Derived Release Limits for The SRBT Pembroke Facility - 2021 Update

Final Report prepared for:

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Acronyms and Abbreviations

ALARA	As Low As Reasonably Achievable
Bq	becquerels
CNL	Canadian Nuclear Laboratories
CNSC	Canadian Nuclear Safety Commission
COG	CANDU Owners Group
CSA	Canadian Standards Association
DCF	Dose Conversion Factor
DRL	derived release limit
EC	Environment Canada
EMP	Environmental Monitoring Program
ERA	Environmental Risk Assessment
GBq	Giga-becquerels
Ha	absolute humidity
HT	elemental tritium
HTO	tritium oxide
OBT	organically bound tritium
PAS	Passive Air Sampler
RME	Reasonable Maximum Exposure
SA	Specific Activity
SRBT	SRB Technologies (Canada) Inc.
Sv	Sieverts
TJF	Triple Joint Frequency

1.0 INTRODUCTION

1.1 Facility Description

Since 1991, SRB Technologies (Canada) Inc. (hereafter referred to simply as “SRBT”) has operated a tritium light manufacturing facility in the City of Pembroke, Ontario. The facility is located on the perimeter of the City within a relatively large block of land zoned for various forms of commercial or industrial use.

The light manufacturing process requires the use of elemental tritium (HT), which can be readily oxidized to tritium oxide (HTO) during and after operations. Tritium is transported to the facility (as HT), in accordance with defined possession limits, and stored on uranium getter beds until use. Over the past decade, SRBT has typically processed in the order of 30 million GBq of tritium per annum.

The general procedure of light production involves transfer of stored HT to segments of glass tubing, which are immediately sealed upon filling. The transfer process occurs under a high degree of control, maximizing HT transfer efficiency and minimizing the potential for fugitive tritium release. While SRBT continuously works to keep any fugitive emissions of HT or HTO *As Low As Reasonably Achievable* (ALARA), a very small portion of the tritium process stock can escape during processing. Ventilation control systems subsequently convey fugitive tritium from the interior working space of the facility, away from workers. The fugitive tritium is released to atmosphere with ventilation exhaust via two exhaust stacks located at the north-west corner of the building. The release of tritium (both as HT and HTO) to atmosphere is the only process-related release of radionuclides from the SRBT facility.

The facility also intermittently generates small amounts of liquid effluents as part of facility maintenance. This includes ongoing clean-up of residual tritium in active work zones (Zones 2 and 3) and subsequent collection of cleanup water for controlled disposal via the municipal sewer system. This results in intermittent delivery of small amounts of tritium in wash water to the municipal sewer system. The tritium in wash water is monitored and quantified on-site. This monitoring has shown that the magnitude of this non-process release is very small, with releases to sewer constituting an average of about 0.03% of total tritium emissions to air in recent years.

Other waste streams (e.g. broken light sources, crushed glass stubs, contaminated materials are managed as controlled wastes and they are appropriately handled and disposed at the Canadian Nuclear Laboratories (CNL) Chalk River facility. Facility wastes associated with liquid scintillation counting are stored and shipped to EnergySolutions’ Canada Walker Operations (ESWO) facility is located in Brampton, Ontario. Both the CNL Chalk River facility and the ESWO operate under a CNSC Waste Nuclear Substance License (WNSL).

Overall, the release of HT and HTO to atmosphere via exhaust stacks is the only significant routine operational release of radionuclides from SRBT to the environment.

1.2 DRL Requirement and Current Status

The SRBT facility is a licensed Class 1 nuclear facility. As such, SRBT maintains an overall Environmental Management System (EMS) and an Environmental Protection Program (EPP). The EMS and EPP are consistent with the requirements outlined in the Canadian Nuclear Safety Commission (CNSC) Regulatory Document REGDOC-2.9.1 (CNSC, 2020). REGDOC-2.9.1 sets the requirement for Class 1 nuclear facilities to monitor emissions and the environment and to assess public exposure and dose associated with facility emissions. In turn, these steps serve to achieve radiological protection of the environment and the public. Derived release limits (DRLs) are calculated to inform and support the EMS and EPP and to serve as comparative criteria to demonstrate compliance with REGDOC-2.9.1.

As per standard practice, DRLs are to be regularly reviewed and updated as warranted. Typically, the review frequency for most Class 1 nuclear facilities is every five years. DRLs were first calculated for the SRBT facility in 1990, prior to the onset of operations (Lemire and Dixon, 1990). Following that initial calculation, the DRLs for the SRBT Pembroke facility have been subject to review and/or update on multiple occasions, as follows:

- 1996 - DRLs recalculated using revised models and more site-specific characteristics (Canatom, 1996),
- 2004 - DRLs reviewed, but not recalculated (Grey, 2004),
- 2006 - full revision and recalculation of DRLs (EcoMetrix, 2006), following newly developed Guidance (COG, 2003) and
- 2008 - minor revision of DRLs (EcoMetrix, 2008)

Most recently SRBT facility DRLs were subject to full review and re-calculation in 2016. There were several key developments that were considered in the 2016 revision of the SRBT facility's DRLs. This included the following:

- Updates of the technical guidance for DRL determination in Canada (i.e., COG, 2008 and 2013, and CSA, 2008 and 2014),
- Substantial enhancement of SRBT's environmental monitoring program (EMP),
- The completion of focused studies of the environmental fate and transport of tritium releases from SRBT,
- The initiation of meteorological monitoring on the grounds of the SRBT facility

Since 2016, the primary development of potential relevance to SRBT's DRLs has been the completion of the first iteration of an Environmental Risk Assessment (ERA) for the facility (SRBT, 2021b). The ERA included a human health risk assessment focused on tritium and based on exposure and dose calculations consistent with those applied in the 2016 DRL determination. The ERA did not identify or incorporate any aspects of human exposure and dose assessment that deviated from the 2016 DRL determination.

Other than the ERA, there have been only minor developments of relevance to the determination of DRLs for the SRBT facility. With the 2019 reaffirmation of CSA N288.1-14, there have been no changes in the DRL models applied to assess tritium fate and transport. In addition, there have been no major changes at the SRBT facility, such as changes to stack dimensions or major changes to ventilation systems, that would significantly influence the atmospheric dispersion of tritium releases from the facility. In addition, there have been no changes in the characterization of the public that would affect the calculation of public exposure to tritium in the environment. Since 2016, the only new information that could meaningfully influence the calculation of DRLs for the SRBT facility is the meteorological data collected from the on-site weather station over the period of 2016 to present. Typically, time-averaged measures of meteorological parameters are not expected to vary to the point where DRLs would be subject to major changes. Despite an absence of compelling factors, the SRBT facility DRLs have been subject to full recalculation as a matter of diligence and commitment to the ALARA principle.

1.3 Current Objectives

This report has been prepared to provide complete and detailed documentation of an independent professional calculation of DRLs for elemental tritium (HT) and tritium oxide (HTO) releases to atmosphere from the SRBT facility. The objective of this effort, conducted on behalf of SRBT, is to provide an up-to-date determination of DRLs for HT and HTO emissions to air from the SRBT facility in its state of operation at the end of 2020. This also coincides with the pending requirement to renew SRBT's operating license.

This report also provides review and recommendations with regard to select aspects of ongoing monitoring and reporting of tritium emissions to the environment and their radiological implications (e.g. future DRL review/update, environmental monitoring efforts, meteorological monitoring and data processing).

1.4 Scope of Work

The main tasks completed to meet the stated objectives are as follows:

1. All recent documentation of possible relevance to tritium DRLs for the SRBT Pembroke Facility has been initially reviewed, including the following:
    - The most recent DRL document (Morris, 2017),

- Current DRL Guidance (CSA, 2014),
- The recent ERA report for the facility (SRBT, 2021b)
- SRBT Annual Compliance and Performance Reports from 2016 to 2020, and
- meteorological datasets provided by SRBT for the period of 2016 to 2020.

2. The equations and parameter values serving as the basis for DRL calculation have been adjusted where warranted by the above-mentioned information, and in a manner consistent with current DRL Guidance.
3. Where feasible, the current DRL model has have been subject to additional site-specific validation for the SRBT facility over the period of relevance.
4. In a manner consistent with contemporary DRL Guidance (specifically CSA N288.1-14), DRLs for HT and HTO have been calculated using the revised and validated DRL model.

Section 2 of this report describes these various steps in summary, with complete details provided in the various Appendices. The outcome of this process, including the recommended DRLs for the SRBT facility, is presented and discussed in Section 3.

2.0 METHODOLOGY

2.1 Applied Guidance

This DRL calculation has been completed in accordance with the current DRL guidance for nuclear facilities in Canada. This includes the latest revision of Canadian Standards Association (CSA) Standard N288.1 (2014), which was reaffirmed in 2019. The CSA Guidance has been developed primarily for CANDU nuclear power-generating facilities in Canada. However, the guidance is general enough that it may be applicable to other nuclear facilities, so long as the radionuclides of interest are among those of relevance to CANDU processes. Tritium is one of the most important radionuclides at CANDU facilities.

For atmospheric releases, the DRL Guidance is intended for routine, continuous, low-level emissions. The guidance may also apply in the case of periodic short-term releases if they are controlled and associated with normal operations, occur throughout the full operational period, and are not significantly episodic in terms of magnitude. If releases are known to occur at a particular time of day or year, then the guidance may still apply if the meteorological data representing the time frame of relevance are applied. SRBT's emission patterns have been reviewed, and they are such that the DRL Guidance is deemed to be applicable. Specifically, this application of the DRL Guidance for the determination of DRLs for SRBT is deemed to satisfy Clauses 1.3 and 8.2.3 of the CSA N288.1-14. To ensure that the atmospheric dispersion model is reliably representative, direct validation of that dispersion model for SRBT over the period of 2015 to 2020 has been conducted. The validation is discussed in Appendix D.

Full details of the atmospheric dispersion model and all other equations and parameters used to quantify exposure and dose along all pathways considered in SRBT DRL calculations are provided in Appendix A. Appendix A includes brief explanations of the general theory of those aspects of the noted guidance that are pertinent to the DRLs for SRBT. It also provides specific rationale for all instances in which the models have been parameterized to consider site-specific information.

In summary, the application of the DRL Guidance in the current DRL calculations for the SRBT facility confers certain general aspects to the process, as follows:

- The DRL calculation follows the Pathways approach,
- Parameter values in the DRL equations are based on site-specific data to the extent possible,
- Since stack emissions of tritium are the only source of radionuclide release to be considered, a principal driver of the DRL calculation is the model estimation of atmospheric dispersion,

- The partitioning of tritium in the environment is largely modeled following specific activity (SA) principles, and
- The degree of exposure of members of the public to tritium in the environment is conservatively quantified following reasonable maximum exposure (RME) assumptions.

2.2 Pathways Approach

In keeping with current Canadian DRL Guidance, estimation of DRLs for releases of tritium (HT and HTO) to air from the SRBT facility follows a “pathways” approach. The full exposure pathway for a given member of the public is represented by a series of transfers between the discrete environmental compartments (physical or biological media) that comprise that exposure pathway. Each compartment is numbered, and the quantity in a given compartment (denoted generically as “I”) is denoted by "Xi". Transfer from compartment "i" to compartment "j" is characterized by a transfer parameter "Pij", such that the amount present in compartment "j" under steady-state conditions due to transfer from compartment "i" to compartment j is $P_{ij}X_i$.

The compartments and transfer parameters that have been considered in the DRL estimation for the SRBT facility are summarized in Tables 1 and 2, and depicted graphically in Figure 1. The numbering sequence follows a fixed convention, and compartments that are <u>not</u> explicitly represented in the SRBT scenario (i.e., soil (3), aquatic animals (6), aquatic plants (7), and sediment (8)) are omitted from Tables 1 and 2.

The magnitude of the quantity in any compartment j is:

$$X_j = \sum_i P_{ij} X_i \qquad [2.1]$$

where the summation is over all compartments, i, transferring into compartment j. If all the values of P_{ij} are known, then the individual X_js may be calculated for any given release rate X_0. For example:

$$X_1 = P_{01} X_0 (a)$$
$$X_2 = P_{02} X_0 (w)$$
$$X_3 = P_{13} X_1 + P_{23} X_2 = P_{01} P_{13} X_0 (a) + P_{02} P_{23} X_0 (w)$$
$$X_4 = P_{14} X_1 + P_{34} X_3 + P_{24} X_2$$
$$= P_{01} [P_{14} + P_{13} P_{34}] X_0 (a) + P_{02} [P_{24} + P_{23} P_{34}] X_0 (w)$$

where: $X_0 (a)$ = release rate to atmosphere, and
$X_0 (w)$ = release rate to surface water.

Table 1: Pathway Compartments of Relevance to SRBT

Compartment No.	Compartment Name	Units
0	Source	$Bq{\cdot}s^{-1}$*
1	Atmosphere	$Bq{\cdot}m^{-3}$*
1a	Atmosphere (soil-based transformation of HT to HTO)	$Bq{\cdot}m^{-3}$
2w	Ground Water (well)	$Bq{\cdot}m^{-3}$
4	Forage and Crops	$Bq{\cdot}kg^{-1}$
5	Animal Produce	$Bq{\cdot}kg^{-1}$
9	Human Dose	$Sv{\cdot}a^{-1}$

Table 2: Transfer Parameters of Relevance to SRBT

Transfer Parameter	Compartments From	To	Parameter Units
P_{01}	Source	Atmosphere	$s{\cdot}m^{-3}$
P_{11a}	Atmosphere (HT)	Atmosphere (HTO)*	unitless
P_{12w}	Atmosphere	Shallow well	unitless
P_{14}	Atmosphere	Forage and Crops	$m^3{\cdot}kg^{-1}$
P_{15}	Atmosphere	Animal Produce	$m^3{\cdot}kg^{-1}$
$P_{(i)19}$	Atmosphere	Dose (inhalation)	$Sv{\cdot}a^{-1}{\cdot}Bq^{-1}{\cdot}m^3$
$P_{(e)19}$	Atmosphere	Dose (immersion)	$Sv{\cdot}a^{-1}{\cdot}Bq^{-1}{\cdot}m^3$
P_{24}	Well Water	Forage and Crops	$L{\cdot}kg^{-1}$
P_{25}	Well Water	Animal Produce	$L{\cdot}kg^{-1}$
$P_{(i)29}$	Well Water	Dose (ingestion)	$Sv{\cdot}a^{-1}{\cdot}Bq^{-1}{\cdot}L$
$P_{(e)29}$	Well Water	Dose (immersion)	$Sv{\cdot}a^{-1}{\cdot}Bq^{-1}{\cdot}L$
P_{45}	Forage and Crops	Animal Produce	$kg{\cdot}kg^{-1}$
P_{49}	Plant Produce	Dose (ingestion)	$Sv{\cdot}a^{-1}{\cdot}Bq^{-1}{\cdot}kg$
P_{59}	Animal Produce	Dose (ingestion)	$Sv{\cdot}a^{-1}{\cdot}Bq^{-1}{\cdot}kg$

* P_{11a} is a bulk composite transfer parameter encompassing transfer of HT to soil, oxidation of HT to HTO by soil microbes, and re-emission of HTO from soil to the atmosphere at ground level.

In the case of SRBT, there are routine operational releases of tritium (as HT or HTO) to atmosphere (Pathway P_{01}), and all other pathways identified in Table 2 are explicitly included in the current DRL calculations.. Under the DRL guidance, the exposure to tritium through the ingestion of soil (i.e., pathway $P_{(i)29}$) is acknowledged as negligible and this pathway is not explicitly included in the current calculation of DRLs. Appendix A of this report does include equations that can be applied to quantify and confirm the magnitude of dose associated with soil ingestion. The DRLs reported herein exclude this pathway, but the relative contribution to public dose has been estimated for comparative purposes (see Table 10).

HTO is also released from SRBT in controlled batches to the municipal sewage system, which in turn discharges treated sewage effluent to the Ottawa River. The release of

HTO to the municipal sewage system is subject to prescribed release limits as part of the conditions of the current operating license. Under the DRL Guidance, these small releases are not fully consistent in nature with the aqueous discharges to which the Guidance applies. Further, the amounts of HTO released to sewer are relatively very small, typically totaling about 0.03% of total annual releases to atmosphere. In consideration of these factors, the release to the municipal sewage system is not explicitly included in the calculation of DRLs for the facility. The primary pathway of exposure is the ingestion of fish caught through recreational fishing in the Ottawa River, or possibly external immersion while swimming in the river. Estimation of the dose rate associated with such exposure is beyond the scope of the current DRL analysis.

The DRL calculation process does consider the transfer of tritium in air to ground water (P_{12w}), and in turn the exposure of members of the public to tritium in domestic well water supplies used for drinking, bathing/swimming, irrigation of crops and watering of livestock.

It should be noted that there are two pathways from atmosphere-to-dose (*i.e.*, inhalation and immersion). These are denoted $P(i)_{19}$ and $P(e)_{19}$, respectively, and $P_{19} = P(i)_{19} + P(e)_{19}$. For HTO, pathway $P(e)_{19}$ is implicitly captured in $P(i)_{19}$, so only a single transfer parameter is applied (P_{19}). In the case of HT, the DRL Guidance notes that external dose is trivial and can be ignored in the calculation of DRL. Similarly, there are internal and external pathways for exposure to well water, denoted $P(i)_{29}$ (drinking) and $P(e)_{29}$ (swimming/bathing). The external and internal exposure pathways for both air and water are explicitly included in the DRL calculations for SRBT.

For tritium as HTO, there is a non-inhalation dose incurred as a result of adsorption through the skin of tritium vapour in air. In the current DL guidance, this dose is handled implicitly as part of the inhalation dose. For this purpose, the inhalation dose conversion factors (DCF) for tritium (HTO) are implicitly multiplied by a factor of 1.5 to account or the dose associated with skin adsorption (see Appendix A, Section A.11). Accordingly, the current DRL determination does not give explicit consideration to dose due to air immersion ($P_{(e)19}$). This is completely consistent with applicable DRL Guidance.

Since isotopes of tritium (^3H) are freely exchanged between organisms and environmental media, many of the P_{ij} values for ^3H are based on the *Specific Activity* (SA) concept, rather than trace element partitioning and accumulation concepts that are applicable to the large majority of radionuclides considered in the current DRL Guidance.

In the case of tritium releases (as HT or HTO), the SA approach quantifies the concentration in plant and animal products based on concentrations in air, implicitly capturing any intermediate transfers involving the soil compartment. For this reason, P34 (transfer from soil to plants) and P35 (transfer from soil to animal) are effectively ignored in the assessment of tritium releases from the SRBT facility. Human doses due to tritium in soil (via ingestion or groundshine) are understood to be trivial and are not directly considered herein.

For any particular radionuclide and representative person, the DRL is obtained by dividing the dose per unit release (X_9/X_0) into the relevant dose limit. For the purpose of DRL calculation, actual release rates are not required and X_0 can be assigned an arbitrary 1 Bq/s release rate. The dose limit considered in this case is 1 mSv/a, which is the upper limit of effective dose received by and committed to a person who is not a nuclear energy worker, as identified in Section 13 of the *Radiation Protection Regulations*.

DRL for Releases to Atmosphere (Bq • s^{-1})

$$DRL = \frac{annual\ dose\ limit\ (Sv \bullet a^{-1})}{\left[\frac{X_9}{X_0\ (a)}\right](Sv \bullet a^{-1} \bullet Bq^{-1} \bullet s)} \qquad [2.2]$$

The DRL in Bq • s^{-1} may be multiplied by 6.048×10^5 s • wk^{-1} to obtain DRL in Bq • wk^{-1}.

In calculating the value of X_9/X_0, care must be taken in setting up Equation [2.2] to ensure that the values of P_{01} and P_{02} are chosen at the point(s) where transfer from air to crops, animals or man occurs. For the case of release to atmosphere in which immersion, inhalation, and the point of food and crop production occur at the same downwind distance, X_9/X_0 takes the following form:

$$\frac{X_9}{X_0(a)} = P_{01}\,[P(e)_{19} + P(i)_{19} + P_{14}\,P_{49} + P_{15}\,P_{59} + P_{14}\,P_{45}\,P_{59}] \qquad [2.3]$$

The ICRP distinguishes between stochastic effects, for which the Annual Effective Dose Limit is 0.001 Sv, and deterministic effects, for which the Annual Skin Dose Limit is 0.05 Sv. For tritium, stochastic effects are limiting and are the basis of determination of the DRLs for SRBT.

The general procedure for calculation of the DRL for release of tritium to air is as follows:

1. Identify exposure pathways and appropriate groups of representative persons, preferably from site-specific surveys. Exposure pathways may be different for different age classes. There may be more than one group of representative persons, and different radionuclides (e.g. HT vs. HTO) may be limited by different groups.
2. Develop appropriate expressions for X_9/X_0 (a) based on the generalized transfer model and Equation [2.1].

3. Select appropriate values for the transfer parameters that are relevant to the representative group(s) under consideration. Site-specific values should be used when available. The origin and values of transfer parameters are described in detail in Appendix A.
4. Calculate DRLs for each potential representative person, following Equation [2.2]. Calculations are to be done separately for different age classes. Following CSA N288.1-14, there are three age classes; 1) 0 to 5 years old (nominally represented by a 1-yr old), 2) 6 to 15 years old (represented by a 10-year old, and 3), 16 to 70 years old (represented by a standardized adult).
5. Select the smallest of the calculated DRLs in Step 4 above as the limiting DRL for the facility for the particular radionuclide.

The full expressions for X_9/X_0 developed for SRBT DRL calculation are presented in Section 3.3

2.3 Representing the Public

DRLs are calculated so that they are reflective of exposure and dose experienced by identifiable groups whose various characteristics pre-dispose them to having a relatively high degree of exposure. These relatively highly exposed groups have previously been referred to as members of *critical groups.* The most recent DRL Guidance has adopted the term *representative person.* CSA N288.1-14 defines the *representative person* as an individual with characteristics that reflect those of the group that receives the highest doses from a particular source. The Guidance further stipulates that DRLs should be developed by considering a representative person with average rather than extreme characteristics within this most exposed group.

The process of identifying and characterizing highly exposed groups and representative persons for the current calculation of DRLs for the SRBT facility is consistent with the process followed in 2016. The basic steps taken to determine potential critical group locations are as follows:

- Determine distinct life styles or activity profiles present in relatively close proximity to SRBT,
- Within each defined wind sector, identify the most proximate locations at which each identified group type is found,
- Apply the atmospheric dispersion model to determine the degree of exposure to SRBT stack emissions experienced at each of these locations,
- For each group type, select the one location with the highest degree of atmospheric exposure

The process of identifying representative persons and their locations is described in detail in Appendix B. In summary, an urban residential group (three age classes) and a worker group (one age class) have been identified as the two representative person types considered in this DRL calculation. This is consistent with the representative persons considered in the 2016 DRL calculation.

The diet of the resident group is partly composed of plant and animal food products from local sources. For DRL purposes, local plant produce is obtained from a backyard garden at the representative person's residence, and also from a local market garden (Bouden's), which is located about 1.9 km ESE of SRBT.

The source of all animal products consumed by the residential group is conservatively assumed to be Saar's dairy farm, located approximately 3.5 km to the S of the SRBT facility. This is the closest known farm with livestock production, and it lies within a relatively high frequency wind sector (see Table 3). At this location, it is assumed that all livestock water is obtained from an on-site shallow well, and that all feed is grown at this location. Overall, this is considered to be a very conservative representation of the source of animal products consumed by representative members of the public. Model validation efforts (see Appendix D) confirm that the model representation is reasonably conservative.

Table 3 – Summary of Directional Wind Frequencies

Wind Direction		Petawawa 1989-2004[1]	SRBT 2011 to 2015[2]		SRBT 2017 to 2019[3]	
From	To		24-hr	12-hr	24-hr	12-hr
N[4]	S	4.16%	5.90%	6.03%	5.31%	5.23%
NNE	SSW	2.45%	6.10%	6.55%	7.04%	7.19%
NE	SW	2.53%	5.20%	5.34%	5.88%	6.12%
ENE	WSW	2.38%	4.43%	5.01%	3.12%	3.47%
E	W	3.79%	5.56%	5.75%	3.29%	3.41%
ESE[5]	WNW	10.58%	5.32%	5.02%	4.00%	4.18%
SE	NW	12.17%	5.72%	6.10%	2.72%	2.89%
SSE	NNW	4.64%	5.86%	6.11%	3.73%	3.68%
S	N	3.49%	5.26%	5.08%	3.91%	3.99%
SSW	NNE	3.69%	5.66%	5.18%	5.00%	4.89%
SW	NE	4.86%	6.49%	6.01%	4.91%	4.58%
WSW	ENE	6.26%	8.16%	7.34%	7.20%	5.84%
W	E	9.41%	7.74%	7.24%	13.40%	12.22%
WNW[6]	ESE	10.68%	9.19%	9.75%	14.87%	15.94%
NW	SE	11.35%	7.80%	8.05%	10.43%	11.31%
NNW	SSE	7.55%	5.59%	5.44%	5.19%	5.06%

1 - wind data collected at CFB Petawawa, used for the 2006 DRL calculation
2 - wind data collected on-site at SRBT, used for the 2016 DRL calculation
3 - wind data collected on-site at SRBT, used for the current DRL calculation
4 - Saar's farm is located S of SRBT
5 - the most exposed residential group in the current period is located to the WNW of SRBT
6 - Bouden's market garden is located ESE of SRBT

The residential group has been characterized in two different manners with respect to the degree to which food and water intake is obtained from local sources. In the "generic" case, food and water intakes of the resident group are based on the default fractions recommended in the DRL Guidance. The SRBT DRL calculation also considers a "site-specific" case, in which available survey results regarding Pembroke residents within close proximity (~2 km) to the SRBT facility are applied. Specifically, the site-specific case encompasses exposure to well water (via ingestion and immersion) on the basis that 0.5% of the total residential water supply originates from the local well. For the ingestion of both plant and animal food products, the survey-derived local fractions have **not** been applied in the site-specific case, owing to the degree of uncertainty associated with the survey results. The survey results and site-specific characterization of representative persons are discussed further in Appendix B (Section B.3.1).

The actual location of both the worker and residential receptors was determined by an initial estimation of the degree of exposure to tritium in the atmosphere at a series of candidate representative locations. This process is discussed in detail in Appendix B. The locations of the residential and worker groups are depicted in Figure 2. The residential group type was assessed at 11 locations, and workers were assessed at three commercial locations in immediate proximity to SRBT. For each potential worker or residential group location, the atmospheric dispersion coefficient (P01) was determined using the atmospheric dispersion model developed for the site. Based on these results (i.e., the highest P01 yields the highest degree of exposure), the closest residence in the west-northwest (WNW) sector was selected as the location of the representative residential person. This is a slight shift from the residential critical group location established for the 2016 DRL determination, which was in the northwest sector. For workers, the highest P01 value was associated with Messer Gases (formerly Linde Gases), and thus this has been selected as the representative worker group location, consistent with 2016.

2.4 Transport and Exposure Models

The environmental transport and exposure models which have been applied in determining the DRLs for the SRBT Facility are derived entirely from the current Canadian DRL Guidance.

The DRL model developed for the SRBT Pembroke facility has incorporated inputs recommended in the DRL Guidance, and calculates transport and human exposure and dose as per the recommended equations in that Guidance. Specifically, the SRBT DRL model incorporates the following main components of relevance to DRL estimation:

- A sector-averaged Gaussian plume atmospheric dispersion model, with additional consideration of effects of plume momentum and buoyancy, and also building wake effects. To account for possible limitations of the model with respect to SRBT emission sources, the model has been applied with and without consideration of thermal buoyancy (see discussion in Appendix D).

- Quantification of exposure in consideration of the full spectrum of pathways of relevance. In this case, the pathways are inhalation, atmospheric immersion, water ingestion, water immersion, and the ingestion of locally produced plant and animal products.

- Specific activity models to determine the environmental partitioning of tritium in the form of HT, HTO or organically bound tritium (OBT), consistent with original conservative theory of Peterson and Davis, 2002.

- Oxidation of HT and generation of atmospheric HTO by soil bacteria, also consistent with conservative theory of Peterson and Davis, 2002.

The full details of these models and their parameterization are provided in Appendix A, and major considerations are discussed in the following sections.

2.4.1 Atmospheric Transport

Releases of radionuclides to water the SRBT Pembroke facility are not subject to DRL requirements, as discussed in Section 2.2. Releases to air are the sole focus in examining public dose and DRLs. As a result, the most critical fate and transport process of relevance to DRL calculations is atmospheric dispersion. The atmospheric dispersion model employed as part of the current estimation of public dose and DRLs for the SRBT facility follows accepted principals of Gaussian plume methods for estimating lateral dispersion. The model accounts for number of phenomena that affect plume rise and spread particularly in relatively close proximity to source (e.g. building wake effects, momentum, thermal buoyancy). Previous history of application of un-modified Gaussian plume models to assess exposure and doses to public receptors near nuclear power generation facilities in Canada show that the model tends to be conservative; that is, it predicts levels of radionuclides in air that are higher than measured. The level of conservatism is typically in the order of 2 or 3-fold, and tends to be higher at greater proximity to source (refer to discussion of uncertainty in Section A.2.1 of Appendix A).

The model application has encompassed two main updates in terms of site-specific data input, including:

- Review and update, where warranted, of key aspects of the exhaust fans and stacks, resulting in minor adjustments to stack characteristics, and

- Recently recorded triple joint frequency data from SRBT's on-site meteorological monitoring station (see Appendix C).

Following update of the model to reflect the noted inputs, the model was subject to a brief validation exercise. The current validation builds upon a full validation of the model completed as part of the 2016 DRL revision. For current and previous validation purposes, the predicted levels of HTO were compared to the actual measures recorded over the time period in question. Both the predictions and the measures are reflective of the presence of HTO that would have resulted from the oxidation of HT releases. The details of this validation exercise are provided in Appendix D.

Based on the validation efforts to date, the atmospheric dispersion model has been adjusted to exclude the effects of thermal buoyancy in its current application for determining SRBT's DRLs. This is expected to confer at least a two-fold conservatism in the resulting DRLs. The atmospheric dispersion model, as applied herein, thus represents the SRBT facility in a manner that is equally or more conservative than applications at other nuclear facilities in Canada (see discussion in Section A.2.1 of Appendix A).

2.4.2 Groundwater Partitioning

The groundwater model assumes that the residential well established as the source of drinking water for the representative person is a shallow well that functions essentially like a cistern (see section A.4 of Appendix A). In a study of groundwater near the SRBT facility, this has been demonstrated to be a very conservative representation of residential wells in Pembroke (EcoMetrix, 2008). The study effectively confirmed that tritium in groundwater, particularly in nearby residential wells, originates from emissions to air, and that the model in the DRL guidance is applicable. The findings of a separate review of all historical emissions (SRBT, 2007) from the facility supports this conclusion. The 2008 groundwater study also notes that comparison of model results with contemporary measures needs to account for the presence of tritium associated with historical emissions and the time required to reach equilibrium between air and groundwater. Results to date of ongoing groundwater monitoring at multiple wells in the vicinity of the SRBT facility has strongly corroborated the findings of the 2008 study.

Direct comparison of measured concentrations of tritium in residential wells with those predicted by the groundwater model applied herein shows that model estimates are within the range of recent measures (see Section D.2.3., Appendix D). In the current context, it is not possible to make reliable quantitative adjustments for the influence of historical emissions on groundwater. However, it is reasonable to assume that there is some influence. With that assumption, the model estimates for HTO in groundwater that are in line with measured HTO activity may in fact be over-estimates to some degree. Overall, the applied groundwater model does not under-estimate and may well over-estimate tritium activity in private residential wells.

2.4.3 Partitioning to Food Products

The uptake of tritium into plant and animal food products is governed by specific activity (SA) models, described in detail in Sections A.3 (plant produce) and A.7 to A.10 (animal produce) of Appendix A. The SA models are designed to represent long term equilibrium of tritium in the environment with tritium in living tissues. They are conservatively parameterized to slightly over-predict tritium levels in food. The models also account for the formation of organically bound tritium (OBT) in food products.

Concentrations of tritium in plant and animal products were calculated as part of the validation effort, and results were compared to available measures from the same period (see Section D.2.4, Appendix D). Overall, the 2016 DRL model application yields estimates of tritium in fruits and vegetables at the relevant locations that are conservatively representative of locally grown produce. The model estimates of tritium in milk at the nearest dairy farm location (Saar's farm) were also conservatively representative in comparison to direct measures of samples collected over the past 5 years.

Overall, when considering average conditions over a multi-year time frame, as appropriate for determining the DRL, the SA models used to determine the levels of tritium in food products are judged to be reasonably conservative. The moderate level of conservatism associated with the environmental partitioning models is combined with additional conservatism in the quantification of human exposure to yield an overall level of conservatism that is consistent with the RME (reasonable maximum exposure) concept.

3.0 RESULTS AND CONCLUSIONS

3.1 Changes and Updates

The current SRBT DRL calculations have been completed in the same general manner as the last iteration of DRL calculations in 2016. In both instances, DRL calculations have been conducted in accordance with contemporary Canadian DRL guidance (i.e., CSA N288.1-14), following a pathways approach. The 2014 CSA Guidance was reaffirmed in 2019, and there are no changes relative to the last DRL calculation in 2016.

The current DRLs have been conservatively quantified in accordance with the RME concept, and using site-specific data to the extent possible at this time. Relative to the DRL calculations completed in 2016, the current DRLs are reflective of the following changes in site-specific data;

- update of meteorological data collected from the on-site weather station, and
- update of stack exit velocities as determined through ongoing routine monitoring.

Aside from these specific updates, the values of all parameters in equations applied for DRL calculation purposes remain unchanged relative to 2016.

3.1.1 Site-Specific Data Application

The current determination of DRLs for the SRBT facility in Pembroke applies the current DRL Guidance in a site-specific manner to the extent possible. Prior to 2016, SRBT had initiated monitoring efforts that expanded the available data of relevance to DRL calculations. This included the establishment of on-site meteorological monitoring (see Appendix C for details), and the daily monitoring of ventilation flow rates. These site-specific data are directly relevant to modelling of atmospheric dispersion, which is a critical component of the overall DRL calculation for SRBT.

SRBT also maintains their Environmental Monitoring Program (EMP) which, provides reliable and representative data used to validate various components of the environmental transport and partitioning models used in the DRL calculation (see Appendix D).

