

1E200



DOE ORDER #
93 RF 15008

DIST.	LTR	ENC
AMARAL, M.E.		
BENEDETTI, R.L.		
BENJAMIN, A.		
BERMAN, H.S.		
BRANCH, D.B.		
CARNIVAL, G.J.		
COPP, R.D.		
DAVIS, J.G.		
FERRERA, D.W.		
HANNI, B.J.		
HARMAN, L.K.		
HEALY, T.J.		
HEDAHL, T.		
HILBIG, J.G.		
HUTCHINS, N.M.		
KIRBY, W.A.		
KUESTER, A.W.		
MAHAFFEY, J.W.		
MANN, H.P.		
MARX, G.E.		
McDONALD, M.M.		
McKENNA, F.G.		
MONROSE, J.K.		
MORGAN, R.V.		
POTTER, G.L.		
PIZZUTO, V.M.		
RISING, T.L.		
S...IDLIN, N.B.		
SETLOCK, G.H.		
STEWART, D.L.		
SULLIVAN, M.T.		
SWANSON, E.R.		
WILKINSON, R.B.		
WILLIAMS, S. (ORC)		
WILSON, J.M.		
WYANT, R.B.		
BUSBY, W.S.	X	X
LAKE, D.Y.Q.		
<i>C. A. Peterman</i>	X	
<i>G. B. ...</i>	X	
<i>H. F. ...</i>	X	
CORRES. CONTROL	X	X
RECORDS CTR (2)	X	X
ERM TRACKING		
TRAFFIC		

EG&G ROCKY FLATS

EG&G ROCKY FLATS, INC.
ROCKY FLATS PLANT, P.O. BOX 464, GOLDEN, COLORADO 80402-0464 • (303) 966-7000

December 9, 1993

93-RF-15008

Bruce K. Thatcher
Environmental Restoration Division
DOE, RFO

TRANSMITTAL OF THE DOCUMENTS FOR THE INDUSTRIAL AREA ENVIRONMENTAL
EVALUATION (IA EE) – BDP-030-93

Enclosed please find the documents regarding the Industrial Area Environmental Evaluation (IA EE). Included in the package is the Industrial Area Implementation Plan, Industrial Area Environmental Evaluation Field Sampling Plan, Phase I Data Summary, Addendum to the Phase I Data Summary, Phase II Data Summary, Phase III Data Summary, and the Technical Memorandum Industrial Area Environmental Evaluation. Although some of these documents have been previously transmitted, this package covers the entire IA EE.

If there are any further questions regarding this transmittal, please contact me at extension 8659 or Suzanne Berman of my staff at extension 8670.

Bruce D. Peterman
Industrial Area Lead Project Manager
ERM/Remediation Project Management



BDP:tjr

Orig. and 1 cc – B. K. Thatcher

Enclosures:
As Stated

cc:
R. H. Birk – DOE, RFO w/o Encs.
S. R. Grace – " " " "

CLASSIFICATION

UCNI		
UNCLASSIFIED	X	X
CONFIDENTIAL		
SECRET		

AUTHORIZED CLASSIFIER SIGNATURE

DOCUMENT CLASSIFICATION REVIEW WAIVER PER

DATE CLASSIFICATION OFFICE

IN REPLY TO RFP CC NO:

ACTION ITEM STATUS

PARTIAL/OPEN

CLOSED

LTR APPROVALS:

ORIG & TYPIST INITIALS

Bdp TJR-dqr

INDUSTRIAL AREA ENVIRONMENTAL EVALUATION IMPLEMENTATION PLAN

EG&G ROCKY FLATS, INC.
Golden, Colorado

ENVIRONMENTAL MANAGEMENT
OCTOBER 12, 1993

QUALITY



INTEGRITY



CREATIVITY



RESPONSIVENESS

RUST ENVIRONMENT &
INFRASTRUCTURE

Formerly SEC Donohue



TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1.0 INTRODUCTION	1-1
2.0 STAFFING PLAN	2-1
3.0 IMPLEMENTATION SCHEDULE	3-1

LIST OF FIGURES

<u>Figure No.</u>	<u>Title</u>
1	Staffing Plan
2	Implementation Schedule

APPENDIX A - Addendum Technical Proposal
APPENDIX B - Resumes

1.0 INTRODUCTION

RUST Environment & Infrastructure (RUST E&I) was awarded a letter subcontract from EG&G Rocky Flats, Inc. (EG&G) on October 5, 1993. The letter subcontract, ASC 343770NR3, partially authorizes funds to perform the Industrial Area Environmental Evaluation (IAEE). The balance of funding will be authorized no later than November 12, 1993.

The subcontract award was based on an Addendum Technical and Cost Proposal, dated September 9, 1993 responding to a Statement of Work (SOW) dated July, 1993. The Addendum Technical Proposal, contained in Appendix A, proposed a reduced scope which excluded physical sampling of tissues.

This implementation plan has been prepared to provide two deliverables noted in the SOW, consisting of a Staffing Plan and an Implementation Schedule. All RUST E&I Team personnel requiring RAD Worker training have received it.

2.0 STAFFING PLAN

The RUST E&I Team will include the following personnel:

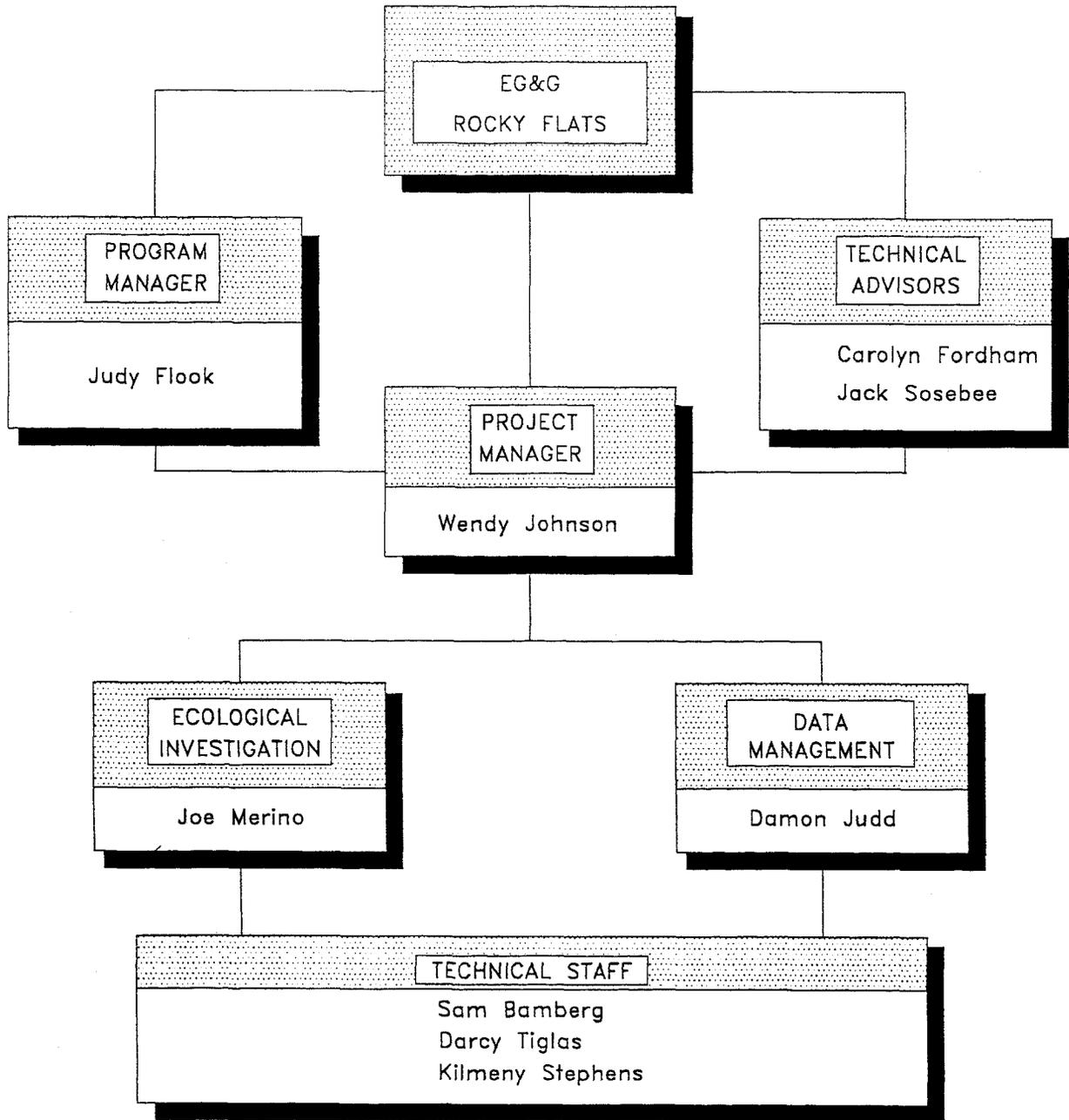
- Program Manager: Judy Flook;
- Project Manager: Wendy Johnson;
- Ecological Investigation Manager: Joe Merino; and
- Data Management Manager: Damon Judd.

Figure 1 illustrates the Project Organization Chart. Appendix B contains resumes of project personnel.

3.0 IMPLEMENTATION SCHEDULE

The Implementation Schedule for the IAEE is shown in Figure 2. The submittal of the final IAEE Technical Memorandum is currently scheduled for March 2, 1994. The Implementation Schedule does not reflect meetings with the Risk Assessment Technical Working Group because the requirement for such meetings no longer exists. The initial Draft Technical Memorandum submittal date of December 15 has been extended to December 22, 1993, with all other related milestones extended by a week, according to agreement on this matter at the kickoff meeting with EG&G personnel on October 6, 1993.

Figure 1
STAFFING PLAN FOR THE
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION



TECHNICAL PROPOSAL

This proposal is submitted by RUST Environment & Infrastructure, Inc. (RUST) to EG&G Rocky Flats, Inc. (EG&G) in response to Request for Proposal 343770 NR3. It describes RUST's approach to the implementation of the Industrial Area (IA) Environmental Evaluation (EE) at the Rocky Flats Plant (RFP).

RUST will use a phased approach, according to "Ecological Assessment of Superfund Sites: An Overview" (EPA 9345.0.051, 1991). RUST will also optimize use of existing RFP data including chemical, ecological, and Contaminant of Concern (COC) data to efficiently narrow and focus the IA EE. Two key elements of the risk assessment are the identification of COCs and the identification of key receptor species. The potential COC list can be rapidly developed by using COC data from other Operable Units (OUs) and comparing it with IA chemical data. The toxicity assessment will be simplified, accordingly.

Potential ecological risk will be assessed in two areas of the IA ecosystem: 1) in the evaluation of indirect risk to key species because of transport of contaminants through the food chain; and 2) in the evaluation of direct risk to species populations, because of contaminant effects on the individuals in the population.

The IA ecosystem is a degraded or man-altered system lacking significant elements of a natural ecosystem characteristic of surroundings RFP areas. Natural systems exist as patches or small inclusions within reclaimed areas. Previous field data suggest that these systems do not support a diverse flora or fauna, and the food chain (and thus the transport pathway) is limited.

RUST is confident that it can efficiently and effectively develop a qualitative estimate of potential ecological risk with limited field work, and maximum use of existing data. Referenced literature will consist primarily of Department of Energy (DOE) and Environmental Protection Agency (EPA) documents.

The specific technical approach and underlying assumptions are detailed in each of the following sections addressing each specific task requirement in Request for Proposal 343770. General assumptions pertaining to all work proposed include the following:

- EG&G will provide all escorts;
- The EG&G Environmental Evaluation field trailer and associated field equipment will be available for use;
- The IA EE will strictly entail a qualitative risk characterization;
- The approach will follow that specified in OU4 TM3 and "Ecological Assessment of Superfund Sites: An Overview", (EPA 9345.0.051, 1991);

- EG&G will supply all historical data and associated documents referenced in the request for proposal;
- The Risk Assessment Technical Working Group (RATWG) meetings will be scheduled once a month;
- Literature searches will be limited to literature that is easily accessible;
- EG&G will provide the Global Positioning System (GPS) equipment for surveying activities;
- EG&G will provide binoculars for use in the protected area; and
- EG&G will provide analytical and data validation support.

The RUST team will include the following subcontractors:

- Terra Technologies*;
- RA Consultants; and
- S.M. Stoller.

Resumes for key personnel are included in Attachment A of the original proposal. Attachment B of the original proposal contains the completed offer information.

1.0 Task 1 - Preliminary Planning

Planning and coordination of the IA EE will consist of several subtasks associated with the comprehensive approach presented in Tasks 2 through 10 below. This planning and coordination will assure the designed approach follows procedures necessary and sufficient to characterize the potential environmental effects to biota under the "no action" scenario.

The first step in the planning process is to develop a staffing plan and schedule of activities. This is a Project Management function, which is a part of this Task 1. The staffing plan identifies technical requirements and available technical staff with their specific assignments and capabilities. The schedule will present activities to be accomplished in the field and office along with an estimated time for completion.

Data Quality Objectives (DQOs) will be prepared to lay the framework for data collection. These objectives will address the types of data needed, data uses and the desired level of certainty associated with conclusions drawn from qualitative data. DQOs also assist in establishing a framework for sample design and analysis programs.

* Listed by the owner, Carolyn Fordhan, in the original proposal

The Field Sampling Plan (FSP) will be prepared following RFP Standard Operating Procedures (SOPs). The FSP is the umbrella plan which outlines the objectives and activities necessary to collect adequate data for the environmental evaluation of the IA. The Sampling and Analysis Plan (SAP) will also be developed to illustrate the flow of data from collection, through reduction and into analysis and interpretation that satisfies DQOs. The general tasks and DQOs will have a goal of providing data to:

- Qualitatively describe the ecological setting of the IA;
- Identify COCs and key species;
- Construct a conceptual site release and transport;
- Determine toxicity effects and exposures from easily accessible literature values and existing data; and
- Summarize assumptions and uncertainties associated with the evaluation and characterization of ecological risk.

Project management in this task will include periodic planning during project execution, and meetings with contractor staff, EG&G staff and RATWG. Project management activities may include project updates, course corrections and deliverables status with contractor staff, performance meetings, field logistical coordination meetings, and Plan of Day meetings with the EG&G Project Team. The RUST team will prepare meeting notes as deliverables where required.

2.0 Task 2 - Data Collection/Evaluation and Conceptual Model Development (Phase I)

Task 2 represents the initial element of Phase I. Phase I consists of problem formulation based on literature and data searches. This task will include a review, evaluation and data summary of available RFP chemical and ecological data pertinent to the IA. Generally, the data are expected to reflect species present, their distribution and habitat requirements, and potential COCs. This data collection will identify data gaps, and assist in the construction of the food web model and preliminary identification of exposure pathways. The selection criteria for COCs will be the lowest tissue concentrations in key species (or their surrogate) that are correlated with adverse affects for the COC in question as obtained from the literature.

COCs identified in this task for RFP will narrow the scope of toxicity assessment to those contaminants which meet the selection criteria and are known to cause harm to biota. Toxicity literature pertaining to COCs will be obtained from EPA data base IRIS available for search at the EPA Region VIII library. This information will be used in the conceptual model development and evaluation, and will support the historical and field data evaluation specific to the IA.

3.0 Task 3 - Ecological Field Investigation (Phase I)

The ecological field investigation, also part of Phase I, will consist of qualitative observations and quantitative assessments of plant and animal populations within the IA areas. Sampling methodologies and procedures will follow those approved in the SOP manual. The purpose of

this investigation is to describe the existing biological system in terms of habitat type and quality, species presence, trophic relationships, potential contaminant sources and contaminant uptake in tissues of key species.

The habitat surveys will be qualitative assessments of type, extent and quality, including plant and animal species present. Particular attention will be given to the potential presence of endangered, threatened or special status species and habitats, and migratory/raptor bird species. Quantitative vegetation sampling will include cover, composition and importance values, and an estimate of productivity for key species. Live trapping of small mammals will be conducted along established transects with Sherman live traps over a 3 to 5 day period. Relative abundance estimates will be calculated from the trapping data. Bird survey data also will be gathered along established transects to record and identify bird species, their numbers and use of the area. Large mammal surveys will include qualitative assessments of presence identified by sign, vocalizations of sightings.

4.0 Task 4 - Toxicity Assessment (Phase II)

Phase II activities consist of toxicity and exposure assessments, Tasks 4 and 5. The objective of the toxicity assessment is to evaluate the COCs identified in Task 2 relative to their potential to cause harm to biota identified as key species. This will be accomplished by review and evaluation of the toxicity data gathered from the literature in Task 2, and the comparison of these data with established criteria indicating potential harm to IA species. The criteria are the lowest tissue concentrations in key species which indicate a potential adverse effect, determined through easily accessible literature. These data will be compared to existing RFP tissue analysis data.

5.0 Task 5 - Exposure Assessment and Pathways Model Development (Phase II)

A site-specific exposure pathways-receptor model will be developed, based on the ecological field survey results to evaluate transport of contaminants to bio-receptors. This model will be a refinement of the food web model produced during Task 2 with data gathered during Task 3 and 4, in that the model will establish pathways from contaminants in the soil and water to the bio-receptors, or key species. The pathways identified and evaluated will be those that are complete, that is, those for which data will support the presence of a source, a release mechanism, a transport mechanism, an exposure route, and an affected ecological receptor. This model will rely on easily accessible literature and existing RFP contaminant-tissue values to estimate potential effects to key species.

Site specific data needs will consist of contaminant concentrations in source materials (soil, water, air), intermediate food chain items (vegetation, prey species) and target species (raptor/predator).

6.0 Task 6 - Preliminary Contamination Characterization (Phase III)

Phase III includes the preliminary contamination characterization and uncertainty analysis, Tasks 6 and 7. Threat or risk to receptor populations and habitats will be based on direct observations in the field, literature data which identifies harm or injury types, and qualitative evaluations linking source concentrations with bio-receptors via bioconcentration, bioaccumulation and biomagnification. Uncertainty analyses will be conducted to address limits of conclusions and data. The magnitude of effects to biota will also be addressed based on available field and literature data.

Ecosystem effects, such as species diversity, productivity, dominance, predator-prey relationships, may be difficult to infer since the IA ecosystem is a man-altered system, and there is a lack of control. However, a qualitative evaluation will be made based on existing RFP ecological data. The ecological significance of the characterization of contamination will be discussed in terms of selected ecosystem and species population parameters.

7.0 Task 7 - Uncertainty Analysis (Phase III)

The uncertainty analysis will address uncertainty in the toxicity and exposure assessment and uncertainty in the risk characterization. With respect to the toxicity assessment, uncertainty develops from qualitative evaluations such as estimating the potential for bio-receptor toxicity, derivation of toxicity values, and estimating the potential for synergistic or antagonistic interactions with other substances. Uncertainty in the exposure assessment is related to the accuracy with which exposure pathways correctly predict receptor contact with contaminated media and corresponding model inputs of contaminant concentrations. Risk characterization uncertainty is influenced by the assumptions regarding exposures and toxicities which are affected by the sampling and analysis programs, and the literature data used in the model.

Uncertainty will be described qualitatively, at a minimum, in terms of over and under estimation of risk.

8.0 Task 8 - Planning of Ecotoxicological Field Investigation (Phase III)

Phase III can also include ecotoxicological investigations. However, because the scope of this IA EE is limited to a qualitative assessment, activities for Task 8 are deferred for future definition. No work will be performed for this task.

9.0 Task 9 - Ecotoxicological Field Investigation (Phase III)

Activities for Task 9 are deferred for future definition for the same reasons as those indicated for Task 8. No work will be performed for this task.

10.0 Task 10 - Environmental Evaluation Technical Memorandum

An EE Technical Memorandum (TM) will be prepared that discusses, evaluates and summarizes all data gathered in the different tasks of this investigation. This will include information and narrative descriptions of site environmental characteristics, contaminant substances, exposure pathways model inputs and results, risk characterization, potential remediation criteria, and uncertainty analyses.

The EE TM will be prepared with RFP guidance EMDPG-21000-GD.02.RO. Data will be organized into the following sections:

- INTRODUCTION (TASK 1)
- PROBLEM FORMULATION (TASK 2)
- SITE DESCRIPTION (TASK 3)
- ANALYSIS AND PRELIMINARY RESULTS (TASKS 4 and 5)
- RISK CHARACTERIZATION (TASK 6)
- UNCERTAINTY ANALYSIS (TASK 7)

This task is limited to a compilation of data collected primarily in tasks 4, 5, 6, and 7. A formal comprehensive report will not be prepared.

11.0 Task 11 - Geographic Information Systems (GIS) Capabilities

All pertinent field data including habitat boundaries and descriptions, locations of animal species, and chemical samples, will be entered into a centralized database which will be managed using RUST's existing Geographic Information System (GIS). The RUST GIS already includes many layers of base map information for the Rocky Flats Plant site as a result of previous site investigations. The GIS that RUST uses is based on ARC/INFO and is identical to the system used by EG&G. Therefore, two-way data transfers from the GIS can be easily provided to accommodate new data layers that are developed as a result of this effort.

Detailed descriptive data regarding species identification, ecological, and chemical sampling results, and other pertinent data can input directly into RUST's database management system which is linked to the GIS. This capability allows the GIS to be used to map various combinations of habitat and species types along with the results of chemical samples. This capability also provides an efficient mechanism for transferring data into the EG&G Rocky Flats Environmental Data System (RFEDS) if desired.

The GIS will also be used to present both the qualitative and quantitative assessments of plant and animal populations within the various OUs. High-quality presentations of the results of field activities and follow-on data evaluation can be easily generated using the capabilities of the GIS. Changes which occur due to additional field sampling and/or integration of data collected for

other OUs can be readily incorporated using the GIS to reflect the most current state of understanding.

The GIS will also be used to assist in the development of the exposure assessment and contaminant pathways modeling effort. The GIS will serve as a data organization and presentation tool for the modeling. Site specific data can be extracted from the GIS, input to the model, and the model results can then be displayed along with other base map information.

12.0 Task 12 - Technical Deliverables and Schedule

The specific deliverables and anticipated schedule are listed in the following sections:

- RATWG meeting minutes will be provided for 5 days of meetings;
- Draft IA EE Report will be submitted on December 15, 1993 (15 copies);
- Final IA EE Report will be submitted on February 18, 1994 (15 copies); and
- Original Field Notes/Books will be provided 30 days after project completion.

RUST ENVIRONMENT & INFRASTRUCTURE

Biographical Data

JUDITH E. FLOOK, CPG
SENIOR GEOLOGIST

EXPERIENCE SUMMARY

Ms. Flook has extensive experience in the investigation and remediation of hazardous and radioactive waste sites under the Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) guidelines. She has conducted numerous investigations and remediations in projects involving complex logistics associated with high security Department of Energy (DOE) mixed waste sites. She has performed extensive data assessment and evaluation activities, geologic mapping, and has designed and developed numerous environmental databases utilizing Geographic Information Systems (GIS). She was also responsible for the design and implementation of an extensive vadose zone investigation at the Rocky Flats Plant.

EXPERIENCE RECORD

1991-Date **RUST Environment & Infrastructure, Division Manager.**
EG&G Rocky Flats, Golden, Colorado: Ms. Flook was responsible as Program Manager for the implementation of the Solar Ponds Phase I RCRA Facility Investigation/Remedial Investigation at the Rocky Flats Plant. The mixed waste project is continuing and entails a multi-year program consisting of radiometric and geophysical surveys, soil sampling, drilling of boreholes and the installation of vadose zone monitoring wells and piezometers. All pre-existing and new field data are being managed and analyzed with the aid of a GIS utilizing ARC INFO software. The project also includes a Baseline Risk Assessment consisting of a Human Health Risk Assessment and an Environmental Evaluation. The majority of the work is being performed inside the high security Protected Area (PA).

EG&G Rocky Flats, Golden, Colorado: Ms. Flook was responsible as

1988-1991 S.M. Stoller Corporation, Technical Director.

EG&G Rocky Flats, Golden, Colorado: Ms. Flook was responsible as Senior Project Manager for site-wide surface water monitoring program (including general technical support for remedial investigations and feasibility studies) at the Rocky Flats Plant. The general support included the design and implementation of the first Surface Water Monitoring Program required by the Interagency Agreement (IAG) between the DOE, the Environmental Protection Agency, and the Colorado Department of Health.

EG&G Rocky Flats, Golden, Colorado: Ms. Flook was responsible as Senior Project Manager for geologic characterization and mapping of the Rocky Flats Plant and the surrounding regions. The mapping project identified new structures in the vicinity of the plant that were later confirmed through subsurface investigations.

EG&G Rocky Flats, Golden, Colorado: Ms. Flook was Senior Project Manager for the preparation of environmental evaluations and the development of standard operating procedures for ecological surveys at the Rocky Flats Plant. She was also responsible for the oversight of field sampling, borehole drilling, and aquifer testing activities. She also served as Senior Project Manager for the design and implementation of environmental database and GIS applications at the Rocky Flats Plant.

Rockwell International, Golden, Colorado. Ms. Flook was responsible for the preparation and analysis of schedules in support of the Draft IAG. Critical Path Analysis and Resource loading scenarios were conducted using computer-based scheduling software ARTEMIS. Results of the scheduling analysis were used as a basis of negotiation of the IAG by DOE.

Rockwell International, Golden, Colorado. Ms. Flook was Senior Project Manager for the preparation of the Rocky Flats fiscal year 1989 and 1990 Five Year Plan for Environmental Restoration. The work involved extensive interaction and coordination with the DOE Rocky Flats

- 1987-1988 Nuclear Assurance Corporation, Hydrogeologist.**
Nuclear Fuels Services, Erwin, Tennessee: Ms. Flook was Site Manager for the characterization of a mixed waste site which entailed the installation of 29 monitoring wells, some of which were located in a high-security PA. The work included the utilization of pressure transducers and remote data-loggers for the continuous monitoring of water levels. Vadose zone monitoring was also performed. The work was conducted as part of a decommissioning program for three surface impoundments.
- 1981-1987 Rocky Mountain Energy, Market Analyst.** Ms. Flook served as Market Analyst specializing in uranium and hazardous waste industries, and providing analytical support to an acquisition task force which resulted in the parent company's purchase of a hazardous waste company.
- 1975-1981 Rocky Mountain Energy, Uranium Geologist.**
Ms. Flook was Project Geologist responsible for the design and implementation of multiple uranium exploration projects in the Western U.S., which included extensive geochemical reconnaissance, geologic mapping, numerous rotary and diamond core drilling programs, and regional basin analyses, for Rocky Mountain Energy.
- 1974-1975 Lucius Pitkin, Inc., Uranium Geologist.**
Ms. Flook served as a Staff Geologist conducting regional uranium resource evaluations. She developed and maintained extensive computer-generated base maps and structure contour maps. She performed extensive field evaluations which included measurement of geologic sections and geochemical sampling of soils, stream sediments, surface water and ground water.
- 1973-1974 Leonard Rice Consulting Water Engineers, Hydrologist.**
Ms. Flook performed groundwater resource evaluations and water rights investigations in Colorado. She participated in pump tests and report preparation. She also assisted in surface water runoff modeling and flood plain analysis.

EDUCATION

M.B.A., Business Administration, University of Phoenix, 1986
B.A., Geology, The Colorado College, 1973

Judith E. Flook, CPG
Senior Geologist
Page 4

PROFESSIONAL AFFILIATIONS/REGISTRATIONS

American Institute of Professional Geologists
National Ground Water Association
Colorado Ground Water Association
Computer Oriented Geological Society
Certified Professional Geologist, No. 7601
Registered Professional Geologist, State of Tennessee, No. 0654
Active DOE Q Clearance

SPECIAL TRAINING

OSHA 40 hour Health & Safety Training (annually renewed)
OSHA 8 hour Supervisor Training
EG&G Rocky Flats General Employee Training, 1992
EG&G Rocky Flats 8 hour Radiation Worker Training, 1992
American Heart Association CPR/First Aid certified
Vadose Zone Monitoring at Hazardous Waste Sites, Vadose Zone Research Laboratory,
1992

RUST ENVIRONMENT & INFRASTRUCTURE

Biographical Data

JACKSON B. SOSEBEE, JR.
SENIOR CONSULTANT

EXPERIENCE SUMMARY

Mr. Sosebee has experience directing, managing, and conducting projects involving radioactive and hazardous waste, environmental chemistry, water quality, geology, chemical analysis, quality assurance/quality control, data management, and statistics. He has extensive experience in project planning under the requirements of RCRA, CERCLA, and relevant DOE orders.

EXPERIENCE RECORD

1988-Date RUST Environment & Infrastructure, Senior Project Manager.
EG&G Rocky Flats, Golden, Colorado: Mr. Sosebee is serving as Task Manager, Data Evaluation for Phase I RFI/RI investigation of the Solar Evaporation Ponds (OU4) for EG&G Rocky Flats. Included in the program are radiometric surveys, surficial soil surveys of chemical contamination, vadose zone monitoring, and geophysical surveys. Mr. Sosebee is responsible for Geographic Information System (GIS) applications, data management, and quality assurance/quality control.

EG&G Rocky Flats Plant, Golden, Colorado: Mr. Sosebee served as a Project Scientist in the preparation of a RFI/RI workplan for the 400/800 Building Area (Operable Unit 12) at the Rocky Flats Plant in Golden, Colorado for EG&G Rocky Flats. He conducted statistical analyses of existing soil contamination data and assisted with portions of the plan related to data quality objectives, quality assurance/quality control, and statistics.

John Hancock Mutual Life, Ranch Property, Colorado: Mr. Sosebee was Project Director for an environmental assessment of leaking underground storage tanks at a property southeast of Colorado Springs owned by John Hancock Mutual Life Insurance Co. The project determined the nature, extent, and source of petroleum hydrocarbon contaminants in ground water and the contaminants' potential impacts on a nearby stream and reservoir. Oversight of tank testing, closure, and replacement of the tanks was also provided.

National Renewable Energy Laboratory, Colorado: Mr. Sosebee directed

Jackson B. Sosebee, Jr.
Senior Consultant
Page 2

this ground water monitoring program for the U.S. Department of Energy. Activities included installation and development of eight monitoring wells, preparation of field and laboratory QA plans, collection of samples for analysis of organic and inorganic parameters, statistical analyses of data, and preparation of annual reports.

Hamilton Army Airfield, California: Mr. Sosebee served as Technical Director for an environmental investigation and alternatives assessment of Hamilton Army Airfield in Novato, California for the U.S. Army Toxic and Hazardous Materials Agency. The project evaluated the extent to which past activities at the airport may have adversely affected surface water and ground water quality. The project involved installation of monitoring wells; collection and analysis of soil, sediment, surface water, and ground water samples; and hydraulic tests.

Grand Fork and Minot Air Force Bases, North Dakota: Mr. Sosebee managed environmental assessments at Grand Forks Air Force Base and Minot Air Force Base in North Dakota for the U.S. Air Force. These Phase I investigations were conducted as part of the U.S. Air Force Installation Restoration Program and evaluated the potential for past and present base activities to adversely affect water quality in streams, lakes, and ground water at and adjacent to the base. The U.S. Air Force Hazard Assessment Rating Methodology was used to assess the potential for off-site migration of contaminants.

Odessa Chromium Superfund Sites, Odessa, Texas: Mr. Sosebee served as Project Scientist for an evaluation of chromium contamination in soil and ground water at two Superfund sites in Texas for Sequa Corporation. The project included review of the remedial investigation report and related documents, evaluation of RODs at other Superfund sites where alternative water supplies were selected as the preferred remedy, review of costs incurred during the remedial investigation/feasibility study, design of a well sampling program to investigate vertical stratification of chromium in the aquifer, and calculation of the amount of chromium in the aquifer.

Jackson B. Sosebee, Jr.
Senior Consultant
Page 3

1974-1988 Environmental Science and Engineering, Inc., Vice President.

Rocky Mountain Arsenal, Commerce City, Colorado: As Program Manager, Mr. Sosebee had overall responsibility for all aspects of this remedial investigation/feasibility study conducted for the U.S. Army. Project objectives included determination of the nature and extent of contamination in ground water, streams, lakes, sediments, and soil; evaluation of alternative remedial actions; and providing technical support to the U.S. Department of Justice. The ground water program included installation of over 60 monitoring wells, analysis of 1,200 ground water samples, and measurement of water levels in 800 wells. The soil program involved drilling and sampling and analysis of samples from over 2,000 sites.

U.S. Army Depot Activities, Arizona and New Mexico: Mr. Sosebee managed environmental assessments of Ft. Wingate Depot Activity, New Mexico and Navajo Depot Activity, Arizona for the U.S. Army Toxic and Hazardous Materials Agency. Contaminants in ground water, streams, lakes, sediments, and soils were characterized, and the potential for contaminant migration was determined. The studies were a Phase II component of the U.S. Army Installation Restoration Program.

Rocky Mountain Arsenal, Commerce City, Colorado: Mr. Sosebee managed a contamination assessment of areas adjacent to Rocky Mountain Arsenal, Colorado for the U.S. Army Toxic and Hazardous Materials Agency. The project determined ground water quality, identified areas of significant public exposure related to consumption of contaminated ground water, and established a permanent ground and surface water quality monitoring network. Plume boundaries were identified, and hydrogeologic properties of the study area were determined.

EDUCATION

M.S., Environmental Studies, University of Montana, 1974
B.A., Geology, University of Colorado at Denver, 1988
B.S., Chemistry, Texas Tech University, 1969

Jackson B. Sosebee, Jr.
Senior Consultant
Page 4

PROFESSIONAL AFFILIATIONS AND REGISTRATIONS

Certified Professional Geologist, No. 7631
Certified Ground Water Professional, No. 317
Registered Professional Geologist, State of Wyoming, No. PG - 2358
American Chemical Society
National Ground Water Association
Colorado Ground Water Association
Computer Oriented Geological Society
American Institute of Professional Geologists

PUBLICATIONS AND PRESENTATIONS

Mr. Sosebee has presented and published 14 papers regarding hazardous waste, water quality, air quality, environmental chemistry, soil contamination, quality control, computers, and biological systems.

SPECIAL TRAINING

OSHA 40 hour Health & Safety Training (annually renewed)
OSHA 8 hour Supervisor Training, 1992
EG&G Rocky Flats General Employee Training, 1992
EG&G Rocky Flats 8 hour Radiation Worker Training, 1992

RUST ENVIRONMENT & INFRASTRUCTURE

Biographical Data

JOSE-MARIA MERINO, PH.D.
Senior Scientist

EXPERIENCE SUMMARY

Dr. Merino has over 20 years experience in environmental consulting including program design, data collection and analysis, report preparation, project management and regulatory review and permit preparation. This experience has been gained by conducting projects for the Department of Energy, Department of Defense, Environmental Protection Agency, Bureau of Land Management, and various state and private industry clients. Representative expertise offered by Dr. Merino includes ecological field study design and statistical evaluation, threatened and endangered species surveys, Biological Assessments, Environmental Assessments and Environmental Impact Statements, reclamation and restoration of disturbed lands, RCRA/CERCLA investigations and ecological risk assessments.

EXPERIENCE RECORD

1989 - Date RUST Environment & Infrastructure, Senior Ecologist.

Dr. Merino is a senior ecologist and provides program design and management to a variety of environmental projects within the Rocky Mountain area and the western states. In this capacity Dr. Merino has participated in the following projects: OU4 ecological risk assessment planning at the Rocky Flats Plant; preparation of RFA/RFI documents and ecological risk assessments for the Tooele Munitions Depot; design and conduct of the ecological risk assessment at the Midvale Slag Superfund site; and in the development of a Biodiversity Management Guideline for Chemical Waste Management Inc. for use on a national level.

1989 - Date Engineering-Environmental Management, Inc., Senior Ecologist.

Dr. Merino provides ecological program design and management to ecological risk assessments, and management for NEPA compliance and RCRA/CERCLA projects. Dr. Merino has conducted ecological risk assessments in California, Utah and Louisiana. He has also conducted threatened and endangered species surveys for over 75 species in the states of California, Utah, Arizona, Colorado, Wyoming, South Dakota and Ohio; and prepared 10 EAs/EISs throughout the western United States. Dr. Merino was also involved in the initial planning and preparation of work plans and field sampling plans for environmental evaluations at the Rocky Flats Plant for Woman Creek, Other Process Waste Lines and Walnut Creek.

1988 - 1989 Salazar Associates, International, Inc., Senior Scientist and Vice President.

As a Vice President Dr. Merino directed the daily activities of the environmental staff in the conduct of EAs, site assessments, and various engineering projects. He also provided direction to business development, contract negotiation and general technical administration.

1986 - 1988 Advanced Sciences, Inc., Office Manager and Senior Scientist.

Dr. Merino provided office administration, business development, project management and program design to a variety of company activities. Projects conducted at DOE facilities in which Dr. Merino participated are briefly described below:

Rocky Flats Plant, Golden, Colorado: Dr. Merino participated in the preparation of a conceptual plan for cut-off trench and monitoring at the old sanitary landfill. He also was the project manager for the preparation of work plans for the low priority solid waste management units.

Feed Materials Production Center, Fernald, Ohio: Dr. Merino functioned as program manager for the site wide RI/FS at this facility. He directed the preparation of work plans, field sampling plans, and all other documents necessary for EPA approvals to commence the field work. In addition, Dr. Merino designed the initial ecological studies to characterize and evaluate risk to plant and animal species from releases of contaminants from the FMPC. Dr. Merino also participated in EAs to satisfy NEPA requirements related to CERCLA actions.

Sandia National Laboratories, Albuquerque, New Mexico: Dr. Merino was the project manager for the preparation of an environmental assessment for the construction and operation of the Strategic Defenses Facility.

Nevada Test Site, Mercury, Nevada: As a graduate student, Dr. Merino participated in a multi-year study to describe ecosystems of the Nevada Test Site. In this capacity, Dr. Merino conducted studies in various vegetation communities to describe parasite-host relationship, plant-host relationships, and small mammal and reptile populations.

1983 - 1986 In-Situ, Inc., Environmental Project Manager.

Dr. Merino designed and conducted environmental and ecological studies for private industry clients in precious metal mining, coal and oil shale. Project types included EISs, mined land reclamation permit documents, aquatic resource studies, threatened and endangered species surveys and resource management plans. These projects were conducted mainly in Utah, Colorado and Wyoming. Program design and statistical evaluations were a major component of ecological studies.

JOSE-MARIA MERINO, PH.D
SENIOR SCIENTIST
PAGE 3

1982 - 1983 Woodward-Clyde Consultants, Vice President, Office Manager and
and Senior Scientist.
1972 - 1976 Dr. Merino designed and managed a variety of ecological studies in
freshwater, amrine and terrestrial ecosystems in the preparation of EISs,
EAs, technical reports and baseline monitoring studies for clients in
mining, energy and power distribution throughout the western and Rocky
Mountain states. In this capacity Dr. Merino conducted studies for big
game, small mammals, predators, game fish and vegetation for most major
western ecosystems.

EDUCATION

Ph.D. Ecology, University of California, Riverside and San Diego State University, 1981.
M.S. Brigham Young University, 1967.
Ph.D. Brigham Young University, 1961.

PROFESSIONAL AFFILIATIONS AND REGISTRATIONS

Ecological Society of America
American Association for the Advancement of Science
National Association of Hispanic Engineers

SPECIAL TRAINING

OSHA 40 hour Health & Safety Training (annually renewed)
OSHA 8 hour Supervisor Training
EG&G Rocky Flats General Employee Training, 1993
EG&G Rocky Flats 8 hour Radiation Worker Training, 1993

RUST ENVIRONMENT & INFRASTRUCTURE

Biographical Data

DAMON D. JUDD
SENIOR SCIENTIST

EXPERIENCE SUMMARY

Mr. Judd has over 11 years experience in the development and application of digital spatial analysis techniques to environmental problems including mineral exploration, vegetation and soils analyses, hydrologic and geologic conceptualization and modeling, and hazardous/mixed waste investigations. He has worked with numerous hardware and software systems in support of remote sensing, geographic information systems (GIS), and database management applications.

EXPERIENCE RECORD

1993-Date **RUST Environment & Infrastructure, Manager, Computer Applications.**
EG&G Rocky Flats, Inc., Golden, Colorado: Mr. Judd is developing GIS capabilities for a multi-year RCRA Facility Investigation/Remedial Investigation (RFI/RI) at the Solar Evaporation Ponds Operable Unit 4. He is utilizing ARC/INFO and ORACLE software on a Sun Sparc 10, Model 20 Workstation to manage and analyze data collected during the RFI/RI which will be used for the preparation of a Baseline Risk Assessment.

1991-1993 **Environmental Systems Research Institute, Inc., Technical Specialist.**
Mr. Judd developed a menu-driven application for a GIS-based street classification system for long-range planning purposes for the City of Phoenix.

National Park Service, Lakewood, Colorado: Mr. Judd assisted in GIS data conversion, needs analysis, and system implementation for the Rocky Mountain region.

DOE National Renewable Energy Laboratory, Golden, Colorado: Mr. Judd developed a demonstration of the combined use of remote sensing and GIS techniques for evaluating potential wind energy sites in New York.

Confidential Client, Denver, Colorado: Mr. Judd developed a custom GIS demonstration for cable television and telecommunication related purposes.

Damon D. Judd
Senior Scientist
Page 2

1988-1991

Morrison Knudsen Corporation, Project Scientist.

DOE, Weldon Spring Site, St. Louis Missouri: As Project Database Manager, Mr. Judd was responsible for the design and implementation of an integrated information system to support GIS, database, and engineering design applications.

Rocky Mountain Arsenal, Denver, Colorado, Senior Analyst: Mr. Judd applied GIS and database management techniques to assist in the ongoing RI/FS effort.

Confidential Client, Boise, Idaho: Mr. Judd developed a viewshed analysis of a proposed open-pit mine site in southwest Idaho using GIS techniques.

1986-1988

Boise Cascade Corporation, Programmer/Analyst.

Mr. Judd assisted in conversion to an automated timber resource information system. Also developed specialized software for forestry applications.

1985-1986

Idaho Department of Water Resources, Analyst.

Idaho Water Rights, Boise, Idaho: Mr. Judd participated in a state-wide effort to adjudicate water rights based on the acreage of irrigated croplands as determined from digital satellite imagery and other data sources.

EDUCATION

B.A., Geography, University of California at Santa Barbara, Santa Barbara, California, 1981.

PROFESSIONAL AFFILIATIONS/REGISTRATIONS

American Society of Photogrammetry and Remote Sensing (ASPRS)
American Congress on Surveying and Mapping (ACSM)
Urban and Regional Information Systems Association (URISA)

SPECIAL TRAINING

Total Quality Management, 1991
DOE Environmental Regulations, 1991

Damon D. Judd
Senior Scientist
Page 3

PUBLICATIONS

- Judd, D.D., "Down to Earth", a monthly technical column in *Earth Observation Magazine*.
- Judd, D. D., K. Johnson, and A. Haak October 14-15, 1992. "A Comparison of GIS-based Methods for Estimating the Volume of Contaminated Soils", GIS in the Rockies, Golden, Colorado.
- Judd, D.D. Sept. 20-23, 1992. "Integrated Management and Analysis of Tourism-Related Resources", 1992 World Congress on Adventure Travel and Eco-Tourism, Whistler Resort, British, Columbia.
- Judd, D.D. March 5, 1992. "Environmental Mapping and Data Analysis using a Geographic Information System", Tenth High Altitude Revegetation Workshop, Fort Collins, Colorado.
- Johnson, D. Judd, and D. Bott May 20-24, 1991. "A Tightly Coupled GIS and Data Base System for Hazardous Waste Site Information Management", Eleventh Annual ESRI Users Conference, Palm Springs, California.
- Judd, D.D. and K. Johnson May 14-18, 1990. "ARC/INFO - An Integral component of a Hazardous Waste Information System", Tenth Annual ESRI Conference, Palm Springs, California.
- Hardy, R.J., D.D. Judd, and R.L. Graw May 1-4, 1990. "Temperature-Corrected Dispersion Modeling of Volatile Emissions from Hazardous Waste Sites", 1990 EPA/Air and Waste Management Association International Symposium on Measurement of Toxic and Related Air Pollutants, Research Triangle Park, North Carolina.
- Judd, D.D. January, 1986. "Processing Techniques for the Production of an Experimental Computer Generated Shaded-Relief Map", *The American Cartographer*, V. 13, No. 1.
- Quirk B., L. Kalman, D. Judd, M. Richards, J. Feuquay 1985. "Selected Annotated Bibliographies for Image Mapping; Geometric Registration, Resampling, Contrast Enhancement, Spatial Filtering, and Color Calibration", USGS Open File Report 85-51.

RUST ENVIRONMENT & INFRASTRUCTURE

Biographical Data

**WENDY M. JOHNSON, CIH
SCIENTIST I**

EXPERIENCE SUMMARY

Ms. Johnson has expertise in the development and administration of environmental health and safety programs. This has included the recognition, evaluation, and control of chemical, physical, ergonomic, biological and radiological hazards at hazardous and mixed waste sites. She has extensive experience providing health and safety and risk assessment support on environmental programs at the Department of Energy (DOE) and Department of Defense (DOD) sites.

EXPERIENCE RECORD

1993-Date **RUST Environment & Infrastructure, Manager, Life Sciences.**
EG&G Rocky Flats, Golden, Colorado: Ms. Johnson is currently coordinating the Baseline Risk Assessment effort for the Operable Unit 4 Solar Ponds Phase I RFI/RI. This Baseline Risk Assessment consists of a human health risk assessment and an environmental evaluation. The human health risk assessment is evaluating risks for onsite and offsite receptors under current and future land use conditions. The environmental evaluation is an ecotoxicological investigation to determine the potential impacts to onsite biota and for contaminant dispersal via biotic activities from soils within the study area.

EG&G Rocky Flats, Golden, Colorado: Ms. Johnson is currently providing technical support and oversight to the Site Safety Officer (SSO) and Health and Safety Specialists (HSSs) for the Operable Unit 4 Solar Ponds Phase I RFI/RI. This involves ensuring the implementation of the Health and Safety Plan (HASP) during field activities in the radiological control areas and the buffer zone. This RFI/RI is performed pursuant to an Interagency Agreement among the DOE, EPA, and CDH. As required by this agreement, the purpose of this project is to characterize source materials and soils at the Solar Ponds.

1991-1993 NFT, Incorporated, Project Scientist.

DOE Rocky Flats Office, Golden, Colorado: Ms. Johnson conducted a waste minimization study as part of an effort to reduce the solid waste disposed in the Rocky Flats landfill. The objective of the study was to reduce the solid waste generated by the Rocky Flats Plant. This study involved an inventory and evaluation of the solid waste generated on plantsite.

DOE Rocky Flats Office, Golden, Colorado: Ms. Johnson participated in a compliance audit of the DOE Orders. This audit examined the DOE at Rocky Flats Plant and their compliance orders from headquarters. This project involved examination of all area of occupational health, industrial safety, and radiological health.

Westinghouse Hanford, Richland, Washington: Ms. Johnson assisted in an inventory and evaluation of the Treatment Storage and Disposal Facilities on plantsite. This project was a characterization of the mixed and hazardous waste that had been produced at Hanford and an identification of the waste codes associated with the waste as it related to RCRA, NRC, and DOE Orders.

Mason Hanger Pantex Plant, Amarillo, Texas: Ms. Johnson participated in an inventory of the defense weapons ready for disassembly. This project involved the identification of each individual part of the weapon and the classification the waste code associated the part contamination.

1986-1991 EBASCO Environmental, Project Scientist.

EG&G Rocky Flats, Golden, Colorado: Ms. Johnson served as the SSO during the remedial investigation of Operable Unit 1 881 Hillside RI. Her major responsibilities were preparation and implementation of the HASP. She also ensured the proper levels of protection associated with the hazards of mixed and hazardous waste contamination. She was also responsible for maintenance of the logbooks, files and other miscellaneous documentation pertaining to health and safety field operations. Other responsibilities included air monitoring, industrial hygiene surveys, employee exposure tracking, and employee training.

EG&G Rocky Flats, Golden, Colorado: Ms. Johnson served as a HSS during the Phase I Geological Characterization. This project involved preparation of the HASP, technical support to the field crews, and employee radiation exposure tracking.

Westinghouse Hanford, Richland, Washington: Ms. Johnson participated as part of a team that was responsible for the recognition and evaluation of chemical, physical, ergonomic, and biological hazards at several of the tank farms on the Hanford Plant. This project included area industrial hygiene surveys, air monitoring and sample result evaluation.

U.S. Army Rocky Mountain Arsenal, Denver, Colorado: Ms. Johnson assisted in the preparation of the risk assessments required for several of the interim response actions. The purpose of these risk assessments were to identify the risks to the onsite and offsite receptors during the construction of the interim response actions.

U.S. Army Rocky Mountain Arsenal, Denver, Colorado: Ms. Johnson served as the site health and safety supervisor for the remedial investigation. She was responsible for the HASP preparation and implementation. She also participated in the monitoring and control of hazards associated with military chemical agents, asbestos, solvents, heavy metals, and pesticides. She provided oversight to field crews working in levels of protection B, C, and D.

U.S. Army Rocky Mountain Arsenal, Denver, Colorado: Ms. Johnson served as a health and safety officer for the Basin F Interim Response. She was responsible for the implementation of the HASP which including extensive environmental monitoring. All the work during this project was performed in levels of protection B and C.

U.S. Army Rocky Mountain Arsenal, Denver, Colorado: Ms. Johnson conducted an asbestos survey of several of the buildings at the Arsenal that were identified for demolition. She was responsible for the asbestos identification, air monitoring, bulk sampling, sample preparation, sample evaluation, and report preparation.

EDUCATION

M.S., Mine Health and Safety, Colorado School of Mines, In Progress

B.S., Environmental Health, Minor - Chemistry, Colorado State University, 1984

Wendy M. Johnson, CIH
Scientist I
Page 4

PROFESSIONAL AFFILIATIONS/REGISTRATIONS

U.S. Department of Energy "Q" Clearance
American Industrial Hygiene Association (National and Rocky Mountain Section)
Colorado Hazardous waste Management Society
Society of Risk Assessors
Certified Industrial Hygienist, No. 5152
Certified Safety Professional, No. 11013

SPECIAL TRAINING

EG&G Rocky Flats Plant Radiation Worker Training, 1991
EG&G Rocky Flats Plant General Employee Training, 1992
EG&G Rocky Flats Plant RCRA Training, 1992
AHERA Inspector/Manager, 1988; Annual updates 1989-1991
OSHA 8 hour Hazardous Waste Supervisors Training, 1989
OSHA 40 hour Health & Safety Training (annually renewed)

**RA CONSULTANTS
PRESIDENT**

Biographical Data

**SAMUEL A. BAMBERG, PH.D.
ECOLOGIST**

EXPERIENCE SUMMARY

Dr. Bamberg is a biologist and ecologist with 21 years experience in environmental consulting related to resource development. He has worked in environmental studies and permitting for all types of resource utilization including mining for metals, uranium, and industrial minerals; and in development for industrial, commercial, and residential sites; has specialized in biological resource evaluation and reclamation in extreme and arid environments. Recently he has conducted risk assessment studies on human health and ecological consequences at hazardous waste sites (under CERCLA) and from mining and smelting activities. He has been an expert witness at public hearings, and provided information in court proceedings.

EXPERIENCE RECORD

1983-Date President, RA Consultants, Denver, CO.

Formed a firm that conducts environmental and ecological assessment studies for resource developments, mining projects and waste containment systems: permitting, reclamation and construction management for development and mining projects. Recently has conducted risk assessment studies on human health and ecological consequences from hazardous waste sites and mining. Recent projects include:

- Prepared environmental evaluation work plans for five operable units and implementation at OU3 and OU4 at the Rocky Flats Plant.
- Performed a risk assessment for proposed gold mine of the hazards on the site, the potential for component failure or release of contaminants and exposure, and possible adverse consequences on the environment.
- Prepared a report of the risks to human health from drinking ground water contaminated from previous mining and smelting activity in a Superfund site in a mountain environment.
- Performed a risk assessment for the closure of a metals refinery to determine the quantitative probabilistic risk that a failure would occur in the containment systems proposed for stored wastes. The techniques for the probabilistic risk analysis involved coupling the failure mode analysis with the likelihood that the wastes would enter an environmental pathway and cause some consequence to adjacent aquatic ecosystems or a population at risk.
- Determined the health risks to a human population at risk from the release of heavy metals and radionuclides from an operating uranium mill.

Samuel A. Bamberg, Ph.D.

Ecologist

Page 2

- Performed a human health risk analysis for the closure and proposed remedial actions of a large and longtime operating uranium mill. The risk analysis was a qualitative comparative analysis of the health risks involved if various remedial actions were taken on tailings wastes piles, and other chemical and radioactive wastes stored or disposed of onsite. The risk analysis estimated health risks during the remedial action construction, cleanup and reclamation phase, and in the near term and longterm periods following closure.
- Conducted a vegetation analysis and mapping for a large 25 square mile proposed coal mine in North Dakota.
- Completed a vegetation and land use resource maps for a 70 square mile Superfund site in the southern Deerlodge Valley in Montana using GIS.
- Mapped vegetation and wetland along two proposed powerline corridors in North Dakota and Montana.
- Conducted biological and vegetation resource evaluation and mapping for mining projects in Colorado, Utah, Arizona, Nevada, California, New York and South Carolina.
- Conducted vegetation and wetland resource evaluation and mapping for a National Wildlife refuge in North Dakota; and six master drainage studies along the Front Range in Colorado.

1980-1982 Manager and Project Coordinator for Health, Safety, and Environment, Mine Development, Anaconda Minerals Co., Denver, CO.

Managed mine development projects for health and environmental aspects for base metals and industrial minerals. Scoped full programs for baseline and related engineering studies, hired contractors and supervised work, meet with state and federal regulatory agencies, and prepared permit applications.

1978-1980 Environmental Coordinator, Urangesellschaft USA Inc., Denver, CO.

Obtained permits and licenses for uranium mining and exploration; conducted siting and radiological studies for uranium tailings disposal.

1977-1978 Senior Ecologist, Stone and Webster Engineering Corp., Denver, CO.

Managed and coordinated environmental programs to assess impacts for conventional and nuclear power plants, energy development and mining of coal and uranium.

1974-1977 Program Manager, EG&G Environmental Consultants, Inc., Denver, CO.

Managed environmental studies for mining projects, chemical facilities and power plants. Assessed radiological effects of a proposed nuclear-excavated canal in a desert climate.

Samuel A. Bamberg, Ph.D.

Ecologist

Page 3

- 1970-1974** **Research Coordinator, Laboratory of Nuclear Medicine and Radiation Biology, UCLA: Civil Effects Test Operations, Nevada Test Site, Mercury, NV.** Conducted and coordinated biological studies in a desert ecosystem, and determined the effects of chronic gamma and fallout radiation on plant populations. Member of Executive Board for Desert Biome, US/IBP Analysis of Ecosystem. Editorial review for ecological publications and proposals.
- 1970-1972** **Partner, Ecoview, Walnut Creek, CA.** Founding partner of environmental consulting firm. Conducted studies for developments in Lake Tahoe Basin, flood control projects in Walnut Creek Basin, California, and effects of geothermal development.
- 1965-1970** **Research Associate, Desert Research Institute, University of Nevada, Reno.**
Conducted research on desert ecosystems in Nevada and California.

EDUCATION

Ph.D., Ecology, Soils, University of California, Davis, CA, 1964
M.A., Ecology, University of Colorado, Boulder, CO, 1961
B.A., Biology, Geology, University of Tennessee, Knoxville, TN, 1955

PROFESSIONAL AFFILIATIONS

Society for Risk Analysis
Colorado Hazardous Waste Management Society
Society of Wetland Scientists
Society for Ecological Restoration

SPECIAL TRAINING/CERTIFICATIONS

OSHA 40 hour Hazardous Waste Handling (grandfathered)
OSHA 8 hour Hazardous Waste Refresher Course
EG&G Rocky Flats General Employee Training, 1992
EG&G Rocky Flats 8 hour Radiation Worker Training, 1992

CAROLYN L. FORDHAM, M.S.
Toxicologist

SPECIALIZATION

Toxicology, Human Health Risk Assessment, Ecological Risk Assessment

RECENT EXPERIENCE

Rocky Mountain Arsenal; Colorado; Technical Expert - Providing input for the ongoing Ecological Risk Characterization at Rocky Mountain Arsenal. Offer toxicological support, modeling advice, and review documents. Evaluate positions and scientific defensibility of options presented by client and other parties.

Cornhusker Army Ammunition Plant; Nebraska; Technical Expert - Currently providing technical assistance for the CAAP site in Nebraska. Led a field team that evaluated potential human health receptors and exposure pathways, and evaluated habitat and potential ecological receptors. Will provide input and comments to the human health and ecological risk assessment for this site.

Lowry Landfill; Colorado; Technical Expert - Served as a technical expert for the citizens living near the Lowry Landfill. Reviewed and commented on EPA's human health risk assessment. Interpreted guidance and risk assessment results in layman's terms for the citizens. Attended public meeting to discuss the content of the risk assessment and potential health impacts.

Confidential Client; Colorado; Ecological Risk Assessment Manager - Currently writing a risk assessment for a large mining site. Groundwater, surface water, sediment and soil are the media of concern. Wetlands and uplands are being evaluated. Risk to aquatic as well as terrestrial biota will be determined.

Endangered Species Survey; Midwest Region; Ecologist - Conducted an endangered species survey for the U.S. Fish and Wildlife Service for a species of small mammal. Field techniques included habitat identification, vegetation transects, and live trapping of small mammals.

Rocky Mountain Arsenal Offpost Operable Unit; Colorado; Risk Assessment Manager - Performed the ecological risk assessment for the Offpost Operable Unit. Risk assessment activities included evaluation of aquatic and terrestrial ecosystems, evaluation of risk to domestic livestock and crops, and protection of federally protected wildlife species.

Human Health Risk Assessment; Colorado; Risk Assessment Manager - Provided risk assessment services and technical support for a RCRA Facilities Investigation at an oil refinery. Risk assessment services included assistance with work plans and design of site exposure models. In addition, advice regarding soil sampling study design and statistical interpretation of historic data were provided.

Environmental Protection Agency; Washington, D.C.; Technical Expert - Served on Ecological Risk Assessment Forum in Washington, D.C. to help the EPA develop guidelines for Environmental Risks. Primary author on risk assessment case study to be included as part of the guidelines.

CAROLYN L. FORDHAM, M.S.

Page 2

Louisiana Army Ammunition Plant; Louisiana; Risk Assessment Manager - Directed human health and ecological risk assessment focused on contamination by Army munitions compounds. Seven separate areas on the site were considered. Fate and transport in groundwater, surface water, and soil were modeled.

Tobayanna Army Depot; Pennsylvania; Ecologist - Performed wetlands delineation in areas downgradient of site. Identification of wetlands was based on soil characteristics as well as species of vegetation.

Phillips Petroleum; Puerto Rico; Risk Assessment Manager - Conducted exposure pathway and receptor identification at an oil refinery according to current RCRA regulations. Both human and ecological receptors were evaluated.

Camp LeJeune Marine Corps Base; North Carolina; Risk Assessment Manager - Directed human health and ecological risk assessment focused on contamination by solvents and heavy metals. Three separate areas on the site were considered: one heavy industrial site, one mercury dump site, and one chemical disposal site. Human health and ecological risks were modeled.

Confidential Client; California; Risk Assessment Manager - Conducted human health evaluation as litigation support for a benzene spill. Evaluated benzene exposure resulting from volatilization from soil and groundwater contamination. Volatilization from the abiotic source media was predicted with fate and transport modeling. Risk to human health was determined according to EPA and California risk assessment guidelines.

Eagle River Flats; Alaska; Environmental Toxicologist - Assisted in design of multidisciplinary investigation to define unknown cause of waterfowl mortality. Tasks included conducting avian onsite and laboratory bioassays to identify etiology of disease, exposure route, and source of unknown toxicant. In addition, conducted sampling for bacterial culture, alga toxins, tissue analysis, and histopathology. Performed gross necropsies on wild waterfowl and bioassay birds. Initiated QA/QC program.

Rocky Mountain Arsenal; Colorado; Environmental Toxicologist - Performed endangerment, toxicity, and exposure assessments for human and nonhuman exposed populations according to EPA methodology. Determined hazard assessment for biota based on toxicological and ecological data. Duties included addressing risk of toxic effects of various contaminants to wildlife populations, tracing pathways of contaminants through diverse ecosystems, definition of persistence and fate of contaminants in biological systems, identification of routes of exposure to various biological receptors, and establishing sediment, soil, and water criteria for protection of biota. Coauthored biota remediation/investigation report.

USAF Plant 78; Utah; Risk Assessment Manager - Performed human health and ecological risk assessment for a Stage 2 contamination investigation at a R&D manufacturing facility for rocket propellants under the U.S. Air Force Installation Restoration program. Estimated contaminant exposure of human and non-human populations. Also designed aquatic sampling program to estimate adverse impacts on aquatic biota downstream of site.

Standard Oil Company; Alaska; Project Toxicologist - Performed bioaccumulation study of organic and heavy metal contamination, Prudhoe Bay, Alaska. Responsible for designing and implementing *in situ*

CAROLYN L. FORDHAM, M.S.

Page 3

bioassay tests to determine waste water toxicity and established QA/QC protocol for extensive water, soil, and biota sampling program.

U.S. Fish and Wildlife Service: Colorado: Toxicologist/Field Biologist - Conducted acute toxicity tests according to EPA guidelines for the re-registration of various rodenticides; developed new methods of bait formulation; trapped wild mammals for toxicity testing; enforced animal welfare and GLP regulations; and performed analyses to determine extent of wildlife damage to agricultural crops. Duties included assessing the efficacy of pesticides on target organisms in natural environment, and assessing effects on nontarget wildlife populations.

EDUCATION

Ph.D.	Candidate	Environmental Health	Colorado State University
M.S.	1985	Toxicology	Colorado State University
B.S.	1980	Zoology/Ecology	University of Maryland

AFFILIATIONS

Sigma Xi Research Society
Society for Environmental Toxicology and Chemistry (SETAC)
American Society for Testing and Materials (ASTM)

PRESENTATIONS AND PUBLICATIONS

Fordham, C.L. 1992. Effects of Composted Sewage Sludge on the Earthworm *Lumbricus terrestris*. In: *Ecotoxicology of Earthworms*. P.W. Greig-Smith, H. Becker, P.J. Edwards, and F. Heimbach, eds. pp. 238-244.

Chandler, A.B. and C.L. Fordham. 1991. Development of Uncertainty Factors for Nonhuman Receptors. In: *The Analysis, Communication, and Perception of Risk*. Ed: B.J. Garrick and W.C. Gekler. Plenum Press, N.Y. pp 145-152.

Ford, K.L. W.A. Tucker, C.L. Fordham, and R.L. Osborn. 1991. *Endangerment Assessment Techniques for Biota at Rocky Mountain Arsenal*. In Press.

Fordham, C.L. and D.P. Reagan. 1991. Pathways Analysis Method for Estimating Water and Sediment Criteria at Hazardous Waste Sites. *Environmental Toxicology and Chemistry*. Vol 10:949.

CAROLYN L. FORDHAM, M.S.

Page 4

- Reagan, D.P. and C.L. Fordham. 1990. An Approach for Selecting Indicator Species to Monitor Ecosystem Effects Resulting from Chemical Changes in Soil and Water. Proceedings of the International Symposium on Ecological Indicators. October 16-19, 1990. Miami, FL. In Press.
- Reagan, D.P., C.L. Fordham, R.H. Chesson, R.D. Beane, and N.W. Clippinger. 1990. Abnormal Waterfowl Mortality on Eagle River Flats, Alaska. Annual meeting of the Society for Environmental Toxicology and Chemistry, Arlington, VA. November 1990.
- Fordham, C.L. 1988. Overview of the Endangerment Assessment Process First Annual Meeting, Rocky Mountain Chapter, Society for Environmental Toxicology and Chemistry. Laramie, Wyoming, May 21, 1988.
- Fordham, C.L. and D.P. Reagan. 1988. A Bioaccumulation Model to Evaluate Ecological Risk and Estimate Cleanup Criteria for Water and Sediments at Hazardous Waste Sites. Annual Meeting of the Society for Environmental Toxicology and Chemistry. Arlington, Virginia, November 15, 1988.
- Matschke, G.H., C.L. Fordham, S.G. Hurlbut, and R.M. Engeman. 1987. Comparative Toxicity of Strychnine to Eight Species of Ground Squirrels - Proceedings of the Eight Great Plains Wildlife Damage Control Workshop Proceedings. April 28-30, 1987. Rapid City, South Dakota.
- Matschke, G.H., and C.L. Fordham. 1986. Standard Norway Rat Acute Bait Laboratory Test for Fish and Wildlife Registration 6704-36, Parts A and B. Final report. Mammal Damage Section, Denver Wildlife Research Center, U.S. Fish and Wildlife Service, Denver, Colorado.

DARCY A. TIGLAS
Plant Ecologist

EXPERTISE: Terrestrial Ecology
Reclamation/Revegetation Planning
Wetland Delineation and Impact Analysis

EDUCATION: M.S., Range Science, Colorado State University, 1990
B.A., Biology & Political Science, Central University of Iowa-Pella,
1987
A.A., Liberal Arts, Cottey College, 1984

PROFESSIONAL QUALIFICATIONS:

Four years of experience as a range scientist/plant ecologist, including field studies and data analysis for two RCRA/CERCLA projects, a proposed natural gas pipeline, and reclamation research.

EXPERIENCE SUMMARY:

- Key team member in quantitative and qualitative ecological studies for five high-priority operable units at Rocky Flats. The studies involve intensive surveys of community composition and structure in potentially affected areas and reference areas and collection of tissue samples for laboratory analysis.
- Performed an ecological evaluation for a proposed residential development near Boulder, Colorado, and designed a wetland mitigation and enhancement program. Included the design of shoreline revegetation and creation of an island.
- At Dames & Moore, participated in a variety of tasks involving plant ecology, wildlife ecology, technical writing, and mapping. Conducted baseline field studies, data analysis, and threatened or endangered species surveys. Developed vegetation maps for EG&G at Rocky Flats and for EPA at Baxter Springs, Kansas. Monitored desert tortoise populations in the Mojave Desert.
- At Colorado State University, worked as a graduate research assistant in the Range Science Department. Proposed, coordinated, and completed revegetation research on the effects of chemical mulches on soil abiotic factors and management strategies for four subspecies of big sagebrush.

PROFESSIONAL ASSOCIATIONS/CERTIFICATIONS:

Society of Range Management
40-Hour Hazardous Waste Site Health and Safety Training
8-Hour Radiation Protection Training

DRAFT

INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
FIELD SAMPLING PLAN

EG&G ROCKY FLATS PLANT

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL MANAGEMENT

OCTOBER 11, 1993

IAEE FIELD SAMPLING PLAN

EG&G ROCKY FLATS PLANT
DRAFT FIELD SAMPLING PLAN

Manual:
Procedure No.:
Page:
Effective Date:
Organization:

Field Sampling Plan - IAEE
1.0, Rev. 0
1 of 8
10/12/93
Environmental Management

Approved By:

TITLE:

Industrial Area Environmental Evaluation

Name

____/____/____
(Date)

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1.0 INTRODUCTION	2
2.0 SITE BACKGROUND	2
3.0 DATA QUALITY OBJECTIVES (DQOs)	3
4.0 FIELD INVESTIGATIONS	4
4.1 HABITAT SURVEYS	5
4.2 VEGETATION SURVEYS	6
4.3 WILDLIFE SURVEYS	6
5.0 REFERENCES	8

LIST OF TABLES

<u>Table No</u>	<u>Title</u>
1	Industrial Area Environmental Evaluation Data Quality Objectives

LIST OF FIGURES

<u>Figure No.</u>	<u>Title</u>
1	Industrial Area Environmental Evaluation Individual Hazardous Substance Sites.
2	Industrial Area Environmental Evaluation East Drainage
3	Industrial Area Environmental Evaluation North Pond and Seep
4	Industrial Area Environmental Evaluation Northwest Drainage
5	Industrial Area Environmental Evaluation West Railroad

1.0 INTRODUCTION

This Field Sampling Plan (FSP) addresses the specific field investigation requirements for the Industrial Area Environmental Evaluation (IAEE) at the Rocky Flats Plant (RFP). The proposed field investigations consist of Task Three of Phase I of the IAEE. The field investigations for the IAEE have been planned in recognition of the limited extent of ecological systems within the Industrial Area (IA). The following sections address the Site Background, Data Quality Objectives, and Field Investigations.

2.0 SITE BACKGROUND

The IAEE field investigations will be performed to determine the ecological effects of exposure to contaminants. The IA includes Operable Units (OUs) 8, 9, 10, 12, 13, and 14. Data already generated from OUs 4 and 6 will be incorporated in the IAEE. These OU locations and corresponding Industrial Hazardous Substance Site (IHSS) locations are shown in Figure 1. The OUs cover a large portion of buildings and surrounding ground at the RFP site. Data from the field investigations will be used to determine the general site characteristics and ecological setting of this highly developed area of the RFP. The general approach for the IAEE was initially developed in the Environmental Evaluation (EE) Technical Memorandum, Addendum to Final Phase I RFI/RI Work Plan for OU9 (DOE, 1992). Further refinements were developed in EE work performed at OU4 and have been incorporated in this FSP. Specific sites to be surveyed within the IA were identified through a site reconnaissance survey conducted on October 7, 1993.

Field investigation activities will include the following:

- Confirmation of habitats and vegetation mapping units involved in the IA;
- Descriptive, qualitative surveys of habitats and plant and animal communities for information and data input into the Conceptual Model to be developed in Task Two of Phase I; and
- Determination of the presence of habitats for potential target taxa, including song birds, raptors, mammals, threatened and endangered species, or other species of concern.

EG&G ROCKY FLATS PLANT
DRAFT FIELD SAMPLING PLAN

Manual:
Procedure No.:
Page:
Organization:

Field Sampling Plan - IAEE
1.0, Rev. 0
3 of 8
Environmental Management

The field procedures to be used in the field investigations will follow RFP Standard Operating Procedures Manual Volume V: Ecology (EG&G 1992). During Phase I of the IAEE only qualitative ecological field data will be collected. No quantitative procedures will be used to estimate population densities or production of key species. In addition, no tissue samples will be collected, and no toxicity testing or histopathological assessments will be conducted.

Other IAEE tasks including the determination of Chemicals of Concern (COCs), development of the Conceptual Release and Transport Model, toxicity and contamination assessment are not addressed as part of this FSP.

3.0 DATA QUALITY OBJECTIVES (DQOs)

The DQO process for the IAEE follows that recommended by the Environmental Protection Agency (EPA, 1987 and EPA, 1990), and involves the preparation of statements that define data requirements and data uses. Three primary objectives relating to data requirements apply to the IAEE FSP:

- Describe the ecological setting of the IA;
- Identify key plant and animal species; and
- Collect data for the development of a Conceptual Model.

Table 1 summarizes each major objective with corresponding data requirements, data types, survey activities, and data use. Data collection will be limited to surveys. No physical samples will be taken. All activities will generate "qualitative", rather than "quantitative" data. "Qualitative" refers to the use of general observation and estimation of parameters of a population based on representative samples. "Quantitative" infers comprehensive empirical measurement and assessment of all samples of a population. Qualitative estimation provides an acceptable level of accuracy when applied by qualified senior personnel experienced with the site.

IAEE FIELD SAMPLING PLAN

EG&G ROCKY FLATS PLANT
DRAFT FIELD SAMPLING PLAN

Manual:
Procedure No.:
Page:
Organization:

Field Sampling Plan - IAEE
1.0, Rev. 0
4 of 8
Environmental Management

TABLE 1
INDUSTRIAL AREA ENVIRONMENTAL EVALUATION
DATA QUALITY OBJECTIVES

Specific Objective	Data Type	Survey Activity	Data Use
1. Describe Ecological Setting of the IA	Vegetation	Releve Plot Estimation/ Observation	Conceptual Model Risk Analysis
	Small Mammals	Trapping/Observation/ Description	Conceptual Model Risk Analysis
	Habitat	Observation/Mapping/ Description	Conceptual Model Risk Analysis
2. Identify Key Plant and Animal Species	Vegetation	Observation/Releve Plot Estimation	Conceptual Model Risk Analysis
	Small Mammals	Observation/Trapping	Conceptual Model Risk Analysis
3. Collect Data for Conceptual Model	Raptors, Reptiles, Other Wildlife	Observation/Description	Conceptual Model
	Large Mammals	Observation/Description	Conceptual Model
	Feeding Patterns	Observation/Description	Conceptual Model

The data collected will be used to identify site-specific receptor species and to construct a conceptual release and transport model based on an IA trophic level scheme. The ultimate use is to evaluate actual and potential risks to plant and animal species in and around the Industrial Area. If ecotoxicological investigations are warranted based on this phased study, then additional DQOs will be developed as the IAEE continues.

4.0 FIELD INVESTIGATIONS

A site reconnaissance survey was conducted on October 7, 1993. The number and extent of areas with sufficient vegetation communities and associated habitats for surveying were noted. A total of four study areas were identified. Two principal study areas with functional vegetation communities were identified along two main drainages to the east and northeast of the IA. Two

EG&G ROCKY FLATS PLANT
DRAFT FIELD SAMPLING PLAN

Manual:
Procedure No.:
Page:
Organization:

Field Sampling Plan - IAEE
1.0, Rev. 0
5 of 8
Environmental Management

locations with minor habitat development were also observed. One consists of ponds to the north of Building 700 complex and another consists of a narrow drainage in the southcentral portion of the IA along the railroad tracks in the 400 Building area.

The four study areas are shown in Figures 2 through 5. These areas include:

<u>Area</u>	<u>Figure</u>
East Drainage Area	2
North Pond & Seep	3
Northwest Drainage	4
West Railroad	5

Locations for proposed surveying are shown for each study area in Figures 2 through 5.

Throughout the IA a weedy vegetation type exists that will be characterized but not mapped. Some areas of the IA have been landscaped with tree plantings and sod. These will be noted and characterized but not qualitatively evaluated. The primary tasks for this FSP consist of typing and describing general habitats with respect to condition and extent, and qualitatively describing the corresponding vegetation and wildlife components. These tasks are described in the following sections.

4.1 HABITAT SURVEYS

The habitat types within the IA will be determined and mapped, then described for present conditions and extent, according to SOP EE.11. The principal plant and animal species in each habitat will be noted, and the potential for threatened and endangered species will be evaluated. Buildings, parking lots, and roads cover much of the IA, and these will not be mapped into habitats. The aquatic habitat is extremely limited in the IA and consists of managed seeps around buildings and surface discharge along earthen drainage ways. Aquatic habitats will be located, qualitatively evaluated, but not surveyed.

EG&G ROCKY FLATS PLANT
DRAFT FIELD SAMPLING PLAN

Manual:
Procedure No.:
Page:
Organization:

Field Sampling Plan - IAEE
1.0, Rev. 0
6 of 8
Environmental Management

4.2 VEGETATION SURVEYS

Vegetation surveys will be performed qualitatively to provide data on plant community composition. Qualitative assessment techniques to describe vegetation characteristics will consist of approximately of 15 releve plots located in the Northwest and East Drainage study areas and 5 releve plots each in the North Pond and Seep Area and the West Railroad Area.

The survey objectives include the identification of the principal primary producer species and the potential for protected species occurrence. The vegetation will be identified according to community type and correlated to the habitat nomenclature and descriptions in the SOP EE.11. Lists of species and principal abiotic features will be observed and noted for each area and habitat type. Much of the vegetation in the IA occurs in reclaimed areas or has been disturbed by construction and operation of the RFP. This vegetation is heterogenous in composition and variable, with no natural vegetation communities present.

4.3 WILDLIFE SURVEYS

Wildlife surveys will be conducted to gather qualitative data on wildlife species within the IA. The objectives of the wildlife surveys are to: (1) describe existing wildlife habitats; (2) identify potential transport pathways through trophic levels; (3) identify key species; (4) identify protected species and habitats, if present; and (5) develop a conceptual food web model.

IAEE FIELD SAMPLING PLAN

EG&G ROCKY FLATS PLANT
DRAFT FIELD SAMPLING PLAN

Manual:
Procedure No.:
Page:
Organization:

Field Sampling Plan - IAEE
1.0, Rev. 0
7 of 8
Environmental Management

Song birds, small mammals, and larger predators may use the area daily, seasonally or sporadically, or wander through as vagrants. The wildlife survey will document the presence of terrestrial species and provide information to describe and delineate habitats. Five major activities will be performed during the wildlife surveys:

- Live trapping to assess small mammal populations, using SOP EE.06, with the following numbers of traps:
 - East Drainage: 50 Traps
 - North Pond & Seep: 10 Traps
 - Northwest Drainage: 15 Traps
 - West Railroad: 25 Traps
- Qualitative song bird transects to record all species observed and their behavior and numbers according to SOP EE.07;
- Wildlife use records of the habitats by identification of animal trace and by observation, relying on vocalizations, scat identification, burrows, runs, remains, and direct observation;
- Wildlife species use linkage to identified and delineated habitat types using SOP EE.11; and
- Evaluation of the presence or potential for threatened and endangered wildlife species and species and habitats of concern.

All observations and field data, including notes will be recorded in appropriate field forms found in the RFP Ecology SOPs.

IAEE FIELD SAMPLING PLAN

EG&G ROCKY FLATS PLANT
DRAFT FIELD SAMPLING PLAN

Manual:
Procedure No.:
Page:
Organization:

Field Sampling Plan - IAEE
1.0, Rev. 0
8 of 8
Environmental Management

5.0 REFERENCES

- DOE, 1992. Environmental Evaluation Technical Memorandum Addendum to Final Phase I RFI/RI Work Plan. Rocky Flats Plant Original Process Waste Lines. Operable Unit No. 9, June 1992.
- EG&G, 1992. Standard Operating Procedures Manual, Volume V, Ecology, Manual No. 5-21200-OPS-EE, Golden, Colorado. EG&G Rocky Flats, Inc. (Currently undergoing review).
- EPA, 1987. Data Quality Objectives for Remedial Response Activities. Directive PB90-272634, March 1987.
- EPA, 1990. Guidance for Data Useability in Risk Assessment. Interim Final. EPA/540/G90/DO8. Directive: 9285.7-05, October 1990.

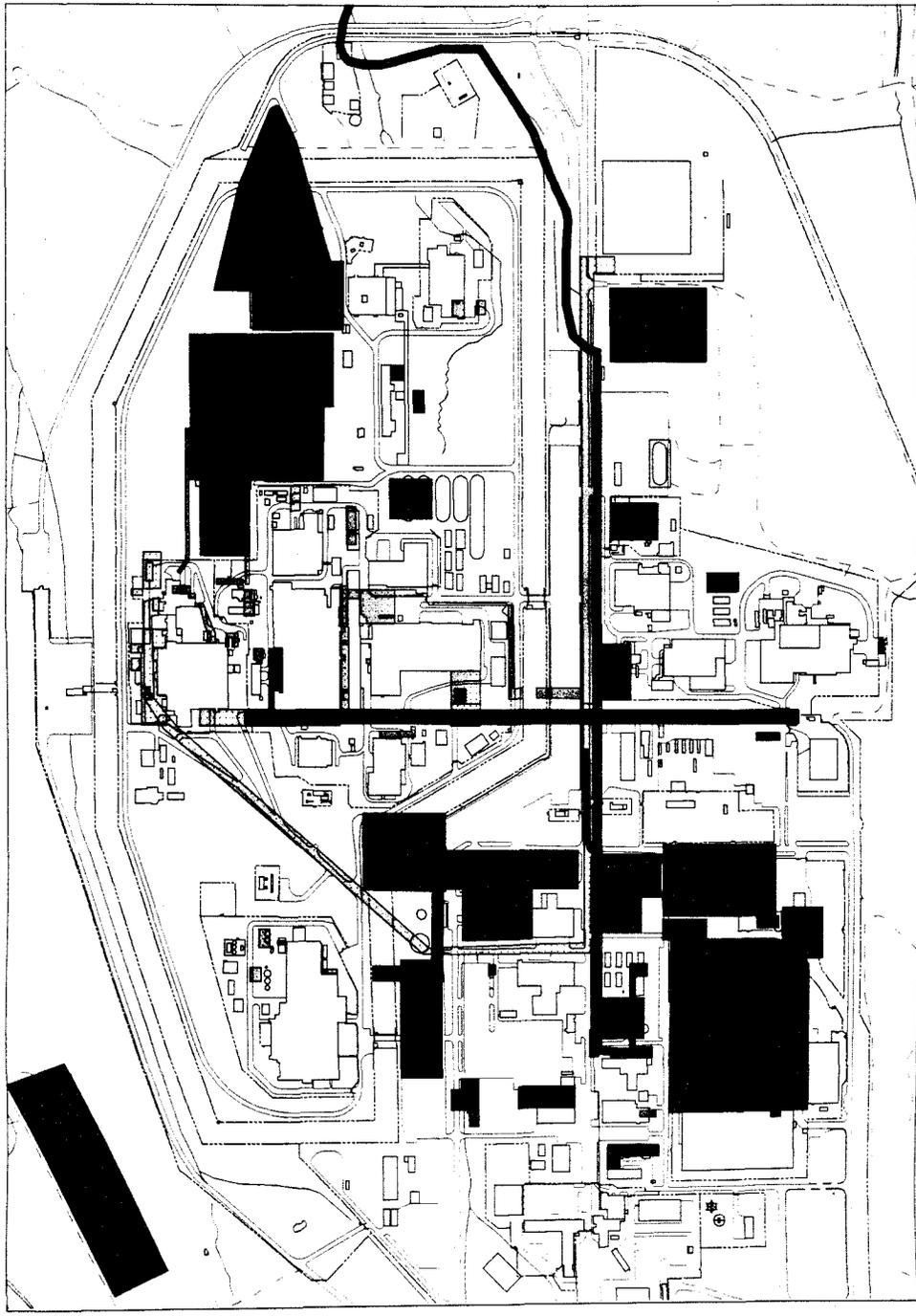


- Drainage
- Pond
- Buildings
- Fence
- Paved Road
- Dirt Road
- OU8
- OU9
- OU10
- OU12
- OU13
- OU14
- OU4
- OU6



PREPARED FOR
 U.S. DEPARTMENT OF ENERGY
 ROCKY FLATS PLANT
 GOLDEN, COLORADO

FIGURE 1
 INDUSTRIAL AREA
 ENVIRONMENTAL EVALUATION
 INDIVIDUAL HAZARDOUS
 SUBSTANCE SITES





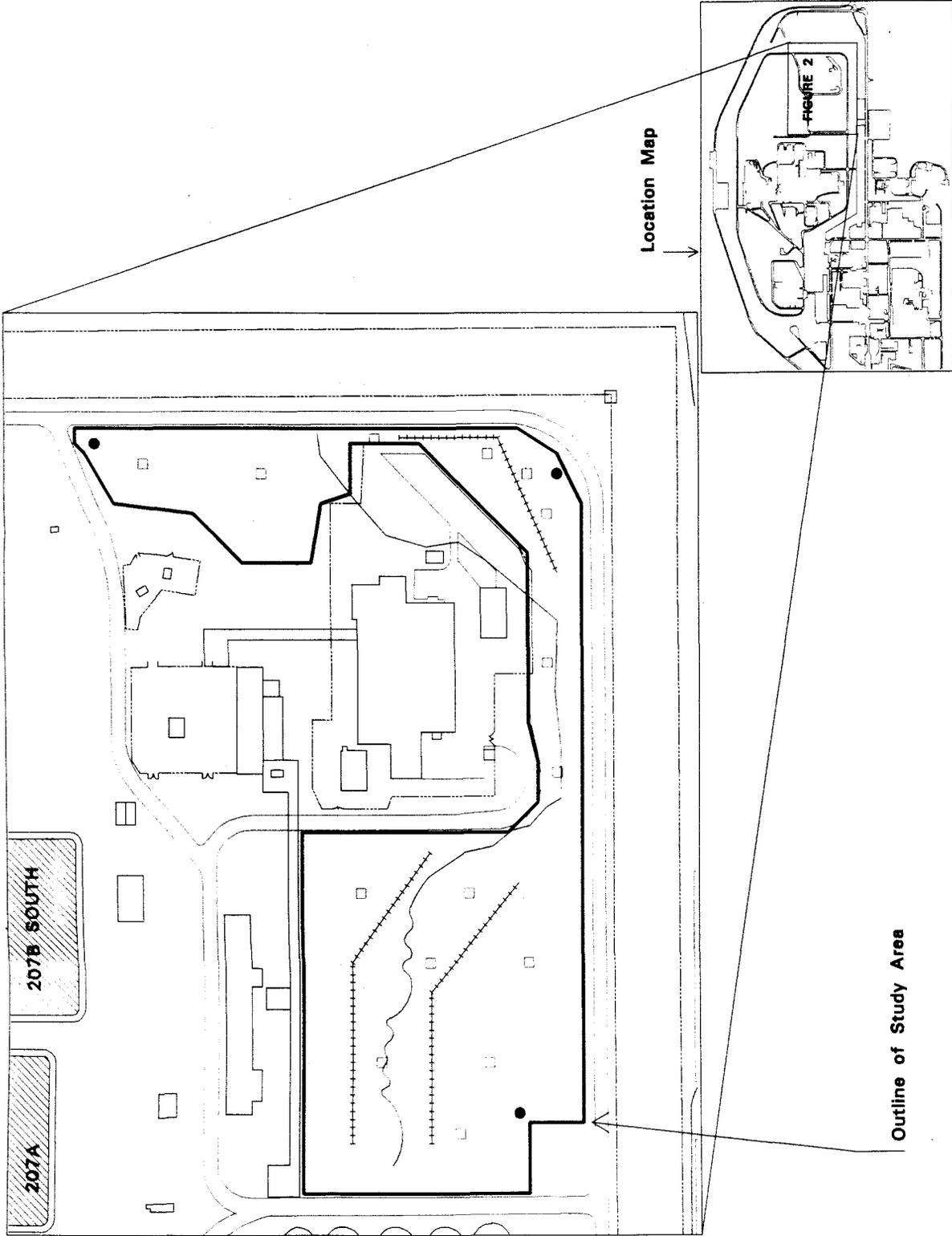
- Drainage
- Buildings
- ▨ Pond
- Fence
- Paved Road

- Outline of Study Area
- ++ Small Mammal Trap Lines
- Vegetation Plots
- Bird Observation Points

Scale: 1 Inch = 180 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 2
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
EAST DRAINAGE



Outline of Study Area

Location Map

FIGURE 2



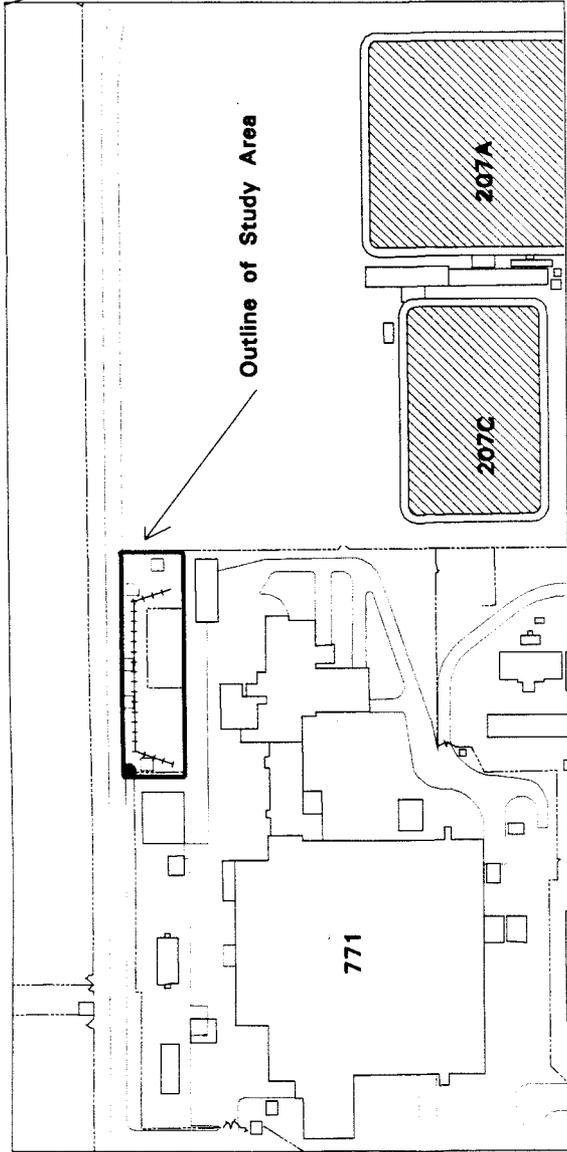
- Pond
- Building
- Fence
- Paved Road

- Outline of Study Area
- Small Mammal Trap Lines
- Vegetation Plots
- Bird Observation Points

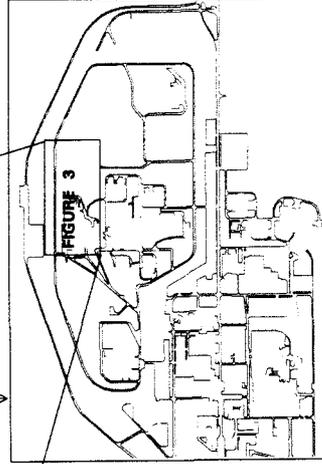
Scale: 1 inch = 150 feet

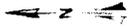
PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 3
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
NORTH POND AND SEEP



Location Map





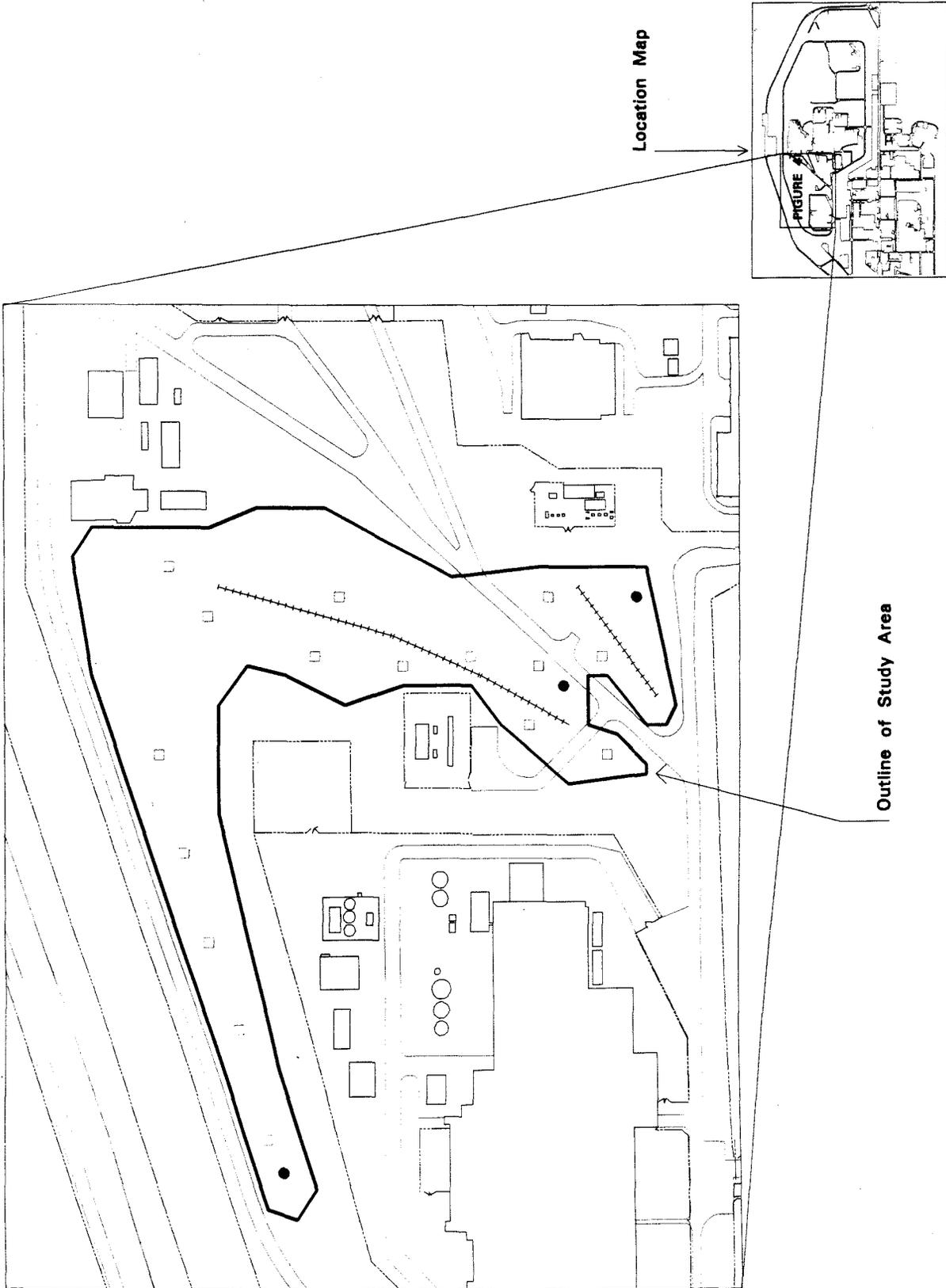
- Drainage
- Building
- Elevation
- Fence
- Paved Road

- Outline of Study Area
- Small Mammal Trap Lines
- Vegetation Plots
- Bird Observation Points

Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 4
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
NORTHWEST DRAINAGE



Outline of Study Area

Location Map

FIGURE 4



- Drainage
- Buildings
- Fence
- Paved Road

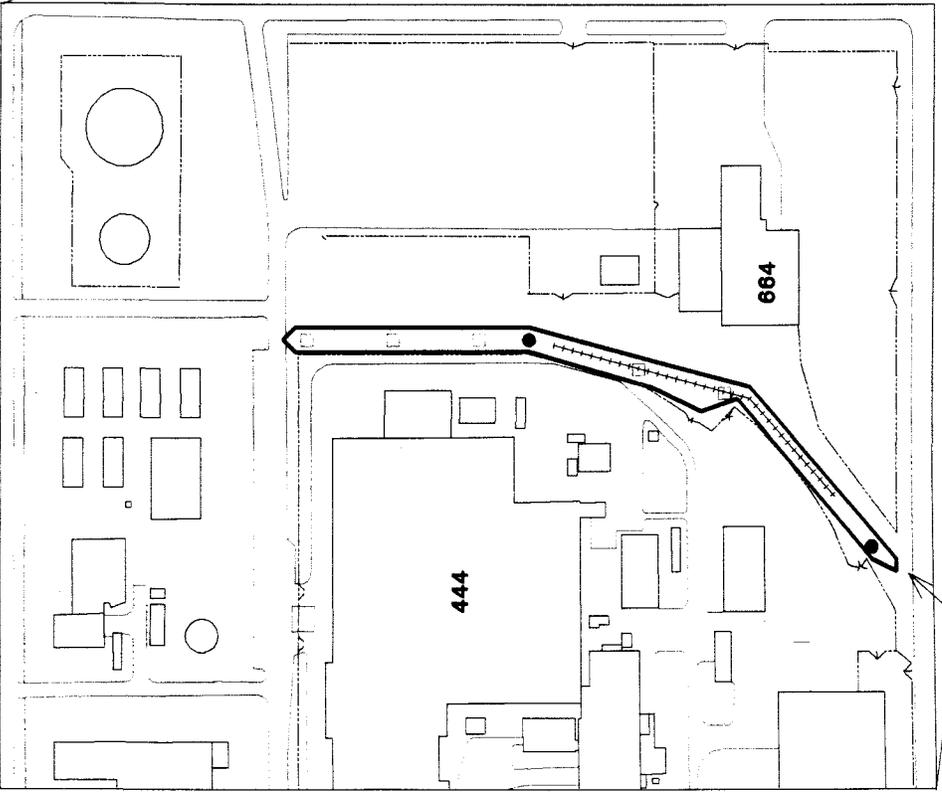
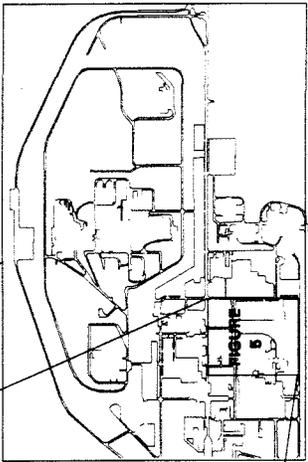
- Outline of Study Area
- ++ Small Mammal Trap Lines
- Vegetation Plots
- Bird Observation Points

Scale: 1 inch = 160 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 8
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
WEST RAILROAD

Location Map



Outline of Study Area

DRAFT

PHASE I DATA SUMMARY
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION

ROCKY FLATS PLANT
INDUSTRIAL AREA
OPERABLE UNIT NOS. 8, 9, 10, 12, 13, and 14

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL MANAGEMENT PROGRAM

OCTOBER 1993

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
EXECUTIVE SUMMARY	iii
1.0 INTRODUCTION	1-1
2.0 IDENTIFICATION OF HABITAT TYPES	2-1
3.0 VEGETATION SURVEY	3-1
4.0 SMALL MAMMAL SURVEY	4-1
4.1 EAST DRAINAGE STUDY AREA	4-2
4.2 NORTH POND AND SEEP STUDY AREA	4-2
4.3 NORTHWEST DRAINAGE STUDY AREA	4-2
4.4 WEST RAILROAD STUDY AREA	4-3
4.5 WEST AREA STUDY AREA	4-3
5.0 BIRD SURVEY	5-1
6.0 REFERENCES	6-1

**TABLE OF CONTENTS
(Continued)**

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>
3.1	Vegetation Species by Habitat
4.1	Results of Small Mammal Live Trapping at the East Drainage Study Area, October 14 Through 16, 1993
4.2	Results of Small Mammal Live Trapping at the North Pond and Seep Study Area, October 14 Through 16, 1993
4.3	Results of Small Mammal Live Trapping at the Northwest Drainage Study Area, October 14 Through 16, 1993
4.4	Results of Small Mammal Live Trapping at the West Railroad Study Area, October 14 Through 16, 1993
4.5	Results of Small Mammal Live Trapping at the West Area Study Area, October 14 Through 16, 1993

LIST OF FIGURES

<u>Figure No.</u>	<u>Title</u>
1	Industrial Area Environmental Evaluation Individual Hazardous Substance Sites
2	Industrial Area Environmental Evaluation East Drainage
3	Industrial Area Environmental Evaluation North Pond and Seep
4	Industrial Area Environmental Evaluation Northwest Drainage
5	Industrial Area Environmental Evaluation West Railroad
6	Industrial Area Environmental Evaluation West Area

APPENDICES

APPENDIX A - HABITAT AND VEGETATION SURVEY

APPENDIX B - SMALL MAMMAL SURVEY

EXECUTIVE SUMMARY

Phase I field investigations for the Industrial Area Environmental Evaluation (IAEE) were completed in October, 1993 at the Rocky Flats Plant. Activities completed include the identification of habitats, a vegetation survey, and a small mammal survey. A planned song bird survey was delayed by access requirements and will be complete by early November. Surveys were conducted in each of the five study areas delineated in the IAEE Field Sampling Plan.

Habitats were identified and mapped by foot traverse. Species lists were also recorded. Eight habitat types identified within the Industrial Area (IA) include disturbed (annual/forb), mesic grass (mixed grassland), xeric grass (short grass), short marsh, tall marsh, deciduous woodland (woodland), reclaimed grassland, and ornamental plantings. Vegetation was surveyed with the Relevé methodology. Vegetation species were identified within the habitats and were recorded. No sensitive species or unique vegetation were observed.

A small mammal survey was conducted using live trapping for three nights in each of the study areas. A total of 130 live traps were set, producing a total of 37 captures of three species from 390 trap nights. The trapping results are summarized below:

SPECIES	NUMBER TRAPPED
White-footed deer mouse	16
Western harvest mouse	8
Prairie Vole	13
TOTAL	- 37

Bird surveys are expected to produce minimal sightings, with nesting activities completed and fall migration underway. Year-round residents such as the Starling will likely be observed.

1.0 INTRODUCTION

This Phase I Data Summary addresses the Phase I field activities conducted during October, 1993 to satisfy the Work Plan requirements for the Industrial Area Environmental Evaluation (IAEE). Field activities were performed as outlined in the IAEE Field Sampling Plan (IAEE FSP) (DOE, 1993). The objectives, approach, and detailed methodologies used to conduct the field investigations are referenced in the IAEE FSP and EG&G Rocky Flats Plant (EG&G) Environmental Management Operating Procedures Manual. The purpose of this report is to briefly summarize field activities and results of the ecological investigation.

The report is divided into the four following sections:

- Identification of Habitat Types;
- Vegetation Survey;
- Small Mammal Survey; and
- Song Bird Survey.

All surveys and investigations followed the Ecology Standard Operating Procedures prepared by EG&G (EG&G, 1992a and 1992b).

2.0 IDENTIFICATION OF HABITAT TYPES

Rocky Flats Plant (RFP) is composed of a wide variety of habitat types. The Industrial Area (IA) of the RFP, although the most disturbed and limited in terms of areal extent, also has diverse habitats. The distribution and abundance of plants and animals is influenced by many different features, including topography, aspect, soil type, previous and continuous disturbance, and microclimatic differences across the site. An understanding of present vegetative communities and wildlife habitat characteristics and usage provides important information to remediation efforts and restoration planning.

The extent of the habitats in the IA is limited to relatively undisturbed or reclaimed sites that total about 25 acres or, 6 percent of the Industrial Area. These habitats are fragmented and small with roads and disturbed surfaces interspersed throughout. Other habitats in associated Operable units (OUs) 1, 2, 4, 6, and 7 that are adjacent to and in the Industrial Area, and not included in these field surveys, occupy about another 30 acres. Figure 1 illustrates the Industrial Hazardous Substance Sites associated with the IA.

The IA was traversed on foot by two ecologists to characterize and map the different habitat types. The characterization of the IA habitats was conducted following EG&G SOP EE.11 (EG&G, 1992a). Topographic features, such as aspect and slope, were noted. Plant species lists were made to better understand ecological relationships of the area. Dominant species were recorded along with their spatial foliar dominance to a particular habitat type. The results of the characterization indicate that the IA area is composed of a mosaic of different habitat types. Discrete habitat differentiation was not possible in some areas, since a complex of several habitat types was present. This mosaic of habitat types was caused principally by intermittent surficial soil disturbance.

Habitat types identified in the IA area include disturbed (annual/forb), mesic grass (mixed grassland), xeric grass (short grass), short marsh, tall marsh, deciduous woodland (woodland),

reclaimed grassland, and ornamental plantings. Specific habitats were mapped in five different study areas illustrated in Figures 2 through 6.

The disturbed (annual/forb) habitat type was found throughout the IA. All study areas had this habitat type, including the East Drainage, North Pond and Seep, the Northwest Drainage, the West Railroad, and the West Area. These areas have had previous or frequent surficial soil disturbance due to road building and maintenance, mowing, earthmoving, and storage of cargo facilities.

The mesic grassland (mixed grassland) habitat type occurs in the Northwest Drainage and the West Area. These areas of about two to four acres are remnants of the original prairie. Several pristine prairie habitat types come together to compose the mesic grassland and they include tall grass prairie, northern mid-grass prairie, and southern mid-grass prairie. This habitat type was the most diverse with upwards of eighty species identified.

There were several small areas of xeric grassland (short grass) habitat located at the Northwest Drainage and at the West area. Although small, the xeric grassland habitat type was also very diverse with approximately 60 species identified. The xeric grassland habitat type was found on more gravelly outcrops with bare ground and rock, and exposed to harsh wind and weather conditions.

Due to a number of seeps, ditches, and diverted water sources, the short marsh habitat type occurs extensively throughout the IA. Short marsh was found at the East Drainage, North Pond and Seep, West Railroad, and West Area.

The water levels vary seasonally along the ditches and sloughs where the tall marsh habitat occurs. Cattails dominate areas with receding and stagnant water levels up to two feet deep. Therefore, in many areas of the IA, tall marsh has infiltrated canals and roadside ditches and maintained its dominance in shallow creeks which run through the Protected Area.

Deciduous woodland (soodland habitat) areas were encountered at the East Drainage, Northwest Drainage, and in the West Area. Since creeks and streams are small and flow intermittently at Rocky Flats, large areas of riparian woodland development have been minor. Creeks and streams are sparsely populated with single individuals or small pockets of mature trees.

Reclaimed grassland was found at all study sites, except the West Area. Disturbed areas are reclaimed with aggressive species in order to revegetate a site as quickly and as thoroughly as possible. Generally, native species take a long time to establish, so introduced species are used instead. Some native species have been hybridized to have more aggressive characteristics, such as faster establishment. Since the IA has largely been disturbed much of the area is composed of reclaimed grassland.

Ornamental plantings were observed throughout the IA. These ornamental plantings are not well maintained, but the understories are groomed and mowed at least once annually. These areas seemed to be major grouping sites for wildlife, such as deer and cottontail rabbits. Evidence of herbivory was noticed on the trees and grasses in and around ornamental plantings.

3.0 VEGETATION SURVEY

Vegetation was surveyed on October 13, 14, and 15, 1993 using Relevé methodology. Parameters collected included species richness, estimated plant foliar cover, and species dominance. Locations for the data collection were among numerous habitat types in the East Drainage, North Pond and Seep, Northwest Drainage, West Railroad, and West Area study areas. The surveys were conducted using the Relevé Survey Data Form (Form EE 5.10). Table 3.1 summarizes the vegetation species found within the habitats.

Dominant disturbed (annual/forb) species within the weedy/disturbed habitat include common sunflower (*Helianthus annuus*), Russian-thistle (*Salsola iberica*), klamath weed (*Hypericum perforatum*), curlycup gumweed (*Grindelia squarrosa*), Western ragweed (*Ambrosia psilostachya*), burning-bush (*Kochia iranica*), diffuse knapweed (*Centaurea diffusa*), cheat-grass (*Bromus tectorum*), Japanese brome (*Bromus japonicus*), Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), and bull thistle (*Cirsium vulgare*).

Dominant graminoid species within the mesic grasslands (mixed grassland) habitat include needle-and-thread (*Stipa comata*), prairie junegrass (*Koeleria macrantha*), big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Canada bluegrass (*Poa compressa*), Kentucky bluegrass (*Poa pratensis*), sideoats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*), and mountain muhly (*Muhlenbergia montana*). A small pocket southeast of the Northwest Drainage is dominated by sleepygrass (*Stipa robusta*) and green needlegrass (*Stipa viridula*). Dominant forb species include blazing star (*Liatris punctata*), trailing fleabane (*Erigeron flagellaris*), smooth goldenrod (*Solidago missouriensis*), spreading fleabane (*Erigeron divergens*), and western yarrow (*Achillea lanulosa*). Other associated plants include false gromwell (*Onosmodium molle*), slimflower scurfpea (*Psoralea tenuiflora*), narrow-leaved umbrellawort (*Oxybaphus linearis*), wavy-leaf thistle (*Cirsium undulatum*), aster (*Aster ericoides*), western wheatgrass (*Agropyron smithii*), and prairie coneflower (*Ratibida columnaris*). Half-shrubs include wild rose (*Rosa acicularis*) and snowberry (*Symphoricarpos occidentalis*).

TABLE 3.1
Vegetation Species by Habitat

<u>HABITAT</u>	<u>VEGETATION SPECIES</u>
Distrubed (annual/forb)	Sunflower, Russian-Thistle, Klamath Weed, Curlycup Gumweed, Western Ragweed, Burning Bush, Diffuse Knapweed, Cheat-grass, Japanese Brome, Canada Thistle, Musk Thistle, Bul Thistle
Mesic Grassland (mixed grassland)	Needle-and-Threadgrass, Prairie Junegrass, Big Bluestem, Canada Bluegrass, Kentucky Bluegrass, Sideoats Grama, Blue Grama, Mountain Muhly
Xeric Grassland (short grass)	Red Three-Awn, Fendler Three-Awn, Buffalo Grass, Hairy Grama, Ring Muhly, Aster, Mountain Bladder-Pod, Prairie Sage, Golden Aster, Filaree, Green Milkweed, Goldenrod, Winged Eriogonum, Segoe-Lily, Sagewort, Broom Snakeweed, Spanish Bayonet, Prickly Pear
Short Marsh	Spike Rush, Rush, Baltic Rush, Soft Rush, Redtop Bentgrass, Timothy, Meadow Fescue, Nebraska Sedge, Foxtail Barley, Water Cress, Cress, Horseweed, Common Evening-Primrose, Violet, Lady's Thumb
Tall Marsh	Common Evening Primrose, Catnip, Field Mint, Foxtail, Houndstongue, Plains Cottonwood, Russian-Olive, Peach-Leaved Willow
Deciduous Woodland (Woodland)	Plains Cottonwood, Russian-Olive, Peach-Leaved Willow, Creek Willow, Choke Cherry, Coyote Willow, Leadplant, Sandbar Willow
Reclaimed Grassland	Smooth Brome, Crested Wheatgrass, Intermediate Wheatgrass, Hybrid Native Side-Oats Grama, Alfalfa, White Sweet Clover, Yellow Sweet Clover, Wild Licorice
Ornamental Plantings	Ponderosa Pine, Russian-Olive, Plains Cottonwood, Juniper, Sheep Fescue

Dominant xeric grasses in the xeric (short grass) habitat included red three-awn (*Aristida longiseta*), Fendler three-awn (*Aristida fendleriana*), buffalo-grass (*Buchloe dactyloides*), hairy grama (*Bouteloua hirsuta*), ring muhly (*Muhlenbergia torreyi*). Dominant xeric forbs included aster (*Aster porteri*), mountain bladder-pod (*Lesquerella montana*), prairie sage (*Artemisia ludoviciana*), golden aster (*Heterotheca fulcrata*), and filaree (*Erodium cicutarium*). Associated plants included green milkweed (*Asclepias viridiflora*), goldenrod (*Solidago mollis*), winged eriogonum (*Eriogonum alatum*), and sego-lily (*Calochortus gunnisonii*). Half-shrubs associated with the xeric habitat type include common sagewort (*Artemisia campestris*) and broom snakeweed (*Gutierrezia sarothrae*). Succulents included Spanish bayonet (*Yucca glauca*) and cacti species included prickly pear cactus (*Opuntia compressa*).

The short marsh habitats dominated by sedges (*Carex* sp.) and rushes (*Juncus* sp.) with some tall marsh and deciduous woodland overstory species. Dominant short marsh grass-like species include spike rush (*Eleocharis acicularis*), rush (*Juncus torreyi*), baltic rush (*Juncus balticus*), soft rush (*Juncus effusus*), redtop bentgrass (*Agrostis stolonifera*), rush (*Juncus articulatus*), timothy (*Phleum pratense*), meadow fescue (*Festuca pratensis*), Nebraska sedge (*Carex nebraskensis*), and foxtail barley (*Hordeum jubatum*). Dominant forbs for this type included water-cress (*Nasturtium officinale*), cress (*Rorippa palustris*), horseweed (*Conyza canadensis*), common evening-primrose (*Oenothera stigosa*), violet (*Viola nuttallii*), and Lady's thumb (*Persicaria maculata*).

The tall marsh habitat type in the drainages was dominated by broad-leaved cattails (*Typha latifolia*) with an understory of short marsh species and an overstory of sparse deciduous riparian tree species. Common evening-primrose, catnip (*Nepeta cataria*), and field mint (*Mentha arvensis*) are commonly associated with the tall marsh. Some areas have small sandbars on which foxtail (*Alopecurus pratensis*) dominates. Houndstongue (*Cynoglossum officinale*) was also found among the tall marsh. Overstory trees include plains cottonwood (*Populus deltoides*), Russian-olive (*Elaeagnus angustifolia*), and peach-leaved willow (*Salix amygdaloides*).

Large trees present within the woodland habitat include plains cottonwood, Russian-olive, peach-leaved willow, and crack willow (*Salix fragilis*). Smaller tree species include choke cherry (*Prunus virginiana*), coyote willow (*Salix exigua*), leadplant (*Amorpha fruticosa*), and sandbar willow (*Salix interior*). The East Drainage showed evidence of the development of a potential deciduous woodland because of the many plains cottonwood seedlings along the ditch area. On the east side of the hillside deciduous woodland area, there were several dead snags and downed trees which may indicate a change in water availability and flow for the area, and a topographical shift of vegetation.

Dominant reclamation grasses within the reclaimed grassland areas include smooth brome (*Bromopsis inermis*), crested wheatgrass (*Agropyron cristatum*), intermediate wheatgrass (*Agropyron intermedium*), and a hybrid native side-oats grama. Crested wheatgrass, intermediate wheatgrass, and side-oats grama are bunchgrasses that aid in water and wind erosion control on steep hillsides and slopes. Forbs used in reclamation included alfalfa (*Medicago sativa*), white sweet clover (*Melilotus alba*), and yellow sweet clover (*Melilotus officinalis*). Due to the original disturbance of these sites and the large amount of exposed soil, many weedy species were also present. At the Northwest Drainage and the East Drainage areas, wild licorice (*Glycyrrhiza lepidota*) grows throughout the reclaimed grassland.

Some of the ornamental plantings were native and others were introduced species. The West Area had four rows of trees, including ponderosa pine (*Pinus ponderosa*), Russian-olive, plains cottonwood, and juniper (*Juniperus* sp.) that appeared to serve as a wind break. The understory is composed of a mosaic of mesic and xeric grassland species with sheep fescue (*Festuca ovina*) also dominating the site.

4.0 SMALL MAMMAL SURVEY

A small mammal survey was conducted at five IA locations between October 14 and 16, 1993 using procedures from SOP EE.6. Live trapping surveys were conducted for three nights by placing a Sherman collapsible live trap at five meter spacings along trap lines as shown in Figures 2 through 6. Five study areas were selected for an ecological evaluation to determine the extent of potential contaminant transport through foodweb pathways. These five trapping locations corresponded to areas within the IA that represented patches of wildlife habitat that appeared to sustain viable populations of small mammals. In addition, these areas also were selected for vegetation characterization and habitat evaluation.

The traps were baited with commercial grain feed in the late afternoon and were checked the next morning between 0800 and 1000 hours. A total of 130 live traps were set in the following numbers in each study area:

·	East Drainage:	40 traps;
·	North Pond and Seep:	10 traps;
·	Northwest Drainage:	40 traps;
·	West Railroad:	20 traps; and
·	West Area:	<u>20 traps.</u>
	TOTAL	130 traps

The live traps were placed in vegetation close to drainage flow through these areas. It was reasoned that if contaminants were present in drainage flow, small mammals inhabiting the area would be exposed to contamination through direct contact or through ingestion of vegetation food items. The one exception occurred in the West Area where live traps were not placed in a drainage. A total of 390 trap nights produced 37 captures of three species as discussed below for each study area.

4.1 EAST DRAINAGE STUDY AREA (Figure 2)

Seventeen small mammals representing three species were caught over three trap nights at this location and are summarized in Table 4.1. The species were:

- White-footed deer mouse: 8 males;
- Western harvest mouse: 2 males and 2 females; and
- Prairie vole: 4 males and 1 female.

All the deer mice were juveniles (less than 12 grams total body weight) and were dispersing from their nests. Two subadult and two juvenile western harvest mice also were caught. Four of the five prairie voles were adults and one was a juvenile. Subadults and juveniles in the trapped population indicate successful reproduction in this study area. The one subadult female harvest mouse was reproductive. One adult vole and two juvenile deer mice were each recaptured once.

4.2 NORTH POND AND SEEP STUDY AREA (Figure 3)

Six small mammals representing three species were caught over three trap nights at this location and are summarized in Table 4.2. The species were:

- White-footed deer mouse: 1 male;
- Western harvest mouse: 1 male; and
- Prairie vole: 4 females.

The deer mouse was a subadult and non-reproductive. The harvest mouse was a non-reproductive adult. Three adult and one subadult prairie voles were captured. There were no recaptures at this site. This area supports a small population of voles and provides more suitable habitat for this species than for the deer mouse or western harvest mouse because of the small habitat size.

4.3 NORTHWEST DRAINAGE STUDY AREA (Figure 4)

Eleven small mammals representing three species were caught over three trap nights at this location and are summarized in Table 4.3. The species were:

- White-footed deer mouse: 1 males and 3 females ;
- Western harvest mouse: 1 male and 1 female; and
- Prairie vole: 1 male and 3 females.

Two adult and two juvenile deer mice were caught, along with 2 juvenile harvest mice. On the second trap night between traps 8 and 9, five juvenile mice were seen as the traps were being set. They could have been either deer mice or harvest mice. The high number of juveniles observed indicate young dispersal during this period, and successful reproduction. Two adult and two subadult prairie voles were also captured in this drainage. One deer mouse and one prairie vole were recaptured.

4.4 WEST RAILROAD STUDY AREA (Figure 5)

Only one juvenile female western harvest mouse was captured at this location as is indicated in Table 4.4. The trapping area was in a well vegetated drainage way with a wildlife trail through the bottom of it. The trail was probably in use by feral cats and cottontail rabbits, however, none were observed during the three days of trapping. This area is a narrow linear strip of disturbed/weedy and short marsh habitat which is probably marginal for the support of viable small mammal populations because of its small size.

4.5 WEST AREA STUDY AREA (Figures 6A and 6B)

Only two deer mice were captured at this study site over the three day trapping period, as is summarized in Table 4.5. Both were subadults, male and female. Neither of the individuals were reproductive. This area is a mixture of mesic and xeric prairie species with strong sign of cottontail and mule deer usage.

Each morning each trap was checked to see if the bait had been removed without tripping the trap. About six traps were sprung by wind during the three trapping events, and three traps were robbed of bait. The East and Northwest Drainage sites showed good small rodent activity. The West Railroad site had no indication of small rodent activity, and the West Site indicated stronger cottontail activity.

