Human Health Risk Assessment for Radiological and Chemical Contaminants at Site with Historical Contamination

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Abstract

A Human Health Risk Assessment was carried out for a uranium conversion facility in Ontario, located on a site with a history of contamination. The HHRA assessed risk to workers and the public from exposure to radionuclides and non-radionuclides in soil and groundwater associated with the site. The results indicated that there is no undue risk from exposure to radionuclides. Small potential long-term risks were identified with exposure of hypothetical receptors to arsenic, but this exposure was below Canadian background levels. Recommendations are provided to address residual uncertainty.

1. Introduction

This paper summarizes a human health risk assessment (HHRA) carried out as part of a larger series of studies for Cameco Corporation's Port Hope Conversion Facility (PHCF) in Port Hope, Ontario. The PHCF is a uranium conversion facility located on a site with a history of industrial use by multiple users, starting in the mid-to-late 1800s. The site is shown in Figure 1.

Figure 1 Cameco Corporation's Port Hope Conversion Facility Site, Port Hope, Ontario

2. Background

The Port Hope Conversion Facility (PHCF) receives uranium trioxide for conversion to either uranium hexafluoride (UF_6) or uranium dioxide (UO_2). Cameco routinely monitors releases of radioactive and non-radioactive chemicals to the environment (to air, water and waste) to ensure that they meet regulatory requirements. Cameco also monitors concentrations in the environment (air, soil, water and sediment).

The historic operations on the site were recognized to have resulted in surface and sub-surface contamination on the site and in the surrounding environment at the time Cameco was formed in 1988. A legal agreement exists between the federal government and the municipalities of Port Hope and Clarington for the clean up and long-term safe management of historic low-level radioactive waste. The Port Hope Area Initiative (PHAI) led by Atomic Energy of Canada Limited (AECL) and Cameco's Vision 2010 project are being developed to address this historic contamination in the municipality, including the Port Hope Harbour (Harbour) and site, respectively. The Vision 2010 project involves the removal of several old or under-utilized buildings, the removal of contaminated soils, building materials and stored historical wastes, and the construction of some new buildings where necessary to improve the efficiency of the facility.

Cameco retained SENES Consultants Limited (SENES) to carry out a Site-Wide Risk Assessment (SWRA) based on information readily available as of December 2008 [1]. The SWRA addressed regulatory expectations provided at the start of the project by the Canadian Nuclear Safety Commission (CNSC) and the Ontario Ministry of the Environment (MOE). The SWRA was submitted to the CNSC in June 2009. The SWRA included the fundamental elements of a risk assessment, such as:

- Screening for Contaminants of Potential Concern (COPCs);
- Site Characterization;
- Conceptual Site Model;
- Hazard Assessment and Exposure Assessment; and
- Risk Characterization, etc.

In addition, the SWRA included unique features such as a site-specific hydrodynamic and contaminant transport model and the derivation of Risk-Based Performance Objectives for the site.

The SWRA addressed risks from both radiological and chemical contaminants associated with the PHCF operations. They included scenarios for both present-day soil conditions and post-Vision 2010 soil conditions.

The results of the SWRA were used to provide risk-informed feedback on risk-sensitive information gaps as well as information on the potential need for mitigative and preventative measures to ensure that there is no undue risk to workers or members of the public associated with PHCF operations.

The SWRA also developed site-specific risk-based performance objectives for groundwater. This was done by performing inverse calculations to determine groundwater loadings to surface water at which the receptors will not be adversely affected.