In summary, the instances of use of site-specific data in this iteration of DRL estimation include:

- o Triple joint frequency wind data (speed, direction, stability), which are a key determinant of atmospheric dispersion,
- o Absolute humidity levels, affecting the calculations used to represent the transformation of HT to HTO, tritium uptake in plants, and tritium transfer from atmosphere to groundwater (shallow wells).

- Stack and facility characteristics, affecting the atmospheric dispersion model.
- Characteristics of representative persons, based in part on previous site survey results.
- Measures of tritium activity in air (outdoor and indoor), groundwater from multiple private residential wells, plant and animal produce from multiple locations. These measures have been used to validate the DRL models as appropriate for use at SRBT (see Appendix D).

3.1.2 Public Characterization

The characterization of members of the public established for the calculation of SRBT DRLs (i.e., representative persons) is consistent with that of the 2016 DRL update. The residential group of representative persons is assessed at the location of the closest residence in each wind sector around the SRBT facility where residential dwellings exist within 2 - 3 km. This is deemed to be consistent with CSA Standard's recommendations to assign site-specific attributes of representative persons that are realistic, and not unduly conservative.

There are 11 candidate residential locations in total, each assumed to have the same characteristics of relevance to potential exposure to tritium in the environment. The sub-classes of the residential representative person include a 1-yr old infant, a 10-yr old child, and an adult.

The representative worker is assigned to each of three workplace locations in very close proximity to SRBT stacks. The "at-home" exposure of the worker occurs at what is determined to be the location where exposure to stack emissions (i.e., P_{01}) is the highest of all 11 residential locations (see Appendix B). This is considered to be a considerably conservative assumption in characterizing the worker group.

3.1.3 Facility Characteristics

At present, SRBT restricts its tritium processing operations to the period between 7:00 a.m. and 7:00 p.m. This restriction avoids the discharge of emissions during times when wind conditions lead to relatively low rates of dispersion. For the purpose of DRL determination, and in keeping with the DRL Guidance, it is has been deemed appropriate to use meteorological data that are representative of the period of operations (i.e., 12-hr data rather than 24-hr).

Since 2008, there has been no processing of tritium at SRBT during periods of precipitation. This does not affect the DRL calculation directly, but does have implications to various measures of tritium collected through the EMP and their use in developing and validating the environmental partitioning models used in DRL calculations.

3.2 Transfer Parameters

The noted changes in model assumptions, equations, and parameter values, are all determinants of the transfer parameters (Pij) that combine to yield the DRLs for HT and HTO. The derived values for the full range of transfer parameters are discussed in detail in Appendix A. Summaries of the transfer parameters (Pij values) developed for SRBT DRL determination are presented in Tables 4 through 8.

Notable aspects of Pij values include the following:

- P_{01} (Table 4) for the worker is now about 50% higher relative to 2016 while P_{01} for the resident group is about 13% lower, in both cases owing to differences in wind-related variables.

- Transfer parameters for plant (Table 5) and animal (Table 6) food products have exhibited only minor change since 2016, owing to changes in humidity values used in the SA equations of relevance. The net transfer parameter values differ only slightly from default values reported in the current DRL Guidance.

- The human dose transfer parameters (Table 7) have not changed relative to those used in 2016. The generic transfer parameters for human dose do not differ significantly from default values reported in the DRL Guidance. For exposure to well-water, the generic parameters are about 2 orders of magnitude greater than the corresponding site-specific values. This simply reflects the difference in assumed rates of reliance on private wells for residential water supply.

Table 4 - Transfer Parameters for Air and Water

Transfer Parameter	Units	2016	2021
P_{01} - Residential - West-northwest[1]	s/m^3	8.92E-06	6.75E-06
P_{01} - Worker Group	s/m^3	3.54E-05	5.26E-05
P_{01} - Bouden's Market garden	s/m^3	6.41E-07	1.42E-06
P_{01} - Saar's Dairy Farm	s/m^3	3.81E-07	4.48E-07
P_{11a}	no units	0.0228	0.0233
P_{12g} (well)	m^3/L	46.15	45.45

P_{01} values reflect 12-hr wind data and an omission of thermal buoyancy

1 - the most exposed residence now lies in the WNW sector compared to the NW in 2016

Table 5 - Transfer Parameters for Plant Food Products

Transfer Parameter	Plant Type	2016	2021
$P_{14\ HTO}$	Fruit	53.7	52.8
	Vegetables	53.7	52.8
	Root Vegetables	47.1	46.3
	Livestock Feed	7.75	7.62
$P_{14\ HT}$	Fruit	5.40	5.40
	Vegetables	5.40	5.40
	Root Vegetables	4.74	4.74
	Livestock Feed	0.78	0.78
$P_{14\ HTO\text{-}OBT}$	Fruit	2.34	2.30
	Vegetables	2.34	2.30
	Root Vegetables	4.91	4.83
	Livestock Feed	20.34	19.99
$P_{14\ HT\text{-}OBT}$	Fruit	0.24	0.24
	Vegetables	0.24	0.24
	Root Vegetables	0.49	0.49
	Livestock Feed	2.05	2.05

All values reported in units of m^3 per kg

Table 6 - Transfer Parameters for Animal Food Products

Transfer Parameter	Animal Type	2016	2021
$P_{15\ HTO}$ (m^3 per kg)	Beef	0.86	0.85
	Milk	0.55	0.55
	Pork	0.92	0.91
	Poultry	1.94	1.91
	Eggs	1.94	1.91
$P_{15\ OBT}$ (m^3 per kg)	Beef	0.09	0.09
	Milk	0.02	0.02
	Pork	0.12	0.12
	Poultry	0.19	0.19
	Eggs	0.16	0.15
$P_{25\ HTO}$ (L per kg)	Beef	0.59	0.59
	Milk	0.80	0.80
	Pork	0.39	0.39
	Poultry	0.54	0.54
	Eggs	0.54	0.54
$P_{25\ OBT}$ (L per kg)	Beef	0.07	0.07
	Milk	0.03	0.03
	Pork	0.06	0.06
	Poultry	0.06	0.06
	Eggs	0.05	0.05
$P_{45\ HTO}$ (kg per kg)	Beef	0.474	0.474
	Milk	0.451	0.451
	Pork	0.452	0.452
	Poultry	0.683	0.683
	Eggs	0.688	0.688
$P_{45\ OBT}$ (kg per kg)	Beef	0.031	0.031
	Milk	0.006	0.006
	Pork	0.079	0.079
	Poultry	0.044	0.044
	Eggs	0.046	0.046

Table 7 - Human Dose Transfer Parameters

Transfer Parameter	Infant		10-yr old		Adult	
	2016	2021	2016	2021	2016	2021
$P(i)_{19\ HTO}$	2.18E-07	2.18E-07	2.94E-07	2.94E-07	2.52E-07	2.52E-07
$P(i)_{19\ HT}$	1.45E-11	1.45E-11	1.96E-11	1.96E-11	1.68E-11	1.68E-11
$P(i)_{29\ HTO}$ - generic	1.62E-08	1.62E-08	1.20E-08	1.20E-08	2.16E-08	2.16E-08
$P(e)_{29\ HTO}$ - generic	5.61E-11	5.61E-11	1.07E-10	1.07E-10	1.29E-10	1.29E-10
$P(i)_{29\ HTO}$ -site-specific	8.10E-11	8.10E-11	6.02E-11	6.02E-11	1.08E-10	1.08E-10
$P(e)_{29\ HTO}$ - site-specific	2.80E-13	2.80E-13	5.37E-13	5.37E-13	6.44E-13	6.44E-13
$P_{49\ HTO\ -\ Fruit}$	8.11E-10	8.11E-10	6.22E-10	6.22E-10	5.96E-10	5.96E-10
$P_{49\ HTO\ -\ Vegetables}$	4.78E-10	4.78E-10	6.10E-10	6.10E-10	9.61E-10	9.61E-10
$P_{49\ HTO\ –\ Root\ Veg.}$	1.60E-10	1.60E-10	2.70E-10	2.70E-10	3.59E-10	3.59E-10
$P_{49\ OBT\ -\ Fruit}$	1.99E-09	1.99E-09	1.57E-09	1.57E-09	1.37E-09	1.37E-09
$P_{49\ OBT\ -\ Vegetables}$	1.17E-09	1.17E-09	1.54E-09	1.54E-09	2.21E-09	2.21E-09
$P_{49\ OBT\ –\ Root\ Veg.}$	3.93E-10	3.93E-10	6.80E-10	6.80E-10	8.26E-10	8.26E-10
$P_{59\ HTO\ -\ Beef}$	1.69E-10	1.69E-10	2.36E-10	2.36E-10	6.53E-10	6.53E-10
$P_{59\ HTO\ -\ Dairy}$	1.80E-08	1.80E-08	7.99E-09	7.99E-09	3.77E-09	3.77E-09
$P_{59\ HTO\ -\ Pork}$	1.14E-10	1.14E-10	1.61E-10	1.61E-10	2.61E-10	2.61E-10
$P_{59\ HTO\ -\ Poultry}$	2.69E-10	2.69E-10	3.37E-10	3.37E-10	5.13E-10	5.13E-10
$P_{59\ HTO\ –\ Egg}$	6.97E-11	6.97E-11	1.24E-10	1.24E-10	2.53E-10	2.53E-10
$P_{59\ OBT\ -\ Beef}$	4.15E-10	4.15E-10	5.94E-10	5.94E-10	1.50E-09	1.50E-09
$P_{59\ OBT\ -\ Dairy}$	4.41E-08	4.41E-08	2.01E-08	2.01E-08	8.67E-09	8.67E-09
$P_{59\ OBT\ -\ Pork}$	2.80E-10	2.80E-10	4.06E-10	4.06E-10	6.01E-10	6.01E-10
$P_{59\ OBT\ -\ Poultry}$	6.60E-10	6.60E-10	8.48E-10	8.48E-10	1.18E-09	1.18E-09
$P_{59\ OBT\ –\ Egg}$	1.71E-10	1.71E-10	3.13E-10	3.13E-10	5.83E-10	5.83E-10

3.3 Full Expression of X9/X0

For the residential receptor group (infant, child, adult), all exposure to tritium in air (inhalation, immersion) occurs at the most exposed residential location (west-northwest). Exposure to well water (ingestion, immersion) also occurs at this residential location. Backyard garden produce grown at this residence accounts for 30% of the total intake of plant products. The remaining 70% of ingested plant products originates from Bouden's market. All animal products are obtained from Saar's Farm.

For the residential group, the full site-specific expression of X9/X0 for release of HTO to air is as follows:

X9/X0 =

***P*01(Res-WNW)** $\{P_{19} + P_{12}\, P(e)_{29} + P_{12}\, P(i)_{29} + 0.3 \cdot [P_{14\_HTO}$ (fruit) P_{49_HTO} (fruit) + $P_{14\_HTO\text{-}OBT}$ (fruit) P_{49_OBT} (fruit) + P_{14_HTO} (vegetables) P_{49_HTO} (vegetables) + $P_{14\_HTO\text{-}OBT}$ (vegetables) P_{49_OBT} (vegetables) + P_{14_HTO} (root vegetables) P_{49_HTO} (root vegetables) + $P_{14\_HTO\text{-}OBT}$ (root vegetables) P_{49_OBT} (root vegetables)]} +

***P*01(Bouden's)** · 0.7 · [P_{14_HTO} (fruit) P_{49_HTO} (fruit) + $P_{14\_HTO\text{-}OBT}$ (fruit) P_{49_OBT} (fruit) + P_{14_HTO} (vegetables) P_{49_HTO} (vegetables) + $P_{14\_HTO\text{-}OBT}$ (vegetables) P_{49_OBT} (vegetables) + P_{14_HTO} (root vegetables) P_{49_HTO} (root vegetables) + $P_{14\_HTO\text{-}OBT}$ (root vegetables) P_{49_OBT} (root vegetables)] +

***P*01(Saar's Farm)** [P_{15_HTO} (beef) P_{59_HTO} (beef) + P_{15_OBT} (beef) P_{59_OBT} (beef) + $P12$ P_{25_HTO} (beef) P_{59_HTO} (beef) + $P12$ P_{25_OBT} (beef) P_{59_OBT} (beef) + P_{14} (livestock feed) P_{45_HTO} (beef) P_{59_HTO} (beef) + $P14$ P_{45_OBT} (beef) P_{59_OBT} (beef) +

P_{15_HTO} (dairy) P_{59_HTO} (dairy) + P_{15_OBT} (dairy) P_{59_OBT} (dairy) + $P12$ P_{25_HTO} (dairy) P_{59_HTO} (dairy) + $P12$ P_{25_OBT} (dairy) P_{59_OBT} (dairy) + P_{14} (livestock feed) P_{45_HTO} (dairy) P_{59_HTO} (dairy) + P_{14} P_{45_OBT} (dairy) P_{59_OBT} (dairy) +

P_{15_HTO} (pork) P_{59_HTO} (pork) + P_{15_OBT} (pork) P_{59_OBT} (pork) + $P12$ P_{25_HTO} (pork) P_{59_HTO} (pork) + P_{12} P_{25_OBT} (pork) P_{59_OBT} (pork) + P_{14}(livestock feed) P_{45_HTO} (pork) P_{59_HTO} (pork) + P_{14} P_{45_OBT} (pork) P_{59_OBT} (pork) +

P_{15_HTO} (poultry) P_{59_HTO} (poultry) + P_{15_OBT} (poultry) P_{59_OBT} (poultry) + $P12$ P_{25_HTO} (poultry) P_{59_HTO} (poultry) + P_{12} P_{25_OBT} (poultry) P_{59_OBT} (poultry) + P_{14}(livestock feed) P_{45_HTO} (poultry) P_{59_HTO} (poultry) + P_{14} P_{45_OBT} (poultry) P_{59_OBT} (poultry) +

P_{15_HTO} (egg) P_{59_HTO} (egg) + P_{15_OBT} (egg) P_{59_OBT} (egg) + $P12$ P_{25_HTO} (egg) P_{59_HTO} (egg) + $P12$ P_{25_OBT} (egg) P_{59_OBT} (egg) + P_{14}(livestock feed) P_{45_HTO} (egg) P_{59_HTO} (egg) + P_{14} P_{45_OBT} (egg) P_{59_OBT} (egg)]

For the residential receptor group, the full site-specific expression of X9/X0 for release of HT to air is as follows:

X9/X0 =

P_{01}(Res-WNW) {P_{19_HT} + P_{11aHT_HTO} [P_{19_HTO} + P_{12} $P(e)_{29}$ + P_{12} $P(i)_{29}$]} +

P_{01}(Res-WNW) · 0.3 · [$P_{14\_HT\_HTO}$ (fruit) P_{49_HTO} (fruit) + $P_{14\_HT\_OBT}$ (fruit) P_{49_OBT} (fruit) + $P_{14\_HT\_HTO}$ (vegetables) P_{49_HTO} (vegetables) + $P_{14\_HT\_OBT}$ (vegetables) P_{49_OBT} (vegetables) + $P_{14\_HT\_HTO}$ (root vegetables) P_{49_HTO} (root vegetables) + $P_{14\_HT\_OBT}$ (root vegetables) P_{49_OBT} (root vegetables)] +

P_{01}(Bouden's) · 0.7 · [$P_{14\_HT\_HTO}$ (fruit) P_{49_HTO} (fruit) + $P_{14\_HT\_OBT}$ (fruit) P_{49_OBT} (fruit) + $P_{14\_HT\_HTO}$ (vegetables) P_{49_HTO} (vegetables) + $P_{14\_HT\_OBT}$ (vegetables) P_{49_OBT} (vegetables) + $P_{14\_HT\_HTO}$ (root vegetables) P_{49_HTO} (root vegetables) + $P_{14\_HT\_OBT}$ (root vegetables) P_{49_OBT} (root vegetables)] +

P_{01}(Saar's Farm) P_{11aHT_HTO} [P_{15_HTO} (beef) P_{59_HTO} (beef) + P_{15_OBT} (beef) P_{59_OBT} (beef) + P_{12} P_{25_HTO} (beef) P_{59_HTO} (beef) + P_{12} P_{25_OBT} (beef) P_{59_OBT} (beef) +

P_{15_HTO} (dairy) P_{59_HTO} (dairy) + P_{15_OBT} (dairy) P_{59_OBT} (dairy) + P_{12} P_{25_HTO} (dairy) P_{59_HTO} (dairy) + P_{12} P_{25_OBT} (dairy) P_{59_OBT} (dairy) +

P_{15_HTO} (pork) P_{59_HTO} (pork) + P_{15_OBT} (pork) P_{59_OBT} (pork) + P_{12} P_{25_HTO} (pork) P_{59_HTO} (pork) + P_{12} P_{25_OBT} (pork) P_{59_OBT} (pork) +

P_{15_HTO} (poultry) P_{59_HTO} (poultry) + P_{15_OBT} (poultry) P_{59_OBT} (poultry) + P_{12} P_{25_HTO} (poultry) P_{59_HTO} (poultry) + P_{12} P_{25_OBT} (poultry) P_{59_OBT} (poultry) +

P_{15_HTO} (egg) P_{59_HTO} (egg) + P_{15_OBT} (egg) P_{59_OBT} (egg) + P_{12} P_{25_HTO} (egg) P_{59_HTO} (egg) + P_{12} P_{25_OBT} (egg) P_{59_OBT} (egg)] +

P_{01}(Saar's Farm) [$P_{14\_HT\_HTO}$ (livestock feed) P_{45_HTO} (beef) P_{59_HTO} (beef) + $P_{14\_HT\_OBT}$(livestock feed) P_{45_OBT} (beef) P_{59_OBT} (beef) +

$P_{14\_HT\_HTO}$ (livestock feed) P_{45_HTO} (dairy) P_{59_HTO} (dairy) + $P_{14\_HT\_OBT}$ (livestock feed) P_{45_OBT} (dairy) P_{59_OBT} (dairy) +

$P_{14_HT_HTO}$_(livestock feed) P_{45_HTO} (pork) P_{59_HTO} (pork) + $P_{14\_HT\_OBT}$ (livestock feed) P_{45_OBT} (pork) P_{59_OBT} (pork) +

P14HT_HTO (livestock feed) P_{45_HTO} (poultry) P_{59_HTO} (poultry) + $P_{14\_HT\_OBT}$ (livestock feed) P_{45_OBT} (poultry) P_{59_OBT} (poultry) +

$P_{14\_HT\_HTO}$ (livestock feed) P_{45_HTO} (egg) P_{59_HTO} (egg) + $P_{14\_HT\_OBT}$ (livestock feed) P_{45_OBT} (egg) P_{59_OBT} (egg)]

For the worker receptor, exposure to tritium in air at the work place occurs for 2000 hours a year. Inhalation and immersion pathways are thus adjusted by a factor of 0.228. The value of P_{01} applied to exposure of the worker to air while at work is the highest of all potential worker groups considered in the initial identification of receptors (i.e., 5.26E-05 s/m^3, see Table 4). The balance of inhalation and air immersion exposure occurs at home, and factor of 0.772 is applied. The value of P_{01} applied to exposure of the worker while at home is the highest of all potential residential groups (i.e., 6.75E-06 s/m^3, see Table 4). This value of P_{01} is also applied to backyard garden produce, which constitutes 30% of the total intake of plant products. The other 70% of ingested plant products originates from Bouden's market. All animal products are obtained from Saar's Farm. The values of P_{19} are specific to the worker. For all other dose transfer parameters (P_{29}, P_{49}, P_{59}), the values for the residential adult are applied.

The full site-specific expression of X9/X0 for release of HTO to air is as follows:

X9/X0 =

P_{01}(work) P_{19}_HTO (worker) +

P_{01}(Res-WNW) · 0.772 · P_{19}_HTO (adult) +

P_{01}(Res-WNW) {P_{12} $P(e)_{29}$ + P_{12} $P(i)_{29}$ + 0.3 · [P_{14_HTO} (fruit) P_{49_HTO} (fruit) + $P_{14\_HTO-OBT}$ (fruit) P_{49_OBT} (fruit) + P_{14_HTO} (vegetables) P_{49_HTO} (vegetables) + $P_{14\_HTO-OBT}$ (vegetables) P_{49_OBT} (vegetables) + P_{14_HTO} (root vegetables) P_{49_HTO} (root vegetables) + $P_{14\_HTO-OBT}$ (root vegetables) P_{49_OBT} (root vegetables)]} +

P_{01}(Bouden's) · 0.7 · {P_{14_HTO} (fruit) P_{49_HTO} (fruit) + $P_{14\_HTO-OBT}$ (fruit) P_{49_OBT} (fruit) + P_{14_HTO} (vegetables) P_{49_HTO} (vegetables) + $P_{14\_HTO-OBT}$ (vegetables) P_{49_OBT} (vegetables) + P_{14_HTO} (root vegetables) P_{49_HTO} (root vegetables) + $P_{14\_HTO-OBT}$ (root vegetables) P_{49_OBT} (root vegetables)} +

P_{01}(Saar's Farm) {P_{15_HTO} (beef) P_{59_HTO} (beef) + P_{15_OBT} (beef) P_{59_OBT} (beef) + $P_{12\ P25\_HTO}$ (beef) P_{59_HTO} (beef) + $P_{12\ P25\_OBT}$ (beef) P_{59_OBT} (beef) + P_{14} (livestock feed) P_{45_HTO} (beef) P_{59_HTO} (beef) + $P_{14\ P45\_OBT}$ (beef) P_{59_OBT} (beef) +

P_{15_HTO} (dairy) P_{59_HTO} (dairy) + P_{15_OBT} (dairy) P_{59_OBT} (dairy) + P_{12} P_{25_HTO} (dairy) P_{59_HTO} (dairy) + $P_{12\ P25\_OBT}$ (dairy) P_{59_OBT} (dairy) + P_{14} (livestock feed) P_{45_HTO} (dairy) P_{59_HTO} (dairy) + $P_{14\ P45\_OBT}$ (dairy) P_{59_OBT} (dairy) +

P_{15_HTO} (pork) P_{59_HTO} (pork) + P_{15_OBT} (pork) P_{59_OBT} (pork) + $P_{12\ P25\_HTO}$ (pork) P_{59_HTO} (pork) + $P_{12\ P25\_OBT}$ (pork) P_{59_OBT} (pork) + P_{14} (livestock feed) P_{45_HTO} (pork) P_{59_HTO} (pork) + P_{14} P_{45_OBT} (pork) P_{59_OBT} (pork) +

P_{15_HTO} (poultry) P_{59_HTO} (poultry) + P_{15_OBT} (poultry) P_{59_OBT} (poultry) + $P_{12\ P25\_HTO}$ (poultry) P_{59_HTO} (poultry) + $P_{12\ P25\_OBT}$ (poultry) P_{59_OBT} (poultry) + P_{14} (livestock feed) P_{45_HTO} (poultry) P_{59_HTO} (poultry) + $P_{14\ P45\_OBT}$ (poultry) P_{59_OBT} (poultry) +

P_{15_HTO} (egg) P_{59_HTO} (egg) + P_{15_OBT} (egg) P_{59_OBT} (egg) + P_{12} P_{25_HTO} (egg) P_{59_HTO} (egg) + P_{12} P_{25_OBT} (egg) P_{59_OBT} (egg) + P_{14} (livestock feed) P_{45_HTO} (egg) P_{59_HTO} (egg) + $P_{14\ P45\_OBT}$ (egg) P_{59_OBT} (egg)}

The full site-specific expression of X9/X0 for the worker for release of HT is as follows:

X9/X0 =

$\boldsymbol{P}_{01}$**(work)** $[P_{19\_HT}$ (worker) $+ P_{11aHT\_HTO}\, P_{19\_HTO}$ (worker)] +

$\boldsymbol{P}_{01}$**(Res-WNW)** **[**P_{19_HT} (adult) $+ P_{11aHT\_HTO} \cdot 0.772 \cdot P_{19\_HTO}$ (adult)] +

$\boldsymbol{P}_{01}$**(Res-WNW)** P_{11aHT_HTO} **[**$P_{12}\, P(e)_{29} + P_{12}\, P(i)_{29}$] +

$\boldsymbol{P}_{01}$**(Res-WNW)** · 0.3 · [$P_{14\_HT\_HTO}$ (fruit) P_{49_HTO} (fruit) + $P_{14\_HT\_OBT}$ (fruit) P_{49_OBT} (fruit) + $P_{14\_HT\_HTO}$ (vegetables) P_{49_HTO} (vegetables) + $P_{14\_HT\_OBT}$ (vegetables) P_{49_OBT} (vegetables) + $P_{14\_HT\_HTO}$ (root vegetables) P_{49_HTO} (root vegetables) + $P_{14\_HT\_OBT}$ (root vegetables) P_{49_OBT} (root vegetables)] +

$\boldsymbol{P}_{\mathbf{01}}$**(Bouden's)** · 0.7 · [$P_{14\_HT\_HTO}$ (fruit) P_{49_HTO} (fruit) + $P_{14\_HT\_OBT}$ (fruit) P_{49_OBT} (fruit) + $P_{14\_HT\_HTO}$ (vegetables) P_{49_HTO} (vegetables) + $P_{14\_HT\_OBT}$ (vegetables) P_{49_OBT} (vegetables) + $P_{14\_HT\_HTO}$ (root vegetables) P_{49_HTO} (root vegetables) + $P_{14\_HT\_OBT}$ (root vegetables) P_{49_OBT} (root vegetables)] +

$\boldsymbol{P}_{\mathbf{01}}$**(Saar's Farm)** P_{11aHT_HTO} [P_{15_HTO} (beef) P_{59_HTO} (beef) + P_{15_OBT} (beef) P_{59_OBT} (beef) + $P_{\mathbf{12}}$ P_{25_HTO} (beef) P_{59_HTO} (beef) + $P_{\mathbf{12}}$ P_{25_OBT} (beef) P_{59_OBT} (beef) +

P_{15_HTO} (dairy) P_{59_HTO} (dairy) + P_{15_OBT} (dairy) P_{59_OBT} (dairy) + $P_{\mathbf{12}}$ P_{25_HTO} (dairy) P_{59_HTO} (dairy) + $P12$ P_{25_OBT} (dairy) P_{59_OBT} (dairy) +

P_{15_HTO} (pork) P_{59_HTO} (pork) + P_{15_OBT} (pork) P_{59_OBT} (pork) + $P_{\mathbf{12}}$ P_{25_HTO} (pork) P_{59_HTO} (pork) + $P_{\mathbf{12}}$ P_{25_OBT} (pork) P_{59_OBT} (pork) +

P_{15_HTO} (poultry) P_{59_HTO} (poultry) + P_{15_OBT} (poultry) P_{59_OBT} (poultry) + $P_{\mathbf{12}}$ P_{25_HTO} (poultry) P_{59_HTO} (poultry) + $P_{\mathbf{12}}$ P_{25_OBT} (poultry) P_{59_OBT} (poultry) +

P_{15_HTO} (egg) P_{59_HTO} (egg) + P_{15_OBT} (egg) P_{59_OBT} (egg) + $P12$ P_{25_HTO} (egg) P_{59_HTO} (egg) + $P_{\mathbf{12}}$ P_{25_OBT} (egg) P_{59_OBT} (egg)] +

$\boldsymbol{P}$**01(Saar's Farm)** [$P_{14\_HT\_HTO}$ (livestock feed) P_{45_HTO} (beef) P_{59_HTO} (beef) + $P_{14\_HT\_OBT}$(livestock feed) P_{45_OBT} (beef) P_{59_OBT} (beef) +

$P_{14\_HT\_HTO}$ (livestock feed) P_{45_HTO} (dairy) P_{59_HTO} (dairy) + $P_{14\_HT\_OBT}$ (livestock feed) P_{45_OBT} (dairy) P_{59_OBT} (dairy) +

$P_{14\_HT\_HTO\_}$(livestock feed) P_{45_HTO} (pork) P_{59_HTO} (pork) + $P_{14\_HT\_OBT}$ (livestock feed) P_{45_OBT} (pork) P_{59_OBT} (pork) +

$P_{\mathbf{14HT\_HTO}}$ (livestock feed) P_{45_HTO} (poultry) P_{59_HTO} (poultry) + $P_{14\_HT\_OBT}$ (livestock feed) P_{45_OBT} (poultry) P_{59_OBT} (poultry) +

$P_{14\_HT\_HTO}$ (livestock feed) P_{45_HTO} (egg) P_{59_HTO} (egg) + $P_{14\_HT\_OBT}$ (livestock feed) P_{45_OBT} (egg) P_{59_OBT} (egg)]

3.4 DRL Results

Based on the noted transfer parameters, the site-specific and generic DRLs for the SRBT facility are presented in Table 08 for HTO and in Table 09 for HT. These tables contrast the current DRLs to those reported most recently in 2016. Table 10 provides a summary of the relative contribution of relevant exposure pathways to the total dose rate of the worker and the 10-yr old child. These two representative persons are exposed to all relevant pathways and exhibit relatively high dose rates for the group of representative persons that have been considered.

Table 08 - Summary of SRBT DRLs for HTO

Representative Group Member	2021 DRL (GBq/wk)				2016 DRL (GBq/wk) (12-hr TJF data)	
	24-hr TJF Data		12-hr TJF Data			
	Generic	Site-Specific	Generic	Site-Specific	Generic	Site-Specific
1-yr Old	6.78E+04	2.30E+05	8.30E+04	2.90E+05	6.48E+04	2.24E+05
10 yr Old	7.96E+04	1.99E+05	9.67E+04	2.45E+05	7.39E+04	1.88E+05
Adult	5.67E+04	2.20E+05	6.83E+04	2.71E+05	5.13E+04	2.08E+05
Worker	4.41E+04	1.04E+05	4.95E+04	**1.08E+05**	7.77E+04	**1.63E+05**

Bold value represents the recommended DRL for formal adoption

Table 09 - Summary of SRBT DRLs for HT

Representative Group Member	2021 DRL (GBq/wk)				2016 DRL (GBq/wk) (12-hr TJF data)	
	24-hr TJF Data		12-hr TJF Data			
	Generic	Site-Specific	Generic	Site-Specific	Generic	Site-Specific
1-yr Old	2.30E+06	6.71E+06	2.89E+06	7.24E+06	2.45E+06	6.32E+06
10 yr Old	2.76E+06	7.62E+06	3.43E+06	6.83E+06	2.74E+06	5.61E+06
Adult	2.07E+06	6.98E+06	2.53E+06	6.90E+06	1.94E+06	**5.54E+06**
Worker	1.67E+06	5.01E+06	1.90E+06	**3.63E+06**	3.04E+06	5.69E+06

Bold value represents the recommended DRL for formal adoption

Table 10 - Pathway Contribution to Total HTO Dose

Representative Group Member	Site-Specific Scenario		Generic Scenario	
	Worker	10-yr old	Worker	10-yr old
Air inhalation	90.5%	70.4%	41.5%	20.1%
Water Ingestion	0.6%	1.19%	54.1%	68.0%
Water immersion	0.004%	0.004%	0.3%	0.2%
Plant Ingestion	7.5%	16.2%	2.7%	3.5%
Animal ingestion	1.4%	12.3%	1.4%	8.1%
Soil Ingestion	<0.001%	<0.001%	<0.1%	<0.1%

Based on 12-hr TJF data
Plant and animal ingestion dose includes OBT
Soil ingestion not included in DRL. Value estimated for comparative purposes only.

3.5 Recommendations

3.5.1 DRL Assignment

It is recommended that the site-specific DRLs be adopted for the SRBT facility, as they conservatively represent conditions that actually exist at present, notwithstanding the inclusion of a non-existent well at the residence of the representative person. It is also recommended that DRLs derived using the 12-hr TJF wind data be adopted, as these are most representative of actual emission occurrences at SRBT and also represent the higher degree of exposure for the worker (*i.e.*, the limiting case).. Further, validation efforts (see Appendix D) have shown that the use of 12-hr TJF data yields reasonably conservative estimates of tritium in air at distances of relevance to the representative groups.

Following these recommendations, the current limiting DRLs based on 12-hr wind data and site-specific attributes of representative persons are:

- **1.08E+05 GBq/wk for HTO**: approximately 34 percent lower than the 2016 DRL (1.63E+05 GBq/wk), and
- **3.63E+06 GBq/wk for HT**: approximately 34 percent lower than the 2016 DRL (5.54E+06 GBq/wk).

The noted decrease in DRL values relative to 2016 is driven by various changes affecting the atmospheric dispersion model, most notably wind direction frequencies, and also by conservative adjustments in model assumptions (i.e., assuming the worker is also subject to residential exposure levels equal to the *most exposed* residence rather than an *average* levels for all candidate residential locations).

3.5.2 Routine Updates

The current DRL revision has encompassed a number of updates of relevance to other activities undertaken by SRBT as part ongoing efforts to assess the fate of tritium emissions from their facility. Most notably, the processing of on-site meteorological data collected in recent years has resulted in the update of various parameters used in other assessment efforts. The following recommendations relate to changes of select parameter values in those other assessment efforts.

The empirical ratio of tritium in air to tritium in soil-water may be used at times to approximate levels of tritium in local groundwater supplies. Based on the latest data obtained from on-site monitoring, the current annual average value for this ratio (i.e., P_{12g}) is 45.5 m^3 per L, as applied in the DRL model. Air-to-groundwater transfer (P_{12g}) is only expected to occur during months when the ground is not frozen (i.e., April to November, inclusive). Considering only the period of April to November, the average value of P_{12g} becomes 40.5 m^3 per L. This latter value is more suitable for interpretation of site groundwater data. SRBT has also applied similar ratios generated on a monthly basis to analyze and interpret monitoring results. Table 11 provides revised monthly values.

SRBT also routinely assesses the effective stack height for facility emissions, based in part on the mean wind speed in the direction of the representative person. Based on meteorological data used in the 2016 DRL, the mean wind-speed blowing from SRBT towards the representative person (i.e., to the northwest) at the time was 2.44 m/s. Based on the latest on-site TJF wind data, the revised mean wind-speed of relevance (i.e., to the west-northwest) is 2.28 m/s.

