7. RADIOLOGICAL AND ENVIRONMENTAL IMPACTS OF CONSTRUCTION AND NORMAL OPERATION

This Section summarises the methods that have been used to estimate the radiological impacts of routine operation of K2 (Section 7.1). It also considers other impacts that may arise as a consequence of both construction and routine operation of K2 (Sections 7.2 and 7.3). Radiological impacts associated with unplanned releases of radioactive materials are discussed in Section 8.

7.1 Radiological impacts

7.1.1 Introduction

The general methodology adopted to assess environmental impacts of treated radioactive emissions was the impact pathway analysis. It describes the route by which emissions generated by the NPP travel in the environment to potentially impact on humans and other components of the environment (natural and man-made). These routes or pathways are illustrated in Figure 7.1. The importance of each pathway depends on the physical and chemical characteristics of the radionuclides emitted and the environment that is analysed.

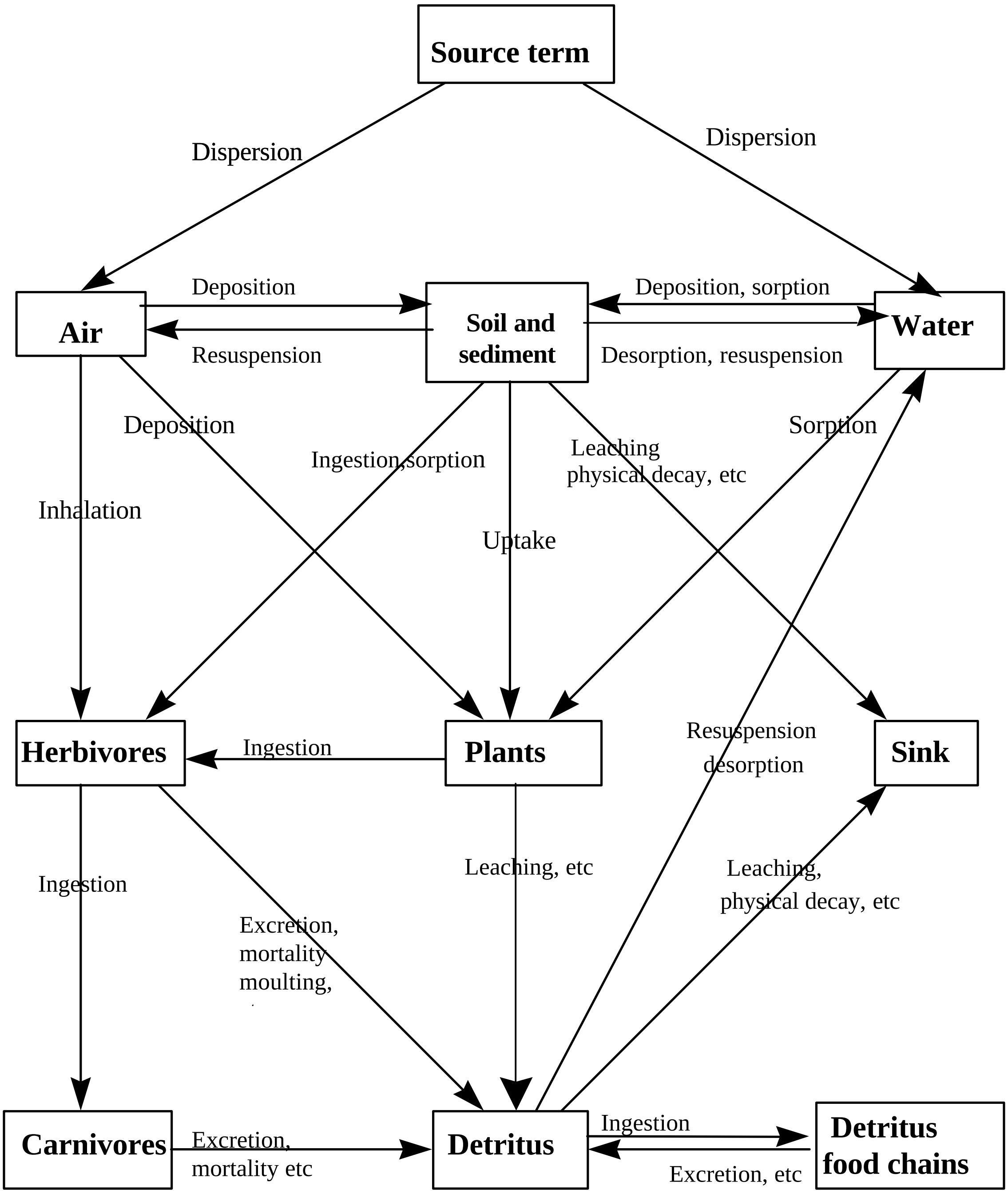
The physical and chemical characteristics of the radionuclide which influence its dispersion and transfer through the environment include the physical half-life (some pathways are short relative to the physical half-life, e.g. inhalation, whereas others are much longer e.g. migration through soils to groundwater), the form of the radiation emitted by the radionuclide (α,β,γ), and the extent to which the radionuclide forms inorganic or organic compounds which can either speed or retard its transfer in the environment.

The behaviour of radionuclides in the environment has been studied since the early 1950's and many parameters influencing the behaviour of specific radionuclides in the environment have been determined. This has led to the development of generalised environmental pathway models.

Such models are used to assess the impact of radionuclides released from a nuclear facility, on a nuclide-by-nuclide basis, assuming that emissions occur on a continuous basis throughout its operating life-time. Concentrations of radionuclides in various environmental media (e.g. air, water, soil, plant and animal foodstuffs) are calculated and then combined with information on human behavioural and dietary habits to estimate human exposure. Well-established conversion factors are then used to estimate dose and risk from external exposure, inhalation and dietary intake by combining radionuclides and pathways either for selected groups of the exposed population (average individual dose) or for a larger subset of the population (collective dose).

