

JOINT PANEL
ON
OCCUPATIONAL AND ENVIRONMENTAL RESEARCH
FOR URANIUM PRODUCTION IN CANADA

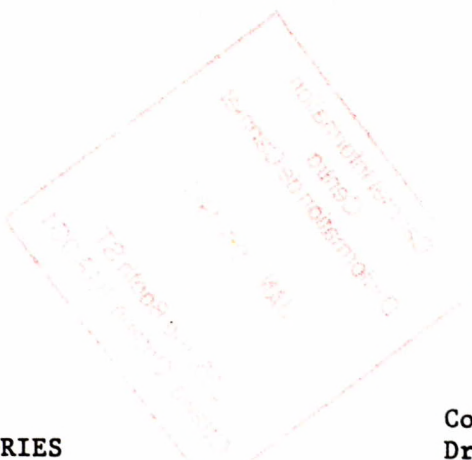
1987 ANNUAL REPORT

Published by:
MINING RESEARCH LABORATORIES
Canada Centre for Mineral & Energy Technology
Energy, Mines and Resources Canada

on behalf of:
The Joint Panel on Occupational & Environmental
Research for Uranium Production in Canada

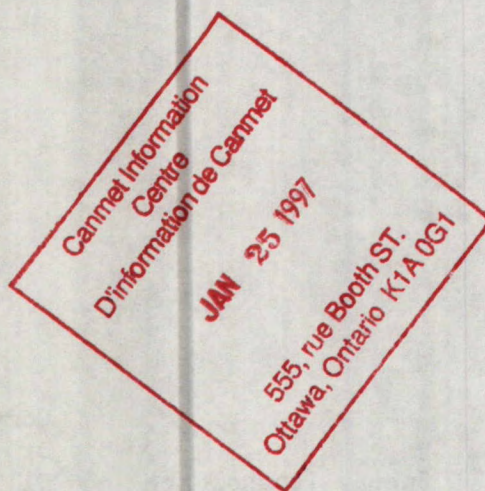
1988

Compiled by:
Dr. R.O. Tervo
Elliot Lake Laboratory
MRL, CANMET
Energy, Mines & Resources Canada
P.O. Box 100, Elliot Lake, Ont.



MRL 87-000 C.2

MRL 87-000 C.2



CONTENTS

	<u>Page</u>
FOREWORD	1
EXECUTIVE	2
SUPPORTING MEMBER ORGANIZATIONS	2
ASSOCIATE MEMBER ORGANIZATIONS	3
TERMS OF REFERENCE	4
JOINT PANEL ACTIVITIES	9
REPORTS BY WORKING GROUPS	9
ACTIVE RESEARCH PROJECTS	10
Atomic Energy of Canada Ltd. (AECL)	10
Atomic Energy Control Board (AECB)	10
Canadian Institute for Radiation Safety (CAIRS)	14
Denison Mines Limited (DEN)	14
Energy, Mines and Resources Canada (EMR)	15
Environment Canada (DOE)	18
Health and Welfare Canada (NHW)	20
Indian Affairs and Northern Development (DIAND)	21
Rio Algom Mines Limited (RIO)	21
Saskatchewan Environment (SE)	21
Saskatchewan Research Council (SRC)	21
United Steelworkers of America (USW)	22
PROJECTS COMPLETED DURING 1987	23
MATRIX OF RESEARCH AREAS	25
PUBLICATION FILE	26
Atomic Energy Control Board (AECB)	26
Atomic Energy of Canada Ltd. (AECL)	28
Canadian Institute for Radiation Safety (CAIRS)	30
Energy, Mines and Resources Canada (EMR)	30
Environment Canada (DOE)	39
Indian Affairs and Northern Development (DIAND).....	41
Saskatchewan Dept. of Environment	42
Saskatchewan Research Council (SRC)	43
SUPPORTING MEMBER REPRESENTATIVES	45

FOREWORD

1987 Annual Report of the Joint Panel

I am pleased to submit the 1987 Annual Report of the Joint Panel on Occupational and Environmental Research for Uranium Production in Canada. These annual reports have been recognized as a valuable source of information for the members and others interested in this subject, and, as such, receive wide circulation. At a time when cooperation is being fostered among Provincial and Federal regulatory and research agencies, industry members and universities, it is worth pointing out that the Joint Panel has been performing this function for over 10 years as a voluntary association of organizations with an active and continuing involvement in research on the occupational and environmental effects of uranium production. Members accept the obligation to inform each other of progress in their on-going work, to contribute to the development of a comprehensive program of research and to make final research results available to the public.

The Panel wishes to thank the Saskatchewan Research Council as well as CANMET for hosting the 1987 sessions of the Panel.

The Panel gratefully acknowledges the contribution made by Dr. J.E. Udd of CANMET's Mining Research Laboratories for providing the services of Dr. R. Tervo as Secretary, and for publishing the Annual Report.

L.D. Brown.
Chairman

JOINT PANEL ON OCCUPATIONAL AND ENVIRONMENTAL RESEARCH
FOR URANIUM PRODUCTION IN CANADA

EXECUTIVE - 1987

Chairman: Dr. L.D. Brown, Certified Health Specialist
Occupational Health and Safety Branch
Saskatchewan Human Resources, Labour & Employment
1870 Albert St., Regina, Sask. S4P 3V7
Tel: 306-787-4486

Secretary: Dr. R.O. Tervo, Manager
Elliot Lake Laboratory, MRL, CANMET
Energy, Mines and Resources Canada
P.O. Box 100, Elliot Lake, Ont. P5A 2J6
Tel: 705-848-2236

Industrial Representative*: Mr. L. Price, Key Lake Mining Corp.

Provincial Agencies Representative: Dr. L.D. Brown, Saskatchewan Labour.

Federal Agencies Representative*: Dr. J. Bigu, CANMET, EMR Canada.

Union Representative*: Mr. H. Seguin, USWA.

*See membership list, page 45, for addresses and telephone numbers.

SUPPORTING MEMBER ORGANIZATIONS, 1987

Atomic Energy of Canada Limited (AECL)
Atomic Energy Control Board (AECB)
Canadian Institute for Radiation Safety (CAIRS)
Denison Mines Limited (DEN)
Eldorado Resources Limited (ERL)
Energy, Mines and Resources Canada (EMR)
Environment Canada (DOE)
Health and Welfare Canada (NHW)
Indian Affairs and Northern Development Canada (DIAND)
Key Lake Mining Corporation
Ministry of Labour, Ontario (MOL)
Rio Algom Limited (RIO)
Saskatchewan Environment (SE)
Saskatchewan Human Resources, Labour and Employment (HURLE)
Saskatchewan Mining Development Corporation (SMDC)
United Steelworkers of America (USWA)

ASSOCIATE MEMBER ORGANIZATIONS, 1987

Cigar Lake Mining Corporation. Saskatchewan
Department of Consumer Affairs and Environment, Newfoundland and Labrador
Department of Mines and Energy, Newfoundland and Labrador
Department of Mines and Petroleum Resources. British Columbia
Labour Canada
Mines Accident Prevention Association of Ontario
Ministry of the Environment. Ontario
Ministry of Northern Development and Mines. Ontario
Saskatchewan Research Council
Saskatchewan Mining Association
Technical Advisory Committee on the Nuclear Fuel Waste Management Program
Uranerz Exploration and Mining Limited

TERMS OF REFERENCE

1.0 INTRODUCTION

- 1.1 The name of the panel shall be "The Joint Panel on Occupational and Environmental Research for Uranium Production in Canada".
- 1.2 Where appropriate, the name of the panel may be shortened to "The Joint Panel".
- 1.3 The Joint Panel is a Canadian organization whose members have voluntarily agreed to share information regarding research into the effects of uranium production on the health and safety of workers and the protection of the environment.

2.0 OBJECTIVES

- 2.1 The primary objectives of the Joint Panel shall be:
 - (a) identification of those areas related to the occupational health and environmental effects of uranium production in which there is a need for research; and
 - (b) stimulation of research in areas in which a need has been identified.
 - (c) the production areas of interest are mining and milling.
- 2.2 To meet its primary objectives the Joint Panel will:
 - (a) produce and distribute an annual inventory of current and completed research in relevant areas being conducted by Supporting Members (the Annual Report); and
 - (b) provide a forum for the exchange and dissemination of information on proposed, current and completed research.

3.0 MEMBERSHIP

- 3.1 Supporting Membership is open to any organization that actively and continually supports research on the occupational or environmental effects of uranium production.
- 3.2 Associate Membership is open to those organizations who:
 - (a) have responsibility or authority relating to occupational or environmental effects of uranium production, but do not actively support research activities; or
 - (b) are interested in the activities of the Joint Panel, but do not qualify as, or do not wish to become, a Supporting Member.
- 3.3 Admission to membership in the Joint Panel shall be granted by simple majority vote of the Supporting Members present at any meeting of the Joint Panel.

- 3.4 Any Supporting Member who is not active in the work of the Joint Panel may be reclassified as an Associate Member by simple majority vote of the Supporting Members present at any meeting of the Joint Panel if such action is requested by the Executive.
- 3.5 Participation on the Joint Panel will in no way constrain members from pursuing their own organizational or institutional objectives.

4.0 SUPPORTING MEMBER ORGANIZATIONS

- 4.1 A Supporting Member is expected to contribute to the development of a comprehensive program of research compatible with its roles and responsibilities.
- 4.2 A Supporting Member is expected to recognize its obligation to make information widely available by:
 - (a) providing information to the membership of the Joint Panel on current research which they are supporting;
 - (b) reviewing reports prepared by other Supporting Members and providing comments;
 - (c) participating in the activities of the Joint Panel.
- 4.3 A Supporting Member is expected to recognize the need to make final research results available to the membership and to the public.
- 4.4 Each organization that is a Supporting Member shall designate an individual as its Representative on the Joint Panel.
- 4.5 Each Supporting Member shall advise members of the Joint Panel of the individual or unit within their organization to which requests for publication should be directed. This information will be included in the Annual Report.

5.0 THE EXECUTIVE

- 5.1 The affairs of the Joint Panel will be administered by the Executive.
- 5.2 The Executive shall consist of the Secretary of the Joint Panel and four other individuals. Each of these other individuals must be the designated Representative of a Supporting Member.
- 5.3 The individuals who are members of the Executive will be chosen to represent four groups that have Supporting Members on the Joint Panel. the four groups being:
 - (a) The Federal Government;
 - (b) The Provincial Government;
 - (c) Industry: and
 - (d) Labour.

- 5.4 It shall be the responsibility of each group to select one individual who will represent the group on the Executive. A selected individual shall serve on the Executive for four years from the 1st of January following his selection.
- 5.5 All decisions of the Executive shall be by consensus. The Executive may decide any matter placed before it on behalf of the Joint Panel.
- 5.6 Where a consensus on any matter cannot be reached by the members of the Executive, the question shall be referred to the Supporting Members at the next meeting of the Joint Panel, at which time the matter will be decided by a simple majority vote of the Supporting Members present.
- 5.7 The Executive is authorized to make news releases, in the name of the Joint Panel, from time to time regarding the functioning of the Panel, its role, and the nature and extent of research being conducted.

6.0 THE CHAIRMAN

- 6.1 The Executive shall select from among its number an individual to serve as Chairman. The selected individual shall serve as Chairman for 1 year from the 1st of January following his selection.
- 6.2 The Chairman will preside at all meetings of the Joint Panel and of the Executive.
- 6.3 In case of the absence of the Chairman from any meeting, any other member of the Executive may preside.
- 6.4 The Chairman, in consultation with the other members of the Executive, shall be responsible for arranging the meetings of the Joint Panel.

7.0 THE SECRETARIAT

- 7.1 Energy, Mines and Resources Canada (EMR) will provide the necessary Secretariat and publish the Annual Report.
- 7.2 EMR will appoint an individual to be the Secretary of the Joint Panel.
- 7.3 EMR may designate the individual who is the Secretary as their Representative to the Joint Panel, or may designate some other individual.

8.0 MEETINGS

- 8.1 The Joint Panel will meet semi-annually. Normally there will be a Spring meeting (generally in June) and a Fall meeting (generally in December).
- 8.2 Each meeting of the Joint Panel will include time for:
 - (a) conducting business relating to the functioning of the Panel;
 - (b) distribution of information relating to research projects; and

(c) technical sessions.

- 8.3 Notice of each meeting shall be sent, by the Secretariat, to the designated Representative of each Supporting Member and to each Associate Member. Included with the notice of meeting will be an agenda.
- 8.4 Attendance at meetings is restricted to designated Representatives of each Supporting Member, and alternates. Associate Members and observers invited by a member of the Executive. However, technical sessions are open to any interested person at the discretion of the Executive.

