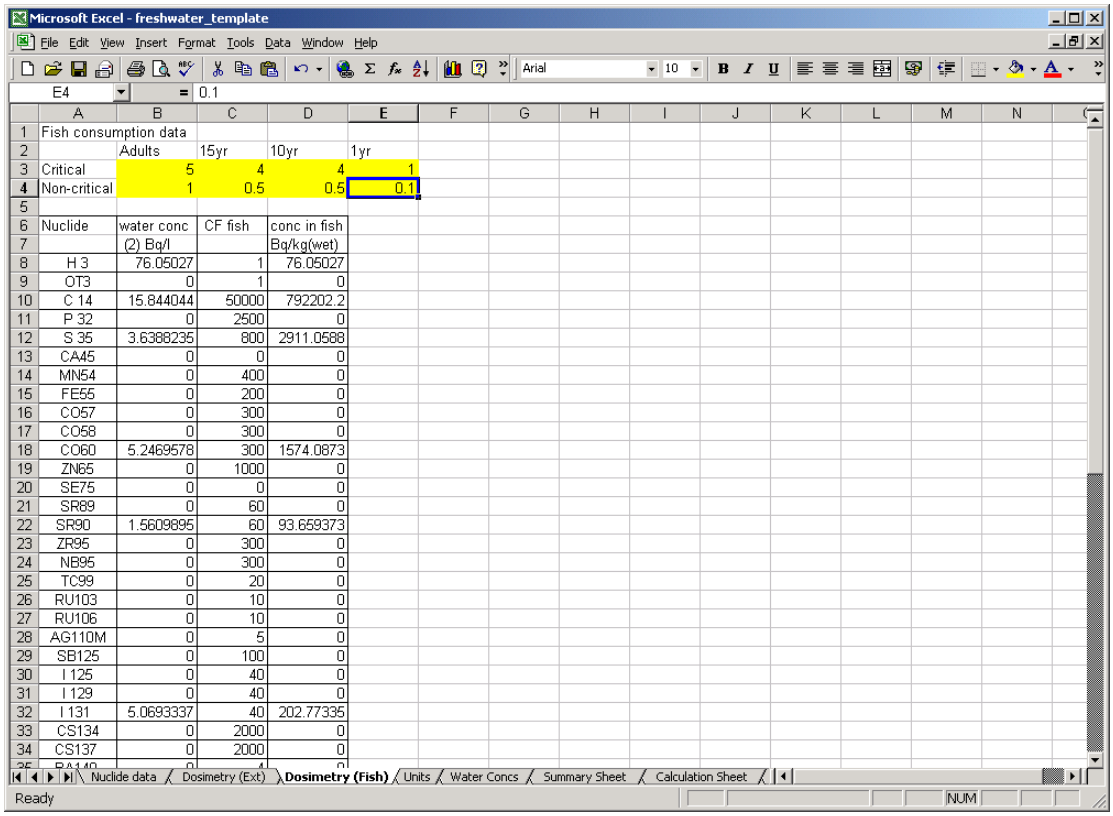


Figure 28: Fish consumption data is entered in the 'Dosimetry (Fish)' sheet

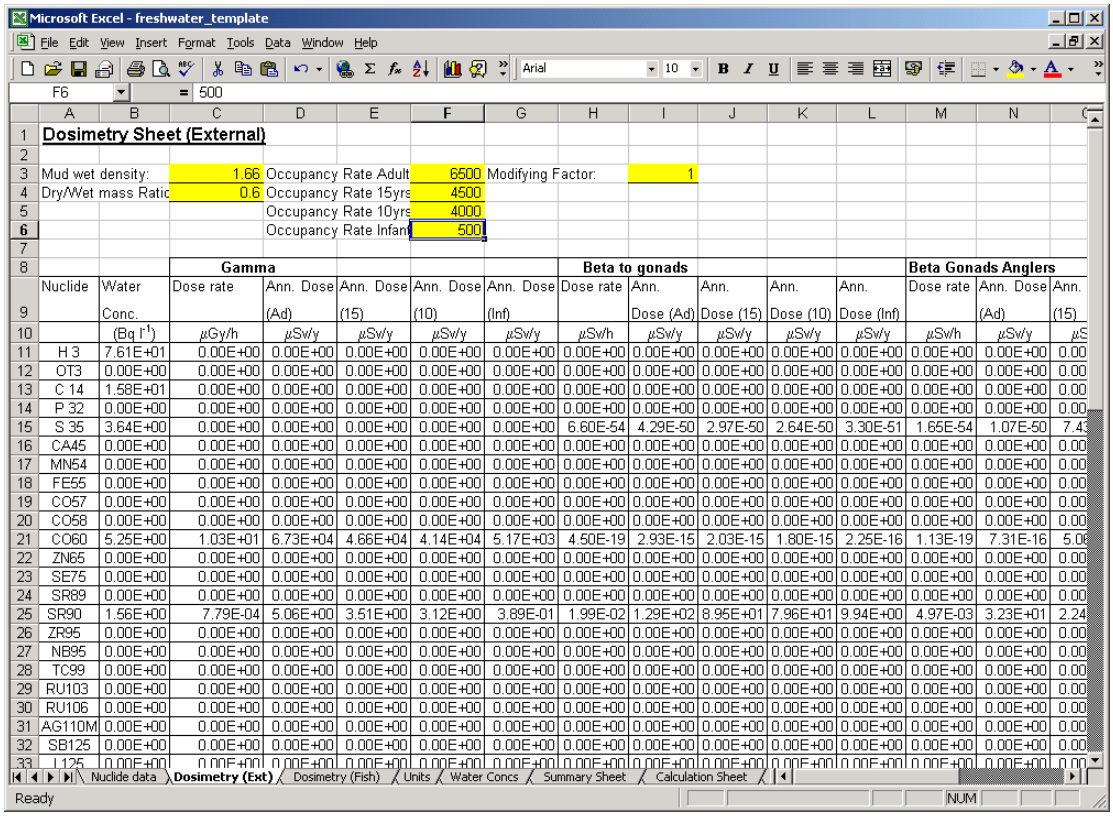


Figure 29: Occupancy rates are entered in the 'Dosimetry (Ext)' sheet

Appendix B – Excel Lake Assessments Model

(Lake_Master.xls)

A simple Excel spreadsheet has been developed to model the effects of radionuclide discharge into a non-marine lake environment in which the WAT/ADO suite is invalid. This model is utilised in a similar way to the freshwater model – details of the hydrographic parameters, discharges and consumption/occupancy are input by the user in order to calculate water concentrations and effective doses to specified groups. As with the freshwater model, to avoid accidental alteration of the intrinsic model only the areas highlighted in yellow can be modified. Figure 30 shows the calculation sheet for the adult critical group – similar sheets exist for different age groups and non-critical consumers.

