SEPA
Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

Radiological Habits Survey

Chapelcross 2015

Public Report

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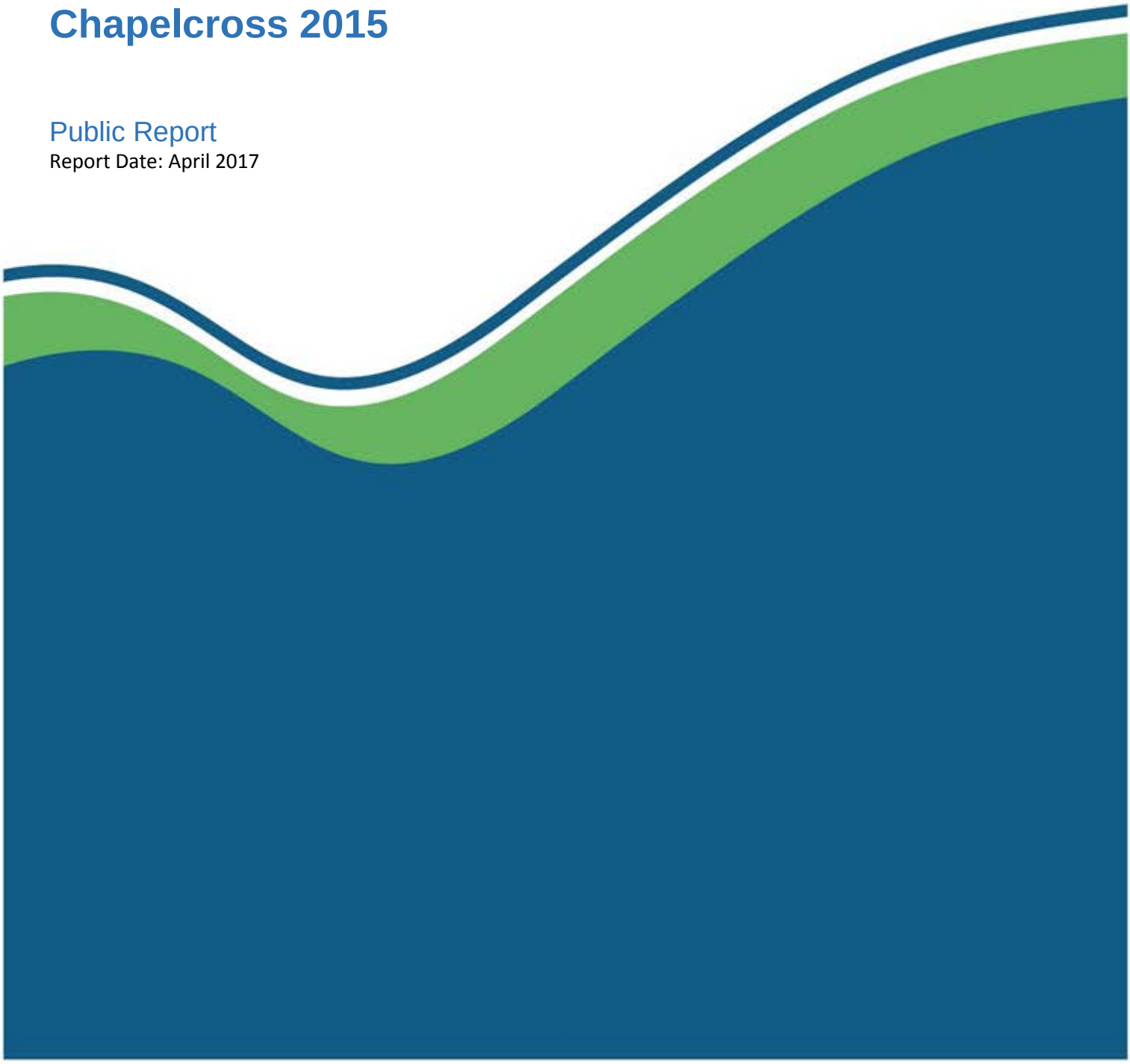

Radiological Habits Survey: Chapelcross 2015

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Foreword

This report details the output of the latest Radiological Habits Survey at Chapelcross, which was undertaken in 2015 by the University of Stirling operating under contract to SEPA. This study was one of the first surveys undertaken by a new contractor with a differing approach from the previous contractor in 2010. In order to demonstrate that this new approach was robust and to provide reassurance, as part of its quality assurance, SEPA requested that the contractor put in significant extra verification of data than it would have required had a similar approach been adopted.

Steps proposed by the contractor involved undertaking a resurvey during 2016 with a subset of the 2015 group to produce additional data for higher routes of exposure. Data gathered from the survey was then compared to the previous 2010 survey, and provides broadly comparable data which gives reassurance that differing approaches can result in the identification of those higher-rate consumers and locations with the highest occupancy. This data verification exercise was considered useful and has been added to the methodology for future reports.

SEPA considers that approaches from this and previous habits surveys are both equally valid and thus provide a robust study into the exposure pathways around the Chapelcross site. This extra verification has provided significant confidence in the findings of the Chapelcross report, as the approach has now been validated; SEPA has not requested such further validation in future reports using this approach.

Contents

Summary

This report presents the findings of the 2015 Chapelcross Habits Survey to determine the habits and consumption patterns of people living and undertaking recreational activities in the vicinity of the, Magnox Limited operated, Chapelcross nuclear site. The site is authorised by SEPA under RSA 93 to discharge both gaseous radioactive waste from a number of outlets as well as liquid radioactive waste through a pipeline outfall into the Solway Firth. Sources of direct radiation are also present.

The survey targeted the three areas that were likely to be affected by discharges from the site, defined as;

- An aquatic survey area; covering the Solway Firth and its intertidal areas from Gretna in the east to Glencaple in the west
- A terrestrial survey area; extending 20 km around the site to the coast within Scotland
- The direct radiation survey area; extending 1 km from the site boundary and along the pipeline to the coast

During the survey, a number of potential exposure pathways were investigated through methods including postal and face-to-face surveys and general observations. The survey was conducted in two parts: (i) the face-to-face survey during the summer of 2015, which was undertaken during and after the local school summer holiday period; and (ii) a follow up survey during spring 2016.

As a result of a change in contractor followed by a new approach, SEPA wished to test the appropriateness of the new methodology to ensure a robust and representative approach. The survey confirmed broadly comparable results from the 2015 survey and that of the previous contractors of the 2010 survey, suggesting that both methods appear to be robust in determining high-rate consumption and occupancy. The follow up survey also included a resurvey of small samples of 2015 participants to assess whether there are any seasonal factors that might influence the habits results. Collectively, the habits survey is hereinafter referred to as ‘Chapelcross 2015 Habits Survey’.

Research was also undertaken to trace the food pathways and production from both farming and fishing industry within the survey area. However, access to such data was not possible due to issues of data protection and commercial confidentiality. This hindered attempts to trace pathways for foodstuff grown or reared around Chapelcross and their potential influence on the local population and beyond the survey area.

Data obtained during the survey included the consumption of foods produced within the terrestrial survey area; occupancy of both terrestrial areas and within the direct radiation survey area; consumption of aquatic food from within the aquatic survey area; occupancy of aquatic and intertidal areas; and the handling of equipment used within the aquatic survey area. A habits and radiometric survey along the length of the discharge pipeline was also undertaken.

Interviews with members of the public were carried out over a period of 14 days and data for 317 individuals are presented and discussed for the summer 2015 campaign and a further nine individuals were re-surveyed and 34 new surveys were made during a five-day survey of the April 2016 campaign. Whilst the 2016 face-to-face surveys were targeted more towards land workers, the results were broadly similar to those reported in the 2015 survey, which tended to confirm the findings of the more extensive 2015 face-to-face surveys. Those high-rate individuals are identified using established methods comprising a ‘cut-off’ to define the high-rate group and 97.5th percentiles for dose assessment analysis.

The aquatic survey area

Haaf net and stake net fishing were reported to be undertaken from the Nith Estuary and the Solway Firth. Shrimping was also undertaken on the Solway Firth. Fish, crustaceans, molluscs and wildfowl are all consumed by adults. The mean consumption rates for adult high-rate groups for each of these food groups were:

- 47 kg y^{-1} for fish (salmon, cod, mackerel, sea bass, pollock, trout, Dover sole, kipper and sea trout)
- 20.8 kg y^{-1} for crustaceans (brown crab, common lobster and shrimp)
- 3.0 kg y^{-1} for molluscs (razor clams and scallops)
- 16.3 kg y^{-1} for wildfowl (pink-footed goose)

One child was found to consume 7.8 kg y^{-1} of fish. No infants were found to consume aquatic foods. The 2016 survey data did not specifically target fishermen who were likely to return high consumption rates and overall 2016 values were lower than those reported for 2015 and 2010.

No consumption of algae was identified but samphire and wild mushrooms from the saltmarsh area were consumed.

Aquatic activities included angling, boat maintenance, canoeing, commercial fishing, Haaf netting, kayaking, kite surfing, lifeboat volunteering, rowing, safety boat duties, sailing, sea angling, stake netting, sub-aqua diving, outdoor swimming, power boating, water skiing, and working on a boat.

Intertidal activities included bait digging, beachcombing, boat maintenance, collecting mussels, razor clams, seaweed, samphire or winkles, handling creels/stake/Haaf/poke nets, dog walking, fixing moorings, horse riding, paddling, photography, playing, research/educational purposes, rock pooling, sand yachting, walking and wildfowling. The activities found for adults involving the handling or maintenance of equipment included boats and boating equipment, clothes and overalls, diving gear, fishing gear, swimming gear.

The mean rates for the adult high-rate group for occupancy within the aquatic survey area were:

- 1 095 h y^{-1} for intertidal activities
- 1 460 h y^{-1} for activities in the water
- 1 460 h y^{-1} activities on the water
- 563 h y^{-1} handling equipment

A total of 43 in-situ gamma dose rate measurements were made over intertidal surfaces during the survey period. A coastal survey was also undertaken with the handheld mobile gamma spectrometry system.

The terrestrial survey area

The mean consumption rates for the high-rate groups for terrestrial foods were:

- 13.4 kg y^{-1} green vegetables
- 28.8 kg y^{-1} other vegetables

- 14.1 kg y^{-1} root vegetables
- 187 kg y^{-1} potatoes
- 30.4 kg y^{-1} domestic fruit
- 13.9 kg y^{-1} wild fruit
- 2.75 kg y^{-1} wild mushrooms
- 36.2 kg y^{-1} beef
- 12.4 kg y^{-1} game
- 16.8 kg y^{-1} poultry
- 15.3 kg y^{-1} sheep
- 1.04 kg y^{-1} honey
- 415 l y^{-1} milk
- 13.1 kg y^{-1} eggs

The mean consumption rates reported in the 2016 were similar to or lower than those reported for 2010 and 2015. Comparison of the 97.5th percentile also showed similar values between the 2015 and 2016 surveys, with the single exception of potatoes where consumption rates were higher in 2016 (236 kg y^{-1}) compared with 2015 (183 kg y^{-1}).

Fourteen gamma dose rate measurements were taken in the terrestrial environment. This was supplemented by a car borne gamma spectrometry survey of the study area supplemented by handheld gamma spectrometry system along the Chapelcross effluent pipeline and main rivers draining the survey area and Chapelcross in particular.

The direct radiation survey area

The highest occupancy rates in 2015, within the direct radiation area were as follows (holidays not taken into account):

- 8 760 h y^{-1} for the total occupancy rate (for a resident)
- 7 665 h y^{-1} for the indoor occupancy rate (for a resident)
- 5 840 h y^{-1} for the outdoor occupancy rate (for a resident)

The highest occupancy values for 2016, within the direct radiation area were generally lower:

- 7 244 h y^{-1} for the total occupancy rate (for a resident)

- 5 280 h y^{-1} for the indoor occupancy rate (for a resident)
- 2 624 h y^{-1} for the outdoor occupancy rate (for a resident)

Comparisons with previous surveys

The results of the Chapelcross 2015 Habits Survey were compared with the last habits survey carried out at Chapelcross in 2010.

In the aquatic survey area, the overall mean consumption rate for the adult high-rate group for fish, crustaceans and molluscs increased in 2015 compared to 2010. The main species of fish consumed by adults were salmon and sea trout in 2010 compared with salmon and cod in 2015. The main crustaceans consumed by adults in 2010 were brown crab and shrimps compared with brown crab, lobster and shrimps in 2015. Mollusc consumption was not identified in 2010 compared to scallops and razor clams being consumed in 2015. The consumption of marine plants (Samphire) by adults was identified in both 2010 and 2015.

The only fish species consumed by children was cod in 2015. No infants were found to consume other forms of aquatic food in 2015, whilst Salmon and Sea trout were identified in the 2010 survey.

The handling of aquatic equipment was found to be greater in 2015 than that previously reported in 2010. Activities included boat maintenance, handling clothes and overalls, diving gear, fishing gear and outdoor swimming gear.

Adult consumption rates increased in the 2015 survey for the following food groups: vegetables (green), vegetables (potatoes), fruit (domestic), fruit (wild), meat (beef), meat (poultry), meat (sheep) and milk in comparison to the 2010 survey. Consumption rates decreased in the 2015 survey in the following food groups: vegetables (root), meat (game) and honey in comparison to the 2010 survey. In 2015 the total occupancy, highest indoor occupancy and highest outdoor occupancy decreased from 2010.

Dose Assessment

Of all the pathways identified and considered, the highest retrospective dose for all exposure pathways was 0.0093 mSv from the 2015 survey data. The highest retrospective dose for all exposure pathways from the 2016 survey data was lower at

0.0014 mSv. The doses from the 2016 survey were generally lower than those from the 2015 survey.

For the 2015 survey, the highest dose from internal exposure associated with the terrestrial food pathway was 0.00021 mSv arising from the consumption of beef, game (venison, rabbits and hares) and milk. The highest dose from external exposure was from doses received by people spending time in the intertidal environment (0.000023 mSv). The highest dose from internal exposure associated with the aquatic food pathway was 0.0000085 mSv arising from the consumption of fish. The highest dose from external exposure in the aquatic environment was from doses received by people handling fishing gear and sediment (0.0093 mSv).

These are very small compared with the 1 mSv annual public dose limit.

Suggestions for changes to the monitoring programme

The following suggestions for changes to the current environmental monitoring programme are provided for consideration;

- Blackberries (Seafield), samphire (Brow Well and Priestside Marsh), wild mushrooms (saltmarsh between Brow Well and Priestside Marsh) and rosehips (Powfoot) may be worth considering for inclusion in either as an ad-hoc survey or within SEPA's routine monitoring programme.

List of abbreviations and definitions

BCMS – British Cattle Movement Service

BSS - Basic Safety Standards

CEFAS - Centre for Environment, Fisheries and Aquaculture

DCC - Dose conversion coefficient

DEFRA – Department of Environment, Food and Rural Affairs

ERL - Environmental Radioactivity Laboratory, University of Stirling

GPS - Global positioning system

Haaf net fishing - a fishing technique which dates back to the Viking invaders, using a large rectangular netted frame, which fishermen carry and advance into the oncoming tide.

HP laundry - Health Physics Laundry

HSE - Health and Safety Executive

ICRP - International Commission on Radiological Protection

ILW - Intermediate Level Waste

LOD - Limit of Detection

MoD - Ministry of Defence

MoGSS - Mobile Gamma Spectrometry System

NDAWG - National Dose Assessment Working Group

ONR - Office of Nuclear Regulation

RIFE- Radioactivity in Food and the Environment

RSA- Radioactive Substances Act 1993

SEPA - Scottish Environment Protection Agency

SGAS – Scottish Government Agriculture Statistics

UKAS - United Kingdom Accreditation Service

Chapelcross 2015 survey: collectively refers to the survey undertaken between the 9th and 22nd August 2015 and a second survey undertaken between the 18th and 22nd April 2016.

Units

Bq - Becquerel

Gy - gray

Sv – Sievert

kg - kilogram

g - gram

l - litre

y - year

h - hour

M – mega (one million; E6)

m – milli (one thousandth; E-3)

µ – micro (one millionth; E-6)

1. Introduction

1.1 Regulatory Context

Chapelcross is a nuclear licensed site that operated four Magnox reactors. The site started the decommissioning process in 2004 and this process is still ongoing. The site holds an Authorisation under the Radioactive Substances Act 1993 (as amended) (RSA93), which allows the disposal of solid, liquid and gaseous radioactive wastes. The impact of the disposal of the wastes is monitored in accordance with the requirements of Article 35 of the 96/29 Euratom Treaty to ensure that the total dose to the representative person is below both the legal limits of 1 mSv committed effective dose and the 50 mSv skin annual dose limit.

The discharge of radioactive waste from the site may result in the exposure of the public as a result of direct radiation shine, or through inhalation or ingestion of contaminated materials, primarily foodstuffs (Smith and Jones, 2003). It is also recognised that enhanced doses from external exposure due to authorised discharges and the consumption of locally sourced foods may occur as a result of contemporary and historical discharges accumulating in the environment (Dale *et al.,* 2008; Tyler *et al*., 2013). It is the responsibility of the Scottish Environment Protection Agency (SEPA) to regulate the discharges from site so as to ensure that the public are not exposed to doses in excess of the legal limits. Exposure to direct shine from nuclear, radiation or waste facilities is the responsibility for the Office of Nuclear Regulation (ONR), (within a nuclear licensed site), and the Health and Safety Executive (HSE), (outside a nuclear licensed site) where any direct exposure impacts on facility workers.

1.2 Definition of the Representative Person

The optimal approach for retrospectively assessing doses to the public is through a combination of site-specific habit data and an environmental monitoring programme to determine ambient dose rates and concentrations in foodstuffs. The actual doses received by an individual are dependent upon age, size, metabolism in addition to the various interactions they may have with exposure routes. Thus, the standard

approach is to identify and consider these sources of exposure in appropriate groups.

The concept of the *representative person* was introduced by ICRP (2006) and recommended to replace the previously used concept of the *critical group* in 2007 (ICRP, 2007). The *representative person* is the individual that represents the more highly exposed members of the public and is typically defined by a cut-off, for example the top 97.5 % of the dose distribution within one or more routes of exposure. Within this concept, if the dose received by the *representative person(s)* can be demonstrated to be within the accepted dose limits (retrospective) and constraints (prospective), then the public as a whole is considered to be protected.

1.3 Dose Limits and Constraints

The system of dose limitation recommended by the International Commission on Radiological Protection (ICRP, 2007) and subsequently required by the Radioactive Substances Basic Safety Standards (BSS) requires that dose equivalents received by individuals shall not exceed the limits set out in Article 13 of Council Directive 96/29/Euratom (CEC, 1996).

The *retrospective* maximum permissible dose limit is set out as 1 mSv y^{-1}. For *prospective* assessments, the dose constraints used by SEPA are:

(i) 0.3 mSv y^{-1} for any single source of radioactivity, and
(ii) 0.5 mSv y^{-1} for a single site from which radioactive discharges are made.

It is also accepted by the UK Government that it should be possible to operate existing nuclear facilities without exceeding the 0.3 mSv y^{-1} constraint (Hunt *et al.,* 1982; Leonard *et al.,* 1982; Sherlock *et al.,* 2006). It is therefore incumbent upon SEPA to ensure that these dose limits/constraints are not exceeded for all authorised discharges of ionising radiation to the environment.

1.4 Survey Aim

The aim of the survey is to collect data to allow a bespoke assessment to be made which identifies the representative person(s). The identification of the representative person is a result of known information on the consumption of local foods and

occupancy times in combination with data from SEPA's routine environmental monitoring programme. This survey aims to collect data on the consumption rates of locally grown foods and occupancy times. The survey also aims to identify any pathways which the routine programme may not currently adequately cover and, as a result, may recommend removal of monitoring that is has become redundant or adoption of new monitoring due to changes in habits. The survey achieves this by:

(i) Collecting data on a range of habits/activities by the general public in the environment immediately surrounding the nuclear site and surrounding areas that might lead to exposure to radioactivity or radiation from any combination of licensed liquid or gaseous discharges, or direct radiation from on-site activities at Chapelcross;

(ii) Collecting information on consumption of food grown or produced (including wild & free foods and any novel pathway) in the survey area and determining an annual rate of consumption for each individual surveyed and household members of all ages; and,

(iii) Identify the amounts of radioactivity, radiation and subsequent doses to individual members of the general public as a result of the discharges or operations of the nuclear site.

The previous habits survey was undertaken during the period 9th to the 22nd August 2010 (Clyne *et al*., 2013). This report presents the findings for the 2015 habits survey of the Chapelcross and the inner Solway area as far west as Glencaple on the Nith Estuary, as far east as Gretna and as far north as Creca for the face-to-face survey and Langholm for the postal survey. The report includes the findings of a follow up survey between the 18th and 22nd April 2016 to assess whether there are any differences or changes in habits at a different time of the year.

2. Chapelcross Survey Area

2.1 Introduction

This chapter describes the site characteristics including recent and potential onsite activities, a prospective dose assessment from licensed discharges to air and sea, and the surrounding types of land cover.

In preparation for the survey, a visit to the site and a meeting with the site operators was held in May 2015. Attendance at a stakeholder meeting in June 2015 held in Annan raised the profile of the face-to-face survey and the forthcoming postal questionnaire. A small news article in the local paper also reported the forthcoming habits survey.

2.2 Chapelcross Site Activity

2.2.1 Current Activity

Built and commissioned between 1955 and 1959, Chapelcross was Scotland's first commercial nuclear power station built on a 92 hectare site that was once a World War II training airfield RAF Annan. Chapelcross had four Magnox reactors and ceased power generation in 2004. Since 2010, the site has completed de-fuelling and asbestos removal work. The site's pipeline outfall continues to discharge liquid radioactive waste into the Solway Firth. Although defueled, the site retains sources of radioactivity, which produce 'shine[1]'. Gaseous releases of radioactivity have reduced with the cessation of power generation, but past and current releases to air have led to tritium (^{3}H) contamination in and around the site. In 2015, the programme to remove the heat exchangers started.

The site has a burn (Gullielands Burn), which flows into the site through the north east boundary and is culverted beneath site before it leaves the site along the south western boundary. There is also a 'badger run' to the east of the site, which also facilitates the movement of rabbits and hares on and off site.

[1] Ionizing radiation emanating from sources on-site that may be measurable off-site

2.2.2 Changes Since 2010

According to Magnox's Chapelcross Site Strategic Environmental Assessment Site Specific Baseline published in September 2014, the site will be in a semi-quiescent state from 2017 to 2023 with a much reduced maintenance schedule. From 2023 to 2028, it will be making the final preparations for entry into care and maintenance.

The waste and processing plants have discharged gaseous ^{3}H throughout their operational lifetime. This will continue at a reduced scale during plant decommissioning until final site clearance. Near future plans include the remediation of contaminated land areas (within the site boundary) in addition to the retrieval and processing of Intermediate Level Waste (ILW) and the drain down and stabilisation of the redundant fuel cooling ponds. These activities will result in minor but regular radioactive gaseous and liquid discharges.

The Dumfries and Galloway Council Annan Regeneration Steering Group in 2015 contains an action plan report from a consultant that describes a 'conceptual' idea after decommissioning for the pipeline to become a public pathway (http://www.dumgal.gov.uk/CHttpHandler.ashx?id=10903&p=0).

2.3 Estimated Activity Concentrations from Licensed Discharges from Chapelcross.

Permitted discharges of ^{3}H (6.5E+12 Bq y^{-1}), alpha (1.0E+9 Bq y^{-1}, assessed as ^{239}Pu) and non-alpha (1.0E+12 Bq y^{-1}, assessed as ^{137}Cs or ^{60}Co) from Chapelcross were used to calculate aquatic activity concentrations in water using the DORIS model within PC-CREAM (Public Health England, 2008). A continuous release was assumed in modelling unfiltered seawater, fish, seaweed, crustaceans and molluscs over a 50-year period resulting in an equilibrium concentration in environmental radioactivity. For all element dependent parameters (sediment distribution coefficients, K_d and deep water), local compartment details (depth, coastline length, volumetric exchange rate, suspended sediment load, sedimentation rate, sediment density and diffusion rate) and regional model information (volume, depth, suspended sediment load, sedimentation rate, sediment density, diffusion rate) the default values of the Chapelcross area on PC-CREAM were used.

Activity concentration values reported at 50 years for unfiltered seawater in the immediate vicinity of Chapelcross were estimated to be 9.16E-2 Bq l^{-1} for ^{3}H, 6.93E-6 Bq l^{-1} for alpha and 1.31E-2 Bq l^{-1} for non-alpha. Activity concentrations in different foodstuffs were estimated and presented in Table 2.1. The gamma dose rate for intertidal and saltmarsh areas was estimated to be 6.35E-4 µSv h^{-1}.

Table 2.1 Modelled activity concentrations from PC Cream in marine foodstuffs

Foodstuff	^{3}H Bq kg^{-1}	Alpha Bq kg^{-1}	Non-alpha Bq kg^{-1}
Fish	9.16E-2	1.04E-2	3.81E-1
Crustaceans	9.16E-2	6.93E-4	3.82E-1
Molluscs	9.16E-2	1.04E-2	3.82E-1

Atmospheric activity concentrations were also modelled using the PLUME model in PC CREAM. The permitted discharges from Chapelcross were modelled and included ^{3}H (2.3E+14 Bq y^{-1}) and all other nuclides (5.15E+09 Bq y^{-1}, modelled as both ^{137}Cs and ^{60}Co as an analogue for all other nuclides). PLUME was set to calculate activity concentrations released for a range of stack heights. The activity concentrations in air for discharges from Chapelcross from the 37 m stack height are reported here over a range of distances from 500 m to 25 km. The MET stability scheme was applied using the default settings. However, the data extracted for the dose rates were based on the MET Pasquill D, selected by reviewing the local meteorological data (see Chapter 8). The activity concentrations in air are presented in Table 2.2.

Table 2.2 Activity concentrations in air (Bq m^{-3}) for ^{137}Cs and ^{3}H for a discharge of 5.15E+9 Bq y^{-1} and 2.3E+14 Bq y^{-1} respectively at a 37m stack height

Distance (m)	^{137}Cs	^{3}H
500	8.48E-05	3.82E+00
1000	4.61E-05	2.09E+00
5000	3.72E-06	1.79E-01
10000	1.16E-06	6.01E-02
15000	5.77E-07	3.23E-02
20000	3.48E-07	2.10E-02
25000	2.33E-07	1.51E-02

The GRANIS (external exposure model) and RESUS (resuspension model) modules in PC-CREAM were used to estimate the external dose rates at the same specified distances from the Chapelcross site, using the data presented in Table 2.2. The MET stability scheme was applied using the default settings. The data extracted for the dose rates were based on the MET Pasquill D with rain category as being most typical of the UK weather. Tables 2.3 and 2.4 report the estimated external doses modelled from PC-CREAM for Adults, Children and Infants using either ^{137}Cs or ^{60}Co (Table 2.3 or Table 2.4 respectively) as the analogue for the "all other nuclides".

Table 2.3 Modelled total external annual doses (microSv) in the 50th year to Adults, Children and Infants at the specified distances from a 37m stack at Chapelcross using ^{137}Cs as the analogue for all other nuclides after 50 years of release.

Distance (m)	Adult	Child	Infant
500	1.00E+00	8.99E-01	6.73E-01
1000	5.27E-01	4.73E-01	3.54E-01
5000	5.27E-02	4.75E-02	3.61E-02
10000	1.88E-02	1.70E-02	1.31E-02
15000	1.05E-02	9.54E-03	7.37E-03
20000	7.04E-03	6.38E-03	4.94E-03
25000	5.17E-03	4.69E-03	3.63E-03

Table 2.4 Modelled total external annual doses (microSv) in the 50th year to Adults, Children or Infants at the specified distances from a 37m stack at Chapelcross using ^{60}Co as the analogue for all other nuclides after 50 years of release.

Distance (m)	Adult	Child	Infant
500	1.10E+00	9.95E-01	7.68E-01
1000	5.75E-01	5.22E-01	4.02E-01
5000	5.90E-02	5.39E-02	4.25E-02
10000	2.14E-02	1.97E-02	1.57E-02
15000	1.21E-02	1.11E-02	8.93E-03
20000	8.09E-03	7.45E-03	6.00E-03
25000	5.95E-03	5.48E-03	4.42E-03

2.4 Survey area

Following the assessment of the radionuclide concentrations modelled by PC-CREAM within the Solway and surrounding environment, the 2015 survey area was defined by two main factors to remain consistent with previous Chapelcross habits surveys:

(i) to cover all potential pathways of exposure

(ii) to cover the same areas used in previous habits surveys conducted in the Chapelcross area for direct comparison and identify any changes since the 2010 survey.

The survey area for the marine pathway covered the Solway and its intertidal areas from Glencaple (in the west) to Gretna (in the east) and is related to its liquid discharges (Figure 2.1). This is further than the 2010 report, which extended west as far as Scar Point (Clyne et al., 2013). To assess the impact of atmospheric discharges the terrestrial survey area covered a 20 km area around the site, this was largely addressed by postal (see Chapter 4) and face-to-face surveys. The direct radiation survey area relating to shine was represented by the immediate public areas around Chapelcross and up to 1 km distance from the site boundary. A pipeline habits survey was undertaken during the same survey period and covered the complete 6 km length of the liquid effluent discharge pipeline to its outfall at Seafield.

2.5 Land Cover Data

The land cover data for the survey area are shown in Figure 2.2 (EDINA online 2007) and shows that the area is dominated by *arable* and *improved grassland.* This is summarised in Table 2.5, which provides a summary of the land cover types within the 1 km, 5 km and 10 km and 20 km zones surrounding the Chapelcross site. The table shows that the proportions of these land cover types remain reasonably consistent with increasing area surrounding the site.

Figure 2.1 The Chapelcross Survey Area of the inner Solway Firth, from Glencaple in the Nith Estuary (west) to Gretna (east).

