



Radiation Protection Monitoring Service

**NUCLEAR REACTOR SURVEILLANCE
PROGRAM
2010 REPORT TO THE
ASSURANCE MONITORING GROUP**

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**Ontario Ministry of Labour
Radiation Protection Monitoring Service**

**Nuclear Reactor Surveillance Program
2010 Report to the
Assurance Monitoring Group**

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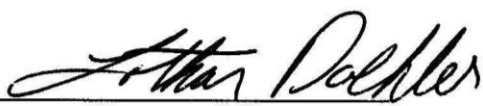
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TABLE OF CONTENTS

List of Figures, Maps & Tables	iv
Executive Summary	v
1.0 Introduction	1
1.1 RPMS Structure/History	1
1.2 RPMS Programs	1
2.0 Reactor Surveillance Program	2
2.1 Purpose.....	2
2.2 Objective	2
2.3 Annual Report and Data Integration	2
3.0 Surveillance Programs	2
3.1 Surveillance Criteria	2
3.2 Program Design	3
3.3 Site Selection & Program Summary	3
3.4 Derived Survey Concentrations.....	4
3.5 Minimum Detectable Concentration.....	5
3.6 Data Handling for Unreported Values	5
3.7 Air Monitoring Programs.....	14
3.7.1 General Information	14
3.7.2 Air Particulate Monitoring Program.....	14
3.7.3 Tritium-in-Air Monitoring Program.....	16
3.7.4 Air Monitoring Results	16
3.8 Water Monitoring Programs.....	18
3.8.1 General information.....	18
3.8.2 Drinking Water Monitoring Program.....	18
3.8.3 Drinking Water Monitoring Results	19
3.9 On-Going Special Studies	21
3.9.1 Precipitation Monitoring	21
3.9.2 Recreational Surface Water Monitoring	21
3.9.3 Milk Monitoring – Farm Sampling	21
3.9.4 Foodbasket Monitoring Program – Milk & Vegetation	22
3.9.5 On-Going Special Studies Results.....	23
4.0 G8/G20 Partnership with Health Canada	26
5.0 Summary of 2010 ORSP	27
5.1 Overall Program Performance	27
5.2 Summary of Dose Calculation	28

6.0	Outlook for 2011	29
7.0	Acronyms & Abbreviations.....	30
8.0	References.....	32
Appendix 1	Laboratory Quality Assurance and Control.....	33
Appendix 2	Dose Calculation	35
Appendix 3	8-Year Summary of Results	38
Appendix 4	Water Treatment Plant Sampling Results	42

LIST OF FIGURES, MAPS & TABLES

Table 1	Derived Survey Concentrations for Water and Air.....	4
Table 2a	RPMS Surveillance Areas – Bruce, Essex and Ottawa.....	6
Table 2b	RPMS Surveillance Areas – Darlington, Pickering and Toronto	7
Map 1	Arthur Control Site.....	8
Map 2	Bruce Surveillance Area	9
Map 3	Darlington Surveillance Area	10
Map 4	Essex Surveillance Area.....	11
Map 5	Ottawa Valley Surveillance Area.....	12
Map 6	Toronto / Pickering Surveillance Area	13
Figure 1	Typical Air Monitoring Station	15
Figure 2	Close-up of Air Particulate Sampler.....	15
Figure 3	Tritium-in-Air Sampler	15
Table 3a	Air Particulate Monitoring Results.....	17
Table 3b	Tritium-in-Air Monitoring Results	17
Table 4a	Drinking Water Monitoring – Tritium Analysis.....	19
Table 4b	Drinking Water Monitoring – Gamma Analysis.....	20
Table 4c	Drinking Water Monitoring – Gross-Alpha/Gross-Beta Analysis.....	20
Table 5a	Precipitation Monitoring Results	23
Table 5b	Surface Water Monitoring Results	23
Table 5c	Farm Milk Monitoring – Tritium Analysis	24
Table 5d	Farm Milk Monitoring – Beta and Gamma Analysis	24
Table 5e	Foodbasket – Milk Monitoring Results.....	25
Table 5f	Foodbasket – Vegetation Monitoring Results.....	25
Table A-1	Ingestion Pathways and Consumption Rates*	35
Table A-2	Sampling Area & Total Incremental Dose Received	37
Table A-3	8-year Results –Tritium in Drinking Water	38
Table A-4	8-year Results –Tritium in Air.....	38
Table A-5	8-year Results –Tritium in Precipitation	39
Figure A-1	8-year Results –Tritium in Drinking Water Compared to Ontario Standard.....	40
Figure A-2	8-year Results –Tritium in Drinking Water	40
Figure A-3	8-year Results –Tritium in Air.....	41
Figure A-4	8-year Results –Tritium in Precipitation	41

EXECUTIVE SUMMARY

The Radiation Protection Monitoring Service (RPMS) continues to serve as the “watch-dog of Ontario” as it monitors the environment around the province’s nuclear installations. Through the operation of the Ontario Reactor Surveillance Program (ORSP) the RPMS provides assurance to the public living and working in the vicinity of nuclear installations that their health, safety, welfare and property is not affected by emissions from nuclear facilities. Also, the RPMS provides radioanalytical support to the Provincial Nuclear Emergency Response Plan (PNERP) should an event occur which would require the activation of this plan.

The RPMS is the only Province of Ontario laboratory capable of measuring radioactivity in environmental samples. It is the laboratory arm of the Radiation Protection Service (RPS) and operates within the Operations Division of the Ministry of Labour. When first established in the 1960’s the laboratory was affiliated with the Ministry of Health. It was transferred to the Ministry of Labour in 1978 where it was originally known as the “Radiation Protection Laboratory.”

The RPMS is accredited by the Canadian Association for Laboratory Accreditation (CALA) as meeting the requirements of ISO 17025 for its Quality System and several of the methodologies. The RPMS is licensed by the Ministry of Environment under the Safe Drinking Water Act 2002 and the Drinking Water Testing Services Regulation (O. Reg. 248/03) to perform radioanalytical testing on drinking water samples.

Under the PNERP the RPMS is responsible for monitoring radioactivity in the environment around all nuclear installations in Ontario and must notify Emergency Management Ontario (EMO) of any abnormal (above ambient background) results. This has led to the establishment of the ORSP which includes a network of environmental monitoring stations located around the Bruce, Darlington and Pickering nuclear power generating installations and in the vicinity of the Chalk River Nuclear Laboratories located north of Ottawa. An additional station is in the Amherstburg area to monitor the Fermi-2 nuclear power reactor south of Detroit, Michigan. Environmental samples collected at these locations are analyzed by the RPMS for specific radionuclides. Air, drinking water and foodstuff (milk) are routinely sampled at all locations. The results provided in this report are a summary of the measurements and analyses carried out by the RPMS in 2010. The RPMS collected 1422 samples in support of the ORSP, on which 2846 analyses were completed. The measured concentrations of radionuclides monitored in 2010 were well below those concentrations that would result in a dose commitment of 0.1 mSv to the public from either inhalation or ingestion. When compared with the results from previous years, no significant changes in the measurements have been observed.

The measurements show tritium (^3H) is present in larger concentrations than the other radionuclides being measured. Based on a dose calculation the incremental dose to the public from tritium in 2010 is estimated to be less than 0.6% of 0.1 mSv, which is approximately 3,000 times less than the dose received from natural background.

In conclusion, the purpose of the Ontario Reactor Surveillance Program has been achieved and the public in the vicinity of nuclear installations can be assured that their health, safety, welfare and property are not adversely affected by emissions from the nuclear facilities.

Nuclear Reactor Surveillance Program

2010 Report to the

Assurance Monitoring Group

1.0 INTRODUCTION

1.1 RPMS STRUCTURE/HISTORY

The Radiation Protection Service (RPS) is a part of Specialized Professional Services that operates within the Occupational Health and Safety Branch (OHSB) of the Ministry of Labour.

The RPS is comprised of two services; the Radiation Protection Field Service (RPFS) whose main role is to enforce radiation safety in Ontario workplaces and the Radiation Protection Monitoring Service (RPMS).

The RPMS operates the only Province of Ontario laboratory capable of measuring radioactivity in environmental samples. The history of the RPMS goes back to the 1960's when the laboratory was originally affiliated with the Ministry of Health. In 1978 it was transferred to the Ministry of Labour and up until 1999 was known as the "Radiation Protection Laboratory".

The laboratory operates a Quality System to assure the production of high-quality data through measurements that are accurate, reliable and reproducible. The RPMS is accredited by the Canadian Association for Laboratory Accreditation (CALA) as meeting the requirements of ISO 17025 for the Quality System. Receiving this accreditation provides formal recognition of the Quality System by an independent science based organization. Appendix 1 provides further details of the Quality System.

The RPMS is licensed by the Ministry of Environment under the Safe Drinking Water Act 2002 (SDWA) and the Drinking Water Testing Services Regulation (O.Reg 248/03) to perform radioanalytical testing on drinking water samples. Should an exceedance be detected in the analysis of drinking water samples, the RPMS is required to immediately notify the Ministry of the Environment.

1.2 RPMS PROGRAMS

The main role of the RPMS is the operation of the Ontario Reactor Surveillance Program (ORSP) to continually monitor radioactivity in the environment around nuclear installations. In the event of a radiological emergency the role of the RPMS is to provide radioanalysis in support of the Provincial Nuclear Emergency Response Plan (PNERP).

A network of monitoring sites is located around Ontario's three nuclear power generating installations at Bruce, Darlington and Pickering, and around the Chalk River reactor site located north of Ottawa. A site is also in the Amherstburg area to monitor the Fermi-2 nuclear power reactor south of Detroit, Michigan.

The RPMS also provides radioactivity measurements of raw and treated water in support of the Ministry of Environment's Drinking Water Surveillance Program

(DWSP). Measurements are made in support of other MOE programs in such matrices as surface water, air filters and swipe-tests.

2.0 REACTOR SURVEILLANCE PROGRAM

2.1 PURPOSE

The purpose of the Ontario Reactor Surveillance Program (ORSP) is to assure the public living and working in the vicinity of nuclear installations in Ontario that their health, safety, welfare and property is not affected by emissions from nuclear facilities.

2.2 OBJECTIVE

A key responsibility of the Ministry of Labour, as set out in the PNERP is to monitor radioactivity in the environment around all nuclear installations in Ontario and to notify Emergency Management Ontario (EMO) of any abnormal (above ambient background) results.[R-1]

This responsibility has led to the creation of the Ontario Reactor Surveillance Program whose objective is to establish, operate and maintain a radiological surveillance network to assess air and water concentrations in the Ontario portions of secondary zones around designated nuclear installations.

2.3 ANNUAL REPORT AND DATA INTEGRATION

The RPMS generates an Annual Report to the Assurance Monitoring Group (AMG), an interministry group organized by Emergency Management Ontario that is responsible for ingestion control measures. This Report includes a brief description of the monitoring programs, summary statistics and concluding discussion.

3.0 SURVEILLANCE PROGRAMS

3.1 SURVEILLANCE CRITERIA

The average member of the population receives an annual radiation dose of 2 to 3.4 millisievert (mSv) from background radiation. This natural background radiation is made up of cosmic radiation, plus radiation from potassium, uranium and thorium that are present in the soil, and radon gas in houses.[R-2]

Health Canada's guidelines for the radiological characteristics of drinking water are based on a committed effective dose of 0.1 mSv from one year's consumption of drinking water.[R-3] This figure is 10% of the International Commission on Radiation Protection (ICRP) suggested dose limit to the public.

Ontario's current Drinking Water Quality Standards for radionuclide concentrations are also based on the 0.1 mSv dose limit.[R-5] Subsequently, the objective of the ORSP is to measure radionuclide concentrations which if received for a year would give a dose commitment of 0.1 mSv to a member of the public from either inhalation or ingestion.

3.2 PROGRAM DESIGN

The radioactive elements associated with routine and accidental release from a CANDU reactor are well known and may follow a variety of pathways before entering the human system. To monitor these radionuclides in the environment requires specific programs be in place. Air, drinking water and food are each of particular concern. The ORSP is comprised of three principal surveillance programs and four special studies programs.

Surveillance programs:

- air particulates
- tritium-in-air
- drinking water

Special Studies programs:

- precipitation
- recreational surface waters
- milk
- foodbasket – milk and vegetation

3.3 SITE SELECTION & PROGRAM SUMMARY

Five nuclear installations are currently in operation within or near Ontario's borders. Located north of Ottawa on the Ottawa River are the Chalk River Nuclear Laboratories. The Darlington and Pickering nuclear generating facilities are situated along the northern shore of Lake Ontario. The Pickering generating facility is on the eastern edge of the Greater-Toronto-Area while the Darlington generating facility is located east of Oshawa. The Bruce Power generating facility is situated on the north-east shore of Lake Huron. The Fermi-2 reactor, located 15 km south of Detroit, Michigan rounds out the list. This facility is near Windsor, another large urban centre.

Seven surveillance areas have been designated for use, and are listed below:

RPMS Surveillance Areas

1. Arthur – control station
2. Bruce – Bruce Power (formerly “Bruce Nuclear Power Development”)
3. Darlington – Darlington Nuclear Generating Station
4. Essex – Fermi-2 Nuclear Generating Station (located in Michigan)
5. Pickering – Pickering Nuclear Generating Stations
6. Ottawa – Chalk River Nuclear Laboratories
7. Toronto – water treatment plants

Sampling sites were located within each area using weighting factors for population density and distance from the facility. A complete listing of the monitoring sites and the programs carried out at these sites is provided in Tables 2a and 2b. Maps 1 – 6 show the location of the individual monitoring sites within their respective surveillance areas.

The town of Arthur was selected as a control site as it is located mid-way between the Bruce and Pickering/Darlington Surveillance areas. Air samples collected here receive minimal possible exposure from these installations. Drinking water samples taken at Arthur, as measured by an independent laboratory, are very low in tritium and are used as a background blank by the RPMS.

Water treatment plants in the eastern part of the Toronto Surveillance Area are used to monitor drinking water for emissions from the Pickering nuclear generating facility. There are no water treatment plants in the Pickering Surveillance Area.

3.4 DERIVED SURVEY CONCENTRATIONS

Health Canada's guidelines for the radiological characteristics of drinking water, are based on a committed effective dose of 0.1 mSv from one year's consumption of drinking water.[R-3]

For the purpose of monitoring radionuclides the 0.1 mSv committed effective dose is expressed as a Derived Survey Concentration (DSC). The DSC has been determined for each of the radionuclides that are of interest in water using the Ontario Drinking-Water Quality Standards. In the absence of a formal exposure guideline for radionuclides in air the DSC has been determined using the associated DSC for water divided by 10. Together, the DSC for water and air are listed in Table 1.