Feral cats were observed at the East and Northwest Drainage sites. The animal trail through the West Railroad site is probably used by feral cats and cottontail rabbits. No cats were seen at the North Pond and Seep site or at the West Site. It is postulated that cats are very effective in

keeping the rodent population at low levels. Another observation from experience at other sites is that deer mice avoid tall, dense grassy areas. Mowed grasses or sparse short grasses are more conducive to deer mouse populations. Deer mice were captured at the edges of tall grass and voles were captured in more dense grass habitat.

TABLE 4.1

**Results of Small Mammal Live Trapping at
the East Drainage Study Area, October 14 through 16, 1993**

Small Mammal Species

White-footed deer mouse (*Peromyscus maniculatus*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	3	2	3
Females	0	0	0
 Number of Age Classes:			
Juveniles	8	8	8
Number of Reproductives:	0	0	0
Number of Recaptures:	-	1	1

Western harvest mouse (*Reithrodontomys megalotis*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	2	0
Females	0	1	1
 Number of Age Classes:			
Subadults	2	2	2
Juveniles	2	2	2
Number of Reproductives:	0	0	1
Number of Recaptures:	-	0	0

Prairie vole (*Microtus ochrogaster*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	1	3	0
Females	0	0	1
 Number of Age Classes:			
Adults	4	4	4
Juveniles	1	1	1
Number of Reproductives:	0	0	0
Number of Recaptures:	-	1	0

TABLE 4.1

Results of Small Mammal Live Trapping at
the East Drainage Study Area, October 14 through 16, 1993

Small Mammal Species

White-footed deer mouse (*Peromyscus maniculatus*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	3	2	3
Females	0	0	0
Number of Age Classes:			
Juveniles	8	8	8
Number of Reproductives:	0	0	0
Number of Recaptures:	-	1	1

Western harvest mouse (*Reithrodontomys megalotis*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	2	0
Females	0	1	1
Number of Age Classes:			
Subadults	2	2	2
Juveniles	2	2	2
Number of Reproductives:	0	0	1
Number of Recaptures:	-	0	0

Prairie vole (*Microtus ochrogaster*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	1	3	0
Females	0	0	1
Number of Age Classes:			
Adults	4	4	4
Juveniles	1	1	1
Number of Reproductives:	0	0	0
Number of Recaptures:	-	1	0

TABLE 4.2

Results of Small Mammal Live Trapping at the
North Pond and Seep Study Area, October 14 through 16, 1993

Small Mammal Species

White-footed deer mouse (*Peromyscus maniculatus*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	1
Females	0	0	0
Number of Age Classes:			
Subadults	1	1	1
Number of Reproductives:	0	0	1
Number of Recaptures:	-	0	0

Western harvest mouse (*Reithrodontomys megalotis*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	1	0	0
Females	0	0	0
Number of Age Classes:			
Adults	1	1	1
Number of Reproductives:	0	0	0
Number of Recaptures:	-	0	0

Prairie vole (*Microtus ochrogaster*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	2	2
Number of Age Classes:			
Adults	3	3	3
Subadults	1	1	1
Number of Reproductives:	-	0	0
Number of Recaptures:	-	0	0

TABLE 4.3

Results of Small Mammal Live Trapping at
the Northwest Drainage Study Area, October 14 Through 16, 1993

Small Mammal Species

White-footed deer mouse (*Peromyscus maniculatus*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	1	1	0
Females	2	1	0
Number of Age Classes:			
Adults	2	2	2
Juveniles	2	2	2
Number of Reproductives:	0	0	0
Number of Recaptures:	-	1	0

Western harvest mouse (*Reithrodontomys megalotis*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	1	0
Females	0	0	1
Number of Age Classes:			
Juveniles	2	2	2
Number of Reproductives:	0	0	0
Number of Recaptures:	-	0	0

Prairie vole (*Microtus ochrogaster*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	1
Females	0	2	1
Number of Age Classes:			
Adults	2	2	2
Subadults:	2	2	2
Number of Reproductives:	0	1	0
Number of Recaptures:	-	0	0

TABLE 4.4

Results of Small Mammal Live Trapping at the
West Railroad Study Area, October 14 Through 16, 1993

Small Mammal Species

White-footed deer mouse (*Peromyscus maniculatus*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	0	0
Number of Age Classes:	None		
Number of Reproductives:	None		
Number of Recaptures:	None		

Western harvest mouse (*Reithrodontomys megalotis*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	0	1
Number of Age Classes:			
Juveniles	0	1	0
Number of Reproductives:	0	0	0
Number of Recaptures:	-	0	0

Prairie vole (*Microtus ochrogaster*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	0	0
Number of Age Classes:	None		
Number of Reproductives:	None		
Number of Recaptures:	None		

TABLE 4.5

**Results of Small Mammal Live Trapping at the
West Area Study Area, October 14 Through 16, 1993**

Small Mammal Species

White-footed deer mouse (*Peromyscus maniculatus*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	1	0
Females	0	1	0
 Number of Age Classes:			
Subadults	0	2	0
Number of Reproductives:	0	0	0
Number of Recaptures:	-	0	0

Western harvest mouse (*Reithrodontomys megalotis*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	0	0
 Number of Age Classes: None			
Number of Reproductives: None			
Number of Recaptures: None			

Prairie vole (*Microtus ochrogaster*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	0	0
 Number of Age Classes: None			
Number of Reproductives: None			
Number of Recaptures: None			

5.0 BIRD SURVEY

The bird surveys will be conducted on October 28, 29 and November 1, 1993 now that permission has been received to enter the Protected Area with binoculars. For this bird survey period breeding bird species have completed their nesting activities and young have left the nests. Fall migration has commenced and many species, such as Say's Phoebe, have left or are leaving the area to winter elsewhere, while others remain as year-round residents such as the Starling. The bird survey will identify those species presently within the Industrial Area OU.

FIGURES



Drainage
Buildings
Fence
Paved Road

Xeric Grassland
Xeric/Mesic Grass
Disturbed/Mesic Grass

— Outline of Study Area

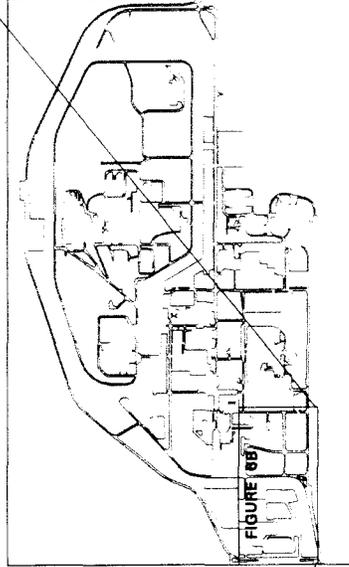
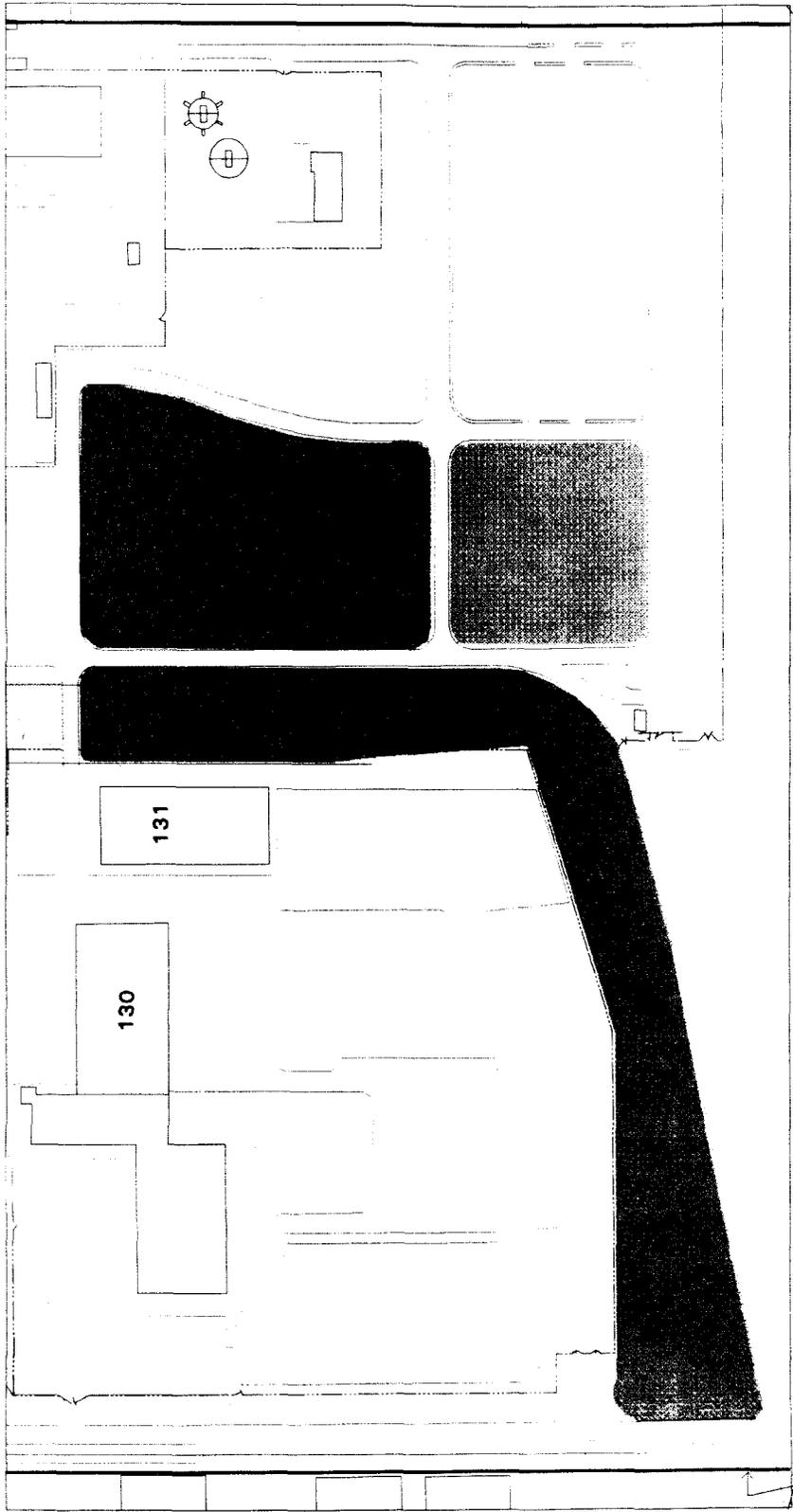
--- Small Mammal Trap Lines

● Bird Observation Points

Scale: 1 inch = 300 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 98
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
WEST AREA



Location Map

Outline of Study Area

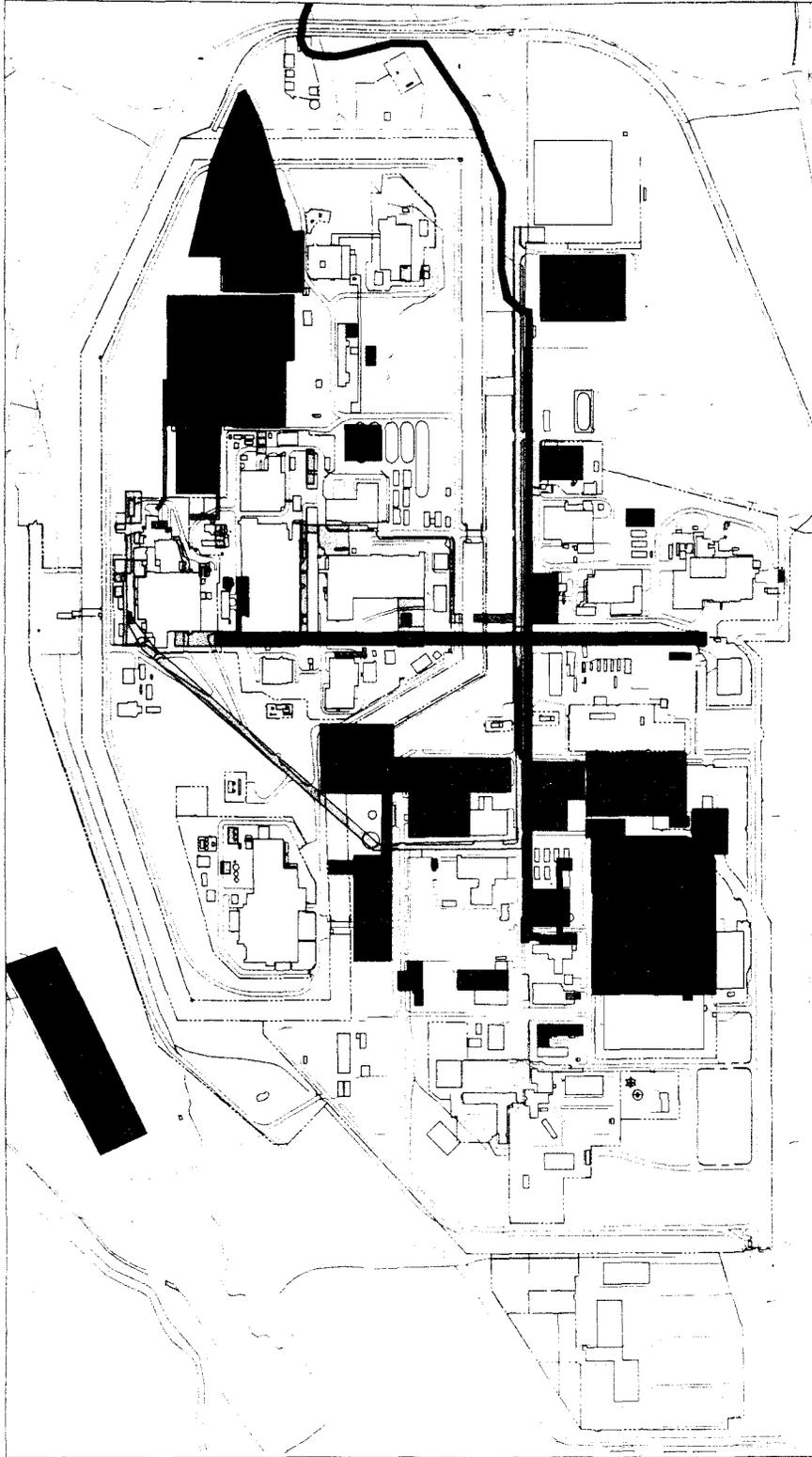


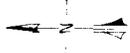
- Drainage
- Pond
- Buildings
- Fence
- Paved Road
- Dirt Road
- OU8
- OU9
- OU10
- OU12
- OU13
- OU14
- OU4
- OU6

250 0 250 500 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 1
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
INDIVIDUAL HAZARDOUS
SUBSTANCE SITES





Drainage
Buildings
Fence
Paved Road

Xeric Grassland
Xeric/Mesic Grass.
Disturbed/Mesic Grass.

— Outline of Study Area

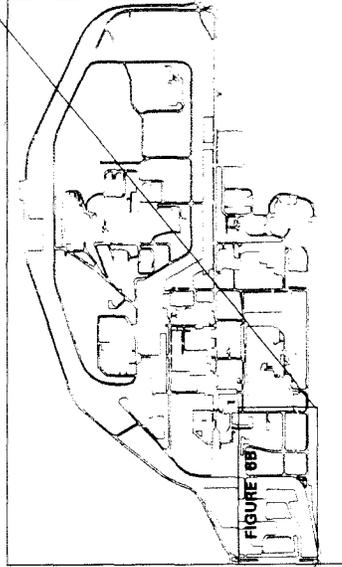
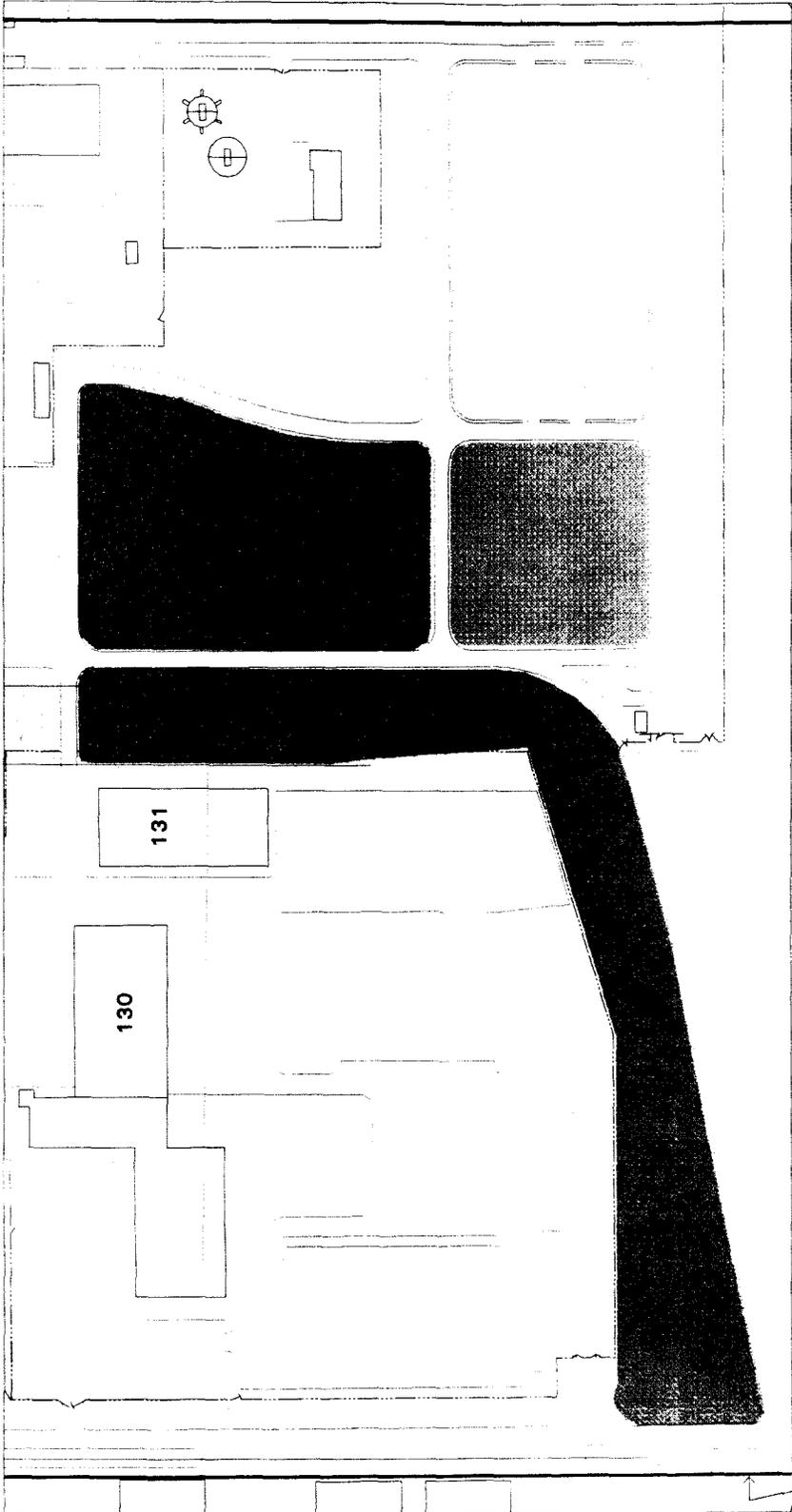
--- Small Mammal Trap Lines

● Bird Observation Points

Scale: 1 inch = 300 feet

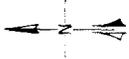
PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 98
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
WEST AREA



Location Map

Outline of Study Area

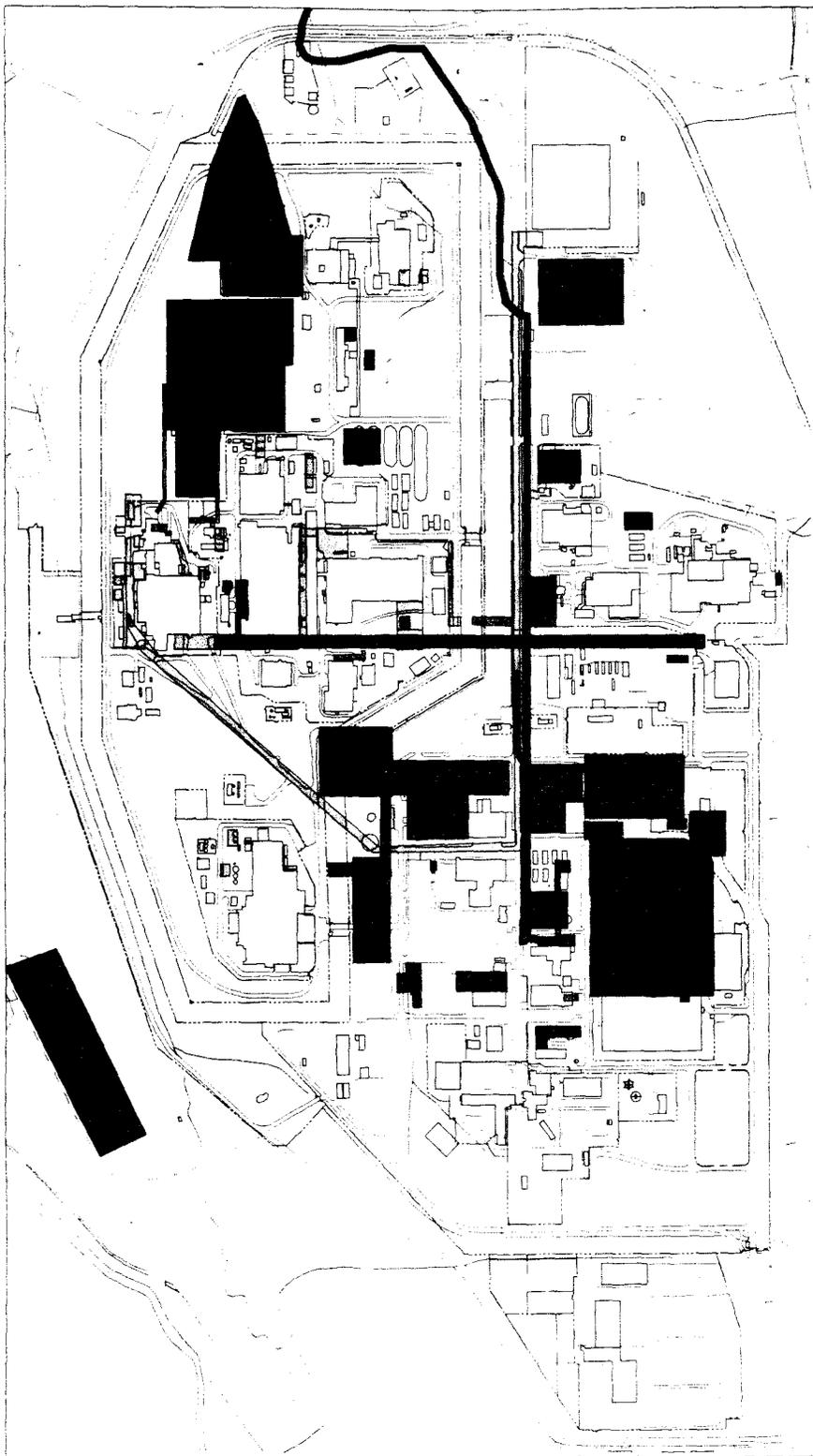


- Drainage
- Pond
- Buildings
- Fence
- Paved Road
- Dirt Road
- OU8
- OU9
- OU10
- OU12
- OU13
- OU14
- OU4
- OU6



PREPARED FOR
 U.S. DEPARTMENT OF ENERGY
 ROCKY FLATS PLANT
 GOLDEN, COLORADO

FIGURE 1
 INDUSTRIAL AREA
 ENVIRONMENTAL EVALUATION
 INDIVIDUAL HAZARDOUS
 SUBSTANCE SITES





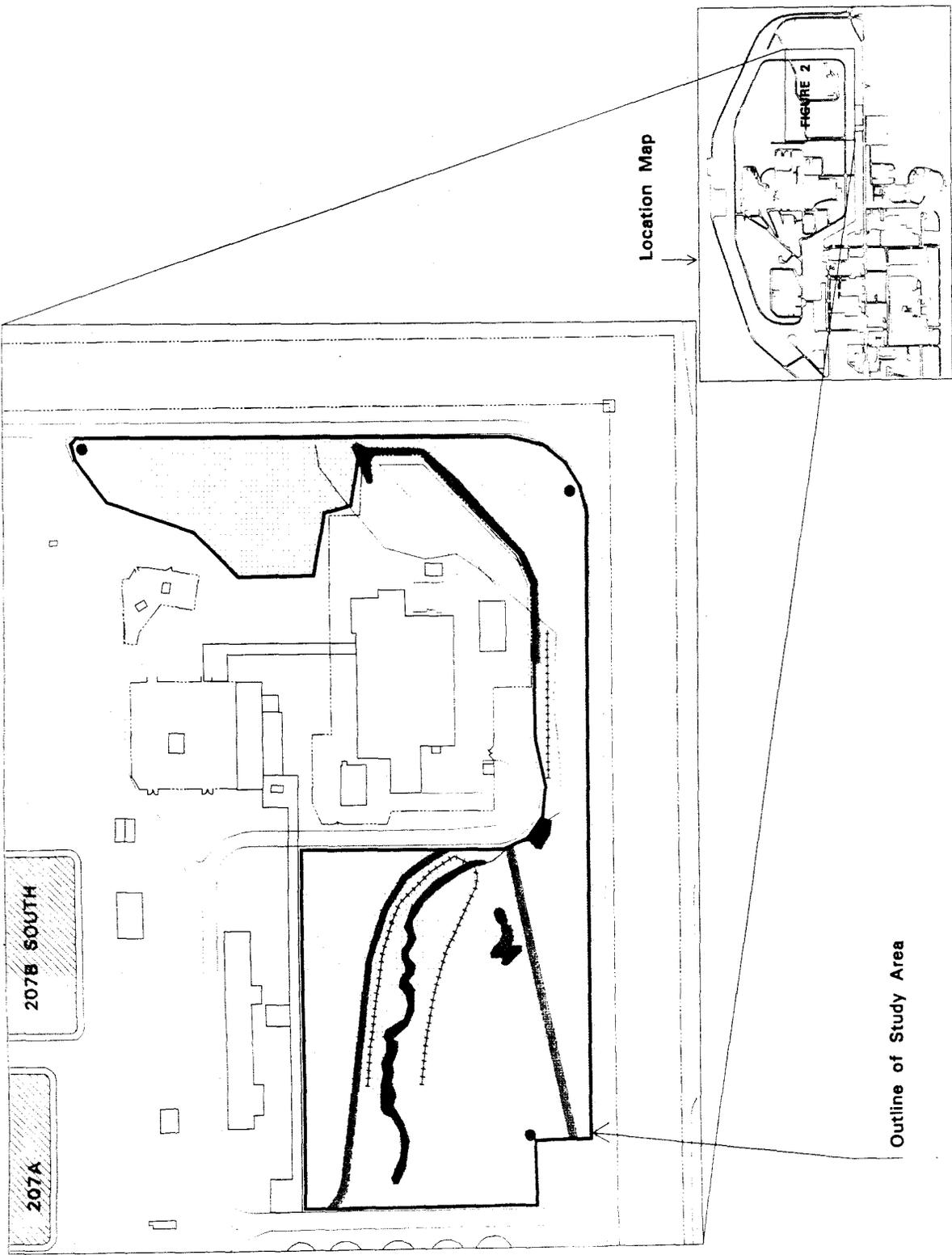
- Drainage
- Pond
- Buildings
- Fence
- Paved Road
- Sidewalk
- Rock
- Reclaimed Grassland
- Short Marsh
- Tall Marsh
- Disturbed
- Bare Ground
- Deciduous Woodland
- Disturbed/Reclaimed

- Outline of Study Area
- ... Small Mammal Trap Lines
- Bird Observation Points

Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 2
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
EAST DRAINAGE



Location Map

Outline of Study Area

207B SOUTH

207A

FIGURE 2



- Drainage
- ▨ Pond
- Buildings
- - - Fence
- Paved Road

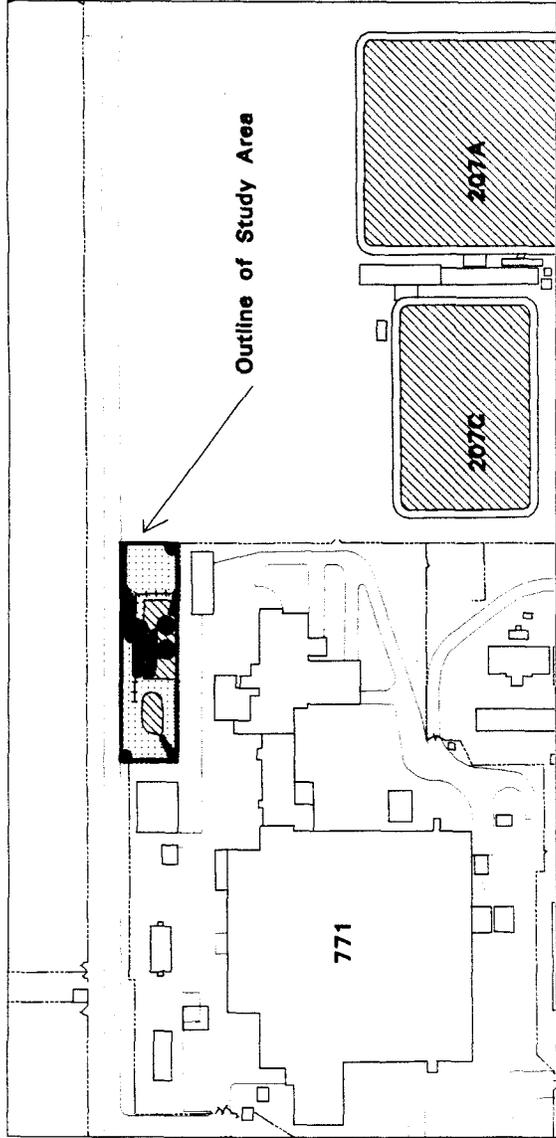
- Tank
- Short Marsh
- Tall Marsh
- ▨ Disturbed/Reclaimed

- Outline of Study Area
- Small Mammal Trap Lines
- Bird Observation Points

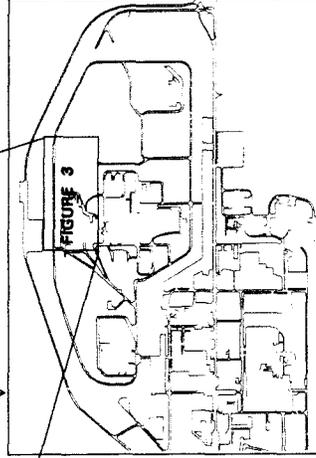
Scale: 1 inch = 150 feet

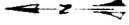
PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 3
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
NORTH POND AND SEEP



Location Map





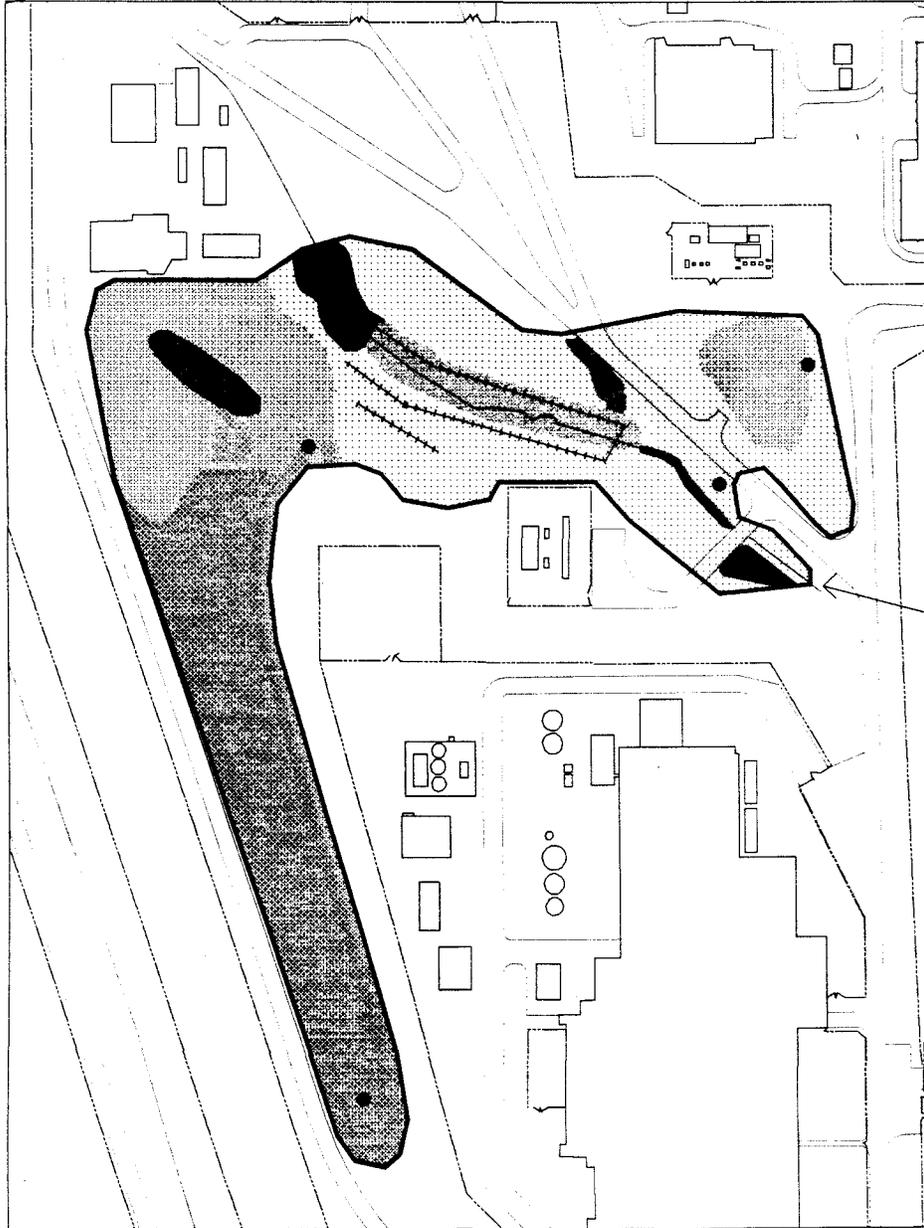
- Drainage
- Buildings
- Fence
- Paved Road
- Disturbed
- Bare
- Reclaimed Grassland
- Reclaimed/Disturbed
- Reclaimed/Mesic Grass
- Mesic Grassland
- Short Marsh
- Tall Marsh
- Deciduous Woodland
- Riparian Shrub
- Xeric/Mesic Grass

- Outline of Study Area
- Small Mammal Trap Lines
- Bird Observation Points

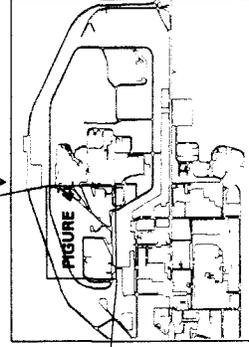
Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

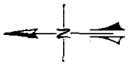
FIGURE 4
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
NORTHWEST DRAINAGE



Location Map



Outline of Study Area



- Drainage
- Buildings
- Fence
- Paved Road

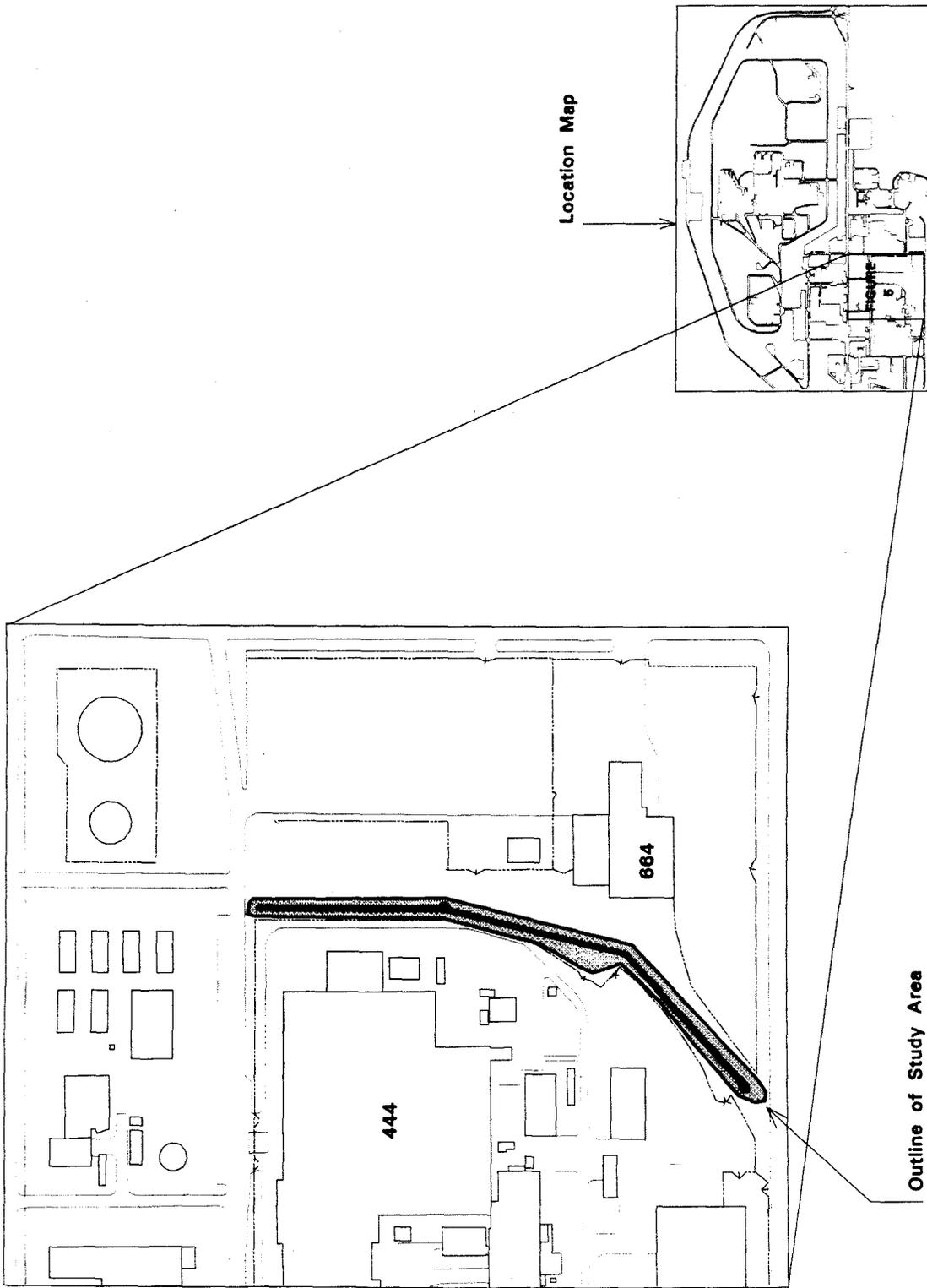
- Short Marsh
- Disturbed

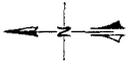
- Outline of Study Area
- Small Mammal Trap Lines
- Bird Observation Points

Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 3
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
WEST RAILROAD





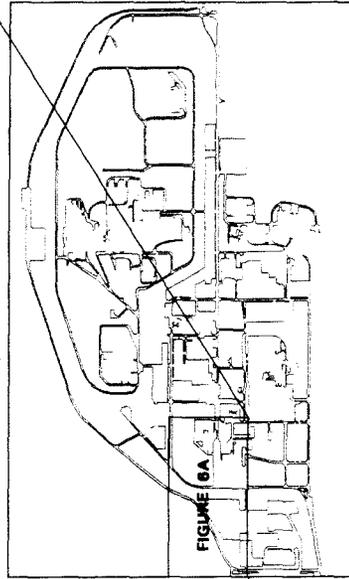
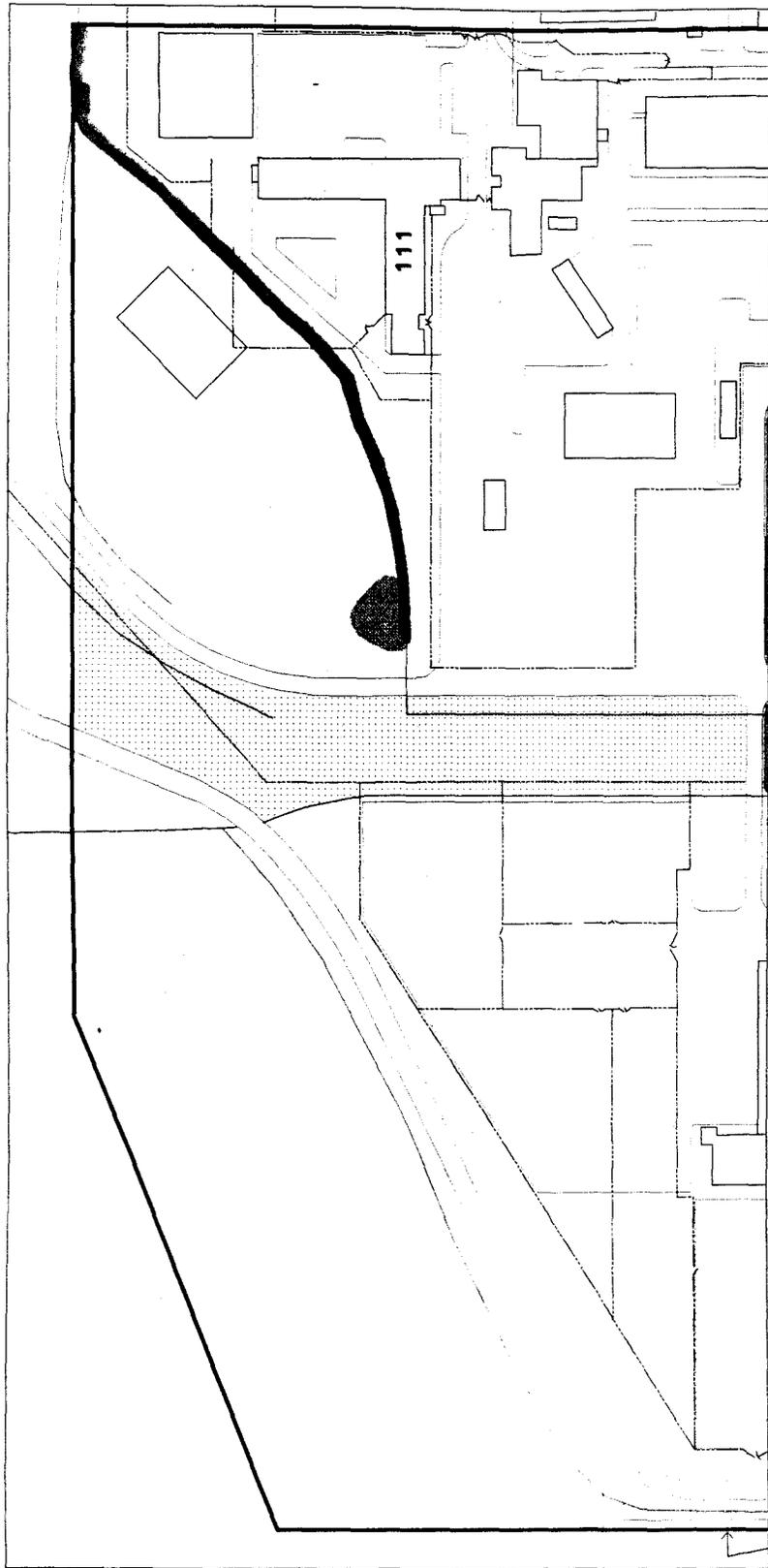
- Drainage
- Buildings
- Fence
- Paved Road
- Ornamental Trees
- Disturbed/Mesic Grass
- Short Marsh
- Tall Marsh

— Outline of Study Area

Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 6A
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
WEST AREA



Location Map

Outline of Study Area

FORM 5.10 RELEVE SURVEY DATA FORM

Plot (Releve) No. m-x grassland Date 10-14-93

Plot (Releve) Size variable (length by width in meters)

Community Type Mixed mesic/eric grassland - NW drainage

Comments/Phenology mid-fall bloom - seed set

Observers SAB

DAT

Field Notebook No.: JA04 page 2

Common Name & Species Code	Cover Class
1 st co Stipa comata	2, 1
2 Gusa Gutierrezia sarothrae	+, +
3 Ar lu Artemisia ludoviciana	+, 3
4 Ar lo Aristida longiseta	2, +
5 Poco Poa compressa	+, 2
6 Kaha Koleria pyramidata	1, 1
7 Er fl Erigeron flagellaris	1, +
8 Ange Andropogon gerardii	1, 1
9 Ansc Andropogon scoparia	2, 1
10 Cael Carex pleocharis	+, 2
11 Bocu Bouteloua curtipendula	+, 1
12 Bogr Bouteloua gracilis	1, 1
13 Htr Harbouria frachyleuca	+, +
14 Popr Poa pratensis	+, +
15 Esp Senecio spartioides	+, +
16 Dapa Dalea purpurea	+, +
17 Arca Artemisia campestris	+, +
18 Agle Achillea lanulosa	+, +
19 Mto Muhlenbergia torreyi	+, +
20 Ar fe (arvensis fendleri)	+, +
21 Raco Ratibida columnifera	+, +
22 Almi Alyssum minus	+, +
23 Trda Tridaxnagon dubius	+, +
24 Amps Ambrosia psilostachya	+, +
25 He vi Heterotheca villosa	+, +

5 = >75% 1 = <5%
 4 = 50 - 75% + = few
 3 = 25 - 50% r = solitary
 2 = 5 - 25%

Common Name & Species Code	Cover Class
26 Lemo Lesquerella montana	+, +
27 Viam Vicia americana	+, -
28 Bohi Bouteloua hirsuta	1, 1
29 Lipu Liatris punctata	+, +
30 Rozc Rosa acicularis	+, 1
31 Asp Aster porteri	+, +
32 Artr Artemisia frigida	+, +
33 Pste Psoralea tenuiflora	+, +
34 Stvi Stipa viridula	+, 1
35 Oxi Oxalis Oxypappus wisneri	+, +
36 Smoc Symphoricarpos occidentalis	+, +
37 Opec Opuntia compressa	+, +
38 Hean Helianthus annuus	+, +
39 Luse Lactuca scariola	+, +
40 Onmo Onosmodium molle	+, +
41 Paja Paronichia jamesii	+, +
42 Chfu Chenopodium Chenopodium fulcrata	+, +
43 Somi Solidago missouriensis	+, +
44 Yagl Yucca glauca	+, +
45 Hype Hypericum perforatum	+, +
46 Tat Taraxacum officinale	+, +
47 Gvsq Grindelia squarrosa	+, +
48 Ciun Cirsium undulatum	+, +
49 Ar fe arvensis fendleri	+, +
50 Spcr Sporobolus cryptandrus	+, +

51 Phhe Phacelia hederifolia +, -
 52 Kueu Kuhnia eupatorioides +, +
 53 Phvi Physalis virginiana +, +
 54 Canu Carduus nutans +, +
 55 St ro Stipa robusta +, +
 56 Ve th Verbascum thapsus +, +
 57 Pa vi Panicum virgatum +, +
 58 Ag sm Agropyron smithii +, +
 59 Ag sm Carex microcarpa +, +

① 21% slope
 24% aspect
 ② 137 asp
 12% slope
 1 Ponderosa p

80 El ca - +
 79 Elymus canadensis +
 Bromus tectorum +
 78 Pogt - +
 Potentilla gracilis +
 77 Ph he - +
 Physalis hederifolia +
 76 Gaa - +
 Galactia dysotis +
 75 - +
 74 - +
 73 - +
 67 - +
 68 - +
 Astragalus surtidanus +
 66 Somo - +
 70 - +
 71 - +
 72 - +
 60 - +
 61 - +
 62 - +
 63 - +
 64 - +
 65 - +
 66 - +

FORM 5.10 RELEVE SURVEY DATA FORM

Plot (Releve) No. 16 / main grassland Date 10-11-97
 Plot (Releve) Size √ (length by width in meters)
 Community Type Reclaimed grassland - Medic clonal - NW drainage extension
 Comments/Phenology N hillside W of NW drainage
 Observers DAT SAB Field Notebook No.: I 104 - P.2

Common Name & Species Code	*Cover Class
1 Phpr Phleum pratense	+
2 Popr Poa pratensis	1
3 Agin Agropyron intermedium	2
4 Bocu Bouteloua curtipendula	1
5 Ansc Andropogon scoparia	1
6 Hype Hypericum palmatum	+
7 Oebi Oenothera biennis	+
8 Phar P. arundinacea	+
9 Ansc	
10 POCO Poa compressa	+
11 Sper Sporobolus cryptandrus	+
12 Tavi Panicum virgatum	
13 Brin Bromus inermis	
14 Dagl Dactylis glomerata	
15 Agcy Agropyron cristatum	
16 Arku Artemisia ludoviciana	
17 Lasc Lactuca scariola	
18 Juba Juncus balticus	
19 Asp: Aster porteri	
20 Trida Tragopogon dubius	
21 edi Centaurea diffusa	
22 Oxi Oxalis dillenata	
23 Erdi Erigeron divergens	
24 H C Cr ss Prindelia squarrosa	
25 Weth Verbascum thapsus	

5 = >75% 1 = <5%
 4 = 50 - 75% + = few
 3 = 25 - 50% r = solitary
 2 = 5 - 25%

Common Name & Species Code	*Cover Class
26 Lipu Liatris punctata	
27 Agsm Agropyron smithii	
28 Ange Andropogon gerardii	1
29 Sesp Senecio spidioides	
30 Cusa Mulinum spidioides	
31 Arlo Aristida longiseta	
32 Mea Melilotus alba	1
33 Spoc Symphoricarpos occidentalis	
34 Acla Achillea lanulosa	
35 Canu Carduus nutans	
36 Ciar Cirsium arvense	1
37 Aasp Asclepias speciosa	
38 Rucr Rumex crispus	
39 Somo Solidago mollis	
40 Cent aria Phar ogalis	
41 Viam Vicia americana	
42 Hevi Heterotheca villosa	
43 Coza Conyza canadensis	
44 Elca Elymus canadensis	
45 Viola nuttalliana	
46 Ropy Rorippa palustris	
47 Meof Melilotus officinalis	
48 Hean Helianthus annuus	
49 Fasc Fallopia	
50 Almi Allysium minus	

51 Hatr Harbouria trachypleura
 52 Pogr Potentilla gracilis
 53 Taraxacum officinale
 54 Muhlenbergia torreyi
~~55 Phpr~~
 56 Eues
 57 Arca Artemisia campestris

Rose ac
 Pae ac
 ponderosa pine
 1 spruce seedling

65 Geri Geranium richardsonii
 66 Stco Stipa comata
 67 Muna Muhlenbergia montana
 68 Prja Paronchia jamesii
 69 Som Solidago missouriensis
 70 Onmo Onosmodium molle
 71 Sep Senecio platensis
 72 Pae
 73 Lile Linum lewisii

74 Bria Bromus japonicus
 75 Yucca glauca
 76 Lida Linaria clidm
 77 Raco Ratioidia columnaris
 78 Pese Penstemon secundiflorus
 79 Pese Penstemon
 80 Prvi Prunella virginiana
 81 Daba Dalea purpurea
 82 Arde Artemisia fendleri
 83 Chru Chrysoopsis fulcrata
 84 Casth Castilleja integra

FORM 5.10 RELEVE SURVEY DATA FORM

West grassland

Plot (Releve) No. XG

Date 10-15-93

Plot (Releve) Size various (length by width in meters)

Community Type serotinal grassland

Comments/Phenology

Observers SAB

DAT

Field Notebook No.:

Common Name & Species Code	*Cover Class
1 Ansc Andropogon scoparia	2, 2, 2
2 Bogr Bouteloua gracilis	2, 2, 1
3 Buda Buchleria dactyloides	+, +, 2
4 Meof Meof melilotus officinalis	+, +, +
5 Poco Poa compressa	2, 2, 3
6 Plla Plantago lanceolata	1, 1, 1
7 Muwr Muhlenbergia wrightii	1, -, 1
8 Aspo Aster porteri	+, +, 1
9 Lase Lactuca scariola	+, 1, 1
10 Amps Ambrosia psilostachya	1, 1, 1
11 Bocu Bouteloua curtipendula	1, 1, +
12 Mumo Muhlenbergia montana	1, +, +
13 Dapu Dalea purpurea	+, -, +
14 Lipu Liatris punctata	1, +, +
15 Spcr Sporobolus cryptandrus	+, -, +
16 Almi Alyssum minus	+, +, -
17 Pst e Psoralea tenuiflora	+, -, -
18 Plla Plantago patagonica	+, +, -
19 Bohi Bouteloua hirsuta	+, 1, +
20 Ange Andropogon gerardii	2, 3, 3
21 Arlo Aristida longiseta	+, -, +
22 Cedi Centaurea diffusa	+, +, +
23 Lemo Lesquerella montana	+, -, -
24 Tr du Tragopogon dubius	+, -, -
25 Arlu Artemisia ludoviciana	1, +, -

5 = >75% 1 = <5%
 4 = 50 - 75% + = few
 3 = 25 - 50% r = solitary
 2 = 5 - 25%

Common Name & Species Code	*Cover Class
26 Arca Artemisia campestris	+, -, -
27 Sihy Sitanion hystrix	+, -, +
28 Asvi ^{Acroptas viridis Florus} Green milkweed	+, -, -
29 Stco Stipa comata	+, -, -
30 Coar Co	+, +, +
31 Grsq Grindelia squarrosa	+, +, +
32 Paja Paronychia jamesii	+, -, -
33 Brja Bromus japonicus	+, -, +
34 Cacl Carex eleocharis	+, +, -
35 Aasm Agropyron smithii	+, -, -
36 Crfm Chrysopsis fulcrata	+, -, -
37 Somo Solidago mollis	+, -, -
38 Koma Koleria macrantha	+, -, -
39 Brte Bromus tectorum	+, -, +
40 Arfe Aristida fendleri	+, -, -
41 Vehr Verbena brachychaeta	+, +, -
42 Brin Bromus inermis	+, +, +
43 Erdi Erigeron divergens	+, -, +
44 Canu Carduus nutans	+, -, -
45 Ciar Cirsium arvense	+, +, -
46 Veth Verbascum thapsis	+, -, +
47 Meal Melilotus alba	+, +, +
48 Phvi Virginia grandiflora	-, +, -
49 Feov Festuca ovina	+, 2, 1
50 Dupa Dysodia papposa	-, +, +

51. Hean Helianthus annuus	-, +, -
52. Hype Hypericum perforatum	-, +, +
53. Erci Erodium cicutarium	-, +, +
54. Sela Scorzonera laciniata	-, +, -
55. Erf1 Erigeron flaggilaris	-, +, -
56. Popr Poa pratensis	-, +, -
57. Oebi Oenothera biennis	+, -, +
58. Taof Taraxacum officinalis	-, -, +
59. P... P... p... p...	-, -, +

① 15 blue spruce mowed annually
 some surficial soil disturbance
 flat slope + creeps

② small Prvi growing Blue spruce perimeter on west + north

Center-shelter belt
 Quvi 1st row west
 Elan 2nd row
 Pde 3rd row
 Pipo 4th row east
 Deer + rabbit +
 herbivory present

60. Ruer - - +
 61. Coar Rumer crispus +
 62. Holu Convolvulus arvensis +
 63. Muto Hordeum jubatum +
 Muhlenbergia torreyi

FORM 5.10 RELEVE SURVEY DATA FORM

Upper portion of
Northwest drainage
~~crest~~

Plot (Releve) No. SM-TM Date 10-15-93

Plot (Releve) Size irregular (length by width in meters)

Community Type Short marsh / tall marsh

Comments/Phenology _____

Observers SAB

DAT

Field Notebook No.: _____

Common Name & Species Code	*Cover Class
1 Poca <i>Poa compressa</i>	
2 Agr <i>Agropyron trachycalum</i>	
3 AAssp <i>Asclepias speciosa</i>	
4 Fepr <i>Festuca pratensis</i>	
5 Juba <i>Juncus balticus</i>	
6 Ciar <i>Cirsium arvense</i>	
7 Nece <i>Nepeta cataria</i>	
8 Scac <i>Scirpus acutus</i>	
9 Aast <i>Agrostis stolonifera</i>	
10 Rucr <i>Rumex crispus</i>	
11 Juef <i>Juncus effusus</i>	
12 Oebi <i>Oenothera biennis</i>	
13 Hean <i>Helianthus annuus</i>	
14 Eppa <i>Epilobium paniculatum</i>	
15 Tyla <i>Typha latifolia</i>	
16 Sepa <i>Scirpus pallidus</i>	
17 Popa <i>Poa palustris</i>	
18 Cane <i>Canex nebrascensis</i>	
19 Scac <i>Scirpus acutis</i>	
20 Elac <i>Eleocharis acicularis</i>	
21 Mear <i>Mentha arvensis</i>	
22 Agin <i>Agropyron intermedium</i>	
23 Ropa <i>Rorippa palustris</i>	
24 Seva <i>Scirpus validus</i>	
25 Phpr <i>Phleum pratensis</i>	

Common Name & Species Code	*Cover Class
26 Popr <i>Poa pratensis</i>	
27 Veth <i>Verbascum thapsis</i>	
28 Pavi <i>Panicum virgatum</i>	
29 Sesp <i>Senecio spartioides</i>	
30 Meof <i>Melilotus officinale</i>	
31 Meal <i>Melilotus alba</i>	
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	

① side banks w/
Prvi seedlings
weedy flora simil
to railroad site
Small inclusions of
TYLA
Short marsh gradi
to tall marsh first
down drainage
w/ Saam + fringe
of short marsh +
weedy species
Fringed by Saex as
we get to bottom
of drainage w/
Pode seedlings
end of surface draina
have ponded water
Tyla + Seva dominat.

5 = >75% 1 = <5%
4 = 50 - 75% + = few
3 = 25 - 50% r = solitary
2 = 5 - 25%

FORM 5.10 RELEVE SURVEY DATA FORM

Plot (Releve) No. TM Date 10-14-93
 Plot (Releve) Size irregular (length by width in meters)
 Community Type Tall marsh - NW drainage
 Comments/Phenology _____
 Observers SAB DIAT Field Notebook No.: JATON - page 2

Common Name & Species Code	*Cover Class
1 Tyla <i>Typha latifolia</i>	
2 Eppa <i>Cephalium paniculatum</i>	
3 SAEX <i>Salix exigua</i>	
4 ASSP <i>Asclepias speciosa</i>	
5 Fepr <i>Festuca pratensis</i>	
6 Gllc <i>Glycyrrhiza lepidota</i>	
7 BRIN <i>Bromus inermis</i>	
8 AGST <i>Agrostis stolonifera</i>	
9 CTAR (<i>Cirsium arvense</i> Canada thistle)	
10 AMER (<i>Amorpha fruticosa</i> Leadplant)	
11 JUBA <i>Juncus balticus</i>	
12 Seva <i>Scirpus validus</i>	
13 Alpr <i>Alopecurus pratensis</i>	
14 Popr <i>Poa pratensis</i>	
15 Naof <i>Rasturtium officinale</i>	
16 Hoju <i>Hordeum jubatum</i>	
17 Soar <i>Sonchus arvensis</i> Sowthistle	
18 Oebt <i>Oenothera biennis</i> Tall primrose	
19 Cuof (<i>Cynoglossum officinale</i> Ground Houndstongue)	
20 Cane <i>Carex nebraskensis</i>	
21 Rucr <i>Rumex crispus</i>	
22	
23	
24	
25	

Common Name & Species Code	*Cover Class
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	

① Spotty & disturbed thru area
 inclusions of short marsh in narrow tall marsh stand

5 = >75% 1 = <5%
 4 = 50 - 75% + = few
 3 = 25 - 50% r = solitary
 2 = 5 - 25%

FORM 5.10 RELEVE SURVEY DATA FORM

Plot (Releve) No. TM 1

Date 10-14-93

Plot (Releve) Size variable (length by width in meters)

Community Type Tall Marsh - E drainage

Comments/Phenology _____

Observers SAB

DAT

Field Notebook No.: TABU, Page 2

1- Aspect 26°
Slope 10°

2- Aspect 5°
Slope 40°

Common Name & Species Code	*Cover Class
1 Ty la <i>Typha latifolia</i>	x, x
2 Po de <i>Populus deltoides</i>	x, -
3 Ph pr <i>Phleum pratense</i>	x, -
4 Sa am <i>Salix amygdaloides</i>	x, -
5 El an <i>Elaeagnus angustifolia</i>	x, -
6 Sa ex <i>Salix exigua</i>	x, -
7 Po pr <i>Poa pratensis</i>	x, +
8 Me ar <i>Mentha arvensis</i>	x, +
9 Ec cr <i>Echinochloa crus-galli</i>	x, +
10 Ru or <i>Rumex crispus</i>	x, +
11 As sp <i>Asclepias speciosa</i>	x, +
12 De tr <i>Desmodium illinoense</i>	x
13 Cl ac <i>Eleocharis acicularis</i>	x, +
14 Vi ne <i>Viola nuttalliana</i>	x, +
15 Fa pr <i>Festuca pratensis</i>	x, +
16 Ag st <i>Agrostis stolonifera</i>	x, +
17 Cl ar <i>Cirsium arvense</i>	- , +
18 Ju ba <i>Juncus balticus</i>	- , +
19	
20	
21	
22	
23	
24	
25	

Common Name & Species Code	*Cover Class
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	

5 = >75% 1 = <5%
 4 = 50 - 75% + = few
 3 = 25 - 50% r = solitary
 2 = 5 - 25%

Oest

FORM 5.10 RELEVE SURVEY DATA FORM

Plot (Releve) No. TM 1

Date 8-14-93

Plot (Releve) Size Variable (length by width in meters)

Community Type North Pond - Tall Marsh

Comments/Phenology Fall-going dormant

Observers SAB DAT

Field Notebook No.: TA04, Page 2

Common Name & Species Code		*Cover Class	Common Name & Species Code		*Cover Class
1	Tyla Typha latifolia	x	26		
2	Ju ef Juncus effusus	x	27		
3	Al pa Alopocurus pratensis	x	28		
4	Ju to Juncus torreyi	x	29		
5	Sc am Scirpus americana	x	30		
6	Ec cr Echinochloa crus-gallii	x	31		
7	Po co Poa compressa	x	32		
8	Ho ju Hordeum jubatum	x	33		
9	Ep pa Epilobium paniculatum	x	34		
10	De st Denothera strigosa	x	35		
11	Sal am Salix amygdaloides	x	36		
12	Pe ma Persicaria maculatum	x	37		
13	Ju ef Juncus	x	38		
14	Ru cr Rumex crispus	x	39		
15	Na of Nasturtium officinale	x	40		
16	Pop de (seedling) Populus deltoides	x	41		
17	Coca Carex canadensis	x	42		
18	El ac Eleocharis acicularis	x	43		
19	Br ja Bromus japonicus	x	44		
20			45		
21			46		
22			47		
23			48		
24			49		
25			50		

5 = >75% 1 = <5%
 4 = 50 - 75% + = few
 3 = 25 - 50% r = solitary
 2 = 5 - 25%

FORM 5.10 RELEVE SURVEY DATA FORM

Plot (Releve) No. DC Date 11-14-93
 Plot (Releve) Size variable (length by width in meters)
 Community Type Deciduous woodland - NW drainage
 Comments/Phenology mid-fall
 Observers SAB DAI Field Notebook No.: IA01, Page 2

Common Name & Species Code	*Cover Class
1 <u>Pode</u> <i>Populus deltoides</i>	
2 <u>Saam</u> <i>Salix amygdaloides</i>	
3 <u>Saex</u> <i>Salix exigua</i>	
4 <u>T^{pa}</u> <i>Tamarix parviflora</i>	
5 <u>Ela</u> <i>Elaeagnus angustifolia</i>	
6 <u>Prvi</u> <i>Prunus virginiana</i>	
7 <u>DBH</u> - <u>Pode</u>	
8 <u>seedlings to 12"</u>	
9 <u>5 trees</u>	
10	
11 <u>slowing water</u>	
12 <u>good stream</u>	
13 <u>superior develop</u>	
14 <u>not weedy</u>	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	

Common Name & Species Code	*Cover Class
26 <u>Deciduous woodland</u>	
27	
28 <u>furthest south</u>	
29 <u>Saam</u>	
30 <u>Pode</u>	
31	
32 <u>several seedlings of Pode &</u>	
33 <u>Saam</u>	
34 <u>Saex also present</u>	
35	
36 <u>DBH 13"</u>	
37 <u>28' tall Pode</u>	
38	
39	
40 <u>100 x 35' area</u>	
41 <u>26 Pode</u>	
42 <u>DBH - 4 - 12"</u>	
43 <u>reclaimed grass - BETA dominant</u>	
44 <u>several young PRVI</u>	
45	
46	
47	
48	
49	
50	

5 = >75% 1 = <5%
 4 = 50 - 75% + = few
 3 = 25 - 50% r = solitary
 2 = 5 - 25%

FORM 5.10 RELEVE SURVEY DATA FORM

1- Slope 5°
2- Aspect 40°

Plot (Releve) No. DW-1

Date 10-14-93

Plot (Releve) Size _____ (length by width in meters)

Community Type Deciduous Woodland - East Drainage

Comments/Phenology _____

Observers SAB DAT Field Notebook No.: TAOU Page 2

Common Name & Species Code	*Cover Class
1 POPE Populus deltoides	15 stems
2 DBH seedlings from 8-15 inches	
3 small compact stand	
4 50 feet height	
5 60 x 35'	
6	
7	
8	
9 Ribes cereum	
10 Prunus virginiana	
11	
12 understory is reclaimed grassland	
13 w/ Brn as dominant	
14	
15 4 dead snags + downed	
16 trees	
17	
18	
19	
20	
21	
22	
23	
24	
25	

Common Name & Species Code	*Cover Class
26 Drainage (SE Area - east drainage)	
27	
28 Cottonwood seedlings + young trees (20-30')	
29 Kumian olives (15%)	
30 narrow band of wet meadow, short marsh (75)	
31 some patches of tall marsh (10%)	
32	
33 average 8-10 ft wide	
34 800 ft long (east to west)	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	

5 = >75% 1 = <5%
4 = 50-75% + = few
3 = 25-50% r = solitary
2 = 5-25%

FORM 5.10 RELEVE SURVEY DATA FORM

Plot (Releve) No. RG

Date 10-14-93

Plot (Releve) Size variable (length by width in meters)

Community Type Reclaimed grassland - NW drainage

Comments/Phenology mid-fall

Observers DAT SAB Field Notebook No.: IX04 - Page 2

1, 2, 3

Common Name & Species Code	*Cover Class
1 Ager <i>Agropyron cristatum</i>	1, 2, +
2 Agin <i>Agropyron intermedium</i>	3, -, -
3 Popr <i>Poa pratensis</i>	+, 1, +
4 stvi <i>Stipa viridula</i>	2, -, -
5 stro <i>Stipa robusta</i>	1, -, -
6 Trid <i>Tragopogon dubius</i>	+, +, +
7 Spcr <i>Sporobolus cryptandrus</i>	+, -, +
8 Ciar <i>Cirsium arvense</i>	1, +, +
9 Ansc <i>Andropogon scoparium</i>	+, -, +
10 Ostr <i>Oenothera strigosa</i>	+, -, +
11 Ros ^{ac} <i>Rosa acicularis</i>	2, -, -
12 Syoc <i>Symphoricarpos occidentalis</i>	1, -, +
13 Ario <i>Aristida longiseta</i>	+, -, -
14 Gvsg <i>Grindelia squarrosa</i>	+, +, +
15 Cand <i>Carduus nutans</i>	+, -, -
16 Boca <i>Bouteloua curtipendula</i>	+, -, +
17 Brin <i>Bromus inermis</i>	+, -, 4
18 Lase <i>Lactuca scariola</i>	+, +, +
19 Veth <i>Verbascum thapsus</i>	+, +, +
20 Dagl <i>Dactylis glomerata</i>	+, -, -
21 Pavi <i>Panicum virgatum</i>	+, -, -
22 Lida <i>Linaria dalmatica</i>	+, -, -
23 Almi <i>Alyssum minus</i>	+, +, +
24 Phpr <i>Phleum pratense</i>	-, 1, +
25 Me al <i>Melilotus alba</i>	-, 1, +

5 = >75% 1 = <5%
 4 = 50 - 75% + = few
 3 = 25 - 50% r = solitary
 2 = 5 - 25%

Common Name & Species Code	*Cover Class
26 Amps <i>Ambrosia psilostachya</i>	-, 1, +
27 Cadi <i>Centaurea diffusa</i>	-, +, -
28 Hevi <i>Heterotheca villosa</i>	-, +, -
29 Yebi <i>Verbascum blattaria</i>	-, +, +
30 Assp <i>Asclepias speciosa</i>	-, r, +
31 Asp <i>Aster porteri</i>	-, -, +
32 Arfr <i>Artemisia frigida</i>	-, -, +
33 Gile <i>(wild licorice)</i>	-, -, +
34 Meof <i>Melilotus officinalis</i>	-, -, +
35 Agst <i>(red top bent)</i>	-, -, +
36 Civi <i>(Bull thistle)</i>	-, -, +
37 Aspa	-, -, +
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	

① 29° aspect
87° slope

② 93°
22° slope
1 Podc
1 ELAN
1 SAAM
SEWAL SAEX

③ 53° Aspect
Slope 20

FORM 5.10 RELEVE SURVEY DATA FORM

Plot (Releve) No. 86

Date 10-14-93

Plot (Releve) Size ✓ (length by width in meters)

Community Type Reclaimed (disturbed) grassland complex - North Pond

Comments/Phenology late fall

Observers SJB

DAF

Field Notebook No.: I 104, Page 2

Common Name & Species Code	*Cover Class
1 Ag cr Agropyron cristatum	1
2 Br in Bromus inermis	2
3 Ag sm Agropyron Smithii	1
4 Ag in Agropyron intermedium	T
5 Me al Melilotus alba	1
6 Me of Melilotus officinale	1
7 Al mi Alyssum minus	T
8 Amps. Ambrosia psilostachya	T
9 Lact lactuca scariola	1
10 Po pr Poa pratensis	T
11 Po co Poa compressa	T
12 Tr du Tragopogon dubius	T
13 He vi Heterotheca villosa	T
14 Sp cr Sporobolus cryptandrus	1
15 Gr sq Grindelia squarrosa	T
16 Ar lo Aristida lehmannii	T
17 Er fl Erigeron flagellaris	T
18 Ce di Centaurea diffusa	T
19 Ve bl Verbascum blattaria	T
20 He an Helianthus annuus	R
21 As po Aster porteri	T
22 Ph pr Phleum pratense	T
23 Ag tr Agropyron trachypodium	T
24	
25	

Common Name & Species Code	*Cover Class
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	

5 = >75% 1 = <5%
 4 = 50 - 75% + = few
 3 = 25 - 50% r = solitary
 2 = 5 - 25%

FORM 5.10 RELEVE SURVEY DATA FORM

Plot (Releve) No. 1 - Date 10-14-93
 Plot (Releve) Size Irregular (length by width in meters)
 Community Type Reclaimed grassland - E drainage 0850
 Comments/Phenology Fall dormant, Aspect 299, 6% slope
 Observers SAB, DAT Field Notebook No.: 1104 Page 2

Common Name & Species Code	*Cover Class	Common Name & Species Code	*Cover Class
1 <u>Ag cr</u> <i>Agropyron cristatum</i> <i>sp. of wheatgrass</i>	4+, +, +	26 <u>Ve th</u> <i>Verbascum thapsus</i> <i>mullein</i>	- , - , + , +
2 <u>Gr se</u> <i>Lectura sericeola</i>	2-, +, +	27 <u>Gr po co</u> <i>Poa compressa</i> <i>C. filago</i>	- , - , +, -
3 <u>Co cr</u> <i>Convolvulus arvensis</i>	1-, +, -	28 <u>Po pr</u> <i>Poa pratensis</i> <i>R. blaugras</i>	- , - , +, +
4 <u>Gr og</u> <i>Grindelia squarrosa</i> <i>E. yellow</i>	3-, +, +	29 <u>Ther</u> <i>Thalictrum</i>	- , - , +, -
5 <u>Al mi</u> <i>Alyssum minus</i>	+ , - , - , -	30 <u>Ar po</u> <i>Aster porteri</i>	+ , - , +, +
6 <u>Br in</u> <i>Bromus inermis</i> <i>smooth brome</i>	2, 5, - , 5	31 <u>Ch fu</u> <i>Chrysopsis fulcrata</i>	- , - , +, -
7 <u>Amp s</u> <i>Ambrosia psilostachya</i>	+ , - , - , 1	32 <u>Hyp e</u> <i>Hypericum patulum</i> <i>St. Johnswort</i>	- , - , +, -
8 <u>Bo ca</u> <i>Bouteloua gracilis</i> <i>S. B. grass</i>	1 r, 3, -	33 <u>Gr Ci</u> <i>Eragrostis ciliatum</i> <i>stinkgrass</i>	- , - , +, -
9 <u>Bu da</u> <i>Buchloe dactyloides</i>	+ , - , - , -	34 <u>Sp cr</u> <i>Sporobolus cryptandrus</i> <i>Sand couch</i>	- , - , - , -
10 <u>Br ja</u> <i>Bromus japonicus</i>	+ , - , +, -	35 <u>GL LE</u> <i>Glycyrrhiza lepidota</i> <i>Wild licorice</i>	- , - , - , -
11 <u>Tr du</u> <i>Tragopogon dubius</i>	r, - , +, -	36 <u>Asp</u> <i>Asclepias speciosa</i> <i>showy milkweed</i>	- , - , - , +
12 <u>Me of</u> <i>Melilotus officinalis</i> <i>off. milk clover</i>	r, +, 1, -	37 <u>Fe ar</u> <i>Festuca arvensis</i>	- , - , - , -
13 <u>Ag in</u> <i>Agropyron intermedium</i> <i>int. wheatgrass</i>	+ , +, - , -	38 <u>Canu</u> <i>Carduus nutans</i> <i>Musk thistle</i>	- , - , - , -
14 <u>Ta of</u> <i>Taraxacum officinale</i>	+ , - , - , -	39 <u>Ar lo</u> <i>Aristida longiseta</i> <i>Red threeawn</i>	- , - , - , -
15 <u>Bo gr</u> <i>Bouteloua gracilis</i> <i>Bluegrass</i>	+ , - , - , -	40 <u>Ag sm</u> <i>Agropyron smithii</i> <i>Wheatgrass</i>	- , - , - , -
16 <u>Ca di</u> <i>Centaurea diffusa</i>	r, - , - , -	41 <u>Ag sm</u> <i>Agropyron smithii</i> x <i>Ag in</i>	- , - , - , -
17 <u>Cis ar</u> <i>Cisium arvense</i>	1/2+, +, +	42 <u>Dy pa</u> <i>Dysodia papposa</i> <i>Fetid madrigold</i>	- , - , - , -
18 <u>Ag st</u> <i>Agrostis striatifera</i> <i>red top</i>	- , +, - , -	43	
19 <u>Cit ar</u>	- , +	44	
20 <u>Ju ba</u> <i>Juncus balticus</i>	- , +, - , -	45	
21 <u>Ps or</u> <i>Psoralea tenuiflora</i> <i>slim scurvy pea</i>	- , +, - , -	46	
22 <u>Vi am</u> <i>Vicia americana</i>	+ , +, -	47	
23 <u>Me al</u> <i>Melilotus alba</i> <i>white milkweed</i>	+ , 1, -	48	
24 <u>He vi</u> <i>Hemerocilla villosa</i> <i>leaving aster</i>	- , +, +, -	49	
25 <u>Li da</u> <i>Linaria dalmatica</i>	- , +, -	50	

① aspect 142 slope 10%
 ② aspect 277 slope 20% disturbed waxy/grass mix
 ④ aspect 1040 slope 3-50 North-facing Stumped
 ⑤ aspect 1490 slope 5° south-facing completely disturbed

5 = >75% 1 = <5%
 4 = 50-75% + = few
 3 = 25-50% r = solitary
 2 = 5-25%

SMALL MAMMAL
LIVE TRAPPING DATA FORM

EE6A

Site East Drainage EG&G Project No. _____

Page 1 of 1

Date Oct 14 1993 Time: 0932

Grid or Line No. LINE # 1 (1-20); #2 (21-40) Grid/Line Size 40 Traps

Temperature (°C) 25.0° F Wind Speed < 5 mph Cloud Cover (%) 70%

Habitat Type(s) Reclaimed Grassland - 1st 30 traps / Disturbed #31-40

Comments Cool nights

Observer(s)/Field Notebook No.(s): Joe Merino / Grace Bevert

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
1	Per. Man. PEMA1	N/A	M	J Subad	N	9	60	53	
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13	Prairie Vole moco1	N/A	M	Ad	N	55	120	40	
14									
15									
16									
17									
18									
19									
20									
24	PER MAN PEMA1	N/A	M	J Subad	N	10g	65	67	
38	PEMA1	N/A	M	J Subad	N	11g	65	70	

Handwritten note: #1 (side of 1992 bag)

Completed by: JOE MERINO *Joe M Merino* 10/14/93

Subcontractor: RUST

SMALL MAMMAL
LIVE TRAPPING DATA FORM

EE6A

Site East Drainage EG&G Project No. _____

Page 1 of 3

Date Oct 15, 1993 Time: 0835

Grid or Line No. #1 (1-30) Grid/Line Size 10 traps

Temperature (°C) 24.5 F Wind Speed < 5 mph Cloud Cover (%) 60%

Habitat Type(s) Reclaimed / Disturbed grassland

Comments Frost on traps in drainage

Observer(s)/Field Notebook No.(s): Joe Merino / ~~Neil S.~~ NEIL S.

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	Optional Length		Other/Moon Phase
							Head & Body	Tail	
1	Rei Meg REME1	N	F	SB	N	13	62	62	
2	-								
3	Mic Orc - ^{MIOC 1} dead in trap	N	M	A	N	34	96	35	
4	-								
5	-								
6	-								
7	-								
8	-								
9	-								
10	Mic Orc MIOC 1	N	M	A	N	50	97	38	
11	Mic Rei Meg REME 1 ⁵ Plan - 2 in trap	N	M	J	N	8	56	53	
12	-								
13	Mic Orc - ^{MIOC 1} Recap	N	M	A	N	34	103	32	
14	Pet Man PEMA 1 ^{WANT 10-20-93}	N	M	JASB	N	11	68	65	
15	-								

Completed by: JOE MERINO Joe Merino 10-15-93

Subcontractor: RUST

SMALL MAMMAL
LIVE TRAPPING DATA FORM

EE6A

Site East Drainage EG&G Project No. _____

Page 1 of 3

Date 16 Oct '93 Time: 8:30

Grid or Line No. #1 (1-30) Grid/Line Size 30 traps

Temperature (°C) 3 45° F Wind Speed < 5 mph Cloud Cover (%) 85%

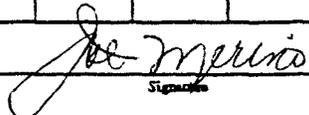
Habitat Type(s) Reclaimed Grassland / ~~Disturbed~~

Comments

frost on traps - cool nights

Observer(s)/Field Notebook No.(s): JOE MERINO / WENDY JOHNSON

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
1	Per. MAN. FEMALE	N	M	J	N	9	60	55	
2	---								
3	---								
4	---								
5	---								
6	---								
7	---								
8	---								
9	---								
10	---								
11	---								
12	---								
13	---								
14	---								
15	---								

Completed by: JOE MERINO  10-16-93

Subcontractor: _____

SMALL MAMMAL
LIVE TRAPPING DATA FORM

EE6A

Site East Drainage EG&G Project No. _____
 Page 2 of 3
 Date 10-16-93 Time: _____
 Grid or Line No. Line #1 (1-30) Grid/Line Size 30' x 40'
 Temperature (°C) _____ Wind Speed _____ Cloud Cover (%) _____
 Habitat Type(s) _____
 Comments (See pg 1 of 3)

Observer(s)/Field Notebook No.(s): JOE MERINO / ~~XXXXXXXXXX~~ WENDY JOHNSON

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
16	—								
17	Per. Man FEMA 1	N	M	J	N	8	58	55	
18	—								
19	—								
20	—								
21	—								
22	Per. Man FEMA 1	N	M	J	N	8	53	55	
23	—								
24	—								
25	—								
26	MIC DRC MIOCA 1	N	F	J	N	15	78	23	
27	—								
28	—								
29	—								
30	—								

Completed by: JOE MERINO Joe Merino 10-16-93
Print Name Signature Date

Subcontractor: _____

SMALL MAMMAL
LIVE TRAPPING DATA FORM

EE6A

Site NW Drainage EG&G Project No. _____
 Page 1 of 2
 Date Oct 19 1993 Time: 0920
 Grid or Line No. #1 (1-20) Grid/Line Size 20 traps
 Temperature (°C) _____ Wind Speed _____ Cloud Cover (%) _____
 Habitat Type(s) _____
 Comments (See pg 2 of 2)

Observer(s)/Field Notebook No.(s): J Merino/Neil S.

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
1	-								
2	-								
3	-								
4	-								
5	trapped								
6	-								
7	-								
8	-								
9	-								
10	-								
11	-								
12	-								
13	-								
14	Per Man PEMA 1	N	M	JSB	N	11	58	55	
15	Mic Orc MIOC 1	N	F	A	R	43	108	36	
16	-								
17	Mic Orc MIOC 1	N	F	SA	N	28	98	26	
18	-								
19	-								
20	-								

Completed by: JOE MERINO Joe Merino 10-15-93
Print Name Signature Date

Subcontractor: RUST

SMALL MAMMAL
LIVE TRAPPING DATA FORM

EE6A

Site NW Drainage EG&G Project No. _____
 Page 2 of 2
 Date Oct 15 1993 Time: 0915
 Grid or Line No. #2 (21-40) Grid/Line Size 20 traps
 Temperature (°C) 45.5°F Wind Speed <5 mph Cloud Cover (%) 60
 Habitat Type(s) Reclaimed Grassland/Riparian
 Comments Traps set close to drainage

Observer(s)/Field Notebook No.(s): Joe Merino / Neil S

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
21	-								
22	-								
23	-								
x 24	Per Man PEMA 1	N	M	J	N	8	58	53	
25	-								
x 26	Per Man - dead in trap PEMA 1	N	F	A	N	20	73	67	
27	-								
28	-								
29	-								
30	-								
31	-								
32	-								
33	-								
34	-								
35	-								
36	-								
37	-								
38	-								
39	-								
40	-								

Completed by: JOE MERINO Joe Merino 10-15-93
Print Name Signature Date

Subcontractor: RVST

SMALL MAMMAL
LIVE TRAPPING DATA FORM

EE6A

Site NW Drainage EG&G Project No. _____
 Page 1 of 2
 Date 16 OCT 1993 Time: 0940
 Grid or Line No. Line # 1 (1-20) Grid/Line Size 20
 Temperature (°C) 25.0° F Wind Speed 2.5 mph Cloud Cover (%) 75
 Habitat Type(s) Riparian & Disturbed/Reclaimed
 Comments Traps close to drainage

Observer(s)/Field Notebook No.(s): Joe Merino / Wendy Johnson

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
1	—								
2	—								
3	—								
4	—								
5	Per mey RENEI	N	F	SA	N	6	52	42	
6	—								
7	—								
8	—								
9	MIC OTC MIOTL	N	F	A	N	37	112	40	
10	—								
11	—								
12	—								
13	—								
14	—								
15	—								
16	—								
17	MIC OTC MIOTL	N	M	SA	N	23	88	27	
18	—								
19	—								
20	—								

Completed by: JOE MERINO *Joe Merino* 10-16-93
Print Name Signature Date

Subcontractor: RUST

SMALL MAMMAL
LIVE TRAPPING DATA FORM
EE6A

Site NW Drainage EG&G Project No. _____
 Page 2 of 3
 Date 16 OCT '93 Time: _____
 Grid or Line No. Line #2 (21-40) Grid/Line Size 20 traps
 Temperature (°C) _____ Wind Speed _____ Cloud Cover (%) _____
 Habitat Type(s) _____
 Comments (See Sheet #1) for this date

Observer(s)/Field Notebook No.(s): Joe Merino / Wanda Johnson

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
21	—								
22	—								
23	— bait gone								
24	—								
25	—								
26	—								
27	—								
28	—								
29	—								
30	—								
31	—								
32	— bait gone								
33	—								
34	—								
35	—								
36	—								
37	—								
38	—								
39	—								
40	—								

Completed by: JOE MERINO Joe Merino 18-16-93
Print Name Signature Date
 Subcontractor: RUST

SMALL MAMMAL
LIVE TRAPPING DATA FORM

EE6A

Site WEST ~~1A~~ AREA EG&G Project No. _____

Page 1 of 1

Date OCT 14 1993 Time: 8:57 AM

Grid or Line No. #1 (1-10) #2 (11-20) Grid/Line Size 20 TRAPS

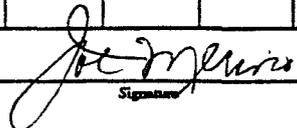
Temperature (°C) ≈ 55°F Wind Speed 5 mph Cloud Cover (%) 75

Habitat Type(s) XERIC GRASSLAND

Comments No traps tripped but #3. All bait in traps
No captures. LINE #1 (1-10); Line #2 (11-20)

Observer(s)/Field Notebook No.(s): JOE MERINO / BRUCE BEVORT

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
1	—								
2	—								
3	— tripped								
4	—								
5	—								
6	—								
7	—								
8	—								
9	—								
10	—								
11	—								
12	—								
13	—								
14	—								
15	—								
16	—								
17	—								
18	—								
19	—								
20	—								

Completed by: JOE MERINO  10-18-93

Subcontractor: RUST

SMALL MAMMAL
LIVE TRAPPING DATA FORM

EE6A

Site WEST AREA EG&G Project No. _____
 Page 2 of 2
 Date Oct 15, 1993 Time: 10:20 AM
 Grid or Line No. #1 (1-10) #2 (11-20) Grid/Line Size _____
 Temperature (°C) 60°F Wind Speed 5 mph Cloud Cover (%) 60
 Habitat Type(s) XERIC GRASSLAND
 Comments _____

Observer(s)/Field Notebook No.(s): JOE MERINO

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
1	—								
2	—								
3	—								
4	—								
5	—								
6	—								
7	—								
8	—								
9	—								
10	—								
11	Per man PEMA1	N	F	JA	N	13	60	BROKEN OFF	
12	Per man PEMA 1	N	M	SA	N	17	70	55	
13	—								
14	—								
15	—								
16	—								
17	—								
18	—								
19	—								
20	—								

Completed by: JOE MERINO
Print Name

Joe Merino
Signature

10-15-93
Date

Subcontractor: BUST

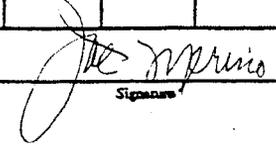
SMALL MAMMAL
LIVE TRAPPING DATA FORM

EE6A

Site Wast Area EG&G Project No. _____
 Page 1 of 1
 Date 16 - Oct '93 Time: 7:30 AM
 Grid or Line No. #1 (1-10) #2 (11-20) Grid/Line Size _____
 Temperature (°C) 25.5°F Wind Speed 5-10 mph Cloud Cover (%) 65
 Habitat Type(s) XERIC GRASSLAND
 Comments COOL ? BREEZY

Observer(s)/Field Notebook No.(s): JOE MERINO / WENDY JOHNSON

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
1	-								
2	-								
3	-								
4	-								
5	-								
6	-								
7	-								
8	-								
9	-								
10	-								
11	-								
12	-								
13	-								
14	-								
15	-								
16	-								
17	-								
18	-								
19	-								
20	-								

Completed by: JOE MERINO  16-16-93
Print Name Signature Date

Subcontractor: ROST

SMALL MAMMAL
LIVE TRAPPING DATA FORM

Site West South RR Tracks EE6A _____ EG&G Project No. _____
 Page 1 of 1
 Date Oct 14 1993 Time: 1340
 Grid or Line No. #1 (1-20) Grid/Line Size 20 traps
 Temperature (°C) 40-45°F Wind Speed < 5 mph Cloud Cover (%) 60
 Habitat Type(s) DISTURBED/RECLAIMED w/ SHORT MARSIT
 Comments No traps triggered - No ball taken closed all traps
 Observer(s)/Field Notebook No.(s): JOE MERINO/ BRUCE BEVET

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
1	—								
2	—								
3	—								
4	—								
5	—								
6	—								
7	—								
8	—								
9	—								
10	—								
11	—								
12	—								
13	—								
14	—								
15	—								
16	—								
17	—								
18	—								
19	—								
20	—								

Completed by: JOE MERINO Joe Merino 10-13-93
Print Name Signature Date
 Subcontractor: RUST

SMALL MAMMAL
LIVE TRAPPING DATA FORM

Site West RR Tracks EE6A _____ EG&G Project No. _____
 Page 1 of 1
 Date Oct 15, 1993 Time: 10:05 AM
 Grid or Line No. #1 Grid/Line Size 20 traps
 Temperature (°C) ~ 60°F Wind Speed < 5 mph Cloud Cover (%) 60
 Habitat Type(s) RECLAIMED GRASSLAND w/ SHORT MARSH
 Comments _____

Observer(s)/Field Notebook No(s): JMERINO

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
1	-								
2	-								
3	-								
4	-								
5	-								
6	-								
7	-								
8	-								
9	-								
10	-								
11	✓								
12	-								
13	-								
14	-								
15	✓								
16	-								
17	-								
18	-								
19	-								
20	-								

Completed by: JSE MERINO JSE Merino 10-16-93
Print Name Signature Date

Subcontractor: RUST

SMALL MAMMAL
LIVE TRAPPING DATA FORM

Site West RR Tracks EE6A _____ EG&G Project No. _____
 Page 1 of 1
 Date 16-Oct 93 Time: 1045
 Grid or Line No. #1 (1-20) Grid/Line Size _____
 Temperature (°C) 24.5° F Wind Speed ~5 mph Cloud Cover (%) 10%
 Habitat Type(s) RECLAIMED GRASSLAND w/ SHORT MARSH
 Comments _____

Observer(s)/Field Notebook No.(s): JOE MERINO / WENDY JOHNSON

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
1	-								
2	-								
3	-								
4	-								
5	-								
6	-								
7	-								
8	-								
9	-								
10	-								
11	-								
12	<u>Peromyscus RENE 1</u>	<u>N</u>	<u>F</u>	<u>J</u>	<u>N</u>	<u>7</u>	<u>62</u>	<u>61</u>	
13	-								
14	-								
15	-								
16	-								
17	-								
18	-								
19	-								
20	-								

Completed by: JOE MERINO Joe Merino 10-16-93
Print Name Signature Date

Subcontractor: BUST

SMALL MAMMAL
LIVE TRAPPING DATA FORM

Site POND AND SEEP EE6A _____ EG&G Project No. _____
 Page 1 of 1
 Date 16 OCT 93 Time: 0915
 Grid or Line No. #1 Grid/Line Size 10 traps
 Temperature (°C) 4 45°F Wind Speed 2.5 mph Cloud Cover (%) 60
 Habitat Type(s) RECLAIMED w/ TALL & SHORT MARSH
 Comments _____

Observer(s)/Field Notebook No.(s): JOE MERINO/WENDY JOHNSON

Trap No.	Species	Marked Y/N	Sex	Age Class	Repro	Wt(g)	(Optional) Length		Other/Moon Phase
							Head & Body	Tail	
1	mic. ORC	N	F	A	N	39	100	35	
2	mic ORC	N	F	^W BSA	N	28	100	27	
3	—								
4	dead Per man ^{caught tail in trap}	N	M	SA	Y	11	65	68	
5	—								
6	— MUSKRAT —								BATT GONE
7	—								
8	—								
9	—								
10	—								

Completed by: JOE MERINO Joe Merino 10-16-93
Print Name Signature Date
 Subcontractor: RUST

DRAFT

ADDENDUM TO THE PHASE I DATA
SUMMARY INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION

ROCKY FLATS PLANT
INDUSTRIAL AREA
(OPERABLE UNIT NOS 8, 9, 10, 12, 13 and 14)

US DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL MANAGEMENT PROGRAM

NOVEMBER 1993

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1.0 INTRODUCTION	1-1
2.0 BIRD SURVEY	2-1
3.0 REFERENCES	3-1

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>
1	BIRD SPECIES OBSERVED IN THE INDUSTRIAL AREA DURING A THREE DAY SURVEY, OCTOBER 28 TO NOVEMBER 8, 1993

LIST OF FIGURES

<u>Figure</u>	<u>Title</u>
1	INDUSTRIAL AREA ENVIRONMENTAL EVALUATION EAST DRAINAGE
2	INDUSTRIAL AREA ENVIRONMENTAL EVALUATION NORTH POND AND SEEP
3	INDUSTRIAL AREA ENVIRONMENTAL EVALUATION NORTHWEST DRAINAGE
4	INDUSTRIAL AREA ENVIRONMENTAL EVALUATION WEST RAILROAD
5	INDUSTRIAL AREA ENVIRONMENTAL EVALUATION WEST AREA

APPENDICES

APPENDIX A - SONG BIRD SURVEY

1.0 INTRODUCTION

This document is an addendum to the Phase I Data Summary (DOE, 1993a) that was submitted on October 27, 1993. The Phase I Data Summary and this addendum are intended to satisfy the Work Plan requirements for the Industrial Area Environmental Evaluation (IAEE). The bird survey was not conducted during the original field program because of access restrictions. Field activities were performed as outlined in the IAEE Field Sampling Plan (DOE, 1993b). The purpose of this addendum is to briefly summarize field activities and results of the bird survey.

The bird survey was conducted late in the Fall. Bird species had completed their nesting activities and young had left the nests. Fall migration had commenced and many species, such as Say's Phoebe, had left or were leaving the area to winter elsewhere, while others remained as year-round residents such as the Starling. The purpose of the bird survey was to identify those species presently within the Industrial Area.

All surveys and investigations followed the Ecology Standard Operating Procedures prepared by EG&G (EG&G, 1992a and 1992b).

2.0 BIRD SURVEY

The IAEE bird survey was conducted between 8:00 a.m. and 11:00 a.m. hours on three separate mornings from October 28 to November 8, 1993. The following areas were surveyed:

- East Drainage;
- North Pond and Seep;
- Northwest Drainage;
- West Railroad; and
- West Area.

Birds within each study area were identified by first traversing and then locating birds from an observation point. All birds were identified and a statement was entered into the log book to note the birds' activity when observed. Approximately 30 minutes were spent at each study area except at the North Pond and Seep and West Railroad where 10 minutes were spent in observations. Figures 1 through 5 show observation locations and traverse routes for each study area.

The weather during the survey periods was generally cool and breezy. During the first two survey periods, the sky was overcast and snow was forecast for the following day. On the last day of the survey the temperature was at 32°F but the sky was clear. The majority of birds were observed in willows and trees in the drainage. Few birds were observed flying or perched on fences or telephone wires.

A total of 14 species were observed in the five study areas combined, and these observations are summarized in Table 1. This list includes birds seen flying overhead and those using the habitat within the study area. The most abundant bird was the European Starling which generally occurred in small groups flying overhead or feeding around a trash bin in the West Area. The most diverse assemblage of birds occurred in the Northwest Drainage study area. Most of the birds were observed feeding or perched in the willows or Russian olive trees. No birds were observed in and around the West Railroad, and only two species were identified within the North Pond and Seep.

One interesting observation was that of the Brown-capped race of the Rosey Finch which spends summers at higher elevations and had moved down into the IA for the winter. This species and the Slate-colored race of the Dark-eyed Junco were abundant in the Northwest Drainage study area. Another interesting observation was that of a Ferruginous Hawk flying overhead at the Northwest Drainage. This species is a Federal Category 2 species.

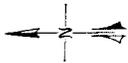
3.0 REFERENCES

- DOE, 1993a. Phase I Data Summary Industrial Area Environmental Evaluation. Rocky Flats Plant. Draft. October, 1993.
- DOE, 1993b. *Industrial Area Environmental Evaluation Field Sampling Plan*. Rocky Flats Plant. October 15, 1993.
- EG&G, 1992a. *Standard Operating Procedures Manual, Volume V, Ecology, Manual No. 5-21200-OPS-EE*. Golden, Colorado. EG&G Rocky Flats, Inc. (Currently undergoing review).
- EG&G, 1992b. *Standard Operating Procedures Manual, Volume I, Field Operations, Manual No. 5-2100-OPS-FO*. Golden, Colorado. EG&G Rocky Flats, Inc. (revision 5/12/92).
- Robbins, C.S., B. Brun, and H.S. Zim. 1966. *Birds of North America*. Western Publishing Co., Inc., Golden Press, NY, p. 340.

TABLE 1
BIRD SPECIES OBSERVED IN THE INDUSTRIAL AREA
DURING A THREE DAY SURVEY -- OCTOBER 28 TO NOVEMBER 8, 1993

SPECIES	EAST DRAINAGE	NO. POND & SEEP	NORTHWEST DRAINAGE	WEST RAILROAD	WEST AREA
Raven	4	0	0	0	2
Rock Dove	2	3	3	0	0
House Finch	5	0	6	0	0
Cassin's Finch	0	0	1	0	0
Starling	9	4	0	0	20
American Robin	0	0	0	0	2
House Sparrow	2	3	0	0	0
Vesper Sparrow	0	1	8	0	3
Dark-eyed Junco (slate-colored race)	0	0	8	0	3
Rosey Finch (Brown-capped race)	0	0	3	0	0
Unknown Sparrows*	0	0	11	0	0
American Kestrel	1	0	0	0	1
Ferruginous Hawk	0	0	1	0	0
Herring Gull	1	0	1	0	0
TOTAL BIRDS	24	11	41	0	30
TOTAL SPECIES	7	4	9	0	6
SPECIES USING HABITAT AND NOT FLYING OVERHEAD	3	2	6	0	5

* These sparrows were deep into the willows and could not be identified with certainty.



- Drainage
- Pond
- Buildings
- Fence
- Paved Road
- Tank
- Short Marsh
- Tall Marsh
- Disturbed/Reclaimed

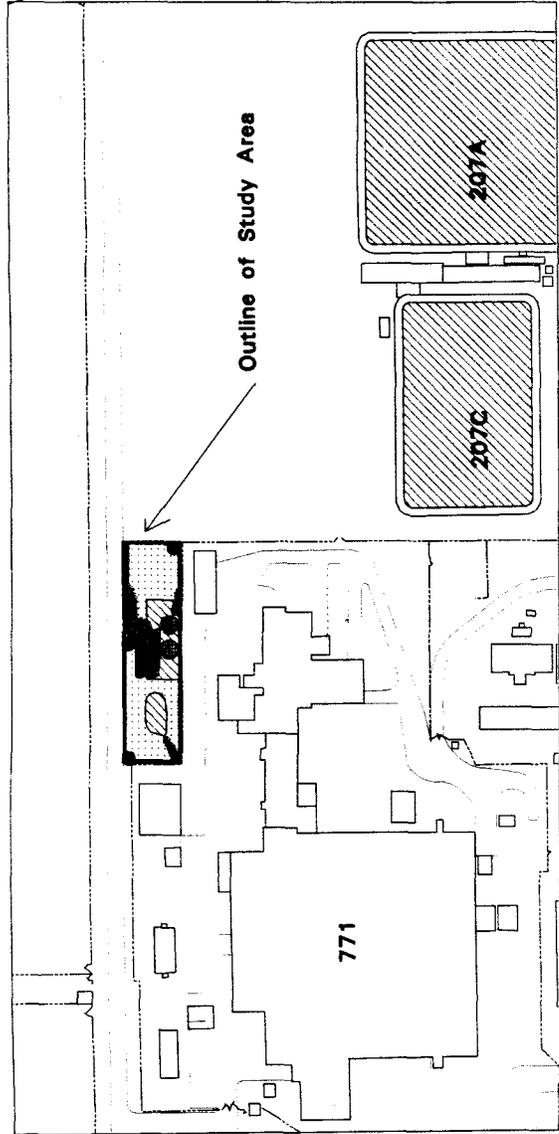
— Outline of Study Area

● Bird Observation Points

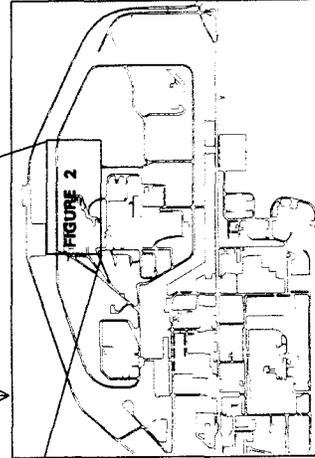
Scale: 1 inch = 150 feet

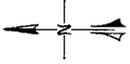
PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 2
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
NORTH POND AND SEEP



Location Map





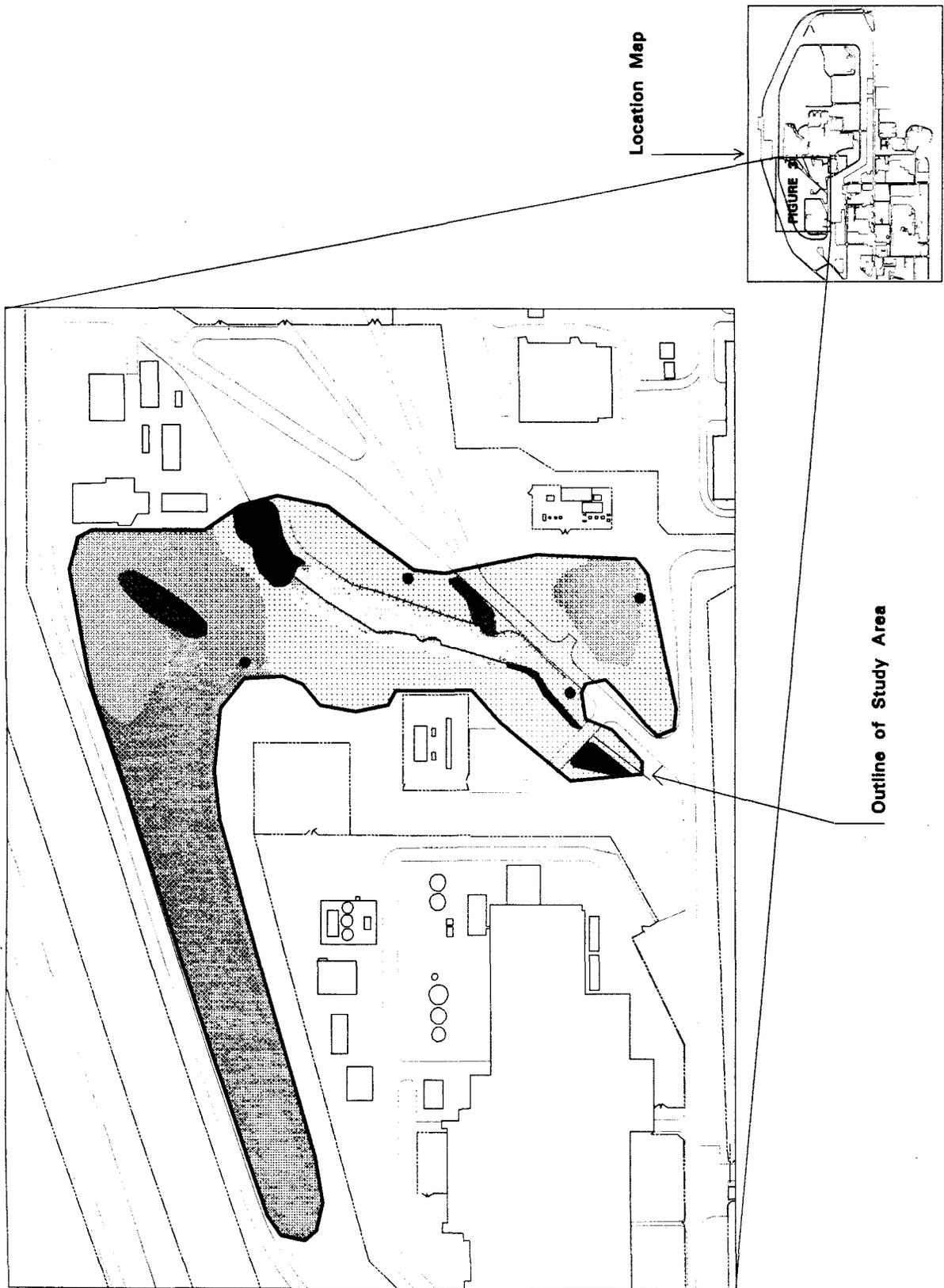
- Drainage
- Buildings
- Fence
- Paved Road
- Disturbed
- Bare
- Reclaimed Grassland
- Reclaimed/Disturbed
- Reclaimed/Mesic Grass.
- Mesic Grassland
- Short Marsh
- Tall Marsh
- Deciduous Woodland
- Riparian Shrub
- Xeric/Mesic Grass.

- Outline of Study Area
- Traverse Route
- Bird Observation Points

Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY MOUNTAIN PLANT
GOLDEN, COLORADO

FIGURE 3
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
NORTHWEST DRAINAGE



Outline of Study Area

Location Map



--- Drainage
 □ Buildings
 --- Fence
 --- Paved Road

■ Short Marsh
 ▨ Disturbed

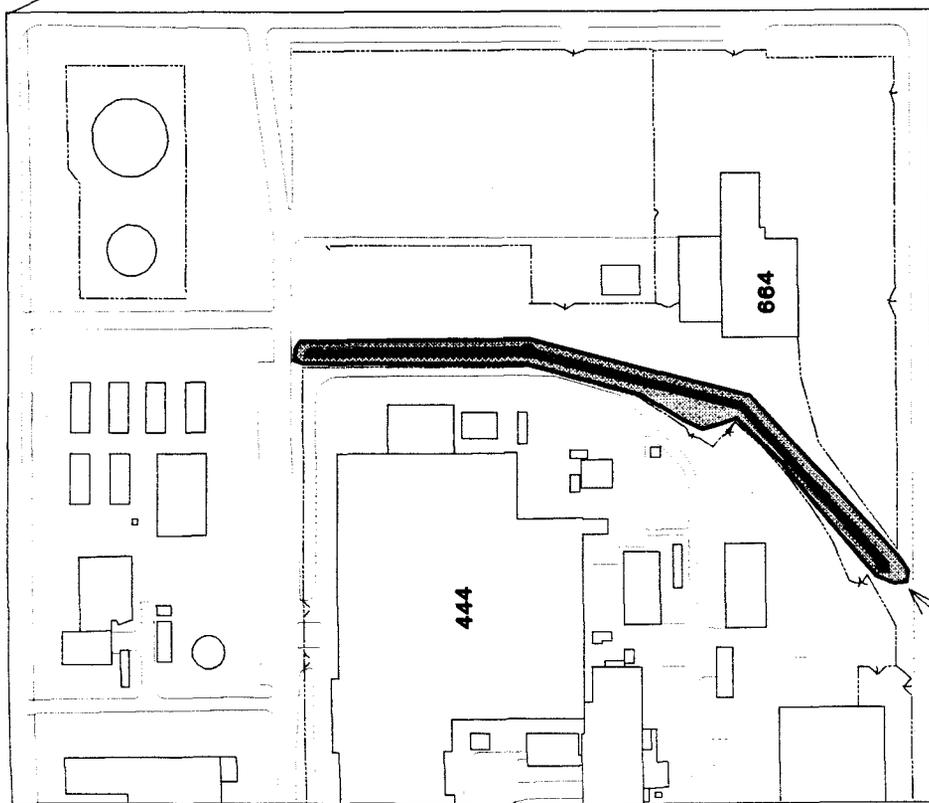
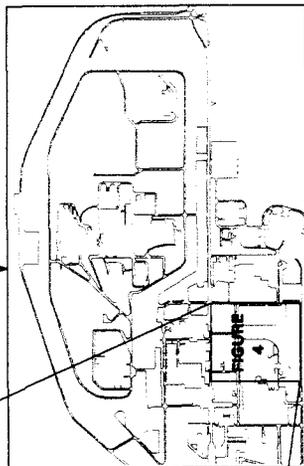
— Outline of Study Area
 ● Bird Observation Points
 — Traverse Route

Scale: 1 inch = 150 feet

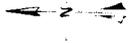
PREPARED FOR
 U.S. DEPARTMENT OF ENERGY
 ROCKY FLATS PLANT
 GOLDEN, COLORADO

FIGURE 4
 INDUSTRIAL AREA
 ENVIRONMENTAL EVALUATION
 WEST RAILROAD

Location Map



Outline of Study Area



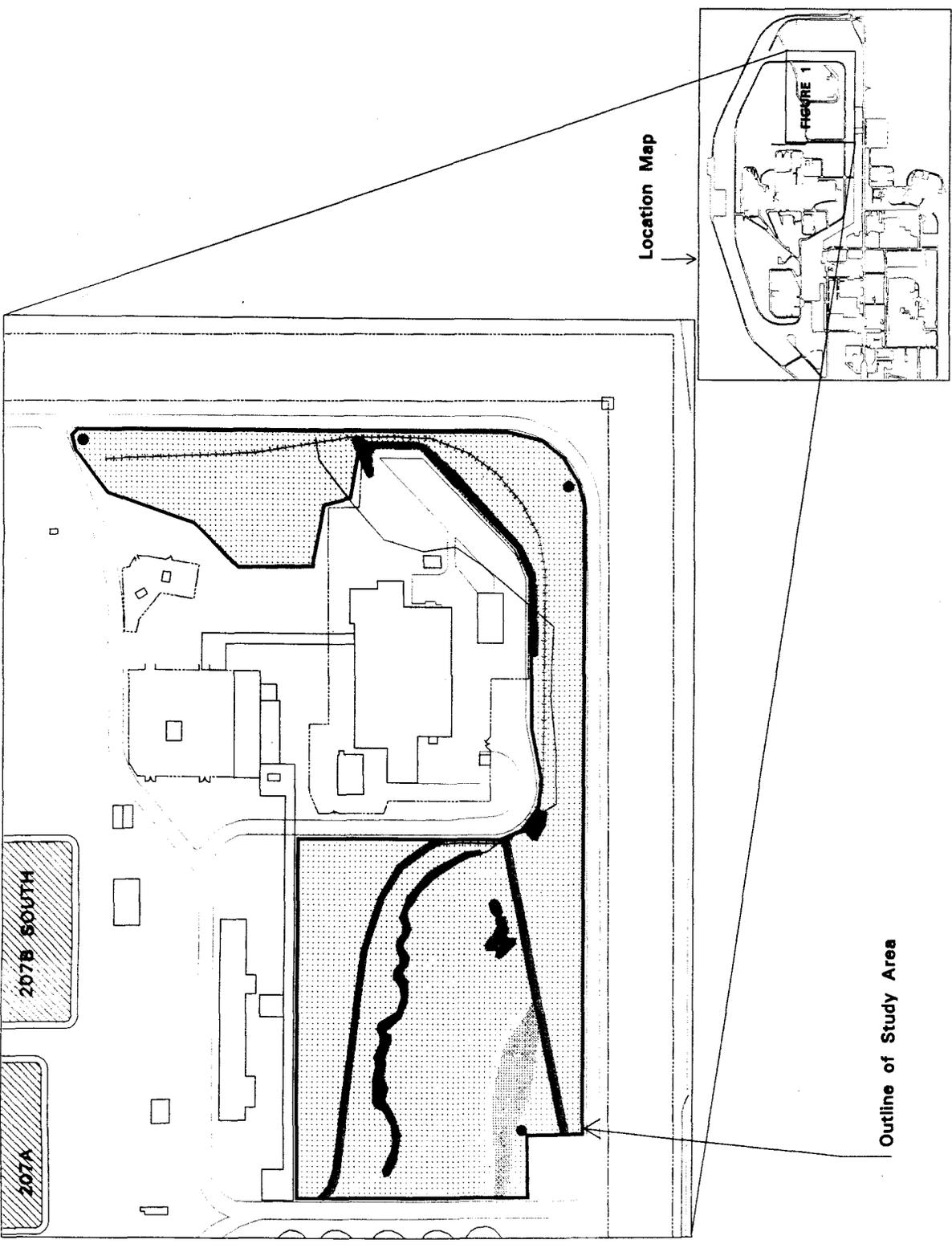
- Drainage
- Pond
- Buildings
- Fence
- Paved Road
- Sidewalk
- Rock
- Reclaimed Grassland
- Short Marsh
- Tall Marsh
- Disturbed
- Bare Ground
- Deciduous Woodland
- Disturbed/Reclaimed

- Outline of Study Area
- Traverse Route
- Bird Observation Points

Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 1
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
EAST DRAINAGE



Location Map

Outline of Study Area



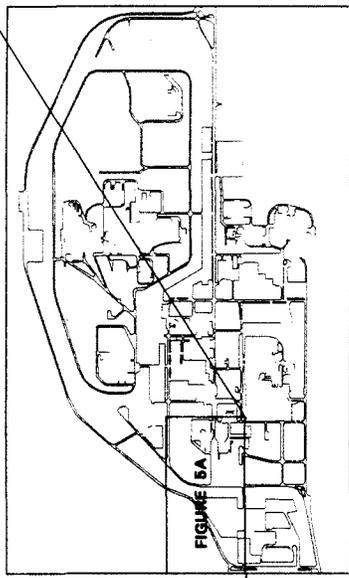
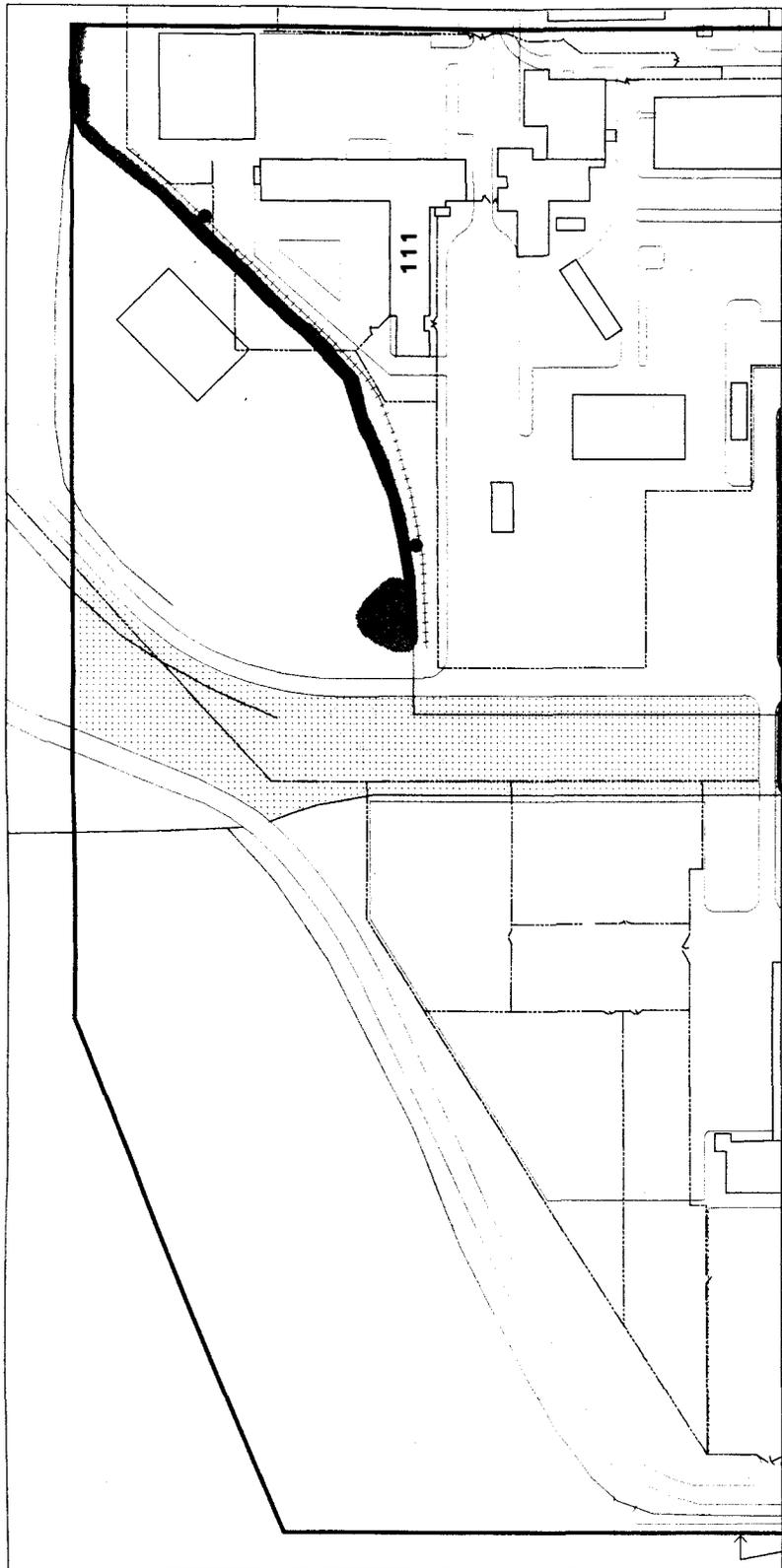
- Drainage
- ▭ Buildings
- - - Fence
- Paved Road
- Ornamental Trees
- ▨ Disturbed/Mesic Grass
- Short Marsh
- Tall Marsh

- Outline of Study Area
- - - Traverse Route
- Bird Observation Points

Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY PLATS PLANT
GOLDEN, COLORADO

FIGURE 5A
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
WEST AREA



Location Map

Outline of Study Area



- Drainage
- Buildings
- Fence
- Paved Road

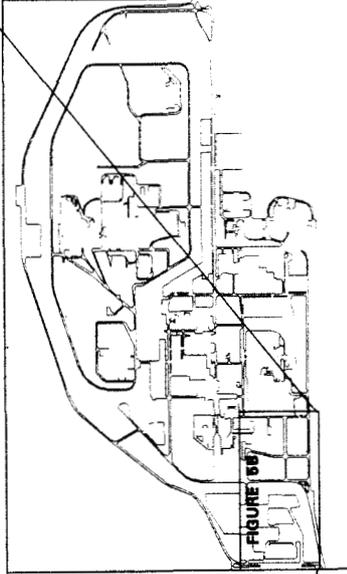
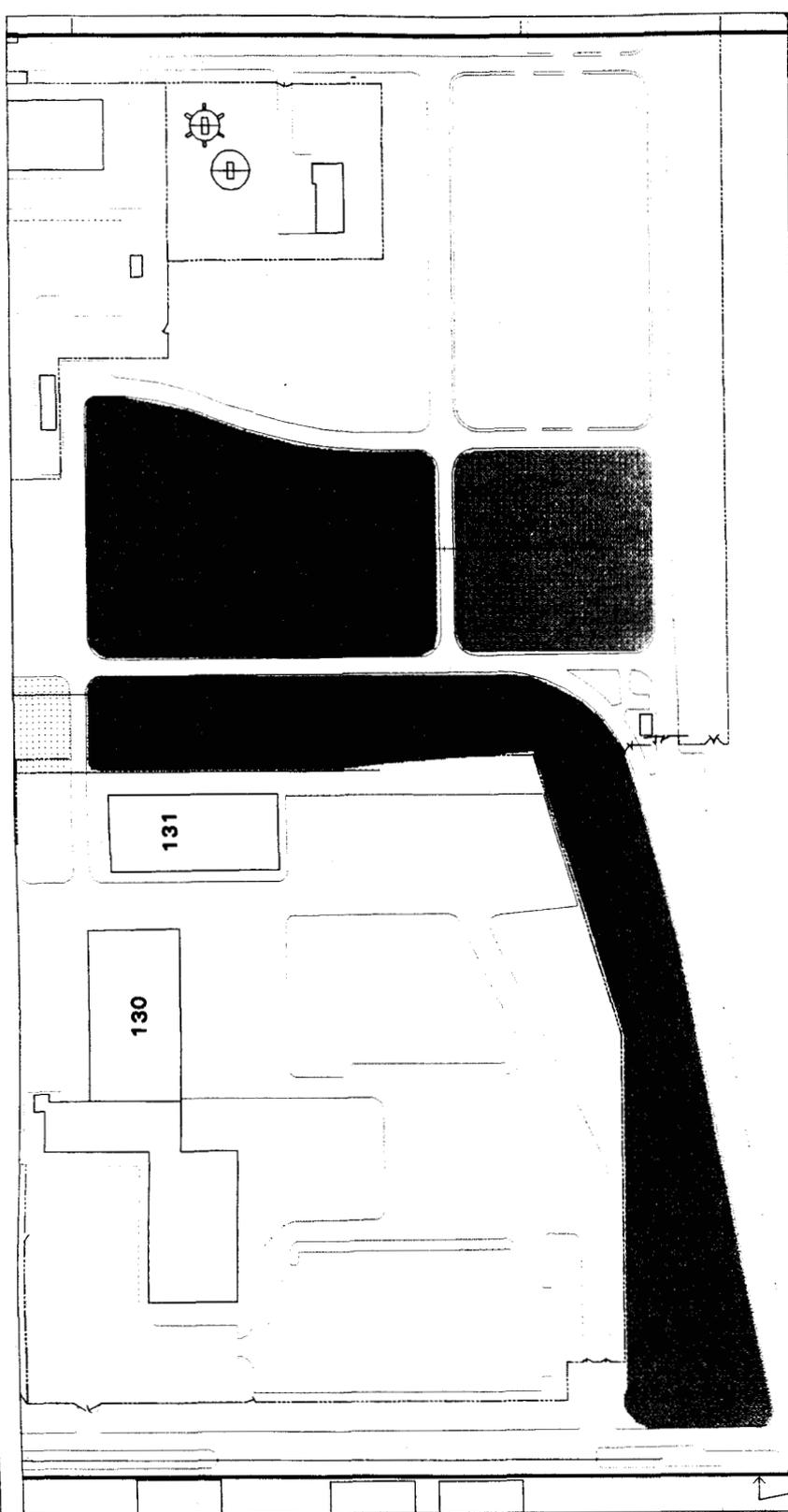
- Xeric Grassland
- Xeric/Mesic Grass.
- Disturbed/Mesic Grass.