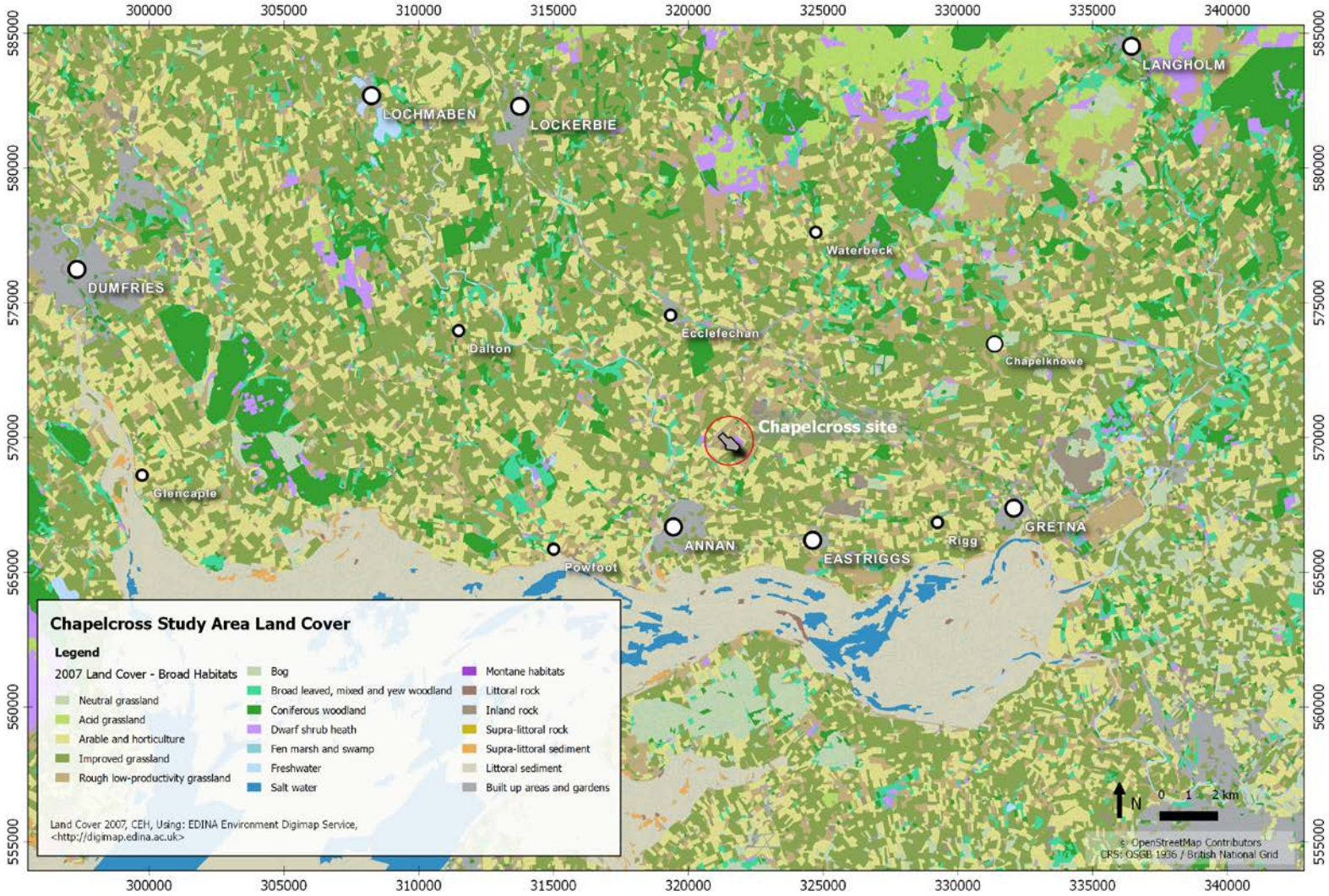

Figure 2.2 Land cover data for the Area around Chapelcross and the Solway Firth (EDINA online, 2007)

Table 2.5 Area of land cover in hectares with buffer zones surrounding Chapelcross Nuclear Site (reported to 3 significant figures) (Derived from EDINA online, 2007).

LC 2007 Broad Habitat	Within 1 km	Within 5 km	Within 10 km	Within 20 km
Acid grassland	0.00	9.28	242	5 620
Arable and horticulture	197	2 790	7 890	25 300
Bog	0.00	26.9	872	3 140
Broad leaved, mixed and yew woodland	16.6	253	1 380	4 900
Built up areas and gardens	14.8	397	561	1 750
Coniferous woodland	8.46	367	1 650	9 880
Dwarf shrub heath	14.5	51.3	330	2 130
Freshwater	0.00	36.9	105	496
Improved grassland	151	3 300	10 600	38 000
Inland rock	17.5	274	490	1 450
Littoral rock	0.00	4.43	51.2	93.6
Littoral sediment	0.00	211	4 430	19 100
Neutral grassland	0.00	20.4	67.9	2 020
Rough low-productivity grassland	147	1 240	3 940	12 400
Salt water	0.00	9.05	1 000	3 480
Supra-littoral sediment	0.00	7.85	82.4	348
Total	**566**	**9 000**	**33 700**	**130 000**

2.6 Soil Data

The soil data for the study area surrounding the Chapelcross site are presented in Figure 2.3 and reproduced from data provided by the Macaulay Land Use Research Institute. The Chapelcross site itself and immediate surrounding environment is dominated by non-calcareous gleys. Further afield, the soils are dominated by peaty gleys and brown earths with a few pockets of basin peats.

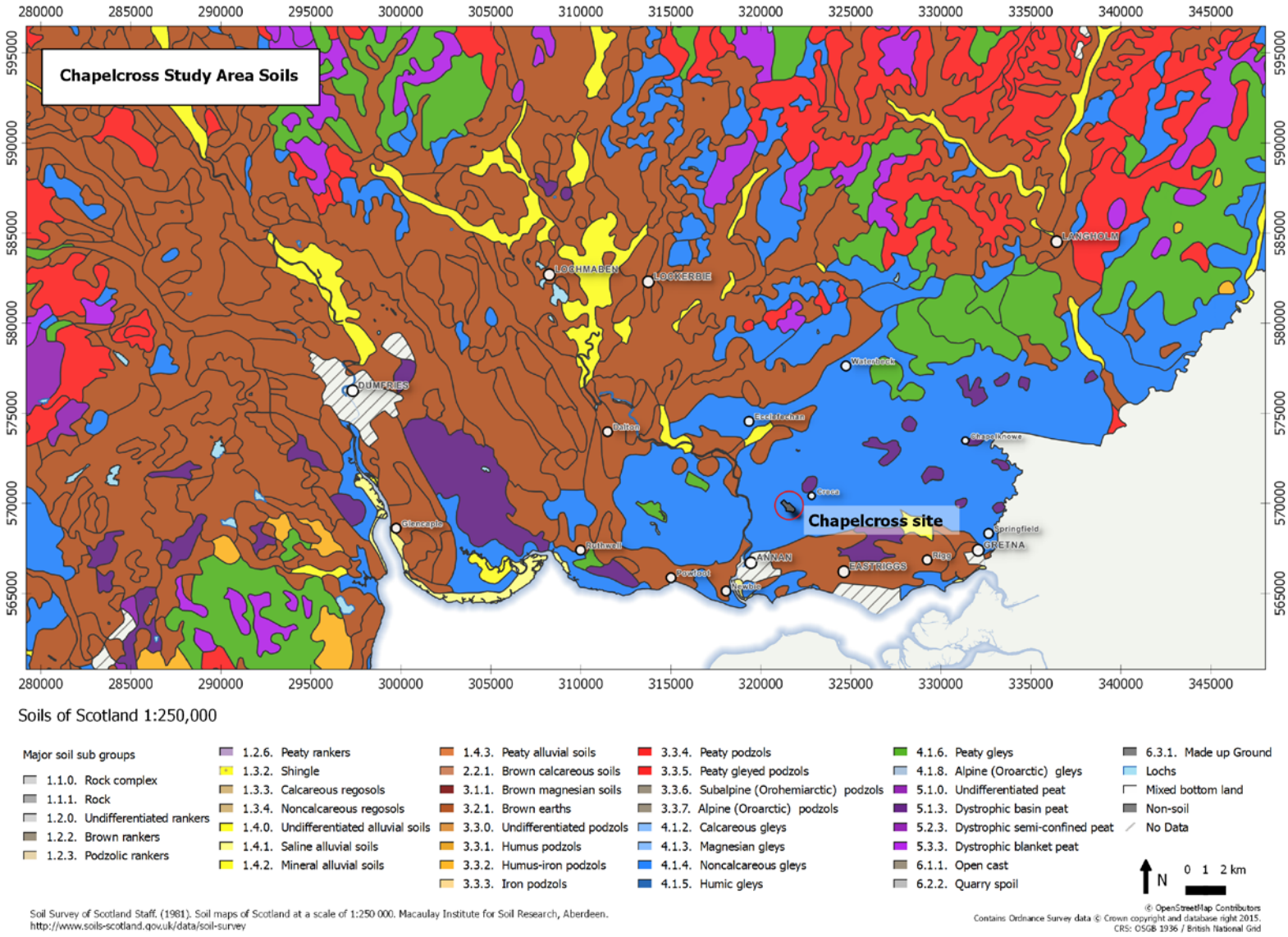

Figure 2.3 Soil types surrounding the Chapelcross Nuclear site (Macaulay Institute for Soil Research).

2.7 Crop Production

The Scottish Agricultural Census data for the parishes (defined by postcodes as used by the Scottish Government) surrounding the Chapelcross has been summarised for 2014 in Table 2.5. The data were kindly supplied by the Environment and Forestry Directorate of the Scottish Government. A total of 9 005 hectares of land are available for production in these parishes, including woodland. Crop production is dominated by barley (918 hectares), whilst the remaining agricultural land is dominated by grazing (6 524 hectares). Table 2.6 summarises the number of holdings, the area under production for crops and the estimated yield.

In addition, potatoes, peas and beans and other vegetables are produced in these parishes. Soft fruit and orchard fruit are also grown. Table 2.7 summarises the remaining use of the agricultural land in the parishes surrounding Chapelcross.

Table 2.6 Summary of commercial crop production in the Chapelcross area (2014). Total values account for the number of holdings growing more than one crop.

Crops and fallow land	Number of Holdings	Area Hectares	Estimated Yield, tonnes
Wheat	10	139	1 350
Winter barley	16	259	2 150
Spring barley	32	659	4 060
Total barley	36	918	5 990
Oats, triticale and mixed grain	10	83.9	584
All other crops	11	82.9	
Fallow land	16	56.5	
Total crops, fallow and set-aside	**49**	**1 420**	

Table 2.7 Summary of other agricultural land in the Chapelcross area (2014). Total values account for the number of holdings with more than one grazing classification.

Cultivated, grazing and other	Holdings	Hectares
Grass under 5 years' old	82	1 810
Grass 5 years and older	182	4 510
Rough grazing	28	198
Total grass and rough grazing	193	6 520
Utilised agricultural area (crops, grass and grazing land)	**197**	**7 940**
Woodland	42	875
Other land	84	189
Total	**200**	**9 000**

2.8 Dairy Production

Information sought on dairy-based farming activity was also provided by Scottish Government Agriculture Statistics (SGAS), which included herd size, the number of farms undertaking dairy farming at the parish level and total milk production for the whole of Dumfries & Galloway (Table 2.1.). Milk production figures from individual farms could not be accessed. Only the dairy processors and the farmers themselves hold such data, with milk sent to 1 of 4 dairy processors (Appendix 1a). Access to the dairy production data was not possible through the nearest milk processing plant at Lockerbie. All traceability of locally procured milk is lost once the milk enters the dairy processor as it is mixed with milk from all farms before entering the wider market. Other organisations were contacted for individual farm level production without success (Appendix 1b).

2.9 Livestock

2.9.1 Beef Cattle

Information on livestock-based beef farming activity is presented in Table 2.8 from data supplied by SGAS. The data indicates no major changes in the scale of beef farming over the past 5 years. Information on livestock movements, traceability or pathways into the local or wider market was not available. Such data are held by the

British Cattle Movement Service (BCMS; Appendix 2a), but could not be accessed due to issues of commercial confidentiality and data protection.

Contact with farmers as part of the 2016 surveys indicated one farm moved some livestock for sale to Newcastle (Appendix 2b). Most animals are sold through local auction marts at Carlisle, Longtown, Dumfries and Lockerbie with sales information available on-line (Appendix 2f, 2g & 2h). However, the websites do not publish data to identify from where the animals came or whether the animals went to slaughter and to which abattoir.

Some information about cattle sales to local suppliers or retailers can be established from the animal sales at local mart's published on-line. For example, records indicate that one Annan butcher bought beef sourced from a single farm within the 5 km zone (Appendix 2f). Direct contact with the butcher indicated that the animals were slaughtered at Lockerbie. These sales only form a small proportion of total beef bought at auction with other beef coming from outside the survey area. These data further confirm that most beef bought locally is sourced from outside the survey area. No other information was found relating to any beef products sold locally and sourced from the three agricultural parishes.

It was generally not possible to obtain data on the type and numbers of animals slaughtered and where the carcasses were sold on to for processing from abattoirs (Appendix 2i). With the exception of the butchers in Annan, information for meat processing within the three parishes around Chapelcross could not be accessed. The butcher in Annan bought carcasses from the abattoir and butchered the meat in the shop.

2.9.2 Sheep & Lamb

Data on holdings, lamb and sheep numbers are compiled in Table 2.8. In general, once the animals leave the farm all traceability is lost with regard to specific pathways from the survey area and into the UK or European meat market. Such data is held by BCMS but could also not be accessed. No evidence was found of any mutton trade from the area.

Information from other sources was explored and revealed that lambs are generally sold through one of several auction marts in the area but only limited information on

numbers sold is published on-line (Appendix 2f, 2g & 2h). Such information from the nearest auction mart (Appendix 2f) could not identify inter-farm movements or any lambs sold to local retailers in the survey area. Contact was made with a specialist lamb abattoir based in Dornock (Appendix 3a) for information on lamb movement traceability. However, no information on animal numbers or whether any meat is processed and/or sold locally was made available. However, the abattoir did state that most of their lamb is sold to Europe with no specific traceability back to survey area.

2.9.3 Pig Farming

Data on pig farming and the number of holdings engaged in this activity are included in Table 2.8. In most cases, pig movements off-farm to the wider UK market were not traceable due to the reasons already described.

2.9.4 Other Livestock Activity

SGAS provided data on other types of livestock farming in the survey area are presented in Table 2.8. The SGAS data indicated that five farms within the survey area kept goats with an average herd size of 23 animals. However, no farms with goats were identified as part of this survey. Deer farming was not present in any of the three agricultural parishes. The nearest deer farming enterprise was based at Lockerbie (Appendix 5a).

Table 2.8. Livestock numbers and holdings in survey area and at regional and national level (Source: SGAS)

2010-2015	Holdings			Animal Numbers			Dumfries & Galloway	2011 to 2015 Scotland	3 Parishes	
Animal Category	Max	Min	5-Year Mean	Max	Min	5-Year Mean	Mean	Mean	% Av D&G	% Av Scot
Total Dairy Cattle	37	32	35	6 046	4 716	5 200	11 1971	268 935	4.64	1.93
Total land (Dairy cattle) Ha.	35	31	33	3 241	2 960	3 118				
Total Female Beef Cattle	71	61	65	3 563	3 080	3 395				
Total land (Beef cattle) Ha.	68	58	63	6 410	5 831	6 091				
Total Male Cattle	74	64	69	3 156	2 503	2 791.5				
Total Calves	72	65	68	4 581	3 791	4 155	12 3367	528 597	3.37	0.79
Total Non-Dairy Cattle			68	11 300	9 374	10 342	18 5803	986 883	5.57	1.05
Total Cattle	78	72	75	16 900	14 965	15 542	42 3357	1 795 440	3.67	0.87
Lambs	38	34	36	8 142	6 856	7 454	50 7942	3 257 179	1.47	0.23
Total sheep	42	40	41	14 056	12 489	13 252	100 6377	6 710 252	1.32	0.20
Total land (Sheep) Ha.	42	40	41	4 131	2 349	3 580				
Total pigs	13	8	11	1 034	32	273	10 689	345 097	2.56	0.08
Total land (Pigs) Ha.	13	8	11	871	463	660				
Fowls for producing eggs	32	27	29	496	367	410	29 4426	5 074 063	0.14	0.01
Fowls for breeding	20	16	18	76	62	71	23 1186	1 171 961	0.03	0.01
Broilers & other table fowls	9	2	5	59	19	30	218 799	8 337 104	0.01	0.00
Total Poultry	33	29	31	777	633	693	893 611	14 583 130	0.08	0.00
Goats and kids	7	4	5	30	19	23	167	1 191	13.89	1.94
Deer	0	0	0	0	0	0	476	3 512	0.00	0.00
Beehives	3	0	1	6	0	2	131	935	1.53	0.21

2.9.5 Fallen Animals

Under current regulations (*Animal By-Products (Scotland) Regulations 2003. SSI 2003/411*) concerning the disposal of dead animals from the farm, fallen animals cannot be disposed of on-site at farms and have to be processed by specialised companies. However, no such company is located within the survey area. The nearest is based at Dumfries (Appendix 6).

The company (Appendix 6) website, reports that all animal parts are processed with most of the flesh and bones rendered and sold as fuel to power stations. The hides are sold for leather and certain other animal parts are sold for pet food. The company collect all types of animals from across the region for processing, including: beef and dairy cattle (25% and 65% of total animals processed respectively). Sheep, lambs, pigs, horses and deer (mainly roadkill) make up the rest of the animals. The company also confirmed meat and bones, once rendered, are sold for burning in a power station. Information on numbers or destination of by-products could not be established.

2.9.6 Egg and Poultry

Egg Production

Official data from SGAS suggests that egg production is not a major activity across the survey area (Table 2.8), although SGAS does not compile data from holdings with fewer than 50 chickens. This is because such holdings have no legal requirement under *The Avian Influenza (Preventive Measures) (England) Regulations 2006* to register with the Department of Environment, Food and Rural Affairs (DEFRA), although they are encouraged to do so.

From the SGAS data, over the past five years, there have been, on average, 410 laying hens on each of the 29 farms identified with no major change in scale over this period. Hen numbers appear to be too low for commercial egg production whilst too high for personal consumption alone. An internet search revealed there were no commercial egg layers located in the survey area and only two within 10 km of Chapelcross. DEFRA confirmed that they could not provide information on egg production at the farm level due to commercial sensitivity. Contact with local shops

and butchers in the Annan area (Appendices 2c - 7b) confirmed that they did not source their eggs from any of the holdings within the survey zone.

Broiler Production

SGAS statistics Table 2.8 indicate broiler production is not prevalent across the survey area and represents less than 0.1% of total production in Dumfries and Galloway with no evidence of commercial scale activity. The very low average numbers of broilers per farm (30) suggests animals are slaughtered, on farm for personal consumption rather that sent away to an abattoir. However, no farms in the survey reported keeping broilers and no traceability of movement off farm could be established during the 2016 survey.

Contact with local retailers about their supply chain found no evidence of locally reared broilers being sold. Local retailers (Appendix 2c, 2d & 2d) sourced their poultry from a supplier based in Penrith, Cumbria (Appendix 8a). One of the butchers (Appendix 2d) reported that some of their chickens bought from the Penrith supplier were sourced more locally from a poultry farm, based in Eaglesfield, (Appendix 8b), which is outside the 5 km area. This is not an all year round supply source and the butcher could not confirm what proportion of total chickens sold were sourced from this farm. No one was on-site when the farm was visited during the survey.

No pathway could be quantified for the consumption of locally sourced poultry meat.

2.9.7 Beekeeping

SGAS data (Table 2.8) show no bee keeping activity in the survey area was recorded until 2014 & 2015 when 6 hives from a total of 3 holdings were counted.

2.10 External Exposure Pathways: Local Business and Commuting Information

2.10.1 Introduction

Information was sought on tracing local business and commuting information to identify potential external exposure pathways and the scale of any relevant activities compared to the wider economy of the survey area. A list of over 100 companies, centred on Annan, was compiled (Appendix 9, Table A9.1) with over 61 contacted

starting in Annan and expanding outwards. A total of 20 companies responded. Companies contacted included boiler makers, engineers, retailers, feed merchants, and sawmills. These companies employed between two and 130 people.

2.10.2 Range of Local Companies and Scale

According to the latest statistics, across Dumfries & Galloway region, local employment is dominated by the service sector (80%), including the public sector (34.4%) and retail activities (18.7%). Agriculture only represented 1.5% or a total of 900 people (www.SNS.gov.uk). Around the Chapelcross site, land-based activities are more prevalent. Such economic activities tend to employ low numbers of people. Outdoor workers in the area include farmers and estate workers. Chapter 7 provides further detail on occupancy levels. Other economic activities closest to the site include an industrial estate, a scrapyard and a swimming centre: each with low numbers of employees. Along the coast, the number of people employed in the fishing industry is very small and appears to be declining. However, such workers spend a higher than average length of time in the vicinity of the coast and therefore may have possibly higher exposure to an aquatic source.

Annan is the major urban centre in the survey area and has the highest concentration of economic activity in the survey area. Work is largely associated with the service industry and workers tend to spend more time indoors and therefore. Higher numbers of people are employed in these industries compared to those working outdoors. Public sector workers are evident in Annan with the police station and hospital reporting staff numbers of approximately 35 and 40, respectively.

Occupancy times based on those working or living within one kilometre of the site are discussed further in Chapter 7.

2.10.3 Commuting Pattern of Local Workers

Commuting patterns offer another potential exposure pathway and enquiries were made with the companies (Appendix 9, Table A9.2) regarding the form of transport and route staff took to and from work.

The majority of workers in Anna either live in the town or regularly commute on a on a route that does not involve passing the Chapelcross site. Staff from Annan

hospital and a timber products manufacturer were dominated by those living in the town 32/40 and 29/47, respectively (Appendix 9, Table A9.2). The main commuter routes were from Dumfries and Gretna, with some people traveling in from Carlisle and from as far as Castle Douglas. All commuters that responded drove in by car with only one or two cycling.

Only those living or working close to or north of the site passed Chapelcross on a regular basis taking approximately 1 to 2 minutes to travel passed the site. The area has a low population density. However, this activity represents a key exposure pathway and monitoring of such commuting should continue to form part of future habits surveys.

3. Methods

3.1 Introduction

To provide consistency and traceability to previous habit surveys, the methods employed and described in this chapter are largely based on the approach outlined in Leonard *et al.* (1982), and National Dose Assessment Working Group (NDAWG) (2013). The previous habit surveys in 2010 provided a useful frame of reference for undertaking this survey of the Chapelcross site. Chapter 2 described the desktop study undertaken to characterise and define the habits survey, including:

(i) a review of site activities
(ii) the modelling of the atmospheric and marine discharges from the site to define the survey area boundary
(iii) an assessment of the land cover and agricultural activity.

The 2015 habits survey of Chapelcross covers activities and food consumption. The following new methods were introduced to the the survey:

(i) an extensive postal survey
(ii) a mobile radiometric survey to characterise the heterogeneity of radiation in the environment surrounding the Chapelcross site
(iii) a GPS tracking on a limited number of volunteers to quantify and verify the time spent by individuals undertaking different outdoor habits and providing an estimate of uncertainty on occupancy estimates provided by the public
(iv) a series of informal meetings during and after the face-to-face surveys to validate the data and findings.

3.2 Postal Survey

To obtain a provisional independent assessment of the activity and food consumption habits of the local community living within the study area through the survey, a postal questionnaire for households was designed, piloted and distributed to 1000 households found within zones shown in Figure 3.1. The households were selected using random sampling method, numbers varied according to the number of

households found within each area. The survey included a map for identifying the range of activities undertaken by household members. The sample included populations living in the following geographical areas (see Figure 3.1):

(i) Between 1 km and 5 km from the site (zone 2B)
(ii) Between 5 km and 10 km from the site (zone 3B)
(iii) Between 10 km and 20 km from the site (zone 4B)
(iv) Zones 2-4 were repeated within the modelled plume area which were identified using PC CREAM (Figure 2.1)
(v) Zone 1A concentrated on households located within a 1 km radius around the plant

Postcodes for all the geographical areas described above, and shown in Figure 3.1, were generated. The electoral register was grouped for each of the zones (Figure 3.1) and contact details were randomly selected. To better understand the habits of individuals within the area of the predicted plume model (Figure 3.1) and using prevailing wind data, 86 surveys were posted to people living north east of the Chapelcross works, under the prevailing wind. Considering the reduced number of households located under the modelled plume, surveys were randomly distributed to the houses: Zone A1 receiving 248 (24.8% of total sample) surveys; zone A2 receiving 69 (6.9%) surveys; zone A3 receiving 57 (5.70%) and zone A4 receiving 156 (15.6%) surveys. Zones B2, B3 and B4 (Figure 3.1) receiving 156 (15.6%), 156 (15.6%) and 158 (15.8%), respectively. Sampling and surveying at different distances from the site enabled exploration of the relationship between distance and habits and provided a means of producing additional potentially useful data. The postal survey produced an independent data set from a broader cross section of the population living in the area, again potentially providing the means to identify new or missed habits that might provide useful focus to target some of the face-to-face surveys or information groups.

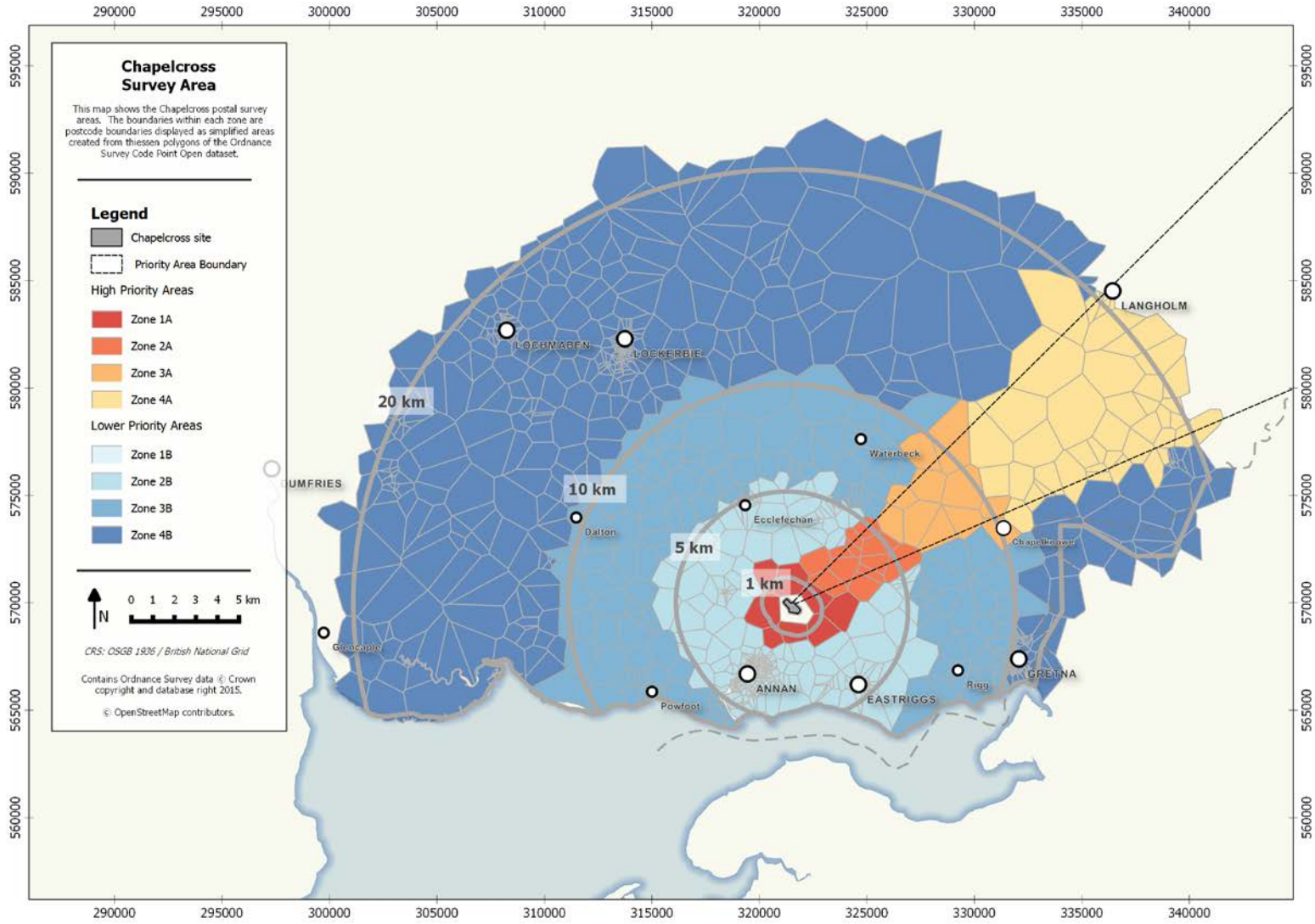

Figure 3.1 Map showing the postal survey zones for the Chapelcross Survey.

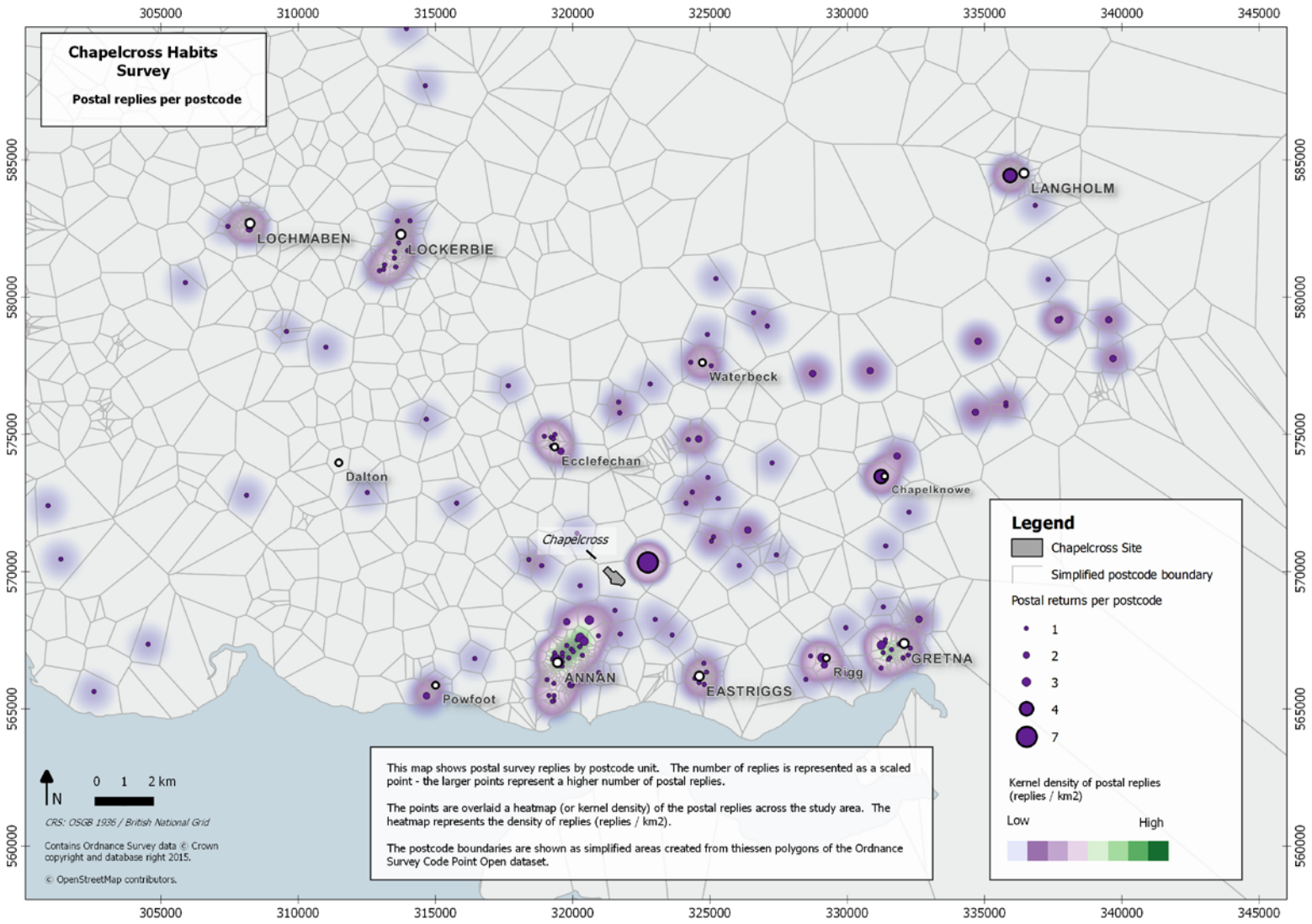

Figure 3.2 Map showing actual responses from across the survey area.