In the first stage, calculations are performed making use of conservative (pessimistic) assumptions so as to deliberately overestimate resulting intakes of radionuclides by man or of dose to man.

Figure 7.1
The major processes that affect radionuclide transport in ecosystems



(Boxes represent ecosystem components and the arrows represent the flow of materials)

In general, only if the results of such calculations indicate results which are greater than a given factor of the appropriate dose limit (say greater than 10% of the limit) is it necessary to undertake more detailed assessments using more realistic data and assumptions. Such detailed assessments might take into account factors such as 'seasonality' (i.e. the pattern of discharge throughout the year), the results of site-specific investigations (e.g. radionuclide transfer, specific habits) and time-dependency (e.g. the ways in which radionuclide concentrations in different media change with time over the period of the discharge).

The basic approach that has been undertaken to the K2 radiological assessment is summarised here along with the results obtained for atmospheric and liquid releases.

7.1.2 Basic assessment approach

The radiation dose at a particular location for a specific exposure pathway and radionuclide was evaluated taking into account:

- the release rate into the environment (the "source term");
- the dilution factor corresponding to the location of interest for unit discharge to the atmosphere or aquatic environment;
- the distribution coefficient (or bioaccumulation factor) used to relate ambient atmospheric or aquatic concentrations to those in other environmental media of interest;
- the intake rate or exposure duration associated with the environmental medium and exposure pathway of interest;
- an appropriate dose conversion factor for the mode of exposure.

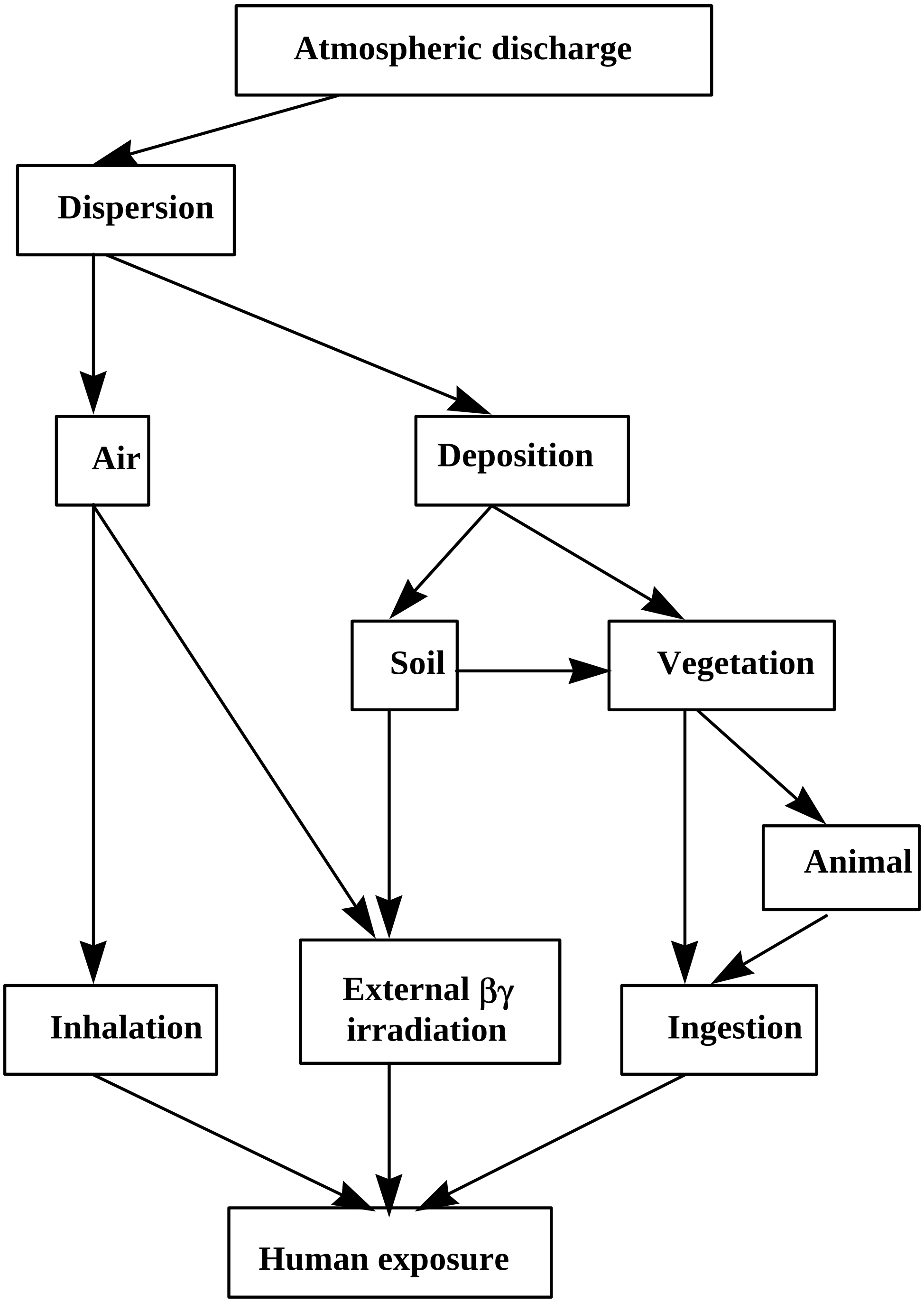
The pathways for atmospheric releases which were considered in the assessment are summarised in Figure 7.2.

The approach is based on the premise that, for each component of the calculations, a dynamic equilibrium can be assumed to exist between environmental concentrations in the media of interest.