9.0 RESEARCH REPORTS

- 9.1 In order to have a common format for research reports, a system of three forms will be used. The forms will be designated as:
 - (a) FORM 1: STATEMENT OF PROJECT
 - (b) FORM 2: REPORT OF PROJECT PROGRESS
 - (c) FORM 3: PROJECT COMPLETION REPORT
- 9.2 FORM 1 will be used to advise the members of the Joint Panel of any relevant research project which is to be undertaken or which has commenced but has not previously been reported.
- 9.3 FORM 2 will be used to advise the members of the Joint Panel of any progress that has been made or of any changes of the scope of a project.
- 9.4 FORM 3 will be used to advise of the completion or early termination of a project.
- 9.5 A matrix indicating the various areas of active research of interest to the Joint Panel will be maintained, and each project will be identified as to its position on the matrix.
- 9.6 A similar matrix indicating areas of completed research projects will also be maintained.
- 9.7 Each project will be assigned a reference number by the Secretariat. Project reports will be identified by this number.
- 9.8 A summary of the distribution of active research projects on the matrix will be maintained by the Secretariat, and a copy of this summary will be distributed at each meeting of the Joint Panel.

10.0 TECHNICAL SESSIONS

- 10.1 The technical sessions held at meetings of the Joint Panel will consist of presentations of invited papers, discussions of current topics and/or field trips.

- 10.2 It shall be the responsibility of the Executive to organize the technical sessions.
- 10.3 In selecting papers or topics for presentation at technical sessions, preference will be given to topics related to completed or ongoing research projects.

JOINT PANEL ACTIVITIES - 1987

Two regular business meetings were held during 1987.

Summer Meeting

The summer meeting was held on June 23-24, at the Saskatchewan Research Council in Saskatoon, with Stella Swanson of SRC acting as host. Ten organizations were represented, Sask. HURLE (Human Resources, Labour and Employment), CANMET, AECB, Environment Canada, SRC, DIAND, Sask. Environment, Sask. Mining Association, Key Lake Mining Corp., and the Technical Advisory Committee of AECL.

As well as the usual review of project progress, D. Lawson of Environment Canada presented a poster review of the effects of U nat. Pb-210, Ra-226, and Th-228 on fish exposed to uranium mine tailings. He also commented that a brochure has been prepared for public consumption, tailored to a non-technical audience.

At the technical session, C. Potter of Sask. Environment presented a report on the status of decommissioning projects at uranium mines in Saskatchewan.

A tour of SRC facilities was conducted on June 24.

Fall Meeting

The 1987 fall meeting of the Joint Panel was held at CANMET's Elliot Lake Laboratory. Ten organizations were represented, Sask. HURLE, CANMET, DIAND, NHW, AECB, CAIRS, Key Lake Mining Corp., Rio Algom Mines Ltd., Denison Mines Ltd., USWA, and Ontario Ministry of the Environment. At the technical session, E. Joe of CANMET explained the Reactive Acid Tailings Program. A tour of the Laboratory followed, with a detailed presentation of the radiation instrumentation calibration facility.

On the following day, a field trip to the Eldorado Nuclear Refinery in Blind River took place. An excellent tour was provided by C. Bowser, appreciated by all who attended.

REPORTS BY WORKING GROUPS

High Grade Ores - J. Bigu is reviewing the literature and will mail his findings to P. Duport, AECB, and D. Lawson, Environment Canada.

Internal Dosimetry - The project is complete, and a final report should be available soon.

Personal Dosimetry - The report (J. Bigu) will be available soon and will be circulated.

Occupational Hazards - This working group is still under consideration by USWA and AECB.

Close-Out Procedure - Presently inactive.

ACTIVE RESEARCH PROJECTS

ATOMIC ENERGY OF CANADA LTD. (AECL)

Environmental Effects

- 101. Environmental pathways analysis - Aquatic (Chalk River).
- 102. Environmental pathways analysis - Terrestrial (Pinawa).
- 103. Environmental pathways analysis - Effects of water flow on sorption of radionuclides (Pinawa).
- 104. Experimental pathways analysis - Sorption of nuclides onto geologic material (Pinawa).
- 105. Effect of groundwater components on UO_2 dissolution (Pinawa).
- 106. Actinide - rock interaction (Pinawa).
- 107. Environmental impact and stabilization of naturally radioactive wastes (Chalk River).

Assessment of Radiation Hazards

- 108. Quantification of radiation risks (Chalk River).

Radiation Dosimetry

- 109. Radiation dosimetry and instrumentation development (Chalk River).
- 110. Internal dosimetry modelling (Chalk River).
- 111. Deposition of attached and unattached radon daughters (Chalk River).

Assay Methods

- 112. Bioassay of actinides (Chalk River).
- 113. In vivo monitoring (Chalk River).

ATOMIC ENERGY CONTROL BOARD (AECB)

- 209. Study of the health effects of inhaled radioactive dust.
- 210. The Canadian National Dose Registry study.
- 219. Measurement of the thickness of bronchial epithelium.
- 220. Ontario miners morbidity follow-up feasibility study.
- 222. Comparison of the techniques used in estimating past exposures to radon daughters in Canadian mines.
- 227. Characterization of long-lived dust at a Saskatchewan mine-mill.

- 228. Movement of radionuclides between water and sediments.
- 229. The waste management implications of concentrating slimes - II.
- 232. Determination of radon and thoron fluxes in uranium mines (Ontario).
- 233. Determination of radon flux in uranium mines (Saskatchewan).
- 234. Calibration of wire screen collectors in the measurement of the unattached fractions of radon and thoron progeny in air.
- 235. Modified personal alpha-dosimeter for Canadian uranium miners.
- 238. Transfer parameter: non-domesticated animals.
- 239. Effect on radionuclides in plants: literature survey.
- 240. Transfer of radionuclides to human milk - Phase 2 feasibility.
- 241. Technical evaluation of an instant working level meter.
- 242. Catalog of data on uranium uptake, organ burden and excretion.
- 243. Ontario miners mortality study - an update.
- 244. Remeasurement of Th-230 in the pore water of Lacnor tailings.
- 245. Radiation sensitivity of organisms other than man: a review.
- 246. Effect of soil on radionuclides in plants: a field study.

HIGHLIGHTS. ATOMIC ENERGY CONTROL BOARD - H. Stocker

Since the publication of the 1986 Annual Report, the Atomic Energy Control Board (AECB) has reported on the completion of eight research projects and the publication of six reports.

At the June 23, 1987 meeting of the Joint Panel, the AECB reported that since the previous meeting of the Joint Panel (November 25th, 1986) five research projects had been completed and three reports had been published. The published reports discuss the development of automated laboratory based procedures and equipment for:

- i) determining the thorium content of soil samples and aerosols (INFO-2011); and
- ii) alpha-particle spectroscopy (INFO-0233).

A third research report on the radionuclide content of fish taken from waters in the vicinity of uranium mines and mills had also been published (INFO-0231-1, INFO-0231-2).

The report "Development of an Automated Method for Determination of Thorium in Soil Samples and Aerosols" describes methods for thorium detection in water, aerosol and solid samples of approximate sensitivities of 1.0 µg/L, 0.5 µg/g and 1.0 µg/g, respectively. At thorium levels of ten times the

detection limit, the accuracy is estimated to be $\pm 10\%$ for liquids and aerosols, and $\pm 15\%$ for solid samples. The estimated precision for all samples is $\pm 5\%$.

The report "Laboratory System for Alpha-Particle Spectroscopy" (project matrix No. 230) describes a system that can analyze, unattended, ten samples for up to 65,000 seconds per sample.

The report "Survey of Data on the Radionuclide Content of Fish in Canada" presents a compilation, in the form of a computerized database, of uranium and thorium decay-series radionuclide concentrations in various tissues of fish found in Canada. The majority of the data pertains to Saskatchewan, with limited information from Ontario, British Columbia and the Northwest Territories. Most of the radionuclide measurements are of U(total), Ra-226, and Pb-210.

In addition the AECB had published three reports which were prepared by Board staff and pertain to regulatory and licensing concerns for uranium mines and mills:

- i) Regulatory criteria for the disposal of radioactive wastes (INFO-0217)
- ii) Licencing of uranium mine and mill waste management systems (INFO-0218)
- iii) Decommissioning of uranium mines and mills - Canadian regulatory approach and experience (INFO-0219).

Five new research projects were added to the AECB project list. These studies include:

<u>Title</u>	<u>AECB Ref. No.</u>	<u>Matrix No.</u>
1. Transfer parameter: non-domesticated animals.	86.4.5	238
2. Effect of soil on radionuclides in plants: literature survey.	86.4.6	239
3. Transfer of radionuclides to human milk: phase 2 feasibility.	86.4.9	240
4. Technical evaluation of an instant working level meter.	86.3.6	241
5. Catalog of data on uranium uptake, organ burden, and excretion.	86.8.21	242

At the October 28, 1987 meeting of the Joint Panel, the AECB reported that three additional research projects has been completed, and three additional reports had been published. Two of these reports pertain to the transfer of radionuclides through ecological systems:

- i) Review of effect of soil on radionuclide uptake by plants (INFO-0230);
- ii) Transfer parameters in the water/forage/moose pathway (INFO-0244).

The third report discusses the effect of humidity on inhaled aerosols

in the respiratory tract:

- iii) The effect of changes in humidity on the size of submicron aerosols (INFO-0245).

A fourth AECB report had been published that discusses the transfer of radionuclides from the uranium and thorium decay chains through the aquatic and terrestrial environment:

- iv) Transfer of radionuclides of the uranium and thorium decay chains in aquatic and terrestrial environments (INFO-0237 (E)).

This report was prepared by a member of the AECB staff and does not correspond to any of the AECB studies listed in earlier Board submissions to the Joint Panel.

The following is a brief presentation of the salient points of these projects.

The report "Review of effect of soil on radionuclide uptake by plants" reviews the available data on the absorption of uranium, thorium, and lead from soils by plant roots and discusses the mechanisms underlying this process. The report also includes an extensive compilation of plant/soil concentration ratios relevant to regions in proximity to Canadian nuclear facilities.

The report "Transfer parameters in the water/forage/moose pathway" presents the findings of a study for which moose tissue samples and associated water and drinking water samples were collected from the Serpent River Drainage Area (study area) and outside of the watershed (controls) during the fall of 1985. No statistical difference was found between study and control samples.

The third report on ecological transfer of radionuclides, "Transfer of radionuclides of the uranium and thorium decay chains in aquatic and terrestrial environments", examines the environmental and experimental factors which cause variations in the transfer coefficient that characterizes the pathway model used in several studies reported on in the literature. The author of the report also formulates generalizations on the transfer of the different radionuclides through the multiple environmental compartments.

The report "The effect of changes in humidity on the size of submicron aerosols", presents the findings of a study that consisted of a literature search and experimental work. It was found that:

1. the size of inhaled natural atmospheric aerosol increases presumably as a result of its partial hygroscopic nature;
2. growth is very sensitive to relative humidity in the range 95-100% (believed to exist in the respiratory tract);
3. supersaturation in the respiratory system may occur on inhaling very cold air: and
4. growth occurs on insoluble particles: surface wettability is believed to be important in the process.

In addition, the influence of ionizing radiation and air ions on the tendency of water vapour to nucleate is discussed.

In addition, four new projects were added to the AECB project list. These studies include:

<u>Title</u>	<u>AECB Ref. No.</u>	<u>Matrix No.</u>
1. Ontario miners mortality study - an update.		243
2. Remeasurement of Th-230 in the pore water of Lacnor tailings.	5.112.1	244
3. Radiation sensitivity of organisms other than man: a review.	3.116.1	245
4. Effect of soil on radionuclides in plants: a field study.	3.109.2	246

CANADIAN INSTITUTE FOR RADIATION SAFETY (CAIRS)

HIGHLIGHTS OF CAIRS ACTIVITIES - E. Becker

301. Training - The first radiation safety training module has been completed under a contract to the AECB. The module was demonstrated to government officials in Ontario, Manitoba and Saskatchewan; to uranium company officials in Saskatoon and Elliot Lake; to worker representatives in Elliot Lake, and to Westinghouse in Port Hope.
302. Lung Cancer Detection - Enrolment in the CAIRS Early Lung Cancer Detection Program was up to 2,600 uranium workers in Elliot Lake in early 1988. The program is sponsored by Rio Algom Ltd. and Denison Mines Ltd. It is free to the workers, voluntary and confidential. Recruitment at the two mining companies continues.
303. Personal Alpha-Dosimeters - Phase 1 of a research contract with the AECB and CANMET was completed in 1987. The second phase of the contract continues. The work involves the modification to Canadian mining conditions of a French personal alpha-dosimeter. An agreement with the French Atomic Energy Commission has been reached for CAIRS to produce the new dosimeter heads in Canada under licence to the CEA, subject to successful testing at CEA laboratories in France. The new dosimeter has been tested at the CANMET laboratories in Elliot Lake and at Rio Algom Ltd., and AMOK Ltd. uranium mines.

