PARTICLES RETRIEVAL ADVISORY GROUP (DOUNREAY)

ANNUAL REPORT TO SEPA AND DSRL

SUMMARY OF PRAG(D) RECOMMENDATIONS AND FINDINGS DURING THE PERIOD APRIL 2010 TO MARCH 2011

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1. INTRODUCTION

Dounreay site has developed a "Particles BPEO" which resulted in the site deciding to undertake a programme of targeted offshore removal of particles, as recommended by the Dounreay Particles Advisory Group (DPAG). As the source of the particles is finite, this programme will ultimately mitigate their migration onto publicly accessible areas. This programme will also improve understanding of the extent of the contamination, the effectiveness of removal of particles and, ultimately, permit the definition of end-points for both the retrieval work and, potentially, the beach monitoring work. It was noted that expert scrutiny of the information generated would allow the progress of the BPEO implementation to be independently reviewed and improve public confidence. As a direct result, SEPA formed the Particles Retrieval Advisory Group (Dounreay), (PRAG(D)).

The principal duties, operation and current membership of PRAG(D) are summarised in Appendix 1. This Report fulfils one of the duties.

2. ANNUAL REVIEW

2.1 Work Programme

The work programme of PRAG for 2010/11 was agreed by members together with SEPA, NDA and DSRL. This work programme focussed on five areas:

1. Comparison of expected numbers, activity, depth and distribution of particles retrieved from offshore operations with expectations from earlier DPAG reports. Implications for the Retrieval Programme in 2011 and subsequently;

2. Performance of the new retrieval equipment with respect to its efficiency of detection and recovery as well as coverage. Identification of modifications and improvements;

3. The significance of mobile particles in terms of understanding their behaviour and future movement, especially onto beaches;

4. The significance of buried particles that may not be retrievable, particularly any implications for health;

5. Implications of the limited data available from beach monitoring since the Fourth DPAG Report.

2.2 Particles recovered offshore

In its Third Report, DPAG recommended that serious consideration should be given to targeted removal of *significant* particles in the marine environment. In its Fourth Report, DPAG welcomed information from DSRL that it intended to undertake offshore recovery of particles and that it accepted a recommendation from DPAG that a sentry box system would be adopted. This system is intended to provide an early warning if high activity particles were moving toward the mouth of Sandside Bay. Continued monitoring will indicate also whether disturbance of the seabed by the retrieval work is causing any change in the numbers of particles being mobilised.

Since the work of DPAG was completed, three years of offshore recovery work, 2008, 2009 and 2010, have been undertaken. This work has demonstrated that offshore recovery of particles buried at depth is possible and provided information on areas where further refinement of the monitoring and recovery technique was possible.

DRSL appointed a different contractor for the 2010 season's work, using a new system for particle retrieval. This year's report includes a review of the performance of this new system.

PRAG(D) identified a target area for the 2010 operation which encompassed the highest expected density of *significant* particles, an approach supported by the Committee on Medical Aspects of Radiation in the Environment (COMARE).

The recovery of 428 particles by the new ROV is a welcome result. It provides further confirmation that it is feasible for DSRL to use ROV-based technology to carry out the DPAG's recommendation that the higher-activity particles in the offshore plume should be removed in order to cut off the long-term supply of lower activity particles to beaches.

In order to capitalise on this success, several issues now arise.

a) What comparison can be made between the distribution of particles in the area surveyed in 2010, and the distribution predicted in this area by DPAG in the Fourth Report?

b) What is the current ROV's efficiency at recovering the particles it detects?

c) What is the efficiency of the current operating approach at detecting particles?

d) In the light of (b) and (c) what is the best approach for recovering a given percentage of *Significant, Relevant* or *Minor* particles from any chosen area of sea floor?

e) What implications do (a) and (d) have for achieving an appropriate level of remediation?

The performance of the new ROV has proven satisfactory. The larger parent vessel has facilitated the use of the system in poorer weather conditions than in previous years and the larger storage tanks also led to a higher utilisation factor.

2.2.1. Distribution of recovered particles within the 2010 survey area, and comparison with DPAG predictions

Figure 1 shows the distribution of *Significant* particles recovered in the 2010 survey. (Also included are particles that were detected but not recovered. These are termed '*in situ*' particles by DSRL. They are included with the *Significant* particles because it is thought that their non-recovery may have been due to burial at a greater depth than could be reached by the ROV recovery tool and, if this is the case, then they are likely to have been in the *Significant* category as lesser activity would have been fully screened by the sediment and therefore undetectable.) The spatial density of particles on the sea bed has been contoured by DSRL using a kernel density method and shown by colour shading. The parameters of the kernel density method used were adjusted to give a spatial resolution of about 100 m, as this was also the resolution employed by DPAG in drawing the contours of particle density in Figure 5.5 of the Fourth Report. The DPAG contours are shown superimposed on the colour-shaded kernel density contours in Figure 1. The general pattern is the same for both. Both sets of contours define a ridge or spine in which the particle densities are higher, with decreasing spatial densities on either side. This spine runs roughly parallel to the coast from the southwest side of the survey area. The highest spatial densities are on the part of the spine nearest to the Diffuser, and they fall off gently along the spine to the northeast. The fall-off in densities down the flanks of the spine is much steeper, i.e. to sea-ward or northwest and towards the shore or southeast.

Figure 2 makes a similar comparison for *Relevant* and *Minor* particles. There is a generally similar ridge form in both sets of contours, but the kernel density pattern does not indicate much decrease of the density along the spine of the ridge. There is nevertheless an agreement between the area enclosed by the DPAG 50 particle.ha^{-1} contour and the area mapped for 2010 finds in which densities are above 20 particles.ha^{-1}. The effect of previous removals may be seen in the form of a re-entrant in this kernel density contour in its southern part, where it crosses an area that was searched by ROV in 2008 (outlined in brown).