Table 1 Derived Survey Concentrations for Water and Air

Radionuclide	DSC – Water* (Bq/L)	DSC – Air (Bq/m ³)
Be-7	4000	400
Co-60	2	0.2
Sr-90	5	0.5
Cs-134	7	0.7
Cs-137	10	1.0
H-3	7000	700
I-131	6	0.6

*[R-5]

3.5 MINIMUM DETECTABLE CONCENTRATION

The amount of radioactivity in a sample is calculated from the difference between the count rate with the sample in the counter and the “background” count rate when there is no sample in the counter. The background count rate is produced by the natural radiation present in the earth, fall-out from atomic bombs and cosmic radiation from space. Because of the random nature of radioactive decay, there is a statistical uncertainty associated with every measurement.

The minimum detectable activity (MDA) for a particular nuclide, analysis method, and counter is the smallest amount of radioactivity that will be distinguished from background in 95 out of 100 measurements. The minimum detectable concentration (MDC) is the minimum detectable activity expressed in terms of concentration per unit volume. Often, these terms are used interchangeably since the difference between MDA and MDC is in the conversion of the units.

In this report, the MDC is used as the majority of measurements are quoted in concentration units. For most nuclides, the MDC has been set at 10% of the DSC. For tritium in drinking water, the laboratory MDC is 5 Bq/L which is less than 0.1% of the DSC.

3.6 DATA HANDLING FOR UNREPORTED VALUES

Often, in the analysis of environmental sampling the results are reported as less than the Minimum Detectable Concentration (MDC). This will produce a right-centred distribution of the results which are cut off below the MDC. It is important that these unreported or missing values be managed efficiently or an inaccurate inference may be drawn from the data.

A number of different strategies, referred to as “data imputation,” can be applied where the missing values are replaced by a single value. This value may be chosen as the MDC, the MDC/2 or the $MDC/\sqrt{2}$. The effect of using this approach may however bias the data if a large number of missing values make up the data.

An alternative to data imputation is the use of regression estimation as a technique to replace the missing values. This is the approach that has been used with the results of measurements from the water treatment plants that are made by the RPMS. In this method the variable with the missing values is treated as the dependent variable. The data is ranked from smallest to largest with those values that are below the MDC treated as the smallest values. The non-censored data is plotted on a scatter plot and should result in a straight line. Using this result a line of best fit can be drawn or calculated which will yield the regression equation. Through the use of this equation missing values can be predicted and the median and standard deviation of the data can be estimated.[R-4]

Table 2a RPMS Surveillance Areas – Bruce, Essex and Ottawa

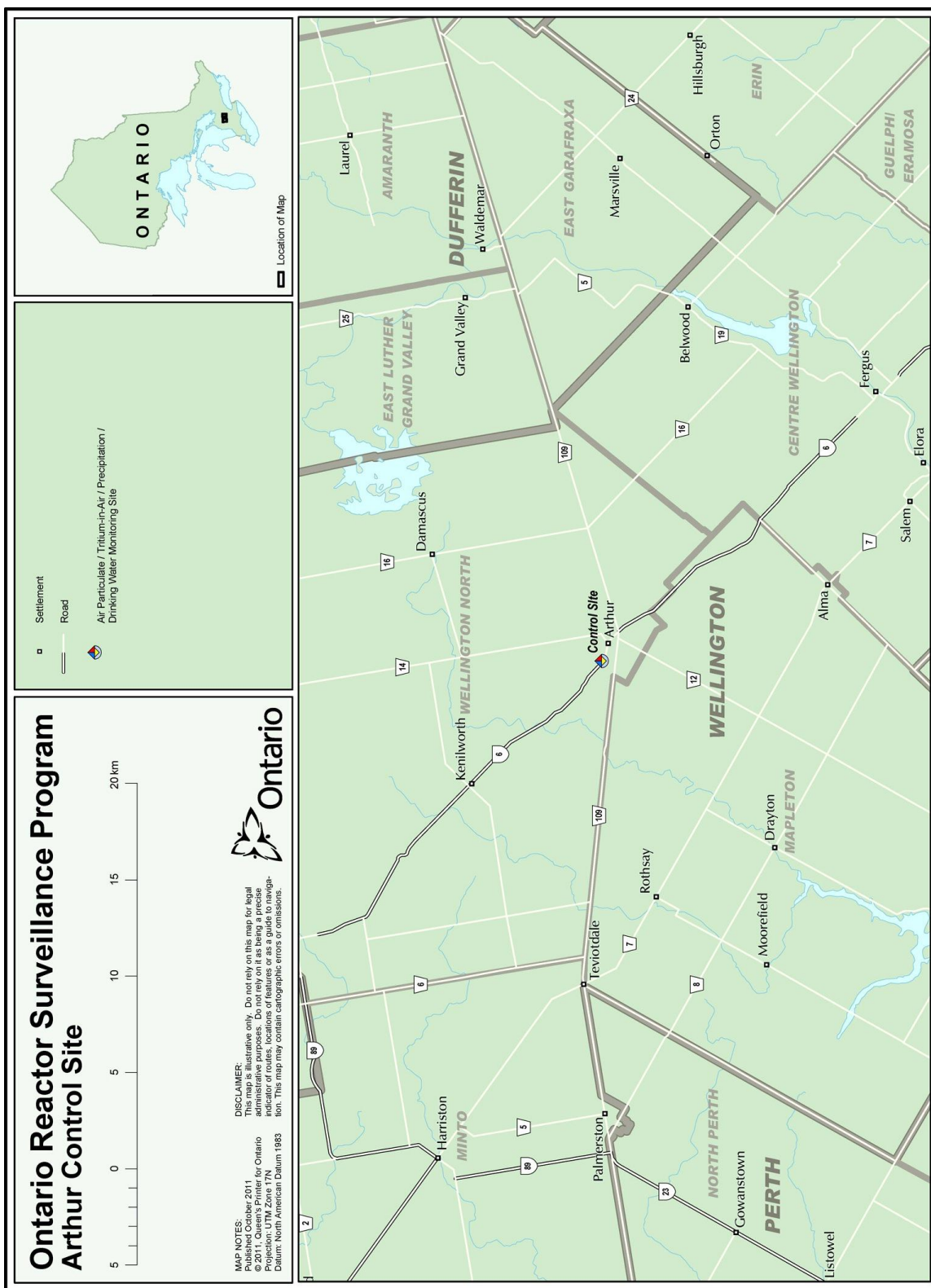
Surveillance Area	Monitoring Site	Map Number	Air Particulate	Tritium-in-Air	Drinking Water	Precipitation	Recreational Surface Waters	Foods – Milk
Control Site	Arthur	1	✓	✓	✓	✓		
Bruce	Kincardine WTP	2			✓	✓		
	Southampton WPCP	2			✓			
	Bruce Power GS Visitor's Centre	2	✓	✓		✓		
	Tiverton P.S.	2	✓	✓				
	Scott Point P.S.	2	✓	✓				
	6 dairy farms	2						✓
	Inverhuron Park Beach, Scott Point & Port Elgin Beaches	2					✓	
Essex	Canadian Coast Guard Station	4	✓					
	Amherstburg WTP	4			✓			
	Harrow-Colchester WTP	4			✓			
	Wheatley WTP	4			✓			
Ottawa	Deep River WTP	5	✓		✓			
	Pembroke WTP	5			✓			
	Petawawa WTP	5	✓		✓			

Table 2b RPMS Surveillance Areas – Darlington, Pickering and Toronto

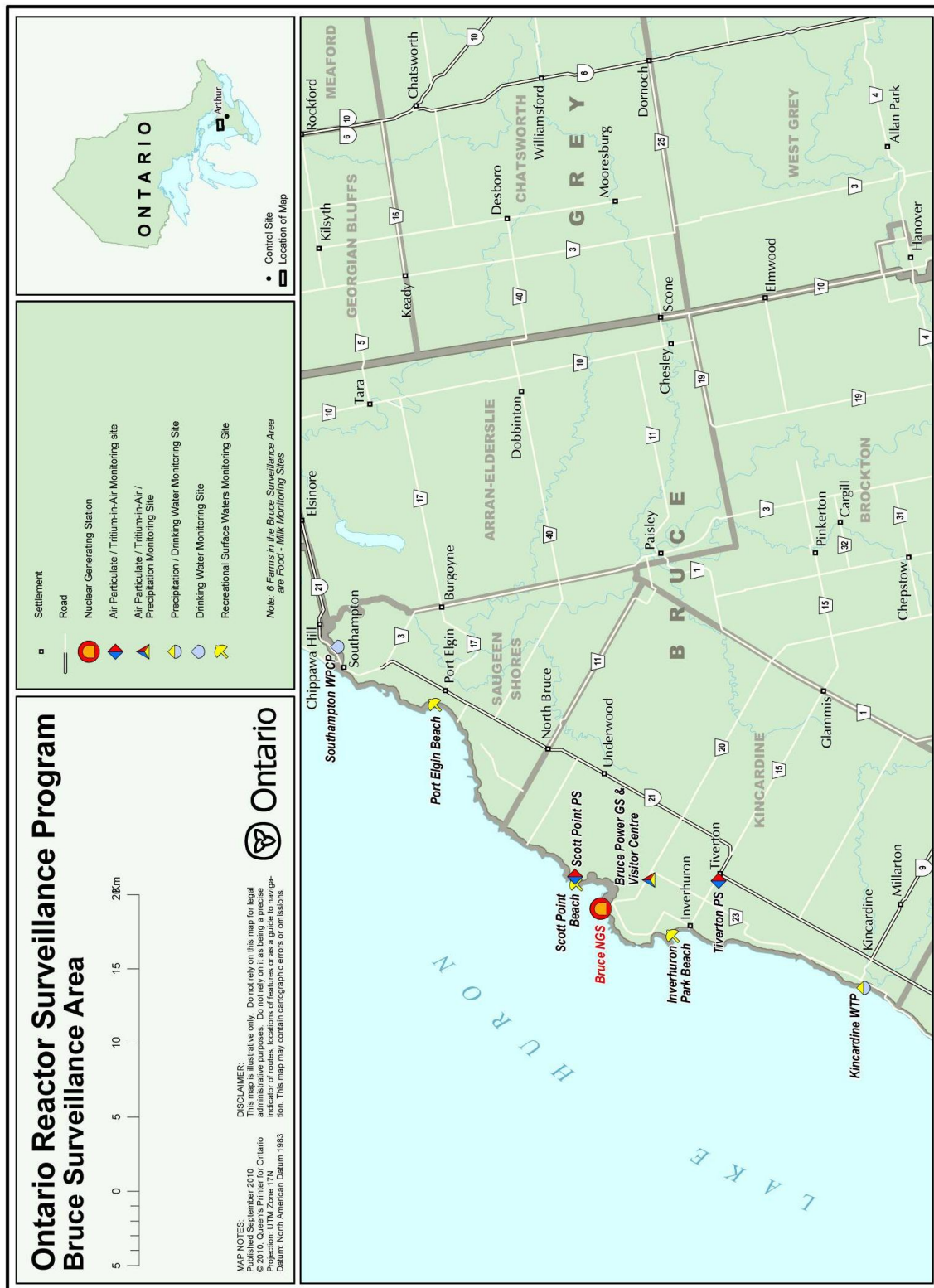
Surveillance Area	Monitoring Site	Map Number	Air Particulate	Tritium-in-Air	Drinking Water	Precipitation	Recreational Surface Waters	Foods – Milk
Darlington	Ajax WTP	3	✓		✓	✓		
	RCMP Bowmanville	3	✓	✓		✓		
	Bowmanville WTP	3			✓			
	Ken Hooper Fire Hall	3	✓					
	Trull's Road Emergency Services*	3	✓					
	Newcastle WTP	3			✓			
	Oshawa WTP	3	✓		✓			
	Whitby WTP	3			✓			
	Nash Rd. P.S.	3	✓					
	Harmony Creek WPCP	3	✓					
	Courtice WPCP*	3	✓			✓		
	Port Darlington WPCP*	3	✓			✓		
	Darlington Provincial Park Beach & Port Darlington West Beach	3					✓	
Pickering	Pickering Fire Hall #5	6	✓	✓		✓		
	Ajax-Pickering Hospital	6	✓					
	Liverpool P.S.	6	✓	✓		✓		
	Duffin Creek WPCP	6	✓	✓		✓		
	9 dairy farms							✓
	Liverpool Beach Playground & Rotary Park Beach	6					✓	
Toronto	Horgan WTP	6			✓			
	R.C. Harris WTP	6			✓			
	Island WTP	6			✓			
	R. L. Clarke WTP	6			✓			
Toronto-west	Radiation Protection Service	6	✓		✓			
	Lakeview WTP	6			✓			
	Lorne Park WTP	6			✓			

