Queensland Government

Environmental report -

Radiation monitoring on North Stradbroke Island

2008 - 2010

Radiation Health Unit
Environmental Health Branch
Queensland Health

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Contents

Radiation monitoring on North Stradbroke Island

2008 - 2010

1. Executive summary

The mineral sand mined by Consolidated Rutile Limited (CRL) on North Stradbroke Island contains small amounts of the radioactive elements uranium and thorium. The monazite in the mineral sands is the predominant source of the radioactivity in the sands extracted from the island.

The Radiation Health Unit has conducted a series of tests and inspections to determine the nature of the mineral sands at certain locations on North Stradbroke Island (both on and off mining leases). These tests and inspections were prompted by the concerns of a citizens group, Stradbroke Island Management Organisation (SIMO), about the safe storage and transport of mineral sands to and from the island.

The types of radiation monitoring activities conducted in and near Dunwich included:

- gamma radiation surveys of some sites known to have been, or suspected of having been, affected by elevated levels of radioactive material
- sampling and radio-assay of stockpiles of mineral sands, material spilled from trucks, and of soil and sand from various locations
- sampling and radio-assay of water from selected locations
- sampling to test for particulates in air.

The investigations were carried out over a period from September 2008 to November 2010. Samples were analysed by Queensland Health Forensic & Scientific Services (QHFSS).

External gamma radiation surveys

An initial walk-over of selected sites of interest to SIMO was conducted in September 2008. Gamma radiation levels were measured at these sites. No unexpected radiation levels were found. While some areas of elevated radiation levels were found, they were consistent with radiation levels measured during previous surveys conducted by the Radiation Health Unit from the late 1980s to the early 1990s.

Gamma radiation levels in the parks at Banksia Street and to the north of the Junner Street jetty were less than 0.05µSv/h (microsieverts/hour). This is indistinguishable from natural background radiation which, in Australia, is approximately 0.1µSv/h.

Radiation levels in the following locations had slightly elevated levels of radiation (0.1 to 0.4µSv/h). These locations are known to be places where mineral sand residues had been deposited many years ago:

- the forest at the corner of Mallon Street and Mitchell Crescent
- the waste sand piles north-east of the Dunwich water treatment plant.

An extensive gamma radiation survey conducted at the park between Ballow Road and Mallon Street revealed an average gamma radiation level of 0.55µSv/h.

Sand / soil sampling

Samples of sand and soil were collected for analysis, by gamma spectroscopy, of their radionuclide concentrations (particularly ^{238}U and ^{232}Th).

To assist in understanding these results, note that the naturally occurring sand on North Stradbroke Island from which minerals are extracted contains uranium and thorium at concentrations up to approximately 20Bq/kg (becquerels/kilogram). Typical worldwide levels of these radionuclides in soil range from approximately 10 to 100Bq/kg[*].

The concentration at which material containing uranium and thorium is classified as a radioactive substance, and therefore of sufficient concern to warrant regulation through licensing under the *Radiation Safety Act 1999*, is 10,000Bq/kg.

Processed mineral sands

Samples of mineral sand were collected from various stockpiles (partly processed material, product, and tailings) located on premises controlled by CRL at Dunwich and Pinkenba. The concentrations of ^{238}U and ^{232}Th in these samples were consistent with data provided by CRL about their products and previous measurements of samples taken from similar locations.

Additionally, the results show that only the tailings material described as 'zircon mags' has a high enough concentration of ^{238}U and ^{232}Th to be classified as a radioactive substance and therefore subject to licensing under the *Radiation Safety Act 1999*.

Rehabilitated mining areas

On areas where rehabilitation is taking place, the tailings returned to North Stradbroke Island are covered by approximately 10 metres of clean soil/sand. Soil samples collected from the surface of rehabilitated areas contained material with ^{238}U and ^{232}Th concentrations of less than 10Bq/kg.

Public areas

Soil and sand samples were collected from various locations around Dunwich accessible to the public. In order to obtain some indication of the highest radiation levels that are likely to be found, most of the samples chosen were those that appeared to show an obvious mineral sand content.

In these samples the radionuclide content of the material ranged from 4 to 580Bq/kg of ^{238}U, and from less than 6 to 2,100Bq/kg of ^{232}Th. These concentrations are less than the levels at which a material would be subject to licensing under the *Radiation Safety Act 1999*.

The sampled material had a wide range of uranium and thorium content which would in part be of natural occurrence and in part due to the extracted mineral sands being deposited on the ground.

Leachability of mineral sand

TCLP (toxicity characteristics leaching procedure) is a test which assesses the potential for radionuclides in a material to contaminate groundwater. The Radiation Safety Regulation 2010 specifies the TCLP criteria at which it is acceptable to dispose of mineral substances without requiring an approval.

Samples of mineral sands from various stages in the processing cycle (naturally occurring source sand, partly processed material, product, and tailings) were subjected to a TCLP test. The amount of radioactive material leached from these samples is below the criteria stated in the Regulation.

These results show the potential for deposited mineral sand products and tailings to contaminate groundwater is acceptably low.

[*] UNSCEAR 2001 - Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly

Water sampling

Samples of water collected from natural watercourses and the drinking water supply show the radiation levels to be acceptably low. Gross alpha and beta concentrations in each of these samples were less than the radiological screening levels in the Australian Drinking Water Guidelines (<0.5Bq/l).

Air sampling

No measurable or significant amount of radioactive material was detected in the samples collected during testing for particulates in air at the Junner Street jetty and surrounds.

Personal radiation dose assessment

Radiation dose to persons is controlled by setting dose limits where a radiation source is the subject of a possession licence, or prescribing criteria for the release of radioactive material into the environment.

Queensland's radiation safety legislation imposes annual radiation dose limits to limit the dose to which a person is exposed as the result of the carrying out of a radiation practice. For a member of the public, that dose limit is 1,000µSv (microsieverts).

To help ensure these limits are not exceeded, Queensland Health seeks to ensure doses to individuals due to the release of radionuclides into the environment are constrained, in their design, to less than 300µSv/year above background. For comparison, natural background radiation, to which we are all exposed, is approximately 2,000µSv/year.

The most significant pathway by which a member of the public on North Stradbroke Island may be exposed to radiation related to mineral sands is though external gamma exposure.

A reasonable case assessment is that of an individual spending time at a location where elevated radiation levels are found. Consider a person spending 1.5 hours each day of the year at the Ballow Road park where the average radiation level is 0.55µSv/h. Their annual radiation dose would be 250µSv above background. This is acceptably low and less than the 300µSv criterion mentioned above.

Conclusion

The outcomes of these tests are consistent with previous monitoring and testing and do not reveal any evidence to suggest that activities associated with the mining, processing and transport (both to and from the island) of mineral sand on North Stradbroke Island is adversely affecting occupational or public health, from a radiological perspective.

2. Introduction

This report presents the findings of a series of tests and inspections carried out by the Radiation Health Unit into activities associated with mineral sand mining, carried out by Consolidated Rutile Limited (CRL) on North Stradbroke Island.

The mineral sand mined on the island contains small amounts of the radioactive elements uranium and thorium. The monazite in the mineral sands is the predominant source of the radioactivity in the sands extracted from the island. Further details of the CRL mining activities are described in Appendix 1.

The investigations were in response to the concerns of citizens group (Stradbroke Island Management Organisation - SIMO) about the transport of mineral sands to and from North Stradbroke Island, and deposits of mineral sand on various sites at Dunwich.

Their concerns seem to have been prompted by observations of dust and spillage of material from trucks travelling to the island but might also have been prompted as a result of a recent proposal by CRL to vary its mining related activities.

2.1 The regulatory environment

The activities associated with mineral sand mining carried out by CRL are regulated by a variety of government departments.

Within the bounds of the mining leases on North Stradbroke Island, mining must be carried out in accordance with legislation administered by the Department of Employment, Economic Development and Innovation (Queensland Mines and Energy).

The investigations carried out on the mining leases were done with the assistance of DEEDI.

The environmental arrangements for dealing with tailings, including their return to the mining lease, are administered by the Department of Environment and Resource Management (Environmental Protection Agency). The radiological aspects of these arrangements were prepared many years ago in liaison with Queensland Health.

Queensland Health, under the *Radiation Safety Act 1999* (the Act), regulates activities involving radioactive material, but this is limited to places outside the bounds of mining leases.

During the separation of the components of the mineral sands, a material known as zircon mags is collected and, due to its elevated levels of radioactivity, this material is classified as a radioactive substance. The zircon mags represent approximately 18% of the tailings material transported back to the island.

The possession and transport of zircon mags is regulated under the Act:

- CRL is required to hold a licence, issued under the Act, to possess the uranium and thorium contained within the zircon mags. CRL is also required to have a Radiation Safety and Protection Plan for managing the radiation hazards of the zircon mags.
- Persons transporting the zircon mags are required to be licensed under the Act to do so, and the requirements to be met during the transport of the material are identical to those required both nationally and internationally. These requirements are specified in the ARPANSA Code of Practice for the Safe Transport of Radioactive Material.

Despite some limitations on its regulatory powers, Queensland Health is able to conduct a wide range of radiological monitoring activities, perform public health assessments, and provide advice and direction regarding any required remedial action to ensure that the radiation dose received by any person from exposure to the radionuclides in the mineral sand is less than a prescribed dose limit (1mSv/year).

2.2 Queensland Health investigations

The Radiation Health Unit has conducted a series of tests and inspections to determine the nature of the mineral sands and assess public health impacts.