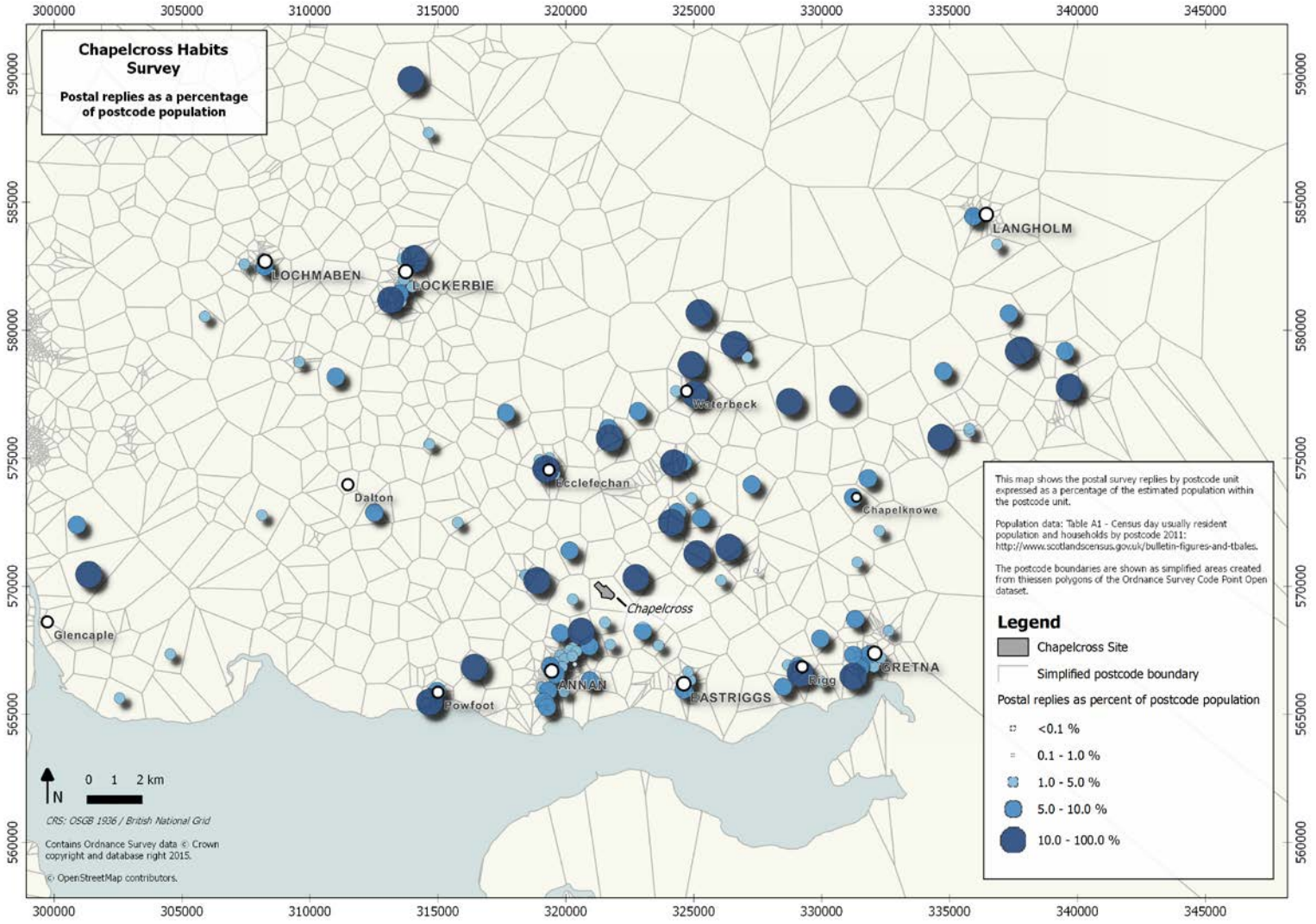

Figure 3.3. Showing the percentage response per size of local population (local population from postcode headcounts 2011).

The survey and information was mailed out and a reminder was sent out after two weeks to people who had not returned the survey. A total of 194 responses were received. The distribution of the questionnaire responses, by postcode, is shown in Figure 3.2. The response rate expressed as a percentage of the estimated number of individuals who live in each postcode is shown in Figure 3.3.

The postal survey helped refine and revise the face-to-face survey tools and identify the optimal areas to target the face-to-face surveys. It also provided additional information on sites to be identified for the collection of observation data and indicated the optimum timings to visit each site. Further information and contacts were obtained with regard to both individuals and a wider range of activities that might merit further investigation in the later survey work.

3.3 Radiometric Survey

The radiometric surveys comprised a carborne gamma spectrometry survey, in-situ gamma dose rate and beta skin dosimetry. The carborne survey work is described in Appendix 10.

3.3.1 In-Situ Dosimetry

The ERL has ISO 17025:2005 accredited procedures for the deployment and recording of gamma dose rate in air. Measurements were undertaken at all locations where occupancy or location was likely to lead to higher exposure to radioactivity or radiations as a result of site activities. These included areas that may have elevated radionuclide concentrations where fine sediment is known to accumulate (e.g. saltmarshes and mudflats). The effective dose from terrestrial gamma radiation was calculated and reported in μSv h^{-1}. Further details of the in-situ methodology can be found in Appendix 11.

3.3.2 Beta Dosimetry

A ruggedized Thermo BP19RD /Electra instrument was deployed to assess the beta dosimetry of skin dose [H'(0.07)]. The BP19RD provided a wide area monitor instrument (100 cm^2) and was used to monitor items that were used in the Solway and potentially exposed to the higher radioactivity concentrations, i.e. close to

licensed discharge points. Further details of the beta skin dosimetry can be found in Appendix 12.

3.3.3 Sampling

Soil cores and sediment scrapes were collected at five locations to assess whether the Chapelcross ^{137}Cs discharges could be distinguished from Sellafield derived ^{137}Cs and the external dose rate attributable to Chapelcross estimated (Figure 3.6). The cores were collected to 300 mm depth with a 105 mm diameter adapted golf-hole corer. Following extraction, the cores were sliced into 50 mm sections. All sampling, preparation and subsequent analysis by laboratory based gamma spectrometry was undertaken in accordance with ISO 17025 accredited protocols.

Figure 3.6 Map of sampling locations for 300 mm length cores and sediment surface scrapes

3.4 GPS Tracking

A total of four wearable GPS tracking units were deployed to individuals for a 4 to 6 day period. The GPS tracker units provided empirical data on areas visited and duration of the visit and provide an independent tool to verify time estimates provided from the 2015 face-to-face surveys. Further details of the system deployed are described in Appendix 13.

3.5 Conduct of the survey

The pre-survey preparations involved discussion with SEPA to discuss any specific requirements for the Chapelcross habits survey. Past survey reports and maps for this site were investigated giving substantial and vital information. A directory of key groups involved in activities in the area was compiled from web searches and from contacting people within the local area with relevant knowledge pertaining to the survey. The proposed programme was then established and passed to SEPA for comment. The approach to the face-to-face surveys is described in more detail in Appendix 14.

A meeting with Chapelcross site representatives provided details of the sites current activities, local information and the potential radiation pathways. The University of Stirling staff were invited by Magnox (Chapelcross) to attend a stakeholders meeting which was between Magnox, local businesses and local residents within the area. This provided further relevant site specific information and is reported in Chapter 2.

Prior to the survey period an article was placed in the local newspaper informing local residents of the survey. During the survey period members of the face-to-face survey team were invited to and attended a local Annan Harbour Action Group meeting regarding the re-generation and dredging of the harbour.

The fieldwork component of the survey was conducted between 13th August 2015 and 26th August 2015. One follow-up visit was also undertaken in the area in April 2016. Information was gathered from informal meetings with groups and information collated from the past reports, web searches and local people. Four members of staff from the University of Stirling conducted the face-to-face interviews, observations and gamma dose rate and beta dose rate measurements. Two additional members of staff undertook the pipeline survey, consisting of a mobile gamma spectrometry survey and gamma dose rate measurements. In addition, saltmarsh cores were also collected at five locations to assess impact of discharges from Chapelcross. The pipeline survey and sediment sampling were undertaken during the same period as the face-to-face surveys.

People interviewed had a range of occupations and were undertaking a number of different activities including, but not limited to: fishermen; anglers; dog walkers; people taking part in activities on intertidal areas; people that lived beside intertidal areas; beekeepers; farmers; photographers; cyclists; allotments gardeners and people that worked and lived near the Chapelcross site. The intertidal sites were visited throughout the survey period, taking account of the tide times to ensure an optimum opportunity to interview fishermen.

3.6 Meetings and Informal Contacts

In the 2015 survey, a range of meetings with relevant parties and individuals as well as a 'standard' face-to-face interview schedule. The multi-methods approach provided a means to 'triangulate' (verify) the data acquired through the different approaches: for example, to check occupancy and activity data against the 'snapshot' observations recorded over a limited number of days in one season acquired from the individual face-to-face interviews. The meetings also provided some additional information about local produce grown by householders, allotment owners, horticulturalists and farmers and consumption of particular types of local food such as honey and game. The information gathered also facilitated some snowballing of the survey because the individual meetings provided additional contacts to follow up on. These groups were approached prior to, during and after the face-to-face interviews by telephone and email.

Prior to and during the survey a directory of local groups, bodies and organisations relevant to the survey was compiled. The directory proved an invaluable resource through the survey period both for gaining informal contacts and for use as a checklist against which responses and non-responses from potentially important groups with regard to activity, occupancy, exposure and local food consumption could be recorded. The directory was revised during the survey with updated information. The directory development required extensive web searches, follow up telephone calls and use of earlier contacts across organisations and businesses.

Various related informal meetings were also held with groups such as contacts with community councils, community groups and centres, social clubs, youth groups and other local organisations and business groups. The information gathered helped to

ensure the face-to-face interviews were relevant to the survey, comprehensive and covered all the key topics necessary. The meetings also supplemented information from the postal survey and the face-to-face interviews, and provided an opportunity to gain more information or address omissions relating to the face-to-face surveys. Information gained related to the type of activity or type, quantity and rate of food consumption. This also included the provision of information on new developments and location of activities and change in activities.

3.7 Data Conversion

During the face-to-face interviews data on food consumption were recorded in units provided by respondents (e.g. pounds, grams, and ounces) and later converted into kilograms per year. In some cases, respondents were unable to estimate food consumption in kilograms per year and instead gave approximations such as the number of plants grown or the length and number of rows, these data were converted into consumption rates using conversion weights where possible e.g. one broccoli plant typically yields 700 g (Garden Forum Horticulture, 2009; Hessayon, 2014) so that all consumption figures were reported in kilograms per year.

3.8 Data Rounding and Grouping

All data collected from the face-to-face and postal surveys were reported to two significant figures. For the food consumption data, the total annual consumption (kg) of different food types were calculated by multiplying the quantity (kg) and frequency (number of times per year). The food items were placed into groups with similar attributes (Table 3.1). Respondents were given the option to add any additional food items in ‘Other’ food category.

The time respondents spent carrying out activities was calculated by multiplying frequency (occasions per year) and duration (hours) taking into account seasonality where appropriate. Respondents accounted for any holidays and working hours within their survey replies. In addition to food consumption a ‘liquid’ category was also added and respondents who carried out aquatic activities that could result in the inadvertent ingestion of water, e.g. outdoor swimming/sailing, were identified to

account for this pathway. Quantities estimated were reported following personal communication.

Table 3.1 Food groups used in the habits survey

Food group	Example of foods within this group
Green leafy vegetables	asparagus, broccoli, brussel sprouts, cabbage, calabrese, cauliflower, celery, chard, herbs, kale, kohi rabi, lettuce, pak choi, rhubarb, spinach
Other domestic vegetables (legumes)	broad bean, French bean, pea, runner bean,
Root vegetables	beetroot, carrot, celeriac, fennel, garlic, Jerusalem artichoke, leek, onion, parsnip, radish, shallot, spring onion, swede, turnip
Potato	potato
Domestic fruit	apple, blackberry, blackcurrant, blueberries, corn, courgette, cucumber, gooseberry, grape, marrow, pear, pepper, plum, raspberry, redcurrant, squash, strawberry, tayberry, tomato
Milk	milk, yoghurt, cheese
Cattle meat	beef, buffalo
Pig meat	pork
Sheep meat	lamb, mutton
Poultry	chicken, duck, goose, partridge, pheasant, quail, turkey
Eggs	eggs
Wild/free foods	blackberry, chestnuts, crab apples, damson, dandelion root, garlic, elderberry, elderflower, mushrooms, nettle, raspberry, rowanberry, sloe, strawberry
Honey	honey
Venison	venison
Fish	bass, cod, Dover sole, kipper (herring), mackerel, pollock, salmon, sea trout, trout (freshwater)
Crustaceans	brown crab, common lobster, shrimps
Molluscs	mussels, razor clams, scallops, winkles
Wild fowl	mallard, pink-footed goose, teal, widgeon

The age groupings used in this report are based on International Commission of Radiological Protection (ICRP) recommendations and are listed below in Table 3.2

Table 3.2 ICRP age groups used in the dose assessment

Name of age group	Referred to	Age range
Group 1	Infant	0-5 year old
Group 2	Child	6-15 year old
Group 3	Adult	16 year old and over

3.9 Qualitative and Quantitative Observation

Whilst undertaking the face-to-face surveys, observational data were acquired on obvious changes to each location such as new build housing, along with information on site usage and numbers of individuals undertaking specific habits. Observations were acquired over a specified time period, e.g. 20 minutes, and on-shore and offshore (including intertidal) activities were noted. The number of individuals, their gender and their approximate age group undertaking each activity were also noted or estimated where large numbers were observed, e.g. beach activities. Some individuals were approached where possible and subsequent face-to-face surveys were conducted. Contact with individuals during face-to-face interviews frequently allowed the accuracy of observations to be checked and sometimes to be expanded: for example, dog walkers might also engage in beachcombing and sailing at other times. Along with noting the weather conditions at the time of survey, this approach provided a basis for making a comparison with habits at different times and within and out with the period of the local school holidays.

3.10 Dose Assessment Tool

The habits dose assessment spreadsheet tool collates the data from the face-to-face survey for Chapelcross and uses the consumption rates and habits data to calculate a retrospective dose to each interviewed member of the public, covering the total exposure from all pathways. It should be noted that only the consumption of locally produced food has been included in the retrospective dose assessment (i.e. food from outside the survey area is not included within the assessment). The retrospective dose includes an assessment of the exposure from shine associated

from discharges and on-site activities. The dose assessment was carried out following the guidance in NDAWG and ICRP for the *Representative Person*.

Activity concentrations for the different foodstuffs consumed were taken from the last five years of Chapelcross monitoring data published in RIFE (2009-2014). Dose coefficients for different age groups are described by ICRP (2012). As described in section 3.7, data for the 2015 Chapelcross Habits Survey were collected in three age groups.

The tool analyses four general exposure pathways:

(i) *Internal terrestrial*, which includes the consumption of locally produced meat, fruit and vegetables;

(ii) *External terrestrial,* which determines the external doses from exposure to radiation present in the terrestrial environment as a result of deposition from atmospheric discharges and direct exposure through shine from on-site activities with radioactive materials;

(iii) *Internal aquatic*, which includes ingestion of fish, crustaceans, molluscs and inadvertent consumption of seawater. A proxy for inadvertent drinking of water was calculated by multiplying the time spent on aquatic activities by the known average of water ingested in such activities as described in Leonard *et al.* (2014), McBride (2012) and Stone *et al.* (2008); and,

(iv) *External aquatic,* which estimates the dose from external exposure through aquatic activities e.g. from radionuclides present in the aquatic environment (in water and sediments in saltmarshes or intertidal areas).

The direct exposure to shine from on-site activities was included in the analysis using in-situ measurements. These data were estimated by measuring the gamma dose rate and subtracting a nearby background and independently by mobile gamma spectrometry. These data were used to calculate direct exposure to members of the public that regularly travelled through the area close to the site.

The representative person was calculated independently for the total consumption and habits first and then by each exposure pathway. To identify the representative person, the 97.5 percentile rate cut off method was applied (see Chapter 1).

4. Aquatic Radiation Pathways

4.1 Introduction

The survey locations were established from the work presented in Chapter 2 and to allow comparators to be drawn with the previous Chapelcross Habits Survey and Pipeline Survey undertaken in 2010. The sites were visited throughout the survey period and observations of offshore and onshore activities were undertaken at each site. Each site was visited at different times of day according to the survey schedule, site activity and proximity to the Chapelcross site and pipeline.

4.2 Postal Survey Results

Of the 1000 postal surveys that were sent out to households in the survey area 194 households returned their surveys, 42 of the surveys were returned either incomplete or illegible and the remaining 152 postal returns were used in analysis along with extra information obtained on behalf of other household members. The postal survey proved useful for identifying popular activities (Figure 4.1) along with where households take part in certain activities, as respondents were asked to mark down where they carry out their activities on a map of the survey area. This information was mapped onto a heat map[2] to identify popular areas and activities around Chapelcross works (Figure 4.2). These areas were later factored into the schedule for the face-to-face surveys.

In addition to location, households were asked to indicate how often they participate in certain activities which was converted into number of days per year; most days (260 days per year), once or twice a week (104 days per year), once or twice a month (24 days per year), once or twice a year (2 days year) or never (0 days per year). No information on how long individuals spent doing these activities was captured. The results of the aquatic radiation pathway can be found in sections 4.2.1, 4.2.2 and terrestrial radiation pathways in sections, 5.2.1 and 5.2.2.

[2] A heat map is a graphical representation of data where the individual values contained in a matrix are represented as colours which progress in intensity or colour is in proportion to the magnitude of the value.

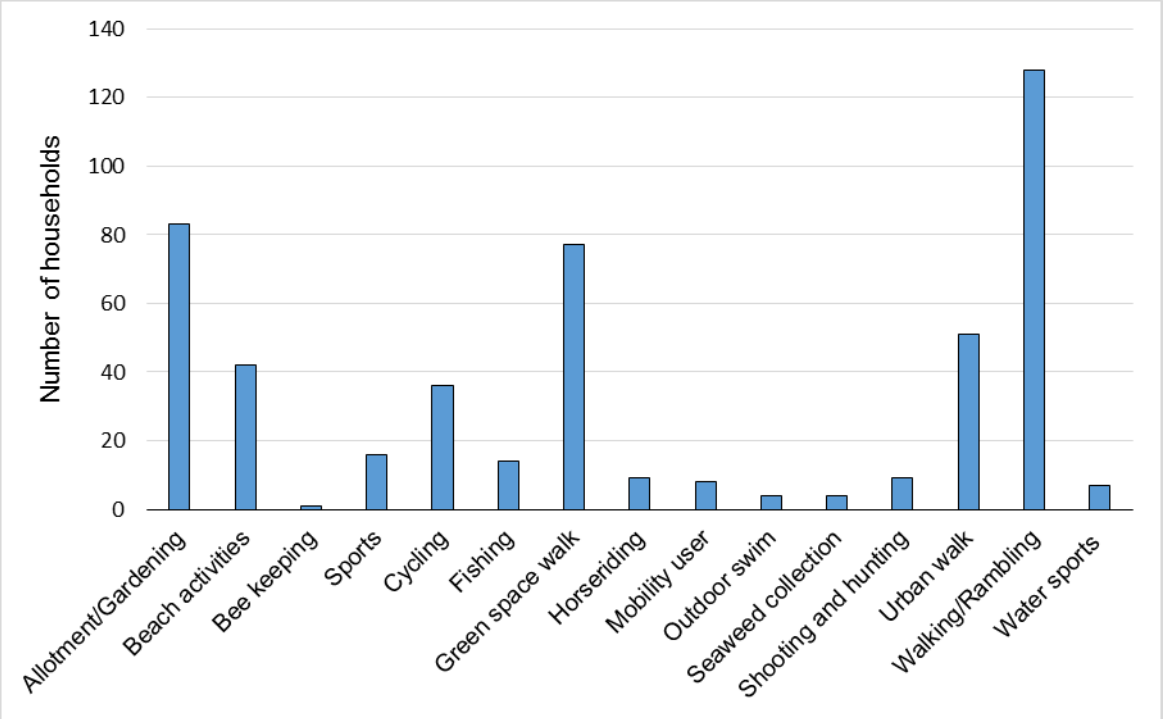

Figure 4.1 Overview of the number of household participating in activities within the survey area.

4.2.1 Internal Exposure

Each household was asked to indicate how often members of their household consume local fresh or frozen fish/crustaceans/molluscs (Table 4.1). The 152 household postal returns showed that 37 individuals from within the households consume crab, lobster, mussels and 141 consume fish such as cod, salmon, haddock and mackerel each varying in frequency. A summary of results from the postal survey shows that respondents consume fish (79%) more frequently than they consume crustaceans and molluscs (21%). A total of 51% of individuals consume fish 104 days per year with a low number of respondents consuming fish every day (8%). For crustaceans the highest number of respondents consume crustacean/molluscs twice a year.

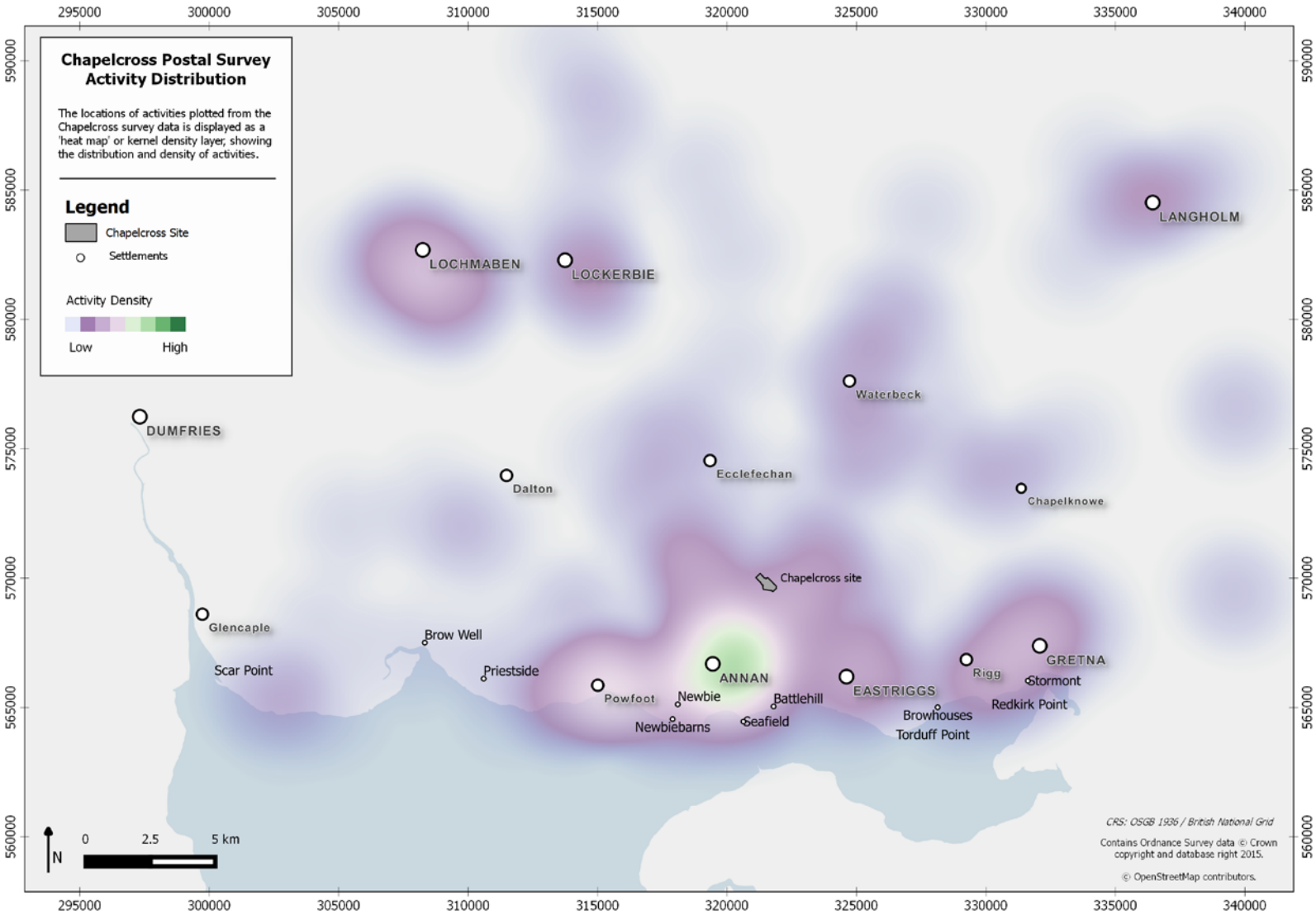

Figure 4.2 Heat map showing where respondents carry out activities within the survey area.

Table 4.1 Summary of how often members of a household consume aquatic food types.

Food type	Frequency (days per year) 260	104	24	2	Total
Crustacean/molluscs (Crab, lobster, mussels)	1 (0.5%)	6 (3%)	14 (9%)	16 (9%)	37 (21%)
Fish (cod, salmon, haddock, mackerel)	14 (9%)	90 (51%)	33 (23%)	4 (2%)	141 (79%)
Total	15	96	47	20	178

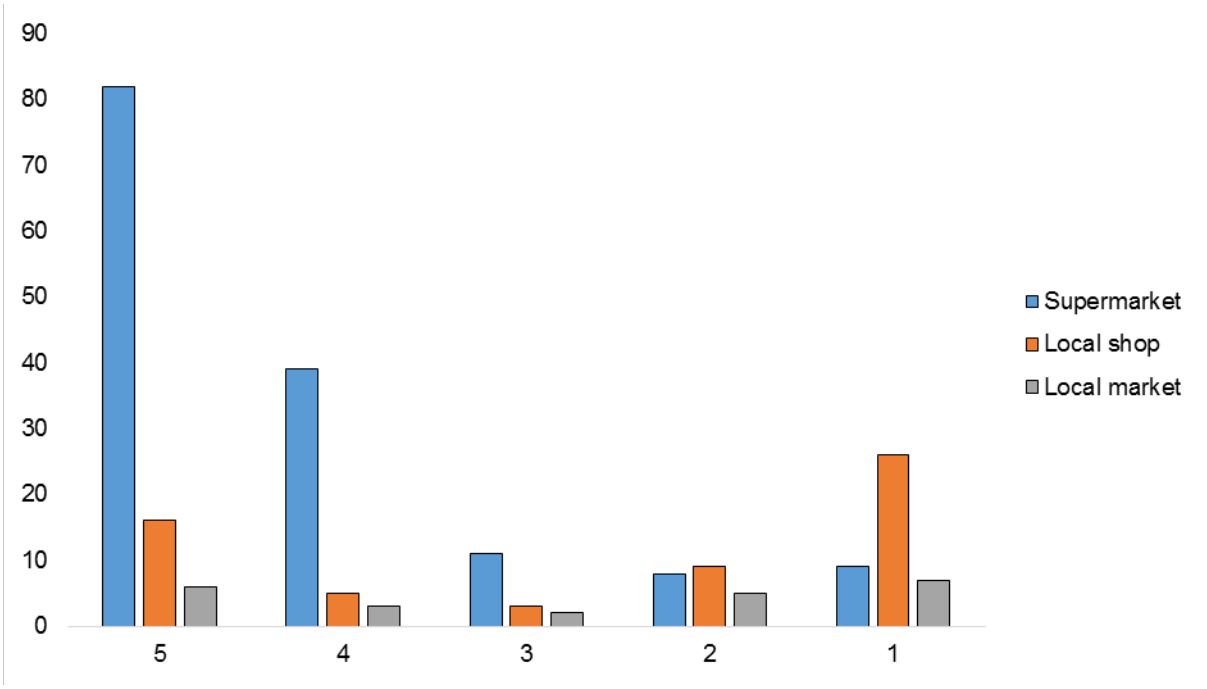

Figure 4.3 Summary of how often respondents obtain fish/crustaceans/molluscs from supermarkets/local shops or local markets. Scale: 5 (always) to 1 (occasional).

Participants were also asked to provide information on where their household sourced their aquatic food (a supermarket, local shop or local market) and how often they buy at these sources on a scale of 0-5 (0=never, 5=always). The results of where and how often people source their aquatic food is displayed in Figure 4.3. Results show that the supermarket is the most popular source for fish/crustaceans/molluscs and out of the 149 individuals that recorded to shop at a supermarket 55% of them always use this source. Fifty-nine individuals indicated that they sourced their aquatic food from a local shop and 23 from a local market.

4.2.2 External Exposure

A number of households carry out aquatic or intertidal activities within the survey area. The frequency and total number of visits are presented in Table 4.2 with the

highest number of respondents taking part in beach activities (e.g. walking, paddling, beachcombing) followed by outdoor swimming and water sports.

Table 4.2. Total number of individuals participating in aquatic activities within the survey area.

	Frequency (days per year)				
Activity	**260**	**104**	**24**	**2**	**Total**
Beach activity	4	6	15	17	42
Fishing	1	0	5	8	14
Outdoor swim	0	0	1	3	4
Seaweed collection	0	0	1	3	4
Water sports	0	3	1	3	7

4.3 Aquatic Survey Area Descriptions

The aquatic survey area stretches from Glencaple to Gretna and covers all of the Scottish side of the Solway Firth and its intertidal areas, see Figure 2.1. There are several main watercourses that run into the Solway Firth. These are the rivers Nith, Annan, Eden, Esk, the Kirtle Water and the Channel of Lochee Water. The highest tidal ranges in Scotland are in the Solway and the Solway possesses many hidden channels and strong currents. The average spring tidal range can be between 7 and 8 metres with the strong currents having the ability to shift great amounts of sand over a large distance.

A large area of the saltmarsh particular to the Solway is a Site of Special Interest (SSSI) and the inner Solway flats are a Special Protected Area (SPA) for birds. There is a nature reserve at Caerlaverock.

The survey sites are reported from west to east.

4.3.1 Glencaple

Glencaple is the furthest west site within the survey area situated on the banks of the River Nith. During the period of survey, it had one boat which was permanently moored at the pier with a couple living on the boat. The boat did not move from the pier. Anecdotal evidence reports the couple are to be moving away from this area in the near future. The shore is accessible from the banks of the River Nith with the substrate being mostly mud with rocks.

4.3.2 Scar Point and Caerlaverock

Scar Point (Figure 4.4) is situated south of Glencaple at the mouth of the River Nith. The shoreline here is dominated by saltmarsh with Scar Point being just to the east of the Caerlaverock Nature Reserve. Caerlaverock was observed to be a more popular area than Scar Point with approximately 22 dog walkers, cyclists, nature watchers and walkers noted during the survey period. There was a small caravan and camping site situated beside the Caerlaverock car park (the Castle Corner Campsite) where a total of four campervans and caravans observed throughout the survey period. Large intertidal areas between Scar Point and Caerlaverock are saltmarsh and during very high tides, large extensive sections tend to be inundated by the sea. During the face-to-face interviews, a gamekeeper confirmed that wildfowling was undertaken within the Scar Point and Caerlaverock area from 1st September to the 20th February each year. It was reported during the face-to-face interviews that foraging for wild produce was undertaken in the Caerlaverock area, including samphire and wild mushrooms. Cattle were observed to be grazing on the saltmarsh area of Scar Point and Caerlaverock.