3.5.3 Environmental Monitoring

The data made available through SRBT's current EMP allows for direct assessment of tritium in the environment along all relevant pathways. A pathways breakdown of public dose rates (see Table 10) shows that exposure to tritium in air (inhalation and skin absorption) contributes a significant percentage of total dose. If private wells are assumed as the residential water supply source, tritium in well water is equally important. The current EMP provides direct measures of tritium in air and water at multiple locations in relatively close proximity to SRBT, and thus provides measures of relevance to important public exposure pathways.

The available monitoring data also provide site-specific values for parameters of relevance to DRL calculations and the general predictive assessment of tritium fate and transport. Meteorological monitoring initiated at the SRBT facility in 2009 has provided site specific data for wind, temperature and humidity that have proven suitable for the purpose of DRL calculations.

Overall, SRBT's current monitoring efforts provide adequate data for DRL calculation, and no modifications are recommended at this time.

Table 11 – Revised Monthly Air-to-groundwater Transfer Parameters for SRBT

Year	Endpoint	Monthly Readings[1]											
		J	F	M	A	M	J	J	A	S	O	N	D
2016	Temp (C)	-7.9	-9.1	-14.9	NA	NA	NA	21.1	21.4	16.0	8.6	2.9	-5.7
	Dew Point (C)	-10.2	-12.3	-19.4	NA	NA	NA	15.7	16.1	12.1	5.2	0.4	-8.3
	RH (%)	83.9	78.1	69.3	NA	NA	NA	73.0	74.0	79.4	80.2	84.3	82.6
	Ha (g/m^3)	2.3	2.0	1.1	NA	NA	NA	13.1	13.5	10.6	6.8	4.9	2.7
2017	Temp (C)	-5.5	-5.4	-5.6	6.2	11.7	17.4	19.8	18.0	16.5	11.3	-0.3	-10.2
	Dew Point (C)	-8.0	-8.7	-11.1	1.3	6.9	12.4	15.0	14.0	13.0	7.5	-3.5	-13.3
	RH (%)	82.9	78.9	67.1	73.8	75.6	75.2	75.6	79.3	81.7	78.8	79.8	78.9
	Ha (g/m^3)	2.7	2.6	2.1	5.2	7.6	10.7	12.6	11.9	11.2	7.9	3.8	1.8
2018	Temp (C)	-10.6	-5.9	-2.4	1.9	14.8	17.6	22.3	21.0	15.7	6.1	-2.2	-6.9
	Dew Point (C)	-13.4	-9.3	-7.7	-4.7	6.1	11.4	15.6	16.7	12.3	2.5	-4.4	-8.9
	RH (%)	80.3	78.1	69.1	66.1	61.1	70.4	68.9	78.1	81.6	78.5	85.3	86.2
	Ha (g/m^3)	1.8	2.5	2.7	3.4	7.1	10.0	13.0	14.0	10.7	5.7	3.5	2.5
2019	Temp (C)	-13.3	-9.8	-4.1	3.9	10.5	16.9	22.2	19.2	14.5	8.1	14.5	-4.4
	Dew Point (C)	-16.3	-13.2	-9.6	-1.1	5.3	11.0	16.1	13.3	10.7	4.7	10.5	-6.7
	RH (%)	78.9	76.8	68.4	73.0	72.6	71.2	70.7	71.3	79.3	80.9	78.7	84.8
	Ha (g/m^3)	1.4	1.8	2.4	4.4	6.8	9.8	13.4	11.3	9.7	6.6	9.6	3.0
2020	Temp (C)	-6.9	-7.0	-0.3	4.2	12.1	18.5	23.1	18.4	13.8	6.7	3.7	-4.4
	Dew Point (C)	-9.2	-11.0	-5.2	-3.6	3.0	12.5	17.3	15.1	10.0	3.0	-0.1	-6.5
	RH (%)	84.0	74.5	72.0	60.9	58.8	71.1	72.5	82.4	79.2	78.5	77.6	85.3
	Ha (g/m^3)	2.5	2.2	3.3	3.7	5.8	10.8	14.5	12.7	9.2	5.9	4.7	3.0
5-yr Avg	*Temp (C)*	*-8.8*	*-6.8*	*-5.8*	*4.1*	*12.8*	*17.6*	*21.7*	*19.6*	*15.3*	*8.2*	*3.7*	*-6.3*
	Dew Point (C)	*-11.4*	*-10.3*	*-10.9*	*-2.3*	*5.4*	*11.8*	*15.9*	*15.0*	*11.6*	*4.6*	*0.6*	*-8.7*
	RH (%)	*82.0*	*77.4*	*69.4*	*66.9*	*65.1*	*72.0*	*72.2*	*77.0*	*80.2*	*79.4*	*81.1*	*83.6*
	Ha (g/m^3)	*2.1*	*2.3*	*2.3*	*4.1*	*6.8*	*10.3*	*13.3*	*12.7*	*10.3*	*6.6*	*5.3*	*2.6*
Derived P12g[2]		**139.8**	**131.3**	**129.6**	**73.3**	**44.0**	**29.0**	**22.5**	**23.7**	**29.2**	**45.7**	**56.5**	**115.0**

1 - based on hourly readings (24-hr) from onsite monitoring station.

2 - calculated using the equation P12G_HTO = 1,000 • RFsw ÷ Ha, where RFsw = 0.3 and Ha is in units of g/L

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FIGURES

APPENDICES

APPENDIX A: DETAILS AND BASIS OF DRL CALCULATIONS

A.1 General Considerations

The theory and equations used to calculate DRLs for the SRBT facility are based directly on the recommendations of the current DRL Guidance for nuclear facilities in Canada. This includes the DRL Guidance Document prepared for the CANDU Owners Group (COG, 2013), and the Canadian Standards Association (CSA) Standard N288.1 (2014). The COG DRL Guidance document was effectively the seed document for the CSA standard, and the two are highly consistent in the overall approach for quantifying transport, fate and dose impacts of tritium. The CSA Standard N288.1-14 is adopted as the explicit reference for specific technical aspects of the 2021 SRBT DRL calculations.

Following the DRL Guidance, the assessment of public exposure to radionuclide releases initially considers the fate and transport of relevant radionuclides in the environment following their release (to air or water), and subsequently considers exposure (internal or external) of humans to the radionuclides in the surrounding environment. Reasonable maximum exposure (RME) assumptions are appropriate for quantifying human intake and behavioural parameters. However, model parameters that determine environmental dispersion and partitioning of contaminants should be selected in a more realistic manner. This is primarily to preclude multiplicative compounding of conservatism when concentration, partitioning and intake parameters on the same exposure pathway are all given upper limit values. The degree of conservatism depends on the number of parameters involved.

The modelling exercise completed to estimate DRLs for the SRBT facility has followed the RME approach. Substantial but reasonable conservatisms have been maintained in characterizing human intake patterns and behaviours that are key factors in the magnitude of dose. Environmental fate and transport processes have also been modelled in a conservative manner, but not excessively conservative.

Following the DRL Guidance, SRBT's DRL calculations have incorporated site-specific data wherever possible and relevant. This Appendix specifies all instances of the use of site-specific data.

The SRBT DRL calculations have considered both generic and site-specific scenarios. The differentiation is based solely on the characteristics of the identified critical groups. Specifically, DRLs have been calculated for generic receptors using the default input fractions for all food intakes and also for domestic water supply. The site-specific scenario encompasses food and water intake fractions that have been derived from a survey of residents in the vicinity of the SRBT facility (see Appendix B, Table B2). Results for both scenarios are reported and discussed in the main body of the report. Distinction between generic and site-specific considerations is relevant only to the ingestion of food and water (pathways P_{29}, P_{49}, and P_{59}).

The representative members of the public considered in these DRL calculations include residential and worker groups. The age-class representation of the residential group primarily follows CSA N288.1-14, which recommends three age classes; 1) 0-5 yrs of age ("infant"), 2) 6-15 yrs (10-year old "child)", and 16-70 yrs ("adult").

For the period of current consideration (2016 to 2020), the residential representative person is located approximately 300 m to the WNW of the SRBT stacks. This location represents the residence with the highest degree of exposure to atmospheric releases from SRBT. This determination was based on initial applications of the atmospheric dispersion model (see Section A.2) to candidate residential locations in closest proximity to SRBT (see Appendix B).

The residential group members are subject to exposure to tritium as HT, HTO and OBT through exposure to the atmosphere, groundwater, and food ingestion (plant and animal products).

The worker group is represented as an "adult" (i.e, 16-70 years of age) and generally characterized in accordance with specifications for adults given in the DRL guidance. The location of exposure of the adult worker is the most exposed of the three candidate commercial locations in close proximity to SRBT (see Appendix B). The worker is characterized as spending 2000 hours per annum at the workplace, where inhalation is taken as the only significant exposure pathway. The worker is also assumed to reside within 2 km of SRBT, and is subject to the same set of exposures as is the residential group. The rate of exposure to atmospheric releases at the worker's residence is conservatively taken as the same exposure rate at the most exposed residential location. Appendix B provides further details with respect to the characterization of the worker receptor.

A.2 Atmospheric Dispersion (P_{01})

A.2.1 Sector-Averaged Gaussian Plume Model

The downwind concentration of radioactivity in air (X_1, Bq • m^{-3}) due to an atmospheric release at a rate $X_0(a)$ Bq • s^{-1} is given by:

$$X_1 = P_{01}\, X_0(a) \qquad [A.1]$$

where P_{01} (s • m^{-3}) is the transfer parameter from source to air at the receptor location.

Long-term average values of P_{01} resulting from a continuous release are calculated from the sector-averaged version of the Gaussian plume model, which assumes a laterally uniform concentration in each wind direction sector because of wind meander over prolonged release periods. The mathematical statement of the sector-averaged Gaussian plume model is:

$$(P_{01})_j = [(2/\pi)^{1/2} / (x\, \Delta\theta)] \sum_{i,k} [F_{ijk}\, D_k \exp(-H_{ik}^2 / 2\Sigma_{zi}^2) / (u_k\, \Sigma_{zi})]\,, \qquad [A.2]$$

where $(P_{01})_j$ is the ground-level transfer factor for receptor j (s • m^{-3}),
- x is the distance between the source and receptor j (m),
- $\Delta\theta$ is the width of the sector over which the plume spreads (radians),
- F_{ijk} is the triple joint frequency of occurrence of stability class i and wind speed class k when the wind blows toward receptor j,
- D_k is a factor that takes account of decay and ingrowth for wind speed class k,
- H_{ik} is the effective release height for stability class i and wind speed class k (m),

Σ_{zi} is the vertical dispersion parameter for stability class i, including spreading due to building wake effects (m), and

u_k is the mean wind speed for speed class k ($m \bullet s^{-1}$).

The summation in Equation [A.2] is taken over all atmospheric stability classes i (*i.e.*, Pasquill classes A to F) and wind speed intervals k.

The SRBT facility releases tritium to the atmosphere through two different stacks or vents, which are only separated by a distance of a few meters. Rather than modelling each stack individually, the two releases are combined into one virtual source located at the centre of that facility. The relevant characteristics of the stacks are presented in Table A.1.

Equation [A.2] makes no provision for depletion of the airborne plume due to deposition, reflection from elevated inversions (including the thermal internal boundary layer), fumigation, or complex topography. The omission of depletion processes is one contributing factor to the demonstrated conservatism of the model.

Table A.1: SRBT Stack Attributes for Atmospheric Dispersion Model

Parameter	Stack 1 (Bulk Stack)	Stack 2 (Rig Stack)	Average (both stacks)
Height of stack (m above ground)[1]	11.093	11.855	11.474
Inside diameter [1](m)[2]	0.3556	0.4572	0.4064
Nearby building height, h_b (m)	5	5	5
Exhaust Velocity[2] (m/s)	17.92	17.39	17.65
Exhaust Temp (°C)[3]	20	20	20
Annual average air temp (°C)[4]	20		

1 - Based on 2006 maintenance and inspection report

2 - Average velocities calculated from daily readings collected from 2016 to 2020 (see Appendix E).

3 - Assume exhaust temperature is equivalent to standard room temperature

4 – Assume air temperature is equal to gas temperature to negate thermal buoyancy effects

Effective Release Height

Stack gases emitted from the SRBT facility have a non-zero exit velocity and a density less than that of ambient air, due to gas temperature being higher than ambient air temperature over most of the year. Thus, the emitted gases will rise above the physical height of release due to excess momentum and buoyancy. The plume may also be entrained into the wake behind the stack (downwash) or behind adjacent buildings (entrainment) and pulled down below its physical height of release. The effective release height of the plume (H_{ik}, m) is determined by the net effect of these processes, as described by the following equation:

$$H_{ik} = h_s - (\Delta h_d)_k - (\Delta h_{en})_k + (\Delta h_{b,m})_{ik} \quad [A.3]$$

where: h_s is the physical height of the stack (m),
$(\Delta h_d)_k$ is the correction for downwash (m),
$(\Delta h_{en})_k$ is the correction for entrainment (m), and
$(\Delta h_b)_{ik}$ is the correction for plume rise due to buoyancy or momentum (m).

Downwash: When the release occurs from an isolated stack, some of the emitted material may be drawn downward into the low pressure region on the lee side of the stack. This effect occurs when the stack exit velocity, w_o, is less than or equal to 1.5 u, where u is the wind speed at stack height. In practice, Equation [A.2] is applied to each wind speed class in turn so that the mean wind speeds u_k for each class are used in the calculation and Δh_d depends on wind speed class. In this case, the release height is reduced by an amount:

$$(\Delta h_d)_k = 2\,(1.5 - w_o/u_k) \bullet D \qquad [A.4]$$

where D is the inside diameter of the stack (m). When $w_o > 1.5\,u_k$, $(\Delta h_d)_k = 0$.

The release height corrected for downwash is:

$$(h')_k = h_s - (\Delta h_d)_k \qquad [A.5]$$

where h_s is the physical height of the stack above the ground.

Building Entrainment: The plume may be drawn down into the aerodynamic cavity in the lee of any building located within three building heights of the stack, provided the building is upwind or downwind of the stack. The correction factor for entrainment, Δh_{en}, is applied after the correction factor for downwash (*i.e.*, Δh_{en} is subtracted from h′) and results in an effective release height of:

$$h'' = h' - \Delta h_{en}\,. \qquad [A.6]$$

The magnitude of Δh_{en} depends on the height of the stack relative to the height, h_b, of the building. If h′ from Equation [A.5] is greater than 2.5 h_b, the plume escapes the cavity, entrainment does not occur and $\Delta h_{en} = 0$. On the other hand, if $h' < h_b$, the plume is assumed to be fully entrained and $h'' = 0$. For intermediate cases, in which h′ lies between h_b and 2.5 h_b, the entrainment correction depends on wind speed. For speeds below a threshold value u_t, the wake is not developed, entrainment does not occur and $\Delta h_{en} = 0$. For speeds greater than u_t, the plume is partially entrained and:

$$\Delta h_{en} = 1.5\,h_b - 0.6\,h' \qquad [A.7]$$

A value of u_t of 2.5 $m \bullet s^{-1}$ is adopted for this application.

Plume Rise: The gases emitted from SRBT facility stacks have a typical exit velocity of approximately 18 $m \bullet s^{-1}$ (see Table A.1). The gas temperature has been previously reported as typically in the range of 25 – 30 ^{0}C (Canatom, 1996). For the purpose of the current DRL calculation, this value could not be confirmed and it has been assumed that stack gas temperature is equivalent to standard room temperature (20 ^{0}C). Under this assumption, buoyancy is likely to be negligible in summer but could still be important in non-summer periods.

The equations for the final height of rise of a buoyant plume depend on atmospheric stability and wind speed, as indicated below:

Unstable or neutral conditions: $\Delta h_{b,u,n} = 1.6\ F^{1/3}\ (3.5\ x^*)^{2/3} \bullet u^{-1}$. [A.8]

Stable conditions, $u > 1$ m s^{-1}: $\Delta h_{b,s} = 2.4\ [F / (u \bullet S)]^{1/3}$. [A.9]

Stable conditions, $u \leq 1$ m s^{-1}: $\Delta h_{b,c} = 5\ F^{1/4} \bullet S^{-3/8}$. [A.10]

The parameter F appearing in these equations is the buoyancy flux parameter ($m^4 \bullet s^{-3}$), defined as:

$$F = (T_g - T_a)\ g\ w_o\ (D/2)^2 / T_g\ , \quad [A.11]$$

where: T_g is the stack gas temperature (K),
T_a is the temperature of the ambient air (K),
g is the gravitational acceleration (9.8 m • s^{-2}), and
w_o is the exit velocity (m • s^{-1}),.

For model validation purposes (see Appendix D), average ambient air temperatures obtained from SRBT's on-site meteorological monitoring station were used in equation A.11. Ultimately, it was decided to exclude the effects of thermal buoyancy from the DRL model, achieved by setting T_a equal to T_g.

The parameter x^* is the distance (m) at which atmospheric turbulence begins to dominate the growth of the plume and is given by:

$$x^* = 14\ F^{5/8} \text{ when } F < 55\ m^4 \bullet s^{-3}\ , \text{ and}$$
$$x^* = 34\ F^{2/5} \text{ when } F > 55\ m^4 \bullet s^{-3}\ . \quad [A.12]$$

S is a stability parameter that gives the buoyant restoring acceleration per unit vertical displacement:

$$S = (g / T_a)\ (0.0098 + dT_a/dz)\ , \quad [A.13]$$

where z is the vertical coordinate. Since the vertical temperature gradient dT_a/dz is not measured routinely at the stations, S is assigned broadly applicable default values of 5 x 10^{-4} s^{-2} for class E conditions and 1.2 x 10^{-3} s^{-2} for class F.

Vertical Dispersion due to Atmospheric Turbulence: The methods for determining the vertical spread of a plume due to atmospheric turbulence have a semi-empirical basis. The dispersion parameters due to atmospheric turbulence, σ_{zi}, are functions of downwind distance, stability class and terrain roughness, z_o:

$$\sigma_{zi} = g_i \bullet (x) \bullet F(x, z_o)\ , \quad [A.14]$$

where $g_i(x) = a_1\ x^{b1}/(1 + a_2\ x^{b2})$

and $F(x, z_o) = \ln\{c_1\ x^{d1}\ [1 + (c_2\ x^{d2})^{-1}]\}$ when $z_o > 0.1$ m and
$F(x, z_o) = \ln\ \{ c_1\ x^{d1}\ /(1 + c_2\ x^{d2})\ \}$ when $z_o \leq 0.1$ m.

The parameters a_1, a_2, b_1 and b_2 depend on atmospheric stability class and are listed in Table A.2. Parameters c_1, c_2, d_1 and d_2 depend on z_o as shown in Table A.3, which also indicates the type of surface cover associated with different values of z_o. A value z_o = 0.4 m has been adopted for use in the calculation of DRLs for SRBT. This is appropriate for most wind direction sectors since the terrain in the vicinity of SRBT can be best characterized as "rural area or small villages". In those sectors where the terrain is wooded or under city-like conditions, the terrain is rougher and would be characterized by a larger z_o value. Use of z_o = 0.4 for these sectors is conservative since σ_{zi} is smaller than it would be with a larger z_o value, and the plume undergoes less dispersion and concentrations are higher.

Table A.2: Stability-dependent Parameters Used to Calculate Vertical Dispersion

Stability Class	a_1	b_1	a_2	b_2
A	0.112	1.060	5.38×10^{-4}	0.815
B	0.130	0.950	6.52×10^{-4}	0.750
C	0.112	0.920	9.05×10^{-4}	0.718
D	0.098	0.889	1.35×10^{-3}	0.688
E	0.0609	0.895	1.96×10^{-3}	0.684
F	0.0638	0.783	1.36×10^{-3}	0.672

Table A.3: Roughness-dependent Parameters Used to Calculate Vertical Dispersion

Roughness Length (m)	Representative Surface	c_1	d_1	c_2	d_2
0.01	Lawns, water bodies	1.56	0.048	6.25×10^{-4}	0.45
0.04	Ploughed land	2.02	0.0269	7.76×10^{-4}	0.37
0.1	Open grassland	2.72	0	0	0
0.4*	Rural areas, small villages	5.16	-0.098	18.6	-0.225
1.0	Forest, cities	7.37	-0.0957	4.29×10^{3}	-0.60
4.0	Cities with tall buildings	11.7	-0.128	4.59×10^{4}	-0.78

* used in the determination of DRLs for SRBT

The equations for σ_{zi} are based on experimental data obtained primarily at downwind distances less than 1 km and can be used with confidence at distances as close as 100 m from the source. The SRBT DRL calculations consider worker receptors that are within 100 m of the SRBT stacks. The atmospheric dispersion model has been subject to empirical validation for these and other locations to assure its applicability at such close proximity. See Appendix D for the details and results of validation.

Plume Broadening due to Building Wake Effects: If the plume is caught in the cavity downwind of the building, building-induced turbulence may enhance its vertical spread as well as reducing its effective release height. The magnitude of this effect depends strongly on the number and location of buildings in the vicinity of the source and on their orientation with respect to the wind and to each other. The modelling of this relies on a term representing the spread due to the building, which is added quadratically to the spread due to atmospheric turbulence. When the effective release height is less than h_b, the vertical dispersion parameter due to atmospheric turbulence, σ_{zi}, is modified to account for enhanced plume spreading due to building wake effects in the following way:

$$\Sigma_{zi} = (\sigma_{zi}^2 + C_b \bullet A_b \bullet \pi^{-1})^{1/2} = \sigma_{max} ,$$
[A.15]

where A_b is the cross-sectional area of the building affecting the plume and C_b is an empirical constant with a value lying between 0.5 and 2.0. A value $C_b = 1$ is adopted here. When $H \geq 2.5\ h_b$, the plume is unaffected by building-induced turbulence and $\Sigma_{zi} = \sigma_{zi}$. When $h_b \leq H < 2.5\ h_b$, Σ_{zi} is assumed to vary linearly between σ_{zi} and σ_{max}, according to:

$$\Sigma_{zi} = \sigma_{max} - (H - h_b)\ (\sigma_{max} - \sigma_{zi}) \bullet (1.5h_b)$$
[A.16]

The effect of the building on σ_{zi} is arbitrarily limited by the restriction that $\Sigma_{zi} < 3^{1/2}\ \sigma_{zi}$. If Σ_{zi} as calculated from Equation [A.14] or [A.13] exceeds $3^{1/2}\ \sigma_{zi}$, then Σ_{zi} is set equal to $3^{1/2}\ \sigma_{zi}$.

The cross-sectional area for use in Equation [A.15] was set at 381 m^2, the product of reported building length (76.2 m) and height (5 m) (Canatom, 1996).

Meteorological Data

The meteorological information required to implement Equation [A.2] (i.e., the joint frequency table F_{ijk} and mean wind speeds) should be based on site-specific measurements made on the meteorological towers at the site of interest, or the nearest off-site tower if site-specific data are not available. Data for the most recent 3 to 5 years should be used in the analysis. Ideally, all measurements should be hourly averages.

In 2009, a meteorological monitoring station was installed on the grounds of the SRBT facility. The station has been active since May 2009, providing continuous measures of wind speed and direction, temperature and humidity. Data from this station for the 5-year period of 01 January 2015 to 31 December 2020 have been used to prepare the joint-frequency (F_{ijk}) datasets used for the current DRL calculation. These datasets are presented and discussed in detail in Appendix C.

Sector Averaging

Some weather statistics, particularly the frequencies of occurrence of wind direction and atmospheric stability, can change substantially between adjacent compass sectors. This makes it difficult to assign appropriate statistics to a receptor that lies near a sector boundary. For SRBT DRL calculations, this is addressed by calculating P01 for the sector of interest and the nearest adjacent sector. An effective value of P01 for the receptor is then determined as follows:

$$P_{01eff} = [(11.25 + \varepsilon)\ PS1 + (11.25 - \varepsilon)\ PS2]\ /\ 22.5\ (s \bullet m^{-3}) \qquad [A.17]$$

Where:

- PS1 is the P_{01} value for the sector containing the receptor,
- PS2 is the P_{01} value for the adjacent sector, and
- the receptor lies an angular distance ε from the boundary of the two sectors.

In consideration of equations A.1 to A.17, excluding thermal buoyancy (Equations A.8 to A.11), and incorporating site-specific meteorological data representing the hours of operation of SRBT (*i.e.*, 7:00 to 19:00), the resulting values of P01 for the locations of interest to the DRL calculation are as follows:

- Representative Residence ~300 m WNW - P_{01} = 6.75 E-06 s/m^3
- Representative Worker ~60 m SE - P_{01} = 5.26 E-05 s/m^3
- Boudens market garden ~1900 m ESE - P_{01} = 1.42 E-06 s/m^3
- Saar dairy farm ~3500 m S - P_{01} = 4.47 E-07 s/m^3

A.2.2 Tritium Transformation from HT to HTO

HT imparts a very low radiological dose relative to HTO because it is taken up very slowly by body tissue and fluids. However, HT released to the atmosphere diffuses into soil pore spaces where it is oxidized to HTO by micro-organisms. Some of this HTO is taken up by plants through their roots with transpiration water and some is emitted to the atmosphere. This HTO is available for uptake by animals and humans through inhalation and ingestion. Doses from an atmospheric release of HT are therefore determined primarily by the behaviour of the HTO following its formation in soil. The HT model currently applied has special pathways for the transfer of HT in air (compartment 1) to HTO in air (compartment 1a) and for the transfer of HT in air to HTO in plants (compartment 4). The remainder of the HT model (formation of OBT, transfer to animals and humans) is the same as that for HTO.

Once HTO concentrations in air and plants are known following an HT release, the remainder of the HT model (transfer to animals and humans) is the same as that for HTO, and HT will not be addressed specifically hereafter in this document. There is no direct transfer of HT to plants, animals or water bodies and the inhalation pathway for HT can be ignored since it imparts a dose only 0.2% as large as that from re-emitted HTO.

The model describing the transfer of HT in air to HTO in air is described in this section. The computation of the pathway for HTO re-emitted to air is formulated as:

$$P_{11a} = R_{HT} \bullet H_a \bullet f_{oxid} \qquad [A.18]$$

where:
- P_{11a} = transfer parameter from HT in air to HTO in air (Bq • m^{-3}/(Bq • m^{-3})
- R_{HT} = ratio of HTO concentration in air moisture (Bq • L^{-1}) to HT concentration in air (Bq • m^{-3})
- f_{oxid} = fraction of year when oxidation may occur (unitless)
- H_a = absolute humidity (L • m^{-3})

The current CSA DRL Guidance recommends a default value of 4 for RHT (ratio of HTO concentration in air moisture to HT concentration in air) specifically for the Chalk River Lab (CRL) facility. The recommended default value is 8 for locations where soil type is different from the sandy loam soils reported for CRL. The available soil survey mapping (Gillespie et al., 1964) indicates that most of the residential area of Pembroke is occupied by sandy loam soils. It is thus justifiable to adopt a value of RHT appropriate for sandy loam soils (i.e., RHT = 4).

The absolute humidity, H_a, should be reflective of the period when the ground is not frozen or snow covered, and should be assigned a site-specific or regionally representative value for use in Equation [A.18]. For the model application to the SRBT facility, a value of 0.0087 L • m^{-3} was assigned, based on local humidity data measured at the SRBT facility for the period of 2016 to 2020 (see Appendix C).

The factor f_{oxid} is applied to the inhalation/skin absorption pathway for both animals and humans to allow for the decrease in HT oxidation and HTO reemission rates when the ground is frozen or snow covered. This is the estimated fraction of the year when soil is not frozen or snow covered and can be treated as a fixed value. The default value recommended in the DRL Guidance is 0.67 for eastern Ontario and Quebec. Site-specific data should be used if available. For the SRBT facility in Pembroke, the value of f_{oxid} was established in 2006 as 0.6, based on the frost-free period reported in the Environment Canada Climate Normal database, using Petawawa as the surrogate location. The on-site meteorological monitoring station at SRBT does not report the frost-free period. To be conservative (i.e., to achieve a higher value for P_{11a}), the default value of 0.67 has been adopted for this current DRL determination.

Based on the noted information (both generic and site-specific, where available) the value of transfer parameter P_{11a} becomes 0.0233. That is, just over 2% of HT released to atmosphere is converted to HTO in the DRL model currently applied to SRBT.

It is important to note that this model is based on the assumption that the soil surface is directly exposed to HT in the overlying air. In certain cases, this assumption may be grossly conservative, and the model will greatly over-estimate the extent to which HT is oxidized to HTO by soil micro-organisms. This would be the case where the receptor location was in close proximity to the release source and the plume was subject to elevation, or when the surrounding area was significantly developed and the ground surface was occupied by buildings, pavement or other impermeable surfaces. Urban or industrial developments greatly reduce the area of open ground surface, and thus reduce the transfer of HT in air to soil. Also, if a plume is subject to any elevation within short distances of release, the concentration of HT in air at the soil surface (i.e., at zero height) can be much lower than an average predicted HT concentration at a height of relevance to human exposure (1 – 2 m). The construct of the atmospheric dispersion model currently applied is such that predicted atmospheric concentrations of HT, used directly by the soil oxidation model in Eq. [A.18], are conservatively representative of conditions above the soil surface.

Occupancy Factors

The default value of f_o is taken to be 1, *i.e.*, the individuals in the critical group are assumed to spend 100% of their time at the exposure location. In the determination of DRLs for the SRBT Facility in Pembroke, there is no discrimination between time spent indoors and time spent outdoors. Inhalation dose is calculated assuming exposure to the outdoor air 100% of the time, regardless of being indoors or out. Outdoor occupancy is only a factor when considering external exposure pathways (e.g. groundshine, air immersion) and the capacity of building to provide shielding against such exposure. These pathways are not relevant to the determination of radiation exposure of tritium in the current model as applied to determine DRLs for the SRBT facility.

A.3 Deposition on Crops and Forage (P_{14})

A.3.1 Tritiated (^3H) Water (HTO)

Transfer of tritiated water (HTO) from air to plants is difficult to model because, among other characteristics, the transfer process is countercurrent to the normal direction of water transfer in plants. Water is normally drawn by plant roots from the soil and is transpired to the air by way of the stomates in the plant leaves. The HTO enters the plant from the air through the leaves because HTO follows its own concentration gradient, countercurrent to the transpiration stream. In general, the exchange between air and leaf is quite rapid so that HTO concentrations in plants can change hourly in response to changes in air moisture HTO concentrations.

The plant also receives HTO from the soil water by way of the transpiration stream, because soil water also takes up HTO from air. Soil water HTO concentrations are usually observed to be lower than air moisture HTO concentrations. This is because precipitation, which is the primary source of soil water (and soil tritium), does not always fall when the plume is present and, when it does, it has insufficient time to come into equilibrium with air moisture as it falls through a shallow plume near ground level.

Based on these concepts and using a specific activity approach, the transfer parameter from air HTO to HTO in the plant on a fresh weight basis, $P_{14\ HTO}$ ($m^3 \cdot kg^{-1}$), is given by:

$$P_{14\_HTO} = RF_p \cdot (1 - DW_p) / H_a \qquad [A.19]$$

where:
- RF_p = reduction factor that accounts for the effect of soil water HTO concentrations that are lower than air moisture HTO concentrations (unitless)
- DW_p = dry/fresh weight ratio for plant products (kg dry plant / kg fresh or stored plant)
- H_a = atmospheric absolute humidity ($L \cdot m^{-3}$)

The values of RF_p are empirical. The DRL Guidance recommends a default value of 0.68, which is the arithmetic mean of the empirical data reported in the literature. This default value has been assumed for this application for SRBT's DRL.

Median values of DW_p vary with crop. Values adopted herein to represent broader classifications are taken from the DRL Guidance (CSA, 2014 - Table G5), as follow:

Fruit and vegetables:	0.10	(value for generic fruit and vegetables)
Root Vegetables:	0.21	(value for potatoes)
Livestock Feed:	0.87	(value for generic feed crops)

The absolute humidity, H_a, should be site-specific, and in this instance should reflect conditions encountered during the growing season. Based on data collected at the SRBT site from 2016 to 2020 (Appendix C), the value appropriate for the growing season is 0.0116 $L \bullet m^{-3}$.

Based on this information, the values of the transfer parameter P_{14_HTO} for the purpose of calculating SRBT's DRLs are as follow:

Fruit and vegetables:	52.8	$m^3 \bullet kg^{-1}$
Root Vegetables:	46.3	$m^3 \bullet kg^{-1}$
Livestock Feed:	7.62	$m^3 \bullet kg^{-1}$

A.3.2 Elemental Tritium (HT)

As discussed in Section A.2.2, HT is oxidized to HTO by microorganisms in the soil. Some of the HTO so formed is taken up by plants through their roots with transpiration water and some is emitted to the atmosphere, where it can enter plants through their leaves.

The specific activity model used to predict HTO concentrations in plants can be applied to HT as well, with some modifications. Because the source of HTO for an HT release is in the soil, tritium concentrations in soil water are higher than those in plant water, which in turn are higher than those in air moisture. The reduction factor RF_p of HTO concentration in plant water to HTO concentration in air moisture is therefore different for an HT release than for an HTO release. Moreover, RF_p for an HT release is based on the HT concentration in air rather than on the HTO concentration.

The transfer parameter from air HT to HTO in the plant on a fresh weight basis, $P_{14\ HT}$ ($m^3 \bullet kg^{-1}$), is given by:

$$P_{14\_HT} = CF_{HT} \bullet (1 - DW_p) \qquad [A.20]$$

where: CF_{HT} = oxidation/re-emission/absorption factor for plants, equal to the ratio of HTO concentration in plant water to HT concentration in air ($Bq \bullet L^{-1}$ plant HTO per $Bq \bullet m^{-3}$ air HT)

DW_p = dry/fresh weight ratio for plant products (kg dry plant / kg fresh or stored plant) (see Section A.3.1)

The DRL Guidance reports that the best estimate for CF_{HT} is 6 Bq • L^{-1} HTO per Bq • m^{-3} HT (default value). This empirically derived value applies to all plant types since the data do not show any significant difference among leafy vegetables, tubers and fruit crops.

Based on this information, the values of the transfer parameter P_{14_HT} are as follows:

Fruit and Vegetables:	5.40	$m^3 \cdot kg^{-1}$
Root Vegetables:	4.74	$m^3 \cdot kg^{-1}$
Livestock Feed:	0.78	$m^3 \cdot kg^{-1}$

A.3.3 Organically Bound Tritium (OBT)

In addition to HTO in plant water, tritium is synthesized into plant organic structures to form OBT. Because the plant obtains the H used in synthesis from the plant water, it is reasonable to model the OBT by assuming a similar specific activity in organically bound H as in the plant water. It cannot be the same specific activity because isotopic discrimination is important for ^3H since ^3H is three times the mass of ^1H. This means that ^3H, the heavier atom, reacts more slowly than ^1H in all processes, including diffusion and chemical reactions, and that tritium activity in the organic phase (in terms of water equivalent) is less than activity in the aqueous phase.