The investigations were carried out over a period from September 2008 to November 2010 on North Stradbroke Island (both on and off mining leases) and at Pinkenba. Soil and water samples were analysed by Queensland Health Forensic & Scientific Services (QHFSS).

The types of radiation monitoring activities conducted included:

- gamma radiation surveys of some sites known to have been, or suspected of having been, affected by elevated levels of radioactive material
- sampling and radio-assay of stockpiles of mineral sands, material spilled from trucks, and of soil and sand from various locations
- leachability tests of mineral sands
- sampling and radio-assay of water from selected locations
- sampling to test for radionuclide particulates in air.

Inspections were also carried out to assess:

- whether the transport of the mineral sand is in compliance with legislated requirements
- the way the return of the zircon mags to the mining lease is conducted to ensure it is consistent with good radiological practice.

A more detailed summary of the investigations carried out is presented in Appendix C. Results of the investigations are presented in the following sections.

3. External gamma radiation surveys

Gamma radiation surveys were conducted at various locations throughout the course of the investigation. The results of these surveys are presented in Appendix D.

3.1 Initial walk over of sites of interest

Gamma radiation levels were measured during an initial walk-over of selected sites of interest to SIMO on 11 September 2008. No unexpected radiation levels were found. While some areas of elevated radiation levels were found, they were consistent with radiation levels measured during previous survey conducted by the Radiation Health Unit from the late 1980s to the early 1990s.

Radiation levels in the following locations in Dunwich had slightly elevated levels of radiation (100 to 400nSv/h). These locations are known to be places where mineral sand residues had been deposited many years ago:

- a portion of the park between Ballow Road and Mallon Street
- the forest at the corner of Mallon Street and Mitchell Crescent
- the waste sand piles north-east of the Dunwich water treatment plant.

Gamma radiation levels in the parks at Banksia Street and to the north of the Junner Street jetty were less than 50nSv/h. This is indistinguishable from natural background radiation which, in Australia, is approximately 100nSv/h.

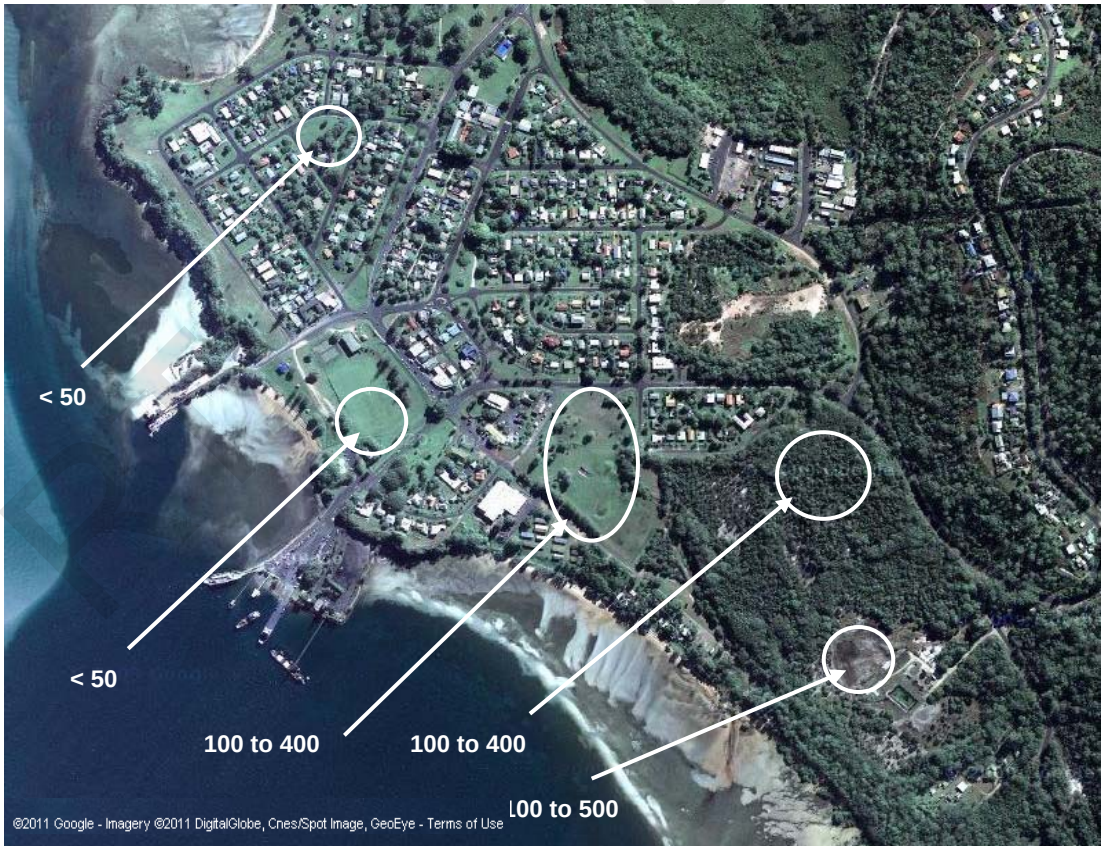

Figure 3a *Locations at which dose rate (nSv/h) was measured during initial walk-over with SIMO – 11-09-2008*

3.2 Ballow Road park

Extensive gamma radiation surveys were conducted at the Ballow Road park (Figure 3b) in April 2009 and April 2010. The results were again consistent with radiation levels measured during previous surveys. The average gamma radiation level was 550nSv/h.

Figure 3b *Ballow Road park*

A total of 364 readings were taken during the surveys: they ranged from 69 to 2,400 nSv/h. Detailed results for this survey are presented in Appendix D – Tables D4 to D9.

Figure 3c shows the distribution of gamma dose rate readings in the park:

- 77% of readings from 0 up to 500 nSv/hr
- 19% of readings from 500 to less than 1,000 nSv/hr
- 4 % of readings from 1,000 to 2,400 nSv/hr

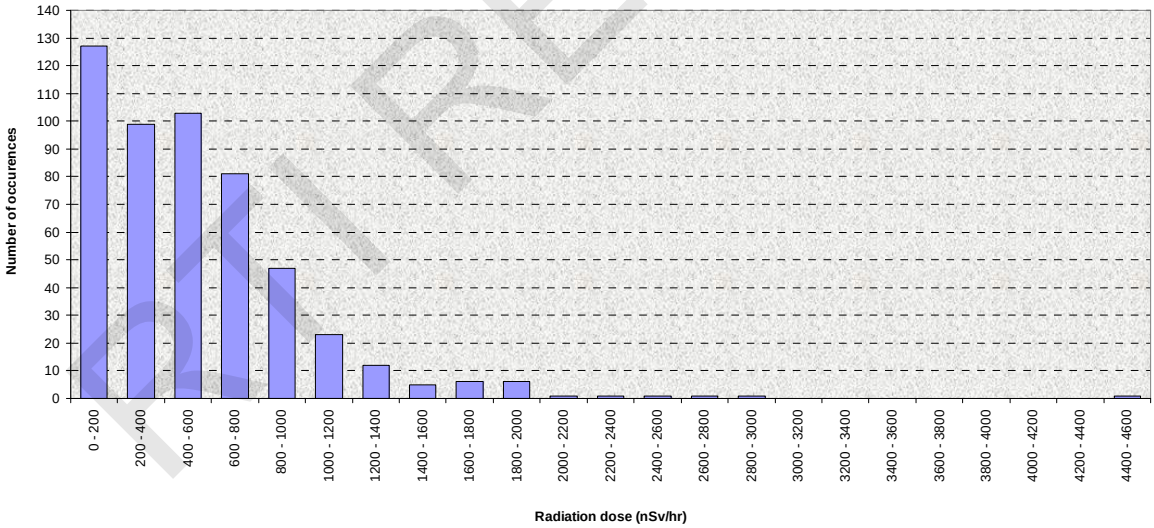

Figure 3c *Distribution of gamma dose rate readings from the Ballow Road park survey*

3.3 CRL premises

Pinkenba mill

Gamma radiation dose rates were measured during a visit to the Pinkenba mill on 8 December 2008. Results are shown in Appendix D – Table D2.

Dose rates in the areas where persons generally work or transit were between 100 to 700nSv/h. Dose rates at about 1m from various stockpiles were consistent with previous results reported by CRL. As expected the dose rate is greater for those stockpiles with greater ^{238}U and ^{232}Th concentrations.

North Stradbroke Island

Gamma radiation levels were measured during a walk over of CRL properties in March 2009. The areas covered were those where:

- initial separation of the mineral sands occurs
- returned tailings are deposited
- rehabilitation was underway or complete.

In summary the results (Appendix D – Table D3) show:

- External gamma dose rate at rehabilitated areas are at natural background levels, indicating satisfactory clean cover over the mineral sand tailings.
- Gamma dose rate near stockpiles of mineral sands were consistent with previous results, and with similar stockpiles at Pinkenba.

4. Sand / soil sampling

Samples collected were of two types:

- mineral sands from various stages in the processing cycle (including naturally occurring source sand, product and tailings) located on premises controlled by CRL at Dunwich and Pinkenba
- soil and sand from publicly accessible areas around Dunwich.

The samples were analysed by gamma spectroscopy which is able to measure the activity concentrations of the radionuclides uranium-238 (^{238}U) and thorium-232 (^{232}Th). Results are presented in Appendix E.

To assist in understanding these results, note that the naturally occurring sand on North Stradbroke Island from which minerals are extracted contains uranium and thorium at concentrations up to approximately 20Bq/kg (becquerels/kilogram). Typical worldwide levels of these radionuclides in soil range from approximately 10 to 100Bq/kg[†].