- Outline of Study Area
- Traverse Route
- Bird Observation Points

Scale: 1 inch = 300 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 99
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
WEST AREA



Location Map

Outline of Study Area

DRAFT

PHASE II DATA SUMMARY
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION

ROCKY FLATS PLANT
INDUSTRIAL AREA
OPERABLE UNIT NOS. 8, 9, 10, 12, 13, and 14

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL MANAGEMENT PROGRAM

NOVEMBER 1993

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1.0 INTRODUCTION	1-1
2.0 ECOLOGICAL DATA SUMMARY	2-1
3.0 ENVIRONMENTAL MEDIA CHEMICAL CONCENTRATION SUMMARY ..	3-1
4.0 TOXICITY ASSESSMENT	4-1
5.0 EXPOSURE ASSESSMENT	5-1
6.0 REFERENCES	6-1

LIST OF TABLES

<u>Table</u>	<u>Title</u>
1	Potential Contaminants of Concern

LIST OF FIGURES

<u>Figure</u>	<u>Title</u>
1	Industrial Area Environmental Evaluation Generalized Food Web
2	Industrial Area Environmental Evaluation Sink Food Web for Great Horned Owl
3	Industrial Area Environmental Evaluation Sink Food Web for Great Horned Owl without Feral Cat Pathway
4	Industrial Area Environmental Evaluation Sink Food Web for American Kestrel
5	Industrial Area Environmental Evaluation Sink Food Web for Feral Cat

1.0 INTRODUCTION

The Industrial Area (IA) Environmental Evaluation (EE) Phase II Data Summary describes the results of three major activities. These activities are a continuation of Phase I, which included an ecological field survey of plant communities and animal habitats within the IA. The following activities completed during this phase included:

- Existing ecological and abiotic environmental media data were reviewed. The review addressed a listing of species recorded during past surveys, and those observed during the July and October through November 1993 field surveys. Habitat and species distribution and dominance was also noted. Abiotic environmental media data were also reviewed, summarized and evaluated with respect to suitability for inclusion as Contaminants of Concern (COCs).
- Potential COCs were selected. The chemicals were evaluated for toxicity to biota based on a data search and literature review of toxicological data found in TOMES, an Environmental Protection Agency (EPA) toxicological data base. These data are summarized in Table 1 to show, among other things, Lethal Dose to 50 percent of the population (LD50s), No Observed Adverse Effect Level (NOAEL) data or Lowest Observed Adverse Effect Level (LOAEL) data, and other data pertinent to the COCs.
- A generalized foodweb for the IA ecosystem was constructed. The foodweb provides data for the selection of key receptor species and the construction of a sink foodweb to illustrate pathway-receptor models for contaminant transport from source to biotic receptor. The pathway-receptor model will be used in the evaluation of potential ecological risk.

The three activities culminated in identifying data gaps where additional data are needed for the pathway-receptor models and for calculating tissue contaminant residue accumulation. In order to perform a quantitative characterization of risk, validated concentration values for tissues (key species of vegetation and wildlife) and environmental media are required.

2.0 ECOLOGICAL DATA SUMMARY

A vegetation survey conducted in the mid 1970's by Weber et al (1974) reported the presence of over 300 vascular plants representative of tall grass, mid grass and short grass prairie, and of foothill and montane vegetation communities. A vegetation map prepared for the RFP in the late 1970's identified 16 vegetation mapping units grouped into prairie, pasture and valley-side. The groupings were separated based on plant species composition (Clark et al 1980). Because much of the land surrounding the IA has been undisturbed for almost 20 years, recent observations show that plant succession in annual/weed communities is moving to perennial grasslands. Similar observations also have been made within the Protected Area (PA). Current mapping studies identify 17 vegetation mapping units. A comparison between these recent studies and Clark et al (1980) mapping units is presented in DOE (1990).

The major vegetation mapping units found within the IA include the following:

- Reclaimed Grassland - (20%);
- Disturbed (annual/forb) - (4%);
- Deciduous woodland - (1%);
- Mesic Grassland - (1%);
- Xeric Grassland - (1%);
- Short Marsh - (1%);
- Tall Marsh - (1%); and
- Ornamental (tree) Plantings - (1%).

Percentages next to the mapping unit represent the vegetation type occupying space within the IA. The majority of space in the IA is occupied by buildings/structures (70%), pond/impoundment (6%), and disturbed/barren land (10%) (DOE 1992). The percentages add up to 116%, probably because of two different survey periods and refinement of vegetation mapping units.

A variety of grasses, forbs and weedy species occur within these habitat types. Based on a qualitative survey conducted during July and October 1993, dominant species which are potential food sources for wildlife within the IA are:

- Smooth brome (*Bromopsis inermis*);
- Crested wheatgrass (*Agropyron cristatum*);
- Diffuse knapweed (*Centaurea diffusa*);

- Klamath weed (*Hypericum perforatum*);
- Curlycup gumweed (*Grindelia squarrosa*);
- Annual sunflower (*Helianthus annuus*);
- White sweetclover (*Melilotus alba*);
- Yellow sweetclover (*Melilotus officinalis*);
- Russian Olive (*Eleagnus angustifolia*); and
- Willow (*Salix spp.*).

Small mammal surveys conducted during July and October-November 1993 revealed that the IA provides habitat for a small number of species. The largest herbivore is the mule deer that moves in and out of the IA, particularly in the west area. The cottontail rabbit appears to be common throughout the IA, but mainly in the annual grass/weedy forb and xeric grassland habitat types. The deer mouse, prairie vole and harvest mouse were the common small herbivorous mammals. These species were most abundant in the reclaimed grassland habitat near sources of water and tall grass cover. The vole and harvest mouse are considered herbivorous but probably include some insects in their diets, while the deer mouse is omnivorous. A small population of pocket gophers exists in the reclaimed/mesic grassland along the northwest drainage.

Because of migratory patterns in songbirds, the IA supports year round residents, spring nesting species and winter visitors. Common year round residents include the house sparrow, house finch and European starling, while the black-eyed juncos and rosey finches winter in the IA drainages. Common nesting species observed within the IA were the American robin, Say's phoebe, house sparrow, house finch, European starling, barn swallow and cliff swallow.

Many of the above small mammal and bird species form the prey base for raptors, and feline and canine predators.

Feral cats were observed in the East Drainage, North Pond and Seep, Northwest Drainage and West Area study areas. Although drainage structures may provide canine predators access to the IA from the buffer zone, this was not confirmed. Scat found within the IA were not analyzed in detail and could have been from feral cats or smaller canids.

Two owl casts were found within the IA, and probably were from the great-horned owl. This raptor hunts for small mammals and will also take cottontail rabbits and feral cats. No carcasses of either were found within the IA. The American kestrel was commonly observed perched on fence and telephone poles. Within the IA this species will also feed on small mammals, insects and an occasional bird.

Based on the results of the existing data review and ecological field survey, a generalized foodweb was constructed for the IA and is illustrated in Figure 1. This figure indicates that the great-horned owl and American kestrel are at the top of the foodweb in the IA. However, because these species have large home ranges, the IA prey base probably contributes to a relatively small proportion of their diet. The feral cat, on the other hand, appears to hunt exclusively in the IA, therefore a large proportion of feral cat food items are from the IA. One exception to this are songbirds that may move in and out of the IA on a seasonal basis.

3.0 ENVIRONMENTAL MEDIA CHEMICAL CONCENTRATION SUMMARY

The IA Remedial Investigation is just beginning, therefore a review of the data was not possible. However, potential COCs were selected by reviewing the following sources: *Reconstruction of Historical Rocky Flats Operations & Identification of Release Points* (ChemRisk, 1992); OU4 Draft Summary Table of Contaminants of Concern in Surficial Soil and Vadose Soil, Phase I IM/IRA-EA; and *State of Colorado's Health Studies on Rocky Flats* (CDH, 1993). A list of potential COCs is provided in Table 1. Existing data that are not part of an ongoing RFI/RI suggest that the nature and extent of contamination within the IA is not well understood and is based on waste stream identification, ground water and surface water monitoring, previous site uses, or knowledge of how materials were stored or disposed. Validated environmental media data are not yet available for review.

4.0 TOXICITY ASSESSMENT

The objective of the toxicity assessment is to evaluate the COCs identified in the data evaluated relative to their potential to cause harm to biota identified as key species. This was accomplished by review and evaluation of the toxicity data gathered from the literature, and the comparison of these data with established criteria indicating potential harm to IA species. The criteria to be used are the lowest tissue concentrations or daily doses in key species which indicate a potential adverse effect, determined through easily accessible literature.

Presently, no tissue analysis data exists for IA plant and animal species. Therefore, the literature review consisted of evaluating the toxicity of potential COCs based on experimental results performed on laboratory animals. This information was compared to contaminant concentration ranges found in OU4 soils or vadose zone (Table 1). The data review suggests that volatile organics occur in concentration ranges far below published LOAEL or NOEL for laboratory mice and rats, and no animal toxicity data are available for radionuclides. However, LOAEL or NOEL for laboratory test animals are below or within the concentration ranges reported for Beryllium, Cadmium, Nickel, Silicon and Strontium at OU4. These data suggest that these metals should be investigated further as COCs, and used in the pathway-receptor model to evaluate potential ecological risk to key species.

5.0 EXPOSURE ASSESSMENT

Pathway-receptor models were developed from the generalized foodweb into sink foodwebs to evaluate potential exposure of biotic species to contaminants. Sink foodwebs include all food chains leading to a particular species considered important in that foodweb because of its special status (i.e. endangered), importance in the ecosystem, or economic importance to man, either as a game animal or food source. Sink foodwebs were constructed for the great-horned owl, feral cat and American kestrel. These sink foodwebs, or pathway-receptor models, are illustrated in Figures 2 through 5. Two foodwebs were constructed for the great-horned owl to illustrate contribution from the small mammal pathway by itself, and from the small mammal and feral cat pathway combined (Figures 2 and 3).

The great-horned owl and American kestrel were selected for evaluation because both are protected species. However, these two species probably rely on IA biota for only a small percentage of their daily diet. The feral cat, on the other hand, probably derives a great percentage of its food items from small mice and birds resident within the IA boundaries.

The emphasis of this evaluation was qualitative in nature and did not address quantitative issues. The pathway-receptor models appropriate for a quantitative analysis of the IA use the approach proposed by Thomann (1981) which evaluates bioaccumulation, bioconcentration and biomagnification from estimates of exposure by biota to COCs. Since bioconcentration occurs from direct exposure to water in an aquatic environment, it is not relevant in this evaluation. Bioaccumulation (contaminant concentrations from diet and drinking water) is assumed to be derived mainly from the diet, therefore the water term can be eliminated. Biomagnification, on the other hand, is the increase in tissue contaminant concentration as it moves from one trophic level to the next higher trophic level in the food chain. This value is an important part of the model development.

In the quantitative calculation of contaminant residue accumulation in biota, tissue concentration values are required along with values for contaminant concentrations in water, sediment, or soils. In addition, food habits (diet items and amounts consumed) along with some estimate of

6.0 REFERENCES

- ChemRisk. 1992. *Reconstruction of Historical Rocky Flats Operations & Identification of Release Points*. August 1992. ChemRisk. A Division of McLaren/Hart. 1135 Atlantic Avenue. Alameda, CA 94501.
- Clark, S.V., Wegger, P.J., Komarkova, V., Weber, W.A. 1980. *Map of Mixed Prairie Grassland Vegetation Rocky Flats, Colorado*. Occasional Paper No. 35, Boulder, Colorado: Institute of Arctic and Alpine Research, University of Colorado.
- CDH, 1993. *State of Colorado's Health Studies on Rocky Flats*. Health Advisory Panel's Report to Colorado Citizens on the Phase I Study. October 1993.
- DOE, 1990. *Environmental Assessment for 881 Hillside (High Priority Sites) Interim Remedial Action*. Rocky Flats Plant, Golden, Colorado. DOE/EA-0413.
- DOE, 1992. *Environmental Evaluation Technical Memorandum Addendum to Final Phase I RFI/RI Work Plan*. Rocky Flats Plant Original Process Waste Lines (Operable Unit No. 9). June 1992.
- Thomann, R.V. 1981. *Equilibrium Model of Fate of Microcontaminants in Diverse Aquatic Food Chains*. Canadian Journal of Fisheries, Aquatic Sciences. 38:280-296.
- Weber, W.A., G. Kunkel and L. Schultz. 1974. *A Botanical Inventory of the Rocky Flats AEC Site*. University of Colorado, Boulder, Colorado. Report prepared for the U.S. Atomic Energy Commission under Contract No. AT(11-1)-2371.

TABLE 1
Rocky Flats Industrial Area Environmental Evaluation
Potential Contaminants of Concern

Contaminant of Concern	Toxicity Information	Concentration Ranges from OU4	Applicable or Relevant and Appropriate Requirements (ARAR)	Carcinogen Classification
INORGANICS				
Beryllium	LD ₅₀ : Intravenous - rat 496 mg/kg NOAEL: 0.95 mg/kg/day	1.1 - 9.6 mg/kg	0.2 mg/kg ¹	B2; probable human carcinogen
Cadmium	LD ₅₀ : Ingestion - mouse 790 mcmol Cd/kg NOAEL: 0.005 mg/kg/day	1.1 - 380 mg/kg	40 mg/kg ¹	B1; probable human carcinogen
Chromium	Chronic toxicity studies with rats showed no significant adverse effects	4.2 - 48.4 mg/kg	400 mg/kg ¹	A; human carcinogen
Mercury	Rats were injected with metallic mercury and observed for their lifetimes, sarcomas were seen only in those tissues that had been in direct contact with the metal	0.05 - 18 mg/kg	20 mg/kg ¹	D; not classifiable as to human carcinogenicity
Nickel	LD ₅₀ : Ingestion - Rat 2.0 g/kg NOAEL: 5 mg/kg/day	10 - 180 mg/kg	2000 mg/kg ¹	EPA has not evaluated for potential human carcinogenicity
Silicon	LD ₅₀ : Ingestion - Rat 3160 mg/kg	463 - 11300 mg/kg		
Strontium	NOAEL: 375 mg/kg/day	22 - 510 mg/kg	8 pCi/l ²	EPA has not evaluated for potential human carcinogenicity
RADIONUCLIDES				
Americium-241		0 - 6.1 pCi/g	0.05 pCi/l ³	
Plutonium-230/240		0 - 25 pCi/g	0.05 pCi/l ³	
Thorium			500 pCi/l ³	

TABLE 1
Rocky Flats Industrial Area Environmental Evaluation
Potential Contaminants of Concern

Contaminant of Concern	Toxicity Information	Concentration Ranges from OU4	Applicable or Relevant and Appropriate Requirements (ARAR)	Carcinogen Classification
Tritium		0.11 - 62 pCi/ml	20,000 pCi/l ²	
Uranium-233/234		0 - 21 pCi/g		
Uranium-235		0 - 0.87 pCi/g		
Uranium-238		0 - 11 pCi/g	5 pCi/l ³	
VOLATILE ORGANICS				
Carbon Tetrachloride	LD ₅₀ : Ingestion - Rat 2350 mg/kg NOAEL: 1 mg/kg/day	6 - 29 µg/l	5 mg/kg ¹	B2; probable human carcinogen
Chloroform	LD ₅₀ : Ingestion - rat 300 mg/kg LOAEL: 12.9 mg/kg/day	6 - 29 µg/l	100 mg/kg ¹	B2; probable human carcinogen
Methylene Chloride	NOAEL: 5 mg/kg/day	0 - 6000 µg/kg	90 mg/kg ¹	B2; probable human carcinogen
Tetrachloroethylene	LD ₅₀ : Ingestion - rat 2629 mg/kg NOEL: 14 mg/kg/day	6 - 29 µg/kg	10 mg/kg ¹	The evaluation for this chemical is under review by an EPA inter-office agency work group.
1,1,1-Trichloroethane	LD ₅₀ : Ingestion - human estimation 500 mg/kg	6 - 29 µg/kg	200 µg/l ²	D; not classifiable as to human carcinogenicity
1,1,2,2-Tetrachloroethane		6 - 29 µg/kg	30 mg/kg ¹	C; possible human carcinogen

LD₅₀: Lethal dose to 50% of the population

NOAEL: No observed adverse effect level

LOAEL: Lowest observed adverse effect level

NOEL: No observed effect level

¹ Values from the Corrective Action for Solid Waste Management Units (SWMUs) at Hazardous Waste Management Facilities, Proposed Rule, Vol. 55, No. 145, Friday, July 27, 1990

² Maximum Contaminant Level

³ Colorado Department of Health Standard

REVISION NO. 4

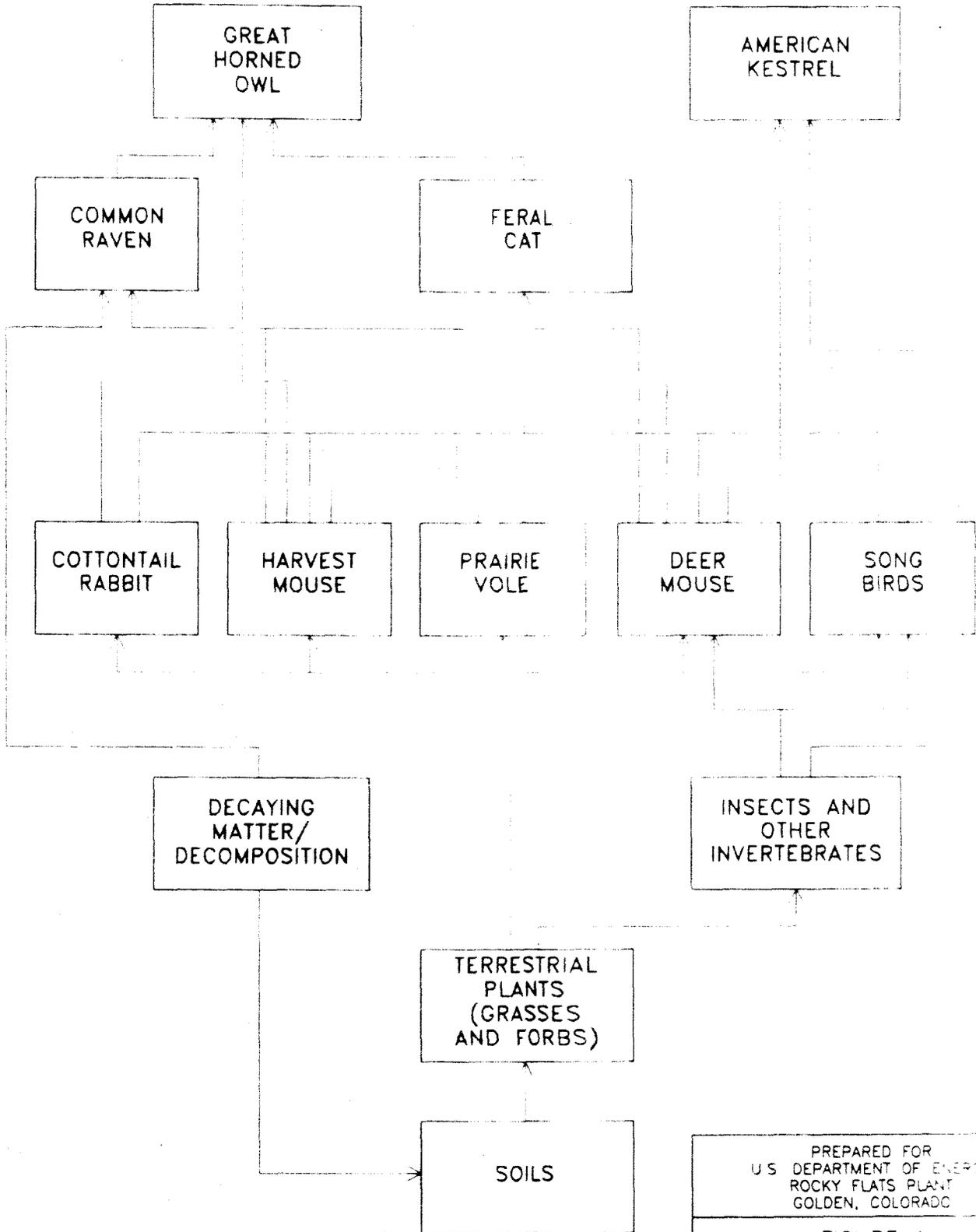
FILE NAME C:\KJS\FWGEN

DATE 11/17/93

DRAWN BY KJS

APPROVED BY *Jason*

CHECKED BY *WJ*



PREPARED FOR
 U.S. DEPARTMENT OF ENERGY
 ROCKY FLATS PLANT
 GOLDEN, COLORADO

FIGURE 1
 INDUSTRIAL AREA
 ENVIRONMENTAL EVALUATION
 GENERALIZED FOOD WEB

REVISION NO. 4

FILE NAME C:\KJVS\FWGH0

DATE 11/17/93

DRAWN BY KJS

APPROVED BY *JM*

CHECKED BY *WJ*

GREAT HORNED OWL

FERAL CAT

COTTONTAIL RABBIT

PRAIRIE VOLE

DEER MOUSE

SONG BIRDS

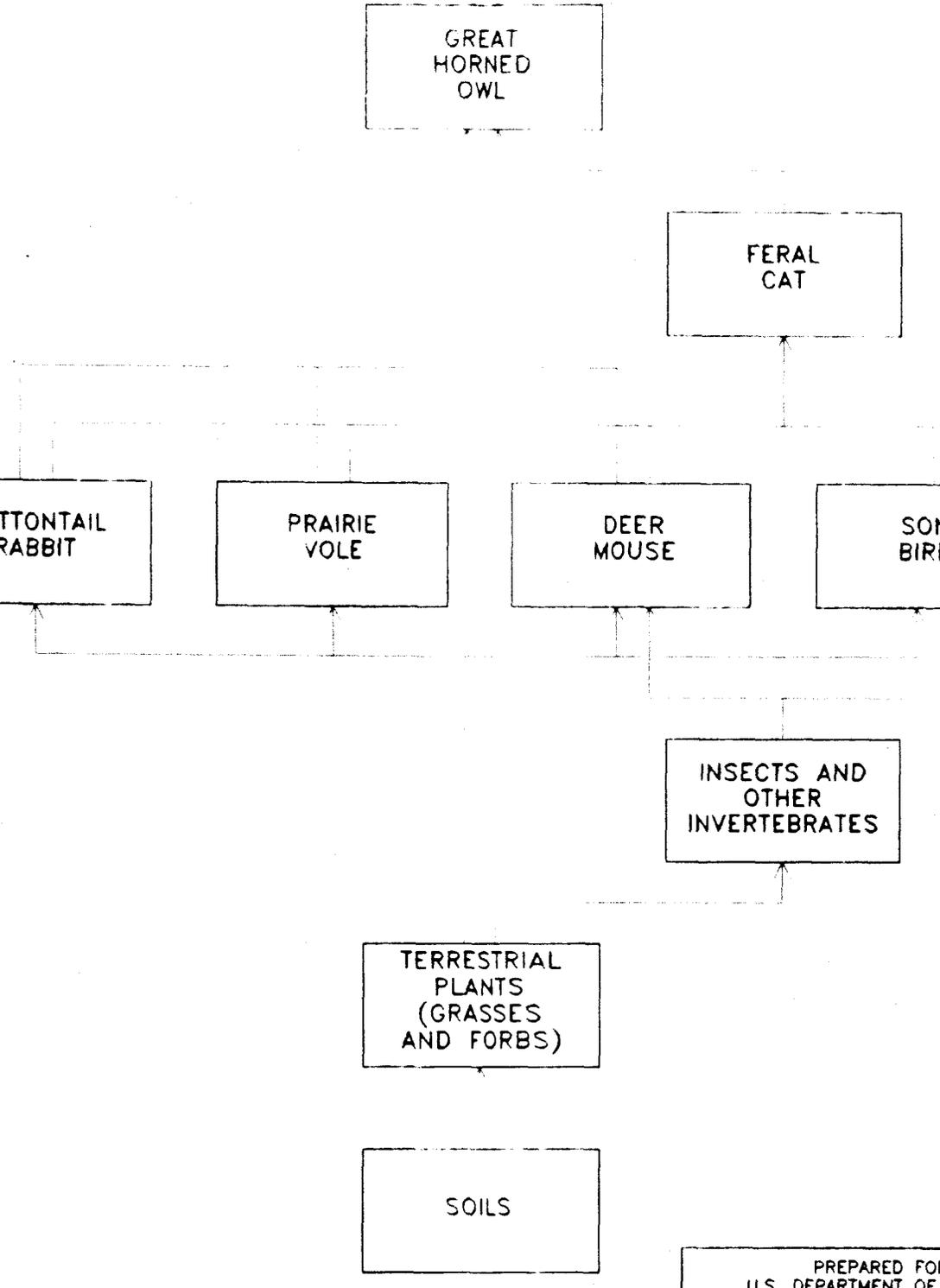
INSECTS AND OTHER INVERTEBRATES

TERRESTRIAL PLANTS (GRASSES AND FORBS)

SOILS

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 2
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR GREAT HORNED OWL



REVISION NO. 1

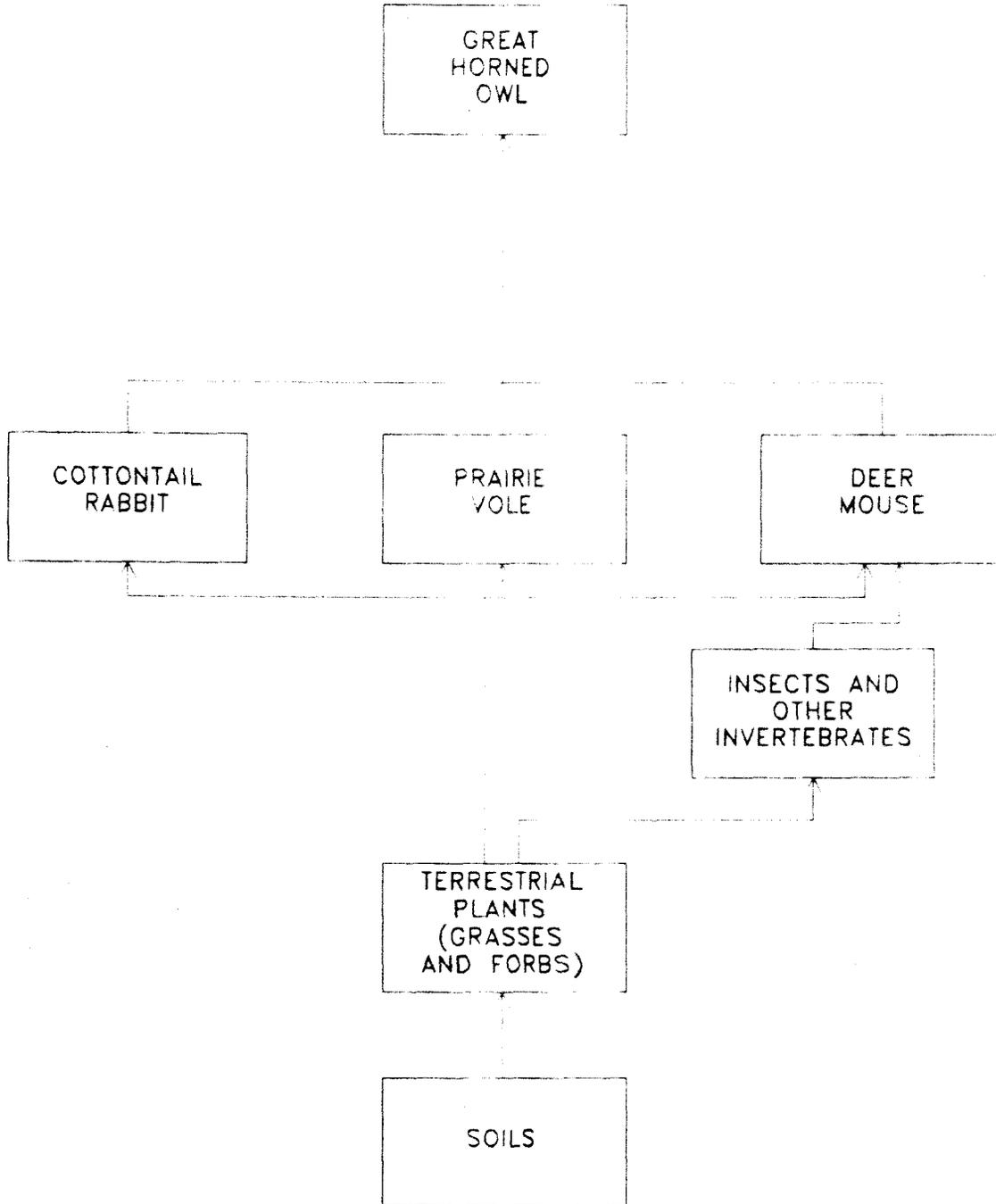
FILE NAME C:\KJS\FWGHOF3

DATE 11/17/93

DRAWN BY KJS

APPROVED BY *Jmm*

CHECKED BY *Wg*



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 3
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR GREAT HORNED OWL
WITHOUT FERAL CAT PATHWAY

REVISION NO 3

FILE NAME C:\KJS\FWC

DATE 11/17/93

DRAWN BY KJS

APPROVED BY *JPM*

CHECKED BY *UR*

FERAL
CAT

COTTONTAIL
RABBIT

PRAIRIE
VOLE

HARVEST
MOUSE

DEER
MOUSE

SONG
BIRDS

INSECTS AND
OTHER
INVERTEBRATES

TERRESTRIAL
PLANTS
(GRASSES
AND FORBS)

SOILS

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 4
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR FERAL CAT

REVISION NO. 3

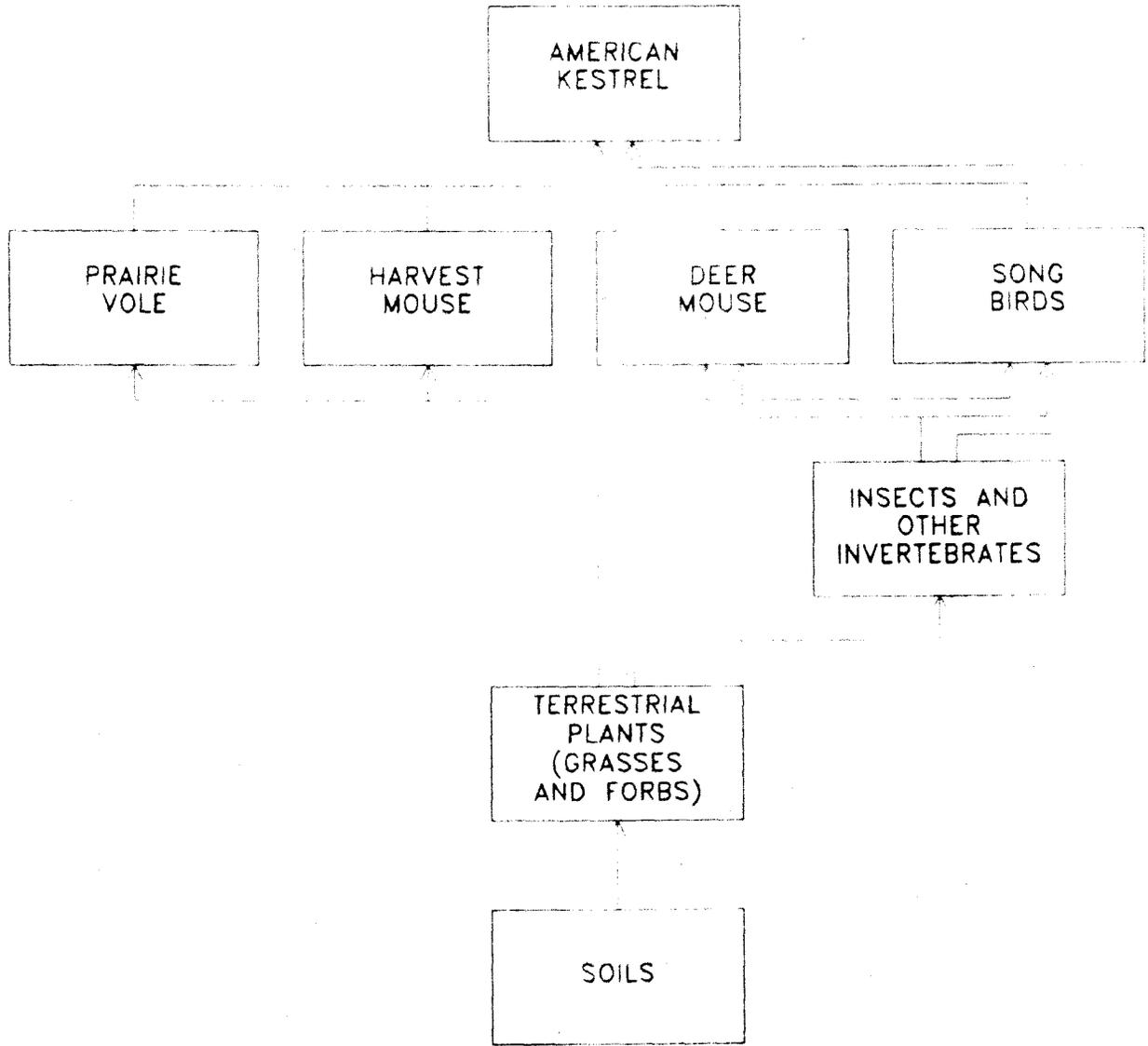
FILE NAME C:\KJS\FWAK

DATE 11/17/93

DRAWN BY KJS

APPROVED BY *[Signature]*

CHECKED BY *[Signature]*



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 5
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR AMERICAN KESTREL

DRAFT

PHASE III DATA SUMMARY
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION

ROCKY FLATS PLANT
INDUSTRIAL AREA
OPERABLE UNIT NOS 8, 9, 10, 12, 13 and 14

US DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL MANAGEMENT PROGRAM

DECEMBER 1993

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

Table No. Table

- 1 ROCKY FLATS INDUSTRIAL AREA ENVIRONMENTAL EVALUATION
 POTENTIAL CONTAMINANTS OF CONCERN
- 2 FOOD CONSUMPTION AND FOOD ITEM PERCENTAGES USED TO ESTIMATE
 BIOACCUMULATION FACTORS
- 3 RATES OF WATER AND SOIL INGESTION FOR SELECTED SPECIES
- 4 SUMMARY OF BIOACCUMULATION FACTORS FOR KEY SPECIES IN
 INDUSTRIAL AREA FOOD WEB PATHWAYS
- 5 SOIL AND WATER CRITERIA ESTIMATED FROM BIOMAGNIFICATION
 FACTORS FOR FERAL CAT

LIST OF FIGURES

Figure No. Figure

- 1 INDUSTRIAL AREA ENVIRONMENTAL EVALUATION GENERALIZED FOOD
 WEB
- 2 INDUSTRIAL AREA ENVIRONMENTAL EVALUATION SINK FOOD WEB FOR
 GREAT HORNED OWL
- 3 INDUSTRIAL AREA ENVIRONMENTAL EVALUATION SINK FOOD WEB FOR
 GREAT HORNED OWL WITHOUT FERAL CAT PATHWAY
- 4 INDUSTRIAL AREA ENVIRONMENTAL EVALUATION SINK FOOD WEB FOR
 FERAL CAT
- 5 INDUSTRIAL AREA ENVIRONMENTAL EVALUATION SINK FOOD WEB FOR
 AMERICAN KESTREL

APPENDICES

APPENDIX A - TOXICOLOGICAL DATA ON POTENTIAL CONTAMINANTS OF
CONCERN OF THE INDUSTRIAL AREA

EXECUTIVE SUMMARY

The Industrial Area (IA) Environmental Evaluation (EE) Phase III Data Summary includes results of the Preliminary Contamination Characterization and Uncertainty Analysis tasks. These tasks were limited to literature research and an evaluation of toxicological and exposure data.

Toxicological profiles were provided as brief summaries of information on each potential contaminant of concern (COC) and its behavior in environmental media. Some of the information provided by the literature search include data such as fate and transport, lethal doses, concentrations in environmental media, environmental magnification factors, health hazard classifications, and maximum permissible tissue concentrations.

A conceptual food web and pathway-receptor model was developed based on the ecological field investigations conducted during July, October and November 1993, and ecological data gathered in past studies of RFP.

As part of the exposure assessment, and related to the generalized food web, sink food webs were developed for key raptor or predator species. A sink food web illustrates major contaminant pathways through the food chain from soils (water and sediments) to higher order consumers at the top of a food chain. These sink food webs provided the structure for the conceptualization of contaminant transport and calculation of bioaccumulation, bioconcentration and biomagnification factors used in an ecological risk assessment.

The pathways proposed in this Phase III Data Summary are not complete in the sense of including all potential pathways existing for each species at the top of the food chain. For example, insects, reptiles and carrion are not included in these pathways for those species which are omnivores or which switch food items on a seasonal basis. However, these pathways are intended to best illustrate major routes of contaminant movement from source to biotic receptors.

A bioaccumulation model was used to evaluate the terrestrial pathway using the following assumptions for bioconcentration factors (BCFs):

- The chemical concentration in the soil is in equilibrium with the chemical concentration in vegetation tissue. In other words, vegetation tissue concentration equals chemical soil concentration and each have a BCF of 1.
- The first order consumers (cottontail rabbit, bird, and deer mouse) each have a BCF of 2. A BCF of 2 was also assumed for the feral cat, kestrel and great-horned owl at the third level of the food chain. A BCF of 1.5 was assumed for the great-horned owl at the fourth level.

Nine of the 19 COCs identified were qualitatively characterized for risk. The biomagnification factor (BMF) for strontium of 52.37 mg/kg is the only BMF falling within the range of concentrations detected at OU4. Hence, strontium appears to present a risk to biota in the IA. No risk characterization could be conducted for chromium, mercury, all the radionuclides and

1,1,2,2-tetrachloroethane because of the lack of data applicable to the biota from the IA. Toxicity profile data indicate that there is a potential for injury to species from release of these contaminants.

The absence of site-specific information required conservative assumptions regarding data inputs to the analysis. Assumptions were made with respect to COCs, toxicities, and risk characterization. The result is conservative estimates of risk parameters, and an overly conservative risk estimate.

1.0 INTRODUCTION

The Industrial Area (IA) Environmental Evaluation (EE) Phase III Data Summary includes results of the Preliminary Contamination Characterization and Uncertainty Analysis tasks. The Preliminary Contamination Characterization task consisted of the preparation of toxicological profiles, an exposure assessment, and risk characterization. Estimated risk to receptor populations and habitats was based on direct observations in the field, literature data which identify harm or injury types, and general assumptions linking potential source concentrations with bio-receptors through bioconcentration, bioaccumulation and biomagnification. The magnitude of effects to biota was also estimated and incorporated into a pathway-receptor model.

The Uncertainty Analysis task qualitatively addressed uncertainty in the toxicity and exposure assessments and uncertainty in the risk characterization. With respect to the toxicity assessment, uncertainty was developed from qualitative evaluations such as estimating the potential for bio-receptor toxicity, derivation of toxicity values, and estimating the potential for synergistic or antagonistic interactions with other substances. Uncertainty in the exposure assessment is related to the accuracy with which exposure pathways correctly predict receptor contact with contaminated media and corresponding model inputs of contaminant concentrations. Risk characterization uncertainty is influenced by the assumptions regarding exposures and toxicities which are affected by the sampling and analysis programs, and the literature data used in the model.

The Scope of Investigation is addressed in Section 2.0, the Toxicological Profiles appear in Section 3.0, the Exposure Assessment and Risk Characterization are discussed in Section 4.0, and the Uncertainty Analysis appears in Section 5.0.

2.0 SCOPE OF INVESTIGATION

The scope of this Phase III investigation was limited to literature research data evaluation of toxicological and exposure data. The chemical data provided by EG&G included soils and ground water analyses from the Operable Unit (OU4) characterization and monitoring program. These data were reviewed and compared with Applicable or Relevant and Appropriate Requirements (ARARs) to select potential COCs, as part of Phase II of this IAEE (DOE, 1993c). Three databases located at the Environmental Protection Agency (EPA) Region VIII were searched to compile a list of toxicological profiles of these COCs. These databases included the Toxicology Occupational Medicine and Environmental Series (TOMES), the Integrated Risk Information System (IRIS), and the Hazardous Substance Data Base (HSDB). From these profiles, toxicological information important to the risk characterization was compiled for inclusion into a pathway-receptor model. In addition to the databases, other select technical documents were also reviewed to provide information necessary to the calculation of appropriate factors for chemical uptake and transport through a food chain. The uncertainty analysis of this phase of the risk characterization addressed the assumptions and lack of data which impacted results and conclusions of characterization.

Limitations of this Phase III investigation are significant in light of the fact that no tissue samples were collected. In addition, the databases failed to provide adequate toxicological data for radionuclides and other potential COCs. Numerous general assumptions were made for input factors to the pathway-receptor model. It should also be emphasized that all site-specific chemical data reviewed were collected at Operable Unit 4 (OU4) and may not reflect the entire range of possibilities for potential contaminants within the IA.

Extensive investigations of radionuclide concentrations in vegetation and small mammals have been conducted by Colorado State University and are summarized in a report entitled *Radioecological Investigations at Rocky Flats* (Whicker and Ibrahim, 1993). These investigations were focused on Operable Unit 2. None of the findings of these investigations have been incorporated in this Phase III investigation.

3.0 TOXICOLOGICAL PROFILES

The toxicological profiles provide brief information on each of the potential COCs and its behavior in environmental media. Health effects studies using laboratory animals or native species are summarized as available. The types of information in the databases and literature which are important in this assessment include data such as fate and transport, lethal doses, concentrations in environmental media, environmental magnification factors, health hazard classifications, and maximum permissible tissue concentrations (MPTCs). These types of data were not available for all of the potential COCs. Toxicological profiles are provided for the following potential COCs:

- Inorganics
 - Beryllium;
 - Cadmium;
 - Chromium;
 - Mercury;
 - Nickel;
 - Silicon; and
 - Strontium.

- Radionuclides
 - Americium-241;
 - Plutonium-230/240;
 - Thorium;
 - Tritium;
 - Uranium-233/234;
 - Uranium-235; and
 - Uranium-238.

- Volatile Organics
 - Carbon Tetrachloride;
 - Chloroform;
 - Methylene Chloride;
 - Tetrachloroethylene;
 - 1,1,1-Trichloroethane; and
 - 1,1,2,2-Tetrachloroethane.

These potential COCs were selected for the exposure assessment as part of the IAEE Phase II Data Summary (DOE, 1993c) and were based on a review of the following sources:

Reconstruction of Historical Rocky Flats Operations & Identification of Release Points (ChemRisk, 1992); *OU4 Draft Summary Table of Contaminants of Concern in Surficial Soil and Vadose Soil, Phase I IM/IRA-EA*; and *State of Colorado's Health Studies on Rocky Flats* (CDH, 1993). Table 1 provides additional information pertaining to the COCs and Appendix A contains detailed printouts of data taken from the databases for each potential COC.

3.1 INORGANICS

3.1.1 Beryllium

Beryllium toxicity was determined in life-term studies in rats. A total of 52 weanling Long-Evans rats of each sex received up to 5 parts per million (ppm) beryllium in drinking water. Exposure was for the lifetime of the animals. At natural death the rats were dissected and gross and microscopic changes were noted in heart, kidney, liver, and spleen. There were no effects on these organs or on lifespan, urinalysis, serum glucose, cholesterol, and uric acid, or on numbers of tumors

Similar studies were carried out on Swiss (CD strain) mice in groups of 54 mice of each sex at doses of approximately 0.95 milligrams per kilogram per day (mg/kg/day). Female animals showed decreased body weight compared with untreated mice. Male mice exhibited slight increases in body weight. These effects were not considered adverse, therefore, 0.95 mg/kg/day is considered a No Observed Adverse Effect Level (NOAEL).

Beryllium is classified by the EPA as a probable human carcinogen, B2. Beryllium has been shown to induce lung cancer in rats through inhalation. Human epidemiology studies are considered to be inadequate for carcinogenicity.

3.1.2 Cadmium

Exposure of Wistar rats by inhalation to cadmium as cadmium chloride resulted in significant increases in lung tumors. Injection site tumors have been reported as a consequence of intramuscular or subcutaneous administration of cadmium metal to rats and mice. Seven studies

in rats and mice where cadmium salts (acetate, sulfate, chloride) were administered orally have shown no evidence of carcinogenic response.

Cadmium is classified by the EPA as a probable human carcinogen, B1. There is limited evidence from occupational epidemiologic studies of cadmium. Sufficient evidence exists of carcinogenicity in rats and mice by inhalation and intramuscular and subcutaneous injection.

3.1.3 Chromium

Chronic toxicity studies of chromium evaluated hexavalent and trivalent chromium administered in drinking water to rats. Groups of eight male and eight female Sprague-Dawley rats were fed hexavalent chromium for one year. The control group received distilled water. A second experiment involved three groups of 12 males and nine female rats. One group was given 25 ppm chromium, a second received 25 ppm chromium in the form of chromic chloride, and the controls again received distilled water. No significant adverse effects were seen in appearance, weight gain, or food consumption, and there were no pathologic changes in the blood or other tissues in any treatment group. The rats receiving 25 ppm of chromium showed an approximate 20 percent reduction in water consumption.

Chromium is classified by the EPA as a human carcinogen, A. Dose response relationships have been established for exposure to both chromium III and chromium VI compounds. Only chromium VI has been found to be carcinogenic in animal studies, and therefore only chromium VI is classified as a human carcinogen.

3.1.4 Mercury

One study administered three groups consisting of 60 male and 60 female mice doses ranging from 0 to 30 ppm methyl mercury chloride in the diet for 78 weeks. The majority of the 30 ppm group died from neurotoxicity by week 26. Histopathology on kidney tissue from all surviving after 53 weeks revealed renal tumors in 13 out of 16 males in the 15 ppm group. One adenoma was detected among 37 controls surviving to week 53 or beyond, and no tumors were seen in either control or exposed females.

Mercury is not classified by the EPA as a human carcinogen.

3.1.5 Nickel

One study reported the results of a two-year feeding study using rats given 0, 100, 1000 or 2500 ppm nickel. Weights in the high-dose male and female rats significantly decreased compared with controls. Body weight was also reduced for those receiving 1000 ppm. This reduction was significant for females at week six and from weeks 26 through 104, whereas males showed body weight reduction only at 52 weeks. Groups of female rats on the 1000 or 2500 ppm nickel diets of 50 and 125 mg Nickel per kilogram of body weight (Ni/kg bw) had significantly higher heart-to-body weight ratios and lower liver-to-body weight ratios than controls. No significant effects were reported at 100 ppm (five mg Ni/kg bw). The dose of 1000 ppm (50 mg Ni/kg bw) is a NOAEL.

EPA has not evaluated soluble salts of nickel, as a class of compounds, for potential human carcinogenicity.

3.1.6 Silicon

Concentrations of free silicic acid were measured in male and female shrimp collected from the Dutch Wadden Sea at various stages of their development, considering differences in sex and responses to temperature and salinity. Whole animal silicon levels were decreased in larger animals which indicated that relatively high silicon concentrations were present in the exoskeleton. Higher silicon concentrations in males were associated with a size effect. Females were found to have a high silicon content of the egg shells. At higher temperatures internal silicon concentrations are increased. In response to environmental salinity the internal silicon concentration are highest at normal sea-water salinities.

The published lethal dose to 50 percent of the population (LD50) value via the oral route for the rat is 3160 mg/kg.

3.1.7 Strontium

Young animals are more sensitive to excessive strontium intakes than adult animals because their bones are actively growing. Both young and adult rats of both sexes were provided a diet

containing 1.8 percent strontium as strontium carbonate. The exposure continued for up to seven months with several interim sacrifices. After only three weeks of exposure, the young rats exhibited a "rachitic gait" with the most obvious changes occurring in the distal end of the femur and the proximal end of the tibia. Conversely, it was three months before any change was observed in the adult rats, this being the appearance of fine traverse lines in the upper tibial metaphysis. Because young rats consume more food per kg body weight, it is difficult to ascertain how much more sensitive young animals would be at a dose adjusted on a mg per kg of body weight per day basis.

Strontium has not been evaluated by the EPA for evidence of human carcinogenic potential

3.2 RADIONUCLIDES

Data on radionuclides were extremely limited in the EPA data bases. The following discussions relate the minimal information taken from the databases concerning concentrations in vegetation and other general descriptions. Extensive data on concentrations of plutonium and americium in vegetation and small mammals at Rocky Flats have been compiled and are reported in *Radioecological Investigations at Rocky Flats* (Whicker and Ibrahim, 1993). This study focused on Operable Unit 2 and was not incorporated into this IAEE.

3.2.1 Americium

Information was not available in the EPA data base for americium.

3.2.2 Plutonium

The levels of plutonium found in field-grown native plants and agricultural crops are due to surface contamination rather than soil plant transfer. Plutonium concentration depends on plant species, on the type and age and status of vegetation, on the pH, cation exchange capacity, mineral and organic composition of the soil, on the physical and chemical composition of the soil, and on the physical and chemical form of contamination, as well as its duration. The highest uptake of plutonium in cheat grass occurs, for example, when plutonium is present in the soil as the stable citrate complex or as a complex with macromolecules, like humic acid or fulvic acid

Plutonium has not been evaluated completely by the EPA.

3.2.3 Thorium

During a three to four year period, concentrations of thorium were determined in soils and native vegetables at various sites around a typical uranium mining and milling operation in Wyoming. Plant and soil concentration ratios for thorium isotopes were estimated for tailings exposed to weather, the edge of a tailings impoundment, an area downwind from exposed tailings, a reclamation area, and several background, native range locations. Concentrations of thorium in soil and vegetation were elevated above background by two orders of magnitude at all sites disturbed by mining and milling activities. This study demonstrated that under certain conditions vegetation can accumulate thorium.

Thorium has not been evaluated completely by the EPA.

3.2.4 Tritium

Currently, the tritium present in the environment and the relative contribution of the sources have been estimated to be about 0.5 to 1 megacurie from nuclear reactors and about 1×10^3 megacuries from nuclear explosions. Bomb produced tritium still exceeds natural tritium in the environment.

Tritium has not been evaluated completely by the EPA.

3.2.5 Uranium

Uranium is a radioactive element with the atomic number 92, and as found in natural ores, has an atomic weight of approximately 238. The two principal natural isotopes are uranium-235 (0.7 percent of natural uranium), which is fissile, and uranium-238 (99.3 percent of natural uranium), which is fissionable by fast neutrons and is fertile. Natural uranium also includes a minute amount of uranium-234.

Uranium has not been evaluated by the EPA for evidence of human carcinogenic potential

3.3 VOLATILE ORGANICS

3.3.1 Carbon Tetrachloride

Oral toxicity of carbon tetrachloride was determined by acute, subacute and subchronic studies in rats. Male Sprague-Dawley rats were given 1, 10, or 33 mg carbon tetrachloride/kg/day by corn gavage, 5 days per week for 12 weeks. Liver lesions, as evidenced by mild centrilobular vacuolization and statistically significant increases in serum sorbitol dehydrogenase activity, were observed at the 10 and 33 mg/kg/day doses in a dose-related manner. Therefore, the Lowest Observed Adverse Effect Level (LOAEL) was established at 10 mg/kg/day and the NOAEL was 1 mg/kg/day.

Carbon tetrachloride is classified by the EPA as a probable human carcinogen, B2. This is based on its carcinogenicity in rats, mice, and hamsters.

3.3.2 Chloroform

A long-term exposure study in beagle dogs was conducted for chloroform. In the study beagle dogs were administered chloroform in a toothpaste base in gelatin capsules. A control group composed of 16 males and 16 females received the dose, and additional control groups of eight animals of each sex were administered an alternative toothpaste or were left untreated. Experimental groups of eight male and eight female dogs received 15 or 30 mg chloroform/kg/day for six days/week. Treatment was continued for seven and a half years. Fatty cysts, considered to be treatment-related, were observed in livers of some dogs in both treatment groups. Nodules of altered hepatocytes were considered treatment-related but not dose-dependent. The LOAEL was determined to be 12.9 mg/kg/day.

Chloroform is classified by the EPA as a probable human carcinogen, B2. This is based on an increased incidence of several tumor types in rats and mice.

3.3.3 Methylene Chloride

A twenty-four month chronic toxicity and oncogenicity study in rats was conducted for methylene chloride. The chosen study was conducted with 85 rats of each sex for 2 years. A high-dose

recovery group of 25 rats of each sex, as well as two control groups of 85 and 50 rats of each sex, was also tested. Many effects were monitored. Treatment related histological alterations of the liver were evident at nominal doses of 50 mg/kg/day or higher. The low nominal dose of 5 mg/kg/day was determined to be the NOAEL.

Methylene chloride is classified by the EPA as a probable human carcinogen, B2. This is based on an increased incidence of hepatocellular neoplasms and alveolar/bronchiolar neoplasms in male and female mice, and increased incidence of benign mammary tumors in both sexes of rats, salivary gland sarcomas in male rats and leukemia in female rats.

3.3.4 Tetrachloroethylene

One study exposed Swiss-Cox mice to tetrachloroethylene in corn oil by gavage at doses of 0, 20, 100, 200, 500, 1500, and 2000 mg/kg, five days per week for six weeks. Liver toxicity was evaluated by several parameters including liver weight per body weight ratio, hepatic triglyceride concentration, DNA content, histopathological evaluation, and serum enzyme levels. Increased liver triglycerides were first observed in mice treated with 100 mg/kg. Liver weight per body weight ratios were significantly higher than controls for animals treated with 100 mg/kg.

A NOEL of 14 mg/kg/day was established in a second study. Groups of 20 Sprague-Dawley rats of both sexes were administered doses of 14, 400, or 1400 mg/kg/day in drinking water. Males in the high-dose group and females in the two highest groups exhibited depressed body weights. Evidence of hepatotoxicity (increased liver and kidney weight/body weight ratios) were also observed at the higher doses.

3.3.5 1,1,1-Trichloroethane

One study treated Osborne-Mendel rats with 750 or 1500 mg/kg technical-grade 1,1,1-trichloroethane 5 times/week for 78 weeks by gavage. The rats were observed for an additional 32 weeks. Twenty rats of each sex served as untreated controls. Low survival of both male and female treated rats may have precluded detection of a significant number of tumors late in life. Although a variety of neoplasms was observed in both treated and matched control rats, they

were common to aged rats and were not dose-related. The control and treated groups had 20 and 50 animals of each sex, respectively. Only 25 to 45 percent of those treated survived until the time of terminal sacrifice. A variety of neoplasms were observed in treated groups, but the incidence was not statistically different from the matched controls.

1,1,1-Trichloroethane is not classified by the EPA as a carcinogen. There are no reported human data and animal studies that have demonstrated carcinogenicity.

3.3.6 1,1,2,2-Tetrachloroethane

In a bioassay study male and female Osborne Mendel rats and mice were gavaged with technical grade 1,1,2,2-tetrachloroethane in corn oil, 5 days per week. Treatment was over 78 weeks for the rats and 12 weeks for the mice. The high and low average doses were, respectively, 108 and 62 mg/kg/day for males, 76 and 43 mg/kg/day for female rats, and 282 and 142 mg/kg/day for mice of both sexes. Control groups consisted of 20 animals of each sex and species. Treated controls received corn oil at the same rate as the high-dose animals. Untreated controls were not intubated. Ten of the high-dose female rats died within the first five weeks of the study, but the association between increased dosage and elevated mortality was not statistically significant for male rats. Significantly increased mortality was also evident in the high-dose mice of both sexes. No statistically significant incidence of neoplasms was observed in rats. A highly significant dose-related increase in the incidence of hepatocellular carcinomas was observed in both male and female mice.

1,1,2,2-Tetrachloroethane was classified by the EPA as a possible human carcinogen, C. This is based on the increased incidence of hepatocellular carcinomas in mice.

4.0 EXPOSURE ASSESSMENT AND RISK CHARACTERIZATION

The following sections address the development of a conceptual food web and pathway-receptor model, assumptions for the pathway-receptor model, calculation of bio-factors and risk characterization.

4.1 DEVELOPMENT OF A CONCEPTUAL FOOD WEB AND PATHWAY-RECEPTOR MODEL

Much of the data provided by the toxicological profiles have been gathered from studies on laboratory mice and rats. To the extent practical, these data were included in the exposure assessment. However, the attempt was to structure a contamination characterization as close as possible to existing ecological conditions at the IA. The approach was to construct a conceptual model of the IA food web based on the ecological field investigations conducted during July, October and November 1993, and ecological data gathered in past studies of RFP. This resulted in the conceptual food web model for the IA as shown in Figure 1, developed to represent existing ecological conditions.

As a part of the exposure assessment, and related to the generalized food web, sink food webs were developed for key raptor or predator species, as shown in Figures 2-5. A sink food web illustrates major contaminant pathways through the food chain from soils (water or sediments) to higher order consumers at the top of a food chain. These sink food webs provide the structure for the conceptualization of contaminant transport and calculation of bioaccumulation, bioconcentration and biomagnification factors used in an ecological risk assessment.

Based on the generalized food web for the IA shown in Figure 1, the following pathways were identified for evaluation:

- Pathway #1: Soil → Plants → Bird → Feral Cat → Great-horned Owl
- Pathway #2: Soil → Plants → Deer Mouse → Feral Cat → Great-horned Owl
- Pathway #3: Soil → Plants → Cottontail Rabbit → Feral Cat → Great-horned Owl
- Pathway #4: Soil → Plants → Deer Mouse → Great-horned Owl
- Pathway #5: Soil → Plants → Cottontail Rabbit → Great-horned Owl

- Pathway #6: Soil → Plants → Bird → Great-horned Owl
- Pathway #7: Soil → Plants → Deer Mouse → American Kestrel
- Pathway #8: Soil → Plants → Bird → American Kestrel
- Pathway #9: Soil → Plants → Bird → Feral Cat
- Pathway #10: Soil → Plants → Deer Mouse → Feral Cat
- Pathway #11: Soil → Plants → Cottontail Rabbit → Feral Cat

These pathways are not complete in the sense of including all potential pathways existing for each species at the top of the food chain. For example, insects, reptiles and carrion are not included in these pathways for those species which are omnivores or which switch food items on a seasonal basis. However, these pathways best illustrate major routes of contaminant movement from source to biotic receptors.

4.2 ASSUMPTIONS FOR THE PATHWAY RECEPTOR MODEL

The bioaccumulation model proposed by Thomann (1981) and modified by Fordham and Reagan (1991) was used to evaluate the pathways identified for the IA. This model includes multiple food chains and links chemical concentrations in soil, sediment or water to tissue concentrations in biota by estimating exposures to COCs. The original use of this model was to evaluate chemical transfer through an aquatic food chain. For the IA the model was modified to only evaluate the terrestrial pathway since no significant aquatic systems occur within the IA. Several assumptions were made for bioconcentration factors (BCFs):

- The chemical concentration in the soil is in equilibrium with the chemical concentration in vegetation tissue. In other words, vegetation tissue concentration equals chemical soil concentration and each have a BCF of 1.
- The first order consumers (cottontail rabbit, bird, and deer mouse) each have a BCF of 2. Bioconcentration is uptake of a chemical from water. It is generally accepted that terrestrial species have negligible uptake from water. Small mammals generally receive most of their water from food items and not from direct water ingestion. A BCF of 2 was also assumed for the feral cat, kestrel and great-horned owl at the third level of the food chain. A BCF of 1.5 was assumed for the great-horned owl at the fourth level. These BCFs are very conservative.
- The same BCFs were used for each COC because the databases revealed little or no data on BCFs.

4.3 CALCULATION OF BIOACCUMULATION AND BIOMAGNIFICATION FACTORS

Bioaccumulation factors (BAFs) apply to second, third, and fourth order consumers. BAFs were calculated in the following manner:

- Food Chain Level 1) $C_{\text{soil}} = C_{\text{vegetation}} ; BCF_{\text{vegetation}} = 1$
- Food Chain Level 2) $BAF_2 = BCF_2 + f_2 BCF_1$
- Food Chain Level 3) $BAF_3 = BCF_3 + f_3 BCF_2 + f_3 f_2 BCF_1$
- Food Chain Level 4) $BAF_4 = BCF_4 + f_4 BCF_3 + f_4 f_3 BCF_2 + f_4 f_3 f_2 BCF_1$

where:

- C = chemical concentration
- BAF = bioaccumulation factor
- BCF = bioconcentration factor
- f_i = the food term.

f_i , the food term is calculated as follows:

$$f_i = \frac{A \times D \times I}{L}$$

where:

- A = assimilation efficiency, weight absorbed
- D = daily food intake, gram of body weight per day
- I = percent of food item in daily diet
- L = loss rate, a fraction/day.

To be conservative, an assimilation efficiency of 0.9 was used. This value indicates that for every 10 mg of chemical ingested, 9 mg is assimilated. Spacie and Hamelink (1985) used this value for PCBs and DDT. Loss rate, or depuration, is the loss of the chemical due to growth, dilution, excretion and metabolism. For avian species the value of 0.36 was used, and for mammals, 0.4 (ESE, 1988).

Table 2 was constructed to present data on animal weights, ingestion rates, animal diet items. Table 3 presents data on water and soil injection for selected species. These data provide input for calculations to estimate BAFs. A food term was calculated for each key species using the above food term formula. These food terms were then substituted into the appropriate food chain level formula (Levels 1, 2, 3 and 4) and BAFs were calculated for each key species in each

pathway. Each food chain level represents a BAF calculation for a key species. For example, Level 2 represents the level for the bird, cottontail rabbit and the deer mouse, while Level 4 only includes the great-horned owl. These data are summarized in Table 4.

Biomagnification results in an increase of chemical tissue concentrations as the tissue is passed up the food chain. This is a result of bioconcentration and bioaccumulation at each level of the food chain. Whereas BAF values are for single food chains, BMF values represent overall accumulation in the identified food web. A total BMF was calculated for each predator/raptor by the following general formula:

$$BMF_i = BCF_i + \text{sum of } f_i BAF_{i-1}$$

The total BMFs were calculated with the following results:

$$\begin{aligned} \text{Total BMF}_{\text{feral cat}} &= 7.16 \\ \text{Total BMF}_{\text{kestrel}} &= 20.42 \\ \text{Total BMF}_{\text{great-horned owl}} &= 23.14. \end{aligned}$$

Total BMFs were used to evaluate maximum allowable concentrations of a chemical in soil, water or sediment by relating environmental media concentrations to maximum acceptable tissue concentrations (MATC) in target species:

$$\frac{\text{MATC}}{\text{Total BMF}} = C_{\text{water, soil or tissue}} \text{ ("no effects" level)}$$

This value can be compared to existing chemical concentrations in environmental media as a first approximation of a water, soil or sediment criterion. For example, strontium has a rat NOAEL of 375 mg/kg/day as shown in Table 1, and the feral cat also has an identical NOAEL, which adjusted for its weight (1250 g) is 468 mg/kg/day. An assumption of 468 mg/kg as the MATC, results in:

$$\frac{468 \text{ mg/kg}}{7.16} = 65.36 \text{ mg/kg}$$

Comparing 65.36 mg/kg with the range of strontium concentrations (22 through 510 mg/kg) from Table 1 would suggest that 65.36 mg/kg strontium in the soil may cause harm to the feral cat.

In this calculation, no factor for uncertainty was used. Accepted practice is to multiply certain estimated values by an "uncertainty factor". The higher the factor, the higher the associated uncertainty. Uncertainty factors can be used to convert effects to a chronic NOEL range from 5 through 1,000, and a factor of 5 can be used for species interspecific variation. Total uncertainty factors then range from 5 to 5,000.

Table 5 summarizes soil and water criteria estimated from BMFs for a feral cat. It lists NOEL/LOAEL used as MATC and divided by the calculated BMF for the feral cat to estimate a soil concentration assumed to represent a "no effects" level. The table lists NOEL/LOAEL, estimated "no effects", and estimated daily doses of the chemical from published ingestion rates of soil or water. These data suggest that ingestion of soil or water is a negligible route of chemical entry into the food chain.

4.4 RISK CHARACTERIZATION

Only one set of formulae was used in the calculation of bio-factors. This assumes that all chemicals behave identically. This is not the case, but in the absence of site-specific data on bioaccumulation or bioconcentration data, and literature values, conservative assumptions were made to perform qualitative risk characterization. From these values a BMF was also estimated and used to calculate a first order "no effects" level representing a soil concentration at which "no effect" results to biota. Next, using water and soil estimated ingestion rates, daily doses to biota were also estimated. These data indicated that the water and soil ingestion routes contribute negligible chemical amounts to biota. Data are needed on the concentrations of chemicals in site biota tissues to compare with estimated factors, criteria and ingestion rates to quantitatively characterize risk to biota from site contaminants. These data are potentially available from the radioecological investigations already conducted at Rocky Flats (Whicker and Ibrahim, 1993).

Nine of the 19 COCs identified were qualitatively characterized for risk. Table 5 presents soil and water criteria estimated from BMFs for a feral cat. The BMF for strontium of 52.37 mg/kg is the only BMF falling within the range of concentrations detected at OU4. Hence, strontium appears to present a risk to biota in the IA. No risk characterization could be conducted for

chromium, mercury, all the radionuclides and 1,1,2,2-tetrachloroethane because of the lack of data applicable to the biota from the IA. Toxicity profile data indicate that there is a potential for injury to species from releases of these contaminants.

5.0 UNCERTAINTY ANALYSIS

The uncertainty analysis for the Phase III investigation was conducted qualitatively and addressed uncertainty in the toxicity and exposure assessment and uncertainty in the risk characterization. The assumptions of exposure, bioconcentration factors, and lack of site-specific data all increase the uncertainty of any conclusions of potential risk to biota from site releases. Uncertainty in the exposure assessment is related to the accuracy with which exposure pathways correctly predict receptor contact with contaminated media and corresponding model inputs of contaminant concentrations. Risk characterization uncertainty is also influenced by the assumptions regarding exposures and toxicities which are affected by the sampling and analysis programs, and the literature data used in the model.

The absence of site-specific information required conservative assumptions regarding data inputs to the analysis. Assumptions were made with respect to COCs, toxicities, and risk characterization. The result is conservative estimates of risk parameters, and an overly conservative risk estimate. Most of the data used to evaluate potential risk to the biota were based on the literature values except the identification of receptor species, or target taxa, and chemical concentrations found in OU4 soils and water. All values characterizing bioaccumulation, bioconcentration and biomagnification were computed from literature data for similar or related species, or for species data gathered at other locations. For example, data on animal weights were gathered from four different sources. However, weights of the mice were taken from measurements of species collected at the IA during the ecological survey. The literature values for ingestion rates, diet food items and body weights were used to calculate food terms in the bioaccumulation formula.

There was limited information on BAFs, BCFs or BMFs from the literature reviewed, so conservative estimates were made in the calculation of these terms. Because there was limited information, all assumptions for BAFs, BCFs, and BMFs were identical. Hence, only one food term for each species was calculated. In other words, whether evaluating cadmium or strontium, the BAFs, BCFs and BMFs were identical for each species. This resulted in only one total BMF

per key species instead of a BMF for each chemical evaluated. Although these values were calculated to be conservative, it is possible that in reality, one or more of these chemicals accumulates in tissues far greater than estimated.

Loss rates, or depuration, and assimilation efficiency data also were not site-specific, so literature values were used from a study on turkeys and rats. These rates were used in the food term formula for the key species of small mammals, the feral cat and the two raptors. Soil chemical concentrations were assumed to be in equilibrium with vegetation tissues, such that a soil chemical concentration of 5 mg/kg was the same for vegetation tissue. Each of these parameters and assumptions had a level of uncertainty attached to them, such that the final estimate of biomagnification could over-estimate risk.

Two other parameters, the NOEL and LOAEL were used to estimate a soil/water risk criterion and a "no effects" level. The value generally used in this calculation is the MATC. No MATCs were found in the EPA data base search for the COCs evaluated, so the NOEL or LOAEL were used as substitutes. Generally, an uncertainty factor ranging from 5 to 5000 can be applied when using these values for soil or water risk criteria.

Because of the lack of site-specific data, it was not possible to validate any of the calculated factors or parameters. Thus, it is not possible to determine the accuracy of estimates of bioaccumulation and transfer through the food chain. It was also assumed in this assessment that dermal and inhalation exposures routes were insignificant in chemical accumulation in tissues. The values calculated from NOEL/LOAELs to estimate daily doses from water or soil ingestion suggested this was the case.

The results of the risk characterization of the COCs evaluated indicate that strontium concentrations in the soils are a potential risk to biota. However, even though the assumptions used were thought to be conservative, they may not be conservative enough. To better evaluate the potential risk to biota from IA contamination, site-specific chemical concentration data should be gathered and evaluated through the pathway-receptor model used in this study.

6.0 REFERENCES

- Chem Risk, 1992. *Reconstruction of Historical Rocky Flats Operations and Identification of Release Points*. August 1992, Chem Risk. A Division of McLaren/Hart. 1135 Atlantic Avenue, Alameda, CA 94501.
- CDH, 1993. State of Colorado's Health Studies on Rocky Flats. Health Advisory Panel's Report to Colorado Citizens on the Phase I Study. October 1993.
- DOE, 1993a. *Industrial Area Environmental Evaluation Field Sampling Plan*. Rocky Flats Plant. October 15, 1993.
- DOE, 1993b. *Phase I Data Summary Industrial Area Environmental Evaluation*. Rocky Flats Plant. October, 1993.
- DOE, 1993c. *Phase II Data Summary Industrial Area Environmental Evaluation*. Rocky Flats Plant. November, 1993.
- EG&G, 1992a. *Standard Operating Procedures Manual, Volume V, Ecology, Manual No. 5-21200-OPS-EE*. Golden, Colorado. EG&G Rocky Flats, Inc. (Currently undergoing review).
- EG&G, 1992b. *Standard Operating Procedures Manual, Volume I, Field Operations Manual. 5-2100-OPS-FO*. Golden, Colorado. EG&G Rocky Flats, Inc. (revision 5/12/92).
- Environmental Science and Engineering, Inc. (ESE), 1988. Rocky Mountain Arsenal Biota Assessment Phases I and II Final Technical Plan. July 1988.
- EPA. 1993. Integrated Risk Information System (IRIS) Access Date: October 31, 1993.
- Fordham, C.L. and D.P. Reagan, 1991. Pathways Analysis Method for Estimating Water and Sediment Criteria at Hazardous Waste Sites. Environmental Toxicology and Chemistry.
- Hall, E.R. 1981. *Mammals of North America*. Second Edition. Wiley and Sons, NY. 1181 pp.
- Hazardous Substance Data Base (HSDB). 1993. Access Date: October 31, 1993.
- Jones, J.K., D.M. Armstrong, and J.R. Choate, 1985. Guide to Mammals of the Plains States. University of Nebraska Press. Lincoln, Nebraska. 371 pp.
- Sherrod, S.K., 1978. Food Habits of North American Falconiformes. Raptor Research 12.
- Spacie, A. and J.L. Hamelink, 1985. *Bioaccumulation In Fundamentals of Aquatic Toxicology*. G.M. Rand and S.R. Petrocelli, eds. McGraw-Hill. New York. pp. 495-525.

Toxicology Occupational Medicine and Environmental Series Data Base (TOMES). 1993.
Access Date: October 31, 1993. Micro Medex, Inc.

Whicker, F.W. and Ibrahim, S.A. 1993. *Radioecological Investigations at Rocky Flats*. Rocky Flats Plant. April 30, 1993.

TABLES

TABLE 1
Rocky Flats Industrial Area Environmental Evaluation
Potential Contaminants of Concern

Contaminant of Concern	Toxicity Information	Concentration Ranges from OU4	NOEL/LOAEL		Applicable or Relevant and Appropriate Requirements (ARAR)	Carcinogen Classification
			H ₂ O Ingestion (l/kg bw/day)	Soil Ingestion (g soil/g bw)		
INORGANICS						
Beryllium	LD ₅₀ : Intravenous-rat 496 mg/kg NOAEL: 0.95 mg/kg/day	1.1-9.6 mg/kg	7.6 mg/l	3,393 mg/kg	0.2 mg/kg ¹	B2; probable human carcinogen
Cadmium	LD ₅₀ : Ingestion-mouse 790 mcmol Cd/kg NOAEL: 0.005 mg/kg/day	1.1-380 mg/kg	0.25 mg/l	6.76 mg/kg	40 mg/kg ¹	B1; probable human carcinogen
Chromium	Chronic toxicity studies with rats showed no significant adverse effects	4.2-48.4 mg/kg			400 mg/kg ¹	A; human carcinogen
Mercury	Rats were injected with metallic mercury and observed for their lifetimes, sarcomas were seen only in those tissues that had been in direct contact with the metal	0.05-18 mg/kg			20 mg/kg ¹	D; not classifiable as to human carcinogenicity
Nickel	LD ₅₀ : Ingestion - Rat 2.0 g/kg NOAEL: 5 mg/kg/day	10 -180 mg/kg	40 mg/l	17,857 mg/kg	2000 mg/kg ¹	EPA has not evaluated for potential human carcinogenicity
Silicon	LD ₅₀ : Ingestion - Rat 3160 mg/kg	463-11300 mg/kg	25,230 mg/l	1.1x10 ⁷ mg/kg		
Strontium	NOAEL: 375 mg/kg/day - Rat	22-510 mg/kg	18,750 mg/l	5.1x10 ⁵ mg/kg	8 pCi/l ²	EPA has not evaluated for potential human carcinogenicity
RADIONUCLIDES						
Americium-241		0-6.1 pCi/g			0.05 pCi/l ³	
Plutonium-230/240		0-25 pCi/g			0.05 pCi/l ³	
Thorium					500 pCi/l ³	
Tritium		0.11-62 pCi/ml			20,000 pCi/l ²	
Uranium-233/234		0-21 pCi/g				
Uranium-235		0-0.87 pCi/g				
Uranium-238		0-11 pCi/g			5 pCi/l ³	

TABLE 1
Rocky Flats Industrial Area Environmental Evaluation
Potential Contaminants of Concern

Contaminant of Concern	Toxicity Information	Concentration Ranges from OUA	NOEL/LOAEL		Applicable or Relevant and Appropriate Requirements (ARAR)	Carcinogen Classification
			H ₂ O Ingestion (l/kg bw/day)	Soil Ingestion (g soil/g bw)		
VOLATILE ORGANICS						
Carbon Tetrachloride	LD ₅₀ : Ingestion - Rat 2350 mg/kg NOAEL: 1 mg/kg/day	6-29 µg/l	8 mg/l	3.6x10 ³ mg/kg	5 mg/kg ¹	B2; probable human carcinogen
Chloroform	LD ₅₀ : Ingestion - rat 300 mg/kg LOAEL: 12.9 mg/kg/day	6-29 µg/l	103.2 mg/l	4.6x10 ⁴ mg/kg	100 mg/kg ¹	B2; probable human carcinogen
Methylene Chloride	NOAEL: 5 mg/kg/day	0-6000 µg/kg	250 mg/l	6.8x10 ³ mg/kg	90 mg/kg ¹	B2; probable human carcinogen
Tetrachloroethylene	LD ₅₀ : Ingestion - rat 2629 mg/kg NOEL: 14 mg/kg/day	6-29 µg/kg	112 mg/l	5x10 ⁴ mg/kg	10 mg/kg ¹	The evaluation for this chemical is under review by an EPA inter-office agency work group.
1,1,1-Trichloroethane	LD ₅₀ : Ingestion - human estimation 500 mg/kg	6-29 µg/kg	2500 mg/l	1x10 ⁶ mg/kg	200 µg/l ²	D; not classifiable as to human carcinogenicity
1,1,2,2-Tetrachloroethane		6-29 µg/kg			30 mg/kg ¹	C; possible human carcinogen

LD₅₀: Lethal dose to 50% of the population

NOAEL: No observed adverse effect level

LOAEL: Lowest observed adverse effect level

NOEL: No observed effect level

¹ Values from the Corrective Action for Solid Waste Management Units (SWMUs) at Hazardous Waste Management Facilities, Proposed Rule, Vol. 55, No. 145, Friday, July 27, 1990

² Maximum Contaminant Level

³ Colorado Department of Health Standard

TABLE 2
FOOD CONSUMPTION AND FOOD ITEM PERCENTAGES
USED TO ESTIMATE BIOACCUMULATION FACTORS

SPECIES	DAILY FOOD CONSUMPTION (g/kg. bw/day) ^a	AVERAGE WEIGHT (grams)	FOOD ITEMS	PERCENT IN DIET
Great Horned Owl	202.5	1500 ¹	Invertebrates Birds Mammals	8.1 ¹ 29.7 ¹ 62.1 ¹
American Kestrel	30	115 ¹	Insects Small Birds Reptiles Mammals	51.8 ² 16.4 ² 4.5 ² 27.3 ²
Feral Cat	50	1250	Insects Mammals	50 ³ 50 ³
Cottontail Rabbit	120	1450	Insects Plants	50 ³ 50 ³
Song Bird	40	40	Plants Insects Earthworms	50 ⁴ 25 ⁴ 25 ⁴
Prairie Vole	70	50 ⁵	Insects Plants	50 ³ 50 ³
Harvest Mouse	20	15 ⁵	Insects Plants	50 ³ 50 ³
Deer Mouse	25	20 ⁵	Insects Plants	50 ³ 50 ³

^a g/kg bw/day = grams/kilogram body weight/day

¹ Craighead and Craighead, 1969

² Sherrod, 1978

³ Jones et. al, 1985
Hall, 1981

⁴ ESE, 1988

⁵ DOE, 1993b

TABLE 3
RATES OF WATER AND SOIL INGESTION
FOR SELECTED SPECIES

Species	Weight of Animal (grams)	Water (l/kg bw/day) ^a	Soil (g/kg bw/day) ^a
Cotton Rat	160	0.125	0.00028
White-footed Mouse	17.5	0.02	0.00074
Rabbit	1450	0.165	0.0613
Cat	1250	0.05	0.0022
Raptor	1500	0.10	---
Chipmunk	90	---	0.0016

^a l/kg bw/day = liters/kilogram body weight/day
g/kg bw/day = grams/kilogram body weight/day

TABLE 4
SUMMARY OF BIOACCUMULATION FACTORS
FOR KEY SPECIES IN INDUSTRIAL AREA FOOD WEB PATHWAYS

Pathway*	Cottontail Rabbit	Deer Mouse	Bird	Feral Cat	Kestrel	Great Horned Owl
1			4.5	7.85		13.7
2		5.05		8.35		28.58
3	2.19			5.77		16.80
4		5.05				28.58
5	2.19					16.80
6			4.5			13.7
7		5.05			24.63	
8			4.5		14.52	
9			4.5	7.85		
10		5.05		8.35		
11	2.19			5.77		

* Pathways include the following:

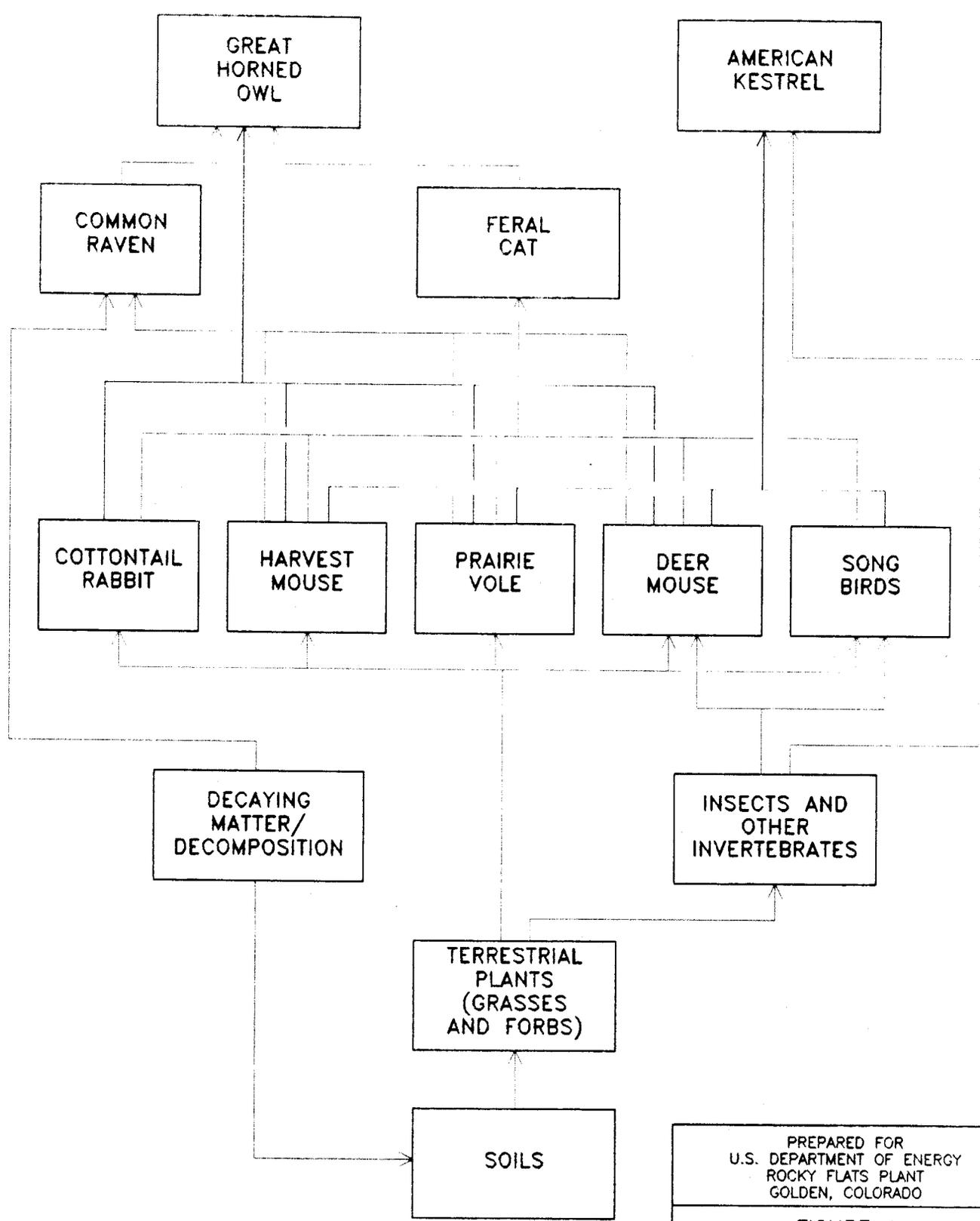
- Pathway #1: Soil → Plants → Bird → Feral Cat → Great-horned Owl
- Pathway #2: Soil → Plants → Deer Mouse → Feral Cat → Great-horned Owl
- Pathway #3: Soil → Plants → Cottontail Rabbit → Feral Cat → Great-horned Owl
- Pathway #4: Soil → Plants → Deer Mouse → Great-horned Owl
- Pathway #5: Soil → Plants → Cottontail Rabbit → Great-horned Owl
- Pathway #6: Soil → Plants → Bird → Great-horned Owl
- Pathway #7: Soil → Plants → Deer Mouse → American Kestrel
- Pathway #8: Soil → Plants → Bird → American Kestrel
- Pathway #9: Soil → Plants → Bird → Feral Cat
- Pathway #10: Soil → Plants → Deer Mouse → Feral Cat
- Pathway #11: Soil → Plants → Cottontail Rabbit → Feral Cat

TABLE 5
SOIL AND WATER CRITERIA ESTIMATED FROM
BIOMAGNIFICATION FACTORS FOR FERAL CAT

Potential COCs	NOEL/LOAEL (mg/kg)	Soil/Water Criteria NOEL/LOAEL BMF Cat mg/kg	Soil Daily Dose to Feral Cat mg/l	Water Daily Dose (Feral Cat) mg/l	Concentration Range at OU4
Beryllium	0.95	0.133	2.9×10^{-4}	0.007	1.1 - 9.6 mg/kg
Cadmium	0.005	0.0007	1.5×10^{-6}	3.5×10^{-5}	1.1 - 380 mg/kg
Nickel	5.0	0.698	1.5×10^{-3}	0.035	10 - 180 mg/kg
Silicon	3160.0	441.34	0.97	22.07	463-11,300mg/kg
Strontium	375.0	52.37	0.115	2.62	22 - 510 mg/kg
Carbon Tetrachloride	1.0	0.14	$3.1 \times 10^{-4} \mu\text{g/l}$	$0.007 \mu\text{g/l}$	6 - 29 $\mu\text{g/l}$
Chloroform	12.9	1.8	$3.96 \times 10^{-3} \mu\text{l}$	$0.09 \mu\text{g/l}$	6 - 29 $\mu\text{g/l}$
Methylene Chloride	5.0	0.698	1.5×10^{-6}	0.035	0 - 6 mg/kg
Tetrachloroethylene	14.0	1.96	4.3×10^{-3}	0.098	.006-.029 mg/kg

FIGURES

CHECKED BY *WD* APPROVED BY *VJF* DRAWN BY KJS DATE 12/6/93 FILE NAME C:\KJS\FWGEN REVISION NO. 5



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 1
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
GENERALIZED FOOD WEB

REVISION NO. 5

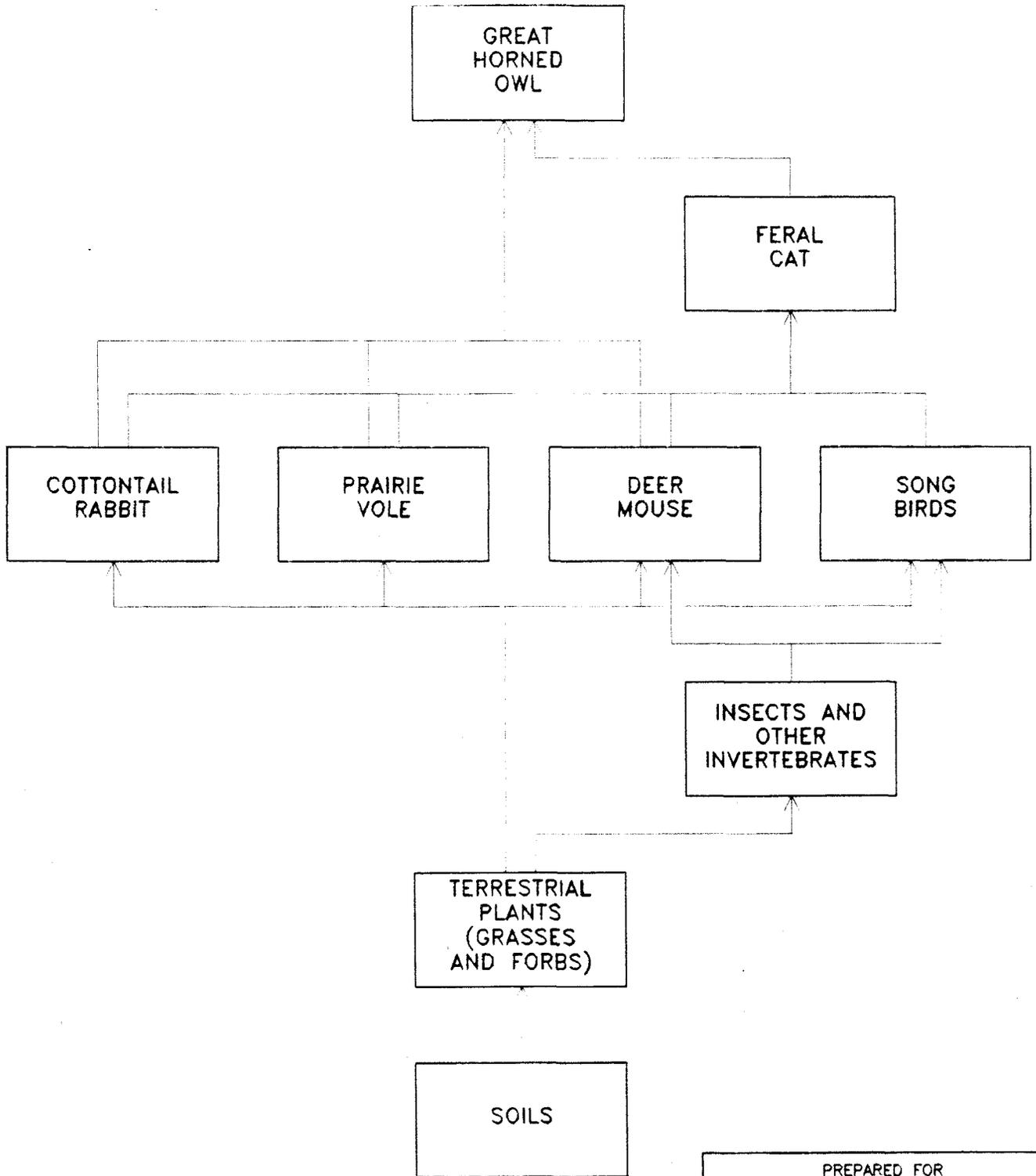
FILE NAME C:\KJS\FWGH0

DATE 12/6/93

DRAWN BY KJS

APPROVED BY *UFA*

CHECKED BY *WJ*



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 2
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR GREAT HORNED OWL

REVISION NO. 2

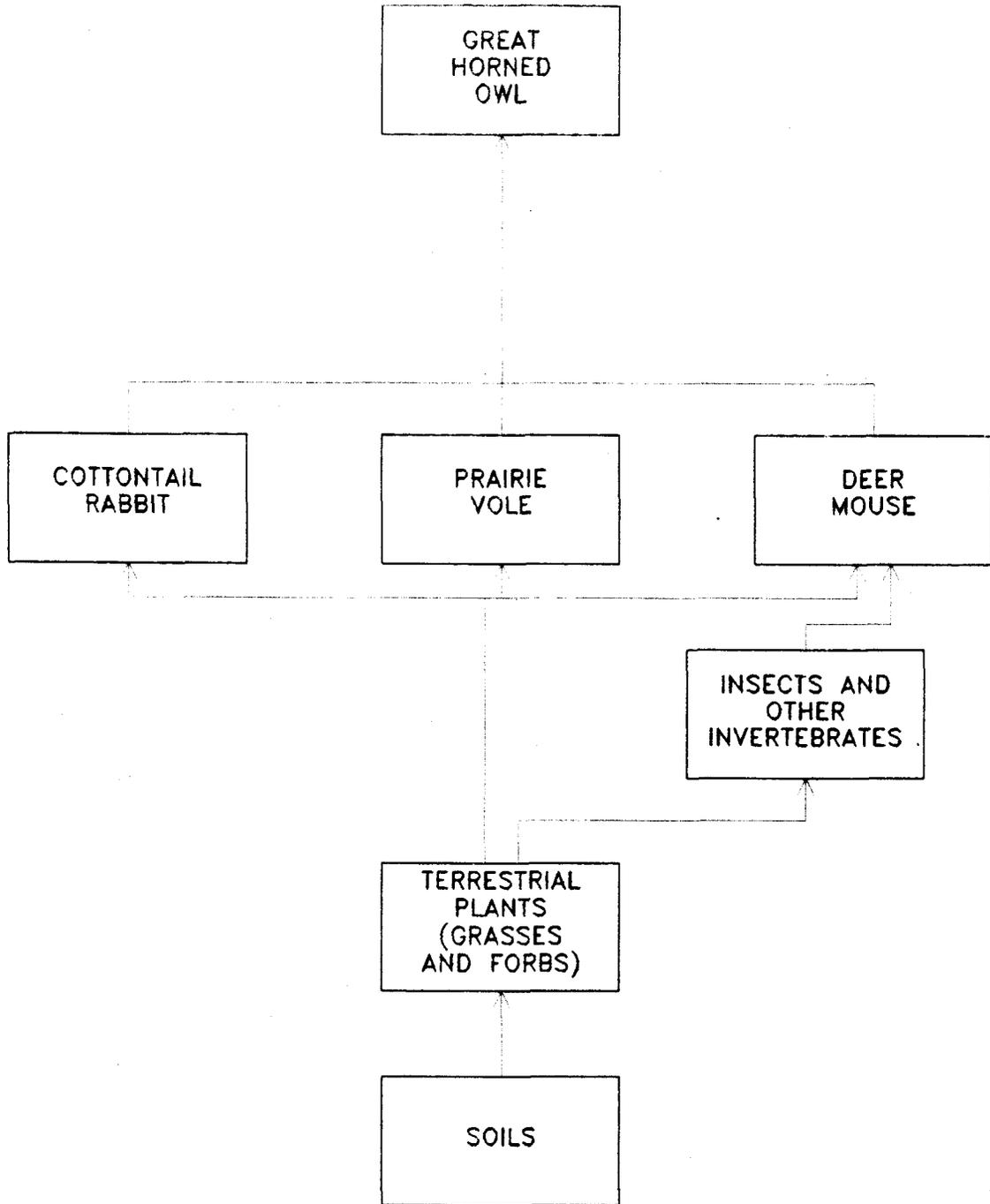
FILE NAME C:\KJS\FWGHOF3

DATE 12/6/93

DRAWN BY KJS

APPROVED BY *[Signature]*

CHECKED BY *WS*



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 3
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR GREAT HORNED OWL
WITHOUT FERAL CAT PATHWAY

REVISION NO. 4

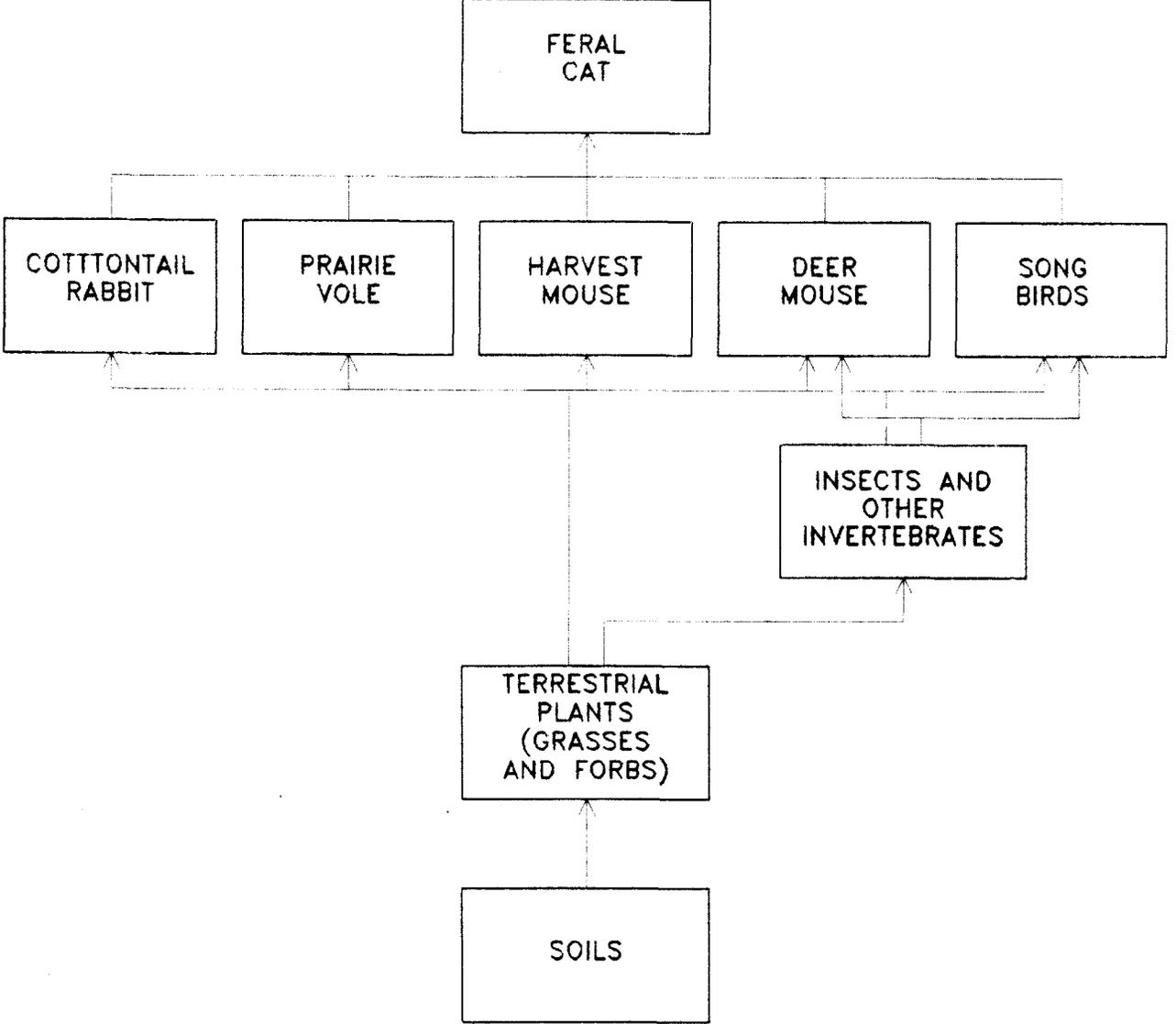
FILE NAME C:\KJS\FWFC

DATE 12/6/93

DRAWN BY KJS

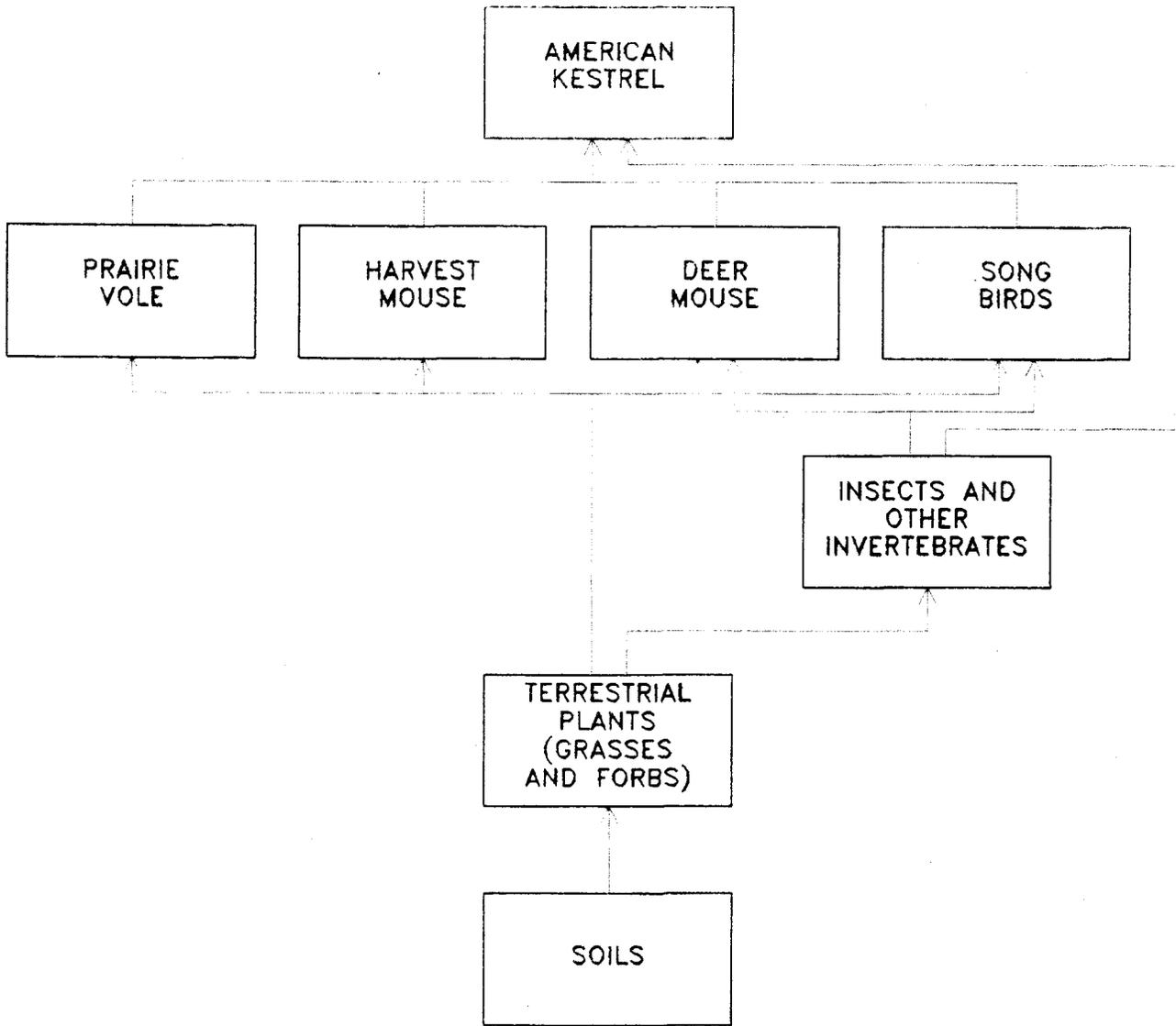
APPROVED BY *[Signature]*

CHECKED BY *[Signature]*



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 4
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR FERAL CAT



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 5
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR AMERICAN KESTREL

APPENDIX A

TOXICOLOGICAL DATA ON POTENTIAL COCs OF THE INDUSTRIAL AREA

APPENDIX A OF THE PHASE III DATA SUMMARY

The toxicological data in the following pages have been compiled from databases located at EPA Region VIII: TOMES, IRIS, and HSDB and pertain to the following potential COCs for the Rocky Flats Industrial Area:

- INORGANICS

- Beryllium
- Cadmium
- Chromium
- Mercury
- Nickel
- Silicon
- Strontium

- RADIONUCLIDES

- Americium - Information was not available from TOMES
- Plutonium
- Thorium
- Tritium
- Uranium

- VOLATILE ORGANICS

- Carbon Tetrachloride
- Chloroform
- Methylene Chloride
- Tetra Chloroethylene
- 1,1,2,2,- Tetrachloroethane

Topic: CHROMIUM

factor of 1×10^3 compared to normal plants. /Total chromium/ **PEER REVIEWED** [Lyon GL et al; Planta 88: 282-7 (1969) as cited in Nat'l Research Council Canada; Effects of Chromium in the Canadian Envir p.50 (1976) NRCC No.15017

3. Seaweed showed an accumulation factor of 1×10^2 . /Total chromium/ **PEER REVIEWED** [Boothe PN, Knauer GA; Limnol Oceanogr 17: 270-4 (1974) as cited in Nat'l Research Council Canada; Effects of Chromium in the Canadian Envir p.50 (1976) NRCC No.15017

Human Exposure

Probable Routes of Human Exposure:

1. The toxicologically important routes of entry are inhalation and ingestion. /Chromium metal and insoluble salts (as Cr)/ **PEER REVIEWED** [NIOSH. Pocket Guide to Chemical Hazards. 5th Printing/Revision. DHHS (NIOSH) Publ. No. 85-114. Washington, D.C.: U.S. Dept. of Health and Human Services, NIOSH/Supt. of Documents, GPO, Sept. 1985. 83
2. Exposure to the metal and its insoluble and soluble salts is generally via inhalation of dusts or fumes; the current threshold limit values for these compounds range from 0.05-0.5 mg/cu m /Chromium metal and its salts/ **PEER REVIEWED** [Baselt RC; Biological Monitoring Methods for Industrial Chemicals p. 81 (1980)

Average Daily Intake:

1. The mean daily dietary intake of chromium from air, water, and food has been estimated to be 0.3, 4.0, and 280 ug, respectively. A recent study estimated a median value of 240 ug as the daily dietary intake of chromium from foods in Belgium; however, inhalation intake in occupationally exposed people and cigarette smokers may far exceed the inhalation intake in the general population. /Chromium ad Chromium cmpd/ **PEER REVIEWED** [DHHS/ATSDR; Toxicological Profile for Chromium (Draft) p.83 (10/87)
2. The US Food and Nutrition Board has recommended a safe and adequate dietary intake of 50-200 ug chromium/day ... /Total chromium/ **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 245
3. Estimated safe and adequate daily dietary intakes of chromium: infants: 0-0.5 yr: 0.01-0.04 mg; 0.5-1 yr: 0.02-0.06 mg; children and adolescents: 1-3 yr: 0.02-0.08 mg; 4-6 yr: 0.03-0.12 mg; 7-10 yr: 0.05-0.2 mg; 11+ yr: 0.05-0.2 mg; adults: 0.05-0.2 mg /From table/ /Total chromium/ **PEER REVIEWED** [Gilman, A.G., L.S. Goodman, and A. Gilman. (eds.). Goodman and Gilman's The Pharmacological Basis of Therapeutics. 7th ed. New York: Macmillan Publishing Co., Inc., 1985. 1548
4. ... In the range of 0.03-0.1 mg. ... 280, 4, and 0.28 ug from food, water, and air. /Total chromium/ **PEER REVIEWED** [Friberg, L., Nordberg, G.F., Kessler, E. and Vouk, V.B. (eds). Handbook of the Toxicology of Metals. 2nd ed. Vols I, II.: Amsterdam: Elsevier Science Publishers B.V., 1986., p. V2 189



Topic: CHROMIUM

- API Air Quality Monograph #70-15: Chromium p.1-28 (1970)
as cited in NAS; Medical and Biological Effects of
Environmental Pollutants: Chromium p.15 (1974)
6. Air emissions containing chromium result from the following major industries: paper mills, organic & inorganic petro-chemicals, fertilizers, steel and metal foundries, motor vehicles, glass, cement, asbestos manufacture, textile mills and seam generation power plants. **PEER REVIEWED** [Dean JG et al; Envir Sci Technol 6: 518-22 (1972) as cited in Nat'l Research Council Canada; Effects of Chromium in the Canadian Envir p.52 (1976) NRCC No.15017
 7. Wastewater treatment sludge from the production of chrome yellow, orange, and green pigments, chrome oxide green pigments, molybdate orange, zinc yellow, and iron blue pigments, and oven residue from chrome oxide green pigments contain toxic metals including hexavalent chromium. An est 4300 metric tons of sludge are generated per yr (50-60% of this in 1980 or 2100-2600 lb). These wastes are frequently disposed of in unlined lagoons and landfills or dumped in the open creating a potential for toxic environmental contamination. /Total chromium/ **PEER REVIEWED** [USEPA; Background Document, Resource Conservation and Recovery Act Subtitle C: Identification and Listing of Hazardous Waste p.188, 202 (1980)
 8. New York City emits 4.4×10^8 g/yr Cr. 43% of the daily Cr in New York City sewer burden and 24% of chromium emission from New York City to vapor are from electroplating wastes, while residential waste and rain water runoff contribute 28% and 9%, respectively. /Total chromium/ **PEER REVIEWED** [Klein LA et al; J Water Poll Control Fed 46: 2653-62 (1974) as cited in Nat'l Research Council Canada; Effects of Chromium in the Canadian Envir p.58 (1976) NRCC No.15017
 9. The sources of chromium in waste streams are from its use as a corrosion inhibitor and from dyeing and tanning industries. /Total chromium/ **PEER REVIEWED** [Brown, K.W., G. B. Evans, Jr., B.D. Frentrup (eds.). Hazardous Waste Land Treatment. Boston, MA: Butterworth Publishers, 1983. 252

Environmental Fate

Environmental Fate:

1. TERRESTRIAL FATE: In order to decide on a suitable sampling depth for grassland soil treated with sewage sludge and to assess implications for grazing animals, a field trial on two soils was designed to estimate the distribution of metals in grassland soil profiles following surface applications of sludge. Soil cores were taken using specialized equipment to 30 cm depth and divided into seven sections. Movement from the soil surface to a depth of 10 cm was observed for all of the seven metals; cadmium, chromium, copper, molybdenum, nickel, lead and zinc, but most of the metal (60%-100%, mean 87%) remained in the upper 5 cm of soil. Sampling to a depth of 5 or 7.5 cm would be most suitable for

Topic: CHROMIUM

monitoring long-term grassland treated with surface applications of sludge. **PEER REVIEWED** [Davis RD et al: Environ Pollut 49 (2): 99-116 (1988)]

2. Aquatic Fate: ... Most of the chromium in surface waters may be present in particulate form as sediment. Some of the particulate chromium would remain as suspended matter and ultimately be deposited in sediments. ... The exact chemical forms of chromium in surface waters are not well defined. Although most of the soluble chromium in surface waters may be present as Cr(VI), a small amount may be present as Cr(III) organic complexes. Hexavalent chromium is the major stable form of chromium in seawater; however, Cr(VI) may be reduced to Cr(III) by organic matter present in water, and may eventually deposit in sediments. /Chromium/ **PEER REVIEWED** [USEPA; Health Assessment Document: Chromium p.3-18 (1984) EPA 600/8-83-014F]
3. Atmospheric Fate: Under normal conditions, chromium(III) and Cr(0) are relatively unreactive in the atmosphere. Cr(VI) in air may react with particulate matter or gaseous pollutants to form Cr(III). However, these atmospheric reactions have not been extensively studied. ... Chromium is removed from air through wet and dry depositions. The total yearly deposition of chromium in urban areas may vary from 0.12 ug/sq m to 3 ug/sq m. In general, urban areas have higher total deposition than rural areas. Chromium concentration in a wet deposition may vary from 0.004 to 0.060 ug/ml and 0.0006 to 0.034 ug/l for urban and rural areas, respectively. The precipitated chromium from the air enters surface water or soil. /Chromium/ **PEER REVIEWED** [USEPA; Health Assessment Document: Chromium p.3-17 (1984) EPA 600/8-83-014F]
4. TERRESTRIAL FATE: Uptake is greater from ultrabasic soils by a factor of 5-40 than on calcareous or silica-based soils. /Total chromium/ **PEER REVIEWED** [Schroeder HA et al; J Chron Dis 15: 941-4 (1962) as cited in NAS; Medical and Biological Effects of Environmental Pollutants: Chromium p.12 (1974)]
5. ATMOSPHERIC FATE: Chromium is associated with particulate matter in the air, and is not expected to exist in gaseous form. /Total chromium/ **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Chromium in the Canadian Envir p.22 (1976) NRCC No.15017]
6. Atmospheric Fate: Chromium (Cr) is most highly concn in the smallest particles collected from ambient air. Bulk analysis does not allow adequate characterization of these particles. /Total chromium/ **PEER REVIEWED** [Natusch DFS et al; Science 183: 202-4 (1974)]

Environmental Transport

Bioconcentration:

1. Snails showed an accumulation factor of 1×10^6 . /Total chromium/ **PEER REVIEWED** [Levine EP; Science 133: 1352-3 (1961) as cited in Nat'l Research Council Canada; Effects of Chromium in the Canadian Envir p.50 (1976) NRCC No.15017]
2. Leptospermum scoparium, a shrub, showed an accumulation

Topic: CHROMIUM

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Pollution Sources

Natural Occurring Sources:

1. CHROMIUM IS FOUND IN NATURE ONLY IN THE COMBINED STATE & NOT AS THE ELEMENT. ... **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V2 108 (1973)
2. Chromium is widely distributed; avg concn 125 mg/kg in the continental crust, but rare in natural waters. /Chromium and chromium compd/ **PEER REVIEWED** [USEPA; Ambient Water Quality Criteria Doc: Chromium p.C-4 (1980) EPA 440/5-80-035
3. PRESENT IN SMALL QUANTITIES IN ALL SOILS & PLANTS & ... CONSIDERED AGRICULTURALLY AS A DELETERIOUS ELEMENT. CERTAIN SOILS WITH A RELATIVELY HIGH CONTENT (0.2-0.4%) ARE SAID TO BE INFERTILE; CITRUS TREES GROWN ON THEM SHOW YELLOWING OF FOLIAGE ... **PEER REVIEWED** [Browning, E. Toxicity of Industrial Metals. 2nd ed. New York: Appleton-Century-Crofts, 1969. 119
4. /IRON CHROMITE (FeO.Cr₂O₃), WHICH IS FOUND/ IN NATURE ONLY IN THE COMBINED STATE & NOT AS THE ELEMENT. ... DERIVED MAINLY FROM CHROMITE (FeO.Cr₂O₃) ... FOUND IN CONSIDERABLE QUANTITIES IN RHODESIA, RUSSIA, SOUTH AFRICA, NEW CALEDONIA & THE PHILIPPINES & CONTAINS 40-50% CHROMIUM ... **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V2 108 (1973)
5. CHROMIUM OCCURS IN NATURE MOSTLY AS CHROME IRON ORE (FeO.Cr₂O₃). CHROMIUM IS PRESENT IN SMALL QUANTITIES IN ALL SOILS & PLANTS, @ 1-2.5 PPB IN SEA WATER, & @ ABOUT 200 PPM IN THE EARTH'S CRUST. THE NORMAL HUMAN ADULT BODY CONTAINS ABOUT 6 MG CR, WITH TISSUE CONCEN OF 0.02-0.04 PPM CR ON DRY WT BASIS. **PEER REVIEWED** [Venugopal, B. and T.D. Luckey. Metal Toxicity in Mammals, 2. New York: Plenum Press, 1978. 248
6. IT IS PRESENT IN MINOR AMT IN IGNEOUS ROCKS & IS MUCH MORE ABUNDANT IN BASIC & ULTRABASIC TYPES THAN IN THE MORE SILICIC TYPES OF ROCKS. **PEER REVIEWED** [National Research Council. Drinking Water & Health Volume 1. Washington, DC: National Academy Press, 1977. 241
7. The most common meteorites, ie chondrites, contain 3,000 ug/g (ppm) chromium. /Total chromium/ **PEER REVIEWED** [NAS; Medical and Biological Effects of Environmental Pollutants: Chromium p.2 (1974)
8. Chromium in air associated with large particles (> 5 um diam) originates from wind blown soil and soil forming processes. /Total chromium/ **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Chromium in the Canadian Envir p.26 (1976) NRCC No.15017
9. The abundance of chromium in various materials is as follows: 80-200 ppm in the continental crust, 125 ppm avg; 1,000-3,400 ppm in ultramafic igneous rocks, 1,800 ppm

Topic: CHROMIUM

avg; 40-600 ppm in basaltic igneous rocks, 220 ppm avg; 2-90 ppm in granitic igneous rocks, 20 ppm avg; 30-590 ppm in shales and clays, 120 ppm avg; and 10-1,000 ppm in coals, 20 ppm avg. /Total chromium/ **PEER REVIEWED** [Bowen HJM ed; Trace Elements in Biochem (1966) as cited in NAS; Medical and Biological Effects of Environmental Pollutants: Chromium p.9 (1974)]

Artificial Sources:

1. Drinking water generally contains the same chromium levels as the surface and groundwaters, which serve as its source. Although some piping materials contain significant levels of chromium (corrosion resistant steel, 8-14%; cement, 5-120 ppm chromium), little is leached into the water. However, it should be noted that Cr(III) may be oxidized to Cr(VI) during the chlorination process. /Total chromium/ **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Chromium in the Canadian Environment p.36 (1976) NRCC No 15017]
2. ... IT COULD OCCUR AS WATER POLLUTANT FROM CHROME CHEMICAL PLANTS OR IN LOSSES DURING PIGMENT PRODN OR LEATHER TANNING OPERATIONS. /TOTAL CHROMIUM/ **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V2 106 (1980)]
3. The two largest sources of chromium emission in the atmosphere are from the chemical manufacturing industry and combustion of natural gas, oil, and coal. Other sources include wind transport from road dust, cement producing plants because cement contains chromium, the wearing down of asbestos brake linings from automobiles or similar sources of wind carried asbestos since asbestos contains chromium, incineration of municipal refuse and sewage sludge, exhaust emission from automotive catalytic converters, emissions from cooling towers that use chromium compounds as rust inhibitors, waste waters from electroplating, leather tanning, and textile industries when discharge into surface waters, and solid wastes from chemical manufacture of chromium compounds or from municipal incineration when disposed of improperly in landfill sites. /Total chromium/ **PEER REVIEWED** [DHHS/ATSDR; Toxicological Profile for Chromium (Draft) p.1 (10/87)]
4. Particles emitted from coal fired power plants contained 2.3-31 ppm, chromium emitted gases contained 0.22-2.2 mg/cu m. Conc'n were reduced by fly ash collection to 0.19-6.6 ppm and 0.018-0.5 mg/cu m, respectively. /Total chromium/ **PEER REVIEWED** [Sullivan RJ; Preliminary Air Poll Survey of Chromium and its Compounds p.1-75 (1969) NAPCA Pub. APTD 69-34 as cited in NAS; Medical and Biological Effects of Environmental Pollutants: Chromium p.15 (1974)]
5. The burning of wood in fireplaces, campfires, leaf burning, and rubbish incineration contribute chromium to the air. /Total chromium/ **PEER REVIEWED** [Schroeder HA;

Topic: CADMIUM

Four studies of workers exposed to cadmium dust or fumes provided evidence of a statistically significant positive association with prostate cancer (Kipling and Waterhouse, 1967; Lemen et al., 1976; Holden, 1980; Sorahan and Waterhouse, 1983), but the total number of cases was small in each study. The Thun et al. (1985) study is an update of an earlier study (Lemen et al., 1976) and does not show excess prostate cancer risk in these workers. Studies of human ingestion of cadmium are inadequate to assess carcinogenicity.