The approach adopted is deliberately conservative i.e. it is designed to lead to overestimates of actual concentrations in the environment during the period required for the establishment of a dynamic equilibrium.

The key parameters in the approach are summarised below.

Figure 7.2
Pathways for an atmospheric release of a radionuclide into the environment



Dispersion factor: For atmospheric releases, the dispersion factor corresponding to the routine discharge of a particular radionuclide is defined as the steady-state air concentration at ground level at a particular location assuming unit release rate of the radionuclide. Key parameters affecting dispersion are wind direction and velocity, atmospheric stability, ground surface cover (such as fields or forest) and rainfall. Dispersion calculations are typically based on a Gaussian plume model, which is parameterised by longitudinal and vertical measures of plume-spreading, based on empirically-derived relationships involving readily available meteorological data**.** In order to reduce the assessment calculations, the required parameters are typically divided into discrete ranges or categories, which are recorded hourly throughout the year.

For aquatic releases a simplified but pessimistic approach was adopted assuming that any discharges are evenly dispersed throughout the waters of the cooling reservoir and that water is drunk direct and continuously from the reservoir.

Distribution coefficient: The distribution coefficient, or bioaccumulation factor, describes the steady-state ratio between the activity concentration in two interrelated environmental media, such as the ratio between the concentration in the milk of grazing animals and the concentration in pasture. In addition to its obvious simplicity, the benefit of such an approach is that it uses commonly available empirical ratios, based on measurements of radioactivity in the environment that are themselves obtained under steady-state or slowly-varying levels of environmental radioactivity. A number of generic databases have been compiled for use in dose assessment [7.1]. In selecting data from these databases or when utilising site-specific data, upper bound values are used to ensure the conservatism of the calculations. This is particularly important in the present assessment given the known radioecological sensitivity of the Ukrainian Pollissa.

Reference group habit data: In order to assess human exposure, various habit data have to be derived for combination with radionuclide concentrations in specific environmental media. The general approach here for individual exposure is to define a "reference group" of the population which, by virtue of their specific habits, can be expected to receive the highest exposures. Guidance on the definition and selection of reference groups has been provided by ICRP in several publications [7.2-7.5]. Factors to be taken into account include age, life-style, occupancy, occupation, dietary intakes etc. Individual dose is obtained by averaging over all members of the selected reference group. For collective dose assessment average rather than extreme behaviour is assumed. Pathways considered in the radiological assessment are summarised in Table 7.1.

Dosimetric factors: In the case of radiation exposure by inhalation or ingestion, the dose conversion factor relates the intake to the committed individual effective dose. It is therefore necessary to consider the metabolism of the ingested radionuclide. Values of internal dose conversion factors, and models for their evaluation, are recommended and periodically reviewed by ICRP. For external irradiation, a relatively straightforward geometrical model can usually be used to relate the dose incurred to the time-integrated concentration of radioactivity in the medium of interest.

Table 7.1
Pathways considered in the radiological assessment

Stage of Pathway		Units
SOURCE	Releases reported Electricity generated	Bq/y, Bq/s kWh/y
TRANSPORT/DISPERSION DEPOSITION	Gaussian plume (Air) Box model, river and sea (Aquatic) Deposition velocity	Bq/m^3 per unit of release m/s
CONTAMINATION IN ENVIRONMENT	Radioecology transfer coefficients and models to determine the concentration in: • food consumed • liquid consumed • ground surface area • air	 Bq/kg Bq/l Bq/m^2 Bq/m^3
HUMAN EXPOSURE	Standard man characteristics • inhalation Consumption statistics • food • water Dose	 m^3 Kg 1itres Sv, man.Sv

7.1.3 Confidence in assessment calculations

The scope of any environmental transfer model used to assess radiological exposure is limited by the natural variation in, and complexity of, the environment. Models used for dose assessment are primarily tools used for decision-making; that is, they represent a means for combining complex information on source terms, environmental and meteorological factors, land use and population distributions into the decision framework. Thus, for example, information from the models might be used to differentiate between the impact associated with different plant siting and process options, to identify individuals potentially concerned by nuclear power plant operation, and for comparison with regulatory limits.

Since assessment models can rarely simulate all reality there is a need to compensate by either:

- making use of maximising assumptions and upper ranges in parameter values (i.e. conservative assumptions); or
- utilising uncertainty analysis techniques e.g. by assigning probability distribution functions to each of the model parameters.

The latter has some disadvantages in comparing results with regulatory endpoints. As a consequence, the former cautious approach was adopted for the present assessment.

Additionally, as noted in Section 7.1.1, if the calculations result in estimated doses greater than a given fraction of the regulatory dose limit, there will be a requirement for more detailed assessments making use of site-specific data.

7.1.4 Atmospheric releases

7.1.4.1 Source terms

The predicted release rate to atmosphere for K2, is as shown in Table 6.2 (Section 6) as provided by Kyivenergoproekt [7.6].

Although this prediction was based on recent calculations, experience in the operation of reactor unit 1 of KNPP shows that the calculated releases are much higher than what is observed and monitored at the plant. (Section 6.2.6.1). As a consequence, the assessment of radiological consequences of airborne releases was undertaken taking into account the stated amount of airborne releases for K1 in 1995. This was considered to be closer to the likely releases for the proposed Unit 2.

The source term used for calculations of radiological consequences is given in Table 7.2.