Based on these concepts, the transfer parameter from air HTO to OBT in the plant on a fresh weight basis, $P_{14\ HTO\text{-}OBT}$ ($m^3 \cdot kg^{-1}$), is given by:

$$P_{14\_HTO\text{-}OBT} = RF_p \cdot DW_p \cdot ID_p \cdot WE_p / H_a \qquad [A.21]$$

where:
- RF_p = reduction factor that accounts for the effect of soil water HTO concentrations that are lower than air moisture HTO concentrations (unitless) (see Section A.3.1)
- DW_p = dry/fresh weight ratio for plant products (kg dry plant/kg fresh or stored plant (see Section A.3.1)
- ID_p = isotopic discrimination factor for plant metabolism (unitless)
- WE_p = is the water equivalent of the plant dry matter (L water / kg dry plant) or the water created after perfect combustion per kg plant dry matter
- H_a = atmospheric absolute humidity (L • m^{-3})

The transfer parameter from air HT to OBT in the plant on a fresh weight basis, $P_{14\_HT\text{-}OBT}$ ($m^3 \cdot kg^{-1}$), is given by:

$$P_{14\_HT\text{-}OBT} = CF_{HT} \cdot DW_p \cdot ID_p \cdot WE_p \qquad [A.22]$$

The DRL Guidance reports literature values for parameter ID_p range from 0.64 to 1.3, and. the arithmetic mean of the observed data is 0.7 (default value). The DRL Guidance recommends a default value of 0.56 for parameter WE_p , based on theoretical derivations pertaining to the complete combustion of plant materials.

The absolute humidity, H_a, is reflective of the growing season in this instance. It should be assigned a site-specific value, where available. The meteorological data obtained through on-site monitoring at SRBT indicate a value of 0.0116 L • m^{-3} (see Appendix C).

Once HTO concentrations in air and plants are known following an HT release, the remainder of the HT model (transfer to animals and humans) is the same as that for HTO, and HT will not be addressed specifically hereafter in this document. There is no direct transfer of HT to plants or animals.

Based on this information, the transfer parameter from air HTO to OBT in the plant on a fresh weight basis, $P_{14\ HTO\text{-}OBT}$, is as follows:

Fruit and vegetables:	2.34	$m^3 \bullet kg^{-1}$
Root Vegetables:	4.91	$m^3 \bullet kg^{-1}$
Livestock Feed	22.85	$m^3 \bullet kg^{-1}$

Similarly, the transfer parameter from air HT to OBT in the plant on a fresh weight basis, $P_{14\ HT\text{-}OBT}$, is as follows:

Fruit and vegetables:	0.27	$m^3 \bullet kg^{-1}$
Root Vegetables:	0.56	$m^3 \bullet kg^{-1}$
Livestock Feed:	2.34	$m^3 \bullet kg^{-1}$

A.4 Transfer from Atmosphere and Soil to Wells

A.4.1 Transfer from Soil to Groundwater Wells (P_{32w})

The general groundwater model for DRL calculations focuses on the human receptor using water taken from a well. It is assumed that the input to groundwater originates in the atmosphere and has been transferred from the soil zone to the groundwater via infiltration. Extensive study of the relationship between tritium release to air and groundwater in the vicinity of SRBT has been conducted. The study has confirmed this assumption (see discussion in Appendix D).

The radionuclide concentrations in the groundwater are derived from the concentrations in the infiltration water, adjusted only for the radioactive decay that may occur over the duration of travel from the point of initial entry to the groundwater system (as infiltration water) to the well intake zone. The application of this model in the determination of DRLs specifically for the SRBT Pembroke Facility conservatively assumes that all wells are shallow. Levels of tritium in the well water are not subject to any decay and are equivalent to those in the infiltration water. This is highly conservative representation of wells intended for use as a drinking water source. A review of available records describing residential wells in the vicinity of SRBT suggests an average well depth of >30 m (EcoMetrix, 2008).

A.4.2 Tritiated Water (HTO) Transfer to Soil Pore Water

Tritium in air will exchange with soil water, and the exchange may be limited by diffusion and mixing. The reduction in HTO concentration in soil water is difficult to predict, so empirical values are used.

The transfer from air to soil water, P_{1G_HTO} ($m^3 \cdot m^{-3}$, equivalent to unitless) is computed as:

$$P_{1G\_HTO} = 1{,}000 \cdot RF_{sw} \div H_a \quad [A.23]$$

where: RF_{sw} = the ratio of HTO concentration in soil water to that in air moisture ($Bq \cdot L^{-1}$ soil water per $Bq \cdot L^{-1}$ air moisture, equivalent to unitless)
H_a = atmospheric absolute humidity ($L \cdot m^{-3}$)

The few data available for RF_{sw} at Pickering and CRL are consistent with a best estimate of 0.3 (default value). The annual average absolute humidity, H_a, has been assigned a site-specific value of 0.0066 $L \cdot m^{-3}$ (see data in Appendix C). Thus, for the calculation of transfer of HTO in air to HTO in a shallow well as part of the SRBT DRL calculation:

$$P_{1G\_HTO} = 45{,}454\ m^3 \cdot m^{-3}\ \ (\text{or } 45.45\ m^3 \cdot L^{-1})$$

The wells at the critical group residence and at the dairy farm are characterized as shallows wells in the SRBT DRL calculation. The DRL Guidance does provide equations for the attenuation of tritium as result of radioactive decay during downward migration of groundwater to deeper well intake zones. To be conservative, these equations are not applied in the SRBT DRL calculation, even though the average depth of residential wells on record within 1 km of SRBT is about 30 m (see Appendix E).

A.4.3 Transfer from Air to Soil (P_{13})

Atmospheric tritium (as HT or HTO) is not anticipated to partition to soil solids in the same manner that many other radionuclides will partition. Following the specific activity concept any tritium that is transferred to the soil matrix will ultimately be in the form of tritiated water that occupies the pore space in the soil matrix. The subsequent transfer of tritium from soil to the food chain will be a function of specific activity equilibrium between plants and the soil porewater. In part for this reason, the direct partitioning of tritium to soil solids is not explicitly included in DRL calculations. The absence of explicit modelling of the P_{13} pathway for tritium also reflects the well-developed understanding that the dose rate associated with incidental soil ingestion by humans is negligible in contrast to total dose rates associated with an atmospheric release.

For purposes of roughly approximating HTO in soil, it can be conservatively assumed that the surface soil layer consists of 50% porewater on a mass basis. Thus, the P_{13} pathway can be assigned a value of half of transfer parameter P_{1G_HTO}, or 22.7 $m^3 \cdot kg^{-1}$ **(**fresh weight**)**. The application of this parameter in context of soil ingestion is discussed in Section A.15

A.5 Plant Uptake from Soil (P_{34})

For tritium, the transfer from soil is incorporated in the transfer from the air. Therefore, for ^3H:

$$P_{34\_HTO} = 0;\ P_{34\_HT} = 0;\ P_{34\_OBT} = 0.$$

A.6 Transfer to Crops by Spray Irrigation (P_{24})

Plants may be exposed to HTO in irrigation water, and this may occur in settings where the air is only minimally contaminated with ^3H, such as in instances when there is a release to a water body that serves as the source of irrigation water, but there is no significant release to air. In the case of SRBT, the primary release is to air, and the presence of tritium in well water that may be used as irrigation water is driven by the airborne tritium. Under the specific activity approach, only the tritium in air need be considered.

$$P_{24\_HTO} = 0$$

A.7 Transfer from Vegetation to Animal Produce (P_{45})

A.7.1 Tritiated (^3H) Water (HTO)

The transfer of HTO from feed to animals, P45_HTO (unitless), is modelled in the same way as the transfer from drinking water to animals. It is assumed that the specific activity of tritium in the portion of the water of the animal food product (meat, milk, or eggs) derived from feed is the same as that in the water available in the plant feed materials. Animals take in some water with the aqueous portion of their feed and derive another fraction from the metabolic decomposition of the organic matter in the feed. Accordingly, the HTO transfer from feed to animals is calculated as

$$P_{45\_HTO} = k_{af} \bullet ((1 - f_{OBT}) \bullet f_{w\_pw} + 0.5 \bullet f_{w\_dw}) \bullet (1 - DW_a)/(1 - DW_p) \quad [A.24]$$

where:
- k_{af} = fraction of feed from contaminated sources (unitless)
- $f_{w\ pw}$ = is the fraction of the animal water intake derived from water in the plant feed (unitless)
- f_{OBT} = fraction of total tritium in the animal product in the form of OBT as a result of HTO ingestion (unitless)
- f_{w_dw} = is the fraction of the animal water intake that results from the metabolic decomposition of the organic matter in the feed (unitless)
- $(1 - DW_a)$ = water content of the animal food product (meat, milk or egg) (L water per kg fresh weight of animal product)
- $(1 - DW_p)$ = water content of plant (L water / kg fresh or stored plant) (see Section A.3.1)

The fraction of animal water intake that is ingested as plant water, f_{w_pw}, and as metabolic water from oxidative metabolism of plant dry matter, f_{w_dw}, depends on the type of feed ingested. Their values are constrained by the requirement that $f_{w\_w} + f_{w\_pw} + f_{w\_dw} + f_{w\_sw} = 1$, and f_{w_sw} is very small. The recommended values are in Table A.5.

Table A.5: Parameter Values for Relevant Attributes of Animal Food Products

Parameter	Beef	Milk	Poultry	Eggs	Pork
Fraction of feed from local sources (K_{af})	1	1	1	1	1
Fraction of water from local sources (K_{aw})	1	1	1	1	1
Fraction of water from decomposition (fw-dw)	0.071	0.062	0.171	0.171	0.16
Fraction of water from drinking (f_{w-w})	0.413	0.495	0.765	0.785	0.785
Fraction of the animal water intake derived from inhalation and skin absorption	0.008	0.004	0.018	0.018	0.012
Water in food product per unit fresh weight (FW_a) (L per fresh kg)	0.7	0.9	0.7	0.7	0.5
Dry matter in food product per unit fresh weight (DW_a)(kg dry per kg fresh)	0.3	0.1	0.3	0.3	0.5
Water equivalent of dry matter, after perfect combustion (WE_a) (L per dry kg)	0.8	0.67	0.8	0.84	0.9
Dry matter in food product per unit fresh weight of plant feed (DW_p)(kg dry per kg fresh)	0.87	0.87	0.87	0.87	0.87
Water equivalent of dry matter in plant feed, after perfect combustion (WE_p) (L per dry kg)	0.56	0.56	0.56	0.56	0.56
fraction of total tritium in the animal product in the form of OBT as a result of HTO ingestion through feed (f_{OBT}) (unitless)	0.11	0.04	0.1	0.08	0.13
OBT/HTO ratio in the animal as a result of HTO ingestion through water (f'_{OBT}) (unitless)	0.12	0.042	0.11	0.087	0.15

The fraction of feed and water from contaminated sources, k_{af} and k_{aw}, is specific to the livestock operation for domestic animals. Purchase of feed supplements is very common, and there is active trade in bulk feed particularly to compensate for variations in crop yield and animal numbers year to year. The supply of livestock drinking water may originate from on-site wells (shallow or deep), or piped municipal service. Parameters k_{af} and k_{aw} should be specified on a site-specific basis. In absence of such site-specific data, a value of unity (1) has been used as a conservative default for both parameters in the calculation of SRBT's DRLs.

A.7.2 Organically Bound Tritium (OBT)

Some of the OBT in animal products arises from the direct incorporation of plant OBT following ingestion of the dry matter portion of the feed. About half the plant OBT taken into the body remains as OBT, with the rest converted to HTO. Animals derive another fraction, f_{OBT}, from the conversion of plant HTO to OBT in the body following ingestion. The transfer from plant to animal is written in terms of the OBT concentration in the plant. The transfer parameter from OBT activity in plants to OBT activity in the animal on a fresh weight basis, $P_{45\ OBT}$ (unitless), is therefore given by:

$$P_{45\_OBT} = k_{af} \bullet (f_{OBT} \bullet f_{w\_pw} + 0.5 \bullet f_{w\_dw}) \bullet DW_a \bullet WE_a / (DW_p \bullet WE_p) \qquad [A.25]$$

where: k_{af} = fraction of feed from contaminated sources (unitless)
f_{OBT} = fraction of total tritium in the animal product in the form of OBT as a result of HTO ingestion (unitless)
f_{w_pw} = is the fraction of the animal water intake derived from water in the plant feed (unitless)
f_{w_dw} = is the fraction of the animal water intake that results from the metabolic decomposition of the organic matter in the feed (unitless)
DW_a = dry matter in the animal food product (meat, milk or egg) per total fresh weight of the animal food product (kg dry • per kg fresh weight)
WE_a = is the water equivalent of the animal product dry matter (L water/ kg dry weight product) or the water created after perfect combustion per kg dry product
DW_p = dry/fresh weight ratio for plant products (kg dry plant / kg fresh or stored plant) (see Section A.3.1)
WE_p = is the water equivalent of the plant dry matter (L water/kg plant) (see Section A.3.3)

The application of this model for SRBT DRL calculation assumes 100% of livestock feed is grown on site at a nearby farm, and also that 100% of the livestock water source is obtained from an on-farm shallow well.

Using the parameter values noted herein, the values for the transfer of HTO from plants (generic feed crops) to animal produce (unitless) are presented in Table A.6.

Table A.6: Plant Ingestion Transfer Parameters for Animal Produce

Transfer Parameter	Beef	Milk	Poultry	Eggs	Pork
$P_{45\ HTO}$	0.474	0.451	0.683	0.688	0.452
P_{45_OBT}	0.031	0.006	0.044	0.046	0.079

A.8 Transfer from Soil to Animal Produce (P_{35})

The contribution of tritium from soil ingestion is negligible and is at least partially incorporated in the specific activity approach defined for the other pathways. Therefore:

$P_{35\_HTO} = 0$; $P_{35\_HT} = 0$; $P_{35\_OBT} = 0$

A.9 Transfer from Air to Animal Produce (P_{15})

The transfer of HTO from air to animals, P15 HTO (m3 kg^{-1} fw), is modeled in the DRL Guidance (CSA, 2014) in the same way as transfer from drinking water and plants to animals. It is assumed that the specific activity of tritium in the portion of the water of the animal product (meat, milk or eggs) derived from inhalation is the same as that in air moisture. Accordingly, the HTO transfer from air to animals is:

$$P15\ HTO = (fw\_sw) \cdot (1 - DWa) / Ha \quad [A.26]$$

where:

fw_sw = fraction of the animal water intake derived from inhalation and skin absorption

DWa = dry weight of the animal food product per total fresh weight of the animal food product (kg dw per kg fw)

Ha = atmospheric absolute humidity ($L \cdot m^{-3}$)

The specific-activity transfer of HTO from environment to animal produce is dominated by the ingestion of food and water. Combined, these routes of uptake account for about 98% of the total water found in animal products (meats, dairy products, eggs). Only about 2% of the total water amount originates through inhalation and skin absorption. Thus, only 2% of the tritium would originate directly from atmosphere. Values for parameters fw_sw and DW_a have been provided in Table A.5. Based on data collected at the SRBT site (see Appendix C), the value appropriate for annual average humidity is 0.0066 $L \cdot m^{-3}$. Table A.7 presents the derived values of P_{15_HTO} (m^3 per kg fw) applied in the SRBT DRL calculation.

Table A.7: Inhalation Transfer Parameters for Animal Produce

Transfer Parameter	Beef	Milk	Poultry	Eggs	Pork
$P_{15\ HTO}$	0.85	0.55	1.91	1.91	0.91
$P_{15\ OBT}$	0.09	0.02	0.19	0.15	0.12

A.10 Transfer from Well Water to Animal Produce (P_{25})

A.10.1 Tritiated (^3H) Water (HTO)

The transfer of HTO to the animal by way of ingestion of water, $P_{25\ HTO}$ ($L\ kg^{-1}$), assumes that the specific activity of ^3H in a portion of the water of the animal food product (meat, milk or egg) is the same as that in the water ingested as water. The portion of water with the same specific activity is that portion of the animal's water intake derived from direct water ingestion (as opposed to water ingested with feed). The equation for this is:

$$P_{25\ HTO} = k_{aw} \cdot f_{w\_w} \cdot (1 - DW_a) \quad [A.27]$$

where:

k_{aw} = fraction of water from contaminated sources (unitless) (see Section A.7)

f_{w_w} = is the fraction of the animal water intake derived from direct ingestion of water (unitless)

DW_a = dry/fresh weight ratio for animal food product (meat, milk or egg) (L kg dry weight per kg fresh weight)

The fraction of animal water intake that is ingested as liquid water, f_{w_w}, depends on the type of feed ingested. When animals ingest dry feed, such as poultry and pigs in modern indoor production, there is little aqueous water in the feed. There is metabolic water in the feed, the amount of water released during oxidative metabolism. The remainder of the animal water requirements are met by direct ingestion of liquid water. In contrast, animals on pasture and feral animals will ingest some water as aqueous water in their feed and so have less need to ingest liquid water directly. For animals fed dry feed, $f_{w\_w} = 0.8$ and for animals fed some portion of their diet as fresh feed, f_{w_w} is in the range of 0.3 to 0.5. Both livestock and wild animals ingest relatively dry feed in winter. Values of f_{w_w} are constrained by the requirement that $f_{w\_w} + f_{w\_pw} + f_{w\_dw} + f_{w\_sw} = 1$. Furthermore, these values do not vary appreciably and so can be considered constants.

The dry/fresh weight ratio DW_a varies from 0.1 for milk to as low as 0.5 for pork. For eggs, poultry meat and beef the value of DW_a is 0.3. Values of FW_a are constrained by the requirement that $FW_a + DW_a = 1$ (DW_a is defined in Section A.7.2).

Values of all the relevant parameters for various animal food products have been shown in Table A.5.

A.10.2 Organically Bound Tritium (OBT)

Metabolic processes result in the formation of a small amount of OBT in animals following ingestion of water contaminated with HTO. Estimates of this amount are available from a model developed by Galeriu et al. (2007) in the form of a parameter f_{OBT}, defined as the fraction of total tritium in the animal product in the form of OBT as a result of HTO ingestion. A related parameter, $f'_{OBT} = fOBT / (1 - f_{OBT})$ gives the fraction of the HTO concentration in the animal product in the form of OBT (the OBT/HTO ratio). The transfer parameter from HTO concentration in water to OBT concentration in the animal on a fresh weight basis, $P_{25\ OBT}$ (L kg^{-1}), is therefore given by:

$$P_{25\ OBT} = P_{25\ HTO} \bullet f'_{OBT} \qquad [A.28]$$

where: f'_{OBT} = OBT/HTO ratio in the animal as a result of HTO ingestion (unitless)

Values for parameter f'_{OBT} are provided in Table 17 of the CSA DRL Guidance (*i.e.*, 0.042 for cow milk, 0.12 for beef, 0.15 for pork, 0.11 for poultry, and 0.087 for eggs).

Using the parameter values recommended herein (See Table A.5), the transfer parameters used to determine the uptake of tritium from water into animal products is as follows:

Table A.8: Water Ingestion Transfer Parameters for Animal Produce

Transfer Parameter	Beef	Milk	Poultry	Eggs	Pork
$P_{25\ HTO}$	0.59	0.80	0.54	0.54	0.39
$P_{25\ OBT}$	0.07	0.03	0.06	0.05	0.06

A.11 Transfer from Atmosphere to Humans ($P(i)_{19}$)

The transfer parameter $P(i)_{19}$ relates the dose from inhalation of radioactive material (Sv·• a^{-1}) to the concentration in air (Bq·• m^{-3}). It is given by:

$$P(i)_{19} = I \bullet (DCF)_i \bullet 1.5 \bullet (OF)_i \qquad [A.29]$$

where:
- I = inhalation rate ($m^3 \bullet a^{-1}$)
- $(DCF)_i$ = dose coefficient for inhalation ($Sv \bullet Bq^{-1}$)
- $(OF)_i$ = occupancy factor, or fraction of time an individual is exposed to the inhalation hazard.

In the absence of site-specific survey data, the default value of $(OF)_i$ is 1. Conservative inhalation rates and dose coefficients $(DCF)_i$ are given in Table A.10, along with other human attributes relevant to the assessment of tritium dose for the SRBT facility. The factor of 1.5 is applied to account for the absorption of atmospheric HTO through the skin (see discussion below). The inhalation rates used herein (Table 10) for non-worker receptors are 95th percentile values taken from the current DRL Guidance (CSA N288.1-14, Table 19). Parameters from the ICRP Respiratory Tract Model (ICRP 66) have been used to conservatively quantify inhalation exposure of workers considered in the SRBT DRL calculation. This includes an inhalation rate of 1.2 m^3 per hour (10,512 m^3 per annum) and a working duration of 2000 hrs per annum (*i.e.*, OF = 0.228). This inhalation rate only applies during the time spent at work, and the default value for adults (i.e., 8,400 m^3/a) is applied during the time that the worker spends at home.

Absorption of HTO Through the Skin

Tritiated water vapour (HTO) can also enter the body by absorption through the skin. Available studies indicate that the amount of tritium entering the body by inhalation is approximately equal to the amount entering by skin absorption. In this application, the amount of HTO entering the body by skin absorption is assumed to be equal to approximately 50% of the amount of water entering by inhalation, as per CSA Guidance. The external exposure to tritium as HTO is handled implicitly as part of the inhalation pathway, simply by applying a factor of 1.5 in equation A.29.

The values of transfer parameter $P(i)_{19}$ developed for the SRBT DRL calculation are presented in Table A.9.

Table A.9: Transfer Parameter Values - Inhalation Dose

Transfer Parameter	Infant (1-2 yr)	10-yr old	Adult	Worker
$P(i)_{19\ HTO}$	2.18E-07	2.94E-07	2.52E-07	7.20E-08
$P(i)_{19\ HT}$	1.45E-11	1.96E-11	1.68E-11	4.80E-12

The inhalation dose associated with HT is usually very small relative to the dose associated with the HTO generated through HT oxidation (see Section A.2.2). The HT inhalation dose can be ignored in the DRL calculation. For the SRBT DRL calculations, the HT inhalation dose is nonetheless included.

Table A.10: Parameter Values for Select Human Attributes

Parameter	Resident			Adult Worker[1]
	Infant	Child	Adult (male)	
Inhalation rate (m^3 per annum)	2740	7850	8400	10512
Inhalation occupancy factor	1	1	1	0.228
Water occupancy factor	0.014	0.028	0.028	NA
Skin area (m^2)	0.72	1.46	2.19	2.19
Dose Conversion Factors (Sv per Bq):				
Inhalation - HT	5.30E-15	2.50E-15	2.00E-15	2.00E-15
Inhalation – HTO[2]	5.30E-11	2.50E-11	2.00E-11	2.00E-11
Ingestion - HTO	5.30E-11	2.50E-11	2.00E-11	NA
Ingestion - OBT	1.30E-10	6.30E-11	4.60E-11	NA

All values are conservative default values, obtained from DRL Guidance, unless stated otherwise
1 The adult worker is assumed to be exposed only to tritium in air at the workplace for 2000 hrs/year. The default Adult inhalation rate applies during the time when the worker is at home.
2 The DCFs for HTO inhalation presented here differ from those in Table C.1 of CSA N288.1-14. The latter have been multiplied by a factor of 1.5 to account for skin absorption

A.12 Human Intake of Plant or Animal Products

A.12.1 Human Diet

Human diet is complex. Dietary constituents and their relative abundance in the diet of any individual may depend on many factors, including age, gender, child-bearing status, work being done and temperature. Beyond such physiological determinants, there are also strong personal preferences, such as vegetarianism. There is also wide variability in the proportion of diet derived from local sources. The diet of one individual can be composed of markedly different amounts and types of various categories of food. In recognizing this variability, age-specific intake rates have been established to represent reasonable upper bounds of the rate of consumption of particular food types.

The proportion of these food products derived locally should be based on site-specific surveys, if possible. Partial results of a survey initiated to ascertain patterns of local food consumption by members of the public residing near the SRBT facility were available for consideration in this model application. The results of this survey are provided in Appendix E of this DRL Report. The food and water intake rates and proportions of which are obtained from local sources (generically and site-specific) are shown in Table A.11.

Table A.11: Details of Human Food and Water Intakes

Intake type	Default conservative intake (kg/a)[1]			Home-grown fraction	
	Infant	Child	Adult	Generic	Site-specific[2]
Water[3]	305.5	481.8	1080.4	1	0.005
Beef[4]	7.3	21.4	74.2	0.44	0.34
Pork	4.9	14.6	29.7	0.44	0.24
Poultry	11.5	30.6	58.3	0.44	0.18
Egg	3.0	11.3	28.8	0.44	0.09
Milk/Dairy	340	319	188	1	0.43
Total Animal Products	366	397	379		
Fruit	76.5	124.3	149.1	0.2	0.29
Above-ground vegetables	36.1	97.6	192.2	0.25	0.29
Root vegetables	12.1	43.2	71.8	0.25	0.29
Total Plant Products	124.7	265.1	413.1		

1 - all food intake rates (fresh weight basis) are expressed in units of kg/a, taken from Table G9c of CSA, 2014, converted from the reported units of g/d (i.e., x 365 and ÷ 1000)
2 - based on available responses to SRBT site survey (see Appendix E)
3 - water intake rates are 95th percentile values, taken from Table 21 of CSA, 2014
4 - total beef intake includes offal and veal

A.12.2 Internal Dose

The internal dose from ingestion of food (plant and animal products) is computed as the product of the intake rate and the internal dose coefficient (see Table A.8). These intakes should be adjusted for the fraction that is from a contaminated source, and for any contaminant removal processes. The general equations for internal dose arising from these intakes are:

$$P_{49} = \rho_f \bullet g_f \bullet I_f \bullet (DCF)_f \quad Sv \bullet a^{-1} \bullet Bq^{-1} \bullet kg \qquad [A.28]$$

$$P_{59} = \rho_f \bullet g_f \bullet I_f \bullet (DCF)_f \quad Sv \bullet a^{-1} \bullet Bq^{-1} \bullet kg \qquad [A.29]$$

where:
- $(DCF)_f$ = dose coefficient for intake by ingestion ($Sv \bullet Bq^{-1}$)
- ρ_f = "removal" factor for food processing - note contaminant concentrations can be increased or reduced by processing
- g_f = fraction of plant or animal produce from contaminated source
- I_f = intake of plant or animal produce ($kg \bullet a^{-1}$)

Where critical group diets have not been specifically characterized, conservative default values of food intake are recommended. The conservative default value of 1 for the removal fraction (ρ_f) has been assumed in this application.

For plant produce, the intake fractions for SRBT critical groups are 0.3 (i.e. 30%) for backyard gardens and 0.7 (70%) for Bouden's market garden.

The food ingestion transfer parameters (P_{49} and P_{49}) applied in the SRBT DRL calculation are presented in Tables A.12 to A.19.

Table A.12: Generic Ingestion Transfer Parameters – HTO in Plant Products

Transfer Parameter	Infant	Child	Adult
P_{49} HTO - Fruit	8.11E-10	6.22E-10	5.96E-10
P_{49} HTO - Vegetables	4.78E-10	6.10E-10	9.61E-10
P_{49} HTO – Root Vegetables	1.60E-10	2.70E-10	3.59E-10

Table A.13: Site-specific Ingestion Transfer Parameters – HTO in Plant Products

Transfer Parameter	Infant	Child	Adult
P_{49} HTO - Fruit	1.18E-09	9.01E-10	8.65E-10
P_{49} HTO - Vegetables	5.55E-10	7.08E-10	1.11E-09
P_{49} HTO – Root Vegetables	1.86E-10	3.13E-10	4.16E-10

Table A.14: Generic Ingestion Transfer Parameters – OBT in Plant Products

Transfer Parameter	Infant	Child	Adult
P_{49} OBT - Fruit	1.99E-09	1.57E-09	1.37E-09
P_{49} OBT - Vegetables	1.17E-09	1.54E-09	2.21E-09
P_{49} OBT – Root Vegetables	3.93E-10	6.80E-10	8.26E-10

Table A.15: Site-specific Ingestion Transfer Parameters – OBT in Plant Products

Transfer Parameter	Infant	Child	Adult
P_{49} OBT - Fruit	2.88E-09	2.27E-09	1.99E-09
P_{49} OBT - Vegetables	1.36E-09	1.78E-09	2.56E-09
P_{49} OBT – Root Vegetables	4.56E-10	7.89E-10	9.58E-10

Table A.16: Generic Ingestion Transfer Parameters – HTO in Animal Products

Transfer Parameter	Infant	Child	Adult
$P_{59\ HTO - Beef}$	1.69E-10	2.36E-10	6.53E-10
$P_{59\ HTO - Dairy}$	1.80E-08	7.99E-09	3.77E-09
$P_{59\ HTO - Pork}$	1.14E-10	1.61E-10	2.61E-10
$P_{59\ HTO - Poultry}$	2.69E-10	3.37E-10	5.13E-10
$P_{59\ HTO – Egg}$	6.97E-11	1.24E-10	2.53E-10

Table A.17: Site-specific Ingestion Transfer Parameters – HTO in Animal Products

Transfer Parameter	Infant	Child	Adult
$P_{59\ HTO - Beef}$	1.31E-10	1.82E-10	5.05E-10
$P_{59\ HTO - Dairy}$	7.74E-09	3.43E-09	1.62E-09
$P_{59\ HTO - Pork}$	6.22E-11	8.78E-11	1.43E-10
$P_{59\ HTO - Poultry}$	1.10E-10	1.38E-10	2.10E-10
$P_{59\ HTO – Egg}$	1.43E-11	2.54E-11	5.18E-11

Table A.18: Generic Ingestion Transfer Parameters – OBT in Animal Products

Transfer Parameter	Infant	Child	Adult
$P_{59\ OBT - Beef}$	4.15E-10	5.94E-10	1.50E-09
$P_{59\ OBT - Dairy}$	4.41E-08	2.01E-08	8.67E-09
$P_{59\ OBT - Pork}$	2.80E-10	4.06E-10	6.01E-10
$P_{59\ OBT - Poultry}$	6.60E-10	8.48E-10	1.18E-09
$P_{59\ OBT – Egg}$	1.71E-10	3.13E-10	5.83E-10

Table A.19: Site-specific Ingestion Transfer Parameters – OBT in Animal Products

Transfer Parameter	Infant	Child	Adult
$P_{59\ OBT - Beef}$	3.21E-10	4.59E-10	1.16E-09
$P_{59\ OBT - Dairy}$	1.90E-08	8.65E-09	3.73E-09
$P_{59\ OBT - Pork}$	1.53E-10	2.21E-10	3.28E-10
$P_{59\ OBT - Poultry}$	2.70E-10	3.47E-10	4.83E-10
$P_{59\ OBT – Egg}$	3.50E-11	6.41E-11	1.19E-10

A.13 Drinking Water Intake by Humans ($P(i)_{29}$)

The transfer parameter for dose from drinking water intakes is given by:

$$P(i)_{29} = \rho \bullet k''_w \bullet I_w \bullet (DCF)_f \qquad (Sv \bullet a^{-1} \bullet Bq^{-1} \bullet L) \qquad [A.30]$$

where:
- $(DCF)_f$ = dose coefficient for intake by ingestion ($Sv \bullet Bq^{-1}$)
- I_w = drinking water intake rate ($L \bullet a^{-1}$)
- k''_w = fraction of drinking water intake from the contaminated source ($0 < k''_w \leq 1$)
- ρ = removal factor to account for processes such as sedimentation and removal of radionuclides by water treatment plants.

Age-dependent $(DCF)_f$ for ingestion have been provided in Table A.10 (Section A.11). The conservative default value for k''_w is 1. The site survey (see Appendix E) has indicated a value for k''_w of 0.005, reflecting the fact that all residential developments in the area surrounding SRBT are serviced with municipal drinking water, originating from the Ottawa River. Private wells are generally not used as a significant source of drinking water. The value of ρ has been assigned a default value of 1.

The drinking water intake rate I_w can be highly variable depending on the age of the individual, the ambient temperature, and the level of physical activity. The total daily fluid intake can come from a wide variety of sources including tap water, milk, soup, soft drinks, alcoholic beverages, etc. A common conservative assumption is that all fluid intake comes from the contaminated source (tap water or well water).

In the CSA DRL Guidance (2014), it is recommended that the EPA 95th percentile values (shown in Table A.20) be adopted as the default drinking water intake rates. These values have been adopted as a conservative measure in the calculation of DRLs for the SRBT facility.

The total water intake is assumed to include all water from the household tap consumed directly as a beverage or used to prepare foods and beverages. For the 1-year old infant, this includes water used to prepare powdered milk. If these infants drink fresh milk rather than powdered milk, the fresh milk intake rates should be subtracted from the total water intake rates (Table A.20) to give the net tap water intake rates For other age groups, the water intake rates in Table A.20 are assumed to be additive to their fresh milk intake rates.

The water ingestion transfer parameter ($P(i)_{29}$) used in the SRBT DRL calculation is presented in Table A.21.

Table A.20: Recommended Total Drinking Water Intake Rates ($L \bullet day^{-1}$)

ICRP Age Groups	U.S. EPA Mean Intake Rate	U.S. EPA 95th Percentile Intake Rate
Infant	0.271	0.837
Child	0.414	1.32
Adult	1.04	2.96

Table A.21: Transfer Parameter Values – Water Ingestion Dose

Transfer Parameter	Infant	Child	Adult
$P(i)_{29\ HTO}$ - Generic	1.62E-08	1.20E-08	2.16E-08
$P(i)_{29\ HTO}$ - Site-specific	8.10E-11	6.02E-11	1.08E-10

A.14 Water Immersion Dose ($P(e)_{29}$)

Radiation dose received from water immersion can result from:

a) swimming in contaminated water, either at beaches or in swimming pools; or
b) taking baths.