II.A.3. ANIMAL CARCINOGENICITY DATA

Exposure of Wistar rats by inhalation to cadmium as cadmium chloride at concentrations of 12.5, 25 and 50 ug/cu.m for 18 months, with an additional 13-month observation period, resulted in significant increases in lung tumors (Takenaka et al., 1983). Intratracheal instillation of cadmium oxide did not produce lung tumors in Fischer 344 rats but rather mammary tumors in males and tumors at multiple sites in males (Sanders and Mahaffey, 1984). Injection site tumors and distant site tumors (for example, testicular) have been reported by a number of authors as a consequence of intramuscular or subcutaneous administration of cadmium metal and chloride, sulfate, oxide and sulfide compounds of cadmium to rats and mice (U.S. EPA, 1985). Seven studies in rats and mice where cadmium salts (acetate, sulfate, chloride) were administered orally have shown no evidence of a carcinogenic response.

II.A.4. SUPPORTING DATA FOR CARCINOGENICITY

Results of mutagenicity tests in bacteria and yeast have been inconclusive. Positive responses have been obtained in mutation assays in Chinese hamster cells (Dom and V79 lines) and in mouse lymphoma cells (Casto, 1976; Ochi and Ohsawa, 1983; Oberly et al., 1982).

Conflicting results have been obtained in assays of chromosomal aberrations in human lymphocytes treated in vitro or obtained from exposed workers. Cadmium treatment in vivo or in vitro appears to interfere with spindle formation and to result in aneuploidy in germ cells of mice and hamsters (Shimada et al., 1976; Watanabe et al., 1979; Gilliavod and Leonard, 1975).

 II.B. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM ORAL EXPOSURE

Not available. There are no positive studies of orally ingested cadmium suitable for quantitation.

 II.C. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM INHALATION EXPOSURE

II.C.1. SUMMARY OF RISK ESTIMATES

Inhalation Unit Risk -- $1.8E-3$ per (ug/cu.m)

Extrapolation Method -- Two stage; only first affected by exposure; extra risk

Air Concentrations at Specified Risk Levels:

Risk Level	Concentration
-----	-----

IRIS

Topic: CADMIUM

E-4 (1 in 10,000)	6E-2 ug/cu.m
E-5 (1 in 100,000)	6E-3 ug/cu.m
E-6 (1 in 1,000,000)	6E-4 ug/cu.m

II.C.2. DOSE-RESPONSE DATA FOR CARCINOGENICITY, INHALATION EXPOSURE

See Table Document

II.C.3. ADDITIONAL COMMENTS (CARCINOGENICITY, INHALATION EXPOSURE)

The unit risk should not be used if the air concentration exceeds 6 ug/cu.m, since above this concentration the unit risk may not be appropriate.

II.C.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY, INHALATION EXPOSURE)

The data were derived from a relatively large cohort. Effects of arsenic and smoking were accounted for in the quantitative analysis for cadmium effects.

An inhalation unit risk for cadmium based on the Takenaka et al. (1983) analysis is 9.2E-2 per (ug/cu.m). While this estimate is higher than that derived from human data [1.8E-3 per (ug/cu.m)] and thus more conservative, it was felt that the use of available human data was more reliable because of species variations in response and the type of exposure (cadmium salt vs. cadmium fume and cadmium oxide).

II.D. EPA DOCUMENTATION, REVIEW, AND CONTACTS (CARCINOGENICITY ASSESSMENT)

II.D.1. EPA DOCUMENTATION

U.S. EPA. 1985. Updated Mutagenicity and Carcinogenicity Assessment of Cadmium: Addendum to the Health Assessment Document for Cadmium (May 1981, EPA 600/B-B1-023). EPA 600/B-83-025F.

The Addendum to the Cadmium Health Assessment has received both Agency and external review.

II.D.2. REVIEW (CARCINOGENICITY ASSESSMENT)

Agency Work Group Review -- 11/12/86

Verification Date -- 11/12/86

II.D.3. U.S. EPA CONTACTS (CARCINOGENICITY ASSESSMENT)

William E. Pepelko / ORD -- (202)260-5904 / FTS 260-5904

David Bayliss / ORD -- (202)260-5726 / FTS 260-5726

=====

IRIS

Topic: CADMIUM

human renal cortex (i.e., the critical level) not associated with significant proteinuria (i.e., the critical effect). A toxicokinetic model has been used to determine the highest level of exposure associated with the lack of a critical effect. Since the fraction of ingested Cd that is absorbed appears to vary with the source (e.g., food vs. drinking water), it is necessary to allow for this difference in absorption when using the toxicokinetic model to determine an RfD.

I.A.5. CONFIDENCE IN THE ORAL RfD

Study: Not applicable

Data Base: High

RfD: High

The choice of NOAEL does not reflect the information from any single study. Rather, it reflects the data obtained from many studies on the toxicity of cadmium in both humans and animals. These data also permit calculation of pharmacokinetic parameters of cadmium absorption, distribution, metabolism and elimination. All of this information considered together gives high confidence in the data base. High confidence in either RfD follows as well.

I.A.6. EPA DOCUMENTATION AND REVIEW OF THE ORAL RfD

U.S. EPA. 1985. Drinking Water Criteria Document on Cadmium. Office of Drinking Water, Washington, DC. (Final draft)

Agency RfD Work Group Review: 05/15/86, 08/19/86, 09/17/87, 12/15/87, 01/20/88, 05/25/88

Verification Date: 05/25/88

I.A.7. EPA CONTACTS (ORAL RfD)

Ken Bailey / ODW -- (202)260-5535 / FTS 260-5535

Warren Banks / OWRS -- (202)260-7893 / FTS 260-7893

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE RfC)

Substance Name -- Cadmium

CASRN -- 7440-43-9

A risk assessment for this substance/agent is under review by an EPA work group.

IRIS

Topic: CADMIUM

I. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Cadmium

ASRN -- 7440-43-9

Last Revised -- 06/01/92

Section II provides information on three aspects of the carcinogenic risk assessment for the agent in question; the U.S. EPA classification, and quantitative estimates of risk from oral exposure and from inhalation exposure. The classification reflects a weight-of-evidence judgment of the likelihood that the agent is a human carcinogen. The quantitative risk estimates are presented in three ways. The slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per (mg/kg)/day. The unit risk is the quantitative estimate in terms of either risk per ug/L drinking water or risk per ug/cu.m air breathed. The third form in which risk is presented is a drinking water or air concentration providing cancer risks of 1 in 10,000, 1 in 100,000 or 1 in 1,000,000. Background Document 2 (Service Code 5) provides details on the rationale and methods used to derive the carcinogenicity values found in IRIS. Users are referred to Section I for information on long-term toxic effects other than carcinogenicity.

II.A. EVIDENCE FOR CLASSIFICATION AS TO HUMAN CARCINOGENICITY

II.A.1. WEIGHT-OF-EVIDENCE CLASSIFICATION

Classification -- B1; probable human carcinogen

Basis -- Limited evidence from occupational epidemiologic studies of cadmium is consistent across investigators and study populations. There is sufficient evidence of carcinogenicity in rats and mice by inhalation and intramuscular and subcutaneous injection. Seven studies in rats and mice wherein cadmium salts (acetate, sulfate, chloride) were administered orally have shown no evidence of carcinogenic response.

II.A.2. HUMAN CARCINOGENICITY DATA

Limited. A 2-fold excess risk of lung cancer was observed in cadmium smelter workers. The cohort consisted of 602 white males who had been employed in production work a minimum of 6 months during the years 1940-1969. The population was followed to the end of 1978. Urine cadmium data available for 261 workers employed after 1960 suggested a highly exposed population. The authors were able to ascertain that the increased lung cancer risk was probably not due to the presence of arsenic or to smoking (Thun et al., 1985). An evaluation by the Carcinogen Assessment Group of these possible confounding factors has indicated that the assumptions and methods used in accounting for them appear to be valid. As the SMRs observed were low and there is a lack of clear cut evidence of a causal relationship of the cadmium exposure only, this study is considered to supply limited evidence of human carcinogenicity.

An excess lung cancer risk was also observed in three other studies which were, however, compromised by the presence of other carcinogens (arsenic, smoking) in the exposure or by a small population (Varner, 1983; Sorahan and Waterhouse, 1983; Armstrong and Kazantzis, 1983).

Topic: CHROMIUM

factor of 1×10^3 compared to normal plants. /Total chromium/ **PEER REVIEWED** [Lyon GL et al; Planta 88: 282-7 (1969) as cited in Nat'l Research Council Canada; Effects of Chromium in the Canadian Envir p.50 (1976) NRCC No.15017

3. Seaweed showed an accumulation factor of 1×10^2 . /Total chromium/ **PEER REVIEWED** [Boothe PN, Knauer GA; Limnol Oceanogr 17: 270-4 (1974) as cited in Nat'l Research Council Canada; Effects of Chromium in the Canadian Envir p.50 (1976) NRCC No.15017

Human Exposure

Probable Routes of Human Exposure:

1. The toxicologically important routes of entry are inhalation and ingestion. /Chromium metal and insoluble salts (as Cr)/ **PEER REVIEWED** [NIOSH. Pocket Guide to Chemical Hazards. 5th Printing/Revision. DHHS (NIOSH) Publ. No. 85-114. Washington, D.C.: U.S. Dept. of Health and Human Services, NIOSH/Supt. of Documents, GPO, Sept. 1985. 83
2. Exposure to the metal and its insoluble and soluble salts is generally via inhalation of dusts or fumes; the current threshold limit values for these compounds range from 0.05-0.5 mg/cu m /Chromium metal and its salts/ **PEER REVIEWED** [Baselt RC; Biological Monitoring Methods for Industrial Chemicals p. 81 (1980)

Average Daily Intake:

1. The mean daily dietary intake of chromium from air, water, and food has been estimated to be 0.3, 4.0, and 280 ug, respectively. A recent study estimated a median value of 240 ug as the daily dietary intake of chromium from foods in Belgium; however, inhalation intake in occupationally exposed people and cigarette smokers may far exceed the inhalation intake in the general population. /Chromium ad Chromium cmpd/ **PEER REVIEWED** [DHHS/ATSDR; Toxicological Profile for Chromium (Draft) p.83 (10/87)
2. The US Food and Nutrition Board has recommended a safe and adequate dietary intake of 50-200 ug chromium/day ... /Total chromium/ **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 245
3. Estimated safe and adequate daily dietary intakes of chromium: infants: 0-0.5 yr: 0.01-0.04 mg; 0.5-1 yr: 0.02-0.06 mg; children and adolescents: 1-3 yr: 0.02-0.08 mg; 4-6 yr: 0.03-0.12 mg; 7-10 yr: 0.05-0.2 mg; 11+ yr: 0.05-0.2 mg; adults: 0.05-0.2 mg /From table/ /Total chromium/ **PEER REVIEWED** [Gilman, A.G., L.S. Goodman, and A. Gilman. (eds.). Goodman and Gilman's The Pharmacological Basis of Therapeutics. 7th ed. New York: Macmillan Publishing Co., Inc., 1985. 1548
4. ... In the range of 0.03-0.1 mg. ... 280, 4, and 0.28 ug from food, water, and air. /Total chromium/ **PEER REVIEWED** [Friberg, L., Nordberg, G.F., Kessler, E. and Vouk, V.B. (eds). Handbook of the Toxicology of Metals. 2nd ed. Vols I, II.: Amsterdam: Elsevier Science Publishers B.V., 1986., p. V2 189

Topic: CHROMIUM

5. IN USA VARIES WIDELY DUE TO DIET AND GEOGRAPHY. EST RANGE FROM 5 TO 115 UG/DAY WITH AN AVG OF 60-65 UG/DAY ... TO 5-500 UG/DAY, WITH AN AVG OF 280 UG/DAY ... /CHROMIUM AND CHROMIUM CMPD/ **PEER REVIEWED** [National Research Council. Drinking Water & Health Volume 1. Washington, DC: National Academy Press, 1977. 242

Probable Exposures:

1. EXPOSURE TO CHROMIUM METAL DOES NOT GIVE RISE TO PULMONARY FIBROSIS OR PNEUMOCONIOSIS. **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, OH:American Conference of Governmental Industrial Hygienists, 1986. 139
2. Stainless steel use in mixing containers in the baking industries may be the source of extraneous chromium in food. **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Chromium in the Canadian Envir p.43 (976) NRCC No.15017
3. Common operations in which exposure to chromium metal or insoluble chromium salts may occur includes the following: 1) use in fabrication of alloys; 2) use in preparation of alloy steels to enhance corrosion and heat resistance; 3) use in fabrication of plated products for decoration or increased wear resistance; 4) use in production of non ferrous alloys to impart special qualities to the alloys; 5) use in production and processing of insoluble salts; 6) use as chemical intermediates; use in textile industry in dyeing, silk treating, printing, and moth proofing wool; 7) use in leather industry in tanning; use in photographic fixing baths; 8) use as catalysts for halogenation, alkylation, and catalytic cracking of hydrocarbons; and 9) use as fuel additives and propellant additives; in photographic fixing baths and in ceramics. /Chromium metal and insoluble chromium salts/ **PEER REVIEWED** [Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) PublicationNo. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981. 3
4. Common operations in which exposure to soluble chromic and chromous salts may occur include the following: 1) use in textile treatment in dyeing, printing, moth proofing, and water proofing; use in tanning of leather in gloves, garments, and shoe uppers; 2) use in manufacture of pigments of green varnishes, inks, paints, and glazes; 3) use in metal treatment and polishing; 4) use in photographic fixing baths for hardening of emulsions; use as catalysts and in manufacture of catalysts; and 5) use in chemical synthesis; use as corrosion inhibitors. /Sol chromic & chromous salts (as Cr)/ **PEER REVIEWED** [Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) PublicationNo. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office,

Topic: CHROMIUM

Jan. 1981. 3

5. OCCUPATIONAL EXPOSURE: CHROMIUM & ITS CMPD ARE FOUND IN 3 MAIN TYPES OF INDUST ACTIVITY: (I) MOST CR DERIV ARE USED IN METALLURGICAL INDUST ... (II) CHROMIUM CMPD ARE ... COMPONENT OF REFRACTORY MATERIALS ... & (III) MANY OF HIGHLY COLORED CHROMATE SALTS ... ARE USED IN PIGMENT, PAINT, TANNING & DYEING INDUSTRIES. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V23 243 (1980)
6. In decreasing order, the est levels of exposure are: 1) occupational; 2) food; 3) water; and 4) air. /Total chromium/ **PEER REVIEWED** [USEPA; Drinking Water Criteria Document: Chromium (Draft) p.1 (7/27/81) EPA 68-02-3651
7. ... Inhalation of the dust and fumes released during the manufacture of dichromate from chromite ore; inhalation of chromic acid mist during the electroplating and surface treatment of metals; and skin contact in various manufacturing processes. /Total chromium/ **PEER REVIEWED** [Sittig, M. Handbook of Toxic and Hazardous Chemicals and Carcinogens, 1985. 2nd ed. Park Ridge, NJ: Noyes Data Corporation, 1985. 245

HSDB

Topic: CHROMIUM

EXPOSURE STANDARDS & REGULATIONS

Standards & Regulations

Immediately Dangerous to Life or Death:

1. No evidence could be found for the existence of an IDLH.
QC REVIEWED [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 70

Acceptable Daily Intake:

1. Estimated Adequate and Safe Intake (EASI) levels for chromium: Infants: 1) age 0.0 to 0.5 yr: 0.01 to 0.04 mg/day, 2) age 0.5 to 1.0 yr: 0.02 to 0.06 mg/day; Children: 1) age 1 to 3 yr: 0.02 to 0.08 mg/day, 2) age 4 to 6 yr: 0.03 to 0.12 mg/day, 3) age 7 to 10 yr: 0.05 to 0.20 mg/day, and 4) age > or = to 11 yr: 0.05 to 0.20 mg/day; and Adults: 0.05 to 0.20 mg/day. /Chromium, from table/ **PEER REVIEWED** [NAS; Recommended Dietary Allowances (1980) as cited in USEPA; Health Assessment Document: Chromium p.6-2 (1984) EPA 600/8-83-014F

Occupational Permissible Levels

OSHA Standards:

1. Meets criteria for OSHA medical records rule. /Total chromium/ **PEER REVIEWED** [29 CFR 1910.20 (7/1/88)
2. 8 hr Time-Weighted avg: 1 mg/cu m /Chromium, metal & insol salts (as Cr)/ **PEER REVIEWED** [29 CFR 1910.1000 (7/1/88)

Threshold Limit Values:

1. Time Weighted Avg (TWA) 0.5 mg/cu m (1981) **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 17
2. Excursion Limit Recommendation: Excursions in worker exposure levels may exceed three times the TLV-TWA for no more than a total of 30 min during a work day and under no circumstances should they exceed five times the TLV-TWA, provided that the TLV-TWA is not exceeded. **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 5

Other Standards and Regulations

RCRA Requirements:

1. A solid waste containing chromium may or may not become characterized as a hazardous waste when subjected to the Toxicant Extraction Procedure listed in 40 CFR 261.24, and if so characterized, must be managed as a hazardous waste. **PEER REVIEWED** [40 CFR 261.24 (7/1/88)

Topic: CADMIUM

crops shall not exist or occur, unless in compliance with requirements given in 40 CFR 257.3-5, which limit cadmium content in the solid waste. /Cadmium containing solid waste/ **PEER REVIEWED** [40 CFR 257.3-5 (7/1/88)]

CRA Requirements:

1. A solid waste containing cadmium may or may not become characterized as a hazardous waste when subjected to the Toxicant Extraction Procedure listed in 40 CFR 261.24, and if so characterized, must be managed as a hazardous waste. **PEER REVIEWED** [40 CFR 261.24 (7/1/88)]
2. The Environmental Protection Agency has amended its regulations concerning ground-water monitoring with regard to screening suspected contamination at land based hazardous waste treatment, storage, and disposal facilities. /There are/ new requirements to analyze for a specified core list of chemicals plus those chemicals specified by the Regional Administrator on a site specific basis. ... /Total cadmium (all species) and sulfide are included on this list./ /Total cadmium (all species) and sulfide/ **PEER REVIEWED** [52 FR 25942 (7/9/87)]

Topic: CADMIUM

1. CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Cadmium

CASRN -- 7440-43-9

Last Revised -- 10/01/89

The Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Please refer to Background Document 1 in Service Code 5 for an elaboration of these concepts. RfDs can also be derived for the noncarcinogenic health effects of compounds which are also carcinogens. Therefore, it is essential to refer to other sources of information concerning the carcinogenicity of this substance. If the U.S. EPA has evaluated this substance for potential human carcinogenicity, a summary of that evaluation will be contained in Section II of this file when a review of that evaluation is completed.

I.A.1. ORAL RfD SUMMARY

See Table Document

I.A.2. PRINCIPAL AND SUPPORTING STUDIES (ORAL RfD)

U.S. EPA. 1985. Drinking Water Criteria Document on Cadmium. Office of Drinking Water, Washington, DC. (Final draft)

A concentration of 200 ug cadmium (Cd)/gm wet human renal cortex is the highest renal level not associated with significant proteinuria (U.S. EPA, 1985). A toxicokinetic model is available to determine the level of chronic human oral exposure (NOAEL) which results in 200 ug Cd/gm wet human renal cortex; the model assumes that 0.01% day of the Cd body burden is eliminated per day (U.S. EPA, 1985). Assuming 2.5% absorption of Cd from food or 5% from water, the toxicokinetic model predicts that the NOAEL for chronic Cd exposure is 0.005 and 0.01 mg Cd/kg/day from water and food, respectively (i.e., levels which would result in 200 ug Cd/gm wet weight human renal cortex). Thus, based on an estimated NOAEL of 0.005 mg Cd/kg/day for Cd in drinking water and an UF of 10, an RfD of 0.0005 mg Cd/kg/day (water) was calculated; an equivalent RfD for Cd in food is 0.001 mg Cd/kg/day (see Section VI.A. for references).

I.A.3. UNCERTAINTY AND MODIFYING FACTORS (ORAL RfD)

UF = 10. This uncertainty factor is used to account for intrahuman variability to the toxicity of this chemical in the absence of specific data on sensitive individuals.

MF = 1.

I.A.4. ADDITIONAL COMMENTS (ORAL RfD)

Cd is unusual in relation to most, if not all, of the substances for which an oral RfD has been determined in that a vast quantity of both human and animal toxicity data are available. The RfD is based on the highest level of Cd in the

Topic: CADMIUM

POSSIBLE STANDARDS & REGULATIONS

Standards & Regulations

Immediately Dangerous to Life or Death:

1. NIOSH has recommended that cadmium dust (as Cd) be treated as a potential human carcinogen. /Cadmium dust (as Cd)/
QC REVIEWED [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 56

Occupational Permissible Levels

OSHA Standards:

1. Meets criteria for OSHA medical records rule. /Cadmium dust and cadmium fume/ **PEER REVIEWED** [29 CFR 1910.20 (7/1/87)
2. 8-hr Time-Weighted avg: 0.1 mg/cu m; acceptable ceiling concentration 0.3 mg/cu m /Cadmium fume/ **PEER REVIEWED** [29 CFR 1910.1000 (7/1/87)
3. 8-hr Time-Weighted avg: 0.2 mg/cu m; acceptable ceiling concentration 0.6 mg/cu m /Cadmium dust/ **PEER REVIEWED** [29 CFR 1910.1000 (7/1/87)

NIOSH Recommendations:

1. NIOSH recommends that the substance be treated as a potential human carcinogen. /Cadmium dust and cadmium fume/ **PEER REVIEWED** [NIOSH/CDC. NIOSH Recommendations for Occupational Safety and Health Standards Sept. 1986. (Supplement to Morbidity and Mortality Weekly Report 35 No. 15, Sept. 26, 1986),p. 7S

Threshold Limit Values:

1. Time Weighted Avg (TWA) 0.05 mg/cu m /Cadmium dusts & salts, as Cd/ **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 14
2. Excursion Limit Recommendation: Excursions in worker exposure levels may exceed three times the TLV-TWA for no more than a total of 30 min during a work day and under no circumstances should they exceed five times the TLV-TWA, provided that the TLV-TWA is not exceeded. /Cadmium dusts & salts, as Cd/ **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 5
3. Notice of Intended Change (first notice appeared in 1987-88 edition): The ACGIH has listed chemicals for which a limit has been proposed for the first time, or for which a change in the "Adopted" listing has been proposed. The proposed limits should be considered trial limits that will remain in the listing for a period of at least two years. If, after two years no evidence comes to light that questions the appropriateness of the values herein, the values will be reconsidered for the "Adopted" list. Time Weighted Avg (TWA) 0.01 mg/cu m (total dust); Time Weighted Avg (TWA) 0.002 mg/cu m respirable fraction. /Cadmium & compounds, as Cd/ **QC REVIEWED** [American

Topic: CADMIUM

Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 39

4. Notice of Intended Change (first notice appeared in 1987-88 edition): The ACGIH has listed chemicals for which a limit has been proposed for the first time, or for which a change in the "Adopted" listing has been proposed. A2. A2= Suspected human carcinogen. /Cadmium & compounds, as Cd; Total dust; Respirable fraction/ **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 39
5. BEI (Biological Exposure Index): Cadmium in urine (timing is not critical) is 10 ug/g creatinine. The determinant is usually present in a significant amt in biological specimens collected from subjects who have not been occupationally exposed. Such background levels are incl in the BEI value. (1988-1989 adoption) /Cadmium/ **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 63
6. BEI (Biological Exposure Index): Cadmium in blood (timing is not critical) is 10 ug/l. The determinant is usually present in a significant amt in biological specimens collected from subjects who have not been occupationally exposed. Such background levels are incl in the BEI value. (1988-1989 adoption) /Cadmium/ **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 63

Other Standards and Regulations

Water Standards:

1. The ocean dumping, or transportation for dumping, of materials containing the following constituents as other than trace contaminants will not be approved on other than an emergency basis: ... cadmium or cadmium compounds. /Cadmium and compounds/ **PEER REVIEWED** [40 CFR 227.6(3) (7/1/88)
2. Toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations. /Cadmium and inorganic and organic cadmium compounds/ **PEER REVIEWED** [40 CFR 401.15 (7/1/88)
3. The maximum contaminant level (MCL) of cadmium as Cd ion in drinking water is 0.01 mg/l. /Cadmium as Cd ion/ **PEER REVIEWED** [40 CFR 141.11 (7/1/88)

Soil Standards:

1. Cadmium. A facility or practice concerning application of solid waste to within one meter (three feet) of the surface of land used for the production of food-chain

Topic: CADMIUM

/Cadmium aerosols or fumes/ **PEER REVIEWED** [USEPA; Health Assessment Document: Cadmium p.2-3 (1981) EPA-600/8-81-023

3. Cadmium constitutes a significant environmental pollutant and humans are exposed through food, water, air and especially, heavy smoking. **PEER REVIEWED** [Gosselin, R.E., R.P. Smith, H.C. Hodge. Clinical Toxicology of Commercial Products. 5th ed. Baltimore: Williams and Wilkins, 1984.,p. III-78

Average Daily Intake:

1. 50 ug **PEER REVIEWED** [Gilman, A.G., L.S.Goodman, and A. Gilman. (eds.). Goodman and Gilman's The Pharmacological Basis of Therapeutics. 7th ed. New York: Macmillan Publishing Co., Inc., 1985. 1617

Probable Exposures:

1. EXPOSURE ... HAS BEEN HIGH IN PAST ... CONCN OF SEVERAL MG/CU M OF AIR WERE REPORTED ... /IN/ 1976 ... ACCUMULATOR FACTORY ... /SHOWED/ AIR CONCN OF CADMIUM AS APPROX 0.04 MG/CU M. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work).,p. V11 49 (1976)
2. Workers in smelters and other metal-processing plants may be exposed to high concentrations of cadmium in the air. **PEER REVIEWED** [Gilman, A.G., L.S.Goodman, and A. Gilman. (eds.). Goodman and Gilman's The Pharmacological Basis of Therapeutics. 7th ed. New York: Macmillan Publishing Co., Inc., 1985. 1617
3. Cadmium appears in the workplace in solder, a neutron absorbent in the nuclear industry, alkaline storage batteries, an amalgam in dentistry, a stabilizer for polyvinyl chloride, engravings and pigments. Some occupations at risk include alloy makers, battery makers, engravers, textile workers, welders, solder workers and zinc and lead refiners. **PEER REVIEWED** [Ellenhorn, M.J. and D.G. Barceloux. Medical Toxicology - Diagnosis and Treatment of Human Poisoning. New York, NY: Elsevier Science Publishing Co., Inc. 1988. 1018
4. OCCUPATIONAL EXPOSURE: EXPOSURE OCCURS PRIMARILY IN SMELTING & REFINING ZINC, LEAD & COPPER ORES CONTAINING CADMIUM, SPRAYING CADMIUM CONTAINING PIGMENTS, PROCESSING SCRAP CONTAINING CADMIUM, ETC. /CADMIUM, ALLOYS, COMPOUNDS/ **PEER REVIEWED** [International Labour Office. Encyclopedia of Occupational Health and Safety. Volumes I and II. New York: McGraw-Hill Book Co., 1971. 233

Body Burdens:

1. To assess the pathophysiologic significance of increased body burdens of cadmium (Cd), cross-sectional evaluation of renal function and calcium, phosphorus and vitamin D metabolism was carried out in 38 industrial workers exposed to Cd for 11-37 yr. Average airborne concentrations of Cd ranged from 5 - 229 ug/cu m. Mean kidney Cd burden was 7.4 +/- 4.4 mg in nonsmokers and 12.3 +/- 7.2 mg for smokers. Mean liver Cd in nonsmokers was

Topic: CADMIUM

4.5 +/-2.6 ug/g and 7.9 +/-4.9 ug/g in smokers. Liver or kidney Cd burden was considered elevated in 31% of the workers. Creatinine clearance was normal in all workers. Maximal urinary concentrating ability was abnormal in a significant fraction (52%) of the men. **PEER REVIEWED** [Greenberg A et al; Arch Environ Health 41 (2): 69-76 (1986)]

2. /IN MAN/ ABOUT HALF OF TOTAL BODY BURDEN IS FOUND IN LIVER & KIDNEYS ... CADMIUM IN THESE ORGANS IS MAINLY BOUND TO A LOW MOLECULAR WEIGHT PROTEIN, IN FORM OF A METALLOTHIONEIN ... **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work).,p. V2 90 (1973)]

Topic: CADMIUM

Artificial Sources:

1. Liberation during smelting and refining of ores where it is a by-product of zinc, lead and copper-bearing ores. Liberation during recovery of metal by processing scrap; during melting and pouring of cadmium metal; during casting of alloys for cadmium-copper, cadmium-lead, cadmium-bismuth, cadmium-silver, cadmium-nickel, cadmium-lead-silver, cadmium-lead-silver-nickel, cadmium-lead-bismuth-tin, and cadmium-gold products used for coating telephone cables, trolley wires, welding, electrodes, automatic sprinkling systems, steam boilers, fire alarms, high pressure/temperature bearings, starting switches, aircraft relays, light duty circuit breakers, low temperature solder, and jewelry. Liberation during fabrication of metal, alloys, or plated steel. Liberation during casting and use of solders; during melting of cadmium ingots for paint and pigment manufacture used for coloring of plastics and ceramic glazes, electroplating, and in chemical synthesis. Liberation during coating on metals by hot dipping or spraying. Liberation during manufacture of nickel-cadmium batteries for use in radio-portable telephones, convenience appliances, and vented cells used in airplanes, helicopters, and stand-by power and lighting. /Cadmium, cadmium oxide/ **PEER REVIEWED** [Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981. 3
2. ... ALL OF THE CADMIUM AND/OR ITS SALTS ... USED AS STABILIZERS AND PIGMENTS IN PLASTICS COULD ENTER THE ENVIRONMENT, A PROCESS PARTICULARLY FACILITATED BY INCINERATION. THUS, DISPOSAL OF PLASTICS COULD CONTRIBUTE TO POLLUTION BY CADMIUM. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V11 50 (1976)
3. Ceramic artists can be exposed to many hazardous materials, generally related to dry clays, glazes and kiln use. Glazes can contain lead, antimony, arsenic, barium, beryllium, boron, chromium, cobalt, cadmium, copper, vanadium and other materials which all have potential toxic effects. **PEER REVIEWED** [Hart C; J Environ Health 49 (5): 282-86 (1987)
4. ... FORMS READILY FROM CONTACT OF CADMIUM VAPOR WITH AIR ... FOUND WHERE CADMIUM IS PRESENT IN EMISSIONS FROM THERMAL PROCESSES ... **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V2 82 (1973)

Environmental Transport

Volatilization from Water/Soil:

1. Cadmium can enter the air from natural sources. **PEER

HSDB

opic: CADMIUM

REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work).,p. V2 79 (1973)

Environmental Concentrations
Water Concentrations:

1. Cadmium can enter surface waters from the natural sources ... and from a variety of manufacturing operations that involve either cadmium itself or zinc that contains a cadmium impurity. Cadmium can enter the water environment from the plating operations when spent plating solutions are discarded. The production of refined cadmium metal is a potential source of cadmium in nearby surface waters (from ore tailings and washings). **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work).,p. V2 80 (1973)
2. ENVIRONMENTAL ACCUMULATION: GROUNDWATER CONTAMINATION FROM ELECTROPLATING OPERATIONS HAS BEEN REPORTED TO CAUSE ... CONCN OF UP TO 3.2 MG/L. **PEER REVIEWED** [National Research Council. Drinking Water & Health Volume 1. Washington, DC: National Academy Press, 1977. 212

Atmospheric Concentrations:

1. In the atmosphere of the working environment cadmium concentrations of 1-3 mg/cu m and 0.17-0.46 mg/cu m have been reported. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work).,p. V2 79 (1973)
2. Analysis indicates that retention levels resulting from present and predicted future concentrations of cadmium in the ambient air are well below kidney dysfunction level. Compared with 10 ug critical level, average urban air results in a daily cadmium retention of less than 0.1 ug. ... Estimates of maximum anticipated annual average ambient cadmium concentrations around the primary sources indicate that very low concentrations should result if the sources, both existing and new, comply with current ambient air standards for particulate matter. These annual average concentrations were estimated to range from a high of about 0.13 ug/cu m, for sewage sludge incinerators, to as little as 0.002 ug/cu m for municipal incinerators. **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982.,p. 4-1

Human Exposure

Probable Routes of Human Exposure:

1. /Cadmium/ absorption, in humans may include: cutaneous absorption and transplacental absorption. **PEER REVIEWED** [USEPA; Health Assessment Document: Cadmium p.2-4 (1981) EPA-600/8-81-023
2. Inhalation of cadmium in the form of aerosols or fumes.

Topic: CHROMIUM

6.0 RANGE OF TOXICITY

6.1 EFFECTIVE DOSE

6.1.1 ADULT

- A. Although the role of chromium as an essential nutrient in humans is not fully delineated, the estimated requirement for chromium in humans is about 1 mcg/day (Clinical Nutrition Cases, 1988).
- B. Chromium is important in glucose and lipid metabolism, and chromium deficiency may be one factor associated with the development of atherosclerosis (Schroeder et al, 1970).

6.2 MINIMUM LETHAL EXPOSURE

A. ORAL EXPOSURE

1. Soluble hexavalent salts (chromic acid (trioxide), sodium dichromate, potassium dichromate, ammonium dichromate) are approximately 100 times more toxic than trivalent salts (chromic oxide, chromic sulfate, chromium phosphate, chromium carbonate).
 2. Death was reported in a 14-year-old boy after ingestion of 1.5 grams of potassium dichromate, despite gastric lavage and administration of dimercaprol, ascorbic acid, peritoneal dialysis, and exchange transfusion (Kaufman et al, 1970).
- B. SKIN EXPOSURE: Dermal corrosion of an area less than 10 percent of body surface area has resulted in death. Fatal nephritis has occurred due to use of chromium trioxide to cauterize a wound (Major, 1922).

6.3 MAXIMUM TOLERATED EXPOSURE

- A. CHROMIC ACID: 5 and 15 grams of chromic acid have been ingested by an adult with survival (Pederson & Morch, 1978; Fristedtr et al, 1965).
- B. METALLIC CHROMIUM is nontoxic.
- C. TRIVALENT CHROMIUM has not been associated with toxicity.
- D. POTASSIUM DICHROMATE:
 1. Symptoms have occurred after as little as 0.5 gram of potassium dichromate (Partington, 1950).
 2. Ingestion of about 16 grams of potassium dichromate was reported to result in survival in a 48-year-old man (Philipson, 1892).
 3. An 18-year-old girl recovered after developing intravascular hemolysis and renal failure following ingestion of a few grams of potassium dichromate (Sharma et al, 1978).
- E. CHROMIUM PIGMENTS: Ingestion of a paint containing insoluble chromate ore resulted in seizures in a 14-month old child, with an onset of one week postingestion; no gastrointestinal or renal dysfunction were noted (Sander & Camp, 1939).
- F. INHALATION EXPOSURE: Nasal involvement is frequent following inhalation of concentrations greater than 0.1 milligram/cubic meter.

6.4 TOXIC SERUM/PLASMA/BLOOD CONCENTRATIONS

- A. In a nonfatal ingestion of approximately 50 mL of 10% sodium dichromate solution by a 24 month-old, the following chromium levels were reported (Walpole et al,

TOMES(R) Medical Management

Topic: CHROMIUM

1985).

Day	Serum mcg/L	Urine mcg/L	Peritoneal Dialysate mcg/L
1	210	-	2
2	9	300	1
3	13	60	
4	12	-	
5	-	80	
6	-	150	
22	5		

Ref

Values 5 5-10

- B. The following whole blood, plasma/serum, and urine chromium levels were reported after a 44-year-old male ingested an unknown amount of chromic acid. On presentation he was tachypneic, tachycardic, and had abdominal tenderness. His course was complicated by metabolic acidosis, hypotension, acute tubular necrosis, and renal failure treated with hemodialysis, anemia and ulcerations of the esophagus, stomach, and duodenum. Although the patient was discharged 24 days after admission, he was found dead at home one month after ingestion (Saryan & Reedy, 1988).

Days post- ingestion	Whole Blood (mcg/dL)	Plasma/ Serum (mcg/dL)	Urine (mcg/L)
1	-	96	-
3	-	-	5130
4	24	33	-
9	14	21	142

Topic: CADMIUM

5.0 RANGE OF TOXICITY

5.2 MINIMUM LETHAL EXPOSURE

- A. INHALATION: Exposure to probably less than 2500 min x mg/m(3) of cadmium oxide fumes or cadmium chloride aerosol is probably fatal (Friberg et al, 1985). 500 min x mg/m(3) is dangerous.
- B. ORAL: Lethal oral doses have ranged upwards from 150 grams (Bernard & Lauwerys, 1984; Buckler et al, 1986). Following oral ingestion, death results from shock due to fluid loss or acute renal failure, and cardiopulmonary depression.

5.3 MAXIMUM TOLERATED EXPOSURE

- A. ACUTE INGESTION: Acute ingestion of as little as 10 milligrams of inorganic cadmium has caused severe symptoms.
- B. CHRONIC: Long term daily oral intake of more than 1 milligram of cadmium may result in severe bone disease (Friberg et al, 1985).

5.4 TOXIC SERUM/PLASMA/BLOOD CONCENTRATIONS

- A. Blood cadmium above 0.5 microgram/deciliter warrants careful investigation.
- B. Chronic toxicity is associated with urinary excretion of 20 micrograms cadmium/gram creatinine.

6.5 LD50/LC50

- A. Andersen et al (1986) reported the following effect of dose on mortality in mice following oral ingestion of cadmium:

Dose mcmol Cd/kg	Mortality (%)
140	0/10 (0)
270	3/64 (5)
530	14/57 (25)
790	38/42 (90)

- B. LCLO (Inhalation-human): 39 milligrams/cubic meter for 20 minutes (Sax, 1984).

6.6 CALCULATIONS

A. SI UNIT CONVERSION

1. CADMIUM (Serum)

- a. To convert Traditional Units (micrograms/deciliter) into SI Units (micromoles/Liter), multiply Traditional Units by 0.08897.
- b. To convert SI Units (micromoles/Liter) into Traditional Units (micrograms/deciliter), divide SI Units by 0.08897.

Topic: CADMIUM

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL
Pollution Sources

Natural Occurring Sources:

1. Coal and other fossil fuels contain cadmium and their combustion releases the element into the environment. ****PEER REVIEWED**** [Gilman, A.G., L.S.Goodman, and A. Gilman. (eds.). Goodman and Gilman's The Pharmacological Basis of Therapeutics. 7th ed. New York: Macmillan Publishing Co., Inc., 1985. 1617
2. Occurs in a greenockite (cadmium sulfide) ore containing zinc sulfide also with lead and copper ores containing zinc. /Found/ in Canada, central and western USA, Peru, Australia, Mexico and Zaire. ****PEER REVIEWED**** [Sax, N.I. and R.J. Lewis, Sr. (eds.). Hawley's Condensed Chemical Dictionary. 11th ed. New York: Van Nostrand Reinhold Co., 1987. 196
3. The principal cadmium-bearing mineral in primary deposits is sphalerite which also contains zinc. ****PEER REVIEWED**** [Nat'l Research Council Canada; Cadmium p.16 (1979) NRCC No. 16743
4. Among sedimentary rock types, the carbonaceous shales, formed under the reducing conditions, contain the most cadmium. ****PEER REVIEWED**** [Nat'l Research Council Canada; Cadmium p.16 (1979) NRCC No.16743
5. Cadmium content: Peat: <1-3 ppm based on 10 samples; Coal: <1-20 ppm based on 12 samples; bitumens, solid hydrocarbons, asphalts <1-3 ppm based on 6 samples. ****PEER REVIEWED**** [Nat'l Research Council Canada; Cadmium p.30 (1979) NRCC No.16743
6. Cadmium concentrations in: phosphatic rock: up to 100 mg/kg; igneous rock: 0.001 mg/kg. ****PEER REVIEWED**** [Korte F; Ecotoxicol Environ Safety 7 (1): 3-8 (1983)
7. Volcanic action is considered to be the major natural source of cadmium. This is related to the very large quantities of particulate matter emitted, together with high enrichment of cadmium in volcanic aerosols. An investigation into trace element emissions from Mount Etna in Sicily estimated that 2.8×10^{-2} tons/day, or about 10 tons/year of cadmium was discharged into the atmosphere. ****PEER REVIEWED**** [Baut-Menard P, Arnold M; Geophys Res Lett 5: 245-248 (1978)
8. Cadmium content /in/: sphalerite: 0.0001-2%; greenockite: 77.8%; hawleyite: 77.8%; chalcopyrite: < 0.4-110 ppm; marcasite: <0.3-<50 ppm; arsenopyrite: < 5 ppm; galena: < 10-3000 ppm; pyrite: < 0.06-42 ppm; pyrrhotite: trace; tetrahedrite: 80-2000 ppm; magnetite: 0-0.31 ppm; cadmium oxide: 87.5%; limonite: <5-1000 ppm; wad and manganese oxides: <10-1000 ppm; anglesite: 120- >1000 ppm; barite: < 0.2 ppm; anhydrite and gypsum: < 0.2 ppm; calcite: < 1-23 ppm; smithsonite: 0.1-2.35%; otavite: 65.18%; pyromorphite: < 1-8 ppm; scorodite: <1-5.8 ppm; beudantite: 100-1000 ppm; apatite: 0.14-0.15 ppm; bindheimite: 100-1000 ppm; silicates: 0.03-2.8 ppm. ****PEER REVIEWED**** [Nat'l Research Council Canada; Cadmium p.17 (1979) NRCC No.16743 .

Topic: BERYLLIUM COMPOUNDS

- d. Intraperitoneal - hamsters: 20 mg/kg
- 4. Beryllium Hydroxide Intravenous - rats: 3.8 mg/kg (IARC, 1980)
- 5. Beryllium Sulfate (IARC, 1980)
 - a. Oral - rats-mice: 80 mg/kg
 - b. Subcutaneous - rats-mice: 1.5 mg/kg
 - c. Intraperitoneal - rats: 18 mg/kg
 - d. Intravenous - rats: 7.2 mg/kg
 - e. Intravenous - monkeys: 0.6 mg/kg
 - f. Subcutaneous - rabbits: 1.5 mg/kg
- 6. Beryllium Phosphate (IARC, 1980)
 - a. Oral - rats: 82 mg/kg
 - b. Intravenous - rats: 4.2 mg/kg
 - c. Intravenous - mice: 1.4 mg/kg
- 7. Beryllium Acetate Intraperitoneal - rats: 317 mg/kg (IARC, 1980)
- 8. Beryllium Carbonate Intraperitoneal - guinea-pigs: 50 mg/kg (IARC, 1980)
- 9. Beryllium Sulfate Tetrahydrate Intravenous - mice: 265 mcg/kg
- B. TCLO
 - 1. Beryllium Inhalation - human: 300 mg/m³ (Sax, 1986)
- 6.7 OTHER
 - A. Beryllium poisoning is largely limited to workers smelting ore (20%) or milling beryllium alloys. Family and neighborhood contact from dust laden clothing and emissions (80%) have been reduced by industrial hygiene practice.
 - B. Acute Beryllium poisoning is uncommon due to industrial hygiene measures.
 - C. In the most heavily exposed worker groups, no more than 1 in 20 is affected by chronic beryllium disease. Some "host" factor as well as beryllium exposure is required (Cullen et al, 1986).
 - D. Rats pretreated with ferric ammonium citrate (40 mg/kg IP) survived longer following IV beryllium sulfate than the control group that was pretreated with saline. The authors propose that beryllium is bound by ferritin and eliminated in the feces (Lindenschmidt et al, 1986).
 - E. Hot-pressed beryllium may be more soluble than beryllium metal (Andre et al, 1987).

Topic: BERYLLIUM COMPOUNDS

6.0 RANGE OF TOXICITY

6.2 MINIMUM LETHAL EXPOSURE

- A. A poor prognosis is associated with chronic beryllium disease. The reported mortality rate was 30% in 1972 (Finkel, 1983).
- B. Beryllium Case Registry data indicate the extent of delay in onset of chronic beryllium disease is highly variable (Hardy et al, 1967):

Time after Exposure	Number of Cases Reported
10 years or more	12
5 to 10 years	56
1 to 5 years	89
1 month to 1 year	27
1 month	126

- C. Exposure to a fume source of beryllium may pose a greater risk for development of adverse effects compared to dust exposures (Cullen et al, 1986).
- D. Rats and mice exposed to an aerosol of 13 micrograms beryllium/liter developed acute lung injury (Sendelbach et al, 1986).

6.3 MAXIMUM TOLERATED EXPOSURE

- A. Roentgenographic evidence of chronic beryllium disease persisted for 20 years with no other sign or symptom of illness (Finkel, 1983).
- B. Beryllium Case Registry data indicate the extent of delay in onset of chronic beryllium disease is highly variable (Hardy et al, 1967):

Time after Exposure	Number of Cases Reported
10 years or more	12
5 to 10 years	56
1 to 5 years	89
1 month to 1 year	27
1 month	126

- C. Exposure to a fume source of beryllium may pose a greater risk for development of adverse effects compared to dust exposures (Cullen et al, 1986).
- D. Rats and mice exposed to an aerosol of 13 micrograms beryllium/Liter developed acute lung injury (Sendelbach et al, 1986).

6.5 LD50/LC50

A. LD50

- Beryllium Intravenous - rat: 496 mcg/kg (Sax, 1986)
- Beryllium Chloride (IARC, 1980)
 - Intramuscular - mice: 12 mg/kg
 - Oral - rats: 86 mg/kg
 - Intraperitoneal - rats: 4.4 mg/kg
 - Intraperitoneal - guinea-pigs: 50 mg/kg
- Beryllium Fluoride (IARC, 1980)
 - Oral-acute - rats-mice: 100 mg/kg
 - Subcutaneous - mice: 20 mg/kg
 - Intravenous - mice: 1.8 mg/kg

Topic: BERYLLIUM

risk may not be appropriate.

II.C.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY,
INHALATION EXPOSURE)

The estimate of risk for inhalation exposure was based upon an epidemiologic study having several confounding variables. The estimates of exposure levels and duration were also somewhat uncertain. While a quantitative assessment based on several animal studies resulted in a similar estimate of risk (which increases the confidence somewhat), the quality of the available studies was poor (that is, they were conducted at single dose levels or lacked control groups).

II.D. EPA DOCUMENTATION, REVIEW, AND CONTACTS
(CARCINOGENICITY ASSESSMENT)

II.D.1. EPA DOCUMENTATION

Source Document -- U.S. EPA, 1986, 1991

Source Document Review -- The values in 1986 Health Assessment Document for Beryllium and the 1991 Drinking Water Criteria Document for Beryllium received Agency and external review.

Other EPA Documentation -- None

II.D.2. REVIEW (CARCINOGENICITY ASSESSMENT)

Agency Work Group Review -- 05/04/88, 02/01/89, 12/07/89

Verification Date -- 05/04/88 (inhalation); 02/01/89 (oral)

II.D.3. U.S. EPA CONTACTS (CARCINOGENICITY ASSESSMENT)

William Pepelko / OHEA -- (202)260-5904

David Bayliss / OHEA -- (202)260-5726

opic: BERYLLIUM

II.B.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY, ORAL EXPOSURE)

The estimate is derived from a study which did not show a significant increase in tumorigenic response. While this study is limited by use of only one non-zero dose group, the occurrence of high mortality and unspecified type and site of the tumors, it was used as the basis of the quantitative estimate because exposure occurred via the most relevant route. Oral risk estimates derived by extrapolation from studies in other species/strains for the intravenous and inhalation routes (also highly uncertain) are within an order of magnitude.

II.C. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM INHALATION EXPOSURE

II.C.1. SUMMARY OF RISK ESTIMATES

Inhalation Unit Risk -- $2.4E-3$ per (ug/cu.m)

Extrapolation Method -- Relative risk

Air Concentrations at Specified Risk Levels:

Risk Level	Concentration
E-4 (1 in 10,000)	$4E-2$ ug/cu.m
E-5 (1 in 100,000)	$4E-3$ ug/cu.m
E-6 (1 in 1,000,000)	$4E-4$ ug/cu.m

II.C.2. DOSE-RESPONSE DATA FOR CARCINOGENICITY, INHALATION EXPOSURE

See Table Document

II.C.3. ADDITIONAL COMMENTS (CARCINOGENICITY, INHALATION EXPOSURE)

Human data were used for the inhalation exposure quantitation despite limitations in the study. Humans are most likely to be exposed by inhalation to beryllium oxide, rather than other beryllium salts. Animal studies by inhalation of beryllium oxide have utilized intratracheal instillation, rather than general inhalation exposure.

Effective dose was determined by adjusting for duration of daily (8/24 hours) and annual (240/365 days) exposure, and the fraction of the lifetime at risk (i.e., time from onset of employment to termination of follow-up). The risk estimates were based on the data of Wagoner et al. (1980) in which the smoking adjusted, expected lung cancer deaths were found to range from 13.91 to 14.67, in comparison to 20 observed.

Relative risk estimates of 1.36 and 1.44 were derived and the 95% confidence limits of these estimates, 1.98 and 2.09, respectively, were used to estimate the lifetime cancer risk. Note that all of the above estimates are based on one data set using a range of estimated exposure and exposure times.

Because of uncertainties regarding workplace beryllium concentration and exposure duration, unit risks were derived using two estimates each of concentration, fraction of lifetime exposed and relative risk. The recommended value is the arithmetic mean of the 8 derived unit risks.

The unit risk should not be used if the air concentration exceeds 4 ug/cu.m, since above this concentration the unit

Topic: BERYLLIUM

detected in 5.4% of the samples /and/ concentrations ranged from 0.01 to 1.22 mg/l with a mean value of 0.19 ug/l. /Total beryllium/ **PEER REVIEWED** [Kopp JF, Kroner RC; Fed Water Pollut Control Admin (1967) as cited in USEPA; Ambient Water Quality Criteria Doc: Beryllium p.C-1 (1980) EPA 440/5-80-024

2. Analysis of surface, ground, and rain waters have shown ... that beryllium concentrations are well below 1.0 ug/l. /It was/ reported that the maximum beryllium concentration in 20 rain water samples and 56 river water samples (from 5 different Australian rivers) was 0.18 ug/l. ... Even heavily polluted Rhine and Main rivers in Germany, the concentrations were below 0.02 ug/l. /Total beryllium/ **PEER REVIEWED** [USEPA; Ambient Water Quality Criteria Doc: Beryllium p.A-1 (1980) EPA 440/5-80-024

Effluents Concentrations:

1. BASED ON ENRICHMENTS RELATIVE TO COAL AS A FUNCTION OF FLY ASH PARTICLE SIZE, BERYLLIUM BEHAVIOR WAS BETWEEN A) LITTLE OR NO ENRICHMENT IN THE SMALL PARTICLE FRACTION & B) ENRICHMENTS INCR WITH DECR PARTICLE SIZE. /Total beryllium/ **PEER REVIEWED** [COLES DG ET AL; ENVIRON SCI TECHNOL 13 (4): 455 (1979)

Sediment/Soil Concentrations:

1. Soil concn generally range from 0.1-40 ppm, with the average around 6 ppm. **PEER REVIEWED** [Brown, K.W., G. B. Evans, Jr., B.D. Frentrup (eds.). Hazardous Waste Land Treatment. Boston, MA: Butterworth Publishers, 1983. 244

Atmospheric Concentrations:

1. URBAN AIR METAL PARTICLE CONCENTRATION IN THE US 1964-1965. POLLUTANT BERYLLIUM; AVERAGE CONCEN LESS THAN 0.0005 UG/CU M; MAX CONCEN 0.010 UG/CU M. /TOTAL BERYLLIUM/ **PEER REVIEWED** [Doull, J., C.D. Klaassen, and M. D. Amdur (eds.). Casarett and Doull's Toxicology. 2nd ed. New York: Macmillan Publishing Co., 1980. 411
2. At a beryllium extraction plant in Ohio, concentrations were /approximately/ 2 mg/cu m over a 7 year period. /Total beryllium/ **PEER REVIEWED** [Breslin AJ, Harris WB; AMA Arch Ind Health 19: 596 (1959) as cited in USEPA; Ambient Water Quality Criteria Doc: Beryllium p.C-2 (1980) EPA 440/5-80-024
3. Beryllium was present in 12% of 440 /air/ samples analyzed from 16 cities. Concentrations ranged from 0.001 to 0.002 ug/cu m in urban areas and 0.00013 ug/cu m in more rural areas. /Total beryllium/ **PEER REVIEWED** [USEPA; Ambient Water Quality Criteria Doc: Beryllium p.C-2 (1980) EPA 440/5-80-024

Food Survey Results:

1. ... Beryllium concentrations (dry weight) of 0.08 mg/kg in polished rice, 0.12 mg/kg in toasted bread, 0.17 mg/kg in potatoes, 0.24 mg/kg in tomatoes, and 0.33 mg/kg in head lettuce. /Total beryllium/ **PEER REVIEWED** [Petzow G, Zorn H; Chemlker Vig 98: 236 (1974) as cited in USEPA; Ambient Water Quality Criteria Doc: Beryllium p.C-1 (1980) EPA 440/5-80-024
2. Beryllium levels (ppm in ash) for different foodstuffs

Topic: BERYLLIUM

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Pollution Sources

Natural Occurring Sources:

1. ESTIMATES OF ABUNDANCE IN EARTH'S CRUST VARY FROM 2 TO 10 PPM. NATURAL ISOTOPES: 9 (100%); RADIOACTIVE ISOTOPES (MASS NUMBERS): 6-8; 10-12. ... FOUND IN PHENACITE, CHRYSOBERYL ... PRECIOUS FORMS OF BERYL: EMERALD, AQUAMARINE. /TOTAL BERYLLIUM/ **PEER REVIEWED** [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 166.
2. Beryllium is concentrated in silicate minerals relative to sulfides. In common crystalline rocks, the element is enriched in the feldspar minerals relative to ferromagnesium minerals and apparently replace the silicon ion; 85-95% of the total crystal beryllium may be bound in the feldspar structures. ... The greatest known concentrations of beryllium are found in certain pegmatite bodies, where crystals of beryl account for a few percent of the total pegmatite volume, and may be found in several of the strata of zoned dykes. The element is sometimes concentrated in hydrothermal veins, and some granitic rocks contain sufficient amounts to permit the crystallization of small amounts of beryl. /Total beryllium/ **PEER REVIEWED** [Beus AA; Geochemistry 5: 432 (1966) as cited in USEPA; Ambient Water Quality Criteria Doc: Beryllium p.A-1 (1980) EPA 440/5-80-024
3. CERTAIN FOSSIL FUELS CONTAIN BERYLLIUM CMPD, ACCOUNTING FOR THE PRESENCE OF BERYLLIUM IN SOME COMMUNITY AIR SAMPLES AND TISSUES OF CITY RESIDENTS. /TOTAL BERYLLIUM/ **PEER REVIEWED** [Hamilton, A., and H. L. Hardy. Industrial Toxicology. 3rd ed. Acton, Mass.: Publishing Sciences Group, Inc., 1974. 57

Artificial Sources:

1. Ceramic artists can be exposed to many hazardous materials, generally related to dry clays, glazes and kiln use. Glazes can contain lead, antimony, arsenic, barium, beryllium, boron, chromium, cobalt, cadmium, copper, vanadium and other materials which all have potential toxic effects. /Total beryllium/ **PEER REVIEWED** [Hart C; J Environ Health 49 (5): 282-6 (1987)
2. Beryllium enters the environment principally from coal combustion. Be contents in the ashes from a Czechoslovakian power plant were determined (coarse (> 20 mm) and fine (2.0 to 0.2 mm) fraction from dump, and fine (0.2 mm) fraction from electrostatic precipitators). Acidic and alkali aqueous extracts of these ashes contained various concentrations of Be (1 to 17% of total concentrations). Wastewater showed 3.15 and 3.4 ug Be/l. Thus, secondary long term beryllium pollution emerges from the slag and ash dumps. **PEER REVIEWED** [Kubiznakova J; Water Air Soil Pollut 34 (4): 363-68 (1987)

Environmental Concentrations

Water Concentrations:

1. /The authors/ reported the results of trace metal analysis of 1,577 drinking water samples. ... Beryllium was

pic: BERYLLIUM

were: beans, 0.01; cabbage, 0.05; hen eggs (yolk) 0.01; milk, 0.02; mushrooms, 0.12; nuts, 0.01- 0.47; tomatos, 0.02; and baker's yeast, 0.02. /Total beryllium/ **PEER REVIEWED** [Mechan WR, Smythe LE; Environ Sci Technol 1: 839 (1967) as cited in USEPA; Ambient Water Quality Criteria Doc: Beryllium p.C-1 (1980) EPA 440/5-80-024

Plant Concentrations:

1. In birch, aspen and willow beryllium content may rise as high as 3 mg/kg. Potatoes contain 0.17 mg/kg dry substance, tomatoes 0.24 mg/kg and head lettuce 0.33 mg/kg. /Total beryllium/ **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 112
2. Beryllium in root, stem, and leaf tissues of tobacco (*Nicotiana tabacum* L Md-609) plants grown in McMurtrey's nutrient solution with addition of 0.3, 1.0 and 3.0 mg/l Be were determined by gas chromatography-mass spectrometric analysis using m/l 246 of beryllium trifluoroacetylacetonate chelates. The method was sensitive to about 4 pg of Be. The majority of Be was associated with tobacco roots (0.3, 1.0 and 3.0 mg/l of Be were added to the solution were associated with 374, 427 and 4280 ug Be/g dry wt of tissue, respectively; leaves were associated with 2.14, 2.36 and 81.4 ug Be/g dry wt tissue respectively. **PEER REVIEWED** [Kosak-Channing L; Plant Sci 46 (3): 175-80 (1986)

Milk Concentrations:

1. ACCORDING TO STUDIES ... ON COWS WITH RADIOACTIVE BERYLLIUM, LESS THAN 0.002% OF INJECTED ACTIVITY WAS RECOVERED IN MILK. BIOLOGICAL HALF-LIFE IN MILK WAS 19 HR. /TOTAL BERYLLIUM/ **PEER REVIEWED** [Friberg, L., Nordberg, G.F., Kessler, E. and Vouk, V.B. (eds). Handbook of the Toxicology of Metals. 2nd ed. Vols I, II.: Amsterdam: Elsevier Science Publishers B.V., 1986. 102
2. Beryllium level /reported/ in milk, 0.02 ppm in ash. /Total beryllium/ **PEER REVIEWED** [Mechan WR, Smythe LE; Environ Sci Technol 1: 839 (1967) as cited in USEPA; Ambient Water Quality Criteria Doc: Beryllium p.C-1 (1980) EPA 440/5-80-024

ther Environmental Concentrations:

1. In cigarettes beryllium levels of 0.5-0.7 ug/cigarette were analyzed with 4.5-10% escaping with the smoke. **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 112

man Exposure

robable Routes of Human Exposure:

1. FOOD ... NOT ... SIGNIFICANT SOURCE OF HUMAN EXPOSURE ... NO EVIDENCE THAT BERYLLIUM IS MOVING FROM SOILS INTO FOOD OR FEED PLANTS ... IN AMOUNTS ... DETRIMENTAL ... **PEER REVIEWED** [National Research Council. Drinking Water & Health Volume 1. Washington, DC: National Academy Press, 1977. 232

robable Exposures:

opic: BERYLLIUM

1. The influence of aerosol suspension from clothing on personal monitor exposure estimates was investigated in a beryllium facility. Samples of 100% cotton and 100% Nomex fabrics used at the beryllium facility were tested. The deposition of airborne beryllium into fabrics was significantly enhanced by electrostatic attraction on cotton but not on Nomex fabrics. Both fabrics collected more beryllium in motion than on stationary units. Personal monitors mounted in front of fabrics collected more beryllium when the fabrics were agitated than when monitors were placed in the positions of the nose and mouth. The air concentrations increased as fabric load increased, but leveled off at high fabric load concentrations. Resuspension from cotton was higher than from Nomex. Resuspension of aerosol from garments can cause erroneously high exposure measurements from chest mounted personal monitors. **PEER REVIEWED** [Bohne JE, Cohen BS; Am Ind Hyg Assoc J 46 (2): 73-9 (1985)]
2. Workshirts worn by employees at a beryllium refinery resuspended beryllium containing dust. The old shirts resuspended significantly higher quantities of beryllium to the air than did the washed and unwashed new shirts. A considerable fraction of the Be measured in air was respirable. **PEER REVIEWED** [Cohen BS, Positano R; Am Ind Hyg Assoc J 47 (5): 255-8 (1986)]
3. Fourteen dental casting alloys were analyzed for release of nickel and beryllium into acidic salivary soln in vitro. Corrosion rates at varying pH levels and time in soln were calc over a 120 day period and the possible significance of these rates to allergic reactions or other health hazards were postulated. When the beryllium levels were analyzed for these alloys they were much higher than expected. In each of the alloys, since the nickel compd was often 66-78% of the compd and the beryllium level a max of 2%, the differences in magnitude of nickel vs beryllium concn might be expected to be on the order of 30/1 or greater. The differences were closer to 8/1. Nickel and beryllium containing dental casting alloys have the potential to be a significant hazard to the lab technician, dentist and patient. **PEER REVIEWED** [Covington JS et al; J Prosthet Dent 54 (1): 127-36 (1985)]

Body Burdens:

1. Humans: total body burden: 36 ug Beryllium; 24 ug Beryllium in soft tissue. /Total beryllium/ **PEER REVIEWED** [Nat'l Research Council Canada; Data Sheets on Selected Toxic Elements p.15 (1982) NRCC No. 19252]
2. Humans: Kidney; 0.2 ug beryllium/kg: liver; 1.6 ug beryllium/kg: muscle; 0.75 ug beryllium/kg: bone; 3.0 ug beryllium/kg: hair; 6.0-20.0 ug beryllium/kg /Total beryllium/ **PEER REVIEWED** [Bowen HJM; The Environmental Chemistry of the Elements 103 (1982) as cited in [Nat'l Research Council Canada; Data Sheets On Selected Toxic Elements p.15 (1982) NRCC No. 19252]
3. Human: blood: 0.01 ug beryllium/l /Total beryllium/ **PEER REVIEWED** [Bow HJM; The Environmental Chemistry of the

Topic: BERYLLIUM

Elements 105 (1980) as cited in [Nat'l Research Council Canada; Data Sheets on Selected Toxic Elements p.15 (1982) NRCC No. 19252

4. Humans: lung: 1×10^2 to 1×10^5 ug beryllium/l: blood: 0.02-3.0 ug beryllium/l: urine: 0.02-3.0 ug beryllium/l /Total beryllium/ **PEER REVIEWED** [Reeves AL; Beryllium In Toxicology of Metals Vol 2 93 (1977) EPA-600/1-77-022 as cited in Nat'l Research Council Canada; Data Sheets on Selected Toxic Elements p.15 (1982) NRCC No. 19252
5. The soft tissue burden of an adult is likely to be less than 20 ug and the skeletal burden about 30 ug. /Total beryllium/ **PEER REVIEWED** [Meehan WR, Smythe LE; Environ Sci Technol 1: 839-44 (1967) as cited in USEPA; Health Assessment Document for Beryllium p.4-6 (1987) EPA 600/8-84/0267

Topic: BERYLLIUM

EXPOSURE STANDARDS & REGULATIONS

Standards & Regulations

Immediately Dangerous to Life or Death:

1. NIOSH has recommended that beryllium be treated as a potential human carcinogen. **QC REVIEWED** [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 46

Occupational Permissible Levels

OSHA Standards:

1. During an 8 hr work shift, an employee may be exposed to a concentration of beryllium and beryllium compd above 5 ug/cu m (but never above 25 ug/cu m) only for a maximum period of 30 min. Such exposure must be compensated by exposures to concentrations less than 2 ug/cu m so that the cumulative exposure for the entire 8 hr work shift does not exceed a weighted average of 2 ug/cu m. /Beryllium and beryllium compd/ **PEER REVIEWED** [29 CFR 1910.1000 (7/1/87)

NIOSH Recommendations:

1. NIOSH recommends that the substance be treated as a potential human carcinogen with a 10 hr TWA: 0.5 ug/Be/cu m. **PEER REVIEWED** [NIOSH/CDC. NIOSH Recommendations for Occupational Safety and Health Standards Sept. 1986. (Supplement to Morbidity and Mortality Weekly Report 35 No. 15, Sept. 26, 1986), p. 7S

Threshold Limit Values:

1. Time Weighted Avg (TWA) 0.002 mg/cu m (1979) **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 13
2. A2. A2= Suspected human carcinogen. (1979) **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 13
3. Excursion Limit Recommendation: Excursions in worker exposure levels may exceed three times the TLV-TWA for no more than a total of 30 min during a work day and under no circumstances should they exceed five times the TLV-TWA, provided that the TLV-TWA is not exceeded. **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 5

Other Standards and Regulations

Water Standards:

1. Toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations. /Beryllium and inorganic and organic compd/ **PEER REVIEWED** [40 CFR 401.15 (7/1/88)

Topic: BERYLLIUM

1. CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Beryllium

CASRN -- 7440-41-7

Last Revised -- 02/01/93

The Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Please refer to Background Document 1 in Service Code 5 for an elaboration of these concepts. RfDs can also be derived for the noncarcinogenic health effects of compounds which are also carcinogens. Therefore, it is essential to refer to other sources of information concerning the carcinogenicity of this substance. If the U.S. EPA has evaluated this substance for potential human carcinogenicity, a summary of that evaluation will be contained in Section II of this file when a review of that evaluation is completed.

I.A.1. ORAL RfD SUMMARY

See Table Document

I.A.2. PRINCIPAL AND SUPPORTING STUDIES (ORAL RfD)

Schroeder, H.A. and M. Mitchner. 1975. Life-term studies in rats: Effects of aluminum, barium, beryllium and tungsten. J. Nutr. 105: 421-427.

Fifty-two weanling Long-Evans rats of each sex received 0 or 5 ppm beryllium (as BeSO₄, beryllium sulfate) in drinking water. Exposure was for the lifetime of the animals. At natural death the rats were dissected and gross and microscopic changes were noted in heart, kidney, liver, and spleen. There were no effects of treatment on these organs or on lifespan, urinalysis, serum glucose, cholesterol, and uric acid, or on numbers of tumors. Male rats experienced decreased growth rates from 2 to 6 months of age.

Similar studies were carried out on Swiss (CD strain) mice in groups of 54/sex at doses of approximately 0.95 mg/kg/day (Schroeder and Mitchner, 1975). Female animals showed decreased body weight compared with untreated mice at 6 of 8 intervals. Male mice exhibited slight increases in body weight. These effects were not considered adverse, therefore, 0.95 mg/kg/day is considered a NOAEL.

An unpublished investigation by Cox et al. (1975) indicates a much higher dose level (approximately 25 mg/kg/day) in the diet may be a NOEL.

I.A.3. UNCERTAINTY AND MODIFYING FACTORS (ORAL RfD)

UF -- The uncertainty factor of 100 reflects a factor of 10 each for interspecies conversion and for the protection of sensitive human subpopulations.

MF -- None

I.A.4. ADDITIONAL COMMENTS (ORAL RfD)

This RfD is limited to soluble beryllium salts. Data on the

Topic: BERYLLIUM

Atmospheric Standards:

1. Beryllium ambient air concentration: 0.01 ug/cu m averaged over a 30 day period in the vicinity of the stationary source. /Total beryllium/ **PEER REVIEWED** [40 CFR 61.32 (7/1/88)]
2. Beryllium has been designated as a hazardous air pollutant under section 112 of the Clean Air Act. **PEER REVIEWED** [40 CFR 61.01 (7/1/88)]

RCRA Requirements:

1. As stipulated in 40 CFR 261.33, when beryllium, as a commercial chemical product or manufacturing chemical intermediate or an off-specification commercial chemical product or a manufacturing chemical intermediate, becomes a waste, it must be managed according to federal and/or state hazardous waste regulations. Also defined as a hazardous waste is any container or inner liner used to hold this waste or any residue, contaminated soil, water, or other debris resulting from the cleanup of a spill, into water or on dry land, of this waste. Generators of small quantities of this waste may qualify for partial exclusion from hazardous waste regulations (40 CFR 261.5(e)). **PEER REVIEWED** [40 CFR 261.33 (7/1/88)]
2. The Environmental Protection Agency has amended its regulations concerning ground-water monitoring with regard to screening suspected contamination at land based hazardous waste treatment, storage, and disposal facilities. /There are/ new requirements to analyze for a specified core list of chemicals plus those chemicals specified by the Regional Administrator on a site-specific basis. ... /Total beryllium (all species) is included on this list./ ... /Total beryllium (all species)/ **PEER REVIEWED** [52 FR 25942 (7/9/87)]

opic: BERYLLIUM

terato- genicity or reproductive effects of beryllium are limited. It has been reported to produce embryoethality and terata in chick embryos (Puzanova et al., 1978).

I.A.5. CONFIDENCE IN THE ORAL RfD

Study -- Low
Data Base -- Low
RfD -- Low

Confidence in the study is rated as low because only one dose level was administered. Although numerous inhalation investigations and a supporting chronic oral bioassay in mice exist, along with the work by Cox et al. (1975) which indicates that a higher dose level might be a NOEL, these studies are considered as low to medium quality; thus, the data base is given a low confidence rating. The overall confidence in the RfD is low, reflecting the need for more toxicity data by the oral route.

I.A.6. EPA DOCUMENTATION AND REVIEW OF THE ORAL RfD

Source Document -- U.S. EPA, 1985
The 1985 Drinking Water Criteria Document for Beryllium is currently undergoing Agency review.
Agency Work Group Review -- 12/02/85
Verification Date -- 12/02/85

I.A.7. EPA CONTACTS (ORAL RfD)

Linda R. Papa / OHEA -- (513)569-7587
Krishan Khanna / OST -- (202)260-7588

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE
RfC)

Substance Name -- Beryllium
CASRN -- 7440-41-7
Not available at this time.

=====

IRIS

Topic: BERYLLIUM

I. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Beryllium

HSRN. -- 7440-41-7

Last Revised -- 09/01/92

Section II provides information on three aspects of the carcinogenic risk assessment for the agent in question; the U.S. EPA classification, and quantitative estimates of risk from oral exposure and from inhalation exposure. The classification reflects a weight-of-evidence judgment of the likelihood that the agent is a human carcinogen. The quantitative risk estimates are presented in three ways. The slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per (mg/kg)/day. The unit risk is the quantitative estimate in terms of either risk per ug/L drinking water or risk per ug/cu.m air breathed. The third form in which risk is presented is a drinking water or air concentration providing cancer risks of 1 in 10,000, 1 in 100,000 or 1 in 1,000,000. Background Document 2 (Service Code 5) provides details on the rationale and methods used to derive the carcinogenicity values found in IRIS. Users are referred to Section I for information on long-term toxic effects other than carcinogenicity.

II.A. EVIDENCE FOR CLASSIFICATION AS TO HUMAN CARCINOGENICITY

II.A.1. WEIGHT-OF-EVIDENCE CLASSIFICATION

Classification -- B2; probable human carcinogen.

Basis -- Beryllium has been shown to induce lung cancer via inhalation in rats and monkeys and to induce osteosarcomas in rabbits via intravenous or intramedullary injection. Human epidemiology studies are considered to be inadequate.

II.A.2. HUMAN CARCINOGENICITY DATA

Inadequate. Reported increases, while apparently associated with exposure, did not take a variety of possible confounding factors into account. Wagoner et al. (1980) observed 47 deaths from cancer among 3055 white males employed in beryllium-processing with a median duration of employment of 7.2 months. Among the 2068 followed for 25 years or more, 20 lung cancer deaths were observed. These increased incidences were statistically significant. When lung cancer mortality data became available for 1968-1975, the number of expected deaths was recalculated and the increased incidence was statistically significant only among workers followed 25 years or more (Bayliss, 1980; MacMahon, 1977, 1978). When the number of expected deaths was adjusted for smoking, the increased incidence was no longer significant (U.S. EPA, 1986).

An earlier study of workers from this same beryllium processing plant, and several studies of workers from this plant combined with workers from other beryllium plants, have reported a statistically significant increased incidence of lung cancer (Bayliss and Wagoner, 1977; Mancuso, 1970, 1979, 1980). No adjustment was made for smoking in these studies, and all were limited in their ability to detect a possible increased incidence of lung cancer because of methodological constraints and deficiencies.

II.A.3. ANIMAL CARCINOGENICITY DATA

opic: BERYLLIUM

Sufficient. Based on the evidence for induction of tumors by a variety of beryllium compounds in male and female monkeys and in several strains of rats of both sexes, via inhalation and intratracheal instillation, and the induction of osteosarcomas in rabbits by intravenous or intramedullary injection in multiple studies.

Slight increases in cancer incidence (not statistically significant in comparison with controls) were reported in Long-Evans rats (52/sex/group) administered 5 ppm beryllium sulfate in the drinking water for a lifetime. The authors reported a slight excess of grossly observed tumors in the 5 ppm group (9/33) over controls (4/26) in the male rats. The power of this test to detect a carcinogenic effect was reduced by high mortality (approximately 60% survived a pneumonia epidemic at 20 months) (Schroeder and Mitchener, 1975a).

Schroeder and Mitchener (1975b) administered 5 ppm beryllium sulfate in drinking water to Swiss mice (54/sex/group) over a lifetime. A nonstatistically significant increase in incidence of lymphoma leukemias were reported in the females (9/52) relative to controls (3/47).

An increase in reticulum cell sarcomas of the lungs was seen in male, but not female Wistar-derived rats administered beryllium sulfate in the diet at 5 and 50 ppm, but not at 500 ppm (Morgareidge et al., 1977). The incidence in males equaled 10/49, 17/35, 16/40 and 12/39 for the control, low, intermediate and high dose groups, respectively. Since the results were published only as an abstract, and since no response was seen at the highest dose, these results are considered to be only suggestive for the induction of cancer via this route.

Osteogenic sarcomas were induced in rabbits by intravenous injection of beryllium compounds in at least 12 different studies and by intramedullary injection in at least four studies (U.S. EPA, 1991). Bone tumors were induced by beryllium oxide, zinc beryllium silicate, beryllium phosphate, beryllium silicate and beryllium metal. No bone tumors were reported to be induced by intravenous injection of beryllium oxide or zinc beryllium silicate in rats or guinea pigs (Gardner and Heslington, 1946). Positive results, however, were reported in mice injected with zinc beryllium silicate, although the numbers were not listed (Cloudman et al., 1949). The sarcomas were generally reported to be quite malignant and metastasized to other organs.

Lung tumors, primarily adenomas and adenocarcinomas, have been induced via the inhalation route in both male and female Sprague-Dawley rats during exposure periods of up to 72 weeks by beryllium sulfate (Reeves et al., 1967), in both male and female Sherman and Wistar rats by beryllium phosphate, beryllium fluoride and zinc beryllium silicate (Schepers, 1961), in male Charles River CR-CD rats by beryl ore (Wagner et al., 1969) and in both male and female rhesus monkeys by beryllium sulfate (Vorwald, 1968). Positive results were seen in rats exposed to beryllium sulfate at concentrations as low as 2 ug/cu.m (Vorwald, 1968).

Tumors were also induced by intratracheal instillation of

Topic: BERYLLIUM

metallic beryllium, beryllium-aluminum alloys and beryllium oxide in both Wistar rats and rhesus monkeys. Adenomas, adenocarcinomas and malignant lymphomas were seen in the lungs, with lymphosarcomas and fibrosarcomas present at extrapulmonary sites (Groth et al., 1980; Ishinishi et al., 1980).

II.A.4. SUPPORTING DATA FOR CARCINOGENICITY

Beryllium sulfate and beryllium chloride have been shown to be nonmutagenic in bacterial and yeast gene mutation assays (Simmon et al., 1979). In contrast, gene mutation studies in Chinese hamster V79 and CHO cells were positive (Miyaki et al., 1979; Hsie et al., 1979). Chromosomal aberrations and sister chromatid exchange were also induced by beryllium in cultured human lymphocytes and Syrian hamster embryo cells (Larramendy et al., 1981).

II.B. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM ORAL EXPOSURE

II.B.1. SUMMARY OF RISK ESTIMATES

Oral Slope Factor -- 4.3 per(mg/kg)/day

Drinking Water Unit Risk -- 1.2E-4 per(ug/L)

Extrapolation Method -- Linearized multistage procedure, extra risk

Drinking Water Concentrations at Specified Risk Levels:

Risk Level	Concentration
E-4 (1 in 10,000)	8.3E-1 ug/L
E-5 (1 in 100,000)	8.3E-2 ug/L
E-6 (1 in 1,000,000)	8.3E-3 ug/L

II.B.2. DOSE-RESPONSE DATA (CARCINOGENICITY, ORAL EXPOSURE)

Tumor Type -- gross tumors, all sites combined

Test Animals -- rat/Long-Evans, male

Route -- drinking water

Reference -- Schroeder and Mitchener, 1975a

Human Equiv-

Administered Dose ppm	Equivalent Dose (mg/kg)/day	Human Equivalent Dose (mg/kg/day)	Tumor Incidence
0	0	0	4/26
5	0.54	0.09	9/33

II.B.3. ADDITIONAL COMMENTS (CARCINOGENICITY, ORAL EXPOSURE)

The solubility and speciation of beryllium in air and water media vary, with ambient air characterized by relatively insoluble beryllium compounds such as beryllium oxide and metallic beryllium, and water characterized by more soluble forms. Carcinogenic potency varies according to the form of beryllium present.

Human equivalent doses were calculated using a human body weight of 70 kg, an animal weight of 0.325 kg and length of exposure, experiment and lifespan of 1126 days for treated and control animals.

The unit risk should not be used if the water concentration exceeds 8.3E+1 ug/L, since above this concentration the unit risk may not be appropriate.

IRIS

Topic: CHROMIUM(III)

1. CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Chromium(III)

CASRN -- 16065-83-1

Last Revised -- 03/01/88

The Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Please refer to Background Document 1 in Service Code 5 for an elaboration of these concepts. RfDs can also be derived for the noncarcinogenic health effects of compounds which are also carcinogens. Therefore, it is essential to refer to other sources of information concerning the carcinogenicity of this substance. If the U.S. EPA has evaluated this substance for potential human carcinogenicity, a summary of that evaluation will be contained in Section II of this file when a review of that evaluation is completed.

I.A.1. ORAL RfD SUMMARY

See Table Document

I.A.2. PRINCIPAL AND SUPPORTING STUDIES (ORAL RfD)

Ivankovic, S. and R. Preussmann. 1975. Absence of toxic and carcinogenic effects after administration of high doses of chromic oxide pigment in subacute and long-term feeding experiments in rats. Food Cosmet. Toxicol. 13: 347-351. Groups of 60 male and female rats were fed chromic oxide (Cr2O3) baked in bread at dietary levels of 0, 1, 2, or 5%, 5 days/week for 600 feedings (840 total days). The primary purpose of this study was to assess the carcinogenic potential of Cr2O3. Body weight and food consumption were monitored. The average total amounts of ingested Cr2O3 were given as 360, 720, and 1800 g/kg bw for the 1, 2, and 5% treatment groups, respectively. The animals were maintained on control diets following termination of exposure until they became moribund or died. All major organs were examined histologically. Other toxicologic parameters were not mentioned explicitly, but may have included some or all of those described for the accompanying subchronic study (see below). No effects due to Cr2O3 treatment were observed at any dose level.

Ivankovic and Preussmann (1975) also treated rats (both sexes, 12-19 rats/group) at dietary levels of 0, 2, or 5% Cr2O3 in bread, 5 days/week for 90 days. Food consumption and body weight were monitored. Toxicologic parameters included serum protein, bilirubin, hematology, urinalysis, organ weights, and histopathology. The only effects observed were reductions (12-37%) in the absolute weights of the livers and spleens of animals in the highdose group. Organ weights relative to body weight were not reported. The high dose is equivalent to 1400 mg/kg/day (dose converted using reported data).

Other subchronic oral studies show no indication of adverse

IRIS

Topic: CHROMIUM(III)

effects attributable to trivalent chromium compounds, but dose levels were considerably lower.

I.A.3. UNCERTAINTY AND MODIFYING FACTORS (ORAL RfD)

UF = 100. The factor of 100 represents two 10-fold decreases in mg/kg bw/day dose that account for both the expected interhuman and interspecies variability to the toxicity of the chemical in lieu of specific data.

MF = 10. The additional modifying factor of 10 is adopted to reflect uncertainty in the NOEL because: 1) the effects observed in the 90-day study were not explicitly addressed in the 2-year study and, thus, the highest NOAEL in the 2-year study may be a LOAEL; 2) the absorption of chromium is low (<1%) and is influenced by a number of factors; thus, a considerable potential variation in absorption exists; and 3) animals were allowed to die naturally after feeding stopped (2 years) and only then was histology performed.

I.A.4. ADDITIONAL COMMENTS (ORAL RfD)

This RfD is limited to metallic chromium (III) of insoluble salts. Examples of insoluble salts include chromic III oxide (Cr₂O₃) and chromium III sulfate [Cr₂(SO₄)₃].

Very limited data suggest that Cr III may have respiratory effects on humans. No data on chronic or subchronic effects of inhaled Cr III in animals can be found. Adequate teratology data do not exist, but reproductive effects are not seen at dietary levels of 5% Cr₂O₃.

I.A.5. CONFIDENCE IN THE ORAL RfD

Study: Low

Data Base: Low

RfD: Low

The principal study is rated low because of the lack of explicit detail on study protocol and results. Low confidence in the data base reflects the lack of high-dose supporting data. The low confidence in the RfD reflects the foregoing, but also reflects the lack of an observed effect level. Thus, the RfD, as given, should be considered conservative, since the MF addresses only those factors which might lower the RfD.

I.A.6. EPA DOCUMENTATION AND REVIEW OF THE ORAL RfD

U.S. EPA. 1984. Health Effects Assessment for Trivalent Chromium. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH, OHEA for the Office of Solid Waste and Emergency Response.

The ADI in the 1984 Health Effects Assessment document received an Agency review with the help of two external scientists.

Agency Work Group Review: 11/21/85, 02/05/86

Verification Date: 11/21/85

I.A.7. EPA CONTACTS (ORAL RfD)

Michael L. Dourson / ORD -- (513)569-7544 / FTS 684-7544

Robert Bruce / ORD -- (513)569-7553 / FTS 684-7553

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE
RfC)

Substance Name -- Chromium(III)

IRIS

Topic: CHROMIUM(III)

CASRN -- 16065-83-1

A risk assessment for this substance/agent is under review by an EPA work group.

=====

IRIS

Topic: CHROMIUM(III)

II. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Chromium(III)

CASRN -- 16065-83-1

This substance/agent has been evaluated by the U.S. EPA for evidence of human carcinogenic potential. This does not imply that this agent is necessarily a carcinogen. The evaluation for this chemical is under review by an inter-office Agency work group. A risk assessment summary will be included on IRIS when the review has been completed.

=====

Topic: CHROMIUM(VI)

1. CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Chromium(VI)

CASRN -- 18540-29-9

Last Revised -- 03/01/88

The Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Please refer to Background Document 1 in Service Code 5 for an elaboration of these concepts. RfDs can also be derived for the noncarcinogenic health effects of compounds which are also carcinogens. Therefore, it is essential to refer to other sources of information concerning the carcinogenicity of this substance. If the U.S. EPA has evaluated this substance for potential human carcinogenicity, a summary of that evaluation will be contained in Section II of this file when a review of that evaluation is completed.

I.A.1. ORAL RfD SUMMARY

See Table Document

I.A.2. PRINCIPAL AND SUPPORTING STUDIES (ORAL RfD)

MacKenzie, R.D., R.U. Byerrum, C.F. Decker, C.A. Hoppert and R.F. Langham. 1958. Chronic toxicity studies. II. Hexavalent and trivalent chromium administered in drinking water to rats. Am. Med. Assoc. Arch. Ind. Health. 18: 232-234.

Groups of eight male and eight female Sprague-Dawley rats were supplied with drinking water containing 0-11 ppm (0-11 mg/L) hexavalent chromium (as K₂CrO₄) for 1 year. The control group (10/sex) received distilled water. A second experiment involved three groups of 12 males and 9 female rats. One group was given 25 ppm (25 mg/L) chromium (as K₂CrO₄); a second received 25 ppm chromium in the form of chromic chloride; and the controls again received distilled water. No significant adverse effects were seen on appearance, weight gain, or food consumption, and there were no pathologic changes in the blood or other tissues in any treatment group. The rats receiving 25 ppm of chromium (as K₂CrO₄) showed an approximate 20% reduction in water consumption. This dose corresponds to 2.4 mg chromium(VI)/kg/day based on actual body weight and water consumption data.

For rats treated with 0-11 ppm (in the diet), blood was examined monthly, and tissues (livers, kidneys and femurs) were examined at 6 months and 1 year. Spleens were also examined at 1 year. The 25 ppm groups (and corresponding controls) were examined similarly, except that no animals were killed at 6 months. An abrupt rise in tissue chromium concentrations was noted in rats treated with greater than 5 ppm. The authors stated that "apparently, tissues can accumulate considerable quantities of chromium before

IRIS

Topic: CHROMIUM(VI)

pathological changes result." In the 25 ppm treatment groups, tissue concentrations of chromium were approximately 9 times higher for those treated with hexavalent chromium than for the trivalent group.

Similar no-effect levels have been observed in dogs and humans. Anwar et al. (1961) observed no significant effects in female dogs (2/dose group) given up to 11.2 ppm chromium(VI) (as K_2CrO_4) in drinking water for 4 years. The calculated doses were 0.012-0.30 mg/kg of chromium(VI). In humans, no adverse health effects were detected (by physical examination) in a family of four persons who drank for 3 years from a private well containing chromium(VI) at approximately 1 mg/L (0.03 mg/kg/day for a 70-kg human).

I.A.3. UNCERTAINTY AND MODIFYING FACTORS (ORAL RfD)

UF = 500. The uncertainty factor of 500 represents two 10-fold decreases in dose to account for both the expected interhuman and interspecies variability in the toxicity of the chemical in lieu of specific data, and an additional factor of 5 to compensate for the less-than-lifetime exposure duration of the principal study.

MF = 1.

I.A.4. ADDITIONAL COMMENTS (ORAL RfD)

This RfD is limited to metallic chromium(VI) of soluble salts. Examples of soluble salts include potassium dichromate ($K_2Cr_2O_7$), sodium dichromate ($Na_2Cr_2O_7$), potassium chromate (K_2CrO_4) and sodium chromate (Na_2CrO_4).

Trivalent chromium is an essential nutrient. There is some evidence to indicate that hexavalent chromium is reduced in part to trivalent chromium in vivo (Petrilli and DeFlora, 1977, 1978; Gruber and Jennette, 1978).

The literature available on possible fetal damage caused by chromium compounds is limited. No studies were located on teratogenic effects resulting from ingestion of chromium.

I.A.5. CONFIDENCE IN THE ORAL RfD

Study: Low

Data Base: Low

RfD: Low

Confidence in the chosen study is low because of the small number of animals tested, the small number of parameters measured and the lack of toxic effect at the highest dose tested. Confidence in the data base is low because the supporting studies are of equally low quality, and teratogenic and reproductive endpoints are not well studied. Low confidence in the RfD follows.

I.A.6. EPA DOCUMENTATION AND REVIEW OF THE ORAL RfD

U.S. EPA. 1984. Health Effects Assessment for Hexavalent Chromium. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH for the Office of Solid Waste and Emergency Response, Washington, DC.

U.S. EPA. 1985. Drinking Water Health Advisory for Chromium. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH for the Office of Drinking Water, Washington, DC. (Draft)

IRIS

Topic: CHROMIUM(VI)

I. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Chromium(VI)

CASRN -- 18540-29-9

Last Revised -- 03/01/91

Section II provides information on three aspects of the carcinogenic risk assessment for the agent in question; the U.S. EPA classification, and quantitative estimates of risk from oral exposure and from inhalation exposure. The classification reflects a weight-of-evidence judgment of the likelihood that the agent is a human carcinogen. The quantitative risk estimates are presented in three ways. The slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per (mg/kg)/day. The unit risk is the quantitative estimate in terms of either risk per ug/L drinking water or risk per ug/cu.m air breathed. The third form in which risk is presented is a drinking water or air concentration providing cancer risks of 1 in 10,000, 1 in 100,000 or 1 in 1,000,000. Background Document 2 (Service Code 5) provides details on the rationale and methods used to derive the carcinogenicity values found in IRIS. Users are referred to Section I for information on long-term toxic effects other than carcinogenicity.

II.A. EVIDENCE FOR CLASSIFICATION AS TO HUMAN CARCINOGENICITY

II.A.1. WEIGHT-OF-EVIDENCE CLASSIFICATION

Classification -- A; human carcinogen

Basis -- Results of occupational epidemiologic studies of chromium-exposed workers are consistent across investigators and study populations. Doseresponse relationships have been established for chromium exposure and lung cancer.

Chromium-exposed workers are exposed to both chromium III and chromium VI compounds. Because only chromium VI has been found to be carcinogenic in animal studies, however, it was concluded that only chromium VI should be classified as a human carcinogen.

II.A.2. HUMAN CARCINOGENICITY DATA

Sufficient. Epidemiologic studies of chromate production facilities in the United States (Machle and Gregorius, 1948; Brinton et al., 1952; Mancuso and Hueper, 1951, Mancuso, 1975; Baetjer, 1950; Taylor, 1966; Enterline, 1974; Hayes et al., 1979; Hill and Ferguson, 1979), Great Britain (Bidstrup, 1951; Bidstrup and Case, 1956; Alderson et al., 1981), Japan (Watanabe and Fukuchi, 1975; Ohsaki et al., 1978; Sano and Mitohara, 1978; Satoh et al., 1981) and West Germany (Korallus et al., 1982; Bittersohl, 1971) have established an association between chromium (Cr) exposure and lung cancer. Most of these studies did not attempt to determine whether Cr III or Cr VI compounds were the etiologic agents.

Three studies of the chrome pigment industry, one in Norway (Langard and Norseth, 1975), one in England (Davies, 1978, 1979), and the third in the Netherlands and Germany (Frentzel-Beyme, 1983) also found an association between occupational chromium exposure (predominantly to Cr VI) and lung cancer.

Results of two studies of the chromium plating industry (Royle, 1975; Silverstein et al., 1981) were inconclusive,

IRIS

Topic: CHROMIUM(VI)

Agency Work Group Review: 11/21/85, 02/05/86
Verification Date: 02/05/86
I.A.7. EPA CONTACTS (ORAL RfD)
Kenneth L. Bailey / ODW -- (202)260-5535 / FTS 260-5535
Sue Velazquez / ORD -- (513)569-7571 / FTS 684-7571

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE
RfC)

Substance Name -- Chromium(VI)
CASRN -- 18540-29-9

A risk assessment for this substance/agent is under review by
an EPA work group.

=====

IRIS

Topic: CHROMIUM(VI)

while the findings of a Japanese study of chrome platers were negative (Okubo and Tsuchiya, 1979). The results of studies of ferrochromium workers (Pokrovskaya and Shabynina, 1973; Langard et al., 1980; Axelsson et al., 1980) were inconclusive as to lung cancer risk.

II.A.3. ANIMAL CARCINOGENICITY DATA

Sufficient. Hexavalent chromium compounds were carcinogenic in animal assays producing the following tumor types: intramuscular injection site tumors in Fischer 344 and Bethesda Black rats and in C57BL mice (Furst et al., 1976; Maltoni, 1974, 1976; Payne, 1960; Heuper and Payne, 1959); intraplural implant site tumors for various chromium VI compounds in SpragueDawley and Bethesda Black rats (Payne, 1960; Heuper 1961; Heuper and Payne, 1962); intrabronchial implantation site tumors for various Cr VI compounds in Wistar rats (Levy and Martin, 1983; Laskin et al., 1970; Levy as quoted in NIOSH, 1975); and subcutaneous injection site sarcomas in Sprague-Dawley rats (Maltoni, 1974, 1976).

II.A.4. SUPPORTING DATA FOR CARCINOGENICITY

A large number of chromium compounds have been assayed in *in vitro* genetic toxicology assays. In general, hexavalent chromium is mutagenic in bacterial assays whereas trivalent chromium is not (Lofroth, 1978; Petrellie and Flora, 1977, 1978). Likewise Cr VI but not Cr III was mutagenic in yeasts (Bonatti et al., 1976) and in V79 cells (Newbold et al., 1979). Chromium III and VI compounds decrease the fidelity of DNA synthesis *in vitro* (Loeb et al., 1977), while Cr VI compounds inhibit replicative DNA synthesis in mammalian cells (Levis et al., 1978) and produce unscheduled DNA synthesis, presumably repair synthesis, as a consequence of DNA damage (Raffetto, 1977). Chromate has been shown to transform both primary cells and cell lines (Fradkin et al., 1975; Tsuda and Kato, 1977; Casto et al., 1979). Chromosomal effects produced by treatment with chromium compounds have been reported by a number of authors; for example, both Cr VI and Cr III salts were clastogenic for cultured human leukocytes (Nakamuro et al., 1978).

There are no long-term studies of ingested Cr VI. There appears to be significant *in vivo* conversion of Cr VI to Cr III and III to VI; Cr III is an essential trace element.

II.B. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM ORAL EXPOSURE

Not available.

II.C. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM INHALATION EXPOSURE

II.C.1. SUMMARY OF RISK ESTIMATES

Inhalation Unit Risk -- $1.2E-2$ per (ug/cu.m)

Extrapolation Method -- Multistage, extra risk

Air Concentrations at Specified Risk Levels:

Risk Level	Concentration
------------	---------------

IRIS

Topic: CHROMIUM(VI)

E-4 (1 in 10,000) 8E-3 ug/cu.m
E-5 (1 in 100,000) 8E-4 ug/cu.m
E-6 (1 in 1,000,000) 8E-5 ug/cu.m

II.C.2. DOSE-RESPONSE DATA FOR CARCINOGENICITY, INHALATION EXPOSURE

See Table Document

II.C.3. ADDITIONAL COMMENTS (CARCINOGENICITY, INHALATION EXPOSURE)

The cancer mortality in Mancuso (1975) was assumed to be due to Cr VI, which was further assumed to be no less than one-seventh of total chromium. It was also assumed that the smoking habits of chromate workers were similar to those of the U.S. white male population. The unit risks of Langard et al. (1980), Axelsson et al. (1980), and Pokrovskaya and Shabynina (1973) are 1.3E-1, 3.5E-2 and 9.2E-2 per (ug/cu.m), respectively.

Hexavalent chromium compounds have not produced lung tumors in animals by inhalation. Trivalent chromium compounds have not been reported as carcinogenic by any route of administration. The unit risk should not be used if the air concentration exceeds 8E-1 ug/cu.m, since above this concentration the unit risk may not be appropriate.

II.C.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY, INHALATION EXPOSURE)

Results of studies of chromium exposure are consistent across investigators and countries. A dose-relationship for lung tumors has been established. The assumption that the ratio of Cr III to Cr VI is 6:1 may lead to a 7-fold underestimation of risk. The use of 1949 hygiene data, which may underestimate worker exposure, may result in an overestimation of risk. Further overestimation of risk may be due to the implicit assumption that the smoking habits of chromate workers were similar to those of the general white male population, since it is generally accepted that the proportion of smokers is higher for industrial workers than for the general population.

II.D. EPA DOCUMENTATION, REVIEW, AND CONTACTS (CARCINOGENICITY ASSESSMENT)

II.D.1. EPA DOCUMENTATION

Mancuso, T.F. 1975. International Conference on Heavy Metals in the Environment. Toronto, Ontario, Canada.

U.S. EPA. 1984. Health Assessment Document for Chromium. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH. EPA 600/8-83-014F.

II.D.2. REVIEW (CARCINOGENICITY ASSESSMENT)

The quantification of cancer risk in the 1984 Health Assessment Document has received peer review in public sessions of the Environmental Health Committee of the U.S. EPA's Science Advisory Board.

Agency Work Group Review: 06/26/86

Verification Date: 06/26/86

II.D.3. U.S. EPA CONTACTS (CARCINOGENICITY ASSESSMENT)

Herman J. Gibb / ORD -- (202)260-5898 / FTS 260-5898

IRIS

Topic: CHROMIUM(VI)

Chao W. Chen / ORD -- (202)260-5719 / FTS 260-5719

=====

Topic: MERCURY

6.0 RANGE OF TOXICITY

6.2 MINIMUM LETHAL EXPOSURE

A. PERITONEAL LAVAGE SOLUTIONS: Ten cases of severe toxic reactions, five of which resulted in death, have occurred following peritoneal lavage solutions containing mercuric chloride concentrations of 1/500 to 1/2000. In one case, death occurred after the use of a solution containing as little as 400 milligrams HgCl₂ (Laundry et al, 1984).

B. MERCURY CHLORIDE INGESTION

1. Fatalities have been reported from ingestions of as little as 500 milligrams of mercury chloride (Gosselin et al, 1984).
2. A 27-year-old male succumbed on the 91st day of admission from numerous complications associated with an ingestion of 6 grams of mercury chloride. Hemodialysis was ineffective for the removal of significant amounts of mercury chloride. Six plasma exchanges removed only 17 milligrams of mercury. The patient was not chelated (Sauder et al, 1988).

C. MERCURY VAPOR

1. Four adult occupants of a private home developed shortness of breath which progressed to respiratory failure and death following release of mercury vapor while smelting silver from dental amalgam (Kanluen & Gottlieb, 1991).

6.3 MAXIMUM TOLERATED EXPOSURE

A. ANTISEPTIC MATERIALS (Thimerosal, Merthiolate, Acetomerocetol, and Merbromin) are not readily absorbed and not likely to cause symptoms.

B. ORGANIC MERCURY: Atmospheric levels exceeding 0.01 milligram/cubic meter organic mercury may be toxic. Oral concentrations are unknown; acute toxicity occurred following absorption of 60 to 90 milliliters of mercurial fungicides. The daily "safe" limit for methylmercury contaminated fish is 0.03 milligram.

C. METHYLMERCURY: A single acute ingestion of 45 milligrams of methylmercury resulted in whole blood levels of 1930 and 1007 nanograms/milliliter 2 and 24 hours after ingestion but did not result in symptoms of toxicity (Lund et al, 1984).

D. ELEMENTAL MERCURY

1. As much as 204 grams of elemental mercury has been ingested with little effect (Wright et al, 1980).
2. SPILL: A 20-month-old, 11 kilogram female was found to have a whole blood mercury of 49 micrograms/Liter when admitted for a 6 week illness (anorexia, irritability, insomnia, stomatitis, and red, painful hands and feet). The source of exposure was traced to a small vial containing approximately 5 milliliters of elemental mercury that was spilled on the rug 2 weeks prior to her onset of symptoms. No other family members had symptoms and the mother's whole blood mercury concentration was 5 micrograms/Liter (Taylor et al, 1989).
3. SPILL: Three siblings (33 months, 20 months, 6 years) developed acrodynia attributed to a thermometer broken

Topic: MERCURY

in the children's bedroom 8 months earlier (Muhlendahl, 1990).

- a. The carpeted bedroom was small with floor heating. Breakage of the thermometer occurred in the fall.
 - b. Peak reported chelated urinary mercury concentrations in the children were 250.5, 266.3, and 137.4 micrograms/liter, respectively.
4. VAPOR EXPOSURE: A 3-year-old with clinical manifestation consistent with mercury poisoning was found to have a random urine sample containing 160 micrograms/liter of mercury without a known mercury exposure. The patient and his family were found to be residing in a house (3 months duration) in which the previous resident had collected elemental mercury. A mercury vapor analyzer detected mercury concentrations of 20 to 60 micrograms/cubic meter in 5 rooms and 2 bathrooms (CDC, 1989).
- a. The patient and his family were found to be residing in a house (3 months duration) in which the previous resident had collected elemental mercury. A mercury vapor analyzer detected mercury concentrations of 20 to 60 micrograms/cubic meter in 5 rooms and 2 bathrooms (CDC, 1989).
- E. PHENYLMERCURIC ACETATE: A survey of 74 people living in 19 houses newly-painted with an interior latex paint containing phenylmercuric acetate (median=3.8 millimoles of mercury/liter) showed elevated mercury levels in the air (median=10 nanomoles/cubic meter; range of <0.5 to 49.9) and in the urine (median=4.7 nanomoles/millimole of creatinine; range of 1.4 to 66.5) (Agocs et al, 1990). There was no clinical information provided except for the mention of acrodynia in a 4-year-old boy.
- F. MERCURIC CHLORIDE: Survival was reported following ingestion of 900 milligrams (13.8 milligrams/kilogram) in a 26-year-old woman treated with BAL, hemodialysis, peritoneal dialysis, and plasma exchange beginning 3 hours postingestion (Suzuki et al, 1992).
- 5.4 TOXIC SERUM/PLASMA/BLOOD CONCENTRATIONS
- A. MERCURIC CHLORIDE: Mercury concentrations in stomach contents, blood, and liver were determined by Energy Dispersive X-ray Fluorescence (EDXRF) in a 50-year-old male who ingested an unknown amount of mercuric chloride and died 6 to 14 hours postingestion (Winstanley et al, 1987).
 1. Mercury concentrations were 28×10^3 micrograms/milliliter of mercury (9.5 grams mercuric chloride in the 250 milliliters submitted) in stomach contents, 72 micrograms/milliliter of mercury in blood, and 335 micrograms/gram of mercury in liver.
 2. Determination by other methods was not given for comparison.
 - B. Blood mercury levels of 128 micrograms/liter were achieved via percutaneous absorption, resulting in peripheral neuropathies, following the use of a 5 to 10% ammoniated mercury ointment for 40 years. The equivalent

Topic: MERCURY

to approximately 1.5 to 2 kilograms of elemental mercury were applied to the skin via the ointment over 40 years (Kern et al, 1991).

C. ELEMENTAL MERCURY

1. An elemental mercury spill (0.5 to 1 oz) in the home resulted in a mercury blood level of less than 1 microgram/deciliter and a urine level of 120 micrograms/24 hours in a 4-year-old. Symptoms associated with these levels were severe (fever, insomnia, headache, ataxia, hallucinations, irritability) requiring treatments with BAL and NAP (Florentine & Sanfilippo, 1991).
 - a. The 11-year-old sister had blood levels of 5.5 micrograms/deciliter and a urine level of 58 micrograms/24 hours. Her symptoms, though far less severe, still required treatments with BAL and NAP.
 - b. The 10-year-old brother had blood levels of greater than 2.4 micrograms/deciliter. He remained asymptomatic, but similarly required treatments with BAL and NAP.

6.6 CALCULATIONS

A. SI UNIT CONVERSION: BLOOD

1. To convert traditional units (micrograms/deciliter) into SI units (micromoles/liter), multiply traditional units by 0.04985.
2. To convert SI units (micromoles/liter) into traditional units (micrograms/deciliter), divide SI units by 0.04985.

B. SI UNIT CONVERSION: URINE

1. To convert traditional units (micrograms/24 hours) into SI units (micromoles/day), multiply traditional units by 0.004985.
2. To convert SI units (micromoles/day) into traditional units (micrograms/24 hours), divide SI units by 0.004985.

TOMES(R) Medical Management

Topic: MERCURY

6.0 RANGE OF TOXICITY

6.2 MINIMUM LETHAL EXPOSURE

A. PERITONEAL LAVAGE SOLUTIONS: Ten cases of severe toxic reactions, five of which resulted in death, have occurred following peritoneal lavage solutions containing mercuric chloride concentrations of 1/500 to 1/2000. In one case, death occurred after the use of a solution containing as little as 400 milligrams HgCl₂ (Laundry et al, 1984).

B. MERCURY CHLORIDE INGESTION

1. Fatalities have been reported from ingestions of as little as 500 milligrams of mercury chloride (Gosselin et al, 1984).
2. A 27-year-old male succumbed on the 91st day of admission from numerous complications associated with an ingestion of 6 grams of mercury chloride. Hemodialysis was ineffective for the removal of significant amounts of mercury chloride. Six plasma exchanges removed only 17 milligrams of mercury. The patient was not chelated (Sauder et al, 1988).

C. MERCURY VAPOR

1. Four adult occupants of a private home developed shortness of breath which progressed to respiratory failure and death following release of mercury vapor while smelting silver from dental amalgam (Kanluen & Gottlieb, 1991).

6.3 MAXIMUM TOLERATED EXPOSURE

A. ANTISEPTIC MATERIALS (Thimerosal, Merthiolate, Acetomerocetol, and Merbromin) are not readily absorbed and not likely to cause symptoms.

B. ORGANIC MERCURY: Atmospheric levels exceeding 0.01 milligram/cubic meter organic mercury may be toxic. Oral concentrations are unknown; acute toxicity occurred following absorption of 60 to 90 milliliters of mercurial fungicides. The daily "safe" limit for methylmercury contaminated fish is 0.03 milligram.

C. METHYLMERCURY: A single acute ingestion of 45 milligrams of methylmercury resulted in whole blood levels of 1930 and 1007 nanograms/milliliter 2 and 24 hours after ingestion but did not result in symptoms of toxicity (Lund et al, 1984).

D. ELEMENTAL MERCURY

1. As much as 204 grams of elemental mercury has been ingested with little effect (Wright et al, 1980).
2. SPILL: A 20-month-old, 11 kilogram female was found to have a whole blood mercury of 49 micrograms/Liter when admitted for a 6 week illness (anorexia, irritability, insomnia, stomatitis, and red, painful hands and feet). The source of exposure was traced to a small vial containing approximately 5 milliliters of elemental mercury that was spilled on the rug 2 weeks prior to her onset of symptoms. No other family members had symptoms and the mother's whole blood mercury concentration was 5 micrograms/Liter (Taylor et al, 1989).
3. SPILL: Three siblings (33 months, 20 months, 6 years) developed acrodynia attributed to a thermometer broken

Topic: MERCURY

in the children's bedroom 8 months earlier (Muhlendahl, 1990).

- a. The carpeted bedroom was small with floor heating. Breakage of the thermometer occurred in the fall.
 - b. Peak reported chelated urinary mercury concentrations in the children were 250.5, 266.3, and 137.4 micrograms/liter, respectively.
4. VAPOR EXPOSURE: A 3-year-old with clinical manifestation consistent with mercury poisoning was found to have a random urine sample containing 160 micrograms/liter of mercury without a known mercury exposure. The patient and his family were found to be residing in a house (3 months duration) in which the previous resident had collected elemental mercury. A mercury vapor analyzer detected mercury concentrations of 20 to 60 micrograms/cubic meter in 5 rooms and 2 bathrooms (CDC, 1989).
- a. The patient and his family were found to be residing in a house (3 months duration) in which the previous resident had collected elemental mercury. A mercury vapor analyzer detected mercury concentrations of 20 to 60 micrograms/cubic meter in 5 rooms and 2 bathrooms (CDC, 1989).
- E. PHENYLMERCURIC ACETATE: A survey of 74 people living in 19 houses newly-painted with an interior latex paint containing phenylmercuric acetate (median=3.8 millimoles of mercury/liter) showed elevated mercury levels in the air (median=10 nanomoles/cubic meter; range of <0.5 to 49.9) and in the urine (median=4.7 nanomoles/millimole of creatinine; range of 1.4 to 66.5) (Agocs et al, 1990). There was no clinical information provided except for the mention of acrodynia in a 4-year-old boy.
- F. MERCURIC CHLORIDE: Survival was reported following ingestion of 900 milligrams (13.8 milligrams/kilogram) in a 26-year-old woman treated with BAL, hemodialysis, peritoneal dialysis, and plasma exchange beginning 3 hours postingestion (Suzuki et al, 1992).
- 6.4 TOXIC SERUM/PLASMA/BLOOD CONCENTRATIONS
- A. MERCURIC CHLORIDE: Mercury concentrations in stomach contents, blood, and liver were determined by Energy Dispersive X-ray Fluorescence (EDXRF) in a 50-year-old male who ingested an unknown amount of mercuric chloride and died 6 to 14 hours postingestion (Winstanley et al, 1987).
 1. Mercury concentrations were 28×10^3 micrograms/milliliter of mercury (9.5 grams mercuric chloride in the 250 milliliters submitted) in stomach contents, 72 micrograms/milliliter of mercury in blood, and 335 micrograms/gram of mercury in liver.
 2. Determination by other methods was not given for comparison.
 - B. Blood mercury levels of 128 micrograms/liter were achieved via percutaneous absorption, resulting in peripheral neuropathies, following the use of a 5 to 10% ammoniated mercury ointment for 40 years. The equivalent

Topic: MERCURY

to approximately 1.5 to 2 kilograms of elemental mercury were applied to the skin via the ointment over 40 years (Kern et al, 1991).

C. ELEMENTAL MERCURY

1. An elemental mercury spill (0.5 to 1 oz) in the home resulted in a mercury blood level of less than 1 microgram/deciliter and a urine level of 120 micrograms/24 hours in a 4-year-old. Symptoms associated with these levels were severe (fever, insomnia, headache, ataxia, hallucinations, irritability) requiring treatments with BAL and NAP (Florentine & Sanfilippo, 1991).
 - a. The 11-year-old sister had blood levels of 5.5 micrograms/deciliter and a urine level of 58 micrograms/24 hours. Her symptoms, though far less severe, still required treatments with BAL and NAP.
 - b. The 10-year-old brother had blood levels of greater than 2.4 micrograms/deciliter. He remained asymptomatic, but similarly required treatments with BAL and NAP.

6.6 CALCULATIONS

A. SI UNIT CONVERSION: BLOOD

1. To convert traditional units (micrograms/deciliter) into SI units (micromoles/liter), multiply traditional units by 0.04985.
2. To convert SI units (micromoles/liter) into traditional units (micrograms/deciliter), divide SI units by 0.04985.

B. SI UNIT CONVERSION: URINE

1. To convert traditional units (micrograms/24 hours) into SI units (micromoles/day), multiply traditional units by 0.004985.
2. To convert SI units (micromoles/day) into traditional units (micrograms/24 hours), divide SI units by 0.004985.