Table 7.2
Source term used for calculation of radiological impacts of routine discharges to atmosphere for K2

Radionuclides released	Activity (Bq/year)
H-3	$2.59\ 10^{12}$
Cr-51	$1.96\ 10^{7}$
Mn-54	$2.88\ 10^{6}$
Co-58	$4.20\ 10^{5}$
Co-60	$7.16\ 10^{6}$
Sr-90	$1.08\ 10^{5}$
Y-91	$1.34\ 10^{5}$
I-131	$1.28\ 10^{8}$
I-133	$7.36\ 10^{8}$
Cs-134	$2.78\ 10^{7}$
Cs-137	$3.04\ 10^{6}$
Kr-85m	$1.39\ 10^{13}$
Kr-85	$1.18\ 10^{13}$
Kr-88	$2.39\ 10^{12}$

Radionuclides released	Activity (Bq/year)
Xe-131m	$3.38\ 10^{13}$
Xe-133	$1.45\ 10^{15}$
Xe-135	$7.56\ 10^{13}$

Footnotes:

Inert gases and tritium. The figures given are the predicted discharges to atmosphere (Table 6.2).

Radiocaesium. The figure given for Cs-134 is the predicted discharge (Table 6.2) whereas that for Cs-137 is a factor of 15 lower than the predicted discharge.

Radioiodine. The figure given for I-133 is close to the predicted discharge (Table 6.2) whereas that for I-131 is a factor of 3 lower than the actual discharge in 1995 and a factor of 5 lower than the actual discharge in 1996.

Radiostrontium. The figure given for Sr-90 is substantially higher than the predicted discharge for K2 but is substantially lower than the limit on discharge for K1 in 1995 (Table 5.9).

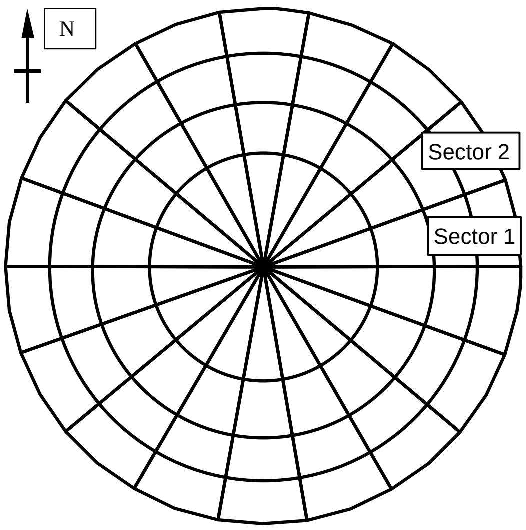
Other isotopes. The figures given other than for Co-58 are generally higher than predicted discharges (Table 6.2) but are substantially lower than the limits on discharge for 1995 (Table 5.9). No source term was available for C-14.

7.1.4.2 Dispersion and deposition

The transport of radionuclides in the atmosphere for local and regional areas was calculated using a Gaussian plume dispersion model.

The 30 km area around the release point was divided into 18 sectors, as shown in Figure 7.3. The wind rose for the site was used to determine the average yearly wind characteristics applicable for each of the 18 sectors. The wind rose was established using data provided by Kyivenergoproekt [7.6].

Figure 7.3
Illustration of scheme of annual segments of the radial grid adopted to represent the spatial distribution of population and radioactivity



7.1.4.3 Individual dose calculation

The total individual dose was evaluated by totalling annual exposure from all potential exposure pathways and released radionuclides. Since dose was assumed to be proportional to the dispersion factor, the potential individual dose for any particular radionuclide would normally be associated with the location corresponding to the minimum dispersion factor. The maximum calculated dose can then be compared with appropriate limits for annual exposure to members of the public.

The individual dose as a function of distance from the NPP is given in Table 7.3. This shows that the maximum potential individual dose (i.e. approximately 3-4x10^{-4} mSv/yr) is for a reference group of people located within 3 km of the NPP in Eastern sectors (sectors 1, 17 and 18). Moreover, Table 7.4, which breaks down the maximum individual dose for the reference group by pathways, shows that 99.6% of the estimated dose is from noble gases.

Table 7.3
Predicted individual dose (microSv/year)

Sector	0-5 km	5-10 km	10-20km	15-20 km	20-25 km	25-30 km
1	0.29	0.007	0.003	0.002	0.002	0.001
2	0.22	0.005	0.002	0.002	0.001	0.0009
3	0.22	0.005	0.002	0.002	0.001	0.0009
4	0.25	0.008	0.002	0.002	0.001	0.001
5	0.27	0.007	0.002	0.002	0.001	0.001
6	0.28	0.007	0.002	0.002	0.001	0.001
7	0.29	0007	0.003	0.002	0.002	0.001
8	0.29	0.007	0.002	0.002	0.001	0.001
9	0.14	0.004	0.001	0.001	0.0008	0.0006
10	0.14	0.004	0.001	0.001	0.0008	0.0006
11	0.12	0.003	0.001	0.0009	0.0006	0.0005
12	0.11	0.003	0.001	0.0008	0.0006	0.0004
13	0.13	0.003	0.001	0.001	0.0006	0.0005
14	0.14	0.004	0.001	0.001	0.0008	0.0006
15	0.21	0.005	0.002	0.002	0.001	0.0008
16	0.35	0.009	0.003	0.003	0.002	0.001
17	0.34	0.008	0.003	0.003	0.002	0.001
18	0.29	0.007	0.003	0.002	0.002	0.001

Table 7.4
Breakdown of the maximum dose between pathways and radionuclide

	Cloud	Ground	Inhalation	Total
H-3	<0.0001%	<0.0001%	0.2824%	0.2825%
Co-58	<0.0001%	0.0002%	<0.0001%	0.0002%
Co-60	<0.0001%	0.0220%	0.0026%	0.0246%
I-131	<0.0001%	0.0047%	0.0107%	0.0154%
I-133	0.0006%	0.0049%	0.0108%	0.0162%
Cs-134	0.0001%	0.0540%	0.0021%	0.0562%
Cs-137	<0.0001%	0.0024%	0.0002%	0.0026%
Kr-85m	3.1774%	<0.0001%	<0.0001%	3.1774%
Kr-85	0.0424%	<0.0001%	<0.0001%	0.0424%
Kr-88	5.8001%	<0.0001%	<0.0001%	5.8001%
Xe-131m	0.3026%	<0.0001%	<0.0001%	0.3026%
Xe-133	64.3053%	<0.0001%	<0.0001%	64.3053%
Xe-135	25.9743%	<0.0001%	<0.0001%	25.9743%
Total	99.6029%	0.0882%	0.3088%	100.0000%

Notes: Ingestion pathway represents less than 0.1% of total dose from any radionuclide; dose rate due to Cr-51, Mn-54, Y-91and Sr-90 represents less than 0.001% of total dose.