Radon in Homes - CAIRS concluded tests of a radon-in-homes monitor (based on the CEA personal alpha-dosimeter) with the Saskatchewan and Alberta governments. Development of the new monitor continues.

DENISON MINES LIMITED (DEN)

302. Sputum cytology, Ontario uranium mines (see CAIRS, RIO, USW).
418. Thickened tailings experiment for close-out of uranium mill tailings at Denison Mines Ltd., (CANMET).

As noted in the EMR Highlights, collaborative studies of the underground environment are being conducted on a regular basis.

ENERGY, MINES AND RESOURCES CANADA (EMR)

- 500. Instrumentation development (to improve and standardize radiation measurement techniques). (DEN.RIO).
- 501. Environmental radon (thoron) daughter and radioactive dust level determination. (DEN.RIO).
- 502. Control strategy development (to identify radon and thoron sources and evaluate control techniques at Canadian uranium mines using continuous monitoring techniques. (DEN.RIO).
- 503. Development of techniques for assessment of air, water and soil contamination by uranium mine tailings areas (includes characterization of tailings and soil profiles). (RIO.DEN).

HIGHLIGHTS OF EMR'S ACTIVITIES - J. Bigu

The objectives are: to develop radiation instrumentation and to undertake studies to determine radiation levels produced in various mining operations; to identify the major factors affecting the release of radioactive products in mine air; and to develop control methods capable of reducing radiation to acceptable levels.

Instrument Development and Technical Evaluation

(EMR 500)

Further testing and calibration work has been conducted on a real-time radon daughter monitor using Dynamic Random Access Memory (DRAM) as an α -particle detector. The instrument is commercially available under the name Radon Sniffer. This monitor is manufactured by Thomson and Nielssen (Ottawa), and represents the second generation of an earlier prototype developed under contract with CANMET.

A contract was awarded by AECB to CANMET to evaluate a new radon daughter Instant Working Level Monitor (IWLM) developed by the Commissariat de l'Energie Atomique (CEA), France, and known under the name Mimil. A calibration of the IWLM has been carried out in the Radon/Thoron Test Facility.

A passive radon gas monitor, using diffused-junction detector technology, has been developed by alpha-NUCLEAR with the technical collaboration of CANMET. The instrument is in the prototype stage and has been evaluated in the Radon/Thoron Test Facility (RTTF) along with the Radon Sniffer and the IWLM Mimil referred to above. More recently the monitor has been tested in the field. Recommendations have been made to improve its sensitivity to measure low radon gas concentrations for environmental use.

National Radon/Thoron Test Facility (RTTF)

A radon/thoron test facility (RTTF) to be used as the national facility for testing and calibrating radiation instrumentation used for AECB compliance and other purposes, has been installed at the CANMET/Elliott Lake Laboratory.

Full operation of this facility is expected in 1988.

The RTTF will make available a wide range of:

1. Radon, thoron and arbitrary mixtures of both;
2. Radon daughters, thoron daughters and arbitrary mixtures of both;
3. Variable temperature;
4. Variable relative humidity;
5. Variable aerosol type, concentration and size distribution;
6. Variable air flow rate;
7. Capabilities have been provided for injecting long-lived radioactive dust to simulate underground uranium mine atmospheres. However, no instrumentation for this purpose has been acquired because of lack of funding. The same applies to gas chromatography to measure tracer gases used in plate-out studies, and air residence measurements.

In addition, the RTTF can be operated in either a flow-through, or a recirculating mode. Special provisions have been made to allow for automatic, unattended, control of the radiation level by means of a computer system, dedicated sensors, and a specially developed software package.

Although a number of modifications have yet to be introduced the RTTF has been operating on an experimental basis since late 1986. A great deal of research work has been conducted thus far. This includes studies on the following:

1. Diffusion characteristics of thoron progeny using batteries of metal wire screens of different sizes. This work was conducted in collaboration with the U.S. Bureau of Mines (Denver Research Center).
2. Electrical characteristics of radioactive aerosols (radon and thoron progenies) using a specially designed electrostatic wedge collector; and
3. Plate-out characteristics of radon progeny and thoron progeny on large surfaces of different materials.

Environmental Radiation Level Determination

(EMR 501)

Because Long-Lived Radioactive Dust (LLRD), and Radioactive Dust (RD) in general, have become important in radiological protection and health physics, their characterization and quantification cannot be stressed adequately. CANMET has carried out numerous studies of LLRD and RD in Ontario and Saskatchewan uranium mines and mills, in collaboration with interested mining companies.

The most recent study on LLRD and RD has been conducted in conjunction with a large exhaust fan/double filter system used to control dust and radiation in a uranium mine.

Long-lived radioactive dust measurements carried out to date include

concentration, size distribution, activity level, MMAD and AMAD. Identification has been carried out by means of α -spectrometry, γ -spectrometry and fluorometry. The above variables permit the exposure risk from this radiological hazard to be estimated. This work is, therefore, of great practical interest from the radiological protection point of view.

Studies on LLRD and RD will be extended as part of a long-term research program aimed at investigating its radiological impact on uranium industry workers.

A study aimed at investigating the relationship between radon progeny Working Levels, WL(Rn), and thoron progeny Working Levels (Tn), in underground uranium mines has been completed. The work has been carried out at Rio Algom Ltd. (Quirke II, Stanleigh and Panel Mines). In general, a reasonably good correlation between WL(Tn) and WL(Rn) has been established. Hence, measurements of WL(Rn) alone could be used in principle to estimate WL(Tn). This procedure, if implemented, could result in considerable savings in manpower requirements and time. (Knowledge of WL(Tn) is important to calculate the total health risk associated with personal exposure in uranium mines. Total radiation exposure in uranium mines is composed of the following contributions: radon progeny, thoron progeny, long-lived radioactive dust, and gamma-radiation.)

A major project has been initiated in order to analyze data (radon, thoron, and their decay products) gathered by Denison Mines Ltd. during 1986/87. This study is aimed at:

1. Validating radiation mine models: and
2. Determining radon and thoron gas fluxes underground at Denison.

A project has been initiated with the Department of Labour of the Government of Newfoundland and Labrador to design a radiation protection program for the St. Lawrence Fluorspar Ltd. mine. The project will consist partly of a field assessment of the radiation conditions underground followed by recommendations to implement a suitable radiation protection program.

Underground Environmental Monitoring and Control Program

(EMR 502)

Radiation, respirable dust and ventilation are three research areas relevant to underground uranium mines. The Elliot Lake Laboratory has recently undertaken a series of combined studies on these areas in collaboration with the local underground uranium mines at Elliot Lake and other non-uranium mines elsewhere. At present the following projects have either been completed or are about to be initiated.

1. Use of wet scrubbers, electrostatic precipitators, e.g., charged water sprays, and mechanical filtration systems to reduce and control long-lived radioactive dust, non-radioactive dust, and radon (thoron) progeny levels in underground uranium mines.
2. Use of ventilation and recirculation as a means of controlling radiation levels in underground uranium and non-uranium mines.
3. Removal of discrete radioactive 'sinks' to improve working radiation conditions in underground mines.

Great emphasis has been placed on radiation control methods and techniques, and an extension of the above projects in a number of different types of mines is being considered for the near future.

Tailings Management to Minimize Environmental Impact - N.K. Dave & T.P. Lim

The project objective is to develop a tailings management technology which is predictive, environmentally safe and cost effective, such that the tailings can be abandoned after inactivity without perpetual treatment or maintenance.

It consists of developing methods of tailings treatment disposal, surface stabilization and cover placement on inactive tailings to reduce the detrimental effects of contaminants transport via wind and water erosion, surface runoff and sub-surface seepage, and hence to minimize the environmental impact.

Thickened tailings experiment for close-out of uranium mill tailings at Denison Mines Ltd (Denison and CANMET) (DEN 418)

An experimental 10,000 tonne thickened tailings pile was constructed in 1982, and its physical and chemical characteristics were measured in detail. Since then the pile has weathered over the last six years. Its characteristic parameters such as physical and chemical stability, saturated and unsaturated zones, hydrogeochemistry, and pore gas oxygen profiles are being reinvestigated to evaluate the use of such a technology as an alternate disposal option for tailings.

Development of techniques for assessment of air, water and soil contamination (Rio Algom, Denison, CANMET, and Laurentian University) (EMR 503)

Techniques are being developed to assess migration of contaminants from uranium tailings via air and water pathways. Radon gas and its progeny profiles are measured in a tailings basin at various depths. The effects of various tailings covers on radon exhalation rates are also investigated to determine suitable covers. Migration of contaminants from tailings to vegetation, to herbivores and insects, and various other food chains are also being studied to evaluate their ultimate impact on man.

ENVIRONMENT CANADA (DOE)

- 605. Interaction of radionuclides from abandoned uranium tailings with organic residues.
- 606. Radionuclide distributions in the vegetation of North Saskatchewan and adjacent North West Territories.
- 607. Radionuclides in Langley Bay, Lake Athabaska, Saskatchewan (includes 609).
- 608. Effects of uranium effluents on an aquatic ecosystem in North Saskatchewan.
- 615. Radioactivity and fish.

HIGHLIGHTS ON SELECTED PROJECTS - P. Vasudev

601. Leachability of radioactive constituents from uranium mine tailings (completed).

A series of long-term studies were conducted both to examine the leachability of major constituents and radioisotopes, and to assess the effect of two treatment methods (solidification and vegetation) on the characteristics of leachates from these wastes. Four bench-scale experiments were conducted to study the leachability of old and new tailings.

The results indicated that the addition of the $(\text{Ba,Ra})\text{SO}_4$ sediments to tailings results in substantial increases in leached radioactivity for all measured radionuclides except lead-210. It was concluded that if sediments were homogeneously codisposed with tailings at the current mass production ratio, there would, under aerobic conditions, probably be little effect on radionuclide levels in seepage from the tailings.

Results also suggested that solidification of tailings and $(\text{Ba,Ra})\text{SO}_4$ sediments, using the Chemfix process, may only delay the release of radionuclides and other substances from the wastes, but will not prevent such a release from eventually occurring.

The vegetation experiments yielded mixed results. Vegetating untreated tailings using a mixture of grasses, to which a layer of sewage sludge was added as a nutrient and source of organic matter, failed over the long term. The leachate from the tailings became acidic as quickly as that from a control portion of the experiment, and the grasses died. Vegetating solidified tailings produced better, but still inconclusive results. The grasses had not died by the end of a seven-year test, but vegetation yields steadily decreased over the duration of the experiment.

It was also concluded that maintaining the Quirke Mine site in a near-saturated state would initially result in lower Ra-226 and SO_4 concentrations. These concentrations, however, would likely be similar once pyrite-oxidizing bacteria had infiltrated the tailings.

607. The effect of uranium mine tailings on radionuclide concentrations in Langley Bay, Saskatchewan.

During the period from 1955 to 1964, the Gunnar Uranium Mine produced approximately 8×10^3 tonnes of uranium oxide and about 5×10^6 tonnes of waste rock and tailings. Large quantities of fine tailings material washed into Langley Bay, a shallow bay opening onto Lake Athabasca. Samples of sediments, fish and macrophytes were analyzed for Ra-226, Pb-210, Th-228 and Uranium.

The sediment data showed the concentrations of radionuclides and some heavy metals to be much higher in Langley Bay than in the control area. Variations in the composition of the Langley Bay sediments may result from the variability of the initial spill of materials from uphill tailings, or from subsequent leaching and depositional effects of runoff and sediment resuspension.

The northern pike and whitefish populations of Langley Bay contained

higher body burdens of radionuclides than those from the control area. The gut contents of whitefish contained the highest concentrations of all four radionuclides in any fish sample from the study. Ingestion of tailings material by these bottom-feeding fish may have increased the radionuclide concentration in the guts.

The question of whether food supply or direct absorption through the gills is the more important path of radionuclide uptake in fish cannot be answered with the present data. Both pike and whitefish are exposed to dissolved radionuclides in Langley Bay water. The effect of this exposure may have been reduced by periodic excursions outside of Langley Bay. Comparing the present data with the extensive review of transfer coefficients presented by Swanson does not clarify the situation. Extensive laboratory work will be required to solve this problem.