Topic: MERCURY

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Pollution Sources

Natural Occurring Sources:

1. MERCURY ORE IS FOUND IN ROCKS OF ALL CLASSES. COMMON HOST ROCKS ARE LIMESTONE, CALCAREOUS SHALES, SANDSTONE, SERPENTINE ($3\text{MGO} \cdot 2\text{SIO}_2 \cdot 2\text{H}_2\text{O}$), CHERT ANDESITE (SODA LIME FELDSPAR), BASALT, & RHYOLITE (ALKALINE FELDSPAR & QUARTZ). MERCURY IS RECOVERED ALMOST ENTIRELY FROM CINNABAR (ALPHA-HGS), 86.2% HG, ALTHOUGH ELEMENTAL MERCURY OCCURS IN SOME ORES. **PEER REVIEWED** [Clayton, G. D. and F. E. Clayton (eds.). Patty's Industrial Hygiene and Toxicology: Volume 2A, 2B, 2C: Toxicology. 3rd ed. New York: John Wiley Sons, 1981-1982. 1769
2. Joint FAO/WHO expert committee on Food Additives (1972) quotes the major source of mercury (Hg) as the natural degassing of the earth's crust ... in the range of 25,000-150,000 ton of Hg/yr. **PEER REVIEWED** [WHO; Environ Health Criteria: Mercury p.43 (1976)
3. The mercury (Hg) content of some common ore and gangue minerals as a result of its coexistence in a deposit with cinnabar, metacinnabar or other Hg minerals is as follows: Tetrahedrite ($\text{Cu}_{12}\text{Sb}_4\text{S}_{13}$) 17.6-21%; Grey copper ores (Cu,As,Sb) XSy 14%; Spalerite (ZnS) 1%; Wurtzite (ZnS) 0.03%; Stibnite (Sb_2S_3) 1.3%; Realgar (AsS) 2.2%; Pyrite (FeS_2) 2%; Galena (PbS) 0.02%; Marcasite (FeS_2) 0.07%; Native gold (Au) 60%; Native silver (Ag) 30%; Barite (BaSO_4) 0.5%; Cerussite (PbCO_3) 0.1%; Flourite (CaF_2) 0.01%; Calcite (CaCO_3) 0.03%; Aragonite (CaCO_3) 3.7%; Siderite (FeCO_3) 0.01%; Pyrolusite (MnO_2) 2%; Hydrated iron oxides $\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$ 0.2%; Graphite (Carbon) 0.01%; and Coal 2%. **PEER REVIEWED** [Jonasson IR, Boyle RW; Bull Can Inst Min Metal 65: 32-9 (1972) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.32 (1979) NRCC No. 16739
4. Fossil Fuels: Coal 10-8530 ppb; Coal in mercuriferous basins 20-300,000 ppb; Crude oils 20-2000 ppb; Petroleum crudes in mercuriferous belts 1900-21,000 ppb; Bitumens, solid hydrocarbons, asphalts, etc 2000-900,000 ppb. **PEER REVIEWED** [Jonasson IR, Boyle RW; Bull Can Inst Min Metal 65: 32-9 (1972) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.39 (1979) NRCC No. 16739
5. Mercury is released into the environment from volcanoes and hot springs. **PEER REVIEWED** [Miller DR, Buchanan JM; Atmos Trans of Mercury: Exposure Commitment and Uncertainty Calculations. MARC Report #14 p.1 (1979)

Artificial Sources:

1. Of greater significance currently in Canada is the mercury liberated from the working and smelting of ores of copper, gold, lead, silver and zinc which normally contain traces of mercury. **PEER REVIEWED** [Jonasson IR, Boyle RW; Bull Can Inst Min Metal 65: 32-9 (1972) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.62 (1979) NRCC No. 16739
2. ... The average emissions of mercury stack losses for USA

Topic: MERCURY

- cinnabar (HgS) roasting operations was 2-3%. **PEER REVIEWED** [Stahl QR; Dept of Health, Education and Welfare p.30 (1969) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.62 (1979) NRCC No. 16739
3. ... Maximum ground-level concn of Hg for 12 USA coal-fired power plants were 0.035-6.9 ug/cu m. **PEER REVIEWED** [Vaugh WP, Fuller SR; Illinois Institute for Environmental Quality Rep ILEQ 71-3 (1971) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.66 (1979) NRCC No. 16739
 4. Mercury (Hg) loss est from Canada fuel consumption and other Canadian sources: In 1974, approximately 12 ton Hg were discharged to the environment as a result of coal combustion. Approximately 90% was discharged to air as vapor, 9% was adsorbed onto fine particulate (controllable by particle-collecting devices) and approximately 1% remained in the bottom or grate ash. **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.66 (1979) NRCC No. 16739
 5. In general, industrial and domestic products, such as thermometers, batteries, and electrical switches which account for a significant loss of mercury to the environment, ultimately become solid waste in major urban areas. **PEER REVIEWED** [British Dept of Environment; Pollution Paper No. 10 p.75 (1977) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.77 (1979) NRCC No. 16739
 6. Anthropogenic sources of airborne mercury (Hg) may arise from the operation of metal smelters or cement manufacture. Water borne pollution may originate in sewage, metal refining operations, or most notably, from chloralkali plants. **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.84 (1979) NRCC No. 16739
 7. Twenty thousand tons of mercury are released into the environment each year by human activities such as combustion of fossil fuels and other industrial release. **PEER REVIEWED** [Friberg, L., Nordberg, G.F., Kessler, E. and Vouk, V.B. (eds). Handbook of the Toxicology of Metals. 2nd ed. Vols I, II.: Amsterdam: Elsevier Science Publishers B.V., 1986. 387
 8. Concentrated local discharges associated with industrial activities and waste disposal. Diffuse discharges generally associated with combustion of fuels containing mercury impurities. Mercury is released in various chemical forms. **PEER REVIEWED** [Miller DR, Buchanan JM; MARC Report: Atmos Trans of Mercury: Exposure Commitment and Uncertainty Calculations #14 p.1 (1979)
 9. ... INADEQUATE & IMPROPER DISPOSAL OF INDUSTRIAL MERCURY WASTES INCR MERCURY LEVELS IN WATER & ATMOSPHERE. ... MICROORGANISMS CONVERT ELEMENTAL MERCURY INTO METHYL MERCURY SALT (CH₃HGCL) & DIMETHYL MERCURY, WHICH ... ESCAPE INTO THE ATMOSPHERE. MOST OF THESE REACTIONS TAKE PLACE IN SEDIMENTS OF RIVER & OCEAN BEDS. ... MAJOR SOURCE

Topic: MERCURY

OF MERCURY CONTAMINATION IS DISPOSAL OF INDUSTRIAL MERCURY WASTES INTO WATER WHERE THE WASTES SETTLE AS SEDIMENT, ONLY TO BE RECYCLED INTO THE WATER & AIR. **PEER REVIEWED** [Venugopal, B. and T.D. Luckey. Metal Toxicity in Mammals, 2. New York: Plenum Press, 1978. 87

Environmental Fate

Environmental Fate:

1. ENVIRONMENTAL ACCUMULATION: TWO CHARACTERISTICS, VOLATILITY & BIOTRANSFORMATION, MAKE HG SOMEWHAT UNIQUE AS ENVIRONMENTAL TOXICANT. ITS VOLATILITY ACCOUNTS FOR HIGH ATMOSPHERIC CONCEN, 20 TO 200 UG/CU M NEAR AREAS CONTAINING HIGH SOIL LEVELS (10 PPM) AS COMPARED TO NORMAL ATMOSPHERIC CONCEN OF 5 UG/CU M. ... GROUND WATER CONCEN IN USA ... BELOW 1 PPB. **PEER REVIEWED** [Doull, J., C.D. Klaassen, and M. D. Amdur (eds.). Casarett and Doull's Toxicology. 2nd ed. New York: Macmillan Publishing Co., 1980. 422
2. IN YATSUSHIRO SEA & MINAMATA BAY, THE CROAKER (ARGYROSONUS ARGENTATUS) WAS A GOOD INDICATOR OF HG POLLUTION. MERCURY MIGRATED FROM SEDIMENT TO THE CROAKER BY WAY OF SUSPENDED PARTICULATE MATTER & ZOOPLANKTON. CONVERSION FROM INORGANIC TO METHYLMERCURY OCCURS AT THE STAGE OF ZOOPLANKTON. **PEER REVIEWED** [NISHIMURA H, KUMAGAI M; WATER, AIR, SOIL POLLUT 20 (4): 401 (1983)
3. Aquatic Fate: In aquatic systems, mercury appears to bind to dissolved matter or fine particulates, while the transport of mercury bound to dust particles in the atmosphere or bed sediment particles in rivers and lakes is generally less substantial. **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.78 (1979) NRCC No. 16739
4. Aquatic Fate: ... Mercury can be desorbed into the water column, transported by water (probably bound or chelated to some fine particles or dissolved substances), and redeposited on the bed sediment. **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.81 (1979) NRCC No. 16739
5. Atmospheric Fate: 50% of volatile form is mercury (Hg) vapor with sizeable portion of remainder being Hg(II) and methylmercury, 25 to 50% of Hg in water is organic. Hg in the environment is deposited and revolatilized many times, with a residence time in the atmosphere of at least a few days. In the volatile phase it can be transported hundreds of kilometers. /Mercury Compounds/ **PEER REVIEWED** [Miller DR, Buchanan JM; Atmospheric Transport of Mercury: Exposure Commitment and Uncertainty Calculations. MARC Report #14 p.3-6 (1979)
6. Aquatic Fate: The conversion, in aquatic environments, of inorganic mercury compd to methyl mercury implies that recycling of mercury from sediment to water to air and back could be a rapid process. /Mercury compd/ **PEER REVIEWED** [Callahan, M.A., M.W. Slimak, N.W. Gabel, et al. Water-Related Environmental Fate of 129 Priority Pollutants. Volume I. EPA-440/4 79-029a. Washington, DC: U.S.Environmental Protection Agency, December 1979.,p.

Topic: MERCURY

14-11

Environmental Transformations

Biodegradation:

1. METHYLMERCURY IS FORMED NATURALLY IN AQUATIC & TERRESTRIAL ENVIRONMENT FROM ELEMENTAL MERCURY. ... METHYLATION IS LIKELY TO OCCUR IN UPPER SEDIMENTARY LAYERS OF SEA OR LAKE BOTTOMS. **PEER REVIEWED** [Friberg, L., Nordberg, G.F., Kessler, E. and Vouk, V.B. (eds). Handbook of the Toxicology of Metals. 2nd ed. Vols I, II.: Amsterdam: Elsevier Science Publishers B.V., 1986. 393
2. Inorganic forms of mercury (Hg) can be converted to organic forms by microbial action in the biosphere. /Inorganic mercury/ **PEER REVIEWED** [Schroeder WH; Envir Sci Tech 16 (7): 394A-400A (1982) as cited in Environment Canada; Tech Info for Problem Spills: Mercury (Draft) p.41 (1982)
3. ... Certain bacteria, particularly of the genus *Pseudomonas*, can convert divalent mercury into metallic mercury. **PEER REVIEWED** [WHO; Environ Health Criteria: Mercury p.49 (1976)
4. Mercury resistant bacteria (eg, *Escherichia coli*), which are able to reduce mercuric metallic mercury Hg(0+) were examined for their ability to remove wastewater aerobically. Growth studies in artificial medium indicated that mercury increases the lag phase, but does not affect the growth rate of these bacteria. Further studies demonstrated that growth was minimal during a phase of rapid Hg removal, after which growth resumed. Small but significant amounts of carbohydrates were required for the Hg(2+) reduction. Prolonged periods of bacterial growth under nonsterile conditions was accomplished without the loss of the mercuric reducing ability of the culture. A continuous culture of the resistant organism was maintained on raw sewage for 2 wk, during which time relatively high concn of Hg (70 mg/l) were removed from the sewage at a rate of 2.5 mg/l/hr and at efficiencies exceeding 98%. **PEER REVIEWED** [Hansen CL et al; Biotechnol Bioeng 26 (11): 1330-3 (1984)
5. Upon entering an aqueous system, virtually any mercurial compd may be microbially converted to methyl mercury. /Mercury compd/ **PEER REVIEWED** [Callahan, M.A., M.W. Slimak, N.W. Gabel, et al. Water-Related Environmental Fate of 129 Priority Pollutants. Volume I. EPA-440/4 79-029a. Washington, DC: U.S.Environmental Protection Agency, December 1979., p. 14-9
6. All forms of mercury (Hg) (metal, vapor, inorganic, or organic) are converted to methyl mercury. Inorganic forms are converted by microbial action in the atmosphere to methyl mercury. /Mercurial compd/ **PEER REVIEWED** [Environment Canada; Tech Info for Problem Spills: Mercury (Draft) p.41 (1982)
7. The mechanism of mercury elimination from wastewater was studied. The mercury-resistant bacterial *Pseudomonas* K62 strain at concn of 6×10^8 cells/ml was incubated for 6 hr with 30 ppm mercuric nitrate. 0% added mercury was removed

Topic: MERCURY

from culture medium in which Pseudomonas was not present; Whereas 47% of added mercury was removed in presence of Pseudomonas. Uptake of mercury was severely inhibited by sodium chloride, sodium sulfate, and mono- and dibasic potassium phosphate. **PEER REVIEWED** [Menzie, C.M. Metabolism of Pesticides, Update II. U.S. Department of the Interior, Fish Wildlife Service, Special Scientific Report - Wildlife No. 212. Washington, DC: U.S. Government Printing Office, 1978. 174

Environmental Transport

Bioconcentration:

1. Mercury bioaccumulates and concentrates in food chain ... concn may be as much as 10,000 times that of water. **PEER REVIEWED** [Environment Canada; Tech Info for Problem Spills: Mercury (Draft) p.42 (1982)
2. Bioconcentration factors of 63,000 for freshwater fish and 10,000 for salt water fish have been found. **PEER REVIEWED** [Sittig M Ed; Priority Toxic Pollutants, Health Impacts and Allowable Limits, p.266-271 (1980) as cited in Environment Canada; Tech Info for Problem Spills: Mercury (Draft) p.43 (1982)
3. As the tissue concn approaches steady-state, net accumulation rate is slowed either by a reduction in uptake rate, possibly due to inhibition of membrane transport, or by an increase in depuration rate, possibly because of a saturation of storage sites, or both. **PEER REVIEWED** [USEPA; Ambient Water Quality Criteria Doc: Mercury p.10 (1984) EPA 440/5-84-026
4. Bioconcentration Factors for Mercury: Marine Plants 1,000; Marine Invertebrates 100,000; Marine Fish 1,670; Freshwater Plants 1,000; Freshwater Invertebrates 100,000; Freshwater Fish 1,000. **PEER REVIEWED** [Callahan, M.A., M.W. Slimak, N.W. Gabel, et al. Water-Related Environmental Fate of 129 Priority Pollutants. Volume I. EPA-440/4 79-029a. Washington, DC: U.S.Environmental Protection Agency, December 1979., p. 14-10
5. Specimens (195) of higher fungi and their substrata collected in the mercury mining area of Amiata and around Siena (central Italy), were analyzed for their total mercury (Hg) content. Wood decomposers and many species of mycorrhizal fungi accumulated the metal at a very low rate; some mycorrhizal species and all the humus decomposers may accumulate up to 100 ug/g/l dry weight of Hg and in the least contaminated sites, up to 63 times as much Hg as the substratum. In mineralized areas, the concn factor rarely exceeded 1. The methylmercury content of 35 /specimens/ (almost all edible), ranged between 0.01 and 3.7 mug/g/l dry weight. **PEER REVIEWED** [Bargagli R, Baldi F; Chemosphere 13 (9): 1059-72 (1984)
6. Fish can accumulate mercury (Hg) to very high levels because accumulation is rapid and elimination is slow. Predators achieve higher concn than do fish lower in the food chain. In Canadian freshwaters, the highest Hg levels are found in lake trout, pike and walleye. In the sea, high Hg concn are found in sharks, swordfish, tuna, and

HSDB

Topic: MERCURY

halibut. **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.89 (1979) NRCC No. 16739

7. Acidification of a body of water might also increase mercury residues in fish even if no new input of mercury occurs, possibly because lower pH increases ventilation rate and membrane permeability, accelerates the rates of methylation and uptake, affects partitioning between sediment and water, or reduces growth or reproduction of fish. **PEER REVIEWED** [USEPA; Ambient Water Quality Criteria Doc: Mercury p.12 (1984) EPA 440/5-84-026

Soil Adsorption/Mobility:

1. In general, the availability of soil mercury (Hg) to plants is low and there is a root barrier to translocation of Hg to plant tops. **PEER REVIEWED** [Steward JWB et al; Joint FAO/IAGA Meetings: Publ IAGA Vienna p.23-4 (1975) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.101 (1979) NRCC No. 16739

Volatilization from Water/Soil:

1. ... In those systems where the residence time of the water is low (rivers and streams), mercury (Hg) is in most cases removed quite quickly, perhaps by as much as 50% per yr: ie the half-life of the Hg would be of the order of 1 yr or more. The mechanisms largely responsible must be (i) ingestion or absorption and subsequent removal by biological materials and organisms, and (ii) transformation to a more volatile chemical form which can escape from the sediment and from the entire aquatic system. **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.81 (1979) NRCC No. 16739
2. Much of the mercury deposited on land, appears to revaporize within a day or two, at least in areas substantially heated by sunlight. **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.78 (1979) NRCC No. 16739
3. Volatilization of mercury from land and lakes was estimated to enhance the atmosphere concn over continental land masses by a factor of 45. **PEER REVIEWED** [Miller DR, Buchanan JM; Atmospheric Transport of Mercury: Exposure Commitment and Uncertainty Calculations. MARC Report #14 p.67 (1979)

Environmental Concentrations

Water Concentrations:

1. The results of ... chemical analysis of water from the pump-out well, provided by SCM (Glidden Coatings and Resins Division), indicated the presence of mercury at < 0.001 ppm concn. **PEER REVIEWED** [USEPA; Subst Risk Notice, 8(e) p.51 (1982) EPA 560/2-83-001
2. Drinking Water (range): 5 to 100 ng Hg/l (est) **PEER REVIEWED** [USEPA; Mercury Health Effects Update p.3-19 (1984) EPA 600/8-84-019F
3. Surface Water: ... The purest surface water (drinking quality) contains less than 30 ng/l based on over 700 samples collected from drinking reservoirs in the Federal

Topic: MERCURY

Republic of Germany. Rivers believed to have low contamination, such as the Danube, and bodies of water such as the Boden Sea, have values close to 150 ng/l based on the analysis of 152 samples. **PEER REVIEWED**

[Bouquiaux J; Proceedings of the Intl Symposium on the Problems of Contamination of Man and His Environment by Mercury and Cadmium p.23 (1974) as cited in WHO; Environ Health Criteria: Mercury p.58 (1976)

4. Drinking Water: In the Federal Republic of Germany, the mercury concn measured was approx 600 ng/l in a sample of potable water. **PEER REVIEWED** [WHO; Environ Health Criteria: Mercury p.59 (1976)
5. Other Waters: In the Federal Republic of Germany, the mercury contamination was approx 400 ng/l in inland waters and between 100 and 1,800 ng/l in rivers. **PEER REVIEWED** [WHO; Environ Health Criteria: Mercury p.59 (1976)
6. The amount of mercury in the oceans has been calculated as 70 million ton using a figure for total ocean volume of 1.37×10^9 cu km and taking the avg Hg content of ocean water as 50 ng/l. **PEER REVIEWED** [WHO; Environ Health Criteria: Mercury p.47 (1976)
7. Natural Waters: Rainwater, snow 0.01-0.48 ppb; Normal stream, river, and lake waters 0.01-0.1 ppb; Coal mine waters (Donets Basin, USSR) 1-10 ppb; Stream and river waters near mercury deposits 0.5-100 ppb; Oceans and seas 0.005-5.0 ppb; Hot springs and certain mineral waters 0.01-2.5 ppb; Normal groundwaters 0.01-0.10 ppb; Groundwaters and mine waters near polymetallic sulfide deposits 1-1000 ppb; Oil field and other saline waters 0.1-230 ppb. **PEER REVIEWED** [Jonasson IR, Boyle RW; Bull Can Inst Min Metal 65: 32-9 (1972) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.40 (1979) NRCC No. 16739

Effluents Concentrations:

1. Mercury is concentrated in the sludges from sewage treatment by a factor of several hundred to several thousand over the levels initially present in the raw sewage. **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.73 (1979) NRCC No. 16739
2. ... A plant in northwestern Ontario is est to have discharged 9 tons of mercury into local waters, with effects traceable 200 miles downstream. **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.84 (1979) NRCC No. 16739

Sediment/Soil Concentrations:

1. ... Mercury is predominantly particle bound in contaminated water ways. **PEER REVIEWED** [WHO; Environ Health Criteria: Mercury p.59 (1976)
2. Volcanic exhalations: Soil air over mercury deposits 0-2000 ng/cu m; Soil and Glacial Deposits: Normal soils 20-150 ppb; Normal tills, glacial clay, sand, etc 20-100 ppb; Soils, tills, etc near mercury deposits, sulfide deposits, etc up to 250 ppm; Soil horizons (normal)- A

Topic: MERCURY

(humic) 60-200 ppb, B 30-140 ppb, C 25-150 ppb; Soil horizons (near mercury deposits)- A (humic) 200-1860 ppb, B 140-605 ppb, C 150-554 ppb. **PEER REVIEWED** [Jonasson IR, Boyle RW; Bull Can Inst Min Metal 65: 32-9 (1972) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.39 (1979) NRCC No. 16739

3. Approximate concn of all forms of mercury in the earth's crust is 80 ppb. **PEER REVIEWED** [Jonasson IR; Mercury in the Natural Environment: A Review of Recent Work: Geological Survey of Canada p.13-14 (1970)

Atmospheric Concentrations:

1. Atmospheric Concn (avg): 2-10 ng Hg/cu m (est) **PEER REVIEWED** [USEPA; Mercury Health Effects Update p.2-4 (1984) EPA 600/8-84-019F
2. The avg concn of mercury (Hg) in the general atmosphere in the USSR was 10 ng/cu m; 0-14 ng/cu m in non-industrialized regions of Japan; the lowest concn in Denver, USA was 2-5 ng/cu m; in San Francisco, USA, levels of 0.5-50 ng/cu m (depending greatly on the direction of the wind) were reported; airborne dust in New York City contained from 1 to 41 ng/cu m and outdoors concn ranged from 0 to 14 ng/cu m; and particle-bound Hg in air above Chicago ranged from 3 to 39 ng/cu m. **PEER REVIEWED** [WHO; Environ Health Criteria: Mercury p.57 (1976)
3. Volcanic exhalations: Atmosphere 2-10 ng/cu m; Air over mercury deposits 30-1600 ng/cu m. **PEER REVIEWED** [Jonasson IR, Boyle RW; Bull Can Inst Min Metal 65: 32-9 (1972) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.39 (1979) NRCC No. 16739
4. Mercury vapor concn in the stack gas of large coal-fired power generating stations in Ontario were found to range from 40 to 80 ug/cu m. ... **PEER REVIEWED** [Booth MR; Ont Hydro Res Q 23 (2): 1 (1971) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.66 (1979) NRCC No. 16739

Food Survey Results:

1. Levels in eggs (440 samples) taken from Denmark, the Federal Republic of Germany and the United Kingdom, ranged from 0 to 100 ug/kg with most of the values between 10 and 20 ug/kg. Levels in meat, meat products, and prepared meat products (318 samples from the United Kingdom) ranged from 0 to 50 ug/kg with most values lying between 10 and 20 ug/kg. Various kinds of cereal and flour (2,133 samples, taken from the Federal Republic of Germany and the United Kingdom) ranged from 0 to 20 ug/kg with most values being close to 3 ug/kg. Mercury levels in cereal products from the same countries (52 samples) ranged up to 50 ug/kg with most values close to 20 ug/kg. Vegetables and fruits (288 samples) from Belgium, the Federal Republic of Germany, and the United Kingdom had mercury levels up to 50 ug/kg with most values close to 7 ug/kg. **PEER REVIEWED** [Bouquiaux J; Proceedings of the Intl Symposium on the Problems of Contamination of Man and His Environment by Mercury and Cadmium p.23 (1974) as cited in WHO; Environ

Topic: MERCURY

Health Criteria: Mercury p.59 (1976)

2. Tuna, 0.2 mg/kg (natural), 10.6 mg/kg (abnormal); eggs, 0.009 mg/kg (natural), 0.029 mg/kg (abnormal); cabbage, 0.09 mg/kg (natural), 0.57 mg/kg (abnormal). /Mercury Compounds/ **PEER REVIEWED** [OECD; Mercury and the Environment p.135-141 (1974)]
3. Tuna, 0.2 mg/kg (natural), 10.6 mg/kg (abnormal); eggs, 0.009 mg/kg (natural), 0.029 mg/kg (abnormal); cabbage, 0.09 mg/kg (natural), 0.57 mg/kg (abnormal). /Mercury Compounds/ **PEER REVIEWED** [OECD; Mercury and the Environment p.135-141 (1974)]

Plant Concentrations:

1. Living organisms: Marine plants 0.01-37 ppb fresh wt; terrestrial plants 0-40 ppb fresh wt; Terrestrial plants in vicinity of mercury deposits 200-30,000 ppb fresh wt. **PEER REVIEWED** [Jonasson IR, Boyle RW; Bull Can Inst Min Metal 65: 32-9 (1972) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.39 (1979) NRCC No. 16739]
2. Mercury and its compounds occur naturally in trace amounts in plants growing in soils with low mercury concentrations (<500 ppb). /Mercury compd/ **PEER REVIEWED** [OECD; Mercury and the Environment p.135-147 (1974)]
3. Maximum levels for mercury are recommended at 0.5 ppm for plant tissue and 0.15 in soil. These recommendations reflect human effects rather than plant responses. **PEER REVIEWED** [Britt DL, Hushon JM; Biological Effects, Criteria and Standards for Hazardous Pollutants Associated with Energy Technologies p. 6-39 (1976) ERDA E (49-1)-3878]

Fish/Seafood Concentrations:

1. Fish Conc (avg): 100-200 ng Hg/g fish (est) **PEER REVIEWED** [USEPA; Mercury Health Effects Update p.2-4 (1984) EPA 600/8-84-019F]
2. Fish and shellfish /concn/ in the United States: Tuna (mainly canned) 0.24 ppm; Unclassified (mainly breaded, including fish sticks) 0.21 ppm; Shrimp 0.46 ppm; Flounder 0.10 ppm; Clams 0.05 ppm; Crabs/lobsters 0.25 ppm; Salmon 0.05 ppm; Oysters/scallops 0.04 ppm; Trout 0.42 ppm; Bass 0.21 ppm; Catfish 0.15 ppm; Sardines 0.06 ppm; Pike 0.61 ppm; Snapper 0.45 ppm; Whiting 0.05 ppm; All other classified 0.21 ppm. **PEER REVIEWED** [USEPA; Mercury Health Effects Update p.3-16 (1984) EPA 600/8-84-019F]
3. Mercury content in muscle tissue of British Columbia fish: Crabs (Squamish) 1.55-13.4 ppm; Crabs (Fraser River Flats) 0.19 ppm; Crabs (West Vancouver) 0.14 ppm; Crabs (Tofino) 0.02 ppm; Dolly Varden (Carpenter Lake) 0.41-1.94 ppm; Dogfish (English Bay) 1.08 ppm; Flounder (Squamish) 1.00-1.42 ppm; Flounder (Fraser River Flats) 0.23 ppm; Flounder (Hecate Strait) 0.11 ppm; Herring (Squamish) 0.14-0.30 ppm; Herring (Prince Rupert) 0.07 ppm; Lake trout (Pinchi Lake) 2.86 ppm; Rainbow trout (Tezzeron Lake) 0.04 ppm. **PEER REVIEWED** [Bligh EG, Armstrong FAJ; Int Council Explor Sea Rep No. CM 1971/E34 p.13 (1971) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.90 (1979) NRCC]

Topic: MERCURY

No. 16739

- Concentrations in edible fish should not exceed 0.5 ppm. /Mercury Compounds/ **PEER REVIEWED** [Britt DL, Hushon JM; Biological Effects, Criteria and Standards for Hazardous Pollutants Associated with Energy Technologies p. 6-38 (1976) ERDA E (49-1)-3878

Animal Concentrations:

- Living organisms: Marine animals; molluscs, fish, seals, etc 0.1-200 ppb; Terrestrial (freshwater) animals; fish, crayfish, etc 0.1-200 ppb; Terrestrial (land) animals; man, birds, etc 1-100 ppb. **PEER REVIEWED** [Jonasson IR, Boyle RW; Bull Can Inst Min Metal 65: 32-9 (1972) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.39 (1979) NRCC No. 16739

Milk Concentrations:

- Mercury levels in milk products (81 samples from the Federal Republic of Germany and the United Kingdom) ranged from 0 to 40 ug/kg with a medium value of 6 ug/kg. **PEER REVIEWED** [Bouquioux J; Proceedings of the Intl Symposium on the Problems of Contamination of Man and His Environment by Mercury and Cadmium p.23 (1974) as cited in WHO; Environ Health Criteria: Mercury p.59 (1976)

Other Environmental Concentrations:

- Volcanic Condensates and Precipitates: Fumarolic condensates 0.3-6 ppb; Sulfuric and hydrochloric acids 0.2-72 ppb; Chloride, sulfate, fluoride and sulfur precipitates 1-14,000 ppb; Hydrous iron oxide precipitates up to 0.1%; Opaline silica sinters, etc at hot spring orifices up to 0.2%. **PEER REVIEWED** [Jonasson IR, Boyle RW; Bull Can Inst Min Metal 65: 32-9 (1972) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.39 (1979) NRCC No. 16739
- 50 ppm of mercury in soil impairs growth of plants. Soils with more than 1,000 ppm must be considered toxic. **PEER REVIEWED** [Manual on Hazardous Substances in Special Wastes, Federal Environmental Agency Waste Management Division (1976) as cited in Environment Canada; Tech Info for Problem Spills: Mercury (Draft) p.43 (1982)

Human Exposure

Probable Routes of Human Exposure:

- The dominant food source of mercury in the human diet is fish and fish products. ... In terms of total mercury (Hg), the diet greatly exceeds other media, including air and water, as a source of human exposure and absorption of Hg. **PEER REVIEWED** [USEPA; Mercury Health Effects Update p.2-4 (1984) EPA 600/8-84-019F
- Accumulation of mercury in the terrestrial and aquatic food chains results in risks for man mainly through the consumption of: fish from contaminated waters; especially predator species, tuna fish, swordfish and other large oceanic fish even if caught a considerable distance off shore; other seafoods including muscles and crayfish; fish-eating birds and mammals; and eggs of fish eating birds. **PEER REVIEWED** [WHO; Environ Health Criteria: Mercury p.55 (1976)

Topic: MERCURY

Average Daily Intake:

1. The intake of total dietary mercury (Hg) has been measured ... over a number of years for various age groups. The average daily intake over the period 1973 to 1982 has been in the range of 2000 to 7000 ng Hg for adults and up to 1000 ng Hg for toddlers and infants. The most recent figures (fiscal year 1981-82) were 3000 ng Hg for adults, 1000 ng Hg for toddlers, and less than 1000 ng Hg for infants. **PEER REVIEWED** [Gartrell M; US Environmental Protection Agency Profile No ECAO-HA-83-3 as cited in USEPA; Mercury Health Effects Update p.3-20 (1984) EPA 600/8-84-019F
2. Assuming an ambient air level of 50 ng/cu m, the average daily intake of metallic mercury vapor would amount to 1 ug/day due to inhalation. ... The average daily intake of those sub-groups of the general population living in specially polluted areas is difficult to estimate with any accuracy. ... Daily intake from occupational exposure is almost impossible to estimate because of the wide variation in exposure conditions in industry. **PEER REVIEWED** [WHO; Environ Health Criteria: Mercury p.64 (1976)

Probable Exposures:

1. ONE OF MAJOR SOURCES OF ... EXPOSURE IS IN CHLOR-ALKALI PLANTS ... /OTHER SOURCES ARE/ MINING & REFINING OF MERCURY ... FROM PROCESSING OF CINNABAR (HGS) ... MFR & USE OF LIQ HG-CONTAINING INSTRUMENTS ... AN OFTEN UNREALIZED SOURCE OF EXPOSURE THROUGH BREAKAGE, SPILLAGE, OR CARELESS HANDLING. **PEER REVIEWED** [Clayton, G. D. and F. E. Clayton (eds.). Patty's Industrial Hygiene and Toxicology: Volume 2A, 2B, 2C: Toxicology. 3rd ed. New York: John Wiley Sons, 1981-1982. 1770
2. ... MOTHERS EXPOSED TO ELEMENTAL MERCURY THROUGH THEIR DENTAL WORK PLACE ... /SHOWED/ SIGNIFICANTLY INCREASED MERCURY CONTENT IN THEIR BABIES' PLACENTA & MEMBRANES. ... EXPOSURE LIMITS FOR WOMEN OF CHILDBEARING AGE & LEVELS AT WHICH TOXICITY MIGHT BE EXPECTED /HAVE BEEN SUGGESTED/. FOR FETUS & NEWBORN, THE TOXIC LEVEL IS GIVEN AS 3 UG HG/G. **PEER REVIEWED** [Shepard, T.H. Catalog of Teratogenic Agents. 4th ed. Baltimore, MD: Johns Hopkins University Press, 1983. 278
3. INHALATION OF VAPOR BY LABORATORY WORKERS IN CLOSED SPACE LED TO BRONCHIAL IRRITATION /& CHARACTERISTIC MERCURY POISONING SYMPTOMS/ ... CHRONIC MERCURIALISM IN FUR-CUTTING & FELT-HAT INDUSTRIES /IS REPORTED/. ALTHOUGH MERCURIC NITRATE WAS MATERIAL USED TO TREAT FUR FROM WHICH FELT WAS MADE, MERCURY WAS GRADUALLY RELEASED FROM FUR & FELT IN FORM OF METALLIC MERCURY VAPOR. ... THE WORKERS HAD MIXED EXPOSURE TO DUST OF MERCURY CMPD (ESP THE NITRATE) & TO VAPOR OF ELEMENT. ... POISONING WAS SIMILAR TO THAT OBSERVED ... /WITH/ METALLIC MERCURY ONLY. **PEER REVIEWED** [Hayes, Wayland J., Jr. Pesticides Studied in Man. Baltimore/London: Williams and Wilkins, 1982. 12
4. NIOSH, IN ITS CRITERIA DOCUMENT ... CONCLUDED THAT THE STD SHOULD BE AT LEAST AS LOW AS 0.05 MG/CU M ... /BECAUSE/

Topic: MERCURY

EREETHISM, RATHER THAN TREMOR, MAY BE THE MOST CHARACTERISTIC SYMPTOM OF CHRONIC MERCURIALISM /OCCURRING IN 33% OF WORKERS ABOVE 0.05 MG/CU M & IN 8% OF WORKERS BELOW THIS LEVEL/. ... /STUDIES OF WORKPLACES REVEAL/ THAT MUCH HIGHER EXPOSURES TO MERCURY VAPOR ... /OCCUR WHEN MEASURED/ BY PERSONAL SAMPLING DEVICES (0.016 TO 0.687 MG/CU M). THESE DIFFERENCES HAVE BEEN ATTRIBUTABLE TO MERCURY CONTAMINATION OF CLOTHING, WHICH MAY CAUSE SIGNIFICANT EXPOSURE AFTER WORK HOURS. **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, OH:American Conference of Governmental Industrial Hygienists, 1986. 358

5. Acute poisoning is major threat in home & on farm, but, because mercury is a cumulative poison, subacute & chronic intoxications are recognized, particularly in industry. **PEER REVIEWED** [Gosselin, R.E., R.P. Smith, H.C. Hodge. Clinical Toxicology of Commercial Products. 5th ed. Baltimore: Williams and Wilkins, 1984.,p. III-262

Body Burdens:

1. The concn of mercury in whole blood is a reasonable measure of the body-burden of Hg and thus is used for monitoring purposes. **PEER REVIEWED** [Berglund F et al; Nord Hyg T Suppl 4: 108-9 (1971) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.153 (1979) NRCC No. 16739

Topic: MERCURY

EXPOSURE STANDARDS & REGULATIONS

Standards & Regulations

Immediately Dangerous to Life or Death:

1. 28 mg/cu m /Vapor/ **QC REVIEWED** [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 140

Allowable Tolerances:

1. For mercury in fish, the permissible level in Canada is 0.5 mg/kg or less. **PEER REVIEWED** [Hugunin AG, Bradley RL; J Milk Food Technol 38: 285-300 (1975) as cited in Nat'l Research Council Canada; Effects of Mercury in the Canadian Environment p.137 (1979) NRCC No. 16739

Occupational Permissible Levels

OSHA Standards:

1. Meets criteria for OSHA medical records rule. **PEER REVIEWED** [29 CFR 1910.20 (7/1/87)
2. During an 8 hr work shift, an employee may be exposed to a concentration of mercury above 1 mg/cu m. **PEER REVIEWED** [29 CFR 1910.1000 (7/1/87)

NIOSH Recommendations:

1. 10-hr Time-Weighted Average 0.05 mg/cu m. /Mercury and inorganic cmpds (as Hg)/ **PEER REVIEWED** [NIOSH. Pocket Guide to Chemical Hazards. 5th Printing/Revision. DHHS (NIOSH) Publ. No. 85-114. Washington, D.C.: U.S. Dept. of Health and Human Services, NIOSH/Supt. of Documents, GPO, Sept. 1985. 152

Threshold Limit Values:

1. Time Weighted Avg (TWA) 0.05 mg/cu m, skin (1982) /All forms except alkyl vapor/ **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 25
2. Excursion Limit Recommendation: Excursions in worker exposure levels may exceed three times the TLV-TWA for no more than a total of 30 min during a work day and under no circumstances should they exceed five times the TLV-TWA, provided that the TLV-TWA is not exceeded. /All forms except alkyl vapor/ **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 5
3. Notice of intent to establish (first notice appeared in 1991-92 edition): BEI (Biological Exposure Index): Total inorganic mercury in blood (end of shift at end of workweek): 15 ug/l. /Mercury/ **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 69
4. Notice of intent to establish (first notice appeared in 1991-92 edition): BEI (Biological Exposure Index): Total inorganic mercury in urine (preshift): 35 ug/g creatinine.

HSDB

Topic: MERCURY

/Mercury/ **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 69

Other Occupational Permissible Levels:

1. Water: Health and Welfare Canada recommends 0.001 mg/l Hg as a maximum acceptable concn in water; Air: The Ontario limit for airborne environmental Hg is 5 ug/cu m. **PEER REVIEWED** [Environment Canada; Tech Info for Problem Spills: Mercury (Draft) p.34 (1982)

Other Standards and Regulations

Water Standards:

1. The maximum contaminant level (MCL) of mercury in drinking water is 0.002 mg/l. **PEER REVIEWED** [40 CFR 141 (7/1/87)
2. Toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations. **PEER REVIEWED** [40 CFR 401.15 (7/1/87)

Atmospheric Standards:

1. Emissions to the atmosphere from mercury ore processing facilities and mercury cell chlor-alkali plants shall not exceed 2300 grams of mercury per 24-hour period. **PEER REVIEWED** [40 CFR 61.52(a) (7/1/87)
2. Emissions to the atmosphere from sludge incineration plants, sludge drying plants, or a combination of these sludge waste water treatment plant processes shall not exceed 3200 grams of mercury per 24-hour period. **PEER REVIEWED** [40 CFR 61.52(b) (7/1/87)

CERCLA Reportable Quantities:

1. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 1 lb or 0.454 kg. The toll free telephone number of the NRC is (800) 424-8802; In the Washington metropolitan area (202) 426-2675. The rule for determining when notification is required is stated in 40 CFR 302.6 (section IV. D.3.b). **PEER REVIEWED** [50 FR 13456 (4/4/85)

RCRA Requirements:

1. When mercury, as a commercial chemical product or manufacturing chemical intermediate or as an off-specification commercial chemical product or a manufacturing chemical intermediate, becomes a waste, it must be managed as a hazardous waste according to Federal and/or State regulations. Also defined as a hazardous waste is any container or inner liner used to hold this waste or any residue, contaminated soil, water, or other debris resulting from the cleanup of a spill into water or on dry land of this waste. Generators of small quantities of this waste may qualify for partial exclusion from hazardous waste regulations (40 CFR 261.5(e)). **PEER REVIEWED** [40 CFR 261.33 (7/1/87)
2. A solid waste containing mercury may become characterized

HSDB

Topic: MERCURY

as a hazardous waste when subjected to the Toxicant Extraction Procedure listed in 40 CFR 261.24, and if so characterized, must be managed as a hazardous waste.

****PEER REVIEWED**** [40 CFR 261.24 (7/1/87)]

FIFRA Requirements:

1. All uses of mercury are cancelled except the following: 1) as a fungicide in the treatment of textiles and fabrics intended for continuous outdoor use; 2) as a fungicide to control brown mold on freshly sawn lumber; 3) as a fungicide treatment to control Dutch elm disease; 4) as an in-can preservative in water based paints and coatings; 5) as a fungicide in water-based paints and coatings used for exterior application; 6) as a fungicide to control "winter turf diseases" such as Sclerotinia boreales, and gray and pink snow mold subject to the following: a. the use of these products shall be prohibited within 25 feet of any water body where fish are taken for human consumption. b. these products can be applied only by or under the direct supervision of golf course superintendents. c. the products will be classified as restricted use pesticides when they are reregistered and classified in accordance with section 4(c) of FEPCA. /Mercury/ ****PEER REVIEWED**** [Environmental Protection Agency/OPTS. Suspended, Cancelled and Restricted Pesticides. 3rd Revision. Washington, D.C.: Environmental Protection Agency, January 1985. 16]

FDA Requirements:

1. Bottled water shall, when a composite of analytical units of equal volume from a sample is examined by the methods described in paragraph (d)(1)(ii) of this section, meet the standards of chemical quality and shall not contain mercury in excess of 0.002 mg/l. ****PEER REVIEWED**** [21 CFR 103.35 (4/1/88)]
2. The color additive FD&C Blue Number 2 shall conform to the specifications in the CFR 74.102 and shall be free from impurities other than those named; including mercury (as Hg) in not more than 1 part per million, to the extent that such other impurities may be avoided by current good manufacturing practice. ****PEER REVIEWED**** [21 CFR 74.102 (4/1/88)]
3. The color additive FD&C Green Number 3 shall conform to the specifications in the CFR 74.203 and shall be free from impurities other than those named; including mercury (as Hg) in not more than 1 part per million, to the extent that such other impurities may be avoided by current good manufacturing practice. ****PEER REVIEWED**** [21 CFR 74.203 (4/1/88)]
4. The color additive FD&C Yellow Number 5 shall conform to the specifications in the CFR 74.705 and shall be free from impurities other than those named; including mercury (as Hg) in not more than 1 part per million, to the extent that such other impurities may be avoided by current good manufacturing practice. ****PEER REVIEWED**** [21 CFR 74.705 (4/1/88)]
5. THE ACTION LEVEL OF 1.0 PPM TOTAL MERCURY IN FISH HAS BEEN

IRIS

Topic: MERCURY (INORGANIC)

I. CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Mercury (Inorganic)

CASRN -- 7439-97-6

A risk assessment for this substance/agent is under review by an EPA work group.

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE (RfC)

Substance Name -- Mercury (Inorganic)

CASRN -- 7439-97-6

A risk assessment for this substance/agent is under review by an EPA work group.

=====

HSDB

Topic: MERCURY

REVISED ON SEPT 12, 1984 BY FDA TO APPLY ONLY TO METHYL
MERCURY. /METHYL MERCURY/ **PEER REVIEWED** [FOOD CHEMICAL
NEWS (SEPT 17): 36-7 (1984)

IRIS

Topic: MERCURY (INORGANIC)

I. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Mercury (Inorganic)

ASRN -- 7439-97-6

Last Revised -- 05/01/91

Section II provides information on three aspects of the carcinogenic risk assessment for the agent in question; the U.S. EPA classification, and quantitative estimates of risk from oral exposure and from inhalation exposure. The classification reflects a weight-of-evidence judgment of the likelihood that the agent is a human carcinogen. The quantitative risk estimates are presented in three ways. The slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per (mg/kg)/day. The unit risk is the quantitative estimate in terms of either risk per ug/L drinking water or risk per ug/cu.m air breathed. The third form in which risk is presented is a drinking water or air concentration providing cancer risks of 1 in 10,000, 1 in 100,000 or 1 in 1,000,000. Background Document 2 (Service Code 5) provides details on the rationale and methods used to derive the carcinogenicity values found in IRIS. Users are referred to Section I for information on long-term toxic effects other than carcinogenicity.

II.A. EVIDENCE FOR CLASSIFICATION AS TO HUMAN CARCINOGENICITY

II.A.1. WEIGHT-OF-EVIDENCE CLASSIFICATION

Classification -- D; not classifiable as to human carcinogenicity

Basis -- No human data are available. Animal and supporting data are inadequate.

II.A.2. HUMAN CARCINOGENICITY DATA

None.

II.A.3. ANIMAL CARCINOGENICITY DATA

When 39 BD III and BD IV rats were injected i.p. over 2 weeks with 0.1 ml metallic mercury and observed for their lifetimes, sarcomas were seen only in those tissues that had been in direct contact with the metal (Druckrey et al., 1957). No concurrent controls were reported.

II.A.4. SUPPORTING DATA FOR CARCINOGENICITY

Mitsumori et al. (1981) fed groups of 60 male and 60 female SPF ICR mice 0, 15 or 30 ppm methyl mercury chloride in the diet for up to 78 weeks. The majority of the 30 ppm groups died from neurotoxicity by week 26. Histopathology on kidney tissue from all animals surviving after 53 weeks revealed renal tumors in 13/16 males in the 15 ppm group (2 adenomas, 11 adenocarcinomas). One adenoma was detected among 37 controls surviving to week 53 or beyond, and no tumors were seen in either control or exposed females. The possible presence of tumors at other sites was not reported in this preliminary communication.

Methyl mercury hydroxide administered in the diet to *Silphoila melanogaster* at 5 mg/L induced chromosomal nondisjunction. Methyl and phenyl mercury produced small increases in the rate of point mutations (Ramel, 1972). The relevance of data from studies of organic mercury to the possible carcinogenicity of inorganic mercury is uncertain.

IRIS

Topic: MERCURY (INORGANIC)

II.B. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM ORAL EXPOSURE
Not available.

II.C. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM INHALATION EXPOSURE
Not available.

II.D. EPA DOCUMENTATION, REVIEW, AND CONTACTS (CARCINOGENICITY ASSESSMENT)

II.D.1. EPA DOCUMENTATION

U.S. EPA. 1987. Drinking Water Criteria Document for Mercury. Prepared for the Office of Drinking Water, Washington, DC. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH. ECAO-CIN-025, February, 1987.

II.D.2. REVIEW (CARCINOGENICITY ASSESSMENT)

The 1987 Drinking Water Criteria Document for Mercury has received Agency and external review.

Agency Work Group Review: 01/13/88

Verification Date: 01/13/88

II.D.3. U.S. EPA CONTACTS (CARCINOGENICITY ASSESSMENT)

W. Bruce Peirano / ORD -- (513)569-7540 / FTS 684-7540

Krishan Khanna / ODW -- (202)260-7588 / FTS 260-7588
=====

TOMES(R) Medical Management

Topic: NICKEL

6.0 RANGE OF TOXICITY

6.1 EFFECTIVE DOSE

6.1.1 ADULT

A. Oral toxicity is low (10 percent), similar to zinc, chromium, and manganese (Errera, 1980). Toxicity via oral exposure is unusual. The usual adult oral intake of nickel is approximately 300 to 600 micrograms/day.

6.3 MAXIMUM TOLERATED EXPOSURE

A. Hogetveit et al (1978) has recommended a plasma level of 10 micrograms/liter be set as the maximum tolerated dose for nickel refinery workers.

6.4 TOXIC SERUM/PLASMA/BLOOD CONCENTRATIONS

A. In 15 workers who accidentally drank water contaminated with 1.63 grams/liter of nickel and developed symptoms, serum nickel concentrations ranged from 13 to 1,340 micrograms/liter and urine nickel concentrations ranged from 0.15 to 12 milligrams/gram creatinine on day 1 postexposure (Sunderman et al, 1988).

6.5 LD50/LC50

A. LD50 (Animal Model):

Toxicity of Nickel and Its Compounds

Nickel (Colloidal and Powdered)

Intravenous	Dogs	LD = 10 to 20 mg/kg
Acute Oral	Dogs	Tolerated: 1 to 3 g/kg
Nickel Salts (Cl, NO ₃ , SO ₄ , O)		
Intravenous	Dogs	LD = 10 to 20 mg/kg
Subcutaneous	Rabbits	LD = 1.3 g/kg
Acute Oral	Rats	<D50 = 2.0 g/kg
Chronic Oral	Cats	Tolerated: 25 mg/kg/day for 200 days
Skin Application	Human	1:10,000 evokes sensitivity reaction

Nickel Carbonyl - Ni (CO)₄

Inhalation	Mice	LC50 = 0.067 mg/L for 30 minutes
Inhalation	Rats	LC50 = 0.24 mg/L for 30 minutes
Inhalation	Cats	LC50 = 1.9 mg/L for 30 minutes
Intravenous	Rats	LD50 = 22 + 1.1 mg/kg
Subcutaneous	Rats	LD50 = 21 + 4.2 mg/kg
Intraperitoneal	Rats	LD50 = 13 + 1.4 mg/kg

(Sunderman Sr, 1981)

B. Comparative acute toxicity of 4 nickel compounds after inhalation by rats indicated the following toxicity ranking: Ni₃S₂, NiSO₄, and NiCl₂ were much more toxic than NiO (Benson et al, 1986).

HSDB

Topic: NICKEL

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL
Pollution Sources

Natural Occurring Sources:

1. ABUNDANCE IN EARTH'S CRUST 0.018%. ... OCCURS FREE IN METEORITES. FOUND IN MANY ORES AS SULFIDES, ARSENIDES, ANTIMONIDES & OXIDES OR SILICATES; CHIEF SOURCES INCL CHALCOPYRITE ... PYRRHOTITE, PENTLANDITE ((FE,NI)₉₅₈) & GARNIERITE (3(MG,NI)O.-2SiO₂.2H₂O); OTHER ORES INCL NICCOLITE ... & MILLERITE (NIS). **PEER REVIEWED** [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 932]
2. NICKEL CONSTITUTES 0.03% OF THE PARTICULATE MATTER SUSPENDED IN ATMOSPHERE. IN ADDITION, THERE IS EVIDENCE THAT PURE NICKEL POWDERS ... OF LESS THAN 1 U IN SIZE ARE DEPOSITED AS METEORITIC DUST FROM STRATOSPHERE. /NICKEL AND NICKEL CMPD/ **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V2 131 (1973)]
3. Natural sources of airborne particles that contain nickel include soil, sea, volcanoes, forest fires, and vegetation. /Nickel and nickel compd/ **PEER REVIEWED** [Davies CN; Atmos Envir 8: 1069-79 (1974) as cited in Nat'l Research Council Canada; Effects of Nickel in the Canadian Environ p.60 (1981) NRCC No.18568]
4. Average concn of nickel in the earth's crust is 60-90 mg/kg. /Nickel and nickel compd/ **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Nickel in the Canadian Environ p.27 (1981) NRCC No.18568]

Artificial Sources:

1. ENVIRONMENTAL ACCUMULATION: NICKEL POWDER'S INCR USAGE ENHANCES PROBABILITY OF ITS APPEARANCE IN ATMOSPHERE @ NICKEL PRODN PLANTS. THE AVG CONCIN IN USA IN 1964 & 1965 WAS 340 NG/CU M. NICKEL FINDS ITS WAY INTO ATMOSPHERE AS RESULT OF COMBUSTION OF COAL, DIESEL OIL & FUEL OIL. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V2 131 (1973)]
2. Food processing methods apparently add to the nickel levels already present in foodstuffs via (1) leaching from nickel containing alloys in food processing equipment made from stainless steel, (2) the milling of flour, and (3) catalytic hydrogenation of fats and oils by use of nickel catalysts. **PEER REVIEWED** [USEPA; Ambient Water Quality Criteria Document : Nickel p.C-7 (1980) EPA 400/5-80-060]

Environmental Fate

Environmental Fate:

1. The atmosphere is a major conduit for nickel as particulate matter. Contributions to atmospheric loading come from both natural sources and anthropogenic activity, with input from both stationary and mobile sources. Various dry and wet precipitation processes remove particulate matter as wash out or fallout from the

Topic: NICKEL

atmosphere with transfer to soils and waters. Soil borne nickel may enter waters by surface runoff or by percolation into ground water. Once nickel is in surface and ground water systems, physical and chemical interactions (complexation, precipitation/dissolution, adsorption/desorption, and oxidation/reduction) occur that will determine its fate and that of its constituents.

/Nickel and compd/ **PEER REVIEWED** [USEPA; Health Assessment Document: Nickel p.20 (1983) EPA 600/8-83-012

Environmental Transformations

Biodegradation:

1. No data was found to suggest that nickel is involved in any biological transformation in the aquatic environment. **QC REVIEWED** [Callahan, M.A., M.W. Slimak, N.W. Gabel, et al. Water-Related Environmental Fate of 129 Priority Pollutants. Volume I. EPA-440/4 79-029a. Washington, DC: U.S.Environmental Protection Agency, December 1979.,p. 15-6

Environmental Concentrations

Sediment/Soil Concentrations:

1. Aerial fallout from a nickel smelter at Port Colborne, Ontario, Canada, resulted in accumulation of nickel ranging from 600 to 6455 mg/kg in the organic soil of a farm. /Nickel and compd/ **PEER REVIEWED** [USEPA; Health Assessment Document: Nickel p.29 (1983) EPA 600/8-83-012
2. Uncontaminated agricultural soils in Canada generally contain less than 30 mg nickel (Ni)/kg. Soils derived from serpentine rock may contain up to 25,000 mg Ni/kg, although a more typical value is 1000 mg/kg. Accumulations of Ni in soil exceeding 1000 mg/kg occur within 1-2 km of large nickel smelters. /Nickel and compd/ **PEER REVIEWED** [Nat Research Council Canada; Effects of Nickel in the Canadian Envir p.28 (1981) NRCC No. 18568

Atmospheric Concentrations:

1. Typical average levels of airborne nickel are: 0.00001-0.003 ug/cu m in remote areas; 0.003-0.03 ug/cu m in urban areas having no metallurgical industry; 0.07-0.77 ug/cu m in nickel processing areas. /Nickel and compd/ **PEER REVIEWED** [Nat'l Research Council Canada; Effects of Nickel in the Canadian Envir p.27 (1981) NRCC No. 18568

Human Exposure

Probable Routes of Human Exposure:

1. Routes of nickel intake for man and animals are inhalation, ingestion, and percutaneous /exposure/. **PEER REVIEWED** [USEPA; Ambient Water Quality Criteria Document: Nickel p.C-19 (1980) EPA 400/5-80-060
2. The toxicologically important routes of entry for nickel, metal & sol compounds (as Ni) are inhalation, skin absorption, ingestion, and skin and/or eye contact. /Nickel and nickel compd/ **PEER REVIEWED** [NIOSH. Pocket Guide to Chemical Hazards. 5th Printing/Revision. DHHS (NIOSH) Publ. No. 85-114. Washington, D.C.: U.S. Dept. of Health and Human Services, NIOSH/Supt. of Documents, GPO, Sept. 1985. 173

Probable Exposures:

HSDB

Topic: NICKEL

1. Occupational groups such as nickel workers and other workers handling nickel comprise the individuals at the highest risk. Women, particularly housewives, are at special risk to nickel induced skin disorders because of the greater than average contact with nickel containing materials. Approximately 47 million individuals, comprising the smoking population of the United States, are potentially at risk for possible co-factor effects of nickel in adverse effects on the respiratory tract. /Nickel and nickel cmpd/ **PEER REVIEWED** [USEPA; Ambient Water Quality Criteria Doc: Nickel p.C-130 (1980) EPA 400/5-80-060
2. HIGHEST RISK OF MORTALITY FROM CANCER OF RESP TRACT IS FOUND AMONG NICKEL MINE WORKERS INVOLVED IN ROASTING, SMELTING, & ELECTROLYSIS. **PEER REVIEWED** [Venugopal, B. and T.D. Luckey. Metal Toxicity in Mammals, 2. New York: Plenum Press, 1978. 296
3. Occupational exposures to nickel and its cmpd occur in (1) mining and comminution of nickel containing ores; (2) nickel refining and smelting; (3) nickel electroplating; (4) producing and using nickel catalysts; (5) fabricating parts and structures by welding, flame spraying, cutting, grinding, and polishing of nickel containing alloys; (6) manufacturing nickel cadmium batteries; (7) constructing nickel molds in glass bottle factories; (8) spraying nickel containing paints (eg, yellow nickel titanate pigment); and (9) recycling or disposal of nickel containing products. /Nickel and nickel cmpd/ **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 455
4. Occupations at risk for nickel dermatitis included metal worker, electroplater, ladies' hairdresser, nurse, tailor, cook, waitress, cleaning women, typist, office clerk, dental assistant, medical assistant, electronics worker, dairy maid, librarian, chemical cleaner, engine fitter, turner, locksmith, car driver, chemical worker, television engineer, and radiologist. **PEER REVIEWED** [Schubert H et al; Contact Dermatitis 16 (3): 122-8 (1987)
5. EPIDEMIOLOGICAL STUDIES CONCLUSIVELY DEMONSTRATE AN EXCESS OF CANCER OF THE NASAL CAVITY & LUNG IN WORKERS IN NICKEL REFINERIES. IT IS LIKELY THAT NICKEL IN SOME FORM IS CARCINOGENIC TO MAN. /NICKEL/ **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work).,p. V11 104 (1976)

Topic: NICKEL

EXPOSURE STANDARDS & REGULATIONS

Standards & Regulations

Immediately Dangerous to Life or Death:

1. NIOSH has recommended that nickel be treated as a potential human carcinogen. **QC REVIEWED** [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 160

Occupational Permissible Levels

OSHA Standards:

1. Meets criteria for OSHA medical records rule. /Nickel, metal and soluble compd, as Ni/ **PEER REVIEWED** [29 CFR 1910.20 (7/1/87)]
2. 8-hr Time-Weighted avg: 1.0 mg/cu m. /Nickel, metal and soluble compd, as Ni/ **PEER REVIEWED** [29 CFR 1910.1000 (7/1/87)]

NIOSH Recommendations:

1. NIOSH recommends that the substance be treated as a potential human carcinogen. /Nickel, inorganic compounds/ **PEER REVIEWED** [NIOSH/CDC. NIOSH Recommendations for Occupational Safety and Health Standards Sept. 1986. (Supplement to Morbidity and Mortality Weekly Report 35 No. 15, Sept. 26, 1986), p. 24S]
2. 10 Hr TWA 15 ug nickel/cu m. /Nickel, inorganic compd/ **PEER REVIEWED** [NIOSH/CDC. NIOSH Recommendations for Occupational Safety and Health Standards Sept. 1986. (Supplement to Morbidity and Mortality Weekly Report 35 No. 15, Sept. 26, 1986), p. 24S]

Threshold Limit Values:

1. Time Weighted Avg (TWA) 1 mg/cu m **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 28]
2. Notice of Intended Change (first notice appeared in 1989-90 edition): The ACGIH has listed chemicals for which a limit has been proposed for the first time, or for which a change in the "Adopted" listing has been proposed. The proposed limits should be considered trial limits that will remain in the listing for a period of at least two years. If, after two years no evidence comes to light that questions the appropriateness of the values herein, the values will be reconsidered for the "Adopted" list. Time Weighted Avg (TWA) 0.05 mg/cu m **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 40]
3. Notice of Intended Change (first notice appeared in 1989-90 edition): A1. A1= Confirmed human carcinogen. **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH,

Topic: NICKEL

1991. 40

Other Occupational Permissible Levels:

1. Max allowable concn (MAC) USSR 0.5 mg/cu m /Nickel, nickel oxide and nickel sulfides as dust/ ****PEER REVIEWED****
[International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983. 1438

Other Standards and Regulations

Water Standards:

1. Toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations. /Nickel and inorganic and organic nickel compd/ ****PEER REVIEWED**** [40 CFR 401.15 (7/1/87)

RCRA Requirements:

1. The Environmental Protection Agency /has promulgated/ ... regulations concerning ground-water monitoring with regard to screening suspected contamination at land based hazardous waste treatment, storage, and disposal facilities. ... /There are/ new requirements to analyze for a specified core list of chemicals plus those chemicals specified by the Regional Administrator on a site-specific basis. ... /Total nickel (all species) is included on this list./ /Total nickel (all species)/ ****PEER REVIEWED**** [52 FR 25942 (7/9/87)

FDA Requirements:

1. Substance added directly to human food affirmed as generally recognized as safe (GRAS). ****PEER REVIEWED**** [21 CFR 184.1537 (4/1/88)

IRIS

Topic: NICKEL, SOLUBLE SALTS

CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Nickel, soluble salts

CASRN -- 7440-02-0

Last Revised -- 01/01/92

The Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Please refer to Background Document 1 in Service Code 5 for an elaboration of these concepts. RfDs can also be derived for the noncarcinogenic health effects of compounds which are also carcinogens. Therefore, it is essential to refer to other sources of information concerning the carcinogenicity of this substance. If the U.S. EPA has evaluated this substance for potential human carcinogenicity, a summary of that evaluation will be contained in Section II of this file when a review of that evaluation is completed.

I.A.1. ORAL RfD SUMMARY

See Table Document

I.A.2. PRINCIPAL AND SUPPORTING STUDIES (ORAL RfD)

Ambrose, A.M., D.S. Larson, J.R. Borzelleca and G.R. Hennigar, Jr. 1976. Long-term toxicologic assessment of nickel in rats and dogs. J. Food Sci. Technol. 13: 181-187.

Ambrose et al. (1976) reported the results of a 2-year feeding study using rats given 0, 100, 1000 or 2500 ppm nickel (estimated as 0, 5, 50 and 125 mg Ni/kg bw) in the diet. Body weights in the high-dose male and female rats were significantly decreased compared with controls. Body weight was also reduced at 1000 ppm. This reduction was significant for females at week 6 and from weeks 26 through 104, whereas males showed body weight reduction only at 52 weeks. Groups of female rats on the 1000 or 2500 ppm nickel diets (50 and 125 mg Ni/kg bw) had significantly higher heart-to-body weight ratios and lower liver-to-body weight ratios than controls. No significant effects were reported at 100 ppm (5 mg Ni/kg bw). The dose of 1000 ppm (50 mg Ni/kg bw) represents a LOAEL for this study, while the dose of 100 ppm (5 mg Ni/kg bw) is a NOAEL. In this study, 2-year survival was poor, particularly in control rats of both sexes (death: 44/50), raising some concern about the interpretation of the results of this study. A subchronic study conducted by American Biogenics Corp. (ABC, 1986) also found 5 mg/kg/day to be a NOAEL, which supports the Ambrose et al. (1976) chronic NOAEL of 5 mg/kg/day.

Dietary exposure of dogs to 2500 ppm Ni (about 63 mg/kg/day) resulted in depressed body weight gain; no effects were seen at either 100 ppm (about 2.5 mg/kg/day) or 1000 ppm Ni (about 25 mg/kg/day) in the diet (Ambrose et al., 1976). This study

IRIS

Topic: NICKEL, SOLUBLE SALTS

demonstrates that rats are the more sensitive of the two species.

ABC (1986) conducted the 90-day study with nickel chloride in water (0, 5, 35 and 100 mg/kg/day) administered by gavage to both male and female CD rats (30 animals/sex/group). The data generated in this study included clinical pathology, ophthalmological evaluations, serum biochemistry, body and organ weight changes and histopathological evaluations of selected organs (heart, kidney, liver).

The body weight and food consumption values were consistently lower than those of controls for the 35 and 100 mg/kg/day dosed males. Female rats in both high-dose groups had lower body weights than controls, but food consumption was unaffected by the test article. Clinical signs of toxicity, such as lethargy, ataxia, irregular breathing, cool body temperature, salivation and discolored extremities, were seen primarily in the 100 mg/kg/day group; these signs were less severe in the 35 mg/kg/day group. The 5 mg/kg/day group did not show any significant clinical signs of toxicity. There was 100% mortality in the high-dose group; 6/30 males and 8/30 females died in the mid-dose group (35 mg/kg/day).

Histopathologic evaluation indicated that deaths of 3/6 males and 5/8 females in the mid-dose group were due to gavage errors. At sacrifice, kidney, liver and spleen weights for 35 mg/kg/day treated males and right kidney weights for 35 mg/kg/day treated females were significantly lower than controls. Based on the results obtained in this study, the 5 mg/kg/day nickel dose was a NOAEL, whereas 35 mg/kg/day was a LOAEL for decreased body and organ weights.

I.A.3. UNCERTAINTY AND MODIFYING FACTORS (ORAL RfD)

UF = 300. An uncertainty factor of 10 is used for interspecies extrapolation and 10 to protect sensitive populations. An additional uncertainty factor of 3 is used to account for inadequacies in the reproductive studies (RTI, 1987; Ambrose et al., 1976; Smith et al., 1990) (see Additional Comments section). During the gestation and postnatal development of F1b litters in the RTI (1987) study, temperatures were about 10 degrees F higher than normal at certain times, which makes evaluation of this part of the reproductive study impossible. In the Ambrose et al. (1976) study, statistical design limitations included small sample size and use of pups rather than litters as the unit for comparison. There were also problems with the statistical analysis of the Smith et al. (1990) study.

The Ni dietary study by Ambrose et al. (1976) identifying a NOAEL of 100 ppm (5 mg/kg/day) is supported by the subchronic gavage study in water (ABC, 1986), which indicated the same NOAEL (5 mg/kg/day).

MF = 1.

I.A.4. ADDITIONAL STUDIES / COMMENTS (ORAL RfD)

In addition to the effects on organ weights described in the critical study, two other sensitive endpoints exist: neonatal mortality and dermatotoxicity. While no reproductive effects have been associated with nickel exposure to humans, several studies in laboratory animals have demonstrated fetotoxicity.

Topic: NICKEL, SOLUBLE SALTS

These studies are described below.

Following the reproductive studies is a discussion of nickel-induced dermatotoxicity in hypersensitive humans. While nickel has long been recognized as a contact irritant, many studies have also demonstrated dermal effects in sensitive humans resulting from ingested nickel. The weight-of-evidence from these studies indicates that ingested nickel may invoke an eruption or worsening of eczema; however, a dose-response relationship is difficult to establish. A few representative studies and review articles are cited below. While the systemic toxicity data (as manifested in organ weight changes) was used as the critical study for the RfD determination, the reproductive/fetotoxicity and the dermatotoxicity were both considered as possible endpoints upon which to base the quantitative risk assessment of nickel. The data for effects on the latter two endpoints do not demonstrate consistent dose-response relationships, and in both cases the available studies are sufficiently flawed so as to prevent their selection as the basis for the oral RfD. It is noted, however, that the RfD based on the Ambrose et al. (1976) study is considered to be protective of all endpoints with the possible exception of hypersensitive individuals as described below.

In addition to the 2-year feeding study used as the basis for the RfD, Ambrose et al. (1976) also reported reproductive toxicity of nickel. The study had some statistical design limitations including small sample size and use of pups rather than litters as the unit for comparison. Furthermore, the results were equivocal and did not clearly define a NOAEL or LOAEL. Because nickel was administered in a laboratory chow diet rather than drinking water, quantifying analogous nickel exposure via drinking water was problematic.

In a 2-generation study (RTI, 1987) nickel chloride was administered in drinking water to male and female CD rats (30/sex/dose) at dose levels of 0, 50, 250 and 500 ppm (0, 7.3, 30.8 and 51.6 mg/kg/day, estimated) for 90 days before breeding (10 rats/sex/group comprised a satellite subchronic nonbreeder group). At the 500 ppm dose level there was a significant decrease in the Po maternal body weight, along with absolute and relative liver weights. Thus, 250 ppm (30.8 mg/kg/day) was a NOAEL for Po breeders. Histopathology was performed for liver, kidney, lungs, heart, pituitary, adrenals and reproductive organs to make this assessment. This NOAEL is higher than the NOAEL derived from the chronic Ambrose et al. (1976) and subchronic gavage (ABC, 1986) assays.

In the RTI (1987) F1a generation (postnatal days 1-4) at the 500 ppm dose level the number of live pups/litter was significantly decreased, pup mortality was significantly increased, and average pup body weight was significantly decreased in comparison with controls. Similar effects were seen with F1b litters of Po dams exposed to 500 ppm nickel. In the 50 and 250 ppm dose groups increased pup mortality and decreased live litter size was observed in the F1b litters. However, these effects seen with F1b litters are questionable

IRIS

opic: NICKEL, SOLUBLE SALTS

because the room temperature tended to be 10 degrees F higher than normal at certain times (gestation-postnatal days) along with much lower levels of humidity. As evidenced in the literature, temperatures that are 10 degrees F above normal during fetal development cause adverse effects (Edwards, 1986). Therefore, the above results seen at 50 and 250 ppm cannot be considered to be genuine adverse effects.

F1b males and females of the RTI (1987) study were randomly mated on postnatal day 70 and their offspring (F2a and F2b) were evaluated through postnatal day 21. This phase included teratological evaluations of F2b fetuses. Evaluation of the data indicated that the 500 ppm dose caused significant body weight depression of both mothers and pups, and increased neonatal mortality during the postnatal development period. The intermediate dose, 250 ppm nickel, produced transient depression of maternal weight gain and water intake during gestation of the F2b litters. The 50 ppm nickel exposure caused a significant increase in short ribs (11%). However, since this effect was not seen in both the higher dose groups, the reported incidence of short ribs in the 50 ppm group is not considered to be biologically significant.

Schroeder and Mitchener (1971) conducted a 3-generation study in which 5 mating pairs of rats were provided drinking water containing 5 mg Ni/L (estimated as 0.43 mg/kg bw). Results of this study indicated significant increases in neonatal mortality and in the number of runts born to exposed rats compared with controls. The major weakness of this study, however, is that the end result is based on a total of five matings. The matings were not randomized and the males were not rotated. The Schroeder and Mitchener (1971) study was conducted in an environmentally controlled facility where rats had access to food and water containing minimal levels of essential trace metals. Because of the interactions of nickel with other trace metals, the restricted exposure to trace metals (chromium was estimated as inadequate) may have contributed to the toxicity of nickel.

Smith et al. (1990) also studied the reproductive and fetotoxic effects of nickel. Four groups of 34 female Long-Evans rats were given drinking water containing nickel chloride in the following concentrations of nickel: 0, 10, 50 or 250 ppm (0, 1.3, 6.8 or 31.6 mg/kg/day) for 11 weeks prior to mating and during two successive gestation periods (G1, G2) and lactation periods (L1, L2). Maternal body weight gain was reduced during G1 in mid- and high-dose females. The reproductive performance of the exposed rats was not affected. Pup birth weight was unaltered by treatment, and weight gain was reduced only in male pups exposed to 50 ppm nickel during L1. The most significant toxicological finding was the increased incidence of perinatal mortality. The proportion of dead pups per litter was elevated at the high dose in L1 and at 10 and 250 ppm in L2. While the perinatal mortality reported in this study is consistent with other reproductive studies on nickel, it is hard to define a NOAEL and LOAEL because of the absence of a clear dose-response trend at the lower doses.

IRIS

Topic: NICKEL, SOLUBLE SALTS

Many studies have been published regarding nickel sensitivity in humans. Of the general population, approximately 8-10% of women and 1-2% of men demonstrate a sensitivity to nickel as determined by a patch test (North American Contact Dermatitis Group, 1973; Prystowsky et al., 1979). Initial sensitization to nickel is believed to result from dermal contact, but recurring flares of eczema, particularly of the hands, may be triggered by ingestion.

The human studies described below are difficult to interpret for several reasons: very small numbers of subjects (mostly women already determined to be sensitive to nickel by a patch test) were used in the studies; many investigators reported a placebo effect; many studies were not conducted in a double-blind manner, thereby introducing investigator bias; and it was often not specified whether subjects had been fasted overnight or whether there were other dietary restrictions. It is important to note that the way in which nickel is consumed may greatly affect its bioavailability. Sunderman et al. (1989) demonstrated that 27+/-17% of the nickel in drinking water was absorbed by healthy humans whereas only 0.7+/-0.4% of the same dose of nickel ingested in food was absorbed (a 40-fold difference). One final point to bear in mind in interpreting these studies is that the subjects were generally given a bolus dose of nickel. The absorption and biokinetics following such an exposure may be quite different from an exposure which is given incrementally throughout the day.

Following an overnight fast, groups of 5 nickel-sensitive women were given 100 mL of water along with one oral dose of nickel sulfate containing 0.6, 1.25 or 2.5 mg nickel (Cronin et al., 1980). The clinical response was observed for the next 24 hours. Worsening of hand eczema was reported in 2/5 female subjects that received 0.6 mg, 3/5 at 1.25 mg and 5/5 at 2.5 mg. Erythema was observed in 1/5 (0.6 mg), 4/5 (1.25 mg) and 4/5 (2.5 mg) women. While there appears to be a good dose-response relationship, this study did not report controls. The response observed at the lowest dose may well be within background levels.

Numerous other studies have been conducted to attempt to establish the relationships between nickel exposure and dermal irritation. Kaaber et al. (1978, 1979) reported worsening of eczema following an oral challenge with 2.5 mg nickel. In the 1978 study, 17/28 subjects experienced aggravation of dermatitis following nickel ingestion. Nine of the 17 that experienced adverse effects from the nickel found that their condition improved when they adopted a low nickel diet. In the 1979 study 9/14 subjects responded negatively to nickel treatment.

Studies conducted by Gawrodger et al. (1986), Burrows et al. (1981) and Jordan and King (1979) offer different results. Jordan and King's double blind, placebo controlled investigation suggested that 0.5 mg supplement to a normal diet was safe with the possible exception of extremely sensitive individuals. Gawrodger et al. (1986) reported that 5/10 women responded to both the 0.4 and 2.5 mg doses of

Topic: NICKEL, SOLUBLE SALTS

nickel, but 10/26 also reacted to a placebo. They determined the LOAEL of their experiment to be 5.6 mg of nickel, a dose at which 100% of the women responded. Burrows et al. (1981) administered 0.5 mg nickel twice a day on two consecutive days to 22 patients, each of whom served as her own control. There was no significant difference between the number of individuals responding to a placebo as compared to nickel. However, the placebo response was high (12/22). The authors concluded that there is probably no connection between nickel in an ordinary diet and exacerbation of dermatitis but that a higher level may aggravate dermatitis in some individuals. Nielsen (1989) describes a study in which 12 nickel-sensitive women were challenged for a 4-day period with a diet providing 490 ug Ni/day. No changes were observed before the start of the nickel challenge to day 0 (start of challenge). On day 4, the eczema of 6 patients was considered to be worse according to both the patients' impressions and a dermatologist's evaluation. The delayed reaction in this study may be attributed to the fact that the dose of nickel was ingested in the diet throughout the day as opposed to studies which employed a bolus dose. This difference may greatly affect the pharmacokinetics of ingested nickel.

While the previous studies on humans with a hypersensitivity to nickel were considered in developing the RfD, none of them were adequate to serve as the basis for the quantitative risk assessment. The RfD is believed to be set at a level which would not cause individuals to become sensitized to nickel; however, those who have already developed a hypersensitivity (e.g., from a dermal exposure) may not be fully protected. One final point to bear in mind in establishing an RfD for nickel is that nickel has been shown to be an essential trace element for several animal species. Rats deprived of nickel exhibit retarded growth and low hemoglobin levels (Schnegg and Kirchgessner, 1977). A requirement for nickel has not been conclusively demonstrated in humans, but nickel is considered to be a normal constituent of the diet. Typical daily intake of nickel ranges from 100-300 ug/day.

I.A.5. CONFIDENCE IN THE ORAL RfD

Study: Low

Data Base: Medium

RfD: Medium

The chronic study (Ambrose et al., 1976) was properly designed and provided adequate toxicological endpoints; however, high mortality occurred in the controls (44/50). Therefore, a low confidence is recommended for the study. The data base provided adequate supporting subchronic studies, one by gavage and the other in drinking water (Po animals of the RTI subchronic study, 1986). A medium confidence level in the data base is recommended since there are inadequacies in the remaining reproduction data.

I.A.6. EPA DOCUMENTATION AND REVIEW OF THE ORAL RfD

U.S. EPA. 1986. Health Assessment Document for Nickel.

Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Research Triangle Park, NC. (Final Report). EPA/600/883/012FF.

IRIS

Topic: NICKEL, SOLUBLE SALTS

U.S. EPA. 1991. Quantification of Toxicologic Effects for Nickel. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH for the Office of Water, Office of Science and Technology, Washington, DC.

The information contained in this assessment was reviewed by the Science Advisory Board in August 1990.

Agency Work Group Review: 04/16/87, 05/20/87, 07/16/87, 05/17/90, 08/14/91

Verification Date: 07/16/87

I.A.7. EPA CONTACTS (ORAL RfD)

Sue Velazquez / ORD -- (513)569-7571 / FTS 684-7571

Jennifer Orme / OW -- (202)260-7586 / FTS 260-7586

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE
(RfC)

Substance Name -- Nickel, soluble salts

CASRN -- 7440-02-0

A risk assessment for this substance/agent is under review by an EPA work group.

=====

Topic: NICKEL, SOLUBLE SALTS

II. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Nickel, soluble salts

CASRN -- 7440-02-0

The U.S. EPA has not evaluated soluble salts of nickel, as a class of compounds, for potential human carcinogenicity.

However, nickel refinery dust and specific nickel compounds - nickel carbonyl and nickel subsulfide - have been evaluated.

Summaries of these evaluations are on IRIS.

=====

Topic: SILICON

0 RANGE OF TOXICITY

4.1 MINIMUM LETHAL EXPOSURE

- A. The minimum lethal human exposure to this agent has not been delineated.

4.2 MAXIMUM TOLERATED EXPOSURE

- A. The maximum tolerated human exposure to this agent has not been delineated.

4.3 WORKPLACE STANDARDS

- A. ACGIH-TLV: 10 mg/m(3) TWA (The value is for total dust containing no asbestos and less than 1% crystalline silica.) (ACGIH, 1992)
- B. OSHA PEL: Listed (OSHA, 1991)
 - 1. Silicon (Total dust)
 - a. Transitional Limit: 15 mg/m(3) PEL-TWA
 - (1) (The transitional PELs are 8-hour TWAs unless otherwise noted.)
 - b. Final Rule Limits: 10 mg/m(3) PEL-TWA; no PEL-STEL; no CEILING
 - (1) (The PEL-STEL Final Rule Limit duration is for 15 minutes, unless otherwise noted.)
Unless otherwise noted, employers in General Industry (ie, those covered by 29 CFR 1910) may use any combination of controls to achieve these limits until December 31, 1993 as set forth in 29 CFR 1910.1000(f)).
 - 2. Silicon (Respirable fraction)
 - a. Transitional Limit: 5 mg/m(3) PEL-TWA
 - (1) (The transitional PELs are 8-hour TWAs unless otherwise noted.)
 - b. Final Rule Limits: 5 mg/m(3) PEL-TWA; no PEL-STEL; no CEILING
 - (1) (The PEL-STEL Final Rule Limit duration is for 15 minutes, unless otherwise noted.)
Unless otherwise noted, employers in General Industry (ie, those covered by 29 CFR 1910) may use any combination of controls to achieve these limits until December 31, 1993 as set forth in 29 CFR 1910.1000(f)).
 - 3. Regulation: Table Z-1-A.-Limits for Air Contaminants in "Permissible Exposure Limits" - 29 CFR Part 1910.1000
The OSHA PELs contained herein may or may not be enforceable, based on the 11th Circuit Court of Appeals ruling of July 7, 1992.
Full-text available on CD-ROM in the Environmental/Safety Library from IHS - call 1-800-525-9083 or your TOMES Plus representative
- C. MSHA STANDARD-AIR: 10 mg/m(3) TWA (RTECS, 1993)
- D. IDLH VALUE: Not Listed (NIOSH, 1990)
- E. ODOR THRESHOLD: Not Listed (CHRIS, 1993)
- F. ENVIRONMENTAL STANDARDS
 - 1. SARA TITLE III
 - a. EHS (EXTREMELY HAZARDOUS SUBSTANCES) LIST: Not Listed (EPA, 1991a)
 - (1) Regulation: "Emergency Planning and Notification" - 40 CFR Part 355 (Appendices A and B)

TOMES(R) Hazard Management

Topic: SILICON

Full-text available on CD-ROM in the
Environmental/Safety Library from IHS - call
1-800-525-9083 or your TOMES Plus representative

- b. SECTION 313: Not Listed (EPA, 1991b)
 - (1) Regulation: "SARA Title III Section 313, Specific Toxic Chemical Listings" - 40 CFR Part 372
Full-text available on CD-ROM in the
Environmental/Safety Library from IHS - call
1-800-525-9083 or your TOMES Plus representative
- 2. CERCLA HAZARDOUS SUBSTANCES LIST: Not Listed (EPA, 1991)
 - a. Regulation: "Designation, Reportable Quantities, Notification" - 40 CFR 302
Full-text available on CD-ROM in the
Environmental/Safety Library from IHS - call
1-800-525-9083 or your TOMES Plus representative
- G. TSCA INVENTORY: Listed (RTECS, 1993)
- H. SHIPPING REGULATIONS
 - 1. SURFACE SHIPMENTS
 - a. DOT-HAZARD Classification (Lewis, 1992)
 - (1) DOT-HAZARD: Flammable solid
 - (2) Label: Flammable solid
 - b. The United States Department of Transportation has recently revised the Hazardous Materials Transport regulations in order to accommodate both North American and International regulations. Whenever hazardous materials are going to be transported, Title 49 CFR, Transportation, Parts 100 to 180 published by the US Dept of Transportation, contain the regulatory requirements and must be consulted (HSDB, 1993).
 - 2. AIR SHIPMENTS
 - a. INTERNATIONAL (IATA, 1991)
 - (1) UN 1346
 - (2) PROPER SHIPPING NAME: Silicon powder, amorphous
 - (3) CLASS OR DIVISION NUMBER: 4.1
 - (4) SUBSIDIARY RISK CLASS OR DIVISION NUMBER: Not listed
 - (5) PRIMARY HAZARD LABEL: Flammable solid
 - (6) SUBSIDIARY RISK HAZARD LABEL: Flammable solid
 - (7) UN PACKING GROUP NUMBER: III
 - (8) PASSENGER AIRCRAFT
 - (a) PACKING INSTRUCTION NUMBER: 419
 - (b) LIMITED QUANTITY PACKAGING INSTRUCTION NUMBER: Y419
 - (c) MAXIMUM NET QUANTITY PER PACKAGE: 25 kg
 - (d) LIMITED QUANTITY PACKAGING MAXIMUM NET QUANTITY PER PACKAGE: 10 kg
 - (9) CARGO AIRCRAFT
 - (a) PACKING INSTRUCTION NUMBER: 420
 - (b) LIMITED QUANTITY PACKAGING INSTRUCTION NUMBER: Not listed
 - (c) MAXIMUM NET QUANTITY PER PACKAGE: 100 kg
 - (d) LIMITED QUANTITY PACKAGING MAXIMUM NET QUANTITY PER PACKAGE: Not listed
 - b. DOMESTIC (HSDB, 1993)
 - (1) Not listed
 - 3. MARITIME SHIPMENTS

TOMES(R) Hazard Management

opic: SILICON

a. DOT-IMO Classification (RTECS, 1993)

(1) DOT-IMO HAZARD: Not listed

(2) Label: Not listed

.4 LD50/LC50

A. PUBLISHED VALUES (RTECS, 1993):

1. LD50 (ORAL) RAT: 3160 mg/kg

Topic: SILICON

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Pollution Sources

Natural Occurring Sources:

1. Silicon is present in the sun and stars and is a principal component of a class of meteorites known as aerolites. It is also a component of tektites, a natural glass of uncertain origin. ... Silicon is not found free in nature, but occurs chiefly as the oxide, & as silicates. Sand, quartz, rock crystal, amethyst, agate, flint, jasper, & opal are some of the /oxide/ forms. Granite, hornblende, asbestos, feldspar, clay, mica ... are but a few of the numerous silicate minerals. **QC REVIEWED** [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 67th ed. Boca Raton, FL: CRC Press, Inc., 1986-87., p. B-34
2. Silicon is important in plant and animal life. Diatoms in both fresh and salt water extract silica from the water to build up their cell walls. /Silica/ **QC REVIEWED** [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 67th ed. Boca Raton, FL: CRC Press, Inc., 1986-87., p. B-34
3. 3 NATURALLY OCCURRING ISOTOPES: 28 (92.18%); 29 (4.71%); 30 (3.12%) ... FOUND AS SILICA (... SANDSTONE) OR AS SILICATE (... ORTHOCLASE, KAOLINITE, ANORTHITE). CONSTITUTES ABOUT 27.6% OF EARTH'S CRUST; SECOND MOST ABUNDANT ELEMENT ON EARTH ... **QC REVIEWED** [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1220

Environmental Transport

Bioconcentration:

1. Conc'n of free silicic acid were measured in male, female, and ovigerous female shrimp (*Crangon crangon*) collected from the Dutch Wadden Sea at various stages of their ontogenetic development, considering differences in sex and responses to temperature and salinity. The shrimp, which ranged from 0.1 to 2.8 g in wt, were transferred to laboratory aquaria and were acclimated to 6 salinities ranging from 5 to 37 ppt at low temp (7-10 deg C) and high temp (16-20 deg C). Decr whole animal silicon levels in larger animals indicate that relatively high silicon conc'n are present in the exoskeleton. Higher silicon conc'n in males and ovigerous females must be ascribed to, respectively, a size effect and the presence of eggs (and a high silicon content of the egg shells). At higher temp internal silicon conc'n are incr. In response to environmental salinity the internal silicon conc'n are highest at normal sea-water salinities. The effects of temp and salinity clarify that in *Crangon crangon*, silicon is an essential element with distinct physiological functions. **QC REVIEWED** [Spaargaren DH; Comp Biochem Physiol (A) 93 (4): 667-71 (1989)

Topic: SILICON

EXPOSURE STANDARDS & REGULATIONS

Occupational Permissible Levels

Threshold Limit Values:

1. Time weighted average (TWA) 10 mg/cu m; the value is for total dust containing no asbestos & <1% free silica. (1986) **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 33]
2. Excursion Limit Recommendation: Excursions in worker exposure levels may exceed three times the TLV-TWA for no more than a total of 30 min during a work day and under no circumstances should they exceed five times the TLV-TWA, provided that the TLV-TWA is not exceeded. **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 5]

Other Standards and Regulations

CERCLA Reportable Quantities:

1. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 5,000 lb or 2270 kg. The toll free telephone number of the NRC is (800)424-8802; in the Washington metropolitan area (202) 426-2675. The rule for determining when notification is required is stated in 40 CFR 302.6 (see section IV. D.3.b). **QC REVIEWED** [50 FR 13456 (4/14/85)]

Topic: STRONTIUM

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Pollution Sources

Natural Occurring Sources:

1. STRONTIUM OCCURS IN NATURE IN CELESTITE (STRONTIUM SULFATE) /USE/ STRONTIANITE (STRONTIUM CARBONATE). IN EARTH'S CRUST ... TOTAL AMT ... /IS EST TO BE/ 430 G/TON; IN SEA WATER 10 PPM. /TOTAL STRONTIUM/ **PEER REVIEWED** [Browning, E. Toxicity of Industrial Metals. 2nd ed. New York: Appleton-Century-Crofts, 1969. 302
2. ... FOUND IN SMALL QUANTITIES ASSOCIATED WITH CALCIUM OR BARIUM MINERALS. /TOTAL STRONTIUM/ **PEER REVIEWED** [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1266

Artificial Sources:

1. Reactor releases of (90)Sr or from bomb tests. **PEER REVIEWED**

Environmental Concentrations

Sediment/Soil Concentrations:

1. World wide sampling of soils revealed strontium compd contents around 300 mg/kg. /Strontium/ **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 632

Atmospheric Concentrations:

1. A relatively high concn of strontium in air dust (600 ug/cu m) was reported. ... Metal fumes generated during welding of steel gave 3 ug strontium/cu m. **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 635

Human Exposure

Probable Exposures:

1. Metal fumes generated during welding of steel ... /Strontium/ **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 635

opic: STRONTIUM

CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Strontium

ASRN -- 7440-24-6

Last Revised -- 10/01/92

The Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Please refer to Background Document 1 in Service Code 5 for an elaboration of these concepts. RfDs can also be derived for the noncarcinogenic health effects of compounds which are also carcinogens. Therefore, it is essential to refer to other sources of information concerning the carcinogenicity of this substance. If the U.S. EPA has evaluated this substance for potential human carcinogenicity, a summary of that evaluation will be contained in Section II of this file when a review of that evaluation is completed.

I.A.1. ORAL RfD SUMMARY

See Table Document

I.A.2. PRINCIPAL AND SUPPORTING STUDIES (ORAL RfD)

Storey, E. 1961. Strontium "rickets": bone calcium and strontium changes. Austral. Ann. Med. 10: 213-222.

Marie, P.J., M.T. Garba, M. Hott and L. Miravet. 1985. Effect of low doses of stable Sr on bone metabolism in rats. Miner. Electrolyte Metab. 11: 5-13.

Skoryna, S.C. 1981. Effects of oral supplementation with stable strontium. Can. Med. Assoc. J. 125(7): 703-712.

Storey (1961) fed young (40-60 g) and adult (200-250 g) female rats (strain unspecified; 3/group) diets with adequate calcium (1.6%), phosphorous (0.9%) and vitamin D for 20 days. The dietary levels of strontium (as strontium carbonate) given to both adult and young rats were 0.19, 0.38, 0.75, 1.0 (young rats only), 1.5 and 3.0%. Assuming young rats consume 10% and adult rats consume 5% of their body weight in food per day, these doses correspond to 190, 380, 750, 1000, 1500 and 3000 mg/kg-day for young rats and 95, 190, 375, 750 and 1500 mg/kg-day for adult rats. Rats were examined for changes in bone mineralization and defects in cartilage. They were weighed at the onset and end of the experiment. Young rats were found to be affected more severely at lower dietary Sr levels than were adult rats. In young rats at 0.38% (380 mg/kg-day) the epiphyseal plate was irregular and slightly widened; however, at 0.75% (750 mg/kg-day) this plate was so irregular that measurements were unreliable. Changes observed with the dose of 0.38% and higher were inhibition of calcification, as evidenced by increasing width of epiphyseal cartilage, presence of uncalcified bone matrix and decreased ash weight of bone. In adults, the first obvious bone change occurred at the 1.5% dietary strontium level (750 mg/kg-day)

Topic: STRONTIUM

and included slightly wider than normal epiphyseal cartilage plate and metaphyseal osteoid seams, which were irregularly increased in extent and width. At the 3% strontium level in adult animals (1500 mg/kg-day), the cartilage plate was much larger. For young rats, the dietary level of 0.19% strontium (190 mg/kg-day) was a NOAEL and 0.38% strontium (380 mg/kg-day) was a LOAEL. For adult rats, the dietary level of 0.75% strontium (375 mg/kg-day) was a NOAEL and 1.5% strontium (750 mg/kg-day) was a LOAEL.

Marie et al. (1985) administered stable strontium to weanling male Sprague-Dawley rats. The purpose of this study was to determine the effect of low doses of stable strontium on mineral homeostasis and bone histology. Rats were divided into groups (8/group) receiving 0, 0.19, 0.27, 0.34 and 0.40% of SrCl₂ in distilled water for 9 weeks. The diet contained 0.5% calcium. Based on body weight and water consumption data, the authors estimated average strontium intakes of 0, 316, 425, 525 and 633 mg/kg-day. The authors concluded that an oral dose lower than 0.40% (633 mg/kg-day) did not produce adverse effects on body growth or on bone mineralization. Rats in the 0.40% (633 mg/kg-day) dose group showed signs of increased mineralization lag time; excessive osteoid thickness associated with a decline in the rate of calcification, which resulted in slow growth rate; and a decreased doublelabeled osteoid surface, which frequently resulted in defective long bone growth. This study identified a NOAEL of 525 mg/kg and a LOAEL of 633 mg/kg-day.

Skoryna (1981) investigated the oral toxicity of stable strontium in male adult RVH hooded rats. The rats (12/group, starting weight of 250 g) were fed ad libitum a standard laboratory diet and divided into four groups, which were administered 0.002, 900, 1900 or 3400 ppm strontium chloride (55% strontium) in their drinking water for 3 years. Assuming that an adult rat consumes water at a rate of 49 mL/day, the experimental doses correspond to 70, 147 and 263 mg/kg Sr/day. The control and experimental groups received adequate amounts of calcium (0.35 ppm) and magnesium (0.0682 ppm) in their drinking water. The animals were weighed and examined weekly. Histologic examinations of bone and observation of body weight changes in rats receiving strontium in drinking water revealed no abnormalities (Skoryna and Fuskova, 1981). The animal tissues from different organs (kidney, lungs, adrenal, brain, heart and muscle) were examined on gross and histologic levels. No evidence of changes in morphology was observed; organs were not weighed. The concentration of strontium in tissues was determined by heated graphite atomization. In addition, strontium levels in the animals' serum were analyzed by standard atomic absorption spectrophotometry. Except for bone, no organ predilection for strontium was observed in either group. A chronic NOAEL of 263 mg/kg-day was identified from this study.

I.A.3. UNCERTAINTY AND MODIFYING FACTORS (ORAL RfD)

UF -- The uncertainty factor of 300 includes 10 for species-to-species extrapolation and 10 for an incomplete data base (including a lack of developmental and reproductive data)

Topic: STRONTIUM

and to account for uncertainties in using data for strontium carbonate to derive a risk estimate that may apply to other salts of strontium. An uncertainty factor of 3 was applied for sensitive subpopulations; a factor of 10 was not warranted because the critical study was performed in young animals, a recognized sensitive subpopulation.

MF -- 1.

I.A.4. ADDITIONAL STUDIES / COMMENTS (ORAL RfD)

Pertinent data to derive an oral RfD based on the toxicity of stable strontium in humans were not located in the available literature. Estimates of dietary strontium intake range from 0.98-2.2 mg/day for adults, with milk providing about one-third of this (Snyder et al., 1975). Absorption of strontium from the gastrointestinal tract varies greatly, ranging from 9-63% (average of 38%) (Snyder et al., 1975). The bioavailability of strontium was estimated to be 20% in 6 healthy adult males administered 2.5 mmol of strontium chloride (Leeuwenkamp et al., 1990). Deficiency of dietary calcium leads to an increased absorption of strontium (Stokinger, 1981).

Use of strontium in the treatment of patients with osteoporosis has been reported. McCaslin and Janes (1959) reported treating 72 patients with daily doses of 1.7 g strontium (as strontium lactate) for periods ranging from 3 months to 3 years. Of the 32 patients who were available for follow-up, 84% experienced marked improvement. Assuming an average body weight of 70 kg, the supplementation to these patients was about 24 mg Sr/kg/day. Skoryna (1981) also reported subjective improvement in patients with osteoporosis receiving 274-1750 mg Sr/day as the gluconate, carbonate or lactate. No adverse side effects were reported in either study. Although these cases have been reported, strontium is not recognized as a standard therapy for osteoporosis (Krane, 1977).

Ingested strontium is distributed in the body in three compartments: plasma extracellular fluid; soft tissue and superficial zone of bone tissue; and bone itself (El Solh and Rousselet, 1981). The average adult is estimated to have a body burden of 320 mg strontium, 99% of which is in the bones (Snyder et al., 1975; Stokinger, 1981). The toxic effect of excessive strontium intakes is inhibition of calcification of epiphyseal cartilage and deformities of long bones at high doses. Strontium causes adverse effects on bone by substituting for calcium in the hydroxyapatite crystal during bone calcification or by displacing calcium from existing calcified matrix (Skoryna, 1984; Kshirsagar, 1985).

As opposed to calcium, which is under homeostatic regulation, strontium appears to be passively absorbed (Comar and Wasserman, 1964). However, several factors may affect the bioavailability of ingested strontium, for example, age and species, the form of strontium, and the composition of the diet, especially with regard to phosphorus, vitamin D and calcium levels. These factors are reviewed in U.S. EPA (1990, 1992).

The adequacy of calcium nutrition is a critical factor

Topic: STRONTIUM

regarding strontium toxicity; rachitic changes are exacerbated by inadequate calcium levels (El Solh and Rousselet, 1981). The effect of dietary calcium on strontium toxicity was also demonstrated by Engfeldt and Hjerquist (1969). Rachitic changes were observed in weanling Sprague-Dawley rats fed a diet containing 0.95% strontium (950 mg/kg-day) and "optimal" 0.69% calcium for 4 weeks. When dietary calcium was raised to 1.6%, no rachitic changes were seen at the same dose of strontium.

Because their bones are actively growing, young animals are more sensitive than adult animals to excessive strontium intakes. In addition to the information presented in the critical study (Storey, 1961), the greater sensitivity of young animals was also demonstrated by Storey (1962). Both young (50-70 g) and adult (200-250 g) rats of both sexes (strain not specified) were provided a diet containing 1.8% strontium as strontium carbonate. The exposure continued for up to 7 months with several interim sacrifices. After only 3 weeks of exposure, the young rats exhibited a "rachitic gait" with the most obvious changes occurring in the distal end of the femur and the proximal end of the tibia. The epiphyseal plate was reported to be "grossly widened" and the "metaphysis was a mass of soft white tissue." Conversely, it was 3 months before any change was observed in the adult rats, this being the appearance of fine traverse lines in the upper tibial metaphysis. The author goes on to portray significant differences in the effects seen in young animals vs. adults provided the same dietary concentration of strontium. Because young rats consume more food per kg body weight, it is difficult to ascertain how much more sensitive young animals would be at a dose adjusted on a mg/kg bw/day basis.

Relatively little information is available regarding the potential for developmental toxicity resulting from exposure to strontium. Pregnant female Wistar rats (3/group) were administered subcutaneous doses of 0, 25, 50, 100 or 200 mg/kg of strontium nitrate (10.3, 20.7, 41.4 or 82.8 mg Sr/kg/day, respectively) during gestational days 9-19 (Lansdown et al., 1972). No effects were seen on the size or body weight of fetuses, litter sizes or the number of resorption sites. Skeletons and zones of calcification were normal and no histologic changes were seen in soft tissues. Although this study reported no teratogenic effects of strontium, the small number of dams exposed and fetuses examined preclude a definite evaluation of the results.

In addition to the information available in rats, Marie and Hott (1986) studied the effects of strontium on weanling mice. Eleven male C57BL/6J mice were provided with drinking water containing 0.27% strontium chloride from 21 to 50 days of age. Another group of 13 untreated mice served as controls. The dose of strontium was based on the earlier study by Marie et al. (1985), which determined this level of strontium to be effective in stimulating bone formation without affecting bone mineralization in rats. In mice, no significant effects were observed in bone formation parameters except an increase in the osteoid surface and a decrease in the number of

IRIS

Topic: STRONTIUM

osteoclasts involved in bone resorption. No effect was seen on total calcified bone volume.

Skeletal abnormalities have also been observed in dogs administered oral doses of strontium (1-3 g strontium phosphate/day) in conjunction with low levels of dietary calcium (Lehnerdt, 1910). substitute for calcium in In addition to the effects exerted on bones, strontium can also physiologic processes such as heart and other skeletal muscle contraction, and ionic transport across red blood cell membranes and nerve cells (reviewed in U.S. EPA, 1990, 1992). However, these effects are reported following intravenous infusion of large doses of strontium, which is of questionable relevance to oral exposures.

Initially, the primary concern of most investigators was the retention and absorption of radioactive strontium from water and food sources. Radioactive strontium is generally used as a tracer element to evaluate toxicokinetic properties (absorption, distribution and excretion). The actual dose of radioactive strontium used for this purpose is frequently unreported. The kinetics of trace amounts of radioisotopes and of stable isotopes, which are usually administered in much higher quantities, may differ.

I.A.5. CONFIDENCE IN THE ORAL RfD

Study -- Medium

Data Base -- Medium

RfD -- Medium

Confidence in the critical studies is rated as medium because together they determine the critical effect and suggest a sensitive population but have difficulties with incomplete reporting of experimental details (e.g., number of animals, experimental protocol). The data base is rated as medium to low because although several studies exist to support these critical studies, they are all in one species and little information is available on reproductive or developmental effects. Also, little is known about the speciation of strontium (e.g., how the toxicity of SrCO₃ relates to other strontium compounds). The confidence in the RfD is medium, reflecting the confidence in the study and the data base.

I.A.6. EPA DOCUMENTATION AND REVIEW OF THE ORAL RfD

Source Document -- This assessment is not presented in any existing U.S. EPA document.

Other EPA Documentation -- U.S. EPA, 1990, 1992

Agency Work Group Review -- 07/18/91, 06/23/92

Verification Date -- 06/23/92

I.A.7. EPA CONTACTS (ORAL RfD)

Susan Velazquez / OHEA -- (513)569-7571

Eletha Brady-Roberts / OHEA -- (513)569-7662

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE

RfC)

Substance Name -- Strontium

CASRN -- 7440-24-6

Not available at this time.

IRIS

Topic: STRONTIUM

II. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Strontium

CASRN -- 7440-24-6

This substance/agent has not been evaluated by the U.S. EPA for evidence of human carcinogenic potential.

=====

Topic: PLUTONIUM

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Pollution Sources

Natural Occurring Sources:

1. Plutonium also exists in trace quantities in naturally occurring uranium ores. It is formed ... by irradiation of natural uranium with the neutrons which are present. ****PEER REVIEWED**** [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 69th ed. Boca Raton, FL: CRC Press Inc., 1988-1989., p. B-28
2. Technologically, (239)plutonium is the most important isotope. It is characterized by a high fission reaction cross-section and is abundant in irradiated natural uranium. /(239)Plutonium/ ****PEER REVIEWED**** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 18(82) 283
3. Occurrence in earth's crust: 10-22%. ****PEER REVIEWED**** [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1087

Environmental Concentrations

Effluents Concentrations:

1. Among the major effluents from the use and processing of nuclear fuel are ... plutonium. ... Of these, only tritium and plutonium can possibly enter water supplies. The predominant form of plutonium release from nuclear power and processing plants is as an aerosol that will have little or no impact on drinking water. Although a single incident has occurred in which as much as 18,750 Ci of plutonium were released from liquid storage on a local basis, none apparently reached off site water supplies. The usual rate of release from liquid storage at a controlled sites is about 1 mCi/yr. ****PEER REVIEWED**** [National Research Council. Drinking Water & Health Volume 1. Washington, DC: National Academy Press, 1977. 865

Atmospheric Concentrations:

1. On the basis of the measured and inferred plutonium concentration in the air of New York and a constant inhalation rate of 20 cu m/day, inhalation intake reflects the amt of radioactivity released by nuclear weapons tests. In 1960 ... the amt diminished & rose again in 1963 to a max of 450 mbecquerel following 1961-1962 /nuclear weapons tests/. ... declined regularly after the Test Ban Treaty of 1963 to a value of about 7 mbecquerel/yr during the period from 1972-1974. ****PEER REVIEWED**** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 726
2. At the end of 1973, it was estimated that 4.2 tons of (239)plutonium & (240) plutonium was dispersed in the atmosphere. This value should be compared to the est release of plutonium into the environment by the accident of the Chernobyl reactor. ... This release can be estimated to be in the maximum of 1 to 2% of the plutonium inside the reactor core, ie, 2.5-5 kg of (239)plutonium & (240)plutonium. /(239)Plutonium and (240)plutonium/ ****PEER**

Topic: PLUTONIUM

REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 720

Food Survey Results:

1. ... The levels of plutonium in food and in the environment are not significant as a radiation hazard, despite its being more toxic than radium as a potent carcinogen ...

PEER REVIEWED [Venugopal, B. and T.D. Luckey. Metal Toxicity in Mammals, 2. New York: Plenum Press, 1978. 169

Plant Concentrations:

1. Most of the plutonium found in field grown native plants & agricultural crops is due to surface contamination rather than soil plant transfer. Plutonium concn depends on plant species, on the type and age and status of vegetation; on the pH; cation exchange capacity; mineral and organic composition of the soil; and on the physical and chemical form of contamination; as well as its duration. The highest uptake of plutonium in cheat grass occurs, for example, when plutonium is present in the soil as the stable citrate complex or as a complex with macromolecules, like humic acid or fulvic acid. **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 721

Human Exposure

Probable Routes of Human Exposure:

1. Absorption through the skin can occur through occupational exposure. Experiments show that the skin is an effective barrier and the percentage absorbed /seldom/ exceeds 0.05% for intact skin. **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 724

Probable Exposures:

1. Contamination of food, water, hands, or careless handling are the main causes of radionuclide ingestion. /Radionuclides/ **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 811
2. In the USA, about 17,000 persons are estimated to have worked with plutonium since 1943-1944. In France, the number in 1986 was about 1000. **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 720

Body Burdens:

1. Since /plutonium/ was produced in 1940 ... the adult human probably has about 2 pCi plutonium in his total body. **PEER REVIEWED** [Venugopal, B. and T.D. Luckey. Metal Toxicity in Mammals, 2. New York: Plenum Press, 1978. 169

Topic: PLUTONIUM

EXPOSURE STANDARDS & REGULATIONS

Occupational Permissible Levels

Other Occupational Permissible Levels:

1. Maximum permissible concentration of (238)plutonium in air 7×10^{-13} u curie/cc; of (239)plutonium in air: 6×10^{-13} u curie/cc. **PEER REVIEWED** [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1087

Other Standards and Regulations

Atmospheric Standards:

1. Emissions of radionuclides /plutonium/ to the ambient air from a facility regulated /by the Nuclear Regulatory Commission/ shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr. **PEER REVIEWED** [54 FR 51697 (12/15/89

Soil Standards:

1. Within a few yr, deposited plutonium penetrates the soil and is no longer available for resuspension. ... /It has been/ calculated that in desert areas the maximum permissible concentration of plutonium in the soil is 100 bq/g ... **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 720

CERCLA Reportable Quantities:

1. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 1000 curie or 3.7×10^{13} becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(234)Plutonium/ **PEER REVIEWED** [54 FR 22524 (5/24/89)
2. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 1000 curie or 3.7×10^{13} becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(235)Plutonium/ **PEER REVIEWED** [54 FR 22524 (5/24/89)
3. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 0.1 curie or 3.7×10^9 becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(236)Plutonium/ **PEER REVIEWED** [54 FR 22524 (5/24/89)
4. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 1000 curie or 3.7×10^{13} becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(237)Plutonium/

- **PEER REVIEWED**** [54 FR 22524 (5/24/89)]
5. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 0.01 curie or 3.7×10^8 becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(238)Plutonium/
****PEER REVIEWED**** [54 FR 22524 (5/24/89)]
 6. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 0.01 curie or 3.7×10^8 becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(239)Plutonium/
****PEER REVIEWED**** [54 FR 22524 (5/24/89)]
 7. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 0.01 curie or 3.7×10^8 becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(240)Plutonium/
****PEER REVIEWED**** [54 FR 22524 (5/24/89)]
 8. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 1 curie or 3.7×10^{10} becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(241)Plutonium/
****PEER REVIEWED**** [54 FR 22524 (5/24/89)]
 9. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 0.01 curie or 3.7×10^8 becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(242)Plutonium/
****PEER REVIEWED**** [54 FR 22524 (5/24/89)]
 10. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 1000 curie or 3.7×10^{13} becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(243)Plutonium/
****PEER REVIEWED**** [54 FR 22524 (5/24/89)]
 11. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 0.01 curie or 3.7×10^8 becquerel. The toll free number of the NRC is (800) 424-8802; in the

Topic: PLUTONIUM

Washington D.C. area (202) 267-2675. /(244)Plutonium/
PEER REVIEWED [54 FR 22524 (5/24/89)]

12. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 100 curie or 3.7×10^{12} becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(245)Plutonium/
PEER REVIEWED [54 FR 22524 (5/24/89)]

Topic: THORIUM

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Pollution Sources

Natural Occurring Sources:

1. OCCURS IN MINERALS THORITE, THORIANITE, ORANGITE, YTTROCRASITE; IN MONAZITE SAND; PRESENT TO EXTENT OF ABOUT 15 PPM IN CRUST OF EARTH. **PEER REVIEWED** [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1343
2. Monazite is the most common and commercially important thorium bearing mineral with important deposits in India, Brazil, and Sri Lanka. Other extensive deposits occur in South Africa, the Soviet Union, Scandinavia, and Australia. **PEER REVIEWED** [Clayton, G. D. and F. E. Clayton (eds.). Patty's Industrial Hygiene and Toxicology: Volume 2A, 2B, 2C: Toxicology. 3rd ed. New York: John Wiley Sons, 1981-1982. 1931
3. LARGE DEPOSITS OF THORIUM MINERALS HAVE BEEN REPORTED IN NEW ENGLAND ... THORIUM THOUGHT TO BE ABOUT 3 TIMES AS ABUNDANT AS URANIUM AND ABOUT AS ABUNDANT AS LEAD OR MOLYBDENUM. ... THERE IS PROBABLY MORE ENERGY AVAILABLE FOR USE FROM THORIUM IN MINERALS OF EARTH CRUST THAN FROM BOTH URANIUM & FOSSIL FUELS. **PEER REVIEWED** [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 69th ed. Boca Raton, FL: CRC Press Inc., 1988-1989.,p. B-37

Environmental Concentrations

Water Concentrations:

1. The radiological impact of former mining activities in the Fen area in southern Norway was assessed. The area is known to have enhanced concn of thorium. ... Uranium and thorium analyses were performed on mine and lake water. The mining activity does not seem to have contaminated drinking water significantly. The tailings from Nb production has enriched radon and thorium concn. The tailings and the possible use of waste rock from the mining are probably the most important environmental results of the mining activities. **PEER REVIEWED** [Stranden E; Health Phys 48 (4): 415-20 (1985)

Sediment/Soil Concentrations:

1. The effect of airborne emissions of radionuclides from coal fired power plants on the environment was studied by measuring the concentrations of the radionuclides (232)thorium, (226)radium, (137)cesium and (40)potassium in soil samples from the local environment (0-15 km). No significant increase in concentrations was found in the area downwind of the plant as compared to the other sectors. Although these radionuclides were detected in the fly ash of the power plant, their amounts were apparently low compared with those naturally present in the soil. (137)Cesium in the soil from nuclear weapon testing does not exhibit a uniform spatial distribution, even though its deposition is fairly homogeneous with regard to the relatively small area of the site examined. The exposure rates found in the study areas in the two series of measurements were remarkably similar and were within the limits determined for Czechoslovakia as a whole. No

Topic: THORIUM

increased radioactivity was detected in the areas of brown coal burning power stations. **PEER REVIEWED** [Mejstrik V, Svacha J; Sci Total Environ 72 (0): 69-80 (1988)]

2. During a 3 to 4 yr period, concn of (238)uranium, (234)uranium, (230)thorium, (232)thorium and (228)thorium were determined in soils and native vegetables at various sites around a typical uranium mining and milling operation in Wyoming. Plant/soil concn ratios for uranium and thorium isotopes were estimated for (1) exposed, weather tailings, (2) the edge of a tailings impoundment, (3) an area downwind from exposed tailings, (4) a reclamation area and (5) several background, native range locations. The (238)uranium/(234)uranium concn ratio of 0.9 to 1.1 in soil and vegetation indicated near radioactive equilibrium of both radionuclides at all locations. Mean concn of the uranium and thorium isotopes in background soil ranged from 44 to 52 mBq/g. Concn of (238)uranium and (230)thorium in soil and vegetation were elevated above background at all sites disturbed by mining and milling activities. Uranium concn in tailing and invading vegetation were an order of magnitude greater than in the background locations, whereas (230)thorium concn were elevated above background by some two orders of magnitude. No demonstrable differences in radionuclide concn between plant groups and collected years were found. The observed concn ratios values for (238)uranium and (230)thorium of 0.81 and 0.69 for vegetation growing on exposed tailing were elevated above native range by factors of 9.0 and 3.6, respectively, and generally higher than other published values. Exceptionally high concn ratios values for (230)thorium (1.9-2.9) observed near the tailings impoundment demonstrate that under certain conditions, vegetation can accumulate (230)thorium to a much greater extent than previously reported. Vegetation concn were lower for (232)thorium relative to (230)thorium and (228)thorium at locations where they are present at similar soil concn. **PEER REVIEWED** [Ibrahim SA, Whicker FW; Health Phys 54 (4): 413-19 (1988)]

Other Environmental Concentrations:

1. Coal samples from Pennsylvania and Utah showed less than 0.006 ppm ... a USA cement sample showed 1.2 ppm thorium. **UNREVIEWED** [Clayton, G. D. and F. E. Clayton (eds.). Patty's Industrial Hygiene and Toxicology: Volume 2A, 2B, 2C: Toxicology. 3rd ed. New York: John Wiley Sons, 1981-1982. 1936]

Human Exposure

Probable Routes of Human Exposure:

1. Because thorium is ubiquitous, daily exposure to this element is constant & was estimated by the International Commission on Radiological Protection (ICRP) at 3 ug. The thorium isotope ratio may change from one population to another due to the different sources of contamination and to differences between the mode of absorption. One mode is by inhalation of soil or ores. ... The other mode of entry is via by food & fluids ... **PEER REVIEWED** [Seiler,

Topic: THORIUM

- H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 690
2. ... Percutaneous absorption. /From table/ **PEER REVIEWED** [Fuscaldo, A., B. J. Erlick, and B. Hindman. (eds.). Laboratory Safety-Theory and Practice. New York: Academic Press, 1980. 267
 3. Thorium intake by an urban group (Bombay) has been estimated using neutron activation followed by simple chemical separation. Daily intake of thorium via all the three sources: food, water and air, is reported. The major contributions of thorium to intake is through food (2.0 ug), followed by water (0.02 ug) and air (0.02 ug). The individual food ingredients such as cereals, pulses, vegetables, milk, etc were also analysed for their thorium content. The cereals were found to contribute most to the daily intake. **PEER REVIEWED** [Dang HS et al; Sci Total Environ 57 (0): 73-78 (1986)

Average Daily Intake:

1. The daily intake of long lived alpha emitting members of the uranium, thorium, and actinium series by New York City residents has been estimated from measurements of diet, water, and air samples. The total daily intakes from inhalation, food, and water consumption in mBq are 18 (234)uranium, 0.7 (235)uranium, 16 (238)uranium, 6 (230)thorium, 4 (232)thorium and 52 (226)radium. From this, it is inferred that the total daily intakes of (228)thorium, and (228)radium are 4 and 35 mBq, respectively. **PEER REVIEWED** [Fisenne IM et al; Health Phys 53 (4): 357-64 (1987)

Probable Exposures:

1. IN MANTLE CUTTING OR MANTLE TRIMMING OPERATIONS & ESP IN RECLAIMING OPERATIONS THERE IS, BESIDES POTENTIAL EXPOSURE TO THORON GAS, POSSIBLY MORE SERIOUS EXPOSURE TO THORIUM BEARING DUSTS. **UNREVIEWED** [Patty, F. (ed.). Industrial Hygiene and Toxicology: Volume II: Toxicology. 2nd ed. New York: Interscience Publishers, 1963. 2279
2. PRINCIPAL HAZARDS FROM THORIUM IN INDUSTRY ARE INHALATION OF THORIUM DUST & OF THORON GAS & ITS DECAY PRODUCTS, & EXPOSURE TO EXTERNAL BETA & GAMMA RADIATION. INHALATION HAZARD IS GREATEST IN DUSTY OPERATIONS SUCH AS GRINDING OF METALS, CERAMICS, HANDLING OF THORIUM POWDER, & CONTAMINATION FROM THORIUM FIRES. **PEER REVIEWED** [Hamilton, A., and H. L. Hardy. Industrial Toxicology. 3rd ed. Acton, Mass.: Publishing Sciences Group, Inc., 1974. 398
3. 273 men were exposed to thorium and other rare earths between 1940 and 1973 at a monazite sand refinery. **UNREVIEWED** [Conibear SA; Health Phys 44 suppl 1: 231-7 (1983)
4. Because thorium is ubiquitous, daily exposure to this element is constant & was estimated by the International Commission on Radiological Protection (ICRP) at 3 ug. **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds.