The dose from taking showers will not be considered since external dose from showering is negligible compared to external dose from immersion in a bathtub and the dose from incidental ingestion of shower water should be only a negligible fraction of the dose from ingestion of drinking water. Dose from the inhalation of volatile radionuclides released from shower water is also expected to be insignificant as there are very few volatile radionuclides that are readily released from water.

In the case of tritium (HTO), water intake by skin diffusion with the person submerged in water while swimming or taking a bath must be considered. This diffusion rate for water-wetted skin is about 0.2 mL • min^{-1}, or 105 L • a^{-1}, per m^2 of skin surface area (Osborne, 1968). The $P(e)_{29}$ for HTO is given by:

$$P(e)_{29} = 105\ S_a \bullet (DCF)_f \bullet (OF)_w \bullet k''_w \quad (Sv \bullet a^{-1} \bullet Bq^{-1} \bullet L)$$ [A.31a] beach swim

$$P(e)'_{29} = \rho 105\ S_a \bullet (DCF)_f \bullet (OF)'_w \bullet k''_w \quad (Sv \bullet a^{-1} \bullet Bq^{-1} \bullet L)$$ [A.31b] taking baths

$$P(e)''_{29} = \rho 105\ S_a \bullet (DCF)_f \bullet (OF)''_w \bullet k''_w \quad (Sv \bullet a^{-1} \bullet Bq^{-1} \bullet L)$$ [A.31c] pool swim

where: S_a = skin surface area (m^2)
$(DCF)_f$ = dose coefficient for ingestion ($Sv \cdot Bq^{-1}$)
ρ = removal factor to account for processes such as sedimentation and removal of radionuclides by water treatment plants

$(OF)_w$	=	water occupancy factor, or fraction of a year's time spent swimming in lake
$(OF)'_w$	=	fraction of a year's time spent taking baths
$(OF)''_w$	=	fraction of a year's time spent in swimming pool
k''_w	=	fraction of drinking water intake from the contaminated source ($0 < k''_w \leq 1$)

Table A.22 summarizes the 95th percentile values of the averaged male and female skin surface areas for the ICRP age groups, based on the EPA Handbook data discussed above. These are taken from Table 22 of the CSA DRL Guidance (2014).

Table A.22: Skin Surface Areas (m^2), 95th Percentile Values

Age Groups	Skin Surface Area (m^2)
Infant	0.72
Child	1.46
Adult	2.19

The water occupancy factor $(OF)_w$ should be based on site specific surveys. Its default value given in Gorman (1986) for swimming is 0.01, corresponding to about 100 hours per year. The U.S. EPA Exposure Factors Handbook (EPA, 1997), Volume III, Table 15-65, p.15-80, provides survey data on the frequency of people swimming in fresh water pools. The 95th percentile value is 30 times a month, or once daily. The average duration of a swim is 1 hour and the 95th percentile value of the swim duration is 3 hours. Using the 95th percentile value for the frequency of swimming and the average duration of one hour per swim, the fraction of the year spent swimming = 365/8760 = 0.042. This default value is assumed to apply to combined beach swimming and indoor pool swimming. It is further assumed that 1/3 of the swimming time is apportioned to beach swimming, mainly during the summer months, and 2/3 to pool swimming. Thus, $(OF)_w = 0.014$ and $(OF)''_w = 0.028$. In the case of SRBT DRLs, well water is the only relevant water source and thus beach swimming is ignored.

The EPA Handbook does not provide data on swimming frequency for infants under 1-year-old. The 3-month-old infant and 1-year-old child are assumed not to engage in swimming.

The EPA Handbook provides data on the frequency and duration of people taking baths (EPA, 1997, Volume III, p.15-16 and p.15-39 to 15-41). About 7% of the people surveyed took one or more baths per day. The average duration of a bath is 20 minutes and the 90th percentile value is 45 minutes. Using the 95th percentile value for the frequency of bath taking (once per day) and the average bath duration of 20 minutes, the default water occupancy factor for bath taking $(OF)'_w$ is (365 x 1/3) hours/8760 hours = 0.014.

The removal factor (ρ) is assumed to be the same for bath water and swimming pools. A default value of 1 is assumed for this factor in this application. Values for effective dose DCF_f have been provided in Table A.10.

The values of transfer parameter $P(e)_{29}$ applied in the calculation of SRBT DRLs are summarized in Table A.23.

Table A.23: Transfer Parameter Values – Water Immersion Dose

Transfer Parameter	Infant	Child	Adult
$P(e)_{29\ HTO}$ - Generic	5.61E-11	1.07E-10	1.29E-10
$P(e)_{29\ HTO}$ - Site-specific	2.80E-13	5.37E-13	6.44E-13

A.15 Soil Ingestion Dose ($P(i)_{39}$)

The CSA Guidance does not provide equations for determining dose rate for HTO as a result of soil ingestion, and this pathway is not explicitly included in the calculation of DRLs for the SRBT facility. However, the CSA Guidance can be adapted to approximate soil ingestion dose if desired.

The transfer parameter for dose from incidental soil ingestion is given by:

$$P(i)_{39} = I_s \bullet EFs \bullet (DCF)_f \qquad (Sv \bullet a^{-1} \bullet Bq^{-1} \bullet Kg) \qquad [A.32]$$

where: $(DCF)_f$ = dose coefficient for intake by ingestion ($Sv \bullet Bq^{-1}$)
I_s = soil intake rate ($kg \bullet d^{-1}$)
EFs = days per year in which soil ingestion could occur

The default value for EFs is taken as 135 days per year, which corresponds to 75% of the six-month summer period. The default values for I_s are provided in Table A.24, and the 95th percentile values are adopted. Age-dependent $(DCF)_f$ for ingestion have been provided in Table A.10 (Section A.11).

It should be noted that the soil intake rates in Table A.24 are dry-weight values. The default parameter value for transfer from air to soil (P13) in section A.4.3 is expressed on a fresh-weight basis. A conversion factor of 2 can be applied to the intake values in Table A.24 to adjust to fresh-weight basis, reflecting the simple assumption that soil porewater accounts for 50% of the fresh weight of surface soil. Following this assumption and equation A.32, the recommended values for transfer parameter P(i)39 are presented in Table A.25.

Table A.24: Recommended Incidental Soil Ingestion Rates (g dw • day^{-1})

ICRP Age Groups	Mean Intake Rate	95th Percentile Intake Rate
Infant	0.061	0.204
Child	0.055	0.185
Adult	0.004	0.02

Table A.25: Transfer Parameter Values – Soil Ingestion Dose

Transfer Parameter	Infant	Child	Adult
$P(i)_{39\ HTO}$	2.92E-12	1.25E-12	1.08E-13

These values are generic in nature. There is not sufficient information to allow development of site-specific values for this parameter, or to develop values applicable for OBT.

The values for P(i)29 are about 3 orders of magnitude lower than the generic values for P(i)29 presented in Table A.21. In the case where a shallow well is the source of drinking water, there will be effective equivalency in HTO concentration between water and soil, and the associated dose rate for soil ingestion will be approximately 3 orders of magnitude lower than that for water ingestion.

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APPENDIX B: RECEPTOR IDENTIFICATION AND CHARACTERIZATION

B.1 General Considerations

In general, DRLs are based on radionuclide exposure and dose to an individual that is representative of the most highly exposed members of the public in vicinity of the facility. This yields DRLs that are protective of ***ALL*** members of the public.

Public dose associated with any radionuclide release will vary depending on the characteristics of select members of the public, including their proximity to the point of release, dietary and behavioural habits, age and other attributes. The standard practice in public dose assessment, including the calculation of DRLs, is to identify groups found in proximity to the facility that are relatively consistent with respect to behavioural factors. Groups whose combined characteristics are such that they may receive the highest dose due to a radionuclide release are identified and assessed as *potential representative groups*. Of these, the group determined to receive the limiting (i.e., highest) dose is ultimately referred to as *the representative group*.

An individual with characteristics that reflect those of the critical group identified for a given radionuclide release is known as the "representative person". DRLs are calculated for the representative person, who is characterized as the average member of the most exposed (i.e., critical) group. That is, the representative person reflects the group average in terms of behavioural characteristics (i.e., amount and origin of food obtained locally, sources of drinking water) and occupies a location that is most highly exposed to facility emissions.

The updated DRL Guidance does provide some new information regarding the general attributes of humans (e.g. food intake rates), but does not include any new recommendations specific to the identification and characterization of critical groups or their members.

The identification and characterization of critical groups was updated in the SRBT DRL calculations completed in 2016, based on the following information:

- Critical group characterization from previous DRL assessments (Canatom, 1996, EcoMetrix, 2006)
- Updated (2010) Official Plans and Zoning By-laws of the City of Pembroke and the Township of Laurentian Valley (Stafford Village),
- Interactive satellite imagery software (Google Earth), and
- Ground-level reconnaissance conducted in April 2014.

For this current iteration of DRL calculations, critical group characteristics from the 2016 DRL Report have been adopted largely without change. The only instance in which there has been an udate of receptor characterisitcs relates to the location of the most exposed residence, which reflects the application of the most recent meterological data. The following sections provide further details of the current characterization and its rationale.

B.2 Group Selection

B.2.1 Surrounding Environment

The selection of representative public groups considers known lifestyles and land-use patterns in proximity to the facility.

Immediately adjacent to SRBT, land is zoned for various commercial and industrial uses. Land-use within ~1 km of SRBT is variable, and includes lands zoned and occupied as residential, commercial, and industrial. Institutional and open space zoning is also present within 1 km of SRBT.

The current zoning of the SRBT facility (M2 – Economic Enterprise) permits a variety of light industrial uses, but excludes residential use. The closest area under residential zoning is Johnson's Meadows, which was originally developed in the 1970s, but has experienced various phases of expansion to date. At the closest point, this residential area is approximately 250 m from SRBT (measuring from the location of the stacks). The centre of this development is situated more-or-less west-northwest of SRBT, thus lying within a relatively low frequency wind sector. This development is fully serviced by the municipality's central water supply, as required under the OP and current zoning by-law (By-law 2020-05).

A narrow band of land along Boundary Road, approximately southeast of SRBT, is also zoned as residential. The closest residential lot in this strip is greater than 200 m from the SRBT stacks, and is serviced by municipal water.

Immediately to the west of SRBT lies the TransCanada Corporate Park, located within an area zoned for Industrial Use. Land generally to the east of SRBT is also zoned for industrial or commercial purposes. To date, these industrial/commercial lands have been subject to limited developent which excludes residential use.

The main portion of the City of Pembroke lies within the northwest to northeast compass sectors relative to SRBT. For the most part, these are relatively low wind frequency sectors. The closest lot is to the north-northeast of SRBT, just over 600 m from the stacks. Other than the noted residential zones, the majority of lands adjacent within 1 km of the SRBT Facility are zoned Industrial.

The available information supports the assumption that members of the public in relatively close proximity to SRBT include urban residents and workers at commercial or industrial facilities.

B.2.2 Location of Exposure

The location of the representative person for the purposes of calculating DRLs is based on the degree of exposure to facility emissions. The assigned locations of both the worker and residential groups of representative persons were determined by an initial estimation of the degree of exposure to tritium in the atmosphere at a series of representative locations. A total of 11 potential residential locations of representative persons were identified by determining the nearest residence (existing or potential) in each wind sector. Five of the 16 compass sectors were screened out of this process because the nearest residence was relatively far from SRBT and also because associated wind frequencies were relatively low.

For worker critical groups, three existing commercial operations were considered as potential representative person groups. These are immediately adjacent to SRBT and the frequency of being down-wind of SRBT ranges from low to relatively high. The locations of the representative person groups and the relative frequency of wind in all compass sectors are depicted in Figure 2 of the main document.

For each potential worker or residential critical group location, the atmospheric dispersion coefficient (P01) was determined using the atmospheric dispersion model developed for the SRBT facility (see Section A.2 of Appendix A). This was done using 24-hr and 12-hr TJF data, and also with and without consideration of thermal buoyancy. The results of this analysis are presented in Table B.1, along with the results of the same process completed in 2016. Note that a higher value of P01 represents a higher level of tritium activity in air.

The analysis of P01 using most recent wind data from the SRBT weather station indicates that the highest degree of residential exposure to SRBT stack emissions occurs at the potential critical group location ~300m to the west-northwest. This is a minor departure from the results of analysis of residential atmospheric exposure patterns conducted in 2016, when the most exposed residential location was located to the northwest of SRBT.

The atmospheric dispersion factor (P01) at the most exposed residential location in 2021 is about 25% lower than it was in 2016. That is, the estimated level of tritium in air per unit emission from SRBT is 25% lower in the 2021 assessment than it was in 2016. Stack characteristics have remained effectively unchanged. The difference in atmospheric dispersion at the residential critical group locations is associated primarily with changes in wind data. When recent on-site wind data are applied, the wind sector where maximum residential exposure was identified in 2016 shows a decline in the frequency at which this location is downwind of SRBT.

For the worker, the highest degree of exposure is at Messer (formerly Linde) gases. This is consistent with the DRL calculation assumptions of 2016. The atmospheric dispersion coefficient for the most exposed worker location is only about 5% lower than it was in 2016.

In all cases, the exclusion of thermal buoyancy from the atmospheric dispersion model does not result in a change in the most exposed location(s), but does lead to higher atmospheric tritium activity at those locations.

Table B.1: Atmospheric Dispersion Coefficients (P01) for Candidate Representative Person Locations

Potential Representative Person Location	Position Relative to SRB		P01 (s/m³)							
			2016 - 12 hr data		2016 - 24 hr data		2021 - 12 hr data		2021 - 24 hr data	
	Direction	Distance (m)	Thermal Buoyancy	No Thermal Buoyancy	Thermal Buoyancy	No Thermal Buoyancy	Thermal Buoyancy	No Thermal Buoyancy	Thermal Buoyancy	No Thermal Buoyancy
Worker-1 - Messer Gases	SE	~30	**1.06E-05**	**3.54E-05**	**5.62E-06**	**3.23E-05**	**1.30E-05**	**5.26E-05**	**6.35E-06**	**4.90E-05**
Worker-2 - 330 Boundary Rd.	NW	~60	9.89E-07	2.09E-05	3.80E-07	1.43E-05	7.90E-07	1.84E-05	2.83E-07	1.31E-05
Worker-3 Med-Eng	S	~50	4.87E-06	2.46E-05	2.16E-06	1.82E-05	5.35E-06	2.60E-05	2.23E-06	2.07E-05
Residential-W	W	~360	2.62E-06	5.63E-06	2.52E-06	7.64E-06	1.50E-06	4.83E-06	1.24E-06	6.04E-06
Residential-WNW	WNW	~300	3.11E-06	6.47E-06	2.99E-06	9.29E-06	1.90E-06	**6.75E-06**	1.59E-06	**8.05E-06**
Residential-NW	NW	~270	**3.94E-06**	**8.92E-06**	**3.42E-06**	**1.07E-05**	2.02E-06	5.08E-06	1.78E-06	6.10E-06
Residential-NNW	NNW	~280	3.59E-06	7.94E-06	3.17E-06	9.96E-06	2.32E-06	5.50E-06	1.86E-06	7.18E-06
Residential-N	N	~330	2.71E-06	5.44E-06	2.60E-06	7.80E-06	2.13E-06	4.75E-06	1.88E-06	6.61E-06
Residential-NNE	NNE	~790	1.17E-06	1.83E-06	1.49E-06	3.28E-06	1.17E-06	2.63E-06	9.78E-07	3.97E-06
Residential-NE	NE	~670	1.20E-06	2.06E-06	1.57E-06	3.70E-06	1.01E-06	1.67E-06	9.68E-07	3.54E-06
Residential-ENE	ENE	~840	1.18E-06	1.99E-06	1.64E-06	3.77E-06	1.07E-06	1.61E-06	1.07E-06	4.00E-06
Residential-SE	SE	~600	2.01E-06	3.40E-06	2.23E-06	4.71E-06	**2.89E-06**	4.89E-06	**2.70E-06**	7.03E-06
Residential-ESE	ESE	~1550	6.95E-07	8.49E-07	9.31E-07	1.27E-06	1.38E-06	1.80E-06	1.14E-06	2.67E-06
Residential-E	E	~2000	4.11E-07	4.97E-07	6.48E-07	8.56E-07	8.65E-07	1.07E-06	7.79E-07	2.14E-06
Bouden's Market Garden	ESE	~1930	5.39E-07	6.41E-07	7.60E-07	9.95E-07	1.13E-06	1.42E-06	9.50E-07	2.24E-06
Saar Dairy Farm	SE	~3500	3.19E-07	3.81E-07	4.30E-07	5.58E-07	3.57E-07	4.48E-07	2.45E-07	6.77E-07

Bold values represent the lowest degree of dispersion of all locations considered, and thus the highest atmospheric tritium activity

B.3 Member Characteristics

In the current DRL determination, the selected group of receptors encompasses those considered in the previous DRL iterations for SRBT, allowing an analysis of DRL trends over SRBT's operational history. This includes an infant and an adult. To achieve consistency with current guidance (i.e., CSA N288.1-14), a 10-year old age class has also been added as a member of the representative person group. A DRL has been calculated for each of the noted age classes at the residential location that has been determined to have the highest degree of exposure to tritium originating from SRBT. In addition, an adult worker receptor has been established at a commercial/industrial site that has been determined to be the most highly exposed of all such sites.

Ideally, certain characteristics of the representative person are based on weighted-average values for relevant parameters, derived from detailed site surveys of residents within the representative group. In 2005, SRBT initiated a site survey of nearby households to obtain information of this nature. The return rate of the survey was low, and the statistical validity of the findings is unknown at this point. The survey results are thus not conclusively representative of the identified groups. However, they do provide an indication of the general habits of the residential group. The results of the 2005 survey are summarized in Table B.2.

B.3.1 Residential Group

In order to represent the residential group in as site-specific a manner as possible at this time, each of the members of the group (adult, 10-year-old child, 1-yr-old infant) have been characterized partly on the basis of the 2005 survey data. In addition, to understand the implications of potential instances of higher exposure, as of yet not known to occur in reality, a conservative generic characterization of each of the age classes has also been assessed in this DRL determination. The generic characterization relies on the default local intake fractions recommended in the current DRL Guidance.

A key difference between the generic and site-specific groups is the presence and use of a well as the sole supply of water for drinking and bathing for the generic group, whereas the site-specific group obtains only 0.5% of their water supply from an onsite well. The latter value is derived from the 2005 site survey, and is consistent with the fact that the residential developments in close proximity to SRBT are all municipally serviced.

For both the generic and site-specific case, the source of well water was an on-site shallow well which is assumed to be conceptually equivalent to a rainwater cistern. This is a conservative characterization of groundwater, since most residential wells are screened to some depth below surface, resulting in attenuation of radionuclides in groundwater is it slowly infiltrates downward. In a focused study of groundwater resources in the vicinity of SRBT (EcoMetrix, 2006), it was determined that residences in Pembroke are all serviced with water from municipal supplies. It was also found that few wells actually exist near SRBT, and those few wells are relatively deep (see Tables E.4 and E.5, Appendix E). The assumption that the members of the representative group collectively obtain their entire water supply from a shallow residential well is extremely conservative.

The other potential difference between the site-specific and generic group members is associated with the rates of consumption of locally-raised plant or animal food products. For both scenarios (generic and site-specific), the source of plant products includes an on-site residential garden at the representative location. As noted in past DRL documents, it is not considered likely that a residential garden would be of sufficient size to provide the quantities of fruit and vegetables that are considered in the DRL calculation. The total amounts of plant produce consumed by members of the critical group are based on recommendations of the DRL Guidance, which are judged to represent reasonable maximum exposure (RME). The actual fraction of that amount considered to be locally produced is also conservatively quantified in this calculation of SRBT DRLs. This is the case even for the site-specific critical group members, since the reported amount of locally produced fruits and vegetables included amounts purchased at farms or market gardens in the area. Foods obtained from these latter sources would also be exposed to tritium emissions from SRBT, but to a much lesser extent. For the calculation of SRBT's DRLs, the representative group backyard garden and a local market garden (Boudens) were both assumed to serve as sources of "local" produce. In previous iterations of DRL calculations for SRBT, it has been assumed that 50% of total produce intake originates from the backyard, and 50% from Boudens. For the current DRLs, the apportioning has been adjusted to 70% for Boudens and 30% for the backyard garden. This adjustment has been made simply to achieve consistency with the assumptions adopted in the public dose calcuations that are reported in SRBT's Annual Compliance Reports.

For animal products, the raising of meaningful numbers of livestock is not expected to occur on urban residential properties. The source of animal products was assigned to the closest known dairy farm (*i.e.*, Saar farm, ~3500 south of SRBT). All local meat (beef pork, poultry), eggs, and dairy products were conservatively assumed to originate from this location.

The survey-based local fractions for plant and animal food products differ from the generic default values provided in the DRL Guidance. For fruit and vegetables, the site-specific fraction derived from survey data (i.e., 29%) is actually slightly higher than the generic default (20-25%). For animal products, the site-specific fractions were consistently lower than generic defaults. In the case of diary and beef products (making up a large majority of animal product intake), the site-site specific fraction is about half of the generic default value.

B.3.2 Worker Group

The worker representative is exposed only to tritium in air while at the work-place for 40 hours per week. The water supply at the workplace is obtained through municipal service. The municipal supply is not measurably affected by SRBT emissions.

The current DRL Guidance does not provide recommendations to characterize members of the public who may be exposed to facility releases while at their place of work. It could be assumed that the 95th percentile average adult inhalation rates would be reasonably representative of adults engaged in work activities in an office or retail environment. In the case of workers engaged in more labour-intensive activities, the application of the average adult inhalation rate might not be an adequately conservative representation of those workers. In absence of detailed information on work-place duties at the commercial facilities near SRBT, a more conservative characterization has been applied. Parameters from the ICRP Inhalation Dose Model (ICRP 66) have been used to quantify inhalation exposure of workers considered in the SRBT DRL calculation.

The worker would also be exposed to tritium in other media when not at work, assuming the worker lived in reasonably close proximity to SRBT. For the DRL calculations, the worker is also assumed to be exposed to tritium in air while at the place of residence for all hours when not at work (i.e., 128 hrs per week). The worker also exhibits the local food and water intake characteristics of the adult member of the residential group, and is thus similarly exposed to tritium in plant and animal products and in well water. In the 2016 DRL calculations, the exposure of the worker while at his/her place of residence was quantified using the average value of P01 for the 11 candidate residential locations, as listed in Table B1. For the current DRL calculations, the exposure of the worker while at home has been adjusted to equal that of the most exposed residential location (Resident WNW). This is considered to be verv conservative.

B.4 Summary of Derived Parameter Values

The information in this appendix has been used to determine the value of several variables involved in this iteration of DRL calculation of for SRBT. This includes the following:

- the distance between the source and receptor (x), as used in Equation A.2 (Section A.2.1, Appendix A), to calculate transfer parameter P01
- the fraction of food from contaminated sources (g_f), used in Equations A.24 and A.25 (Section A12.2, Appendix A) to calculate site-specific transfer parameters P49 and P59, respectively:
    - beef - 0.34
    - dairy - 0.43
    - pork - 0.24
    - poultry - 0.18
    - eggs - 0.09
    - fruits and vegetables - 0.29
- the fraction of drinking water intake from the contaminated source (k''_w), used in Equation A.30 (Section A.13, Appendix A) to calculate transfer parameter P(i)29, and in Equation A.31 (Section A.14) to calculate P(e)29. The site-specific value in all cases is 0.005.

Table B.2 - SRBT Residential Survey Result Summary

Respondent ID	Number of Residents	Local Percentage of Total Food and Water Intakes							
		Fruit and Vegetables	Beef	Pork	Poultry	Eggs	Dairy	Fish	Water (wells)
1	1	3	3	0	0	0	0	0	0
2	2	8	3	3	0	0	70	8	0
3	1	30	8	0	0	0	70	0	0
4	4	0	0	0	0	0	0	0	0
5	4	0	0	0	0	0	70	3	0
6	2	8	3	3	0	0	0	8	0
7	2	70	30	15	15	0	0	0	NS
8	1	3	0	0	0	0	8	0	0
9	2	50	30	30	30	8	70	9	0
10	2	3	70	70	50	0	70	9	0
11	2	50	30	NS	15	NS	NS	15	8
12	1	3	3	3	0	3	50	0	0
13	4	3	90	30	0	0	NS	8	0
14	4	70	90	90	90	15	70	15	NS
15	2	70	30	30	NS	15	90	8	0
16	3	30	NS	NS	NS	NS	NS	NS	NS
17	2	90	50	8	8	90	0	70	0
Weighted Average		28.7	34.1	23.6	17.5	8.5	42.9	9.9	0.5

NS - not specified

APPENDIX C: METEROLOGICAL DATA

C.1 Meteorological Relevance to DRL

The calculation of DRLs for the SRBT facility in Pembroke is dependent on a number of meteorological variables, as follows:

- Temperature – the atmospheric dispersion model allows for the inclusion of the phenomenon of thermal buoyancy, which is determined in part on the basis of average annual outdoor air temperature (see Equation A.11 in Appendix A). Temperature is also the main determinant of the estimated fraction of the year when soil is not frozen or snow covered (F_{oxid}), and when microbiological oxidation of HT to HTO can occur (see Equation A.18, Appendix A),

- Humidity – the environmental fate of tritium released to atmosphere is modeled as a specific activity (SA) process. Absolute humidity (Ha) is a key parameter in the SA equations used to determine:

  - the environmental transformation of HT to HTO due to soil microbiological processes (Equation A.18, Appendix A), and

  - the partitioning of HTO in air to HTO and OBT in plants (Equations A.19 and A.21, Appendix A)

  Ha is also a key parameter in the equation representing transfer of HTO in air to HTO in groundwater (Equation A.23, Appendix A).

- Wind Patterns – the patterns of wind in terms of direction, speed and stability are critical inputs to the atmospheric dispersion model. The triple-joint frequency wind data are the most influential data in modeling the environmental fate of radionuclide emissions to air.

Regionally representative values of these relevant meteorological parameters are provided in the DRL Guidance, but it is recommended that site-specific values be used if available.

C.2 SRBT Data Sources

Regionally representative values of some of the relevant meteorological parameters are provided in the relevant DRL Guidance, but it is recommended that site-specific values be used if available.

In the 2006 calculation of DRLS, data from Environment Canada's monitoring station at Petawawa (~20 km NW of Pembroke) were used as representative of conditions at Pembroke and in the vicinity of the SRBT facility. The Petawawa station was the closest source of relevant meteorological data. In 2010, Environment Canada activated a station at Pembroke, compiling hourly data for most main parameters.

In 2009, an automated weather monitoring station was also installed at the SRBT site. Meteorological data collection commenced on 20 May 2009. The weather station was installed with two main purposes in mind;

1) to provide reliable data to aid in the interpretation of environmental tritium measures, collected as part of SRBT's EMP, and
2) to facilitate atmospheric dispersion modeling.

The selection and configuration of the station were subject to thorough consideration and CNSC review prior to implementation to ensure that the main objectives would be effectively met.

The meteorological monitoring station is located on SRBT property to facilitate control and security, and also to provide data that are most representative of the conditions encountered on the property at the source of emissions to atmosphere. The meteorological tower and instrumentation are located in the western-most corner of the property, ~67 m from the stacks. As per operational specifications, the instruments are located away from buildings at a distance of least 5 times the height of the nearest building.

The station is a HOBO U30 model, equipped with instrumentation for monitoring of the following meteorological endpoints, at the noted precision:

- Temperature (electronic sensor) ± 0.2 ^{0}C
- Relative Humidity (electronic sensor) - accuracy ± 2.5%
- Precipitation (heated tipping-bucket gauge) ± 2-3%
- Barometric Pressure (electronic sensor) - ± 3 mbar
- Solar Radiation (silicon pyranometer) - ± 10 W/m^2
- Wind speed (rotary cup device) - ± 0.5 m/sec, threshold is 0.5 m/s
- Wind direction (rotating vane) - ± 5 degrees

The station is fully automated and functions continuously, with averages of each endpoint recorded at 5-minute intervals.

SRBT has developed and implemented an operational procedure for monitoring, inspection and maintenance, reporting (SRBT, 2019). Data for all noted endpoints has been collected and compiled continuously since the station was activated. Only very minor data gaps have occurred over the seven years of operation.

C.3 Data Availability

SRBT has developed and implemented an operational procedure for monitoring, inspection and maintenance, reporting (SRBT, 2008). Data for all noted endpoints has been collected and compiled continuously since the station was activated.

In the period since the last iteration of DRL calculations, there have been two notable instances where data were not fully available or were identified as potentially inaccurate.

In 2016, the automated download of meteorological data from the station was interrupted by battery failure, resulting in an absence of complete datasets for the months of April, May and June. SRBT has taken steps to avoid further incidents of battery failure.

In April 2020, SRBT detected irregularities in data resulting from weather station anemometer and wind direction sensor malfunction. Corrective maintenance planning has been initiated, but wind-related data for the period April to December 2020 are deemed unreliable.

The implications of the two noted instances of limited data availability to the current DRL analysis are as follows:

- The full dataset from January 2016 to December 2020 has been used to determine a number of variables that are not related to wind speed or direction, including humidity and temperature (see Table C1). To account for missing data over the period of April to June 2016, monthly averages were initially calculated for the 5-year period, and subsequently used to determine annual or seasonal averages.

- For compilation of triple-joint frequency (TFJ) datasets for wind, data for 2016 and 2020 were excluded to avoid potential biases resulting from inclusion of data for only select months (seasons) for those years. The TJF dataset derived for current DRL purposes is based on complete data for each of 2017, 2018 and 2019. Under the CSA Guidance, a three-year dataset is considered acceptable.

C.4 SRBT Meteorological Parameter Values

C.4.1 Temperature

Table C.1 summarizes monthly and annual meteorological measures of temperature and humidity at SRBT. Based on continuous site-specific monitoring over the period of 2016 to 2020, the annual average air temperature at the SRB facility is 6.20 ^{0}C. This is only slightly higher than the average air temperature value of 6.1 ^{0}C assigned for DRL determination in 2016. If only the period of facility operation is considered (i.e., 7:00 a.m. to 7:00 p.m.), the annual average temperature recorded at SRB over the period of 2016 to 2020 is 8.01 ^{0}C.

C.4.2 Humidity

Absolute humidity (Ha) is not measured explicitly at the SRBT metrological station. By convention, absolute humidity is derived from other routine parameters that are recorded at SRBT. There are a variety of equations available to calculate corresponding measures of absolute humidity from available measures of temperature, dew point and/or relative humidity (RH). For current purposes, the following formula has been used:

$$Ha = 6.112 \text{ x } 10^{[(7.5 \text{ x } DP)/(237.7 + DP)]} \text{ x } 100/(46151 \text{ x } (273.15 + T) \text{ x } 1000$$

where;

Ha is Absolute Humidity (g/m^3),

T is temperature (degrees Celsius), and

DP is Dew Point (degrees Celsius).

Using this formula and the data available to date from SRBT's monitoring station, the absolute humidity values assigned for use in the DRL calculation are as follows:

Annual Average: Ha = 6.6 g/m^3

Snow free period: Ha = 8.7 g/m^3, and

Growing season: Ha = 11.6 g/m^3.

These represent the full 24-hr period of data coverage. These absolute humidity values differ only slightly from year to year. The SRBT Ha values are also similar to those used in the last DRL calculation, which were derived from temperature and dew point measures from the Environment Canada station in Petawawa (see Table C.2).

Table C.1: SRBT Site-Specific Temperature and Humidity Values

		Monthly Readings												Average		
Year	Endpoint	J	F	M	A	M	J	J	A	S	O	N	D	Annual	Snow-free Period	Growing Season
2016	Temp (C)	-7.9	-9.1	-14.9	NA	NA	NA	21.1	21.4	16.0	8.6	2.9	-5.7	3.62	14.0	19.5
	Dew Point (C)	-10.2	-12.3	-19.4	NA	NA	NA	15.7	16.1	12.1	5.2	0.4	-8.3	-0.1	9.9	14.6
	RH (%)	83.9	78.1	69.3	NA	NA	NA	73.0	74.0	79.4	80.2	84.3	82.6	78.3	78.2	75.5
	Ha (g/m^3)	2.3	2.0	1.1	NA	NA	NA	13.1	13.5	10.6	6.8	4.9	2.7	6.3	9.8	12.4
2017	Temp (C)	-5.5	-5.4	-5.6	6.2	11.7	17.4	19.8	18.0	16.5	11.3	-0.3	-10.2	6.15	12.6	17.9
	Dew Point (C)	-8.0	-8.7	-11.1	1.3	6.9	12.4	15.0	14.0	13.0	7.5	-3.5	-13.3	2.1	8.3	13.6
	RH (%)	82.9	78.9	67.1	73.8	75.6	75.2	75.6	79.3	81.7	78.8	79.8	78.9	77.3	77.5	77.9
	Ha (g/m^3)	2.7	2.6	2.1	5.2	7.6	10.7	12.6	11.9	11.2	7.9	3.8	1.8	6.7	8.9	11.6
2018	Temp (C)	-10.6	-5.9	-2.4	1.9	14.8	17.6	22.3	21.0	15.7	6.1	-2.2	-6.9	5.95	12.1	19.1
	Dew Point (C)	-13.4	-9.3	-7.7	-4.7	6.1	11.4	15.6	16.7	12.3	2.5	-4.4	-8.9	1.4	6.9	14.0
	RH (%)	80.3	78.1	69.1	66.1	61.1	70.4	68.9	78.1	81.6	78.5	85.3	86.2	75.3	73.8	74.8
	Ha (g/m^3)	1.8	2.5	2.7	3.4	7.1	10.0	13.0	14.0	10.7	5.7	3.5	2.5	6.4	8.4	11.9
2019	Temp (C)	-13.3	-9.8	-4.1	3.9	10.5	16.9	22.2	19.2	14.5	8.1	14.5	-4.4	6.52	13.7	18.2
	Dew Point (C)	-16.3	-13.2	-9.6	-1.1	5.3	11.0	16.1	13.3	10.7	4.7	10.5	-6.7	2.1	8.8	12.8
	RH (%)	78.9	76.8	68.4	73.0	72.6	71.2	70.7	71.3	79.3	80.9	78.7	84.8	75.6	74.7	73.2
	Ha (g/m^3)	1.4	1.8	2.4	4.4	6.8	9.8	13.4	11.3	9.7	6.6	9.6	3.0	6.7	8.9	11.0
2020	Temp (C)	-6.9	-7.0	-0.3	4.2	12.1	18.5	23.1	18.4	13.8	6.7	3.7	-4.4	6.81	12.5	18.4
	Dew Point (C)	-9.2	-11.0	-5.2	-3.6	3.0	12.5	17.3	15.1	10.0	3.0	-0.1	-6.5	2.1	7.1	13.7
	RH (%)	84.0	74.5	72.0	60.9	58.8	71.1	72.5	82.4	79.2	78.5	77.6	85.3	74.7	72.6	76.3
	Ha (g/m^3)	2.5	2.2	3.3	3.7	5.8	10.8	14.5	12.7	9.2	5.9	4.7	3.0	6.5	8.4	11.8
5-yr Avg	*Temp (C)*	*-8.8*	*-7.4*	*-5.4*	*4.0*	*12.3*	*17.6*	*21.7*	*19.6*	*15.3*	*8.2*	*3.7*	*-6.3*	***6.2***	***12.8***	***18.6***
	Dew Point (C)	*-11.4*	*-10.9*	*-10.6*	*-2.0*	*5.3*	*11.8*	*15.9*	*15.0*	*11.6*	*4.6*	*0.6*	*-8.7*	***1.8***	***7.9***	***13.6***
	RH (%)	*82.0*	*77.3*	*69.2*	*68.5*	*67.0*	*72.0*	*72.2*	*77.0*	*80.2*	*79.4*	*81.1*	*83.6*	***75.8***	***74.7***	***75.4***
	Ha (g/m^3)	*2.1*	*2.2*	*2.3*	*4.2*	*6.8*	*10.3*	*13.3*	*12.7*	*10.3*	*6.6*	*5.3*	*2.6*	***6.6***	***8.7***	***11.6***

Monthly averages derived from 5-min. readings at SRBT's weather station. Annual/seasonal averages calculated using monthly means
Snow-free period is April to November (inclusive), Growing season is June to September (inclusive).