Uptake of dissolved materials by macrophytes can occur via roots or submerged foliage depending on species, habitat, and possibly, season. Control (site 1) plant tissues contained higher concentrations of radionuclides than the water at that location, suggesting the ability to concentrate these elements. These plants may act as scavengers for those elements, absorbing radionuclides leached from uphill tailings and depositing them in the sediments when the foliage collapses in the fall.

The study showed that the movement of tailings into Langley Bay has created an area of high radionuclides in sediment and, periodically, in water. Additional material continues to enter the Bay as leachate from the uphill tailings area. These radionuclides have reached high concentrations in the resident whitefish and macrophyte populations, and to a lesser extent, the pike population.

Additional work is currently in progress to: define individual radionuclide variation in the whitefish population; measure the physiological and histopathological impact of high radionuclide concentrations in whitefish; and compare dissolved and food-source pathways of radionuclide uptake.

HEALTH AND WELFARE CANADA (NHW)

703. Bioassay guideline for uranium.

704. Germanium detectors for in vivo measurements.

705. Studies on the solubility of uranium dusts in simulated lung fluid.

HIGHLIGHTS, NHW PROJECTS - M. Limson Zamora, Gary H. Kramer

The bioassay guideline for uranium is in press.

Calibration of the germanium detectors is on-going, but difficulties continue. In-house software is now being tested for the analysis of spectra.

The testing of techniques to simplify the present accepted method of analysis of solubility of uranium dusts in simulated lung fluids continues.

Statistical analysis has commenced for the results obtained in the completed phases of the study relating solubility to aerosol particle size.

INDIAN AFFAIRS AND NORTHERN DEVELOPMENT (DIAND)

- 801. Modelling the effects of uranium mine tailings on a permafrost environment.
- 802. Pattern of uranium, companion elements and radioisotopes in lichen heath associated with the uranium deposits near Baker Lake, N.W.T. prior to mining operations.
- 803. Survey of radionuclides in vegetation, soils and sediments of Keewatin uranium mineralized areas.
- 804. General use document entitled "Radioactivity in the Northern Environment".

HIGHLIGHTS, DIAND PROJECTS - D.M. Barnett

Three drafts of the document. Radioactivity and the Northern Environment have been completed in an attempt to achieve a satisfactory balance of information and thrust. The project is being re-evaluated, taking into account comments from Joint Panel members.

A key element is the role that northern conditions play in distinguishing this document from other general public documents.

RIO ALGOM MINES LIMITED (RIO)

- 850. Surface treatment of tailings (CANMET).
- 302. Sputum cytology, Ontario uranium miners.

As noted in the EMR Highlights, collaborative studies of the underground environment are being conducted on a regular basis with CANMET.

SASKATCHEWAN ENVIRONMENT (SE)

- 860. Evaluate water quality (ground and surface) in and around 'D' pit (with support from AMOK Ltd).

The field work has been completed with data interpretation and writing to follow.

SASKATCHEWAN RESEARCH COUNCIL (SRC)

- 912. Compilation and statistical analysis of a data base on uranium-series radionuclides in aquatic biota in northern Saskatchewan (SHRB).
- 921. Preparation of a brochure and accompanying literature review on radionuclides in fish (DOE).
- 922. Analysis of caribou bones from the Northwest Territories for uranium-series radionuclides, cesium-137 and strontium-90.

923. Development of bioassays for toxicity testing.

HIGHLIGHTS OF SASKATCHEWAN RESEARCH COUNCIL (SRC) - S. Swanson

922. This project provides data on pre-Chernobyl levels of cesium-137 and strontium-90 in caribou. It also provides data on uranium, thorium, radium-226, lead-210 and polonium-210 levels to be used in relation to results of studies such as Sheard et al. (DOE-29).

923. SRC is currently developing bioassay capability using micro-organisms (algae and cyanobacteria), invertebrates (primarily Ceriodaphnia) and fish (rainbow trout). These tests can be used to test the toxicity of a wide variety of effluents, including uranium mill effluents.

UNITED STEELWORKERS OF AMERICA (USW)

302. Sputum cytology, Ontario uranium miners.

PROJECTS COMPLETED DURING 1987

See also the publications file for reports on active projects by each agency.

<u>Project No.</u>	<u>Agency</u>	<u>Title</u>	<u>Output</u>
ATOMIC ENERGY CONTROL BOARD (AECB)			
202.		Ontario miners mortality study (Phase II) (MOL. WCB).	
203.		Newfoundland fluorspar miners statistical mortality study (Statistics Canada, NHW).	
204.		Ontario miners 'alive' follow-up feasibility study.	
205.		Ecological dynamics of uranium mill tailings IV.	Cancelled. no publ.
207.		Epidemiological study of lung cancer mortality in Canadian mining communities.	
208.		Ontario miners SIN evaluation study.	
221.		Study of the size change of inhaled submicron aerosols.	
225.		Determination of concentration factors - game animals.	
230.		Laboratory system for alpha-particle spectroscopy.	
236.		Survey of data on the radionuclide content of fish.	
237.		Adapting dosimetric models for use on AECB electronic data processing systems.	
239.		Effect of soil on radionuclides in plants: a literature survey	INFO-0230
ENVIRONMENT CANADA (DOE)			
601.		Leachability of radioactive constituents from uranium mine tailings.	Report publ. April 1987
603.		CRNL hydrology study.	Report publ. April 1987
612.		Radionuclide content of some Canadian surface waters.	Report publ. May 1987
613.		A discussion of the Environment Canada investigation into radionuclide levels in fish collected from Port Hope harbour.	Report publ. Dec. 1986

614. A literature review of thorium uptake, retention and excretion. Final report
publ. Nov. 86

SASKATCHEWAN RESEARCH COUNCIL (SRC)

911. A study of radionuclide transfer in the flooded Gunnar open pit uranium mine. 2 journal articles
available from P. Tones
920. Evaluation of selected aquatic food concentration factors used in the AECL food chain model LIMCAL. SRC Report
E-901-6-A-87
- DOE-606 Natural uranium radionuclides in the upland vegetation of Northern Saskatchewan and adjacent Northwest Territories. Draft report
921. Preparation of a brochure and accompanying literature review on radionuclides in fish (DOE). SRC Reports
E-901-7-G-87
E-901-2-E-87

JOINT PANEL ON OCCUPATIONAL AND ENVIRONMENTAL RESEARCH
FOR URANIUM PRODUCTION IN CANADA

MATRIX OF RESEARCH AREAS

	OCCUPATIONAL	ENVIRONMENTAL
<u>DEFINE</u> CONDITIONS OF EXPOSURE	AECB 222, 227 232-3-4, 241 AECL 109, 112, 113 CAIRS 302, 303 EMR 501 NHW 705 DEN,RIO,USWA 302	AECB 228, 236, 244, 246 AECL 101, 102, 103, 104, 105 DOE 605-6-7-15 SRC 912, 921, 922
<u>IDENTIFY</u> ADVERSE EFFECTS	AECL 110, 111, 112, 113 EMR 500, 501	AECL 110, 111 DOE 608, 615 EMR 500, 501, 503 DIAND 801, 802, 803, 804 SE 860 SRC 923
<u>RELATE</u> EXPOSURE WITH EFFECT	AECB 209, 210, 220, 242 AECL 108, 110-11-12-13	AECB 239, 240, 245 AECL 108, 110, 111 DOE 615
<u>ASSESS</u> RISK	AECB 219, 235, 243 AECL 108 USW 990	AECB 238 AECL 101, 102 108 DEN 418, 419
<u>CONTROL</u> HAZARD	EMR 502 NHW 703, 704	AECB 229 AECL 107 DOE 601, 605 EMR 503 RIO 850

PUBLICATION FILE

The first Annual Report of the Joint Panel for Occupational and Environmental Research for Uranium Production in Canada was produced in 1977.

This publication file contains references for only the current year, 1987, and the two preceding years, 1985 and 1986. The annual report for 1983 contains all previous lists of publications, as do earlier annual reports.

Publications should be obtained from the public literature or from the organization conducting or sponsoring the work.

The publication list includes specific project reports by member agencies, as well as other reports of relevance not necessarily associated with the projects listed in the Active Projects section.

ATOMIC ENERGY CONTROL BOARD (AECB) PUBLICATIONS: Listings for 1985.

1. Phillips, C.R., Khan, A., Leung, H., "Development of diffusion - based radon daughter dosimeters". INFO-0012.
2. R.A.D. Service and Instruments Ltd., "Design of the passive personal dosimeter for mines using an allyl diglycol carbonate plastic - phase I: basic and feasibility study", INFO-0117.
3. Corkill, D.A., Dory, A.B., "A retrospective study of radon daughter concentrations in the workplace in the fluorspar mines of St. Lawrence, Newfoundland". INFO-0127.
4. Chiu, N.W., Dean, J.R., Sill, C.W., "Techniques of sample attack used in soil and mineral analysis - phase I". INFO-0128-1.
5. Archibald, J.F., "Membrane barriers for radon gas flow restrictions", INFO-0130.
6. Friesen, Kaye and Associates, "An evaluation of the uranium mine radiation safety course", INFO-0182.
7. Ching, S.H., "Derived surface contamination limits for the uranium mining and milling industry", INFO-0138.
8. IEC Beak Consultants Ltd., "Probabilistic calculation of dose commitment from uranium mill tailings". INFO-0139.
9. Linauskas, S.H., Kalos, F., "Study of the efficiency and current use of respiratory protective devices", INFO-0144.
10. Senes Consultants Ltd., "Computer modelling of an underground mine ventilation system", INFO-0145.
11. Avadhanula, M.R., "Dissolution studies of UO_2 in simulated lung fluid", INFO-0147.
12. Dean, J.R., Chiu, N.W., "Analysis of techniques of sample attack for soil and mineral analysis - phase II". INFO-0128-2.

13. DSMA Atcon Ltd., "Elliot Lake study: factors affecting the uranium mine working environment prior to the introduction of current ventilation practices", INFO-0154.

ATOMIC ENERGY CONTROL BOARD (AECB) PUBLICATIONS: Listings for 1986

1. DSMA Atcon Ltd., "Comparison of radon and thoron daughter behaviour in two underground uranium mine environments", INFO-0164.
2. Beak Consultants Ltd., "Derivation of release limits for a typical uranium mining and milling facility", INFO-0165.
3. Duport, P.J. and Edwardson, E., Canadian Institute for Radiation Safety. "Determination of the contribution of respirable long-lived dust to the committed dose equivalent received by uranium mine and mill workers in the Elliot Lake area". INFO-0167-1.2.
4. SENES Consultants Ltd., "Electrostatic purification of uranium mine stope atmospheres", INFO-0173.
5. Walsh, M.L., W & W Radiological and Environmental Consultant Services Inc., "Doses resulting from intrusion into uranium tailings areas". INFO-0182.
6. McElroy, R.G.C. and Johnson, J.R., AECL, Chalk River Nuclear Laboratories. "Passive radon daughter dosimeters". INFO-0184.
7. Phillips, C.R. and Khan, A., University of Toronto, "Analysis of factors affecting aerosol, unattached fraction and radon progeny measurements in mines", INFO-0187.
8. Beak Consultants Ltd. and Golder Associates, "Waste management implications of concentrating slimes - characteristics and potential problems", INFO-0195-1.
9. Beak Consultants Ltd., "The cost of decommissioning uranium mill tailings", INFO-0198.
10. Robertson, R., Becquerel Laboratories Inc., "Feasibility study of the dissolution rates of uranium ore dust, uranium concentrates and uranium compounds in simulated lung fluid". INFO-0205.

ATOMIC ENERGY CONTROL BOARD (AECB): Listings for 1987

1. "Development of an automated method for determining the thorium content of soil samples and aerosols" INFO-2011.
2. "Laboratory system for alpha-particle spectroscopy", INFO-0233.
3. "Survey of data on the radionuclide content of fish in Canada", INFO-0231-1. and INFO-0231-2, Appendix.
4. "Regulatory criteria for the disposal of radioactive wastes". INFO-0217.
5. "Licensing of uranium mine and mill waste management systems", INFO-0218.

6. "Decommissioning of uranium mines and mills - Canadian regulatory approach and experience", INFO-0219.
7. "Review of effect of soil on radionuclide uptake by plants", INFO-0230.
8. "Transfer parameters in the water/forage/moose pathway", INFO-0244.
9. "The effect of changes in humidity on the size of submicron aerosols", INFO-0245.
10. "Transfer of radionuclides of the uranium and thorium decay chains in aquatic and terrestrial environments", INFO-0237 (E).