Topic: THORIUM

New York, NY: Marcel Dekker, Inc. 1988. 690

5. Industrial exposures from stable, nonradioactive thorium occur during handling of various thorium salts in fabrication of thorium ingots from nitrate, in handling thorium salts in various industrial uses, in fume from welding with thoriated tungsten electrodes, in casting & machining of thorium alloy parts, and from fires and explosions from thorium metal powder. /Thorium & compd/ **PEER REVIEWED** [Clayton, G. D. and F. E. Clayton (eds.). Patty's Industrial Hygiene and Toxicology: Volume 2A, 2B, 2C: Toxicology. 3rd ed. New York: John Wiley Sons, 1981-1982. 1933
6. In the production and use of thorium and its compounds, workers may be exposed to ionizing radiation from thorium and its disintegration products such as gas and thoron. /Thorium and compounds/ **PEER REVIEWED** [International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983. 2174
7. Dose estimates are given for internal and external exposure that result, due to radioactive thorium, from the use of the incandescrnt mantles for gas lanterns. The collective, effective dose equivalent for all users of gas mantles is estimated to be about 100 Sv per annum in the Netherlands. For the population involved (ca 700,000 persons) this is roughly equivalent to 5% to 10% of the collective dose equivalent associated with exposure to radiation from natural sources. The major contribution to dose estimates comes from inhalation of radium during burning of the mantles. A pessimistic approach results in individual dose estimates for inhalation of up to 0.2 mSv. **PEER REVIEWED** [Huyskens CJ et al; Sci Total Environ 45: 157-64 (1985)

Body Burdens:

1. 273 men exposed to thorium and other rare earths between 1940 and 1973 at a monazite sand refinery were studied at Argonne National Laboratory from 1976 to 1980. In vivo measurements of body burden were made by counting gamma rays emitted by daughter products of retained thorium and by measuring exhaled thoron. Health status was ascertained through questionnaire, physical exam, and clinical lab tests. Measured body burden was found to be higher in those with a history of longer exposure. All parameters of the complete blood count were examined for evidence of an effect due to thorium. Comparisons of high and low body burden groups showed that only age and cigarette smoking had an effect on complete blood count parameters. **PEER REVIEWED** [Conibear SA; Health Phys 44 Suppl 1: 231-7 (1983)
2. The content of the lung of a male and female resident in the USA in 1975 was 0.12 and 0.20 ppm, respectively; that of the pulmonary lymph node, 0.30 ppm. A freeze dried preparation of a coal miner's lung showed 2.0 ppm. /Total thorium/ **PEER REVIEWED** [Clayton, G. D. and F. E. Clayton (eds.). Patty's Industrial Hygiene and Toxicology:

Topic: THORIUM

Volume 2A, 2B, 2C: Toxicology. 3rd ed. New York: John Wiley Sons, 1981-1982. 1936

3. Determination of the alpha activity of human soft tissues, mainly from the USA and Great Britain, lung, liver, kidney, spleen, muscle, and hair, have been reported to contain about 7 pCi/kg wet tissue for most, although values ranged from as low as 2 pCi/kg in brain to 33 pCi/kg in hair, to which the (232)thorium series is considered to contribute less than 50%. Bone analyses from many sources tend to have an alpha radioactivity 20 times that of soft tissues. /Total thorium/ **PEER REVIEWED** [Clayton, G. D. and F. E. Clayton (eds.). Patty's Industrial Hygiene and Toxicology: Volume 2A, 2B, 2C: Toxicology. 3rd ed. New York: John Wiley Sons, 1981-1982. 1936
4. ... ITS CONCN IN HUMAN SKELETON IS ABOUT 1 FEMTOCURIE/G OF ASH... . /TOTAL THORIUM/ **PEER REVIEWED** [National Research Council. Drinking Water & Health Volume 1. Washington, DC: National Academy Press, 1977. 860

opic: THORIUM

EXPOSURE STANDARDS & REGULATIONS

Occupational Permissible Levels

Other Occupational Permissible Levels:

1. In the eastern block countries ... the threshold limit for thorium has been set at 0.05 mg/cu m in workroom air. /Thorium and compd/ **PEER REVIEWED** [Seiler, H.G., H. Sigel and A. Sigel (eds.). Handbook on the Toxicity of Inorganic Compounds. New York, NY: Marcel Dekker, Inc. 1988. 692

Other Standards and Regulations

Water Standards:

1. ... The following standards have been set for thorium (Th) by various groups: 1. International commission on Radiological Protection (ICRP)--0.5 g/l sol (232)Th; 0.5 to 9 g/l for insol compd. 2. Council for Mutual Economic Aid--4 mg/l for (232)Th; 2.7 mg/l for natural thorium. 3. Sanitary Regulations (USSR)--0.1 mg/l for both (232)Th & natural thorium, based on consumption of 2.2 l of water/day & skeleton as the critical organ. /Thorium & compd/ **PEER REVIEWED** [National Research Council. Drinking Water and Health. Volume 3. Washington, DC: National Academy Press, 1980. 144

CERCLA Reportable Quantities:

1. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 0.001 curie or 3.7×10^7 becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. **PEER REVIEWED** [54 FR 22524 (5/24/89)

Topic: TRITIUM

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Pollution Sources

Natural Occurring Sources:

1. Currently, the tritium present in the environment /from natural sources/ ... estimated to be about ... 10 to 1×10^2 megacuries **PEER REVIEWED** [Doull, J., C.D.Klassen, and M.D. Amdur (eds.). Casarett and Doull's Toxicology. 3rd ed., New York: Macmillan Co., Inc., 1986. 697
2. The principal source of natural tritium is the nuclear reactions induced by cosmic radiation in the upper atmosphere, where fast neutrons, protons, and deuterons collide with components of the stratosphere to produce tritium Tritium has also been observed in meteorites **PEER REVIEWED** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 7(79) 558
3. In 1958 the world's inventory of natural tritium was estimated to be 20 kg in rainwater and 200 g in atmospheric hydrogen. **PEER REVIEWED** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 7(79) 558
4. ... Significant amt of tritium from the sun's surface are believed to be brought to the earth by solar wind and flare emissions. This tritium is rapidly incorporated into water molecules and mixed into the water of the atmosphere, hydrosphere, and biosphere. **PEER REVIEWED** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 19(82) 667

Artificial Sources:

1. ... Present in effluents from nuclear reactors and weapons. Currently, the tritium present in the environment and the relative contribution of the sources have been estimated to be about 0.5 to 1 megacurie from nuclear reactors ... and about 1×10^3 megacuries from nuclear explosions. **PEER REVIEWED** [Doull, J., C.D.Klassen, and M.D. Amdur (eds.). Casarett and Doull's Toxicology. 3rd ed., New York: Macmillan Co., Inc., 1986. 697
2. Bomb produced tritium still exceeds natural tritium in the environment **PEER REVIEWED** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 19(82) 668

Environmental Concentrations

Water Concentrations:

1. In the prenuclear age, tritium content of rainwater ranged from < 1 to > 100 TUs (Tritium Units), depending mainly on the time between evaporation from seawater and precipitation of the water mass. Continental river water and biosphere hydrogen typically contained several TUs. The well mixed surface layer of the oceans generally had a few tenths of a TU, and the deep sea waters had undetectable levels. At the height of bomb testing in

opic: TRITIUM

1963, the tritium content of rainwater attained a maximum of about 1×10^4 TUs in the northern hemisphere and about a tenth as high in the southern hemisphere. The content of surface seawater increased to about 5-20 TU. /TU= Tritium Unit= 1 (^3H atom/ 1×10^{18} H atoms, corresponding to a specific radioactivity in water of about 199 mBq/kg (7.1 dpm/kg)/ **PEER REVIEWED** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984.,p. 19(82) 667

Atmospheric Concentrations:

1. Under normal conditions the total atmospheric content of molecular T_2 gas is only 11 g. **PEER REVIEWED** [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1394
2. The level of tritium in atmospheric hydrogen increased from 3800 TU in 1948-9 to 490000 TU in 1959. /TU (Tritium Unit) signifies a ratio of 1 atom of tritium per 1×10^{18} atoms of hydrogen/ **PEER REVIEWED** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984.,p. 7(79) 558

Topic: TRITIUM

EXPOSURE STANDARDS & REGULATIONS

Occupational Permissible Levels

Other Occupational Permissible Levels:

1. International Commission on Radiological Protection: MPC (maximum permissible concn), 185 kBq/ml (5 uCi/ml) in breathing air (continuous exposure for 40 hr/wk); maximum permitted body burden, 37 MBq (1 mCi). **PEER REVIEWED** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984., p. 7(79) 561

Other Standards and Regulations

CERCLA Reportable Quantities:

1. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 100 curie or 3.7×10^{12} becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. **PEER REVIEWED** [54 FR 22524 (5/24/89)]

Topic: URANIUM

generally higher than that in the earth's crust-on the avg 3 ug/g. **PEER REVIEWED** [Wrenn ME et al; The Potential Toxicity of Uranium in Water p.177 (1987) EPA-600/J-87/096

Artificial Sources:

1. Depleted uranium is a by product of the uranium enrichment process during which natural uranium is enriched by increasing the percentage of the (235U)uranium isotope. **PEER REVIEWED** [Department of the Army; Technical Bulletin on Depleted Uranium TB 9-1300-278 p.1 (1987)]

Environmental Fate

Environmental Fate:

1. Uranium ... has a complex radioactive decay scheme resulting in the emission of different radiations and the production of several radioactive daughter products. **PEER REVIEWED** [National Research Council. Drinking Water & Health. Volume 5. Washington, D.C.: National Academy Press, 1983. 90]
2. AQUATIC FATE: Uranium, thorium, radium, radon, lead, and polonium radionuclide concentrations in ground waters from the Hanford Site indicate that uranium, thorium, and radium are highly sorbed. Relative to radon, these radionuclides are low by factors of 1×10^{-3} to 1×10^{-6} . Uranium sorption is likely due to its reduction from the hexavalent state, where it is introduced via surface waters, to the tetravalent state found in the confined aquifers. The distribution of radionuclides is very similar in all of the confined aquifers and significantly different from the distribution observed in the unconfined and surface waters. Barium correlates well with radium over three orders of magnitude, indicating that stable element analogs may be useful for inferring the behavior of radioactive waste radionuclides in this candidate geologic repository. **PEER REVIEWED** [Smith MR et al; Materials Research Society Proceedings p.10 (1987)]

Environmental Concentrations

Sediment/Soil Concentrations:

1. Natural uranium is present in soils & rocks in concn generally varying between 0.5 & 5 ppm. The avg is approx 1.8 ppm in most soils. **PEER REVIEWED** [National Research Council. Drinking Water & Health. Volume 5. Washington, D.C.: National Academy Press, 1983. 91]

Atmospheric Concentrations:

1. Uranium concentrations in air up to several 100 ug/cu m have been reported for some occupational conditions. **PEER REVIEWED** [Friberg, L., Nordberg, G.F., Kessler, E. and Vouk, V.B. (eds). Handbook of the Toxicology of Metals. 2nd ed. Vols I, II.: Amsterdam: Elsevier Science Publishers B.V., 1986.,p. V2 623]

Human Exposure

Probable Routes of Human Exposure:

1. ... /URANIUM MINING/ HAS NOT BEEN ASSOCIATED WITH MEASURABLE INCREASES IN ENVIRONMENTAL RADIOACTIVITY OUTSIDE IMMEDIATE VICINITY OF MINES. ... FOR URANIUM MILLS & FUEL FABRICATION PLANTS ... PROPER LOCATION & APPROPRIATE CONTROL OF TAILINGS & LIQUID WASTES CAN

Topic: URANIUM

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Pollution Sources

Natural Occurring Sources:

1. URANIUM IS WIDELY DISTRIBUTED IN NATURE & ACCOUNTS FOR 3 TO 4X10⁻⁴% OF EARTH CRUST /2X10⁻⁵%/. IT IS PRESENT IN A VARIETY OF MINERALS & IS ALSO ENCOUNTERED IN SEA WATER. ... CHIEF NATURAL SOURCES ARE HYDROTHERMAL VEINS IN SAXONY, ZAIRE, & CANADA; SEDIMENTARY ROCKS IN COLORADO, UTAH & NEW MEXICO; & PYRITIC CONGLOMERATE BEDS OF PRECAMBRIAN AGE IN WITWATERSTRAND & ONTARIO. **PEER REVIEWED** [International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983. 2237
2. Uranium is an important constituent of about 155 minerals; in another 60 minerals, it is a minor constituent or an impurity. **PEER REVIEWED** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984.,p. 23(83) 505
3. IT OCCURS IN NUMEROUS MINERALS SUCH AS ... URANITE ... AUTUNITE, URANOPHANE, DAVIDITE & TOBERNITE. IT IS ALSO FOUND IN PHOSPHATE ROCK, LIGNITE, /&/ MONAZITE SANDS. ... **PEER REVIEWED** [Weast, R.C. (ed.) Handbook of Chemistry and Physics. 69th ed. Boca Raton, FL: CRC Press Inc., 1988-1989.,p. B-39
4. Selected uranium minerals: Euxenite, polycrase, fergusonite, samarskite, pyrochlore, microlite, brannerite, tyuyamunite, coffinite, thucholite. /From table/ **PEER REVIEWED** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984.,p. 23(83) 507
5. PITCHBLLENDE FOUND IN COLORADO, UTAH, BEAR LAKE IN CANADA, ZAIRE, JOACHIMSTAHL IN CZECHOSLOVAKIA, CORNWALL. **PEER REVIEWED** [The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 1409
6. ... Carnotite /a mineral containing uranium occurs in/ Colorado, New Mexico, France, South Africa, Australia, USSR. **PEER REVIEWED** [Sax, N.I. and R.J. Lewis, Sr. (eds.). Hawley's Condensed Chemical Dictionary. 11th ed. New York: Van Nostrand Reinhold Co., 1987. 1207
7. Uranium content of: Igneous rocks, 0.008 wt%; and ore deposits, 0.1 - 0.9 wt% **PEER REVIEWED** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984.,p. 9(80) 742
8. Acidic rocks with a high silicate content, ie, granite, have a uranium content above average. ... **PEER REVIEWED** [Kirk-Othmer Encyclopedia of Chemical Technology. 3rd ed., Volumes 1-26. New York, NY: John Wiley and Sons, 1978-1984.,p. 23(83) 504
9. ... ESTIMATED THAT THE AVERAGE ... URANIUM CONTENT OF THE TOP 30 CM OF SOIL /IS/ ... 2.3 TONS/SQ KM. **PEER REVIEWED** [International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983. 57
10. The uranium content of rocks varies widely but is

opic: URANIUM

PREVENT SIGNIFICANT POPULATION EXPOSURES. ... **PEER REVIEWED** [Doull, J., C.D.Klassen, and M.D. Amdur (eds.). Casarett and Doull's Toxicology. 3rd ed., New York: Macmillan Co., Inc., 1986. 675

2. Inhalation, skin & eye contact, lung. /Uranium, sol or insol cmpd (as uranium)/ **PEER REVIEWED** [NIOSH. Pocket Guide to Chemical Hazards. 2nd Printing. DHHS (NIOSH) Publ. No. 85-114. Washington, D.C.: U.S. Dept. of Health and Human Services, NIOSH/Supt.of Documents, GPO, February 1987. 235

Average Daily Intake:

1. The United Nations (1977) estimated that the daily adult intake via inhalation is approx 1×10^{-3} pCi. **PEER REVIEWED** [National Research Council. Drinking Water & Health. Volume 5. Washington, D.C.: National Academy Press, 1983. 91
2. The avg daily dietary intake of uranium by man is 1 to 1.5 ug. ... /Total uranium/ **PEER REVIEWED** [Venugopal, B. and T.D. Luckey. Metal Toxicity in Mammals, 2. New York: Plenum Press, 1978. 162
3. The United Nations (1971) estimated ... daily adult intake via inhalation is approx 1×10^{-5} pCi. /Total uranium/ **PEER REVIEWED** [National Research Council. Drinking Water & Health. Volume 5. Washington, D.C.: National Academy Press, 1983. 91

Probable Exposures:

1. AN OCCUPATIONAL EXPOSURE PROBLEM OF SUBSTANTIAL MAGNITUDE ... INVOLVES MINERS WHO WORK UNDERGROUND IN URANIUM MINES. ... **PEER REVIEWED** [Doull, J., C.D.Klassen, and M.D. Amdur (eds.). Casarett and Doull's Toxicology. 3rd ed., New York: Macmillan Co., Inc., 1986. 696
2. Hazards from the production of uranium metal briquettes or in the hot-rolling of uranium rods are relatively small. **PEER REVIEWED** [Clayton, G. D. and F. E. Clayton (eds.). Patty's Industrial Hygiene and Toxicology: Volume 2A, 2B, 2C: Toxicology. 3rd ed. New York: John Wiley Sons, 1981-1982. 1997
3. Exposures of majority of the uranium plant workers were to dust of uranium feed materials to the intermediates, to uranium metal. ... **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, 1986. 617
4. The isotope most dangerous from the point of view of radiation, (235)uranium, comprises less than 1% of natural uranium, but is enriched during the production of nuclear fuels. Higher fractions of (235)uranium increase the irradiation risk. **PEER REVIEWED** [Friberg, L., Nordberg, G.F., Kessler, E. and Vouk, V.B. (eds). Handbook of the Toxicology of Metals. 2nd ed. Vols I, II.: Amsterdam: Elsevier Science Publishers B.V., 1986., p. V2 632
5. The following list includes some common operations in which exposure to uranium or insol cmpd may occur ...

Topic: URANIUM

liberation from mining, grinding, & milling of ores; use of insol cmpd as chemical intermediates in prepn of uranium cmpd; use for nuclear technology; use in nuclear reactors as fuel & to pack nuclear fuel rods; liberation from burning of uranium metal chips & smelting operations; use in ceramics industry for pigments, coloring porcelain, & enamelling; use as catalysts for many reactions; in production of fluorescent glass. /Uranium and insol uranium cmpd as uranium/ **PEER REVIEWED** [Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) PublicationNo. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981. 4

6. OCCUPATIONAL EXPOSURE TO URANIUM USUALLY INVOLVES MIXTURES OF DIFFERENT URANIUM CMPD WITH SOLUBILITES IN WATER AT ROOM TEMP RANGING FROM 1 TO 400,000 MG U/L. DUST PARTICLES CONTAINING URANIUM MAY BE OF VARYING SIZES & DENSITIES. /TOTAL URANIUM/ **PEER REVIEWED** [Friberg, L., Nordberg, G.F., Kessler, E. and Vouk, V.B. (eds). Handbook of the Toxicology of Metals. 2nd ed. Vols I, II.: Amsterdam: Elsevier Science Publishers B.V., 1986.,p. V2 627

Body Burdens:

1. The uranium content of human tissues obtained at autopsy ... reviewed, and est were made of uranium in human bone and soft tissues. The range of natural uranium in the human skeleton (2-62 ug) is attributed to geographic variation and to analytical and sampling uncertainties. Uranium in the skeleton is believed to be roughly in equilibrium with intake. **PEER REVIEWED** [Wrenn ME et al; The Potential Toxicity of Uranium in Water p.178 (1987) EPA-600/J-87/096
2. The natural uranium content of an adult human kidney is approx 0.1 ug or approx 0.004 ug/g kidney tissue. **PEER REVIEWED** [Wrenn ME et al; The Potential Toxicity of Uranium in Water p.178 (1987) EPA-600/J-87/096
3. Careful measurements of uranium concn in human bones from Nepal and Australia /were made/. /The researchers/ calculated the annual alpha doses to bone from (238)uranium to be 0.039 mrad for the Nepalese and 0.009 mrad for the Australians. Such wide variations are not unexpected because of the known geographic differences in uranium concn in human bone. /(238)uranium/ **PEER REVIEWED** [Voegtlin C, Hodge HC (eds); Pharmacology and Toxicology of Uranium Compounds p.VI-8 (1953)
4. UNDER STEADY-STATE CONDITIONS IN OCCUPATIONALLY EXPOSED SUBJECTS, 85% OF THE BODY BURDEN OF URANIUM WAS FOUND IN BONE PROVIDED THAT URANIUM DEPOSITED IN THE LUNG IS EXCLUDED. MORE THAN 90% OF THE REMAINING URANIUM WAS IN THE KIDNEY, & DETECTABLE AMT COULD BE FOUND IN LIVER. /TOTAL URANIUM/ **PEER REVIEWED** [Friberg, L., Nordberg, G.F., Kessler, E. and Vouk, V.B. (eds). Handbook of the Toxicology of Metals. 2nd ed. Vols I, II.: Amsterdam: Elsevier Science Publishers B.V., 1986.,p. V2 629
5. Human body burden: Uranium 0.02 mg/70 kg. /From table;

Topic: URANIUM

EXPOSURE STANDARDS & REGULATIONS

Standards & Regulations

Immediately Dangerous to Life or Death:

1. NIOSH has recommended that uranium (insoluble compounds as U) be treated as a potential human carcinogen. **QC REVIEWED** [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 168

Acceptable Daily Intake:

1. Because there is no evidence that naturally occurring (238)uranium is carcinogenic, a chronic exposure SNARL (Suggested No Adverse Response Level) will be calculated. ... Using an uncertainty factor of 100, and assuming that a 70 kg adult consumes 2 l of water daily & that 10% of the uranium intake is provided by the water, one may calculate a chronic SNARL as ... 0.035 mg/l, or 35 ug/l. **PEER REVIEWED** [National Research Council. Drinking Water & Health. Volume 5. Washington, D.C.: National Academy Press, 1983. 96

Occupational Permissible Levels

OSHA Standards:

1. 8 hr Time-Weighted avg: 0.25 mg/cu m. /Uranium, insol compd/ **PEER REVIEWED** [29 CFR 1910.1000 (7/1/88)
2. Meets criteria for OSHA medical records rule. **PEER REVIEWED** [29 CFR 1910.20 (7/1/88)

Threshold Limit Values:

1. Time Weighted Avg (TWA) 0.2 mg/cu m; Short Term Exposure Limit (STEL) 0.6 mg/cu m (1976) /Uranium (natural) soluble & insoluble compounds, as U/ **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 37

Other Occupational Permissible Levels:

1. Maximum Allowable Concn (MAC) USSR 0.015 mg/cu m (soluble compd), 0.075 mg/cu m (insoluble compd) /Uranium compd/ **PEER REVIEWED** [International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983. 2237

Other Standards and Regulations

Atmospheric Standards:

1. The provisions of the national emission standard for (222)radon emissions from underground uranium mines are applicable to an owner or operator of an active underground uranium mine which has mined or will mine over 100,000 tons of ore during the life of the mine; or has had or will have an annual ore production greater than 10,000 tons, unless it can be demonstrated that the mine will not exceed a total ore production of 100,000 tons during the life of the mine as per 40 CFR 61.20. /Uranium ores/ **PEER REVIEWED** [40 CFR 61.20 (7/1/88)
2. Radionuclides have been designated as a hazardous air pollutants under section 112 of the Clean Air Act. /Radionuclides/ **PEER REVIEWED** [40 CFR 61.01 (7/1/88)

Topic: URANIUM

uranium/ **PEER REVIEWED** [Doull, J., C.D. Klaassen, and M. D. Amdur (eds.). Casarett and Doull's Toxicology. 2nd ed. New York: Macmillan Publishing Co., 1980. 410

Topic: URANIUM, NATURAL

CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Uranium, natural

CASRN -- 7440-61-1

Not available at this time.

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE (RfC)

Substance Name -- Uranium, natural.

CASRN -- 7440-61-1

Not available at this time.

=====

Topic: URANIUM

CERCLA Reportable Quantities:

1. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 0.1 curie or 3.7×10^9 becquerel. The toll free number of the NRC is (800) 424-8802; in the Washington D.C. area (202) 267-2675. /(238)Uranium/ **PEER REVIEWED** [54 FR 22524 (5/24/89)]

Topic: CARBON TETRACHLORIDE

5.0 RANGE OF TOXICITY

6.1 EFFECTIVE DOSE

6.1.1 ADULT

A. When formerly used as an anthelmintic, the recommended adult dose of carbon tetrachloride was 2 to 3 milliliters in capsules (von Oettingen, 1964).

6.1.2 PEDIATRIC

A. The formerly recommended pediatric anthelmintic dose of carbon tetrachloride was 0.13 milliliter/year of age up to 15 years to be followed with Epsom salts (von Oettingen, 1964).

6.2 MINIMUM LETHAL EXPOSURE

A. Carbon tetrachloride has caused deaths after the ingestion of as little as 3 to 5 milliliters. Deaths have occurred as soon as 8 hours after an ingestion (von Oettingen, 1964).

B. The lowest published lethal concentration for a human was 1,000 parts per million or 50,000 parts per million/5 minutes (RTECS, 1988).

C. The lowest published lethal dose in humans was 93 milligrams/kilogram by unknown route (RTECS, 1988).

D. The lowest published lethal dose in humans was 43 milligrams/kilogram by the oral route (RTECS, 1988).

E. The lowest published oral lethal dose in dogs was 1 gram/kilogram (RTECS, 1988).

F. The lowest published lethal inhalation dose in dogs was 14,620 parts per million for 8 hours (RTECS, 1988).

G. The lowest published intravenous lethal dose in dogs was 125 milligrams/kilogram (RTECS, 1988).

H. The lowest published lethal inhalation concentration in cats was 38,110 parts per million for 2 hours (RTECS, 1988).

I. The lowest published lethal inhalation concentration in guinea pigs was 20,000 parts per million for 2 hours (RTECS, 1988).

J. The lowest published lethal inhalation concentration in frogs was 58,000 milligrams/cubic meter (RTECS, 1988).

6.3 MAXIMUM TOLERATED EXPOSURE

A. The toxicity on inhalation is related to the concentration in the air and duration of exposure. Symptoms have been seen after a 30 minute exposure to 160 parts per million concentration in air.

B. Depends on many variables, but may be as low as 3 milliliters by ingestion.

C. The lowest published toxic concentration for inhalation in humans was 20 parts per million (RTECS, 1988).

D. The lowest published toxic oral doses in humans were 1,700 to 1,800 milligrams/kilogram (RTECS, 1988).

E. The lowest published toxic concentration for inhalation in humans was 45 parts per million for 3 days or 317 parts per million for 30 minutes (RTECS, 1988).

F. Rats were given CCl₄ by gavage 5 times per week for 12 weeks. 1 milligram/kilogram had no apparent effect, 10 milligrams/kilogram caused slight hepatic centrilobular vacuolization, and 33 milligrams/kilogram was markedly

Topic: URANIUM, NATURAL

CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Uranium, natural

CASRN -- 7440-61-1

The carcinogen assessment summary for this substance has been withdrawn pending further review by the CRAVE Agency Work Group.

Agency Work Group Review -- 12/17/86, 11/30/88, 03/01/89, 3/03/89, 09/06/89, 12/02/92, 02/02/93

PA Contacts:

Patricia S. Schoeny / OHEA -- 513/569-7544

=====

Topic: CARBON TETRACHLORIDE

hepatotoxic (Bruckner et al, 1986).

- G. Because the odor threshold is greater than 10 parts per million with rapid accommodation, ODOR IS NOT AN ADEQUATE WARNING SIGN TO PREVENT OVEREXPOSURE.

5.4 TOXIC SERUM/PLASMA/BLOOD CONCENTRATIONS

- A. Blood levels of carbon tetrachloride in acutely poisoned patients ranged from 0.1 to 31.5 milligrams/liter (Ruprah et al, 1985).
1. 2 to 5 milligrams/deciliter have been considered toxic blood CCl₄ levels (Winek, 1976).
 2. Whole-blood concentration of CCl₄ four hours after acute ingestion of over 200 milliliters was 31.5 milligrams/liter, the highest ever recorded at the reporting hospital (Mathieson et al, 1985).

5.5 LD50/LC50

- A. LD50 (ORAL) RAT: 2350 mg/kg (RTECS, 1988)
- B. LC50 (INHL) RAT: 8000 ppm/4 hours (RTECS, 1988)
- C. LC50 (SKIN) RAT: 5070 mg/kg (RTECS, 1988)
- D. LD50 (IP) RAT: 1500 mg/kg (RTECS, 1988)
- E. LD50 (ORAL) MOUSE: 8263 mg/kg (RTECS, 1988)
- F. LC50 (INHL) MOUSE: 9526 ppm/8 hours (RTECS, 1988)
- G. LD50 (IP) MOUSE: 572 mg/kg (RTECS, 1988)
- H. LD50 (SC) MOUSE: 31 gm/kg (RTECS, 1988)
- I. LD50 (IP) DOG: 1500 mg/kg (RTECS, 1988)
- J. LD50 (ORAL) RABBIT: 5760 mg/kg (RTECS, 1988)
- K. LD50 (IV) RABBIT: 5840 mg/kg (RTECS, 1988)
- L. LD50 (ORAL) GUINEA PIG: 5760 mg/kg (RTECS, 1988)

5.6 CALCULATIONS

- A. 1 mg/liter = about 159 ppm (Clayton & Clayton, 1982)
- B. 1 ppm = about 6.29 mg/m³ at 25 degrees C (Clayton & Clayton, 1982)

Topic: CARBON TETRACHLORIDE

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Summary

Environmental Fate/Exposure Summary:

1. Large quantities of carbon tetrachloride are produced each year; most of it is used for chemical synthesis of fluorocarbons and this has been declining. Some past solvent uses have been resulted in releases. In the troposphere, carbon tetrachloride is extremely stable (residence time of 30-50 years). The primary loss process is by escape to the stratosphere where it photolyzes. As a result of its emission into the atmosphere and slow degradation, the amount of carbon tetrachloride in the atmosphere has been increasing. Some carbon tetrachloride released to the atmosphere is expected to partition into the ocean. In water systems, evaporation appears to be the most important removal process, although biodegradation may occur under aerobic and anaerobic conditions (limited data). Releases or spills on soil should result in rapid evaporation due to high vapor pressure and leaching in soil resulting in groundwater contamination due to its low adsorption to soil. Bioconcentration is not significant. (SRC) **PEER REVIEWED**

Pollution Sources

Natural Occurring Sources:

1. No natural sources are known(1) but ambient levels may not be totally explained by anthropogenic sources(2). **PEER REVIEWED** [(1) Singh HB et al; Atmospheric distribution, sources and sinks of selected halocarbons, hydrocarbons, SF6 and N2O. pp.65-73 USEPA-600/3-79-107 (1979) (2) Lovelock JE et al; Nature 241: 194-9 (1973)]

Artificial Sources:

1. In Soil: Carbon tetrachloride occurs due to spills, run-off from agricultural sites, dumping, and through landfill leaching; In Surface Waters: Carbon tetrachloride occurs as a result of industrial and agricultural activities, some may reach surface water through rainfall; In Air: the major source of carbon tetrachloride is industrial emission. The total nationwide emissions of carbon tetrachloride in 1978 from all sources was estimated at 65 million lb (4.5 million lb from production facilities). The primary source of these emissions is solvent application. **PEER REVIEWED** [USEPA; Health Assessment Document: Carbon tetrachloride pp.4-2 to 4-9 (1984) EPA-600/8-82-001F]
2. Waste water from iron and steel manufacturing, foundries, metal finishing, paint and ink formulations, petroleum refining and nonferrous metal manufacturing industries contain carbon tetrachloride(1). Its use has been a major contributor to atmospheric concentrations(2-3). **PEER REVIEWED** [(1) USEPA; Treatability Manual pp. 12.4-1 to 4-5 USEPA-600/2-82-001A (1981) (2) IARC Monographs on the evaluation of carcinogenic risk of chemicals to man 1: 53-60 (1972) (3) Singh HB et al; Atmospheric distributions, sources and sinks of selected halocarbons, hydrocarbons, SF6 and N2O. pp. 65-73 USEPA-600/3-79-107]

Topic: CARBON TETRACHLORIDE

REVIEWED** [(1) Neely WB et al; Environ Sci Technol 8: 1113-5 (1974) (2) Veith GD et al; J Fish Res Board Can 36: 1040-8 (1979) (3) Barrows ME et al; Dyn Exp Hazard Assess Toxic Chem Ann Arbor MI: Ann Arbor Science p 379-92 (1980)

2. Bioconcentration factor predicted from water solubility = 14 (calculated); bioconcentration factor = 18 (experimental). /From table/ **PEER REVIEWED** [Kenaga EE; Ecotoxicology and Environmental Safety 4: 26-38 (1980)

Soil Adsorption/Mobility:

1. Measured KOC of 71 was reported(1). Estimated retardation factor in breakthrough sampling in groundwater - 1.44-1.8(2,3). Carbon tetrachloride is expected to be highly mobile in soil and only slightly adsorbed to sediment(4, SRC). **PEER REVIEWED** [(1) Sabljic A; J Agric Food Chem 32: 243-6 (1984) (2) Mackay DM et al; Amer Chem Soc 186th Natl Mtg Preprint Div Environ Chem 23: 368-71 (1983) (3) Goltz MN, Roberts PV; J Cont Hydrology 1: 77-93 (1986) (4) Swann RL et al; Res Rev 85: 17-28 (1984)

Volatilization from Water/Soil:

1. High vapor pressure (108 torr at 25 C)(1) suggests rapid evaporation from dry soil surfaces(SRC). Henry's Law Constant for carbon tetrachloride has been measured to be 3.04×10^{-2} atm-cu m/mole at 24.8 deg C(8). This value suggests that carbon tetrachloride would volatilize rapidly from water and moist soil surfaces. Based on this value of Henry's Law Constant the volatilization half-life from a model river 1 m deep flowing 1 m/sec with a wind speed of 3 m/sec has been estimated to be 3.7 hours(6, SRC). Measured half-life of evaporation from water - minutes to hours(2-7). **PEER REVIEWED** [(1) Gallant RW; Hydrocarbon Process 45: 161-9 (1966) (2) Dilling WL; Environ Sci Technol 11: 405-9 (1977) (3) Chiou CT et al; Environ Inter 3: 231-6 (1980) (4) Smith JH et al; Environ Sci Technol 14: 1332-7 (1980) (5) Mackay D, Yeun ATK; Environ Sci Technol 17: 211-7 (1983) (6) Lyman WJ et al; Handbook of Chemical Property Estimation Methods. NY: McGraw-Hill p. 15-12 to 15-32 NY: McGraw-Hill (1982) (7) Roberts PV, Dandliker PK; Environ Sci Technol 17: 484-9 (1983) (8) Gossett JM, Environ Sci Tech 21: 202-8 (1987)

Environmental Concentrations

Water Concentrations:

1. Surface Water: at various depths of Lake Zurich, Switzerland, concns of approx 25 parts/trillion were measured with no significant variation; Ground Water: levels in the industrial sector near Lake Zurich were reported at levels from 190-3600 parts/trillion and the compound was detected in 4/18 samples. **PEER REVIEWED** [Giger W et al; Aquatic Poll: Transform Bio Eff pp.101-23 (1978) as cited in USEPA; Health Assessment Document: Carbon tetrachloride p.4-5 (1984) EPA-600/8-82-001F
2. /CARBON TETRACHLORIDE/ ... DETECTED @ LEVELS HIGHER THAN THOSE FOUND IN RAW WATER, SUGGESTING ... /IT/ HAD LEACHED FROM PVC PIPE. LEVELS ... WERE 52 TO 125 TIMES HIGHER THAN CONCIN IN RAW WATER. **PEER REVIEWED** [National Research Council. Drinking Water & Health, Volume 4. Washington,

Topic: CARBON TETRACHLORIDE

(1979)

Environmental Fate

Environmental Fate:

1. TERRESTRIAL FATE: Carbon tetrachloride is slightly removed during infiltration of river water into adjacent wells(1). However, carbon tetrachloride is expected to evaporate rapidly from soil due to its high vapor pressure and migrate into ground water due to its low soil adsorption coefficient. No data are available on biodegradation in soil(SRC). **PEER REVIEWED** [(1) Zoeteman BCJ; Chemosphere 9: 231-49 (1980)]
2. AQUATIC FATE: Evaporation from water is a significant removal process (half-life - minutes to hours). Based upon field monitoring data, the estimated half-life in rivers is 3-30 days; in lakes and groundwater, 3-300 days(1). Biodegradation may be important under aerobic or anaerobic conditions, but the data are limited. Adsorption to sediment should not be an important process(SRC). **PEER REVIEWED** [(1) Zoeteman BCJ; Chemosphere 9: 231-49 (1980)]
3. ATMOSPHERIC FATE: Carbon tetrachloride is very stable in the troposphere with residence times of 30-50 years. Its main loss mechanism is diffusion to the stratosphere where it photolyzes. It is estimated that <1% of the carbon tetrachloride released to the air is partitioned into the oceans(1). **PEER REVIEWED** [(1) Galbally IE; Science 193: 573-6 (1976)]

Environmental Transformations

Biodegradation:

1. Biodegradation in screening tests has been noted(1), but acclimation may be necessary(2). Degradation does occur in 16 days under anaerobic conditions(3). **PEER REVIEWED** [(1) Tabak HH; J Water Pollut Control Fed 53: 1503-18 (1981) (2) Heukelekian H, Rand MC; J Water Pollut Control Assoc 29: 1040-55 (1955) (3) Bower EJ, McCarty PL; Appl Environ Microbiol 45: 1286-94 (1983)]

Abiotic Degredation:

1. Hydrolysis half-life in water is 7000 years at 25 deg C(1). Direct photolysis is not important in the troposphere, but irradiation at higher energies (195-254 NM) such as found in the stratosphere results in degradation(2,3). Carbon tetrachloride is stable in the troposphere with residence time of 30-50 years(2). It does not react significantly with any active species in the atmosphere(5). The half-life for reaction with hydroxyl radicals is >330 years(4). **PEER REVIEWED** [(1) Mabey W, Mill T; J Phys Chem Ref Data 7: 383-415 (1978) (2) Molina MJ, Rowland FS; Geophys Res Lett 1:309-12 (1974) (3) Davis DD et al; J Phys Chem 79: 11-7 (1975) (4) Cox RA et al; Atmos Environ 10: 305-8 (1976) (5) Galbally IE; Science 193: 573-6 (1976)]

Environmental Transport

Bioconcentration:

1. Carbon tetrachloride has a low potential to bioconcentrate(1). Log of the bioconcentration factor in trout is 1.24(1,2), in bluegill sunfish - 1.48(3). **PEER

opic: CARBON TETRACHLORIDE

DC: National Academy Press, 1981. 66

3. SURFACE WATER: Marine - surface 0.12-0.85 parts/trillion carbon tetrachloride, at 300 m depth - 0.15 parts/trillion (1,2,3). Fresh - 0-9 ppb(4-10). 14 heavily industrialized rivers 1-3 ppb, 6 of 204 samples pos(11). Great lakes - 9-47 parts/trillion (12,13). USEPA STORET DATA BASE - 8,858 water samples, 12% pos., median concn 0.10 ug/L(14). **PEER REVIEWED** [(1) Singh HB et al; Atmospheric distribution, sources and sinks of halocarbons, hydrocarbons, SF6 and N2O. p. 57 USEPA-600/3-79-107 (1979) (2) Singh HB et al; J Air Pollut Control Assoc 27: 332-6 (1977) (3) Murray AJ, Riley JP; Nature 242: 37-8 (1973) (4) Ewing BB et al; Monitoring To Detect Previously Unrecognized Pollutants In Surface Waters. p. 72 USEPA-560/6-77-015 (1977) (5) Haberer K, Normann S; Gas-wasserfach: Wasser/Abwasser 120: 302-7 (1979) (6) Ohio R Valley Water Sanit Comm; EPA grant R-804615 (1979) (7) Ohio R Valley Water Sanit Comm; 1977 Mainstream Assessment (1978) (8) Ohio R Valley Water Sanit Comm; 1978-9 Mainstream Assessment (1980) (9) Dreisch FA et al; Survey of Huntington and Philadelphia River Water Supplies For Purgable Organic Contaminates. p. 10-11 USEPA-903/9-81-003 (1980) (10) Coniglio WA et al; Occurrence Of Volatile Organics In Drinking Water. Briefing (1980) (11) Ohio R Valley Water Sanit Comm; 1980-81 Main Stream Assessment (1982) (12) Kaiser KLE, Valdmanis I; J Great Lakes Res 5: 106-9 (1979) (13) Konasewich D et al; Great Lakes Quality Review Board Report (1978) (14) Staples CA et al Environ Tox Chem 4: 131-42 (1985)
4. GROUNDWATER: 3-20 ppb carbon tetrachloride for 27 US cities(1), 5 ppb Netherlands(2). As of June 1984, analyzed for but not found in 1174 community wells and 617 private wells in Wisconsin(3). **PEER REVIEWED** [(1) Coniglio WA et al; Occurrence Of Volatile Organics In Drinking Water. Briefing (1980) (2) Zoeteman BCJ et al; Chemosphere 9: 231-49 (1980) (3) Krill RM, Sonzogni WC; J Am Water Works Assoc 78: 70-5 (1986)
5. DRINKING WATER: 0.1-30 ppb carbon tetrachloride in 181 US cities - surface water source(1), 0.2-13 ppb in 39 US cities - groundwater source(1), 0-190 parts/trillion in 9 homes - Love Canal(2), 135-400 ppb wells in NJ and NY(3), 0-4 ppb - 80 US cities(4). **PEER REVIEWED** [(1) Coniglio WA et al; Occurrence Of Volatile Organics In Drinking Water. Briefing (1980) (2) Barkley J et al; Biomed Mass Spectrom 7: 139-47 (1980) (3) Burmaster DE; Environ 24: 6-13,33-6 (1982) (4) Symons JM et al; J Amer Water Works Assoc 67: 634-47 (1975)
6. RAIN: La Jolla, CA 2.8 parts/trillion, industrial area in England 300 parts/trillion carbon tetrachloride(1). SNOW: Southern and Central California 0.33-0.36 parts/trillion, Alaska 2.2 parts/trillion(1). **PEER REVIEWED** [(1) Su C, Goldberg ED; Mar Pollut Transfer 1976: 353-74 (1976)

Effluents Concentrations:

1. Wastewater from a wastewater treatment plant, Los Angeles county CA; 12-16 ppb. **PEER REVIEWED** [Young; Ann Rep S

Topic: CARBON TETRACHLORIDE

CA. Coastal Water Res, 1978

2. Industries with mean concentrations >90 ppb - non-ferrous metals manufacturing, paint and ink formulation, rubber processing, mean range 90-700, max range 1700-1800(1). USEPA STORET DATA BASE - 1,343 effluent samples 5.5% pos., median concn <5.0 ug/L(4). Detected in leachate from a municipal landfill in southern California, max concn 11 ppb(2). Detected in leachate from Occidental Chemical Co landfill in Niagara Falls, NY(3). **PEER REVIEWED** [(1)USEPA; Treatability Manual USEPA-600/282-001A p. I.12.4-1 to 4-5 (1981) (2) Wood JA, Porter ML; J Air Pollut Control Assoc 37: 609-15 (1987) (3) Talian SF et al; pp. 525-42 in Proc AWWA Water Quality Technol Conf. Harrisburg PA: Gannett Fleming Water Resourc Eng (1986) (4) Staples CA et al; Environ Tox Chem 4: 131-42 (1985)
3. ENVIRONMENTAL ACCUMULATION: ... HAS BEEN FOUND ... EFFLUENT WATER FROM COMMERCIAL MANUFACTURING SOURCES AND SEWAGE TREATMENT PLANT EFFLUENT WATER TAKEN FROM 43 SITES IN US AND EUROPE. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V20 375 (1979)
4. Release of tetrachloromethane to the environment (air) in 1978: total, 39,880 kkg (production, 1,300-1,900 kkg; grain fumigant, 12,000 kkg; intermediate, 480 kkg; identified solvent uses, 1,400; miscellaneous, 24,400 kkg). /From table/ **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982., p. 3-3
5. Release of tetrachloromethane to the environment (land) in 1978: total, 130 kkg (production, 110 kkg; grain fumigant, < 1 kkg; intermediate, 5 kkg; identified solvent uses, 5 kkg; miscellaneous, < 10 kkg). /From table/ **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982., p. 3-3
6. Release of tetrachloromethane to the environment (water) in 1978: total, 360 kkg (production, 50 kkg; grain fumigant, < 1 kkg; intermediate, < 1 kkg; identified solvent uses, 110 kkg; miscellaneous, 200 kkg). /From table/ **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982., p. 3-3

Sediment/Soil Concentrations:

1. USEPA STORET DATA BASE - 361 sediment samples, 0.8% pos., median concn <5.0 mg/kg dry weight basis(1). **PEER REVIEWED** [(1) Staples CA et al; Environ Tox Chem 4: 131-42 (1985)

Atmospheric Concentrations:

1. NORTHERN HEMISPHERE - 110.9-142.3 parts/trillion, SOUTHERN HEMISPHERE - 68.9-125.4 parts/trillion(1-4). MARINE REMOTE

Topic: CARBON TETRACHLORIDE

- Pacific - 4.1-70 parts/trillion and Atlantic - 0.2-71.2 parts/trillion(5-7). Atlantic 1984-1985, 140 parts/trillion(24). URBAN/SUBURBAN - 0.19 ppb mean 1747 samples (16), 0-42.4 ppb(2,8-16). RURAL/REMOTE - 0.13 ppb mean 728 samples(16), 0.082-0.24 ppb(2,11,16,18-20). INDUSTRIALIZED AND SOURCE DOMINATED AREAS - 0.59 ppb mean 285 samples(16), 0-70 ppb(17,21-22). The amount of carbon tetrachloride has been increasing in the atmosphere(23), at the rate of 25 ppb/yr(24). **PEER REVIEWED** [(1) Singh HB et al; Atmospheric distribution, sources and sinks of selected halocarbons, hydrocarbons, SF6 and N2O EPA-600/3-79-107 p. 3 (1979) (2) Rasmussen RA et al; Science 211: 285-7 (1981) (3) Singh HB; Geophys Res Lett 4: 101-4 (1977) (4) Cox RA et al; Atmos Environ 10: 305-8 (1976) (5) Lovelock JE et al; Nature 241: 194-6 (1973) (6) Murray AJ, Riley JP; Nature 242: 37-8 (1973) (7) Vedder JF et al; Geophys Res Lett 5: 33-6 (1978) (8) Bozzelli JW, Kebbekus BB; Final report New Jersey Inst Technol 80 pp (1979) (9) Lillian D et al; Amer Chem Soc Symp Ser 17: 152-8 (1975) (10) Lillian D et al; Environ Sci Technol 9: 1042-8 (1975) (11) Su C, Goldberg ED; Mar Pollut Transfer Windom HL et al eds Lexington, MA: DC Heath Co pp. 353-74 (1976) (12) Singh HB et al; Atmos Environ 15: 601-12 (1981) (13) Pellizzari ED et al; Formulation of preliminary assessment of halogenated organic compounds in man and environmental media EPA-560/13-79-006 (1979) (14) Singh HB et al; Atmospheric measurements of selected hazardous organic chemicals EPA-600/S3-81-032 (1981) (15) Bozzelli JW, Kebbekus BB; J Environ Sci Health 17: 693-713 (1982) (16) Brodzinski R, Singh HB; Volatile organics in the atmosphere: an assessment of available data SRI Inter Contract 68-02-3452 p.13 (1982) (17) Grimsrud EP, Rasmussen RA; Atmos Environ 9: 1014-7 (1975) (18) Singh HB et al; J Air Pollut Control Assoc 27: 332-6 (1977) (19) Pack DH; Atmos Environ 11: 329-44 (1977) (20) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975) (21) Pellizzari ED; Environ Sci Technol 16: 781-5 (1982) (22) Barkley J et al; Biomed Mass Spectrom 7: 139-47 (1980) (23) Galbally IE; Science 193: 573-6 (196) (24) Class T, Ballschmitter K; Chemosphere 15: 413-27 (1986)

2. USEPA TEAM Study - New Jersey, outdoor air: 86 samples Fall 1981, weighted median 0.87 ug/cu m; 60 samples Summer 1982, weighted median 0.68 ug/cu m(1). USEPA TEAM Study - New Jersey, personal air: 344 samples Fall 1981, weighted median 1.5 ug/cu m; 148 samples Summer 1982, weighted median 0.85 ug/cu m(1). **PEER REVIEWED** [(1) Wallace LA et al; Environ Res 43: 290-307 (1987)]

Food Survey Results:

1. The USEPA Pesticide Labs detected 0.005 to 2.61 mg/kg CCl4 in flour from 11 US cities with an average level of 0.051 mg/kg. **PEER REVIEWED** [USEPA; Health Assessment Document: Carbon Tetrachloride p.4-10 (1984) EPA-600/8-82-001F]
2. Carbon tetrachloride levels of 0.0002 to 0.0003 mg/kg were detected in flour. However bread and biscuits made from

Topic: CARBON TETRACHLORIDE

this flour contained undetectable levels of carbon tetrachloride. **PEER REVIEWED** [Bondi A, Alamot E; Evaluation of some pesticide residues in food, WHO Pesticide Residues Series, No 1, 1972

3. Carbon tetrachloride was detected at levels of 76 to 115 mg/kg in wheat, 10 to 21 mg/kg in flour, 28 to 39 mg/kg in oats, and 43 to 88 mg/kg in bran that had been fumigated with the recommended fumigant dosages. **PEER REVIEWED** [Lynn GE, Vorches Jr, eds; J Assoc Ag Chem 52: 800 (1957) as cited in USEPA; Health Assessment Document: Carbon Tetrachloride p.4-11 (1984) EPA-600/8-82-001F
4. Carbon tetrachloride was detected at 200 to 400 mg/kg in wheat and corn after application of a fumigant. Residual carbon tetrachloride decr to 1-10 mg/kg 6 months after fumigation. By 12 months post-fumigation, the wheat and corn contained a max of 4.7 mg/kg carbon tetrachloride. **PEER REVIEWED** [Scudamore KA, Heuser SG; Pestic Sci 4: 1-12 (1973) as cited in USEPA; Health Assessment Document: Carbon tetrachloride p.4-11 (1984) EPA-600/8-82-001F
5. A range of 3-18 ng/g in fats, fruits and vegetables, meat, tea and bread with oils and fats being at the high end of range (16-18 ng/g)(1). Possible residues in grain products - 50 ppm (raw cereals), 10 ppm (milled cereals), and 0.05 ppm (cooked cereal products)(2). 7 samples of grains had a residues range of 2.9-20.1 ppm(3). Residues detected in grains (wheat, corn, oats) ranged between 0.003-49 ppm and intermediate grain-based foods (corn muffin mix, cake mix, flour, etc) ranged between 0.0-100 ppb(4). Detected in a variety of table ready food items (ppb): chocolate chip cookies, 1.3; plain granola, 3.4; butter, 6; cheddar cheese, 1.1; peanut butter, 0.44; evaporated milk, 0.10; boiled green peas, 0.18; fried, breaded shrimp, 0.88; cooked pork sausage, 0.44; and frozen fried chicken dinner, 0.76(5). **PEER REVIEWED** [(1) McConnell G et al; Endeavor 34: 13-8 (1975) (2) IARC; Monographs on the evaluation of carcinogenic risk of chemicals to man 1: 54 (1972) (3) McMahon BM; J Assoc Off Anal Chem 54: 964-5 (1971) (4) Heikes DL, Hopper ML; J Assoc Off Anal Chem 69: 990-8 (1986) (5) Heikes DL; J Assoc Off Anal Chem 70: 215-26 (1987)

Plant Concentrations:

1. /Carbon tetrachloride/ residue in wheat germ with a high fat content was found to be less than 50% of that found in bran. **PEER REVIEWED** [Hayes, Wayland J., Jr. Pesticides Studied in Man. Baltimore/London: Williams and Wilkins, 1982. 145

Fish/Seafood Concentrations:

1. Mollusks - 2-114 ppb, fish - 3-209 ppb, with medians of 11 and 19 ppb respectively(1). USEPA STORET DATA BASE - 97 biota samples, 0% pos., detection limit 0.05 mg/kg wet weight basis(2). **PEER REVIEWED** [(1) Dickson AG, Riley JP; Mar Pollut Bull 7: 167-9 (1976) (2) Staples CA et al; Environ Tox Chem 4: 131-42 (1985)

Milk Concentrations:

1. 3 ppm milk from cows treated with veterinary medication

Topic: CARBON TETRACHLORIDE

containing carbon tetrachloride(1). **PEER REVIEWED** [(1) IARC; Monographs on the evaluation of carcinogenic risk of chemicals to man 1: 55 (1972)

Human Exposure

Probable Routes of Human Exposure:

1. There are 3 primary routes of exposure - water and other fluids, inhalation, and ingestion of foodstuffs(1). Significant amounts (30 million pounds) each year are used for degreasing products, fire extinguishers, grain fumigants, etc(2). Some humans may receive high exposure from these minor uses(SRC). Ambient air levels are low (parts/trillion) with urban/ suburban and rural values being similar. Drinking water levels are also generally low (ppb) unless contaminated. CCl₄ has also been found in some veterinary medicines(3). **PEER REVIEWED** [(1) USEPA; Ambient Water Quality Criteria for Carbon Tetrachloride p.C-1 (1980) EPA-440/5-80-026 (2) Chemical Marketing Reporter February 21 Chemical Profile (1983) (3) IARC; Monographs on the evaluation of carcinogenic risk of chemicals to man 1: 53-5 (1972)
2. Inhalation of vapor, percutaneous absorption, ingestion and skin and eye contact. **PEER REVIEWED** [Sittig, M. Handbook of Toxic and Hazardous Chemicals and Carcinogens, 1985. 2nd ed. Park Ridge, NJ: Noyes Data Corporation, 1985. 195

Average Daily Intake:

1. Air intake - (assume 0.1-4 ppb) 12-511 ug; Water intake - (assume range of 0.1-30 ppb) - 0.2-60 ug; Food - insufficient data. (SRC) **PEER REVIEWED**

Probable Exposures:

1. ... WORKERS EXPOSED TO CARBON TETRACHLORIDE ARE PRIMARILY THOSE AT BLAST FURNACES & STEEL MILLS, IN THE AIR TRANSPORTATION INDUSTRY, & IN MOTOR VEHICLE & TELEPHONE & TELEGRAPH EQUIPMENT MANUFACTURING ... **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V20 378 (1979)
2. Approx 4500 workers are exposed during production processes, and 52000 more workers are exposed during industrial use and consumption of the chemical. ... EPA estimates that 8 million people living within 12.5 miles of manufacturing sites are exposed to avg levels of 0.5 ug/cu m, with peaks of 1580 ug/cu m. ... Estimates indicate that 19 million people are exposed to carbon tetrachloride through the ambient air, 20 million are exposed through drinking contaminated water, and 2 million are exposed to contaminated soil or landfills. **PEER REVIEWED** [Sittig, M. Handbook of Toxic and Hazardous Chemicals and Carcinogens, 1985. 2nd ed. Park Ridge, NJ: Noyes Data Corporation, 1985. 194
3. NIOSH (NOES Survey 1981-1983) has statistically estimated that 58,208 workers are potentially exposed to carbon tetrachloride in the USA(1). However, this estimate does not include exposure to tradename compounds which contain

Topic: CARBON TETRACHLORIDE

carbon tetrachloride(SRC). NIOSH (NOHS Survey 1972-1974) has statistically estimated that 1,380,232 workers are potentially exposed to carbon tetrachloride in the USA(2). In breathing zone air of workers involved in the production of chlorinated rubbers for road paint (in Italy), mean concn 3.5-6.9 mg/cu m(3). Inhalation of high concentrations is largely restricted to occupational environments(SRC). It has been estimated that 160,000 workers have potential exposure to carbon tetrachloride(4). **PEER REVIEWED** [(1) NIOSH; National Occupational Exposure Survey (NOES) (1983) (2) NIOSH; National Occupational Hazard Survey (NOHS) (1974) (3) Brugnone F et al; pp. 575-8 in Developments in the Science and Practice of Toxicology; Hayes AW et al eds: Elsevier Science (1983) (4) NIOSH; Criteria for a recommended standard. Occupational exposure to carbon tetrachloride. NTIS PB-250-424 p.16 (1975)

Body Burdens:

1. Detected not quantified in 5 of 6 samples of mother's milk in 4 urban sites - Pennsylvania - 1, New Jersey - 2, Louisiana - 1(1). In blood from workers exposed to carbon tetrachloride during production of chlorinated rubbers for road paint (in Italy), mean concn 3.3-6.5 ug/L(2). Detected in expired air of carefully selected normal, healthy human subjects (non-smokers), 387 samples from 54 subjects, 29.7% samples pos., mean concn 1.4 ng/L(3). USEPA TEAM Study - New Jersey, 322 breath samples Fall 1981, weighted median 0.69 ug/cu m, 148 breath samples Summer 1982 - 0.17 ug/cu m(4). **PEER REVIEWED** [(1) Pellizzari ED et al; Bull Environ Contam Toxicol 28:322-8 (1982) (2) Brugnone F et al; pp. 575-8 in Developments in the Science and Practice of Toxicology; Hayes AW et al eds: Elsevier Science (1983) (3) Krotoszynski BW et al; J Anal Tox 3: 225-34 (1979) (4) Wallace LA et al; Environ Res 43: 290-307 (1987)

Topic: CARBON TETRACHLORIDE

EXPOSURE STANDARDS & REGULATIONS

Standards & Regulations

Immediately Dangerous to Life or Death:

1. NIOSH has recommended that carbon tetrachloride be treated as a potential human carcinogen. ****QC REVIEWED**** [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 60

Acceptable Daily Intake:

1. 0.025 mg/l /Adjusted acceptable daily intake (AADI)/ ****PEER REVIEWED**** [USEPA; Drinking Water Criteria Doc: Carbon Tetrachloride p.viii (1985)

Allowable Tolerances:

1. The insecticide carbon tetrachloride is exempted from the requirement of a tolerance for residues, when used as a fumigant after harvest, for the following grains: Barley, corn, oats, popcorn, rice, rye, sorghum (milo), and wheat. This exemption /expired/ on Jul 31, 1990. ****PEER REVIEWED**** [40 CFR 180.1005 (7/1/91)

Occupational Permissible Levels

OSHA Standards:

1. During an 8 hr work shift, an employee may be exposed to a concentration of carbon tetrachloride above 25 ppm (but never above 200 ppm) only for a maximum period of 5 min in any 4 hr. Such exposure must be compensated by exposures to concentrations less than 10 ppm so that the cumulative exposure for the entire 8 hr work shift does not exceed a weighted average of 10 ppm. /Transitional limits/ must continue to be achieved by any combination of engineering controls, work practices, and personal protective equipment during the phase-in period, Sept 1, 1989 through Dec 30, 1992. Final rule limits become effective Dec 31, 1992. ****PEER REVIEWED**** [29 CFR 1910.1000 (7/1/90)
2. 8 hr Time-Weighted avg: 2 ppm (12.6 mg/cu m). /Final rule limits/ shall be achieved by any combination of engineering controls, work practices and personal protective equipment during the phase-in period, Sept 1, 1989 through Dec 30, 1992. Final rule limits become effective Dec 31, 1992. ****PEER REVIEWED**** [29 CFR 1910.1000 (7/1/90)

NIOSH Recommendations:

1. 60 min Short-Term Exposure Limit: 2 ppm, 12.6 mg/cu m ****PEER REVIEWED**** [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 60
2. NIOSH usually recommends that occupational exposures to carcinogens be limited to the lowest feasible concn. ****PEER REVIEWED**** [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 230

Threshold Limit Values:

1. Time Weighted Avg (TWA) 5 ppm, 31 mg/cu m, skin (1986) ****PEER REVIEWED**** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological

Topic: CARBON TETRACHLORIDE

ExposureIndices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 15

2. Excursion Limit Recommendation: Excursions in worker exposure levels may exceed three times the TLV-TWA for no more than a total of 30 min during a work day and under no circumstances should they exceed five times the TLV-TWA, provided that the TLV-TWA is not exceeded. **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological ExposureIndices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 5
3. A2, skin. A2= Suspected human carcinogen. (1986) **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological ExposureIndices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 15

Other Occupational Permissible Levels:

1. Japan: 10 ppm. **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, 1986. 110

Other Standards and Regulations

Water Standards:

1. Designated as a hazardous substance under section 311(b)(2)(A) of the Federal Water Pollution Control Act and further regulated by the Clean Water Act Amendments of 1977 and 1978. These regulations apply to discharges of this substance. **PEER REVIEWED** [40 CFR 116.4 (7/1/90)
2. Toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations. **PEER REVIEWED** [40 CFR 401.15 (7/1/90)
3. The national revised primary drinking water maximum contaminant level for carbon tetrachloride for community and non-transient, non-community water systems is 0.005 mg/l. **PEER REVIEWED** [40 CFR 141.61 (7/1/90), amended by 56 FR 3593 (1/30/91)
4. The levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10⁻⁵, 10⁻⁶, and 10⁻⁷. The corresponding recommended criteria are 4.0 ug/l, 0.4 ug/l, and 0.04 ug/l, respectively. **PEER REVIEWED** [USEPA; Quality Criteria for Water 1986: Carbon Tetrachloride (May 1, 1986) EPA 440/5-86-001

Atmospheric Standards:

1. This action promulgates standards of performance for equipment leaks of Volatile Organic Compounds (VOC) in the Synthetic Organic Chemical Manufacturing Industry (SOCMI). The intended effect of these standards is to require all newly constructed, modified, and reconstructed SOCMI process units to use the best demonstrated system of continuous emission reduction for equipment leaks of VOC, considering costs, non air quality health and environmental impact and energy requirements. Carbon

Topic: CARBON TETRACHLORIDE

tetrachloride is produced, as an intermediate or a final product, by process units covered under this subpart.

****PEER REVIEWED**** [40 CFR 60.489 (7/1/90)]

CERCLA Reportable Quantities:

1. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 10 lb or 4.54 kg. The toll free number of the NRC is (800) 424-8802; In the Washington D.C. metropolitan area (202) 426-2675. The rule for determining when notification is required is stated in 40 CFR 302.4 (section IV. D.3.b). ****PEER REVIEWED**** [40 CFR 302.4 (7/1/90)]

RCRA Requirements:

1. U211; As stipulated in 40 CFR 261.33, when carbon tetrachloride, as a commercial chemical product or manufacturing chemical intermediate or an off-specification commercial chemical product or a manufacturing chemical intermediate, becomes a waste, it must be managed according to Federal and/or State hazardous waste regulations. Also defined as a hazardous waste is any residue, contaminated soil, water, or other debris resulting from the cleanup of a spill, into water or on dry land, of this waste. Generators of small quantities of this waste may qualify for partial exclusion from hazardous waste regulations (40 CFR 261.5). ****PEER REVIEWED**** [40 CFR 261.33 (7/1/90)]
2. D019; A solid waste containing carbon tetrachloride may or may not become characterized as a hazardous waste when subjected to the Toxicity Characteristic Leaching Procedure listed in 40 CFR 261.24, and if so characterized, must be managed as a hazardous waste. ****PEER REVIEWED**** [40 CFR 261.24 (7/1/90)]

FIFRA Requirements:

1. The insecticide carbon tetrachloride is exempted from the requirement of a tolerance for residues, when used as a fumigant after harvest, for the following grains: Barley, corn, oats, popcorn, rice, rye, sorghum (milo), and wheat. This exemption /expired/ on Jul 31, 1990. ****PEER REVIEWED**** [40 CFR 180.1005 (7/1/91)]
2. Cancelled, all products. Criteria of Concern; oncogenicity, toxic effect on liver and kidneys. Reference: 51 FR 4104 Nov 12, 1986. FIFRA Sec. 3 registration cancelled for nonpayment of 1989 maintenance fee, October 12, 1989. ****PEER REVIEWED****

FDA Requirements:

1. Carbon tetrachloride is an indirect food additive for use only as a component of adhesives. ****PEER REVIEWED**** [21 CFR 175.105 (4/1/90)]

Topic: CARBON TETRACHLORIDE

1. CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Carbon tetrachloride

CASRN -- 56-23-5

Last Revised -- 06/01/91

The Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Please refer to Background Document 1 in Service Code 5 for an elaboration of these concepts. RfDs can also be derived for the noncarcinogenic health effects of compounds which are also carcinogens. Therefore, it is essential to refer to other sources of information concerning the carcinogenicity of this substance. If the U.S. EPA has evaluated this substance for potential human carcinogenicity, a summary of that evaluation will be contained in Section II of this file when a review of that evaluation is completed.

I.A.1. ORAL RfD SUMMARY

See Table Document

I.A.2. PRINCIPAL AND SUPPORTING STUDIES (ORAL RfD)

Bruckner, J.V., W.F. MacKenzie, S. Muralidhara, R. Luthra, G.M. Kyle and D. Acosta. 1986. Oral toxicity of carbon tetrachloride: Acute, subacute and subchronic studies in rats. *Fund. Appl. Toxicol.* 6(1): 16-34.

Male Sprague-Dawley rats were given 1, 10, or 33 mg carbon tetrachloride/kg/day by corn oil gavage, 5 days/week for 12 weeks. Liver lesions, as evidenced by mild centrilobular vacuolization and statistically significant increases in serum sorbitol dehydrogenase activity, were observed at the 10 and 33 mg/kg/day doses in a dose-related manner. Therefore, the LOAEL was established at 10 mg/kg/day (converted to 7.1 mg/kg/day) and the NOAEL was 1 mg/kg/day (converted to 0.71 mg/kg/day).

I.A.3. UNCERTAINTY AND MODIFYING FACTORS (ORAL RfD)

UF -- UF allows for interspecies and intrahuman variability and extrapolation from subchronic to chronic duration of exposure.

MF = None

I.A.4. ADDITIONAL COMMENTS (ORAL RfD)

A 1983 draft of the Bruckner et al. (1986) study was used as the basis for the RfD by the RfD Work Group at a 05/20/85 verification meeting. When this study was subsequently published (Bruckner et al., 1986), no change to the verified value was required.

Subchronic studies in mice gavaged with carbon tetrachloride in corn oil (Condie et al., 1986; Hayes et al., 1985) support the critical effect and the magnitude of the NOAEL and LOAEL found in the rat studies. Additional studies (Alumot et al., 1976; NCI, 1976) in rats lend moderate support to the choice

IRIS

pic: CARBON TETRACHLORIDE

of a NOAEL in the chosen rat study.

I.A.5. CONFIDENCE IN THE ORAL RfD

Study -- High

Data Base -- Medium

RfD -- Medium

The principal study was well conducted and good dose-response was observed in the liver, which is the target organ for carbon tetrachloride toxicity; thus, high confidence was assigned. Four additional subchronic studies support the RfD, but reproductive and teratology endpoints are not well investigated; thus, the data base rates a medium confidence. Medium confidence in the RfD follows.

I.A.6. EPA DOCUMENTATION AND REVIEW OF THE ORAL RfD

U.S. EPA. 1985. Drinking Water Criteria Document for Carbon Tetrachloride. Office of Drinking Water, Washington, DC.

Public review of RfD following ODW proposal of RMCL in June 1984.

Science Advisory Board review of RfD on January 14, 1986.

Agency Work Group Review -- 05/20/85

Verification Date -- 05/20/85

I.A.7. EPA CONTACTS (ORAL RfD)

Krishan Khanna / OST -- (202)260-7588

Michael L. Dourson / OST -- (513)569-7544

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE
(RfC)

Substance Name -- Carbon tetrachloride

CASRN -- 56-23-5

Not available at this time.

=====

IRIS

Topic: CARBON TETRACHLORIDE

II. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Carbon tetrachloride

CASRN -- 56-23-5

Last Revised -- 06/01/91

Section II provides information on three aspects of the carcinogenic risk assessment for the agent in question; the U.S. EPA classification, and quantitative estimates of risk from oral exposure and from inhalation exposure. The classification reflects a weight-of-evidence judgment of the likelihood that the agent is a human carcinogen. The quantitative risk estimates are presented in three ways. The slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per (mg/kg)/day. The unit risk is the quantitative estimate in terms of either risk per ug/L drinking water or risk per ug/cu.m air breathed. The third form in which risk is presented is a drinking water or air concentration providing cancer risks of 1 in 10,000, 1 in 100,000 or 1 in 1,000,000. Background Document 2 (Service Code 5) provides details on the rationale and methods used to derive the carcinogenicity values found in IRIS. Users are referred to Section I for information on long-term toxic effects other than carcinogenicity.

II.A. EVIDENCE FOR CLASSIFICATION AS TO HUMAN CARCINOGENICITY

II.A.1. WEIGHT-OF-EVIDENCE CLASSIFICATION

Classification -- B2; probable human carcinogen

Basis -- Carcinogenicity in rats, mice, and hamsters

II.A.2. HUMAN CARCINOGENICITY DATA

Inadequate. There have been three case reports of liver tumors developing after carbon tetrachloride exposure. Several studies of workers (Milham, 1976; Blair et al., 1979) who may have used carbon tetrachloride have suggested that these workers may have an excess risk of cancer.

II.A.3. ANIMAL CARCINOGENICITY DATA

Sufficient. Carbon tetrachloride has produced hepatocellular carcinomas in rats, mice, and hamsters, the species evaluated to date.

Hepatocellular carcinomas developed in Osborne-Mendel, Japanese, and Wistar rats, but not Sprague-Dawley or Black rats, following s.c. injection of carbon tetrachloride. Hyperplastic nodules were noted in Buffalo rats treated s.c. (Reuber and Glover, 1967a,b, 1970). Sensitivity varied among strains, and trends in incidence appeared inversely related to severity of cirrhosis.

Fifty Osborne-Mendel rats/sex were administered carbon tetrachloride by corn oil gavage at 47 and 94 mg/kg/injection for males and 80 and 159 mg/kg for females 5 times/week for 78 weeks. At 110 weeks, only 7/50 high-dose males and 14/50 high-dose females survived; 14/50 low-dose males and 20/50 low-dose females survived. The incidence of hepatocellular carcinomas was increased in animals exposed to carbon tetrachloride as compared with pooled colony controls. The apparent decrease in the incidence of hepatocellular carcinomas in high-dose female rats compared with the low-dose females (1/14 vs. 4/20, respectively) was attributed by the authors to increased lethality before tumors could be

Topic: CARBON TETRACHLORIDE

expressed (NCI, 1976a,b, 1977).

In this same study, using the same dosing schedule, male and female B6C3F1 mice received 1250 or 2500 mg/kg carbon tetrachloride. The incidences of hepatocellular carcinomas in males were 5/77, 49/49, and 47/48 in the control, low- and high-dose groups, respectively, and 1/80, 40/40, and 43/45 in the control, low- and high-dose groups, respectively.

Carbon tetrachloride administered by gavage has also been shown to produce neoplastic changes in livers of five additional strains of mice (C3H, A, Y, C, and L) (Andervont, 1958; Edwards, 1941; Eschenbrenner and Miller 1943; Edwards and Dalton, 1942; Edwards et al., 1942). In the last study, 56 male and 19 female L mice, which have a low incidence of spontaneous hepatomas, were treated with 0.1 mL of 40% carbon tetrachloride 2 or 3 times/week over 4 months, for a total of 46 treatments. Animals were killed 3 to 3.5 months after the last treatment. The combined hepatoma incidence of treated male mice was 47% (7/15 vs. 2/71 in the untreated male controls); treated females showed an incidence of 38% (3/8 vs. 0/81 in the untreated female controls).

As part of a larger study of liver carcinogens, Della Porta et al. (1961) treated Syrian golden hamsters (10/sex/dose) with carbon tetrachloride by gavage, weekly for 30 weeks. For the first 7 weeks, 0.25 mL of 0.05% carbon tetrachloride in corn oil was administered; this dose was halved for the remainder of the exposure period. All animals were observed for an additional 25 weeks. All of the 10 hamsters that were killed or dying between weeks 43 and 55 had liver cell carcinomas, compared with 0 in controls.

II.A.4. SUPPORTING DATA FOR CARCINOGENICITY

Carbon tetrachloride was not mutagenic to either *S. typhimurium* or *E. coli* (McCann et al., 1975; Simmon et al., 1977; Uehleke et al., 1976). At low concentrations, carbon tetrachloride did not produce chromatid or chromosomal aberrations in an epithelial cell line derived from rat liver (Dean and Hodson-Walker, 1979). In vivo unscheduled DNA synthesis assays have likewise been negative in male Fischer 344 rats (Mirsalis and Butterworth, 1980; Mirsalis et al., 1982). Carbon tetrachloride produced mitotic recombination and gene conversion in *S. cerevisiae*, but only at concentrations which reduced viability to 10% (Callen et al., 1980). Carbon tetrachloride may be metabolized to reactive intermediates capable of binding to cellular nucleophilic macromolecules. Negative responses in bacterial mutagenicity assays may have been due to inadequate metabolic activation in the test systems.

II.B. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM ORAL EXPOSURE

II.B.1. SUMMARY OF RISK ESTIMATES

Oral Slope Factor -- $1.3E-1$ per (mg/kg)/day

Drinking Water Unit Risk -- $3.7E-6$ per (ug/L)

Extrapolation Method -- Linearized multistage procedure, extra risk

Topic: CARBON TETRACHLORIDE

Drinking Water Concentrations at Specified Risk Levels:

Risk Level	Concentration
E-4 (1 in 10,000)	3E+1 ug/L
E-5 (1 in 100,000)	3E+0 ug/L
E-6 (1 in 1,000,000)	3E-1 ug/L

II.B.2. DOSE-RESPONSE DATA (CARCINOGENICITY, ORAL EXPOSURE)

See Table Document

II.B.3. ADDITIONAL COMMENTS (CARCINOGENICITY, ORAL EXPOSURE)

A geometric mean was calculated from the unit risks derived from the four data sets above. Della Porta et al. (1961) did not report controls in this study, but did give incidence rate for vehicle controls in an earlier study. Animal doses are TWA.

The unit risk should not be used if the water concentration exceeds 3E+3 ug/L, since above this concentration the unit risk may not be appropriate.

II.B.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY, ORAL EXPOSURE)

The studies used were all deficient in some respect, precluding the choice of any one study as most appropriate. For all studies, data from males and females were combined because of the small sample sizes. In the first and second studies (Della Porta et al., 1961; Edwards et al., 1942) one dose was tested. Della Porta et al. (1961) did not report concurrent control incidence. In the NCI (1976a,b) studies, tumor incidence in the mice was virtually 100%, and goodness-of-fit criteria were not satisfied for the multistage model. Tumor incidence in rats in these studies was higher at low doses, presumably because early mortality at higher doses precluded tumor formation. The studies lacked pharmacokinetic data. However, a common biological mechanism, cell death and regeneration, leading to development of the same tumor type, was suggested by observations in all the studies. Since the risk estimates from these data (across 3-4 species and strains) only vary by 2 orders of magnitude, a geometric mean was derived as the risk estimate to accommodate the several study deficiencies.

II.C. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM INHALATION EXPOSURE

II.C.1. SUMMARY OF RISK ESTIMATES

Inhalation Unit Risk -- 1.5E-5 per (ug/cu.m)

Extrapolation Method -- Linearized multistage procedure, extra risk

Air Concentrations at Specified Risk Levels:

Risk Level	Concentration
E-4 (1 in 10,000)	7E+0 ug/cu.m
E-5 (1 in 100,000)	7E-1 ug/cu.m
E-6 (1 in 1,000,000)	7E-2 ug/cu.m

II.C.2. DOSE-RESPONSE DATA FOR CARCINOGENICITY, INHALATION EXPOSURE

The inhalation risk estimates were calculated from the oral

Topic: CARBON TETRACHLORIDE

exposure data in Section II.B.2.

II.C.3. ADDITIONAL COMMENTS (CARCINOGENICITY, INHALATION EXPOSURE)

Inhalation risk was calculated assuming an air intake of 20 cu.m/day and 40% absorption rate by humans (U.S. EPA, 1984). This absorption coefficient was based on 30% inhalation in monkeys, and 30% and 57-65% inhalation in humans. A range of estimates of unit risk for inhalation exposures for the four studies cited above was determined, with 1.5E-5 per (ug/cu.m) calculated as the geometric mean for the unit risk. The unit risk should not be used if the air concentration exceeds 7E+2 ug/cu.m, since above this concentration the unit risk may not be appropriate.

II.C.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY, INHALATION EXPOSURE)

See II.B.4.

II.D. EPA DOCUMENTATION, REVIEW, AND CONTACTS (CARCINOGENICITY ASSESSMENT)

II.D.1. EPA DOCUMENTATION

U.S. EPA. 1984. Health Assessment Document for Carbon Tetrachloride. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH. EPA 600/8/82-001F.

II.D.2. REVIEW (CARCINOGENICITY ASSESSMENT)

The 1984 Health Assessment Document for Carbon Tetrachloride received Agency and external review.
Agency Work Group Review -- 11/12/86, 12/04/86
Verification Date -- 12/04/86

II.D.3. U.S. EPA CONTACTS (CARCINOGENICITY ASSESSMENT)

Jean C. Parker / OHEA -- (202)260-5898
Arthur Chiu / OHEA -- (202)260-5898
=====

Topic: CHLOROFORM

6.0 RANGE OF TOXICITY

6.1 EFFECTIVE DOSE

6.1.1 ADULT

A. INHALATIONAL ANESTHETIC

1. INDUCTION: 2 to 4%
2. MAINTENANCE: 1 to 2%

6.2 MINIMUM LETHAL EXPOSURE

- A. Death has occurred following inhalation of chloroform from a handkerchief placed over the mouth and nose for anesthesia prior to surgery. On post-mortem examination the patient was found to have a diseased heart which was thought to have contributed to the death (Matsuki, 1973).
- B. As little as 10 milliliters in an acute ingestion may result in central nervous system depression and death (Baselt, 1982).
- C. The oral lethal dose was estimated to be 0.5 to 5 grams/kilogram (1 ounce to 1 pint) for an average 70 kilogram person (EPA, 1985).

6.3 MAXIMUM TOLERATED EXPOSURE

A. Experimental human exposure (Proctor & Hughes, 1978).

Concentration (ppm)	Observed Complaints
14000 to 16000	Loss of consciousness
Less than 4100	Disorientation
1000	Dizziness, nausea, fatigue, headache
77 to 237 (prolonged exposure)	Digestive disturbances, lassitude, mental dullness
20 to 70	Milder symptoms

- B. Workers (17/68) exposed regularly to chloroform concentrations of 10 to 200 parts per million for 1 to 4 years had hepatomegaly. In a different group of workers exposed to 50 parts per million, no signs or symptoms were observed (Proctor & Hughes, 1978).
- C. Repeated exposures of 25 parts per million for 7 hours duration per exposure produced minor reversible injury to the kidneys and liver in animals. More severe injury was produced at 50 to 85 parts per million (Proctor & Hughes, 1978).
- D. HEPATOTOXICITY: Chloroform is a less potent hepatotoxin than carbon tetrachloride. Decreasing order of chlorinated hydrocarbon-induced hepatotoxicity (Finkel, 1983).
tetrachlorethane
carbon tetrachloride
1,1,2-trichloroethane
chloroform
perchloroethylene
trichloroethylene
methylene dichloride
1,1,1-trichloroethane

6.4 TOXIC SERUM/PLASMA/BLOOD CONCENTRATIONS

- A. Blood concentrations reported after fatalities have ranged from 1 to 12 milligram percent (Allan et al, 1988; Glusti & Chiarotti, 1981).

Topic: CHLOROFORM

5.5 LD50/LC50

- A. LD50 (ORAL) RAT: 300 mg/kg (ITI, 1985)
- B. LCLo (INHL) HUMAN: 10 ppm/1 year (ITI, 1985)
- C. LCLo (ORAL) RAT: 8000 ppm/4 hours (ITI, 1985)
- D. LCLo (ORAL) MOUSE: 2400 mg/kg (ITI, 1985)
- E. LDLo (ORAL) DOG: 1000 mg/kg (ITI, 1985)
- F. LDLo (IV) DOG: 75 mg/kg (ITI, 1985)
- G. LDLo (SC) RABBIT: 800 mg/kg (ITI, 1985)

6.6 CALCULATIONS

- A. One milligram/liter is approximately equal to 206 parts per million (Clayton & Clayton, 1982).
- B. One part per million is approximately equal to 4.89 milligrams/cubic meter at 25 degrees C and 760 torr (Clayton & Clayton, 1982).
- C. One milligram/cubic meter is equal to 0.205 parts per million (Clayton & Clayton, 1982).

5.7 OTHER

- A. Concentration of chloroform in parts per million were reported in various tissues at autopsy of twin 52 year old males in a case of a double suicide by inhalation (Giusti & Chiarotti, 1981).

Concentration
(in ppm)

	Twin A.R.	Twin G.R.
Brain	156	37
liver	86.2	16.2
blood	40	30
gastric	negative	negative

Topic: CHLOROFORM

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Summary

Environmental Fate/Exposure Summary:

1. Chloroform is likely to enter the environment associated with its use as an industrial solvent, extractant and chemical intermediate as well as from its indirect production in the chlorination of drinking water, municipal sewage and cooling water. The majority of the environmental releases from industrial uses are to the atmosphere; releases to water and land will be primarily lost by evaporation and will end up in the atmosphere. Release to the atmosphere may be transported long distances and will photodegrade with a half-life of a few months. Spills and other releases on land will also leach into the groundwater where it will reside for long periods of time. Chloroform will not be expected to bioconcentrate into the food chain but contamination of food is likely due to its use as an extractant and its presence in drinking water. Major human exposure is from drinking water and ambient air, the latter particularly in the vicinity of industrial sources. Exposure may be via inhalation, ingestion, or by cutaneous contact. (SRC)
PEER REVIEWED

Pollution Sources

Natural Occurring Sources:

1. Plant volatile(1). **PEER REVIEWED** [(1) Graedel TE; Chemical Compounds in the Atmosphere. p.324 Academic Press, New York, NY (1978)]

Artificial Sources:

1. Emissions from its production and indirect production (in the manufacture of ethylene dichloride); chlorination of drinking water, municipal sewage, cooling water in electric power generating plants; produced during the atmospheric photodegradation of trichloroethylenes; auto exhaust; from its use as an extractant or solvent, chemical intermediate, dry cleaning agent, fumigant ingredient, in fluorocarbon 22 production, synthetic rubber production (1-2). **PEER REVIEWED** [(1) USEPA; Health Assessment Document for Chloroform. External Review Draft USEPA-600/8-84-004A p. 3-4 to 3-28 (1984) (2) IARC; Some Halogenated Hydrocarbons 20: 402-5 (1979)]
2. Release of chloroform to the environment (air) in 1980: pulp and paper bleaching, 12,100 kkg; chlorination of water, 3,245 kkg; pharmaceutical extractions, 1,525 kkg; automobile exhausts, 965 kkg; atmospheric decomposition of trichloroethylene, 450 kkg; chloroform production, 370 kkg; production of vinyl chloride monomer, 187 kkg; transportation and storage loss 177 kkg; production of F-22, 150 kkg; use as fumigant, 38 kkg. **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982.,p. 3-1]
3. Release of chloroform to the environment (water) in 1980: pulp and paper bleaching, 400 kkg; pharmaceutical extractions, 275 kkg; chlorination of water, 221 kkg;

Topic: CHLOROFORM

chloroform production, 14 kkg; production of vinyl chloride monomer, 2 kkg. **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982.,p. 3-1

4. Release of chloroform to the environment (land) in 1980: pharmaceutical extractions, 290 kkg; production of vinyl chloride monomer, 200 kkg. **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982.,p. 3-1

Environmental Fate

Environmental Fate:

1. TERRESTRIAL FATE: When spilled on land, chloroform would be expected to evaporate rapidly into the atmosphere due to its high vapor pressure. It is poorly adsorbed to soil, especially soil with low organic carbon content such as subsoils and can leach into the groundwater.(SRC) **PEER REVIEWED**
2. AQUATIC FATE: When released into water, chloroform will be primarily lost by evaporation into the atmosphere. Laboratory experiments have measured the half-life for evaporation to be several hours and modeling studies suggest that the volatilization half-life is 36 hours in a river, 40 hours in a pond and 9-10 days in a lake. Field monitoring data suggest the half-life of chloroform to be 1.2 days in the Rhine River and 31 days in a lake in the Rhine basin(1). Chloroform from a municipal treatment plant injected into an estuarine arm of Chesapeake Bay entirely disappeared within 4 km in the spring and within 11 km in winter under ice, and the decrease in concentration cannot be entirely due to dilution(2). Little chloroform will be adsorbed to sediment.(SRC) **PEER REVIEWED** [(1) Zoeteman BCJ et al; Chemosphere 9: 231-49 (1980) (2) Helz GR, Hsu RY; Limnol Oceanogr 23: 858-69 (1978)
3. ATMOSPHERIC FATE: Chloroform released to the atmosphere will degrade by reaction with hydroxyl radicals with a half-life of 80 days. It will be transported long distances and will partially return to earth in precipitation. (SRC) **PEER REVIEWED**

Environmental Transformations

Biodegradation:

1. There are conflicting data on the biodegradation of chloroform. Slow but substantial biodegradation apparently can occur when the proper microbial populations exist and are acclimated to the chemical. Under aerobic conditions, some investigators report little or no degradation in up to 25 wk (1,2,3) while others report considerable degradation: 49% in 7 days, 100% in 28 days; however, a large fraction of this loss was due to volatilization (4); 25% in 14 days(5), and 67% in 24 days(6). Under anaerobic conditions, slow degradation has been reported after acclimation(7) and degradation was reported in river bank (31% in <1 yr) and dune (100% in <3 mo) infiltration(8).

Topic: CHLOROFORM

However, another investigator reported no degradation in 27 weeks in aquifer material in the laboratory(9). **PEER REVIEWED** [(1) Bouwer EJ et al; Environ Sci Technol 15: 569 (1981) (2) Kawasaki M; Ecotox Environ Safety 4: 444-54 (1980) (3) Heukelekian H, Rand MC; J Water Pollut Control Assoc 29: 1040-53 (1955) (4) Tabak HH et al; J Water Pollut Control Fed 53: 1503-18 (1981) (5) Bouwer EJ et al; Water Res 15: 151-9 (1981) (6) Flathman PE, Dahlgran JR; Environ Sci Technol 16:130 (1982) (7) Bouwer EJ, McCarty PL; Appl Environ Microbiol 45: 1286-94 (1983) (8) Zoeteman BCJ et al; Chemosphere 9: 231-49 (1980) (9) Wilson JT et al; Devel Indust Microbiol 24: 225-33 (1983)]

Abiotic Degredation:

1. Chloroform has a negligible rate of hydrolysis(1). Photodegradation does not appear to be a significant loss process in aquatic systems(3). The key photochemical reaction in the atmosphere is the reaction of chloroform with photochemically produced hydroxyl radicals. The half-life for this reaction is 80 days which amounts to a 0.9% loss per sunlit day(4,5). This value compares reasonably well with the 23 week half-life measured when a flask of chloroform filled with ambient air was exposed to sunlight outdoors(7). Chloroform is more reactive in photochemical smog situations (presence of NOx) with an avg degradation rate of 0.8%/hr(6). **PEER REVIEWED** [(1) Mabey W, Mill T; J Phys Chem Ref Data 7: 383-415 (1978) (2) Dilling WL et al; Environ Sci Technol 9: 833-8 (1975) (3) Jensen S, Rosenberg R; Water Res 9: 659-61 (1975) (4) Hampson RF; Chemical Kinetics and Photochemical Data Sheets for Atmospheric reactions. USDOT report FAA-EE-80-17 (1980) (5) Singh HB et al; Atmos Environ 15: 601-12 (1981) (6) Dimitriades B, Joshi SB; Inter Conf on Photochemical oxidant pollution and its control. EPA-600/3-77-001b p 705-11 (1977) (7) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975)]

Environmental Transport

Bioconcentration:

1. Little or no tendency to bioconcentrate; log bioconcentration factor <1 for 4 species of fish(1,2). **PEER REVIEWED** [(1) Barrows ME et al; Dyn Exposure Hazard Assess Toxic Chem Ann Arbor, MI: Ann Arbor Press p 379-92 (1980) (2) Anderson DR, Lusty EB; Acute Toxicity and Bioaccumulation of Chloroform to Four Species of Fresh Water Fish. NUREG/CR-089 Richland, WA: Pacific NW Labs p 8-26 (1980)]
2. After a 14-day exposure to radiolabeled chloroform, the bluegill bioconcentrated chloroform by a factor of 6 times. **PEER REVIEWED** [USEPA; Ambient Water Quality Criteria Doc: Chloroform p.B-2 (1980) EPA 440/5-80-033]

Soil Adsorption/Mobility:

1. Chloroform is adsorbed most strongly to peat moss, less strongly to clay, very slightly to dolomite limestone and not at all to sand(1). The KOC values measured for 2 soils was 34; however, 3 other soils with the lowest organic carbon content in the same study gave no appreciable

Topic: CHLOROFORM

adsorption(3). Field experiments in which chloroform was injected into an aquifer and the concentration in a series of observation wells determined, demonstrated that chloroform is very poorly retained by aquifer material (retardation factor 2-4), less so than other C1- and C2-halogenated compounds studied(2,3). Laboratory percolation studies with a sandy soil gave similar results (retardation factor <1.5)(4). **PEER REVIEWED** [(1) Dilling WL et al; Environ Sci Technol 9: 833-8 (1975) (2) Roberts PV et al; Water Res 16: 1025-35 (1982) (3) Hutzler NJ et al; Amer Chem Soc 186th Mtg Div Environ Chem Preprint 23: 499-502 (1983) (4) Wilson JT et al; J Environ Qual 10: 501-6 (1981)]

Volatilization from Water/Soil:

- Four laboratory studies of the evaporation of chloroform from water gave half lives of 3-5.6 hours with moderate mixing conditions(1-4). A modelling study of chloroform predicts a volatilization half-life of 36 hr in a river, 40 hr in a pond and 9-10 days in a lake(5). A volatile compound such as chloroform would be expected to volatilize rapidly from near surface soils at spill sites(SRC). **PEER REVIEWED** [(1) Smith JH et al; Environ Sci Technol 14: 190-6 (1980) (2) Rathbun RE, Tai DY; Water Res 15: 243-50 (1981) (3) Lyman WJ et al; Handbook of Chemical Property Estimation Methods. Environmental Behavior of Organic Cmpds. New York, NY: McGraw Hill 960 pp (1982) (4) Robert PV, Dandliker PG; Environ Sci Technol 17: 484-9 (1983) (5) USEPA; Health Assessment Document for Chloroform. External Review Draft. EPA-600/8-84-004A p 3-37 to 3-40 (1984)]

Environmental Concentrations

Water Concentrations:

- SEAWATER: Pacific Ocean <0.05 parts per trillion (1); Northeast Atlantic Ocean 4-13 parts per trillion, avg 8 parts per trillion (2); Point Reyes (near shore) 2.8 ppb(3). Gulf of Mexico 4-200 ppb(4). **PEER REVIEWED** [(1) Singh HB et al; Atmospheric distributions, sources and sinks of selected halocarbons, hydrocarbons, SF6 and NO2 EPA-600/3-79-107 134 p (1979) (2) Murray AJ, Riley JP; Nature 242: 37-8 (1973) (3) Singh HB et al; J Air Pollut Control Assoc 27: 332-6 (1977) (4) Sauer TC Jr; Org Geochem 3: 91-101 (1981)]
- DRINKING WATER: US Federal Survey of Finished Waters find a 70.3% occurrence in groundwater supplies(9); 30 Canadian Treatment Facilities (treated water) 35 ppb avg summer, 21 ppb avg winter (93-97% pos, 110 ppb max - raw water had 2-6 ppb avg concn)(1); US 5 City Survey 1-301 ppb(2); Drinking Water wells in NY & NJ 67-490 ppb(3); Other cities report values between 0-190 ppb(4-7) with the values highest in summer and lowest in winter(4) and increasing on contact with residual chlorine(7). National Organic Reconnaissance Survey (80 US water supplies, 1975) 0-311 ppb, National Organics Monitoring Survey (113 finished water supplies, 1976-1977) 32-68 ppb median of positive supplies, 92-100% pos(8). **PEER REVIEWED** [(1)

Topic: CHLOROFORM

- Otson R et al; J Assoc Off Analyt Chem 65: 1370-4 (1982)
 (2) Coleman WE et al; Analysis and Identification of Organic Substances in Water; L Keith Ed, Ann Arbor, MI: Ann Arbor Press p 305-27 (1976) (3) Burmaster DE; Environ 24: 6-13, 33-6 (1982) (4) Kasso WB, Wells MR; Bull Environ Contam Toxicol 27: 295-302 (1981) (5) Smith VL et al; Environ Sci Technol 14: 190-6 (1980) (6) Williams DT et al; Chemosphere 11: 263-76 (1982) (7) Uden PC, Miller JW; J Amer Water Works Assoc 75: 524-7 (1983) (8) Symon JM et al; J Amer Water Works Assoc (1982) (9) Dyksen JE, Hess AF III; J Amer Water Works Assoc p 394-403 (1982)
3. GROUNDWATER: Contaminated wells in NY and NJ 67-490 ppb(1); Groundwater in the Netherlands 5 ppb(2). **PEER REVIEWED** [(1) Burmaster DE; Environ 24: 6-13, 33-6 (1982) (2) Zoeteman BCJ et al; Chemosphere 9: 231-49 (1980)
 4. SURFACE WATER: Ohio River Basin (1980-81, 11 stations, 4972 samples) 72% pos, 832 samples 1-10 ppb, 27 samples >10 ppb(1). 14 Heavily Industrialized River Basins in US (204 sites) 1-120 ppb, 79% pos(2). US - 5 industrial cities 9-31 ppb avg, 394 ppb max(3). 11 Water Utilities on Ohio River 0.8 ppb avg, 4.8 ppb max, 68% pos(4); Delaware River and tributaries - 30 sites 93% of samples >1 ppb(5); Ohio River and tributaries 232 samples 0.1-22 ppb, 72% pos(6); Lakes Erie, Michigan and Huron 1-30 ppb, 11 of 13 sites pos(7). **PEER REVIEWED** [(1) Ohio R Valley Water Sanit Comm; Assessment of water quality conditions 1980-81. Cincinnati, OH table 13 (1982) (2) Ewing BB et al; Monitoring to detect previously unrecognized pollutants in surface waters. USEPA-560/6-77-015 p. 75 (1977) (3) Pellizzari ED et al; Formulation of preliminary assessment of halogenated organic compounds in man and environmental media. USEPA-560/13-79-006 p. 469 (1979) (4) Ohio R Valley Water Sanit Comm; Water treatment process modifications for trihalomethane control and organic substances in the Ohio River. EPA grant no. R-804615 Cincinnati, OH (1979) (5) DeWalle FB, Chain ESK; Proc Ind Waste Conf 32: 908-19 (1978) (6) Ohio R Valley Water Sanit Comm; Assessment of Water Quality Conditions, Ohio River Mainstream 1978-9, Cincinnati, OH p T-53 (1980) (7) Konasewich D et al; Status report on organic and heavy metal contaminants in the Lakes Erie, Michigan, Huron and Superior basins, Great Lakes Qual Board 373p (1978)
 5. RAIN AND SNOW: Detected in rain and snow in Japan(1,2) and 250 parts per trillion rain in West Los Angeles(3). **PEER REVIEWED** [(1) Kato T et al; Yokohama Kokuritsu Daigaku Kankyo Kagaku Kenkyu Senta Kiyo 6: 11-20 (1980) (2) Morita M et al; Kokyo Toritsu Eisei Kenkyusho Kenkyu Nempo 25: 399-403 (1974) (3) Kawamura K, Kaplan IR; Environ Sci Technol 17: 497-501 (1983)

Effluents Concentrations:

1. Rubber and chemical companies - Louisville, KY 22 ppm max(1). Industries whose wastewater levels of chloroform exceed a mean level of 500 ppb are auto and other laundries, aluminum forming, pharmaceuticals, and pulp and

Topic: CHLOROFORM

paper mills; the pharmaceutical industry contributes the largest amount of chloroform with mean and max wastewater concn of 49 and 280 ppb, respectively (2). Auto exhausts typically 27 ug/cm³ (1). **PEER REVIEWED** [(1) USEPA; Ambient Water Quality Criteria for Chloroform. EPA-440/5-80-033 pp C-1 to C-5 (1980) (2) USEPA; Treatability Manual. EPA-600/2-82-001a pp I.12.3-1 to I.12.3-5

Sediment/Soil Concentrations:

1. Not detected in sediment at an industrial location on US river(1). Not detected in Back River sediment off Baltimore(2). **PEER REVIEWED** [(1) Jungclaus GA et al; Environ Sci Technol 12: 88-96 (1978) (2) Helz GR, Hsu RY; Limnol Oceanogr 23: 858-69 (1978)

Atmospheric Concentrations:

1. US RURAL/REMOTE - 532 samples 40 ppt avg(1); Northern Hemisphere - background 17.1 parts per trillion avg(2) US URBAN/SUBURBAN - 1739 samples 72 parts per trillion avg(1); US SOURCE DOMINATED AREAS - 306 samples 820 parts per trillion avg(1). 11 highly industrialized US locations 0-10.9 ppb(3); 10 US cities 32-703 ppt avg, 5112 parts per trillion max(4-6); 3 areas in NJ 710 parts per trillion avg, 15% pos avg of pos samples approx 4 ppb(7). **PEER REVIEWED** [(1) Brodzinsky R, Singh HB; Volatile organic chemicals in the atmosphere: an assessment of available data. SRI Inter EPA contract 68-02-3452 Menlo Park, CA (1982) (2) Singh HB; Geophys Res Lett 4: 101-4 (1977) (3) Pellizzari ED; Quantification of chlorinated hydrocarbons in previously collected air samples. EPA-450/3-78-112 (1978) (4) Singh HB et al; Atmos Environ 15: 601-12 (1981) (5) Singh HB et al; Atmospheric measurements of selected hazardous organic chemicals. EPA-600/53-81-032 (1981) (6) Singh HB et al; Environ Sci Technol 16: 372-80 (1982) (7) Bozzelli JW, Kebbekus BB; J Environ Sci Health 17: 693-713 (1982)

Food Survey Results:

1. In pilot market basket survey of 4 food groups at 5 sites, the results for chloroform were: dairy composite 17 ppb (1 of 5 sites), meat composite - not detected; oil and fat composite - trace (1 of 5 sites); beverage composite 6-32 ppb (4 of 5 sites); high values for individual foods were soft drinks 9-178 ppb; butter 56 ppb; cheese 15-17 ppb; mayonaise 34 ppb(1). England: various samples of food including dairy products, eggs, bread, meat, oils and fats, beverages, fruits and vegetables 0.4-33 ppb, cheese, butter and tea were high(2). Residues were found in fumigated sorghum, barley and corn but generally disappeared within 60 days when aired at 17 deg C(3). **PEER REVIEWED** [(1) Entz RC et al; J Agric Food Chem 30: 846-9 (1982) (2) McConnell G et al; Endeavor 34: 13-8 (1975) (3) IARC; Monograph. Some Halogenated Hydrocarbons 20: 407 (1979)
2. Small amounts of chloroform have been found in tomatoes, muscat grapes and milk and cream. The origin of chloroform in these items is difficult to establish: it might derive

HSDB

Topic: CHLOROFORM

from its use as a solvent for fat extraction of feed or as a pesticide, but vegetable biosynthesis cannot be disregarded. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. VI 62 (1972)

Fish/Seafood Concentrations:

1. Great Britain: various species of marine fish 5-851 ppb(1,2); marine invertebrates 2-1040 ppb(1,2). **PEER REVIEWED** [(1) Dickson AG, Riley JP; Marine Pollut Bull 7: 167-9 (1976) (2) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975)

Animal Concentrations:

1. England: grey seal 7.6-22 ppb (blubber), 0-12 ppb (liver); marine and freshwater birds 0.7-65 ppb(1). **PEER REVIEWED** [(1) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975)

Milk Concentrations:

1. US - 4 urban sites: mothers' milk 7 of 8 samples pos detected, not quantified. **PEER REVIEWED** [Pellizzari ED et al; Bull Environ Contam Toxicol 28: 322-8 (1982)

Human Exposure

Probable Routes of Human Exposure:

1. Humans are exposed to chloroform primarily from chlorinated drinking water supplies although exposure from air which is typically one tenth of that from water would be comparable in source dominated areas. Although data for chloroform in food is fragmentary, the data suggest that intake from this source may be substantive. (SRC) **PEER REVIEWED**
2. May be via inhalation, ingestion, or by cutaneous contact. **PEER REVIEWED** [Schroeder HG; Br J Anaesth 37: 972 (1965)

Average Daily Intake:

1. AIR INTAKE (assume typical concentration 72 ppt) 7.1 ug. WATER INTAKE (assume typical concentration of 32-68 ppb) 64-136 ug; FOOD INTAKE - insufficient data. (SRC) **PEER REVIEWED**
2. ... Although data are scarce, maximum exposure /to chloroform/ due to ingestion of food has been estimated at 0.04 mg/day. **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982., p. 4-1

Probable Exposures:

1. Plant manufacturing medicinal 23-128 ppm; Plant manufacturing film (5 year survey) 7-170 ppm, 47 ppm avg although 2 day sampling by another method gave 30-585 ppm; Pharmaceutical plant in Poland 2-205 ppm(1). **PEER REVIEWED** [(1) NIOSH; Criteria for a recommended standard - occupational exposure to chloroform. NIOSH 75-114 p 57-59 (1974)
2. 1974 NATIONAL OCCUPATIONAL HAZARD SURVEY NOTED THAT WORKERS PRIMARILY EXPOSED TO CHLOROFORM WERE THOSE IN

Topic: CHLOROFORM

HOSPITALS, DEPT STORES & IN BIOL PRODUCTS, INTERNAL COMBUSTION ENGINES, BUILDING PAPER & BOARD INDUST. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V20 407 (1979)

3. The chlorination of drinking water represents the largest source of human exposure to chloroform in the United States, generally ranging from 0.02 - 0.2 mg/day. ... Inhalation exposure is thought to be low; however, somewhat higher exposures are expected in industrialized and urban areas. Another exposure route that may be of significance is absorption of chloroform through the skin. Swimmers may receive up to 1.1 mg/day via this route. **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S. Environmental Protection Agency, July 1982., p. 4-1
4. Shell Chem Co, Rocky Mountain Arsenal - mean TWA were 2.6, 0.4 and 0.2 ppm for production operators, drummers/bottle fillers and maintenance/utility personnel (pesticide plant)(1). Polish pharmaceutical plant 2 - 205 ppm(1); police forensic lab - 8 hr TWA - 15.8 ppm (range 2.6-46.4 ppm)(1); film manufacturing plant using a solvent containing 22% chloroform 1968-72 - 7-170 ppm (mean 47 ppm, 79 samples)(1). **PEER REVIEWED** [(1) Santodonato J et al; Monograph on Human Exposure to Chemicals in the Workplace: Chloroform. NCI contract N01-CP-26002-03, Syracuse Research Corp. July (1985)

Body Burdens:

1. Old Love Canal, Niagara Falls, NY - 9 individuals: breath 3.9-95 ug/cu m, 26 ug/cu m median; blood 1.1-3.0 ng/ml, 1.6 ng/ml median; urine 460-1500 ng/l, 860 ng/l median(1). England - 8 individuals: body fat 5-68 ppb; var organs 1-10 ppb(2); US - 4 urban sites: mothers' milk 7 of 8 samples pos, detected, not quantified(3). **PEER REVIEWED** [(1) Barkley J et al; Biomed Mass Spectrom 7: 139-47 (1980) (2) McConnell G et al; Endeavour 34: 13-8 (1975) (3) Pellizzari ED et al; Bull Environ Contam Toxicol 28: 322-8 (1982)

HSDB

Topic: CHLOROFORM

EXPOSURE STANDARDS & REGULATIONS

Standards & Regulations

Allowable Tolerances:

1. The insecticide chloroform is exempted from the requirement of a tolerance for residues, when used as a fumigant after harvest for the following grains: Barley, corn, oats, popcorn, rice, rye, sorghum (milo), wheat. **PEER REVIEWED** [40 CFR 180.1009 (7/1/88)]
2. Chloroform is exempted from the requirement of a tolerance when used as a solvent in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops only. **PEER REVIEWED** [40 CFR 180.1001 (d) (7/1/88)]

Occupational Permissible Levels

OSHA Standards:

1. Meets criteria for OSHA medical records rule. **PEER REVIEWED** [29 CFR 1910.20 (7/1/88)]
2. Ceiling value of 50 ppm (240 mg/cu m). /Transitional limits/ must continue to be achieved by any combination of engineering controls, work practices and personal protective equipment during the phase-in period, Sept 1 1989 through Dec 30, 1992. **PEER REVIEWED** [54 FR 2920 (1/19/89)]
3. 8 hr Time-Weighted avg: 2 ppm (9.78mg/cu m). /Final rule limits/ shall be achieved by any combination of engineering controls, work practices and personal protective equipment during the phase-in period, Sept 1, 1989 through Dec 30, 1992. Final rule limits become effective Dec 31, 1992. **PEER REVIEWED** [54 FR 2920 (1/19/89)]

NIOSH Recommendations:

1. 2 ppm 60-min (ceiling). Potential human carcinogen ... **PEER REVIEWED** [NIOSH. Pocket Guide to Chemical Hazards. 2nd Printing. DHHS (NIOSH) Publ. No. 85-114. Washington, D.C.: U.S. Dept. of Health and Human Services, NIOSH/Supt.of Documents, GPO, February 1987. 80]

Threshold Limit Values:

1. Time Weighted Avg (TWA) 10 ppm, 49 mg/cu m (1986) **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 16]
2. A2. A2= Suspected human carcinogen. (1986) **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 16]

Other Standards and Regulations

Water Standards:

1. Designated as a hazardous substance under section 311(b)(2)(A) of the Federal Water Pollution Control Act and further regulated by the Clean Water Act Amendments of

Topic: CHLOROFORM

- 1977 and 1978. These regulations apply to discharges of this substance. **PEER REVIEWED** [40 CFR 116.4 (7/1/88)]
2. Toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations. /Halomethanes/ **PEER REVIEWED** [40 CFR 401.15 (7/1/88)]
 3. The national primary drinking water maximum contaminant level (MCL) for Chloroform is 0.10 mg/l. /Total trihalomethanes/ **PEER REVIEWED** [40 CFR 141.12 (7/1/88)]
 4. Based on the consumption of 2 l of drinking water and consumption of 6.5 g of fish and shellfish, the corresponding cancer risk levels and criteria are 1X10⁻⁷: 0.019 ug/l; 1X10⁻⁶: 0.19 ug/l; 1X10⁻⁵: 1.90 ug/l. Based on consumption of fish and shellfish only, the corresponding cancer risk levels and criteria are 1X10⁻⁷: 1.57 ug/l; 1X10⁻⁶: 15.7 ug/l; 1X10⁻⁵: 157 ug/l. **PEER REVIEWED** [USEPA; Ambient Water Quality Criteria Doc: Chloroform E.39 (1980) EPA 440/5-80-033]

Atmospheric Standards:

1. This action promulgates standards of performance for equipment leaks of Volatile Organic Compounds (VOC) in the Synthetic Organic Chemical Manufacturing Industry (SOCMI). The intended effect of these standards is to require all newly constructed, modified, and reconstructed SOCMI process units to use the best demonstrated system of continuous emission reduction for equipment leaks of VOC, considering costs, non air quality health and environmental impact and energy requirements. Chloroform is produced, as an intermediate or final product, by process units covered under this subpart. **PEER REVIEWED** [40 CFR 60.489 (7/1/89)]

EPCRA Reportable Quantities:

1. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 10 lb or 4.54 kg. The toll free number of the NRC is (800) 424-8802; In the Washington D.C. metropolitan area (202) 426-2675. The rule for determining when notification is required is stated in 40 CFR 302.4 (section IV. D.3.b). **PEER REVIEWED** [54 FR 33419 (8/14/89)]

SCA Requirements:

1. Pursuant to section 8(d) of TSCA, EPA promulgated a model Health and Safety Data Reporting Rule. The section 8(d) model rule requires manufacturers, importers, and processors of listed chemical substances and mixtures to submit to EPA copies and lists of unpublished health and safety studies. Methane, trichloro- is included on this list. **PEER REVIEWED** [40 CFR 712.30 (7/1/88)]

CRA Requirements:

1. As stipulated in 40 CFR 261.33, when chloroform, as a commercial chemical product or manufacturing chemical intermediate or an off-specification commercial chemical product or a manufacturing chemical intermediate, becomes

HSDB

Topic: CHLOROFORM

a waste, it must be managed according to Federal and/or State hazardous waste regulations. Also defined as a hazardous waste is any residue, contaminated soil, water, or other debris resulting from the cleanup of a spill, into water or on dry land, of this waste. Generators of small quantities of this waste may qualify for partial exclusion from hazardous waste regulations (40 CFR 261.5).
PEER REVIEWED [40 CFR 261.33 (7/1/88)]

FIFRA Requirements:

1. The insecticide chloroform is exempted from the requirement of a tolerance for residues, when used as a fumigant after harvest for the following grains: barley, corn, oats, popcorn, rice, rye, sorghum (milo), wheat.
PEER REVIEWED [40 CFR 180.1009 (7/1/88)]
2. Chloroform is exempted from the requirement of a tolerance when used as a solvent in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops only. **PEER REVIEWED** [40 CFR 180.1001 (d) (7/1/88)]

FDA Requirements:

1. FDA BANNED USE OF CHLOROFORM AS INGREDIENT (ACTIVE OR INACTIVE) IN HUMAN DRUG & COSMETIC PRODUCTS AS OF JULY 29, 1976. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V20 404 (1979)]
2. Bottled water shall, when a composite of analytical units of equal volume from a sample is examined by the methods described in paragraph (d)(1)(ii) of this section, meet the standards of chemical quality and shall not contain total trihalomethanes in excess of 0.10 mg/l. /Total trihalomethanes/ **PEER REVIEWED** [21 CFR 103.35 (4/1/88)]
3. Chloroform is an indirect food additive for use only as a component of adhesives. **PEER REVIEWED** [21 CFR 175.105 (4/1/88)]
4. Chloroform is an indirect food additive polymer for use as a basic component of single and repeated use food contact surfaces. Polycarbonate resins may be safely used as articles or components of articles or components of articles for use in producing, manufacturing, packing processing, preparing, treating, packaging, transporting, with prescribed conditions. Optional adjuvant substances required in the production of resins may include chloroform. **PEER REVIEWED** [21 CFR 177.1580 (4/1/88)]

IRIS

Topic: CHLOROFORM

A study in rats, using only one treatment dose (Palmer et al., 1979), identified 60 mg/kg/day by gavage as a LOAEL for decreased weight gain, plasma cholinesterase and relative liver weight. Other data in the literature (Jorgenson et al., 1982) also indicate changes in liver fat to be treatment related.

I.A.5. CONFIDENCE IN THE ORAL RfD

Study -- Medium
Data Base -- Medium
RfD -- Medium

The critical study (Heywood et al., 1979) was of chronic duration, used a fairly large number of dogs, and measured multiple endpoints; however, only two treatment doses were used and no NOEL was determined. Therefore, confidence in the study is rated medium. Confidence in the data base is considered medium to low; several studies support the choice of a LOAEL, but a NOEL was not found. Confidence in the RfD is also considered medium to low.

I.A.6. EPA DOCUMENTATION AND REVIEW OF THE ORAL RfD

U.S. EPA. 1985. Drinking Water Criteria Document for Trihalomethanes. Office of Drinking Water, Washington, DC. (External Review Draft)

The 1985 Drinking Water Criteria Document for Trihalomethanes is currently undergoing Agency review.

Agency Work Group Review -- 12/02/85, 05/15/86

Verification Date -- 12/02/85

I.A.7. EPA CONTACTS (ORAL RfD)

Nancy Chiu / OST -- (202)260-7587
Michael L. Dourson / OHEA -- (513)569-7533

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE
RfC)

Substance Name -- Chloroform

CASRN -- 67-66-3

Primary Synonym -- Trichloromethane

A risk assessment for this substance/agent is under review by an EPA work group.

=====

IRIS

Topic: CHLOROFORM

CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Chloroform

CASRN -- 67-66-3

Primary Synonym -- Trichloromethane

Last Revised -- 09/01/92

The Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Please refer to Background Document 1 in Service Code 5 for an elaboration of these concepts. RfDs can also be derived for the noncarcinogenic health effects of compounds which are also carcinogens. Therefore, it is essential to refer to other sources of information concerning the carcinogenicity of this substance. If the U.S. EPA has evaluated this substance for potential human carcinogenicity, a summary of that evaluation will be contained in Section II of this file when a review of that evaluation is completed.

I.A.1. ORAL RfD SUMMARY

See Table Document

I.A.2. PRINCIPAL AND SUPPORTING STUDIES (ORAL RfD)

Heywood, R., R.J. Sortwell, P.R.B. Noel, et al. 1979.

Safety evaluation of toothpaste containing chloroform. III.

Long-term study in beagle dogs. J. Environ. Pathol.

Toxicol. 2: 835-851.

In this study beagle dogs were administered chloroform in a toothpaste base (0.5 mL of toothpaste base/kg/day) in gelatin capsules. A control group composed of 16 males and 16 females received the vehicle, and additional control groups of eight animals/sex were administered an alternative toothpaste or were left untreated. Experimental groups of eight male and eight female dogs received 15 or 30 mg chloroform/kg/day for 6 days/week. Treatment was continued for 7.5 years. Fatty cysts, considered to be treatment-related, were observed in livers of some dogs in both treatment groups. Nodules of altered hepatocytes were considered treatment-related but not dose-dependent. A dose-related increase in SGPT levels was noted and a less marked increase in SGOT was noted in the high-dose animals. The LOAEL was determined to be 12.9 mg/kg/day, and an RfD was set at 0.01 mg/kg/day.

I.A.3. UNCERTAINTY AND MODIFYING FACTORS (ORAL RfD)

UF -- Uncertainty factors of 10 each were applied to the LOAEL of 12.9 mg/kg/day to account for the interspecies conversion, protection of sensitive human subpopulations, and concern that the effect seen was a LOAEL and not a NOEL.

MF -- None

I.A.4. ADDITIONAL COMMENTS (ORAL RfD)

Chloroform is considered to be highly fetotoxic, but not teratogenic (Schwetz et al., 1974; Thompson et al., 1974).

IRIS

Topic: CHLOROFORM

I. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Chloroform

CASRN -- 67-66-3

Primary Synonym -- Trichloromethane

Last Revised -- 03/01/91

Section II provides information on three aspects of the carcinogenic risk assessment for the agent in question; the U.S. EPA classification, and quantitative estimates of risk from oral exposure and from inhalation exposure. The classification reflects a weight-of-evidence judgment of the likelihood that the agent is a human carcinogen. The quantitative risk estimates are presented in three ways. The slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per (mg/kg)/day. The unit risk is the quantitative estimate in terms of either risk per ug/L drinking water or risk per ug/cu.m air breathed. The third form in which risk is presented is a drinking water or air concentration providing cancer risks of 1 in 10,000, 1 in 100,000 or 1 in 1,000,000. Background Document 2 (Service Code 5) provides details on the rationale and methods used to derive the carcinogenicity values found in IRIS. Users are referred to Section I for information on long-term toxic effects other than carcinogenicity.

II.A. EVIDENCE FOR CLASSIFICATION AS TO HUMAN CARCINOGENICITY

II.A.1. WEIGHT-OF-EVIDENCE CLASSIFICATION

Classification -- B2; probable human carcinogen

Basis -- Based on increased incidence of several tumor types in rats and three strains of mice

II.A.2. HUMAN CARCINOGENICITY DATA

Inadequate. There are no epidemiologic studies of chloroform itself. Chloroform and other trihalomethanes are formed from the interaction of chlorine with organic material found in water. Several ecological and casecontrol studies of populations consuming chlorinated drinking water in which chloroform was the major chlorinated organic show small significant increases in the risk of rectal bladder or colon cancer on an intermittent basis. Many other suspected carcinogens were also present in these water supplies.

II.A.3. ANIMAL CARCINOGENICITY DATA

Sufficient. Chloroform has been tested for carcinogenicity in eight strains of mice, two strains of rats and in beagle dogs. In a gavage bioassay (NCI, 1976), Osborne-Mendel rats and B6C3F1 mice were treated with chloroform in corn oil 5 times/week for 78 weeks. Fifty male rats received 90 or 125 mg/kg/day; females initially were treated with 125 or 250 mg/kg/day for 22 weeks and 90 or 180 mg/kg/day thereafter. Male mice received 100 or 200, raised to 150 or 300 mg/kg/day at 18 weeks; females were dosed with 200 or 400, raised to 250 or 500 mg/kg/day. A significant increase in kidney epithelial tumors was observed in male rats and highly significant increases in hepatocellular carcinomas in mice of both sexes. Liver nodular hyperplasia was observed in low-dose male mice not developing hepatocellular carcinoma. Hepatomas have also developed in female strain A mice and NLC mice gavaged with chloroform (Eschenbrenner and Miller, 1945; Rudali, 1967).

Topic: CHLOROFORM

Jorgenson et al. (1985) administered chloroform (pesticide quality and distilled) in drinking water to male Osborne-Mendel rats and female B6C3F1 mice at concentrations of 200, 400, 900, and 1800 mg/L for 104 weeks. These concentrations were reported by the author to correspond to 19, 38, 81, and 160 mg/kg/day for rats and 34, 65, 130, and 263 mg/kg/day for mice. A significant increase in renal tumors in rats was observed in the highest dose group. The increase was dose related. The liver tumor incidence in female mice was not significantly increased. This study was specifically designed to measure the effects of low doses of chloroform.

Chloroform administered in toothpaste was not carcinogenic to male C57B1, CBA, CF-1 or female ICI mice or to beagle dogs. Male ICI mice administered 60 mg/kg/day were found to have an increased incidence of kidney epithelial tumors (Roe et al., 1979; Heywood et al., 1979). A pulmonary tumor bioassay in strain A/St mice was negative as was one in which newborn C57X DBA2/F1 mice were treated s.c. on days 1 to 8 of life (Theiss et al., 1977; Roe et al., 1968).

II.A.4. SUPPORTING DATA FOR CARCINOGENICITY

The majority of tests for genotoxicity of chloroform have been negative. These negative findings include covalent binding to DNA, mutation in Salmonella, a Drosophila sex-linked recessive, tests for DNA damage a micronucleus test, and transformation of BHK cells. By contrast one study demonstrated binding of radiolabeled chloroform to calf thymus DNA following metabolism by rat liver microsomes (DiRenzo, 1982). Chloroform caused mitotic recombination in Saccharomyces (Callen et al., 1980) and sister chromatid exchange in cultured human lymphocytes and in mouse bone marrow cells exposed in vivo (Morimoto and Koizumi, 1983). The carcinogenicity of chloroform may be a function of its metabolism to phosgene, which is known to cross-link DNA. A host-mediated assay using mice indicated that chloroform was metabolized in vivo to a form mutagenic to Salmonella strain TA1537. Likewise urine extracts from chloroform-treated mice were mutagenic (Agustin and Lim-Sylianco, 1978). Chloroform administered to mice in drinking water promoted growth and metastasis of Ehrlich ascites cells injected i.p. (Capel et al., 1979).

II.B. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM ORAL EXPOSURE

II.B.1. SUMMARY OF RISK ESTIMATES

Oral Slope Factor -- $6.1E-3$ per (mg/kg)/day

Drinking Water Unit Risk -- $1.7E-7$ per (ug/L)

Extrapolation Method -- Linearized multistage procedure, extra risk

Drinking Water Concentrations at Specified Risk Levels:

Risk Level	Concentration
E-4 (1 in 10,000)	$6E+2$ ug/L
E-5 (1 in 100,000)	$6E+1$ ug/L

IRIS

Topic: CHLOROFORM

E-6 (1 in 1,000,000) 6E+0 ug/L
 II.B.2. DOSE-RESPONSE DATA (CARCINOGENICITY, ORAL EXPOSURE)
 Tumor Type -- all kidney tumors
 Test Animals -- rat/Osborne-Mendel, male
 Route -- drinking water
 Reference -- Jorgensen et al., 1985

----- Dose -----

Admin- istered (mg/L)	Human Equivalent (mg/kg/day)	Tumor Incidence
0	0	1/50
200	3.4	6/313
400	6.9	7/148
900	14.8	3/48
1800	28.9	7/50

II.B.3. ADDITIONAL COMMENTS (CARCINOGENICITY, ORAL EXPOSURE)
 Historical control kidney tumor incidence was 5/301.
 The unit risk should not be used if the water concentration exceeds 6E+4 ug/L, since above this concentration the unit risk may not be appropriate.

II.B.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY, ORAL EXPOSURE)
 This assay was designed for detection and quantitation of effects at low dose; thus, large numbers of animals were treated and observed for their lifetime. Exposure route and vehicle is relevant to the medium for which the risk estimate was developed.

 II.C. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM INHALATION EXPOSURE

II.C.1. SUMMARY OF RISK ESTIMATES
 Inhalation Unit Risk -- 2.3E-5 per (ug/cu.m)
 Extrapolation Method -- Linearized multistage procedure, extra risk
 Air Concentrations at Specified Risk Levels:

Risk Level	Concentration
E-4 (1 in 10,000)	4E+0 ug/cu.m
E-5 (1 in 100,000)	4E-1 ug/cu.m
E-6 (1 in 1,000,000)	4E-2 ug/cu.m

II.C.2. DOSE-RESPONSE DATA FOR CARCINOGENICITY, INHALATION EXPOSURE

Tumor Type -- hepatocellular carcinoma
 Test Animals -- mouse, B6C3F1, female
 Route -- oral, gavage
 Reference -- NCI, 1976

----- Dose -----

Admin- istered (mg/kg/day)	Human Equivalent (mg/kg/day)	Tumor Incidence
0	0	0/20

Topic: CHLOROFORM

238	9.9	36/45
477	19.9	39/41
Male		
0	0	1/18
138	6.2	18/50
277	12.5	44/45

II.C.3. ADDITIONAL COMMENTS (CARCINOGENICITY, INHALATION EXPOSURE)

This inhalation quantitative risk estimate is based on data from a gavage study. Above doses are TWA; body weights at the end of the assay were 35 g, males and 28 g, females. Vehicle control animals were run concurrently and housed with test animals. All treated animals experienced decreased body weight gain. Survival was reduced in high-dose males and in all treated females.

Experimental data for this compound support complete absorption of orally administered chloroform under conditions of this assay. There are no apparent species differences in this regard. Extrapolation of metabolism-dependent carcinogenic responses from mice to humans on the basis of body surface area is supported by experimental data. The incidence data for both male and female mice were used to derive slope factors of $3.3E-2$ and $2.0E-1$ per (mg/kg)/day, respectively. The unit risk was prepared by taking a geometric mean of the slope factor and assuming 100% for low doses of chloroform in air.

The unit risk should not be used if the air concentration exceeds 400 ug/cu.m, since above this concentration the unit risk may not be appropriate.

II.C.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY, INHALATION EXPOSURE)

Adequate numbers of animals were treated and observed. Risk estimates derived from male rat kidney tumor data ($2.4E-2$) (NCI, 1976) and studies by Roe et al. (1979) ($1.0E-1$) are generally supportive of the risk estimate.

II.D. EPA DOCUMENTATION, REVIEW, AND CONTACTS (CARCINOGENICITY ASSESSMENT)

II.D.1. EPA DOCUMENTATION

U.S. EPA. 1985. Health Assessment Document for Chloroform. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Research Triangle Park, NC for the Office of Air Quality Planning and Standards. EPA 600/8-84-004F.