The concentration at which material containing uranium and thorium is classified as a radioactive substance, and therefore of sufficient concern to warrant regulation through licensing under the *Radiation Safety Act 1999*, is 10,000Bq/kg.

4.1 Processed mineral sands

Samples of mineral sand were collected in August 2008 and March 2009 from various stockpiles (partly processed material, product, and tailings) located on premises controlled by CRL at Dunwich and Pinkenba including the material returned to North Stradbroke Island. Results are in Appendix E – Table E2.

The concentrations of ^{238}U and ^{232}Th in these samples were consistent with data provided by CRL about their products and previous measurements of samples taken from similar locations. Additionally, the results show that only the tailings material described as zircon mags has a high enough concentration of ^{238}U and ^{232}Th to be classified as a radioactive substance and therefore subject to regulation under the *Radiation Safety Act 1999*.

Analysis of samples from the various stages of the mining process shows that:

- The sand from which minerals are extracted contains ^{238}U and ^{232}Th concentrations of 5 to 20Bq/kg.
- Material initially separated at the mine site and awaiting transport for further separation at Pinkenba has ^{238}U and ^{232}Th concentrations from 170 to 2,300Bq/kg.
- The product offered for sale (ilmenite, rutile, and zircon) contains between 20 to 3,000Bq/kg of ^{238}U and ^{232}Th.
- There is a very wide range of uranium and thorium content in the tailings returned to North Stradbroke Island. The concentrations of ^{238}U and ^{232}Th in the tailings described as ‘zircon mags’ range from 10,000 to 54,000Bq/kg; and in the other tailings from less than 10 up to 10,000Bq/kg.

4.2 Mining areas

During a visit in March 2009 to the areas where mining activities had occurred, samples of mineral sand were collected from places where:

- initial separation of the mineral sands occurs
- returned tailings are deposited
- rehabilitation was underway or complete.

Results are in Appendix E – Table E2. In summary the results show:

- Surface soil/sand from the rehabilitated areas contain insignificant quantities of radioactive material
- Mineral sands from other locations on the mine site contain elevated levels of radioactive material consistent with previous results from mineral sand stockpiles.

[†] UNSCEAR 2001 - Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly

On areas where rehabilitation is taking place, the tailings returned to North Stradbroke Island are covered by approximately 10 metres of clean soil/sand. Soil samples collected from the surface of rehabilitated areas contained material with ^{238}U and ^{232}Th concentrations of less than 10Bq/kg. This indicates satisfactory cover of the tailings material.

4.3 Public areas

Soil and sand samples were collected from various locations around Dunwich accessible to the public. In order to obtain some indication of the highest radiation levels that are likely to be found, most of the samples chosen were those that appeared to show an obvious mineral sand content. Results are in Appendix E – Table E1.

In these samples the radionuclide content of the material ranged from 4 to 580Bq/kg of ^{238}U, and from less than 6 to 2,100Bq/kg of ^{232}Th. These concentrations are less than the levels at which a material would be subject to licensing under the *Radiation Safety Act 1999*.

The sampled material had a wide range of uranium and thorium content which would in part be of natural occurrence and in part due to the extracted mineral sands being deposited on the ground.

Junner Street and surrounds

The mineral sand to be taken from the island by barge to Pinkenba is temporarily stockpiled at a loading facility on the southern side of Junner Street at Dunwich. This is close to the location where vehicular and passenger ferries arrive and depart.

Soil and sand samples were collected from areas surrounding the Junner Street jetty at Dunwich in December 2008 and April 2009. The samples have been analysed by QHFSS. In summary the results show:

- Sand from a playground sandpit had an insignificant quantity of radioactive material (less than 6Bq/kg of ^{238}U and ^{232}Th).
- Soil/sand samples from a grassed area and roadway near the Junner Street jetty contained elevated levels of radionuclides up to approximately 430Bq/kg of ^{238}U and 730Bq/kg of ^{232}Th. Note this is less than 10% of the concentration at which these radionuclides would be defined as a radioactive substance.

Sand collected from the beach between Junner and Cunningham Streets had ^{238}U and ^{232}Th concentrations ranging from 45Bq/kg at the northern end of the beach to 290Bq/kg at the southern end (closest to the jetty).

Figure 4a *Mineral sand deposited on roadside, Junner Street*

Adams Beach

Sand collected from Adams Beach (south of the Junner Street jetty) had ^{238}U and ^{232}Th concentrations ranging from 5 to 1,340Bq/kg.

The concentration of uranium and thorium is generally lower in the sand at the southern end of the beach and increases toward the northern end (closer to the barge loading facility). The concentrations of ^{238}U and ^{232}Th were highest in the sample collected at low tide, exhibiting a more obvious content of darker coloured mineral sand.

Figure 4b *Adams Beach showing layers of mineral sand*

Ballow Road park

Samples of soil and sand were collected in April 2009 from the park between Ballow Road and Mallon Street in conjunction with the external gamma radiation survey described in Section 3. The samples contained material with ^{238}U and ^{232}Th concentrations ranging from 30 to 2,100Bq/kg.

The sample with the highest uranium and thorium content was from an area showing an elevated, localised gamma radiation dose rate.

4.4 Dunwich water treatment plant

Sand samples were collected from the Dunwich water treatment plant and the surrounding partly remediated area which is understood to have contained a stockpile of mineral sand. Results are in Appendix E – Table E3.

The samples contained concentrations of ^{238}U and ^{232}Th ranging from 100 to 370Bq/kg

Figure 4c *View of ML118 'Hot sand stockpile' to Dunwich WTP*

5. Leachability of mineral sand

TCLP (toxicity characteristics leaching procedure) is a procedure used to assess the potential for radionuclides in a material to contaminate groundwater. The Radiation Safety Regulation 2010 specifies the leachability criteria for acceptable disposal of mineral substances without requiring an approval. For mineral substances this amount is a gross alpha and beta concentration of less than 5Bq/l.

The previously mentioned samples of mineral sands from various stages in the processing cycle (naturally occurring source sand, partly processed material, product, and tailings) were subjected to testing using the TCLP. The results are presented in Appendix F – Table F1.

The amount of radioactive material leached from these samples was below the criteria stated in the Regulation. These results show the potential for deposited mineral sand products and tailings to contaminate groundwater is acceptably low.

As the mineral sands are not chemically changed during processing, the collected samples are in the same state as they are in the natural environment of North Stradbroke Island. So the mineral sands which are an existing component of Stradbroke Island's natural environment, should not pose any additional risk to flora or fauna since the radioactive elements are not readily available due to the low solubility of the mineral.

Further testing of the most active sample (zircon mags) was carried out by analysing the radionuclide concentrations within the leachate (Appendix F – Table F2). The radionuclides with the greatest concentration were the progeny from the ^{232}Th series.

6. Water sampling

Grab samples of water were collected in April and November 2010 from the following natural watercourses and the drinking water supply:

- the creek running through Adam's Beach
- a stream adjacent to the Ballow Road park
- Brown Lake
- a tap in the park at Junner Street and Ballow Road.

Radioassay results for these samples are presented in Appendix G – Table G1. Gross alpha and beta concentrations in each of these samples were less than the radiological screening levels in the Australian Drinking Water Guidelines (<0.5Bq/l).

These results show the radiation levels in natural watercourses and the drinking water supply to be acceptably low.

Figure 6a *Creek running through Adams Beach from which water sample was taken*

7. Air sampling

Testing for particulates in air at the Junner Street jetty and surrounds was conducted in December 2008 and April 2009 using personal air samplers and a high volume sampler. Note that during air sampling tests the weather was fine with a very mild breeze.

In the initial trials in 2008 no measurable amount of radioactive material was detected in the samples.

The filter papers collected during further air sampling at various publicly accessible locations in 2009 were analysed by QHFSS. The results are presented in Appendix H – Table H1.

The results show gross alpha and beta concentrations indistinguishable from background (as measured on a blank sample). The tests show immeasurable or insignificant amounts of airborne radioactive material.

8. Personal radiation dose assessment

Radiation dose to persons is controlled by setting dose limits where a radiation source is the subject of a possession licence, or prescribing criteria for the release of radioactive material into the environment.

8.1 Member of public exposure

Queensland's radiation safety legislation imposes annual radiation dose limits to limit the dose to which a person is exposed as the result of the carrying out of a radiation practice. For a member of the public, that dose limit is 1,000µSv (microsieverts).

To help ensure these limits are not exceeded, Queensland Health seeks to ensure doses to individuals due to the release of radionuclides into the environment are constrained, in their design, to less than 300µSv/year above background. For comparison, natural background radiation, to which we are all exposed, is approximately 2,000µSv/year.

The pathways for radiation exposure are external exposure, ingestion, and inhalation. The tests conducted during this investigation show:

- external gamma radiation in some locations is above natural background radiation levels
- radioactivity in water is below ADWG levels and acceptably low
- immeasurable or insignificant amounts of radionuclides in air.

Consequently, the most significant pathway by which a member of the public on North Stradbroke Island may be exposed to radiation due to mineral sand mining activities is though external gamma exposure.

A reasonable case assessment is that of an individual spending time at a location where elevated radiation levels are found. Consider a person spending 1.5 hours each day of the year at the Ballow Road park where the average radiation level is 0.55µSv/h. Their annual radiation dose would be 250µSv above background. This is acceptably low and less than the 300µSv criterion mentioned above.