* - New sampling locations installed in December 2010, however no sampling done

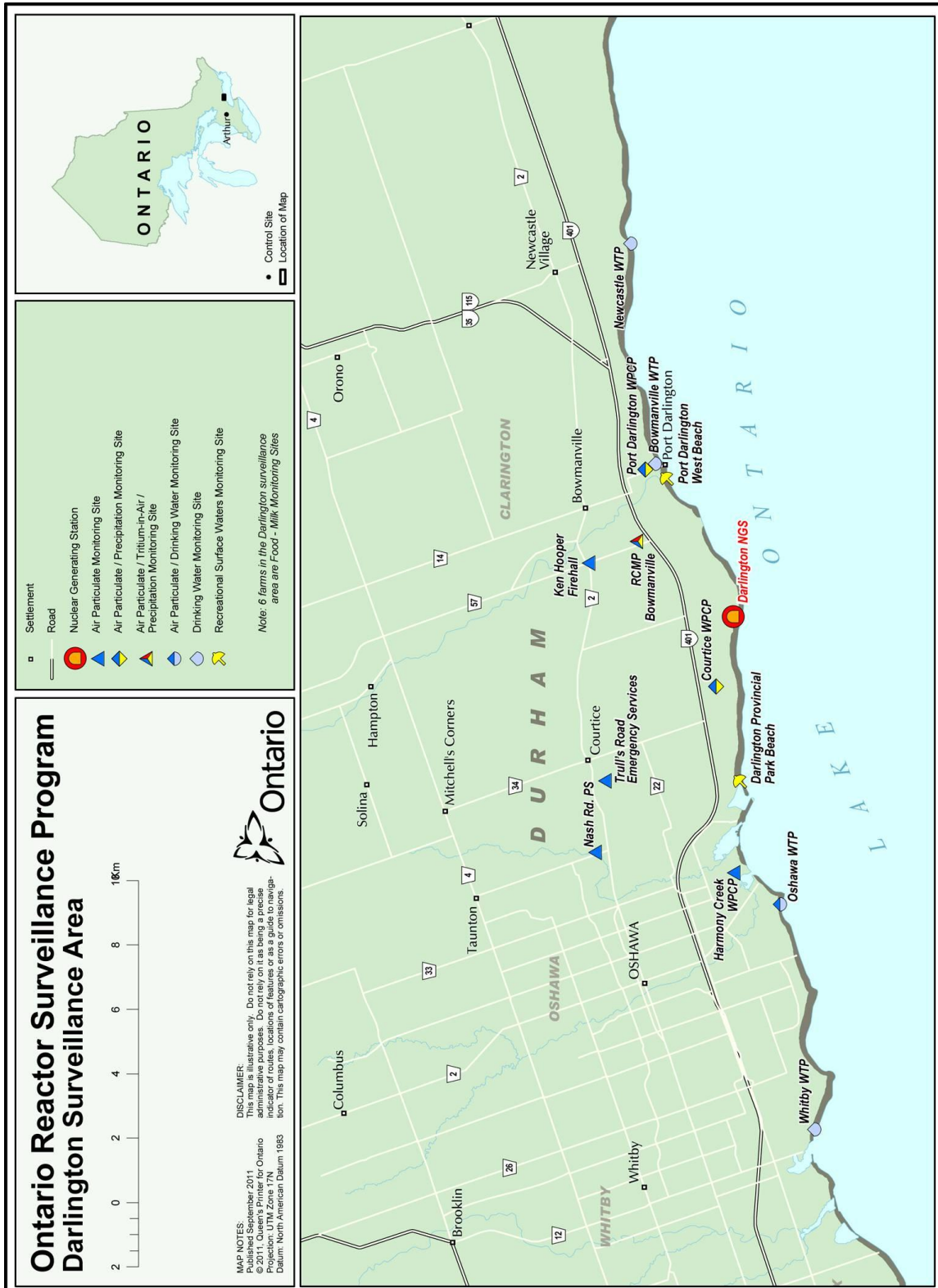
Map 1 Arthur Control Site



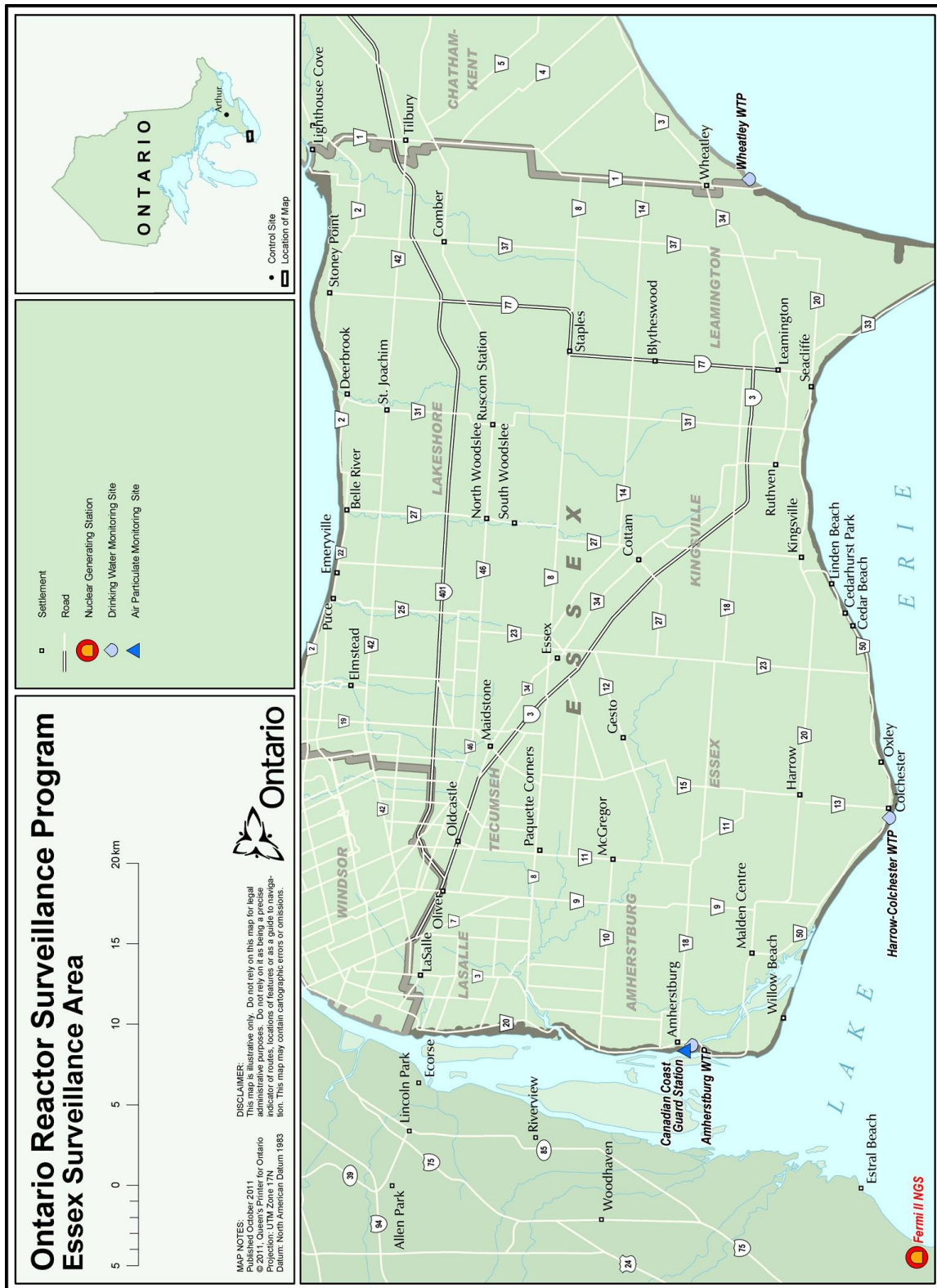
Map 2 Bruce Surveillance Area



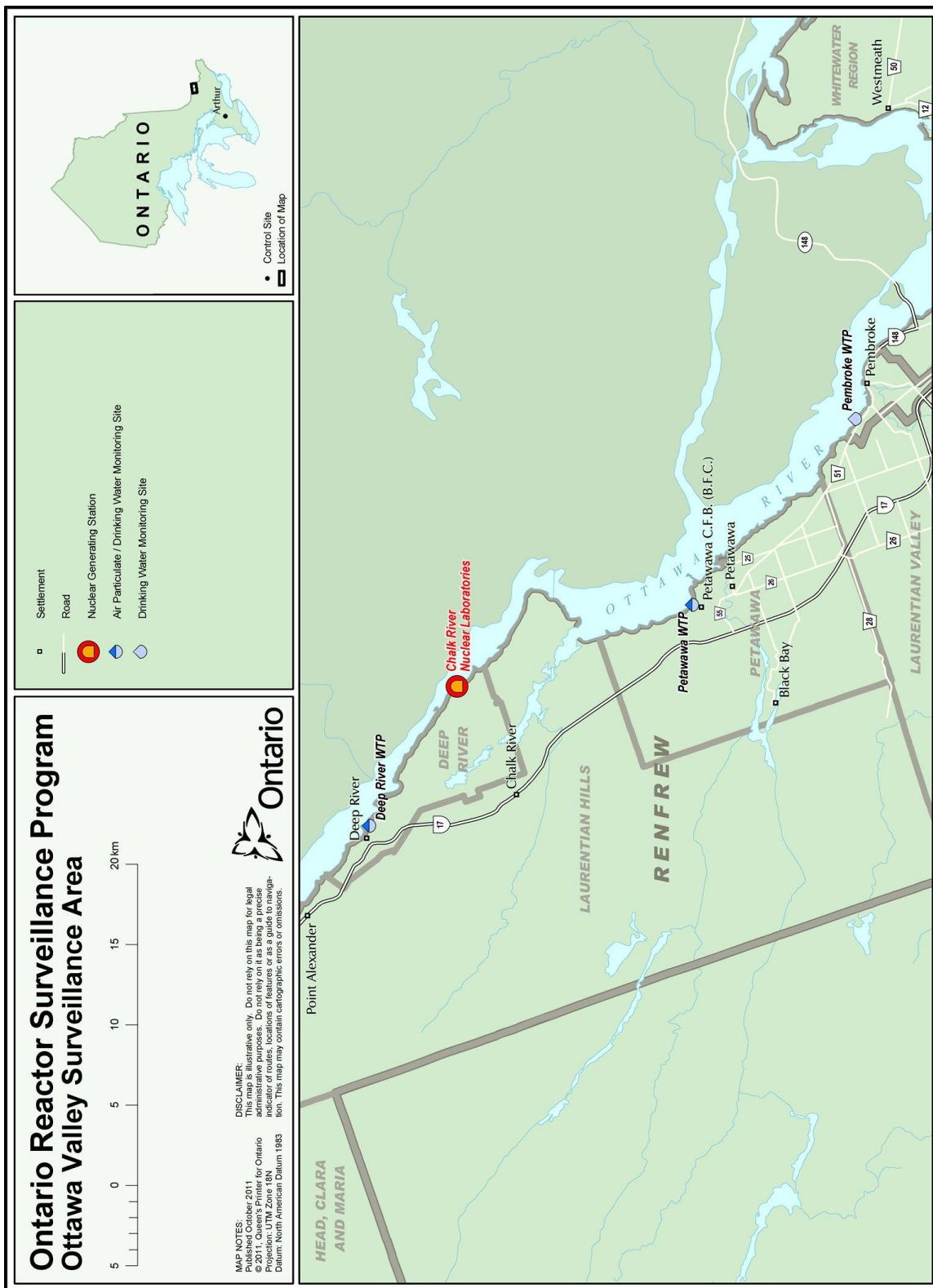
Map 3 Darlington Surveillance Area



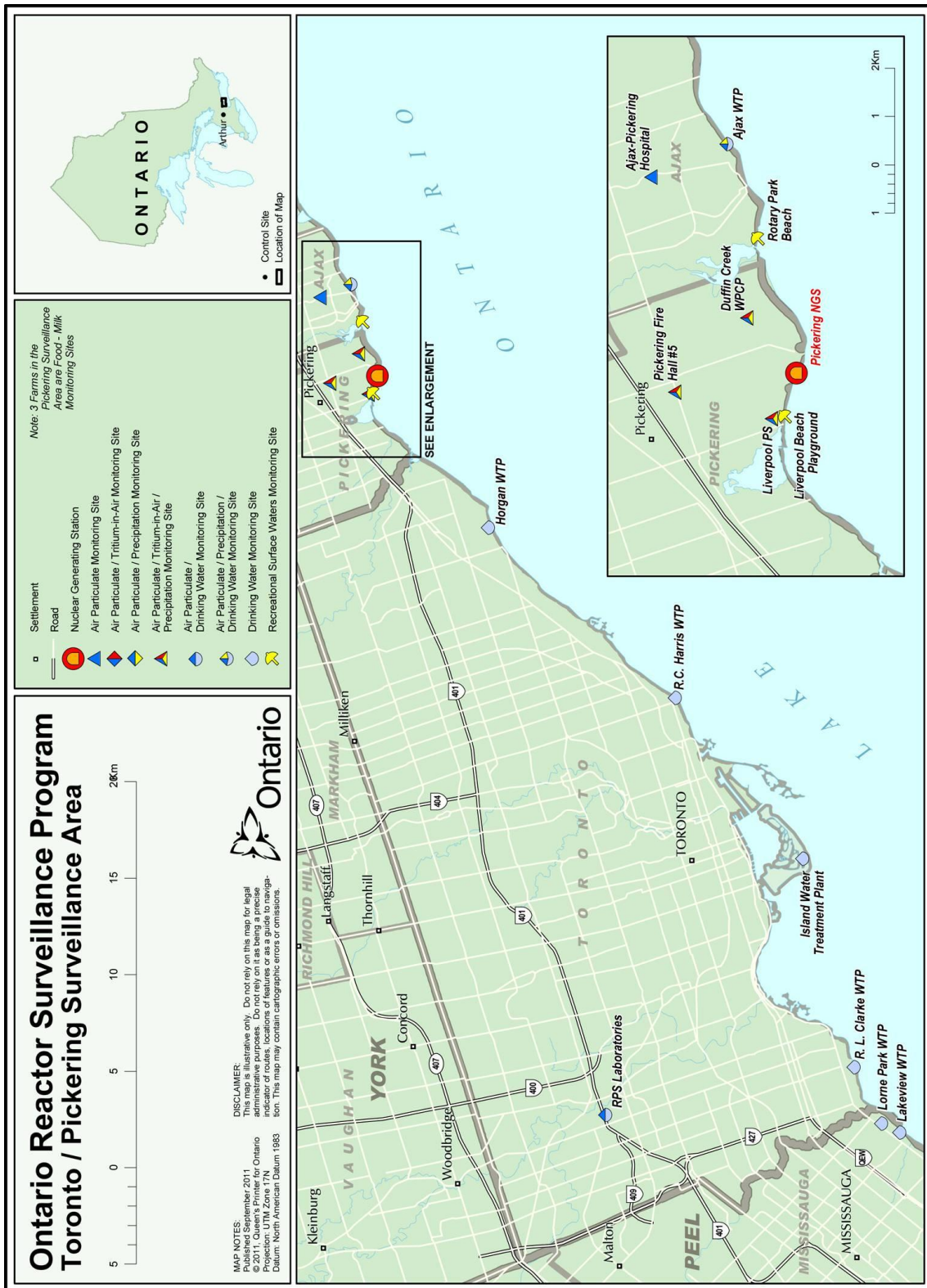
Map 4 Essex Surveillance Area



Map 5 Ottawa Valley Surveillance Area



Map 6 Toronto / Pickering Surveillance Area



3.7 AIR MONITORING PROGRAMS

3.7.1 General Information

The selection of monitoring sites for air sampling was based on a number of criteria. Two factors that were given primary consideration were local population distribution and distance from the nuclear installation. Final site selection was based on the availability of electric power and security concerns.