ATOMIC ENERGY OF CANADA LTD. (AECL): Listings for 1985

1. Avadhanula, M.R., Chatterjee, R.M., Healey, G.J., Horvath, F.J., Measures, M.P., Stocker, H., Pomroy, C., Johnson, J.R. and Dunford, D.W., "Canadian uranium fuel fabrication study: I intake, retention and excretion monitoring results. II comparison of results with metabolic models. Symp. on the Assessment of radioactive contamination in man". Intern. Atomic Energy Agency, Vienna, pp. 297-323, 1985.
2. Champ, D.R., Young, J.L., Robertson, D.E., Abell, K.H., "Chemical speciation of long-lived radionuclides in a shallow groundwater flow system", Water Pollution Research J. of Canada, 19, 35-54, 1984.
3. Champ, D.R., Moltyaner, G.L., Young, J.L. and Lapcevic, P., "A downhole column technique for field measurement of transport parameters", AECL-8905, 1985.
4. Davis, J.L., Killey, R.W.D., Annan, A.P. and Vaughan, C., "Surface and borehole ground penetration radar surveys for mapping geological structure". Proc. of the NWWA/EPA Conf. on Surface and Borehole Geophysical Methods. February 07-09, 1984.
5. Jay, P.C., "Anion contamination of environmental water samples introduced by filtration procedures", Analytical Chemistry, v.57, No. 3, pp 780-782, 1985.
6. Jay, P.C. and Judd, J.M., "The determination of common anion concentrations in surface and groundwater samples by eluent suppressed ion chromatography", Intern. J. Environ. Anal. Chem., v.19, pp. 99-109, 1984.
7. Johnson, J.R., "The relative effect of ventilation on the potential α -energy from ^{222}Rn and ^{220}Rn progeny, Health Physics 49, pp 996-998, 1984.
8. LaFleur, D.W., Pickens, J.F. and Killey, R.W.D., "Hydrogeologic assessment of the 233-Lake area: calibration of a 3-D groundwater model", TR-257, 1985.
9. Lee, D.R. "Method for locating sediment anomalies on lakebeds that can be caused by groundwater flow", J. Hydrol. 79, 197-193, 1985.

10. Male, D.H., "Wind transport of soil aerosols". Technical Record, TR-295, 1985.
11. Moltyaner, G.L., Sudicky, E.A. and Cherry, J.A., "Contaminant transport in heterogeneous porous media: characterization of spatial variability and dispersivity at a field site". Technical Record, TR-258, 1985.
12. Munch, J.H. and Killey, R.W.D., "Equipment and methodology for sampling and testing cohesionless sediments". Groundwater Monitoring Review, vol. 5, No. 1, pp 38-42, 1985.
13. Patterson, M.C., Gentner, N.E., Middlestadt, M.V., Mirzayans, R. and Weinfeld, M., "Hereditary and familial disorders linking cancer proneness with abnormal carcinogen response and faulty DNA metabolism". Epidemiology and Quantitation of Environmental Risks in Humans from Radiation and Other Agents, pp 235-267, Plenum Corp., 1985.
14. Peterman, B.F., "Thoron-in-breath monitoring at CRNL". Report AECL-8706, 1985.
15. Olivier, J.P., Osborne, R.V. and Rafferty, P.J., "Long-term management of uranium mill tailings: results of the OECD/NEA study", AECL-8499, 1984.
16. Sheppard, M.I., "Radionuclide partition coefficients in soils and plants and their correlation", Health Physics, 49, pp 106-111, 1985.
17. Sheppard, M.I. and Sheppard, S.C., "The plant concentration factor concept as applied to natural uranium", Health Physics 48, pp 494-500, 1985.
18. Wuschke, D.M., Gillespie, P.A. and Main, D.E., "Second interim assessment of the Canadian concept for nuclear fuel waste disposal. vol. 1 - summary", Report AECL-8373-1, 1985.

ATOMIC ENERGY OF CANADA LTD. (AECL): Listings for 1986

1. Cornett, R.J., Chant, L. and Link, D., "Sedimentation of Pb-210 in Laurentian Shield Lakes"; Water Pollution Research J. of Canada, vol. 19, pp 97-109, 1985.
2. Lee, D.R., "Method for locating sediment anomalies on lakebeds that can be caused by groundwater flow", J. of Hydrology, vol. 79, pp 187-193, 1985.
3. Champ, D.R., Moltyaner, G.L., Young, J.L. and Lapcevic, P., "A downhole column technique for field measurement of transport parameters", AECL-8905, 1985.
4. Moltyaner, G.L. and Killey, R.W.D., "Field studies of dispersion in porous media: analysis of experimental data", EOS vol 65, p 208, 1984.
5. Munch, J.H. and Killey, R.W.D., "Equipment and methodology for sampling and testing cohesionless sediments". Groundwater Monitoring Review, vol 5, pp 38-42.
6. Zach, R. and Barnard, J.W., "EWAM: a model for predicting food and water ingestion, and inhalation rates of man", AECL-8401, 1985.

CANADIAN INSTITUTE FOR RADIATION SAFETY (CAIRS): Listings for 1985

1. CAIRS Annual Report, March 31, 1985.
2. "Determination of the contribution of long-lived dust to the committed dose equivalent received by uranium mine and mill workers in the Elliot Lake area", report on research completed under contract to the Atomic Energy Control Board of Canada, November 1985.
3. "The uranium mine radiation safety course", UMRSC 2/85, October 1985.
4. "Radiation safety training in uranium mines and mills: a CAIRS proposal", 1985. Title amended in February 1986 to "Radiation safety training in uranium and other mines and mills".
5. "Progress report on CEA dosimeter performance", December 1985.
6. "Proposal: modified personal alpha dosimeter for Canadian uranium mines", January 1986.
7. "Lung cancer detection, a CAIRS program for Ontario uranium miners", January 1986.
8. "Radiation? who cares? CAIRS cares / CAIRS. Qu'est-ce que c'est?" a bilingual brochure on CAIRS' purpose, programs and activities.
9. "Radiation safety bulletin", vol. 4, No. 1, April 1986. Bulletin de radioprotection.

CANADIAN INSTITUTE FOR RADIATION SAFETY (CAIRS): Listings for 1986

1. Action on radiation. The CAIRS action plan to assist Canadians exposed to radiation in the workplace, 1987-1990.
2. CAIRS radiation safety bulletin, vol. 4, No. 1 and 2.
3. Bancroft uranium tailings. Information obtained by CAIRS from the Federal and Ontario governments.
4. Reports on uranium mine radiation safety course, 1/86 and 2/86.
5. Radiation safety for Canadians. An invited brief to the new democratic party's inquiry into nuclear energy.

CANADIAN INSTITUTE FOR RADIATION SAFETY (CAIRS): Listings for 1987

1. "All about radiation". A radiation safety training program for Canada's uranium mine and mill workers. Training manual for Module 1.
2. CAIRS Radiation Safety Bulletin. vol. 5, No. 1 and 2.
3. "Radioactive and toxic wastes from the Bancroft uranium mines. Where are we going? Who is in charge?" CAIRS Report Stage II.
4. "Report: the uranium mine radiation safety course". 1/87 and 2/87.

5. The CAIRS List 1987-1988, La Liste CAIRS. Radiation Safety Training in Canada. Cours de radioprotection au Canada.

ENERGY MINES AND RESOURCES CANADA (EMR): Listings for 1985

1. Dave, N., Lim, T.P. and Cloutier, N., "Ra-226 concentrations in blueberries (Vaccinium Angustifolium Ait.) near an inactive uranium tailings site in Elliot Lake, Ontario, Canada", Division Report MRP/MRL 85-28, CANMET, Energy, Mines and Resources Canada, 1985.
2. Bigu, J., "Theory of diffusion of radon and thoron through membranes under steady-state and time-dependent radiation conditions - part I (steady-state case)", Division Report MRP/MRL 85-51, CANMET, Energy, Mines and Resources Canada, 1985.
3. Bigu, J., "Theory of diffusion of radon and thoron through membranes under steady-state and time-dependent radiation conditions - part II (time-dependent case)", Division Report MRP/MRL 85-52, CANMET, Energy, Mines and Resources Canada, 1985.
4. Bigu, J., "Theoretical considerations regarding the behaviour of a mine model with ventilation under time-dependent radiation conditions", Division Report MRP/MRL 85-53, CANMET, Energy, Mines and Resources Canada, 1985.
5. Bigu, J., "Theoretical considerations regarding the growth and decay of the short-lived decay products of radon and thoron plated-out on large surfaces", Division Report MRP/MRL 85-54, CANMET, Energy, Mines and Resources Canada, 1985.
6. Grenier, M., "Program ALPHAPRINT for the processing of data acquired by an AlphaNUCLEAR Ltd. logger system", Division Report MRP/MRL 85-64, CANMET, Energy, Mines and Resources Canada, 1985.
7. Bigu, J., "Thoron determination using activated carbon and a high purity germanium detector", Division Report MRP/MRL 85-71, CANMET, Energy, Mines and Resources Canada, 1985.
8. Bigu, J. and Frattini, A., "Radon progeny and thoron progeny plate-out on a variety of materials", Division Report MRP/MRL 85-72, CANMET, Energy, Mines and Resources Canada, 1985.
9. Bigu, J., "Theoretical considerations regarding active sampling of time-dependent radon (thoron) atmospheres", Division Report MRP/MRL 85-75, CANMET, Energy, Mines and Resources Canada, 1985.
10. Dave, N., Lim, T.P. and Cloutier, N., "Migration of metals and trace radionuclides from mine tailings to the environment", Division Report MRP/MRL 85-80, CANMET, Energy, Mines and Resources Canada, 1985.
11. Bigu, J. and Grenier, M., "Characterization of radioactive dust in Canadian underground uranium mines", Division Report MRP/MRL 85-81, CANMET, Energy, Mines and Resources Canada, 1985.

12. Grenier, M., "On-filter self-absorption and loading characteristics", Division Report MRP/MRL 85-83, CANMET, Energy, Mines and Resources Canada, 1985.
13. Bigu, J., "Theory and application of radon and thoron progeny monitoring under steady-state and non-steady-state radiation conditions - part I: active sampling", Division Report MRP/MRL 85-88, CANMET, Energy, Mines and Resources Canada, 1985.
14. Bigu, J., "Progress during the first half of 1985 in the environment projects of the CANMET minerals program", presented to Joint Panel at Chalk River, Ontario, 25-26 June, 1985. Division Report MRP/MRL 85-90, CANMET, Energy, Mines and Resources Canada, 1985.
15. Bigu, J., "Theory and application of radon and thoron progeny monitoring and steady-state and non-steady-state radiation conditions - part II: passive sampling", Division Report MRP/MRL 85-91, CANMET, Energy, Mines and Resources Canada, 1985.
16. Bigu, J., "The effect of time-dependent ventilation rates in partially enclosed radioactive environments", Division Report MRP/MRL 85-92, CANMET, Energy, Mines and Resources Canada, 1985.
17. Bigu, J. and Kaldenbach, R., "A microprocessor based continuous monitor with alpha-spectroscopy capabilities for the determination of radon, thoron and their progeny", Division Report MRP/MRL 85-115, CANMET, Energy, Mines and Resources Canada, 1985.
18. Bigu, J. and Grenier, M., "Electrical characteristics of the short-lived decay products of thoron in underground mines", Division Report 85-116, CANMET, Energy, Mines and Resources Canada, 1985.
19. Bigu, J., "Plate-out of radon and thoron progeny on different materials", Division Report MRP/MRL 85-117, CANMET, Energy, Mines and Resources Canada, 1985.
20. Bigu, J., "A method for determining thoron and radon gas concentrations using solid-state alpha-particle detectors", Division Report MRP/MRL 85-120, CANMET, Energy, Mines and Resources Canada, 1985.
21. Bigu, J., "An automated multisensor apparatus for comparative membrane radon and thoron permeability studies", Division Report MRP/MRL 85-123, CANMET, Energy, Mines and Resources Canada, 1985.
22. Bigu, J., "Attachment of radon and thoron progeny to the surface of different materials", Division Report 85-130, CANMET, Energy, Mines and Resources Canada, 1985.
23. Bigu, J., "Progress during the second half of 1985 in the environment projects of the CANMET minerals program", presented to the Joint Panel in Toronto, December 1985. Division Report MRP/MRL 86-1, CANMET, Energy, Mines and Resources Canada, 1986.
24. Bigu, J., "Theoretical models for determining radon and thoron daughter levels in Canadian underground uranium mines - a comparison with experimental data", Health Physics vol 48, No. 4, pp 371-399, April 1985.