After the June 2009 SWRA, Cameco and SENES made a number of refinements. Many of these refinements were based on a discussion of uncertainties in the SWRA. The refinements were incorporated into a SWRA Update [2], which was submitted to the CNSC in December 2009. The SWRA Update included the following:

- Collection and analysis of several additional surface water samples in the Harbour;
- Re-screening for COPCs based on additional data and screening criteria;
- Refined hydrodynamic and contaminant transport modelling and verification, in order to derive more realistic dilution factors from groundwater to the Harbour and Lake Ontario surface water. Simulation of contaminant plumes taking cooling water flow into account;
- Development of scenarios for hypothetical pump-and-treat failure or maintenance outage scenarios (A pump-and-treat system has been installed to protect the present and future quality of groundwater seeping into the Harbour);
- Update of ecological and human health Toxicological Reference Values (TRVs);
- Update of Human Health Risk Assessment (HHRA) calculations and documentation;
- Update of Ecological Risk Assessment (ERA) calculations and documentation;
- Updated derivation of Performance Objectives; and
- Vapour Intrusion Modelling from Groundwater and Soil to Indoor Workers and associated Risk Assessment calculations.

For the remainder of this paper, the term SWRA refers to the June 2009 SWRA and the December 2009 SWRA Update. The SWRA included a HHRA and ERA. This paper discusses the HHRA process and results. A companion paper on the ERA is also being presented at this conference [3].

3. Human Health Risk Assessment (HHRA) objectives and scope

The main objectives of the HHRA were to address the following questions:

Q1: What are the potential net effects on humans resulting from current site groundwater loadings to the Harbour and Lake Ontario? This was assessed in the “Incremental” scenarios, where environmental concentrations were calculated from the estimated loadings of the PHCF into the Harbour and the lake. Current loadings took into account the recent removal of contaminated soil as well as the installation of pump and treat wells on-site. Question Q1 addressed the potential issue of Harbour recontamination following sediment cleanup by PHAI.

Q2: What are the potential total effects on humans resulting from several sources, including current contamination levels in the Harbour and current site soil levels and groundwater concentrations? This was assessed in the “Total” scenarios, where environmental concentrations were based on monitoring data.

The HHRA addressed the above questions Q1 and Q2 for both radioactive and chemical contaminants, for:

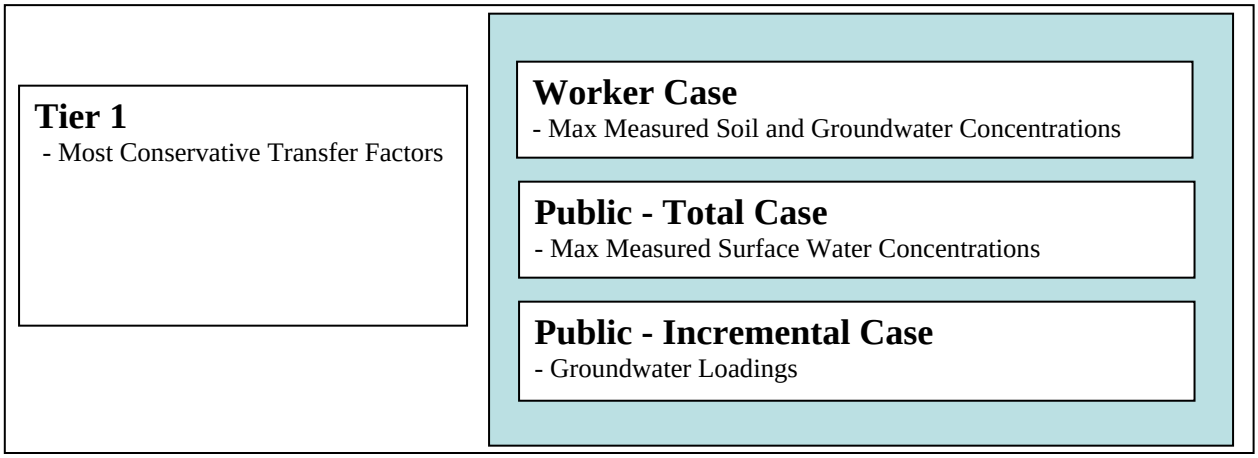
- On-site workers (including short-term contractors, technicians and occasional maintenance workers);
- Off-site members of the public drinking water and/or using Lake Ontario for fishing (off the Centre Pier) and swimming (at the beach). These members of the public may also fall into the Harbour while boating; and
- Worker + resident: members of the public (i.e., local residents) who also work at the site. The estimated risk to this receptor is the sum of the worker and public risks calculated above.