The RPMS operates two air monitoring programs which run concurrently throughout the year. The apparatus used for Air Particulate and Tritium-in-Air monitoring is in continuous operation. Regularly scheduled maintenance by RPMS staff is necessary to ensure reliable operation of the air monitoring equipment.

Samples are collected at regular intervals from the Bruce, Darlington and Pickering Surveillance areas by RPMS staff. By agreement, samples are collected and sent to the laboratory by federal staff in the Essex Surveillance area and municipal staff in the Ottawa Surveillance area.

3.7.2 Air Particulate Monitoring Program

This program is designed to monitor for airborne emissions of fission and activation products that are distributed as particulates throughout the air. The sampling of particulates in air is a necessary component of an emergency preparedness program.

Four new Air Particulate Monitoring stations were added to the network in December 2010. Due to the lateness in the year these units were set-up no results will be provided in this report. Three stations are located in the Darlington Surveillance Area and the fourth is at the Radiation Protection Service. This brings the total number of Air Particulate Monitoring stations in operation to 21. Tables 2a and 2b lists the individual sites of these stations.

Figure 1 shows a typical Air Monitoring station. The apparatus used for Air Particulate monitoring is housed in a locked louvered metal enclosure. Figure 2 presents a close-up of the electric pump, flow controller, timer, calibrated gas meter and open-faced filter cartridge that make up this apparatus. The controller has been adjusted to operate at a flow rate of approximately 7 m³/h (cubic metres per hour). Air is drawn into the enclosure by a 4.0 L/s ventilation fan. The pump exhaust is discharged outside the enclosure.

Polyester reinforced glass microfibre filters are used to capture sub-micron particulates in the air that may have radioactive isotopes attached to them. The filters possess high collection efficiency and are changed every four weeks.

Figure 1 **Typical Air Monitoring Station**

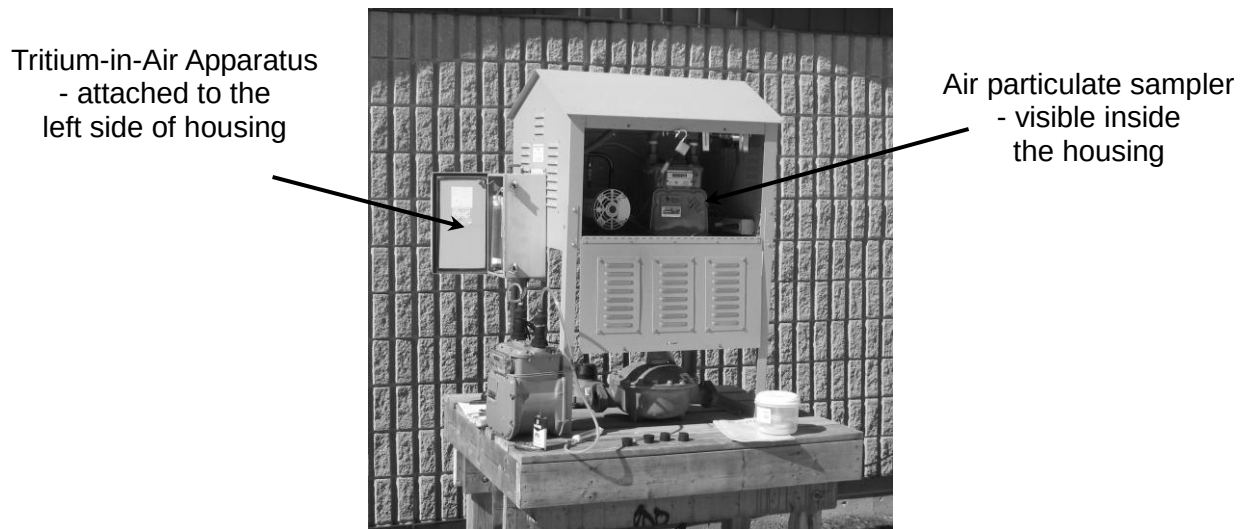


Figure 2 **Close-up of Air Particulate Sampler**

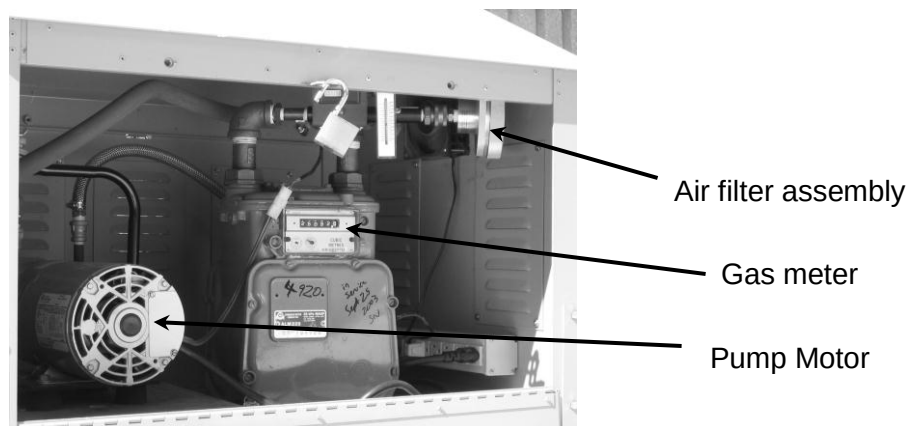
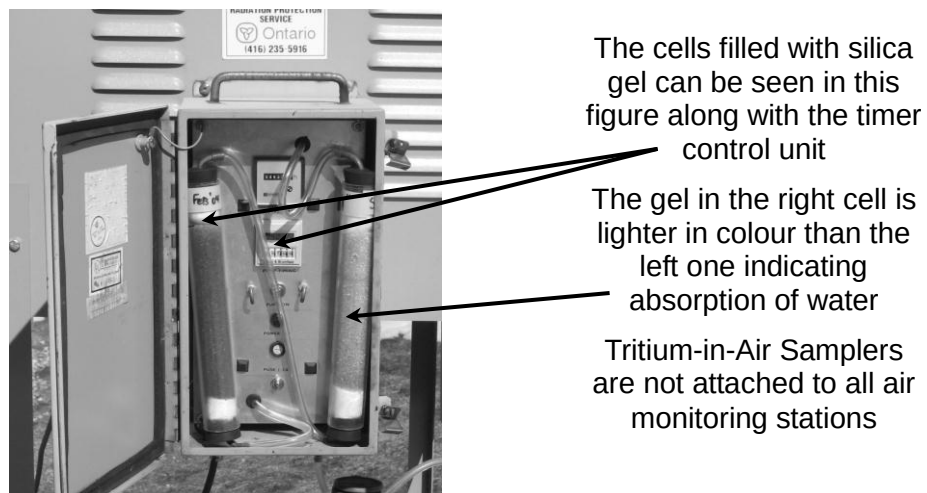


Figure 3 **Tritium-in-Air Sampler**



When the filters first arrive at the laboratory, time is allowed for the short-lived daughters of any naturally occurring radionuclides captured on the filters to decay. The filters are analyzed using high purity germanium detectors and concentration estimates are determined for the gamma emitting nuclides Beryllium-7, Cesium-137 and Iodine-131.

The radionuclide Beryllium-7 is formed naturally in the atmosphere from cosmic ray interactions and is not associated with nuclear power generation. Determining its presence is used as a laboratory indicator. The result of this analysis is reported in $\mu\text{Bq}/\text{m}^3$ (microBecquerels per cubic meter).

The filters are screened for gross beta activity using a proportional counter, as not all radionuclides are gamma emitters. Two-inch diameter discs are cut from each filter in order for them to fit on the sample holder of the proportional counter. Gross beta activity is reported in mBq/m^3 (milliBecquerels per cubic meter).

3.7.3 Tritium-in-Air Monitoring Program

This program is designed to monitor for tritium, an activation product in CANDU nuclear reactors. Tritium is vented to the air from reactors operating in Ontario. Monitoring the levels in the regions near the reactors provides an indication of the exposure received by the public.

There are 8 Tritium-in-Air sampling units currently in operation. Tables 2a and 2b lists the locations of these units.

Each sampling unit consists of a 50 W electrical pump (similar to an aquarium pump) with a timed flow rate controller, a calibrated gas meter and two cylindrical cells filled with silica gel. This assembly is contained in a separate housing that is attached to the outside of the air monitoring station (see Fig. 1). A close-up image of the silica gel cells is provided in Figure 3.

Low flow rates of 0.1 L/min are achieved by cycling the pump on and off for short periods. This low flow rate is necessary in order to prevent the silica gel from becoming saturated with moisture before the end of the measurement period. The gas meter is installed to measure the volume of air that has passed through the cells.

The silica gel cells are replaced at four-week intervals. The cells are weighed before being placed in the field and after they are returned to the laboratory to determine the mass of water vapour absorbed. The silica gel is placed in a tube furnace and the water vapour is desorbed by heating. A stream of dry air removes the water vapour to where it is condensed and collected. Low-level beta counting in a liquid scintillation detector is used to determine the tritium activity in the condensate. The result of this analysis is reported as Bq/m^3 (Becquerels per cubic metre).

3.7.4 Air Monitoring Results

In 2010, a total of 290 environmental samples were collected. These consisted of 196 air filters for the Air Particulate monitoring program and 94 Tritium-in-Air samples. In total, 878 analytical results were obtained for the

air monitoring programs. Tables 3a and 3b provide a summary of the results from the two air monitoring programs for each surveillance area.

In 2010, the results of the Air Particulate monitoring program were found to be consistent with those of previous years. The concentrations of the γ -emitting nuclides were consistently below the minimum detectable concentration (MDC), with the exception of naturally occurring Be-7.

The median value of the gross- β measurements in each surveillance area was well below 1 mBq/m³.

Table 3a Air Particulate Monitoring Results

Surveillance Area	Number of Samples	Be-7 ($\mu\text{Bq/m}^3$)	Cs-137 ($\mu\text{Bq/m}^3$)	I-131 ($\mu\text{Bq/m}^3$)	Gross- β (mBq/m ³)
Arthur	13	3500	< 80*	< 80*	0.78
Bruce	37	3400	< 80*	< 80*	0.77
Darlington	78	3300	< 80*	< 80*	0.75
Essex County	5	3000	< 80*	< 80*	0.75
Ottawa Valley	12	3200	< 80*	< 80*	0.60
Pickering	51	3100	< 80*	< 80*	0.74

* MDC for each nuclide

The median concentrations in the Tritium-in-Air monitoring program, shown in Table 3b, ranged from 0.05 to 1.1 Bq/m³. These concentrations are comparable to those observed in previous years. The larger value that is presented here is just less than 0.4% of the DSC for tritium-in-air of 700 Bq/m³.

Table 3b Tritium-in-Air Monitoring Results

Surveillance Area	Number of Samples	Median Measurement (Bq/m ³)	Measurements > DSC*
Arthur	12	0.05	0
Bruce	36	1.1	0
Darlington	12	0.24	0
Pickering	34	0.86	0

* DSC – Derived Survey Concentration

3.8 WATER MONITORING PROGRAMS

3.8.1 General information

The water treatment plants (WTPs) in closest proximity to the nuclear installations being monitored were selected in each surveillance area.

Due to the fact that there are no water treatment plants in the Pickering Surveillance Area the water treatment plants in the eastern part of the Toronto Surveillance Area are used to monitor drinking water for emissions from the Pickering nuclear generating facility.

Lorne Park and Lakeview WTPs are located in Peel Region, just west of the Toronto boundary. Samples from these facilities, along with tap water samples taken at the Radiation Protection Service, form a subset of the Toronto Surveillance Area called “Toronto-west”. This will be referred to in the data tables presented for this section.

The WTPs for all surveillance areas are listed in Tables 2a and 2b, and their locations shown on the respective maps.

3.8.2 Drinking Water Monitoring Program

This program is designed to monitor for fission and activation products that may be found in waters that are used as sources of public drinking water. Drinking water is sampled from selected water treatment plants in communities that are within the ORSP surveillance areas.

WTP personnel collect a fixed amount of treated water every day and combine this to form either weekly or monthly composite samples. The weekly composites are from WTPs within the Bruce, Darlington, Pickering and Toronto Surveillance Areas. Every four weeks an RPMS staff member collects the weekly composite samples. Monthly water sample composites are collected from WTPs in the Essex and Ottawa Surveillance Areas. At the end of each month, these samples are sent to the RPMS. Refer to Tables 2a and 2b for the names of the individual WTPs.

Monthly composite tap water samples are collected at the Radiation Protection Service, Etobicoke. This is done to provide a distribution evaluation sample of drinking water in the Metropolitan Toronto area.

The composites are analysed for tritium using liquid scintillation counting. Once completed, the composites are combined with samples received in previous months, forming quarterly composites. The quarterly composites are screened for gross- α and gross- β activities, and analysed for γ -emitters by gamma spectroscopy. The concentrations of the isotopes Cobalt-60, Iodine-131, Cesium-134 and Cesium-137 are reported in Bq/L.

3.8.3 Drinking Water Monitoring Results

There were 557 weekly and 114 monthly drinking water samples collected and individually analysed for tritium content. From these, 84 quarterly composites were prepared. These were screened for gross- α and gross- β activities, and analysed for γ -emitters by gamma spectroscopy. A total of 1175 analyses were completed on the water samples in 2010. The results of these measurements are summarized in the following tables.

The results of the tritium analysis for drinking water samples that are collected weekly at each of the water treatment plants in the Bruce, Darlington and Pickering (Toronto) Surveillance Areas are presented in graphical form in Appendix 4. Measurements that were reported as less than the minimum detectable concentration (MDC) of 5 Bq/L are shown on the graphs as 2.5 Bq/L. The graphs have been included to demonstrate the range and variability in the sampling results that is found from site to site.

Table 4a Drinking Water Monitoring – Tritium Analysis

Surveillance Area	Number of Samples	Median Value ⁺ (Bq/L)	Measurements > DSC*
Bruce	101	6.6	0
Darlington	260	5.3	0
Essex	42	4.6	0
Ottawa	36	6.0	0
Toronto	196	4.5	0
Toronto-west	36	4.4	0

⁺ Determined using Linear Regression

* MDC Tritium-in-Drinking Water = 5 Bq/L

The median concentrations of tritium in drinking water range from 4.4 Bq/L in the Toronto-west Surveillance Area to 6.6 Bq/L in the Bruce Surveillance Area. As in 2009, the upper value presented here is just under 0.10% of the DSC of 7000 Bq/L for tritium in drinking water. When compared with measurements from previous years, as shown in Graph A-2 “8-year Results – Tritium in Drinking Water”, the 2010 results indicate a modest decrease in the level of tritium in drinking water in all regions.