Figure 4.4 View looking south west from Scarpoint at Caerlaverock

4.3.3 Brow Well and Priestside Marsh

Brow Well is situated on the eastern side of the Caerlaverock Nature Reserve and access to the saltmarsh shore is available at this point which leads eastwards to Priestside Marsh. Access to Priestside Marsh (Figure 4.5) is only available from Brow Well or from Powfoot to the east. Only one couple (who live locally) sightseeing was noted at Brow Well. Between Brow Well and Priestside marsh 17 dog walkers, ramblers and nature watchers were noted during the survey period. Samphire and wild mushroom collecting were identified and it was identified that foraging for wild fruit was additionally undertaken in this area (Appendix 25).

During the survey period this area of saltmarsh was used for grazing cattle (in the upper area of the saltmarsh cattle were observed grazing within a fenced area) and was noted to be popular with wildfowlers throughout the face-to-face surveys although none were observed.

Figure 4.5 Looking eastwards over Priestside Marsh

4.3.4 Powfoot

Continuing eastwards from Priestside Marsh the saltmarsh stretches to Powfoot with a large sandy expanse popular with locals and tourists from outside the survey area either visiting for the day or staying in the caravan site. Many people were found to live outside the survey area, but spend spring and summer at the caravan site. This area was very popular with dog walkers, nature watchers and families. Four people were observed using quad bikes on the sandy expanse at low tide who were sampling mussels for marine research (the research institute was undetermined). One horse rider was also observed on several occasions during the survey period. Four persons were also observed horse riding westwards from Powfoot to Priestside Bank. The shore line continues from the caravan site into Powfoot itself with the substrate being sand, mud and saltmarsh (Figure 4.6). Many local dog walkers were noted here. Foraging for wild fruit was undertaken at this site and wildfowling was identified.

Figure 4.6 A view looking east toward Powfoot

4.3.5 Newbiebarns

The shore line at Newbiebarns was mainly stones with mud and was accessed by a path to the shore. There was a path that followed the shore towards an area known locally as “The Point”. This was a short circular walk taking you away from the shore towards Newbie than back towards Newbiebarns. During the survey period eight walkers and dog walkers, one jogger and one cyclist were noted. One person regularly collected flowers locally and it was identified that foraging for wild fruit was undertaken at this site. One local was reported to beachcomb after each high tide looking for large pieces of wood or trees that had been washed up for his own use. This person’s family previously owned the stake net in this area. It is understood that stake net fishing no longer occurs, which is a change since the previous survey in 2010. Wildfowlers were observed at this site. Cattle were observed grazing on the saltmarsh.

4.3.6 Annan Harbour

Annan Harbour was visited during the survey period and was a popular area (Figure 4.2) with dog walkers and tourists from out with the survey area and with locals. The Annan Harbour Action Group is an active group run by people with an interest in the future of Annan Harbour. Two members of staff were invited to one of the meetings which they attended on 20th August 2015. The information gained from this meeting was that the Annan Harbour Action Group was keen to extend the area of dredging of the River Annan by approximately 100 metres, although this was not currently possible due to the presence of boats. Both boats require to be moved by their owners before any dredging can continue further up the River Annan. All the previous dredged material has been deposited along the banks beside T N Trawlers – a commercial scallop fishing and processing company. The dredged material has been seeded with *whin*[3] and grass and this is now growing. This seeding was hoped to reduce dredged substrate being washed away during high tides. It was reported in the meeting that it appeared the material had not moved since being deposited.

[3] *Whin* is a spiny dense evergreen shrub (gorse)

The Harbour had one commercial scallop trawler, two small fishing boats moored just passed the slip and two unused boats which block the river further into the River Annan. The substrate is mud and silt. Figure 4.6 shows Annan Harbour and the T N Trawlers commercial scallop trawler moored and Figure 4.7 which shows the two unused boats.

The area around Annan Harbour provides a large area for parking and this is reported to regularly flood on high tides. There is a mechanic/engineering yard, boat yard and Farm Direct wholesale store beside the car park.

Figure 4.6 Annan Harbour showing scallop trawler

Figure 4.7 Two unused boats and several small fishing boats moored at Annan Harbour

4.3.7 Galabank Park

Galabank Park is located off Battery Street in Annan, on the riverside of the River Annan, separated from the river by a stone wall and grassy riverbank. The surrounding area is grass with a sloped embankment covered with vegetation and trees that backs onto a road and residential housing

4.3.8 Waterfoot

From Annan Harbour, continuing to the end of Waterfoot Road that runs through the merse to Waterfoot (Figure 4.8), the shore can be accessed and is predominantly mud, sand and saltmarsh. This site is situated on the eastern shores of the River Annan and was noted to be popular with cyclists, joggers and walkers. Several families were observed walking. The merse (saltmarsh) area east from the River Annan was noted to be grazed by cattle. Haaf net fishing was reported to be active from Waterfoot with sea trout and salmon being caught although no interviews were obtained and no observation of this was noted at this site.

One individual used to collect mussels and razor clams at Waterfoot, but no longer does as they stated the quality of the mussels were poor given that they were too silty/sandy.

Figure 4.8 Waterfoot looking eastwards over the merse

4.3.9 Seafield and Battlehill

The shore continues to Seafield and Battlehill (Figure 4.9) and is predominantly mud and stone with large expanses of sand and mud exposed at low tide. Stake net fishing and haaf net fishing (by licence) are active at both these sites with access down onto the shore at Seafield by foot and also access for a tractor for the stake net fishing. At Battlehill access to the shore was by foot only but a tractor was situated on the shore itself which the fishermen used when working with the stake nets. Both salmon and sea trout are caught here. No poke net fishing occurs at this or any site at present, in contrast to poke net fishing identified at Seafield in the previous survey in 2010. This area between Seafield and Battlehill was the main fishing area for both stake net fishing and haaf net fishing. The shore area around Seafield and Battlehill is regularly used by dog walkers, walkers, joggers, nature

watchers and locals. Cyclists were observed on the access road to the areas. Foraging for wild fruit was identified at both Seafield and Battlehill, in addition, mushrooms were collected at Seafield. The outfall pipe from Chapelcross is visible at Seafield and exits from the end of a stone faced embankment into the Solway Firth. One man was identified walking his dog daily along Seafield and to the outfall pipe. The outfall pipe is exposed at low tide. Cattle were grazing in the surrounding fields of Seafield and Battlehill.

One individual who was interviewed stated they used to collect mussels and razor clams at Battlehill and Seafield but no longer does this due to their quality. He stated the mussel bed is covered over with sand as a result from Estuary dredging.

Figure 4.9 View looking west at Battlehill

4.3.10 Browhouses

Browhouses is a small community beside the shore of the Solway Firth. Onshore activities were dominated by locals walking and dog walking. Tourists were also observed, including two tourists in the layby in their campervan and a couple dog walking and nature watching whilst visiting family in the area. The shore, accessible

via several paths, was observed to be grazed by cattle that were retained behind a fenced in area of the upper saltmarsh. The shore was predominantly mud and rock with mud, sand and seaweed was visible at low tide as shown in Figure 4.10. Foraging for wild fruits and wild mushrooms were identified at this site.

Haaf net fishing was reported in this area, for both sea trout and salmon. However, none were observed during the survey periods.

Figure 4.10 View looking inland at Browhouses

4.3.11 Redkirk Point

This site was accessible by a very rough road and only three persons were observed at this site. Two people had been walking along the shore and one person reported he regularly spent time at this site metal detecting. Access to the shore was from a path leading from the road and was mainly rock, mud and sand. A haaf net and rowing boat were observed at this site, but no active fishing was observed. It was however reported that haaf net fishing did take place here. The surrounding land was

agricultural and cattle were observed to be grazing in the field nearby. See Figure 4.11.

Figure 4.11 View towards the east at Redkirk Point

4.3.12 Stormont

This area was popular with wildfowlers. Some people set out from Stormont (Figure 4.12) to row over the River Esk and then walk over the exposed sand at low tide towards the Mersehead on the English side for wildfowling (Figure 4.13). Haaf net fishing took place at Stormont with a haaf net visible at the site. However, none individuals were observed. Maize was growing in a field nearby and cattle were observed grazing on the area of the saltmarsh between Stormont and east of Redkirk Point. Moreover it was observed some cattle were free grazing and smaller number cattle were grazing behind a fenced area of the upper saltmarsh. Nature watchers and dog walkers were also noted at this site.

Fig 4.12 View looking east at Stormont

Figure 4.13 Wildfowlers walking over to Mersehead on the English side of the Solway having rowed over the River Esk channel from Stormont to the exposed sand at low tide.

4.4 Commercial seafood operations and controls

4.4.1 Stake Net, Haaf Net and Poke Net Fishing

Salmon and sea trout are traditionally caught in the Solway and the stake net, haaf net and poke net fishing season commenced on 28th February running until 9th September in 2015. However, when the fishermen take out their lease or licence, due to conservation measures, it comes with conditions imposed upon them that delays the fishing season to commence on 1st May 2015. The fishing rights belong to the Annan Common Good Fund. A further measure to ensure the conservation of fish species was to reduce the number of licences issued to 30. As reported during face-to-face interviews, and confirmed by a contact through Dumfries and Galloway Council, no poke net fishing licences were renewed or issued in 2015. Licences were issued for haaf net fishing in 2015 and this (and as for poke net fishing) is done annually. The stake nets are leased per stake net for five years and only one stake

net was leased in 2015, though this requires two to three people to tend. For the 2015 stake net, haaf net and poke net fishing season there was a catch quota of five salmon per licence and for sea trout there is a catch quota of two within a 24 hour period. Fishing was not allowed over the weekend period from 1800 hrs Friday to 0600 hrs Monday.

Stake nets, shown in Figure 4.14, are supported by wooden poles approximately three metres in height with a cross wall of netting containing many small nets facing the sea. The fish are guided by the netting wall towards the trap when the tide comes in as they swim along the shore and then cannot escape. The nets are checked at each low tide. Any fish caught are retrieved and debris, if any, is cleared from the nets.

Figure 4.14 Stake nets at Battlehill

Haaf nets are rectangular and strung from wooden beams of approximately five metres in length with poles at either end and a central pole ‘handle’ is used to complete the scoop. The fishermen wade out to around a metres depth into the river

channel holding the net facing the current. The net is used like a scoop and any fish swimming into the net are scooped up and caught. Haaf net fishing usually involves several people together standing in a line, fishing at 90 degrees to the shore to the shore together, to trap any fish.

During extremely high tides and weekends the fishermen regularly check their nets to remove any debris from them. A tractor is used at the Battlehill site to get to the stake nets.

At the end of the fishing season the fishermen dismantle the stake nets and a tractor is used to help remove the nets. The nets are then repaired and stored, with any nets damaged beyond repair discarded. The haaf nets are dismantled and any damaged netting repaired. The net is then cleaned to remove sand and any debris is picked off. The net and beams are stored until the following season and it was identified during the survey that some haaf net fishermen stored this at home and some stored them in a fishing store on site.

The licences for persons practicing poke net fishing had not been renewed due to the restrictions of the quantity they were allowed to catch and times of fishing. This is identified as changed from the 2010 survey where poke net fishing took place.

Contact was made with the Solway Firth partnership. Haaf net and stake net fishermen on the Nith and Solway sold their fish to the Glasgow markets. Catches consisted of salmon (including grilse), sea trout and occasionally seabass and flounder. Seabass and flounder were a by-catch. Salmon were caught on the Nith and the Solway at Battlehill, Seafield and Browhouses. Trout were caught on the Solway at Battlehill, Seafield, Browhouses.

In June 2015, it was announced that Dumfries and Galloway Council had terminated the lease in the Solway Firth near Annan for stake netting of salmon. The ban was geared to boost salmon numbers in nearby rivers. A recent meeting in Annan during October 2015 highlighted the fears of local fishermen due to *the Scottish Government currently considering a possible ban of salmon fishing on the* Scottish side of the Solway Firth. The Scottish Governments aim being to ensure there is no threat to vulnerable stocks of salmon. The Annan Common Good Fund sub-committee outlined its response to this move highlighting its importance of the

“unique methods of fishing” now only occurring in the Solway and the devastating impact it will have on stake net, poke net and haaf net fishermen. This was reported by BBC Scotland in October 2015.

In early 2016, contact was made with several organisations (Appendix 16a - 16e) including net fishermen to identify any changes in fishing practices since 2015. In 2016, conservation measures were introduced by the Scottish government with the aim of ensuring the sustainability of the fish stocks. The complete ban that was put in place was partially lifted following an appeal by the net fishermen. In 2016, three salmon per season are allowed to be taken per net fisherman along the River Annan. There are no restrictions for trout to be taken by net fishing, but the net fishermen are encouraged to release the larger, breeding trout and only take the smaller fish, typically between 2-3 lb of trout per day.

The Annan Common Good Fund reported that no stake or poke netting will take place in 2016 along the coast. Haaf net fishermen are allowed to catch three salmon per season. This is in contrast to the 2015 policy where up to 5 salmon per licence was allowed. For clarification, the net fishermen are allowed to take only two trout per tide per day in 2016; the same as in 2015. Net fishing was still not allowed over the week-end as in 2015.

Three new net fishermen were surveyed in 2016 and one-re-surveyed from 2015. Fish caught appeared to be for personal consumption although one B&B in Cummertrees sold sea trout, sourced from the area, to passing trade. This appeared to be an isolated enterprise. The proprietors of the B&B could not provide details on any fish quantities sold this way. Further monitoring of the fishing policy is recommended in future surveys with particular attention paid to net fishing along the rivers.

Within the survey area, a fish van is known to sell produce but the fish were generally sourced from the East Coast. On occasions, stake and haaf net fishermen have also sold fish to the fish van. There are other commercial fish processing activities in the survey area, such as Young Seafood Ltd in Annan (but this is part of a pub food chain) and St James Smokehouse in Annan which deals with salmon from outside the study area.

4.4.2 Commercial Trawling

With Annan harbour closed to commercial fishing boats, the nearest port for recorded fish or shellfish landings is at Kirkcudbright. No information on whether fish landed at Kirkcudbright is sent to any of the fish processes in Annan has been made available. For references purposes, information on fish landings and type in the Dumfries and Galloway coastal area can be found on the SGAS website (*www.gov.scot/Topics/Statistics/Browse/Agriculture-Fisheries*).

Efforts were made in 2015 and 2016 to identify the consumption of sea fish caught commercially in the survey area, but none could be identified. Consequently, little new knowledge would be gained from any further investigations. However, given the proposed plans to develop Annan Harbour, this should be reviewed in future surveys.

4.4.3 Shellfish Activity

The SGAS data indicates there were no landings of commercial shell fish at Annan harbour and confirms the findings of the 2015 survey that in general consumption of shellfish sold was not from the survey area. However, one person interviewed had collected 27 kg of shrimp from the Solway in 2015. These were packed for home selling in the area. Another individual interviewed identified that they consumed scallops caught by a fishing vessel based in Annan (Appendix 17). The follow-up survey in 2016 also confirmed that shrimp fishing was undertaken by the one individual fisherman in 2015 and continued in 2016. However, continued monitoring of the status of Annan harbour for commercial boats should be included in future surveys.

4.5 Food Processors and Retailers

4.5.1 Fish Processing

Fish processing is a major activity in the survey area, with three companies based in Annan (Appendix 18a, 18b & 18c). However, it was not possible to obtain information from processors for commercial reasons. All fish processed came from outside the survey area with no evidence of a local source. Consequently, no pathway could be

identified for the consumption of local fish products from these processors. The 2016 re-survey confirmed the findings from 2015 that most people buy processed fish from non-local sources.

4.5.2 Shellfish Processing

With Annan harbour closed, the nearest shellfish landings are recorded at Kirkcudbright and no information on where the shellfish were caught was available. There is one trawler based shellfish company located in Annan (Appendix 17), which process scallops in a unit next to Annan harbour. Communication with the company indicated that the scallops were sourced from outside the area and from no one specific area. There is no local market for the scallops, apart from approximately 10 kg per week sold locally at the door. The rest are sent to Europe. Given that there are no local sources then the consumption of processed fish is from non-local sources.

4.6 Non-commercial fishing and angling

The website, *Fishpal*, (www.fishpal.com) reported that the inner Solway is not a major sea angling area. However, the same website also stated a range of fish have been caught in the inner Solway Firth area that covers one or more of the agricultural parishes. Sea angling on the Scottish Inner Solway for flatfish, seabass and grey mullet occurs. Flounders can be caught in large numbers and occasionally Dover sole. No data on the numbers of people who undertake sea angling in the area could be found or details on the catch and return policy.

One person interviewed used to collect mussels and razor clams at Waterfoot, Annan . However, this person no longer does because the quality was considered not satisfactory because of problems with silt and sand. Similarly, another person used to collect mussels and razor clams at Battlehill and Seafield but no longer does so. The 2016 survey re-surveyed an individual from 2015 who reported that they plan to discontinue sea fishing in the area.

No pathways could be identified for the consumption of sea fish caught in the survey's coastal area or any potential impact on the representative person(s). Future surveys should again try to contact sea anglers in different ways including: on-line

fishing sites (http://www.fishpal.com; www.britishseafishing.co.uk/west-coast-of-Scotland), social media (Scottish Federation of Sea Anglers Facebook group) or target sea anglers through targeted face-to-face surveys.

4.7 Wildfowling

A number of wildfowling clubs shoot in the survey area. These include the Scottish Solway Wildfowlers' Association Inner Solway Group.

Wildfowling occurs in the survey area along the Solway coast, at Powfoot, Priestside, near Annan, at Caerlaverock and on the Scarpoint coastline. Nine wildfowlers have been identified in the survey period. Widgeon, teal, pintail, mallard, snipe, pink footed geese and grey lag geese are for example shot in the area with a maximum of 16.32 kg y^{-1} being consumed. Geese and duck are also shot at Browhouses, the Kirkpatrick Estate.

4.8 Other Pathways

There was one report of an outdoor swimmer in a tributary of the Esk. Paddling, children playing and sunbathing at sites such as Powfoot and Galabank Park, Annan were common. Walking groups such as the Annan Walking group and ramblers used paths in the area as did cyclists, dog walkers, runners and some horse riders on the beach. Campers were present at Caerlaverock and Stormont. With the presence of the nearby RSPB reserve, it is not unusual during the year to see birdwatchers on the intertidal area searching for waders, geese and duck. Youth groups such as the Annan Guides and Annan Scouts also visited the shoreline on occasions. Volunteer workers linked to the Annan Harbour Action Group could also be present on the shoreline and the group had built two skiffs and planned to join the Scottish Coastal Rowing Association, but were not active in 2015 and no rowing was observed here.

The Nith Inshore Rescue, a volunteer group, based at the Nith Inshore Rescue Lifeboat Station Glencaple in Dumfries had in the past rescued fishing boats stuck on stake nets at Battlehill. They have also rescued wildfowlers at Caerlaverlock.

Shooting of rabbit, deer and pheasant for human consumption was also reported at Caerlaverock, Priestside and Newbiebarns although this activity was not usually along the shore line or intertidal areas.

Wild mushrooms were collected on saltmarshes and along the shore near Thwaite, between Priestside Marsh and Brow Well and on the Waterfoot shore. Samphire was also collected for human consumption in the area again near Thwaite and additionally between Priestside Marsh and Brow Well and at Waterfoot Merse.

4.9 Internal Exposure

4.9.1 Adults' Consumption Rates

Table 4.3 presents a summary of the consumption rates for aquatic food types including; fish, crustaceans, molluscs and wildfowl. Mean adult consumption rates for the high-rate groups and the observed 97.5th percentile rates, the high-rate group was determined using a cut off method. The generic mean and generic 97.5th percentile rates based on national habit data are also included (Smith and Jones, 2003).

Adults consumed salmon (16 individuals), cod (10 individuals), mackerel (9 individuals), sea bass (9 individuals), pollock (5 individuals), trout (4 individuals), Dover sole (1 individuals), kipper (1 individual), and sea trout (1 individual) all sourced from within the aquatic survey area. The observed maximum consumption (quantity*frequency) of fish was 47 kg y^{-1} and this individual consumed salmon (45 kg y^{-1}) and trout (2 kg y^{-1}), all were self-caught on the coast near Annan.

Crustacean consumption consisted of mainly brown crab, common lobster and shrimps. Of the crustaceans consumed, two individuals consumed brown crab, 1 individual consumed common lobster and two individuals consumed shrimps. The highest consumption was 20.8 kg y^{-1}, this individual consumed brown crab (20.8 kg y^{-1}) sourced from a local fish van, and this fish was mainly sourced from outside the survey area, however, some fish was occasionally sourced from local stake and haaf net fishermen. Mollusc consumption consisted of razor clams (one individual) and scallops (one individual) consumed by adults. The observed maximum consumption was 3 kg y^{-1} this individual consumed scallops sourced from a fishing vessel in based in Annan (Appendix 17). Seven individuals were found to consume wildfowl,

the highest consumption was around 16 kg y^{-1} of pink-footed goose, and the source of this was not identified.

Table 4.3 Summary of adults' consumption rates of foods from the aquatic survey area (2015) (ND refers to no data).

Food Group	Number of observations	Number of people in the high-rate group	Observed maximum for the high-rate group (kg y^{-1})	Observed minimum for the high-rate group (kg y^{-1})	Observed mean for the high-rate group (kg y^{-1})	Observed 97.5th percentile (kg y^{-1})	Full dataset – Observed mean (kg y^{-1})	Full dataset – Hypothetical 97.5th percentile (kg y^{-1})	National Data mean (kg y^{-1})	National data 97.5th percentile (kg y^{-1})
Fish	25	1	47.0	47.0	47.0	NA	10.4	46	15	40
Crustaceans	2	1	20.8	20.8	20.8	NA	11.1	20	4	10
Molluscs	2	1	3.00	3.00	3.00	NA	2.30	2.9	4	10
Wildfowl	7	1	16.3	16.3	16.3	NA	3.3	16	ND	ND

4.9.2 Children and Infant Consumption Rates

Table 4.4 presents a summary of children's and infants' consumption rates of fish, crustaceans, molluscs and wildfowl from the aquatic survey area. Mean consumption rates for the high-rate groups and the observed 97.5th percentile rates are included in Table 4.4. The generic mean and generic 97.5th percentile rates based on national habit data are also included (Smith and Jones, 2003).

For the child age group, cod was the only fish species to be consumed by children. The observed maximum consumption was 7.8 kg y^{-1}, all of which was sourced from a fishmonger in Dumfries. No infants were found to consume aquatic foods.

Table 4.4 Summary of children's and infants' consumption rates of foods from the aquatic survey area (2015).

Food Group	Number of observations	Number of people in the high-rate group	Observed maximum for the high-rate group (kg y^{-1})	Observed minimum for the high-rate group (kg y^{-1})	Observed mean for the high-rate group (kg y^{-1})	Observed 97.5th percentile (kg y^{-1})	Full dataset – Observed mean (kg y^{-1})	Full dataset – Hypothetical 97.5th percentile (kg y^{-1})
Child age group (6 - 15 years old)								
Fish	6	4	7.8	7.8	7.8	NA	6.1	7.6
Crustaceans	0	0	0	0	0	NA	0	0
Molluscs	0	0	0	0	0	NA	0	0
Wildfowl	0	0	0	0	0	NA	0	0
Infant age group (0 - 5 years old)								
Fish	0	0	0	0	0	NA	0	0
Crustaceans	0	0	0	0	0	NA	0	0
Molluscs	0	0	0	0	0	NA	0	0
Wildfowl	0	0	0	0	0	NA	0	0

4.10 External Exposure

Occupancy rates for adults in intertidal, aquatic (in water), aquatic (on water) and handling rates of equipment can be found in Table 4.5. Intertidal activities for adults included bait digging, beachcombing, boat maintenance, collecting mussels, razor clams, seaweed and winkles, crabbing, dog walking, fixing moorings, handling creels/haaf stake/poke nets, horse-riding, paddling, playing, research/educational purposes, rock pooling and wildfowling. The highest intertidal occupancy rate was 1,095 h y^{-1} for a respondent who spent time beachcombing (365 h y^{-1}), dog walking (730 h y^{-1}).

Activities in the water included swimming, haaf netting, sub-aqua diving and paddling**.** The highest occupancy rate for adults in the water was 1460 h y^{-1} for a respondent who goes haaf netting 4 hours every day in the Solway**.** Activities on the water included angling, boat maintenance, being on a dive boat, canoeing,

commercial fishing, commute via boat, jet skiing, rowing, safety boat duties, sailing, power boating, water skiing, and working on a boat**.** The highest occupancy rate for adults on the water was 1460 h y^{-1} for a respondent who goes stake netting. Adults were also found to handle equipment within the survey area, the activities for adults involving handling equipment included boat maintenance, handling clothes and overalls, diving gear, fishing gear and outdoor swimming gear. The highest level of handling equipment was 624 h y^{-1} this respondent spent time handling boating equipment, at Annan boatyard.

Table 4.5 Summary of adults' external exposure for intertidal, aquatic and handling of equipment (2015).

Activity	Number of observations	Number of people in the high-rate group	Observed maximum for the high-rate group (h y^{-1})	Observed minimum for the high-rate group (h y^{-1})	Observed mean for the high-rate group (h y^{-1})	Observed 95.7th percentile (h y^{-1})
Intertidal	134	1	1095	1095	1095	NA
Aquatic (in water)	17	1	1460	1460	1460	NA
Aquatic (on water)	30	1	1460	1460	1460	NA
Handling Equipment	21	2	624	502	563	NA

Table 4.6 presents a summary of the children and infants' intertidal, aquatic (in water), aquatic (on water) occupancy rates and handling rates of equipment. Intertidal activities for children and infants included beachcombing, boat maintenance, collecting mussels, collecting seaweed, dog walking, paddling, playing on the intertidal area and rock pooling. The highest occupancy rate for children on the intertidal zone was 730 h y^{-1} for a respondent who spent time dog walking on the intertidal zone (1 hour twice daily). For infants, the highest occupancy was 730 h y^{-1} for an infant who spends time dog walking (365 h y^{-1}) and beachcombing (365 h y^{-1}) on the intertidal area.

Activities on the water included sea angling, boat maintenance, canoeing, rowing, safety boat duties, sailing, sports fishing and working on a boat. The highest

occupancy rate for children carrying out activities on the water was 16 h y^{-1}. This respondent goes sea angling at Newbie. For infants, the highest occupancy was 12 h y^{-1} who occasionally goes kayaking with family. No children or infants were identified handling equipment or carrying out activities in the water during the survey period.

Table 4.6 Summary of children's and infants' external exposure for intertidal, aquatic and handling of equipment

Activity	Number of observations	Number of people in the high-rate group	Observed maximum for the high-rate group (h y^{-1})	Observed minimum for the high-rate group (h y^{-1})	Observed mean for the high-rate group (h y^{-1})	Observed 95.7th percentile (h y^{-1})
Child age group (6 - 15 years old)						
Intertidal	15	2	730	730	730	NA
Aquatic (in water)	0	0	0	0	0	NA
Aquatic (on water)	1	1	16	16	16	NA
Handling Equipment	0	0	0	0	0	NA
Infant age group (0 - 5 years old)						
Intertidal	14	1	730	730	730	NA
Aquatic (in water)	0	0	0	NA	NA	NA
Aquatic (on water)	1	1	12	12	12	NA
Handling Equipment	0	0	0	0	0	NA

Gamma dose rate measurements over different substrates within the survey area can be found in Section 6.3.

5. Terrestrial Radiation Pathways

5.1 Introduction

Chapter 5 reports all inland routes of exposure immediately adjacent to the Chapelcross site, coastal and intertidal areas (Figure 2.1). The observations made at each site are also presented. The results from the postal survey reports are presented to provide an overview of the habits within the 25 km study area immediately around the Chapelcross site perimeter. The results from the GPS tracker experiment are further presented to provide some temporal and spatial resolution in the habits of individuals and corroborate the occupancy estimates provided by the public. This chapter reports postal survey results, terrestrial area site descriptions, private food production details and the results from the face-to-face consumption levels for privately produced food stuffs.

5.2 Postal Survey Results

5.2.1 Internal Exposure

A list of terrestrial food items used in the postal survey is shown in Table 5.1. The results show that dairy products such as cow milk, cheese and yoghurt are the most frequently consumed food type with 119 respondents out of 145 consuming it daily. Wild meat, such as rabbit and game, was the least selected food type with only 42 respondents consuming it; 29 of which only consumed wild meat twice a year.

For terrestrial food types respondents were asked to estimate where they source fresh or frozen terrestrial food from a supermarket, local shop, allotment/garden or a local market. On using the full dataset respondents selected terrestrial food items from the supermarket on a daily basis (572 selections). Figures 5.1 and 5.2 show how frequently respondents use supermarkets to source meat, vegetables and potatoes.

Table 5.1. Summary of terrestrial food types and how frequently each food type is consumed.

	Frequency (days per year)				
Food type	**260**	**104**	**24**	**2**	**Total**
Beef, lamb, pork	23	86	32	2	143
Green Vegetables	42	85	15	2	144
Chicken, (duck, goose, wildfowl)	26	90	22	4	142
Cow and goats' milk, cheese and/or yoghurt	119	22	4	0	145
Honey	23	23	26	14	86
Leeks or onions	50	74	19	2	145
Lettuce, tomatoes, cucumber	47	79	14	3	143
Pies, burgers, sausages, haggis made from local meat	5	51	65	11	132
Potatoes	88	52	6	0	146
Root vegetables	44	88	12	2	146
Shop bought apples, pears and/or berries	75	49	14	2	140
Wild meat such as rabbit or game	1	3	9	29	42
Wild/ free food including berries, apples, pears, mushrooms in season	13	26	23	23	85
Total	556	728	261	94	1639

5.2.2 Outdoor Activities

The postal survey showed walking, spending time on an allotment/gardening, greenspace walking, urban walking and bee keeping were the highest reported terrestrial activities. Walking was reported 128 times with 79% walking on a daily basis within the local area. Allotments/gardening was selected by 83 individuals with 60% participating on a daily basis (Table 5.2).