25. Bigu, J., "Use of an automated fluxmeter employing solid-state diffused-junction alpha-detectors and a meteorological package to determine surface radon flux", IEEE Transactions on Nuclear Science, vol NS-31, No. 6, pp 1599-1606, December 1984.
26. Bigu, J., "Effect of electric fields on ^{220}Rn progeny concentration", Health Physics (Note), vol 49, No. 3, pp 512-516, September 1985.
27. Bigu, J. and Raz, R., "A passive radon/thoron daughter personal dosimeter using an electrostatic collector and a diffused-junction detector", Rev. Sci. Instrum., vol 56, No. 1, pp 146-153, 1985.
28. Bigu, J., "Radon daughter and thoron daughter deposition velocity and unattached fraction under laboratory-controlled conditions and in underground uranium mines", J. Aerosol Science vol 16, No. 2, pp 157-165, 1985.
29. Bigu, J., "Removal of airborne thoron (radon) daughters on mine walls and other surfaces by convective deposition and electrostatic plate-out", Proc. Int. Conf. on Occup. Radiation Safety in Mining 1984.
30. Bigu, J., "Non steady-state radiation mine model - practical applications to personal dosimetry and environmental monitoring", Proc. Int. Conf. on Occup. Radiation Safety in Mining 1984.
31. Bigu, J., "A method for determining thoron gas concentrations", Proc. Conf. Environmental Radiation '85, Colorado, January 1985.
32. Dave, N., Lim, T.P. and Cloutier, N., "Ra-226 concentrations in blueberries (Vaccinium Angustifolium Ait.) near an inactive uranium tailings site in Elliot Lake, Ontario, Canada", Environ. Poll. Series B, vol 10, pp 301-314, 1985.
33. Dave, N., Lim, T.P. and Cloutier, N., "Migration of metals and trace radionuclides from mine tailings to the environment", Proc. Int. Conf. on Heavy Metals in the Environment, Athens, Greece, September 1985.
34. Bigu, J. and Grenier, M., "Characterization of radioactive dust in Canadian underground uranium mines", Proc. 2nd U.S. Mine Ventilation Congr., Reno, Nevada, 1985, pp 269-279.
35. Bigu, J., "The effect of time-dependent ventilation rates in partially enclosed radioactive environments", Proc. Ventilation Congr., Toronto, Ont., October 1985.
36. Bigu, J. and Kaldenbach, R., "A microprocessor based continuous monitor with alpha-spectroscopy capabilities for the determination of radon, thoron and their progeny", Radiation Protection Dosimetry, vol 12, No. 3, pp 251-260, 1985.

ENERGY, MINES AND RESOURCES CANADA (EMR): Listings for 1986

1. Bigu, J., "Progress during the second half of 1985 in the environment projects of the CANMET Minerals Program", presented at Joint Panel meeting, Toronto, Ontario, December 1985. Division Report M&ET/MRL 86-1(OP).

2. Grenier, M., "Hazardous gases and substances found in underground mine air", Division Report M&ET/MRL 86-26(TR), 1986.
3. Hardcastle, S., Grenier, M. and Bigu, J., "Determination of environmental variables underground - measurement techniques and instrumentation", presented at CIM Meeting (Algoma Branch), Elliot Lake, Ontario, January 10, 1986. Division Report M&ET/MRL 86-30(OP).
4. Bigu, J., "Plate-out of radon/thoron progeny on large surfaces", Division Report M&ET/MRL 86-50(TR), 1986.
5. Bigu, J., "Calibration of the Pylon AB-5/AEP system, a continuous radon daughter Working Level Monitor", Division Report M&ET/MRL 86-64(TR), 1986.
6. Bigu, J., "Calibration of the Pylon AB-5/EL and AB-5/PRD systems, two continuous radon gas monitors", Division Report M&ET/MRL 86-64(TR), 1986.
7. Bigu, J., "Effect of several radiation control measures for remedial purposes in a dwelling in the Elliot Lake area", Division Report M&ET/MRL 86-66(TR), 1986.
8. Bigu, J., "Status of personal alpha-particle dosimetry in the uranium industry: a brief overview", presented at Joint Panel meeting, Saskatoon, Sask., May 27-28, 1986, Division Report M&ET/MRL 86-71(OP), 1986.
9. Bigu, J., "Progress during the first half of 1986 in the environment projects of the CANMET Minerals Program", presented at Joint Panel meeting Saskatoon, Sask, May 27-28, 1986. Division Report M&ET/MRL 86-72(OP), 1986.
10. Bigu, J., "A review of the underground environment research program at the Elliot Lake Laboratory", Division Report M&ET/MRL 86-75(TR), 1986.
11. Bigu, J., "Long-lived radioactivity associated with quartz dust in hard rock underground uranium mines", Division Report M&ET/MRL 86-89(TR), 1986.
12. Bigu, J., "On the plate-out of radon and thoron progeny on large surfaces", presented at 191st Meeting of the American Chemical Society, New York, April 13-18, 1986. Division Report M&ET/MRL 86-90(OP,J).
13. Bigu, J., "Radiation control systems for the reduction of radon daughter concentrations", presented at 31st Annual Meeting of the Health Physics Society, Pittsburgh, June 29-July 3, 1986. Division Report 86-98(OP).
14. Thomson, I., Nielsen, T. and Bigu, J., "A portable radon/thoron dosemeter for personal and environmental monitoring", presented at 31st Annual General Meeting of the Health Physics Society, Pittsburgh, July 1, 1986. Division Report M&ET/MRL 86-102(OP).
15. Grenier, M., Hardcastle, S., Frattini, A. and Butler, K., "Comparison of dust sampling instruments in coal and uranium ore dust clouds in a dust chamber", Division Report M&ET/MRL 86-104(TR), 1986.
16. Grenier, M., "A simple apparatus for the determination of effective radium content of radium bearing substances", Division Report M&ET/MRL 86-115(TR).

17. Bigu, J. and Frattini, A., "Evaluation of a charged water spray system for radiation control purposes in a hard rock underground uranium mine", Division Report M&ET/MRL 86-128(TR), 1986.
18. Bigu, J., "Calibration of radiation instrumentation in a radon/thoron test facility of the walk-in type", Division Report M&ET/MRL 86-133(TR), 1986.
19. Bigu, J., "Calibration of radon and radon progeny instrumentation of the active and passive type in a large radon/thoron test facility of the walk-in type", Division Report M&ET/MRL 86-134(TR), 1986.
20. Bigu, J., Grenier, M., Hardcastle, S., "Characteristics of long-lived radioactive dust in a conveyor belt drift", Division Report M&ET/MRL 86-140(TR), 1986.
21. Li, H. and Bigu, J., "Energy dependence of ultra-thin CaSO_4 TM chips to radon and thoron progeny", Division Report M&ET/MRL 86-158(TR), 1986.
22. Bigu, J., "The effect of time-dependent ventilation rates in partially enclosed radioactive environments", Proc. 1st Int. Symp. on Ventilation for Contaminant Control, pp 477-488, H.D. Goodfellow (Ed.), Elsevier, 1986.
23. Dave, N.K., Cloutier, N. and Lim, T.P., "Radionuclide levels in vegetation growing on uranium tailings, Elliot Lake, Ontario", Proc. 7th Annual Symp. on Management of Uranium Mill Tailings, Low-Level Waste and Hazardous Waste, vol. II, pp 263-271, Fort Collins, Colorado, Feb. 6-8, 1985.
24. Bigu, J., "Thoron determination using activated carbon and a high purity germanium detector", Health Physics 51:4:535, October 1986.
25. Bigu, J. and Vandrish, G., "Radon (thoron) daughter measurements with an automated programmable radiation monitor", Envir. Monitoring and Assessment 6:59-70, 1986.
26. Bigu, J. and Grenier, M., "Electrical characteristics of the short-lived decay products of thoron in underground uranium mines", Am. Ind. Hyg. Assoc. J. 47:6:308-311, June 1986.
27. Bigu, J., "A method for determining thoron and radon gas concentrations using solid-state alpha-particle detectors", Int. J. Applied Radiation and Isotopes, 37:7:567-573, 1986.
28. Bigu, J., "An automated multi-sensor apparatus for comparative membrane radon and thoron permeability studies", Nuclear Instrum. and Methods in Physics Research, vol A251, 366-373, 1986.
29. Bigu, J., "Attachment of radon and thoron progeny to the surface of different materials", J. Aerosol Science 17:4:753-755; 1986.
30. Cloutier, N.R., Clulow, F.V., Lim, T.P. and Dave, N.K., "Metal (Cu, Ni, Fe, Co, Zn, Pb) and Ra-226 levels in meadow voles Microtus pennsylvanicus living on nickel and uranium mill tailings in Ontario, Canada; environmental and tissue levels", Environmental Pollution (Series B) vol 10, pp 19-46; 1985.

31. Clulow, F.V., Cloutier, N.R., Dave, N.K. and Lim, T.P., "Radium-226 concentrations in faeces of snowshoe hares, Lepus americanus, established near uranium mine tailings", J. Environ. Radioactivity, vol. 3, pp 305-314; 1986.
32. Cloutier, N.R., Clulow, F.V., Lim, T.P. and Dave, N.K., "Metal (Cu, Ni, Fe, Co, Zn, Pb) and Ra-226 levels in tissues of meadow voles Microtus pennsylvanicus living on nickel and uranium mine tailings in Ontario, Canada: site, sex, age and season effects with calculation of average skeletal radiation dose"; Environmental Pollution (Series A), vol. 41, pp 295-314; 1986.
33. Cloutier, N.R., Clulow, F.V., Lim, T.P. and Dave, N.K., "Transfer coefficient of ^{226}Ra from vegetation to meadow voles, Microtus pennsylvanicus, on U mill tailings"; Health Physics vol 50, No. 6, pp 775-780; 1986.
34. Burns, B., Clulow, F.V., Cloutier, N.R., Dave, N.K. and Lim, T.P., "Transfer coefficient of ^{226}Ra from food to young weaned meadow voles, Microtus pennsylvanicus, in the laboratory", Health Physics, vol. 52, No. 2, pp 207-211; 1987.

ENERGY MINES AND RESOURCES CANADA (EMR): Listings for 1987

1. Bigu, J., Palmer, B. and Montgomery, I., "Results of a long-term dosimetry program at Rio Algom Limited (Stanleigh Mine)", Division Report MRL 87-42 (TR), 1987.
2. Bigu, J., Palmer, B. and Montgomery, I., "Results of a long-term personal dosimetry program at Rio Algom (Quirke Mines)", Division Report MRL 87-49 (TR), 1987.
3. Bigu, J. and Edwardson, E., "Characterization of long-lived radioactive dust emissions in physico-chemical operations in a uranium mill", Division Report MRL 87-64(TR), 1987.
4. Bigu, J. and Edwardson, E., "Characterization of long-lived radioactive dust clouds generated in mechanical operations in a uranium mill", Division Report MRL 87-65(TR), 1987.
5. Hardcastle, S. and Butler, K., "Evaluation of the climate and airflow in a flood leaching stope", Division Report MRL 87-68(TR), 1987.
6. Knight, G. and Hardcastle, S., "Efficiency tests on a wet dust collector in a hard rock mine", Division Report MRL 87-95(TR), 1987.
7. Bigu, J. and Duport, P., "Characterization of long-lived radioactive dust clouds generated in uranium mill operations", Division Report MRL 87-105 (TR), 1987.
8. Bigu, J., "The use of tailings as backfill in underground uranium mines", Division Report MRL 87-105(TR), 1987.
9. Grenier, M. and Bigu, J., "Underground evaluation of a fan/filter system for dust reduction capabilities", Division Report MRL 87-109(TR), 1987.