8.2 Occupational exposure

CRL provided the following data on the annual personal doses of its employees at Pinkenba:

- Rutile & Zircon operator (including inhalation without dust protection) 2.5 to 3.5mSv
- Other workers < 1.2 mSv

This is consistent with an annual dose that may be expected given the dose rates (shown in Appendix D – Table D2) measured at the Pinkenba plant.

9. Investigation of transport arrangements

There are three streams of tailings material returned to North Stradbroke Island:

- ilmenite reject
- zircon tails
- zircon mags.

The level of radioactivity in the zircon mags is such that this material is classified as a radioactive substance under the *Radiation Safety Act 1999*. Consequently this material is required to be transported back to the island by a person who holds a licence, issued under the Act, to transport radioactive substances. The zircon mags are required to be transported in accordance with the ARPANSA *Code of Practice for the Safe Transport of Radioactive Material (2008)*.

Approximately one truck load per day of zircon mags is returned to the island via public vehicular ferry.

9.1 Transport of zircon mags

In September and December 2008, officers of the Radiation Health Unit carried out inspections to investigate compliance with the transport requirements of the Radiation Safety Act 1999.

The outcomes of the investigation were:

- the drivers of the vehicles held a current transport licence
- the zircon mags were transported in covered trucks bearing radiation warning placards
- the vehicles had only two placards (one at front and one at rear) rather than the three placards required by the Code of Practice (see Figure 8a).

Figure 9a *Covered and placarded vehicles carrying zircon mags – note front and rear signs*

CRL were reminded of the requirements for transport of radioactive material, in particular the requirements for placarding of vehicles. CRL subsequently arranged for modification of the vehicles to accommodate placards at the sides of the vehicles (see Figure 8b).

Figure 9b *Modification to allow placarding on sides of vehicle*

9.2 Transport training course

From December 2008 to February 2009 a reassessment of the transport training course provided by CRL to the drivers of the vehicles carrying zircon mags. During the early part of this reassessment, it was identified that CRL needed to modify part of the training course.

While all essential safety requirements were appropriately covered by the original course, improvements were suggested in regard to signage and administrative requirements. As a consequence of this, CRL modified its training course to emphasise correct procedures and compliance with the Code of Practice.

10. Properties affected by radiological contaminant

In its register of contaminated land sites Radiation Health has a record of 49 sites on North Stradbroke Island that have been investigated for radiological contamination, most usually by landfill containing mineral sands. These sites are listed in Appendix B – Tables B1 and B2.

In the 1980's, Queensland Health conducted radiation surveys on these sites to determine whether remediation was required. Queensland Health was involved in monitoring any remedial action.

The records relating to these sites were reassessed approximately 10 years ago with a view to deciding whether the sites should be recorded on the Environmental Protection Agency's Environmental Management Register (EMR).

Many of the reassessed sites had a level of radioactive contamination that was sufficient for Queensland Health to advise the Environmental Protection Agency that those sites should be listed on the EMR.

During the course of these investigations no land owner requested a new radiation survey or a reassessment of their property.

The outcomes of the investigations do not suggest the need for any change to the status of sites on the registers.

11. Conclusion

The outcomes of these tests are consistent with previous monitoring and testing and do not reveal any evidence to suggest that activities associated with the mining, processing and transport (both to and from the island) of mineral sand on North Stradbroke Island is adversely affecting occupational or public health, from a radiological perspective.

Appendix

A Mineral sand mining - Technical summary

Mineral sands

Australia has extensive deposits of mineral sands, most of which occur on the east coast of Australia between Sydney and Fraser Island or on the southern section of the coast of Western Australia, that have been mined since the 1930's. The mineral sand contains varying concentrations of radioactive uranium and thorium.

Most sand consists of grains of the mineral quartz (SiO2). Mineral sands are old sands that contain concentrations of the minerals; rutile, ilmenite, zircon, and monazite.

- Rutile and ilmenite are oxides containing the element titanium.
- Zircon is a silicate containing the element zircon.
- Monazite is a rare earth phosphate containing the elements cerium, lanthanum, neodymium, and thorium in various proportions.

While the main products of mineral sands mining are titanium oxide and zircon, monazite is also a significant component. Western Australian mineral sands deposits contain up to 10% heavy minerals, of which 1-3% is monazite (i.e. 0.3% monazite in the deposit). The minerals sands deposits on the east coast contain much lower amounts of monazite.

The monazite in the mineral sands mined on North Stradbroke Island does contain the radioactive element thorium and it is the monazite which is the predominant source of the radioactivity in the mineral sands extracted from this location.

Activities on North Stradbroke Island

In 2007, approximately 50,000,000 tonnes of sand was mined on North Stradbroke Island by CRL. The desired minerals (Rutile, Zircon, Ilmenite) account for about 0.6% of the mass mined‡. Table 1a provides a summary of the mass of material mined and produced during 2007.

The mineral sand being mined on North Stradbroke Island is separated, on the island, into two streams:

- the rutile-zircon stream containing 0.3% monazite by weight
- the ilmenite stream containing 0.1% monazite by weight.

There are no chemicals used in the mining and processing of mineral sands §. The separation on North Stradbroke Island is done by physical methods using the physical characteristics of the different minerals. No chemical changes to any minerals are effected during the process. Physical processes used at the North Stradbroke Island mine are;

- Screening, that relies on different particle sizes.
- Wet gravity, that relies on different specific gravity for each mineral.
- Magnetic separation, that relies on the different magnetic properties of the minerals.

In 2007 approximately 171,000 tonnes of sand in the "rutile-zircon stream" were removed from the island and taken to Pinkenba by barge. Prior to being loaded into the barge this sand (containing the higher concentration of monazite) is temporarily stored at Dunwich in enclosed bins.

In the same year approximately 195,000 tonnes of sand in the "ilmenite stream" were removed from the island and taken to Pinkenba by barge. Prior to being loaded into the barge this sand (with the lower concentration of monazite) is temporarily stored in an open stockpile.

(In the previous year the amount of sand removed was approximately 182,000 tonnes in the "rutile-zircon stream" and 196,000 tonnes in the "ilmenite stream".)

‡ Data in this appendix about tonnage of material is supplied by CRL
§ Advice from CRL

Figure A1 *Enterprise mine on North Stradbroke Island*

Figure A2 *Dredge pond at Enterprise where initial extraction of mineral sand occurs*

Approximately 75,000 tonnes of silica sands, not containing monazite, is removed from the island by trucks using the public ferry from Dunwich to Cleveland.

In addition to the sands trucked by CRL, approximately 75,000 tonnes of silica sands from a silica sand company, not containing monazite, is also removed from the island each year by trucks using the public ferry from Dunwich to Cleveland, and a local concrete company also takes approximately 10,000 tonnes of river sands and gravel to North Stradbroke Island each year.

Figure A3 *CRL Dunwich barge loading facility next to ferry terminal*

Processing at Pinkenba

The mineral sand is further processed at the Pinkenba mill by physical separation of its components into a number of streams. No chemical changes to any minerals are effected during the process.

Separation techniques used in the concentration and processing of mineral sands rely solely on the physical characteristics of the different minerals. Physical processes used at the Pinkenba processing plant are:

- Screening, that relies on different particle sizes.
- Wet gravity, that relies on different specific gravity for each mineral.
- Magnetic separation, that relies on the different magnetic properties of the minerals.
- Electrostatic separation, that relies on the different surface conductivity of the minerals.

After processing by physical separation, the useful minerals (rutile, ilmenite and zircon) are packaged for sale.

Figure A4 *CRL Pinkenba Mill*

Return of tailings to North Stradbroke Island

A consequence of extracting useful material from the mineral sand is the production of unwanted or unsaleable material. These tailings, which are returned to North Stradbroke Island, are separated into three different streams. Of the 34,000 tonnes of material returned to North Stradbroke Island in 2007:

- 15,000 tonnes was ilmenite reject containing approximately 0.5% monazite by weight,
- 13,000 tonnes was zircon tails containing approximately 1% monazite by weight,
- 6,000 tonnes was zircon mags containing approximately 10% monazite by weight.

The ilmenite reject and the zircon tails are not classified as being radioactive substances due to their low concentrations of radioactive elements. However, the level of radioactivity in the zircon mags is such that this material is regulated under the Radiation Safety Act 1999 hence the possession, and any transport, of this material must be in accordance with that Act.

The zircon mags in addition to other tailings are returned to the island, transported by covered trucks using the public ferry. The trucks carrying the zircon mags have sealed tailgates and are required to be appropriately placarded. Approximately one truck load per day of zircon mags is returned to the island.

When returned to North Stradbroke Island, the zircon mags are returned to the mining lease where they are covered with 10 metres of clean material to reduce the hazard posed by the elevated levels of radioactivity in this material.

Figure A5 Tailings returned to North Stradbroke and covered with 10m of clean sand

Figure A6 Rehabilitated area on old Ibis mine site

Safety concerns

The occupational health issue of specific relevance to the mineral sands industry is radiation. Just as with other minerals, the concentration of mineral sands in deposits may vary widely.

In ore, or general heavy mineral concentrate, the radiation levels are very low. However, when the radioactive material is concentrated during processing the radiation levels are increased, creating the need for controls to protect some designated employees.

The most significant potential radiation problem is inhaled thorium in mineral sands dust, so dust control is the most important objective in radiation safety. Exposure to external gamma radiation still needs to be controlled in the mineral sands industry, due principally to uranium and thorium in zircon.

Radiation safety in mining operations is managed by implementing Radiation Protection Series No.9 - *Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* published by ARPANSA.