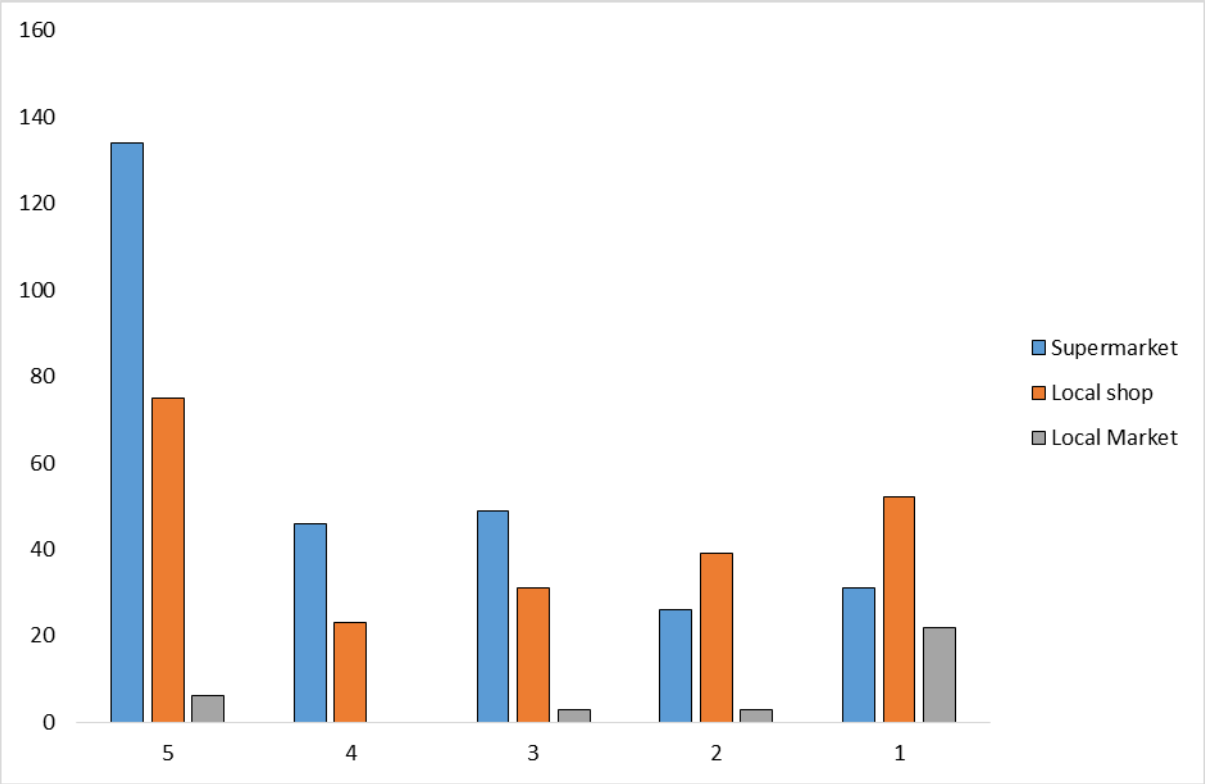

Figure 5.1 Summary of how often respondents obtain meat from supermarkets/local shops or local markets. Scale: 5 (always) to 1 (occasional).

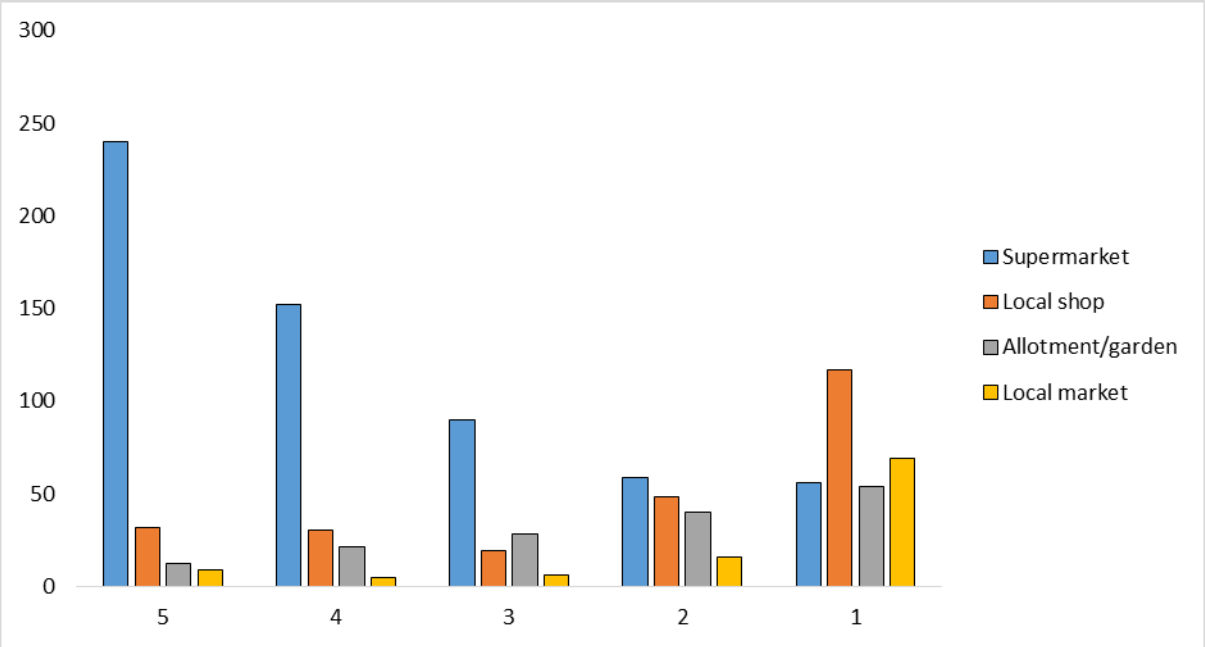

Figure 5.2 Summary of how often respondents obtain vegetables (green, root, potatoes) from supermarkets, local shops, allotment/gardens or local markets. Scale: 5 (always) to 1 (occasional).

Table 5.2 Summary of how often respondents participate in outdoor terrestrial activities.

	Frequency (days per year)				
Activity	**260**	**104**	**24**	**2**	**Total**
Allotment/gardening	50	23	10	0	83
Bee keeping	4	6	15	17	42
Cycling	3	15	11	7	36
Green space walking	38	20	14	5	77
Horse-riding	4	3	1	1	9
Mobility user	4	2	2	0	8
Shooting and hunting	1	2	4	2	9
Sports	1	11	3	1	16
Urban walking	12	18	15	6	51
Walking	101	24	2	1	128

5.3 Terrestrial Survey Area Descriptions

The terrestrial survey area stretches from Glencaple, in the west, to Gretna, in the east. This survey area has many small built areas with communities ranging from as small as one house to towns. The two main towns within the survey area are Annan and Gretna and they serve the local population with a rail link, direct access to the major roads north and south and a good supply of local shops and services. Much of the land within the survey area is agricultural with either cattle or crops (see Table 2.5).

The survey sites are reported from west to east:

5.3.1 Glencaple

Glencaple is the furthest west site within the survey area situated on the banks of the River Nith. It is a small village comprising of residential houses, hotel, shop/tea-room and the Nith Inshore Rescue – an independent lifeboat serving the Dumfries area.

5.3.2 Ruthwell

East from Brow Well is the small conurbation of Ruthwell. The village comprises of residential houses with the main road running through Ruthwell. Face-to-face interviews were undertaken in this village. The surrounding area is laid to agriculture.

5.3.3 Newbie

Newbie is a small village inland from the Solway Firth shore line. Residential housing is apparent and is surrounded by agricultural land and cattle grazing. Access to the shore is via the road and a path, which is part of the circular walk accessible from Newbiebarns. This area was relatively quiet during the survey period with several residents observed out in their gardens and walking.

5.3.4 Newington Park

This area is a park in the middle of a square surrounded by housing. Activities were predominantly children and families playing at the park, walking through the park and people dog walking with numbers approximately 50 in total during the times surveyed. The surrounding area to the park was residential overlooking the gardens of houses. A main road was situated nearby and was relatively busy with traffic.

5.3.5 Waterfoot Park

Waterfoot Park is situated along Waterfoot Road towards the merse area. No children or families were observed playing at this park. However, the area surrounding it was popular with dog walkers, families, cyclist and walkers passing by. The surrounding area is agricultural and cattle were grazing the merse at the time of the survey.

5.3.6 Springfield

Travelling north of Annan towards Chapelcross, Springfield is a small community with approximately five residential houses surrounded by agricultural land. Face-to-face surveys were undertaken at this site.

5.3.7 Chapelcross

The Chapelcross site discharges radioactive wastes via stacks to the atmosphere, liquid radioactive wastes via a pipeline outfall into the Solway Firth and contains sources for direct radiation. Several employees were interviewed at the Chapelcross site and several Chapelcross employees were encountered throughout the face-to-face survey period. Refer to Chapter 2 for further details of the Chapelcross site.

5.3.8 Creca

Creca is a small village and is the nearest populated area to Chapelcross. Interviews were undertaken within the survey period at Creca. The surrounding area is agricultural.

5.3.9 Old Graitney

Old Graitney is inland from Stormont and the area has several houses surrounded largely by agricultural land. One local person was interviewed here and three other people were observed walking.

5.3.10 Gretna

Gretna is a populated town and is the most eastern site from Chapelcross, situated near the mouth of the River Esk between the River Sark to its east and the Kirtle Water to its west. It is linked to Old Graitney by the saltmarsh which leads towards the Solway Firth. Access to the north and south of Gretna is easily accessible via the nearby motorway and the area is well served by a railway link.

5.4 Private Food Production

5.4.1 Meat Production

The postal survey revealed the following: At least three households in the survey area reared and consumed their own beef, pork and lamb.

5.4.2 Allotments

Two allotments were identified within the 5 km radius of Chapelcross. Both these allotments are run by the Dumfries and Galloway Council and are based in Annan, John Bell Allotments and the Greenknowe allotments at Seaforth. The John Bell Allotments (Figure 5.3) are situated beside the railway line and access is by car or by foot over the railway bridge. The Greenknowe allotments are situated beside Hecklegirth Primary School.

Face-to-face interviews were carried out at the John Bell Allotments site. There was no access available to the Greenknowe allotment site as it was locked. Despite plots

appearing to be allocated and worked, no plot holders were observed on each occasion that it was visited.

The allotment size was difficult to determine for Greenknowe allotments at Seaforth due to the inability to gain access, despite evidence of being regularly worked. The John Bell site was an active and productive site with plot holders producing a wide variety of fruit and vegetables. Dumfries and Galloway Council confirmed that the John Bell allotments hold 37 plots and the Greenknowe allotments at Seaforth hold 11 plots. A number of the plot holders interviewed were specific with the yield of their products, many of which had a record of the amount of each vegetable and fruit planted and the yield. Face-to-face interviews at the John Bell allotments indicated that much of the produce on the survey list were produced to varying degrees by one or more allotment owner. The food grown at the allotments was consumed by the growers and their families and friends.

Over the survey period, 96 people were interviewed who grew their own fruit and vegetables within their own home gardens and allotments. However, fully quantitative information was difficult to acquire or interpret from all interviews. Of these 96 interviews, 40 individuals yielded data of sufficient quality for quantitative estimates of food quantities grown and consumed.

Further to a conversation with an allotment holder, who reported that there was interest by Hecklegirth Primary School to undertake allotment activities. A member of staff at the school reported that while they have been offered a plot space at an allotment, nothing is yet in place.

Figure 5.3 John Bell allotments, Annan.

5.4.3 Egg Production

Local egg production appears to be based on small scale, domestic activity mainly for personal consumption. The 2016 re-survey confirmed the 2015 findings that there is a small proportion of the local population who keep hens or buy from a local source with the majority of the population buying eggs in shops sourced from non-local pathways. In 2015, 26 people surveyed, stated they kept hens for eggs and 15 bought locally, with one farm near Eastriggs (Appendix 7c) also keeping hens for personal consumption only. In 2016, eight new households were identified as keeping hens whilst another four households obtained their eggs from a confirmed local supplier - neighbour or work colleague. One or two households also sold eggs at the roadside to passing trade. One such enterprise was a B&B (Apendix7d) and on a visit was told they have approximately 15 hens laying seven to eight eggs per day. Most were for personal consumption and B&B guests, but some were sold at the roadside. The enterprise was unable to provide pathways beyond the roadside selling.

5.4.4 Production of Honey

The production of honey is very much weather-dependent as wet cold weather reduces the bees' frequency in coming out of the hive. In 2015, the wet cool summer meant that it was reported that the bees have not been able to leave the hive as often as previous years. Coupled with this, the cool wet weather also affected the growth of flowers. These two factors resulted in 2015 honey production being significantly lower than that for 2014 as was reported by three beekeepers around the Annan area.

Beekeepers are not required to be a member of a bee keeping association or be registered therefore the precise numbers in the Annan area are unknown. The Carlisle Beekeepers (which covers Carlisle and the south of Scotland) is reported to have around 60 members.

Within the survey area 13 beekeepers were identified (Mousewald, Ruthwell, Cummertrees, Kirtlebridge, Newbie and Annan) however interviews were achieved with only three beekeepers. It was reported from a member of the Carlisle Beekeepers that several of the 13 beekeepers identified distributed their honey within the local community whilst the majority producing honey for their own families' consumption.

One individual interviewed near Kirtlebridge, kept one active hive and did not harvest any honey this year due to the poor honey production. Normally, this individual consumes their own honey and gifts it to family and friends.

A second individual interviewed from near East Riggs, kept eight active hives which produced approximately in total 18 kg in 2015. This quantity was reported to be poor due to the particularly poor weather. Of the 18 kg, 4.5 kg was kept and consumed, 4.5 kg was gifted to friends and 4.5 kg was sold locally. The remainder was left in the hives.

The third individual, kept approximately 12 active hives. Of these, six to eight hives were kept for honey production each producing approximately 10 kg each for 2015. This interviewee reported this mass to around half the normal 20 kg produced from each hive due to the weather. The remaining four to six hives were kept to produce bees to sell. Of the total 60 – 80 kg produced in 2015, 9.5 kg was used for their own

consumption and for cooking demonstrations, 4.5 kg was gifted to friends and family, with the remaining honey sold through a local retailer in Annan and at the Royal Highland Show, Edinburgh.

The 2016 follow-up survey confirmed 2015 information that there was a small, but active bee-keeping community in the survey area. Three of the beekeepers, surveyed in 2015 were re-surveyed in 2016, and all stated honey was for personal or family consumption only. No further information on the sale of honey products was identified in 2016 and no evidence of roadside selling of honey emerged.

5.5 Commercial Food Production

5.5.1 Cereals and Milling Operations

No evidence was found that cereals grown in the survey area were for human consumption and again there was limited information on crop movement once they left the farm. Checks were made with millers and processors (Appendix 19a & 19b) outside the area to confirm they did not source any cereals from the survey area. Contact with farmers in the area indicated most cereals were grown for animal feed. See Section 4.2 for further details.

Given the lack of traceability of cereals from the survey area, using a local source of animal feed on the dose pathway assessment has only been partially successful. No impact, on potential exposures could be quantified.

5.5.2 Potato Production

Only one seed potato grower and merchant (Appendix 20a) was identified within the survey area. When contacted, they stated they mainly serviced the wider UK and European market, but did supply two local growers (Appendix 20b & 20c). Personal communication with both local growers identified that they sold some potatoes locally and this represented a pathway. One farm was contracted to a large UK potato company (Appendix 20d) and this was the primary route for their crops, but they had also supplied a relatively small quantity of potatoes to a now defunct delicatessen in Annan (Appendix 2e) along with carrots. The other farm (Appendix 20c) sold some potatoes at the farm gate and to local retailers outside the survey area in and around Dumfries. The quantity of potatoes sold at the farm gate could not be meaningfully

established from speaking with the farmer. No person surveyed in either year bought potatoes from either farm. The 2016 survey confirms the 2015 survey findings that most people bought their potatoes from sources that were not local.

5.5.3 Soft- and Orchard-Fruits

It is unclear on which farms soft fruit and orchard fruit were grown in the area, or if any were sent to for either market or processing. No such operations were identified during either survey period. The website www.pickyourownfarms.org.uk/scotland also provided no indication of such activity within Dumfries and Galloway area. No pathways could be identified for the consumption of these commercial crops.

5.5.4 Break Crops

Enquiries were made with arable farmers in the area to establish whether they use outside contractors periodically (i.e. every 5 to 7 years) to incorporate an alternative (break) crop as part of the rotation cycle. Contact with two farmers (Appendix 4b & 20c) indicated they did not operate such a practise, but it did occur on other farms on an ad-hoc basis and was very much dependent on the local farm and type of crops grown. No information on alternative crops sown as part of local rotations or on which farm was obtained from the two farmers. SGAS data identified both peas and beans were grown in the three parishes and could be used as a break crop. Further investigations would be needed to provide a complete overview of this practice.

5.6 Animal Feed

5.6.1 Commercial Feed

Pathways and traceability of animal feed were not investigated in the Chapelcross 2015 report. This was redressed during the 2016 survey due to the large-scale nature of livestock based agriculture in the three local parishes. However, the SGAS data did not provide information that distinguished between crops grown for animal feed or human consumption.

There is one commercial animal feed producer located approximately 3 km from Chapelcross (Appendix 21a). The company used a range of 40 different ingredients depending upon feed type, but did not source any ingredients locally at all. There

was a small-scale horse and dog feed merchant based in the survey area (Appendix 21b) that bought all commercial feed from outside the area. Most agricultural merchants across the region also sold animal feed. The main Annan agricultural merchant (Appendix 21c) provided a range of animal feeds for differing livestock and its' website indicated feed ingredients were sourced from across the UK with no local suppliers identified. Investigations indicate commercial feed did not provide an indirect pathway for consumption via a local source of meat.

5.6.2 On-Farm Crops for Animal Feed

On-farm growing of crops for animal feed has been identified on at least three farms in 2015. However, difficulty in contacting farmers limited the ability to assess the scale of such activity. Despite this, crops grown for feed include: barley, wheat and oats (Appendix 21d). One farmer at Dornock, (Appendix 4a) grew approximately 100 t y^{-1} of barley for their animals, whilst another farm at Stormont (Appendix 22c) grew approximately 60 t y^{-1} of maize and supplied one or two other farms as well. No details on quantities of crops sold on were provided. The growing of crops for animal feed appeared to be relatively common in the survey area. It is unclear what quantities of feed individual livestock consume on an annual basis and information was lacking on hay and silage production and animal consumption rates. No information on crops grown or bought in from other areas was available.

It is therefore difficult to assess the impact that animal feed grown given the lack of traceability of the consumption of locally sourced meat.

5.6.3 Dairy Production

Dairy Industry

Direct contact with dairy farms in the survey area indicated that on seven farms, milk production on each farm varied between 432 000 litres and 5 096 000 litres per year and herd sizes from between 160 to 520 cattle. Dumfries & Galloway Council also conducted a survey of milk production based on postcode areas. Within the DG12 postcode area, milk production totalled 98 800 litres per day from 14 farms.

Given the lack of traceability of milk both on- and off- farms in the survey area, no pathway could be identified for the consumption of locally produced dairy products.

Assessment can be made on the bulked dairy sample for regional analysis. It was not possible to obtain information on animal movements within or outside the survey area without access to the data held by BCMS. However, data made available by the SGAS remain the best source of information on milk production, albeit for the larger Dumfries and Galloway area. Reviewing these data may identify changes in production that could warrant further consideration when assessing regional exposures.

Consumption of Milk

The 2016 resurvey survey supported the findings of the 2015 survey and the new surveys undertaken in 2016 also confirmed that there was no shift in the buying patterns of milk across the local population with the majority of milk purchased through supermarkets and local shops.

Only limited information was found on locally produced milk, pasteurised or unpasteurised that was being consumed on the farm by any farmer or their family. Most dairy farmers, when contacted, stated they did not drink milk direct from the farm. However, one farmer's wife stated she drank approximately one pint per day on the farm whilst another person contacted as part of the follow-up surveys reported consuming milk sourced directly from a farm at Kirtlebridge. No further information relating to on-farm milk consumption was established. In contrast, personal consumption of milk bought at the supermarket by the farmers contacted ranged from zero to 1.1 litre/day for adults and between 0.4 and 0.5 litres per day for children under 16 years old.

5.6.4 Livestock

Beef Cattle

Interviews with farmers during the 2016 survey confirmed the findings from 2015 confirming that most people bought beef from supermarkets with only a few people buying from local butchers and retailers (Appendix 2c, 2d & 2e). No further information could be obtained on animal movements directly from other farms to other parts of the country for slaughter and/or processing without access to the data from BCMS. It was not possible to assess whether some animals were slaughtered

on farms for personal consumption. Such slaughter and consumption is permissible under *The Food Hygiene Regulation 853/2004*.

Sheep & Lamb

There was no evidence of any farm animals being slaughtered for personal consumption on the farm. Lamb sold by local butchers is sourced from outside the survey area. The 2016 survey confirms findings from 2015 that most people continue to buy lamb from supermarkets with a few people buying from local butchers.

Pig Farming

The 2016 survey found limited information regarding small-scale pig consumption in the area and the traceability of pigs entering the local food chain. The 2016 survey also confirmed findings from 2015, that most people source their pork from non-local sources.

Some pig production from farms in the survey area appeared to be for personal consumption and others for the local market. One farmer (Appendix 4a) disclosed they may buy a couple of pigs a year from a farmer near Annan and consumed for their own family's consumption. Quantities of pork consumed were not divulged. Communication with one of the Annan butchers (Appendix 2d) revealed they source some of their pork from a farmer in the Eastriggs area (Appendix 4b). This farm currently has three sows and one boar, producing approximately 6 to 10 piglets per litter with two litters per year. The farm is contracted to supply Dunabie butchers with two pigs per fortnight. The arrangement started in March 2016 and is insufficient for a year round supply to the butcher. The butcher therefore also sources pork from Lockerbie. The quantities bought by the butcher were not made available nor how much was sold through the shop. The farmer also stated that he cured belly pork from a couple of pigs for bacon on the farm for personal consumption over the winter period. His pigs are slaughtered at Lockerbie abattoir. A follow-up survey also noted a net fishermen sourced some of his pork from the same Eastriggs farm, although on a small scale and not all year round. Quantities of pork from this source were not divulged.

With limited information available on post-farm pig movements, further in-depth investigation would seem of limited value unless data on animal movements can be

obtained from BCMS. Currently only limited information on a pathway can be identified for pork product consumption. However, continual targeting of the farming sector as part of future habits surveys may provide additional information. Continued monitoring of data from SGAS is also recommended as part of the 5-yearly habits survey to identify any major changes in such activity.

5.7 Butchers & Retailers

Butchers and delicatessens in Annan (Appendix 2c – 2e) were contacted during the 2016 survey. One (Appendix 2c) sourced meat from the local farms outside the survey area, and had long standing relationship with these farms. Meat was sourced through the local auction mart in Dumfries and occasionally it was sourced from a farm in the survey area (Appendix 2f). However, this is very much on an ad-hoc basis as he states he has a regular supplier of meat from farms that are from outside the survey area. A second (Appendix 2d) with connections to a local farm near Lockerbie, sourced significant quantities of meat from their own farm, from outside the survey area but sourced some of their pork from a farm at Eastriggs, as described in Section 5.5.10 (Appendix 4b). This arrangement started in 2016 and is insufficient to supply the butcher all year round and so other pork is supplied from Lockerbie. The third (Appendix 2e) sources some potatoes and carrots from a farmer (Appendix 20b) within the survey area. The retailer could not quantify sales of such foodstuff.

The 2016 survey confirms the 2015 findings with no major change in the buying habits of the local population and most shopping undertaken at larger retailers who generally source their products from across the UK. A small proportion of the population continued to shop in independent retailers.

In general, there was no major initiative to promote local food sourced from the survey area due to the relatively small area and the overall scale of agriculture across the whole of Dumfries and Galloway. Given the lack of traceability, no major pathways could be identified for the consumption local products. Continued monitoring of the local retailers and processors in future habits surveys is advisable for changes in traceability and consumption patterns.

5.8 Private Water Supplies

Information in 2016 was sought to establish if such supplies posed a potential significant internal exposure pathway. Data were requested from Dumfries & Galloway Council via a Freedom of Information request. Data were organised based on distance from Chapelcross with priority given to those within one kilometre. A total of 102 properties were identified as having a private water supply.

Of these 102 private water supplies, no properties or businesses registered within one kilometre of the site were identified as having a private water supply. There were only four properties within a 5 km radius of Chapelcross that had their own private water supply. These four properties were all farms, with the nearest located just 1.1 km from the site. Contact with farmers from the three agricultural parishes indicated the majority of private water supplies were for animal use only and Scottish Water provided a mains supply for human consumption.

Given the lack of traceability in livestock movements and lack of human consumption, no pathway could be identified for the consumption via private water supplies.

5.9 Whisky distilling

Annandale Distillery, which closed in 1919 re-opened in 2014, makes whisky although none is for sale yet. The first sales for Annandale Whisky are expected in 2018. Currently the distillery is open to the public for tours and has a café and gift shop. Based on communications with the company, water used in the process to make the whisky comes from a borehole that taps into an aquifer 90 metres below the distillery. The process uses 13,000 litres per mash and Annandale Distillery are set-up to mash six times per week: 78,000 litres per week. Any other wash water is supplied by a Scottish Water supply. A negligible amount of water is used for cooling as Annandale Distillery has an adiabatic cooler. The barley used is both peated and unpeated. The peated barley is sourced from Inverness and the unpeated barley is sourced from Pencaitland.

5.10 Fresh Water-Based Angling Activities

Information was sought on fishing activity, stocking rates and the returns policy along the rivers Annan and Kirtle Water from hatcheries, fishing clubs and river boards. No rivers were reported to have been stocked in recent years. Data are provided in Appendix 23a & 23b. There is a pond-based fishing centre located between Powfoot and Annan (Appendix 4c). Contact with the centre found that they do stock the ponds but all the fish are returned live.

The 2015 survey indicated a total of 25 people and 6 children consumed fish from within the survey area. Of these, three were re-surveyed in 2016 with two stating they continued to eat fish. These data suggest consumption of freshwater fish is a potential pathway and anglers remain a target group for future surveys.

5.11 GPS Survey Results

To provide more details on the use of the environment around the Chapelcross survey area, four individuals were selected during the 2015 survey to wear trackers based from the knowledge gained of their habits from the face-to-face interviews. Trackers were deployed for a period of one week. Two were given to Chapelcross site employees and two were given to residents living locally (one of which worked at Chapelcross) (Appendix 15).

5.12 Internal Exposure

5.12.1 Internal Exposure Adult Consumption Rate

Consumption data for locally produced foodstuffs potentially affected by atmospheric releases from Chapelcross are presented in Table 5.5 for adults and Table 5.6 for children. No consumption of locally produced foodstuffs were identified by infants in 2015. The Table also provides the mean and 97.5% consumption rates and national data (Smith and Jones, 2003) for comparison.

Consumption of locally produced foods were identified for green and root vegetables, potatoes, domestic fruit, wild fruit, beef, game, poultry, sheep, cow's milk and honey.

Three observed mean consumption rates for the high-rate consumer group were found to be greater than the 97.5% value for the full 2015 dataset. These were for other vegetables, domestic fruit and game. Three of the observed mean consumption rates for the high-rate consumer group were found to exceed the national 97.5% consumption rate. This was for potatoes, beef and milk. The remaining eight groups for which data were collected in the 2015 survey were all found to have lower mean consumption rates for the high-rate consumer group than the national 97.5% consumption rate.

5.12.2 Children and Infant's Consumption Rates

Table 5.6 presents a summary of the children consumption rates. No information on infants' consumption rates of foods from the local survey area could be identified.

Child consumption of locally produced foods was identified for green and root vegetables, potatoes, domestic fruit, wild fruit, beef, poultry and milk. No consumption of other vegetables, game, lamb/mutton or honey was observed.

Table 5.5 Summary of adult consumption rate of foods from the terrestrial survey area (2015)

Food type	Number of observations	Number of people in the high-rate group	Observed maximum for the high-rate group (kg y^{-1} or l y^{-1})	Observed minimum for the high-rate group (kg y^{-1} or l y^{-1})	Observed mean for the high-rate group (kg y^{-1} or l y^{-1})	Observed 97.5th percentile (kg y^{-1} or l y^{-1})	Full dataset – Observed mean (kg y^{-1} or l y^{-1})	Full dataset – Hypothetical 97.5th percentile (kg y^{-1} or l y^{-1})	National Mean (kg y^{-1} or l y^{-1})	National 97.5th percentile (kg y^{-1} or l y^{-1})
Green Vegetables	17	5	17.4	8.97	13.4	17.2	5.9	16.7	15	45
Other Vegetables	13	1	28.8	28.8	28.8	28.8	5.51	22.4	20	50
Root Vegetables	16	6	19.5	9.5	14.1	18.8	7.22	17.4	10	40
Potatoes	15	2	187	187	187	187	35.8	187	50	120
Fruit – Domestic	24	2	42.8	18	30.4	42.2	5.88	28.6	20	75
Fruit - Wild	41	9	24	8.8	13.9	22.4	4.95	16	7	25
Mushrooms - Wild	18	4	4	2	2.75	NA	1.06	3.58	3	10
Meat - Beef	40	6	73	24.4	36.2	68.8	13.1	39.9	15	45
Meat - Game	11	1	12.4	12.4	12.4	12.4	2.29	10.2	NA	NA
Meat - Poultry	25	21	31.2	10.4	16.8	26	14.5	25.0	10	30
Meat - Sheep	12	4	20.8	7.8	15.3	20.5	6.55	19.6	8	25
Honey	1	1	1.04	1.04	1.04	1.04	1.04	1.04	2.5	9.5
Milk	20	10	723	365	415	651	281	570	95	240
Eggs	11	9	21.2	9	13.1	20.6	11.8	20.4	8.5	25

Table 5.6 Summary of children's consumption rates

Food type	Number of observations	Number of people in the high-rate group	Observed maximum for the high-rate group (kg y^{-1} or l y^{-1})	Observed minimum for the high-rate group (kg y^{-1} or l y^{-1})	Observed mean for the high-rate group (kg y^{-1} or l y^{-1})	Observed 97.5th percentile (kg y^{-1} or l y^{-1})	Full dataset – observed mean (kg y^{-1} or l y^{-1})	Full dataset – hypothetical 97.5th percentile (kg y^{-1} or l y^{-1})
Green Vegetables	9	4	15.3	6.06	9.97	15.03	5.7	14.5
Other Vegetables	0	0	0	0	0	0	0	0
Root Vegetables	6	5	4.15	2.06	2.86	4.13	2.6	4.12
Potatoes	7	1	17.6	17.6	17.6	17.6	3.92	15.6
Fruit - Domestic	7	2	15.3	8.05	11.7	15.1	3.91	14.2
Fruit - Wild	2	1	4.69	4.69	4.69	4.69	3.1	4.61
Meat – Beef	9	8	13	7.8	11.2	13	10.1	13
Meat – Game	0	0	0	0	0	0	0	0
Meat – Poultry	3	3	11.8	10.4	11.4	11.8	11.4	11.8
Meat – Sheep	0	0	0	0	0	0	0	0
Honey	0	0	0	0	0	0	0	0
Milk	7	6	365	146	219	365	193	365

6. Direct Radiation Exposure

6.1 Introduction

Gamma dose rate can vary markedly at small scales and as a result of direct shine from Nuclear power plant activities. Acquiring a spatial understanding of the spatial variation in dose rate is important in understanding the implications of the habits of the local population. A mobile and in-situ gamma dose rate survey was undertaken over two periods in the summer of 2015 and the spring of 2016.

To achieve large-scale coverage, a Mobile Gamma-ray Spectrometry System (MoGSS) was used to measure the differential dose estimations for the natural occurring gamma emitting radionuclides (^{40}K and the ^{238}U and ^{232}Th decay series) alongside estimates for anthropogenic ^{137}Cs. The ability to separate the contributors is especially important given that the dose from Chapelcross activity can be singled out from the highly changeable background elements. Both handheld and carborne gamma spectrometry systems were used. This type of capability is not possible using conventional gamma dose rate measurements. However, this approach is unable to assess the occurrence of the most abundance radionuclide released from Chapelcross ^{3}H.

The MoGSS data were used to help target follow up in-situ terrestrial gamma dose rate measurements, which were undertaken at all face-to-face survey locations and at any location where an apparent anomaly was observed. Beta dosimetry was undertaken over the intertidal environments of the Chapelcross area to estimate the skin dose associated with the anthropogenic radioactivity in the environment. Measurements were made on fishing equipment and articles of clothing that were frequently immersed in Solway waters around the Chapelcross discharge area and beyond and therefore representing the potentially highest points of contact.