Because parts of the 2010 survey area had already been searched before the latest survey was made, it is appropriate to compare the DPAG contours with the total numbers of particles found in all years, rather than with just the 2010 finds. This comparison is made in Figures 3 and 4 for *Significant* and *Relevant & Minor* respectively. Unsurprisingly, the agreement between the general patterns is closer. For *Significant* particles (Figure 3) the highest densities lie in the areas predicted by DPAG, while the spread of finds within the 2010 survey area confirms the more general concept of a plume of particles with its axis lying parallel to the shore and with densities falling off seawards and towards the shore. The same agreement is evident for *Relevant & Minor* particles in Figure 4.

The general concept of a plume is confirmed by the 2010 survey, but there is a discrepancy between the contour values for DPAG, and the kernel density values based on all finds. In general, the kernel density values are lower than DPAG's predictions in the axial parts of the plume. The kernel density values are 50 to 75 % of the DPAG contours' values. The possible reasons for this discrepancy, and its implications, are outlined below.

2.2.2 ROV efficiency in recovering particles

With regard to efficiency in recovering particles that had already been detected, the DSRL Report LRP(10)P140 (*Dounreay Seabed Remediation Project – Particle Detection and Retrieval using a Seabed Crawler ROV in 2010*) finds that 97% of particles that were detected were also subsequently recovered.

2.2.3 ROV efficiency in detecting particles

Efficiency in detecting particles can be divided into two aspects.
First, there is the question of whether the particles recovered by the ROV have roughly the same distribution of activities as those previously recovered through

Diver Operations. The answer is that the proportions of the three categories (*Significant, Relevant* and *Minor*) are very similar between Diver Operations and the 2010 ROV recoveries, as Table 1 shows. The numbers of particles in the three central columns in the upper half of the table are taken from Table 1 in LRP(10)P140. The numbers for 2010 in the right hand column are revised figures provided by DSRL on 23rd January 2011, following correction of ship-board readings of particle activities with laboratory readings. The lower half shows proportions and their 95% confidence intervals.

It is evident that the 2010 ROV campaign gave a lower proportion of *Significant* particles and a higher proportion of *Minor*, compared to Diver Operations. Although there is overlap in the 95% confidence intervals, a two-tailed Z-test showed that the difference in proportions of *Significant* particles was statistically significant at the 95% confidence level (i.e. there is less than a 5% chance that the proportions actually found in Diver Operations and in 2010 ROV Operations resulted from random sampling of identical populations). Since we have no preconception that the ROV would be either more or less efficient than divers at detecting *Significant* particles in an otherwise identical population, the two-tailed test is more appropriate than a one-tailed test. Had the latter been used, the significance level would have been 99%. When the same statistical test is applied to the difference in proportions of *Minor* particles, the 2010 and Diver Operations are found to differ significantly at the 90% level in a two-tailed test and the 95% level in a one-tailed test.

In 2009 and 2007-8 the differences from Diver Operations were reversed, with higher proportions of *Significant* particles and lower proportions of *Minor* particles being recovered by the ROVs. These differences were less marked in 2009 than in 2007-8, perhaps reflecting the improvements in equipment and operating technique made over those years.

Table 1 Estimates of the efficiency of the ROV in detecting particles.

A. Particle numbers	Diver Ops	2007 & 2008 ROV	2009 ROV	2010 ROV
Significant	213	31	28	74
Relevant	258	18	38	118
Minor	459	10	49	236
Total	930	59*	115	429
Proportions with ^{upper} and $_{lower}$ 95% confidence limits				
Significant	$0.229^{0.257}_{0.203}$	$0.525^{0.647}_{0.400}$	$0.243^{0.329}_{0.174}$	$0.173^{0.212}_{0.140}$
Relevant	$0.277^{0.307}_{0.250}$	$0.305^{0.431}_{0.203}$	$0.330^{0.421}_{0.251}$	$0.276^{0.320}_{0.236}$
Minor	$0.494^{0.526}_{0.462}$	$0.169^{0.285}_{0.095}$	$0.426^{0.517}_{0.340}$	$0.551^{0.598}_{0.504}$

The lower proportion of *Significant* particles among the ROV recoveries may be due to factors other than a straightforward difference in performance. Table 2 presents figures on the numbers of particles recovered from the 2010 survey area before 2008 (almost all of these were diver finds), and by the Fathoms ROV in 2008 and 2009. One hundred and twelve particles were recovered before 2008 from the area later covered by the 2010 ROV survey. The proportion of *Significant* particles among these was higher (0.348) than in the total sample of diver finds (0.229, see Table 1). For the two Fathoms ROV surveys in 2008 and 2009, taken together, the proportion of *Significant* particles was even higher at 0.434. Altogether, 188 particles had already been removed from the area surveyed in 2010, of which 72 (38%) were *Significant*, 51 (27%) *Relevant* and 65 (35%) *Minor*. These earlier recoveries therefore removed *Significant* particles in greater proportion than their presence in the entire Diver Operations sample, whereas the *Minor* particles were reported to be in a lower proportion. The proportion of *Relevant* particles is almost exactly the same as in the overall Diver Operations sample. Therefore, the lower proportion of *Significant* particles found by the ROV in 2010 could be because of a distortion of the population remaining in the area after the earlier removals. Another reason is that the whole group of particles originally present within the 2010 survey area may not be representative of the entire plume in its proportions of *Significant, Relevant* and *Minor* particles.