NA - not available (due to battery failure)

Table C.2: Comparative Summary of Temperature and Humidity Measures from Other Relevant Sources

Source	Endpoint	Monthly Readings												Average		
		J	F	M	A	M	J	J	A	S	O	N	D	Annual	Snow-free Period	Growing Season
E.C.Petawawa[1] (2000-2004)	Temp (C)	-11.7	-9.5	-2.5	4.6	11.6	16.8	19.3	19.0	14.9	7.2	1.2	-6.9	5.3	11.8	17.5
	Dew Point (C)	-15.7	-14.2	-8.2	-3.2	5.4	11.0	14.2	14.0	10.7	3.2	-2.3	-10.0	0.4	6.6	12.5
	RH (%)	72.7	70.0	67.4	61.4	69.8	72.4	74.8	75.7	78.6	77.7	78.8	79.4	73.2	73.6	75.3
	Ha (g/m^3)	1.6	1.7	2.7	3.8	6.9	9.8	12.0	11.8	9.7	5.9	4.1	2.4	6.0	8.0	10.8
E.C. Pembroke (2010 - 2013)	Temp (C)	-10.9	-8.1	-1.6	4.5	13.8	17.7	20.8	18.8	13.8	8.3	0.4	-5.4	6.0	12.3	17.8
	Dew Point (C)	-13.7	-11.7	-7.4	-2.6	6.5	11.6	13.9	13.4	9.9	4.8	-3.1	-7.7	1.1	6.8	12.2
	RH (%)	80.7	76.3	68.0	64.5	66.7	71.5	69.0	74.0	80.2	80.8	78.8	84.2	74.6	73.2	73.7
	Ha (g/m^3)	1.8	2.1	2.8	3.9	7.3	10.1	11.7	11.4	9.2	6.6	3.9	2.8	6.1	8.0	10.6
SRB (2011-2015)	Temp (C)	-11.3	-9.7	-2.8	5.0	14.3	18.1	20.7	19.2	15.1	8.6	1.4	-4.9	6.1	12.8	18.3
	Dew Point (C)	-14.2	-13.5	-8.2	-1.9	7.3	12.3	14.8	14.7	11.3	4.9	-2.0	-7.2	1.5	7.7	13.3
	RH (%)	79.8	74.7	68.7	65.0	66.7	71.9	71.6	77.1	79.6	79.5	79.0	84.5	74.8	73.8	75.0
	Ha (g/m^3)	1.7	1.8	2.7	4.2	7.7	10.7	12.4	12.4	10.1	6.7	4.2	3.0	6.5	8.5	11.4
SRB[2] (2016-2020)	Temp (C)	-8.8	-7.4	-5.4	4.0	12.3	17.6	21.7	19.6	15.3	8.2	3.7	-6.3	6.2	12.8	18.6
	Dew Point (C)	-11.4	-10.9	-10.6	-2.0	5.3	11.8	15.9	15.0	11.6	4.6	0.6	-8.7	1.8	7.9	13.6
	RH (%)	82.0	77.3	69.2	68.5	67.0	72.0	72.2	77.0	80.2	79.4	81.1	83.6	75.8	74.7	75.4
	Ha (g/m^3)	2.1	2.2	2.3	4.2	6.8	10.3	13.3	12.7	10.3	6.6	5.3	2.6	6.6	8.7	11.6

1 – Environment Canada data from Petawawa were used to calculate DRLs for SRBT in 2006
2 – Data from the on-site station at SRBT are used in the current calculation of SRBT DRLs

C.4.3 Wind Patterns

The SRBT meteorological monitoring station records the direction and speed of wind every 5 minutes. The resulting raw data from the period of 01 January 2017 to 31 December 2019 have been processed to develop the triple-joint frequency (TJF) dataset for use as input to the atmospheric dispersion model. The use of the 2017-2019 data is consistent with the DRL Guidance recommendation to use the most recent 3-5 years of data.

The processing of wind data initially involves reduction of raw data collected on 5-minute intervals to obtain representative hourly readings for speed and direction. Each hourly reading is assigned to one of 6 velocity classes, and to one of 16 cardinal compass sectors. The velocity classes are taken from the DRL Guidance, and are presented in Table C.3

Table C.3: Wind Speed Classes

Wind Speed Class	Wind Speed (m/s)
1	$u \leq 2$
2	$2 < u \leq 3$
3	$3 < u \leq 4$
4	$4 < u \leq 5$
5	$5 < u \leq 6$
6	$u > 6$

Each resulting hourly reading is also assigned to an atmospheric stability classes (i.e., one of Pasquill classes A to F). The stability class is a determinant of vertical dispersion. Stability class determination is achieved using the Modified Sigma Theta method, based on the standard deviation of horizontal wind direction. This is in accordance with recommendations of the DRL Guidance. In this process, standard deviation among 5-minute measures within each hourly period is calculated. The single pass method of Yamartino (1984) was applied to account for the discontinuous scale of wind direction. Stability classes are assigned as per Table C.4.

Table C.4: Stability Classes in Terms of Sigma Theta

Stability Class	Sigma Theta (degrees)
A	$\sigma\theta > 22.5$
B	$17.5 < \sigma\theta \leq 22.5$
C	$12.5 < \sigma\theta \leq 17.5$
D	$7.5 < \sigma\theta \leq 12.5$
E	$3.7 < \sigma\theta \leq 7.5$
F	$\sigma\theta \leq 3.7$

In using the Sigma Theta method, the meandering of the wind direction at night may lead to large $\sigma\theta$ values when the atmosphere is actually stable in the vertical. To take this into account, class D is assigned to night-time hours for which σ_θ >12.5o and u < 2 m/s.

Once the various classes have been established, each hour in the meteorological record is assigned to a combination of direction, speed and stability. Then the frequency of occurrence of each speed/direction/stability class combination is determined as the ratio of the number of hours in that combination to the total number of hours in the record. The mean wind speed in each speed class is determined as the average over all hours assigned to that class.

Following this method, a series of Triple Joint Frequency (TJF) files have been created for the SRBT site. For the full 3-year period (2017-2019), a TJF file was created for the full 24 hours of data coverage, and also for the period of relevance to the operational hours of SRBT (i.e., 7:00 a.m. to 7:00 p.m.). These files have been used directly in the calculation of DRLs. The two TJF files are presented in tabular format in Tables C.5 (24-hr) and C.6 (12-hr).

As noted, wind patterns are a critical determinant of the degree of public exposure to emissions of radionuclides to air. Wind direction patterns in particular are a primary determinant of the location of the most highly exposed member(s) of the public that are the focus of DRL calculations. Table C.7 provides a comparative summary of directional frequencies from current SRBT data (24-hr and 12-hr) and from the TJF data used in the 2006 DRL calculation (i.e., 1998-2004 data from E.C. Petawawa station).

There are generally similar patterns evident when comparing the three data sets. In all cases, winds from the W, WNW and NW are relatively frequent, which is reflective of regional prevailing wind patterns. Overall, the SRBT data (both 24-hr and 12-hr) depict a more uniform distribution of winds over the various compass sectors. Also, the SRBT data exhibit a more-east west distribution, compared with a more pronounced southeast to northwest orientation indicated by the Petawawa data. This may be due to the effect of topographic channeling by the Ottawa River valley, which has a greater east-west aspect at Pembroke (SRBT) than it does further north at Petawawa. The tendency for winds within a valley to blow more or less parallel to the valley axis is well documented (e.g. Carrera et al., 2009).

The directional patterns evidenced by SRBT on-site data do not differ significantly when comparing the 24-hr data and the 12-hr data. However, there are noteworthy differences in regard to stability. Winds in the 12-hr period were assigned to stability classes D, E or F (i.e., the more stable classes) a total of about 74% of the time. Over the full 24-hr period, winds were in these same classes about 86% of the time. Overall, the slightly less stable winds of the 12 hour period are expected to lead to a greater degree of dispersion than winds over the full 24-hr period. The implications of this have been considered in the selection of TJF data for the current DRL calculations (see Appendix B).

Table C.5: Triple-Joint Frequency Wind Data for SRBT - 24-hr Period

Sector (from)	Stability Class	Velocity Class (average class speed in m/s)					
		0.94	**2.48**	**3.48**	**4.46**	**5.45**	**7.06**
N	A	0.363%	0.061%	0.027%	0.015%	0.004%	0.000%
NNE	A	0.252%	0.034%	0.011%	0.004%	0.000%	0.004%
NE	A	0.206%	0.023%	0.015%	0.000%	0.000%	0.000%
ENE	A	0.244%	0.053%	0.000%	0.000%	0.000%	0.000%
E	A	0.218%	0.046%	0.004%	0.000%	0.000%	0.000%
ESE	A	0.160%	0.057%	0.008%	0.000%	0.000%	0.004%
SE	A	0.176%	0.057%	0.011%	0.008%	0.000%	0.008%
SSE	A	0.172%	0.046%	0.015%	0.011%	0.004%	0.000%
S	A	0.279%	0.076%	0.019%	0.015%	0.000%	0.004%
SSW	A	0.240%	0.092%	0.038%	0.011%	0.000%	0.000%
SW	A	0.252%	0.111%	0.034%	0.031%	0.008%	0.000%
WSW	A	0.263%	0.111%	0.065%	0.031%	0.004%	0.000%
W	A	0.427%	0.111%	0.057%	0.008%	0.008%	0.011%
WNW	A	0.420%	0.137%	0.027%	0.023%	0.008%	0.000%
NW	A	0.412%	0.088%	0.057%	0.019%	0.011%	0.000%
NNW	A	0.340%	0.065%	0.019%	0.000%	0.000%	0.000%
N	B	0.080%	0.031%	0.015%	0.000%	0.000%	0.000%
NNE	B	0.080%	0.031%	0.011%	0.000%	0.000%	0.004%
NE	B	0.084%	0.023%	0.000%	0.000%	0.000%	0.004%
ENE	B	0.095%	0.023%	0.015%	0.000%	0.000%	0.000%
E	B	0.061%	0.011%	0.011%	0.000%	0.000%	0.000%
ESE	B	0.053%	0.034%	0.000%	0.000%	0.004%	0.000%
SE	B	0.034%	0.019%	0.004%	0.004%	0.000%	0.000%
SSE	B	0.046%	0.034%	0.019%	0.000%	0.000%	0.000%
S	B	0.065%	0.053%	0.034%	0.004%	0.004%	0.008%
SSW	B	0.050%	0.061%	0.019%	0.004%	0.000%	0.000%
SW	B	0.069%	0.061%	0.031%	0.008%	0.000%	0.000%
WSW	B	0.080%	0.073%	0.027%	0.015%	0.011%	0.000%
W	B	0.134%	0.057%	0.042%	0.008%	0.000%	0.000%
WNW	B	0.115%	0.073%	0.034%	0.004%	0.008%	0.000%
NW	B	0.233%	0.145%	0.034%	0.015%	0.004%	0.004%
NNW	B	0.214%	0.126%	0.019%	0.004%	0.000%	0.004%
N	C	0.103%	0.080%	0.050%	0.004%	0.008%	0.000%
NNE	C	0.141%	0.088%	0.027%	0.004%	0.004%	0.004%
NE	C	0.130%	0.095%	0.031%	0.000%	0.004%	0.000%
ENE	C	0.053%	0.042%	0.015%	0.011%	0.004%	0.000%
E	C	0.050%	0.050%	0.011%	0.015%	0.000%	0.000%
ESE	C	0.065%	0.073%	0.019%	0.011%	0.004%	0.004%
SE	C	0.057%	0.061%	0.015%	0.019%	0.000%	0.008%
SSE	C	0.073%	0.099%	0.031%	0.004%	0.011%	0.000%
S	C	0.092%	0.095%	0.069%	0.011%	0.011%	0.008%
SSW	C	0.115%	0.080%	0.065%	0.008%	0.008%	0.008%
SW	C	0.107%	0.122%	0.111%	0.046%	0.008%	0.004%
WSW	C	0.095%	0.130%	0.076%	0.046%	0.011%	0.000%
W	C	0.206%	0.176%	0.084%	0.027%	0.008%	0.008%
WNW	C	0.401%	0.252%	0.183%	0.061%	0.008%	0.019%
NW	C	0.256%	0.256%	0.130%	0.069%	0.019%	0.011%
NNW	C	0.122%	0.084%	0.069%	0.015%	0.000%	0.000%

Table C.5 (Cont.): Triple-Joint Frequency Wind Data for SRBT - 24 hr Period

Sector (from)	Stability Class	Velocity Class (average class speed in m/s)					
		0.94	**2.48**	**3.48**	**4.46**	**5.45**	**7.06**
N	D	0.515%	0.290%	0.076%	0.050%	0.023%	0.011%
NNE	D	0.523%	0.344%	0.183%	0.038%	0.057%	0.015%
NE	D	0.382%	0.324%	0.149%	0.095%	0.042%	0.011%
ENE	D	0.282%	0.134%	0.088%	0.023%	0.008%	0.000%
E	D	0.260%	0.191%	0.088%	0.027%	0.019%	0.004%
ESE	D	0.309%	0.214%	0.118%	0.046%	0.008%	0.000%
SE	D	0.340%	0.179%	0.103%	0.053%	0.019%	0.008%
SSE	D	0.279%	0.374%	0.084%	0.061%	0.023%	0.023%
S	D	0.386%	0.305%	0.183%	0.042%	0.038%	0.000%
SSW	D	0.439%	0.546%	0.141%	0.073%	0.038%	0.004%
SW	D	0.565%	0.386%	0.191%	0.107%	0.046%	0.050%
WSW	D	0.985%	0.454%	0.328%	0.191%	0.027%	0.019%
W	D	1.679%	0.603%	0.340%	0.122%	0.031%	0.027%
WNW	D	1.813%	0.889%	0.550%	0.340%	0.221%	0.099%
NW	D	1.233%	0.595%	0.485%	0.305%	0.183%	0.107%
NNW	D	0.756%	0.370%	0.221%	0.115%	0.050%	0.031%
N	E	0.393%	0.321%	0.195%	0.126%	0.088%	0.061%
NNE	E	0.336%	0.519%	0.382%	0.363%	0.313%	0.191%
NE	E	0.290%	0.492%	0.359%	0.252%	0.244%	0.107%
ENE	E	0.240%	0.176%	0.156%	0.122%	0.023%	0.011%
E	E	0.225%	0.240%	0.195%	0.118%	0.027%	0.000%
ESE	E	0.153%	0.218%	0.214%	0.130%	0.050%	0.000%
SE	E	0.099%	0.149%	0.141%	0.088%	0.008%	0.027%
SSE	E	0.183%	0.240%	0.233%	0.134%	0.046%	0.023%
S	E	0.149%	0.260%	0.202%	0.065%	0.053%	0.023%
SSW	E	0.214%	0.366%	0.263%	0.145%	0.088%	0.031%
SW	E	0.260%	0.252%	0.252%	0.145%	0.061%	0.031%
WSW	E	0.534%	0.401%	0.374%	0.229%	0.103%	0.088%
W	E	1.210%	0.928%	0.733%	0.324%	0.141%	0.198%
WNW	E	0.970%	1.069%	0.970%	0.618%	0.546%	0.622%
NW	E	0.683%	0.618%	0.599%	0.504%	0.374%	0.389%
NNW	E	0.424%	0.309%	0.237%	0.195%	0.107%	0.122%
N	F	1.374%	0.149%	0.145%	0.229%	0.214%	0.214%
NNE	F	1.126%	0.233%	0.347%	0.454%	0.340%	0.576%
NE	F	1.191%	0.145%	0.195%	0.389%	0.321%	0.275%
ENE	F	1.099%	0.080%	0.061%	0.053%	0.008%	0.000%
E	F	0.943%	0.240%	0.145%	0.076%	0.015%	0.000%
ESE	F	1.573%	0.210%	0.095%	0.130%	0.023%	0.011%
SE	F	0.809%	0.107%	0.069%	0.023%	0.011%	0.008%
SSE	F	1.008%	0.248%	0.111%	0.073%	0.011%	0.011%
S	F	1.061%	0.088%	0.092%	0.065%	0.034%	0.015%
SSW	F	1.504%	0.130%	0.069%	0.073%	0.057%	0.023%
SW	F	1.244%	0.099%	0.103%	0.046%	0.046%	0.027%
WSW	F	1.889%	0.134%	0.195%	0.103%	0.057%	0.050%
W	F	3.015%	0.615%	0.851%	0.687%	0.340%	0.187%
WNW	F	1.973%	0.584%	0.561%	0.477%	0.397%	0.401%
NW	F	1.286%	0.176%	0.248%	0.229%	0.210%	0.443%
NNW	F	0.763%	0.046%	0.122%	0.073%	0.057%	0.115%

Table C.6 - Triple-Joint Frequency Wind Data for SRBT - 12-hr Period

Sector (from)	Stability Class	Velocity Class (average class speed in m/s)					
		1.11	**2.49**	**3.49**	**4.46**	**5.45**	**6.99**
N	A	0.685%	0.099%	0.046%	0.015%	0.008%	0.000%
NNE	A	0.449%	0.068%	0.023%	0.008%	0.000%	0.008%
NE	A	0.365%	0.046%	0.030%	0.000%	0.000%	0.000%
ENE	A	0.449%	0.107%	0.000%	0.000%	0.000%	0.000%
E	A	0.403%	0.084%	0.008%	0.000%	0.000%	0.000%
ESE	A	0.297%	0.114%	0.015%	0.000%	0.000%	0.008%
SE	A	0.320%	0.099%	0.023%	0.015%	0.000%	0.015%
SSE	A	0.327%	0.084%	0.030%	0.023%	0.008%	0.000%
S	A	0.449%	0.152%	0.038%	0.030%	0.000%	0.008%
SSW	A	0.419%	0.175%	0.076%	0.023%	0.000%	0.000%
SW	A	0.434%	0.205%	0.068%	0.061%	0.008%	0.000%
WSW	A	0.479%	0.198%	0.107%	0.053%	0.000%	0.000%
W	A	0.746%	0.198%	0.114%	0.015%	0.015%	0.023%
WNW	A	0.761%	0.244%	0.046%	0.046%	0.015%	0.000%
NW	A	0.692%	0.152%	0.107%	0.038%	0.023%	0.000%
NNW	A	0.624%	0.114%	0.038%	0.000%	0.000%	0.000%
N	B	0.129%	0.061%	0.023%	0.000%	0.000%	0.000%
NNE	B	0.129%	0.061%	0.015%	0.000%	0.000%	0.000%
NE	B	0.160%	0.046%	0.000%	0.000%	0.000%	0.008%
ENE	B	0.327%	0.084%	0.030%	0.023%	0.008%	0.000%
E	B	0.122%	0.015%	0.023%	0.000%	0.000%	0.000%
ESE	B	0.107%	0.068%	0.000%	0.000%	0.008%	0.000%
SE	B	0.068%	0.038%	0.008%	0.008%	0.000%	0.000%
SSE	B	0.084%	0.068%	0.023%	0.000%	0.000%	0.000%
S	B	0.107%	0.099%	0.068%	0.008%	0.008%	0.015%
SSW	B	0.099%	0.122%	0.038%	0.008%	0.000%	0.000%
SW	B	0.129%	0.114%	0.061%	0.015%	0.000%	0.000%
WSW	B	0.107%	0.137%	0.053%	0.030%	0.023%	0.000%
W	B	0.259%	0.107%	0.076%	0.015%	0.000%	0.000%
WNW	B	0.198%	0.137%	0.068%	0.008%	0.015%	0.000%
NW	B	0.426%	0.282%	0.068%	0.030%	0.008%	0.008%
NNW	B	0.380%	0.228%	0.038%	0.008%	0.000%	0.008%
N	C	0.167%	0.137%	0.099%	0.008%	0.015%	0.000%
NNE	C	0.244%	0.160%	0.053%	0.000%	0.008%	0.008%
NE	C	0.221%	0.167%	0.053%	0.000%	0.008%	0.000%
ENE	C	0.091%	0.084%	0.030%	0.023%	0.008%	0.000%
E	C	0.076%	0.099%	0.023%	0.030%	0.000%	0.000%
ESE	C	0.122%	0.122%	0.038%	0.023%	0.008%	0.008%
SE	C	0.114%	0.114%	0.030%	0.030%	0.000%	0.015%
SSE	C	0.137%	0.183%	0.053%	0.008%	0.023%	0.000%
S	C	0.152%	0.137%	0.129%	0.023%	0.023%	0.015%
SSW	C	0.198%	0.145%	0.122%	0.015%	0.015%	0.015%
SW	C	0.183%	0.221%	0.205%	0.091%	0.015%	0.008%
WSW	C	0.145%	0.259%	0.129%	0.091%	0.023%	0.000%
W	C	0.266%	0.320%	0.152%	0.053%	0.015%	0.015%
WNW	C	0.647%	0.479%	0.350%	0.114%	0.015%	0.038%
NW	C	0.457%	0.495%	0.259%	0.129%	0.030%	0.015%
NNW	C	0.190%	0.137%	0.114%	0.030%	0.000%	0.000%

Table C.6 (cont.): Triple-Joint Frequency Wind Data for SRBT - 12 hr Period

Sector (from)	Stability Class	Velocity Class (average class speed in m/s)					
		1.11	**2.49**	**3.49**	**4.46**	**5.45**	**6.99**
N	D	0.282%	0.297%	0.099%	0.068%	0.030%	0.015%
NNE	D	0.396%	0.419%	0.259%	0.038%	0.091%	0.023%
NE	D	0.312%	0.373%	0.236%	0.152%	0.084%	0.015%
ENE	D	0.198%	0.122%	0.122%	0.046%	0.008%	0.000%
E	D	0.175%	0.236%	0.114%	0.038%	0.023%	0.008%
ESE	D	0.198%	0.266%	0.129%	0.046%	0.008%	0.000%
SE	D	0.205%	0.167%	0.145%	0.068%	0.023%	0.000%
SSE	D	0.213%	0.419%	0.122%	0.068%	0.046%	0.038%
S	D	0.198%	0.297%	0.304%	0.068%	0.061%	0.000%
SSW	D	0.198%	0.578%	0.167%	0.114%	0.038%	0.008%
SW	D	0.236%	0.335%	0.244%	0.175%	0.076%	0.091%
WSW	D	0.510%	0.373%	0.502%	0.312%	0.046%	0.023%
W	D	0.677%	0.738%	0.525%	0.175%	0.046%	0.038%
WNW	D	0.906%	1.012%	0.837%	0.517%	0.327%	0.145%
NW	D	0.571%	0.670%	0.738%	0.510%	0.282%	0.152%
NNW	D	0.373%	0.342%	0.327%	0.190%	0.091%	0.046%
N	E	0.335%	0.282%	0.251%	0.152%	0.114%	0.061%
NNE	E	0.259%	0.457%	0.396%	0.441%	0.464%	0.274%
NE	E	0.289%	0.403%	0.304%	0.365%	0.396%	0.145%
ENE	E	0.167%	0.167%	0.236%	0.167%	0.046%	0.023%
E	E	0.198%	0.259%	0.198%	0.160%	0.038%	0.000%
ESE	E	0.137%	0.213%	0.205%	0.167%	0.084%	0.000%
SE	E	0.091%	0.129%	0.167%	0.091%	0.015%	0.030%
SSE	E	0.107%	0.236%	0.152%	0.122%	0.068%	0.046%
S	E	0.160%	0.282%	0.228%	0.076%	0.068%	0.030%
SSW	E	0.167%	0.282%	0.289%	0.167%	0.122%	0.038%
SW	E	0.152%	0.167%	0.244%	0.175%	0.068%	0.038%
WSW	E	0.236%	0.274%	0.396%	0.358%	0.145%	0.114%
W	E	0.495%	0.837%	1.065%	0.556%	0.190%	0.282%
WNW	E	0.419%	1.065%	1.225%	0.966%	0.845%	0.890%
NW	E	0.312%	0.441%	0.662%	0.700%	0.601%	0.487%
NNW	E	0.213%	0.244%	0.221%	0.221%	0.160%	0.190%
N	F	0.875%	0.084%	0.107%	0.190%	0.274%	0.221%
NNE	F	0.639%	0.137%	0.251%	0.350%	0.396%	0.670%
NE	F	0.753%	0.107%	0.152%	0.297%	0.350%	0.282%
ENE	F	0.685%	0.076%	0.076%	0.061%	0.008%	0.000%
E	F	0.654%	0.205%	0.129%	0.061%	0.030%	0.000%
ESE	F	1.332%	0.205%	0.076%	0.152%	0.023%	0.000%
SE	F	0.662%	0.107%	0.061%	0.008%	0.023%	0.000%
SSE	F	0.594%	0.213%	0.084%	0.061%	0.015%	0.023%
S	F	0.479%	0.091%	0.061%	0.084%	0.015%	0.023%
SSW	F	0.959%	0.084%	0.038%	0.061%	0.076%	0.038%
SW	F	0.502%	0.061%	0.091%	0.046%	0.053%	0.008%
WSW	F	0.274%	0.068%	0.122%	0.137%	0.068%	0.053%
W	F	0.852%	0.403%	0.997%	1.103%	0.540%	0.312%
WNW	F	0.966%	0.426%	0.578%	0.586%	0.556%	0.495%
NW	F	0.685%	0.107%	0.183%	0.282%	0.282%	0.426%
NNW	F	0.244%	0.038%	0.046%	0.068%	0.030%	0.107%

Table C.7: Comparative Summary of Directional Frequency Patterns

Wind Direction		Petawawa 1989-2004[1]	SRB 2011 to 2015[2]		SRB 2017 to 2019[3]	
From	To		24-hr	12-hr	24-hr	12-hr
N[4]	S	4.16%	5.90%	6.03%	5.31%	5.23%
NNE	SSW	2.45%	6.10%	6.55%	7.04%	7.19%
NE	SW	2.53%	5.20%	5.34%	5.88%	6.12%
ENE	WSW	2.38%	4.43%	5.01%	3.12%	3.47%
E	W	3.79%	5.56%	5.75%	3.29%	3.41%
ESE	WNW	10.58%	5.32%	5.02%	4.00%	4.18%
SE	NW	12.17%	5.72%	6.10%	2.72%	2.89%
SSE	NNW	4.64%	5.86%	6.11%	3.73%	3.68%
S	N	3.49%	5.26%	5.08%	3.91%	3.99%
SSW	NNE	3.69%	5.66%	5.18%	5.00%	4.89%
SW	NE	4.86%	6.49%	6.01%	4.91%	4.58%
WSW[6]	ENE	6.26%	8.16%	7.34%	7.20%	5.84%
W	ENE	9.41%	7.74%	7.24%	13.40%	12.22%
WNW[5]	ESE	10.68%	9.19%	9.75%	14.87%	15.94%
NW	SE	11.35%	7.80%	8.05%	10.43%	11.31%
NNW	SSE	7.55%	5.59%	5.44%	5.19%	5.06%

1 - wind data collected at CFB Petawawa, used for the 2006 DRL calculation
2 - wind data collected on-site at SRBT, used for the 2016 DRL calculation
3 - wind data collected on-site at SRBT, used for current DRL calculation
4 - Saar farm is located S of SRBT
5 - the representative person is located to the WNW of SRBT
6 - Bouden’s market garden is located ENE of SRBT

C.5 Summary of Derived Parameter Values

The information in this appendix has been used to determine the value of several variables involved in this iteration of DRL calculation of for SRBT. This includes the following:

- the joint frequency of occurrence of stability class i and wind speed class k when the wind blows toward receptor j (F_{ijk}), as used in Equation A.2 (Section A.2.1, Appendix A) to calculate transfer parameter P_{01}. The F_{ijk} values for the SRBT site are also used in the validation of the atmospheric dispersion model (see Appendix D). Values for all allowable combinations appear in Tables C.5 and C.6.
- the temperature of the ambient air (T_a), as used in Equation A.11 (Section A.2.1, Appendix A) to determine the effect of plume rise of parameter P_{01}. Plume rise is excluded in the DRL calculation, but is considered in validation efforts (see Appendix D). Annual average air temperature has been determined to be 6.2 degrees C. Considering only the hours of operation (i.e., 7:00 to 19:00), the average temperature is 8.01 degrees C.
- absolute humidity (H_a), when the ground is not frozen or snow covered, as used in Equation A.18 (Section A.2.2, Appendix A) to calculate transfer parameter P_{11a}. A site-specific value of 0.0087 L • m^{-3} has been assigned.
- absolute humidity (H_a) during the growing season, as used in Equation A.19 to calculate transfer parameter $P_{14\text{-}HTO}$, and Equation A.21 (Section A.3.3, Appendix A) to calculate $P_{14\text{-}HTO\text{-}OBT}$. A site-specific value of 0.0116 L • m^{-3} has been assigned.
- absolute humidity (H_a), on an average annual basis, as used in Equation A.23 (Section A.4.2, Appendix A) to calculate transfer parameter $P_{12G\text{-}HTO}$, and Equation A.26 (Section A.9) to calculate $P_{15\text{-}HTO}$. A site-specific value of 0.0066 L • m^{-3} has been assigned.

APPENDIX C REFERENCES

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APPENDIX D: MODEL VALIDATION

D.1 General Considerations

The theory and specification equations used in the calculation of SRBT's DRLs are taken from the current scientific guidance available for nuclear facilities in Canada (CSA N288.1-14). The current Canadian guidance is itself reflective of the most up-to-date scientific understanding of the environmental fate and transport of radionuclides and their dose impacts. The underlying theory and equations have been developed on the basis of continual refinement, a significant aspect of which has been validation through empirical analysis. The CNSC has also recently conducted a series of studies on the environmental fate of tritium (CNSC 2009, 2010). These studies generally reinforced the current DRL models as conservatively representative of the true environmental dynamics of tritium.

These high-level assessments have encompassed review of theory as well as empirical validation with data collected at various sites, including SRBT. Overall, the theory and equations presented in the current guidance have been continuously demonstrated to be conservatively representative of the phenomenon and processes which they are meant to represent. This is particularly the case for tritium, which is one of the most important and widely studied radionuclides at nuclear facilities in Canada. Main conclusions from these studies include the following:

- The sector-averaged Gaussian plume model of atmospheric dispersion tends to predict annual average concentrations of tritium in air that are higher than measured, generally within a factor of 2.
- Concentrations of tritium in precipitation, soil and groundwater are directly a function of atmospheric concentrations, assuming an absence of a significant up-gradient source of tritium in liquid form released directly to groundwater.
- Specific Activity equations provide a reliable means to conservatively quantify biological partitioning of tritium in plants and animals.

D.2 Site-Specific Validation

In addition to the general validation of the models applied herein, there has been considerable effort to provide site-specific validation of the theory and equations used to predict the environmental fate of tritium released to atmosphere from the SRBT facility. The previous determinations of DRLs (EcoMetrix, 2006, Morris, 2017) included empirical validation of several aspects of the applied model, including atmospheric dispersion, partitioning to groundwater, and partitioning to produce. That validation was based on the following:

- direct measures of stack emissions of tritium (HT and HTO) over the period of 2000-2015,
- direct measures of HTO in air at 13 monitoring stations from 2000-2015,
- direct measures of HTO in groundwater samples from 7 residential wells from 2006 to 2015,
- direct measures of HTO in samples of garden produce collected at numerous locations over the period of 2000-2015, and

- direct measures of HTO in samples of milk from a local dairy from 2006 to 2015.

A key outcome of these previous validation efforts was that the atmospheric dispersion model was adjusted to exclude the effects of thermal buoyancy in its application for determining SRBT's DRLs. This adjustment was found to confer at least a two-fold conservatism in the resulting DRLs. The models applied to estimate tritium activity in residential wells and locally obtained food products were found to be conservative by as much as an order of magnitude or more.

Since the last determination of DRLs in 2016, SRBT's environmental monitoring program (EMP) has provided a continuation of the data that have been previously considered in validation efforts. Over the period of 2016 to 2020, the routine monitoring undertaken as part of SRBT's EMP has included the following:

- Measures of cumulative HTO in air at 40 outdoor passive air sampling (PAS) stations in total, with 35 established within 2 km of SRBT, and an additional 5 stations established at distances greater than 5 km.
- Measures of HTO in groundwater samples collected monthly or less (depending on distance and other factors) from a total of up to 46 wells. This includes as many as 34 wells established strictly for monitoring purposes, and 12 existing wells in the community that serve as a source of domestic or commercial water supplies. The number of wells sampled in a given year has varied as the Groundwater Monitoring Program has evolved, with sampling of certain wells discontinued as warranted by monitoring results.
- Ongoing measures of HTO in cumulative samples of precipitation collected monthly at 8 locations that are in common with PAS monitoring.
- Measures of HTO in samples of multiple types of garden produce collected each growing season at multiple locations (5 to 8, depending on availability) in the vicinity of SRBT.
- Measures of HTO in samples of milk collected every four months from a local producer and a local distributor.