Sediment cores were also taken to help estimate the Chapelcross contribution to the external dose rate in the coastal environment. All data were captured during the survey period.

6.2 Mobile Gamma Spectrometry Survey

6.2.1 Survey Area

To obtain as broader spatial sample as possible and to investigate as many possible environments two systems operating MoGSS were deployed. Firstly, two large volume sodium iodide detectors were mounted in a box on top of a car, which was driven along the major roads within the area of interest. The system, with a combined detector volume of eight litres, has high counting efficiency but was restricted to areas of vehicular access and thus could only be used on roads and carparks (Figure 6.1). To focus in on smaller areas not accessible by vehicle, and to crucially cover the coastline and measure the dose at relevant access points, two separate backpack systems were used (Figure 6.1). Each backpack system comprised of a 71 × 71 mm sodium iodide detector. All MoGSS units produced a differential energy spectra recorded at one second integration times alongside high accuracy (<0.6 m) differential GPS readings. Further details and information on calibration can be found in Appendix 10.

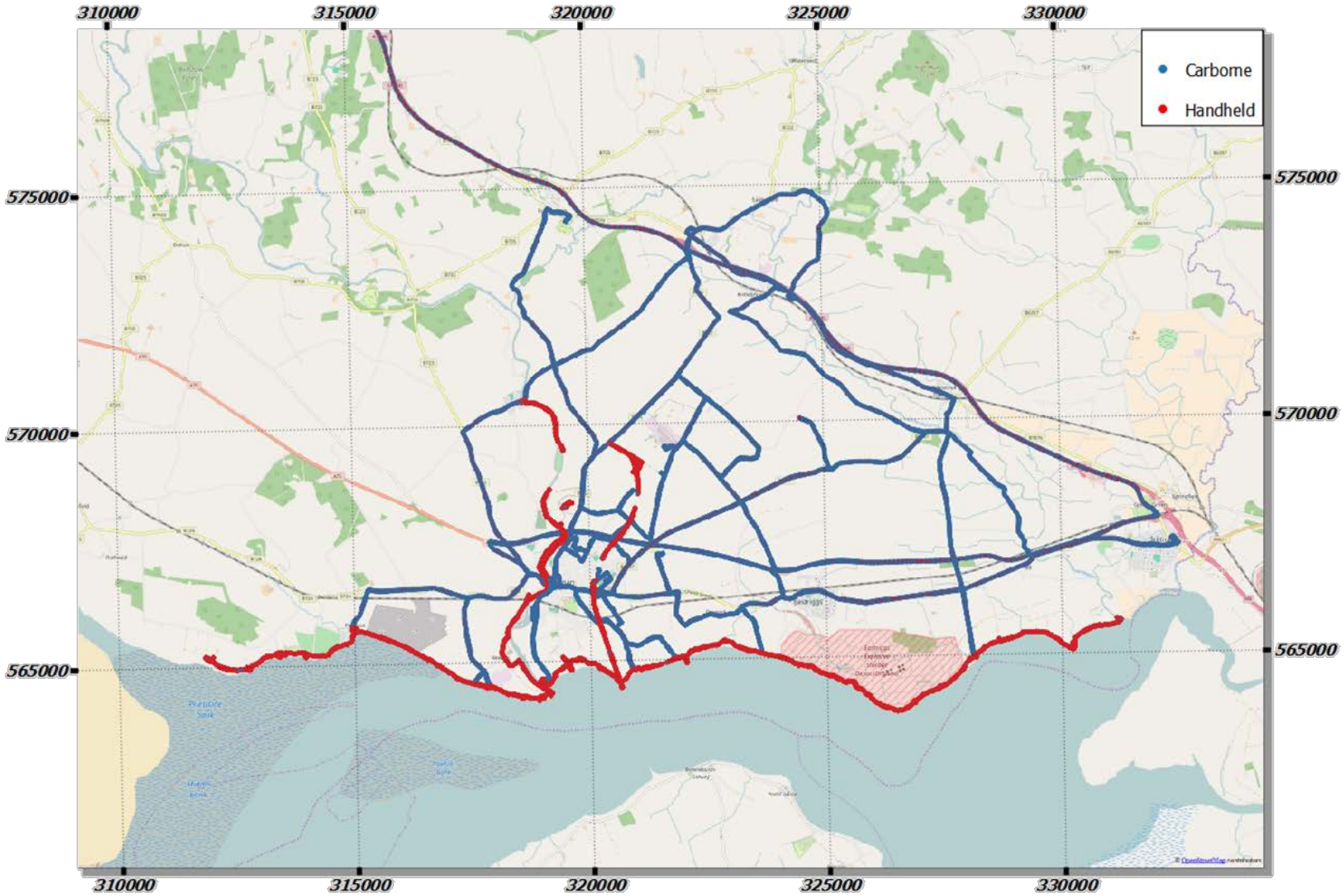

Figure 6.1. Coverage for backpack and road MoGSS systems

6.2.2 Mobile Gamma Survey Results

Over 111 000 spectral measurements were made (27 262 – road survey; 88 986 – backpack) and Figure 6.1 demonstrates the coverage by individual systems. The estimated dose distribution for both systems is presented in Appendix 25, Figure A25.1. The dose from ^{137}Cs is generally higher for backpack data, which is due to much of the backpack data being collected were obtained close to the pipeline and around the coast (Figure 6.1).

Considerable heterogeneity is observed, especially in relation to the pipeline and coastline data (Appendix 25, Figure A25.2). Higher radiation measurements attributable to ^{137}Cs were observed along the pipeline. Considerable heterogeneity was observed in the dose rate, with values in excess of 0.2 µGy h^{-1} (200 nGy h^{-1}) estimated. Maximum values of approximately 0.75 µGy h^{-1} were found in localised areas along the pipeline. The MoGSS detector was held just above the ground surface alongside the pipeline. The distribution and values are similar to those reported by Tipple *et al*. (2002) and any differences could be explained by the differences in the measurement geometry. The elevated levels could be related to ^{137}Cs particulate material trapped between the old pipeline and the new pipeline lining. The land use around the elevated readings at the start and end of the pipeline is farmland/fields and the elevated levels (above 0.1 µGy h^{-1}) in the middle of the pipeline is surrounded by a housing estate (Annan) and fields (Appendix 25. Figure A25.3).

Around the Chapelcross power station itself and the upper part of the pipeline, the vast majority of the gamma dose rate is also from ^{137}Cs (Appendix 25; Figure A25.4 and A25.5). The data show the ^{137}Cs count rate around the Chapelcross perimeter fence and elevated areas are observed at the site entrance corresponding to gamma dose rate of between 0.05 and 0.1 µGy h^{-1} (Appendix 25, Figure A25.5 and A25.6), similar to those found by in-situ gamma dose rate (Table 6.1). Within Annan itself (not directly next to the pipeline), any variation in dose rate is attributable to elevated natural radiation, for example high concentrations of ^{40}K from road and building construction materials (Appendix 25; Figure A25.3)

6.3 In-Situ Gamma Dosimetry

6.3.1 Terrestrial Areas

A total of 14 in-situ gamma dose rate measurements were collected along with the MoGSS survey. Of these, six in-situ gamma dose rate measurements were taken along the effluent pipeline to compliment the MoGSS measurements. Both sets of measurements in combination allowed both high and low radiation environments to be identified and source of the radiation confirmed. The gamma dose rate measurements were then used to confirm the terrestrial gamma dose rate by using UKAS accredited procedures. Dose rate measurements were refined by allocating a ^{226}Ra calibration for those points dominated by natural series radionuclides (<0.06 µGy h^{-1}) and a ^{137}Cs calibration for higher radiation environments that could be attributed to ^{137}Cs (>0.06 µGy h^{-1}). From these measurements, excess dose rates could be estimated for public exposure. Figure 6.8 provides a summary of the terrestrial dose rate measurements, including the effluent pipeline.

Table 6.1 Summary of gamma dose rate measurements collected across the terrestrial environments and along effluent pipeline.

Location	GPS Location	Surface	Gamma Dose Rate (µGy h^{-1})	Uncertainty 2 σ (µGy h^{-1})
Annan allotments	NY 19806 66782	soil	0.0281	0.004
Chapelcross car park	NY 21786 69479	tarmac	0.0504	0.005
Chapelcross ne gate	NY 21229 70262	tarmac	0.0318	0.004
Whinnyrig car park	NY 20893 64787	tarmac	0.0338	0.004
Ruthwell Farm	NY 10314 67380	grass	0.0300	0.004
Caerlaverock Castle	NY 02334 65134	grass	0.0298	0.004
Waterfoot Park	NY 19085 64596	grass	0.0334	0.004
Annan park	NY 14696 81806	grass	0.0302	0.004
Effluent pipeline	NY 20471 64961	gravel path	0.0913*	0.007
Effluent pipeline	NY 20642 64448	gravel path	0.1450*	0.009
Effluent pipeline	NY 20615 64527	grass	0.0409	0.004
Effluent pipeline	NY 20997 69110	grass	0.1190*	0.008
Effluent pipeline	NY 21032 68962	grass	0.1560*	0.010
Effluent pipeline	NY 21040 68918	grass	0.1130*	0.008

*Using ^{137}Cs calibration

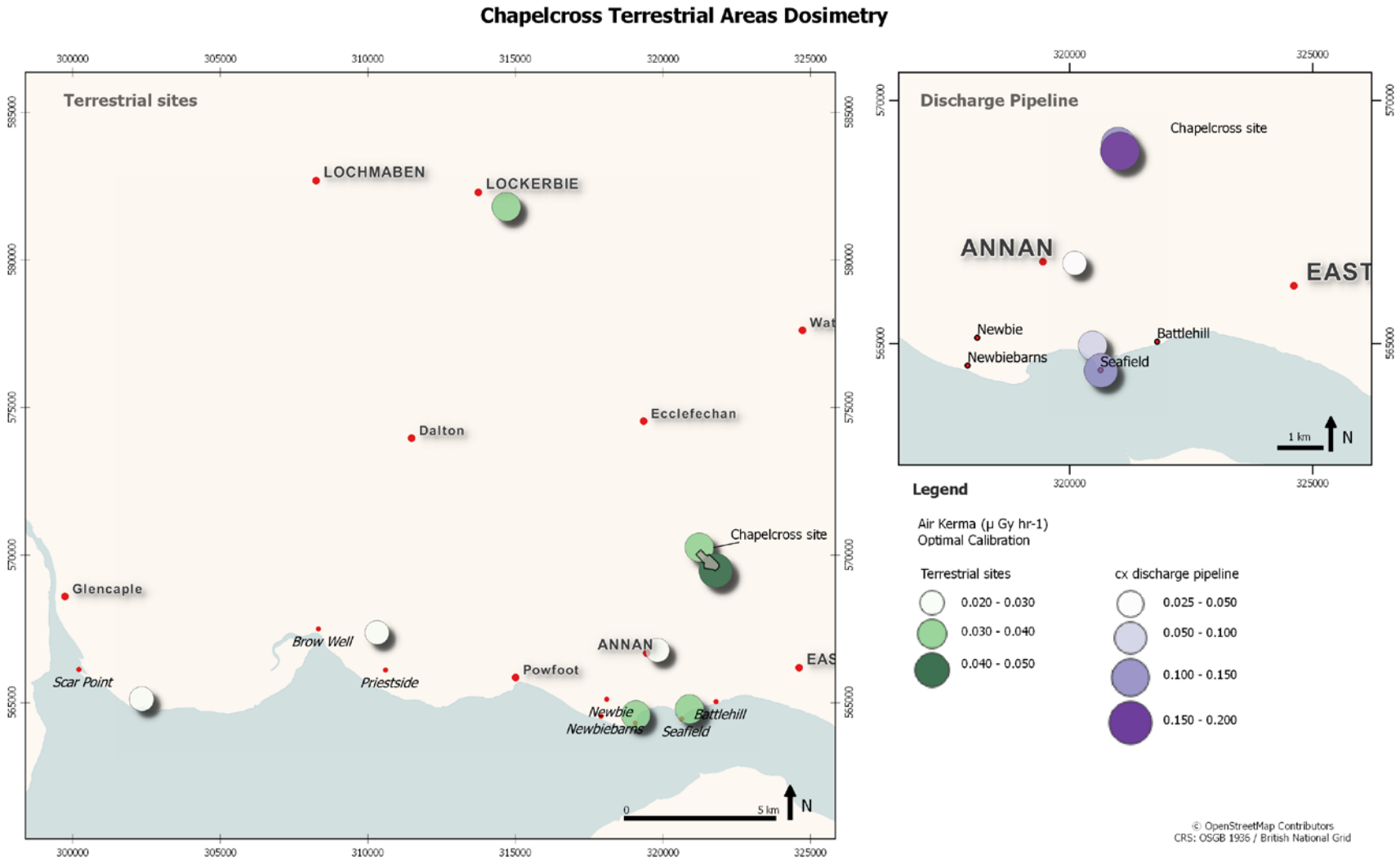

Figure 6.8 Summary of the gamma dose rate measurements in the terrestrial environment surrounding Chapelcross including coastal paths.

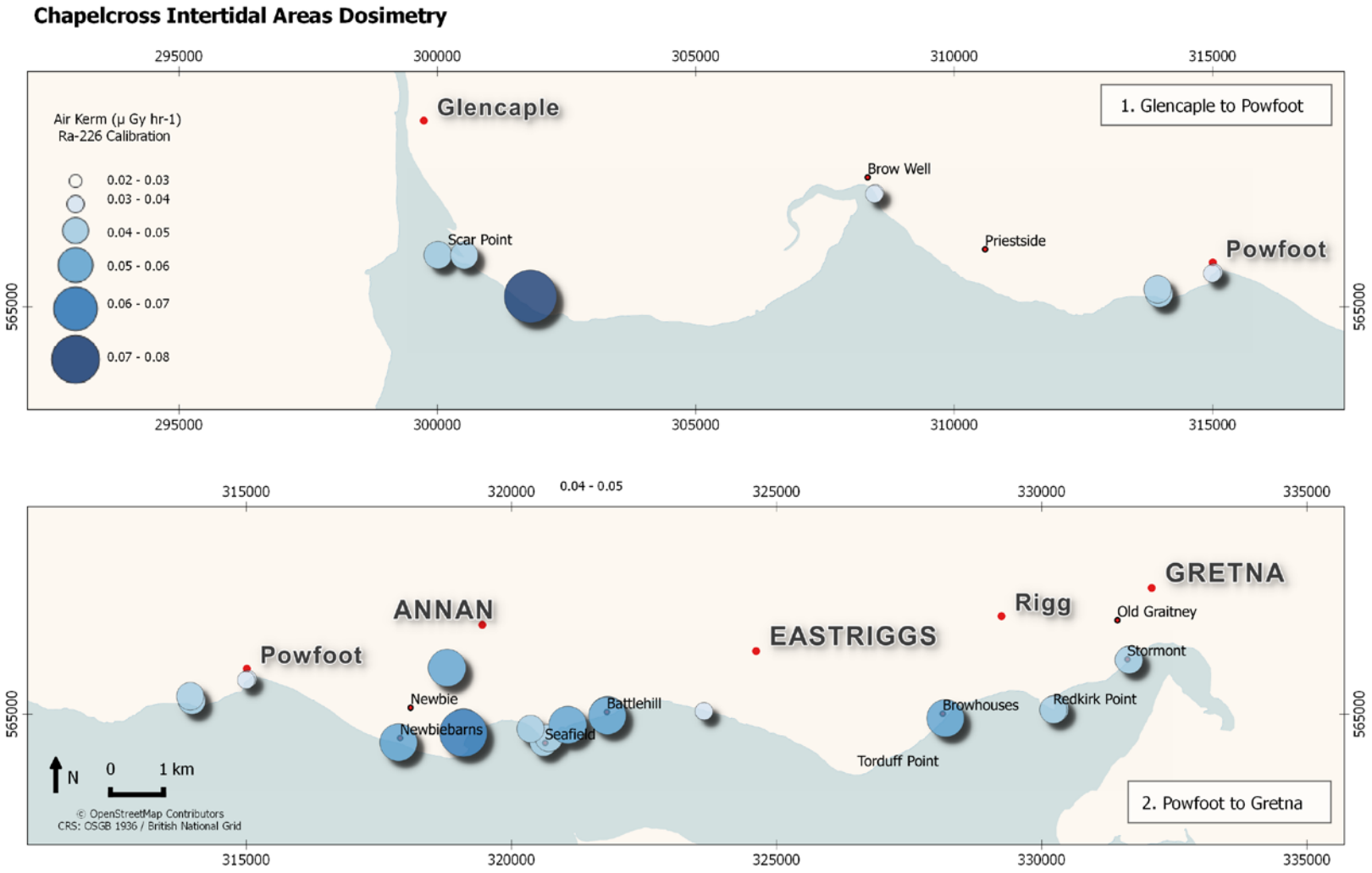

Figure 6.9 The distribution of intertidal gamma dose rate measurements for the inner Solway including coastal paths

6.3.2 Intertidal areas

A total of 43 in-situ terrestrial gamma dose rate measurements were made over intertidal surfaces. At each site, gamma dose rate measurements were made over the dominant intertidal surfaces observed. The lowest values were observed over sand and pebbly surfaces (with intrinsic and cosmic component removed) whilst the highest doses were associated with saltmarshes (Table 6.2). Figure 6.9 shows the geographical distribution of the dose rate measurements. The highest value observed was at Caerlaverock saltmarsh. It is well documented that the dose rate measurements observed over these intertidal surfaces is considered attributable to the legacy of Sellafield discharges in the mid-1970s. The doses are largely driven by ^{137}Cs associated with the clays and silts within the saltmarshes and intertidal surfaces.

Table 6.2 Terrestrial gamma dose rate recorded over different intertidal substrates

	Gamma dose rate over Substrate type (μGy h^{-1})							
Location (n)	**Salt-marsh**	**2 σ**	**Mud**	**2 σ**	**Sand**	**2 σ**	**Pebbles**	**2 σ**
Annan Harbour (1)			0.0406	0.004				
Battlehill (3)	0.0447	0.004						
Browhouses (4)	0.0441	0.004	0.0287	0.004				
Brow Well (2)	0.0302	0.004						
Caerlaverock (3)	0.0586	0.005						
Dornock Brow (2)	0.0338		0.0301	0.004				
Newbiebarns (1)			0.0451	0.004				
Powfoot (3)	0.0363	0.004			0.0278	0.004		
Priestside Bank (2)					0.0335	0.004		
Redkirk Point (4)			0.0369	0.004			0.0357	0.004
Scar Point (3)	0.0266	0.004	0.0357	0.004				
Seafield (5)	0.0458	0.004						
Stormont (5)			0.0399	0.004			0.0275	0.004
Waterfoot (5)	0.0507	0.005						
Mean	0.0412		0.0361		0.0307		0.0316	
Maximum	0.0586		0.0451		0.0335		0.0357	

6.4 In-Situ Beta Dosimetry

Beta dosimetry of skin dose [H*(0.07)] was measured largely over intertidal and saltmarsh surfaces. All measurements were around the 0.2 μSv h^{-1} per cm^{-2} lower detection limit. During the follow up survey in spring 2016, a number of contacts from

the face-to-face survey were followed up to assess the beta dosimetry on a number of additional surfaces including nets, fishing equipment and articles clothing used for activities in the intertidal area. The results for the positive measurements (above the estimated lower detection limit of around 0.2 µSv h^{-1}) are presented in Table 6.3.

Table 6.3. Positive measurements of Beta skin dose H'(0.07) measured in April 2016.

Surface	GPS	H'(0.07) µSv h^{-1}	2 σ uncertainty
Haafnet post	NY 2203 6496	1.23	0.31
Haafnet	NY 2203 6496	0.89	0.37
Mud surface	NY 2203 6496	2.63	0.43
Fish bag	NY 1984 6677	0.38	0.29
Jacket	NY 1980 6676	0.24	0.31

6.5 Sample Analyses: Estimating the Chapelcross Contribution to Gamma Dose Rate over Intertidal Surfaces.

During the survey period sediment cores were extracted from five saltmarshes to 300 mm depth at locations shown in Figure 3.6. Samples were prepared and analysed for gamma-emitting radionuclides with UKAS accredited methods. The presence of the ^{137}Cs and ^{241}Am subsurface at between 200 and 300 mm depth indicates that the cores represent at least 40 years of sediment and Sellafield discharge history (Tyler, 1999). Table 6.4 provides a summary of ^{137}Cs activity deposition (Bq m^{-2}) and the mean ^{241}Am/^{137}Cs derived from 50 mm slice taken from each core sampled at the five sites.

The influence of ^{137}Cs discharged from the Chapelcross site should be observed on the ^{241}Am/^{137}Cs ratio observed in the sediment samples. The influence from Chernobyl cannot be excluded from this, but the ratio is consistent with depth and so pre- and post- dates the input from Chernobyl (1986). A systematic change in this ratio can be observed in Table 6.4 suggesting an increase in Chapelcross ^{137}Cs in the sediment with increasing distance from the Inner Solway at Browhouses decreasing towards Powfoot in the west. Assuming that the inner Solway is least influenced by Chapelcross discharges, as discharges tend to occur at high tide and on the ebb tide, then the ratio may be used to estimate the contribution from Chapelcross to the ^{137}Cs distribution. These results are presented in Table 6.4.

Table 6.4 Summary of the estimated ^{137}Cs contributions from Chapelcross in saltmarsh sediments.

Location	$^{241}Am/^{137}Cs$ Ratio	2 σ	^{137}Cs Bq m^{-2}	2 σ	Estimated Chapelcross ^{137}Cs Bq m^{-2}	2 σ
Browhouses	1.064	0.04	36 700	853	n/a	-
Dornockbrow	1.034	0.03	49 700	1 210	1 570	59
Seafield 1	1.012	0.04	39 000	1 070	3 430	165
Seafield 2	0.972	0.03	31 800	791	2 720	108
Powfoot	0.858	0.04	22 200	512	4 640	241

Table 6.5 summarises the gamma dose rate over the saltmarshes at the locations where the sediment cores were sampled. Dose conversion coefficients from ICRU 53 (1995) were used to convert the activity deposition (Bq m^{-2}) to gamma dose rate, assuming a relatively uniform depth distribution. Table 6.5 shows how the ^{137}Cs contribution to gamma dose rate varies from 10 to 20%. In the same way the Chapelcross contribution from Table 6.2 can be used to estimate the Chapelcross contribution to gamma dose rate. This ranges from 0.0002 µGy h^{-1} to 0.0006 µGy h^{-1}, with a mean value of 0.0004 µGy h^{-1} (0.00036 µGy h^{-1}) or between 0.6 % and 2 % of the gamma dose rate. This is a very similar value to the estimate derived from PC CREAM of 0.000635 µGy h^{-1} (Section 2.2).

Table 6.5 Summary of the Gamma Dose Rate Measurements and Chapelcross contribution to Gamma Dose Rate.

Location	In-situ gamma dose rate μGy h^{-1}	2 σ	Gamma dose rate from ^{137}Cs μGy h^{-1}	Chapelcross ^{137}Cs μGy h^{-1}	Percent ^{137}Cs contribution μGy h^{-1}	Percent Chapelcross ^{137}Cs contribution μGy h^{-1}
Browhouses	0.0338	0.004	0.0051	n/a	15.0	n/a
Dornockbrow	0.0338	0.004	0.0069	0.0002	20.3	0.64
Seafield 1	0.038	0.004	0.0054	0.0005	14.2	1.25
Seafield 2	0.0349	0.004	0.0044	0.0004	12.6	1.07
Powfoot	0.0302	0.004	0.0031	0.0006	10.1	2.12

6.6 Effect of Natural Features and Built Structures and Shielding From Radiation

6.6.1 Introduction

This section considers the shielding effects of environmental and built structures on direct shine from nuclear sites. Much research has already been published on the shielding effects of buildings from depositional and cloud sources (Burson and Profio's, 1977; Mechbach *et al*., 1987; Dickson 2013) and typical reductions factors have been reported for gamma radiation range from 1 (no effect; e.g. vehicles) to 0.6 (masonry buildings). The results vary significantly depending on the construction materials used. The shielding effects of tides on gamma dose rates for houseboat dwellers and fishermen using riverbanks is described by Punt *et al*., 2011. In addition, Punt *et al.,* describes the shielding effect of clothing on beta skin dose rate.

Distance and the inverse square rule is a fundamental concept, which will affect the dose from exposure to direct gamma shine. Here consideration is given only to the effect of natural features and built structures in reducing the exposure to gamma radiation.

6.6.2 Reduction Factor for Gamma Shine

The MoGSS survey around the Chapelcross site and pipeline showed that ^{137}Cs was the primary radionuclide contributing to the shine. The following discussion on reduction factors will therefore focus on the radiation from ^{137}Cs.

The *mass attenuation* coefficient for the primary gamma photon from ^{137}Cs (at 662 keV) is approximately 0.0765 $cm^2\ g^{-1}$ (Tyler, 1999). At this energy, the *attenuation coefficient* is dominated by the density of the material through which the gamma photon travels. Table 6.6 provides examples of the attenuation coefficients for a range of materials and the depth through which half the gamma photons are attenuated by half. The density listed is an example and can vary for some materials, such as sandstone from 2.3 to 2.8 g cm^{-3}.

6.6.3 Natural Features

Natural features in the landscape will interfere with the line of sight between the individual and the source of radiation. Table 6.6 shows the typical $D_{½}$ for a range of environmental media.

Table 6.6 The gamma attenuation properties for a range of environmental media and building materials (density values compiled from a number of web based sources)

Material	Density g cm^{-3}	Attenuation Coefficient cm^{-1}	Half Depth ($D_{½}$) cm	Depth (cm) for a shielding factor of 0.97
Soil (sandy)	1.6	0.122	5.66	28.3
Peat (wet)	0.9	0.069	10.1	50.5
Wood (pine)	0.5	0.038	18.1	90.5
Wood (oak)	0.9	0.069	10.1	50.5
Chipboard	0.65	0.05	13.9	69.5
MDF	0.72	0.055	12.6	63
Concrete	2	0.153	4.53	22.7
Aircrete blocks	0.5	0.038	18.1	90.5
Facing bricks	1.8	0.138	5.03	25.2
Concrete block with mortar	1.28	0.97	7.13	35.7
Sandstone	2.5	0.191	3.62	18.1
Glass	2.5	0.191	3.62	18.1
Thermal board	0.032	0.002	283	1 420
Plaster	0.80	0.061	11.3	56.6

6.6.4 Built Structures

Building structures are complex and have evolved with time to improve thermal insulation. Table 6.7 below provides examples of typical external wall constructions for three different ages of property and the gamma dose reduction factor that might be anticipated. However, this does not take account of windows, which will result a very small reduction factor. A variety of construction types for timber-framed houses exist, but in these cases the reduction factor will be dominated by the thickness of the facing brick and may be of the order of 0.7.

Table 6.7 Examples of wall construction and the resulting reduction factor to gamma dose reduction (information derived from web-based sources)

Wall Type	Construction materials and thicknesses	Reduction Factor
Cavity Wall	10.3 cm facing brick 5.0 cm clear cavity 10 cm aerated block 4 cm thermal board	0.84
Solid Wall	1.5 cm render 21.5 cm aerated block 3 cm thermal board	0.6
Traditional Farmhouse wall	>25 cm of sandstone	>0.99
Glass thickness	Double Glazing 2 x 4 mm	0.015

An overall mean reduction factor of 0.61 is assumed for the purposes of doses associated with occupancy within places of work and home.

6.7 Occupancy Rates

6.7.1 Occupancy Data for the Survey Area

A summary of the types of activities that respondents participate in within the survey area can be found in Table 6.8. The face-to-face interviews revealed that individuals take part in a range of terrestrial, aquatic and intertidal activities within the survey area (Table 6.8) with the highest number of individuals taking part in dog walking (150 respondents) with the most frequent walker spending 1 460 hours a year dog walking in Annan. For the aquatic activities, angling was the most popular (9

respondents) and dog walking was the most popular intertidal activity (99 respondents).

Table 6.8 Summary of the activities and total number of respondents that take part in the activities. The location of the maximum occupancy is also given.

Activity type	Activity	Number of respondents	Maximum occupancy (h y^{-1})	Location (if provided)
Terrestrial	Allotment	21	624	John Bell allotments
Terrestrial	Archery	1	13	-
Terrestrial	Bee keeping	5	180	Kirtlebridge
Terrestrial	Bird/nature watching	92	1 460	Solway Coast
Terrestrial	Bowling	4	104	-
Terrestrial	Cycling	90	730	Annan/Powfoot/Newbie
Terrestrial	Clay pigeon shooting	2	60	Cocklicks Farm Social Club
Terrestrial	Dog walking	150	1 460	Annan
Terrestrial	Gardening	154	2 152	Annan
Terrestrial	Golfing	21	624	-
Terrestrial	Horse riding	8	626	Dumfries
Terrestrial	Playing	60	1 460	-
Terrestrial	Rambling/walking	149	1 248	-
Terrestrial	Running	25	365	Powfoot
Terrestrial	Shooting	1	18	Brow Well
Terrestrial	Sitting/picnicking	54	416	-
Terrestrial	Sports	16	832	Gretna area
Terrestrial	Collecting wild produce	47	104	Caerlaverock
Aquatic	Angling – Sea	9	416	Newbiebarns
Aquatic	Angling - Freshwater	8	144	River Annan
Aquatic	Boat maintenance	6	104	-
Aquatic	Canoeing	1	3	Solway
Aquatic	Commercial fishing/creeling	1	468	Powfoot
Aquatic	Rowing	2	104	-
Aquatic	Safety boat duties	2	96	Glencaple
Aquatic	Sailing	4	416	Annan Harbour & Solway
Aquatic	Sports fishing	0		
Aquatic	Sub-aqua diving	1	4	Solway
Aquatic	Swimming	3	12	Powfoot/Solway
Aquatic	Power boating	5	48	Solway – enters at Annan slipway
Aquatic	Water skiing	1	15	-
Aquatic	Working on a boat	1	104	-
Intertidal	Bait digging	3	104	Priestside
Intertidal	Beachcombing	42	365	Waterfoot
Intertidal	Boat maintenance	0	-	-

Activity type	Activity	Number of respondents	Maximum occupancy (h y^{-1})	Location (if provided)
Intertidal	Collecting mussels	1	36	Solway
Intertidal	Collecting razor clams	3	52	-
Intertidal	Collecting seaweed	2	4	Solway
Intertidal	Collecting shrimps	1	27	Solway
Intertidal	Collecting winkles	1	52	-
Intertidal	Crabbing	0	-	-
Intertidal	Handling creels/haaf/ stake/poke nets	7	340	Browhouses
Intertidal	Dog walking	99	730	Browhouses
Intertidal	Fixing moorings	1	1	Browhouses
Intertidal	Haaf netting	7	1 460	
Intertidal	Horse riding	4	312	Newbiebarns
	Kite surfing	1	104	Powfoot
Intertidal	Paddling	19	104	
Intertidal	Playing	33	208	Annan
Intertidal	Research/educational purposes	3	72	-
Intertidal	Rock pooling	13	260	Newbie
Intertidal	Stake netting	5	1 460	Annan
Intertidal	Wildfowling	8	366	Scarpoint coastline
Maintaining equipment	Boats and boating equipment	7	624	Annan Boatyard
Maintaining equipment	Clothes and overalls	7	365	-
Maintaining equipment	Diving gear	0	-	
Maintaining equipment	Fishing gear	8	52	At home - Annan
Maintaining equipment	Swimming gear	2	30	Caerlaverock

6.7.2 2015 Occupancy rates within the 1 km of Chapelcross (inside/outside work or home)

Individuals living or working within the immediate area of Chapelcross were asked to estimate how much time they spend inside and outside their home or workplace. The results presented in Table 6.9 show the time spent indoors and outdoors on an annual basis. Fourteen individuals interviewed lived within one kilometre of Chapelcross, the highest amount of time spent indoors for one individual was 7 665 h y^{-1} and the highest amount of time spent in the immediate area outside their house

was 5 840 h y^{-1}. It should be noted that the high figures for indoor occupancy at home do not take into account any holiday period away from home.