Table A1 *Mass balance of sand mined on North Stradbroke Island in 2007*

Of the 50,000,000t of sand mined in 2007, 366,000t of mineral sand is initially separated out for further processing

Mineral sand taken from North Stradbroke Island to Pinkenba		
in the Rutile-Zircon stream	171,000 t	
in the Ilmenite stream	195,000 t	
Total		**366,000 t**
Product - Mineral extracted at Pinkenba and offered for sale		
Rutile	80,000 t	
Zircon	60,000 t	
Ilmenite	178,000 t	
Sub Total		*318,000 t*
Product - Other sand extracted at Pinkenba and sold for construction / bedding etc		
Silica tails	14,000 t	
Sub Total		*14,000 t*
Tailings - Mineral sand tails returned to NSI		
Zircon tails	13,000 t	
Zircon mags	6,000 t	
Ilmenite reject	15,000 t	
Sub Total		*34,000 t*
Total		**366,000 t**

References

Geoscience Australia, Commonwealth of Australia
Uranium Information Centre Ltd, *Mineral Sands, Nuclear Issues Briefing Paper 25, January 1998*

Appendix

B Radiation Health register of contaminated land sites

Table B1 *Sites which have a status of 'Managed' in the Radiation Health register of contaminated land sites*

RHU Site No.	Site Address	Site Suburb	Lot	Plan
2021*	14 Mermaid Street	Dunwich	10	D90426
2020*	16 Mermaid Street	Dunwich	9	D90426
2019*	18 Mermaid Street	Dunwich	8	D90426
2016*	24 Mermaid Street	Dunwich	5	D90426
2015*	26 Mermaid Street	Dunwich	4	D90426
2060*	11 Mallon Street	Dunwich	6	D90419
2074*	13 Mallon Street	Dunwich	7	D90419
2061*	19 Mallon Street	Dunwich	10	D90419
2038*	Adams Beach Camping Reserve, Ballow Road	Dunwich	163	SL8381
2039*	30 Finnegan Street	Dunwich	2	D90426
2159*	2 Stradbroke Place	Dunwich	4	D90419
4065*	Site F	Dunwich	95	SL5238
2022	12 Mermaid Street	Dunwich	11	D90426
2018	20 Mermaid Street	Dunwich	7	D90426
2017	22 Mermaid Street	Dunwich	6	D90426
4056	8 Mallon Street (CRL premises)	Dunwich	15	D90415
2073	9 Mallon Street	Dunwich	5	D90419
2075	15 Mallon Street	Dunwich	8	D90419
2031	Mitchell Park, Mallon Street	Dunwich	2	D90450
2032	Area O – Sportsground (part of Ballow Rd park)	Dunwich	80	SL4783
4107	28 Finnegan Street (cnr Mermaid Street)	Dunwich	3	D90426
4053	Ballow Road (ex CRL stores)	Dunwich	29	SL4907
4057	Barton & Mermaid Streets (roads and footpaths)	Dunwich		
4061	Ballow Rd (part of old CRL Bayside disposal site)	Dunwich		
4064	Site E (part of old CRL Bayside disposal site)	Dunwich	82	USL20272
4073	Junner Street (jetty area)	Dunwich	94	SL12302
4117	Barton Street (part of Ballow Rd park)	Dunwich	3	USL20272
4132	Dunwich Council Depot, Mitchell Crescent	Dunwich	128	SL12274
2050	Dredge Pond (Enterprise Mine)	North Stradbroke Island		
4069	Amity Point Jetty	North Stradbroke Island	19	SL806442

* DERM has confirmed these are also on the EMR

Table B2 *Sites which do not have a status of 'Managed' in the Radiation Health register of contaminated land sites*

Site No.	Site Address	Site Suburb	Lot	Plan
1576	c/o Post Office	Dunwich		
1576	School	Dunwich		
1657	Industrial Estate	Dunwich		
1657	Sturt Street	Dunwich		
2033	Dickson Way	Dunwich		
2046	Cnr Logan & Bayly Crescent, Lot 16 / Section 14	Dunwich		
2047	Lot 14 Oxley Parade	Dunwich		
2049	Substation	Dunwich		
2053	Weighbridge Yard	Dunwich		
2054	Office & Workshop Sites	Dunwich		
2059	Lot 4	Dunwich		
2059	Mallon Street	Dunwich		
2076	17 Mallon Street	Dunwich	9	D90419
2077	42 Mallon Street	Dunwich	11	D90411
2095	Stuart Street	Dunwich		
4059	Barracks Area – Portion 76	Dunwich		
4060	Deep Drain – Barton Street	Dunwich		
4156	Dunwich Water Treatment Plant	Dunwich		
1270	Coast Road	North Stradbroke Island		
1887	SEQEB Beenleigh-Dunwich Depot	North Stradbroke Island		

Appendix

C Timeline of events and test conducted in relation to mineral sands

12 June 2008	Ms Jackie Cooper, representing the Stradbroke Island Management Committee (SIMO), wrote to the Honourable Andrew McNamara MP, Minister for Sustainability, Climate Change and Innovation, Member for Hervey Bay, regarding transport of mineral sands to and from North Stradbroke Island. Her letter was forwarded to the Minister for Health for response.
18 July 2008	A Radiation Health Unit officer (LW) went to ferry terminal at Redland Bay. No trucks carrying radioactive material were observed.
25 July 2008	The Radiation Health Unit prepared a Brief to the Minister (MI15603) to inform the Minister about matters associated with the mineral sand mining industry on North Stradbroke Island. Accompanying the Brief were Ministerial letters to Ms Cooper and The Honourable Phillip Weightman MP, Member for Cleveland.
July 2008	The Radiation Health Unit reviewed the scope of mineral sand mining activities conducted on North Stradbroke Island by Consolidated Rutile Limited (CRL) and collected data on the radiological characteristics of the mineral sands.
8 August 2008	The Radiation Health Unit prepared an updated Brief to the Minister to inform the Minister about matters associated with the mineral sand mining industry on North Stradbroke Island
18 August 2008	The Radiation Health Unit was advised by Ms Elise Staples, Ministerial Adviser, that the Minister's Office had the Ministerial letter MI15603 but that it had not yet sent it to Ms Jackie Cooper. From Ms Cooper's perspective it may have appeared that her concerns were not being addressed by Queensland Health.
19 August 2008	Samples of mineral sand were collected (by CRL) from various stockpiles located on premises controlled by CRL at Dunwich and Pinkenba, including the material returned to North Stradbroke Island. (Results in Appendix E.)
22 August 2008	Officers of the Environmental Health Branch met with representatives from SIMO at Dunwich on North Stradbroke Island to listen to and clarify the concerns of SIMO and to gain an understanding of the key issues which the Radiation Health Unit can provide input into to better target its investigations.
9 September 2008	A Radiation Health Unit officer (SC) went to ferry terminal at Redland Bay. One vehicle (placarded and load covered) carrying radioactive material was observed.
11 September 2008	An initial walk-over of sites of particular interest to SIMO was conducted by an officer of the Radiation Health Unit (SC) in the presence of Ms Lucy Trippett, representing SIMO. No unusual levels of radiation were found. (Results in Appendix D.)
12 September 2008	The Radiation Health Unit prepared updated Ministerial letters to Ms Cooper (MI156035) and to The Honourable Phillip Weightman MP, Member for Cleveland (MI156168). The Radiation Health Unit also prepared Ministerial letters to The Honourable Geoffrey Wilson MP, Minister for Mines and Energy, and The Honourable Reginald Mickel MP, Minister for Transport, Trade, Employment and Industrial Relations to notify them of the issues with regard to mining of mineral sands on North Stradbroke Island and to inform them of the investigative activities of Queensland Health.
19 September 2008	Responded to Freedom of Information request by Mr Simon Baltais. Completed 22 September 2008
7 November 2008	Ms Cooper wrote to the Minister seeking information about the results of inspections carried out to date (MI159065).

8 December 2008 Visit by SC to CRL, Pinkenba to inspect processing plant and measure dose rates in work areas and from mineral sand stockpiles. (Results in Appendix D.)

9 December 2008 The Radiation Health Unit prepared a Ministerial letter to Ms Cooper to advise her of the results of investigations to date (MI159065). The letter was sent to Ms Cooper on 22 December 2008.

15 December 2008 Officers of the Radiation Health Unit (SC, EE, RL) visited Dunwich to conduct a variety of tests:

- Air sampling tests near the Junner Street jetty at Dunwich using personal air samplers and a high volume sampler. (Results in Appendix H.)
- Soil and sand samples collected from areas surrounding the Junner Street jetty at Dunwich. (Results in Appendix E.)
- Inspections to investigate compliance with the transport requirements of the Radiation Safety Act 1999. Observed truck carrying zircon mags driving onto ferry to NSI.

December 2008 *(to February 2009)* - The Radiation Health Unit assessed the transport training course provided by Consolidated Rutile Limited (CRL) to its drivers. Radiation Health had, during the early part of this reassessment, identified a need for CRL to modify part of the training course. As a consequence of this, CRL has modified its training course to emphasise correct practices where deficiencies had been found.

28 January 2009 Ms Cooper wrote to the Minister regarding the monitoring of activities related to mineral sand mining on North Stradbroke Island carried out by Consolidated Rutile Limited (MI160794).

24 February 2009 The Radiation Health Unit prepared a Brief to the Minister to inform the Minister of radiation monitoring activities on North Stradbroke Island (MI160794) and a Ministerial letter to Ms Cooper to advise her of the results of investigations to date. The letter was sent to Ms Cooper on 13 March 2009.

3 March 2009 Officers of the Radiation Health Unit (SC, EE) visited the mining areas operated by Consolidated Rutile Ltd on North Stradbroke Island accompanied by a Department of Mines representative (Kevin Hedges) to discuss the mining process and relevant health and safety concerns.