There are a number of measures in place to ensure that the data collected through the various EMP efforts are reliable, including the collection of duplicate samples and independent replicate sampling by independent and qualified third parties, including the CNSC.

Each year, the empirical data collected by SRBT is used to ensure that the levels of HTO in various environmental media are well within acceptable limits, and also that they are consistent with the science-based expectations. The results of these efforts are reported in SRBT Annual Compliance Reports (ACR). Over the period of 2016 to 2020, the assessment of EMP measures has concluded that observed measures of tritium in various environmental media are consistent with what would be expected on the basis of facility emissions and the applied fate and transport theory.

For current purposes, additional quantitative validation has been completed using select data compiled over the period since the 2016 DRL calculation. In this effort atmospheric dispersion is the main focus of validation. This focus is in part warranted by the fact that atmospheric dispersion is the dominant process affecting all pathways of public exposure.

D.2.1 Atmospheric Dispersion

Procedure

Validation of the DRL model for atmospheric dispersion consists of direct comparison of model estimates with direct measures of HTO in air collected through SRBT's EMP. Comparisons have been conducted using model estimates of average annual tritium activity in air at a total of 31 locations for which direct measures are available. The model was applied for validation purposes in a manner consistent with its application for the calculation of DRLs. This has been done in consideration of average conditions over the 5-year period from 2016 to 2020. Site-specific data were used for modeling purposes, including facility emissions, triple-joint-frequency (TJF) wind data, ambient air temperature, and stack exit velocity measures. Details of these data are presented in Appendix C (wind and temperature data) and Appendix E (stack exit velocity), with a summary in Tables D.1 and D.2. The modeling of atmospheric dispersion over the 2016-2020 period is based on the average rate of total equivalent HTO emissions over this period (i.e., 9,625 GBq/a, or 3.05E+05 Bq/s). The predictive modeling also uses average wind data for the period of 2016 to 2019, inclusive, which reflects limitations in the availability of complete meteorological data for the full period, as discussed in Appendix C.

The atmospheric dispersion validation has given consideration to a few key factors that have been previously identified as influential on the degree to which the model effectively reflects conditions at SRBT. The validation has been conducted to assess the implications of two of these factors; 1) thermal buoyancy, and 2) the time of day of emissions. The validation process is also affected by the reliability of the direct measures of tritium in air that serve as the basis of comparison. The potential bias of passive tritium air monitors has also been reassessed in the current validation effort. The potential influence of tritium from sources other than SRBT has also been considered.

Table D.1 - Atmospheric Dispersion Validation Variables

Year	Average Temperature[1] 24-hr	Average Temperature[1] 12-hr[2]	Exit Velocity[3]
2016	NC	NC	17.08
2017	6.15	7.75	17.41
2018	5.95	7.47	17.10
2019	6.52	8.25	18.47
2020	6.81	8.58	18.16

1 - temperature data obtained from on-site weather station
2 - data specific to period of 7:00 to 19:00

3 - average of readings for given year (see App. E)
NC - not calculated due to missing data (see App. C)

Table D.2: SRBT Facility Tritium Emissions

Year	HT (GBq/a)	HTO (GBq/a)	Total HTO Equivalent[1]	
			GBq/a	Bq/s
2016	22,652	6,293	6,821	2.16E+05
2017	17,624	7,198	7,609	2.41E+05
2018	22,439	10,741	11,264	3.57E+05
2019	19,911	11,858	12,322	3.91E+05
2020	15,431	9,755	10,115	3.21E+05

All values in units of GBq
1 - HT emissions converted to HTO using factor P_{11a} (0.02278), and added to HTO emissions

Results – Outdoor Air

The results of the validation of the atmospheric dispersion model for outdoor air are summarized in Table D.3 to D.6, with full detailed results provided in Table D.7 through D.19. The main conclusions from the outdoor air validation efforts are as follows:

- The model generally generates results that are in reasonable agreement with available measures.
- The results generated using TJF data corresponding to the operational hours at SRBT (i.e., 12-hr data, 7:00 to 19:00) are slightly less conservative overall than results generated using the full range of TJF data, but are still generally conservative for the 250-500 m distance and slightly more conservative at distances <100 m (i.e., at the location of the worker group, where the DRL is limiting)
- The exclusion of thermal buoyancy provides a degree of conservatism that is deemed acceptable, with model results being about 25% to 40% higher than measures.
- The degree of agreement and conservatism tends to decline with distance, but conservatism at the distance of residential critical groups (250 to 500 m) is relatively high (i.e., approximately 40% to 70%)). It should be noted that many of the measures of HTO in air at distances >500 m are very low and frequently less than method detection limits.
- If an allowance is made for potential bias of the passive air samplers, the model results inclusive of thermal buoyancy are roughly equivalent to measures (i.e., ~70% to 120% agreement at 250-500m).

- If the effects of atypically high detection limits in 2020 are taken into account, the predictive model applied for DRL purposes (i.e., 12-hr data with no thermal buoyancy, no adjustment for background or possible sampler bias), the model results are about double the observed measures within 500 m of the source (see Tables D.6 and D.19).

In the previous DRL calculation, it was determined that the inclusion of thermal plume rise in the model yields results that have a relatively low degree of conservatism. Current validation efforts yield similar outcome, but also identify that the inclusion of thermal plume buoyancy may be acceptable, pending resolve of potential bias associated with the passive air monitor technology currently employed at SRBT. For the purpose of the current DRL calculation, the model has been configured to exclude thermal buoyancy and achieve the higher level of conservatism. The model has also been applied using the 12-hr TJF data which are directly representative of the periodicity of emissions from SRBT. The use of the 12-hr subset of available TJF data conforms to the recommendations of the DRL Guidance.

Table D.3 - Summary of Model Comparison with Measures - Thermal Buoyancy Excluded

Distance Category	No adjustment		Adjusted for background[1]	
	24-hr TJF	12-hr TJF[2]	24-hr TJF	12-hr TJF[2]
<100m	140%	164%	144%	169%
250 m	185%	146%	200%	158%
500 m	271%	173%	318%	202%
1000 m	141%	86%	176%	107%
2000 m	51%	33%	65%	42%
All Distances Combined	174%	124%	**201%**	**142%**

All values represent the model estimate as a percentage of actual measure of HTO in air

1 - Measures reduced by 0.1 Bq/m^3 to account for the presence of tritium from sources other than SRBT

2 – TJF dataset includes only the hours of 7:00 to 19:00 to correspond with hours of operation at SRBT

Table D.4 - Summary of Model Comparison with Measures - Thermal Buoyancy Included

Distance Category	No adjustment		Adjusted for background[1]	
	24-hr TJF	12-hr TJF[2]	24-hr TJF	12-hr TJF[2]
<100m	22%	44%	22%	45%
250 m	56%	69%	60%	75%
500 m	75%	82%	87%	96%
1000 m	42%	53%	52%	66%
2000 m	20%	26%	26%	34%
All Distances Combined	**49%**	**60%**	**57%**	**70%**

All values represent the model estimate as a percentage of actual measure of HTO in air

1 - Measures reduced by 0.1 Bq/m^3 to account for the presence of tritium from sources other than SRBT

2 – TJF dataset includes only the hours of 7:00 to 19:00 to correspond with hours of operation at SRBT

Table D.5 - Summary of Model Comparison with Measures - Adjusted for Possible Sampler Bias

Distance Category	Measures adjusted by 30%[1]		Measures adjusted by 50%[1]	
	24-hr TJF	12-hr TJF[2]	24-hr TJF	12-hr TJF[2]
<100m	31%	63%	31%	88%
250 m	80%	99%	80%	138%
500 m	107%	117%	107%	163%
1000 m	60%	76%	60%	106%
2000 m	29%	37%	29%	52%
All Distances Combined	**71%**	**86%**	**71%**	**120%**

All values represent the model estimate as a percentage of actual measure of HTO in air
Model estimates include effect of thermal buoyancy
1 - Measures have been reduced by 30% or 50% to account for possible bias of PAS
2 – TJF dataset includes only the hours of 7:00 to 19:00 to correspond with hours of operation at SRBT

Table D.6 - Summary of Model Comparison with Measures - Adjusted to Exclude Results for 2020

Distance Category	No Thermal Buoyancy			
	No adjustment for background		Adjusted for background	
	24-hr TJF	12-hr TJF	24-hr TJF	12-hr TJF
<100m	157%	184%	162%	190%
250 m	235%	185%	260%	206%
500 m	375%	241%	474%	307%
1000 m	204%	124%	285%	173%
2000 m	71%	46%	103%	67%
All Distances Combined	234%	166%	**292%**	**204%**

All values represent the model estimate as a percentage of actual measure of HTO in air
Model estimates exclude effect of thermal buoyancy
Measures represent the average of measures for the period of 2016 to 2019, inclusive

Table D.7 - Comparison of Model Estimates with Direct Measures - 24-hr Wind Data, No Thermal Buoyancy

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.51	1.38	1.16	1.32	2.88	1.45	2.42	167%
2	N500	0.31	0.71	0.51	0.58	1.44	0.71	1.65	232%
3	N1000	0.31	0.34	0.32	0.35	1.24	0.51	0.58	113%
4	NW250	0.87	1.92	2.46	2.49	3.89	2.33	2.73	117%
5	NW500	0.44	0.62	0.73	0.71	1.89	0.88	0.87	99%
6	NW1000	0.31	0.37	0.42	0.38	1.14	0.52	0.41	79%
7	NW2000	0.32	0.4	0.32	0.35	1.10	0.50	0.16	32%
8	W250	0.75	0.96	1.10	1.28	3.67	1.55	1.68	108%
9	W500	0.33	0.58	0.64	0.77	1.98	0.86	1.45	169%
10	W1000	0.37	0.4	0.40	0.60	1.35	0.62	0.84	134%
11	SW250	0.31	0.71	0.70	0.80	1.65	0.83	2.97	356%
12	SW500	0.31	0.31	0.31	0.36	1.81	0.62	1.23	199%
13	SW1000	0.31	0.31	0.31	0.35	0.95	0.45	0.44	98%
14	SW2000	0.31	0.31	0.31	0.35	1.02	0.46	0.29	62%
15	S250	0.9	0.65	0.86	1.01	1.92	1.07	2.33	218%
16	S500	0.31	0.34	0.35	0.48	0.97	0.49	1.72	351%
17	S1000	0.31	0.31	0.31	0.35	1.02	0.46	0.20	44%
18	SE250	1.41	2.1	2.64	2.73	4.19	2.61	3.26	125%
19	SE500	0.79	0.95	1.31	1.50	3.01	1.51	2.36	156%
20	SE1000	0.31	0.36	0.39	0.50	1.56	0.62	0.93	149%
21	SE2000	0.31	0.31	0.31	0.35	0.95	0.45	0.30	66%
22	E250	1.68	1.53	1.75	3.00	4.82	2.56	5.10	200%
23	E500	0.31	0.65	0.64	0.51	1.44	0.71	3.45	485%
24	E1000	0.32	0.34	0.34	0.35	1.02	0.47	1.88	397%
25	NE250	1.16	3.04	3.10	2.63	3.24	2.63	5.09	193%
26	NE500	0.31	0.69	0.66	0.62	1.22	0.70	3.36	479%
27	NE1000	0.31	0.35	0.34	0.35	1.02	0.47	0.54	115%
28	NE2000	0.31	0.31	0.31	0.34	0.89	0.43	0.18	43%
PAS #1	S <100	1.7	2.96	4.58	6.10	7.25	4.52	5.98	132%
PAS #2	NW <100	1.99	3.5	4.33	4.22	4.91	3.79	3.64	96%
PAS #3	SW <100	0.89	2.47	3.24	3.51	3.92	2.81	5.35	191%

Table D.8 - Comparison of Model Estimates with Direct Measures - 24-hr Wind Data, No Thermal Buoyancy, Background[1] Excluded

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.41	1.28	1.06	1.22	2.78	1.35	2.42	179%
2	N500	0.21	0.61	0.41	0.48	1.34	0.61	1.65	270%
3	N1000	0.21	0.24	0.22	0.25	1.14	0.41	0.58	140%
4	NW250	0.77	1.82	2.36	2.39	3.79	2.23	2.73	123%
5	NW500	0.34	0.52	0.63	0.61	1.79	0.78	0.87	112%
6	NW1000	0.21	0.27	0.32	0.28	1.04	0.42	0.41	98%
7	NW2000	0.22	0.3	0.22	0.25	1.00	0.40	0.16	40%
8	W250	0.65	0.86	1.00	1.18	3.57	1.45	1.68	116%
9	W500	0.23	0.48	0.54	0.67	1.88	0.76	1.45	191%
10	W1000	0.27	0.3	0.30	0.50	1.25	0.52	0.84	159%
11	SW250	0.21	0.61	0.60	0.70	1.55	0.73	2.97	404%
12	SW500	0.21	0.21	0.21	0.26	1.71	0.52	1.23	237%
13	SW1000	0.21	0.21	0.21	0.25	0.85	0.35	0.44	126%
14	SW2000	0.21	0.21	0.21	0.25	0.92	0.36	0.29	80%
15	S250	0.8	0.55	0.76	0.91	1.82	0.97	2.33	241%
16	S500	0.21	0.24	0.25	0.38	0.87	0.39	1.72	441%
17	S1000	0.21	0.21	0.21	0.25	0.92	0.36	0.20	56%
18	SE250	1.31	2	2.54	2.63	4.09	2.51	3.26	130%
19	SE500	0.69	0.85	1.21	1.40	2.91	1.41	2.36	167%
20	SE1000	0.21	0.26	0.29	0.40	1.46	0.52	0.93	178%
21	SE2000	0.21	0.21	0.21	0.25	0.85	0.35	0.30	86%
22	E250	1.58	1.43	1.65	2.90	4.72	2.46	5.10	208%
23	E500	0.21	0.55	0.54	0.41	1.34	0.61	3.45	565%
24	E1000	0.22	0.24	0.24	0.25	0.92	0.37	1.88	504%
25	NE250	1.06	2.94	3.00	2.53	3.14	2.53	5.09	201%
26	NE500	0.21	0.59	0.56	0.52	1.12	0.60	3.36	559%
27	NE1000	0.21	0.25	0.24	0.25	0.92	0.37	0.54	146%
28	NE2000	0.21	0.21	0.21	0.24	0.79	0.33	0.18	55%
PAS #1	S <100	1.6	2.86	4.48	6.00	7.15	4.42	5.98	135%
PAS #2	NW <100	1.89	3.4	4.23	4.12	4.81	3.69	3.64	99%
PAS #3	SW <100	0.79	2.37	3.14	3.41	3.82	2.71	5.35	198%

Table D.9 - Comparison of Model Estimates with Direct Measures - 12-hr Wind Data, No Thermal Buoyancy

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.51	1.38	1.16	1.32	2.88	1.45	1.81	125%
2	N500	0.31	0.71	0.51	0.58	1.44	0.71	1.11	157%
3	N1000	0.31	0.34	0.32	0.35	1.24	0.51	0.36	70%
4	NW250	0.87	1.92	2.46	2.49	3.89	2.33	2.36	101%
5	NW500	0.44	0.62	0.73	0.71	1.89	0.88	0.64	73%
6	NW1000	0.31	0.37	0.42	0.38	1.14	0.52	0.30	57%
7	NW2000	0.32	0.4	0.32	0.35	1.10	0.50	0.11	23%
8	W250	0.75	0.96	1.10	1.28	3.67	1.55	1.30	84%
9	W500	0.33	0.58	0.64	0.77	1.98	0.86	1.11	129%
10	W1000	0.37	0.4	0.40	0.60	1.35	0.62	0.62	99%
11	SW250	0.31	0.71	0.70	0.80	1.65	0.83	2.84	340%
12	SW500	0.31	0.31	0.31	0.36	1.81	0.62	0.91	147%
13	SW1000	0.31	0.31	0.31	0.35	0.95	0.45	0.31	69%
14	SW2000	0.31	0.31	0.31	0.35	1.02	0.46	0.20	44%
15	S250	0.9	0.65	0.86	1.01	1.92	1.07	1.51	142%
16	S500	0.31	0.34	0.35	0.48	0.97	0.49	1.25	255%
17	S1000	0.31	0.31	0.31	0.35	1.02	0.46	0.13	29%
18	SE250	1.41	2.1	2.64	2.73	4.19	2.61	2.32	89%
19	SE500	0.79	0.95	1.31	1.50	3.01	1.51	1.65	109%
20	SE1000	0.31	0.36	0.39	0.50	1.56	0.62	0.62	99%
21	SE2000	0.31	0.31	0.31	0.35	0.95	0.45	0.19	43%
22	E250	1.68	1.53	1.75	3.00	4.82	2.56	3.76	147%
23	E500	0.31	0.65	0.64	0.51	1.44	0.71	2.02	284%
24	E1000	0.32	0.34	0.34	0.35	1.02	0.47	0.98	206%
25	NE250	1.16	3.04	3.10	2.63	3.24	2.63	3.67	139%
26	NE500	0.31	0.69	0.66	0.62	1.22	0.70	1.59	227%
27	NE1000	0.31	0.35	0.34	0.35	1.02	0.47	0.27	57%
28	NE2000	0.31	0.31	0.31	0.34	0.89	0.43	0.09	21%
PAS #1	S <100	1.7	2.96	4.58	6.10	7.25	4.52	6.10	135%
PAS #2	NW <100	1.99	3.5	4.33	4.22	4.91	3.79	4.59	121%
PAS #3	SW <100	0.89	2.47	3.24	3.51	3.92	2.81	6.64	236%

Table D.10 - Comparison of Model Estimates with Direct Measures - 12-hr Wind Data, No Thermal Buoyancy, Background[1] Excluded

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.41	1.28	1.06	1.22	2.78	1.35	1.81	134%
2	N500	0.21	0.61	0.41	0.48	1.34	0.61	1.11	182%
3	N1000	0.21	0.24	0.22	0.25	1.14	0.41	0.36	87%
4	NW250	0.77	1.82	2.36	2.39	3.79	2.23	2.36	106%
5	NW500	0.34	0.52	0.63	0.61	1.79	0.78	0.64	82%
6	NW1000	0.21	0.27	0.32	0.28	1.04	0.42	0.30	70%
7	NW2000	0.22	0.3	0.22	0.25	1.00	0.40	0.11	29%
8	W250	0.65	0.86	1.00	1.18	3.57	1.45	1.30	90%
9	W500	0.23	0.48	0.54	0.67	1.88	0.76	1.11	146%
10	W1000	0.27	0.3	0.30	0.50	1.25	0.52	0.62	118%
11	SW250	0.21	0.61	0.60	0.70	1.55	0.73	2.84	386%
12	SW500	0.21	0.21	0.21	0.26	1.71	0.52	0.91	175%
13	SW1000	0.21	0.21	0.21	0.25	0.85	0.35	0.31	89%
14	SW2000	0.21	0.21	0.21	0.25	0.92	0.36	0.20	56%
15	S250	0.8	0.55	0.76	0.91	1.82	0.97	1.51	156%
16	S500	0.21	0.24	0.25	0.38	0.87	0.39	1.25	320%
17	S1000	0.21	0.21	0.21	0.25	0.92	0.36	0.13	37%
18	SE250	1.31	2	2.54	2.63	4.09	2.51	2.32	92%
19	SE500	0.69	0.85	1.21	1.40	2.91	1.41	1.65	117%
20	SE1000	0.21	0.26	0.29	0.40	1.46	0.52	0.62	118%
21	SE2000	0.21	0.21	0.21	0.25	0.85	0.35	0.19	56%
22	E250	1.58	1.43	1.65	2.90	4.72	2.46	3.76	153%
23	E500	0.21	0.55	0.54	0.41	1.34	0.61	2.02	331%
24	E1000	0.22	0.24	0.24	0.25	0.92	0.37	0.98	261%
25	NE250	1.06	2.94	3.00	2.53	3.14	2.53	3.67	145%
26	NE500	0.21	0.59	0.56	0.52	1.12	0.60	1.59	265%
27	NE1000	0.21	0.25	0.24	0.25	0.92	0.37	0.27	73%
28	NE2000	0.21	0.21	0.21	0.24	0.79	0.33	0.09	27%
PAS #1	S <100	1.6	2.86	4.48	6.00	7.15	4.42	6.10	138%
PAS #2	NW <100	1.89	3.4	4.23	4.12	4.81	3.69	4.59	124%
PAS #3	SW <100	0.79	2.37	3.14	3.41	3.82	2.71	6.64	245%

1 - All measures have been reduced by 0.1 Bq/m3 to account for the presence of tritium originating from sources other than SRBT

Table D.11 - Comparison of Model Estimates with Direct Measures - 24-hr Wind Data, Thermal Buoyancy Included

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	**N250**	0.51	1.38	1.16	1.32	2.88	1.45	0.74	51%
2	**N500**	0.31	0.71	0.51	0.58	1.44	0.71	0.42	59%
3	**N1000**	0.31	0.34	0.32	0.35	1.24	0.51	0.15	29%
4	**NW250**	0.87	1.92	2.46	2.49	3.89	2.33	0.78	33%
5	**NW500**	0.44	0.62	0.73	0.71	1.89	0.88	0.22	25%
6	**NW1000**	0.31	0.37	0.42	0.38	1.14	0.52	0.11	20%
7	**NW2000**	0.32	0.4	0.32	0.35	1.10	0.50	0.05	10%
8	**W250**	0.75	0.96	1.10	1.28	3.67	1.55	0.36	23%
9	**W500**	0.33	0.58	0.64	0.77	1.98	0.86	0.31	36%
10	**W1000**	0.37	0.4	0.40	0.60	1.35	0.62	0.18	29%
11	**SW250**	0.31	0.71	0.70	0.80	1.65	0.83	0.76	91%
12	**SW500**	0.31	0.31	0.31	0.36	1.81	0.62	0.37	59%
13	**SW1000**	0.31	0.31	0.31	0.35	0.95	0.45	0.16	36%
14	**SW2000**	0.31	0.31	0.31	0.35	1.02	0.46	0.11	24%
15	**S250**	0.9	0.65	0.86	1.01	1.92	1.07	0.84	78%
16	**S500**	0.31	0.34	0.35	0.48	0.97	0.49	0.46	93%
17	**S1000**	0.31	0.31	0.31	0.35	1.02	0.46	0.07	15%
18	**SE250**	1.41	2.1	2.64	2.73	4.19	2.61	1.21	46%
19	**SE500**	0.79	0.95	1.31	1.50	3.01	1.51	0.90	60%
20	**SE1000**	0.31	0.36	0.39	0.50	1.56	0.62	0.38	61%
21	**SE2000**	0.31	0.31	0.31	0.35	0.95	0.45	0.14	32%
22	**E250**	1.68	1.53	1.75	3.00	4.82	2.56	1.76	69%
23	**E500**	0.31	0.65	0.64	0.51	1.44	0.71	1.01	142%
24	**E1000**	0.32	0.34	0.34	0.35	1.02	0.47	0.54	114%
25	**NE250**	1.16	3.04	3.10	2.63	3.24	2.63	1.51	57%
26	**NE500**	0.31	0.69	0.66	0.62	1.22	0.70	0.87	124%
27	**NE1000**	0.31	0.35	0.34	0.35	1.02	0.47	0.15	32%
28	**NE2000**	0.31	0.31	0.31	0.34	0.89	0.43	0.06	15%
PAS #1	**S <100**	1.7	2.96	4.58	6.10	7.25	4.52	1.32	29%
PAS #2	**NW <100**	1.99	3.5	4.33	4.22	4.91	3.79	0.50	13%
PAS #3	**SW <100**	0.89	2.47	3.24	3.51	3.92	2.81	0.64	23%

Table D.12 - Comparison of Model Estimates with Direct Measures - 24-hr Wind Data, Thermal Buoyancy Included, Background[1] Excluded

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.41	1.28	1.06	1.22	2.78	1.35	0.74	55%
2	N500	0.21	0.61	0.41	0.48	1.34	0.61	0.42	69%
3	N1000	0.21	0.24	0.22	0.25	1.14	0.41	0.15	36%
4	NW250	0.77	1.82	2.36	2.39	3.79	2.23	0.78	35%
5	NW500	0.34	0.52	0.63	0.61	1.79	0.78	0.22	28%
6	NW1000	0.21	0.27	0.32	0.28	1.04	0.42	0.11	25%
7	NW2000	0.22	0.3	0.22	0.25	1.00	0.40	0.05	12%
8	W250	0.65	0.86	1.00	1.18	3.57	1.45	0.36	25%
9	W500	0.23	0.48	0.54	0.67	1.88	0.76	0.31	41%
10	W1000	0.27	0.3	0.30	0.50	1.25	0.52	0.18	35%
11	SW250	0.21	0.61	0.60	0.70	1.55	0.73	0.76	104%
12	SW500	0.21	0.21	0.21	0.26	1.71	0.52	0.37	71%
13	SW1000	0.21	0.21	0.21	0.25	0.85	0.35	0.16	46%
14	SW2000	0.21	0.21	0.21	0.25	0.92	0.36	0.11	31%
15	S250	0.8	0.55	0.76	0.91	1.82	0.97	0.84	86%
16	S500	0.21	0.24	0.25	0.38	0.87	0.39	0.46	117%
17	S1000	0.21	0.21	0.21	0.25	0.92	0.36	0.07	20%
18	SE250	1.31	2	2.54	2.63	4.09	2.51	1.21	48%
19	SE500	0.69	0.85	1.21	1.40	2.91	1.41	0.90	64%
20	SE1000	0.21	0.26	0.29	0.40	1.46	0.52	0.38	72%
21	SE2000	0.21	0.21	0.21	0.25	0.85	0.35	0.14	41%
22	E250	1.58	1.43	1.65	2.90	4.72	2.46	1.76	71%
23	E500	0.21	0.55	0.54	0.41	1.34	0.61	1.01	165%
24	E1000	0.22	0.24	0.24	0.25	0.92	0.37	0.54	145%
25	NE250	1.06	2.94	3.00	2.53	3.14	2.53	1.51	60%
26	NE500	0.21	0.59	0.56	0.52	1.12	0.60	0.87	145%
27	NE1000	0.21	0.25	0.24	0.25	0.92	0.37	0.15	40%
28	NE2000	0.21	0.21	0.21	0.24	0.79	0.33	0.06	19%
PAS #1	S <100	1.6	2.86	4.48	6.00	7.15	4.42	1.32	30%
PAS #2	NW <100	1.89	3.4	4.23	4.12	4.81	3.69	0.50	14%
PAS #3	SW <100	0.79	2.37	3.14	3.41	3.82	2.71	0.64	24%

1 - All measures have been reduced by 0.1 Bq/m3 to account for the presence of tritium originating from sources other than SRBT

Table D.13 - Comparison of Model Estimates with Direct Measures - 12-hr Wind Data, Thermal Buoyancy Included

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.51	1.38	1.16	1.32	2.88	1.45	0.85	58%
2	N500	0.31	0.71	0.51	0.58	1.44	0.71	0.46	65%
3	N1000	0.31	0.34	0.32	0.35	1.24	0.51	0.21	41%
4	NW250	0.87	1.92	2.46	2.49	3.89	2.33	1.05	45%
5	NW500	0.44	0.62	0.73	0.71	1.89	0.88	0.27	30%
6	NW1000	0.31	0.37	0.42	0.38	1.14	0.52	0.16	31%
7	NW2000	0.32	0.4	0.32	0.35	1.10	0.50	0.08	17%
8	W250	0.75	0.96	1.10	1.28	3.67	1.55	0.47	30%
9	W500	0.33	0.58	0.64	0.77	1.98	0.86	0.40	46%
10	W1000	0.37	0.4	0.40	0.60	1.35	0.62	0.26	42%
11	SW250	0.31	0.71	0.70	0.80	1.65	0.83	1.22	147%
12	SW500	0.31	0.31	0.31	0.36	1.81	0.62	0.47	75%
13	SW1000	0.31	0.31	0.31	0.35	0.95	0.45	0.22	50%
14	SW2000	0.31	0.31	0.31	0.35	1.02	0.46	0.16	34%
15	S250	0.9	0.65	0.86	1.01	1.92	1.07	0.85	79%
16	S500	0.31	0.34	0.35	0.48	0.97	0.49	0.54	110%
17	S1000	0.31	0.31	0.31	0.35	1.02	0.46	0.11	23%
18	SE250	1.41	2.1	2.64	2.73	4.19	2.61	1.27	48%
19	SE500	0.79	0.95	1.31	1.50	3.01	1.51	0.96	64%
20	SE1000	0.31	0.36	0.39	0.50	1.56	0.62	0.44	70%
21	SE2000	0.31	0.31	0.31	0.35	0.95	0.45	0.16	37%
22	E250	1.68	1.53	1.75	3.00	4.82	2.56	1.83	72%
23	E500	0.31	0.65	0.64	0.51	1.44	0.71	1.04	147%
24	E1000	0.32	0.34	0.34	0.35	1.02	0.47	0.61	129%
25	NE250	1.16	3.04	3.10	2.63	3.24	2.63	1.90	72%
26	NE500	0.31	0.69	0.66	0.62	1.22	0.70	0.81	116%
27	NE1000	0.31	0.35	0.34	0.35	1.02	0.47	0.18	38%
28	NE2000	0.31	0.31	0.31	0.34	0.89	0.43	0.07	17%
PAS #1	S <100	1.7	2.96	4.58	6.10	7.25	4.52	2.34	52%
PAS #2	NW <100	1.99	3.5	4.33	4.22	4.91	3.79	1.13	30%
PAS #3	SW <100	0.89	2.47	3.24	3.51	3.92	2.81	1.40	50%

Table D.14 - Comparison of Model Estimates with Direct Measures - 12-hr Wind Data, Thermal Buoyancy Included, Background[1] Excluded

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.41	1.28	1.06	1.22	2.78	1.35	0.85	63%
2	N500	0.21	0.61	0.41	0.48	1.34	0.61	0.46	76%
3	N1000	0.21	0.24	0.22	0.25	1.14	0.41	0.21	51%
4	NW250	0.77	1.82	2.36	2.39	3.79	2.23	1.05	47%
5	NW500	0.34	0.52	0.63	0.61	1.79	0.78	0.27	34%
6	NW1000	0.21	0.27	0.32	0.28	1.04	0.42	0.16	39%
7	NW2000	0.22	0.3	0.22	0.25	1.00	0.40	0.08	21%
8	W250	0.65	0.86	1.00	1.18	3.57	1.45	0.47	32%
9	W500	0.23	0.48	0.54	0.67	1.88	0.76	0.40	52%
10	W1000	0.27	0.3	0.30	0.50	1.25	0.52	0.26	50%
11	SW250	0.21	0.61	0.60	0.70	1.55	0.73	1.22	167%
12	SW500	0.21	0.21	0.21	0.26	1.71	0.52	0.47	90%
13	SW1000	0.21	0.21	0.21	0.25	0.85	0.35	0.22	64%
14	SW2000	0.21	0.21	0.21	0.25	0.92	0.36	0.16	44%
15	S250	0.8	0.55	0.76	0.91	1.82	0.97	0.85	87%
16	S500	0.21	0.24	0.25	0.38	0.87	0.39	0.54	138%
17	S1000	0.21	0.21	0.21	0.25	0.92	0.36	0.11	29%
18	SE250	1.31	2	2.54	2.63	4.09	2.51	1.27	50%
19	SE500	0.69	0.85	1.21	1.40	2.91	1.41	0.96	68%
20	SE1000	0.21	0.26	0.29	0.40	1.46	0.52	0.44	83%
21	SE2000	0.21	0.21	0.21	0.25	0.85	0.35	0.16	47%
22	E250	1.58	1.43	1.65	2.90	4.72	2.46	1.83	75%
23	E500	0.21	0.55	0.54	0.41	1.34	0.61	1.04	171%
24	E1000	0.22	0.24	0.24	0.25	0.92	0.37	0.61	164%
25	NE250	1.06	2.94	3.00	2.53	3.14	2.53	1.90	75%
26	NE500	0.21	0.59	0.56	0.52	1.12	0.60	0.81	135%
27	NE1000	0.21	0.25	0.24	0.25	0.92	0.37	0.18	49%
28	NE2000	0.21	0.21	0.21	0.24	0.79	0.33	0.07	22%
PAS #1	S <100	1.6	2.86	4.48	6.00	7.15	4.42	2.34	53%
PAS #2	NW <100	1.89	3.4	4.23	4.12	4.81	3.69	1.13	31%
PAS #3	SW <100	0.79	2.37	3.14	3.41	3.82	2.71	1.40	52%

1 - All measures have been reduced by 0.1 Bq/m3 to account for the presence of tritium originating from sources other than SRBT

Table D.15 - Comparison of Model Estimates with Direct Measures - 24-hr Wind Data, Thermal Buoyancy Included, Corrected[1] by 30%