Table 6.9 Occupancy rates of those individuals working or living within 1 km of Chapelcross

Survey ID	Indoors at home (h y^{-1})	Outdoors at home (h y^{-1})	Indoors at work (h y^{-1})	Outdoors at work (h y^{-1})
101			2 555	365
127			1 300	624
138	4 745	1 460		
137	3 650	1 460		
138	4 745	2 002		
139	4 745	2 002		
001		1 460		
034		2 920		
051		548		
151			1 040	1 300
152	4 380	4 380		
153	7 300	1 460		
154	5 840	2 920		
211	7 665	1 095		
212	2 920	5 840		
213	6 935	1 825		
223	4 745	1 460	2 738	274

7. 2016 Re-assessment of Internal and External Habits Pathways

7.1 Introduction

SEPA wished to test the appropriateness of the new methodologies used by the new contractor undertaking the habits survey to ensure a robust approach was being used. The follow-up surveys were therefore undertaken in part to validate the 2015 surveys, whilst also identifying any major changes to both internal and external exposure paths from 2015 in addition to any new pathways being identified. New surveys were also conducted in April 2016 that targeted specific groups which may have potentially higher routes of exposure due to their food consumption or external habits.

7.2 2016 Habits Reassessment

7.2.1 Sampling criteria

Candidates were selected from the 2015 survey pool for follow-up surveys to assess changes in habits reported at a different time of the year, in this case spring 2016. The selection criteria were based on high, medium and low dose rates with, where possible, a minimum of three people from each of the groups contacted. The classes were based on the relative ranking of total doses received by individuals. Individuals who received doses in the upper 60% of the dose distribution were classed as *highly exposed* (there was only one individual in this category). The *medium class* was defined as above 10% and below 60% and the *low class* as below 10%. The one individual identified in the highly exposed group could not be contacted. The numbers re-surveyed from each group were as follows:

High-risk exposure (0)

Medium-risk exposure (5)

Low-risk exposure (4)

Targeted groups of people were contacted via telephone, e-mail or face-to-face and, where possible, re-surveyed in 2016 to compare against the first set of results collected in 2015. Those people who were willing to be contacted electronically were sent a form to complete.

7.2.2 Reassessment of External Pathway Habits

Terrestrial Based Activities

Four people in the medium risk group stating they were engaged in the same activities for the same length of time (Table 7.1). The exception to this was from survey interviewee 358, where the individual reported they would be spending less time in their allotment and bird watching in 2016 but more time cycling.

The low risk group also reported the same types of activities in both years. However, there was more variation in time spent doing those same activities. The estimated time spent undertaking some activities was 50% lower in 2016 than 2015. No new pathways were identified in the 2016 survey.

Aquatic Based Activities

No aquatic activities were reported by the medium risk group in either year. In the low risk group one person stated he fished this year and not the previous year whilst another (survey 393) was a keen sea angler recording 96 hours in 2015 but had decided to stop in 2016. One person recorded spending fewer hours power boating in 2016 than in 2015.

7.2.3 Intertidal Based Activities

No changes were reported in the intertidal activities for the medium risk group where dog walking and sand yachting activities were recorded in both years. No changes were anticipated in 2016 by the individual who maintained his boating equipment at home.

In the low risk group, one person reported they were not collecting mussels or clams in 2016, which they did last year. One person recorded a new pathway, harbour cleaning, in 2016 with a six-hour activity period estimated for the year. Other activities reported were the same in both years including boat and equipment maintenance.

Table 7.1. Seasonal changes in activities (h y^{-1}) reported

Activity	Dose Rate: / Survey ID:	Low 346	Low 393	Low 394	Low 395	Med 358	Med 399	Med 400	Med 401	Med 402
TERRESTRIAL:	Year									
Allotment	2015					913	108			
	2016					730	108			
Bee Keep	2015	72		13	39					
	2016	52		15.6	26					
Bird or	2015	730	365		183	913			1 095	1 095
Nature Watch	2016	365	365		78	365			1 095	1 095
Dog Walk	2015		730		208				183	183
	2016		365		274				183	183
Gardening	2015	208		540	273	730			364	364
	2016	208		386	12	730			364	364
Cycling	2015			52		24				12
	2016			52		38				12
Rambling/Walk	2015		365	156	39		52		208	26
	2016		182.5	156	104		52		208	26
Running	2015					13				
	2016					26				
Sit/Picnic	2015									
	2016					108				
Forage	2015	8		4		108	2			
	2016	6		4			0			
Outdoor	2015						6			
Bootcamp	2016						6			
AQUATIC:										
Sea Angling	2015	0	96							
	2016	8	0							
Rowing	2015				4					
	2016				4					
Power Boat	2015				12					
	2016				4					
INTERTIDAL:										
Beachcombing	2015			3	52					
	2016			3	52					
Collect Mussel	2015		36							
	2016		0							
Collect Clams	2015		6							
	2016		0							
Dog Walk	2015								26	
	2016								26	
Collect Samphire	2015				2					
	2016				2					
Harbour clean	2015				0					
	2016				6					
Sand Yacht	2015								6	
	2016								6	
MAINTENANCE:										
Boat and	2015								3	
equipment	2016								3	

7.2.4 Re-assessment of Internal Exposure Pathway Habits

Comparison data from the nine 2015/2016 re-surveys are presented in Table 7.2. In general, most people in 2016 did not report any major change in the types of food they consumed or the amount they ate. The medium risk group did not report any change in the type and quantity of fruit or vegetables grown and consumed. Similarly, there were no changes to the amount of honey, eggs and dairy products consumed from a local source. One person consumed less beef in 2016, whilst they froze approximately half the quantity of lamb they will consume in 2016; this is in comparison to them eating their lamb fresh in 2015.

In the low risk group, only minor changes to the quantities of fruit and veg consumed were reported. A new pathway was identified from the survey of 346, who stated they would be collecting wild foods this year - an activity not undertaken previously in 2015. The same survey also reported an increase in fresh meat consumed in 2016 due to a change in local supplier who sources meat from a local source, which resulted in twice as much beef, and pork and lamb being included in the survey.

The follow-up surveys provide a snapshot of any change from a relatively small sample size. With the exception of individual 346, generally interviewing the same individuals during a different season revealed little change in their food consumption habits.

Table 7.2 Changes in consumption rates (kg y^{-1}) reported ('Own' refers to either home grown, or reared food or food sourced locally)

	Dose Rate:	Low		Low	Low		Low		Medium		Medium	Medium	Medium	Medium
	Survey ID:	346		358	393		395		394		399	400	401	402
	Sourced:	Own	Purchased	Own	Fresh	Purchased	Own	Frozen	Own	Frozen	Own	Own	Own	Own
Food Group	YEAR	kg y^{-1}	kg y^{-1}	kg y^{-1}	kg y^{-1}	kg y^{-1}	kg y^{-1}	kg y^{-1}	kg y^{-1}	kg y^{-1}	kg y^{-1}	kg y^{-1}	kg y^{-1}	kg y^{-1}
Green Vegetables	2015			4.22			11.6		4.97		13.9	13.9	3.81	3.81
	2016			4.22			10.4		4.97		13.9	13.9	3.81	3.81
Other Vegetables	2015			1.82			0.60		1.45		1.40	1.40	9.32	9.32
	2016			1.82			0.60		1.45		1.40	1.40	9.32	9.32
Root Vegetables	2015			4.15			32.3		14.7		3.94	3.94	7.20	7.50
	2016			4.15			30.7		14.7		2.96	2.96	7.20	7.50
Potatoes	2015			3.74			0.00		7.99		17.6	17.6	1.75	1.75
	2016			3.74			0.00		7.99		17.6	17.6	1.75	1.75
Domestic Fruit	2015	7.61		1.62			15.6		18.0		0.67	0.67	15.9	15.9
	2016	7.51		1.62			15.6		18.0		0.67	0.67	15.9	15.9
Wild Foods	2015	0.00					0.09		15.1				2.55	2.55
	2016	0.15					0.00		15.1				2.55	2.55
Cattle Meat	2015	15.6							5.20					
	2016	31.2							1.20					
Sheep Meet	2015		0.00						2.40	0.00				
	2016		31.2						2.20	1.20				
Pork	2015		0.00											
	2016		20.8											
Wild Fowl	2015	1.00												
	2016	0.00												
Venison	2015													
	2016													
Fish	2015	1.00					0.90	0.00						
	2016	0.00					0.00	0.30						
Honey	2015	0.73					0.73		0.36					
	2016	0.73					0.73		0.36					
Eggs	2015	9.05		12.1					9.05					
	2016	9.05		12.1					21.2					
Dairy Foods	2015								104					
	2016								104					

7.3 2016 External Exposure

7.3.1 Introduction

A new survey was conducted in April 2016 that targeted specific groups likely to have higher routes of exposure to ensure that the most representative person(s) were identified during the 2015 survey campaign of workers for the traceability of internal and exposure pathways. The targeted groups included:

i) Land-based workers who work outdoors
ii) Workers representing the wider economy across the survey area
iii) Individuals who lived and/or worked close to the Chapelcross site

Particular attention was paid to those working in outdoor industries that spend more of their time working in the environment. The surveys included individuals working in the terrestrial and aquatic environment: net fishermen, farmers and other land workers as well as those living and working within one kilometre of Chapelcross.

7.3.2 Activity Related Habits

Data collected on activity-related habits are in Table 7.3. With the exception of a boat restoration project by a gamekeeper, no new terrestrial, aquatic or intertidal pathways were identified in any of the groups. The highest activities across the groups were terrestrial-based with the land-workers reporting highest activity times followed by those living or working within one kilometre of the site. The land workers reported activity time outdoors of over 1 800 h y^{-1} due to the nature of their work. Farmers' terrestrial residency time varied from zero to over 300 hours per year, although these figures excluded hours at work, which averaged approximately 2 000 h y^{-1} each.

For those not engaged in outdoor work the main activities outdoors were dog walking and gardening although activity times varied greatly between them.

Those spending the greatest amount of time undertaking coastal and intertidal activities were fishermen, although one land-worker, a volunteer for the RNLI, spends approximately 120 h y^{-1} with the organisation in the boat on the water. The land workers also reported spending 60 h y^{-1} on work related activities in the

intertidal zone. Time spent undertaking maintenance duties tended only a few hours and associated with cleaning fishing equipment and clothing.

Overall, the 2016 surveys confirmed that land-workers including farmers spent more time outdoors than those employed in other sectors of the economy. The data highlighted these potential exposure pathways.

Table 7.3 Activity for targeted groups (h y^{-1})

	Survey ID	Terrestrial	Coastal	Intertidal	Mainenance
Business Sector	**342**	782	0	0	0
	343	52	0	0	0
	351	736	0	0	0
	354	215	0	0	0
	348	13	0	0	0
* Also a farmer's wife	**356***	26	0	0	0
Farmers	**349**	0	0	0	0
	392	123	0	0	0
	403	7.8	0	0	0
** Farmer's wife	**404****	393	0	26	0
Net Fishermen	**344**	260	230	36	6
	365	194	119	0	1.75
	366	683	424	0	3
Child	**350**	0	0	0	0
	353	736	0	0	0
Land Workers	**405**	1 507	120	60	21
(Excluding Farmers)	**406**	1 175	0	60	2
	407	1 175	0	60	1
	408	2 871	20	10	1
Living Within 1 km	**367**	0	0	0	0
	368	835	0	26	0
	373	432	0	0	0
	374	121	0	0	0
	382	53	0	0	0
Working Within 1 km	**379**	385	0	0	0
	380	365	0	0	0
	381	0	0	0	0
Both Live & Work 1 km	**382**	216	0	0	0
Partner of Fisherman	**345**	208	0	0	0
Partner of worker	**352**	736	0	0	0
Partner of worker	**355**	215	0	0	0

7.4 Internal Exposure: 2016 Food Consumption

7.4.1 Introduction

One of the aims of the 2016 surveys was to identify any new pathways for the consumption of food.

A total of 34 new face-to-face surveys were performed. Of these, nine people reported they did not buy any food types that were sourced locally or grew or reared their own or picked any food in the wild. Overall, consumption of locally sourced food varied greatly across the differing occupations with those engaged in land working or fishing tending to consume more meat, vegetables and fish. Most food was eaten fresh with limited quantities of meat frozen before consumption. Relevant data are in Table 7.4.

7.4.2 Fruit & Vegetable Consumption

The majority of people did not grow their own fruit and vegetables, stating that they purchased food from the local supermarket or the independent Farm-Direct shop in Annan, apart from two land workers. The highest consumption rates for locally sourced or grown foods were reported by a farmer's wife and a gamekeeper, with potatoes 240 kg y^{-1} and 200 kg y^{-1} eaten respectively dominating this. The highest consumption value for potatoes observed in 2015 was 187 kg y^{-1}. They also ate a relatively large quantity of other vegetables including: sprouts, cabbage and courgettes. Both stated they had large gardens for growing produce. They also tended to grow a wider variety of foodstuffs compared to other people and picked the largest quantities of wild foods. None of the interviewees grew sufficient fruit and vegetables for year round consumption of any one-foodstuff and, where eaten, all fruit and vegetables were eaten fresh. Only two new individuals who worked within one kilometre of the site reported (captured in the 2015 data) grew their own food. The surveys did not identify any new individual living with one kilometre of Chapelcross that grew their own food.

Table 7.4. Food consumption rates (kg yr^{-1})

	Fresh Grown/Rear	Frozen	Purchased	Fresh Grown/Rear	Purchased	Fresh Grown/Rear	Purchased	Fresh Grown/Rear	Purchased	Fresh Grown/Rear	Purchased	Fresh Grown/Rear	Purchased	Fresh Grown/Rear	Fresh Grown/Rear	Fresh Grown/Rear	Frozen
SURVEY ID:	**344**	**344**	**344**	**365**	**365**	**366**	**367**	**349**	**349**	**356**	**356**	**392**	**392**	**403**	**404**	**405**	**408**	**408**
OCCUPATION/DISTANCE:	**NET FISHERMEN**							**FARMERS**							**LAND WORKERS**			
Green Vegetables	0.50														24.7		20.8	
Other vegetables															59.0		26.0	
Root Vegetables						26.0									2.4		17.1	
Potatoes						26.0						80			240		200	
Domestic Fruits						2.25				0.50					42.5	9.00	22.4	
Wild Foods	0.50			0.23		3.90									0.95		1.05	
Cattle Meats								78		52								
Sheep Meats	13							26			3.00				3.60			
Pork			3.00						7.80	13					3.60			
Total Poultry Meats										3.90							1.5	
Farmed Venison																		
Game Foods			3.00							1.00							58.7	54
Fowl Foods																	3	
Crustaecean Foods					0.05													
Mollusc Foods																		
Total Fish	8.55	3.00		4.00									3.00					
Honey													0.12					
Total Eggs							9.05	4.52		12.6				12.1	30.2		45.2	
Dairy Foods															291			

Table 7.4. Food consumption rates (kg yr^{-1}) continued

	Purchased	Purchased	Fresh Grown/Rear	Fresh Grown/Rear	Fresh Grown/Rear	Fresh Grown/Rear	Purchased	Fresh Grown/Rear	Fresh Grown/Rear	Frozen	Purchased	Fresh Grown/Rear	Fresh Grown/Rear	Purchased	Purchased
SURVEY ID:	**373**	**374**	**379**	**382**	**383**	**348**	**348**	**354**	**345**	**345**	**345**	**355**	**350**	**350**	**353**
OCCUPATION/DISTANCE:	**LIVE 1KM**		**WORK 1KM**		**BOTH**	**BUSINESS**			**PARTNERS**				**CHILDREN**		
Green Vegetables			0.55						0.50						
Other vegetables			0.45												
Root Vegetables			1.10												
Potatoes			6.50												
Domestic Fruits			4.00	14.0	14.0										
Wild Foods									0.50						
Cattle Meats						78.0							78		
Sheep Meats						26.0			13				26		
Pork							7.80				3.00			7.80	
Total Poultry Meats															
Farmed Venison															
Game Foods											3.00				
Fowl Foods															
Crustaecean Foods															
Mollusc Foods															
Total Fish									8.55	3.00					6.50
Honey	0.24	0.24													
Total Eggs			18.1			4.52		4.52				4.52	4.52		
Dairy Foods															

7.4.3 Meat Consumption

The survey confirmed that most people bought the majority of their meat from the supermarket. Only two individuals purchased their meat from local butchers in Annan. There was some difficulty in quantifying the amount of meat people ate from the local source as neither of the local butchers were able to find a local source capable of providing a year round supply.

The main type of meat sourced locally was pork, from a farm based in the Eastriggs area with one of the butchers (Appendix 4b) reported eating 7.8 kg y^{-1} of pork as a family from this farm (Table 7.4). A net fisherman also reported eating 3 kg y^{-1} of pork from the same farm. A farmer at Dornock ate 52 kg y^{-1} of beef from their own farm and also shot geese on the farm, but could not provide an accurate weight of goose consumed (Table 7.4). The family also sourced some pork and lamb from Annan parish farms, but would not provide details on this pathway. Another farmer sourced beef and lamb from his father's farm located in the survey area.

No locally sourced game and fowl were consumed, with the exception of a local gamekeeper who ate significant amounts of locally sourced meat: primarily pheasants (20-30 per year, approximately 4.5 kg) and wild venison (10 per year, approximately 300 kg fresh), which he shot himself. He froze approximately half the quantities for eating throughout the year. He also shot mallard (approximately 1.5 kg) and teal (approximately 1.5 kg). Consumption of local poultry and fowl was low with only person reporting they shot and ate geese on their farm.

No surveys identified anyone who lived or worked within one kilometre of the site as consuming meat from a local source.

7.4.4 Fish, Crustacean and Mollusc Consumption

Generally, few people ate any of this type of food from a local supply with most reporting they bought from a supermarket or mobile fishmonger and confirmed the findings from 2015.

Net fishermen and their families ate the most fish with highest consumption of any individual being 8.55 kg y^{-1} consisting of salmon and sea trout. The aforementioned gamekeeper also reported fishing for a couple of salmon and sea trout, but only in

the River Nith. These data confirm there is a pathway for the consumption of fish, which should continue to be targeted in future Habits surveys, especially given the changing policy towards net fishing on the Solway Firth.

One person ate approximately 0.05 kg y^{-1} of shrimps caught off the mouth of the river Annan. This confirms a report from the 2015 surveys that there is a pathway for the consumption of shrimps from the coastal area of the survey area. The new surveys did not identify anyone living or working within one kilometre of the site who ate fish from a local source.

7.4.5 Honey, Eggs and Dairy Food Consumption

The 2016 surveys identified an additional three individuals that consumed honey from a local supplier. One was a farmer and other two work within one kilometre of the site. This confirms the findings from the 2015 surveys that honey production is a niche market.

Several people kept hens on a small scale. A gamekeeper (section 7.4.4) kept the greatest number of hens, approximately 30, and consumed 780 eggs y^{-1}, more than the highest value identified in 2015. Other people consumed between 78 and 520 eggs y^{-1} from a local source.

Only one new person surveyed reported drinking milk from local source in the 2016 survey, consuming approximately 291 l y^{-1} of milk from their own farm. All other people surveyed bought honey, eggs and milk from the supermarket.

The 2016 survey identified several new pathways for the consumption of fruit and vegetables, meat, fish, milk and eggs not identified in 2015.

7.5 Summary of food consumption rates

Table 7.5 presents a summary of the survey results for food consumption for the 2016 surveys. The table excludes the survey date for the 3 children surveyed (shown in Table 7.4).

Table 7.5 Summary of adults' consumption rates for foods from the terrestrial and aquatic area (2016)

Food Type	Average Consumed Fresh (kg y^{-1} or l y^{-1})	Minimum Consumned (kg y^{-1} or l y^{-1})	Maximum Consumned (kg y^{-1} or l y^{-1})	97.5th Percentile (kg y^{-1} or l y^{-1})	National Mean (kg y^{-1} or l y^{-1})	National 97.5 percentile (kg y^{-1} or l y^{-1})
Green Vegetables	9.40	0.5	24.7	24.3	15	45
Other vegetables	28.5	0.5	59.0	57.4	20	50
Root Vegetables	11.7	1.1	26.0	25.3	10	40
Potatoes	111	6.5	240	236	50	120
Domestic Fruits	13.6	0.5	42.5	38.9	20	75
Foods - Wild	1.19	0.2	3.9	3.5	7	25
Mushrooms - Wild	1.00	1.00	1.00	1.00	3.0	10
Cattle Meats	52.0	52.0	52.0	52.0	15	45
Sheep Meats	8.15	3.0	13.0	13.0	8.0	25
Pork	6.37	3.0	13.0	12.2	15	40
Poultry Meats	2.70	1.5	3.9	3.8	10	30
Wild Venison	38.3	3.0	109	104		
Game*	2.86	1.0	4.73	4.63		
Wildfowl	3.00	3.0	3.0	3.0		
Crustacean	0.05	0.05	0.05	0.05	4.0	10
Mollusc Foods	0.00	0.00	0.00	0.00	4.0	10
Total Fish	5.23	3.00	8.55	8.55	15	40
Honey	0.20	0.12	0.24	0.24	2.5	9.5
Total Eggs	13.6	4.52	45.2	41.5	8.5	25
Dairy Foods	291	291	291	291	95	240

*includes Pheasant and rabbit

7.6 2016 Resurvey of occupancy rates within the 1 km of Chapelcross (inside/outside work or home)

A total of 22 people said they either lived or worked within one kilometre of the Chapelcross site, with an additional three both living and working near the site. Data collected are in Appendix 24, Table 24.1. Data were also compiled from all those who travelled past the site on a regular basis, regardless of where they lived.

7.6.1 Living within 1 km of Chapelcross

Sixteen individuals, six new survey and ten re-surveyed, lived in Creca village: 14 adults and two children under the age of 16. Four of the people interviewed were retired, one person worked away during the week and another person was currently not working. With the exception of children, all other individuals were employed.

For the adults, total annual occupancy times ranged from 1 429 h y^{-1} to a maximum of 7 244 h y^{-1}. The two children reported annual occupancy times of 3 968 h y^{-1}. Overall, individuals spent more time indoors than outdoors regardless of the time of year. However, there was a distinct seasonal difference in occupancy time for all people regarding the length of time spent indoors and outdoors. Perhaps unsurprisingly, indoor occupancy rates were higher over autumn/winter than spring/summer and higher outdoors in summer than winter. The highest indoor occupancy times for any one individual was 2 576 hours and 2 704 hours in spring/summer and autumn/ winter respectively. The highest number of hours spent outdoors for any one individual in spring/summer and winter were 1 610 hours and 1 014 hours respectively. Variations in occupancy times may be explained by those not in work, those working away or those who are retired.

7.6.2 Working within 1 km of Chapelcross

Four people worked at the Chapelcross site with a further five stating they worked nearby either on a farm, an industrial estate in Creca or at a salvage yard close to the site. Seven of the interviewees reported differing seasonal occupancy rates depending upon the length of time they spent indoors or outdoors. Despite these differences, annual total occupancy rates for these people were relatively consistent, ranging from 2 475 h y^{-1} to 2 672 h y^{-1}.

However, annual occupancy totals for a farmer and his wife differed with the husband recording an annual total of 4 636 h y^{-1} with the high outdoor residency time reflecting the nature of his job. His wife reported a much lower annual figure of 2 648 h y^{-1}.

7.6.3 Living & Working within 1 km of Chapelcross

Three people surveyed stated that they both lived and worked within one kilometre of the site and they reported high combined (living and working) annual occupancy times, ranging from 7 365 h y^{-1} to 8 186 h y^{-1}.

This supplementary work has provided more detail on the external exposure pathways for those closest to the site. Continued monitoring of people who live and/or work within one kilometre of Chapelcross will enable any changes in such occupancy rates to be identified.

8. Doses to the representative person

8.1 Introduction

The information collected within the 2015 habits survey has been used to estimate retrospective doses to people living around Chapelcross and in the surrounding area between 2010 and 2015. The data collected have identified individuals who consume locally produced food and who have activities that may lead them to receiving an exposure to radioactive materials present in the environment. It should be noted that the Chapelcross discharges are well within permitted discharge limits. The data are firstly considered for the aquatic exposure pathway, secondly terrestrial pathways and finally a combined dose assessment encompassing both aquatic and terrestrial. Critically, all three assessments include internal and external pathways. The retrospective doses for the 2015 survey and the re-survey/follow up survey are given in each section.

The dose assessment was conducted in stages. Firstly, PC-CREAM 08 was used to run the atmospheric dispersion model PLUME along with the GRANIS (external exposure model) and RESUS (resuspension model) to estimate the external dose rates at distances of 0.5 km, 1 km, 5 km, 10 km, 15 km, 20 km and 25 km from the centre of the Chapelcross site for the actual Chapelcross discharges from the site in 2014 (RIFE 20). The atmospheric releases were for tritium (3E13 Bq y^{-1}) and "all other radionuclides" (3.56E8 Bq y^{-1}). In the case of the latter, ^{137}Cs was used as a conservative analogue. A stack height of 37 m was used following discussions with the site and the SEPA local inspector. The remaining PLUME model parameters used were the defaults in the software (e.g. roughness was assumed to be mainly agricultural around Chapelcross). The MET stability scheme was applied using the default settings. Data extracted for the dose rates were based on the MET Pasquill D, based on the typical weather conditions for this area Appendix 26.

The GRANIS model within PC-CREAM was run using the generic air, wet and dry soil compositions, but by assuming an undisturbed wet soil for each of the different depths of soil (0-1 cm, 1-5 cm, 5-15 cm, 15-30 cm and 30-100 cm). These factors are taken into account by considering the shielding of the soil matrix and the transfer

of the radionuclides in question through the soil profile. As it was a retrospective assessment, the assessment was run for one year.

The RESUS model was also run to estimate activity concentrations in air arising from the resuspension of previously deposited radionuclides. The formula used is independent of the radionuclide except for the fact that radioactive decay is taken into account. The model was also run for one year.

Having set up PC-CREAM to estimate the external dose to people living or spending time at different distances from the site, the effective external dose was then determined by running the assessor model for the atmospheric individual dose within PC-CREAM.

Within the assessor model, the three supporting models were selected along with the one year option and the stack height of 37 m. The selected distances were also re-input and the receptor was assumed to spend all their time at the location (i.e. a full year). Therefore, when the values were entered into the habits dose assessment spreadsheet tool, the time the people actually spent at each location was then multiplied by the hourly dose rate. In terms of meteorological data, it was assumed that 80% of the weather occurred in category D and with 10% rain in C and D as the default. These assumptions were checked against climate data from Eskdalemuir and found to be comparable with the weather data parameters. Rainfall was based on the number of days with rain, resulting in a percentage rainfall value to around 24%. However, in reality, it is unlikely that there are 24 hrs of rain for each day recorded and so the 10% assumption in PC Cream was assumed to be reasonable (Appendix 28).

The external dose rates estimated are shown in Figure 8.1 for adults, which are spatially integrated estimates derived from the PC-CREAM output. Similar figures are available in Appendix 29 for the child and infant (Figures A29.1 and A29.2). Using georeferenced data from the habits survey, the external dose to individuals was estimated based on the time spent in the areas covered by the different concentric circles in Figure 8.1 and specifically for those living and working within one kilometre of the site. For those living within one kilometre, an overall mean reduction factor of 0.61 was assumed based on the values given in Table 6.7.

Any elevated levels of radiation measured during carborne in-situ monitoring survey around the Chapelcross site (called direct shine) was also included in the retrospective dose assessment. The number of times an interviewee passed by the areas of elevated radiation levels and the mode of transport (car, bike, walk etc.) were recorded and used in the retrospective dose assessment.

External doses were determined for people spending time in intertidal areas over different substrates (saltmarsh, mud, sand and pebbles) based on the measurements made over these substrates (Tables 6.2 and 6.5).

The beta dose to the skin was estimated using the beta in-situ measurements reported in Table 6.3. It should be noted that the beta dose is measured to skin and is comparable to a different dose limit (50 mSv y^{-1}) because the beta radiation does not contribute to the effective dose that is reported for the whole body.

Three individuals interviewed in the 2015 survey had high exposures for handling fishing gear and/or handling sediment (1 324, 3 185 and 3 198 hours). This is in part due to the conservative assumptions made that someone handling fishing gear or playing on a muddy beach is in contact with the sediment for the entire period of time that they spend there. Furthermore, the assumptions take no account of potential shielding from, for example, the use of gloves while handling fishing gear.

The retrospective dose estimated to these three individuals was dominated by the external beta contribution. For the evaluation of retrospective doses in the following sections (sections 8.2 and 8.3), the doses from these three individuals have been removed as this is essentially a skin dose. The doses estimated to these three individuals are given in Table 8.1. In all cases, these doses are well within the public effective dose limit (1 mSv) and the skin dose limit (50 mSv).

Table 8.1 Retrospective doses to three individuals with high external beta dose resulting from their handling of fishing gear and sediment in the 2015 survey

Individual	Beta Dose (mSv)	Effective Dose (mSv)	Total Dose (mSv)
1	5.01E-02	1.14E-04	5.02E-02
2	2.12E-02	2.00E-07	2.12E-02
3	1.19E-02	1.06E-04	1.20E-02

To calculate the internal dose to individuals based on their consumption rates as identified in the habits survey, food activity concentrations (wet weight, Bq kg^{-1}) were determined by averaging the monitoring data collected for the RIFE programme over the previous 4 years (RIFE reports 17-20). These activity concentrations for the different foodstuffs by the habit categories listed in Table 3.1. Some assumptions were made in the calculations. For example:

(i) The activity concentration values in the RIFE data were often limit of detection (LOD) values. The dose has been calculated assuming that the activity concentration is therefore at the LOD.
(ii) There were no RIFE monitoring data available for some of the habits categories listed in Table 3.1, e.g. meat – game and so the nearest appropriate category was used to provide the activity concentration. So for poultry and eggs, the data for wildfowl was applied, for sheep, pig, game, venison the data for beef was used.

All the activity concentrations and the external doses were input into a spreadsheet dose assessment tool that summarised the dose based on the habits data for each person. It should be noted that while the individual dose calculations are based on the habits information collected during the surveys, the way the data have been used and the assumptions made mean that the doses are calculated to a stylised person. For example, in the case of external dose from radioactive materials deposited to the terrestrial environment, people were assigned to each concentric circle shown in Figure 8.1 based on where they carried out their activity or lived and then the doses were determined by integrating the dose rate over the concentric circle. Similarly, the internal doses were estimated by multiplying the individual habit consumption rates by the activity concentrations in the food type as measured within the RIFE programme (see Environment Agency *et al,* 2015).