The second question regarding the ROV's efficiency at detecting particles concerns the proportion of those actually present on the sea bed that the ROV detects. The problem here is that we know that the ROV detected and recovered 428 particles in 2010 but we do not know how many were actually present. We must estimate this latter figure and the only basis we have for this is the contour mapping in DPAG's Fourth Report. Integrating the DPAG contour patterns over the 2010 survey area provides an estimate of 312 *Significant* and 810 *Relevant+Minor* particles present in the plume. These figures include all particles later removed, so to estimate the numbers remaining before the 2010 survey started we must subtract all the finds previously made within the survey area. This results in a revised estimate of 240 *Significant* particles and 694 *Relevant + Minor* remaining to be found within the 2010 survey area. The ROV found 74 *Significant* particles, implying an efficiency of 0.31 ± 0.10, the approximately 2-sigma confidence interval being based on the error of 33% for estimated numbers in DPAG's Third and Fourth Reports. For *Relevant & Minor* particles, the ROV recovered 354 particles, implying an efficiency of 0.51 ± 0.17.

Table 2 Particles recovered from 2010 ROV survey area

Year	No. Of Surveys	*Significant*	*Relevant*	*Minor*	Year totals
2010	1	74*	118[1]	236[1]	428
2009	1	3	13	5	21
2008	1	30	14	11	55
Pre-2008	7	39	24	49	112
Totals		146	169	301	616

These estimates of detection efficiency are disappointingly low. They may of course be so because DPAG overestimated the numbers of particles present in the plume. However, they have been checked by DSRL using the kernel density method of contouring, and integration over the 2010 survey area of the kernel density plots for the full plume. This procedure produced estimates of 323 *Significant* and 893 *Relevant & Minor* particles in the 2010 survey area, before any removals. These kernel density estimates are similar to the previous ones based on DPAG's Fourth contours, and imply slightly lower detection efficiencies for the ROV. (Kernel density parameters appropriate to 20 m spatial resolution were used for these integrations.)
Thus, we are in an impasse regarding estimation of ROV efficiency in 2010. Either the ROV is at best 50% efficient or DPAG overestimated the numbers of particles in the plume by factors of at least 2. At this stage this issue cannot be resolved.

1 Data supplied by DSRL 23/2/2011

2.2.4 Discussion of Implications : tactics for ensuring that a given percentage of particles are removed from the sea bed

If we accept that the ROV's efficiency in detecting particles is less than 100%, then the only way to ensure the recovery of a given percentage of the particles present in any area of sea floor is to conduct multiple surveys. Let the target for clean-up be recovery of a proportion P of the particles present. Table 3 shows the numbers (N) of repeated surveys that would be required to achieve different values for P. To recover about 90% of the *Significant* particles might require going over the same ground six times, if the detection efficiency is truly as low as 0.3, or three times if it were 0.5.

Table 3 The numbers (N) of repeated surveys that would be required to achieve different values for P

Significant Particles (E=0.3)		*Relevant* + *Minor* Particles (E=0.5)	
N	P	N	P
1	0.30	1	0.50
2	0.51	2	0.75
3	0.66	3	0.88
4	0.76	4	0.94
5	0.83	5	0.97
6	0.88	6	0.98
10	0.97		

2.2.5 Recommendations for 2011 offshore work

The calculations in Table 3 rest on assumed values for the detection efficiency of the ROV, and these in turn rest on the assumption that the DPAG contours are correct. One alternative is that the DPAG estimates are too high and that the ROV efficiency is much better than they imply. To resolve this issue, we recommend that SEPA and DSRL consider independent methods of determining the detection efficiency of the ROV.

Three approaches are possible:

- The efficiency of the detection system could be modelled mathematically, as was done for the Groundhog system by UKAEA and also by DPAG (Third Report);
- The efficiency could be measured directly using a controlled experiment. This would require the use of a tank facility at which the detection system could be towed through sea water, passing over particles buried in sand to different depths. The alternative of burying particles to different depth on the sea bed would require the use of divers and might present difficulties of licensing as there would be a risk that the test particles might escape into the environment.
- Repeat surveys could be undertaken of well defined areas of sea bed. If X_1 particles are recovered on the first survey and X_2 on the second, the efficiency can be found from $E = (X_1 - X_2)/X_1$

We recommend that a substantial proportion of the survey area covered in 2010 should be re-surveyed in 2011, to allow better estimates to be made of E for *Significant* and *Relevant* + *Minor* particles. Migration of particles across the boundaries of the re-survey area between 2010 and the new survey in 2011 will affect the results (although the migration rate is thought to be slow), so the resurveyed area should be large so as to keep such edge effects to a minimum.

An alternative approach to resurvey would be to cover the same area twice in a single campaign within a short period. This approach could be applied to more than one area in a single campaign, allowing multiple estimates of E to be made, and an idea of uncertainties to be obtained. This approach is also commensurate with the aim of advancing the overall programme, as the areas to be resurveyed could comprise only part of the total area to be surveyed during the campaign as a whole. However, the areas chosen for resurvey should not overlap, as this would invalidate the approach.

In both cases, it will be necessary to resurvey areas containing a sufficient expected number of particles to give statistically significant results.
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Figure 1. The distribution of *Significant* particles recovered in the 2010 survey.