The results of the γ analysis, as shown in Table 4b, were consistently less than the MDC for each nuclide throughout all regions. These results remain comparable to measurements made in previous years.

Table 4b Drinking Water Monitoring – Gamma Analysis

Surveillance Area	Number of Samples	Co-60 (Bq/L)	I-131 (Bq/L)	Cs-134 (Bq/L)	Cs-137 (Bq/L)
Bruce	9	< 0.2*	< 0.6*	< 0.7*	< 1.0*
Darlington	20	< 0.2*	< 0.6*	< 0.7*	< 1.0*
Essex	14	< 0.2*	< 0.6*	< 0.7*	< 1.0*
Ottawa	12	< 0.2*	< 0.6*	< 0.7*	< 1.0*
Toronto	17	< 0.2*	< 0.6*	< 0.7*	< 1.0*
Toronto-west	12	< 0.2*	< 0.6*	< 0.7*	< 1.0*

* MDC = 10% DSC for each nuclide

In 2010, the results of the gross- α analysis were found to be consistently less than the MDC. While some gross- β activity was detected, the median value remains close to the β -MDC of 0.04 Bq/L. This is far below the Ontario Drinking Water screening level of 0.5 Bq/L.[R-5] Very little change has been seen in these concentrations when compared with those of 2009 or other years.

Table 4c Drinking Water Monitoring – Gross-Alpha/Gross-Beta Analysis

Surveillance Area	Number of Samples	Gross- α (Bq/L)	Gross- β (Bq/L)
Bruce	9	< 0.04*	0.04
Darlington	20	< 0.04*	0.06
Essex	14	< 0.04*	0.05
Ottawa	12	< 0.04*	< 0.04*
Toronto	17	< 0.04*	0.06
Toronto-west	12	< 0.04*	0.06

* MDC

3.9 ON-GOING SPECIAL STUDIES

The monitoring of media such as precipitation, surface waters, milk and vegetation provide information regarding the movement of certain radionuclides in the environment. Unlike the surveillance programs, the results of measurements made in the “On-going Special Studies” cannot be used to provide dose estimates. Therefore the objective of the “On-going Special Studies” program is to monitor these media at regular intervals in order to provide information and enable year-to-year comparisons.

3.9.1 *Precipitation Monitoring*

Surface waters, grass and produce may receive radioactive deposits as the result of airborne particulates being washed out by precipitation. While precipitation is not a primary pathway for radiation exposure, the analyses of rain and snowfall samples does serve an important role as part of the emergency preparedness program. The level of tritium in precipitation is of particular interest as tritium is released directly to the atmosphere by the power generators.

Two new precipitation collectors were added in the Darlington Surveillance Area late in 2010. This increases the number of precipitation collectors in use to ten. The locations of all the precipitation collectors are listed in Tables 2a and 2b.

Precipitation collectors are fabricated out of a large funnel placed on top of a four litre plastic bottle. A metal cylinder encloses the funnel and bottle. The bottles are collected every four weeks and are returned to the laboratory for analysis to determine the tritium concentrations of their contents.

3.9.2 *Recreational Surface Water Monitoring*

Between May and October, when recreational activity is greatest, monthly grab samples are taken from the surface waters in public areas adjacent to each nuclear power generating facility. The samples are analysed for tritium using liquid scintillation counting and for γ -emitters using gamma spectroscopy. The results for the isotopes Cesium-134, Cesium-137, Cobalt-60 and Iodine-131 are reported in Table 5b

Two sampling locations are used on opposite sides of each nuclear installation. In the Pickering Surveillance Area, samples are taken at Rotary Park Beach and Liverpool Beach Playground. The two locations used for the Darlington Surveillance Area are Port Darlington West Beach and Darlington Provincial Park. In the Bruce Surveillance Area, samples are taken at Scott Point Beach and Inverhuron Park Beach. A third location was added in the Bruce Surveillance Area in 2009 at Port Elgin Beach. While further north than Scott Point Beach, this location was chosen as it is used more frequently by the public.

3.9.3 *Milk Monitoring – Farm Sampling*

Radioactive materials in precipitation or in air can be deposited on grass or in water that is consumed by dairy cattle. These radionuclides, once ingested, would become concentrated in milk and meat.

Milk sampling for the ORSP is provided through an arrangement with OMAFRA and the Dairy Farmers of Ontario (DFO). Six dairy farms in the

Bruce Surveillance Area and nine in the Darlington and Pickering Surveillance Areas were initially selected for radiological monitoring. In June of 2010 the RPMS received notification that OMAFRA was reorganizing its milk collection and that milk samples provided by the DFO would not be available. This disruption continued until late August when a revised sampling agreement was established between the RPMS, OMAFRA and DFO.

Under the new agreement the DFO now collects samples specifically for the ORSP from selected farms and sends them to the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) laboratory in Guelph. The milk samples are picked up monthly from OMAFRA by RPMS staff.

It should be noted the individual farms that provide milk samples in the On-going Special Studies are not shown on the maps.

Each month, all of the milk samples received from a surveillance area are combined to form a collective composite of the farms. From these composite samples a portion is analyzed for tritium using liquid scintillation counting. The β -emitters Strontium-89 and Strontium-90 are chemically separated and analyzed using proportional counting. Gamma spectroscopy is also conducted on these monthly composites and the isotopes Cesium-134, Cesium-137, Cobalt-60, Iodine-131 and Potassium-40 are reported. Potassium-40 is a naturally occurring radioisotope associated with the formation of the earth. Trace levels of Potassium-40 are found in most food. Determining its presence, like Beryllium-7 in Air Particulate monitoring, is used as a laboratory indicator.

3.9.4 Foodbasket Monitoring Program – Milk & Vegetation

The Foodbasket program has been established to sample the milk that is sold and food that is grown in the Bruce, Darlington and Pickering surveillance areas. This analysis is carried out in an effort to determine the activities of reactor products and other radionuclides in the foodchain of each region. This information enables year-to-year comparisons of these radionuclides.

The change made to the Foodbasket program in 2009 regarding the sampling of milk consumed by the citizens of Ontario was continued in 2010. A sample from each of the three principle manufacturers – Neilson's, Beatrice (Parmalat) and Natre/Sealtest (Agropur) – is purchased for analysis each month. These samples are analyzed for tritium and γ -emitters. The gamma spectroscopy results are reported for the isotopes Cesium-134, Cesium-137, Cobalt-60, Iodine-131 and Potassium-40.

Vegetation samples from the Bruce, Darlington and Pickering surveillance areas were purchased from road-side stands within a few kilometres of the nuclear stations (i.e. < 5 km) during July and August of 2010. A variety of fruits and vegetables were selected based on availability and water content. Among those sampled were raspberries, strawberries, peaches, pumpkin, cucumbers, melon and tomatoes.

Juice was extracted from the fruit and vegetable samples using a household juice extractor. The condensate from the juice extract was analysed for tritium using liquid scintillation counting. The tritium concentration is reported in Bq/kg of sample.

3.9.5 On-Going Special Studies Results

The results of the five sampling programs included in this section are summarized in the following tables.

The results of tritium analysis conducted on precipitation samples collected throughout 2010 extended from less than the MDC to several hundred Bq/L. The median concentrations for the respective surveillance areas, presented in Table 5a, range from < 5 to 92 Bq/L, are comparable to those observed in previous years.

Table 5a Precipitation Monitoring Results

Surveillance Area	Number of Samples	Tritium (Bq/L)
Arthur	13	< 5*
Bruce	25	18
Darlington	26	21
Pickering	39	92

*MDC Tritium-in-Drinking Water = 5 Bq/L

Table 5b lists the results of surface water measurements made at sites adjacent to the Bruce, Darlington and Pickering reactor installations. Median tritium concentrations range from 5.1 up to 23 Bq/L. The activities of γ -emitting nuclides in these samples were extremely low as all of the results were below the MDC. Very little change is noted in these measurements when compared with those obtained in 2009.

Table 5b Surface Water Monitoring Results

Surveillance Area	Number of Samples	Tritium (Bq/L)	Co-60 (Bq/L)	I-131 (Bq/L)	Cs-134 (Bq/L)	Cs-137 (Bq/L)
Bruce	12	23	< 0.2*	< 0.6*	< 0.7*	< 1.0*
Darlington	10	5.1	< 0.2*	< 0.6*	< 0.7*	< 1.0*
Pickering	10	9.5	< 0.2*	< 0.6*	< 0.7*	< 1.0*

* MDC = 10% DSC for each nuclide except tritium

In spite of the disruption in sampling 133 individual monthly samples were received from dairy farms in the Bruce, Darlington and Pickering surveillance areas. Several new farms have been added to the sampling and the number of samples used in the composites has been adjusted accordingly in each region. The median concentrations of tritium in milk are given in Table 5c. These range from < 5 Bq/L in the Darlington/Pickering Surveillance Area to 9.2 Bq/L in the Bruce Surveillance Area. These values are only slightly more than 0.1% of the DSC of 7000 Bq/L for tritium in drinking water. The results of the analysis for Strontium-90 and γ -emitting fission products, shown in Table 5d, were consistently found to be at, or below, the limits of detection. These results remain consistent with measurements made in previous years.

Table 5c Farm Milk Monitoring – Tritium Analysis

Surveillance Area	Bruce	Darlington/ Pickering
Number of Samples	52	81
Tritium (Bq/L)	9.2	< 5*

Table 5d Farm Milk Monitoring – Beta and Gamma Analysis

Surveillance Area	Bruce		Darlington/ Pickering	
Composites from	4 farms	6 farms	8 farms	9 farms
Number of Samples	1	8	1	7
Sr-90 (Bq/L)	< 0.5*	< 0.5*	< 0.5*	< 0.5*
Cs-134 (Bq/L)	< 0.7*	< 0.7*	< 0.7*	< 0.7*
Cs-137 (Bq/L)	< 1.0*	< 1.0*	< 1.0*	< 1.0*
Co-60 (Bq/L)	< 0.2*	< 0.2*	< 0.2*	< 0.2*
I-131 (Bq/L)	< 0.6*	< 0.6*	< 0.6*	< 0.6*
K-40 (g/L)	1.5	1.6	1.7	1.6

* MDC = 10% DSC for each nuclide

The results of the analysis of milk samples collected as part of the Foodbasket program for tritium and fission products were consistently at, or below the limits of detection. These results are very similar to what was obtained 2009 when this program was modified.

Table 5e Foodbasket – Milk Monitoring Results

Milk Processor	Beatrice Foods Canada	Natrel/Agropur Canada	Neilson Dairy Limited
Number of Samples	12	12	13
Tritium (Bq/L)	< 5*	< 5*	< 5*
Co-60 (Bq/L)	< 0.2*	< 0.2*	< 0.2*
Cs-134 (Bq/L)	< 0.7*	< 0.7*	< 0.7*
Cs137 (Bq/L)	< 1.0*	< 1.0*	< 1.0*
I-131 (Bq/L)	< 0.6*	< 0.6*	< 0.6*
K-40 (g/L)	1.70	1.67	1.70

* MDC = 10% DSC for each nuclide except tritium

The results of the vegetation sampling are provided in Table 5f. Where measurable results were obtained, the findings are very low.

Table 5f Foodbasket – Vegetation Monitoring Results

Surveillance Area	Number of Samples	Tritium (Bq/kg)
Bruce	6	13
Darlington/ Pickering	7	6.0

4.0 G8/G20 PARTNERSHIP WITH HEALTH CANADA

Canada hosted the G8 and G20 summits in the summer of 2010. These summits are unofficial annual forums for world leaders to discuss common topics of interest.

The Radiation Protection Service (RPS) in its capacity as a worker radiation protection enforcement /radiation emergency consultation unit and as a radioanalytical laboratory partnered with our federal counterparts at Health Canada to ensure that security systems and radiation monitoring was in place to protect summit attendees.

Prior to the summit the Radiation Protection Field Service (RPFS) was invited to participate in a week long field training exercise organized by Health Canada's Radiation Protection Bureau (RPB), Nuclear Emergency Preparedness and Response Division. The RPFS was also involved in was the registration, installation review, operating procedure review, radiation safety training curriculum review and inspection of thirty four x-ray baggage inspection security scanners both in Huntsville and locations in Toronto.

The Radiation Protection Monitoring Service (RPMS) had originally not anticipated it would be involved in the G20 Summit. Then a request came from Health Canada to assist with the analysis of swipe samples that were to be taken at various sites in order to provide assurance that no radioactive contamination was present.

Swipe samples were to be taken in the washrooms, on the elevators, along handrails and other common points in the hotels and summit venues used by the delegates. A total of 106 samples were received and analyzed by the laboratory over the weekend of June 26-27. This was broken down into two separate batches of 53 samples each. The swipes underwent Gross Alpha/Gross Beta analysis and gamma spectroscopy to determine the presence of radioactive contamination. Emergency procedures were applied for the analysis of the swipes in order to achieve a quick turnaround in the reporting of the results to Health Canada.

Analysis was begun on the first batch of samples early Saturday morning and continued into the evening until the results had been validated. When this was completed the final report was sent to Health Canada. This process was repeated again on Sunday when the second batch of swipes arrived for analysis. The results of the analysis were that no radioactive contamination was detected – all radionuclides were reported as less than the limits of detection (LD).

In recognition for their long hours worked (including through the weekend) RPS staff were awarded with a special "GEM – Going the Extra Mile" Award.