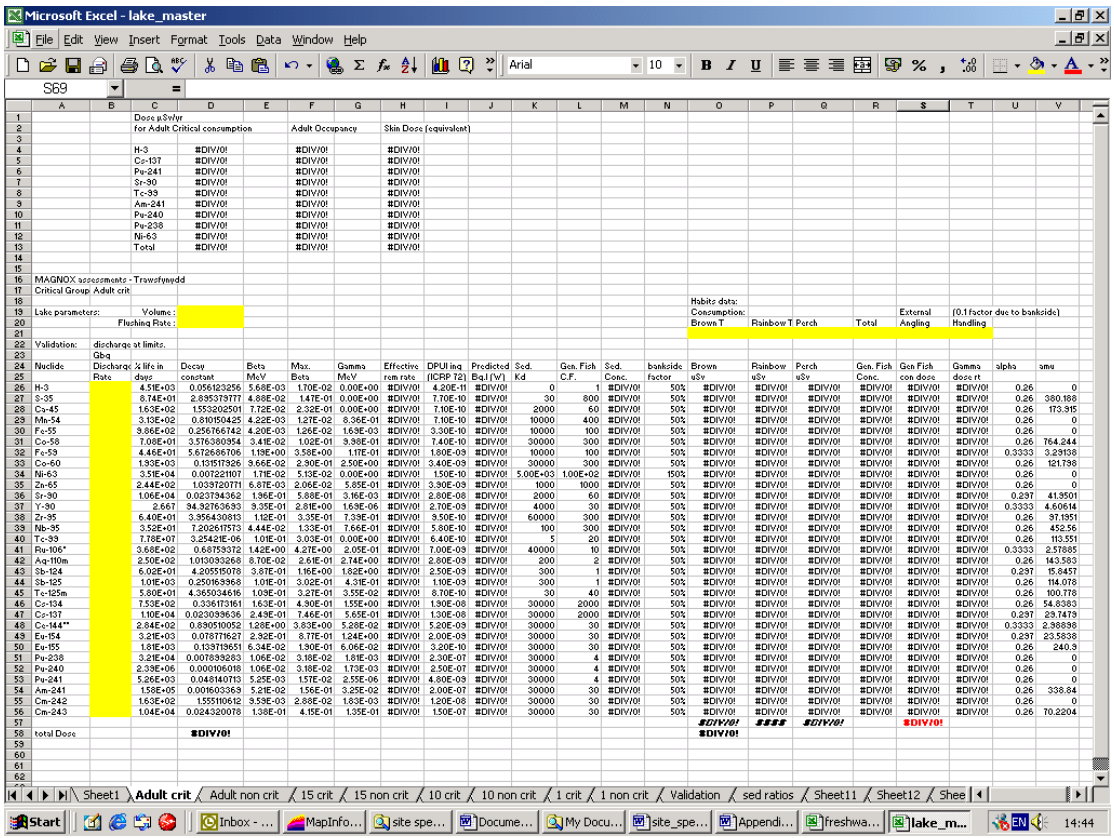
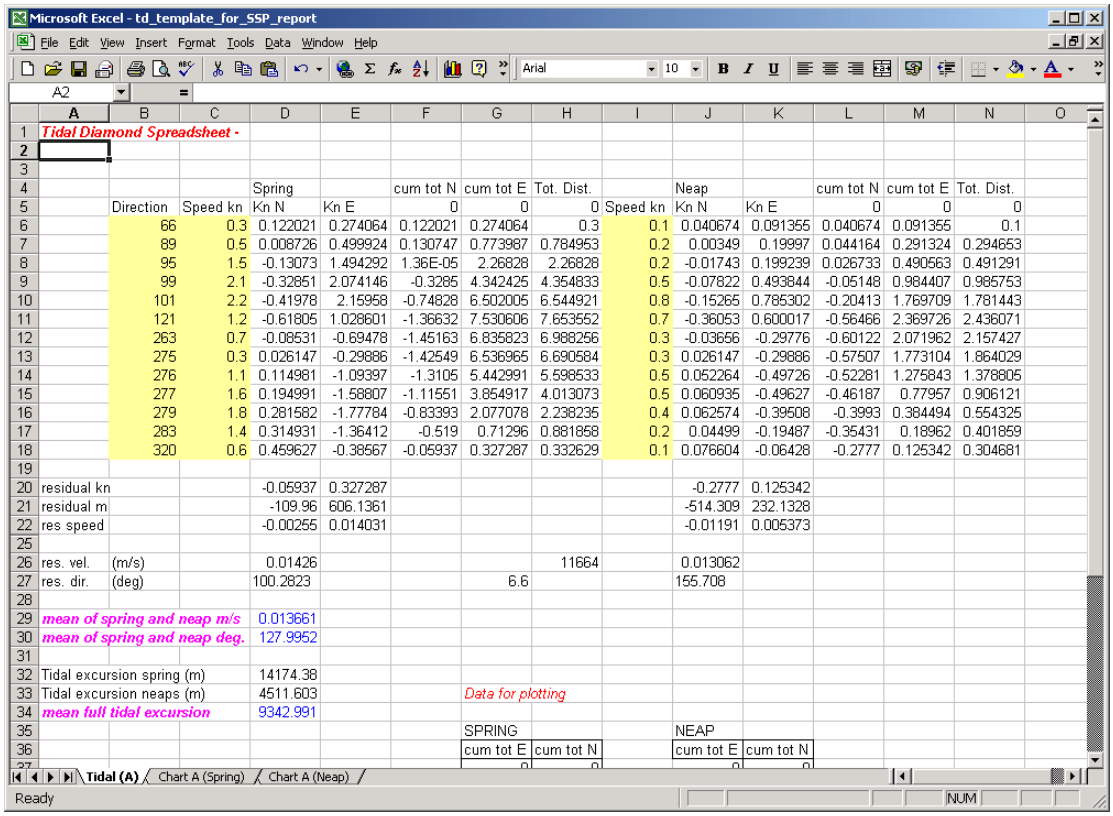