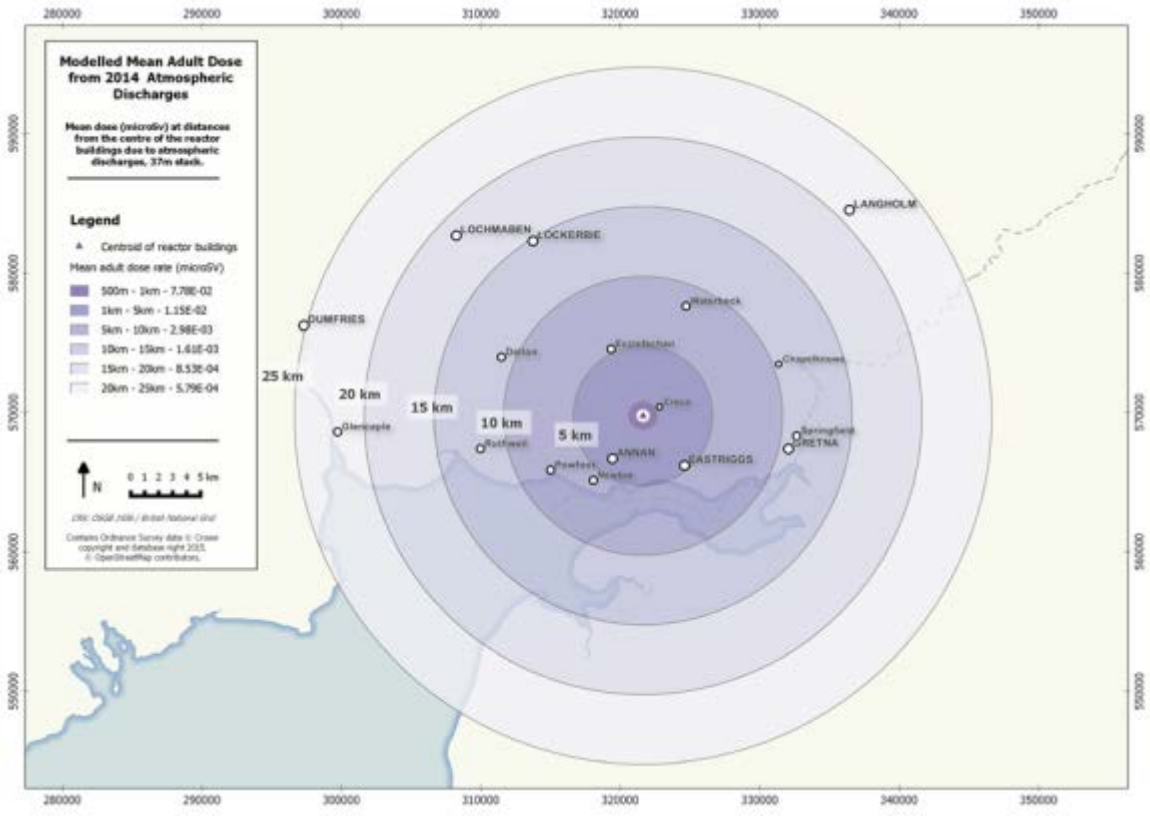

Figure 8.1 Modelled Mean Adult External Doses from 2014 Atmospheric Discharges, assuming equal deposition within around circle.

8.2 Dose Assessment for 2015 Survey

8.2.1 Aquatic radiation pathways

Internal exposure for 2015 survey

The retrospective dose arising from internal exposure (via food sources from the aquatic environment) was used to determine the representative person from this pathway.

The retrospective dose to the most exposed person from this exposure pathway is 8.47E-6 mSv. The dose to the (hypothetical) representative person (97.5%) is 8.30E-6 mSv. In the case of the most exposed person the dose arises from the consumption of locally obtained fish (47 kg y^{-1}).

External exposure for 2015 survey

The retrospective dose arising from external exposure (via people's habit activities in and on the aquatic environment) was used to determine the representative person from this pathway.

The retrospective dose to the most exposed person from this exposure pathway is 9.30E-3 mSv. The dose to the (hypothetical) representative person (97.5%) is 9.04E-3 mSv. In the case of the most exposed person the dose arises from the handling of sediment and fishing gear (280 and 282 h y^{-1} respectively). In this case, the same individual is the most exposed for the internal and external aquatic categories.

8.2.2 Terrestrial radiation pathways

8.2.3 Internal exposure for 2015 survey

The retrospective dose arising from internal exposure (via food sources from the terrestrial environment) was used to determine the representative person from this pathway.

The retrospective dose to the most exposed person from this exposure pathway is 2.1E-4 mSv. The dose to the (hypothetical) representative person (97.5%) is 2.0E-4 mSv. In the case of the most exposed person the dose arises from the consumption of beef (39 kg y^{-1}), game (venison (0.4 kg y^{-1}), rabbits and hares (0.7 kg y^{-1})) and milk (723 l y^{-1}).

8.2.4 External exposure for 2015 survey

The retrospective dose arising from external exposure (via people's habit activities in the terrestrial environment) was used to determine the representative person from this pathway.

The retrospective dose to the most exposed person from this exposure pathway is 2.3E-4 mSv. The dose to the (hypothetical) representative person (97.5%) is 2.2E-4 mSv. The most exposed person's external terrestrial dose was dominated from time spent in the intertidal environment (a total of 730 h y^{-1}).

8.2.5 Overall combined radiation exposure for 2015 survey

The retrospective dose arising from all exposure pathways (e.g. via people's habit activities in and on the aquatic, intertidal or terrestrial environments and the consumption of all foodstuffs derived locally from the aquatic or terrestrial environments) has been used to determine the representative person.

The dose rate to the most exposed person from all exposure pathways is 9.3 E-3 mSv. The retrospective dose to the representative person (97.5%) is 9.1E-3 mSv. In the case of the most exposed person, the dose was dominated by the external aquatic dose (this is in fact the same individual as that for the aquatic pathways consuming 47 kg y^{-1} of fish and from the handling of sediment and fishing gear (280 and 282 h y^{-1} respectively).

These doses are very small in comparison with the 1 mSv public dose limit.

Table 8.2 contains some summarised dose information based on the average doses to different people based on age profile.

Table 8.2 Average dose estimates (mSv) to stylised people averaged by age (2015).

Age Category	Dose (mSv)
Infant	7.3E-4
Child	1.1E-3
Adult	1.1E-3
All	7.2E-4

8.3 Dose Assessment for 2016 Survey

The re-survey data and follow up surveys undertaken in 2016 were re-analysed to determine the dose from each radiation exposure pathway using the same approach and data as for the 2015 survey to allow comparisons to be drawn between the two survey periods. The results are described below.

8.3.1 Aquatic radiation pathways

Internal exposure for 2016 survey

The retrospective dose arising from internal exposure (via food sources from the aquatic environment) was used to determine the representative person from this pathway.

The retrospective dose to the most exposed person from this exposure pathway is 5.9E-6 mSv. The dose to the (hypothetical) representative person (97.5%) is 5.4E-6 mSv. Two people represented the most exposed person and the dose arises from the consumption of locally obtained fish (33.6 kg y-1).

External exposure for 2016 survey

The retrospective dose arising from external exposure (via people's habit activities in and on the aquatic environment) was used to determine the representative person from this pathway.

The retrospective dose to the most exposed person from this exposure pathway is 7.2E-4 mSv. The dose to the (hypothetical) representative person (97.5%) is 7.1E-4 mSv. In the case of the most exposed person the dose arises from the handling of sediment and fishing gear (96 and 60 h y-1 respectively).

8.3.2 Terrestrial radiation pathways

Internal exposure for 2016 survey

The retrospective dose arising from internal exposure (via food sources from the terrestrial environment) was used to determine the representative person from this pathway.

The retrospective dose to the most exposed person from this exposure pathway is 2.6E-4 mSv. The dose to the (hypothetical) representative person (97.5%) is 1.8E-4 mSv. In the case of the most exposed person the dose arises from the consumption of green leafy vegetables (23 kg y^{-1}), root vegetables (17 kg y^{-1}), potatoes (200 kg y^{-1}), domestic fruit (48 kg y^{-1}), eggs (45 kg y^{-1}) and venison (109 kg y^{-1}).

External exposure for 2016 survey

The retrospective dose arising from external exposure (via people's habit activities in the terrestrial environment) was used to determine the representative person from this pathway.

The retrospective dose to the most exposed person from this exposure pathway is 1.4E-3 mSv. The dose to the (hypothetical) representative person (97.5%) is 1.01E-3 mSv. The most exposed person's external terrestrial dose was dominated by direct shine from the site.

8.3.3 Overall combined radiation exposure for 2016 survey

The retrospective dose arising from all exposure pathways (e.g. via people's habit activities in and on the aquatic, intertidal or terrestrial environments and the

consumption of all foodstuffs derived locally from the aquatic or terrestrial environments) has been used to determine the representative person.

The dose rate to the most exposed person from all exposure pathways is 1.4E-3 mSv. The retrospective dose to the (hypothetical) representative person (97.5%) is 1.01E-3 mSv. The most exposed person's total dose was dominated by direct shine from the site.

These doses are very small in comparison with the 1 mSv public dose limit.

9. Comparisons with the Previous Habits Survey

9.1 Introduction

The results from this Chapelcross 2015 Habits Survey can be compared with results from the last habits survey, undertaken in Chapelcross in 2010 by the Centre for Environment Fisheries and Aquaculture Science (CEFAS). The results have been reported in chapters 4 and 5 for both the postal survey and the face-to-face survey. In comparison with the 2010 survey, new data is provided based on the postal survey undertaken in 2015. Unless otherwise stated, the re-surveys and new surveys undertaken in 2016 confirmed the findings of the more extensive 2015 habits survey results.

The aquatic and terrestrial face-to-face survey area in the 2015 survey extended from Glencaple in the west to Gretna in the east. The 2010 survey extended from Scar Point in the west to Gretna in the east. The postal survey area was a 20 km radius from the Chapelcross site.

9.2 Aquatic Survey

9.2.1 Postal Survey - Internal Exposure

A postal survey was undertaken in the 2015 survey and it was determined that respondents consumed fish (cod, salmon, haddock and mackerel) more frequently than crustaceans (crab and lobster) and molluscs (mussels). The majority of respondents sourced their fish/crustaceans/molluscs from supermarkets (55 %) with the remaining respondents sourcing their aquatic food from either a local shop or local market. This is discussed in Section 4.2.1.

9.2.2 Postal Survey - External Exposure

It was reported that of the respondents who undertook aquatic activities, the highest number of respondents participated in beach activities (walking, paddling, beach combing) followed by outdoor swimming and water sports. This is discussed in Section 4.2.2.

9.2.3 Face-to-Face - Adult Consumption Rates – Internal Exposure

In 2015 the mean consumption rate for the adult high-rate group in the face-to-face interviews is substantially increased for fish, crustaceans and molluscs compared with 2010. In 2010 wildfowl consumption was higher compared to wildfowl consumption in 2015. The main species of fish consumed by adults were salmon and sea trout in 2010 compared with salmon and cod in 2015. The main crustaceans consumed by adults in 2010 were brown crab and shrimps compared with brown crab, lobster and shrimp in 2015. Mollusc consumption was not identified in 2010 but was identified in 2015 with scallops and razor clams being consumed. In 2010 the main species of wildfowl consumed by adults were mallard, pink-footed goose and grey lag goose compared with mallard and pink-footed goose in 2015. The consumption of marine/intertidal plant/algae (Samphire) by adults was identified in 2010 and in 2015.

A comparison between 2010, 2015 and 2016 adult consumption rates of aquatic foods in the face-to-face interviews is presented in Table 9.1. The Table also provides the mean consumption rates from national data (Smith and Jones, 2003) for comparison. The 2016 data did not specifically target fishermen who were likely to return high consumption rates and overall 2016 values were lower than those reported for 2015 and 2010.

Table 9.1 Comparison between 2010, 2015 and 2016 adult consumption rates of aquatic foods

Food Group	2010			2015			2016			National
	Number of people in the high-rate group	Maximum consumption rate (kg y^{-1})	Mean consumption rate (kg y^{-1})	Number of people in the high-rate group	Maximum consumption rate (kg y^{-1})	Mean consumption rate (kg y^{-1})	Number of people in the high-rate group	Maximum consumption rate (kg y^{-1})	Mean consumption rate (kg y^{-1})	Mean (kg y^{-1})
Fish	23	12.9	8.7	1	47.0	47.0	0	8.6	5.02	15
Crustaceans	4	20.4	15.3	1	20.8	20.8	0	0.05	0.1	4
Molluscs	4	45.1	ND	1	3.00	3.00	0	0.00	0.00	4
Wild Fowl	4	30.6	0.2	1	16.3	16.3	0	3.00	3.00	ND

9.2.4 Face-to-Face - Children and Infants' Consumption Rates – Internal exposure

The consumption rate of fish, crustaceans, molluscs and wild fowl for children and infants was not determined in 2010, therefore there is no data for comparison. There was no consumption of crustaceans or wildfowl identified for children and infants in 2015. The only fish species consumed for the child age group was cod. No infants were found to consume aquatic food. Refer to Section 4.11.2 for further details.

9.2.5 Face-to-Face - Adults Intertidal Occupancy – External exposure

In contrast to the 2010 survey external exposure was divided into four distinct groups: intertidal activities, aquatic in water activities, aquatic on water activities and the handling of equipment - all of which are discussed in further detail in Section 4.12.

In 2015 intertidal occupancy was highest for dog walking. There is no comparison in 2010.

In 2015 handling of equipment by adults within the survey area was reported. These activities included boat maintenance, handling clothes and overalls, diving gear, fishing gear and outdoor swimming gear. In 2010 the handling of fishing gear was determined as a mean occupancy-handling rate for the high rate group of 290 h y^{-1}. This was observed to be substantially lower, although the handling of fishing gear is only a sub category of the handling of equipment in 2015, so this may account for the substantial increase.

Activities taking place in or on the water were assessed differently in 2015 with mean occupancy rates and 97.5th percentile rates determined. In comparison to the 2010 survey these data were not determined.

9.2.6 Face-to-Face - Adults Handling Fishing Gear and Sediment Related Activities

Nine wildfowlers were identified during the survey and reported to spend time lying on and handling sediment with their hands during their period of wildfowling. Stake net and Haaf net fishermen were also identified to handle sediment when working with nets and retrieving fish. It was reported during the face-to-face surveys that stake net fishermen wore gloves whilst working and Haaf net fishermen did not wear

gloves whilst working. Both parties however wore waders/chest waders and water proof fishing jackets.

These data are presented in Table 9.2. Data reported during the 2016 resurveys confirmed these values.

Table 9.2 The 2015 aquatic external exposure pathways for adults

Activity	Number of people in the high-rate group	Observed maximum for the high-rate group (h y^{-1})	Observed mean for the high-rate group (h y^{-1})
Intertidal	1	1 095	1 095
Aquatic (in water)	1	1 460	1 460
Aquatic (on water)	1	1 460	1 460
Handling equipment	2	624	563
Handling sediment	17	1 738	886

9.2.7 Face-to-Face – Children and Infants Intertidal Occupancy – External Exposure

As with the adult intertidal occupancy, in contrast to the 2010 survey, external exposure was divided into four distinct groups: intertidal activities, aquatic in water activities, aquatic on water activities and the handling of equipment - all of which are discussed in further detail in Section 4.12.

In 2015 the intertidal occupancy for children and infants was determined. These data are presented in Table 9.3.

As with the adults, handling of sediment for children and infants was not determined within the 2015 survey. However, children were noted to be dog walking and collecting wild produce with their families. Activities taking place in or on the water were assessed differently in 2015 with mean occupancy rates and 97.5th percentile rates determined in comparison to these data not being determined in 2010.

Whilst children were identified on intertidal areas, no children or infants were identified handling equipment or carrying out activities in the water during the survey period.

Table 9.3 The 2015 aquatic external exposure pathways for children and infants

Activity	Number of people in the high rate group (h y^{-1})	Observed maximum for the high rate group (h y^{-1})	Observed mean for the high rate group (h y^{-1})
Child (6 - 15 years old)			
Intertidal	2	730	730
Aquatic (in water)	0	0	0
Aquatic (on water)	1	16	16
Handling equipment	0	0	0
Infant (0 - 5 years old)			
Intertidal	1	730	730
Aquatic (in water)	0	0	NA
Aquatic (on water)	1	12	12
Handling equipment	0	0	0

9.3 Terrestrial Survey

9.3.1 Postal Survey – Internal Exposure

A postal survey was undertaken in 2015 and it was determined that dairy products (milk, cheese and yoghurt) was the most frequently consumed food type. Wild meat (rabbit and game) was the food type least consumed. The supermarket was reported to be where respondents most frequently sourced terrestrial food items, although local shops and markets were also used. Refer to Section 5.2 for further details.

9.3.2 Postal Survey – External Exposure

The most frequently selected terrestrial activities within the postal survey in 2015 were spending time on an allotment/gardening, greenspace walking, urban walking and bee keeping. A total of 79% of respondents participated in walking on a daily basis and 60% of respondents participated in allotments/gardening on a daily basis. Refer to Section 5.2 for further details.

9.3.3 Face-to-Face – Adult Consumption Rates – Internal Exposure

Consumption rates of locally produced food items has increased in the 2015 survey in the green vegetable, potatoes, fruit (domestic), fruit (wild), meat (beef), meat (poultry) and meat (sheep) food groups in comparison to the 2010 survey.

Consumption rates decreased in the 2015 survey in the following food groups: vegetables (root), meat (game) and honey in comparison to the 2010 survey.

No other vegetables were identified in 2015 in comparison to what was identified in 2010. A comparison between the 2010, 2015 and 2016 mean rates for adult consumption of the terrestrial food groups is presented in Table 9.4. The Table also provides the mean consumption rates from national data (Smith and Jones, 2003) for comparison. The additional surveys undertaken in 2016 provide similar, if sometimes lower rates of consumption than those reported in 2010 or 2015.

Table 9.4 Comparison between 2010, 2015 and 2016 mean consumption rates of local terrestrial food groups for adults (kg y^{-1} or l y^{-1}).

Food group	**2010** Mean consumption rate for the high-rate group (kg y^{-1} or l y^{-1})	**2015** Mean consumption rate for the high-rate group (kg y^{-1} or l y^{-1})	**2016** Mean consumption rate for the high-rate group (kg y^{-1} or l y^{-1})	**National**
Green Vegetables	22.4	13.4	9.40	15
Other Vegetables	24.3	28.8	28.5	20
Root Vegetables	38.9	14.1	11.7	10
Potatoes	76.6	187	111	50
Fruit - Domestic	23.8	30.4	13.6	20
Fruit - Wild	4.6	13.9	1.19	7
Mushrooms - Wild	0.9	2.75	1.00	3
Meat – Beef	38.5	36.2	69.3	15
Meat - Game	37.7	12.4	23.9	NA
Meat - Poultry	19.1	16.8	2.70	10
Meat - Sheep	6.0	15.3	14.1	8
Honey	9.1	1.04	0.18	2.5
Eggs	21	13.1	14.5	8.5
Milk	420	415	291	95.0

9.3.4 Face-to-Face – Children and Infants' Consumption Rates - Internal Exposure

Table 9.5 presents a comparison of consumption rates for children between the 2010 and 2015 surveys. Potatoes and wild fruit values are very similar and comparable to the National values, whilst the 2010 survey reports higher values for vegetable consumption and the 2015 survey reports higher values for mil consumption.

Table 9.5 The 2015 mean local consumption rate (kg y^{-1} or l y^{-1}) for children

*****Values derived from ratio used in RIFE 2014 Table X2.1.

Food group	**2010** Mean consumption rate for the high-rate group (kg y^{-1} or l y^{-1})	**2015** Mean consumption rate for the high-rate group (kg y^{-1} or l y^{-1})	**National*** kg y^{-1} or l y^{-1})
Green Vegetables	35.8	9.97	6
Other Vegetables	19.3	0	8
Root Vegetables	58.8	4.13	6
Potatoes	16.1	17.8	45
Fruit - Domestic	17.2	11.7	15
Fruit - Wild		4.69	3
Meat – Beef		11.2	15
Meat - Game		0	4
Meat - Poultry		11.4	5.5
Meat - Sheep		0	4
Meat - Honey		0	2
Milk	111	219	110

9.4 Direct Radiation Survey

Table 9.6 presents the comparisons between 2010, 2015 and the additional 2016 survey occupancy rates for people living and working within the direct radiation area (h y^{-1}). No individuals surveyed recall being interviewed in the previous 2010 habits survey.

In 2010 the resident for the highest indoor occupancy was 8 100 h y^{-1} and a different resident for the highest outdoor occupancy was 2 900 h y^{-1}. In 2015, one resident was identified with the highest indoor (7 665 h y^{-1}) and a different resident for outdoor occupancy (5 840 h y^{-1}). In 2010 the highest outdoor occupancy rate was one adult resident who worked in the area. The values surveyed in April 2016 were lower than those reported in 2015 and 2010.

Table 9.6 Comparison between 2010, 2015 and 2016 occupancy rates for people living and working within the direct radiation area (h y^{-1}) (ND is no data).

	2010	**2015**	**2016**
Highest Total	8 400	8 760	7 244
Highest Indoor at home	8 100	7 665	5 280
Highest Outdoor at home	2 900	5 840	2 624
Highest indoor at work	ND	2 738	2 672
Highest outdoor at work	ND	2 373	4 636

In 2015, occupancy rates for those working within the direct radiation area were determined. The highest indoor occupancy for one individual at work was 2 738 h y^{-1} and a different individual had the highest outdoor occupancy, which was 2 373 h y^{-1}. There is no comparison as this was not looked at during the 2010 survey. However, a farmer interviewed in 2016 spent much more time working outdoors than the data collected in 2015 indicated, with an outdoor occupancy value of 4 636 h y^{-1}. The same farmer's wife reported an outdoor occupancy value of 2 648 h y^{-1}.

Children and infants were not identified within the high-rate groups in the 2010 survey. Within the 2015 survey a child resident was identified to have 4 745 h y^{-1} for indoor occupancy and the same child was identified to have 2 002 h y^{-1} for outdoor occupancy. The child spent the rest of their time out with the survey area.

In summary:

- In 2015 the highest total occupancy rate increased from 2010. A slightly lower value was reported during the 2016 survey.
- In 2015 the highest indoor occupancy rate decreased from 2010 for individuals at home. The 2016 survey also returned a lower indoor occupancy than the 2015 survey.
- However, the highest outdoor occupancy rate in 2015 more than doubled the value from 2010, but was lower again from survey data collected in the 2016 survey.

9.5 Pipeline Survey

9.5.1 Pipeline Survey – Dose Rate

The 2015 Habits survey included an assessment of the doses associated with the Chapelcross Effluent Pipeline. The results a described in Section 6.2.2. The gamma dose rate measurements collected at points along the pipeline ranged from levels similar to background (0.04 µGy h^{-1}) to around 0.15 µGy h^{-1}. When extrapolated with the handheld MoGSS a similar pattern of dose rate appears compared with that reported by Tipple *et al.,* 2002. Whilst, the highest dose rates reported in the 2015 survey are slighter higher than those reported in the 2002 survey, the difference can be explained by differences in measurement geometry and location.

9.5.2 Pipeline Survey – Comparison of Occupancy

In 2010, activities identified in the pipeline survey area included individuals walking, dog walking and carrying out grounds maintenance. Similarly, in 2015, individuals were observed walking and dog walking (Table 9.7). Individuals resurveyed in 2016 tended to confirm the data collected in 2015. Other activities identified in 2015 were; bird/nature watching, collecting wild produce and fishing activities (Haaf and stake netting) in the water where the pipeline enters the Solway. The maximum occupancy increased from 730 h y^{-1} to 1095 h y^{-1} in 2015, but the activity carried out by the individual with the highest occupancy rate was dog walking both years.

Table 9.7 2015 Occupancy rates near the Chapelcross pipeline (h y^{-1})

Activity	Maximum Occupancy (h y^{-1})
Bird/nature watching	144
Collecting wild produce	8
Dog walking	1 095
Walking	104
Haaf netting	3
Stake netting	320

9.5.3 Dose Comparison

No dose information is provided in the 2010 report. The doses calculated for the different exposure pathways from data in the 2015 and 2016 surveys are provided in Table 9.8. For all pathways except external terrestrial, the doses for the 2016 survey are lower than or the same order of magnitude as those for 2015. The external terrestrial pathway in 2016 is an order of magnitude higher, but all doses are still well within the 1 mSv public dose limit.

Table 9.8 Comparison of doses calculated from the 2015 and 2016 survey data (mSv y^{-1})

	2015 survey		**2016 survey**	
Pathway	**97.5 percentile dose**	**Maximum dose**	**97.5 percentile dose**	**Maximum dose**
Internal Aquatic	38.3E-6	8.5E-6	5.4E-6	5.9E-6
External Aquatic	9.0E-3	9.3E-3	7.1E-4	7.2E-4
Internal Terrestrial	2.0E-4	2.1E-4	1.8E-4	2.6E-4
External Terrestrial	2.2E-4	2.3E-4	1.0E-3	1.4E-3
All pathways	9.1E-3	9.3E-3	1.0E-3	1.4E-3

10. Recommendations and Suggestions for Monitoring Programme Changes.

10.1 Introduction

The habits survey presents results for occupancy, activity and food consumption from three main sources of community engagement: (i) Postal questionnaire (n = 194); (ii) face-to-face surveys (2015: n = 317; 2016: n = 43, of which nine resampled from 2015 and resurveyed to assess any change); and (iii) a number of meetings and informal contacts. These data have been supplemented with radiometric surveys including: (i) a carborne gamma spectrometry survey (n = 27 262); (ii) handheld mobile gamma spectrometry measurements for the pipeline (n = 88 986); (iii) in-situ gamma dose rate (n = 42 intertidal; n = 15 inland); (iii) additional sediment core sampling with laboratory based gamma spectrometry (n = 30) and (iv) Beta skin dose assessments (n = 23).

10.2 Ongoing Monitoring

The RIFE report demonstrates a comprehensive set of monitoring undertaken annually around the Chapelcross site encompassing a range of food types and environmental substrates. The gamma dose rates reported by RIFE are generally higher than those reported in this assessment, as the dose rates in this report exclude the cosmic contribution. This assessment reports the terrestrial gamma dose rate only. When taking this into account, the results are similar. Terrestrial food samples taken and reported in the RIFE/SEPA Report 2014 (published 2015:pp141-2) covered milk, apples, cabbages, beef, carrots, cauliflower, geese, honey, leeks, rosehips, potatoes, rosehips and wheat. The RIFE report additionally provided grass and soil radiation levels as well as data on seafood taken in the area.

10.3 Conclusions and Recommendations

10.3.1 Additional Targeted Surveys

The 2016 survey proved useful in re-assessing a sample of the 2015 surveys to demonstrate that the data originally collected remained representative, when collected at a different time of year. The new 2016 surveys, which targeted

individuals with potentially high occupancy values such as land workers also returned similar values to the high end values reported in 2015. Follow-up surveys validated findings from 2015 surveys in that, on the whole, few changes in people's activities and food habits occurred. Any changes that were observed were attributable to uncertainty in the supply of food quantities and habits. Focus groups and a body mapping exercise also confirmed habit behaviour data collected on salt marshes, but had indicated an increase in time spent on the salt marshes.

Terrestrial-based activities were the main habits for all farmers, wardens and a gamekeeper. Fishermen reported the highest level of aquatic based activities and ate the most fish. However, overall highest consumption rates were similar to mean consumption rates for the high-rate groups surveyed in 2016 confirmed the findings of the Chapelcross 2015 habits survey.

Overall, the results demonstrated that whilst it is important to assess changes in habits at different times of the year, the 2016 resurveys provided confidence in the representativeness of the data collected in 2015.

10.3.2 Food Production

More detailed investigations in to the traceability of pathways for food products, once off the farm, were not possible through official channels due to issues of commercial confidentiality and data protection. However, the face-to-face interviews provided information on local pathways and it can be concluded that the majority of meat, crop and milk processing occurs outside the Chapelcross Habits study area. In addition, with the exception of some small local pathways, such as potatoes and carrots that were sold through a single local shop, no pathway could be identified linking arable crops grown in the area with human consumption. Furthermore, no cereals were found to be processed by millers outside the survey area. Cereals and arable crops grown appear to be for animal consumption only with very limited traceability between farms. Animal feed producers and suppliers source all their ingredients outside the area. Commercially, there is a local shrimp fishing boat operating out of Annan harbour, which appears to be sold locally. Otherwise, no fish are landed locally and all processed fish are sourced from outside the area, and so do not represent a known pathway.

10.3.3 Radiometric Surveys

A carborne and backpack survey of the roads and coastal area around the area noted localised elevated dose rates at the end of the pipeline and close to the site itself, which are attributable to ^{137}Cs. The coastal survey identified additional access points not on the map with dose rates generally less than 40 nG y^{-1}. Where access points were related to saltmarshes, ^{137}Cs dose rates tended to dominate.

Where positive measures of beta skin dose rate were made *in-situ,* values ranged from 0.240 to 2.625 µSv h^{-1}. These values are low and even continuous contact with an item with the highest beta dose for a whole year would not reach the annual dose limit of 50 mSv for skin.

10.3.4 Dose Assessment

Of all the pathways identified and considered, the highest retrospective dose for all exposure pathways was 0.0093 mSv from the 2015 survey data. The highest retrospective dose for all exposure pathways from the 2016 survey data was lower at 0.0014 mSv. The doses from the 2016 survey were generally lower than those from the 2015 survey.

For the 2015 survey, the highest dose from internal exposure associated with the terrestrial food pathway was 0.00021 mSv arising from the consumption of beef, game (venison, rabbits and hares) and milk. The highest dose from external exposure was from doses received by people spending time in the intertidal environment (0.000023 mSv). The highest dose from internal exposure associated with the aquatic food pathway was 0.0000085 mSv arising from the consumption of fish. The highest dose from external exposure in the aquatic environment was from doses received by people handling fishing gear and sediment (0.0093 mSv).

These are very small compared with the 1 mSv annual public dose limit.

10.3.5 Monitoring Programme

Overall, SEPAs current monitoring programme provides appropriate coverage.

In future surveys, consideration could be given to the following areas:

(i) The dose at the end of the Seafield end of the Chapelcross Effluent pipeline. The reason for this is that differences in measurement geometry may account for small differences in the observed radiation doses rates observed in 2002 and 2015.

(ii) Within the wild/free food groups, we note that the following are the most consumed: (a) blackberries in coastal areas around Annan within the survey area (including along the pipeline and Annan Riverbank); (b) samphire on the saltmarsh area between Brow Well and Priestside Marsh; (c) wild mushrooms along coastal areas of the Solway within the survey area; and (d) rosehips picked at Powfoot. Blackberries are also recommended for consideration in the 2010 Habits. Consideration should be given to the inclusion of these additional food items as a one off or within the routine sampling campaigns. Perhaps the sampling of blackberries could be performed along the pipeline by Seafield, samphire could be sampled on the saltmarsh between Brow Well and Priestside Marsh and wild mushrooms could also be sampled on the saltmarsh between Brow Well and Priestside Marsh.

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