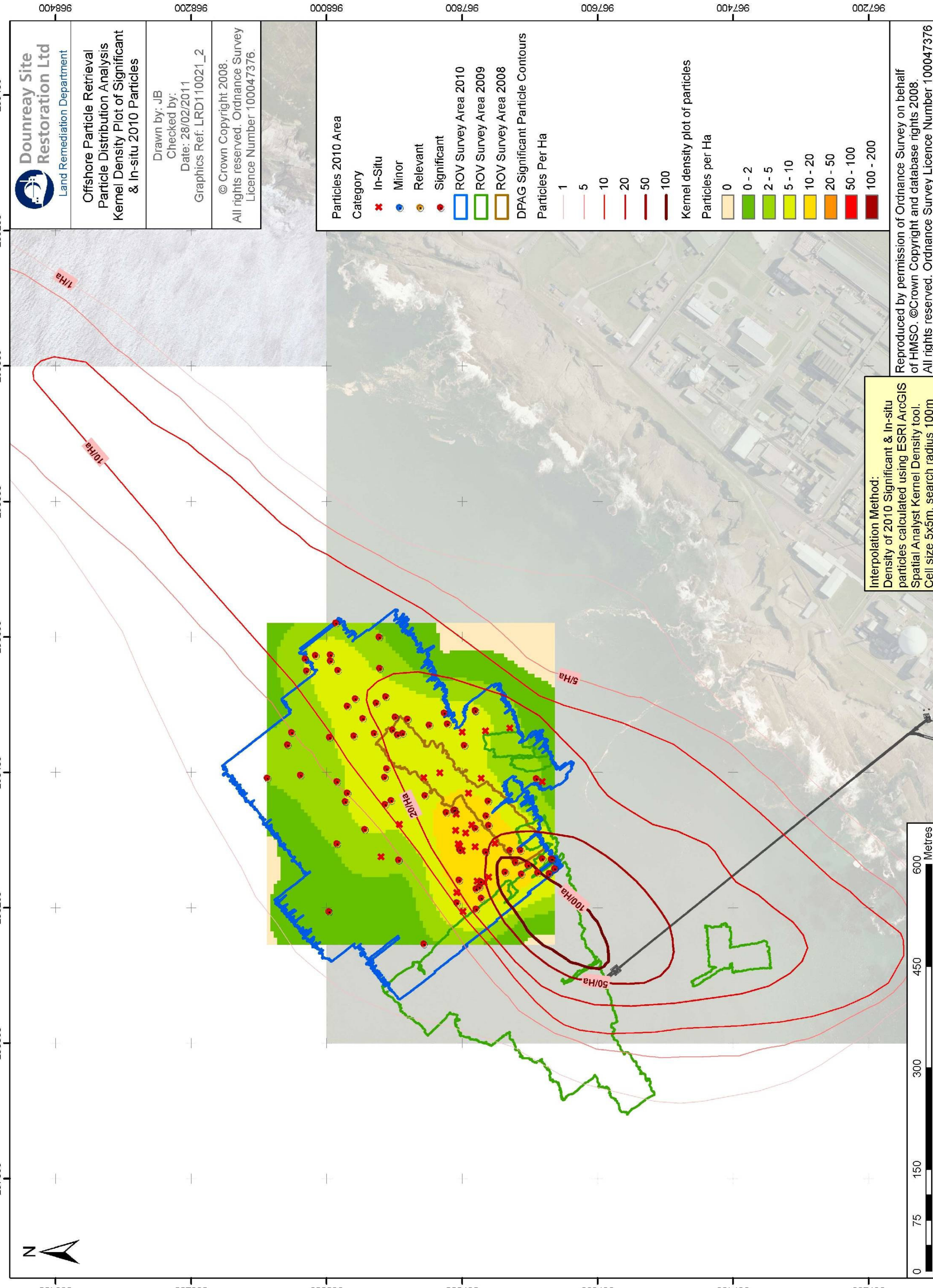


Figure 2. The distribution of for *Relevant* and *Minor* particles recovered in 2010.