The maximum individual dose of $<4x10^{-4}$ mSv per annum is a factor of 500 times lower than the relevant Ukrainian limit of 0.2 mSv per annum for atmospheric releases (Section 5).

Given the contribution of noble gases and cloud exposure to total estimated doses, the uncertainties in the source terms for radionuclides such as I-131, Sr-90 and Cs-137 (Table 7.2) cannot be expected to have any significant effect on the overall conclusion.

7.1.4.4 Collective dose calculation

In order to evaluate collective dose, the doses received by individual members of an exposed population must be integrated. For an atmospheric release, the collective dose is strongly related to the local population distribution. Estimates of collective dose are typically performed by dividing the area around the plant into a number of sectors, corresponding to available information on the wind direction frequency. Each sector is then further divided by annular rings at increasing radii, for which data such as population density and food production statistics are averaged.

Data (population and land use statistics obtained for the area within a 30 km radius of the plant) were provided by Kyivenergoproekt [7.6] and are given in Tables 7.5 and 7.6.

Table 7.5
Population distribution around the NPP [7.6]

	Distance in km					
	0-5	5-10	10-15	15-20	20-25	25-30
Sector 1	7,911	2,067	1,891	2,182	2,707	2,784
Sector 2	0	876	1,756	1,524	2,293	3,080
Sector 3	78	811	6,072	1,401	2,104	2,832
Sector 4	311	618	19,022	1,031	1,538	2,089
Sector 5	311	618	19,022	1,031	1,538	2,089
Sector 6	0	44	0	378	2,333	667
Sector 7	0	44	0	378	2,333	667
Sector 8	0	211	1,300	1,081	8,540	3,250
Sector 9	0	267	1,733	1,316	10,609	4,111
Sector 10	0	176	2,022	1,036	6,133	2,991
Sector 11	0	84	2,311	756	1,658	1,871
Sector 12	0	66	2,099	927	1,704	1,661
Sector 13	0	9	1,462	1,440	1,844	1,031
Sector 14	0	9	1,462	1,440	1,844	1,031
Sector 15	0	6,667	1,600	1,693	1,404	2,498
Sector 16	0	6,667	1,600	1,693	1,404	2,498
Sector 17	11,867	4,110	1,920	2,553	2,691	2,491
Sector 18	15,822	3,258	2,027	2,840	3,120	2,489

Table 7.6
Annual agricultural production within a 30 km radius of the NPP [7.6]

Distance (km)	Milk	Sheep	Beef	Cereals	Fruits and vegetables	Root vegetables
0-5	0.5	0.1	0.1	14.4	0.9	63.4
5-10	1.4	0.2	0.2	43.3	2.6	190.3
10-15	2.3	0.3	0.3	72.1	4.3	317.2
15-20	3.3	0.4	0.4	101.1	6.0	444.1
20-25	4.2	0.5	0.5	129.9	7.7	571.0
25-30	5.1	0.6	0.6	158.7	9.4	697.9

Results (Table 7.7) showed that the calculated total collective dose from airborne discharges for one year's operation, totalled for all elements of the computational grid within a radius of 30 km would be approximately 0.012 man-Sv.

Table 7.7
Total collective dose (man.Sv)