Officers conducted the following tests:

- Further samples of mineral sand were taken from sand stockpiles, returned tailings area, and rehabilitated areas. (Results in Appendix E.)
- Gamma dose rate survey of stockpiles and area where mining activities were carried out. (Results in Appendix D.)

19 April 2009 Ms Cooper wrote to the Minister regarding the monitoring of activities relating to mineral sand mining on North Stradbroke Island (MI162680).

29 April 2009 Officers of the Radiation Health Unit (SC, EE, RL, LW) visited Dunwich to conduct a variety of tests:

- Air sampling at various publicly accessible locations in Dunwich conducted using personal air samplers and a high volume sampler. (Results in Appendix H.)
- Sand samples collected from beach areas surrounding the Junner Street jetty and the park at Ballow Road, Dunwich. (Results in Appendix E.)
- A gamma radiation survey conducted over a portion of the park at Ballow Road, Dunwich. (Results in Appendix D.)

25 May 2009 The Radiation Health Unit prepared a Brief to the Parliamentary Secretary to the Minister to inform the Minister of radiation monitoring activities on North Stradbroke Island (MI162680) and a Departmental letter to Ms Cooper to advise her of the results of investigations to date.

7 August 2009 The Radiation Health Unit prepared an update to MI162680.

22 February 2010 Radiation Health responded to Queensland Mines and Energy, DEEDI in response to a request for advice about a CRL radiation dose report.

13 April 2010 Officers of the Radiation Health Unit (SC, EE, LW) visited Dunwich to conduct a variety of tests:

- Remainder of the gamma radiation survey of the Ballow Road park. (Results in Appendix D.)
- Further sand sampling from Adams Beach, Junner Street and the Ballow Road park. (Results in Appendix E.)
- Water sampling of creeks at Adams Beach and near the Ballow Road park.(Results in Appendix G.)

8 June 2010 Radiation Health responded to DERM in response to a request for advice about the monitoring requirements of DERM and Radiation Health.

2 November 2010 Officers of the Radiation Health Unit (SC, EE) visited Dunwich to conduct the following tests:

- Gamma dose rate survey of Dunwich water treatment plant (WTP). (Results in Appendix D.)
- Sand sampling from Dunwich WTP. (Results in Appendix E.)
- Water sampling from Brown Lake and Junner Street park tap (drinkable water). (Results in Appendix G.)

Appendix

D External gamma radiation surveys

Table D1 *Gamma dose rate measured at locations of interest to SIMO during an initial walk-over in Dunwich - 11 September 2008*

Location	Gamma dose rate (nSv/h)
Park at Banksia Street	< 50
Park at beach, Junner Street	< 50
Forest at corner of Mallon Street and Mitchell Crescent	100 to 400
Park, Ballow Road	100 to 400
"Hot sand pile" (on CRL mining lease near water treatment plant)	100 to 500
Background	50 to 100

1 Measurements made with Bicron microSievert (s/n B405E)

Table D2 *Gamma dose rate measured on CRL premises, Pinkenba - 8 December 2008*

Location type	Description	Gamma dose rate (nSv/h)	CRL dose rate (nSv/h) 19-08-2008
Stockpile	Silica Tails - used for construction sand (30 to 240 nSv/h)	135	100
Area	Bagging	140	
Area	Office	150	
Area	Wet plant	200	
Area	Dry mill - Rutile	200	
Stockpile	Ilmenite plant feed - as it is loaded onto barge at NSI (200 to 350 nSv/h)	275	200 to 600
Stockpile	Hi Tag Non-Mags	300	500
Stockpile	Ilmenite Reject FB11 Bin (300 to 400 nSv/h)	350	
Area	Walking around site between buildings (300 to 700 nSv/h)	500	
Stockpile	Hi-Tag Mags (300 to 900 nSv/h)	600	900
Area	At side of Zircon mags bin (not full) - NSI (500 to 600 nSv/h)	550	
Area	Under Zircon mags bin (not full) at drivers position	700	
Stockpile	Zircon Tails – Trees	900	
Area	Dry mill - Zircon (400 to 1,500 nSv/h)	950	
Stockpile	Zircon Tails yard - 3 to 4 times over fill limit (800 to 1,300 nSv/h)	1,050	
Stockpile	Road spill (1,000 to 2,000 nSv/h)	1,500	1,500 to 5,000
Stockpile	Oversize Zircon - goes back into process ~0.1% monazite	2,500	
Stockpile	Rutile-Zircon concentrate - from loading bin on NSI ~33% Zircon	3,000	1,500 to 2,400
Stockpile	Zircon plant feed - Dry yard (2,000 to 6,000 nSv/h)	4,000	3,000 to 6,000

1 Measurements made with Bicron microSievert

Table D3 *Gamma dose rate measured on CRL premises, North Stradbroke Island - 3 March 2009*

Location type	Description	Gamma dose rate (nSv/h)	Sample ID [1]
Area	Ibis Rehabilitation 2002 - Topsoil at rehabilitated area	20	17
Stockpile	Dry Mill Tails - 2 (Sand used to cover waste material returned to NSI)	50	16
Area	ML118 (Mining Lease SE of Dunwich)	500	21
Stockpile	Dunwich - Concentrates Bin (At barge loading facility awaiting transport to Pinkenba)	1,700	24
Stockpile	Ilmenite stockpile at Enterprise Mine	2,000	19
Stockpile	Rutile Zircon - Dunwich South Bin (At barge loading facility awaiting transport to Pinkenba)	2,900	23
Stockpile	Rutile Zircon stockpile at Enterprise Mine, NSI	4,700	20
Stockpile	Dry Mill Tails - 1 (Combined waste material returned to NSI prior to grading)	10,000	15

1 ID of sand sample collected at the same location as dose rate measurement – see Table E1 for analysis

2 Measurements made with Bicron microSievert

Table D4 *Combined results of Ballow Road park gamma dose rate survey – 29 April 2009 and 13 April 2010*

	Area 1	**Area 2**	**Area 3**	**Area 4**	**Area 5**	**Total area**
Number of measurements	248	101	5	24	137	515
Average Dose rate (nSv/hr)	354	516	1,103	475	918	549
Standard deviation (nSv/hr)	93	294	737	166	558	452
Minimum dose rate (nSv/hr)	69	124	637	267	267	69
Maximum dose rate (nSv/hr)	1820	1300	2400	927	4450	4450

					Area5*	
Number of measurements					111	
Average Dose rate (nSv/hr)					928	
Standard deviation (nSv/hr)					510	
Minimum dose rate (nSv/hr)					279	
Maximum dose rate (nSv/hr)					4130	

Figure D1 *Ballow Road park showing sections surveyed – 29-04-2009 & 13-04-2010*

Table D5 *Ballow Road Park Area 1 gamma dose rate survey – 29 April 2009 and 13 April 2010*

Area 1	1	2	3	4	5	6	7	8	9	10
A	624	674	473	522	1300	980	963	760	386	494
B	663	411	641	949	1630	906	523	536	256	267
C	670	594	371	495	1650	1160	1220	915	370	323
D	686	392	462	1820	919	1060	1020	779	822	841
E	779	590	388	407	436	441	713	938	689	709
F	534	382	442	431	434	720	867	1090	692	660
G	625	620	451	418	338	311	376	454	620	732
H	670	424	376	297	305	235	329	727	382	351
I	659	578	415	274	223	227	224	178	219	192
J	480	231	188	189	204	171	166	150	134	154
K	608	555	478	271	253	216	159	179	123	152
L	606	356	247	235	212	164	176	186	-	165
M	659	549	334	240	149	160	165	179	-	205
N	565	417	304	217	140	111	164	184	108	189
O	605	471	204	172	116	117	153	194	141	104
P	414	173	162	139	132	142	145	134	113	135
Q	513	431	211	181	144	125	122	165	127	150
R	357	245	173	151	118	157	136	146	134	110
S	476	503	316	270	186	129	103	105	119	131
T	275	352	237	146	125	120	126	115	120	115
U	410	344	281	286	181	178	144	101	112	115
V	245	177	169	151	121	117	128	116	121	120
W	180	184	181	162	119	132	110	140	172	170
X	168	195	144	171	185	129	107	145	179	219
Y	237	170	147	126	116	106	84	69	90	353

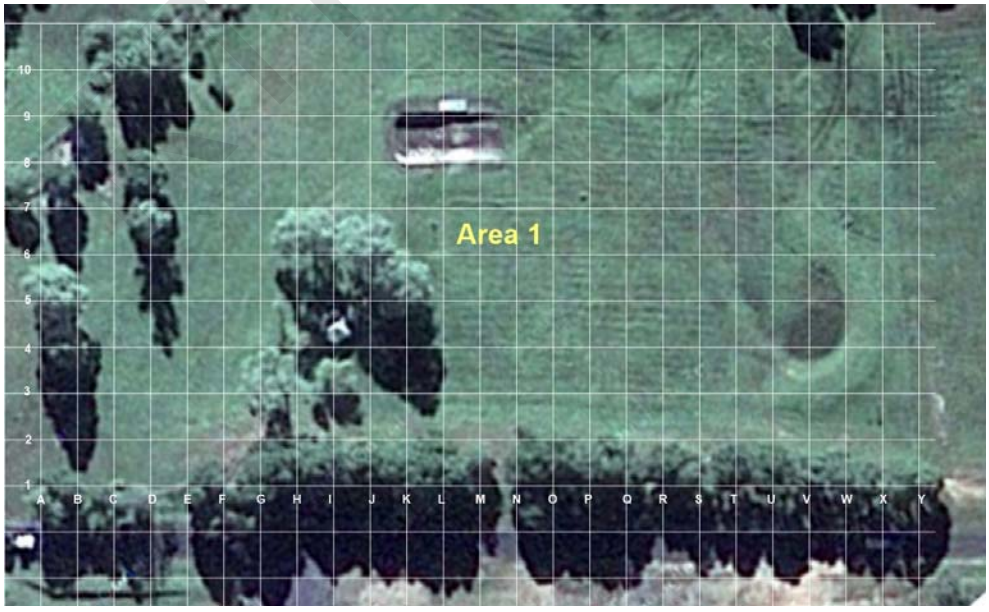

Figure D2 *Ballow Road Park Area 1*

Table D6 *Ballow Road Park Areas 2 & 3 gamma dose rate survey – 29 April 2009 and 13 April 2010*