The HHRA took into consideration receptor characteristics, exposure pathways and mitigating circumstances. Risk was evaluated using toxicological information associated with the particular contaminants of concern, physical site conditions and known characteristics of the people using the site.

The HHRA investigated soil at and groundwater below the PHCF site as well as surface water, air quality and sediment in the Port Hope Harbour. The focus of the HHRA was risk from soil and groundwater pathways, including the loadings from on-site groundwater to the surface water environment (Port Hope Harbour or Lake Ontario). However, other pathways (such as air) are considered where there is readily-available information. Storm water loadings from the site were also included in the scope of the HHRA.

4. HHRA calculations

A screening-level (also called Tier 1) HHRA was carried out for all of the human receptors in the SWRA. This involved conservative assumptions about environmental concentrations, ecological receptor exposure time and hazard assessment parameters. A Tier 2 HHRA was carried out for selected receptors and COPCs. The Tier 2 HHRA involved the use of more realistic parameters, such as concentrations or transfer factors. Figure 2 shows schematically the Tier 1 and Tier 2 HHRA.



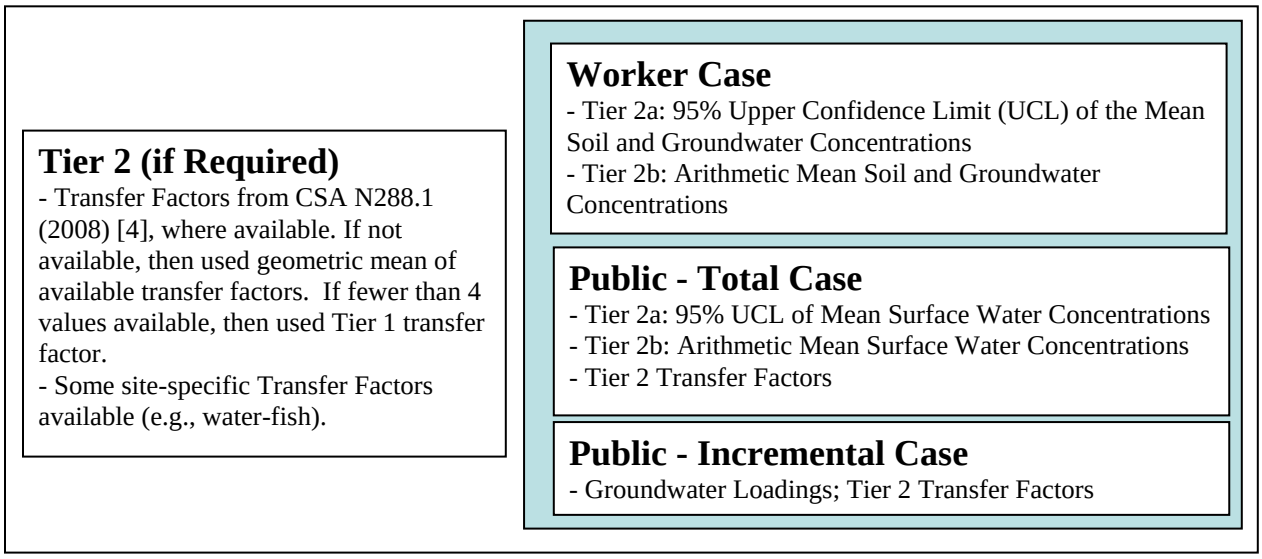


Figure 2 HHRA Tier 1 and 2 Schematic

Details of the HHRA calculations are provided in the SWRA [1],[2]. A brief summary of the methodology is provided in the following sub-sections.