Sector	0-5 km	5-10 km	10-15 km	15-20 km	20-25 km	25-30 km	Total
1	$2.3\ 10^{-3}$	$1.5\ 10^{-5}$	$4.9\ 10^{-6}$	$4.7\ 10^{-6}$	$4.1\ 10^{-6}$	$3.2\ 10^{-6}$	$2.3\ 10^{-3}$
2	0.0	$4.8\ 10^{-8}$	$3.4\ 10^{-6}$	$2.5\ 10^{-6}$	$2.7\ 10^{-6}$	$2.7\ 10^{-6}$	$1.6\ 10^{-5}$
3	$1.7\ 10^{-5}$	$4.4\ 10^{-6}$	$1.2\ 10^{-5}$	$2.3\ 10^{-6}$	$2.4\ 10^{-6}$	$2.5\ 10^{-6}$	$4.0\ 10^{-5}$
4	$7.8\ 10^{-5}$	$3.9\ 10^{-8}$	$4.3\ 10^{-5}$	$1.9\ 10^{-6}$	$2.0\ 10^{-6}$	$2.1\ 10^{-6}$	$1.3\ 10^{-4}$
5	$8.4\ 10^{-5}$	$4.2\ 10^{-6}$	$4.6\ 10^{-5}$	$2.1\ 10^{-6}$	$2.2\ 10^{-6}$	$2.3\ 10^{-6}$	$1.4\ 10^{-4}$
6	0.0	$3.0\ 10^{-7}$	0.0	$7.8\ 10^{-7}$	$3.4\ 10^{-6}$	$7.4\ 10^{-7}$	$5.2\ 10^{-6}$
7	0.0	$3.2\ 10^{-7}$	0.0	$8.2\ 10^{-7}$	$3.6\ 10^{-6}$	$7.7\ 10^{-7}$	$5.5\ 10^{-6}$
8	0.0	$1.4\ 10^{-6}$	$3.1\ 10^{-6}$	$2.2\ 10^{-6}$	$1.2\ 10^{-5}$	$3.5\ 10^{-6}$	$2.2\ 10^{-5}$
9	0.0	$9.8\ 10^{-7}$	$2.2\ 10^{-6}$	$1.4\ 10^{-6}$	$8.1\ 10^{-6}$	$2.4\ 10^{-6}$	$1.5\ 10^{-5}$
10	0.0	$6.3\ 10^{-7}$	$2.6\ 10^{-6}$	$1.1\ 10^{-8}$	$4.7\ 10^{-6}$	$1.7\ 10^{-6}$	$1.1\ 10^{-5}$
11	0.0	$2.4\ 10^{-7}$	$2.4\ 10^{-6}$	$6.5\ 10^{-7}$	$1.0\ 10^{-6}$	$8.7\ 10^{-7}$	$5.1\ 10^{-6}$
12	0.0	$1.8\ 10^{-7}$	$2.0\ 10^{-6}$	$7.5\ 10^{-7}$	$9.7\ 10^{-7}$	$7.1\ 10^{-7}$	$4.6\ 10^{-6}$
13	0.0	$3.0\ 10^{-8}$	$1.7\ 10^{-6}$	$1.4\ 10^{-6}$	$1.3\ 10^{-6}$	$5.4\ 10^{-7}$	$5.0\ 10^{-6}$
14	0.0	$3.2\ 10^{-8}$	$1.9\ 10^{-6}$	$1.6\ 10^{-6}$	$1.4\ 10^{-6}$	$6.0\ 10^{-7}$	$5.5\ 10^{-6}$
15	0.0	$3.5\ 10^{-5}$	$3.0\ 10^{-8}$	$2.7\ 10^{-8}$	$1.6\ 10^{-6}$	$2.1\ 10^{-6}$	$4.4\ 10^{-5}$
16	0.0	$5.8\ 10^{-5}$	$4.9\ 10^{-6}$	$4.4\ 10^{-6}$	$2.6\ 10^{-6}$	$3.5\ 10^{-6}$	$7.3\ 10^{-5}$
17	$4.0\ 10^{-3}$	$3.5\ 10^{-5}$	$5.8\ 10^{-8}$	$6.5\ 10^{-8}$	$4.8\ 10^{-8}$	$3.4\ 10^{-6}$	$4.1\ 10^{-3}$
18	$4.6\ 10^{-3}$	$2.4\ 10^{-5}$	$5.2\ 10^{-6}$	$6.2\ 10^{-6}$	$4.8\ 10^{-6}$	$2.9\ 10^{-6}$	$4.6\ 10^{-3}$
Total	$1.1\ 10^{-2}$	$1.9\ 10^{-4}$	$1.4\ 10^{-4}$	$4.4\ 10^{-5}$	$6.4\ 10^{-5}$	$3.6\ 10^{-5}$	$1.2\ 10^{-2}$

The calculated collective dose for the population living 10 to 30 km from the plant would be about 3 10^{-4} man-Sv. In this area, individual doses would be very low and, according to ICRP 60 [7.5] which assumes a no-threshold linear relationship between dose and risk, would correspond to very low level of individual risk.

7.1.5 Aquatic discharges

The radiological quality of the Khmelnitsky cooling reservoir waters for most parameters is stated to be better than the same values for the Gnilyi Rig river, Viliya river and Goryn river [7.7].

Despite the fact that there no regular water discharge from the NPP to the Gnilyi Rig is foreseen, a calculation was carried out to verify the apparent lack of impact of radionuclide releases. This calculation assessed the effective dose resulting from ingestion of 2 l/day of water from the NPP reservoir and used the GBPCalc software [7.8]. This was considered to be a very pessimistic calculation because:

- water input from the Goryn river was not included;
- when the blow-off occurs the concentration induced by the NPP will decrease;
- the river water is not generally used as drinking water; and
- the blow-off will last only a few days.

Taking the concentrations of radionuclides in the reservoir in September 1996 for Cs-137 as 3 Bq/m^3 and Sr-90 as 20 Bq/m^3, the effective dose resulting from ingestion of 2 l/day can be calculated to be about 5 10^{-4} mSv/year. This is well below the regulatory limit applied in Ukraine of 0.05 mSv/year.

Were the total reported annual discharges to be equally dispersed throughout the volume of the reservoir (120 million m^3) they would result in the following concentrations (based on data for 1995):

Radionuclide	Concentration in water (Bq/m^3)
Co-60	0.016
Sr-90	0.021
Cs-134	18
Cs-137	0.74

Given the fact that the reservoir is being used for commercial fish farming and that the Goryn river is used for non-commercial fishing, any radiological assessment for K2 must consider the potential dose to reference groups via the consumption of contaminated fish. The main interest is with the reservoir since it appears to be a rather closed system. Reported concentration factors for freshwater fish are in the range of 1-100 for Sr-90 and 100-1000 for Cs-137 [7.9]. Combined with assumed consumption rates of approximately 0.2 kg/day, the maximum estimated doses from consumption of fish would be in the order of 0.027 mSv/yr. This figure is approximately 54% of the limit of 0.05 mSv/yr imposed for aquatic discharges by Ukrainian legislation. The latter is, however, very restrictive relative to those that can be derived from ICRP.

A more detailed assessment of the radiological impact of aquatic discharges is required. This will take into account the residence time of discharged radionuclides in the cooling reservoir and their subsequent release to the Goryn river and will consider both drinking water and dietary pathways.

7.1.6 Summary and conclusions

Work undertaken to date indicates that the radiological impacts of routine discharges from K2 will be very small in both individual and collective dose terms. Calculations for atmospheric discharges have indicated a reference group dose less than 1 μSv/annum which is well below the limits applied for members of the public (i.e. 0.25 mSv/yr) and well within internationally accepted radiological protection criteria.