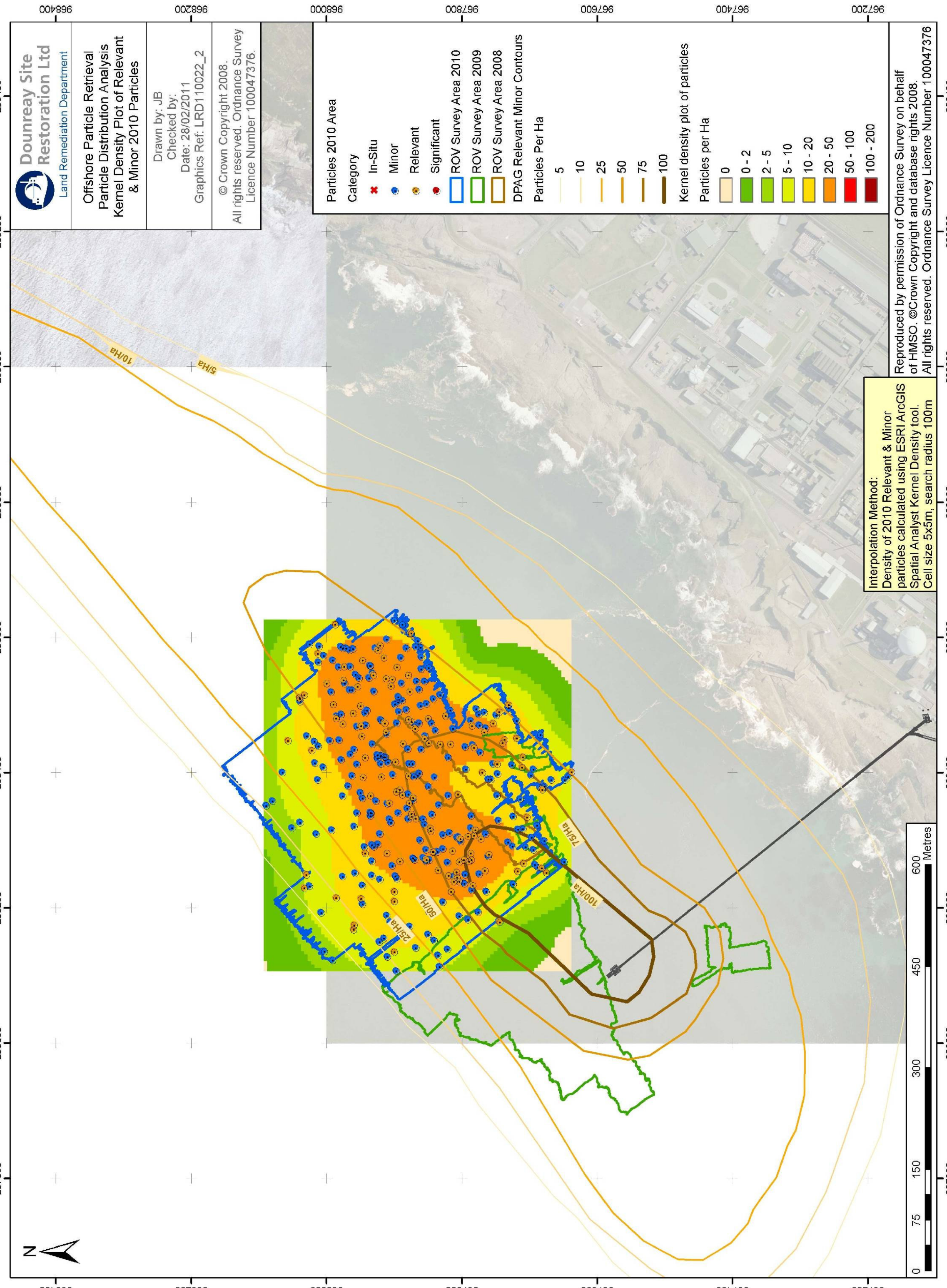


Figure 3. The total number of *Significant* particles found (excluding 2010).

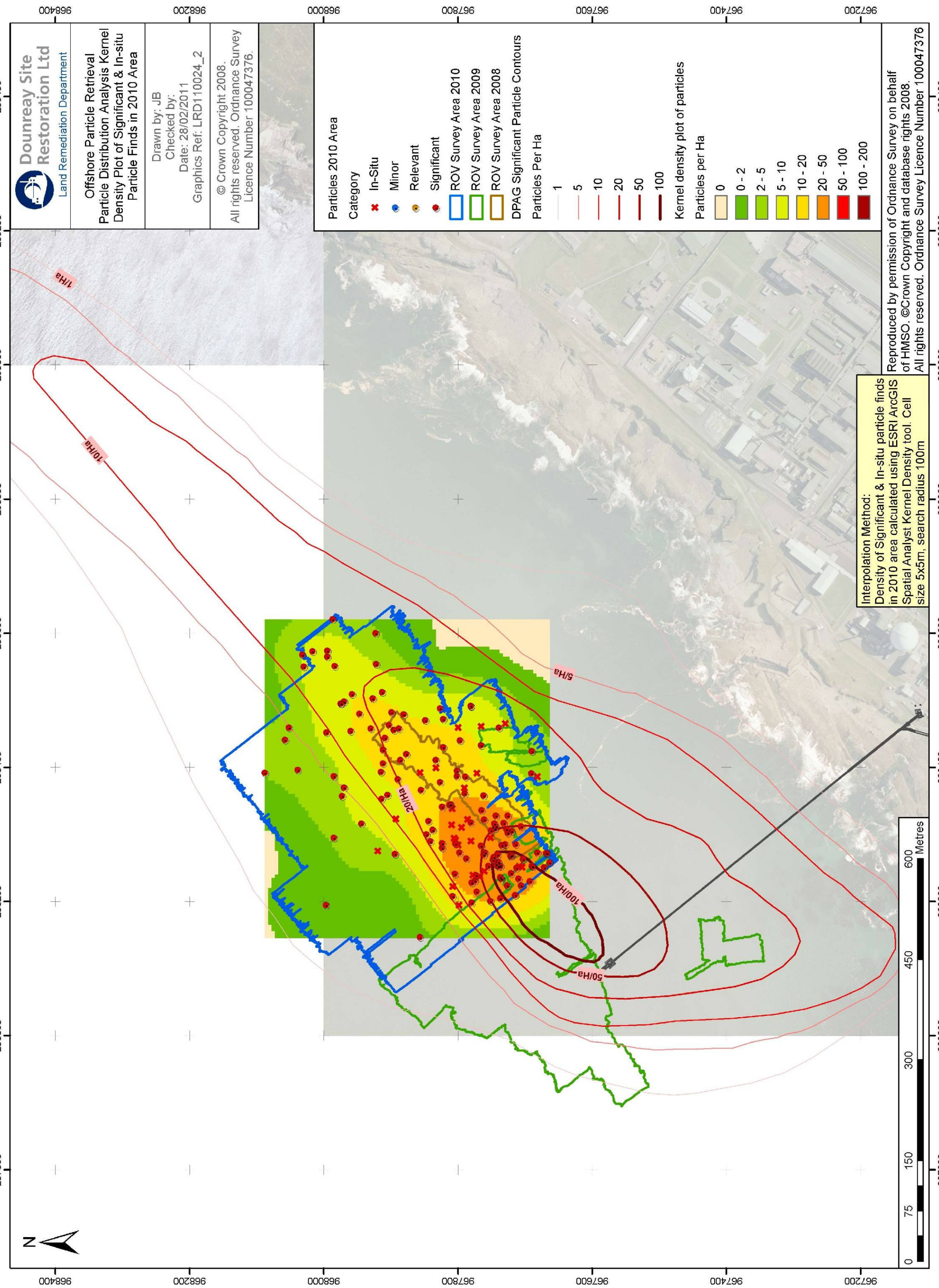
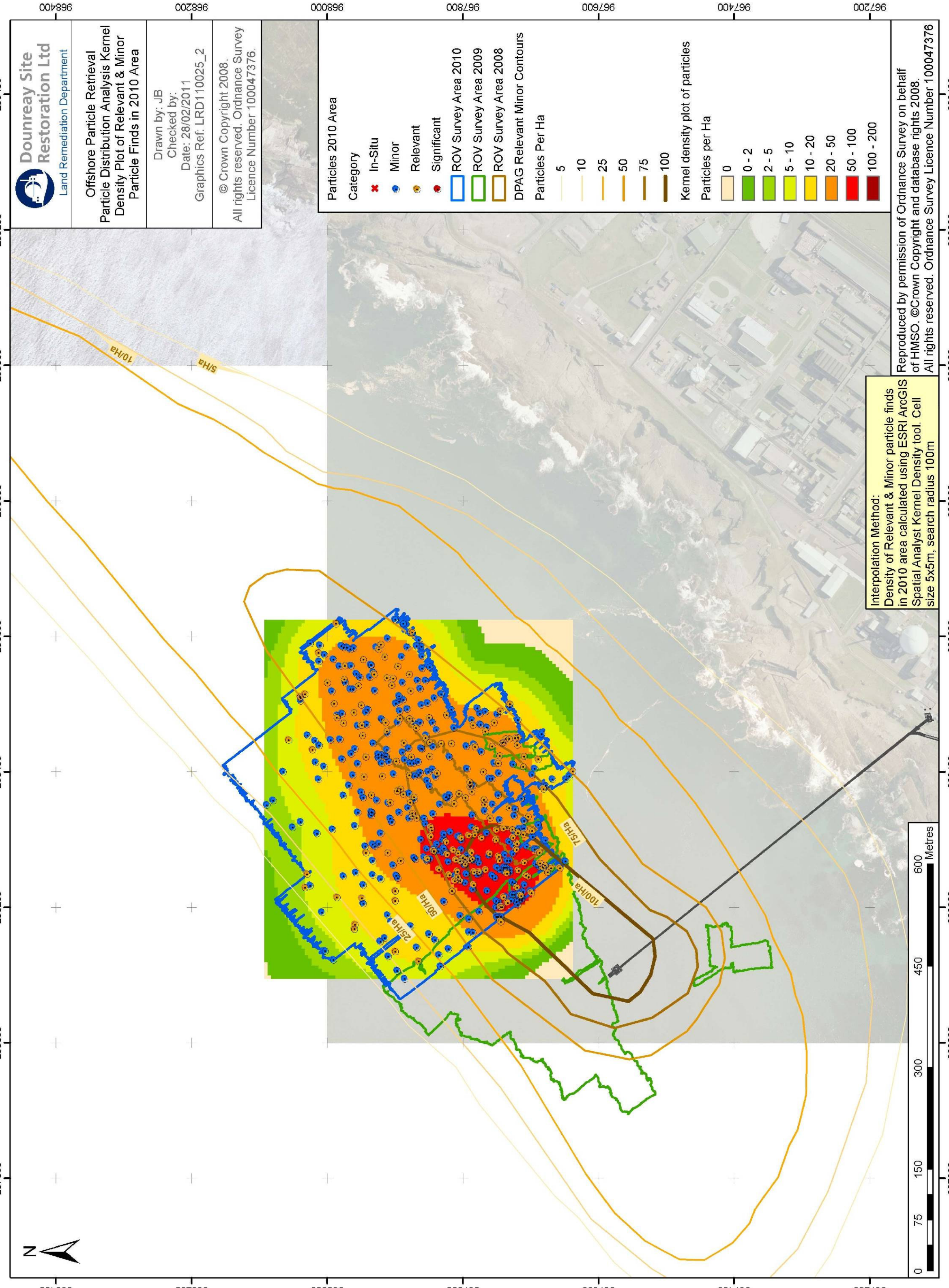