5.0 SUMMARY OF 2010 ORSP

5.1 OVERALL PROGRAM PERFORMANCE

- The objectives of the Ontario Reactor Surveillance Program to establish, operate and maintain a radiological surveillance network to assess radionuclide concentrations in the regions around designated nuclear installations were achieved.
- Surveillance samples were collected in a manner that is representative of what the public would be exposed to. Respirable air, potable water, milk and other foodstuff were sampled at locations in proximity to nuclear installations in Ontario and analysed for specific radionuclides.
- The volume of data gathered in 2010 remains consistent with that collected in previous years. A total of 1422 samples were collected and 2846 analyses reported for the ORSP. The results of these measurements were all well below the DSC's for the monitored radionuclides.
- The measured concentrations of radionuclides monitored in the ORSP were well below the DSC that would result in a dose commitment of 0.1 mSv to the public from either inhalation or ingestion.
- The results of the current year have been compared with the monitoring data of previous years to examine for notable trends or changes. An eight-year summary of results is presented in Appendix 3 which shows the median annual tritium concentration in drinking water, air and precipitation measured by the RPMS in the Bruce, Darlington and Pickering Surveillance Areas. Some moderate variations are noted in the results from year to year; however, no extreme changes are observed in the concentration of tritium in these matrices.
- Graph A-1 is included to demonstrate the extreme difference between the Ontario Drinking Water Standard of 7000 Bq/L and the levels of tritium that have been measured in the ORSP. On this graph these values are barely visible. When compared with measurements from previous years, as shown in Graph A-2, the 2010 results indicate the level of tritium in drinking water has slightly decreased in all regions.
- Graphs A-3 and A-4 show a notable decrease in the tritium concentrations in air and precipitation in the Pickering Surveillance Area to levels not seen since 2003. This is reduction followed a noticeable elevation in 2008. OPG has attributed much of this reduction to the Vacuum Building Outage which began in April 2010.
- Following a disruption of almost three months farm milk sampling has been re-established. A new sampling agreement has been put in place with OMAFRA and the Dairy Farmers of Ontario (DFO) to ensure a continued supply of milk samples for the ORSP. Changes have been made to the farms in both the Bruce Surveillance Area and Pickering Surveillance Area introducing new farms to bring the sampling program is back to its original level.
- Following the recommendations of the 2009 report three new air monitoring stations were established in the Darlington surveillance area. Two new precipitation collectors have also been added in this area. A fourth new station

has been established at the Radiation Protection Services which will provide the RPMS with direct access to sampling data should a nuclear or radiological event occur. These units were set-up in December and subsequently no results have been provided in this report.

In summary, the purpose of the Ontario Reactor Surveillance Program has been met and the public in the vicinity of nuclear installations can be assured their health, safety, welfare and property are not adversely affected by emissions from the nuclear installations.

5.2 SUMMARY OF DOSE CALCULATION

The DSC's are set at levels which if received for one year would give a dose commitment of 0.1 mSv. Based on the findings of environmental monitoring conducted by the RPMS in 2010 tritium (^3H) has been found to be present in greater concentrations than the other radionuclides being measured. The sample dose calculation, presented in Appendix 2, demonstrates the incremental dose to the public from tritium is less than 1% of 0.1 mSv. The annual dose received from natural background in Southern Ontario is around 1.6 mSv.[R-9] In comparison to this the incremental dose from ingestion and inhalation is about 3,000 times smaller.

6.0 OUTLOOK FOR 2011

There are a number of improvements planned for the ORSP in 2011. The following is an outline of some of the potential projects that are planned.

- Obtaining results from the new monitoring stations established in December 2010 and integrating these with those currently in operation.
- Acquiring and replacing equipment for the network is an on-going process as pumps and meters wear out and need to be replaced. Similarly, new instrumentation for use in the laboratory must be obtained and introduced into operation.
- Preparing for the biannual CALA accreditation review of the RPMS which will be conducted in 2011.
- A review of the methods used by the RPMS is to be conducted in 2011. Looking at possible improvements or even new methods to the analysis that is currently in place.
- Investigate ways of linking the sampling network to the laboratory via either cell phone or landline. This would be of great value, as it would provide information on how the apparatus is functioning. An automated or real-time sampling system would be also be beneficial and should be explored as resources permit.

7.0 ACRONYMS & ABBREVIATIONS

α	alpha
β	beta
γ	gamma
^3H	Tritium
m^3/h	cubic metres per hour
L/s	litres per second
Bq	Becquerel
Bq/kg	Becquerel per kilogram
Bq/L	Becquerel per litre
Bq/ m^3	Becquerel per cubic metre
mBq/ m^3	milliBecquerel per cubic metre
$\mu\text{Bq}/\text{m}^3$	microBecquerel per cubic metre
Sv	Sievert
mSv	milliSievert
$\mu\text{Sv}/\text{y}$	microSievert per year
$\mu\text{Sv}/\text{Bq}$	microSievert per Becquerel
AMG	Assurance Monitoring Group (Ontario Government)
CALA	Canadian Association for Laboratory Accreditation
CBRN	Chemical, Biological, Radiological and Nuclear
CRTI	Canadian CBRN Research and Technology Initiative
CSA	Canadian Standards Association
DSC	Derived Survey Concentrations
DFO	Dairy Farmers of Ontario
DOE	Department of Energy (U.S.)
DWSP	Drinking Water Surveillance Program (Ontario Ministry of the Environment)
EML	Environmental Measurements Laboratory (U.S.)
HEA	Hypothetically Exposed Adult
HTO	Tritium Oxide or Tritiated Water Vapour
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiation Protection
ISO	International Organization for Standardization

LLNL	Lawrence Livermore Nuclear Laboratories
MAPEP	Mixed Analyte Performance Evaluation Program
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
MOE	Ministry of the Environment
NIST	National Institute for Science and Technology (U.S.)
NRC	National Research Council (Ontario)
OHSB	Occupational Health & Safety Branch (Ontario Ministry of Labour)
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
ONEP	Ontario Nuclear Emergency Plan
ORSP	Ontario Reactor Surveillance Program
PNERP	Provincial Nuclear Emergency Response Plan
QC	Quality Control
QM	Quality Management
RPB	Radiation Protection Bureau (Health Canada)
RPS	Radiation Protection Service (Ontario Ministry of Labour)
RPFS	Radiation Protection Field Service (Ontario Ministry of Labour)
RPMS	Radiation Protection Monitoring Service (Ontario Ministry of Labour)
SDWA	Safe Drinking Water Act (Ontario)
WPCP	Water Pollution Control Plant
WTPs	Water Treatment Plants

8.0 REFERENCES

- R-1 Responsibilities – Ministry of Labour; Appendix 8 to Annex I, Provincial Nuclear Emergency Response Plan, January 2010
- R-2 Ionizing Radiation: Sources and Biological effects, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000 Report to the General Assembly with Annexes.
- R-3 Summary of Guidelines for Canadian Drinking Water Quality, Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Environmental and Occupational Health, Health Canada, Dec. 2010
- R-4 Environmental Distributions and the Practical Utilisation of Detection Limited Environment Measurement Data, NRPB-W13, June 2002
- R-5 Ontario Drinking-Water Quality Standards, Safe Drinking Water Act, 2002 Ontario Regulation 169/03
- R-6 Guidelines for Calculation Derived Release limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities, Canadian Standards Association, CAN/CSA-N288.1-M87, August 1987
- R-7 Environmental Report 2000, “Calculating Annual Inhalation and Skin Absorption Doses of HTO”, Lawrence Livermore Nuclear Laboratories, UCRL-50027-00, Sept. 2001
- R-8 Compilation of Ingestion and Inhalation Dose Coefficients in Age Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5, ICRP Publication 72, Vol. 26 No. 1, Annals of the ICRP, 1996
- R-9 The Annual Effective Dose from Natural Sources of Ionizing Radiation in Canada. Radiation Protection Dosimetry (2004), Vol. 108, No. 3, pp. 215-226

APPENDIX 1 LABORATORY QUALITY ASSURANCE AND CONTROL

The principal objective in the operation of an analytical laboratory is the production of high-quality data. This is achieved through the use of analytical measurements that are accurate, reliable, and specific for their intended purpose. A thoroughly planned and documented Quality System is necessary to accomplish this intent.

The RPMS is accredited by the Canadian Association for Laboratory Accreditation (CALA) as meeting the requirements of *ISO/IEC 17025 – “General Requirements for the Competence of Testing and Calibration Laboratories”*. This accreditation provides formal recognition by an independent science based organization that this laboratory is competent in performing the assessment of radioactivity in various sample media.

The Quality System encompasses all activities relating to the ORSP with an aim of producing work that is accurate and of a very high-quality. The following terms are used in association with the Quality System – Quality Management (QM), Quality Control (QC) and Quality Assurance (QA). Quality Control (QC) consists of procedures used to verify that prescribed standards of performance in the sampling and analysis activities are met. Quality Assurance (QA) is a system of activities and processes put in place to ensure that the quality control activities are being properly implemented.

Specific QC processes have been put in place to estimate the accuracy and precision of analytical results, and to investigate any sources of error introduced by laboratory practices. Statistical QC employs statistical methods for assessing conformance and controlling the measurement process.

Method QC is integrated into each analytical run to monitor sample preparation, the purity of reagents and solvents, the stability, accuracy and precision of equipment and instrumentation, and the overall performance of the analytical system. Control samples are chosen to address sources of variation and bias particular to an individual method.

Standard reference materials obtained from national and international sources are used exclusively. These materials are certified as to their content, having been rigorously prepared and subjected to thorough analysis. Control samples are used as Method QC Standards, Background and Control Standards for instrument performance, and, Method Blank Standards and Spiked Standards for method performance.

A major component of laboratory QA is the requirement that all laboratory staff rigorously follow a set of documented activities. The use of written Methods and Standard Operating Procedures (SOP's) will ensure the data produced conform to pre-defined criteria and verify that QC procedures have been correctly carried out. Another component of QA is that analytical results be traceable both to the analyst who carried out the test and to the method employed. Written SOP's for sample reception, sample storage and distribution, maintenance of equipment logs, method calibration and standard preparation highlight some of the activities that are part of QA.

The RPMS is licensed by the Ontario Ministry of the Environment to provide radioanalytical testing services to Ontario Drinking Water Systems. This licence is granted under the Safe Drinking Water Act 2002 (SDWA) and the Drinking Water Testing Services Regulation (O.Reg 248/03) making the RPMS the only Provincial

government laboratory legally authorized to analyze Ontario drinking water for radionuclides. In 2010 the RPMS completed two successful inspections by the Ministry of Environment to maintain this drinking Water Testing License.

Participating in inter-laboratory comparison programs demonstrates the proficiency of the RPMS against external unbiased standards and shows that the accuracy of its measurements meets and exceeds required standards. The RPMS took part in two Proficiency studies in 2010. The first was the US Department of Energy's (DOE) Mixed Analyte Performance Evaluation Program (MAPEP) Study 22 and the second was the US DOE MAPEP Study 23. The results submitted by the RPMS for both of these studies were within the acceptable limits of the studies.

APPENDIX 2 DOSE CALCULATION

The incremental doses received by individuals and populations can be determined by calculations resulting from the measurements.

The calculation used here considers the dose received by a Hypothetically Exposed Adult (HEA) positioned at specific sampling sites. It should be noted that this calculation is a first order approximation only and is used to make simple comparisons with existing dose limits and natural background radiation.

The HEA is defined as an adult member of the public who receives the greatest induced dose from all sources. This person is assumed to remain at this location 24 hours per day, 365 days of the year. They would be continually breathing air, drinking water and consuming a specified fraction food that is affected by releases of radioactivity measured at the site. The HEA dose is not received by an actual individual and is used as a health-conservative estimate (i.e. an overestimate) of the highest possible dose to any member of the public.

Based on the results of active sampling, tritium (^3H) is found in larger concentrations than the other radionuclides associated with emissions from the nuclear stations in Ontario. Subsequently, tritium contributes to the largest portion of the dose received. Primarily, these emissions come in the form of tritium oxide or tritiated water vapour (HTO). HTO enters the body by ingestion, inhalation, and dermal absorption. Ingested HTO is distributed throughout the entire body and eliminated at the same rate as body water (apart from the small fraction metabolized). Inhaled HTO dissolves in the fluids of the lung and is absorbed.

Two principle pathways will be considered in determining the dose to the HEA. These are listed in Table A-1, together with the associated sampling programs and annual consumption rates.

Table A-1 Ingestion Pathways and Consumption Rates*

Pathway	Sampling Program	Annual Consumption
Ingestion of drinking water	Drinking Water – Tritium	700 L
Inhalation of air	Tritium-in-Air	8000 m ³

* [R-5]

The annual consumption rates vary depending on which model is used for the intake of food and drink. For the calculation presented here the values that have been used are based on the ICRP reference man and are also recommended for use by the Canadian Standards Association (CSA) for dose pathway calculations.[R-6]

For the purpose of estimating the HEA dose, the tritium concentrations are taken from sampling data collected in the Pickering, Darlington and Bruce areas. The values used for each pathway are as follows:

Ingestion of drinking water – the median annual concentration at water supply plants sampled in the region minus the background concentration.

Inhalation of air – the median annual concentration based on active sampling in the community.

Calculating the annual whole-body dose rate from ingestion of a particular food or drink is expressible as a product of three factors:

- the radionuclide concentration in the food or drink (e.g. Bq/kg or Bq/L)
- the dose coefficient for the radionuclide (e.g. $\mu\text{Sv/Bq}$)
- the rate at which the food or drink is consumed (e.g. kg/y)

The dose contribution from inhalation is calculated in a similar way as the product of the radionuclide concentration in the air, dose coefficient, and the volume of air that is inhaled (i.e. $\text{m}^3/\text{y} \times \text{Bq}/\text{m}^3 \times \mu\text{Sv/Bq}$).

In their Annual Environmental Report, Lawrence Livermore Nuclear Laboratories (LLNL) recommends using a factor of 1.5 for inhalation-plus-dermal-absorption. This is because the skin only absorbs 50% of the tritium the lung absorbs.[R-7]

The dose coefficient for tritium oxide for ingestion, inhalation and skin absorption has a value of $1.8 \times 10^{-5} \mu\text{Sv/Bq}$. This value is from ICRP 96.[R-8]

Using these values, the tritium dose from the ingestion of water for HEA in the Pickering Region is then-

$$\begin{aligned} D_{\text{water}} &= 700 (\text{L/y}) \times 1.8 \times 10^{-5} (\mu\text{Sv/Bq}) \times (4.51 - 0.12) (\text{Bq/L}) \\ &= 5.53 \times 10^{-2} \mu\text{Sv/y} \end{aligned}$$

The inhalation/skin absorption dose ($D_{\text{inh/sa}}$) is determined from-

$$\begin{aligned} D_{\text{inh/sa}} &= 1.5 \times 8000 (\text{m}^3/\text{y}) \times 1.8 \times 10^{-5} (\mu\text{Sv/Bq}) \times 0.86 (\text{Bq}/\text{m}^3) \\ &= 1.86 \times 10^{-1} \mu\text{Sv/y} \end{aligned}$$

The total incremental dose from tritium (D_{total}) is the sum of the contribution via each pathway-

$$\begin{aligned} D_{\text{total}} &= D_{\text{water}} + D_{\text{inh/sa}} \\ &= 5.53 \times 10^{-2} + 1.86 \times 10^{-1} \\ &= 2.41 \times 10^{-1} \mu\text{Sv/y} \end{aligned}$$

Following the same procedure, the total incremental dose for a HEA has been calculated for the Pickering and Darlington Surveillance areas. These values are compared with Health Canada's guideline for the radiological characteristics of drinking water of 0.1 mSv and the typical level of background radiation for southern Ontario and are summarized in Table A-2.