U.S. EPA. 1987. Drinking Water Criteria Document for Trihalomethanes. Office of Drinking Water, Washington, DC. Draft.

NCI (National Cancer Institute). 1976. Report on Carcinogenesis Bioassay of Chloroform. National Cancer Institute, Washington, DC. NTIS PB 264018.

II.D.2. REVIEW (CARCINOGENICITY ASSESSMENT)

The Health Assessment Document for Chloroform received extensive Agency and external review.

The Draft Drinking Water Criteria Document for Trihalomethanes

Topic: METHYLENE CHLORIDE

6.0 RANGE OF TOXICITY

6.2 MINIMUM LETHAL EXPOSURE

- A. The estimated lethal dose is about 0.5 to 5 milliliters/kilogram.
- B. When heated to decomposition, methylene chloride emits highly toxic fumes of phosgene. Exposure to the 1982 threshold limit value (TLV) of 100 ppm has resulted in a carboxyhemoglobin of 3.4% (DiVincenzo & Kaplan, 1981).

Topic: DICHLOROMETHANE

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Summary

Environmental Fate/Exposure Summary:

1. Large quantities of dichloromethane are used each year, primarily in aerosols, paint removers and chemical processing. The major route of human exposure is from air, which can be high near sources of emission, and contaminated drinking water. Most of the dichloromethane will be released to the atmosphere where it will degrade by reaction with photochemically produced hydroxyl radicals with a half-life of a few months. It will be subject to direct photolysis. Releases to water will primarily be removed by evaporation. Biodegradation is possible in natural waters but will probably be very slow compared with evaporation. It will not be expected to significantly adsorb to sediment or to bioconcentration in aquatic organisms. Releases to soil will evaporate rapidly from near-surface soil and partially leach into groundwater where its fate is unknown. Dichloromethane is not expected to bioconcentrate in the food chain, (SRC)

PEER REVIEWED

Pollution Sources

Natural Occurring Sources:

1. None. (SRC) **PEER REVIEWED**

Artificial Sources:

1. Air emissions from dichloromethane used as an aerosol propellant, paint remover, metal degreaser and a urethane foam blowing agent(1). Wastewater primarily from the following industries: Paint and ink, aluminum forming, coal mining, photographic equipment and supplies, pharmaceutical, organic chemical/plastics, rubber processing, foundries and laundries(2). **PEER REVIEWED** [(1) Chemical Marketing Reporter, Feb 28, 1983 Chemical Profile (1983) (2) USEPA; Treatability Manual EPA-600/2-82-001A pp. I.12.2-1 to I.12.2-4 (1981)]
2. Release of dichloromethane to the environment (air) in 1978: total, 199,680 kkg (production, 280 kkg; paint removers, 61,200 kkg; metal degreasing, 43,600 kkg; aerosols, 36,700 kkg; foam blowing agent, 10,700 kkg; pharmaceutical solvent, 5,300 kkg; miscellaneous solvent uses, 41,900 kkg). /From table/ **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982.,p. 3-3
3. Release of dichloromethane to the environment (land) in 1978: total, 28,010 kkg (production, 10 kkg; paint removers, 8,800 kkg; metal degreasing, 6,100 kkg; aerosols, 3,800 kkg; foam blowing agent, 1,200 kkg; pharmaceutical solvent, 2,200 kkg; miscellaneous solvent uses, 5,900 kkg). /From table/ **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982.,p. 3-3
4. ... /Dichloromethane/ is eventually released to the atmosphere /from use/ as a chemical intermediate in the

Topic: DICHLOROMETHANE

manufacture of various drugs, dyes and perfumes, and in the dewaxing of oils ... /and/ as a decaffeinating agent for coffee. ... **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982.,p. 3-1

5. Release of dichloromethane to the environment (water) in 1978: total, 3,665 kkg (production, 30-60 kkg; paint removers, 1,400 kkg; metal degreasing, 1,000 kkg; pharmaceutical solvent, 460 kkg; miscellaneous solvent uses, 760 kkg). /From table/ **PEER REVIEWED** [Kayser, R., D. Sterling, D. Viviani (eds.). Intermedia Priority Pollutant Guidance Documents. Washington, DC: U.S.Environmental Protection Agency, July 1982.,p. 3-3
6. Dichloromethane is formed during the chlorination of water. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work).,p. V20 453 (1979)

Environmental Fate

Environmental Fate:

1. TERRESTRIAL FATE: When spilled on land, dichloromethane is expected to evaporate from near surface soil into the atmosphere because of its high vapor pressure. Although little work has been done on its adsorptivity, it is probable that it will leach through subsoil into groundwater. Degradation in groundwater is unknown. Hydrolysis in soil or groundwater is not an important process under normal environmental conditions(1)(SRC). **PEER REVIEWED** [(1) Dilling WL et al; Environ Sci Technol 9: 833-5 (1975)
2. AQUATIC FATE: Dichloromethane will be primarily lost by evaporation to the atmosphere which should take several hours depending on wind and mixing conditions. When released into a river, dichloromethane levels were non-detectable 3-15 miles from the source(1-2). Biodegradation is possible in natural waters but will probably be very slow compared with evaporation(3). Little is known about adsorption or bioconcentration in aquatic organisms to sediment but these are not likely to be significant processes. Hydrolysis is not an important process under normal environmental conditions(4). **PEER REVIEWED** [(1) DeWalle FB, Chain ESK; Proc Ind Waste Conf 32: 908-19 (1978) (2) Hetz RY; Limnol Oceanogr 23: 858-69 (1978) (3) Stover EL, Kincannon DF; J Water Pollut Control Fed 55: 97-109 (1983) (4) Dilling WL et al; Environ Sci Technol 9: 833-8 (1975)
3. ATMOSPHERIC FATE: Dichloromethane released into the atmosphere will degrade by reaction with hydroxyl radicals with a half life of several months(1-3). It will not be subject to direct photolysis(4). A small fraction of the chemical will diffuse to the stratosphere where it will rapidly degrade by photolysis and reaction with chlorine radicals(1,5). A moderately soluble chemical such as

pic: DICHLOROMETHANE

dichloromethane will be expected to partially return to earth in rain(SRC). **PEER REVIEWED** [(1) Cox RA et al; Atmos Environ 10: 305-8 (1976) (2) Hampson RF; Chemical Kinetic and Photochemical Data Sheets for Atmospheric Reactions. 1 Report FAA-EE-80-17 US Dept. of Transportation (1980) (3) Singh HB et al; Atmos Environ 15: 601-12 (1981) (4) Dilling WL et al; Environ Sci Technol 9: 833-8 (1975) (5) Spence JW et al; J Air Pollut Control Assoc 76: 994-6 (1976)]

Environmental Transformations

Biodegradation:

1. Dichloromethane is reported to completely biodegrade under aerobic conditions with sewage seed or activated sludge between 6 hours to 7 days(1-5). No information could be found concerning its biodegradability under anaerobic conditions, in natural bodies of water or in aquifers. 86-92% conversion to carbon dioxide (CO₂) after a various acclimation period using anaerobic digestion in wastewater(6). **PEER REVIEWED** [(1) Tabak HH et al; J Water Pollut Control Assoc 53: 1503-18 (1981) (2) Davis EM et al; Water Res 15: 1125-7 (1981) (3) Rittman BE, McCarthy PL; Appl Environ Microbiol 39: 1225-6 (1980) (4) Klecka GM; Appl Environ Microbiol 44: 701-7 (1982) (5) Stover EL, Kincannon DF; J Water Pollut Control Fed 55: 97-109 (1983) (6) Gossett JM; Anaerobic Degradation of C₁ and C₂ Chlorinated Hydrocarbons. Air Force Eng Serv Cent, Eng Serv Lab. ESL-TR-85-38 p. 153 (1985)]

Abiotic Degradation:

1. Hydrolysis is not an important degradation process under normal environmental conditions. The minimum reported half-life for hydrolysis is approximately 18 months(1). Since dichloromethane does not absorb light >290 nm(2), it will not degrade by direct photolysis in the troposphere. It does not photodegrade when exposed to sunlight for 1 year in aerated water(1). In the stratosphere, it would undergo photolysis and also degrade by reaction with Cl radicals(3-4). Dichloromethane will degrade by reaction with hydroxyl radicals in the troposphere with a half-life of several months(3,5,6). There is some disparity concerning the photooxidation of dichloromethane in the presence of nitrogen oxides. One investigator reported 11.5% degradation in 6 hours(7) and another reported < 5% degradation in the presence of much higher concentrations of nitrogen oxides(8). The importance of photooxidation is supported by the fact that the highest concentrations of dichloromethane are observed at night or in the early morning(9). **PEER REVIEWED** [(1) Dilling WL et al; Environ Sci Technol 9: 833-8 (1975) (2) Hubrich C, Stuhl F; J Photochem 12: 93-107 (1980) (3) Cox RA et al; Atmos Environ 10: 305-8 (1976) (4) Spence JW et al; J Air Pollut Control Assoc 76: 994-6 (1976) (5) Hampson RF; Chemical Kinetic and Photochemical Data Sheets for Atmospheric Reactions 1 Report FAA-EE-80-17 US Dept of Transportation (1980) (6) Singh HB et al; Atmos Environ 15: 601-12 (1981) (7) Yanagihara S et al; Photochemical Reactivities of

Topic: DICHLOROMETHANE

Hydrocarbons Proceedings of the 4th Clean Air Congress p 472-7 (1977) (8) Dilling WL et al; Environ Sci Technol 10: 351-6 (1976) (9) Singh HB et al; Environ Sci Technol 16: 872-80 (1982)

2. Experimental results showed that dichloromethane decomposed at a rather slow rate under tropospheric conditions with either nitrogen oxide or nitrogen dioxide present; the estimated photodecomposition half life was greater than 250 hr. **PEER REVIEWED** [Callahan, M.A., M.W. Slimak, N.W. Gabel, et al. Water-Related Environmental Fate of 129 Priority Pollutants. Volume II. EPA-440/4-79-029b. Washington, D.C.: U.S.Environmental Protection Agency, December 1979.,p. 39-2
3. Due to the high vapor pressure of dichloromethane, volatilization to the atmosphere is quite rapid. Once in the troposphere, the compd is attacked by hydroxyl radicals ... via hydrogen abstraction. The rate of this reaction is reported to be 1.04×10^{-13} cu cm/sec corresponding to a lifetime of 0.30 yr. The principal product of this photooxidation reaction is reported to be carbon dioxide (CO₂), with carbon monoxide (CO) & some phosgene (COCl₂) being formed in smaller quantities. **PEER REVIEWED** [Callahan, M.A., M.W. Slimak, N.W. Gabel, et al. Water-Related Environmental Fate of 129 Priority Pollutants. Volume II. EPA-440/4-79-029b. Washington, D.C.: U.S.Environmental Protection Agency, December 1979.,p. 39-3
4. A max hydrolytic half-life of 704 yr, extrapolated from experimental data obtained at 100-150 deg C has been reported for dichloromethane @ pH 7 & 25 deg C. This corresponds to a reported first order rate constant for hydrolysis of dichloromethane of 3.2×10^{-11} /sec. The validity of this extrapolation method ... has not been established. The data above are not at all in agreement with the results of the aqueous reactivity experiments ... which indicated a (first order) rate of disappearance @ 25 deg C of 0.039/mo, corresponding to a half life of approx 18 mo for dichloromethane. ... Most of the effect noted /was attributed/ to ionic hydrolysis, although oxidn & vapor phase hydrolysis were also possible in experimental system used. At best ... /the latter/ results can be interpreted as a max rate (minimum half life) for hydrolysis of dichloromethane in aqueous systems. **PEER REVIEWED** [Callahan, M.A., M.W. Slimak, N.W. Gabel, et al. Water-Related Environmental Fate of 129 Priority Pollutants. Volume II. EPA-440/4-79-029b. Washington, D.C.: U.S.Environmental Protection Agency, December 1979.,p. 39-3

Environmental Transport
Bioconcentration:

1. Although experimental data are lacking, dichloromethane would not be expected to bioconcentrate due to its low octanol/water partition coefficient (log Kow is 1.25)(1), from which an estimated BCF of 5 can be estimated using recommended regression equation(2, SRC). **PEER REVIEWED**

Topic: DICHLOROMETHANE

[(1) Hansch C, Leo AJ; Substituent Constants for Correlation Analysis in Chemistry & Biology New York NY. John Wiley & Sons p. 173 (1979) (2) Lyman WJ et al; Handbook of Chemical Property Estimation Methods NY: McGraw-Hill (1982)

Soil Adsorption/Mobility:

1. Little work has been done on the adsorption of dichloromethane to soil. It is adsorbed strongly to peat moss, less strongly to clay, only slightly to dolomite limestone, and not at all to sand(1). A log Koc of 1.68 can be calculated(1), from a reported log Kom of 1.44(2). **PEER REVIEWED** [(1) Dilling WL et al; Environ Sci Technol 9: 838-8 (1975) (2) Sabljic A; J Agric Food Chem 32: 243-6 (1984)

Volatilization from Water/Soil:

1. Dichloromethane has a high Henry's Law coefficient(1) and will evaporate moderately rapidly from water. Half-lives for the evaporation from water of 3-5.6 hours have been determined at moderate mixing conditions(2-3). When released into an estuarine bay, all the chemical dissipated within 4 km of the release point in the spring and within 8 km in the winter under ice(4). Due to its high vapor pressure(5), it will evaporate rapidly from near surface soil. (SRC) **PEER REVIEWED** [(1) Shen T; J Air Pollut Control Assoc 32: 79-82 (1982) (2) Lyman WJ et al; Handbook of Chemical Property Estimation Methods (3) Rathbun RE, Tai DY; Water Res 15: 243-50 (1981) (4) Helz GR, Hsu RY; Limnol Oceanogr 23: 858-69 (1978) (5) Gallant RW; Hydrocarbon Process 45: 161-9 (1969)

Environmental Concentrations

Water Concentrations:

1. DRINKING WATER: 30 Canadian Water Treatment Facilities - 50% positive - 10 ppb, avg, 50 ppb max (summer), 30% pos, 3 ppb avg, 50 ppb max (winter)(1); 10 State survey drinking water from groundwater sources - 2% pos, 3600 ppb max, max surface water conc 13 ppb(2); EPA Region V Survey (83 sites in 5 states: MN, WI, IL, IN, OH) - 8% pos, 1-7 ppb(3), National Organics Monitoring Survey (1976) - 15 of 109 samples positive, 6.1 ppb, mean of positive samples(3). **PEER REVIEWED** [(1) Otson R et al; J Assoc Offic Analyt Chem 65: 1370-4 (1982) (2) Dyksen JE, Hess AF III; J Amer Water Works Assoc 74: 394-403 (1982) (3) USEPA; Ambient Water Quality Criteria for Halomethanes EPA-440/5-80-051 p. C-6 to C-17 (1980)

Effluents Concentrations:

1. Weser R, Germany - 72-179 ppb(1). Industries in which wastewater exceeded an average of 1000 ppb: Coal mining, aluminum forming, photographic equipment and supplies, pharmaceutical mfg, organic chemical/ plastics mfg, paint and ink formulation, rubber processing, foundries, and laundries(2). Max concentration measured was 210,000 ppb in paint and ink industry and aluminum forming(2). Outfalls from 4 municipal treatment plants in southern California with primary or secondary treatment - random samples - < 10 to 400 ppb(3). USEPA STORET database, 1,480

Topic: DICHLOROMETHANE

data points, 38.8% pos, 10.0 ppb median(4). USA, 178 CERCLA hazardous waste disposal sites, 19.2% pos(5). Minnesota municipal solid waste landfills, leachates, 6 sites, 66.7% pos, 64-1300 ppb, contaminated groundwater (by inorganic indices), 13 sites, 53.8% pos, 1-250 ppb, other groundwater (apparently not contaminated as indicated by inorganic indices), 7 sites, 14.3% pos, 2.1-3.9 ppb(6). **PEER REVIEWED** [(1) Von Dueszeln et al; Z Wasser Abwasser Forsch 15: 272-6 (1982) (2) USEPA; Treatability Manual EPA-600/2-82-001A pp I.12.2-1 to I.12.2-4 (1981) (3) Young DR et al; Water Chlorination: Environ Impact Health Effect 4 (Book 2): 871-4 (1983) (4) Staples CA et al Environ Technol Chem 4: 131-42 (1985) (5) Plumb RHJr; Ground Water Monit Rev 7: 94-100 (1987) (6) Sabel GV, Clark TP; Waste Manag Res 2: 119-30 (1984)

2. Water samples collected in Feb & May 1977 from Back River estuary in MD, USA, which received effluent from an urban wastewater treatment plant, contained dichloromethane. The highest levels (66 ug/l) were found in samples taken in the treatment plant just before final chlorination, suggesting that dichloromethane was derived from commercial & industrial activities in the area. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V41 52 (1986)
3. Dichloromethane was detected ... @ levels ranging from 19-95 ug/l in 6 samples of raw sewage & effluent from Canadian sewage treatment plants. Wastewater from a USA specialty chemical plant manufacturing a broad range of chemicals contained 3-8 mg/l dichloromethane. ... Dichloromethane was detected ... at concn ranging from < 0.01 to 1.0 mg/l in volatile fraction of wastewater from Oak Ridge Gaseous Plant in TN, USA. As part of the Swedish Drinking Water Project, dichloromethane was found at 640 ug/l in effluent stream from sulfate pulp mill. The amt of dichloromethane discharged ... was est to be 40 ton/yr. **PEER REVIEWED** [IARC. Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man. Geneva: World Health Organization, International Agency for Research on Cancer, 1972-PRESENT. (Multivolume work)., p. V41 53 (1986)

Sediment/Soil Concentrations:

1. SEDIMENT: Bottom sediment near sewage outfall - Southern California - <4 ppb. In Lake Pontchartrain, New Orleans: 1.5 ppb wet weight in sediment from Inner Harbor Navigation Canal; 3.2 ppb in sediment from Chef Monteur Pass; and not detected in sediment from Rigolets(1-2). USEPA STORET database, 338 data points, 20.0% pos, 13.0 ppb median(3). **PEER REVIEWED** [(1) Young DR et al; Water Chlorination: Environ Impact Health Effect 4 (Book 2): 871-4 (1983) (2) Ferrario JB et al; Bull Environ Contam Toxicol 34: 246-55 (1985) (3) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985)

Atmospheric Concentrations:

1. Background: Global 32 parts per trillion Northern

Topic: DICHLOROMETHANE

Hemisphere - 44 parts per trillion. Southern Hemisphere 20 parts per trillion(1). US Rural/Remote (5 samples) - 45 parts per trillion(2); US-Urban/Suburban: 11 sites - 414-3751 parts per trillion avg; 12,000 parts per trillion max(3-5); avg of 718 samples - 630 parts per trillion(2). US Source - Dominated Areas: Avg of 127 samples - 270 parts per trillion(2), 11 - highly industrialized locations - 10-74,000 parts per trillion(6); Industrial sites in Newark, Elizabeth and Camden, NJ (Summer 1981) - 230-720 parts per trillion geometric mean, 10.2 ppb max(7). Weighted avg (parts/trillion), Eastern Pacific Ocean: Northern hemisphere, 38, Southern hemisphere, 21; global avg, 29(8). **PEER REVIEWED** [(1) Singh HB et al; Atmospheric Distributions, Sources and Sinks of Selected Halocarbons, Hydrocarbons, SF6 and H2O USEPA-600/3-79-107 p. 4 (1979) (2) Brodzinsky R, Singh HB; Volatile Organic Chemicals in the Atmosphere: An Assessment of Available Data SRI Contract 68-02-3452 (1982) (3) Singh HB et al; Atmospheric Measurements of Selected Hazardous Organic Chemicals USEPA-600/5-3-81-032 (1981) (4) Singh HB et al; Environ Sci Technol 16: 872-80 (1982) (5) Singh HB et al; Atmos Environ 15: 601-12 (1981) (6) Pellizzari ED; Quantification of Chlorinated Hydrocarbons in Previously Collected Air Samples USEPA-450/3-78-112 (1978) (7) Harkov R et al; J Air Pollut Control Assoc 33: 1177-83 (1983) (8) Singh HB et al; J Geophys Res 88: 3675-83 (1983)]

Food Survey Results:

1. Intermediate grain based food (1984); 9 varieties, 77.8% pos, 1.9-30 ppb (max concn in bleached flour, followed by a fudge brownie mix; wheat, corn, oats (1984), 10, 2, and 1 samples, respectively: not detected(1). Table ready foods: 19 varieties, 42% pos, 1.4-71 ppb; max concn in cheddar cheese; butter, 7 samples, 100% pos; 1.1-280 ppb; margarine, 7 samples, 100% pos, 1.2-81 ppb; cheese, 4 types 8 samples, 100% pos, 3.9-98 ppb, max concn in Parmesan cheese(2). **PEER REVIEWED** [(1) Heikes DL, Hopper ML; J Assoc Off Anal Chem 69: 990-8 (1986) (2) Heikes DL; J Assoc Off Anal Chem 70: 215-26 (1987)]

Fish/Seafood Concentrations:

1. Bottomfish, Commencement Bay and adjacent waterways, Tacoma, WA 1982, highest avg level, 0.53 ppm, highest level 0.7 ppm(1). Lake Pontchartrain, New Orleans: oysters from Inner Harbor Navigation Canal, 7.8 ng/g (ppb) wet weight; clams from Chef Manteur Pass, 27 ppb; clams from Rigolets, 4.5 ppb(2). **PEER REVIEWED** [(1) Nicola RM; J Environ Health 49: 342-7 (1987) (2) Ferrario JB et al; Bull Environ Contam Toxicol 34: 246-55 (1985)]

Milk Concentrations:

1. Detected in all 8 samples of mother's milk from 4 urban areas(1). Mother's milk in Soviet women manufacturing rubber articles - 74 ppb mean in 17 of 28 samples approx 5 hours after start of work, level declined after termination of work(2). **PEER REVIEWED** [(1) Pellizzari ED et al; Bull Environ Contam Toxicol 28: 322-8 (1982) (2) Jense AA; Res Rev 89: 1-128 (1983)]

Topic: DICHLOROMETHANE

Human Exposure

Probable Routes of Human Exposure:

1. Human exposure primarily will result from ambient air, particularly in the vicinity of these industries. Another source of exposure is from drinking water originating from contaminated groundwater sources. (SRC) **PEER REVIEWED**
2. Methylene chloride can affect the body if it is inhaled ... comes in contact with the eyes or skin ... /or/ is swallowed. **PEER REVIEWED** [Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981. 1

Average Daily Intake:

1. Air intake (assume 0.4-3.8 ppb intake(1-3) - 28-268 ug; Water Intake - (assume 0 ppb for 86% of people and 6.1 ppb average for 14% of people(4) - 0 ug or 12.2 ug; Food Intake - insufficient data(SRC). **PEER REVIEWED** [(1) Singh HB et al; Atmos Environ 15: 601-12 (1981) (2) Singh HB et al; Environ Sci Technol 16: 872-80 (1982) (3) Singh HB et al; Atmospheric Measurements of Selected Hazardous Organic Chemicals. USEPA-600/5-3-81-032 (1981) (4) USEPA; Ambient Water Quality Criteria for Halomethanes USEPA-440/5-80-051 p. C-6 to C-17 (1980)

Probable Exposures:

1. Casting room (1968-1972) - 55-495 ppm; Plastic film factory - 3 year study, 318 samples - 30-5,000 ppm, 627 ppm avg; 1973-1974 study of 7 jobs using dichloromethane: 6 of 7 jobs - 0-74 ppm, chemical plant 0-5,520 ppm(1). Monitoring data suggest that the mean TWA personal exposure to dichloromethane in the workplace may be in the range of 100-200ppm or higher from its use in the production of acetyl sulfonyl chloride and cellulose acetate/triacetate fibers and during paint stripping operations(2). NIOSH (NOES Survey 1981-1983) has statistically estimated that 190,671 workers are exposed to dichloromethane in the USA(4). NIOSH (NOHS Survey 1972-1974) has statistically estimated that 2,175,499 workers are exposed to dichloromethane in the USA(4). **PEER REVIEWED** [(1) NIOSH; Criteria for a Recommended Standard Occupational Exposure to Methylene Chloride NIOSH 76-138 pp.80-81, 152, 164 (1976) (2) Santodonato J et al; Monograph on Human Exposure to Chemicals in the Workplace: Methylene Chloride NCI Contract NO. N01-CP-26002-03 (1985) (4) NIOSH; The National Occupational Exposure Survey (NOES) (1983) (5) NIOSH; The National Occupational Hazard Survey (NOHS) (1974)

Body Burdens:

1. Detected in all 8 samples of mother's milk from 4 urban areas(1). Mother's milk in Soviet women manufacturing rubber articles - 74 ppb mean in 17 of 28 samples approx 5 hours after start of work, level declined after termination of work(2). Whole blood specimens, 250 subjects, not detected to 25 ppb, 0.7 ppb avg(3). **PEER REVIEWED** [(1) Pellizzari ED et al; Bull Environ Contam

Topic: DICHLOROMETHANE

EXPOSURE STANDARDS & REGULATIONS

Standards & Regulations

Allowable Tolerances:

1. The insecticide methylene chloride is exempted from the requirement of a tolerance for residues when used as a fumigant after harvest for the following grains: Barley, corn, oats, popcorn, rice, rye, sorghum (milo), wheat; when used in the postharvest fumigation of citrus fruits. **PEER REVIEWED** [40 CFR 180.1010 (7/1/88)]
2. Methylene chloride is exempted from the requirement of a tolerance when used as a solvent or cosolvent in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops only. **PEER REVIEWED** [40 CFR 180.1001(d) (7/1/88)]

Occupational Permissible Levels

OSHA Standards:

1. During an 8 hr work shift, an employee may be exposed to a concentration of methylene chloride above 1000 ppm (but never above 2000 ppm) only for a maximum period of 5 min in any 2 hr. Such exposure must be compensated by exposures to concentrations less than 500 ppm so that the cumulative exposure for the entire 8 hr work shift does not exceed a weighted average of 500 ppm. **PEER REVIEWED** [54 FR 2920 (1/19/89)]
2. Meets criteria for OSHA medical records rule. **PEER REVIEWED** [29 CFR 1910.20 (7/1/88)]

NIOSH Recommendations:

1. Niosh recommends that methylene chloride be regulated as an occupational carcinogen ... **PEER REVIEWED** [NIOSH. Pocket Guide to Chemical Hazards. 2nd Printing. DHHS (NIOSH) Publ. No. 85-114. Washington, D.C.: U.S. Dept. of Health and Human Services, NIOSH/Supt.of Documents, GPO, February 1987. 162]

Threshold Limit Values:

1. Time Weighted Avg (TWA) 50 ppm, 174 mg/cu m (1988) **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 27]
2. A2. A2= Suspected human carcinogen. (1988) **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 27]

Other Standards and Regulations

Atmospheric Standards:

1. This action promulgates standards of performance for equipment leaks of Volatile Organic Compounds (VOC) in the Synthetic Organic Chemical Manufacturing Industry (SOCMI). The intended effect of these standards is to require all newly constructed, modified, and reconstructed SOCMI process units to use the best demonstrated system of

Topic: DICHLOROMETHANE

continuous emission reduction for equipment leaks of VOC, considering costs, non air quality health and environmental impact and energy requirements. Methylene chloride is produced, as an intermediate or final product, by process units covered under this subpart. **PEER REVIEWED** [40 CFR 60.489 (7/1/89)]

RCRA Requirements:

1. As stipulated in 40 CFR 261.33, when methylene chloride as a commercial chemical product or manufacturing chemical intermediate or an off-specification commercial chemical product or a manufacturing chemical intermediate, becomes a waste, it must be managed according to Federal and/or State hazardous waste regulations. Also defined as a hazardous waste is any residue, contaminated soil, water, or other debris resulting from the cleanup of a spill, into water or on dry land, of this waste. Generators of small quantities of this waste may qualify for partial exclusion from hazardous waste regulations (40 CFR 261.5). **PEER REVIEWED** [40 CFR 261.33 (7/1/88)]
2. When methylene chloride is a spent solvent, it is classified as a hazardous waste from a nonspecific source (F002), as stated in 40 CFR 261.31, and must be managed according to state and/or federal hazardous waste regulations. **PEER REVIEWED** [40 CFR 261.31 (7/1/88)]

FIFRA Requirements:

1. The insecticide methylene chloride is exempted from the requirement of a tolerance for residues when used as a fumigant after harvest for the following grains: Barley, corn, oats, popcorn, rice, rye, sorghum (milo), wheat; /and when/ used in the postharvest fumigation of citrus fruits. **PEER REVIEWED** [40 CFR 180.1010 (7/1/88)]
2. Methylene chloride is exempted from the requirement of a tolerance when used as a solvent or cosolvent in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops only. **PEER REVIEWED** [40 CFR 180.1001(d) (7/1/88)]
3. Under section 3(c)(2)(b) of FIFRA, the Data Call-In Program, existing registrants are required to provide EPA with needed studies. For methylene chloride, responses to the Data Call-In have been evaluated and a chronic/tox decision has been reached. No data is required at this time. **PEER REVIEWED** [USEPA/OPP; Report on the Status of Chemicals in the Special Review Program, Registration Standards Program, Data Call-In Program, and Other Registration Activities p.66 (1988) EPA 540/09-89-037]
4. Under section 3(c)(2)(b) of FIFRA, the Data Call-In Program, existing registrants are required to provide EPA with needed studies. For methylene chloride, responses to the Data Call-In have been evaluated and a Part 158 decision is pending. Responses are under review. **PEER REVIEWED** [USEPA/OPP; Report on the Status of Chemicals in the Special Review Program, Registration Standards Program, Data Call-In Program, and Other Registration Activities p.80 (1988) EPA 540/09-89-037]

IRIS

Topic: DICHLOROMETHANE

1. CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Dichloromethane

CASRN -- 75-09-2

Primary Synonym -- Methylene Chloride

Last Revised -- 03/01/88

The Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Please refer to Background Document 1 in Service Code 5 for an elaboration of these concepts. RfDs can also be derived for the noncarcinogenic health effects of compounds which are also carcinogens. Therefore, it is essential to refer to other sources of information concerning the carcinogenicity of this substance. If the U.S. EPA has evaluated this substance for potential human carcinogenicity, a summary of that evaluation will be contained in Section II of this file when a review of that evaluation is completed.

I.A.1. ORAL RfD SUMMARY

See Table Document

I.A.2. PRINCIPAL AND SUPPORTING STUDIES (ORAL RfD)

National Coffee Association. 1982. 24-Month chronic toxicity and oncogenicity study of methylene chloride in rats. Final Report. Prepared by Hazleton Laboratories America, Inc., Vienna, VA. (Unpublished)

The chosen study appears to have been very well conducted, with 85 rats/sex at each of four nominal dose groups (i.e., 5, 50, 125 and 250 mg/kg/day) for 2 years. A high-dose recovery group of 25 rats/sex, as well as two control groups of 85 and 50 rats/sex, was also tested. Many effects were monitored. Treatment related histological alterations of the liver were evident at nominal doses of 50 mg/kg/day or higher. The low nominal dose of 5 mg/kg/day was a NOAEL.

The supporting data base is limited. A NOAEL of 87 mg/cu.m was reported in one inhalation study (Haun et al., 1972).

[The equivalent oral dose is about 28 mg/kg bw/day (i.e., 87 mg/cu.m x 0.5 x 0.223 cu.m/day/0.35 kg; these exposure values are for rats).]

I.A.3. UNCERTAINTY AND MODIFYING FACTORS (ORAL RfD)

UF = 100. (10a x 10h) The 100-fold factor accounts for both the expected intra- and interspecies variability to the toxicity of this chemical in lieu of specific data.

MF = 1.

I.A.4. ADDITIONAL COMMENTS (ORAL RfD)

None.

I.A.5. CONFIDENCE IN THE ORAL RfD

Study: High

Data Base: Medium

RfD: Medium

IRIS

pic: DICHLOROMETHANE

The study is given a high confidence rating because a large number of animals of both sexes were tested in four dose groups, with a large number of controls. Many effects were monitored and a dose-related increase in severity was observed. The data base is rated medium to low because only a few studies support the NOAEL. Medium confidence in the RfD follows.

I.A.6. EPA DOCUMENTATION AND REVIEW OF THE ORAL RfD
U.S. EPA. 1985. Drinking Water Criteria Document for Methylene Chloride. Office of Drinking Water, Washington, DC. Agency Work Group Review: 06/24/85, 07/08/85, 11/06/85
Verification Date: 11/06/85

I.A.7. EPA CONTACTS (ORAL RfD)
Krishan Khanna / ODW -- (202)260-7588 / FTS 260-7588
Michael L. Dourson / ORD -- (513)569-7544 / FTS 684-7544

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE RfC)

Substance Name -- Dichloromethane

CASRN -- 75-09-2

Primary Synonym -- Methylene Chloride

A risk assessment for this substance/agent is under review by an EPA work group.

IRIS

opic: DICHLOROMETHANE

I. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Dichloromethane

CASRN -- 75-09-2

Primary Synonym -- Methylene Chloride

Last Revised -- 01/01/91

Section II provides information on three aspects of the carcinogenic risk assessment for the agent in question; the U.S. EPA classification, and quantitative estimates of risk from oral exposure and from inhalation exposure. The classification reflects a weight-of-evidence judgment of the likelihood that the agent is a human carcinogen. The quantitative risk estimates are presented in three ways. The slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per (mg/kg)/day. The unit risk is the quantitative estimate in terms of either risk per ug/L drinking water or risk per ug/cu.m air breathed. The third form in which risk is presented is a drinking water or air concentration providing cancer risks of 1 in 10,000, 1 in 100,000 or 1 in 1,000,000. Background Document 2 (Service Code 5) provides details on the rationale and methods used to derive the carcinogenicity values found in IRIS. Users are referred to Section I for information on long-term toxic effects other than carcinogenicity.

II.A. EVIDENCE FOR CLASSIFICATION AS TO HUMAN CARCINOGENICITY

II.A.1. WEIGHT-OF-EVIDENCE CLASSIFICATION

Classification --B2; probable human carcinogen

Basis -- Based on inadequate human data and sufficient evidence of carcinogenicity in animals; increased incidence of hepatocellular neoplasms and alveolar/bronchiolar neoplasms in male and female mice, and increased incidence of benign mammary tumors in both sexes of rats, salivary gland sarcomas in male rats and leukemia in female rats. This classification is supported by some positive genotoxicity data, although results in mammalian systems are generally negative.

II.A.2. HUMAN CARCINOGENICITY DATA

Inadequate. Neither of two studies of chemical factory workers exposed to dichloromethane showed an excess of cancers (Ott et al., 1983; Friedlander et al., 1978; Hearne and Friedlander, 1981). The Ott et al. (1983) study was designed to examine cardiovascular effects, and consequently the study period was too short to allow for latency of site-specific cancers. In the Friedlander et al. (1978) study, exposures were low, but the data provided some suggestion of an increased incidence of pancreatic tumors. This study was recently updated to include a larger cohort, followed through 1984, and an investigation of possible confounding factors (Hearne et al., 1986, 1987). A nonsignificant excess in pancreatic cancer deaths was observed, which was interpreted by EPA (1987a) as neither clear evidence of carcinogenicity in humans, nor evidence of noncarcinogenicity. An update of the Ott et al. (1983) study, based on longer follow-up, indicated possible elevation of liver and biliary tract cancers (TSCA section 8(e) submission no. 8eHQ-0198-0772 FLWP et seq., 1989).

II.A.3. ANIMAL CARCINOGENICITY DATA

Topic: DICHLOROMETHANE

Sufficient. Dichloromethane administered in the drinking water induced a significant increase in combined hepatocellular carcinoma and neoplastic nodules in female F344 rats and a nonsignificant increase in combined hepatocellular carcinoma and neoplastic nodules in male B6C3F1 mice (NCA, 1982, 1983). Two inhalation studies with dichloromethane have shown an increased incidence of benign mammary tumors in both sexes of Sprague-Dawley (Burek et al., 1984) and F344 (NTP, 1986) rats. Male Sprague-Dawley rats had increased salivary gland sarcoma (Burek et al., 1984) and female F344 rats had increased leukemia incidence (NTP, 1986). Both sexes of B6C3F1 mice developed liver and lung tumors after dichloromethane treatment (NTP, 1986).

In a 2-year study by the National Coffee Association (1982, 1983), groups of 85 F344 rats/sex/dose received 5, 50, 125, or 250 (mg/kg)/day of dichloromethane in the drinking water. Control groups consisted of 135 rats/sex. In female rats the incidence of combined hepatocellular carcinoma and neoplastic nodules was statistically significantly increased in the 50 and 250 mg/kg dose groups when compared with matched controls (0/134, 1/85, 4/83, 1/85, and 6/85 in the five dose groups 0, 5, 50, 125, and 250 (mg/kg)/day, respectively). The incidence of hepatocellular carcinoma alone was not significantly increased (0/134, 0/85, 2/83, 0/85, 2/85). The combined incidence of hepatocellular carcinoma and neoplastic nodules in controls and the 4 dose groups (472 rats: 4 with carcinoma and 8 with neoplastic nodules) was similar to that for historical controls (419 rats; 5 with carcinoma, 19 with neoplastic nodules). Male rats showed no increase in liver tumors.

In the same National Coffee Association study (1982, 1983), B6C3F1 mice received 0, 60, 125, 185, or 250 (mg/kg)/day of dichloromethane in drinking water. Treatment groups consisted of 50 female mice and 200, 100, 100, and 125 male mice (low to high dose). One hundred females and 125 males served as controls. Male mice had an increased incidence of combined neoplastic nodules and hepatocellular carcinoma (24/125, 51/200, 30/100, 31/99, 35/125). The increase was not dose-related, but the pairwise comparisons for the two mid-dose groups were reported to be statistically significant (U.S. EPA, 1985a). The hepatocellular carcinoma incidence alone for male mice (which was about 55 to 65% of the total) was not significantly elevated. Female mice did not have increased liver tumor incidence. The EPA (1985b) regarded this study as suggestive but not conclusive evidence for carcinogenicity of dichloromethane.

A gavage bioassay of dichloromethane conducted by NTP (1982) has not been published because of high mortality, much of which was attributed to gavage accidents.

Inhalation exposure of 107 to 109 Syrian hamsters/sex/dose to 0, 500, 1500, or 3500 ppm of dichloromethane for 6 hours/day, 5 days/week for 2 years did not induce neoplasia (Burek et al., 1984). Sprague-Dawley rats (129/sex/dose) were exposed under the same conditions. Female rats administered the highest dose experienced significantly reduced survival from

Topic: DICHLOROMETHANE

18-24 months. Female rats showed a dose-related increase in the average number of benign mammary tumors per rat (1.7, 2.3, 2.6, 3.0), although the numbers of rats with tumors were not significantly increased. A similar response was observed in male rats, but to a lesser degree. In the male rats there was a statistically significant positive trend in the incidence of sarcomas of the salivary gland (1/93, 0/94, 5/91, 11/88); the incidence was significantly elevated at the high dose. There is a question as to whether these doses reached the MTD, particularly in the hamsters and the male rats. In another study (Dow Chemical Co., 1982), 90 Sprague-Dawley rats/sex were exposed by inhalation to 0, 50, 200, or 500 ppm dichloromethane for 20 months (male) or 24 months (female). No salivary tumors were observed, but there was an exposure-related increase in the total number of benign mammary tumors in female rats, although the increase was not statistically significant in any individual exposure group. Groups of 50 each male and female F344/N rats and B6C3F1 mice were exposed to dichloromethane by inhalation, 6 hours/day, 5 days/week for 2 years (NTP, 1986). Exposure concentrations were 0, 1000, 2000, or 4000 ppm for rats and 0, 2000, or 4000 ppm for mice. Survival of male rats was low; however, this apparently was not treatment-related. Survival was decreased in a treatment-related fashion for male and female mice and female rats. Mammary adenomas and fibroadenomas were significantly increased in male and female rats after survival adjustment, as were mononuclear cell leukemias in female rats. Among treated mice of both sexes there were significantly increased incidences of hepatocellular adenomas and carcinomas, and of alveolar bronchiolar adenomas and carcinomas, by life table tests. Adenomas and carcinomas were significantly increased alone as well as in combination. In addition, there were significant dose-related increases in the number of lung tumors per animal multiplicity in both sexes of mice.

Two inhalation assays using dogs, rabbits, guinea pigs, and rats showed no tumors, but were not conducted for the lifetime of the animals (Heppel et al., 1944; MacEwen et al., 1972). Theiss et al., (1977) injected Strain A male mice intraperitoneally with 0, 160, 400, or 800 mg/kg of dichloromethane 16 to 17 times, over 5 to 6 weeks. Survival of the animals was poor. The animals remaining 24 weeks after the first treatment were killed and examined for lung tumors; pulmonary adenomas were found.

II.A.4. SUPPORTING DATA FOR CARCINOGENICITY

Dichloromethane was mutagenic for *Salmonella typhimurium* with or without the addition of hepatic enzymes (Green, 1983) and produced mitotic recombination in yeast (Callen et al., 1980). Results in cultured mammalian cells have generally been negative, but dichloromethane has been shown to transform rat embryo cells and to enhance viral transformation of Syrian hamster embryo cells (Price et al., 1978; Hatch et al., 1983). Although chlorinated solvents have often been suspected of acting through a nongenotoxic mechanism of cell proliferation, Lefevre and Ashby (1989) found methylene chloride to be unable

pic: DICHLOROMETHANE

to induce hepatocellular division in mice.

 I.B. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM ORAL EXPOSURE

II.B.1. SUMMARY OF RISK ESTIMATES

Oral Slope Factor -- $7.5E-3$ per (mg/kg)/day

Drinking Water Unit Risk -- $2.1E-7$ per (ug/L)

Extrapolation Method -- Linearized multistage procedure, extra risk

Drinking Water Concentrations at Specified Risk Levels:

Risk Level	Concentration
E-4 (1 in 10,000)	$5E+2$ ug/L
E-5 (1 in 100,000)	$5E+1$ ug/L
E-6 (1 in 1,000,000)	$5E+0$ ug/L

II.B.2. DOSE-RESPONSE DATA (CARCINOGENICITY, ORAL EXPOSURE)

See Table Document

II.B.3. ADDITIONAL COMMENTS (CARCINOGENICITY, ORAL EXPOSURE)

The slope factor is an arithmetic mean of slope factors derived from NTP(1986) and the National Coffee Association (1983) data, $2.6E-3$ per (mg/kg)/day and $1.2E-2$ per (mg/kg)/day, respectively. The use of liver tumor data from the NTP inhalation bioassay was considered valid since dichloromethane is rapidly absorbed following either inhalation or ingestion.

Dose conversions used the mean body weight for female mice at the midpoint of the bioassay, and an estimated inhalation rate of 0.0407 cu.m/day. To obtain estimates of unit risk for humans, an inhalation rate of 20 cu.m/day was assumed.

Dichloromethane was considered to be well-absorbed as a vapor at low doses. No pharmacokinetic or metabolism data have been used to modify the oral unit risk estimate, because such analyses have not yet been carried out.

The unit risk should not be used if the water concentration exceeds $5E+4$ ug/L, since above this concentration the unit risk may not be appropriate.

II.B.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY, ORAL EXPOSURE)

Adequate numbers of animals were used in both assays. Risk estimates were based on the more sensitive sex in each study. The two risk estimates were within a factor of 5.

 II.C. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM INHALATION EXPOSURE

II.C.1. SUMMARY OF RISK ESTIMATES

Inhalation Unit Risk -- $4.7E-7$ per (ug/cu.m)

Extrapolation Method -- Linearized multistage procedure, extra risk

Air Concentrations at Specified Risk Levels:

Risk Level	Concentration
E-4 (1 in 10,000)	$2E+2$ ug/cu.m
E-5 (1 in 100,000)	$2E+1$ ug/cu.m

IRIS

Topic: DICHLOROMETHANE

E-6 (1 in 1,000,000) 2E+0 ug/cu.m

II.C.2. DOSE-RESPONSE DATA FOR CARCINOGENICITY, INHALATION EXPOSURE

See Table Document

II.C.3. ADDITIONAL COMMENTS (CARCINOGENICITY, INHALATION EXPOSURE)

The unit risk of $4.7E-7$ per (ug/cu.m), which incorporates information on pharmacokinetics and metabolism of dichloromethane, is approximately nine-fold lower than the previous applied dose estimate (U.S. EPA, 1987a,b). Internal dose estimates were based on the metabolism of dichloromethane by the glutathione-s-transferase pathway, as estimated by the model developed by Andersen et al. (1987). The internal dose was corrected for interspecies differences in sensitivity by using the surface area correction factor.

Calculation of a slope factor from the unit risk is inappropriate when pharmacokinetic models are used. (When dose-response relationships are figured on the basis of internal or metabolized dose, a slope factor in terms of per (mg/kg)/day represents a back calculation using different absorption assumptions than the pharmacokinetic models. This introduces possible contradictions.)

The unit risk should not be used if the air concentration exceeds $2E+4$ ug/cu.m, since above this concentration the unit risk may differ from that stated. Since the unit risk is based on a pharmacokinetic model, the risk may change with alterations in exposure patterns. Thus, the unit risk presented here may not be applicable to acute, high exposures.

II.C.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY, INHALATION EXPOSURE)

Adequate numbers of animals were observed and tumor incidences were significantly increased in a dose-dependent fashion. Analysis excluding animals that died before observation of the first tumors produced similar risk estimates, as did time-to-tumor analysis. The use of animal and human metabolism and pharmacokinetic data reduces some of the uncertainty typically associated with dose-risk extrapolation. A great deal of uncertainty still exists, however, in the estimates of internal dose generated by the model of Andersen et al. (1987). Important uncertainties remain regarding the pharmacokinetics, pharmacodynamics, and mechanisms of carcinogenicity for dichloromethane.

II.D. EPA DOCUMENTATION, REVIEW, AND CONTACTS
CARCINOGENICITY ASSESSMENT)

II.D.1. EPA DOCUMENTATION

U.S. EPA. 1985a. Health Assessment Document for Dichloromethane (Methylene Chloride). Final Report. Office of Health and Environmental Assessment, Washington, D.C. EPA/600/8-82/004F.

U.S. EPA. 1985b. Addendum to the Health Assessment Document for Dichloromethane (methylene chloride). Updated carcinogenicity assessment. Prepared by the Carcinogen Assessment Group, OHEA, Washington, DC. EPA/600/882/004FF.

IRIS

pic: DICHLOROMETHANE

U.S. EPA. 1987a. Update to the Health Assessment Document and Addendum for Dichloromethane (Methylene Chloride): Pharmacokinetics, Mechanism of Action and Epidemiology. Review Draft. Office of Health and Environmental Assessment, Washington, DC. EPA/600/8-87/030A.
U.S. EPA. 1987b. Technical Analysis of New Methods and Data Regarding Dichloromethane Hazard Assessments. Review Draft. Office of Health and Environmental Assessment, Washington, DC. EPA/600/8- 87/029A.

II.D.2. REVIEW (CARCINOGENICITY ASSESSMENT)

The Addendum to the Health Assessment Document, the Update to the Health Assessment Document and Addendum, and the Technical Analysis of New Methods and Data for dichloromethane have received Agency and external review, including a review by the Science Advisory Board (SAB). Although the last two documents are not yet finalized and the SAB comments are not yet incorporated, these do not alter this document's analyses or conclusions.

Agency Work Group Review: 11/12/86, 12/04/86, 04/06/89
Verification Date: 04/06/89

II.D.3. U.S. EPA CONTACTS (CARCINOGENICITY ASSESSMENT)

Lorenz Rhomberg / ORD -- (202)260-5723 / FTS 260-5723
Dharm V. Singh / ORD -- (202)260-5898 / FTS 260-5898

=====

Topic: TETRACHLOROETHYLENE

5.0 RANGE OF TOXICITY

6.1 EFFECTIVE DOSE

6.1.1 ADULT

A. ANTHELMINTIC

1. Single Dose: 0.1 to 0.12 milliliter/kilogram orally, up to a maximum of 5 milliliters (Reynolds, 1989). Treatment may be repeated in 4 to 7 days if necessary.
2. Treatment schedules on alternate-day or on 3 consecutive days have also been given (Reynolds, 1989).
3. Patient should be kept in bed for 4 hours after treatment (Reynolds, 1989).
4. Alcohol and fats should be avoided for 24 hours prior to and after treatment (Reynolds, 1989).

6.1.2 PEDIATRIC

A. ANTHELMINTIC

1. Single Dose: 0.1 milliliter/kilogram orally, up to a maximum of 4 milliliters (Reynolds, 1989).
2. Patient should be kept in bed for 4 hours after treatment (Reynolds, 1989).
3. Alcohol and fats should be avoided for 24 hours prior to and after treatment (Reynolds, 1989).

6.2 MINIMUM LETHAL EXPOSURE

- A. The minimum lethal human exposure to this agent has not been delineated.
- B. Mice died following inhalation exposure to 6000 ppm for 4 hours (ACGIH, 1986).

6.3 MAXIMUM TOLERATED EXPOSURE

- A. Industrial experience and human studies shows response based on various concentrations (Clayton & Clayton, 1982):

Concentration (ppm)	Response
50	Odor threshold
200	Minimal eye irritation minimal lightheadedness
400	Strong unpleasant odor eye irritation, slight nasal irritation, incoordination after 2 hours
600	Tolerable unpleasant odor eye and nasal irritation, dizziness, loss of inhibitions after 10 minutes
1000	Intense, irritating odor, eye and respiratory tract irritation, dizziness after 2 minutes
1500	"Gagging" odor, intolerable eye and nose irritation, incoordination within minutes, unconsciousness after 30 minutes

- B. Chronic Occupational Exposures (Proctor et al, 1988)

1. Dry cleaning workers with exposure to concentrations

TOMES(R) Medical Management

pic: TETRACHLOROETHYLENE

- ranging up to 300 ppm had CNS depression and some effects on the autonomic nervous system, but no liver function abnormalities.
2. Electrodiagnostic and neurologic rating scores were abnormal in 20 dry-cleaning workers exposed to between 1 and 40 ppm for an average of 7.5 years.
 3. EEG recordings were abnormal in 4 of 16 factory workers exposed to concentrations between 60 and 450 ppm for from 2 to greater than 20 years.
- C. Humans have been reported to survive an oral dose of 500 milligrams/kilogram (NIOSH, 1976; ACGIH, 1986).
1. When used as an anthelmintic, doses of 2.8 to 4 milliliters (about 4.6 to 6 grams) did not cause fatalities, but resulted in narcotic effects, a sense of exhilaration, and drunkenness (ACGIH, 1986). No liver function test abnormalities were produced by doses of 1 to 8 milliliters (1.5 to 12 grams) (ACGIH, 1986).
- D. With exposure to airborne concentrations of 300 to 1,000 ppm, incoordination and impaired judgement may occur (NFPA, 1986).
1. Two individuals rendered unconscious after acute tetrachloroethylene poisoning had breath concentrations of 85 and 110 ppm (Baselt, 1988). One of these individuals had been exposed to 1,100 ppm tetrachloroethylene for 30 minutes (Baselt, 1988).
 2. In human experiments, concentrations of 1,000 ppm are tolerated for 1.5 hours, while inhalation of 1,500 ppm rapidly causes dizziness and a faint feeling (Baselt, 1988).
- E. In humans, unconsciousness has occurred with exposure to 1,470 ppm for 3.5 hours and 2000 ppm for 1.5 minutes or longer (ACGIH, 1986).
1. Exposure to 500 ppm for 50 minutes has caused tightness in the frontal sinuses, a metallic taste, excessive sweating of the hands and feet, increased salivation, and eye irritation in humans (ACGIH, 1986).
 2. At a concentration of 216 ppm for 2 hours, humans developed difficulty with motor coordination, a thick tongue sensation, eye burning, frontal sinus congestion, and lightheadedness (ACGIH, 1986).
 3. Humans exposed to 100 ppm for 4 hours have complained of mild conjunctivitis (ACGIH, 1986).
 4. In human inhalation studies, prolonged exposure to 200 ppm caused early signs of CNS depression, while a 7-hour per day exposure to 100 ppm did not cause these effects (ACGIH, 1986)
- F. Rabbits exposed to 2,790 ppm, 4 hours daily, 5 days per week for 45 days developed fairly significant liver damage and elevations of hepatic enzyme levels, particularly after the 15th day (Mazza, 1972).
- G. Rats and rabbits exposed to 2,280 ppm, 4 hours daily, 6 days per week for 45 days developed significant reductions in glomerular filtrate, renal plasma flow, and maximum tubular excretion (Branccacio et al, 1971).
- H. Rabbits exposed to 15 mg/L, one hour daily for 15 days

Topic: TETRACHLOROETHYLENE

developed gradual increases in the plasma and urine concentrations of corticosteroids, epinephrine, norepinephrine, and 3-methyl-1-hydroxymandelic acid (Mazza & Brancaccio, 1971). These effects lasted for 30 days following cessation of exposure.

6.4 TOXIC SERUM/PLASMA/BLOOD CONCENTRATIONS

- A. Blood concentration of tetrachloroethylene was 4.4 milligrams/100 milliliters in a 33-year-old worker found dead after being left alone for 20 minutes to work on a dry-cleaning machine (Lukaszewski, 1979).
1. Tissue and urine were also sampled for tetrachloroethylene, and showed 36 mg/100 grams in brain and 0.3 mg/100 grams in lung. No tetrachloroethylene was detected in the urine or stomach contents, and no trichloroacetic acid (a metabolite) was present in the urine (Lukaszewski, 1979).
- B. In normal subjects, exposure to a concentration of 194 ppm for 3 hours resulted in an average peak blood level of 2.6 mg/L (Baselt, 1988). By 30 minutes following cessation of exposure, tetrachloroethylene was no longer detectable in the blood.
1. Blood concentrations were noted to be correlated with both the concentration of tetrachloroethylene in the breathing atmosphere and an individual's degree of physical activity (Baselt, 1988).
- C. The alveolar breath concentrations may approach 50% of the breathing atmosphere concentrations with constant exposure (Baselt, 1988).
1. In normal subjects breathing an atmosphere containing 100 ppm tetrachloroethylene, breath concentrations were: 15 ppm at one hour, 8 ppm at 15 hours, and 4.5 ppm at 71 hours (Baselt, 1988).
 2. Two individuals rendered unconscious after acute tetrachloroethylene poisoning had breath concentrations of 85 and 110 ppm (Baselt, 1988). One of these individuals had been exposed to 1,100 ppm tetrachloroethylene for 30 minutes (Baselt, 1988).
- D. Chlorinated tetrachloroethylene metabolites (trichloroacetic acid and others) in general are not present at greater than 100 mg/L in the urine of individuals occupationally exposed to ambient air concentrations of up to 400 ppm (Baselt, 1988).

6.5 LD50/LC50

- A. Published Values (RTECS, 1989)
1. TCLo (INHL) HUMAN: 96 ppm for 7 hours
 2. TCLo (INHL) MAN: 280 ppm for 2 hours
 3. LDLo (INHL) MAN: 2857 mg/kg
 4. TCLo (INHL) MAN: 600 ppm for 10 minutes
 5. LD50 (ORAL) RAT: 2629 mg/kg
 6. LC50 (INHL) RAT: 34200 mg/m(3) for 8 hours
 7. LD50 (IP) RAT: 4678 mg/kg
 8. LD50 (ORAL) MOUSE: 8100 mg/kg
 9. LC50 (INHL) MOUSE: 5200 ppm for 4 hours
 10. LD50 (SC) MOUSE: 65 grams/kg
 11. LDLo (ORAL) DOG: 4000 mg/kg

pic: TETRACHLOROETHYLENE

- 12. LD50 (IP) DOG: 2100 mg/kg
- 13. LDLo (IV) DOG: 85 mg/kg
- 14. LDLo (ORAL) CAT: 4000 mg/kg
- 15. LDLo (ORAL) RABBIT: 5000 mg/kg
- 16. LDLo (SC) RABBIT: 2200 mg/kg

5.6 CALCULATIONS

- A. 1 mg/L = 1.474 ppm (at 25 degrees C and 760 mmHg)
(Clayton & Clayton, 1982)
- B. 1 ppm = 6.78 mg/m(3) (at 25 degrees C and 760 mmHg)
(Clayton & Clayton, 1982)

Topic: TETRACHLOROETHYLENE

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Summary

Environmental Fate/Exposure Summary:

1. Tetrachloroethylene (PCE) is likely to enter the environment by fugitive air emissions from dry cleaning and metal degreasing industries and by spills or accidental releases to air, soil, or water. If PCE is released to soil, it will be subject to evaporation into the atmosphere and to leaching to the groundwater. Biodegradation may be an important process in anaerobic soils based on laboratory tests with methanogenic columns. Slow biodegradation may occur in groundwater where acclimated populations of microorganisms exist. If PCE is released to water, it will be subject to rapid volatilization with estimated half-lives ranging from <1 day to several weeks. It will not be expected to significantly biodegrade, bioconcentrate in aquatic organisms or significantly adsorb to sediment. PCE will not be expected to significantly hydrolyze in soil or water under normal environmental conditions. If PCE is released to the atmosphere, it will exist mainly in the gas-phase and it will be subject to photooxidation with estimates of degradation time scales ranging from an approximate half-life of 2 months to complete degradation in an hour. Some of the PCE in the atmosphere may be subject to washout in rain based on the solubility of PCE in water; PCE has been detected in rain. Major human exposure is from inhalation of contaminated urban air, especially near point sources such as dry cleaners, drinking contaminated water from contaminated aquifers and drinking water distributed in pipelines with vinyl liners, and inhalation of contaminated occupational atmospheres in metal degreasing and dry cleaning industries. (SRC) **PEER REVIEWED**

Pollution Sources

Natural Occurring Sources:

1. Tetrachloroethylene is not known to occur in nature. (SRC) **PEER REVIEWED**

Artificial Sources:

1. Water pollution by tetrachloroethylene leaching from vinyl liners in asbestos-cement water pipelines for water distribution. **PEER REVIEWED** [Yuskus LR; J Am Water Works Assoc 76 (2): 76-81 (1984)]
2. Vaporization losses from dry cleaning and industrial metal cleaning(1). Wastewater, particularly from metal finishing, laundries, aluminum forming, organic chemical/plastics manufacturing and municipal treatment plants. It is also estimated that emissions account for approximately 90% of the tetrachloroethylene produced in the United States(2). **PEER REVIEWED** [(1) Chemical Marketing Reporter. Chemical Profile March 14, 1983 (1983) (2) Singh HB et al; Atmospheric Distributions, Sources and Sinks of Selected Halocarbons, Hydrocarbons, SF6 and N2O; p.34 EPA-600/3-79-107 (1979)]
3. During chlorination water treatment, it can be formed in

pic: TETRACHLOROETHYLENE

small quantities. **PEER REVIEWED** [National Research Council. Drinking Water & Health Volume 1. Washington, DC: National Academy Press, 1977. 769

Environmental Fate

Environmental Fate:

1. TERRESTRIAL FATE: If tetrachloroethylene (PCE) is released to soil, it will evaporate fairly rapidly into the atmosphere due to its high vapor pressure and low adsorption to soil. It can leach rapidly through sandy soil and therefore may reach groundwater(1-3). Biodegradation may be an important process in anaerobic soils based on laboratory tests with methanogenic columns. Slow biodegradation may occur in groundwater where acclimated populations of microorganisms exist. There is some evidence of slow degradation in subsurface soils from a groundwater recharge project. PCE should not hydrolyze under normal environmental conditions. (SRC) **PEER REVIEWED** [(1) Wilson JT et al; J Environ Qual 10: 501-6 (1981) (2) Tomson MB et al; Water Res 15: 1109-16 (1981) (3) Schwarzenbach RP et al; Environ Sci Technol 17: 472-9 (1983)]
2. AQUATIC FATE: If tetrachloroethylene (PCE) is released in water, the primary loss will be by evaporation. The half-life for evaporation from water will depend on wind and mixing conditions and is estimated to range from 3 hours to 14 days in rivers, lakes and ponds. Chemical and biological degradation are expected to be very slow. PCE will not be expected to significantly bioconcentrate in aquatic organisms or to adsorb to sediment. A mesocosm experiment was conducted to simulate Narraganset Bay during different seasons. Volatilization was the major removal process during all seasons and seasonal differences can be explained by hydrodynamics and the measured half-lives were 25 days in spring, 11 days in winter and 14 days in summer(4). In one experiment in which half-lives were calculated from concentration reduction between sampling points on the Rhine River and a lake in the Rhine basin, half-lives were 10 days and 32 days, respectively(1). In a seawater aquarium, an 8 day half-life was demonstrated to be predominately the result of evaporation(2). In a natural pond, PCE disappeared in 5 and 36 days at low (25 ppm) and high (250 ppm) dose levels, respectively(3). **PEER REVIEWED** [(1) Zoeteman BCJ et al; Chemosphere 9: 231-49 (1980) (2) Jensen S, Rosenberg R; Water Res 9: 659-61 (1975) (3) Lay JP et al; Arch Environ Contam Toxicol 13: 135-42 (1984) (4) Wakeham SG et al; Environ Sci Technol 17: 611-7 (1983)]
3. ATMOSPHERIC FATE: If tetrachloroethylene (PCE) is released to the atmosphere, it will be expected to exist in the vapor phase(5) based on a reported vapor pressure of 18.47 mm Hg at 25 deg C(4). Vapor phase PCE will be expected to degrade by reaction with photochemically produced hydroxyl radicals or chlorine atoms produced by photooxidation of PCE. Estimated photooxidation time scales range from an approximate half-life of 2 months(1,2) to complete

Topic: TETRACHLOROETHYLENE

degradation in an hour(3). Some of the PCE in the atmosphere may be subject to washout in rain based on the solubility of PCE in water (150 ppm(4)); PCE has been detected in rain. **PEER REVIEWED** [(1) Singh HB et al; Atmos Environ 15: 601-12 (1981) (2) Howard CJ; J Chem Phys 65: 4771-7 (1976) (3) Dimitriadis B et al; J Air Pollut Control Assoc 33: 575-87 (1983) (4) Riddick JA et al.; Organic Solvents: Physical Properties and Methods of Purification. Techniques of Chemistry. 4th ed. Wiley-Interscience pp. 1325 (1986) (5) Eisenreich SJ et al; Environ Sci Technol 15: 30-8 (1981)]

Environmental Transformations

Biodegradation:

1. Tetrachloroethylene (PCE) can be transformed by reductive dehalogenation to trichloroethylene (TCE), dichloroethylene and vinyl chloride (VC) under anaerobic conditions. In addition, (14)C-PCE was at least partially mineralized to carbon dioxide. Mineralization of 24% of the PCE occurred in a continuous flow mixed film methanogenic column with a liquid detection time of 4 days. TCE was the major intermediate formed, but traces of dichloroethylene isomers and VC were also found. In other column studies under a different set of methanogenic conditions, nearly quantitative conversion of PCE to VC was found. TCE and VC are major intermediates in PCE biotransformation under anaerobic conditions and the potential exists for the complete mineralization of PCE to CO₂ in soil and aquifer systems and in biological treatment processes. **PEER REVIEWED** [Vogel TM, McCarty PL; Appl Environ Microbiol 49 (5): 1080-3 (1985)]
2. No degradation occurred in 21 days in 3 biodegradability tests with acclimated or unacclimated inocula or in a river die-away test(4). Microbial degradation did not contribute to the removal of tetrachloroethylene (PCE) in a mesocosm experiment which simulated Narraganset Bay, RI(5). Under aerobic conditions there is no degradation in 25 weeks in a batch experiment with a sewage inoculum(1) or when low concentrations of PCE (16 ug/l) were circulated through an acclimated aerobic biofilm column over a period of 1 year(2). While only 3.75% of the PCE treated by conventional, extended and 2-stage activated-sludge pilot plants appeared in the effluent, most of the PCE was discharged to the air from the extended aeration(3). **PEER REVIEWED** [(1) Bouwer EJ et al; Environ Sci Technol 15: 596-9 (1981) (2) Bouwer EJ, McCarty PL; Environ Sci Technol 16: 836-43 (1982) (3) Watanabe H; Gesuido Kyokaiski 20: 29-37 (1983) (4) Mudder TI; Amer Chem Soc Div Env Chem Conf p. 52-3 (1982) (5) Wakeham SG; Environ Sci Technol 17: 611-7 (1983)]
3. There is evidence that slow biodegradation of tetrachloroethylene (PCE) occurs under anaerobic conditions when the microorganisms have been acclimated, yielding trichloroethylene (TCE) as a product(1,2). An experiment in a continuous-flow laboratory methanogenic column using well acclimated mixed culture and a 2-day

pic: TETRACHLOROETHYLENE

detention time had an average PCE removal rate of 76%(3). In a continuous-flow mixed-film methanogenic column with a liquid detention time of 4 days, mineralization of 24% of the PCE present occurred; TCE was the major intermediate formed(72%), but traces of dichloroethylene isomers and VC were also found(4). In other column studies under a different set of methanogenic conditions, nearly quantitative conversion of PCE to VC was found in 10 days(4). Removal of 86% PCE occurred in a methanogenic biofilm column (8 weeks of activation followed by 9-12 weeks of acclimation(5)). **PEER REVIEWED** [(1) Bouwer EJ, McCarty PL; Appl Environ Microbiol 45: 1286-94 (1983) (2) Wilson JT et al; Devel Indust Microbiol 24: 225-33 (1983) (3) Bouwer EJ, McCarty PL; Ground Water 22: 433-40 (1984) (4) Vogel TM, McCarty PL; Appl Environ Microbiol 49: 1080-3 (1985) (5) Bouwer EJ, Wright JP; Am Chem Soc Div Environ Chem. 191st Natl Meet 26: 42-5 (1986)

4. A large reduction of tetrachloroethylene which had been recirculated through a soil column for 14 days was attributed to adsorption and volatilization(2). In a microcosm containing muck from an aquifer recharge basin, 72.8% loss was observed in 21 days against 12-17% in controls, and the metabolites trichloroethylene, cis- and trans-1,2-dichloroethylene, dichloromethane, and chloroethene were identified(3). However, when subsurface samples were aseptically removed from above and below the water table and incubated in the laboratory, no degradation occurred in 16 weeks(4). In one field groundwater recharge project, degradation was observed in the 50 day recharge period(1). **PEER REVIEWED** [(1) Bouwer EJ et al; Environ Sci Technol 15: 596-99 (1981) (2) Bouwer EJ et al; Water Res 15: 151-59 (1981) (3) Parsons F et al; J Amer Wat Works Assoc 76: 56-9 (1984) (4) Wilson JT et al; Ground Water 21: 134-42 (1983)

Abiotic Degredation:

1. Tetrachloroethylene can be transformed by reductive dehalogenation to trichloroethylene under anaerobic conditions. **PEER REVIEWED** [Vogel TM, McCarty PL; Appl Environ Microbiol 49 (5): 1080-3 (1985)
2. Tetrachloroethylene (PCE) reacts with hydroxyl radicals which are produced by sunlight in the troposphere with an estimated half-life of about 2 months or a loss of 1.5% per sunlit day(1,2). Photooxidation in pure air with simulated tropospheric light is much faster than that predicted from the reaction with hydroxyl radicals with complete degradation occurring in 7 days in 1 report(3) and from 0.5% to 100% loss per hour in another(4). The rate of loss is very sensitive to radiation in the 280-330 nm region and increases with increasing PCE concentration, the presence of nitrogen oxides has little effect on the rate of loss(4), and the main reaction product is phosgene (70-85%) with smaller amounts of carbon tetrachloride (8%), dichloroacetyl chloride, and trichloroacetyl chloride(3). The proposed mechanism involved the molecular reaction with chlorine radicals produced by photooxidation

Topic: TETRACHLOROETHYLENE

of PCE(4). **PEER REVIEWED** [(1) Singh HB et al; Atmos Environ 15: 601-12 (1981) (2) Howard CJ; J Chem Phys 65: 4771-7 (1976) (3) Singh HB et al; Environ Lett 10: 253-6 (1975) (4) Dimitriades B et al; J Air Pollut Control Assoc 33: 575-87 (1983)]

3. Photodegradation in the stratosphere is rapid(1). Some photodegradation occurs when tetrachloroethylene (PCE) in air-saturated water is exposed to sunlight. In one year, 75% degradation occurred whereas 59-65% degradation was noted for dark controls(2). When PCE adsorbed to silica gel is irradiated through a pyrex filter, 50-90% is lost in 6 days(3). It is not clear whether PCE adsorbed on particulate matter will photodegrade as readily(SRC). Hydrolysis is not a significant degradative process (half-life 9 months at 25 deg C in purified, de-ionized water)(2). **PEER REVIEWED** [(1) Mueller JPH Korte F; Chemosphere 3: 195-8 (1977) (2) Dilling WL et al; Environ Sci Technol 9: 833-8 (1975) (3) Gaeb S et al; Nature 270: 331-3 (1977)]

Environmental Transport

Bioconcentration:

1. BCF: fathead minnow (*Pimephales promelas*), 38.9(1); bluegill sunfish (*Lepomis macrochirus*) 49(2). Based on a reported log Kow of 3.40(4), a BCF of 226 was estimated(3, SRC). Based on the reported and estimated BCF's, tetrachloroethylene will not be expected to significantly bioconcentrate in aquatic organisms(SRC). **PEER REVIEWED** [(1) Neely WB et al; Environ Sci Technol 8: 1113-15 (1974) (2) Barrows ME et al; Dyn., Exposure Hazard Assess. Toxic Chem. Ann Arbor MI: Ann Arbor Sci. p. 379-92 (1980) (3) Lyman WJ et al; Handbook of Chem Property Estimation Methods NY: McGraw-Hill p. 5-5 (1982) (4) Hansch C, Leo AJ; Medchem Project Issue No. 26 Claremont, CA: Pomona College (1985)]

Soil Adsorption/Mobility:

1. ... Tetrachloroethylene ... /was/ ... slightly adsorbed on ... sand and clay minerals. ... The Henry's adsorption coefficients were approx in proportion to the organic content of the soil samples. **PEER REVIEWED** [Urano K, Murata C; Chemosphere 14 (3-4): 292-9 (1985)]
2. Koc: 209(1); 210(2). In a laboratory system simulating a rapid-infiltration site, tetrachloroethylene (PCE) appeared in the effluent but at significantly reduced concentration levels(3,7) although in a bank-infiltration system in Switzerland and The Netherlands, PCE was rapidly transported to groundwater(4,5). It is estimated that in a bay such as Narraganset Bay, RI, only about 0.01% of PCE is adsorbed to particulate matter(6). **PEER REVIEWED** [(1) Schwarzenbach RP, Westall J; Environ Sci Technol 15: 1360-67 (1981) (2) Chiou CT et al; Science 206: 831-2 (1979) (3) Hutchins SR, Ward CH; J Hydrol (Amsterdam) 67: 223-33 (1984) (4) Gegir W et al; Ges, Wasser, Abwasser 63: 517-31 (1983) (5) Piet GJ et al; Studies Env Sci 17: 557-64 (1981) (6) Wakeham SG et al; Environ Sci Technol 17: 611-7 (1983) (7) Hutchins SR et al; Environ Toxicol

pic: TETRACHLOROETHYLENE

Chem 2: 195-216 (1983)

3. A Koc of 238 was calculated(2,SRC) based on a reported Kom of 137.7 in a peaty soil(1). Based on a reported log Kow of 3.40(3), a Koc of 1,685 was estimated(2,SRC). Based on the reported and estimated Koc's, tetrachloroethylene will be expected to exhibit low to medium mobility in soil(4) and therefore may leach slowly to the groundwater(SRC).
 PEER REVIEWED [(1) Friesel P et al; Fresenius Z Anal Chem 319: 160-4 (1984) (2) Lyman WJ et al; Handbook of Chem Property Estimation Methods NY: McGraw-Hill p. 4-2 to 4-9 (1982) (3) Hansch C, Leo AJ; Medchem Project Issue No.26 Claremont, CA: Pomona College (1985) (4) Swann RL et al; Res Rev 85: 17-28 (1983)]

Volatilization from Water/Soil:

1. Tetrachloroethylene will evaporate rapidly from water based on estimates of half-life for the evaporation from water which range from fractions of an hour to several hours in laboratory experiments(1-4). Two values of the ratio of the volatilization rate constant relative to the reaeration rate of oxygen are 0.52(4) and 0.61(5). Using representative oxygen reaeration rates for various bodies of water, the half-lives for evaporation are as follows: pond 5-12 days; river 3 hr-7 days; lake 3.6-14 days(4,SRC). Measured volatilization half-lives in a mesocosm simulating Narraganset Bay, RI were 11 days in winter, 25 days in spring, and 14 days in summer(6).
 PEER REVIEWED [(1) Dilling WL; Environ Sci Technol 11: 405-9 (1977) (2) Chiou CT et al; Environ Inter 3: 231-6 (1980) (3) Smith JH et al; Environ Sci Technol 14: 1332-7 (1980) (4) Lyman WL et al; Handbook of Chemical Property Estimation Methods NY: McGraw-Hill p. 15-35 (1981) (5) Roberts PV, Dandliker PG; Environ Sci Technol 17: 484-9 (1983) (6) Wakeham SG; Environ Sci Technol 17: 611-7 (1983)]
2. Due to its high vapor pressure (18.47 mm Hg at 25 deg C(1)) and low adsorption to soil, volatilization of tetrachloroethylene from dry soil should be rapid(SRC).
 PEER REVIEWED [(1) Riddick JA et al; Organic Solvents: Physical Properties and Methods of Purification. 4th. Wiley-Interscience pp. 1325 (1986)]

Environmental Concentrations

Water Concentrations:

1. Samples for analysis of volatile organic compounds were collected from 315 wells in the Potomac-Raritan-Magothy aquifer system in southwestern New Jersey and a small adjacent area in Pennsylvania (USA) during 1980-1982. Volatile organic compounds were detected in all 3 aquifer units of the Potomac-Raritan-Magothy aquifer system. Most of the contamination appeared to be confined to the outcrop area. Low levels of contamination were found downdip of the outcrop area in the upper and middle aquifer. Trichloroethylene, tetrachloroethylene and benzene were the most frequently detected compounds. Differences in the distributions of light chlorinated hydrocarbons, /(including tetrachloroethylene)/,

Topic: TETRACHLOROETHYLENE

trichloroethylene, and aromatic hydrocarbons, ie, benzene, were noted and were probably due to differences in the uses of the compounds and the distribution patterns of potential contamination sources. The distribution patterns of volatile organic compounds differed greatly among the 3 aquifer units. The upper aquifer, which cropped out mostly in less-developed areas, had the lowest percentage of wells with volatile organic compounds detected (10% of wells sampled). The concentrations in most wells in the upper aquifer which had detectable levels were <10 ug/l. In the middle aquifer, which cropped out beneath much of the urban and industrial area adjacent to the Delaware River, detectable levels of volatile organic compounds were found in 22% of wells sampled, and several wells contained concentrations >100 ug/l. The lower aquifer, which was confined beneath much of the outcrop area of the aquifer system, had the highest percentage of wells (28%) with detectable levels. This was probably due to vertical leakage of contamination from the middle aquifer and the high percentage of wells tapping the lower aquifer in the most heavily developed areas of the outcrop. **PEER REVIEWED** [Fusillo TV et al; Ground Water 23 (3): 354-60 (1985)]

2. The National Health Department (Italy) had promoted and supported a preliminary survey on the presence of some chlorinated organic compounds in the drinking water. The drinking water of some cities of northern Italy was analyzed for the presence of trichloroethylene, tetrachloroethylene, methylchloroform, carbon tetrachloride, trihalomethanes, polychlorinated biphenyls, and the most common chlorinated pesticides. From March, 1981 to June, 1982, 8 controls were done for 11 sampling points. All water underwent different treatments with carbon. In the raw water, trichloroethylene (47/48) and tetrachloroethylene (34/48) showed the highest frequency of positivity. One well had the highest concentrations of these compounds (trichloroethylene 81-158 ug/l; tetrachloroethylene 15-32 ug/l). In the finished waters, carbon tetrachloride the most abundant trihalomethane formed during chlorination, was detected in 80% of the 39 samples, against 31% in the 48 raw water samples. No polychlorinated biphenyls and chlorinated pesticides were found at the chosen detection limit (0.05 ug/l). **PEER REVIEWED** [Zigliio G et al; Ig Mod 82 (3): 419-35 (1984)]
3. DRINKING WATER: 180 USA cities with finished surface water - 0.3 ppb median, 21 ppb max; 36 US cities with finished groundwater - 3.0 ppb median; roughly 25% of the samples were positive(1). Contaminated wells had much higher concentrations (a maximum of 1.5 ppm)(2,3). 30 Canadian potable water treatment facilities (treated water) 1 ppb avg, 2 ppb max(4); 230 Groundwater public drinking water sources in the Netherlands: 64 are >10 ppb, 12 are >100 ppb, 4 are >1 ppm and 2 are >100 ppm(5). Federal survey of finished waters in USA: Tetrachloroethylene occurred in 26.1% of groundwater supplies, max concentrate in

opic: TETRACHLOROETHYLENE

- groundwater and surface water supplies 1500 and 21 ppb, respectively(6). **PEER REVIEWED** [(1) Coniglio WA et al; Occurrence of Volatile Organics in Drinking Water. p. 7 Unpublished EPA report (1980) (2) Burmaster DE; Environ 24: 6-13, 33-6 (1982) (3) Giger W, Molnar-Kubica E; Bull Environ Contam Toxicol 19: 475-80 (1978) (4) Otson R et al; J Assoc Off Anal Chem 65: 1370-4 (1982) (5) Trouwborst T; Sci Total Environ 21: 41-6 (1981) (6) Dyksen JE, Hess AF III; J Amer Water Works Assoc 74: 394-403 (1982)
4. DRINKING WATER: Maximum concentration in tapwater from bank filtered Rhine water in the Netherlands 50 parts per trillion(1). Old Love Canal, Niagara Falls, NY (9 homes) 350-2900 parts per trillion, 470 parts per trillion median(2). USA surveys: State data, 1569 samples, 14% pos, trace to 3000 ppb, National Organics Monitoring Survey (NOMS, initiated in 1975), 113 samples, 42.4% pos, 0.2-3.1 ppb, National Screening Program (NSP, 1977-1981), 142 samples, 16.9% pos, trace to 3.2 ppb, Community Water Supply Survey (CWSS, 1978), 452 samples, 4.9% pos, 0.5-30 ppb, Ground Water Supply Survey (GWS, 1982, finished drinking water), 466 samples selected at random from 1000 in survey, 7.3% pos, 0.5 ppb median, 23 ppb max(3). **PEER REVIEWED** [(1) Piet GJ, Morra CF; pp. 31-42 in Artificial Groundwater recharge; Huismon L, Olsthorst TN eds; Pitman Pub (1983) (2) Barkley J et al; Biomed Mass Spectrum 7: 139-47 (1980) (3) Cotruvo JA et al; pp. 511-30 in: Organic Carcinogens in Drinking Water (1986)
 5. GROUNDWATER: 27 USA cities, 0.6 ppb median (range 0.1-2 ppb)(1) San Fernando Valley, CA (1981-1983) - 17 of 106 wells exceeded 4 ppb, max 130 ppb(2). 10 British groundwaters: Equal or <2 ppb in 8 waters and higher levels at 2 sites where the aquifer was grossly polluted(3). Groundwater underlying 2 rapid infiltration sites 0.07 and 0.63 ppb(4). Japan, national groundwater survey, 1982, 1,083 shallow wells (most for domestic uses other than drinking water in private homes), 27% pos, 0.2-23,000 ppb, 277 deep wells (public, industrial, and commercial supplies), 30% pos, 0.2-150 ppb(5). **PEER REVIEWED** [(1) Coniglio WA et al; Occurrence of Volatile Organics in Drinking Water. p. 7 Unpublished EPA report (1980) (2) Chemical Engineering 90: 35 (1983) (3) Fielding M et al; Environ Technol Lett 2: 545-50 (1981) (4) Hutchins SR et al; Environ Toxicol Chem 2: 195-216 (1983) (5) Magara Y, Furuichi T; pp. 231-43 in: New Concepts and Development in Toxicol. Chambers PL et al eds. Elsevier Sci Publ (1986)
 6. SURFACE WATER: 154 USA cities - 2.0 ppb median, 13.6% positive(1). Ohio R (1980-81, 11 stations, 4972 samples) - 49% positive, 340 basins in USA (204 sites)-77 sites above 1 ppb, 1 site above 11 ppb(2). Lake Ontario (95 stations) 9 parts per trillion mean standard deviation 65 parts per trillion(3). Rhine R, km 865 (1976-1982) 0.12-0.62 ppb with lower concentrations after 1978(4). Surface of Lake Zurich - 25-140 parts per trillion, greater concentrations below the surface(5,6). STORET Database, 9,323 data

Topic: TETRACHLOROETHYLENE

points, 38.0% pos, 0.100 ppb median(7). **PEER REVIEWED** [(1) Coniglio WA et al; Occurrence of Volatile Organics in Drinking Water. p. 7 Unpublished EPA report (1980) (2) Ewing BB et al; Monitoring to Detect Previously Unrecognized Pollutants in Surface Water. EPA-560/6-77-015 & EPA-560/6-77-015A (1977) (3) Kaiser KLE et al; J Great Lakes Res 9: 212-23 (1983) (4) Malle KG; Z Wasser Abwasser Forsch 17: 75-81 (1984) (5) Grob K, Grob G; J Chrom 90: 303-13 (1974) (6) Schwarzenbach RP et al; Environ Sci Technol 13: 1367-73 (1979) (7) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985)

7. SEAWATER: 0.1 to 0.8 parts per trillion(1,2). May be several orders of magnitude higher (10 ppb) near source, but concentration diminishes rapidly away from source(3). Gulf of Mexico (open and coastal) 0-40 parts per trillion where there is anthropogenic influence and <1 parts per trillion in unpolluted areas(4). Surface seawater Eastern Pacific Ocean 1981 (0-10 m depth), 30 samples, 90% pos, range of pos, 0.1-2.8 parts per trillion, avg of all data, 0.7 parts per trillion(5). **PEER REVIEWED** [(1) Murray AJ, Riley JP; Nature 242: 37-8 (1973) (2) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975) (3) Helz GR, Hsu RY; Limnol Oceanogr 23: 858-69 (1978) (4) Sauer TC Jr; Org Geochem 3: 91-101 (1981) (5) Singh HB et al; J Geophys Res 88: 3675-83 (1983)
8. RAIN/SNOW: West Los Angeles (3/26/82) - 21 parts per trillion(2). Industrial city in England - 150 parts per trillion(1). La Jolla, California - 5.7 parts per trillion(3). Central and Southern California - 1.4 and 2.3 parts per trillion resp(3). **PEER REVIEWED** [(1) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975) (2) Kawamura K, Kaplan IR; Environ Sci Technol 17: 497-501 (1983) (3) Su C, Goldberg ED; Mar Poll Transfer 1976: 353-74 (1976)

Effluents Concentrations:

1. Industrial 1-20 ppb; Municipal treatment plants 1-10 ppb(1); Baltimore Municipal Treatment Plant 8-129 ppb (higher levels in winter)(2). Industries in which mean or maximum levels in raw wastewater exceeded 1 ppm are (number of samples, percent pos, mean, max, ppm): raw wastewater: auto and other laundries (28 samples, 71.4% pos, <8.4 ppm mean, 93 ppm max), aluminum forming (4, 100%, <2.6, <4.0), metal finishing (96, 42.7%, 4.5, 110), organic chemical/plastics manufacturing (number of samples not reported, 19 pos, 5.1 mean, max concn not reported), and paint and ink formulation (36, 55.6%, 0.95, 4.9); treated wastewater: auto and other laundries (5 samples, 80% pos, 0.58 ppm mean, 1.0 ppm max), aluminum forming (16, 87.5%, <0.24, 3.0), metal finishing (not reported), organic chemical/plastics manufacturing (number of samples not reported, 14 pos, 0.047 mean, max concn not reported), and paint and ink formulation (24, 33.3%, 0.19, 0.70)(3). Industrial effluent, STORET Database, 1,390 data points, 10.1% pos, 5.0 ppb median(4). **PEER REVIEWED** [(1) STORET Data Base (2) Helz GR, Hsu RY; Limnol Oceanogr 23:

HSDB

opic: TETRACHLOROETHYLENE

858-69 (1978) (3) US EPA; Treatability Manual. p.I.12.26-1 to I.12.26-5 USEPA-600/2-82-001A (1981) (4) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985)

Sediment/Soil Concentrations:

1. SEDIMENT: Liverpool Bay/172 stations - 4.8 parts per trillion avg(1). STORET Database, 359 data points, 7% pos, <0.050 ppb median(2). **PEER REVIEWED** [(1) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975) (2) Staples CA et al; Environ Toxicol Chem 4: 131-42 (1985)]

Atmospheric Concentrations:

1. U.S. 577 sites, 1 ug/cu m median(5). BACKGROUND: Northern hemisphere background - 40 parts per trillion(3). RURAL/REMOTE: Barrows Alaska - 128 parts per trillion max (Feb), 56 parts per trillion min (Sept)(2). US - remote sites - typical levels 20-130 parts per trillion(1,2,3). Northern and Southern Atlantic, 7 sites, 85.7% pos, 84 samples, range of means of pos, 0.05-0.27 parts per trillion(6). Norwegian arctic air, 9 samples, July 1982, 0.0184 ppb avg, Spring 1983, 0.0382 ppb avg(7). URBAN/SUBURBAN: Seven U.S. cities, 1980-1981 range of means, 0.290-0.590 ppb, 7.60 ppb max, background, 0.050 ppb; 3 cities in NJ, 1981, 6 weeks in summer, range of means, 0.240-0.450(4). **PEER REVIEWED** [(1) Lillian D et al; Amer Chem Soc Symp Ser 17: 152-8 (1975) (2) Khalil MAK, Rasmussen RA; Environ Sci Technol 17: 157-64 (1983) (3) Singh HB et al; Atmospheric Distributions, Sources and Sinks of Selected Halocarbons, Hydrocarbons, SF6 and N2O. EPA-600/3-79-107 p. 88, 117-8 (1979) (4) Andelman JB; Environ Health Persp 62: 313-8 (1985) (5) Eichler DL, Mackey JH; Proc APCA 79th Ann Meeting pp. 17 (1986) (6) Class T, Ballschmiter K; Chemosphere 15: 413-27 (1986) (7) Hov O et al; Geophys Res Lett 11: 425-8 (1984)]
2. Avg worldwide distribution in 1978 (parts per trillion): Northern Hemisphere, 56.0, Southern Hemisphere, 14.0, Global, 35.0(8). URBAN/INDUSTRIAL: USA- Urban/Industrial Areas - typical levels 0.3-1.5 ppb but reaches 10 ppb and even higher(1-5). INDUSTRIAL/SOURCE DOMINATED: Old Love Canal, Niagara, NY - Ambient air outside and inside 9 homes, 109 and 71 parts per trillion median(6). Classroom and playground in school situated near facility, 1.9 and 0.15 ppb, respectively(7). Nursing home situated near former chemical waste dump, 1.2 and 0.2 ppb on first and second floors, respectively(7). **PEER REVIEWED** [(1) Lillian D et al; Amer Chem Soc Symp Ser 17: 152-8 (1975) (2) Pellizzari ED; Quantation of Chlorinated Hydrocarbons in Previously Collected Air Samples. EPA-450/3-78-112 (1978) (3) Singh HB et al; Environ Sci Technol 16: 872-80 (1982) (4) Su C, Goldberg ED; Mar. Pollut Transfer pp. 353-74 (1976) (5) Leoy PJ et al; Atmos Environ 17: 2321-30 (1983) (6) Barkley J et al; Biomed Mass Spectron 7: 139-47 (1980) (7) Monster AC, Smolders JFJ; Int Arch Occup Environ Health 53: 331-6 (1984) (8) Herbert P et al; Chem Ind 24: 861-9 (1986)]

Food Survey Results:

HSDB

Topic: TETRACHLOROETHYLENE

1. Chinese style sauce, 2 ppb; Quince jelly, 2.2 ppb; Crab apple jelly, 2.5 ppb; Grape jelly, 1.6 ppb; Chocolate sauce, 3.6 ppb. Not detected in seven market basket composites of meats (detection limit = 4.6 ppb), oils and fats (detection limit = 13 ppb), beverages (detection limit = 0.5 ppb) or dairy products (detection limit = 2.3 ppb)(1). Various categories of food in England - 0.01-13 ppb, highest values in fats and oils(2). USA, wheat, 10 samples, 20% pos, 1.8-2.1 ppb, corn, 2 samples, 100% pos, 0.45-0.54 ppb; not detected in one sample each of oats and corn grits, 2 samples of corn meal(3). **PEER REVIEWED** [(1) Entz RC, Hollifield HC; J Agric Food Chem 30: 84-8 (1982) (2) McConnell G et al; Endeavour 34: 13-18 (1975) (3) Heikes DL, Hopper ML; J Assoc Off Anal Chem 69: 990-8 (1986)]
2. Tetrachloroethylene concentrations in foods ranged from non-detectable amounts (<0.01 ug/kg) in orange juice to 13 ug/kg in English butter. **PEER REVIEWED** [McConnell G et al; Endeavour 34: 13 as cited in USEPA; Ambient Water Quality Criteria Doc: Tetrachloroethylene p.C-1 (1980) EPA 440/5-80-073]

Plant Concentrations:

1. 13-23 ppb in marine algae(1). **PEER REVIEWED** [(1) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-22 (1975)]

Fish/Seafood Concentrations:

1. 0.3-43 ppb in marine fish, 0.5-176 ppb in marine invertebrates in England(1), 250 ppb in American eel (Delaware River), 1050 ppb in American eel (Newark Bay), 77 ppb in carp (Delaware River), 108 ppb in striped bass (Raritan River), 88 ppb in spot fish (Houston Ship Channel)(2). Rhine River from Strassburg to Lake Constance - a small number of fish 25-100 ppb, a few exceeded 100 ppb(3). **PEER REVIEWED** [(1) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975) (2) Dickson AG, Riley JP; Mar Pollut Bull 7: 167-9 (1976) (3) Binnemann PH et al; A Lebensm - Unters Forsch 176: 253-61 (1983)]

Animal Concentrations:

1. 0.6-19 ppb in grey seal blubber (NE Coast of England); 1.4-39 ppb in marine and freshwater birds (coast of England)(1). **PEER REVIEWED** [(1) Pearson CR, McConnell G; Proc Roy Soc London Ser B 189: 305-32 (1975)]

Milk Concentrations:

1. Not detected (detection limit = 2.3 ppb) in seven market basket composites of dairy products(1). Has been detected in 7 of 8 samples in mother's milk from 4 urban areas in the USA(2). One hour after a visit to a dry cleaning plant, one sample of mother's milk contained 10 ppm tetrachloroethylene. This decreased to 3 ppm after 24 hr(3). **PEER REVIEWED** [(1) Entz RC et al; J Agric Food Chem 30: 846-9 (1982) (2) Pellizzari ED et al; Bull Environ Contam Toxicol 28: 322-8 (1982) (3) Jensen AA; Res Rev 89: 1-128 (1983)]

Human Exposure

Topic: TETRACHLOROETHYLENE

Probable Routes of Human Exposure:

1. Human exposure to tetrachloroethylene will occur through inhalation of contaminated ambient air and ingestion of contaminated drinking water (especially from polluted groundwater sources). Occupationally, exposure will occur from inhalation of contaminated air (especially in urban/industrial areas, in and around metal degreasing and dry cleaning industries). Food does not appear to be a major source, but the data are poor. (SRC) **PEER REVIEWED**

Average Daily Intake:

1. AIR INTAKE (assume 0.3-1.5 ppb(1-5)) 41-207 ug; WATER INTAKE (assume 0.3-3 ppb(6)) 0.6-6 ug; FOOD INTAKE - insufficient data(SRC). **PEER REVIEWED** [(1) Lillian D et al; Amer Chem Soc Symp Ser 17: 152-8 (1975) (2) Pellizzari ED; Quantation of Chlorinated Hydrocarbons in Previously Collected Air Samples. EPA-450/3-78-112 (1978) (3) Singh HB et al; Environ Sci Technol 16: 872-80 (1982) (4) Su C, Goldberg ED; Mar. Pollut Transfer pp. 353-74 (1976) (5) Leoy PJ et al; Atmos Environ 17: 2321-30 (1983) (6) Coniglio WA et al; Occurrence of Volatile Organics in Drinking Water. p. 7 Unpublished EPA report (1980)]

Probable Exposures:

1. Time-weighted average (8-hour) exposures to PCE in the dry cleaning industry are reported as high as 178 ppm in air(1). NIOSH (NOES Survey 1981-1983) has statistically estimated that 129,494 workers are exposed to tetrachloroethylene (PCE) in the USA(2). NIOSH (NOHS Survey 1972-1974) has statistically estimated that 1,597,072 workers are exposed to PCE in the USA(3). **PEER REVIEWED** [(1) NIOSH; Criteria for Recommended Standard. Occupational Exposure to Tetrachloroethylene. NIOSH Pub No 76-185 (1976) (2) NIOSH; The National Occupational Exposure Survey (NOES) (1983) (3) NIOSH; The National Occupational Hazard Survey (NOHS) (1974)]
2. Currently at risk of exposure are more than 500,000 workers, primarily in the dry cleaning & textile industries, which use more than 2/3 of the domestically produced tetrachloroethylene. **PEER REVIEWED** [Ellenhorn, M.J. and D.G. Barceloux. Medical Toxicology - Diagnosis and Treatment of Human Poisoning. New York, NY: Elsevier Science Publishing Co., Inc. 1988. 986]

Body Burdens:

1. Has been detected in 7 of 8 samples in mother's milk from 4 urban areas in the US(1). One hour after a visit to a dry cleaning plant, one sample of mother's milk contained 10 ppm tetrachloroethylene. This decreased to 3 ppm after 24 hr(2). Old Love Canal, NY - 9 individuals: Human breath 600-4500 ng/cu m; Blood 0.35-260 ng/ml; Urine 120-690 ng/ml(3). Human body fat (8 subjects) 0.4-29.2 ppb; Various human organs less than 6 ng/g(4). Alveolar air geometric mean in 136 residents living near 12 dry-cleaning stores were: Living equal to or <5 floors above the stores 5 mg/cu m, adjacent houses 1 mg/cu m, one house away 0.2 mg/cu m, across street <.1 mg/cu m, whereas

Topic: TETRACHLOROETHYLENE

the mean concentration in 18 workers was 73 mg/cu m(5).
PEER REVIEWED [(1) Pellizzari ED et al; Bull Environ Contam Toxicol 28: 322-8 (1982) (2) Jensen AA; Res Rev 89: 1-128 (1983) (3) Barkley J et al; Biomed Mass Spectrom 7: 139-47 (1980) (4) McConnell G et al; Endeavour 34: 13-8 (1975) (5) Verberk MM, Scheffers TML; Environ Res 21: 432-7 (1980)

2. Whole blood, USA survey of 250 (121 males, 129 females), 0.7-23 ppb, 2.4 ppb avg(1). Breath samples (ug/cu m, weighted statistics), Elizabeth and Bayonne, NJ, 1981, 295-339 samples, 93% pos, 280 max, 13.0 avg, 6.8 median(2). Alveolar air in children and teachers in school situated near factory were 24 ug/cu m avg for children and 11 and 47 ug/cu m for the teachers(3). The mean concentration of tetrachloroethylene in the classroom was 13 ug/cu m(3). Alveolar air of residents of a nursing home situated near a former chemical waste dump averaged 7.8 ug/cu m first floor and 1.8 ug/cu m on the second floor, where ambient concentrations averaged 8.2 and 1.6 ug/cu m, respectively(3). USA FY82 National Human Adipose Tissue Survey specimens, 46 composites, 61% pos (>3 ppb, wet tissue concn), 94 ppb max(4). **PEER REVIEWED** [(1) Antoine SR et al; Bull Environ Contam Toxicol 36: 364-71 (1986) (2) Wallace L et al; J Occup Med 28: 603-7 (1986) (3) Monster AC, Smolders JFJ; Int Arch Environ Health 53: 331-6 (1984) (4) Stanley JS; Broad Scan Analysis of the FY82 National Human Adipose Tissue Survey Specimens Vol. I Executive Summary p. 5 USEPA-560/5-86-035 (1986)

Topic: TETRACHLOROETHYLENE

EXPOSURE STANDARDS & REGULATIONS

Standards & Regulations

Immediately Dangerous to Life or Death:

1. NIOSH has recommended that tetrachloroethylene be treated as a potential human carcinogen. **QC REVIEWED** [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 208

Acceptable Daily Intake:

1. Suggested No-Adverse-Response Level (SNARL): In light of the lack of definitive information regarding the quantity of TCE that must be ingested to depress psychophysiological function, it seems appropriate that calculations for a SNARL be based upon quantities of the chemical that are required to produce tissue injury. ... the 0.3 ml/kg (0.49 g/kg) dose appears to be a reasonable "minimum toxic dose" from which to calculate a 24-hr SNARL for contamination of drinking water, assuming that the sole source of TCE during this period will be from 2 l/day of drinking water consumed by a 70 kg human. A safety factor of 100 is applied: 490 mg/kg times 70 kg/100 times 2 l = 172 mg/l. The above considerations ignore the possibility that TCE may be carcinogenic. ... a 7-day standard for drinking water contamination, which was obtained by dividing the 24-hr standard by 7 (172 mg/l/7 days = 24.5 mg/l), should protect against adverse effects by the chemical. **PEER REVIEWED** [National Research Council. Drinking Water and Health. Volume 3. Washington, DC: National Academy Press, 1980. 140

Occupational Permissible Levels

OSHA Standards:

1. Meets criteria for OSHA medical records rule. **PEER REVIEWED** [29 CFR 1910.20 (7/1/87)
2. During an 8 hr work shift, an employee may be exposed to a concentration of tetrachloroethylene above 200 ppm (but never above 300 ppm) only for a maximum period of 5 minutes in any 3 hours. Such exposure must be compensated by exposures to concentrations less than 100 ppm so that the cumulative exposure for the entire 8 hr work shift does not exceed a weighted average of 100 ppm. **PEER REVIEWED** [29 CFR 1910.1000 (7/1/87)

NIOSH Recommendations:

1. NIOSH recommends that tetrachloroethylene be treated as a potential human carcinogen. **PEER REVIEWED** [NIOSH/CDC. NIOSH Recommendations for Occupational Safety and Health Standards Sept. 1986. (Supplement to Morbidity and Mortality Weekly Report 35 No. 15, Sept. 26, 1986), p. 30S

Threshold Limit Values:

1. Time Weighted Avg (TWA) 50 ppm, 339 mg/cu m; Short Term Exposure Limit (STEL) 200 ppm, 1357 mg/cu m (1984) **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 30

Topic: TETRACHLOROETHYLENE

2. BEI (Biological Exposure Index): Perchloroethylene in end-exhaled air prior to the last shift of workweek is 10 ppm. (1989-90 adoption) **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 67
3. BEI (Biological Exposure Index): Perchloroethylene in blood prior to the last shift of workweek is 1 mg/l. (1989-90 adoption) **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 67
4. BEI (Biological Exposure Index): Trichloroacetic acid in urine at end of workweek is 7 mg/l. The determinant is nonspecific, since it is observed after exposure to some other chemicals. These nonspecific tests are preferred because they are easy to use and usually offer a better correlation with exposure than specific tests. In such instances, a BEI for a specific, less quantitative biological determinant is recommended as a confirmatory test. The biological determinant is an indicator of exposure to the chemical, but the quantitative interpretation of the measurements is ambiguous. (1989-90 adoption) **QC REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 67

Other Occupational Permissible Levels:

1. Maximum allowable concentrations range from 10 mg/cu m (1.5 ppm, ceiling value) in the USSR, 140 mg/cu m (20 ppm, TWA) in Sweden, and 250 mg/cu m (37 ppm) in Czechoslovakia to 340 mg/cu m (50 ppm) in the Federal Republic of Germany, Japan. Short-term exposure limits range from 340 mg/cu m (50 ppm) in Sweden to 1250 mg/cu m (183 ppm) in Czechoslovakia and 1340 mg/cu m (200 ppm) in the USA. The acceptable limit in Brazil is 525 mg/cu m (78 ppm) for 48 hr per week. **PEER REVIEWED** [WHO; Environ Health Criteria: Tetrachloroethylene p.35 (1984)
2. Maximum allowable concentrations are 1.0 mg/cu m average per day or 4.0 mg/cu m average per 0.5 hr in Czechoslovakia and 0.06 mg/cu m average per day in the USSR. **PEER REVIEWED** [WHO; Environ Health Criteria: Tetrachloroethylene p.35 (1984)

Other Standards and Regulations

Water Standards:

1. Toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations. **PEER REVIEWED** [40 CFR 401.15 (7/1/88)

TSCA Requirements:

1. Pursuant to section 8(d) of TSCA, EPA promulgated a model Health and Safety Data Reporting Rule. The section 8(d) model rule requires manufacturers, importers, and

pic: TETRACHLOROETHYLENE

processors of listed chemical substances and mixtures to submit to EPA copies and lists of unpublished health and safety studies. As cited in the preamble of 51 FR 41329. Tetrachloroethylene is included on this list. **PEER REVIEWED** [40 CFR 712.30 (7/1/88)]

CRA Requirements:

1. As stipulated in 40 CFR 261.33, when tetrachloroethylene, as a commercial chemical product or manufacturing chemical intermediate or an off-specification commercial chemical product or a manufacturing chemical intermediate, becomes a waste, it must be managed according to Federal and/or State hazardous waste regulations. Also defined as a hazardous waste is any residue, contaminated soil, water, or other debris resulting from the cleanup of a spill, into water or on dry land, of this waste. Generators of small quantities of this waste may qualify for partial exclusion from hazardous waste regulations (40 CFR 261.5). **PEER REVIEWED** [40 CFR 261.33 (7/1/88)]
2. When tetrachloroethylene is a spent solvent, it is classified as a hazardous waste from a nonspecific source (F002), as stated in 40 CFR 261.31, and must be managed according to state and/or federal hazardous waste regulations. **PEER REVIEWED** [40 CFR 261.31 (7/1/87)]
3. The Environmental Protection Agency has amended its regulations concerning ground-water monitoring with regard to screening suspected contamination at land based hazardous waste treatment, storage, and disposal facilities. /There are/ new requirements to analyze for a specified core list of chemicals plus those chemicals specified by the Regional Administrator on a site-specific basis. ... /Tetrachloroethylene is included on this list./ **PEER REVIEWED** [52 FR 25942 (7/9/87)]

opic: TETRACHLOROETHYLENE

. CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- Tetrachloroethylene

CASRN -- 127-18-4

Last Revised -- 03/01/88

The Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Please refer to Background Document 1 in Service Code 5 for an elaboration of these concepts. RfDs can also be derived for the noncarcinogenic health effects of compounds which are also carcinogens. Therefore, it is essential to refer to other sources of information concerning the carcinogenicity of this substance. If the U.S. EPA has evaluated this substance for potential human carcinogenicity, a summary of that evaluation will be contained in Section II of this file when a review of that evaluation is completed.

I.A.1. ORAL RfD SUMMARY

See Table Document

I.A.2. PRINCIPAL AND SUPPORTING STUDIES (ORAL RfD)

Buben, J.A. and E.J. O'Flaherty. 1985. Delineation of the role of metabolism in the hepatotoxicity of trichloroethylene and perchloroethylene: a dose-effect study. *Toxicol. Appl. Pharmacol.* 78: 105-122.

Buben and O'Flaherty (1985) exposed Swiss-Cox mice to tetrachloroethylene in corn oil by gavage at doses of 0, 20, 100, 200, 500, 1500, and 2000 mg/kg, 5 days/week for 6 weeks. Liver toxicity was evaluated by several parameters including liver weight/body weight ratio, hepatic triglyceride concentration, DNA content, histopathological evaluation, and serum enzyme levels. Increased liver triglycerides were first observed in mice treated with 100 mg/kg. Liver weight/body weight ratios were significantly higher than controls for animals treated with 100 mg/kg. At higher doses, hepatotoxic effects included decreased DNA content, increased SGPT, decreased levels of G6P and hepatocellular necrosis, degeneration and polyploidy.

A NOEL of 14 mg/kg/day was established in a second study, as well (Hayes et al., 1986). Groups of 20 Sprague-Dawley rats of both sexes were administered doses of 14, 400, or 1400 mg/kg/day in drinking water. Males in the high-dose group and females in the two highest groups exhibited depressed body weights. Equivocal evidence of hepatotoxicity (increased liver and kidney weight/body weight ratios) were also observed at the higher doses.

I.A.3. UNCERTAINTY AND MODIFYING FACTORS (ORAL RfD)

UF = 1000. The uncertainty factor of 1000 results from multiplying factors of 10 to account for intraspecies variability, interspecies variability and extrapolation of a

IRIS

pic: TETRACHLOROETHYLENE

subchronic effect level to its chronic equivalent.

MF = 1.

I.A.4. ADDITIONAL COMMENTS (ORAL RfD)

Other data support the findings of the principal studies. Exposure of mice and rats to tetrachloroethylene by gavage for 11 days caused hepatotoxicity (centrilobular swelling) at doses as low as 100 mg/kg/day in mice (Schumann et al., 1980). Mice were more sensitive to the effects of tetrachloroethylene exposure than rats. Increased liver weight was observed in mice at 250 mg/kg, while rats did not exhibit these effects until doses of 1000 mg/kg/day were reached. Relative sensitivity to man cannot be readily established but the RfD of 1E-2 mg/kg/day is protective of the most mild effects observed in humans [diminished odor perception/modified Romberg test scores in volunteers exposed to 100 ppm for 7 hours; roughly equivalent to 20 mg/kg/day (Stewart et al., 1961)].

The principal studies are of short duration. Inhalation studies have been performed which indicate that the uncertainty factor of 10 is sufficient for extrapolation of the subchronic effect to its chronic equivalent. Liver enlargement and vacuolation of hepatocytes were found to be reversible lesions for mice exposed to low concentrations of tetrachloroethylene (Kjellstrand et al., 1984). In addition, elevated liver weight/body weight ratios observed in animals exposed to tetrachloroethylene for 30 days were similar to those in animals exposed for 120 days. Several chronic inhalation studies have also been performed (Carpenter, 1937; NTP, 1985; Rowe et al., 1952). None are inconsistent with a NOAEL of 14 mg/kg/day for tetrachloroethylene observed by Buben and O'Flaherty (1985) and Hayes et al. (1986).

I.A.5. CONFIDENCE IN THE ORAL RfD

Study: Low

Data Base: Medium

RfD: Medium

No one study combines the features desired for deriving an RfD: oral exposure, large number of animals, multiple dose groups, testing in both sexes and chronic exposure. Confidence in the principal studies is low mainly because of the lack of complete histopathological examination at the NOAEL in the mouse study. The data base is relatively complete but lacks studies of reproductive and teratology endpoints subsequent to oral exposure; thus, it receives a medium confidence rating. Medium confidence in the RfD follows.

I.A.6. EPA DOCUMENTATION AND REVIEW OF THE ORAL RfD

U.S. EPA. 1985. Health Assessment Document for Tetrachloroethylene (Perchloroethylene). Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Research Triangle Park, NC for the Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA 600/8-82/005F.

U.S. EPA. 1987. Quantification of Toxicological Effects for Tetrachloroethylene. Prepared from the Health Assessment Document for Tetrachloroethylene (Perchloroethylene). Office

IRIS

opic: TETRACHLOROETHYLENE

of Drinking Water, Washington, DC.

Agency Work Group Review: 05/20/85, 08/05/86, 09/17/87

Verification Date: 09/17/87

I.A.7. EPA CONTACTS (ORAL RfD)

Krishan Khanna / OST -- (202)260-7588 / FTS 260-7588

Michael L. Dourson / ORD -- (513)569-7544 / FTS 684-7544

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE
RfC)

Substance Name -- Tetrachloroethylene

CASRN -- 127-18-4

Not available at this time.

=====

IRIS

Topic: TETRACHLOROETHYLENE

II. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- Tetrachloroethylene

SRN -- 127-18-4

This substance/agent has been evaluated by the U.S. EPA for evidence of human carcinogenic potential. This does not imply that this agent is necessarily a carcinogen. The evaluation for this chemical is under review by an inter-office Agency work group. A risk assessment summary will be included on IRIS when the review has been completed.

=====

Topic: TRICHLOROETHANE

5.0 RANGE OF TOXICITY

6.2 MINIMUM LETHAL EXPOSURE

- A. The acute lethal dose to the human has been estimated at 500 to 5000 milligrams/kilogram (Fasset & Irish, 1973).

6.4 TOXIC SERUM/PLASMA/BLOOD CONCENTRATIONS

- A. In three fatal cases of apparent 1,1,1-trichloroethane inhalation blood concentrations of 1,1,1-trichloroethane were 0.003, 0.2, and 7.4 micrograms/gram of blood (Macdougall et al, 1987).
- B. In other reported fatalities, blood levels of trichloroethane have ranged from 2 to 42 milligrams/liter (Jones & Winter, 1983; King et al, 1985).
1. In one reported fatality involving a 15-year-old boy, the blood trichloroethane concentration was 1.7 milligrams/liter (D'Costa & Gunasekera, 1990).

6.6 CALCULATIONS

A. CONVERSION FACTORS

1. 1 part per million = 5.46 milligrams/cubic meter
2. 1 milligram/liter = 183 parts per million

6.7 OTHER

A. INHALATION TOXICITY (Stewart, 1963)

1. Less than 500 parts per million = no physiological effects.
2. 900 to 1000 parts per million = mild, prompt eye irritation and minimal coordination impairment.
3. Above 1700 parts per million = obvious equilibrium disturbances, headache and lassitude.
4. Levels of 10,000 to 26,000 parts per million are most likely needed for anesthesia (Jones & Winter, 1983).

pic: 1,1,1-TRICHLOROETHANE

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Summary

Environmental Fate/Exposure Summary:

- 1,1,1-Trichloroethane is likely to enter the environment from air emissions or in wastewater from its production or use in vapor degreasing, metal cleaning, etc. It can also enter the environment in leachates and volatile emissions from landfills. Releases to surface water will decrease in concn almost entirely due to evaporation. Spills on land will decrease in concentration almost entirely due to volatilization and leaching. Releases to air may be transported long distances and partially return to earth in rain. In the troposphere, 1,1,1-trichloroethane will degrade very slowly by photooxidation and also slowly diffuse to the stratosphere where photodegradation will be rapid. Major human exposure is from air and drinking water. Exposure can be high near sources of emission or where drinking water is contaminated. (SRC) **PEER REVIEWED**

Pollution Sources

Natural Occurring Sources:

- 1,1,1-Trichloroethane is not known to occur as a natural product(1). **PEER REVIEWED** [IARC; Monograph Some Halogenated Hydrocarbons 19: 515-31 (1979)]

Artificial Sources:

- Wastewater and stack and fugitive emissions from production; Volatilization losses from its use in the cold cleaning of metals, vapor degreasing and as a solvent and aerosol, etc(1). Mean emissions rate of 1,1,1-trichloroethane that would contribute to its presence in indoor air are (source - rate (ng/min-sq m): cleaning agents and pesticides - 37,000; painted sheetrock - 31; glued wallpaper - 84; glued carpet 260(2). 1,1,1-Trichloroethane can be released to the environment in leachates from municipal and industrial landfills(3,4,5); it can also be released in volatile emissions from landfills(6). **PEER REVIEWED** [(1) USEPA; Source Assessment: Chlorinated Hydrocarbon Manufacture USEPA-600/2-79-019G (1979) (2) Wallace LA et al; Atmos Environ 21: 385-93 (1987) (3) Battista JR, Connelly JP; VOC Contamination at Selected Wisconsin Landfills - Sampling Results and Policy Implication. Wisconsin Dept of Nat Res, Madison, Wisc. Publ-SW-094 89 (1989) (4) Baker JF; Water Pollut Res J Can 22: 33-48 (1987) (5) Foerst C et al; Vom Wasser 72: 295-305 (1989) (6) Koenig HP et al; J Aerosol Sci 18: 837-40 (1987)]

Environmental Fate

Environmental Fate:

- TERRESTRIAL FATE:** 1,1,1-Trichloroethane evaporates fairly rapidly into the atmosphere because of its high vapor pressure. Because 1,1,1-trichloroethane does not adsorb strongly to soil, it should leach extensively. (SRC) **PEER REVIEWED**
- AQUATIC FATE:** Primary loss will be by evaporation into the atmosphere. Half-life will range from hours to a few weeks

Topic: 1,1,1-TRICHLOROETHANE

depending on wind and mixing conditions. Half-lives in a mesocosm simulating the conditions in Narragansett Bay were 24, 12, and 11 days under spring, summer and winter conditions, respectively(1). Biodegradation and adsorption onto particulate matter will be insignificant relative to volatilization (1). Turbulence in microcosm tanks are substantially less than in the bay or the open ocean so volatilization may be significantly (up to an order of magnitude) faster in the bay or open water than measured in the mesocosms. (SRC) **PEER REVIEWED** [(1) Wakeham SG et al; Environ Sci Technol 17:611-7 (1983)]

3. ATMOSPHERIC FATE: 1,1,1-trichloroethane is fairly stable in the atmosphere and is transported long distances, being found even at the South Pole (1,2,3). It is transported to Barrows, Alaska from the mid-latitudes(1). It is slowly degraded principally by reaction with hydroxyl radicals and has a half-life of 6 months to 25 years (2,4). The global lifetime average has been estimated to be 6.0-6.9 years(7). The rate of degradation is increased by the presence of chlorine radicals and nitrogen oxides. 15% of the 1,1,1-trichloroethane drifts into the stratosphere where it is rapidly degraded by photodissociation (2,4). Due to the large input of 1,1,1-trichloroethane into the atmosphere and its slow degradation, the amount of 1,1,1-trichloroethane in the atmosphere is increasing by 4.8-17% a year (6,4,7). Some of the 1,1,1-trichloroethane returns to earth in rain as is evidenced by its presence in rainwater and a 40% reduction in air concentrations on rainy days(5). **PEER REVIEWED** [(1) Khalil MAK, Rasmussen RA; Environ Sci Technol 17:57-64 (1983) (2) Battelle Columbus Labs; Multimedia Levels: Methylchloroform page 3-1 to 3-6 USEPA-560/6-77-030 (1977) (3) Rasmussen RA et al; Science 211:285-7 (1981) (4) Callahan MA et al; Water-related Environmental Fate of 129 Priority Pollutants Vol II p 45-1 to 45-12 USEPA-440/4-79-029B (1979) (5) Ohta T et al; Atmos Environ 11:985-7 (1977) (6) Khalil MAK, Rasmussen RA; J Air Pollut Control Assoc 31:1274-5 (1981) (7) Prinn R et al; Sci 238: 945-50 (1987)]

Environmental Transformations

Biodegradation:

1. No or very slow degradation in soils. No degradation has been observed in subsurface soils in 27 weeks; However in loamy sand, slow degradation has been observed under acclimated conditions (1,2). Slow degradation may occur in water under anaerobic or aerated conditions; Degradation may take several weeks and acclimation is important (3,4). In seawater, a half-life of 9 months has been determined and vinylidene chloride is the degradation product(5). No degradation in river water has been found(6). No utilization of 1,1,1-trichloroethane occurred in a continuously-fed aerobic biofilm reactor that utilized acetate as its primary substrate(8). However, 98% removal was obtained in a similar anaerobic reactor with a 2 day retention time after 8 wk acclimation(8).