Figure 4. The total number of *Relevant* and *Minor* particles found (excluding 2010).



2.3 Beach Monitoring

Sandside Beach

Over the last 12 months, Sandside Beach was the only publicly accessible beach from which particles have been detected and recovered. Of these 12 months, restrictions in beach access limited monitoring for particles to 5 months, as summarised in Table 4.

Table 4 Summary of Beach finds and correction for monitoring footprint

Monitoring Month in 2010	Number of Particles	Area monitored m^2	Abundance corrected for area monitored (relative to 318,652 m^2)	Comment
May	5	269,552	4.7	5th particle was recovered during the second coverage
August	1	264,267	1.2	
October	3	228,081	2.8	3rd particle recovered during second coverage and not included in corrected abundance. One particle split into 2 fragments
November	2	235,057	2.7	
December	1	176,231	1.8	Particle split into 3 fragments

These numbers are consistent with those reported previously, as shown in Figure 5 (Tyler *et al.,* 2010*;* DPAG 2008) and correspond with those months typically characterised by lower particle abundances.

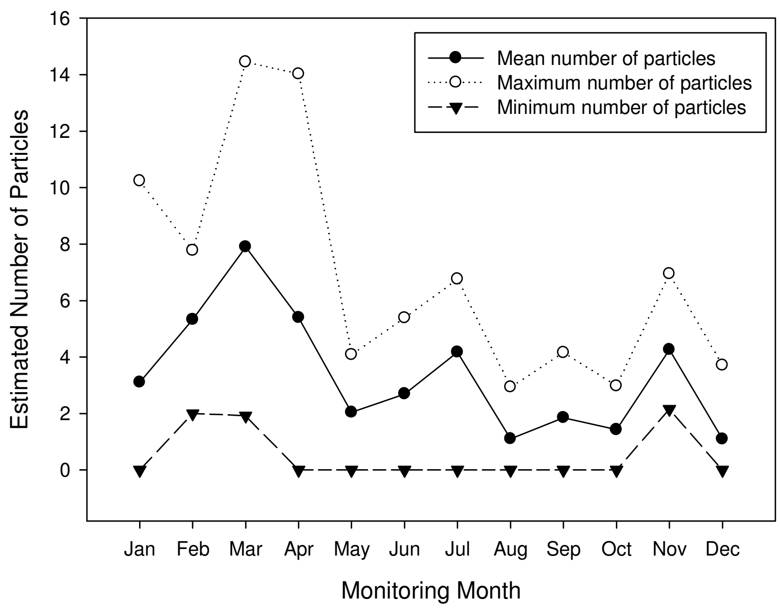


Figure 5. Estimated number of particles on Sandside per monitoring month, corrected for area monitored. Results derived from Groundhog Evolution and Evolution 2 finds from November 2002 to March 2008 (Tyler *et al.,* 2010).

Table 5 Summary of the corrections from mean monthly particle finds to estimated abundances over top 300 mm of beach sand. Data exclude finds found on monthly resurvey.