Table A-2 Sampling Area & Total Incremental Dose Received

Pathway	Bruce Surveillance Area	Pickering Surveillance Area	Darlington Surveillance Area
Ingestion of drinking water	0.082 $\mu\text{Sv/y}$	0.055 $\mu\text{Sv/y}$	0.065 $\mu\text{Sv/y}$
Inhalation of air	0.24 $\mu\text{Sv/y}$	0.19 $\mu\text{Sv/y}$	0.039 $\mu\text{Sv/y}$
Total-Dose	0.32 $\mu\text{Sv/y}$	0.24 $\mu\text{Sv/y}$	0.10 $\mu\text{Sv/y}$
Drinking Water Guideline – 0.1 mSv = 100 μSv			
% of Drinking Water Guideline	0.32%	0.24%	0.10%
Southern Ontario Background Level – 1600 μSv [R-9]			
% of Background	0.020%	0.015%	0.0065%

APPENDIX 3 8-YEAR SUMMARY OF RESULTS

Median values are reported in all tables

Table A-3 8-year Results –Tritium in Drinking Water

	Bruce Surveillance Area		Darlington Surveillance Area		Pickering Surveillance Area	
Year	# of Samples	Concentration (Bq/L)	# of Samples	Concentration (Bq/L)	# of Samples	Concentration (Bq/L)
2003	148	7.3	255	6.4	154	6.4
2004	152	8.5	258	6.2	157	6.2
2005	153	9.0	260	5.9	202	6.0
2006	154	12	260	6.6	203	4.8
2007	154	8.9	260	7.1	203	6.3
2008	148	10	260	7.7	192	6.2
2009	104	6.2	265	6.3	197	4.4
2010	101	6.6	260	5.3	196	4.5

Table A-4 8-year Results –Tritium in Air

	Bruce Surveillance Area		Darlington Surveillance Area		Pickering Surveillance Area	
Year	# of Samples	Concentration (Bq/m ³)	# of Samples	Concentration (Bq/m ³)	# of Samples	Concentration (Bq/m ³)
2003	39	1.5	13	0.29	39	1.5
2004	39	0.66	13	0.35	39	2.2
2005	38	0.64	13	0.35	37	2.3
2006	38	0.82	13	0.40	38	2.0
2007	39	0.98	13	0.45	39	2.3
2008	39	1.1	13	0.27	38	3.1
2009	36	1.0	13	0.38	37	2.4
2010	36	1.1	12	0.18	34	0.9

Table A-5 8-year Results –Tritium in Precipitation

Year	Bruce Surveillance Area		Darlington Surveillance Area		Pickering Surveillance Area	
	# of Samples	Concentration (Bq/L)	# of Samples	Concentration (Bq/L)	# of Samples	Concentration (Bq/L)
2003	25	12	26	15	39	72
2004	25	10	26	22	39	130
2005	23	15	26	19	39	110
2006	26	20	26	18	36	95
2007	26	24	26	24	39	77
2008	25	19	26	22	38	200
2009	26	18	26	21	39	92
2010	26	21	25	10	39	63

Figure A-1 8-year Results –Tritium in Drinking Water Compared to Ontario Standard