Figure 30: Adult critical sheet

Appendix C – Tidal Diamond Spreadsheet

(Tidal_Diamond.xls)

The spreadsheet is designed to calculate the tidal excursion, residual velocity and residual direction for use within the WAT model. Using tidal diamond data from the relevant hydrographic chart, the direction and tidal speed (in knots) is entered in the columns highlighted yellow (see Figure 31). Data for both the spring and neap tides are entered. The sheet then automatically calculates the residual speed and direction, and the tidal excursion. A graph is produced for each state of the tidal cycle to provide a visual perspective of the shape of the tidal diamond (see Figure 32). It should be remembered that this does not correspond to the movement of a physical particle, but is simply a collection of tidal vectors observed at one point over a period of time.



Microsoft Excel - td_template_for_SSP_report

File Edit View Insert Format Tools Data Window Help

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	*Tidal Diamond Spreadsheet -*														
2															
3															
4				Spring		cum tot N	cum tot E	Tot. Dist.		Neap		cum tot N	cum tot E	Tot. Dist.	
5		Direction	Speed kn	Kn N	Kn E	0	0	0	Speed kn	Kn N	Kn E	0	0	0	
6		66	0.3	0.122021	0.274064	0.122021	0.274064	0.3	0.1	0.040674	0.091355	0.040674	0.091355	0.1	
7		89	0.5	0.008726	0.499924	0.130747	0.773987	0.784953	0.2	0.00349	0.19997	0.044164	0.291324	0.294653	
8		95	1.5	-0.13073	1.494292	1.36E-05	2.26828	2.26828	0.2	-0.01743	0.199239	0.026733	0.490563	0.491291	
9		99	2.1	-0.32851	2.074146	-0.3285	4.342425	4.354833	0.5	-0.07822	0.493844	-0.05148	0.984407	0.985753	
10		101	2.2	-0.41978	2.15958	-0.74828	6.502005	6.544921	0.8	-0.15265	0.785302	-0.20413	1.769709	1.781443	
11		121	1.2	-0.61805	1.028601	-1.36632	7.530606	7.653552	0.7	-0.36053	0.600017	-0.56466	2.369726	2.436071	
12		263	0.7	-0.08531	-0.69478	-1.45163	6.835823	6.988256	0.3	-0.03656	-0.29776	-0.60122	2.071962	2.157427	
13		275	0.3	0.026147	-0.29886	-1.42549	6.536965	6.690584	0.3	0.026147	-0.29886	-0.57507	1.773104	1.864029	
14		276	1.1	0.114981	-1.09397	-1.3105	5.442991	5.598533	0.5	0.052264	-0.49726	-0.52281	1.275843	1.378805	
15		277	1.6	0.194991	-1.58807	-1.11551	3.854917	4.013073	0.5	0.060935	-0.49627	-0.46187	0.77957	0.906121	
16		279	1.8	0.281582	-1.77784	-0.83393	2.077078	2.238235	0.4	0.062574	-0.39508	-0.3993	0.384494	0.554325	
17		283	1.4	0.314931	-1.36412	-0.519	0.71296	0.881858	0.2	0.04499	-0.19487	-0.35431	0.18962	0.401859	
18		320	0.6	0.459627	-0.38567	-0.05937	0.327287	0.332629	0.1	0.076604	-0.06428	-0.2777	0.125342	0.304681	
19															
20	residual kn			-0.05937	0.327287					-0.2777	0.125342				
21	residual m			-109.96	606.1361					-514.309	232.1328				
22	res speed			-0.00255	0.014031					-0.01191	0.005373				
25															
26	res. vel.	(m/s)		0.01426				11664		0.013062					
27	res. dir.	(deg)		100.2823			6.6			155.708					
28															
29	*mean of spring and neap m/s*			0.013661											
30	*mean of spring and neap deg.*			127.9952											
31															
32	Tidal excursion spring (m)			14174.38											
33	Tidal excursion neaps (m)			4511.603			*Data for plotting*								
34	*mean full tidal excursion*			9342.991											
35							SPRING			NEAP					
36							cum tot E	cum tot N		cum tot E	cum tot N				
37							0	0		0	0				