Particle category	^{137}Cs Activity	Groundhog Evolution II 20010 Monthly mean rate	Corrected to 300 mm depth equivalent	Corrected for beach area Particle Abundance
Minor	$<10^4$ Bq	1.3	7.5	9.8
	$10^4 - 4x10^4$ Bq	0.2	0.6	0.7
	$4x10^4 - 10^5$ Bq	0.5	1.0	1.3
Relevant	$>10^5$ Bq	0.9	0.9	1.3
All	**Total**	**2.8**	**10.0**	**13.0**

As described in DPAG 2008, it is important to try to standardise the particle find numbers by correcting for monitoring effort (detection probability and area of coverage) and to estimate the abundance by integrating the likely particle abundance over the top 300 mm. For deeply buried low activity particles, the detection probability carries a considerable uncertainty due to the accuracy with which the particle depth can be estimated and the resolution we have on the empirically derived detection probability. Consequently the uncertainty on the abundance of *minor* particles is likely to be in excess of 50 %. Conversely, the confidence in the abundance of the higher activity particles, and especially *relevant* particles, is much better than 50 %. Table 5 summarises the mean monthly particle abundance data. Taking into account the large uncertainties on the abundance of *Minor* particles, the values are comparable to the abundance estimates previously reported (DPAG 2008; PRAG(D) 2009; see Annex 2. The slightly lower estimate of *relevant* particles may reflect the lack of monitoring during the months when sediment was actively moving on the beach, i.e. February, March and April.

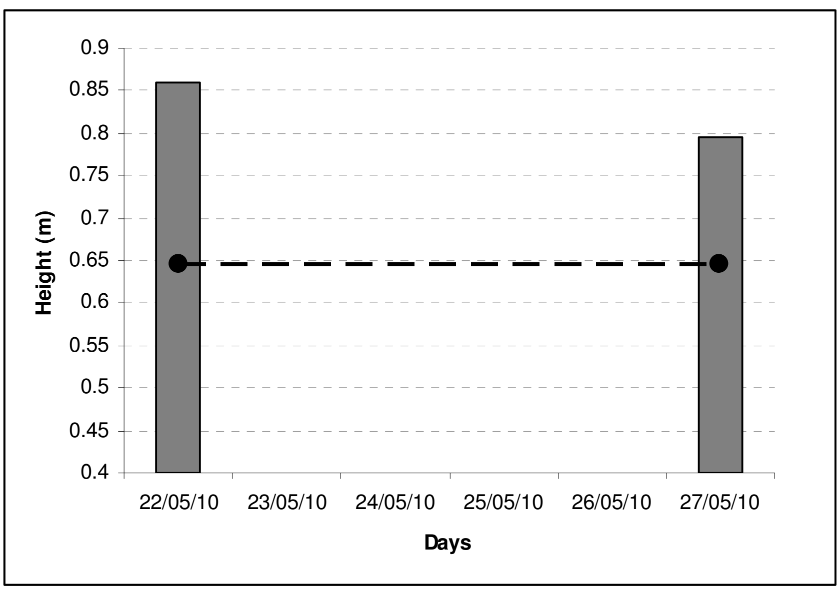


Figure 6. Beach height and particle depth data at the site of particle SSBCH 10/05 recovery May 2010.

Two additional particles were recovered during the secondary enhanced survey undertaken during the monitoring undertaken in May and October 2010. From the beach height data, the particle (SSBCH 10/05; 1.9 x10^4 Bq) recovered as part of the enhanced survey on the 27th May 2010 was likely to have been present on the 22 May 2010 and remained undetected at 220 mm depth. The conclusion is that over the space of five days, sediment erosion effectively brought the particle closer to the surface increasing its probability of detection (Figure 6).

The additional particle (SSBCHH/10/09) detected during the enhanced survey in October 2010 is the lowest activity (4.5 x10^3 Bq) particle detected and recovered on Sandside since monitoring began. The probability of detection based on the 2008 field trial estimates (DPAG 2008) is likely to be low on the 14th October and lower still on the 25th October, as indicated by the particles depths in Figure 7. It is therefore difficult to confidently conclude the provenance of this particle, but it may have been deposited over the eleven intervening days since that location had been covered by statutory monitoring.

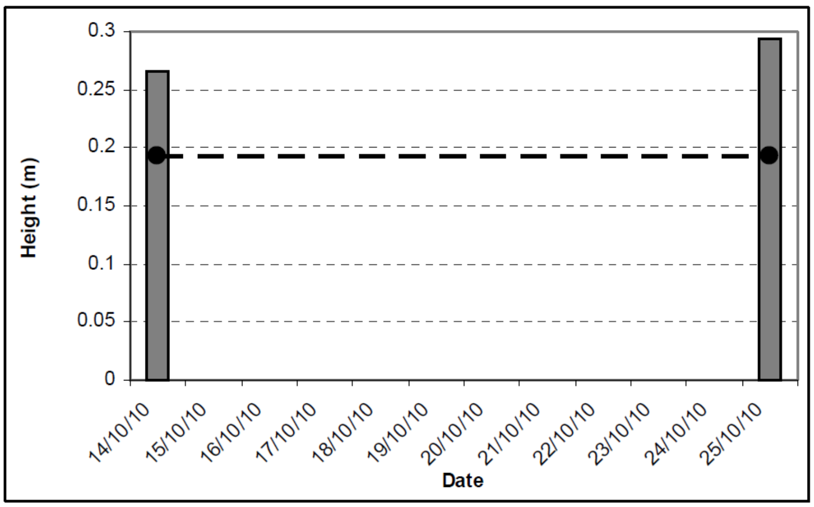


Figure 7. Beach height and particle depth data at the site of particle SSBCH/10/009 recovery (McKay 2010).

Dounreay Foreshore

Over the period of this report till Dec 2010, 3 further particles were detected and removed from the Dounreay Foreshore in February, March and November respectively. Two had activities greater than 1E6, the third had activity of 5.9E4. The number of particles is small, but well within the range recovered from the foreshore in the past few years.