4.1 Conceptual model

Information on the site conditions (including the nature, extent and distribution of the radiological and chemical hazards), potential exposure pathways and opportunities for human receptors that will frequent, use or populate the site, were integrated into a Conceptual Site Model (CSM). The CSM for this study is shown in Figure 3.

4.2 Exposure assessment

The exposure assessment comprised three elements:

- frequency and duration of actual and/or potential exposure;
- determination of potential pathways (routes of exposure); and
- estimation of the magnitude of exposure.

Exposure models used measured and estimated media concentrations as well as receptor characteristics, in order to estimate the doses and intakes to humans from radionuclides and non-radionuclides associated with the facility.

4.3 Hazard assessment

In general, the hazard assessment uses results from animal (and when available, human) studies to determine the likelihood of an adverse health effect occurring as a result of a given exposure. The radiological benchmarks used in the HHRA are based on dose limits established by the CNSC. The non-radiological benchmarks were TRVs, based on a variety of toxicity studies in literature. It should be noted that an exposure level above a criterion does not mean that an effect will occur, but instead means that there is an increased risk of an adverse effect occurring. These benchmarks were compared to the estimated human doses and intakes in order to characterize risk.

4.4 Risk assessment

The risk assessment methodology was based in general on Health Canada's risk assessment methodology [5]. In order to evaluate risk to the human receptors, the doses and intakes estimated in the exposure assessment were compared to the TRVs compiled in the hazard assessment. Hazard quotient (HQ) values were estimated for non-carcinogenic COPCs and risk levels were estimated for carcinogenic COPCs. Estimated doses were compared to the CSNC dose limits selected in the hazard assessment. COPC-receptor combinations that exceeded their thresholds in the Tier 1 (most conservative) assessment were carried through to higher-Tier (more realistic) assessments.