Area 2	A	B	C	D	E	F	G	H	I	J
1	1300	431	1060	521	347	301	330	342	310	996
2	756	486	830	373	314	329	516	545	587	789
3	789	296	567	299	381	1020	987	773		
4	772	712	630	339	595	762	785	1170		
5	159	295	294	952	1300	671	633			
6	145	304	202	998	1080	686				
7	124	283	161	1080	896	558				
8	157	149	191	1070	636	637				
9	176	205	208	535	475					
10	149	234	370	567						
11	153	221	647	620						
12	178	213	789	749						
13	149	247	630							
14	176	233	526							
15	169	325	440							
16	203	362	534							
17	247	361	407							
18	474	487	433							
19	870	656								
20	420	654								
21	594									

Area 3	A	B	C
1	695	2400	637
2	796	987	

Figure D3 *Ballow Road Park Areas 2 and 3*

Table D7 *Ballow Road Park Area 4 gamma dose rate survey – 29 April 2009 and 13 April 2010*

Area 4	A	B	C
1	579	576	325
2	648	481	267
3	741	539	281
4	555	336	356
5	402	296	333
6	652	392	384
7	535	323	379
8	458	927	
9	623		

Figure D4 *Ballow Road Park Area 4*

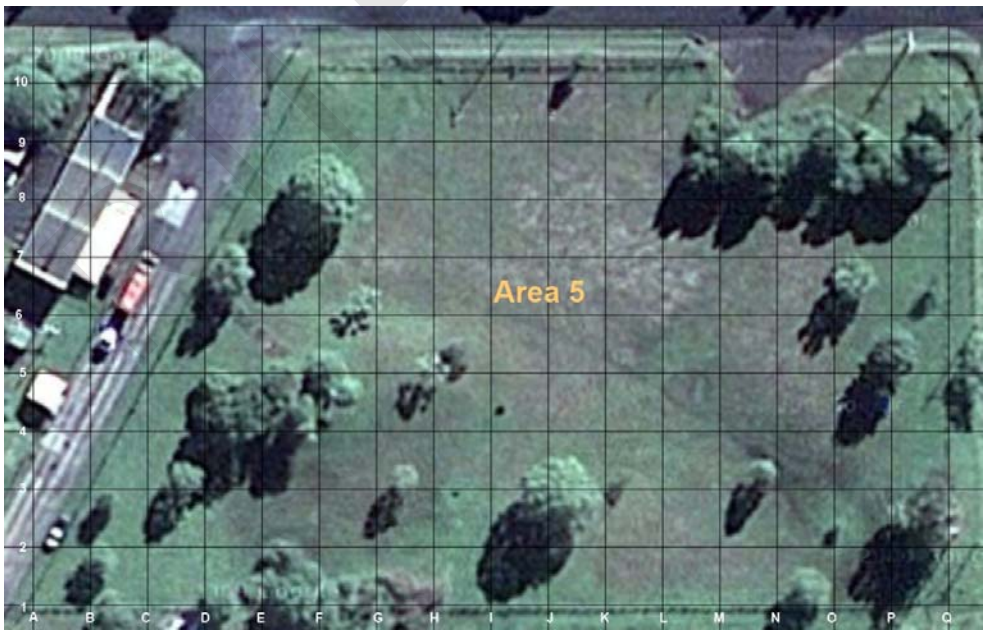

Figure D5 *Ballow Road Park Area 5*

Table D8 *Ballow Road Park Area 5 gamma dose rate survey – 29 April 2009 and 13 April 2010*

Area 5	1	2	3	4	5	6	7	8	9	10
A	512									
B	590	1280								
C	397	1560	1230	1705						
D	508	870	925	1600	2100	350				
E	942	962	1610	1190	817	439	417			
F	758	1020	425	1830	788	404	439	267	455	837
G	851	642	540	440	419	926	537	527	276	1160
H	691	1160	553	596	1640	575	738	1070	992	1230
I	921	716	858	540	569	743	765	955	1310	1280
J	639	719	897	647	472	458	512	546	744	2670
K	822	678	1100	1220	676	524	545	711	2890	4450
L	868	839	844	1000	815	721	463	832	2200	1500
M	716	643	752	940	1000	877	1020	804		
N	455	674	406	473	961	1020	1540		415	483^
O	483	593	641	479	927	893	1520	1850	621	441
P	883	662	657	746	738	843	1090	1250	470	779
Q	1940	1860	1820	1590	954	1160	1140	1260	422	439

Table D9 *Ballow Road Park Area 5* gamma dose rate survey – 29 April 2009 and 13 April 2010*

Area 5*	1*	2*	3*	4*	5*	6*	7*	8*	9*
B*	1250	4130							
C*	1210	2770	1610	1100					
D*	1280	815	1390	1850					
E*		719	955	1090	503				
F*	657	861	1810	920	681	343	283	436	765
G*	564	575	768	775	673	326	479	279	468
H*	868	553	463	497	650	710	650	1170	1660
I*	780	703	1020	916	593	1080	1050	1080	1360
J*	858	540	465	575	542	609	696	939	1520
K*	805	1000	1070	677	687	509	484	953	2200
L*	635	781	1090	805	635	573	598	1630	1550
M*	741	1000	899	1030	1070	669	596		1010
N*	727	645	893	863	1090	967			
O*	628	462	550	981	887	1230			
P*	593	476	578	800	725	1200	1490		
Q*	952	1430	1260	882	1170	1310	1640		

Area 5* has measurements to the left and above the grid points (i.e. D*2* is measured in the middle of the grid D-E/1-2)

Appendix

E Soil sampling

Table E1 *Radioassay of soil/sand samples collected from public areas*[1]

No.	QHFSS Lab. No.	Description	Sample Date	U-238 (Bq/kg)	Th232 (Bq/kg)
31	08PQ1667	A Beach – Adams Beach sand – SE end (S10)	29-04-2009	6 +/- 1	5 +/- 2
26	08PQ1662	A Beach – Adams Beach sand – Midway, adjacent to caravan park (S5)	29-04-2009	55 +/- 3	107 +/- 9
32	09PQ1417	A Beach – Sand from creek bed at Adam's Beach	13-04-2010	60 ± 4	140 ± 10
33	09PQ1418	A Beach – Adam's Beach sand	13-04-2010	134 ± 7	270 ± 20
29	08PQ1665	A Beach – Adams Beach sand – NW end, adjacent to barracks area (S8)	29-04-2009	260 +/- 10	540 +/- 40
39	09PQ1424	A Beach – Adam's Beach sand at low tide	13-04-2010	470 ± 20	1,340 ± 90
25	08PQ1661	BR Park – Ballow Rd Park sand – at top near CRL offices (S4)	29-04-2009	31 +/- 2	43 +/- 4
34	09PQ1419	BR Park – Ballow Rd park sand (Survey C2 maximum dose rate location)	13-04-2010	169 ± 9	530 ± 40
36	09PQ1421	BR Park – Ant nest spoil at Ballow Rd park	13-04-2010	230 ± 10	660 ± 50
35	09PQ1420	BR Park – Sand from creek bed near Ballow Rd park	13-04-2010	680 ± 30	1,800 ± 100
37	09PQ1422	BR Park – Ballow Rd park sand (Survey K10)	13-04-2010	580 ± 30	2,100 ± 100
28	08PQ1664	JS Beach – Sand from beach between Junner & Cunningham Sts – NE end (S7)	29-04-2009	46 +/- 4	45 +/- 6
27	08PQ1663	JS Beach – Sand from beach between Junner & Cunningham Sts – SE end (S6)	29-04-2009	210 +/- 10	290 +/- 20
30	08PQ1666	JS Beach – Sand from beach near ferry terminal at end of Junner St (S9)	29-04-2009	220 +/- 10	540 +/- 40
14	08PQ784	JS Park – Sand from sandpit in playground in park at end of Junner St	15-12-2008	4 ± 2	< 6
38	09PQ1423	JS Park – Sand from park near pier at Junner St	13-04-2010	180 ± 10	380 ± 30
11	08PQ781	JS Park – Composite sand sample 1 from park behind Junner St ferry office	15-12-2008	430 +/- 20	460 +/- 30
12	08PQ782	JS Park – Composite sand sample 2 from park behind Junner St ferry office	15-12-2008	320 +/- 10	720 +/- 40
13	08PQ783	JS Park – Sand deposited on roadside, Junner St	15-12-2008	370 +/- 20	730 +/- 40

1 Results are as provided in QHFSS Report Nos. 08PQ781-784, 08PQ1661-1667, 09PQ1417-1424

Table E2 *Radioassay of soil/sand samples collected from CRL controlled stockpiles and sites*[1]