10. Bigu, J., "Technical evaluation of a radon progeny instant working level meter in an underground uranium mine", Division Report MRL 87-110(TR), 1987.
11. Bigu, J. and Grenier, M., "Evaluation of a fan/filter system to reduce radon (and thoron) progeny in underground uranium mines", Division Report MRL 87-111(TR), 1987.
12. Hardcastle, S., "Airflow determination for radiation emanation investigations of a large worked out area of a uranium mine", Division Report MRL 87-112(TR), 1987.
13. Bigu, J., "Laboratory and field evaluation of a new radon progeny working level monitor using low-power CMOS electronics", Division Report MRL 87-117(TR), 1987.
14. Bigu, J. and Schryer, D., "Radioactivity emissions from bacterially assisted leaching of uranium stopes", Division Report MRL 87-174(TR), 1987.
15. Bigu, J., Grenier, M. and Frattini, A., "Radiation levels in backfilled areas at Denison Mines Limited", Division Report MRL 87-180(TR), 1987.
16. Hardcastle, S. and Cavan, J., "Initial trials of proposed particle counter for underground use", Division Report 87-184(TR), 1987.
17. Grenier, M. and Butler, K., "Evaluation of a split-flow elutriator used in the determination of airborne dust charge distribution", Division Report 87-187(TR), 1987.
18. Bigu, J., "On the plate-out of radon and thoron progeny on large surfaces", Proc. Radon and Its Decay Products: Occurrence, Properties and Health Effects, ACS Symp. Series, American Chemical Society, P.K. Hopke (Ed.), Washington, D.C., Chapter 21, pp 272-284, 1987. (Division Report MRL 86-90).
19. Bigu, J., "The effect of time-dependent ventilation and radon (thoron) gas emanation rates in U/G uranium mines", Proc. 3rd Mine Ventilation Symp., Pennsylvania State University, Chapter 52, pp 353-362, October 12-14, 1987. (Division Report MRL 87-78).
20. Bigu, J., "Control of radiation and dust in underground mines", Proc. of Seminar 'CANMET, Partner with the Quebec Mining Industry', Val d'Or, Quebec, pp 58-774, 24-25 February, 1988. (Division Report MRL 87-172).
21. Dave, N.K., Lim, T.P. and Cloutier, N., "Migration of metals and trace radionuclides from mine tailings to the environment", Proc. Int. Conf. on Heavy Metals in the Environment, Athens, Greece, Sept. 1985 (Division Report MRL 85-80).
22. Dave, N. and Lim, T., "Effect of various tailings covers on radon gas emanation from pyritic uranium tailings", Proc. National Symp. on Mining, Hydrology, Sedimentology and Reclamation, pp 99-104, Springfield, Illinois, December 1987. (Division Report MRL 87-84).

23. Grenier, M. and Bigu, J., "Evaluation des sources et des niveaux de poussiere et taux de radiation dans les mines. Strategies de contrôle", Proc. of Seminar 'CANMET, Partenaire de l'Industrie Miniere Quebecoise', Val d'Or, Quebec, pp 67-78, 24-25 February, 1988. (Division Report MRL 87-182).
24. Hall, A.E., Saindon, J.P., Hardcastle, S.G. and Nel, L., "Controlled recirculation investigation at Ruttan Mine", Proc. 3rd U.S. Mine Ventilation Symp., Pennsylvania State University, J. Mutmanský (Ed.), October 1987.
25. Hardcastle, S. and Sheikh, A., "Evaluation of the air quality and distribution during the rest period of bacterial flood leaching operations in uranium mines", Proc. 3rd Mine Ventilation Symp., Pennsylvania State University, Oct. 12-14, Chapter 51, pp 343-352, 1987. (Division Report MRL 87-75).
26. Bigu, J., "Progress during the second half of 1986 in the environment projects of CANMET's Mineral Program", presented to Joint Panel on Occupational and Environmental Research for Uranium Production in Canada, Hull, Quebec, Nov. 25-26, 1986. (Division Report MEL 87-9).
27. Bigu, J., "A preview of the National Radon/Thoron Test Facility", presented to the Joint Panel on Occupational and Environmental Research for Uranium Production in Canada, Hull, Quebec, Nov. 25-26, 1986. (Division Report MRL 87-19).
28. Bigu, J., "Progress during the first half of 1987 in the environment projects of the CANMET Minerals Program", presented to the Joint Panel on Occupational and Environmental Research for Uranium Production in Canada, Saskatoon, Sask., 23-24 June, 1987. (Division Report MRL 87-83).
29. Bigu, J., "Progress during the second half of 1987 in the environment projects of the CANMET Minerals Program", presented to the Joint Panel on Occupational and Environmental Research for Uranium Production in Canada, Elliot Lake, Ontario, October 28-29, 1987. (Division Report MRL 87-134).
30. Grenier, M., "Wet dust collectors as a means of mineral dust control", presented to Algoma Branch CIM Meeting, Elliot Lake, Ontario, Jan. 19, 1987. (Division Report MRL 87-16).
31. Grenier, M., Hardcastle, S. and Bigu, J., "Evaluation of a water type dust collector at an underground crushing operation", presented to 56th Annual Meeting MAPAO, Toronto, Ontario, May 27-29, 1987; and to American Industrial Hygiene Conf., Montreal Quebec, May 31-June 5, 1987. Division Report MRL 87-51).
32. Hardcastle, S. and Sheikh, A., "Applying tracer gas techniques to evaluate the air distribution in flood leaching stopes", presented to 89th Annual General Meeting of CIM, Toronto, Ontario, May 3-7, 1987. (Division Report MRL 87-41).
33. Hardcastle, S. and Sheikh, A., "A portable computer multi-size, aerosol counting system for use in underground mining environments", presented to American Industrial Hygiene Conf., Montreal, Quebec, May 31-June 5, 1987. (Division Report MRL 87-167).

34. Bigu, J., "Effect of selected variables on airborne thoron progeny concentrations", Health Physics, vol 54, No. 1, pp 93-98, January, 1988. (Division Report MRL 87-61).
35. Grenier, M., Hardcastle, S. and Bigu, J., "Characterization of airborne dust in a belt conveyor drift", CIM Bull., vol 80, No. 908, pp 35-38, December 1987. (Division Report MRL 87-119).
36. Knight, G. and Moore, E., "Comparison of respirable dust samplers for use in hardrock mines". Am. Ind. Hyg. Assoc. J., vol 48, No. 4, pp 354-363, April 1987. (Division Report MRL 84-78).
37. Knight, G. and Moore, E., "Comparison of dust samplers: statistical analysis techniques", Am. Ind. Hyg. Assoc. J., vol 48, No. 4, pp 344-353, April, 1987. (Division Report MRL 85-105).
38. Stokes, Hardcastle, S., "A real-time tracer gas analyzer - an investigational tool for mine ventilation studies", Min. Sci. Tech. J., vol 5, No. 2, pp 187-197, July 1987. (Division Report CRL 87-95).
39. Lim, T.P., Dave, N.K. and Cloutier, N., "High resolution alpha spectroscopy for radium analysis. The effects of sample thickness and filter pore size", Division Report MRL 87-12(J).
40. Knight, G., "A reference size selective sampler for respirable dust", Division Report MRL 87-17(J), 1987.
41. Bigu, J., "Conversion factors for calculating working levels using continuous radon progeny time-integrating monitors", Division Report MRL 87-60(J), 1987.
42. Bigu, J., "Effect of selected variables on airborne thoron progeny concentrations", Division Report MRL 87-61(J), 1987.
43. Bigu, J., " ^{222}Rn and ^{220}Rn relationship in Canadian underground mines", Division Report MRL 87-62(J), 1987.
44. Bigu, J., "Long-lived radionuclides in quartz dust samples from hard rock uranium mines", Division Report MRL 87-67(J), 1987.
45. Bigu, J., Grenier, M., Hardcastle, S., "Effect of a wet scrubber to reduce radioactive aerosol and dust concentrations in underground uranium mines", Division Report MRL 87-85(J), 1987.
46. Bigu, J. and Grenier, M., "Reduction of airborne radioactive dust by means of a charged water spray", Division Report MRL 87-101(J), 1987.
47. Grenier, M., and Bigu, J., "Suppression of airborne dust in hard rock mines by means of electrostatic water sprays", Division Report 87-155(J), 1987.

ENVIRONMENT CANADA (DOE): Listings for 1985

1. "Removal of radium-226 from uranium mining effluents", A final report of a Joint Government-Industry Program, Environment Canada Report No. EPS 3/H/3, 1984.

2. "Joint government-industry program for the removal of radium-226 from uranium mining effluents", Final reports vol II, and vol III (Appendices), 1984.
3. W&W RECS., "Assessment of radiological impact of non-uranium metal mining", Environment Canada report No. IP-21, 1984.
4. Kalin, M., "Long-term ecological behaviour of abandoned uranium mill tailings - 2. Growth patterns of indigenous vegetation on terrestrial and semi-aquatic areas", Report No. EPS 3/HA/2, 1984.
5. Platford, R.F., FitzGerald, J.A., Bobba, A.G. and Joshi, S.R., "Report on the groundwater at the Port Granby radioactive waste management site from 1981 to 1983", Environment Canada, National Water Research Institute, Unpublished report No. 84-9, 1984.
6. Platford, R.F., Bobba, A.G. and Joshi, S.R., "The Port Granby radioactive waste management site", Water Poll. Res. J. Canada vol 19, No. 2, pp 90-96, 1984.
7. Kalin, M., "Port Radium Northwest Territories, an evaluation of environmental effects of the uranium and silver tailings", A report to Environment Canada, Dept. of Indian & Northern Affairs, Health & Welfare Canada, Fisheries and Oceans, 1984.
8. Reardon, E.J. and Moddle, P.M., "Peat moss as an oxygen interceptor material for the management of pyritic uranium tailings", Environment Canada report No. IP-22, 1984.
9. Monenco Analytical Laboratories, "Investigation to remove arsenic and radium-226 from Port Granby effluent using manganese impregnated filters", Report to Eldorado Resources Ltd., and Environment Canada, 1984.
10. Swanson, S., "Laboratory study plan for uptake and effects of radionuclides in aquatic fauna", Environment Canada and Saskatchewan Research Council, SRC Publication No. E-901-13-E-84, 1984.
11. Swanson, S. and Bernstein, J., "Physiological parameters in three fish species from Beaverlodge area, Saskatchewan", Environment Canada, SRC Publication No. E-901-40-E-84, 1984.
12. Raven, K.G., Novakowski, K.S. and Bottomley, D.J., "Hydrogeologic research at the Chalk River research area", Paper presented at the 16th AECL Information Meeting of the Nuclear Fuel Waste Management Program, Winnipeg, September 1983.
13. Novakowski, K.S., Raven, K.G. and Evans, G.V., "A review of radionuclide migration experiments conducted in a plutonic rock environment at CRNL", Paper presented at the 17th AECL Information meeting on Nuclear Fuel Waste Management Program, Ottawa, 1984.
14. Raymond, L. and Lawson, D.W., "Uranium library Saskatchewan district office, Environmental Protection Service", Environment Canada, W&NR, Regina, 1985.

15. Joshi, S.R., "Cs-137, Ra-226 and total uranium in fish from lakes Ontario, Erie, Huron and Superior during 1976-1982", Water Poll. Res. J. Canada, vol 19, pp 110-119, 1984.
16. Joshi, S.R., "Recent sedimentation rates and Pb-210 fluxes in Georgian Bay and Lake Huron", Sci. Total Environment, vol 41, p. 219, 1985.
17. Platford, R.F. and Joshi, S.R., "The chemistry of uranium and related radionuclides in Lake Ontario waters", manuscript in preparation.
18. Novakowski, K.S., Flavelle, P.A., Raven, K.G. and Cooper, E.L., "Determination of groundwater flow pathways in fractured plutonic rock using a radioactive tracer", Int. J. Appl. Radiat. Isot., vol 36, No. 5, p. 399, 1985.
19. Novakowski, K.S., Evans, G.V., Lever, D.A. and Raven, K.G., "A field example of measuring hydrodynamic dispersion in a single fracture", Water Resources Res. vol 21, No. 8, pp 1165-74, 1985.
20. "A study to assess the distribution of radionuclides in the aquatic ecosystem in the vicinity of the Serpent River mouth", A report to Environment Canada, EPS-Ontario Region by Beak Consultants Ltd., 1985.
21. "Benthological, chemical, radiological and chronological evaluation of sediments in Port Hope Harbourn, Ontario", a report to Environment Canada, EPS Ontario Region, by Beak Consultants Ltd. (1985).

ENVIRONMENT CANADA (DOE): Listings for 1986

1. "An assessment of the radiological impact of uranium mining in Northern Saskatchewan, Canada", A report to the Environment Canada and Atomic Energy Control Board, Report EPS 2/MM/1, 1986.
2. Lawson, D.W., "Options for reclaiming the Gunnar uranium tailings, Saskatchewan, Canada", Proc. of Symp. on Geotechnical and Geohydrological Aspects of Waste Management, Fort Collins, Colorado, 5-7 February 1986, pp 339-349.
3. Baweja, A.S., Joshi, S.R. and Demayo, A., "Radionuclide content of some Canadian surface waters: a report on the national radionuclides monitoring program, 1981-1984", Scientific Series No. 156, Inland Waters Directorate, Environment Canada.

ENVIRONMENT CANADA (DOE): Listings for 1987

1. "A discussion of the Environment Canada investigation into radionuclide levels in fish collected from Port Hope Harbour", Environment Canada, Environmental Protection, Ontario Region.
2. Raven, K.G., "Hydrological characterization of a small groundwater flow system in fractured monzonitic gneiss", Inland Waters Directorate, Environment Canada Scientific Series 149, NHRI paper 30, April 1987.
3. Swanson, S.M., "A literature review of radionuclides in fish", SRC Publication E-901-2-E-87, April 1987.