The total collective dose to the population within a 30 km radius of the plant is estimated to be approximately 0.01 man.Sv/yr (i.e. less than 0.00001 man.Sv/megawatt-year of generation). This figure is consistent with international experience.

Pessimistic calculations for aquatic discharges indicate maximum doses from the consumption of farmed fish less than that 0.027 mSv/yr. This figure is 54% of the very restrictive Ukrainian limit of 0.05 mSv/yr. Calculations will be improved by additional studies which will form part of the EAP.

Whereas additional calculations or other evaluations of existing data for liquid releases may not change the conclusions of the work undertaken to date, confirmation of data is needed to improve the confidence that can be placed on the existing results. This subject is discussed further in Section 9.

7.2 Environmental impacts of radioactive discharges

It is part of the basic philosophy of radiation protection that, if man is adequately protected then so will other species [7.3]. The underlying basis for this philosophy has been questioned several times in recent years, prompting detailed studies to determine the likely consequences of radiation exposure on plants and animals living in their natural surroundings. The general conclusion of such studies is that the only circumstances whereby other species may be adversely affected by radiation exposure at levels which relate to acceptable exposure of man, is when such species are under stress from other environmental factors.

The concentration of radionuclides currently in environmental media in the vicinity of KNPP and present as a direct result of operation of KNPP are very low, especially when compared to the natural background or to the influence of the Chornobyl accident of 1986 (Appendix E).

7.3 Environmental impacts of non-radioactive discharges

As for any power station project, impacts of non-radioactive discharges may arise either during completion of construction or operation of the proposed NPP. It is understood (Section 6.6.1) that a programme of measures has been put in hand to prevent or minimise the discharge of hazardous materials. Environmental impacts that will require consideration include:

- during construction:
    - effects of transport;
    - noise;
    - emissions to air and water; and
    - disposal of solid wastes.

- during operation:
    - water quality;
    - discharges of heat to atmosphere and water; and
    - effects on hydrology.

These impacts are considered in this Section taking into account mitigation measures proposed in Section 9.

7.3.1 Construction impacts

The basic construction of the main structures and auxiliary facilities for K2 has been completed. The remaining tasks (corresponding to about 10% of a complete unit construction) are:

- installation of heat transfer systems;
- installation of electrical equipment;
- installation of automatic control systems; and
- refitting and installation of equipment specified as part of the modernisation plan.

It can therefore be deduced that the completion of construction will not require the development of new areas of land, the excavation of foundations, piling, etc, which are the activities usually associated with adverse impacts. Potential construction impacts are limited to:

- dust from construction activities in summer;
- small amounts of surface water contaminated with suspended solids;
- noise from minor construction activities;
- disposal of construction wastes;
- disturbance due to truck and bus traffic, night-working and flood-lighting;
- hazards to pedestrians due to truck traffic;
- local nuisances e.g. mud transported onto roads; and
- social impacts of the temporary workforce of 2000-3000 persons.

The sanitary zone around the NPP reduces the potential for impacts of noise and local nuisances on inhabited areas. The current programme indicates that any such impacts will be limited to a two to three year period.

7.3.2 Impacts during operation

7.3.2.1 Water quality

The quality of water in the Goryn river which receives discharges of bleed water from the NPP heat sink (no more than once a year, under a special authorisation), has to meet specific standards [7.10, 7.11]. The NPP heat sink itself was designed for a specific-purpose, and is exempt from these standards.

The heat sink was not designed for industrial or public water use, nor for fish farming. However, fish farming in the heat sink has been established (Section 3). The heat sink is closed-loop, with filtration water intercepted and returned, thus causing no uncontrolled discharges into the Goryn river. At the same time, no provision is made for discharges of effluents into the heat sink, as the project allows for controlled heat sink blowdown into the Goryn river and a partial break of the filtration flow. Since no provision is made for the discharge of untreated waste/sewage to the reservoir, the qualitative change in water chemistry of the reservoir water compared with the Goryn river water has been predicted only through evaporation during the release of heat from the NPP cooling systems.

In terms of quality, the predicted water and chemical regime of the heat sink is identical to the quality of water in the Gnilyi Rig river, the runoff of which is fully accumulated in the heat sink, and to that of the Goryn river used for the heat sink makeup.

It has been suggested that the NPP has no significant impact on water quality for users downstream, since water for the needs of the station is drawn only outside the growing season and, in the main, during spring floods [7.6]. According to a report from the Ukrainian Ministry for Environmental Protection and Nuclear Safety [7.7], 23 parameters of water quality have been monitored. Based on these data the conclusion was reached that the quality of water in the cooling reservoir for most parameters (apart from sodium, potassium and sulphates) was better than in the waters of the Gnilyi Rig, Vilia river and Goryn river. This conclusion is supported by the data on the chemical content of the cooling reservoir (Table 7.7) from which it has been concluded that concentrations of parameters analysed were much lower than the existing discharge standards.

7.3.2.2 Discharges of heat to water and atmosphere

As noted in Section 4, any NPP is a source of vast amounts of waste heat.

The heat is transferred to the environment, mainly through the evaporative cooling of water in the end absorbers and partially through the convective heat transfer to the ambient air in the end absorbers.

The environmental impact of atmospheric releases of heat from the cooling reservoir may be considered in terms of local and mesoscale effects on climate. Qualitative local effects are reported to include:

- increase in air humidity and temperature;
- increased occurrence of precipitation;
- fog formation;
- icing of ground surfaces; and
- loss of insolation due to shielding by a visible plume of condensed water vapour.

Among these, the impact of low potential heat released from the reservoir is reported to manifest itself in:

- vapour trails extending up to 3 km in winter and 1 km in summer; and
- a local 30-50% decrease in solar radiation.