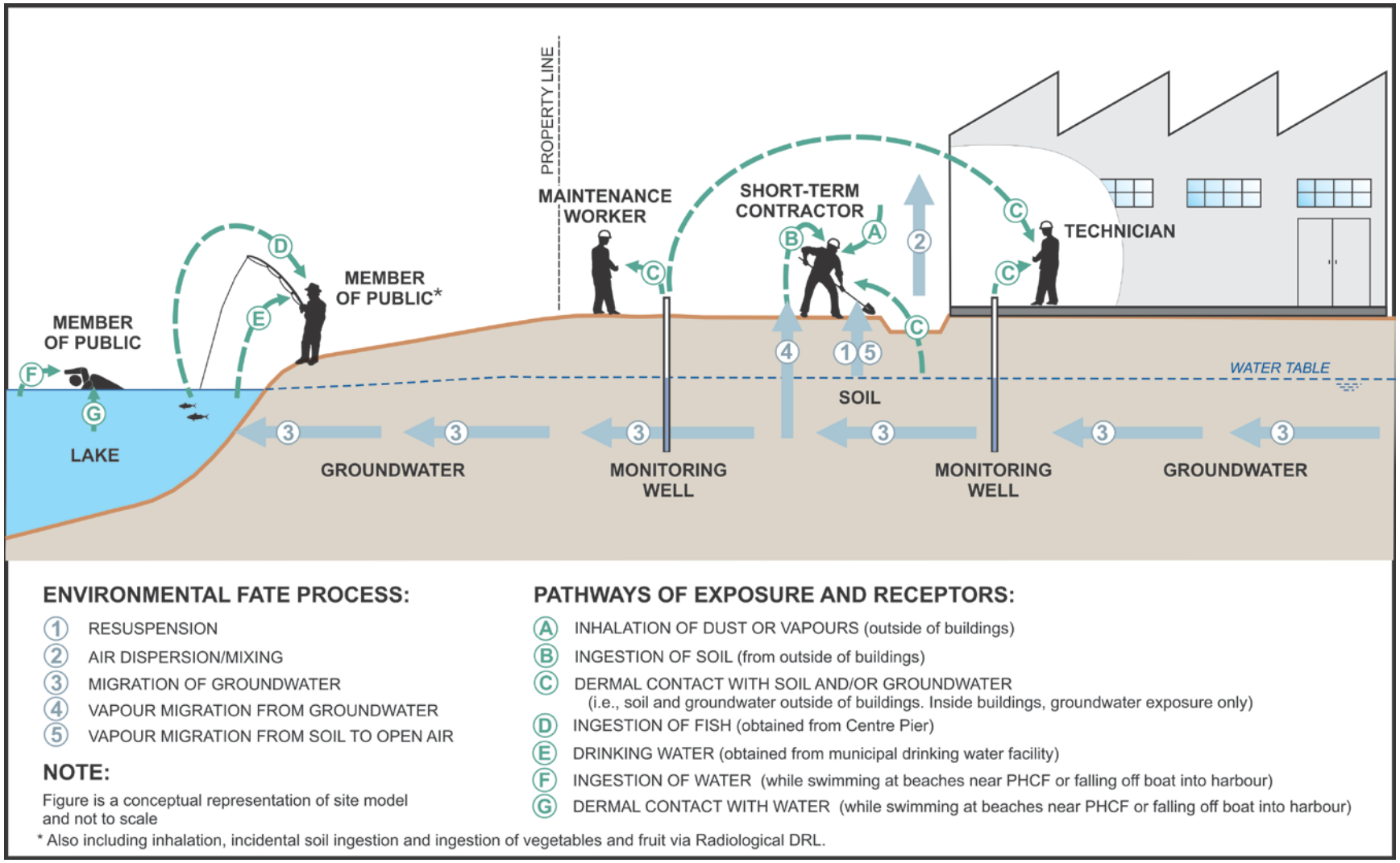


Figure 3 HHRA conceptual site model. Note: the arrow below the short-term contractor represents pathways 1 and 5. The pathway of soil ingestion represents the incidental ingestion of soil by a worker during on-site activities.

5. HHRA results

The quantitative HHRA results were presented in the study report. Due to the extensive number of scenarios and tiers investigated, the detailed results cannot be presented in this short paper. The main conclusions from the HHRA can be summarized as follows:

- There is no immediate undue risk to the public due to contamination in the Harbour and near-shore Lake Ontario. This addressed both Question Q1 ("Incremental") and Question Q2 ("Total") posed above.
- Potential health effects on workers can be mitigated by using personal protective equipment (PPE) and following Cameco's Occupational Health and Safety Procedures. Furthermore, vapour intrusion and risk modelling indicated that there is no undue risk to indoor workers expected from vapour intrusion from soil and groundwater beneath buildings.
- There is no undue risk to human health from exposure to radionuclides for either current conditions (based on the "Total Case") or future net PHCF contribution (based on the "Incremental Case"). It should be noted that only uranium isotopes are associated with current PHCF operations. Consistent with prudent radiological protection principles, Cameco also follows ALARA (i.e., keeping radiation exposure as low as reasonably achievable). This addressed both Question Q1 ("Incremental") and Question Q2 ("Total").
- Small potential long-term risks may be associated with exposure to arsenic. However, the estimated risk to members of the public due to exposure to arsenic from the PHCF is less than the risk from typical Canadian background exposure to arsenic for either current conditions (based on the "Total Case") or future net PHCF contribution (based on the "Incremental Case"). Nevertheless, it would be prudent to reduce releases from the site to the extent that it is practical. This addressed both Question Q1 ("Incremental") and Question Q2 ("Total").
- There is no undue risk to human health from exposure to other PHCF contaminants of potential concern (COPCs) such as uranium and fluoride for either current conditions (based on the "Total Case") or future net PHCF contribution (based on the "Incremental Case"). This addressed both Question Q1 ("Incremental") and Question Q2 ("Total").