4. Waite, D.T., Joshi, S.R. and Sommerstad, H., "The effect of uranium mine tailings on radionuclide concentrations in Langley Bay, Saskatchewan, Canada"; Arch. Environ. Contam. Toxicol., vol. 17, pp. 373-380, 1988.

INDIAN AFFAIRS AND NORTHERN DEVELOPMENT: Listings for 1986

1. Hutchison-Benson, E.A., Lei, T.T., Svoboda, J. and Taylor, H.W., "Fallout and natural radioactivity in the Canadian northern environment", ACUNS Conf. Proc. 'Resources and Dynamics of the Boreal Zone', pp 465-479, 1983.
2. Kershaw, K.A. et al., "The distribution patterns of uranium, companion elements and radioisotopes in lichen heath associated with uranium deposits near Baker Lake, N.W.T. prior to mining operations. II Re-examination of the sulphur, copper and lead content data; the pattern of calcium and potassium concentrations; methodology of radioisotope determinations; and final data analysis", unpublished final report to DIAND, 1984.
3. Lei, T.T., Svoboda, J. and Taylor, H.W., "Distribution of cesium-137 and uranium series radionuclides in soils and vegetation of the Baker Lake area, Keewatin, N.W.T.", in preparation.
4. Looney, J.H.H. et al., "The distribution of uranium and companion elements in lichen heath associated with undisturbed uranium deposits in the Canadian arctic", In Lichen Physiology and Cell Biology, edited by D.H. Brown, 1985.
5. Roulet, N.T. and Woo, M.K., "Hydrology of a wetland in the continuous permafrost region", J. of Hydrology (in press 1986).
6. Roulet, N.T. and Woo, M.K., "Wetland and lake evaporation in the low arctic", Arctic and Alpine res. vol. 18, pp 195-200, 1986.
7. Roulet, N.T. and Woo, M.K., "Low arctic wetland hydrology", Can. Water Resources J., vol 11, pp 69-75, 1986.
8. Svoboda, J., Taylor, H.W. and Lei, T.T., "Survey of the Keewatin uranium mineralization areas with respect to natural occurrence of radionuclides in vegetation, soils and sediments", Environmental Studies Report No. 41, 1986.

SASKATCHEWAN DEPT. OF ENVIRONMENT: Listings for 1985

1. Barsi, R.G., "Present status of uranium mill tailings in Saskatchewan", presented at the Engineering of Waste Management Systems Seminar, Saskatoon, Saskatchewan, August 1985.
2. Beak Consultants Ltd., "An environmental evaluation of the effects of the Eldor Mines Rabbit Lake operations on Wollaston Lake", prepared for Saskatchewan Environment, November 1985.
3. Morin, K.A., "Simplified explanations and examples of computerized methods for calculating chemical equilibrium in water", Computers and Geosciences, vol. 11, No. 4, pp 409-416, 1985.

4. "Radon surveys in Saskatchewan". Saskatchewan Environment, MPCB, March 1985.

SASKATCHEWAN DEPT. OF THE ENVIRONMENT: Listings for 1986

1. Morin, K.A. and Cherry, J.A., "Trace amounts of siderite near a uranium-tailings impoundment, Elliot Lake, Ontario, and its implication in contaminant migration in a sand aquifer", Chemical Geology, vol 55, No. 3-4, 1986 (in press).
2. Morin, K.A., "Validity of redox measurements in hydrogeologic studies", Proc. 3rd Canadian Hydrogeological Conf. (Int. Assoc. of Hydrogeologists), Saskatoon, Sask. April 21-23, 1986.
3. Morin, K.A. and Cherry, J.A., "Field investigation of a small-diameter cylindrical, contaminated ground-water plume emanating from a pyritic uranium-tailings impoundment", Proc. (referred) of the ASTM Symp. on Field Methods for Groundwater Contamination Studies and Their Standardization, February 2-7, 1982, Cocoa Beach, Florida (in press).
4. Morin, K.A., "Physical and chemical hydrogeology of uranium tailings in Canada and the United States of America", Morwijk Enterprises Report ME01-03, 1986.

SASKATCHEWAN RESEARCH COUNCIL (SRC): Listings for 1985

1. Swanson, S.M., 1985, "Food chain transfer of U-series radionuclides in a Northern Saskatchewan aquatic system", Health Physics, 49(5):747-770, 1985.
2. Swanson, S.M., Tones, P.I. and Richert, D., "Compilation and statistical analysis of a data base on uranium-series radionuclides in aquatic biota in Northern Saskatchewan", Interim Report SRC Publ. No. E-901-5-E-85, 1985.
3. Swanson, S.M. and Bernstein, J., "Physiological parameters in three fish species in the Beaverlodge area", SRC Publ. No. E-901-40-E-84, 1984.
4. Sheard, J.W., "A preliminary study of radionuclide distributions in the upland vegetation of northern Saskatchewan. SRC Publ. No. E-902-5-B-85, 1985.
5. Swanson, S.M., "A study of the distribution of naturally occurring radionuclides in freshwater benthos and their environment". Phase II Report. Senes Consultants Ltd., Willowdale, Ontario. 1985.

SASKATCHEWAN RESEARCH COUNCIL (SRC): Listings for 1986

1. Bernstein, J.W. and Swanson, 1987, "Hematological parameters and parasite load in wild fish with elevated radionuclide levels" submitted to Advances in Environmental Science and Technology, under review; presented at 13th Annual Aquatic Toxicology Conf., Moncton, N.B., Nov. 1986.

2. Sheard, J.W., Swanson, S.M. and Godwin, R.C., 1986. (Draft submitted to Environment Canada). "Concentration and distribution of uranium-series radionuclides in vegetation of Northern Saskatchewan, and adjacent Northwest Territories"; University of Saskatchewan, Saskatoon, Sask. Has now been extensively and thoroughly reviewed twice by a team of 18 experts from across Canada. To be released in 1987.
3. Swanson, S.M. and Richert, D., 1987. "Bioconcentration factor parameter distributions and analysis of the aquatic pathway portion of the LIMCAL food chain model"; SRC Report No. E-901-6-A-87.
4. Tones, P.I. (in preparation) "Food chain transfer of uranium series radionuclides in a flooded open-pit mine"; to be submitted to Health Physics.
5. Tones, P.I., 1987. "Aquatic food chain transfer of radionuclides in a flooded open-pit uranium mine"; Presented at 8th Annual Conf. Canadian Radiation Protection Assoc., May 17-29, 1987. Saskatoon, Sask.
6. Tones, P.I., 1986 draft under review. "Limnological and chemical characteristics of the flooded Gunnar uranium mine"; submitted to Journal of Environment Radioactivity.

SASKATCHEWAN RESEARCH COUNCIL (SRC): Listings for 1987

1. Swanson, S.M., 1987, "Radioactivity from uranium mining and its relationship to fish"; SRC Report No. E-901-7-G-87.
2. Swanson, S.M., 1987, "A literature review of radionuclides in fish"; SRC Report No. E-901-2-E-87.

SUPPORTING MEMBER REPRESENTATIVES - 1987

1. Atomic Energy of Canada Limited
Chalk River Nuclear Laboratories,
Chalk River, Ont. K0J 1J0

Dr. D.K. Myers
Head, Biology Branch

613-584-3311
613-687-5581

Alternate:
D. Champ,
Environmental Research Branch

2. Atomic Energy Control Board,
P.O. Box 1046,
Ottawa, Ontario, K1P 5S9

Dr. H. Stocker,
Chief,
Health Effects and Regulatory Documents Section
Regulatory Research Branch

613-995-2866

Alternate:
Mr. E. Rabin,
Scientific Advisor
Health Effects and Regulatory Documents Section
Regulatory Research Branch

613-995-2981

3. Canadian Institute for Radiation Safety,
7 Timmins Road, 7-15
Elliot Lake, Ont. P5A 2R7

Dr. E. Becker, Senior Scientist

705-848-3687

4. Cigar Lake Mining Corp.,
410 - 224 Fourth Ave, S.
Saskatoon, Sask. S7K 5M5

Mr. M. Senior

306-665-2628

5. Denison Mines Ltd.,
P.O. Box B2600,
Elliot Lake, Ont. P5A 2K2

Mr. J.L. Chakravatti,
Sr. Environmental Engineer

705-461-6250

6. Eldorado Resources Limited,
255 Albert Street,
Ottawa, Ont. K1P 1C1

Dr. A. Ashbrook

613-238-5222

7. Energy, Mines and Resources Canada,
Mining Research Laboratories,
CANMET, E.M.R.,
Elliot Lake Laboratory,
P.O. Box 100, Elliot Lake,
Ontario P5A 2J6

Dr. J. Bigu, Research Scientist 705-848-2236
Project Leader, Radiation, Ventilation & Respirable Dust

8. Environment Canada,
Les Terrasses de la Chaudiere, 23rd Floor,
Ottawa, Ont. K1A 0H4

Dr. E.F. Roots, 819-997-2393
Office of the Science Advisor

Alternate:

Dr. P. Vasudev 819-997-1220

9. Health and Welfare Canada,
Health Protection Branch,
Radiation Protection Bureau,
Brookfield Road,
Ottawa, Ontario K1A 1C1

Dr. G. Kramer 613-954-6668
Dr. M. Limson-Zamora 613-998-9715

10. Northern Environment Directorate,
Terrestrial Environment Branch,
Indian Affairs and Northern Development
Les Terrasses de la Chaudiere,
Ottawa, Ontario K1A 0H4

Dr. M. Barnett, 819-994-7458
Environmental Geologist

11. Key Lake Mining Corporation
410 - 22nd Street E.,
Saskatoon, Sask. S7K 5T6

Mr. L. Price 306-665-7000
Director of Environment

12. Ministry of Labour, Ontario,
400 University Avenue,
Toronto, Ontario M7A 1T7

*Dr. H. Aitken, Chief 416-965-8178
Radiation Protection Service,
Special Studies and Services

*Now with CAIRS

13. Rio Algom Limited
P.O. Box 1500
Elliot Lake, Ontario P5A 2K1

Mr. E. Barnes.
Research Superintendent
Process Development
B. Bihari

705-461-4455

705-461-4457

14. Saskatchewan Environment
Mines Pollution Control Branch
12th Floor, 800 Central Avenue
P.O. Box 3003, Prince Albert,
Saskatchewan S6V 4V1

Mr. C. Potter. Manager
Technical Services Section

306-953-2219

15. Saskatchewan Human Resources, Labour and Employment
Occupational Health and Safety Branch.
1870 Albert Street,
Regina, Saskatchewan S4R 3V7

Dr. L.D. Brown.
Chief Radiation Health Specialist

306-787-4486

16. Saskatchewan Mining Development Corporation,
122 - 3rd Avenue N.,
Saskatoon, Saskatchewan S7K 2H6

Mr. C.H. Burton.
Sr. Scientist, Environmental

306-933-6207

17. United Steelworkers of America
92 Frood Road,
Sudbury, Ontario P3C 4Z4

Mr. H. Seguin,
Regional Representative

705-675-2461

Alternate:

Mr. Ed Vance
20 Alberta Road,
Elliot Lake, Ontario P5A 1Z6

705-848-2226

Mr. T. Stevens
12 - 3311 Fairlight Drive
Saskatoon, Sask. S7M 3Y5

306-382-2122

JOINT PANEL ON OCCUPATIONAL AND ENVIRONMENTAL RESEARCH
FOR URANIUM PRODUCTION IN CANADA

APPENDIX

DATE	STATEMENT OF PROJECT	PROJECT #
------	----------------------	-----------

TITLE	MATRIX LOCATION
-------	-----------------

OBJECTIVE

SCOPE OF WORK	ANTICIPATED COST
---------------	------------------

RESEARCHER(S)	ANTICIPATED COMPLETION DATE
---------------	--------------------------------

SPONSOR(S)	CONTACT
------------	---------

JOINT PANEL ON OCCUPATIONAL AND ENVIRONMENTAL RESEARCH
FOR URANIUM PRODUCTION IN CANADA

DATE	REPORT ON PROJECT PROGRESS	PROJECT #
------	----------------------------	-----------

TITLE	MATRIX LOCATION
-------	-----------------

PROGRESS/STATUS

CHANGES	ANTICIPATED COST
	ANTICIPATED COMPLETION DATED

SPONSOR(S)	CONTACT
------------	---------

DATE	PROJECT COMPLETION REPORT	PROJECT #
------	---------------------------	-----------

TITLE	MATRIX LOCATION

DISPOSITION/STATUS

(Please quote abstract of publication if appropriate)

PUBLICATION AVAILABILITY	FINAL COST
--------------------------	------------

SPONSOR (S)	CONTACT