The sanitary zone (which is not inhabited) around the NPP has a radius of 3 km. It therefore limits the potential for any impacts on inhabited areas.

Table 7.8
Chemical composition of KNPP reservoir (mg/l except where otherwise stated) [7.6]

	Suspended substances	Chlorides	Sulphates	Ammonium salt	Nitrate	Nitrite	Oil products	Iron	Phosphates	Oxygen demand (mg 0_2/l)	Dry residue
Maximum Permissible Value	-	350	500	-	45	3.3	0.3	0.3	3.5	30	1000
1996 values	16.9	21.4	62.8	0.3	0.95	0.03	0.1	0.28	0.06	25.5	306

Clearly, such effects result from the present operation of KNPP. The project to complete K2 will effectively result in a doubling of heat losses to the environment and could therefore result in:

- a localised increase in the temperature of the cooling reservoir;
- an overall increased evaporation of water from the reservoir and spraying ponds to atmosphere; and
- an increased extent and duration of the existing local effects referred to above.

Such effects are unlikely to result in significant adverse environmental impacts but will be subject to a detailed investigation as the project develops.

7.3.2.3 Impact of Khmelnitsky reservoir on surface and groundwater in the region

An assessment of the impact of the Khmelnitsky NPP reservoir on surface and groundwater was carried out in 1994 [7.12] and is summarised below.

The impact of the Khmelnitsky NPP reservoir on the Goryn river discharge was assessed on the basis of the river discharge characteristics, a record of which was kept for many years, data on the reservoir water balance as of 1989, 1992 and morphometric indicators of the reservoir.

The error in calculating the standard annual river discharge is between 10 and 15%. Therefore, the actual contribution of factors such as the pumping-in of water from the Goryn river and accumulation of the Gnily Rig discharge is within the range of the standard annual discharge calculation error. Even a purely theoretical prediction of the maximum possible effect of this factor does not substantially alter the above conclusion.

In reference to changes in the level regime of groundwater after the construction of the KNPP reservoir, the impact is manifested most clearly in areas within the Goryn flood plain, downstream of the reservoir dam. The assertion that the construction of the reservoir could have resulted in a drop in the groundwater level and the shallowing of wells in the town of Ostrog and rural localities in the district cannot be substantiated. The reservoir could only have played a positive role here. Should such a process be registered, the reason for it may be an overall decrease in the annual amount of precipitation in recent years, with a special regard to lack of snow that is the primary source of groundwater formation. There may be other factors, including anthropogenic ones, which may have a substantial impact on the decrease in the groundwater levels in the Rivne Region and must be considered separately in each specific case.

It is clear from the above that there have been changes in the groundwater regime as a consequence of construction of KNPP. However any such changes are unlikely to be further affected by completion of K2 since the project does not allow for substantial additional hydrological or other groundworks.

As far as surface hydrology is concerned, information on water utilisation (e.g. Figure 4.8) indicates that completion of K2 will increase annual intakes from the Goryn river from their current level of 3.66 million m^3/yr to 18.26 million m^3/yr. This will only partially be balanced by the increased return to the river (i.e. from 8.56 million m^3/yr at present to 11.38 million m^3/yr), the difference being largely reflected by increased loss of water to atmosphere through the cooling sinks.

Abstraction of water to meet the needs of the project will have to be managed by the NPP under the control of regulatory authorities (Section 9).

7.4 Social and economic impacts

The proposed project has clear benefits to local communities which currently rely on operations at the KNPP for their livelihood, as well as a source of heating and energy supply. It also has benefits for the NPP management in being able to maximise the use of existing facilities and to be able to provide continuity of supply of electricity during outages or periods of maintenance at other units. The increased local population during construction and operation of K2 will place pressures on local facilities such as housing and schooling but such local communities already receive significant support from the NPP management. Mechanisms to optimise the local social and economic impacts will be considered in the EAP (Section 9).

7.5 Compensation issues

At Rivne NPP, financial sanctions apply concerning environmental protection with respect to:

- setting limits for utilisation of natural resources, the release of contaminating substances and waste disposal;
- setting rates for payment for the above; and
- reimbursement in the event that established limits are violated.

The detailed arrangements for of compensation will be considered within the EAP (Section 9).

7.6 References

7.1 IAEA/UIR. Handbook of parameter values for the prediction of radionuclide transfer in temperate environments. IAEA TR 364. IAEA, Vienna.

7.2 Recommendation of the International Commission on Radiological Protection, ICRP Publication 9. 1965.

7.3 Recommendation of the International Commission on Radiological Protection, ICRP Publication 26.

7.4 Recommendation of the International Commission on Radiological Protection, ICRP Publication 30.

7.5 Recommendation of the International Commission on Radiological Protection, ICRP Publication 60. 1991.

7.6 Khmelnitsky NPP – Data for Environmental Impact Assessment – UKKE0000IK – Kyivenergoproekt 1996.

7.7 Ukraine Ministry for Environment Protection and Nuclear Safety – Status of nuclear and radiation safety in Ukraine, 1995.

7.8 GBPCalc Version 1 software. Technical Assistance Section. Environmental Protection Agents USA.

7.9 Coughtrey, P.J. *et al.* Radionuclide distribution and transport in terrestrial and aquatic ecosystems, Volume 1. A.A. Balkema, Rotterdam, 1983.

7.10 BC 4630-88. Sanitary codes and standards of the protection of surface waters against contamination.

7.11 Regulations on the protection of surface waters against contamination by waste water, N166 of 1974.

7.12 Assessment of the Khmelnitsky NPP reservoir on the surface and ground water – Romas N.I. Shumo v Yu.A. – Kyiv State University, KhNPP.