A combined case was performed in which the results from an adult resident receptor were added to the results from a worker receptor (long-term technician), to represent a worker who is also a resident of Port Hope. This combined case identified no new exceedances.

Overall, the conclusions summarized above are consistent with the 2009 CNSC Study entitled "Understanding Heath Studies and Risk Assessments Conducted in the Port Hope Community from the 1950's to the Present"[6].

In order to reduce residual uncertainties in the HHRA, it is suggested that the following gaps be filled:

(i) Storm water data: Data on radionuclides in storm water were not available. In the absence of this data, the amounts of some radionuclides in storm water were estimated based on the measured uranium levels. Cameco has initiated a storm water study in order to provide this information. The data were not available at the time of preparation of the SWRA Update. The results from the storm water study can be used to refine the estimates of all COPC loadings into the Harbour. They may also clarify the contribution of upstream sources to storm water, in which case the associated risks may also be delineated.

(ii) Assessment of the risk of hypothetical failure or maintenance outage of the pump-and-treat system under various 'what-if' scenarios.

Work to fill these gaps is underway or planned for 2010.

6. HHRA summary

Table 1 provides a simplified representation of the overall results of the HHRA. Results are presented as one of the following:

- ✓ Indicates no adverse effect expected from COPCs associated with PHCF operations (see additional notes such as requirement for use of PPE).
- ✕ Indicates the potential for adverse effects from COPCs associated with PHCF operations. Mitigation measures to address these issues will be included in the Site-Wide Environmental Management Plan if warranted.

Question	Members of the Public	Workers
Q1 (Incremental)	✓ Arsenic exposure is below background, but minimizing arsenic risk to the extent that it is practical is recommended	Incremental exposure of workers to soil and groundwater could not be assessed, because it is not possible to differentiate between the historical/background concentrations and the concentrations associated with the current operations. Therefore, only the Total case (based on Total soil and groundwater concentrations) was assessed for workers
Q2 (Total)	✓ Arsenic exposure is below background, but minimizing arsenic risk to the extent that it is practical is recommended	✓ Based on use of Personal Protective Equipment and following Occupational Health & Safety procedures

Table 1 Summary of HHRA results for radioactive and chemical contaminants

The results shown in Table 1 are supported by extensive site characterization data and a multi-source multi pathways-risk assessment. The results are also supported by toxicity testing and field observations. They are consistent with the 2009 CNSC Health Study [5].

Performance Objectives were also provided in the SWRA. However, it is important to note that the PHCF Performance Objectives alone cannot ensure Harbour water quality, because of potential loadings from other non-PHCF sources. Ideally, therefore, the derivation of Performance Objectives for PHCF groundwater would be integrated with the overall water-quality management of the Harbour and near-shore Lake Ontario.

7. References

[1] SENES Consultants Limited, "Port Hope Conversion Facility Site-Wide Risk Assessment: Human Health and Ecological Risk Assessment", Prepared for Cameco Corporation, 2009 June.

[2] SENES Consultants Limited, "Update: Port Hope Conversion Facility Site-Wide Risk Assessment: Human Health and Ecological Risk Assessment", Prepared for Cameco Corporation, 2009 December.

[3] Garisto, N.C., A. Janes and R. Peters, "Ecological Risk Assessment for Radiological and Chemical Contaminants at Site with Historical Contamination", Technical Paper submitted to Canadian Nuclear Society 2010 Annual Conference, Montreal, Quebec, Canada, 2010 January.

[4] Canadian Standards Association, "CSA Guideline N288.1-08 - Guidelines for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities", 2008 September.

[5] Health Canada 2004. "Federal Contaminated Site Risk Assessment in Canada. Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). September.

[6] Canadian Nuclear Safety Commission, "Understanding Health Studies and Risk Assessments Conducted for the Port Hope Community from the 1950s to the Present", INFO-0781, 2009 April.