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.36	0.97	0.81	0.92	2.02	1.02	0.74	73%
2	N500	0.22	0.50	0.36	0.41	1.01	0.50	0.42	85%
3	N1000	0.22	0.24	0.22	0.25	0.87	0.36	0.15	41%
4	NW250	0.61	1.34	1.72	1.74	2.72	1.63	0.78	48%
5	NW500	0.31	0.43	0.51	0.50	1.32	0.61	0.22	36%
6	NW1000	0.22	0.26	0.29	0.27	0.80	0.37	0.11	29%
7	NW2000	0.22	0.28	0.22	0.25	0.77	0.35	0.05	14%
8	W250	0.53	0.67	0.77	0.90	2.57	1.09	0.36	33%
9	W500	0.23	0.41	0.45	0.54	1.39	0.60	0.31	51%
10	W1000	0.26	0.28	0.28	0.42	0.95	0.44	0.18	42%
11	SW250	0.22	0.50	0.49	0.56	1.16	0.58	0.76	130%
12	SW500	0.22	0.22	0.22	0.25	1.27	0.43	0.37	85%
13	SW1000	0.22	0.22	0.22	0.25	0.67	0.31	0.16	51%
14	SW2000	0.22	0.22	0.22	0.25	0.71	0.32	0.11	35%
15	S250	0.63	0.46	0.60	0.71	1.34	0.75	0.84	112%
16	S500	0.22	0.24	0.25	0.34	0.68	0.34	0.46	133%
17	S1000	0.22	0.22	0.22	0.25	0.71	0.32	0.07	22%
18	SE250	0.99	1.47	1.85	1.91	2.93	1.83	1.21	66%
19	SE500	0.55	0.67	0.92	1.05	2.11	1.06	0.90	85%
20	SE1000	0.22	0.25	0.27	0.35	1.09	0.44	0.38	87%
21	SE2000	0.22	0.22	0.22	0.25	0.67	0.31	0.14	46%
22	E250	1.18	1.07	1.23	2.10	3.37	1.79	1.76	98%
23	E500	0.22	0.46	0.45	0.36	1.01	0.50	1.01	203%
24	E1000	0.22	0.24	0.24	0.25	0.71	0.33	0.54	163%
25	NE250	0.81	2.13	2.17	1.84	2.27	1.84	1.51	82%
26	NE500	0.22	0.48	0.46	0.43	0.85	0.49	0.87	177%
27	NE1000	0.22	0.25	0.24	0.25	0.71	0.33	0.15	46%
28	NE2000	0.22	0.22	0.22	0.24	0.62	0.30	0.06	21%
PAS #1	S <100	1.19	2.07	3.21	4.27	5.08	3.16	1.32	42%
PAS #2	NW <100	1.39	2.45	3.03	2.95	3.44	2.65	0.50	19%
PAS #3	SW <100	0.62	1.73	2.27	2.46	2.74	1.96	0.64	33%

1 - All measures have been reduced by 30% to account for possible over-estimation associated with tritium passive air samplers

Table D.16 - Comparison of Model Estimates with Direct Measures - 24-hr Wind Data, Thermal Buoyancy Included, Corrected[1] by 50%

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.36	0.97	0.81	0.92	2.02	1.02	0.74	73%
2	N500	0.22	0.50	0.36	0.41	1.01	0.50	0.42	85%
3	N1000	0.22	0.24	0.22	0.25	0.87	0.36	0.15	41%
4	NW250	0.61	1.34	1.72	1.74	2.72	1.63	0.78	48%
5	NW500	0.31	0.43	0.51	0.50	1.32	0.61	0.22	36%
6	NW1000	0.22	0.26	0.29	0.27	0.80	0.37	0.11	29%
7	NW2000	0.22	0.28	0.22	0.25	0.77	0.35	0.05	14%
8	W250	0.53	0.67	0.77	0.90	2.57	1.09	0.36	33%
9	W500	0.23	0.41	0.45	0.54	1.39	0.60	0.31	51%
10	W1000	0.26	0.28	0.28	0.42	0.95	0.44	0.18	42%
11	SW250	0.22	0.50	0.49	0.56	1.16	0.58	0.76	130%
12	SW500	0.22	0.22	0.22	0.25	1.27	0.43	0.37	85%
13	SW1000	0.22	0.22	0.22	0.25	0.67	0.31	0.16	51%
14	SW2000	0.22	0.22	0.22	0.25	0.71	0.32	0.11	35%
15	S250	0.63	0.46	0.60	0.71	1.34	0.75	0.84	112%
16	S500	0.22	0.24	0.25	0.34	0.68	0.34	0.46	133%
17	S1000	0.22	0.22	0.22	0.25	0.71	0.32	0.07	22%
18	SE250	0.99	1.47	1.85	1.91	2.93	1.83	1.21	66%
19	SE500	0.55	0.67	0.92	1.05	2.11	1.06	0.90	85%
20	SE1000	0.22	0.25	0.27	0.35	1.09	0.44	0.38	87%
21	SE2000	0.22	0.22	0.22	0.25	0.67	0.31	0.14	46%
22	E250	1.18	1.07	1.23	2.10	3.37	1.79	1.76	98%
23	E500	0.22	0.46	0.45	0.36	1.01	0.50	1.01	203%
24	E1000	0.22	0.24	0.24	0.25	0.71	0.33	0.54	163%
25	NE250	0.81	2.13	2.17	1.84	2.27	1.84	1.51	82%
26	NE500	0.22	0.48	0.46	0.43	0.85	0.49	0.87	177%
27	NE1000	0.22	0.25	0.24	0.25	0.71	0.33	0.15	46%
28	NE2000	0.22	0.22	0.22	0.24	0.62	0.30	0.06	21%
PAS #1	S <100	1.19	2.07	3.21	4.27	5.08	3.16	1.32	42%
PAS #2	NW <100	1.39	2.45	3.03	2.95	3.44	2.65	0.50	19%
PAS #3	SW <100	0.62	1.73	2.27	2.46	2.74	1.96	0.64	33%

1 - All measures have been reduced by 50% to account for possible over-estimation associated with tritium passive air samplers

Table D.17 - Comparison of Model Estimates with Direct Measures - 12-hr Wind Data, Thermal Buoyancy Included, Corrected[1] by 30%

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.36	0.97	0.81	0.92	2.02	1.02	0.85	83%
2	N500	0.22	0.50	0.36	0.41	1.01	0.50	0.46	93%
3	N1000	0.22	0.24	0.22	0.25	0.87	0.36	0.21	59%
4	NW250	0.61	1.34	1.72	1.74	2.72	1.63	1.05	65%
5	NW500	0.31	0.43	0.51	0.50	1.32	0.61	0.27	44%
6	NW1000	0.22	0.26	0.29	0.27	0.80	0.37	0.16	45%
7	NW2000	0.22	0.28	0.22	0.25	0.77	0.35	0.08	24%
8	W250	0.53	0.67	0.77	0.90	2.57	1.09	0.47	43%
9	W500	0.23	0.41	0.45	0.54	1.39	0.60	0.40	66%
10	W1000	0.26	0.28	0.28	0.42	0.95	0.44	0.26	60%
11	SW250	0.22	0.50	0.49	0.56	1.16	0.58	1.22	209%
12	SW500	0.22	0.22	0.22	0.25	1.27	0.43	0.47	107%
13	SW1000	0.22	0.22	0.22	0.25	0.67	0.31	0.22	71%
14	SW2000	0.22	0.22	0.22	0.25	0.71	0.32	0.16	49%
15	S250	0.63	0.46	0.60	0.71	1.34	0.75	0.85	113%
16	S500	0.22	0.24	0.25	0.34	0.68	0.34	0.54	157%
17	S1000	0.22	0.22	0.22	0.25	0.71	0.32	0.11	33%
18	SE250	0.99	1.47	1.85	1.91	2.93	1.83	1.27	69%
19	SE500	0.55	0.67	0.92	1.05	2.11	1.06	0.96	91%
20	SE1000	0.22	0.25	0.27	0.35	1.09	0.44	0.44	100%
21	SE2000	0.22	0.22	0.22	0.25	0.67	0.31	0.16	52%
22	E250	1.18	1.07	1.23	2.10	3.37	1.79	1.83	103%
23	E500	0.22	0.46	0.45	0.36	1.01	0.50	1.04	210%
24	E1000	0.22	0.24	0.24	0.25	0.71	0.33	0.61	185%
25	NE250	0.81	2.13	2.17	1.84	2.27	1.84	1.90	103%
26	NE500	0.22	0.48	0.46	0.43	0.85	0.49	0.81	165%
27	NE1000	0.22	0.25	0.24	0.25	0.71	0.33	0.18	55%
28	NE2000	0.22	0.22	0.22	0.24	0.62	0.30	0.07	24%
PAS #1	S <100	1.19	2.07	3.21	4.27	5.08	3.16	2.34	74%
PAS #2	NW <100	1.39	2.45	3.03	2.95	3.44	2.65	1.13	43%
PAS #3	SW <100	0.62	1.73	2.27	2.46	2.74	1.96	1.40	71%

1 - All measures have been reduced by 30% to account for possible over-estimation associated with tritium passive air samplers

Table D.18 - Comparison of Model Estimates with Direct Measures - 12-hr Wind Data, Thermal Buoyancy Included, Corrected[1] by 50%

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2020	2016-2020 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.26	0.69	0.58	0.66	1.44	0.73	0.85	117%
2	N500	0.16	0.36	0.26	0.29	0.72	0.36	0.46	130%
3	N1000	0.16	0.17	0.16	0.18	0.62	0.26	0.21	82%
4	NW250	0.44	0.96	1.23	1.25	1.95	1.16	1.05	91%
5	NW500	0.22	0.31	0.37	0.36	0.95	0.44	0.27	61%
6	NW1000	0.16	0.19	0.21	0.19	0.57	0.26	0.16	63%
7	NW2000	0.16	0.20	0.16	0.18	0.55	0.25	0.08	34%
8	W250	0.38	0.48	0.55	0.64	1.84	0.78	0.47	60%
9	W500	0.17	0.29	0.32	0.39	0.99	0.43	0.40	92%
10	W1000	0.19	0.20	0.20	0.30	0.68	0.31	0.26	83%
11	SW250	0.16	0.36	0.35	0.40	0.83	0.42	1.22	293%
12	SW500	0.16	0.16	0.16	0.18	0.91	0.31	0.47	150%
13	SW1000	0.16	0.16	0.16	0.18	0.48	0.22	0.22	100%
14	SW2000	0.16	0.16	0.16	0.18	0.51	0.23	0.16	68%
15	S250	0.45	0.33	0.43	0.51	0.96	0.53	0.85	158%
16	S500	0.16	0.17	0.18	0.24	0.49	0.25	0.54	220%
17	S1000	0.16	0.16	0.16	0.18	0.51	0.23	0.11	46%
18	SE250	0.71	1.05	1.32	1.37	2.10	1.31	1.27	97%
19	SE500	0.40	0.48	0.66	0.75	1.51	0.76	0.96	127%
20	SE1000	0.16	0.18	0.20	0.25	0.78	0.31	0.44	140%
21	SE2000	0.16	0.16	0.16	0.18	0.48	0.22	0.16	73%
22	E250	0.84	0.77	0.88	1.50	2.41	1.28	1.83	144%
23	E500	0.16	0.33	0.32	0.26	0.72	0.36	1.04	294%
24	E1000	0.16	0.17	0.17	0.18	0.51	0.24	0.61	259%
25	NE250	0.58	1.52	1.55	1.32	1.62	1.32	1.90	144%
26	NE500	0.16	0.35	0.33	0.31	0.61	0.35	0.81	231%
27	NE1000	0.16	0.18	0.17	0.18	0.51	0.24	0.18	77%
28	NE2000	0.16	0.16	0.16	0.17	0.45	0.22	0.07	34%
PAS #1	S <100	0.85	1.48	2.29	3.05	3.63	2.26	2.34	103%
PAS #2	NW <100	1.00	1.75	2.17	2.11	2.46	1.90	1.13	60%
PAS #3	SW <100	0.45	1.24	1.62	1.76	1.96	1.40	1.40	100%

1 - All measures have been reduced by 50% to account for possible over-estimation associated with tritium passive air samplers

Table D.19 - Comparison of Model Estimates with Direct Measures - 12-hr Wind Data, No Thermal Buoyancy, 2020 Measures Excluded

Passive Air Monitor ID	Direction and Approx. Distance (m) from Stacks	2016	2017	2018	2019	2016-2019 Average	Model Result	Average Ratio - Model vs. Measure
1	N250	0.51	1.38	1.16	1.32	1.09	1.81	165%
2	N500	0.31	0.71	0.51	0.58	0.53	1.11	211%
3	N1000	0.31	0.34	0.32	0.35	0.33	0.36	108%
4	NW250	0.87	1.92	2.46	2.49	1.94	2.36	122%
5	NW500	0.44	0.62	0.73	0.71	0.63	0.64	102%
6	NW1000	0.31	0.37	0.42	0.38	0.37	0.30	81%
7	NW2000	0.32	0.4	0.32	0.35	0.35	0.11	33%
8	W250	0.75	0.96	1.10	1.28	1.02	1.30	127%
9	W500	0.33	0.58	0.64	0.77	0.58	1.11	191%
10	W1000	0.37	0.4	0.40	0.60	0.44	0.62	140%
11	SW250	0.31	0.71	0.70	0.80	0.63	2.84	450%
12	SW500	0.31	0.31	0.31	0.36	0.32	0.91	282%
13	SW1000	0.31	0.31	0.31	0.35	0.32	0.31	96%
14	SW2000	0.31	0.31	0.31	0.35	0.32	0.20	63%
15	S250	0.9	0.65	0.86	1.01	0.86	1.51	177%
16	S500	0.31	0.34	0.35	0.48	0.37	1.25	338%
17	S1000	0.31	0.31	0.31	0.35	0.32	0.13	42%
18	SE250	1.41	2.1	2.64	2.73	2.22	2.32	105%
19	SE500	0.79	0.95	1.31	1.50	1.14	1.65	145%
20	SE1000	0.31	0.36	0.39	0.50	0.39	0.62	158%
21	SE2000	0.31	0.31	0.31	0.35	0.32	0.19	60%
22	E250	1.68	1.53	1.75	3.00	1.99	3.76	189%
23	E500	0.31	0.65	0.64	0.51	0.53	2.02	383%
24	E1000	0.32	0.34	0.34	0.35	0.34	0.98	289%
25	NE250	1.16	3.04	3.10	2.63	2.48	3.67	148%
26	NE500	0.31	0.69	0.66	0.62	0.57	1.59	279%
27	NE1000	0.31	0.35	0.34	0.35	0.34	0.27	81%
28	NE2000	0.31	0.31	0.31	0.34	0.32	0.09	29%
PAS #1	S <100	1.7	2.96	4.58	6.10	3.84	6.10	159%
PAS #2	NW <100	1.99	3.5	4.33	4.22	3.51	4.59	131%
PAS #3	SW <100	0.89	2.47	3.24	3.51	2.53	6.64	263%

Potential PAS Bias

The validation efforts in the 2016 DRL Update included a review of possible conservative bias of passive air sampling (PAS) technologies. The review suggests that PAS monitors tend to yield higher measures of tritium in air than active monitors, and their use may lead to reported measures of tritium in air that are greater than the actual activity levels in air. The degree of conservative bias may be anywhere from 10% to almost 2-fold. This has important implications to the understanding of the validity of the DRL atmospheric dispersion model, and any other instance where measures of tritium in air are used in evaluation of models or in quantification of exposure or dose. The current examination of the potential bias of passive monitors suggests that exclusion of thermal buoyancy from the DRL model for SRBT may not be fully warranted.

Detection Limits

In 2020, SRBT began performing all PAS sampling and analysis in-house. SRBT's analysis has typically had a minimum detectable activity (MDA) in the range of 0.7 to 0.8 Bq/m^3, compared to an MDA range of 0.3 - 0.35 Bq/m^3 for the previous third party analysis. SRBT's analysis does provide adequate resolution to allow effective assessment exposure of the public and the environment in comparison to regulatory requirements. However, for current validation purposes the increase in MDA is a factor which results in a relative increase in measured values and an apparent decrease in the conservatism of the model. Review of the SRBT's ACRs for the period of 2016 to 2020 indicate that almost half of reported measures of tritium in air are less than MDA. With the increase in MDA in 2020, the reported station averages for tritium in air were approximately double the average for the period of 2016 to 2019. The inclusion of the 2020 measures, with the elevated MDA, results in an increase of about 37% in the period average for the 31 PAS stations. The exclusion of the 2020 results from the validation analysis results in a substantial increase in the observed conservatism of the atmospheric dispersion model. In the application of the model using 12-hr TJF data and excluding the effects of thermal buoyancy, the predicted levels of tritium in air are about 60% higher than measured overall, and about 80% to 140% higher than measures within 500 m of the SRBT stacks. Further adjustments for background tritium lead to an overall average level of conservatism of about 100% for this model application (see Table D6).

D.2.2 Groundwater (Wells)

At the time of the 2006 DRL calculations, uncertainties and concerns were emerging regarding the presence of tritium in groundwater near the SRBT facility. Since that time, extensive study of the relationship between SRBT emissions and local groundwater resources has been conducted. That main study (EcoMetrix, 2008) included a significant effort to ascertain the relationship between SBT emissions and measured levels of tritium in groundwater and its precursors (rain, soil water). The study effectively confirmed that tritium in groundwater, particularly in off-site residential wells, originates from emissions to air, and that the model in the DRL guidance is applicable. The study also notes that comparison of model results with contemporary measures needs to account for the presence of tritium associated with historical emissions and the time required to reach equilibrium between air and groundwater.

For current purposes, a fairly simplified examination of most recent well monitoring results has been completed to provide additional confirmation of applicability of the DRL model for groundwater. The results of private off-site well sampling conducted since 2016 are summarized in Table D.20. This serves as a simple comparative context for the levels of tritium activity that the DRL model would predict at critical group locations over the same period. For this purpose, the model was applied for two locations of relevance to the DRL calculation; 1) the critical group residence, located approximately 300 m from source, and 2) the dairy farm location, located ~3,500 m from source. The model estimate of HTO in wells at these locations was determined using the average total HTO emission rate over the 2016-2020 period (i.e., 3.05E+05 Bq/s). The model equations for HTO in well water are as follows:

For Residential Well:

$$X_2 = X_0 * P_{01} * P_{12} = 3.05E{+}05 \text{ Bq/s} * 6.75 \text{ E-06 s/m}^3 * 45.454 \text{ m3/L} = 93.6 \text{ Bq/L}$$

For Dairy Farm Well:

$$X_2 = X_0 * P_{01} * P_{12} = 3.05E{+}05 \text{ Bq/s} * 4.48 \text{ E-07 s/m}^3 * 45.454 \text{ m3/L} = 6.2 \text{ Bq/L}$$

In comparison to measured HTO activity in wells, the model estimate of 93.6 Bq/L for the residential well is high in context of the range of the average for the sampled wells since 2016. It is important to note that measures of tritium activity in wells in recent years are likely reflective to some degree of combined emissions since 1991 (the year of onset of operations at SRBT). Emissions in the mid-to-late 90's were in the order of 100 times higher than in the past several years. The degree of influence of these historic emissions cannot be quantified precisely, but there is almost certainly a significant legacy influence on current measures of HTO in groundwater. This influence is expected to continue to wane in time, and this trend is evidenced in Table D.20. If sufficient time is allowed for equilibrium with the current magnitude of atmospheric emissions, the measured HTO activity in groundwater is expected to decline to levels consistent with model projections, or lower. This is in keeping with the conclusions of the detailed groundwater study (EcoMetrix, 2008). If only the last five years of data are considered (e.g. 2016 to 2020) the model estimate for HTO in groundwater at the critical group residence (i.e., 93.6 Bq/L) is almost three times the overall average of the residential wells actively monitored within 2500 m of SRBT (i.e., 35 Bq/L average for wells RW-2 to RW-12). This measured average still reflects higher historical emissions.

The projection of ~6 Bq/L in the dairy farm well is consistent with a number of the monitored private wells located at greater distances from SRBT. In those instances where the measures are relatively low, it should be noted that SRBT is only a partial contributor to the total tritium activity. Some portion is from sources other than SRBT, including historical weapons testing, cosmogenic sources, and other nuclear facilities in the region.

Data from Provincial monitoring conducted on behalf of OPG and Bruce Power indicate that background levels of tritium in air likely range from about 0.05 to 0.1 Bq/m^3. This would theoretically equate to levels of tritium in shallow groundwater in the range of 2 to 4 Bq/L. Samples of water collected from large surface water bodies as part of the same monitoring program show that general ambient tritium activity in watersheds throughout Ontario is in the range of 3 to 4 Bq/L. Using these data, it is reasonable to conclude that the background tritium level in shallow groundwater near SRBT would likely be in the range of 2 to 4 Bq/L. For a number of the monitored wells near SRBT, this would account for the majority of the measured tritium. Overall, the model projection of ~6 Bq/L for the dairy farm well located 3,500 m from source appears to be a reasonable and conservative estimate of HTO activity originating from SRBT.

Table D.20: Summary of Measured Tritium in Private Residential Wells in the Vicinity of SRBT

Well ID and Location		Approx. Distance from SRBT (m)	2016	2017	2018	2019	2020	Average 2006-2010	Average 2011-2015	Average 2016-2020	DRL Model Calculation 2016-2020
RW-1	413 Boundary Rd	465	NS	NS	NS	NS	NS	813	248	NS	24.9
RW-2	185 Mud Lake Rd	1100	70	53	42	41	17	249	113	45	23.6
RW-3	183 Mud Lake Rd	1100	74	68	55	48	47	241	113	58	22
RW-4	711 Bruham Ave	2200	NS	NS	NS	NS	NS	4	4	NS	4.4
RW-5	171 Sawmill Rd	2300	9	9	6	7	6	16	12	7	2.9
RW-6	40987 Hwy 41	1400	10	6	6	6	5	74	26	7	9.0
RW-7	40925 Hwy 41	1600	4	4	4	4	4	20	6	4	10.1
RW-8	204 Boundary Rd	700	175	113	120	NS	NS	267	218	136	35.0
RW-9	206 Boundary Rd	650	54	NS	NS	NS	NS	226	111	54	37.4
RW-10	208 Boundary Rd	625	4	NS	NS	NS	NS	4	4	4	41.3
RW-11	200 Mud Lake Rd	794	NS	NS	NS	NS	NS	6	NS	NS	27.2
RW-12	202 Mud Lake Rd	753	3	NS	NS	NS	NS	18	10	3	30.3
Average								**162**	**79**	**35**	**22**

Reported values are the average of 3 or 4 samples per year, in units of Bq/L

NS - Not Sampled

D.2.3 Food Sources

The validation of the DRL models used to quantify exposure via food consumption is based on comparison of model projections of HTO in various food types to available measures obtained as part of SRBT's EMP. The comparison is relatively simple. Model estimates at locations of relevance to the DRL critical group, averaged over the period of 2016 to 2020, are compared to the range and average of direct measures collected at a variety of locations over the same period.

The application of the model for the purpose of validating potential dose magnitude along the food ingestion pathways (P_{49}, P_{59}) consists of the application of the transfer parameters for the respective pathway. For plant food products, this includes P01 and P14 to represent the net Specific Activity transfer of tritium-in-air to tritium-in-produce. The tritium activity has been calculated for the two sources of local plant products included in the DRL calculation; i.e., the backyard garden at the critical group residence and Bouden's market garden. Model estimates (in units of Bq/kg) are converted to the units of direct measure (Bq/L) assuming 90% water content of all fruits and vegetables. This is consistent with CSA N288.1-14 (see Table G5) which provides a dry/fresh weight ratio (DWp) of 0.1 for generic fruits and vegetables.

For both plant and animal products, the model was applied using the 5-year average (2016 to 2020) tritium emission rate from SRBT. The tritium emission included the direct measure of HTO, plus 2% of the direct measure of HT to implicitly account for oxidative conversion of HT to HTO.

For Residential Garden:

$X_4 = X_0 * P_{01} * P_{14}$ (fruit and veg.) = 3.05E+05 Bq/s * 6.75 E-06 s/m^3 * 54.64 m^3/kg = 112 Bq/kg = 125 Bq/L

$X_4 = X_0 * P_{14}$ (root vegetable) = 3.05E+05 Bq/s * 6.75 E-06 s/m^3 * 47.96 m^3/kg = 98.7 Bq/kg = 110 Bq/L

For Boudens Market Garden:

$X_4 = X_0 * P_{01} * P_{14}$ (fruit and veg.) = 3.05E+05 Bq/s * 1.42 E-06 s/m^3 * 54.64 m^3/kg = 23.7 Bq/kg = 26.3 Bq/L

$X_4 = X_0 * P_{14}$ (root vegetable) = 3.05E+05 Bq/s * 1.42 E-06 s/m^3 * 47.96 m^3/kg = 20.8 Bq/kg = 23.1 Bq/L

For animal food products, the net tritium content in animal products is estimated using P_{01} and P_{15}, P_{14} and P_{45}, and P_{12} and P_{25}. The focus of this validation is local milk, which is the only animal product sampled as part of SRBT's EMP. The model was applied to quantify tritium in milk at Saar's farm, which is the source of local milk considered in the DRL calculation. For milk, model results in units of Bq/Kg were assumed to be equivalent to the units of measure (i.e., Bq/L).

For milk at Saar's Farm:

$X_5 = X_0 * P_{01} * P_{15}$ (milk) = 3.05E+05 Bq/s * 4.48E-07 s/m^3 * 1.97 m^3/kg = 0.269 Bq/kg = 0.269 Bq/L

$X_5 = X_0 * P_{01} * P_{14}$ (forage) * P_{45} (milk) = 3.05E+05 Bq/s * 4.48E-07 s/m^3 * 7.89 m^3/kg * 2.73 kg/kg = 2.95 Bq/kg = 2.95 Bq/L

$X_5 = X_0 * P_{01} * P_{02} * P_{25}$ (milk) = 3.05E+05 Bq/s * 4.48E-07 s/m^3 * 45.454 m^3/L * 0.50 L/kg = 3.13 Bq/kg = 3.13 Bq/L

Total HTO in milk (X_5) = 0.269 + 2.95 + 3.13 = 6.35 Bq/L

Samples of a variety of fruits and vegetables are collected on an annual basis at several residential gardens in close proximity to SRBT (<500m) and also at a local market. The results of analysis of samples collected over the period of 2016 to 2020 are presented in Table D.21.

The results of analysis of HTO generally exhibit expected spatial and temporal variability. The HTO activity level in fruit and vegetable samples varies with distance and compass direction, generally decreasing as distance increases. HTO in produce also exhibits a correlation with the magnitude of emissions, generally decreasing as emissions decrease.

The results also exhibit up to 2-fold variability among different types of produce at any given location. There is no clear pattern to this variability with respect to plant type (e.g., root vegetables consistency higher or lower than above-ground vegetables. This variability could reflect ambient HTO concentrations at time of ripening, or also possibly translocation processes.

The 5-yr average HTO activity measured in produce samples collected at seven nearby residential gardens, and also at a local market, is 51 Bq/L (see Table D.21). The corresponding 5-yr average model estimate of HTO in produce (fruit, above-ground vegetables, root vegetables) at the critical group residence is about 108 Bq/L, and about 23 Bq/L at Boudens. Overall, the current DRL model application yields estimates of tritium in produce at the critical group that are conservatively representative of locally grown produce.

The SRBT EMP reports HTO activity in milk samples obtained in the past 5 years from a local producer typically less than the minimum detectable activity (MDA) which has been in the range of 3 to 5 Bq/L. Provincial monitoring data collected for Bruce Power and OPG indicate background levels of HTO in milk in the range of 2 to 4 Bq/L in recent years. Accounting for background, the activity of tritium in milk samples that is directly associated with SRBT emissions is perhaps only 1 to 2 Bq/L. The DRL model generates an estimate of about 6.3 Bq/L in milk on average over the 2016-2020 period. In absence of any consideration of background tritium activity, the model estimate is about double the reported measures. If background tritium is excluded from available measurements, the model estimate is notably greater than those adjusted measures.

Overall, when considering average conditions over a multi-year time frame, as appropriate for determining the DRL, the SA models used to determine the levels of tritium in food products are demonstrated to be conservatively representative.

Table D.21: Summary of Measured Tritium in Garden Produce in the Vicinity of SRBT

Garden Location	Approx. Distance from SRBT (m)	2016	2017	2018	2019	2020	Average
416 Boundary Rd	400	71	12	87	47	NS	54
408 Boundary Rd	400	45	84	70	45	63	61
406 Boundary Rd	400	65	NS	85	53	48	63
413 Sweezy Court	400	94	37	101	75	45	70
Local Market	1750	8	8	4	8	3	6

All values are the averages of multiple plant types, for units of Bq/L
NS - Not Sampled

Appendix D References

Canadian Nuclear Safety Commission (CNSC). 2009. Investigation of the Environmental Fate of Tritium in the Atmosphere. Report prepared for the CNSC by EcoMetrix Incorporated in association with RWDI Air Inc. (RSP-0247), March 2009. INFO-0792.

Canadian Nuclear Safety Commission (CNSC). 2010. Tritium Studies Project Synthesis Report. INFO-0800 Revision 1.

EcoMetrix Inc. 2008. Comprehensive Report – Groundwater Studies at the SRB Technologies Facility, Pembroke, ON. Report prepared for SRB Technologies (Canada) Inc. by EcoMetrix Inc. EcoMetrix Ref. 07-1471. January, 2008

APPENDIX E: STACK AND WELL INFORMATION

E.1 Stack Characteristics

Ambient air within the tritium processing areas of the SRBT facility is subject to negative pressure management and ventilation through multiple fume hoods. The ventilation is facilitated through two air handling units with a combined airflow capacity of approximately 10,000 cubic feet (~280 m^3) per minute. Since 2006, the physical characteristics of stacks have not been modified. The ventilation system has been subject to routine maintenance and inspection, but no major design modifications.

The ventilation units are subject to routine annual inspection and maintenance by qualified third parties. Airflow through the stacks is also verified on each day of operation, facilitated by pressure measurement instruments (Pitot tubes) installed in 2006.

Average velocity of the two stacks combined is 17.65 m/s based on the daily Pitot tube readings (Table E.1). This is the only parameter that has changed in value since the 2016 DRL calculation. In 2016, the average combined exit velocity was 17.70 m/s. The average velocity is now slightly lower, which has a very minor effect on the dispersion of SRBT emissions, and only when buoyancy is included in the dispersion model.

Table E.2 summarizes the assigned values of various stack attributes considered in the atmospheric dispersion model applied for SRBT DRL calculations.

Table E.1 – Summary of Daily Readings of Exit Velocities

Year	Annual Average (m/s)		
	Bulk Stack	Rig Stack	Combined
2016	17.40	16.76	17.08
2017	17.20	17.62	17.41
2018	16.78	17.43	17.10
2019	18.88	18.06	18.47
2020	19.31	17.01	18.16
Overall	**17.92**	**17.39**	**17.65**

Based on daily Pitot tube readings

Table E.2 – Stack Attributes of Relevance to Atmospheric Dispersion Model

Parameter	Stack 1 (Bulk Stack)	Stack 2 (Rig Stack)	Average (both stacks)
Height of stack (m above ground)[1]	11.093	11.855	11.474
Inside diameter (m)[1]	0.3556	0.4572	0.4064
Exhaust Velocity[2] (m/s)	17.92	17.39	17.65
Exhaust Temp (°C)[3]	20	20	20

1 - Reported upon installation (Kool Temp memo, 2005)
2 - Annual average velocities calculated from daily Pitot tube readings from 2016 to 2020.
3 - Assume exhaust temperature is equivalent to standard room temperature. Only relevant if thermal buoyancy is included in the atmospheric dispersion model.

E.2 Well Characteristics

The exposure to groundwater via ingestion or immersion is encompassed in the SRBT DRL model. Under the generic assumption that 100% of the residential water supply is obtained from a private domestic well at the critical group location, the groundwater exposure pathways become highly significant.

As part of the SRBT groundwater study initiated in 2006, records for all private wells within 5 km of SRBT were obtained from the MOE. Information of possible relevance to the DRL calculation drawn from these well records is summarized in Tables E.3 and E.4.

Within 500 m of SRBT, there are only 3 wells that lie in a direction where the frequency of wind blowing from the direction of SRBT is relatively high. None of these wells lies to the WNW of SRBT, which is the direction of the residential critical group. There is only a single well reported as drawing from overburden, and thus subject to characterization in the DRL model as a shallow well. The overall average depth of wells within 1 km of SRBT is about 30 m.

Table E.3 - Spatial Distribution of Wells on Record within 5 km of SRBT

Direction from SRBT	Distance from SRBT						Total
	<500 m	**0.5 - 1 km**	**1 - 2 km**	**2 - 3 km**	**3 - 4 km**	**4 - 5 km**	
S	0	1	0	7	9	12	29
SSW	0	2	4	17	13	1	37
SW	0	0	5	13	8	9	35
WSW	1	0	0	12	9	28	50
W	1	0	3	12	22	40	78
WNW	1	0	2	31	9	13	56
NW	1	0	7	5	4	37	54
NNW	0	1	0	5	0	0	6
N	0	0	3	0	0	0	3
NNE	2	1	0	2	0	0	5
NE	0	0	0	3	11	0	14
ENE*	0	0	1	22	75	1	99
E*	0	4	2	137	61	16	220
ESE*	1	0	19	24	7	24	75
SE*	1	6	22	13	14	11	67
SSE	1	1	4	7	5	1	19
Total - All Wells	9	16	72	310	247	193	847
Total - Critical Wells*	2	10	40	203	175	55	485

*relatively high frequency wind sectors (i.e., wind blows from direction of SRBT > 7% of time - see Table C.7, Appendix C)

Table E.4 - Characteristics of Wells on Record within 5 km of SRBT

Characteristic	Distance from SRBT					
	<500 m	**500 m - 1 km**	**1 - 2 km**	**2 - 3 km**	**3 - 4 km**	**4 - 5 km**
# of wells in overburden	0	1	4	27	22	12
# of wells in bedrock	9	15	65	267	215	170
Depth (m) - min	11.3	7.6	7.0	4.6	9.8	5.8
Depth (m) - max	64.6	83.8	163.7	128.0	204.2	136.9
Depth (m) - mean	28.7	30.8	42.4	40.2	43.3	40.5
Number of wells	9	16	72	310	247	193

All data derived from Ministry of Environment (MOE) well records

E.3 Summary of Derived Parameter Values

The information in this appendix has been used to determine the value of several variables involved in this iteration of DRL calculation of for SRBT. This includes the following:

- physical stack height (H_s), as used in Equation A.3 (Section A.2.1, Appendix A) to calculate transfer parameter P_{01}. The combined average height of SRBT's stacks is 11.474 m.

- inside diameter of the stack (D), as used in Equation A.4 (Section A.2.1, Appendix A) to calculate the downwash component of transfer parameter P_{01}. The assigned value is 0.4064 m.

- stack gas temperature (T_g), as used in Equation A.11 (Section A.2.1, Appendix A) to calculate the plume rise component of transfer parameter P_{01}. The assigned value is 20 degrees C (293 degrees K).

- stack exit velocity (w_0), as used in Equation A.11 (Section A.2.1, Appendix A) to calculate the plume rise component of transfer parameter P_{01}. The assigned value is 17.65 ($m \bullet s^{-1}$).