Other beaches

During 2010, surveys were carried out at several other beaches around Caithness, including Brims Ness, Crosskirk and Thurso. No particles were detected during these surveys, but the Group felt that it would be premature to recommend any change to the monitoring schedule.

Summary

Although the particles recovered from Sandside in 2010 were low in number taking into account the monitoring effort, timing and detection capability, the estimated particle abundance estimates are consistent with previous estimates reported by DPAG and PRAD(D). Similarly, the number of particles recovered from the Foreshore is consistent with previous years.

The Group welcomes information that agreement has been reached which will lead to arrangements for guaranteed access to the beach for monitoring and recovery purposes. DPAG and COMARE have stressed for some years the need for continuity in this programme for public safety/reassurance and scientific data collection; it will also enable compliance with the requirement placed upon the Regulator by the previous Secretary of State to 'promptly detect and remove' any particles from the beach.

2.3 Implications of the Forward Work Programme

The offshore work planned for 2011, which includes the assessment of the efficiency of the current ROV at detecting particles, will allow the group to make direct comparisons between the current particle plumes and those predicted by DPAG. Once the efficiency of the ROV has been established, a more reliable estimate of the absolute numbers of particles remaining can be made.

Following the publication of a report of the contamination in 1998 (SEPA 1998) SEPA's North Region Board made a statement that the seabed should be returned to a "pristine condition", which would imply the removal of all radioactive materials. From above, it is clear that the detection efficiency, particularly at depth, is not 100% and that the same is true for the recovery efficiency for detected particles. Absolute compliance with the SEPA statement is thus not feasible. From the 2011 data, it should be possible to make estimates of the effort required to remove a given proportion of particles from the seabed. It will then be necessary for a decision to be made as to the target value to be achieved. Note that this will still pertain only to the maximum depth from which *significant* particles can be detected.

A full calendar year of monitoring at Sandside Bay will provide, for the first time, a complete baseline set of seasonal data on particle detection and recovery, which is necessary to inform any future strategies for closure of the contamination problem.

3. APPENDIX 1

PRAG (D) MAIN DUTIES

The main duties of this group are:

- To review information received from DSRL on offshore particles recovered and seabed survey areas, with the aim of determining whether the offshore population diagrams in DPAG Fourth report and the estimates and distributions of *significant*, *relevant* and *minor* particles remain valid. The results of the review will be communicated to SEPA and DSRL;

- To review the effectiveness of offshore particle retrieval, to make recommendations for improvement and review the plan for the next year's recovery operations;

- To consider criteria for determination of the offshore recovery end point;

- To provide commentary on the potential re-population of offshore areas;

- To review beach monitoring information and make recommendations for improvement in techniques and changes in the frequency and extent of monitoring area (in relation to public health and other objectives);

- To assess the rate of particle finds for both offshore and onshore environments, taking account of equipment detection ability and assess whether current health advice with respect to particles requires modification.

Recommendations and findings from the main duties are to be provided to SEPA and DSRL in the form of a summary or report by the end of each financial year. This report forms that annual report.

3.1 Frequency

Three formal meetings of the group are scheduled to occur each year, to review offshore retrieval information and beach monitoring information and comment on plans for future monitoring. Further meetings may be arranged if required, following discussion with SEPA and DSRL.

SEPA and DSRL would provide input to the meetings as observers. An invitation to become observers at meetings has been extended to other interested groups including COMARE, Food Standards Agency, HPA, Scottish Government, NDA, Dounreay Site Stakeholder Group, following discussion with the Chair.

It is anticipated that the group will be required over a period of five years (i.e. terminating in 2014), or until the old diffuser has been sealed and sufficient information has been gained on the effectiveness of the offshore retrieval work. However, the need for the Group will be reviewed after two years, by SEPA and DSRL, to ensure that the Group remained “fit for purpose”.

3.2 Membership

Membership of the Group has been drawn from experts reflecting the main duties of the group and covers a broad range of disciplines including:

1. Monitoring systems (offshore and onshore);
2. Statistical analysis of data;
3. Marine movements around Dounreay;
4. Exposure scenarios.

It was considered that a sound working understanding of the Dounreay particles issue would be beneficial for members. As a result, in the first instance membership was drawn from former DPAG members with expertise in the relevant areas. However, membership will be reviewed as work continues to ensure that appropriate expertise is available to the Group.

Current members are: Professor Alex Elliott (Acting Chair), Professor Tim Atkinson, Professor Marian Scott, Dr Andrew Tyler. The Technical Secretary and administrative support is provided by SEPA.

4. APPENDIX 2

TABLES FROM 2009 REPORT

Table 1 Summary of the corrections from mean monthly particle finds to estimated abundances over top 300 mm of beach sand.

Particle category	^{137}Cs Activity	Groundhog Evolution II 2007 Monthly mean rate	Corrected to 300 mm depth equivalent	Corrected for beach area Particle Abundance
Minor	$<10^4$ Bq	0.50	1.67	2.5
	$10^4 - 4x10^4$ Bq	1.67	2.5	3.6
	$4x10^4 - 10^5$ Bq	0.83	1.0	1.5
Relevant	$>10^5$ Bq	1.17	1.17	1.8
All	**Total**	**4.01**	**6.34**	**9.4**

Table 2 Summary of the corrections from mean monthly particle finds to estimated abundances over top 300 mm of beach sand.

Particle category	^{137}Cs Activity	Groundhog Evolution II 2008/9 Monthly mean rate	Corrected to 300 mm depth equivalent
Minor	$<10^4$ Bq	0.67	2.2
	$10^4 - 4x10^4$ Bq	4.67	7
	$4x10^4 - 10^5$ Bq	0.83	1
Relevant	$>10^5$ Bq	0.67	0.67
All	**Total**	**6.84**	**10.87**