Tidal (A) | Chart A (Spring) | Chart A (Neap)

Ready NUM

Figure 31: Tidal diamond data is entered in the yellow shaded area; the output residual velocity and tidal excursion are in blue

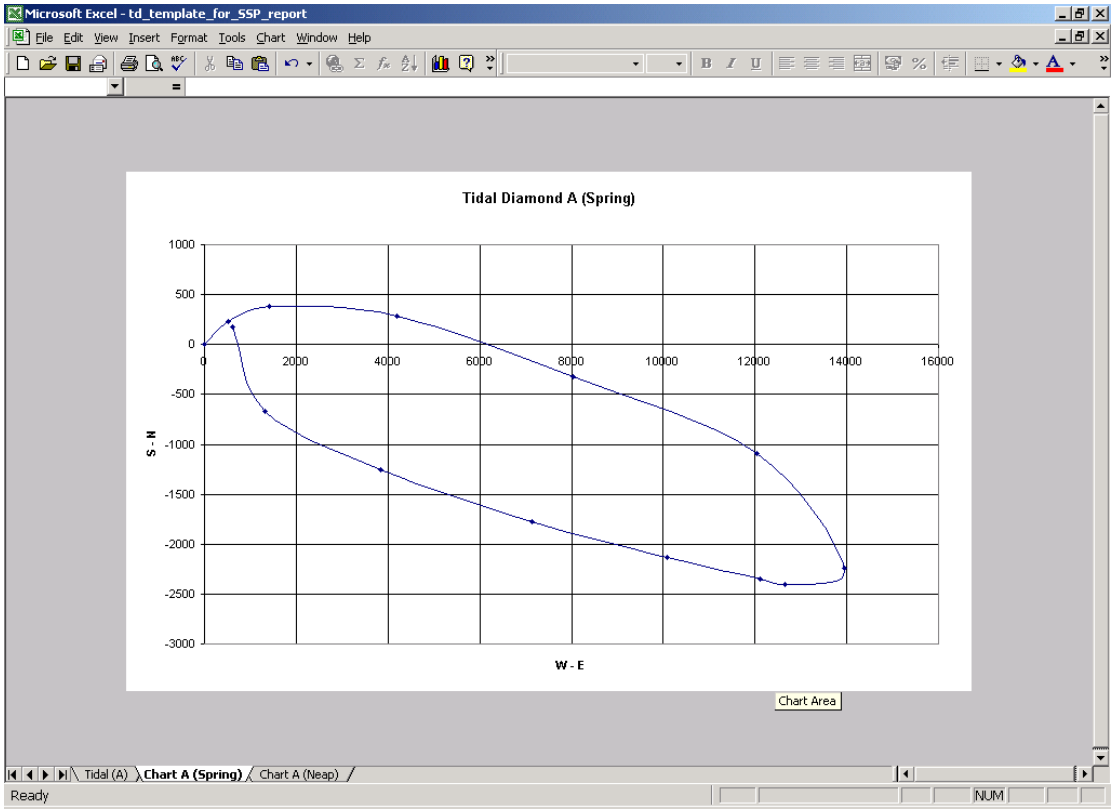


Figure 32: Tidal ellipse plot, from which approximations of the tidal velocity, excursion and offshore extent can be made