No.	QHFSS Lab. No.	Description	Sample Date	U-238 (Bq/kg)	Th232 (Bq/kg)
2[2]	08PQ731	Source sand - NSI natural sand before processing (CRL - Silica sand 2)	19-08-2008	9 +/- 1	8 +/- 3
1[2]	08PQ730	Source sand - NSI natural sand before processing (CRL - Silica sand 1)	19-08-2008	13 +/- 1	16 +/- 3
19	08PQ1180	Process 1 - Ilmenite from stockpile at Enterprise mine.	03-03-2009	200 +/- 10	480 +/- 40
20	08PQ1181	Process 1 - Rutile Zircon from stockpile at Enterprise Mine	03-03-2009	1,420 +/- 70	2,000 +/- 100
22	08PQ1183	Process 2 - Ilmenite stored at Dunwich North Bin - Barge loading facility	03-03-2009	170 +/- 9	480 +/- 30
24	08PQ1185	Process 2 - Mineral sand stored at Dunwich Concentrates Bin - Barge loading facility	03-03-2009	1,590 +/- 70	1,340 +/- 90
23	08PQ1184	Process 2 - Rutile Zircon stored at Dunwich South Bin - Barge loading facility	03-03-2009	1,530 +/- 70	1,700 +/- 100
5[2]	08PQ734	Process 3 - Ilmenite unloaded at Pinkenba (CRL Ilmenite barge)	19-08-2008	170 +/- 8	510 +/- 30
6[2]	08PQ735	Process 3 - Mineral sand unloaded at Pinkenba (CRL Cons barge)	19-08-2008	1,760 +/- 60	2,300 +/- 100
3[2]	08PQ732	Product - Ilmenite offered for sale	19-08-2008	20 +/- 1	41 +/- 4
7[2]	08PQ736	Product - Rutile offered for sale	19-08-2008	480 +/- 20	80 +/- 10
8[2]	08PQ737	Product - Zircon offered for sale	19-08-2008	3,000 +/- 100	540 +/- 40
9[2]	08PQ738	Tails 1 - Zircon tails returned to NSI by truck (CRL - Zircon tails)	19-08-2008	640 +/- 20	390 +/- 30
4[2]	08PQ733	Tails 1 - Ilmenite reject tails returned to NSI by truck (CRL - Ilmenite reject)	19-08-2008	540 +/- 20	1,300 +/- 70
10[2]	08PQ739	Tails 1 - Zircon mags returned to NSI by truck (CRL - Zircon mags)	19-08-2008	10,700 +/- 400	54,000 +/- 3,000
16	08PQ1177	Tails 2 - Dry Mill tails at NSI used as cover (Dry Mill Tails - 2)	03-03-2009	< 10	< 20
15	08PQ1176	Tails 2 - Dry Mill tails at NSI prior to grading (Dry Mill Tails - 1)	03-03-2009	2,700 +/- 100	10,500 +/- 700
17	08PQ1178	Rehab - Topsoil at surface of Ibis Rehabilitation 2002	03-03-2009	< 10	< 5
18	08PQ1179	Rehab - Sand at 50cm below surface of Ibis Rehabilitation 2002	03-03-2009	< 10	< 7

1 Results are as provided in QHFSS Report Nos. 08PQ730-739, 08PQ1176-1185

2 Samples collected by CRL

Table E3 *Radioassay of soil/sand samples collected in and around Dunwich Water Treatment Plant*[1]

No.	QHFSS Lab. No.	Description	Sample Date	U-238 (Bq/kg)	Th232 (Bq/kg)
42	10PQ807	WTP - Sand outside SE fence of Dunwich WTP	02-11-2010	99 ± 5	110 ± 8
41	10PQ806	WTP - Sand within grounds of Dunwich WTP	02-11-2010	125 ± 7	160 ± 10
21	08PQ1182	WTP - Sand from Mining Lease ML118 near Dunwich (‘Hot sand stockpile’)	03-03-2009	180 +/- 10	310 +/- 20
40	10PQ805	WTP - Within grounds of Dunwich WTP	02-11-2010	270 ± 10	370 ± 30

1 Results are as provided in QHFSS Report Nos. 08PQ1176-1185, 10PQ805-807

Appendix

F Leachate tests

Table F1 *Results of TCLP tests on mineral sand samples*[1]

No. [2]	QHFSS Lab. No.	Description	Gross alpha (Bq/l)		Gross beta (Bq/l)	
			pH 2.9	pH 5.0	pH 2.9	pH 5.0
1	08PQ730	Source sand - NSI natural sand before processing (CRL - Silica sand 1)	<0.04	<0.5	<0.1	<0.2
4	08PQ733	Tails - Ilmenite reject tails returned to NSI by truck (CRL - Ilmenite reject)	0.13 +/- 0.01	<0.5	0.38 +/- 0.04	<0.2
5	08PQ734	Process 1 - Ilmenite unloaded at Pinkenba (CRL Ilmenite barge)	<0.04	<0.5	<0.1	<0.2
6	08PQ735	Process 1 - Mineral sand unloaded at Pinkenba (CRL Cons barge)	0.054 +/- 0.006	<0.5	<0.1	<0.2
9	08PQ738	Tails - Zircon tails returned to NSI by truck (CRL - Zircon tails)	0.114 +/- 0.004	<0.6	0.25 +/- 0.02	0.22 +/- 0.02
10	08PQ739	Tails - Zircon mags returned to NSI by truck (CRL - Zircon mags)[3]	1.06 +/- 0.08	1.12 +/- 0.02	1.8 +/- 0.2	0.87 +/- 0.07
15	08PQ1176	Tails - Dry Mill tails material returned to NSI prior to grading (Dry Mill Tails - 1)	0.22 +/- 0.01	<0.6	0.54 +/- 0.05	0.44 +/- 0.04

1 Results are as provided in QHFSS Report No. 09PQ389

2 These are samples as described in Table E2 - a selection of samples of sand partially processed on NSI or sand that is returned to NSI as tailings

3 Gamma spectrometry results of the leachate from this sample are shown in Table H2

Table F2 *Gamma spectrometry analysis of leachate from zircon mags sample*[1]

QHFSS Lab No.	Concentration of radionuclide in leachate (Bq/l)								
	^{238}U *series progeny*					232*Th series progeny*			
	Th234	Ra226	Pb214	Bi214	Pb210	Ra228	Pb212	Bi212	Tl208
08PQ739 Zircon mags [2]	< 0.2	0.9 ± 0.3	0.31 ± 0.09	0.6 ± 0.3	< 0.2	2.3 ± 0.4	1.0 ± 0.1	2.0 ± 0.9	0.2 ± 0.1
09PQ1602B Blank sample	< 0.1	< 0.2	0.16 ± 0.07	0.48 ± 0.09	< 0.2	1.1 ± 0.3	0.13 ± 0.05	0.06 ± 0.09	< 0.03

1 Results are as provided in QHFSS Report No. 09PQ1602: re-analysed

2 Leachate used was the sample at pH2.9

Appendix

G Water sampling

Table G1 *Gross alpha and beta concentrations of water samples*

No.	QHFSS Lab. No.	Description	Sample Date	Gross alpha (Bq/l)	Gross beta (Bq/l)[2]
1	09PQ1425	Water from Adam's Beach Creek	13/04/2010	< 0.1	0.22 +/- 0.03
2	09PQ1426	Water from the mouth of Adam's Beach Creek	13/04/2010	< 0.1	0.29 +/- 0.04
3	09PQ1427	Water from creek next to Ballow Road park	13/04/2010	< 0.1	< 0.2
4	10PQ809	Water from near the shoreline of Brown Lake	2/11/2010	< 0.09	0.21 +/- 0.03
5	10PQ810	Drinkable water from tap in the park adjacent to Junner Street	2/11/2010	< 0.08	< 0.2

1 Results are as provided in QHFSS Report No. 09PQ1425-1427 and 10PQ808-810

2 Corrected for ^{40}K

Appendix

H Air sampling

Table H1 *Radioassay results of filter papers used for air sampling*[1]

Sample ID	QHFSS Lab. No.	Description	Sample Date	Gross alpha (Bq)	Gross beta (Bq)
	Blank	Blank filter paper		0.018 +/- 0.003	0.085 +/- 0.008
29-04-09.1	08PQ1668	Personal sample – R Lyons	29/04/2009	0.024 +/- 0.004	0.15 +/- 0.01
29-04-09.3	08PQ1669	Personal sample – S Carter	29/04/2009	0.016 +/- 0.003	0.10 +/- 0.01
29-04-09.4	08PQ1670	Personal sample – E Edholm	29/04/2009	0.018 +/- 0.003	0.086 +/- 0.008
29-04-09.5	08PQ1671	Personal sample – L Williams	29/04/2009	0.016 +/- 0.002	0.081 +/- 0.008
29-04-09.6	08PQ1672	High volume sample – Logan Crescent	29/04/2009	0.019 +/- 0.002	0.11 +/- 0.01
29-04-09.7	08PQ1673	High volume sample – End of ferry pier, Junner Street	29/04/2009	0.016 +/- 0.002	0.095 +/- 0.009
29-04-09.8	08PQ1674	High volume sample – Middle of ferry pier, Junner Street	29/04/2009	0.017 +/- 0.003	0.078 +/- 0.008
29-04-09.9	08PQ1675	High volume sample – Beach between Junner & Cunningham Sts	29/04/2009	0.015 +/- 0.002	0.072 +/- 0.007

1 QHFSS Report No. 08PQ1668-1675