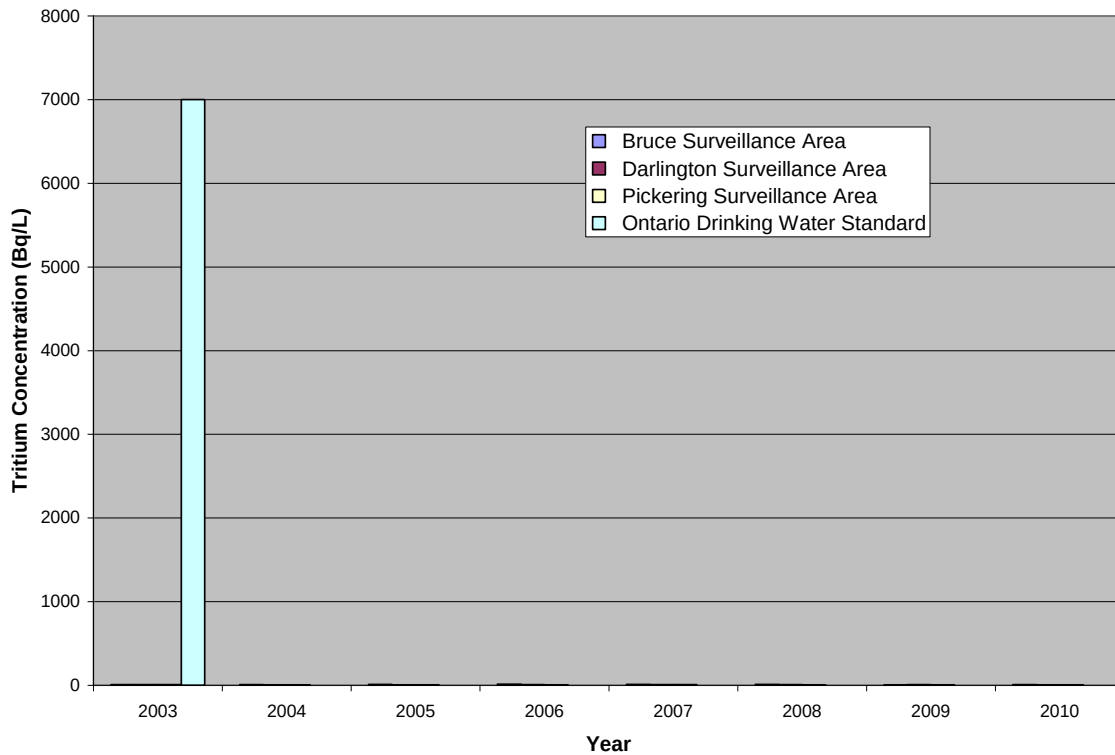


Figure A-2 8-year Results –Tritium in Drinking Water

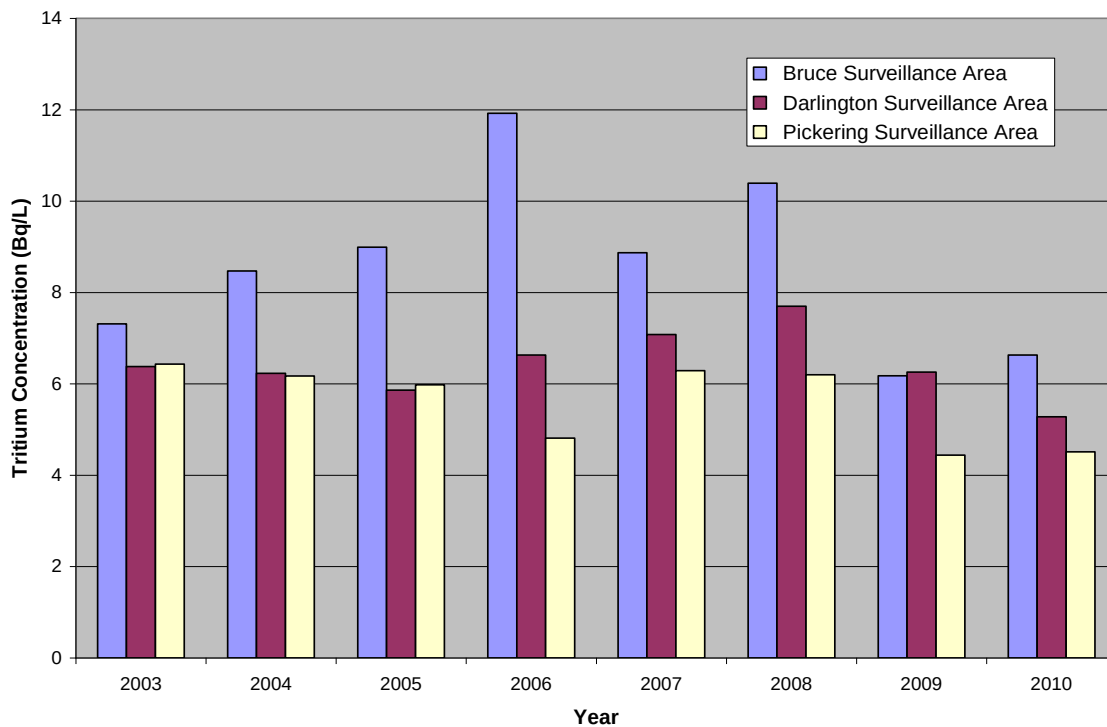


Figure A-3 8-year Results –Tritium in Air

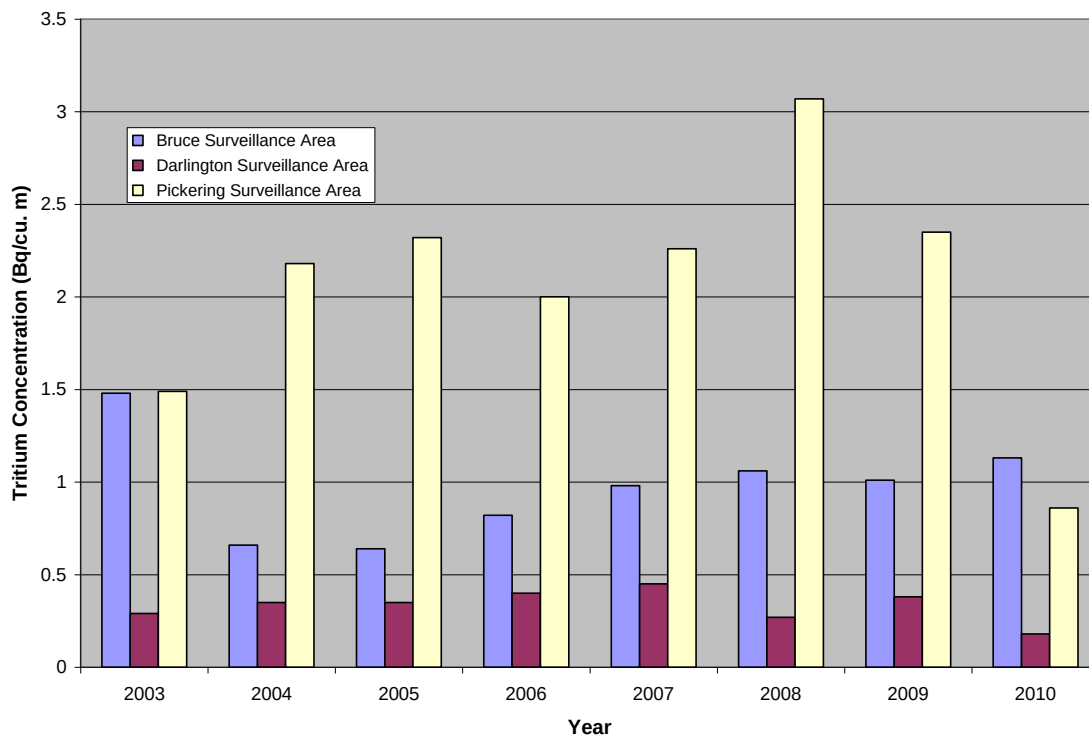
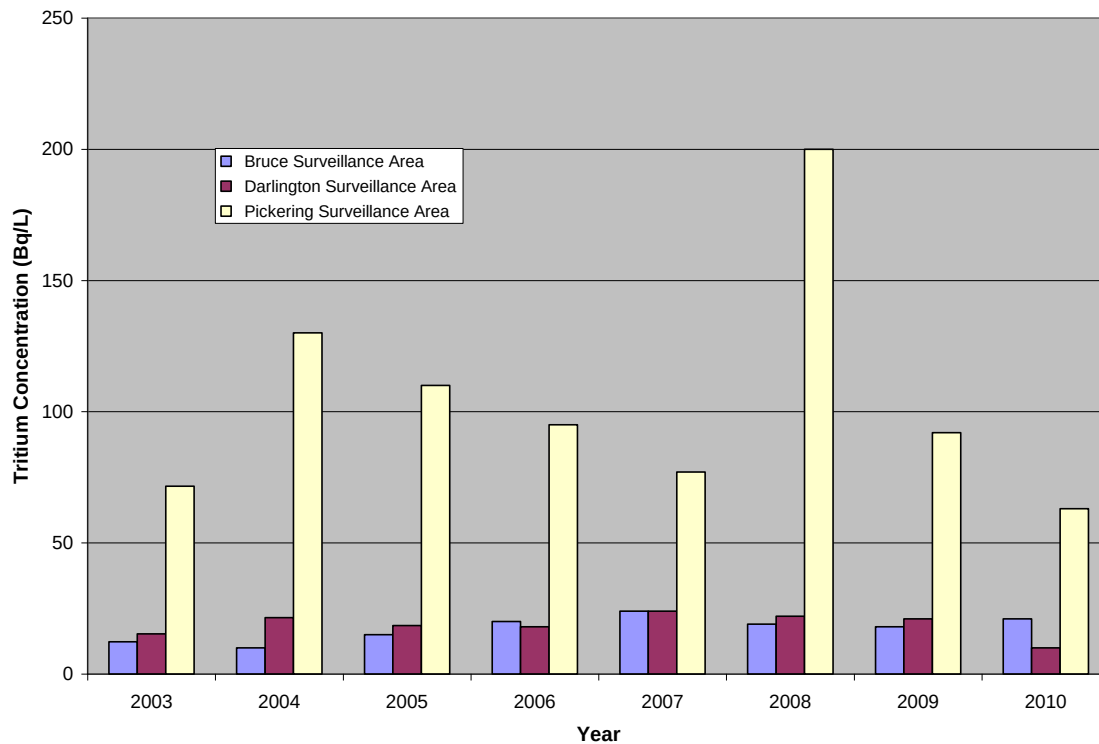
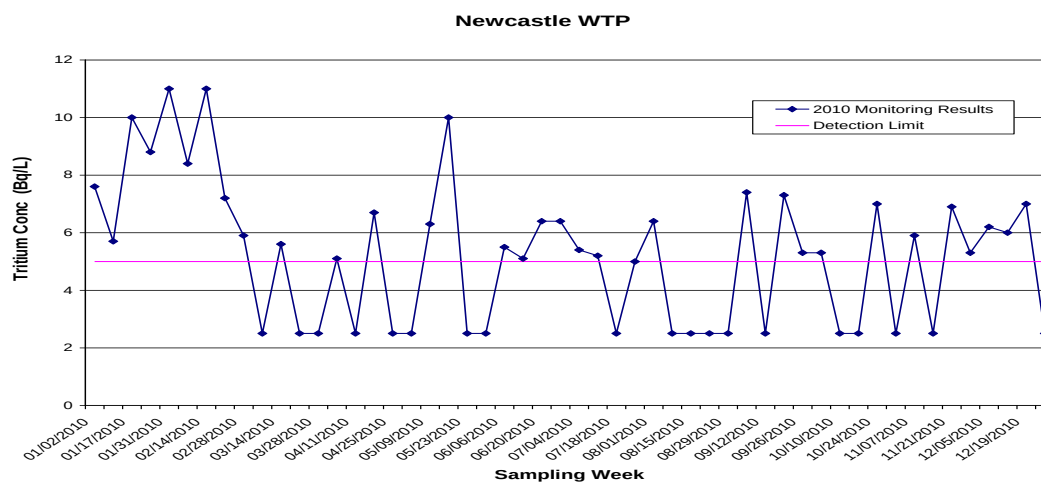
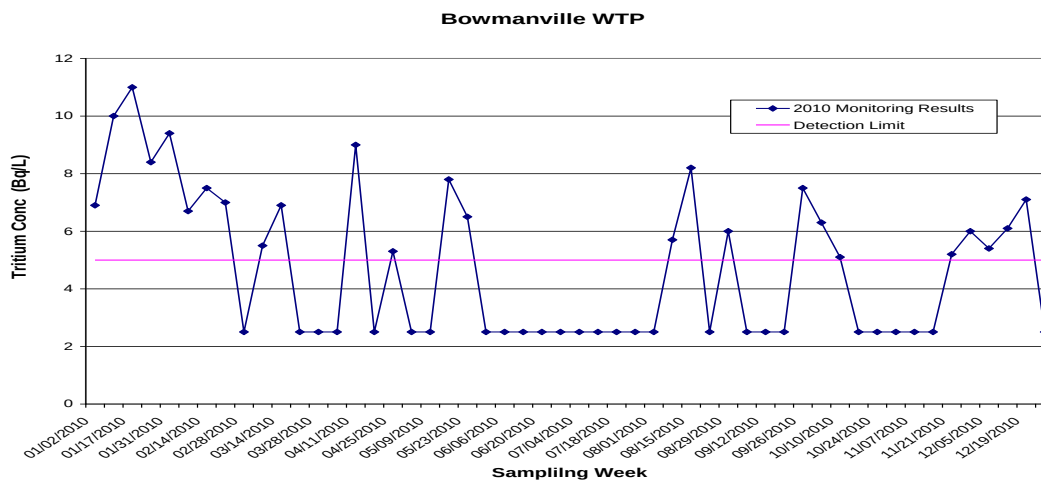
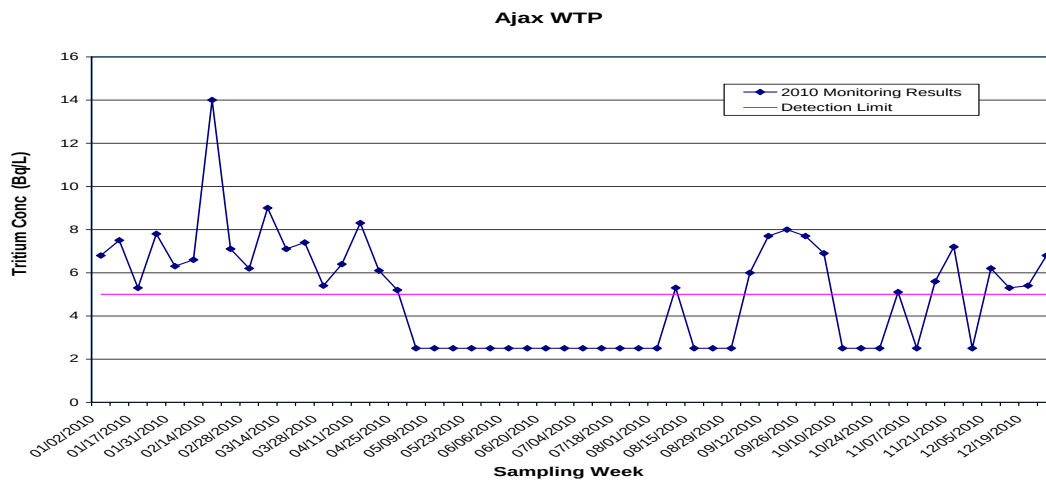
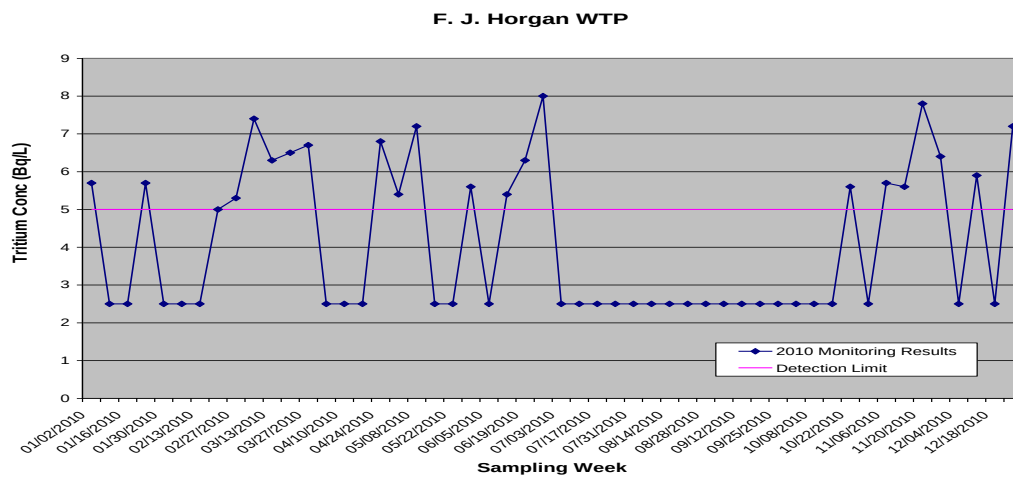
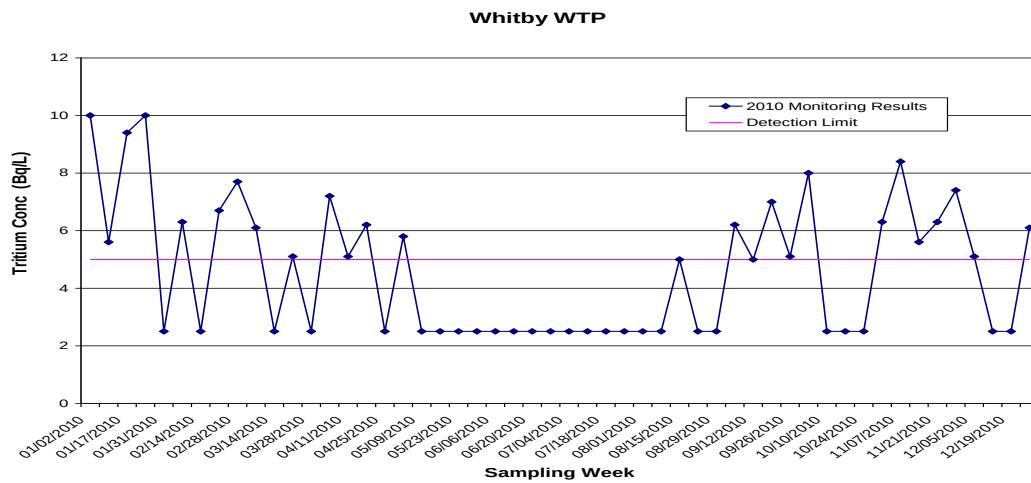
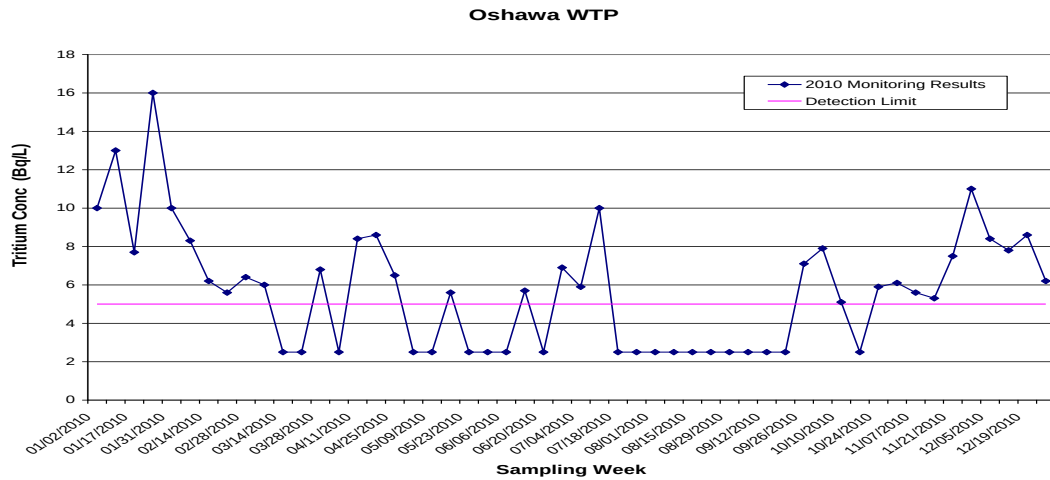


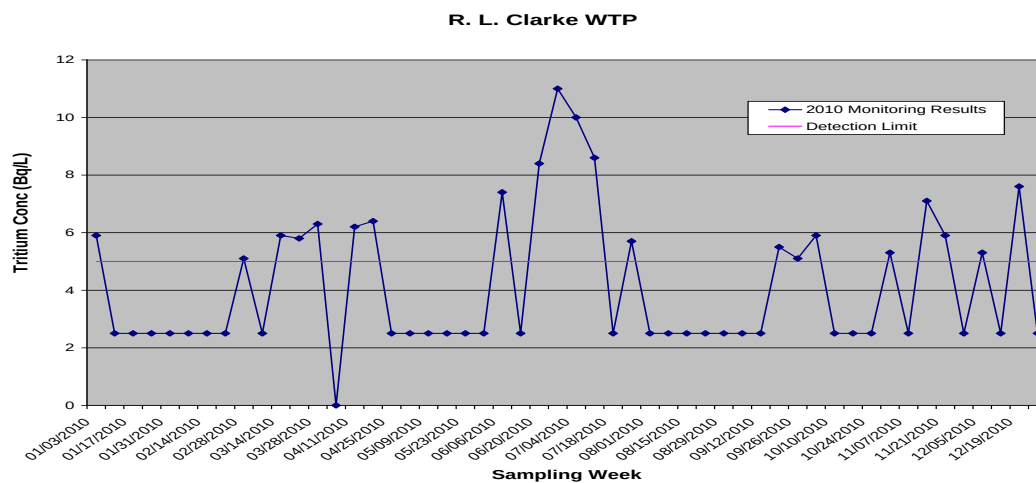
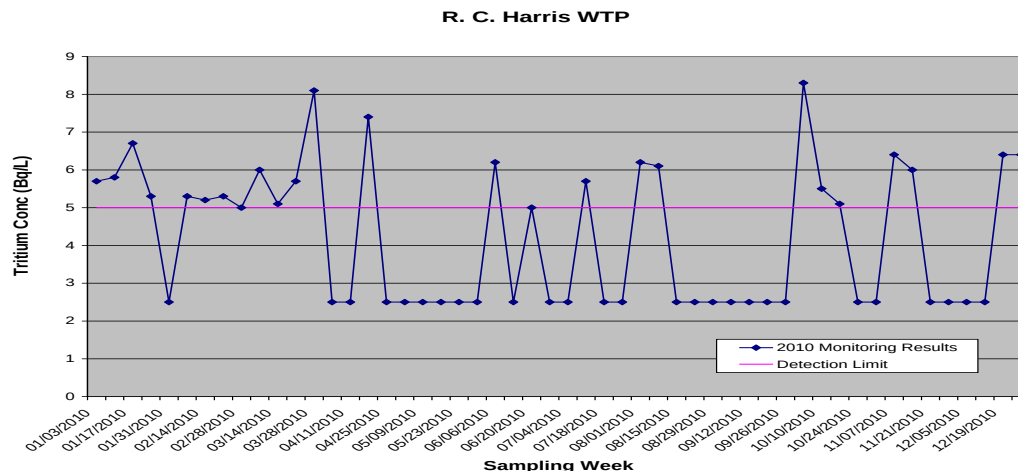
Figure A-4 8-year Results –Tritium in Precipitation



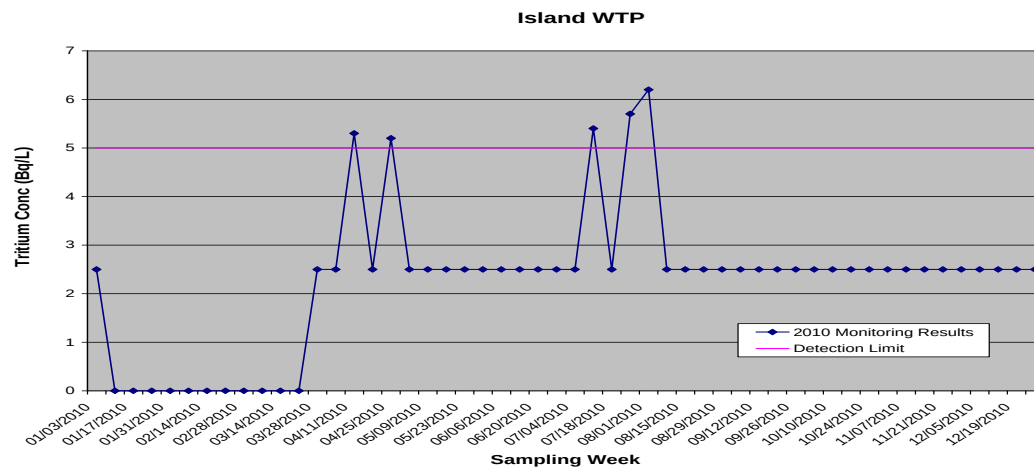
APPENDIX 4 WATER TREATMENT PLANT SAMPLING RESULTS







Note - Zero value indicates missing sample



Note - Zero value indicates missing sample