Topic: 1,1,1-TRICHLOROETHANE

1,1,1-Trichloroethane degraded to vinylidene chloride as a first step in its biotransformation in microcosms containing aquifer water and sediment collected from uncontaminated sites in the Everglades(7). Considerable degradation occurred within two weeks(7). Field evidence of biodegradation in aquifers was obtained by following the concentration of 1,1,1-trichloroethane in a confined aquifer after it was injected with reclaimed groundwater(8). The half-life of 1,1,1-trichloroethane was 231 days with biodegradation given as the probable cause of loss(8). **PEER REVIEWED** [(1) Wilson JT et al; Devel Indust Microbiol 24:225-33 (1983) (2) Bouwer EJ et al; Water Res 15:151-9 (1981) (3) Bouwer EJ, McCarty PL; Appl Environ Microbiol 45:1286-94 (1983) (4) Tabak HH et al; J Water Pollut Control Fed 53:1503-18 (1981) (5) Pearson CR, McConnell G; Proc Roy Soc London B 189:305-32 (1975) (6) Mudder TI; Amer Chem Soc Div Environ Chem p 52-3, Kansas City, MO (1982) (7) Parsons F, Lage GB; J Am Water Works Assoc 77: 52-9 (1985) (8) McCarthy PL et al; Groundwater Pollut Microbiol pp. 89-115 (1984)

2. 1,1,1-Trichloroethane has been shown to undergo biotransformation under methanogenic conditions(1,2,7); the biotransformation proceeds by a reductive dechlorination to 1,1-dichloroethane and chloroethane(1). Laboratory reactors using mixed acclimated anaerobic microbial populations have demonstrated that 1,1,1-trichloroethane can be biodegraded under anaerobic simulations(3,4,5); it was suggested that in-situ anaerobic biodegradation may be a viable alternative for clean-up for various contaminated soil and groundwater sites(5). 1,1,1-Trichloroethane biodegraded in anoxic biofilm columns with an effluent removal that exceeded 99% (at 10 ppb influent) after 9-12 wks of acclimation(6). **PEER REVIEWED** [(1) Vogel TM, McCarty PL; Environ Sci Technol 21: 1208-13 (1987) (2) Henson JM et al; J Indust Microb 4: 29-35 (1989) (3) Vargas C, Alhert RC; J Water Pollut Control Fed 59: 964-8 (1987) (4) Boyer JD et al; Haz Waste Haz Mater 4: 241-61 (1987) (5) Boyer JD et al; J Water Pollut Contr Fed 60: 1843-9 (1988) (6) Bouwer EJ, Wright JP; J Contam Hydrol 2: 155-69 (1988) (7) Strand SE et al; J Water Pollut Control Fed 62: 124-9 (1990)

Abiotic Degredation:

1. Hydrolysis is not a significant degradation process having a half-life of approximately 6 months (1,2). The product of hydrolysis is vinylidene chloride(11). Direct photolysis is not important in the troposphere since 1,1,1-trichloroethane does not absorb light above 290 nm. In the stratosphere, photolysis is important and leads to the chemical's rapid degradation(2,3). 1,1,1-Trichloroethane reacts slowly with hydroxyl radicals which are produced by sunlight in the atmosphere. Based upon a rate constant of 1.19×10^{-14} cu cm/molcule-sec of 25 deg C, the half-life for this reaction is 3.7 yr, assuming a diurnally averaged OH radical concentration of 5×10^5 radicals/cu cm(12). Estimates of half-life in the

Topic: 1,1,1-TRICHLOROETHANE

troposphere range from 0.5 to 2.2 years, much slower than unsaturated chloroalkanes, but much greater than completely chlorinated compounds such as carbon tetrachloride(1,4,5). Products of photooxidation include phosgene, Cl₂, HCl, and CO₂(6,7). Degradation is reported to be greatly increased by exposure to ozone and chlorine but no actual data could be found in regard to 1,1,1-trichloroethane's reactivity with ozone(7). On exposure to nitrogen oxide, less than 5% degradation occurs in 8 hours(8). There is some evidence that photodegradation is catalyzed by surfaces which results in complete degradation within 2 weeks(9). Indirect evidence of photodegradation comes from the fact that levels of 1,1,1-trichloroethane are lowest in the afternoon and 8% less on sunny days than cloudy ones(10). Photodegradation is not observed in water(2). The neutral aqueous hydrolysis rate constants of 1,1,1-trichloroethane at 25 deg C has been experimentally determined to be 1.24X10⁻⁶ /min; the hydrolytic half-life at pH 7 is 1.1 yr(13). The basic hydrolysis rate constant is essentially zero(13). The aqueous hydrolysis half-life of 1,1,1-trichloroethane in water containing subsurface sediment at 25 deg C was measured to be 450 days(14): this is not significantly different than in pure water(14). **PEER REVIEWED** [(1) Callahan MA et al; Water-Related Environmental Fate of 129 Priority Pollutants Vol II page 45-1 to 45-12 USEPA-440/4-79-029B (1979) (2) Dilling WL et al; Environ Technol 9: 833-8 (1975) (3) Hubrich C, Stuhl F; J Photochem 12: 93-107 (1980) (4) Singh HB et al; Atmos Environ 15: 601-12 (1981) (5) Hampson RF; FAA-EE-80-17, US Dept of Transportation (1980) (6) Pearson CR, McConnell G; Proc Roy Soc London B 189: 305-32 (1975) (7) Spence JW, Hanst PL; J Air Pollut Control Fed 28: 250-3 (1978) (8) Dilling WL et al; Environ Sci Technol 10: 351-6 (1976) (9) Buchardt O, Manscher OH; CEC Proceedings, 2nd Meeting (1978) (10) Singh HB et al; Environ Sci Technol 16: 872-80 (1982) (11) Haag WR et al; Am Chem Soc Div Environ Chem Preprint 26: 248-53 (1986) (12) Atkinson R; Chem Rev 85: 69-201 (1985) (13) Jeffers PM et al; Environ Sci Technol 23: 965-9 (1989) (14) Haag WR, Mill T; Environ Sci Technol 22: 658-63 (1988)

Environmental Transport
Bioconcentration:

1. The BCF in bluegill sunfish in a 28 day test was 8.9(2). This indicates that 1,1,1-trichloroethane has little tendency to bioconcentrate in fish. Although the amount of experimental data for 1,1,1-trichloroethane is limited, confidence in this result is increased because values of BCFs in related compounds are similar(1). **PEER REVIEWED** [(1) Barrows ME et al; Dyn Exp Hazard Assess Toxic Chem Ann Arbor Mi: Ann Arbor Sci p. 379-92 (1980) (2) Davies RP, Dobbs AJ; Ater Res 18: 1253-62 (1984)

Soil Adsorption/Mobility:

1. The adsorption of 1,1,1-trichloroethane to soil is proportional to the organic carbon content of the

pic: 1,1,1-TRICHLOROETHANE

soil(4-6). The mineral content of the soil is not a contributing factor(5). The partition coefficient of 1,1,1-trichloroethane to 5 soils (organic carbon 0.1-4.9%) ranged from <0.05 to 0.5 l/g while that adsorbed to sand and clay was too small to determine the isotherms(6). The partition coefficient of 6 chlorinated alkanes including 1,1,1-trichloroethane between bentonite and spring water ranged from 27-76 and between Neckar River sediment and water, 2-108(7). 1,1,1-Trichloroethane is adsorbed strongly to peat moss, less strongly to clay, very slightly to dolomite limestone and not at all to sand(2). It has a low adsorption to silt loam (Koc = 183)(3). From the fact that it is not retained in the soil during bank infiltration, and that it is frequently found in groundwater in high concentrations, one can safely conclude that it is not adsorbed strongly by soils, especially subsurface soils(1). Based upon experimental measurement, the mean Koc range of 1,1,1-trichloroethane in a silty clay soil and sandy loam soil is 81-89(8, SRC).

****PEER REVIEWED**** [(1) Schwarzenbach RP et al; Environ Sci Technol 17: 472-9 (1983) (2) Dilling WL et al; Environ Sci Technol 9: 833-8 (1975) (3) Chiou CT et al; Science 206: 831-2 (1979) (4) Friesel P et al; Fresenius Z Anal Chim 319: 160-4 (1984) (5) Richter RO; Am Chem Soc Div Environ Chem Preprints 23: 193-4 (1983) (6) Urano K, Murata C; Chemosphere 14: 293-9 (1985) (7) Hellmann H; Dtsch Gewaesserkd Mitt 29: 111-5 (1985) (8) Gan DR, Dupont RR; Hazard Waste Hazard Materials 6: 363-83 (1989)

Volatilization from Water/Soil:

1. 1,1,1-Trichloroethane has a high Henry's Law constant (8×10^{-3} atm-cu m/mole(4)) and will volatilize rapidly from water and soil with diffusion through the liquid phase controlling volatilization from water(1,4). Half-life for evaporation from water obtained from laboratory systems range from a fraction of an hour to several hours(2). Using the Henry's Law constant, one would calculate a half-life of 3.7 hr from a model river 1 m deep with a 1 m/sec current and a 3 m/sec wind(4). Using the experimentally determined ratio of the volatilization rate constants of 1,1,1-trichloroethane relative to oxygen, 0.59(5), and the oxygen reaeration coefficients for various bodies of water, one calculates that the volatilization half-lives range from 5.1-10.6 days for ponds, 3-29 hr for rivers, and 3.8-12 days for lakes(4, SRC). Loss in a mesocosm is entirely due to evaporation and half-lives ranged from 24 days in spring to 11 days in winter(3). The cumulative evaporation loss of a mass of 1,1,1-trichloroethane situated 1.0 to 1.3 meters beneath a soil surface for one year has been estimated to be 61.8% in sandy soil and 4.9% in clay soil(6). ****PEER REVIEWED**** [(1) Shen TT; J Air Pollut Control Assoc 32: 79-82 (1982) (2) Dilling WL et al; Environ Sci Technol 9: 833-8 (1975) (3) Wakeham SG et al; Environ Sci Technol 17: 611-7 (1983) (4) Lyman WJ et al; pp. 15-1 to 15-43 in Handbook of Chem Property Estimation

Topic: 1,1,1-TRICHLOROETHANE

Methods NY: McGraw-Hill (1982) (5) Okouchi S; Wat Sci Tech
 18: 137-8 (1986) (6) Jury WA et al; Water Resources Res
 26: 13-20 (1990)

Environmental Concentrations

Water Concentrations:

1. DRINKING WATER - 133 United States cities with finished surface water - 0.4 ppb median, 3.3 ppb max; 23 United States cities with finished groundwater - 2.1 ppb median, 3.0 max, 22% of the samples were positive(1). Contaminated drinking water wells in New York, New Jersey, Connecticut and Maine have values of 950-5440 ppb(2). Results of the 1982 EPA Ground Water Supply Survey for 1,1,1-trichloroethane (466 samples) - 5.8% pos, 0.8 ppb median of positives, 18 ppb max(4). As part of EPA's Total Exposure Assessment Methodology (TEAM) study, the concentration of various toxic substances in drinking water of sample populations was measured(3). The mean (maximum) concentrations of 1,1,1-trichloroethane in Bayonne and Elizabeth, New Jersey, an industrial/chemical manufacturing area, was 0.6 (5.3), 0.2 (2.6), and 0.2 (1.6) ppb in the fall 1981, summer 1982, and winter 1983, respectively(3). For comparison the drinking water of a sample of residents of a manufacturing city without a chemical or petroleum refining industry, Greensboro, NC and a small, rural, and agricultural town in North Dakota contained 0.03 (0.05) and 0.04 (0.07) ppb of 1,1,1-trichloroethane, respectively(3). ****PEER REVIEWED**** [(1) Coniglio WA et al; EPA Briefing. Criteria and Standards Div. Sci Technol Branch. Exp Assess Proj p. 16 (1980) (2) Brumaster DE; Environ 24: 6-13, 33-6 (1982) (3) Wallace LA et al; Environ Res 43: 290-307 (1987) (4) Contruvo JA; Sci Tot Environ 47: 7-26 (1985)
2. GROUNDWATER - Raw groundwater in 13 United States cities - 1.1 ppb median, 13 ppb max, 23% were positive(1). 1,1,1-Trichloroethane has been detected in 18.9% of all groundwater samples analyzed from 178 sites designated as CERCLA (Comprehensive Emergency Response, Compensation and Liability Act) sites by the USEPA monitoring program(2). ****PEER REVIEWED**** [(1) Coniglio WA et al; EPA Briefing. Criteria and Standards Div. Sci Technol Branch. Exp Assess Proj p. 16 (1980) (2) Plumb RH Jr; Ground Water Monit Rev 7: 94-100 (1987)
3. SURFACE WATER - Raw surface water in 105 United States cities - 0.2 ppb median, 1.2 ppb max, 12% positive(1). Large study of the Ohio R. Basin in 1980-1981 (4972 samples) reports 33.6% of samples above 0.1 ppb, 3.9% between 1.0 and 0.3% above 10 ppb(2). In a study of 14 heavily industrialized river basins in 1975-1976, 9% of the sites had values above 1 ppb, and 8 ppb was the maximum value measured(3). At industrial sites, mean values are above 10 ppb with maximum values as high as 334 ppb(4). Concentration 20-800 meters away from outfalls of four producing plants and 1 user was 0.1-169 ppm(5). ****PEER REVIEWED**** [(1) Coniglio WA et al; EPA Briefing. Criteria and Standards Div. Sci Technol Branch. Exp Assess

opic: 1,1,1-TRICHLOROETHANE

Proj p. 16 (1980) (2) Ohio River Valley Water Sanit Comm; Assess of Water Qual Cond 1980-81 Cincinnati, OH (1982) (3) Ewing BB et al; Monitoring To Detect Previously Undetected Pollutants In Surface Waters. Appendix: Organic Analysis Data p 1-129 EPA-560/6-77-015A (1977) (4) Pellizzari ED et al; Formulation of Preliminary Assessment of Halogenated Organic Compounds In Man and Environmental Media p. 38-94 EPA-560/13-79-006 (1979) (5) Battelle Columbus Labs; Multimedia Levels Methylchloroform p. 2.1-2.22 EPA-560/6-77-030 (1977)

4. SEAWATER: Liverpool Bay seawater averaged <0.25 ppb, 3.3 ppb maximum(1). The mean concn of 1,1,1-trichloroethane in arctic seawater collected near Sweden in Aug and Sept 1980 range from about 1.4-1.7 ng/L in the upper 250 meter depths to about 0.4-0.45 ng/L at depths below 1250 meters(2). **PEER REVIEWED** [(1) Pearson CR, McConnell G; Proc Roy Soc London B 189: 305-32 (1975) (2) Fogelquist E; J Geophys Res 90: 9181-93 (1985)
5. RAIN/SNOW - West Los Angeles 26 Mar 82 - 69 parts per trillion(2); La Jolla, Ca - 8.1 parts per trillion (3); an industrial area of England - 0.9 parts per trillion(1). Southern California 6.2 parts per trillion, central California - 0.6 parts per trillion, Alaska 27 parts per trillion(1). **PEER REVIEWED** [(1) Pearson CR, McConnell G; Proc Roy Soc London B 189: 305-32 (1975) (2) Kawamura K, Kaplan LR; Environ Sci Technol 17: 497-501 (1983) (3) Su C, Goldberg ED; Marine Pollut Tfr HL Windom et al eds Lexington MA: DC Heath Co p. 353-74 (1976)

Effluents Concentrations:

1. Mean values in raw wastewater of 15 industries range from 3.6 to 38,000 ug/l with the maximum value range from 10 to 1,300,000 ug/l. The highest values were for the metal finishing industry(1). Mean value of treated wastewater for 11 industries 0.6-89 ug/l with maximum values ranging from 0.6 to 7100 ug/l (1). 18-344 ppb outfall from producing plants (2). **PEER REVIEWED** [(1) USEPA; Treatability Manual page I.12.8-1 to I.12.8-4 EPA-600/2-82-001a (1982) (2) Battelle Columbus Labs; Multimedia levels methylchloroform p 2.1-2.22 (1977)
2. In a comprehensive survey of wastewater from 4000 industrial and publicly owned treatment works (POTWs) sponsored by the Effluent Guidelines Division of the USEPA, 1,1,1-trichloroethane was identified in discharges of the following industrial category (frequency of occurrence, median concn in ppb): timber products (2; 359.7), leather tanning (4; 2.7), iron and steel mfg (6; 34.4), petroleum refining (5; 13.4), nonferrous metals (12; 35.9), paint and ink (36; 9.7), printing and publishing (6; 28.3), ore mining (5; 2.3), coal mining (6; 5.7), organics and plastics (23; 8.5), inorganic chemicals (13; 5.2), textile mills (12; 6.0), plastics and synthetics (12; 1.6), pulp and paper (12; 7.0), rubber processing (10; 24.0), soaps and detergents (1; 26.3), auto and other laundries (10; 6.4), pesticides manufacture (4; 17.0), photographic industries (3; 3.9),

Topic: 1,1,1-TRICHLOROETHANE

pharmaceuticals (20; 3.9), explosives (7; 14.6), plastics mfg (1; 8.3), foundries (5; 54.0), electronics (36; 62.5), electroplating (2; 229.1), organic chemicals (15; 7.2), mechanical products (20; 98.0), transportation equipment (5; 706.3), amusements and athletic goods (4; 33.0), synfuels (8; 6.63), publicly owned treatment works (302; 10.6)(1). The highest effluent concns were 6397 and 6028 ppb in the mechanical products and electronics industry, respectively(1). **PEER REVIEWED** [(1) Shackelford WM et al; *Analyst Chim Acta* 146: 15-27 (1983)]

Sediment/Soil Concentrations:

1. Liverpool Bay marine sediment <5.5 ppb (1). Soil around production plants and user industry 0.06-0.94 ppb; sediment upstream and downstream of production plants and user industry 0.039-2.6 ppb; Average background concentration in soil (St. Francis National Forest) 0.42 ppb; Average background concentration in sediment (St. Francis National Forest) 0.45 ppb (2). **PEER REVIEWED** [(1) Pearson CR, McConnell G; *Proc Roy Soc London B* 189:305-32 (1975) (2) Battelle Columbus Labs; *Multimedia Levels Methylchloroform p 2.1-2.22 EPA-560/6-77-030* (1977)]

Atmospheric Concentrations:

1. RURAL/REMOTE: Rural/remote sites in US (1977-1980) - 60-156 part/trillion, 110 part/trillion avg(1-3). Yearly rate of increase is 12-17%/year(1,2). The baseline 1,1,1-trichloroethane level in the northern hemisphere (60 deg N to 40 deg N) is 200 part/trillion while in the northern hemisphere it is 140 part/trillion(10). URBAN/SUBURBAN: Urban/suburban in US areas (1977-1980) - 420 part/trillion avg, 700-8000 part/trillion maximum, <20% samples may be positive(3-6). SOURCE AREAS: Source dominated areas in US (1977-1980) - 1200 part/trillion avg(3). Although maximum values are usually under 10 ppb, one maximum value of 111 ppb has been reported in New Jersey(7). INDOOR AIR: The concentration of 1,1,1-trichloroethane in a new office building before and after occupancy was 500 and 60 ug/cu m (90 and 10.8 ppb), respectively(9). OTHER: As part of EPA's Total Exposure Assessment Methodology (TEAM) study, the concentration of various toxic substances in the personal air (2 consecutive 12-hr periods) of sample populations was measured as well as the outdoor air near their residences(8). The weighted median results for 1,1,1-trichloroethane in personal air in Bayonne and Elizabeth, New Jersey, an industrial/chemical manufacturing area, was 17, 9.3, and 22 ug/cu m in the fall 1981, summer 1982, and winter 1983, respectively(8). The corresponding results for outdoor air was 4.6, 5.1, and 1.4 ug/cu m(8). For comparison the personal air of a sample of residents of a manufacturing city without a chemical or petroleum refining industry, Greensboro, NC and a small, rural, and agricultural town in North Dakota contained 32 and 25 ug/cu m of 1,1,1-trichloroethane, respectively and the outdoor air 60 and 0.05 ug/cu m(8). **PEER REVIEWED** [(1) Rasmussen RA et al; *Science* 211:

HSDB

opic: 1,1,1-TRICHLOROETHANE

285-7 (1981) (2) Singh HB et al; Atmospheric distribution, sources and sinks of selected halocarbons, hydrocarbons, SF6 and N2O. p. 114-22 EPA-600/3-79-107 (1979) (3) Brodzinsky R, Singh HB; Volatile organic chemicals in the atmosphere: an assessment of available data. p. 12-5 SRI Inter contract 68-02-3452 (1982) (4) Bozzelli JW, Kebbekus BB; Analysis of selected volatile organic substances in ambient air. Air Force Final Report, Apr-Nov 1978 Newark, NJ: NJ Inst Technol p. 80 (1979) (5) Singh HB et al; Atmos Environ 15: 601-12 (1981) (6) Singh HB et al; Atmospheric measurement of selected hazardous organic chemicals EPA-600/S3-81-032 (1981) (7) Pellizzari ED et al; Formulation of preliminary assessment of halogenated organic compounds in man and environmental media p 38-94 EPA-560/13-79-006 (1979) (8) Wallace LA et al; Environ Res 43: 290-307 (1987) (9) Wallace LA et al; Atmos Environ 21: 385-93 (1987) (10) Class T, Ballschmitter K; Chemosphere 15: 413-27 (1986)

2. An evaluated database of US air monitoring data for the years 1970-1987 contains the following data for 1,1,1-trichloroethane (conc is reported as daily median conc): remote sites-1064 samples, 0.132 ppb; rural sites-8 samples, 0.074 ppb; suburban sites-659 samples, 0.587 ppb; urban sites-1118 samples, 0.396 ppb; source dominated sites-133 samples, 0.380 ppb; workplace-3 samples, 1.2 ppb; personal air-1650 samples, 2.454 ppb(1). **PEER REVIEWED** [(1) Shah JJ, Heyerdahl: National Ambient Volatile Organic Compounds (VOCs) Database Update. USEPA/600/3-88-010(a) Research Triangle Park, NC: USEPA p. 45 (1988)

Food Survey Results:

1. 5-10 ng/g oils and fats; 1-4 ng/g fruits and vegetables; 2-7 ng/g meat, tea, bread (1). 1,1,1-Trichloroethane was not found in samples of wheat, corn, oats, corn meal or corn grits(2). Of the 9 samples of intermediate grain-based food analyzed, it was found in 3, namely, yellow corn meal (3.8 ppb), fudge brownie mix (3.0 ppb), and yellow cake mix (0.74 ppb)(1). **PEER REVIEWED** [(1) McConnell G et al; Endeavor 34:13-8 (1975) (2) Heikes DL, Hopper ML; J Assoc Off Anal Chem 69: 990-8 (1986)

Plant Concentrations:

1. <9.4-35 ppb (in analytical work CCl4 was not separable from 1,1,1-trichloroethane) in marine algae (1). **PEER REVIEWED** [(1) Pearson CR, McConnell G; Proc Roy Soc London B 189:305-32 (1975)

Fish/Seafood Concentrations:

1. Three species of fish, mollusks in Irish Sea - 2-16 ppb(1). Flesh of nine samples of various fish from Liverpool Bay and Thames Estuary - 0-5 ppb, gut contained up to 26 ppb (2). Marine invertebrates in bays and estuaries of Great Britain - 0-34 ppb (2). **PEER REVIEWED** [(1) Dickson AG, Riley JP; Marine Pollut Bull 7:167-70 (1976) (2) Pearson CR, McConnell G; Proc Roy Soc London B 189:305-32 (1975)

Animal Concentrations:

HSDB

Topic: 1,1,1-TRICHLOROETHANE

1. Irish Sea and North Sea - fresh and saltwater birds - 2.4 to 26 ppb, grey seal - 2.5 to 7.2 ppb. Frodsham Marsh, England - shrew -2.6 to 7.8 ppb(1). /Methyl chloroform/ ****PEER REVIEWED**** [(1) Battelle Columbus Laboratories; Multimedia levels methyl chloroform. EPA-560/6-77-030 p 5-3 (1977)
2. <16-30 ppb grey seal blubber, <2.3-7 ppb common shrew, <1.1-4.7 ppb in flesh or organs of fresh- and seawater birds (in analytical work CCl4 was not separable from 1,1,1-trichloroethane)(1). ****PEER REVIEWED**** [(1)Pearson CG, McConnell G; Proc Roy Soc London B 189: 305-32 (1975)

Milk Concentrations:

1. Detected in all eight samples of mother's milk from four urban areas(1). Pasteurized milk samples collected from suburban areas in Finland contained a mean 1,1,1-trichloroethane conc of 0.008 ug/L(2). ****PEER REVIEWED**** [(1) Pellizzari ED et al; Environ Sci Technol 16: 781-5 (1982) (2) Kronfeld R, Reunanen M; Bull Environ Contam Toxicol 44: 917-23 (1990)

Other Environmental Concentrations:

1. Of the 1026 brand samples of household products representing 67 products categories (cleaners, polishes, lubricants, and paint removers), 14.1% of samples and 47.8% of product categories contained 1,1,1-trichloroethane ranging from 3.3 to 100%(1). ****PEER REVIEWED**** [(1) Frankenberry M et al; Household products containing methylene chloride and other chlorinated solvents: A shelf survey. Rockville, MD: Westat Inc (1987).

Human Exposure

Probable Routes of Human Exposure:

1. Humans may be exposed to 1,1,1-trichloroethane dermally and by inhalation of air at occupational sites, from using household products containing the chemical, from ambient air or ingestion of contaminated drinking water and food(SRC). ****PEER REVIEWED****
2. Organic solvents such as trichloroethane are found in many easily obtainable products including fingernail polish, paint thinner, caulking compounds, lacquers, antifreeze, & gasoline. Inhalation of trichloroethane in "Liquid paper" has produced several deaths, & manufactures have added oil of mustard as a deterrent to abuse of this product, as well as to their "Liquid Paper Thinner," which contains more of the solvent than the correctional fluid. ****PEER REVIEWED**** [Arena, J.M. and Drew, R.H. (eds.) Poisoning-Toxicology, Symptoms, Treatments. 5th ed. Springfield, IL: Charles C. Thomas Publisher, 1986. 259

Average Daily Intake:

1. AIR INTAKE - rural (assume 0.110 ppb - 12.2 ug; Urban/suburban (assume 0.420 ppb) - 46.5 ug; Residents in source dominated areas (assume 1.20 ppb) - 133.0 ug. WATER INTAKE - surface water source (assume 0.4 ppb) - 0.8 ug; Groundwater source (assume 2.1 ppb) - 4.2 ug. (SRC) ****PEER REVIEWED****

Probable Exposures:

1. Trichloroethane concn of 1.5-350 ppm in ambient air of

opic: 1,1,1-TRICHLOROETHANE

various industries (degreasing, metals, electrical, etc)(1). 11% of 8 hr TWA concentration of 1,1,1-trichloroethane at 3 wastewater treatment plants serving greater Cincinnati were above the 6 ppb detection limit(2). There were 2100 and 3400 ppb and occurred in the plant containing the highest loads of the chemical in its influent(2). NIOSH (NOES Survey 1981-1983) has statistically estimated that 2,155,940 workers are potentially exposed to 1,1,1-trichloroethane in the USA(1). **PEER REVIEWED** [(1) USEPA; Ambient Water Quality Criteria for Chlorinated Ethane p. C5-C13 EPA-440/5-80-029 (1980) (2) Dunovant VS et al; J Water Pollut Control Fed 58: 886-95 (1986) (3) NIOSH; National Occupational Exposure Survey (NOES) (1983)

Body Burdens:

1. Body fat of 8 subjects - 1.6-24 ng/g, various organs - <5.1 ng/g(1). Sample residents of Old Love Canal, breath - 290 ng/cu m median, 2800 ng/cu m maximum, blood - 0.85 ng/ml median, 2.0 ng/ml maximum, urine - 80 ng/l median, 180 ng/l maximum(2). Detected in all eight samples of mother's milk from four urban areas(3). 59% of individuals (39 subjects, 23-54 years of age) from Dusseldorf, West Germany who were not occupationally exposed to 1,1,1-trichloroethane-whole had blood levels of the chemical ranging from <0.1-3.4, ppb median 0.2 ppb(4). Whole blood samples of those occupationally exposed contained 1,1,1-trichloroethane ranging from <0.1-0.2 ppb for motor vehicle mechanics, <0.1 for painters, 0.1-15.5 ppb for precision tool makers, 389.0-2497.9 ppb for dry cleaners using tetrachloroethylene as dry-cleaning agent, and 17.6-48.2 ppb for dry cleaners using trichlorofluoromethane as a dry-cleaning agent(4). Blood samples were drawn during the work day after 4 to 7 hr exposure. In another study, 1,1,1-trichloroethane in the whole blood of 250 patients who suffered from a variety of symptoms that may have been related to exposure to environmental pollutants ranged from not detectable to 26 ppb, 1.0 ppb mean(5). As part of EPA's Total Exposure Assessment Methodology (TEAM) study, the concentration of various toxic substances in breath sample populations was measured(6). The weighted median results for 1,1,1-trichloroethane in Bayonne and Elizabeth, New Jersey, an industrial/chemical manufacturing area, was 6.6, 5.2, and 2.3 ug/cu m in the fall 1981, summer 1982, and winter 1983, respectively(6). For comparison, breath samples of residents of a small, rural, and agricultural town in North Dakota contained 9.3 ug/cu m of 1,1,1-trichloroethane(6). Human tissue sample collected in Turku, Finland in 1987 contained the following levels of 1,1,1-trichloroethane: kidney, 0.1 ug/kg; lungs, 0.1 ug/kg; muscle, 0.4 ug/kg(7). **PEER REVIEWED** [(1) McConnell G et al; Endeavour 34: 13-8 (1975) (2) Barkley J et al; Biomed Mass Spectrom 7: 139-47 (1980) (3) Pellizzari ED et al; Environ Sci Technol 16: 78-5 (1982) (4) Hajimiragha H et al; Int Arch Occup Environ Health 58:

Topic: 1,1,1-TRICHLOROETHANE

EXPOSURE STANDARDS & REGULATIONS

Standards & Regulations

Immediately Dangerous to Life or Death:

1. 1000 ppm **QC REVIEWED** [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 148

Acceptable Daily Intake:

1. 9.4 mg/l based upon a low dose of 375 mg/kg **PEER REVIEWED** [USEPA; Drinking Water Criteria Document for 1,1,1-Trichloroethane (Draft) p.VIII-12 (Jan 85)

Allowable Tolerances:

1. The fungicide 1,1,1-trichloroethane is exempted from the requirement of tolerance for residues when used in the post harvest fumigation of citrus fruits. **PEER REVIEWED** [40 CFR 180.1012 (7/1/90)
2. Residues of 1,1,1-trichloroethane are exempted from the requirement of a tolerance when used as a solvent or cosolvent in accordance with good agricultural practices as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops or to raw agricultural commodities after harvest. **PEER REVIEWED** [40 CFR 180.1001(c) (7/1/90)
3. 1,1,1-Trichloroethane is exempted from the requirement of a tolerance when used as a solvent or cosolvent in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to animals. Limits for 1,1,1-trichloroethane is that it not be > 25% of the pesticide formulation. **PEER REVIEWED** [40 CFR 180.1001(e) (7/1/90)

Occupational Permissible Levels

OSHA Standards:

1. 8 hr Time-Weighted avg: 350 ppm (1900 mg/cu m) **PEER REVIEWED** [29 CFR 1910.1000 (7/1/91)
2. 15 min Short-Term Exposure Limit: 450 ppm (2450 mg/cu m). /Final rule limits/ shall be achieved by any combination of engineering controls work practices and personal protective equipment during the phase-in period, Sept 1, 1989 through Dec 30, 1992. Final rule limits become effective Dec 31, 1992. **PEER REVIEWED** [29 CFR 1910.1000 (7/1/91)

NIOSH Recommendations:

1. Ceiling (15 min): 350 ppm (1910 mg/cu m); Action level: 200 ppm (1091 mg/cu m) TWA; handle with caution. **PEER REVIEWED** [NIOSH/CDC. NIOSH Recommendations for Occupational Safety and Health Standards 1988, Aug. 1988. (Suppl. to Morbidity and Mortality Wkly. Vol. 37 No. 5-7, Aug.26, 1988). Atlanta, GA: National Institute for Occupational Safety and Health, CDC, 1988. 27

Threshold Limit Values:

1. Time Weighted Avg (TWA) 350 ppm, 1910 mg/cu m; Short Term Exposure Limit (STEL) 450 ppm, 2460 mg/cu m (1976) **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological

Topic: 1,1,1-TRICHLOROETHANE

- ExposureIndices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 26
2. Biological Exposure Index (BEI) adoption (1990-91 edition): Methyl chloroform in end-exhaled air prior to the last shift of workweek is 40 ppm. **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological ExposureIndices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 65
 3. Biological Exposure Index (BEI) adoption (1990-91 edition): Trichloroacetic acid in urine at end of workweek is 10 mg/l. The determinant is nonspecific, since it is observed after exposure to some other chemicals. These nonspecific tests are preferred because they are easy to use and usually offer a better correlation with exposure than specific tests. In such instances, a BEI for a specific, less quantitative biological determinant is recommended as a confirmatory test. The biological determinant is an indicator of exposure to the chemical, but the quantitative interpretation of the measurements is ambiguous. **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological ExposureIndices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 65
 4. Biological Exposure Index (BEI) adoption (1990-91 edition): Total trichloroethanol in urine at end of shift at end of workweek is 30 mg/l. The determinant is nonspecific, since it is observed after exposure to some other chemicals. These nonspecific tests are preferred because they are easy to use and usually offer a better correlation with exposure than specific tests. In such instances, a BEI for a specific, less quantitative biological determinant is recommended as a confirmatory test. The biological determinant is an indicator of exposure to the chemical, but the quantitative interpretation of the measurements is ambiguous. **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological ExposureIndices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 65
 5. Biological Exposure Index (BEI) adoption (1990-91 edition): Total trichloroethanol in blood at end of shift at end of workweek is 1 mg/l. The determinant is nonspecific, since it is observed after exposure to some other chemicals. These nonspecific tests are preferred because they are easy to use and usually offer a better correlation with exposure than specific tests. In such instances, a BEI for a specific, less quantitative biological determinant is recommended as a confirmatory test. **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological

HSDB

opic: 1,1,1-TRICHLOROETHANE

ExposureIndices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 65

Other Occupational Permissible Levels:

1. West Germany: 200 ppm (1974); East Germany: 90 ppm (1973); Sweden: 70 ppm (1978); USSR: 4 ppm (1972); Czechoslovakia: 90 ppm (1969) **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, 1986. 382

Other Standards and Regulations

Water Standards:

1. Toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations. /Chlorinated ethanes/ **PEER REVIEWED** [40 CFR 401.15 (7/1/90)
2. The national revised primary drinking water maximum contaminant level for 1,1,1-trichloroethane for community water systems is 0.2 mg/l. **PEER REVIEWED** [40 CFR 141.61 (7/1/90) amended by 56 FR 3593 (1/30/91)

Atmospheric Standards:

1. This action promulgates standards of performance for equipment leaks of Volatile Organic Compounds (VOC) in the Synthetic Organic Chemical Manufacturing Industry (SOCMI). The intended effect of these standards is to require all newly constructed, modified, and reconstructed SOCMI process units to use the best demonstrated system of continuous emission reduction for equipment leaks of VOC, considering costs, non air quality health and environmental impact and energy requirements. 1,1,1-Trichloroethane is produced, as an intermediate or final product, by process units covered under this subpart. **PEER REVIEWED** [40 CFR 60.489 (7/1/90)

CERCLA Reportable Quantities:

1. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 1000 lb or 454 kg. The toll free number of the NRC is (800) 424-8802; In the Washington D.C. metropolitan area (202) 426-2675. The rule for determining when notification is required is stated in 40 CFR 302.4 (section IV. D.3.b). **PEER REVIEWED** [40 CFR 302.4 (7/1/90)

TSCA Requirements:

1. Pursuant to section 8(d) of TSCA, EPA promulgated a model Health and Safety Data Reporting Rule. The section 8(d) model rule requires manufacturers, importers, and processors of listed chemical substances and mixtures to submit to EPA copies and lists of unpublished health and safety studies. 1,1,1-Trichloroethane is included on this list. **PEER REVIEWED** [40 CFR 716.120 (7/1/90)
2. Section 8(a) of TSCA requires manufacturers of this chemical substance to report preliminary assessment information concerned with production, use, and exposure

Topic: 1,1,1-TRICHLOROETHANE

to EPA as cited in the preamble of the 51 FR 41329. **PEER REVIEWED** [40 CFR 712.30 (7/1/90)]

3. Manufacturers and processors of 1,1,1-trichloroethane are required to conduct a developmental toxicity test under TSCA section 4. **PEER REVIEWED** [40 CFR 799.4400 (7/1/90)]
4. A testing consent order is in effect for 1,1,1-trichloroethane for health effects testing. FR citation: 8/23/89. **PEER REVIEWED** [40 CFR 799.5000 (7/1/90)]

RCRA Requirements:

1. U226; As stipulated in 40 CFR 261.33, when methyl chloroform, as a commercial chemical product or manufacturing chemical intermediate or an off-specification commercial chemical product or a manufacturing chemical intermediate, becomes a waste, it must be managed according to Federal and/or State hazardous waste regulations. Also defined as a hazardous waste is any residue, contaminated soil, water, or other debris resulting from the cleanup of a spill, into water or on dry land, of this waste. Generators of small quantities of this waste may qualify for partial exclusion from hazardous waste regulations (40 CFR 261.5). **PEER REVIEWED** [40 CFR 261.33 (7/1/90)]
2. F002; When 1,1,1-trichloroethane is a spent solvent, it is classified as a hazardous waste from a nonspecific source (F002), as stated in 40 CFR 261.31, and must be managed according to state and/or federal hazardous waste regulations. **PEER REVIEWED** [40 CFR 261.31 (7/1/90)]

FIFRA Requirements:

1. The fungicide 1,1,1-trichloroethane is exempted from the requirement of tolerance for residues when used in the post harvest fumigation of citrus fruits. **PEER REVIEWED** [40 CFR 180.1012 (7/1/90)]
2. Residues of 1,1,1-trichloroethane are exempted from the requirement of a tolerance when used as a solvent or cosolvent in accordance with good agricultural practices as inert (or occasionally active) ingredients in pesticide formulations applied to growing crops or to raw agricultural commodities after harvest. **PEER REVIEWED** [40 CFR 180.1001(c) (7/1/90)]
3. 1,1,1-Trichloroethane is exempted from the requirement of a tolerance when used as a solvent or cosolvent in accordance with good agricultural practice as inert (or occasionally active) ingredients in pesticide formulations applied to animals. Limits for 1,1,1-trichloroethane is that it not be > 25% of the pesticide formulation. **PEER REVIEWED** [40 CFR 180.1001(e) (7/1/90)]

FDA Requirements:

1. 1,1,1-Trichloroethane is an indirect food additive for use only as a component of adhesives. **PEER REVIEWED** [21 CFR 175.105 (4/1/90)]

IRIS

Topic: 1,1,1-TRICHLOROETHANE

I. CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- 1,1,1-Trichloroethane

CASRN -- 71-55-6

The oral RfD for this substance has been withdrawn pending further review by the RfD/RfC Work Group.

Contact: Michael L. Dourson / OHEA / 513/569-7533

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE (RfC)

Substance Name -- 1,1,1-Trichloroethane

CASRN -- 71-55-6

A risk assessment for this substance/agent is under review by an EPA work group.

=====

IRIS

opic: 1,1,1-TRICHLOROETHANE

I. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- 1,1,1-Trichloroethane

ASRN -- 71-55-6

Last Revised -- 09/01/90

Section II provides information on three aspects of the carcinogenic risk assessment for the agent in question; the U.S. EPA classification, and quantitative estimates of risk from oral exposure and from inhalation exposure. The classification reflects a weight-of-evidence judgment of the likelihood that the agent is a human carcinogen. The quantitative risk estimates are presented in three ways. The slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per (mg/kg)/day. The unit risk is the quantitative estimate in terms of either risk per ug/L drinking water or risk per ug/cu.m air breathed. The third form in which risk is presented is a drinking water or air concentration providing cancer risks of 1 in 10,000, 1 in 100,000 or 1 in 1,000,000. Background Document 2 (Service Code 5) provides details on the rationale and methods used to derive the carcinogenicity values found in IRIS. Users are referred to Section I for information on long-term toxic effects other than carcinogenicity.

II.A. EVIDENCE FOR CLASSIFICATION AS TO HUMAN CARCINOGENICITY

II.A.1. WEIGHT-OF-EVIDENCE CLASSIFICATION

Classification -- D; not classifiable as to human carcinogenicity.

Basis -- There are no reported human data and animal studies (one lifetime gavage, one intermediate-term inhalation) have not demonstrated carcinogenicity. Technical grade 1,1,1-trichloroethane has been shown to be weakly mutagenic, although the contaminant, 1,4-dioxane, a known animal carcinogen, may be responsible for this response.

II.A.2. HUMAN CARCINOGENICITY DATA

None.

II.A.3. ANIMAL CARCINOGENICITY DATA

Inadequate. The NCI (1977) treated Osborne-Mendel rats (50/sex/dose) with 750 or 1500 mg/kg technical-grade 1,1,1-trichloroethane 5 times/week for 78 weeks by gavage. The rats were observed for an additional 32 weeks. Twenty rats of each sex served as untreated controls. Low survival of both male and female treated rats (3%) may have precluded detection of a significant number of tumors late in life. Although a variety of neoplasms was observed in both treated and matched control rats, they were common to aged rats and were not dose-related. Similar results were obtained when the NCI (1977) treated B6C3F1 hybrid mice with the time-weighted average doses of 2807 or 5615 mg/kg 1,1,1-trichloroethane by gavage 5 days/week for 78 weeks. The mice were observed for an additional 12 weeks. The control and treated groups had 20 and 50 animals of each sex, respectively. Only 25 to 45% of those treated survived until the time of terminal sacrifice. A variety of neoplasms were observed in treated groups, but the incidence not statistically different from matched controls.

Quast et al. (1978) exposed 96 Sprague-Dawley rats of both

IRIS

Topic: 1,1,1-TRICHLOROETHANE

sexes to 875 or 1750 ppm 1,1,1-trichloroethane vapor for 6 hours/day, 5 days/week for 12 months, followed by an additional 19-month observation period. The only significant sign of toxicity was an increased incidence of focal hepatocellular alterations in female rats at the highest dosage. It was not evident that a maximum tolerated dose (MTD) was used nor was a range-finding study conducted. No significant dose-related neoplasms were reported, but these dose levels were below those used in the NCI study.

II.A.4. SUPPORTING DATA FOR CARCINOGENICITY

Mutagenicity testing of 1,1,1-trichloroethane has produced positive results in *S. typhimurium* strain TA100 (Simmon et al., 1977; Fishbein, 1979; Snow et al., 1979) as well as some negative results (Henschler et al., 1977; Taylor, 1978). It was mutagenic for *S. typhimurium* strain TA1535 both with exogenous metabolic activation (Farber, 1977) and without activation (Nestmann et al., 1980). 1,1,1-Trichloroethane did not result in gene conversion or mitotic recombination in *Saccharomyces cerevisiae* (Farber, 1977; Simmon et al., 1977) nor was it positive in a host-mediated forward mutation assay using *Schizosaccharomyces pombe* in mice. The chemical also failed to produce chromosomal aberrations in the bone marrow of cats (Rampy et al., 1977), but responded positively in a cell transformation test with rat embryo cells (Price et al., 1978).

An isomer, 1,1,2-trichloroethane, is carcinogenic in mice, inducing liver cancer and pheochromocytomas in both sexes.

Dichloroethanes, tetrachloroethanes and hexachloroethanes also produced liver cancer in mice and other types of neoplasms in rats. It should be noted that 1,4-dioxane, a known animal carcinogen that causes liver and nasal tumors in more than one strain of rats and hepatocellular carcinomas in mice, is a contaminant of technical-grade 1,1,1-trichloroethane.

II.B. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM ORAL EXPOSURE

Not available.

II.C. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM INHALATION EXPOSURE

Not available.

II.D. EPA DOCUMENTATION, REVIEW, AND CONTACTS (CARCINOGENICITY ASSESSMENT)

II.D.1. EPA DOCUMENTATION

U.S. EPA. 1984a. Health Effects Assessment for 1,1,1-Trichloroethane. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH for the Office of Emergency and Remedial Response, Washington, DC.

U.S. EPA. 1984b. Health Assessment Document for

IRIS

Topic: 1,1,1-TRICHLOROETHANE

1,1,1-Trichloroethane. Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Research Triangle Park, NC. EPA-600/8-82-003F.

II.D.2. REVIEW (CARCINOGENICITY ASSESSMENT)

The 1984 Health Effects Assessment for 1,1,1-Trichloroethane has received limited Agency review. The values in the 1984 Health Assessment Document for 1,1,1-Trichloroethane have received both Agency and public review.

Agency Work Group Review -- 08/05/87

Verification Date -- 08/05/87

II.D.3. U.S. EPA CONTACTS (CARCINOGENICITY ASSESSMENT)

Charlingayya Hiremath / OHEA -- (202)260-5898

=====

Topic: 1,1,2,2-TETRACHLOROETHANE

ENVIRONMENTAL FATE/EXPOSURE POTENTIAL

Summary

Environmental Fate/Exposure Summary:

- Most of the released 1,1,2,2-tetrachloroethane enters the atmosphere where it is extremely stable (half-life >2 years). Some of the chemical will eventually diffuse into the stratosphere where it will rapidly photodegrade. 1,1,2,2-Tetrachloroethane which is released into water will primarily be lost by volatilization in a matter of days to weeks. The volatilization half-lives from a model river and a model pond, the latter considers the effect of adsorption have been estimated to be 6.3 hr and 3.5 days, respectively. 1,1,2,2-Tetrachloroethane is not expected to partition from the water column to organic matter contained in sediments and suspended solids. A measured Koc of 79 in a silt loam, indicates 1,1,2,2-tetrachloroethane will be highly mobile in soil. When disposed of on soil, part of the 1,1,2,2-tetrachloroethane may leach into groundwater. There is evidence that 1,1,2,2-tetrachloroethane slowly biodegrades. A product of biodegradation under anaerobic conditions is 1,1,2-trichloroethane, a chemical which is resistant to further biodegradation. Under alkaline conditions, 1,1,2,2-tetrachloroethane may be expected to hydrolyze. A measured aqueous hydrolysis rate constant of $K_B = 2.3 \times 10^7 \text{ M}^{-1} \text{ yr}^{-1}$ at pH of 9 and 25 deg C corresponds to a half-lives of 1.1 and 111 days at pH of 9 and 7. 1,1,2,2-Tetrachloroethane will not be expected to bioconcentrate into the food chain. The major source of human exposure is from ambient air near industrial sources. (SRC) **QC REVIEWED**

Pollution Sources

Natural Occurring Sources:

- 1,1,2,2-Tetrachloroethane is not known to occur as a natural product(1). **PEER REVIEWED** [(1) IARC; Monograph. Some Halogenated Hydrocarbons 20:477-89 (1979)]

Artificial Sources:

- 1,1,2,2-Tetrachloroethane may be released into the atmosphere in connection with its manufacture of trichloroethylene from acetylene or from its use as a metal degreasing agent, paint, varnish and rust remover, extractant, solvent, as a chemical intermediate, etc.(1,3). 1,1,2,2-Tetrachloroethane can be emitted from hazardous waste landfills(2). **PEER REVIEWED** [(1) Verschueren K; Handbook of Environmental Data on Organic Chemicals 2nd ed New York, NY: Van Nostrand Reinhold Co. p 1075-6 (1983) (2) Harkov R; J Environ Sci Health Part A Environ Sci Eng 20: 491-502 (1985) (3) Kusz P et al; J Chromat 286: 287-291 (1984)]
- ... Byproducts obtained from vinyl chloride, allyl chloride, and epichlorohydrin manufacturing facilities ... included ... 1,1,2,2-tetrachloroethane ... **PEER REVIEWED** [Kusz P et al; J Chromatog 286: 287-91 (1984)]

Environmental Fate

Environmental Fate:

Topic: 1,1,2,2-TETRACHLOROETHANE

1. TERRESTRIAL FATE: 1,1,2,2-Tetrachloroethane may undergo hydrolysis in alkaline soil. A measured aqueous hydrolysis rate constant of $K_B = 2.3 \times 10^7 \text{ M}^{-1} \text{ yr}^{-1}$ at pH of 9 and 25 deg C corresponds to a half-lives of 1.1 and 111 days of pH of 9 and 7(1). A measured Koc of 79 in a silt loam(2), suggests 1,1,2,2-tetrachloroethane will be highly mobile in soil(3) and therefore can leach into groundwater. A calculated Henry's Law constant of $4.55 \times 10^{-4} \text{ atm-cu m/mole}$ at 25 deg C(SRC) suggests volatilization of 1,1,2,2,-tetrachloroethane from moist soils should be important. **PEER REVIEWED** [(1) Kolling HP et al; Hydrolysis Rate Constants, Partition Coefficients and Water Solubilities for 129 Chemicals. A Summary of Fate Constants Provided for the Concentration-based Listing Program, Prepublication. USEPA Environ Res Lab Computer Sci Corp pp. 36 (1987) (2) Chiou CT et al; Science 206: 831-2 (1979) (3) Swann RL et al; Res Rev 85: 16-28 (1983)
2. AQUATIC FATE: Under alkaline conditions, 1,1,2,2-tetrachloroethane may be expected to hydrolyze. A measured aqueous hydrolysis rate constant of $K_B = 2.3 \times 10^7 \text{ M}^{-1} \text{ yr}^{-1}$ at pH of 9 and 25 deg C corresponds to half-lives of 1.1 and 111 days at pH of 9 and 7(1). The primary loss of 1,1,2,2-tetrachloroethane from the aquatic compartment will be by evaporation which should have a half-life of days to weeks depending on the body of water in question. Based upon a calculated Henry's Law constant of $1.55 \times 10^{-4} \text{ atm-cu m/mole}$ at 25 deg C(SRC), the volatilization half-life from a model river has been estimated to be 6.3 hr(2,SRC). Adsorption to sediment would not be a significant loss mechanism. The volatilization half-life from a model pond, which considers the effect of adsorption, has been estimated to be about 3.5 days(3,SRC). Some biodegradation may occur in situations where evaporation is extremely slow and the body of water is rich in microorganisms such as a eutrophic lake. Biodegradation in groundwater is possible but the biodegradation product 1,1,2-trichloroethane is resistant to further biodegradation(SRC). **PEER REVIEWED** [(1) Kolling HP et al; Hydrolysis Rate Constants, Partition Coefficients and Water Solubilities for 129 Chemicals. A Summary of Fate Constants Provided for the Concentration-based Listing Program, Prepublication. USEPA Environ Res Lab Computer Sci Corp pp. 36 (1987) (2) Lyman WJ et al; Handbook of Chemical Property Estimation Methods NY: McGraw-Hill pp. 15-15 to 15-29 (1982) (3) USEPA; EXAMS II Computer Simulation (1987)
3. ATMOSPHERIC FATE: Based upon a vapor pressure of 6.1 mm Hg at 25 deg C(1), 1,1,2,2-tetrachloroethane is expected to exist entirely in the vapor phase in ambient air(2). 1,1,2,2-Tetrachloroethane is practically inert in the troposphere with a half-life exceeding 800 days. As such it will be transported long distances with some of it returning to earth in rain. It can be expected to diffuse slowly into the stratosphere where it will degrade rapidly by photodissociation. With continual release, one might

opic: 1,1,2,2-TETRACHLOROETHANE

expect to find increasing atmospheric concentration(SRC).
 PEER REVIEWED [(1) Engineering Sciences Data Unit;
 Vapor Pressures and Critical Points of Liquids. VII
 Halogenated Ethanes and Ethylenes Eng Sci Data Item 76004
 p. 43 (1976) (2) Eisenreich SJ et al; Environ Sci Technol
 15: 30-8 (1981)

Environmental Transformations

Biodegradation:

1. One investigator who incubated the tetrachloroethane with sewage seed for 7 days and followed that with three successive 7-day subcultures found no significant degradation under these conditions(1). These results are in conflict with those of another investigator who obtained 41% degradation in 24 days in a modified shake flask biodegradability test using an unacclimated inoculum and 19% degradation in a river die-away test while 5 other chlorinated ethanes and ethenes tested were undegraded(2). A continuous flow biofilm column operating under anaerobic conditions with a sewage inoculum achieved 97% steady state removal during 4 months of operation(3). A product of the biodegradation was 1,1,2-trichloroethane(3). The most commonly found products of microbial degradation of these compounds evidently come from reductive dehalogenation, while nonmicrobial degradations tend to involve hydrolysis and/or oxidation(4). **PEER REVIEWED** [(1) Tabak HH et al; J Water Pollut Control Fed 53: 1503-18 (1981) (2) Mudder TI; Amer Chem Soc Div Environ Chem Presentation Kansas City, MO Sept p. 52-3 (1982) (3) Bouwer EJ, McCarty PL; Appl Environ Microbiol 45: 1286-94 (1983) (4) Smith LR, Dragun J; Environ Int 10 (4): 291-8 (1985)

Abiotic Degredation:

1. 1,1,2,2-Tetrachloroethane is virtually inert in the troposphere. The half-life for the reaction with photochemically produced hydroxyl radicals is >800 days or <0.1% loss per 12 hr sunlit day(1). In the stratosphere it may photolyze(2) or degrade rapidly by reaction with chlorine radicals(3). A measured aqueous hydrolysis rate constant of $K_B = 2.3 \times 10^7 \text{ M}^{-1} \text{ yr}^{-1}$ at pH of 9 and 25 deg C corresponds to half-lives of 1.1 and 111 days at pH of 9 and 7(4). **QC REVIEWED** [(1) Singh HB et al; Atmos Environ 15: 601-12 (1981) (2) Callahan MA et al; Water-Related Environmental Fate of 129 priority pollutants. Vol II. EPA-440/4-79-029b p. 47-1 to 47-9 (1979) (3) Spence JW, Hanst PL; J Air Pollut Fed 28: 250-3 (1978) (4) Kolling HP et al; Hydrolysis Rate Constants, Partition Coefficients and Water Solubilities for 129 Chemical. A Summary of Fate Constants Provided for the Concentration-based Listing Program, Prepublication. USEPA Environ Res Lab Computer Sci Corp pp. 38 (1987)

Environmental Transport

Bioconcentration:

1. 1,1,2,2-Tetrachloroethane would not be expected to bioconcentrate in fish. The log of the bioconcentration factor in fish is reported to be 0.9-1(1,2). After 14 days

Topic: 1,1,2,2-TETRACHLOROETHANE

exposure to an average water concn of 9.62 ug/L, the log bioconcentration factor of 1,1,2,2-tetrachloroethane in the tissue of bluegill sunfish (*Lepomis macrochirus*) was 0.9(1-3). **PEER REVIEWED** [(1) Barrows ME et al; Dyn Exposure Hazard Asses Toxic Chem Ann Arbor, MI: Ann Arbor Press p. 379-92 (198)) (2) Kawaski M, Ecotox Environ Safety 4: 444-54 (1980) (3) Veith GD et al; An Evaluation of Using Partition Coefficients and Water Solubility to Estimate Bioconcentration Factors for Organic Chemicals in Fish ASTM STP 707 Aquatic Toxicology Easton JG et al: (ed) Amer Soc Test Mater p. 116-29 (1980)

Soil Adsorption/Mobility:

1. A measured Koc of 79 in a silt loam(1), suggests 1,1,2,2-tetrachloroethane will be highly mobile in soil(2). **PEER REVIEWED** [(1) Chiou CT et al; Science 206: 831-2 (1979) (2) Swann RL et al; Res Rev 85: 16-28 (1983)

Volatilization from Water/Soil:

1. Laboratory measurements of the rate of evaporation of 1,1,2,2-tetrachloroethane from water gave a half-life of 32-56 minutes(1,2). In natural waters one would expect a half-life for volatilization in the order of days to weeks depending on mixing conditions(SRC). Based upon a water solubility of 2962 ppm at 25 deg C(3) and a vapor pressure of 6.1 mm Hg at 25 deg C(4), a Henry's Law Constant of 4.55×10^{-4} atm-cu m/mole has been calculated(SRC). This value indicates volatilization of 1,1,2,2-tetrachloroethane from environmental waters should be important(5). The volatilization half-life from a model river (1 meter deep flowing 1 m/sec with a wind speed of 3 m/sec) has been estimated to be 6.3 hr(5,SRC). The volatilization half-life from a model pond, which considers the effect of adsorption, has been estimated to be 3.5 days(6,SRC). Due to its moderate vapor pressure, volatilization from dry soil will be fairly rapid(SRC). **PEER REVIEWED** [(1) Dilling WL; Environ Sci Technol 11: 405-9 (1977) (2) Neely WB; Control Hazard Mater Proc Natl Conf 3rd p 197-200 (1976) (3) Horvath AL; Halogenated Hydrocarbons: Solubility-Miscibility with Water Marcel Dekker Inc NY NY p. 889 (1982) (4) Engineering Sciences Data Unit; Vapor Pressures and Critical Points of Liquids. VII Halogenated Ethanes and Ethylenes Eng Sci Data Item 76004 p. 43 (1976) (5) Lyman WJ et al; Handbook of Chemical Property Estimation Methods NY: McGraw-Hill pp. 15-15 to 15-29 (1982) (6) USEPA; EXAMS II Computer Simulation (1987)

Environmental Concentrations

Water Concentrations:

1. DRINKING WATER: Detected in 2 of 3 investigations of US drinking water(1,3,4). In treated water from 30 Canadian treatment facilities - 1 site positive (1 ppb) in Aug/Sept, not detected in Nov/Dec(2). Also found in 1 of 13 drinking water wells in Tacoma,WA(5). 1,1,2,2-Tetrachloroethane was listed as a contaminant found in drinking water(6) for a survey of US cities

opic: 1,1,2,2-TETRACHLOROETHANE

including Pomona, Escondido, Lake Tahoe and Orange Co, CA and Dallas, Washington, DC, Cincinnati, Philadelphia, Miami, New Orleans, Ottumwa, IA, and Seattle(7). **PEER REVIEWED** [(1) IARC; Monograph. Some Halogenated Hydrocarbons 20: 477-89 (1979) (2) Otson R et al; J Assoc Off Anal Chem 65:1370-4 (1982) (3) Callahan MA et al; Water-Related Environmental Fate of 129 Priority Pollutants. EPA-440/4-79-029b p 47-1 (1979) (4) Callahan MA et al; Proc Natl Conf Munic Sludge Manage 8th p 55-61 (1979) (5) Schilling RD; Pollut Engr 17: 25-27 (1985) (6) Kool HJ et al; Crit Rev Env Control 12: 307-57 (1982) (7) Lucas SV; GC/MS Anal of Org in Drinking Water Concentrations and Advanced Treatment Concentrates Vol 1 EPA-600/1-84-020A (NTIS PB85-1282329) p. 397 (1984)

2. SURFACE WATER: Detected not quantified - River Glatt, Switzerland(1). Trace to <1 ppb measured samples from the Ohio River(3,4); 1 ppb detected in the Detroit R(5). Trace to 1.9 ppb in the Schuylkill R at Philadelphia, PA(4); 67 of 608 samples pos in representative New Jersey surface waters, max of 3 ppb measured(2). Not detected in raw water for 30 Canadian potable drinking facilities in Aug/Sept and only one facility had detectable amounts in Nov/Dec - 12 ppb(6). Only 12 of 204 sites near heavily industrialized areas across US were positive, positive sites ranged from 1 to 9 ppb(7). 1,1,2,2-Tetrachloroethane is listed as a contaminant of Great Lakes Erie, Ontario, and the St Lawrence River(8). **PEER REVIEWED** [(1) Zuercher I, Giger W; Vom Wasser 47: 37-55 (1976) (2) Page GW; Environ Sci Technol 15: 1475-81 (1976) (3) Ohio River Valley Water Sanit Comm; Assessment of Water Quality Conditions. Ohio River Mainstream 1978-9 Cincinnati, OH p. 34 (1980) (4) Dreisch R et al; Survey of the Huntington and Philadelphia River Water Supplies for Purgeable Organic Contaminants EPA-903/9-81-003 p. 14 (1981) (5) Konasewich D et al; Status Report on Organic and Heavy Metal Contaminants in the Lakes Erie, Michigan, Huron and Superior Basins. Great Lakes Quality Board p. 373 (1978) (6) Otson R et al; J Assoc Off Anal Chem 65: 1370-4 (1982) (7) Ewing BB et al; Monitoring to detect previously unrecognized pollutant in surface waters. EPA-560/6-77-015 p. 75 (1977) (8) Great Lakes Water Quality Board; Report on Great Lakes Water Quality p. 195 (1983)
3. GROUNDWATER: New Jersey - 64 of 1072 representative groundwater sources positive, 2.7 max(1). Detected, not quantified, in 10 most polluted wells from a 408 well survey in New Jersey, with the wells being located under urban land use areas(2). Groundwater samples from near the Hooker Chemical and Plastics Corp disposal site at Love Canal, NY contained 1,1,2,2-tetrachloroethane(3). Six of 7 ground water sample from near the "Valley of Drums", KY contained 1,1,2,2-tetrachloroethane at a concn of 6.4, 18, 12, 5.7, 0.2 and 6.2 ug/L(4). **PEER REVIEWED** [(1) Page GW; Environ Sci Technol 15: 1475-81 (1975) (2) Greenberg M et al; Environ Sci Technol 16: 14-9 (1982) (3) Hauser TR, Bromberg SM; Environ Monit Assess 2: 249-72 (1982) (4)

Topic: 1,1,2,2-TETRACHLOROETHANE

Stonebreaker RD, Smith AJ; Containment and Treatment of a Mixed Chemical Discharge "Valley of Drums" Louisville KY, Contr Haz Mate Spills, Proc Natl Conf p. 1-10 (1980)

Effluents Concentrations:

1. Only the metal finishing industry has mean water effluents exceeding 20 ppb, the mean effluent level of 1,1,2,2-tetrachloroethane for this industry is 290 ppb and the maximum observed level is 570 ppb(1). Detected in samples of effluents from 3 US chemical plants and a US sewage treatment plant(2). Unidentified isomer from industrial effluent South Clair R Sarnia, Ontario detected at 5 sites(3). The biotreatment and final effluents of a Class A oil refinery contained 1,1,2,2-tetrachloroethane at a concn of greater than 50 and less than 10 ug/L, respectively(4). Wastewater from the gaseous diffusion plant operated by Union Carbide at Oak Ridge, TN contained 1,1,2,2-tetrachloroethane in the volatile fraction(5). Leachate from Hooker Chemical and Plastics Corp disposal site at Love Canal, NY contained 1,1,2,2-tetrachloroethane(6). An unspecified isomer of tetrachloroethane was identified as a product of coal combustion(7). **PEER REVIEWED** [(1) USEPA; Treatability Manual. EPA-600/2-82-001a page I.12.10-1 to I.12.10-4 (1981) (2) IARC; Monograph. Some Halogenated Hydrocarbons 20: 477-89 (1979) (3) Konasewich D et al; Great Lakes Water Quality Status Report on Organic and Heavy Metal Contaminants in the Lakes Erie, Michigan, Huron and Superior Basins. Windsor, Ontario, Great Lakes Quality Board 373 p. (1978) (4) Snider EH, Manning FS; Environ Int 7: 237-58 (1982) (5) McMahon LW; Organic Priority Pollutants in Wastewater. NTIS DE83010817 Gatinsburg, TN p. 220-49 (1983) (6) Hauser TR, Bromberg SM; Environ Monit Assess 2: 249-72 (1982) (7) Junk GA et al; Organic Compounds from Coal Combustion. In: ACS Symp Ser 319 (Fossil Fuels Util): 109-23 (1986)

Sediment/Soil Concentrations:

1. Sediment samples from nearby the Hooker Chemical and Plastics Corp disposal site at Love Canal, NY contained 1,1,2,2-tetrachloroethane(1). **PEER REVIEWED** [(1) Hauser TR, Bromberg SM; Environ Monit Asses 2: 249-72 (1982)

Atmospheric Concentrations:

1. RURAL: Not detected in 2 US samples(5). URBAN/SUBURBAN: 853 US sites: 5.4 parts/trillion median, 25% of samples exceed 8.9 ppt, max 4800 ppt, not detected in >25% of samples(5). 0.01-9.4 ppb in urban atmospheres in Japan(8). Trace to 57 ppb avg measured in studies covering major US cities(1,2,3,4,6). INDUSTRIAL: 0 to .25 ppb in 5 industrial sites in US 3 of 5 pos, 2.70 ppb, 3 max with 1 site detected, not quantified(7). US - source dominated areas (60 samples) 0 parts/trillion median, 25% of samples exceed 27 parts/trillion, max 700 parts/trillion(5). 1,1,2,2-Tetrachlorethane was detected in the ambient air at Love Canal, Niagara Falls, NY(9). **PEER REVIEWED** [(1) Singh HB et al; Atmos Environ 15: 601-12 (1981) (2)

Topic: 1,1,2,2-TETRACHLOROETHANE

Singh HB et al; Environ Sci Technol 16: 872-80 (1982) (3)
 Harkov R et al; Toxic and Carcinogenic Air Pollutants in
 New Jersey - Volatile Organic Substances. Unpublished work
 Trenton, NJ: Off Cancer Toxic Sub (1981) (4) Harkov R et
 al; J Air Pollut Control Assoc 33: 1177-83 (1983) (5)
 Brodzinsky R, Singh HB; Volatile Organic Chemicals in the
 Atmosphere: An Assessment of Available Data. SRI Contract
 68-02-3452 198 p (1982) (6) Liou PJ et al; J Water Pollut
 Control Fed 33: 649-57 (1983) (7) Pellizzari ED; Environ
 Sci Technol 16: 781-5 (1982) (8) IARC; Monograph. Some
 Halogenated Hydrocarbons 20: 477-89 (1979) (9) Hauser TR,
 Bromberg SM; Environ Monit Assess 2: 249-72 (1982)

Food Survey Results:

1. Unspecified isomers of tetrachloroethane had been detected, concn not reported, in volatile flavor constituents of broiled beef(1). The Food and Drug Administration's "market basket" collections were demarcated as fatty and non-fatty fractions at the 20% lipid point(2). The high, low and average 1,1,2,2-tetrachloroethane concn of the fatty and non-fatty food groups according to the extracted procedure were 118, 50 and 70 ng/g, and 122, 49 and 84 ng/g, respectively(2). The high, low and average 1,1,2,2-tetrachloroethane concn for the fatty and non-fatty food groups according to the cleaned up procedure were 85, 24 and 58 ng/g, and 89, 8 and 57 ng/g, respectively(2). **PEER REVIEWED** [(1) IARC; Monograph. Some Halogenated Hydrocarbons 20: 477-89 (1979) (2) Daft JL; J Agric Food Chem 37: 560-4 (1989)]

Other Environmental Concentrations:

1. The adsorption isotherms of halogenated aliphatic hydrocarbons by various selected types of inactive microbial biomass were determined. The isotherms were shown to be independent on the initial organic solution concn and could be described by a modified Freundlich adsorption equation. Biosorptive uptake capacities varied among the biomass species. The water solubility and the octanol/water partition coefficient of the tested organics affected the biomass uptake capacity. In general, the least water soluble component showed the greatest tendency to be accumulated by the microbial biomass. The results also suggest that structural differences among the various microbial biomass types and possibly the fragmentation of the microbial cells, also affect the biomass uptake capacity for both single and mixed-solute systems. **PEER REVIEWED** [Tsezos M, Seto W; Water Res 20 (7): 851-858 (1986)]

Human Exposure

Probable Routes of Human Exposure:

1. Humans are primarily exposed to 1,1,2,2-tetrachloroethane from ambient air or from contaminated drinking water. (SRC) **PEER REVIEWED**
2. 1,1,2,2-Tetrachloroethane can affect the body if it is inhaled, if it comes in contact with the eyes or skin, or if it is swallowed. It may be absorbed through the skin. **PEER-REVIEWED** [Mackison, F. W., R. S. Stricoff, and L.

HSDB

Topic: 1,1,2,2-TETRACHLOROETHANE

J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981. 1

Average Daily Intake:

1. AIR INTAKE (assume 5.4 parts per trillion)(1) 0.74 ug; WATER INTAKE (assume 0-1 ppb) 0-2 ug(SRC). **PEER REVIEWED** [(1) Brodzinsky R, Singh HB; Volatile Organic Chemicals in the Atmosphere SRI Contract 68-02-3452 p. 198 (1982)]

Probable Exposures:

1. 1974 National Occupational Hazard Survey concluded that workers most likely to be exposed are those in industrial controls, toiletry preparations, and electric service industries, the latter exposure stemming from use of commercial solvent cleaners(1). NIOSH has estimated that approximately 11,000 persons have occupational contact with 1,1,2,2-tetrachloroethane(5). NIOSH (NOHS Survey 1972-1974) has statistically estimated that 7201 workers are exposed to 1,1,2,2-tetrachloroethane in the USA(2). NIOSH (NOES Survey as of 3-29-89) has statistically estimated that 4,143 workers are potentially exposed to 1,1,2,2-tetrachloroethane in the USA(3). The average indoor air concn of 1,1,2,2-tetrachloroethane equaled the outdoor concn at 0.03 for an office building and 0.02 for a school(4). **QC REVIEWED** [(1) IARC; Monograph. Some halogenated hydrocarbons 20: 477-89 (1979) (2) NIOSH; National Occupational Hazard Survey (NOHS) (1974) (3) NIOSH; National Occupational Exposure Survey (NOES) (1989) (4) Sheldon LS et al; Indoor Air in Public Buildings Vol 1 p. 163 EPA/600 6-88 009a PB89-102503 (1988) (5) Konietzko H; Hazard Asses Chem Dev 3: 401-48 (1984)]

Body Burdens:

1. 1,1,2,2-Tetrachloroethane was detected in the adipose tissue, liver and lungs of humans(1). **PEER REVIEWED** [(1) Geyer HJ et al; Regul Toxicol Pharmacol 6: 313-47 (1986)]

Topic: 1,1,2,2-TETRACHLOROETHANE

EXPOSURE STANDARDS & REGULATIONS

Standards & Regulations

Immediately Dangerous to Life or Death:

1. NIOSH has recommended that 1,1,2,2-tetrachloroethane be treated as a potential human carcinogen. **QC REVIEWED** [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 208

Occupational Permissible Levels

OSHA Standards:

1. 8 hr Time-Weighted avg: 5 ppm (35 mg/cu m). /Transitional limits/ must continue to be achieved by any combination of engineering controls, work practices, and personal protective equipment during the phase-in period, Sept 1, 1989 through Dec 30, 1992. Final rule limits become effective Dec 31, 1992. **PEER REVIEWED** [29 CFR 1910.1000 (7/1/91)
2. 8 hr Time-Weighted avg: 1 ppm (7 mg/cu m). /Final rule limits/ shall be achieved by any combination of engineering controls, work practices and personal protective equipment during the phase-in period, Sept 1, 1989 through Dec 30, 1992. Final rule limits become effective Dec 31, 1992. Skin absorption designation in effect as of Sept 1, 1989. **PEER REVIEWED** [29 CFR 1910.1000 (7/1/91)

NIOSH Recommendations:

1. 10 hr Time-Weighted avg: 1 ppm (7 mg/cu m), skin. **PEER REVIEWED** [Mackison, F. W., R. S. Stricoff, and L. J. Partridge, Jr. (eds.). NIOSH/OSHA - Occupational Health Guidelines for Chemical Hazards. DHHS(NIOSH) Publication No. 81-123 (3 VOLS). Washington, DC: U.S. Government Printing Office, Jan. 1981. 1
2. NIOSH usually recommends that occupational exposures to carcinogens be limited to the lowest feasible concn. **PEER REVIEWED** [NIOSH. NIOSH Pocket Guide to Chemical Hazards. DHHS(NIOSH) Publication No. 90-117. Washington, DC: U.S. Government Printing Office, June 1990 230

Threshold Limit Values:

1. Time Weighted Avg (TWA) 1 ppm, 6.9 mg/cu m, skin (1986) **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 35
2. Excursion Limit Recommendation: Excursions in worker exposure levels may exceed three times the TLV-TWA for no more than a total of 30 min during a work day and under no circumstances should they exceed five times the TLV-TWA, provided that the TLV-TWA is not exceeded. **PEER REVIEWED** [American Conference of Governmental Industrial Hygienists. TLV's Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1991-1992. Cincinnati, OH: ACGIH, 1991. 5

Other Occupational Permissible Levels:

Topic: 1,1,2,2-TETRACHLOROETHANE

1. USSR (1967): 0.7 ppm; Federal Republic of Germany (1967): 1 ppm; Rumania (1967): 1.5 ppm; Yugoslavia (1967): 1 ppm. ****PEER REVIEWED**** [American Conference of Governmental Industrial Hygienists. Documentation of the Threshold Limit Values and Biological Exposure Indices. 5th ed. Cincinnati, OH:American Conference of Governmental Industrial Hygienists, 1986. 563

Other Standards and Regulations

Water Standards:

1. Toxic pollutant designated pursuant to section 307(a)(1) of the Clean Water Act and is subject to effluent limitations. /Chlorinated ethanes/ ****PEER REVIEWED**** [40 CFR 401.15 (7/1/91)
2. The levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10⁻⁵, 10⁻⁶, and 10⁻⁷. The corresponding recommended criteria are 1.7 ug/l, 0.17 ug/l, and 0.017 ug/l, respectively. ****PEER REVIEWED**** [USEPA; Quality Criteria for Water 1986: Chlorinated Ethanes (May 1, 1986) EPA 440/5-86-001

Atmospheric Standards:

1. This action promulgates standards of performance for equipment leaks of Volatile Organic Compounds (VOC) in the Synthetic Organic Chemical Manufacturing Industry (SOCMI). The intended effect of these standards is to require all newly constructed, modified, and reconstructed SOCMI process units to use the best demonstrated system of continuous emission reduction for equipment leaks of VOC, considering costs, non air quality health and environmental impact and energy requirements. Tetrachloroethanes are produced, a intermediates or final products, by process units covered under this subpart. /Tetrachloroethanes/ ****PEER REVIEWED**** [40 CFR 60.489 (7/1/91)

CERCLA Reportable Quantities:

1. Persons in charge of vessels or facilities are required to notify the National Response Center (NRC) immediately, when there is a release of this designated hazardous substance, in an amount equal to or greater than its reportable quantity of 100 lb or 45.4 kg. The toll free number of the NRC is (800) 424-8802; In the Washington D.C. metropolitan area (202) 426-2675. The rule for determining when notification is required is stated in 40 CFR 302.4 (section IV. D.3.b). ****PEER REVIEWED**** [40 CFR 302.4 (7/1/91)

RCRA Requirements:

1. U209; As stipulated in 40 CFR 261.33, when 1,1,2,2-tetrachloroethane as a commercial chemical product or manufacturing chemical intermediate or an off-specification commercial chemical product or a manufacturing chemical intermediate, becomes a waste, it must be managed according to Federal and/or State hazardous waste regulations. Also defined as a hazardous waste is any residue, contaminated soil, water, or other debris resulting from the cleanup of a spill, into water or on dry land, of this waste. Generators of small

IRIS

Topic: 1,1,2,2-TETRACHLOROETHANE

1. CHRONIC HEALTH HAZARD ASSESSMENTS FOR NONCARCINOGENIC EFFECTS

I.A. REFERENCE DOSE FOR CHRONIC ORAL EXPOSURE (RfD)

Substance Name -- 1,1,2,2-Tetrachloroethane

CASRN -- 79-34-5

A risk assessment for this substance/agent is under review by an EPA work group.

I.B. REFERENCE CONCENTRATION FOR CHRONIC INHALATION EXPOSURE (RfC)

Substance Name -- 1,1,2,2-Tetrachloroethane

CASRN -- 79-34-5

Not available at this time.

=====

IRIS

Topic: 1,1,2,2-TETRACHLOROETHANE

I. CARCINOGENICITY ASSESSMENT FOR LIFETIME EXPOSURE

Substance Name -- 1,1,2,2-Tetrachloroethane

ASRN -- 79-34-5

Last Revised -- 01/01/91

Section II provides information on three aspects of the carcinogenic risk assessment for the agent in question; the U.S. EPA classification, and quantitative estimates of risk from oral exposure and from inhalation exposure. The classification reflects a weight-of-evidence judgment of the likelihood that the agent is a human carcinogen. The quantitative risk estimates are presented in three ways. The slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per (mg/kg)/day. The unit risk is the quantitative estimate in terms of either risk per ug/L drinking water or risk per ug/cu.m air breathed. The third form in which risk is presented is a drinking water or air concentration providing cancer risks of 1 in 10,000, 1 in 100,000 or 1 in 1,000,000. Background Document 2 (Service Code 5) provides details on the rationale and methods used to derive the carcinogenicity values found in IRIS. Users are referred to Section I for information on long-term toxic effects other than carcinogenicity.

II.A. EVIDENCE FOR CLASSIFICATION AS TO HUMAN CARCINOGENICITY

II.A.1. WEIGHT-OF-EVIDENCE CLASSIFICATION

Classification -- C; possible human carcinogen

Basis -- Increased incidence of hepatocellular carcinomas in mice

II.A.2. HUMAN CARCINOGENICITY DATA

None.

II.A.3. ANIMAL CARCINOGENICITY DATA

In a bioassay undertaken by NCI (1978) 50 each male and female Osborne Mendel rats and B6C3F1 mice were gavaged with technical grade (90% pure) 1,1,2,2-tetrachloroethane in corn oil, 5 days/week. Treatment was over 78 weeks, followed by observation periods of 32 weeks for the rats and 12 weeks for the mice. The high and low average doses (incorporating varying dosage levels throughout the treatment period) were, respectively, 108 and 62 mg/kg/day for male rats, 76 and 43 mg/kg/day for female rats, and 282 and 142 mg/kg/day for mice of both sexes. Control groups consisted of 20 animals/sex and species. Vehicle controls received corn oil at the same rate as the high-dose animals; untreated controls were not intubated. Ten of the high-dose female rats died within the first 5 weeks of the study, but the association between increased dosage and elevated mortality was not statistically significant for male rats. Significantly increased mortality was also evident in the high-dose mice of both sexes. No statistically significant incidence of neoplasms was observed in rats. A highly significant dose-related increase in the incidence of hepatocellular carcinomas was observed in both male and female mice.

II.A.4. SUPPORTING DATA FOR CARCINOGENICITY

1,1,2,2-Tetrachloroethane is mutagenic for the Salmonella typhimurium missense mutants TA1530 and TA1535 and selectively inhibits growth of E. coli polA (Rosenkranz 1977; Brem et

IRIS

Topic: 1,1,2,2-TETRACHLOROETHANE

al., 1974).

II.B. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM ORAL EXPOSURE

II.B.1. SUMMARY OF RISK ESTIMATES

Oral Slope Factor -- $2.0E-1$ per (mg/kg)/day
 Drinking Water Unit Risk -- $5.8E-6$ per (ug/L)
 Extrapolation Method -- Linearized multistage procedure, extra risk

Drinking Water Concentrations at Specified Risk Levels:

Risk Level	Concentration
------------	---------------

E-4 (1 in 10,000)	$2E+1$ ug/L
E-5 (1 in 100,000)	$2E+0$ ug/L
E-6 (1 in 1,000,000)	$2E-1$ ug/L

II.B.2. DOSE-RESPONSE DATA (CARCINOGENICITY, ORAL EXPOSURE)

Tumor Type -- hepatocellular carcinoma

Test Animals -- Mouse/B6CC3F1

Route -- gavage

Reference -- NCI, 1978

Administered Dose (mg/kg)/day	Human Equivalent Dose (mg/kg)/day	Tumor Incidence
-------------------------------	-----------------------------------	-----------------

0	0	0/20
87	6.56	30/48
174	13.12	43/47

II.B.3. ADDITIONAL COMMENTS (CARCINOGENICITY, ORAL EXPOSURE)

Administered doses are TWAs, adjusted for frequency (5/7 days) and length of exposure (546 days of an assumed lifespan of 637). Control group received vehicle (corn oil) by stomach tube. Weight of animals was assumed to be 0.030 kg. Human equivalent dose was adjusted by $(0.03/70)**1/3$ for body weight.

The unit risk should not be used if the water concentration exceeds $2E+3$ ug/L, since above this concentration the unit risk may not be appropriate.

II.B.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY, ORAL EXPOSURE)

An adequate number of animals was treated. Malignancies increased as a function of treatment dose, and their incidence was significantly increased at both doses.

II.C. QUANTITATIVE ESTIMATE OF CARCINOGENIC RISK FROM INHALATION EXPOSURE

II.C.1. SUMMARY OF RISK ESTIMATES

Inhalation Unit Risk -- $5.8E-5$ per (ug/cu.m)
 Extrapolation Method -- Linearized multistage procedure, extra risk

Air Concentrations at Specified Risk Levels:

Risk Level	Concentration
------------	---------------

E-4 (1 in 10,000)	$2E+0$ ug/cu.m
E-5 (1 in 100,000)	$2E-1$ ug/cu.m

IRIS

Topic: 1,1,2,2-TETRACHLOROETHANE

E-6 (1 in 1,000,000) 2E-2 ug/cu.m

II.C.2. DOSE-RESPONSE DATA FOR CARCINOGENICITY, INHALATION EXPOSURE

The inhalation risk estimates were calculated from the oral exposure data in II.B.2.

II.C.3. ADDITIONAL COMMENTS (CARCINOGENICITY, INHALATION EXPOSURE)

The unit risk should not be used if the air concentration exceeds 2E+2 ug/cu.m, since above this concentration the unit risk may not be appropriate.

II.C.4. DISCUSSION OF CONFIDENCE (CARCINOGENICITY, INHALATION EXPOSURE)

See II.B.4.

II.D. EPA DOCUMENTATION, REVIEW, AND CONTACTS (CARCINOGENICITY ASSESSMENT)

II.D.1. EPA DOCUMENTATION

U.S. EPA. 1980. Ambient Water Quality Criteria for Chlorinated Ethanes. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH for the Office of Water Regulations and Standards, Washington, DC. EPA 440/5-80-029. NTIS PB 81117400.

II.D.2. REVIEW (CARCINOGENICITY ASSESSMENT)

The values in the Ambient Water Quality Criteria Document for Chlorinated Ethanes (1980) received extensive peer and public review.

Agency Work Group Review: 06/26/86

Verification Date: 06/26/86

II.D.3. U.S. EPA CONTACTS (CARCINOGENICITY ASSESSMENT)

Robert E. McGaughy / OHEA -- (202)260-5898

Charalingayya B. Hiremath / OHEA -- (202)260-5725

=====

DRAFT

TECHNICAL MEMORANDUM
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION

ROCKY FLATS PLANT
INDUSTRIAL AREA
OPERABLE UNIT NOS 8, 9, 10, 12, 13 and 14

US DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL MANAGEMENT PROGRAM

DECEMBER 1993

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
EXECUTIVE SUMMARY	iv
1.0 INTRODUCTION	1-1
2.0 SCOPE OF INVESTIGATION	2-1
3.0 SITE DESCRIPTION	3-1
4.0 CONTAMINANTS OF CONCERN AND TARGET TAXA	4-1
5.0 EXPOSURE ASSESSMENT AND RISK CHARACTERIZATION	5-1
5.1 DEVELOPMENT OF A CONCEPTUAL FOOD WEB AND PATHWAY-RECEPTOR MODEL	5-1
5.2 ASSUMPTIONS FOR THE PATHWAYS MODEL	5-2
5.3 CALCULATION OF BIOACCUMULATION AND BIOMAGNIFICATION FACTORS	5-3
5.4 RISK CHARACTERIZATION	5-5
6.0 UNCERTAINTY ANALYSIS	6-1
7.0 REFERENCES	7-1

LIST OF TABLES

<u>Table No</u>	<u>Title</u>
3-1	Vegetation Species by Habitat
3-2	Results of Small Mammal Live Trapping at the East Drainage Study Area, October 14 through 16, 1993
3-3	Results of Small Mammal Live Trapping at the North Pond and Seep Study Area, October 14 through 16, 1993
3-4	Results of Small Mammal Live Trapping at the Northwest Drainage Study Area, October 14 through 16, 1993
3-5	Results of Small Mammal Live Trapping at the West Railroad Study Area, October 14 through 16, 1993
3-6	Results of Small Mammal Live Trapping at the West Area Study Area, October 14 through 16, 1993
3-7	Bird Species Observed in the Industrial Area During a Three Day Survey, October 28 to November 8, 1993
4-1	Rocky Flats Industrial Area Environmental Evaluation Potential Contaminants of Concern

- 6-1 Food Consumption and Food Item Percentages Used to Estimate Bioaccumulation Factors
- 6-2 Rates of Water and Soil Ingestion for Selected Species
- 6-3 Summary of Bioaccumulation Factors for Key Species in Industrial Area Food Web Pathways
- 6-4 Soil and Water Criteria Estimated From Biomagnification Factors For Feral Cat

LIST OF FIGURES

Figure No. Title

- 1 Industrial Area Environmental Evaluation Individual Hazardous Substance Sites
- 2 Industrial Area Environmental Evaluation East Drainage
- 3 Industrial Area Environmental Evaluation North Pond and Seep
- 4 Industrial Area Environmental Evaluation Northwest Drainage
- 5 Industrial Area Environmental Evaluation West Railroad
- 6 Industrial Area Environmental Evaluation West Area
- 7 Industrial Area Environmental Evaluation Generalized Food Web
- 8 Industrial Area Environmental Evaluation Sink Food Web for Great Horned Owl
- 9 Industrial Area Environmental Evaluation Sink Food Web for Great Horned Owl Without Feral Cat Pathway
- 10 Industrial Area Environmental Evaluation Sink Food Web for American Kestrel
- 11 Industrial Area Environmental Evaluation sink Food Web for Feral Cat

EXECUTIVE SUMMARY

The purpose of this Rocky Flats Plant (RFP) Industrial Area (IA) Environmental Evaluation (EE) Technical Memorandum (TM) is to discuss, evaluate, and summarize all data gathered in all three phases of the IAEE. Phase I addressed the field activities and results of the ecological investigation, Phase II described the results of the existing ecological and abiotic environmental media data review, and Phase III consisted of selecting and summarizing the data reviewed into a format useable for the characterization of potential risk to biotic species.

The IAEE was conducted under seven major tasks: Preliminary Planning; Data Collection/Evaluation and Conceptual Model Development (Phase I); Ecological Field Investigation (Phase I); Toxicity Assessment (Phase II); Exposure Assessment and Pathways Model Development (Phase II); Preliminary Contamination Characterization (Phase III); and Uncertainty Analysis (Phase III). Each task was planned and executed to provide data to the next task.

A conceptual food web and pathway-receptor model was developed based on the ecological field investigations conducted during July, October and November 1993, and ecological data gathered in past studies of RFP.

As part of the exposure assessment, and related to the generalized food web, sink food webs were developed for key raptor or predator species. A sink food web illustrates major contaminant pathways through the food chain from soils (water and sediments) to higher order consumers at the top of a food chain. These sink food webs provided the structure for the conceptualization of contaminant transport and calculation of bioaccumulation, bioconcentration and biomagnification factors used in an ecological risk assessment.

The pathways proposed are not complete in the sense of including all potential pathways existing for each species at the top of the food chain. For example, insects, reptiles and carrion are not included in these pathways for those species which are omnivores or which switch food items on a seasonal basis. However, these pathways are intended to best illustrate major routes of contaminant movement from source to biotic receptors.

A bioaccumulation model was used to evaluate the terrestrial pathway using the following assumptions for bioconcentration factors (BCFs):

- The chemical concentration in the soil is in equilibrium with the chemical concentration in vegetation tissue. In other words, vegetation tissue concentration equals chemical soil concentration and each have a BCF of 1.

- The first order consumers (cottontail rabbit, bird, and deer mouse) each have a BCF of 2. A BCF of 2 was also assumed for the feral cat, kestrel and great-horned owl at the third level of the food chain. A BCF of 1.5 was assumed for the great-horned owl at the fourth level.

Nine of the 19 COCs identified were qualitatively characterized for risk. The biomagnification factor (BMF) for strontium of 52.37 mg/kg is the only BMF falling within the range of concentrations detected at OU4. Hence, strontium appears to present a risk to biota in the IA. No risk characterization could be conducted for chromium, mercury, all the radionuclides and 1,1,2,2-tetrachloroethane because of the lack of data applicable to the biota from the IA. Toxicity profile data indicate that there is a potential for injury to species from release of these contaminants.

The absence of site-specific information required conservative assumptions regarding data inputs to the analysis. Assumptions were made with respect to COCs, toxicities, and risk characterization. The result is conservative estimates of risk parameters, and an overly conservative risk estimate.

1.0 INTRODUCTION

The purpose of this Rocky Flats Plant (RFP) Industrial Area (IA) Environmental Evaluation (EE) Technical Memorandum (TM) is to discuss, evaluate, and summarize all data gathered in all three phases of the IAEE. The following is a brief description of each phase of the IAEE.

The Phase I Data Summary (DOE, 1993b) addressed the field activities and results of the ecological investigation as outlined in the IAEE Field Sampling Plan (DOE, 1993a). The objectives, approach, and detailed methodologies used to conduct the field investigations are referenced in the IAEE Field Sampling Plan and EG&G Rocky Flats Plant (EG&G) Environmental Management Operating Procedures Manual.

The Phase II Data Summary (DOE, 1993c) described the results of the existing ecological and abiotic environmental media data review. The review addressed a listing of species recorded during past surveys, and those observed during the July and October through November 1993 field surveys. Habitat and species distribution and dominance were also noted. Abiotic environmental media data were also reviewed, summarized and evaluated with respect to suitability for inclusion as potential contaminants of Concern (COCs). Potential COCs were selected and the chemicals were evaluated for toxicity to biota based on a data search and literature review of toxicological data. A generalized foodweb for the IA ecosystem was constructed. The foodweb provides data for the selection of key receptor species and the construction of a sink foodweb to illustrate pathway-receptor models for contaminant transport from source to biotic receptor.

The Phase III Data Summary (DOE, 1993d) consisted of selecting and summarizing the data reviewed into a format useable in the discussion of potential risk to biotic species. Tables were constructed to present toxicity data, Applicable or Relevant and Appropriate Requirements (ARARs), health classification and chemical concentrations ranges for the IA. Information on target taxa were also prepared with respect to ingestion rates, body weights and food items for each taxon group. Based on the food web model potential transport pathways were identified and

2.0 SCOPE OF INVESTIGATION

The scope of the ecological risk assessment was conducted under seven major task activities as briefly summarized below. Each task was planned and executed to provide data to the next task in order to maintain the flow of information throughout the assessment process.

Task 1 - Preliminary Planning

The planning and coordination of the IAEE included development of a staffing plan and schedule of activities, and the preparation of DQO's to guide the data collection and analysis. In addition, a Field Sampling Plan (DOE, 1993a) was also prepared for guidance in the ecological field survey. The objectives of the planning for ecological risk assessment were:

- Qualitatively describe the ecological setting of the IA;
- Identify COCs and key species;
- Construct a conceptual site release and transport model;
- Determine toxicity effects and exposures from easily accessible literature values and existing data for COCs; and
- Summarize assumptions and uncertainties associated with the evaluation and characterization of ecological risk.

Task 2 - Data Collection/Evaluation and Conceptual Model Development (Phase I)

This task included a review, evaluation and data summary of available RFP chemical and ecological data pertinent to the IA. Generally, the data were expected to reflect species present, their distribution and habitat requirements, and potential COCs. This data review helped identify data gaps, and assist in the construction of the food web model and preliminary exposure pathways. COCs identified in this task for RFP narrowed the scope of toxicity assessment to those chemicals which occurred at elevated levels and are known to cause harm to biota. Toxicity literature pertaining to COCs was obtained from databases available for search at the EPA Region VIII library. This information was used in the conceptual model development and evaluation, and supported the historical and field data evaluation specific to the IA.

Task 3 - Ecological Field Investigation (Phase I)

The ecological field investigation consisted of qualitative observations and quantitative assessments of plant and animal populations within the IA areas. Sampling methodologies and procedures followed those approved in the SOP manual. Results of this field investigation provided information to describe the existing biological system in terms of habitat type and quality, species presence, trophic relationships, and potential contaminant source uptake by key (receptor) species.

The habitat surveys provided qualitative assessments of habitat type, extent and quality, including plant and animal species present. No threatened or endangered species, or protected habitats were identified. Quantitative vegetation sampling included cover and composition. Live trapping of small mammals was conducted along established transects with Sherman live traps over a three day period. Relative abundance estimates were calculated from the trapping data. Bird survey data was gathered along established transects to record and identify bird species, their numbers and use of the area. Sightings of larger mammal included qualitative assessments of presence identified by sign, vocalizations of sightings.

Task 4 - Toxicity Assessment (Phase II)

Phase II activities consisted of toxicity and exposure assessments. The objective of the toxicity assessment was to evaluate the COCs identified in Task 2 relative to their potential to cause harm to biota identified as key species. This was accomplished by review and evaluation of the toxicity data gathered from the literature in Task 2, and the comparison of these data with established criteria indicating potential harm to IA species. The criteria are the lowest tissue concentrations in key species which indicate a potential adverse effect, determined through easily accessible literature. These data will be compared to existing RFP tissue analysis data when these data are available.

Task 5 - Exposure Assessment and Pathways Model Development (Phase II)

A site-specific generalized food web and sink food webs (exposure pathways-receptor models) were developed, based on the ecological field survey results, to evaluate transport of contaminants

to bio-receptors. Each sink foodweb was developed from the generalized food web model produced during Task 2 with data gathered during Task 3 and 4. In order to evaluate identified pathways, they need to be complete, that is, data should exist to support the presence of a source, a release mechanism, a transport mechanism, an exposure route, and an affected ecological receptor. With the lack of site-specific data, we made assumptions about complete pathways, source concentrations and bioaccumulation factors. Instead we relied on easily accessible literature values.

Site specific needs identified in the data review were for contaminant concentrations of IA source materials (soil, water, air), intermediate food chain items (vegetation, prey species) and target species (raptor/predator).

Task 6 - Preliminary Contamination Characterization (Phase III)

Phase III included the preliminary contamination characterization. Threat or risk to receptor populations and habitats were evaluated based on direct observations in the field and literature data, since no site-specific toxicological data were available. Data generated from literature information were used to compute bioconcentration, bioaccumulation and biomagnification factors for key species. In addition, using toxicological data from the literature, first-cut evaluations of potential risk were computed for COCs. Very conservative factors were computed and used to estimate maximum allowable tissue concentrations in bio-receptors.

Task 7 - Uncertainty Analysis (Phase III)

The uncertainty analysis addressed uncertainty in the toxicity and exposure assessment and uncertainty in the risk characterization. The assumptions of exposure, bioconcentration factors, and lack of site-specific data, all increase the uncertainty of any conclusions of potential harm to biota from site releases. Uncertainty in the exposure assessment is related to the accuracy with which exposure pathways correctly predict receptor contact with contaminated media and corresponding model inputs of contaminant concentrations. Risk characterization uncertainty is also influenced by the assumptions regarding exposures and toxicities which are affected by the sampling and analysis programs, and the literature data used in the model. Uncertainty was described qualitatively.

3.0 SITE DESCRIPTION

Rocky Flats Plant (RFP) and environs is composed of a wide variety of habitat types. The IA of the RFP, although the most disturbed and limited in terms of areal extent, also has diverse habitats. Habitat diversity in turn influences the distribution and abundance of plants and animals because of the differences in topography, aspect, soil type, previous and continuous disturbance, and microclimatic across these habitats. An understanding of present vegetative communities and wildlife habitat characteristics and usage provides important information to remediation efforts and restoration planning.

The extent of the habitats in the IA is limited to relatively undisturbed or reclaimed sites and total about 25 acres or, 6 percent of the IA. These habitats are fragmented and small with roads and disturbed surfaces interspersed throughout. Other habitats in associated Operable Units (OUs) 1, 2, 4, 6, and 7 that are adjacent to and in the IA, and not included in these field surveys, occupy about another 30 acres. Figure 1 illustrates the Industrial Hazardous Substance Sites associated with the IA.

The IA was traversed on foot by two ecologists to characterize and map the different habitat types. The characterization of the IA habitats was conducted following EG&G SOP EE.11 (EG&G, 1992a and 1992b). Topographic features, such as aspect and slope, were noted. Plant species lists were made to better understand ecological relationships of the area. Dominant species were recorded along with their spatial foliar dominance to a particular habitat type.

Habitat types identified in the IA area include disturbed (annual/forb), mesic grass (mixed grassland), xeric grass (short grass), short marsh, tall marsh, deciduous woodland (woodland), reclaimed grassland, and ornamental plantings. Specific habitats were mapped in five different study areas illustrated in Figures 2 through 6.

The disturbed (annual/forb) habitat type was found throughout the IA. All study areas had this habitat type, including the East Drainage, North Pond and Seep, the Northwest Drainage, the

West Railroad, and the West Area. These areas have had previous or frequent surficial soil disturbance due to road building and maintenance, mowing, earthmoving, and storage of cargo facilities.

The mesic grassland (mixed grassland) habitat type occurs in the Northwest Drainage and the West Area. These areas of about 10 to 15 acres are remnants of the original prairie. Several prairie habitat types come together to compose the mesic grassland and they include tall grass prairie, northern mid-grass prairie, and southern mid-grass prairie. This habitat type was the most diverse with upwards of eighty species identified.

There were several small areas of xeric grassland (short grass) habitat located at the Northwest Drainage and at the West area. Although small, the xeric grassland habitat type was also very diverse with approximately 60 species identified. The xeric grassland habitat type was found on more gravelly outcrops with bare ground and rock, and exposed to harsh wind and weather conditions.

Due to a number of seeps, ditches, and diverted water sources, the short marsh habitat type may occur throughout the IA wherever these conditions exist. Short marsh was found at the East Drainage, North Pond and Seep, West Railroad, and West Area.

The water levels vary seasonally along the ditches and sloughs where the tall marsh habitat occurs. Cattails dominate areas with receding and stagnant water levels up to two feet deep, or where the subsurface soils remain saturated. Therefore, in many areas of the IA, tall marsh has infiltrated portions of canals and roadside ditches, become established below seeps, and maintained its dominance in shallow creeks which run through the Protected Area.

Deciduous woodland (woodland habitat) areas were encountered at the East Drainage, Northwest Drainage, and in the West Area. Since creeks and streams are small and flow intermittently at Rocky Flats, large areas of riparian woodland development have been minor. Creeks and streams are sparsely populated with single individuals or small pockets of mature trees.

Reclaimed grassland was found at all study sites, except the West Area. Disturbed areas are reclaimed with aggressive species in order to revegetate a site as quickly and as thoroughly as possible. Generally, native species take a longer time to reestablish in disturbed sites, so introduced species are used instead. Some hybridized native grass species also are used for reclamation because they quickly establish on disturbed soils. Some native species have been hybridized to have more aggressive characteristics, such as faster establishment. Since the IA has largely been disturbed much of the area is composed of reclaimed grassland.

Ornamental plantings were observed throughout the IA. These ornamental plantings are not well maintained, but the understories are groomed and mowed at least once annually. These areas seemed to be major grouping sites for wildlife, such as deer and cottontail rabbits. Evidence of herbivory was noticed on the trees and grasses in and around ornamental plantings.

Small mammal surveys conducted during July and October-November 1993 revealed that the IA provides habitat for a small number of species. The largest herbivore is the mule deer that moves in and out of the IA, particularly in the west area. The cottontail rabbit appears to be common throughout the IA, but mainly in the annual grass/weedy forb and xeric grassland habitat types. The deer mouse, prairie vole and harvest mouse were the common small herbivorous mammals. These species were most abundant in the reclaimed grassland habitat near sources of water and tall grass cover. The prairie vole and harvest mouse are considered herbivorous but probably include some insects in their diets, while the deer mouse is omnivorous. A small population of pocket gophers exists in the reclaimed/mesic grassland along the northwest drainage.

Because of migratory patterns in songbirds, the IA supports year round residents, spring nesting species and winter visitors. Common year round residents include the house sparrow, house finch and European starling, while the black-eyed juncos and rosey finches winter in the IA drainages. Common nesting species observed within the IA were the American robin, Say's phoebe, house sparrow, house finch, European starling, barn swallow and cliff swallow.

Many of the above small mammal and bird species form the prey base for raptors, and feline and canine predators.

Feral cats were observed in the East Drainage, North Pond and Seep, Northwest Drainage and West Area study areas. Although drainage structures may provide canine predators access to the IA from the buffer zone, this was not confirmed. Scat found within the IA were not analyzed in detail and could have been from feral cats or smaller canids.

Two owl casts were found within the IA, and probably were from the great-horned owl. This raptor hunts for small mammals and will also take cottontail rabbits and feral cats. No carcasses of either were found within the IA. The American kestrel was commonly observed perched on fence and telephone poles. Within the IA this species will also feed on small mammals, insects and an occasional bird.

Based on the results of the existing data review and ecological field survey, a generalized foodweb was constructed for the IA and is illustrated in Figure 7. This figure indicates that the great-horned owl and American kestral are at the top of the foodweb in the IA. However, because these species have large home ranges, the IA prey base probably contributes to a relatively small proportion of their diet. The feral cat, on the other hand, appears to hunt exclusively in the IA, therefore a large proportion of feral cat food items are from the IA. One exception to this are songbirds that may move in and out of the IA on a seasonal basis.

4.0 CONTAMINANTS OF CONCERN AND TARGET TAXA

The IA RCRA Facility Investigation/Remedial Investigation is just beginning, hence a review of the data was not possible. However, potential COCs were selected by reviewing the following sources: *Reconstruction of Historical Rocky Flats Operations & Identification of Release Points* (ChemRisk, 1992); OU4 Draft Summary Table of Contaminants of Concern in Surficial Soil and Vadose Soil, Phase I IM/IRA-EA; and *State of Colorado's Health Studies on Rocky Flats* (CDH, 1993). A list of potential COCs is provided in Table 4-1 along with toxicological information and concentration ranges in OU4 environmental media. The following chemicals are potential COCs:

Inorganics

- Beryllium
- Cadmium
- Chromium
- Mercury
- Nickel
- Silicon
- Strontium

Radionuclides

- Americium-241
- Plutonium-230/240
- Thorium
- Tritium
- Uranium-233/234
- Uranium-235
- Uranium-238

Volatile Organics

- Carbon Tetrachloride
- Chloroform
- Methylene Chloride
- Tetrachloroethylene
- 1,1,1-Trichloroethane
- 1,1,2,2-Tetrachloroethane

Existing data not part of an ongoing RFI/RI suggest that the nature and extent of contamination within the IA is not well understood and is based on waste stream identification, ground water

and surface water monitoring, previous site uses, or knowledge of how materials were stored or disposed. Validated environmental media data are not yet available for review.

Over 100 vegetation species were identified within the IA from a variety of habitat types. The most common species were the reclamation grasses used for restoration of disturbed areas, and weedy species that have invaded these disturbed areas. Weedy species, particularly kochia, annual sunflower and yellow and white sweetclover, provide a food source to many seed-eating birds. In a similar matter, the grasses also provide cover and food to birds and small mammals. Based on the ecological field investigation, the following species are probably important receptor species for the ecological risk assessment:

Vegetation

- Smooth brome
- Slender wheatgrass
- Crested wheatgrass
- Buffalo grass
- Blue grama
- Annual sunflower
- Kochia
- Yellow and white sweetclover

Small Mammals

- Prairie vole
- Deer mouse
- Harvest mouse
- Cottontail rabbit

Raptors/Predators

- American Kestrel
- Feral Cat
- Great-horned owl

5.0 EXPOSURE ASSESSMENT AND RISK CHARACTERIZATION

The following sections address the development of a conceptual food web and pathway-receptor model, assumptions for the pathway-receptor model, calculation of bio-factors, and risk characterization.

5.1 DEVELOPMENT OF A CONCEPTUAL FOOD WEB AND PATHWAY-RECEPTOR MODEL

Much of the data provided in the toxicological profiles (Section 3.0 of the Phase III Data Summary, 1993d) have been gathered from studies on laboratory mice and rats. To the extent practical, these data were included in the exposure assessment. However, the attempt was to structure a contamination characterization as close as possible to existing ecological conditions at the IA. The approach was to construct a conceptual model of the IA food web based on the ecological field investigations conducted during July, October and November 1993, and ecological data gathered in past studies of the RFP. This resulted in the conceptual food web model for the IA as shown in Figure 7 developed to represent existing ecological conditions.

As a part of the exposure assessment, and related to the generalized food web, sink food webs were developed for key raptor or predator species as shown in Figures 8 through 11. A sink food web illustrates major contaminant pathways through the food chain from soils (water or sediments) to higher order consumers at the top of a food chain. These sink food webs provide the structure for the conceptualization of contaminant transport and calculation of bioaccumulation, bioconcentration and biomagnification factors used in a ecological risk assessment.

Based on the generalized food web for the IA shown in Figure 7, the following pathways were identified for evaluation:

Pathway #1: Soil → Plants → Bird → Feral Cat → Great-horned Owl

Pathway #2: Soil → Plants → Deer Mouse → Feral Cat → Great-horned Owl

Pathway #3: Soil → Plants → Cottontail Rabbit → Feral Cat → Great-horned Owl

Pathway #4: Soil → Plants → Deer Mouse → Great-horned Owl

Pathway #5: Soil → Plants → Cottontail Rabbit → Great-horned Owl

Pathway #6: Soil → Plants → Bird → Great-horned Owl

Pathway #7: Soil → Plants → Deer Mouse → American Kestrel

Pathway #8: Soil → Plants → Bird → American Kestrel

Pathway #9: Soil → Plants → Bird → Feral Cat

Pathway #10: Soil → Plants → Deer Mouse → Feral Cat

Pathway #11: Soil → Plants → Cottontail Rabbit → Feral Cat

These pathways do not include pathways for insects, reptiles or carrion, and are not complete. However, these pathways best illustrate major routes of contaminant movement from source to biotic receptors.

5.2 ASSUMPTIONS FOR THE PATHWAYS MODEL

The bioaccumulation model proposed by Thomann (1981) and modified by Fordham and Reagan (1991) was used to evaluate the pathways identified for the IA. This model includes multiple food chains and can link chemical concentrations in soil, sediment or water to tissue concentrations in biota by estimating exposures to COCs. The original use of this model was to evaluate chemical transfer through an aquatic food chain. For the IA the model was modified to only evaluate the terrestrial pathway since no significant aquatic systems occur within the IA. Several assumptions were made for bioconcentration factors (BCFs):

- The chemical concentration in the soil is in equilibrium with the chemical concentration in vegetation tissue. In other words, vegetation tissue concentration equals chemical soil concentration and each have a BCF of 1.
- The first order consumers (cottontail rabbit, bird, and deer mouse) each have a BCF of 2. Bioconcentration is uptake of a chemical from water. It is generally accepted that terrestrial species have negligible uptake from water. Small mammals generally receive most of their water from food items and not from direct water ingestion. A BCF of 2 was also assumed for the feral cat, kestrel and great-horned owl at the third level of the food chain. A BCF of 1.5 was assumed for the great-horned owl at the fourth level. These BCFs are very conservative.
- The same BCFs were used for each COCs because databases located at EPA Region VIII contained little or no data on BCFs.

5.3 CALCULATION OF BIOACCUMULATION AND BIOMAGNIFICATION FACTORS

Bioaccumulation factors (BAFs) apply to second, third, and fourth order consumers. BAFs were calculated in the following manner:

- Food Chain Level 1) $C_{\text{soil}} = C_{\text{vegetation}} ; BCF_{\text{vegetation}} = 1$
Food Chain Level 2) $BAF_2 = BCF_2 + f_2 BCF_1$
Food Chain Level 3) $BAF_3 = BCF_3 + f_3 BCF_2 + f_3 f_2 BCF_1$
Food Chain Level 4) $BAF_4 = BCF_4 + f_4 BCF_3 + f_4 f_3 BCF_2 + f_4 f_3 f_2 BCF_1$

where: C = chemical concentration
BAF = bioaccumulation factor
BCF = bioconcentration factor
 f_i = the food term.

f_i , the food term is calculated as follows:

$$f_i = \frac{A \times D \times I}{L}$$

where: A = assimilation efficiency, weight absorbed
D = daily food intake
I = percent of food item in daily diet
L = loss rate, a fraction/day.

To be conservative, an assimilation efficiency of 0.9 was used. This value indicates that for every 10 mg of chemical ingested, 9 mg are assimilated. Spacie and Hamelink (1985) used this value for PCBs and DDT. Loss rate, or depuration, is the loss of the chemical due to growth, dilution, excretion and metabolism. For avian species the value of 0.36 was used, and for mammals, 0.4 (ESE, 1988).

Table 6-1 was constructed to present data on animal weights, food ingestion rates, animal diet items. Table 3 presents data on water and soil ingestion for selected species. These data provide input for calculations to estimate BAFs.

A food term was calculated for each key species using the above food term formula. These food terms were then substituted into the appropriate food chain level formula (Levels 1,2,3 and 4) and BAFs were calculated for each key species in each pathway #1 through #11). Each food chain

level represents a BAF calculation for a key species. For example, Level 2 represents the level for the bird, cottontail rabbit and the deer mouse, while Level 4 only includes the great-horned owl. Therefore, each species in that level has a BAF. These data are summarized in Table 6-3.

Biomagnification results in an increase of chemical tissue concentration as the chemical is passed up the food chain. This is a result of bioconcentration and bioaccumulation at each level of the food chain. Whereas BAF values are for single food chains, BMF values represent overall accumulation in the identified food web. A total BMF was calculated for each predator/raptor by the following general formula:

$$BMF_i = BCF_i + \text{sum of } f_i BAF_{i-1}$$

The total BMFs were calculated with the following results:

$$\begin{aligned} \text{Total BMF}_{\text{feral cat}} &= 7.16 \\ \text{Total BMF}_{\text{kestrel}} &= 20.42 \\ \text{Total BMF}_{\text{great-horned owl}} &= 23.14. \end{aligned}$$

Total BMFs were used to evaluate maximum allowable concentrations of a chemical in soil, water or sediment by relating environmental media concentrations to maximum acceptable tissue concentrations (MATC) in target species:

$$\frac{\text{MATC}}{\text{Total BMF}} = C_{\text{water, soil or tissue}} \text{ ("no effects" level)}$$

This value can be compared to existing chemical concentrations in environmental media as a first approximation of a water, soil or sediment criterion. For example, strontium has a rat NOAEL of 375 mg/kg/day as shown in Table 4-1, and we assume that the feral cat also has an identical NOAEL, which adjusted for its weight (1250 g) is 468 mg/kg/day. An assumption at 468 mg/kg as the MATC, results in:

$$\frac{468 \text{ mg/kg}}{7.16 \text{ (BMF}_{\text{feral cat}})} = 65.36 \text{ mg/kg}$$

Comparing 65.36 mg/kg with the range of strontium concentrations (22 through 510 mg/kg) from Table 4-1 would suggest that 65.36 mg/kg strontium in the soil may cause harm to the feral cat. In this calculation, no factor for uncertainty was used. Accepted practice is to multiply certain estimated values by an "uncertainty factor". The higher the factor, the higher the associated uncertainty. Uncertainty factors can be used to convert effects to a chronic NOEL range from 5 through 1,000, and a factor of 5 can be used for species interspecific variation. Total uncertainty factors then range from 5 to 5,000.

Table 6-4 summarizes soil and water criteria estimated from BMFs for a feral cat. It lists NOEL/LOAEL used as MATC and divided by the calculated BMF for the feral cat to estimate a soil concentration assumed to represent a "no effects" level. The table lists NOEL/LOAEL, estimated "no effects", and estimated daily doses of the chemical from published ingestion rates of soil or water. These data suggest that ingestion of soil or water is a negligible route of chemical entry into the food chain.

5.4 RISK CHARACTERIZATION

Only one set of formulae was used in the calculation of bio-factors. This assumes that all chemicals behave identically. This is not the case, but in the absence of site-specific data on bioaccumulation or bioconcentration data, and literature values, conservative assumptions were made to perform qualitative risk characterization. From these values a BMF was also estimated and used to calculate a first order "no effects" level representing a soil concentration at which "no effect" results to biota. Next, using water and soil estimated ingestion rates, daily doses to biota were also estimated. These data indicated that the water and soil ingestion routes contribute negligible chemical amounts to biota. Data are needed on the concentrations of chemicals in site biota tissues to compare with estimated factors, criteria and ingestion rates to quantitatively characterize risk to biota from site contaminants. These data are potentially available from the radioecological investigations already conducted at Rocky Flats (Whicker and Ibrahim, 1993).

Nine of the 19 COCs identified were qualitatively characterized for risk. Table 6-4 presents soil and water criteria estimated from BMFs for a Feral Cat. The BMF for Strontium of 52.37 mg/kg

is the only BMF falling within the range of concentrations detected at OU4. Hence, Strontium appears to present a risk to biota in the IA. No risk characterization could be conducted for chromium, mercury, all the radionuclides and 1,1,2,2-tetrachloroethane because of the lack of data applicable to the biota from the IA. Toxicity profile data indicate that there is a potential for injury to species from releases of these contaminants.

6.0 UNCERTAINTY ANALYSIS

The absence of site-specific information required conservative assumptions regarding data inputs to the analysis. Assumptions were made with respect to COCs, toxicities, and risk characterization. The result is conservative estimates of risk parameters, and an overly conservative risk estimate. Most of the data used to evaluate potential risk to the biota were based on the literature values except the identification of receptor species, or target taxa, and chemical concentrations found in OU4 soils and water.

The absence of site-specific data, required that all values characterizing bioaccumulation, bioconcentration and biomagnification be computed from literature data for similar or related species, or for species data gathered at other locations. For example, data on animal weights were gathered from about four different sources. However, weights of the mice were from species collected at the IA during the ecological survey. These literature values for ingestion rates, diet food items and body weights were used to calculate food terms in the bioaccumulation formula.

There was little information on BAFs, BCFs or BMFs from the literature reviewed, so conservative estimates were made in the calculation of these terms. Because there was little information, all assumptions for BAFs, BCFs, and BMFs were identical. Therefore, only one food term for each species was calculated. In other words, whether evaluating cadmium or strontium, the BAFs, BCFs and BMFs were identical for each species. This resulted in only one total BMF per key species instead of a BMF for each chemical evaluated. Although these values were calculated to be conservative, it is possible that in reality, one or more of these chemicals accumulates in tissues far greater than estimated. Loss rates, or depuration, and assimilation efficiency data also were not site-specific, so literature values were used from a study on turkeys and rats. These rates were used in the food term formula for the key species of small mammals, the feral cat and the two raptors. The other assumption was that soil chemical concentrations were in equilibrium with vegetation tissues, such that a soil chemical concentration of 5 mg/kg

was also the vegetation tissue chemical concentration. Each of these parameters and assumptions had a level of uncertainty attached to them, such that the final estimate of biomagnification could over- estimate risk.

Two other parameters, the NOEL and LOAEL (No Observed Effects Level and Lowest Observed Effects Level) were used to estimate a soil/water criterion and a "no effects" level. The value generally used in this calculation is the MATC (Maximum acceptable tissue concentration). No MATCs were found in the databases located at EPA Region VIII for the COCs evaluated, so the NOEL or LOAEL were used as substitutes. Generally, an uncertainty factor ranging from 5 to 5000 can be applied when using these values for soil or water criteria.

Because of the lack of site-specific data, it was not possible to validate any of the calculated factors or parameters. Thus, it is not possible to know how close or how far off are estimates of bioaccumulation and transfer through the food chain. It was also assumed in this assessment that dermal and inhalation exposures routes were insignificant in chemical accumulation in tissues. The values calculated from NOEL/LOAELs to estimate daily doses from water or soil ingestion suggested this was the case.

The conclusions of the risk assessment based on the assumptions used are that strontium concentrations in the soils are a potential risk to biota. However, even though the assumptions used were thought to be conservative, they may not be conservative enough. To better evaluate the potential risk to biota from IA contamination, site-specific chemical concentration data should be gathered and evaluated through the pathway-receptor model used in this study.

The uncertainty analysis addressed uncertainty in the toxicity and exposure assessment and uncertainty in the risk characterization. The assumptions of exposure, bioconcentration factors, and lack of site-specific data, all increase the uncertainty of any conclusions of potential harm to biota from site releases. Uncertainty in the exposure assessment is related to the accuracy with which exposure pathways correctly predict receptor contact with contaminated media and corresponding model inputs of contaminant concentrations. Risk characterization uncertainty is

7.0 REFERENCES

- Burt, W.H. and Grossenheider, R.P., 1964. *A Field Guide to the Mammals*. Houton Mittlin Co. Boston, p. 284.
- CDH, 1993. State of Colorado's Health Studies on Rocky Flats. Health Advisory Panel's Report to Colorado Citizens on the Phase I Study. October 1993.
- Chem Risk, 1992. Reconstruction of Historical Rocky Flats Operations and Identification of Release Points. August 1992. Chem Risk - a Division of McLaren/Hart, 1135 Atlantic Avenue, Alameda, CA 94501.
- Clark, S.V., Wegger, P.J., Komarkova, V., Weber, W.A. 1980. *Map of Mixed Prairie Grassland Vegetation Rocky Flats, Colorado*. Occasional Paper No. 35, Boulder, Colorado: Institute of Arctic and Alpine Research, University of Colorado.
- DOE, 1993a. *Industrial Area Environmental Evaluation Field Sampling Plan*. Rocky Flats Plant. October 15, 1993.
- DOE, 1993b. *Phase I Data Summary Industrial Area Environmental Evaluation*. Rocky Flats Plant. October, 1993.
- DOE, 1993c. *Phase II Data Summary Industrial Area Environmental Evaluation*. Rocky Flats Plant. November, 1993.
- DOE, 1993d. *Phase III Data Summary Industrial Area Environmental Evaluation*. Rocky Flats Plant. December, 1993.
- EG&G, 1992a. *Standard Operating Procedures Manual, Volume v, Ecology, Manual No. 5-21200-OPS-EE*. Golden, Colorado. EG&G Rocky Flats, Inc. (Currently undergoing review).
- EG&G, 1992b. *Standard Operating Procedures Manual, Volume I, Field Operations Manual*. 5-2100-OPS-FO. Golden, Colorado. EG&G Rocky Flats, Inc. (revision 5/12/92).
- Environmental Science and Engineering, Inc. (ESE), 1988. Rocky Mountain Arsenal Biota Assessment Phases I and II Final Technical Plan. July 1988.
- EPA. 1993. *Integrated Risk Information System (IRIS)*. Access Date: October 31, 1993.
- Frodham, C.L. and D.P. Reagan, 1991. Pathways Analysis Method for Estimating Water and Sediment Criteria at Hazardous Waste Sites. Environmental Toxicology and Chemistry.
- Hall, E.R., 1981. *Mammals of North America*. Second Edition, Wiley and Sons, NY. p. 1181

Hall, R.E. and N.R. Nelson. 1959. *The Mammals of North America. Volume II.* The Ronald Press Co., P. 1083.

Hazardous Substance Data Base (HSDB). 1993. Access Date: October 31, 1993.

Robbins, C.S., B. Brun, and H.S. Zim. 1966. *Birds of North America.* Western Publishing Co., Inc., Golden Press, NY, p. 340.

Spacie, A. and J.L. Hamelink, 1985. *Bioaccumulation In Fundamentals of Aquatic Toxicology.* G.M. Rand and S.R. Petrocelli, eds. McGraw-Hill. New York, pp. 495-525.

Thoman, R.V., 1981. *Equilibrium Model of Fate of Microcontaminants in Diverse Aquatic Food Chains.* Canadian Journal of Fisheries and Aquatic Science 38: 280-296.

Toxicology Occupational Medicine and Environmental Series Data Base (TOMES). 1993. Access Date: October 31, 1993. Micro Medex, Inc.

Whicker, F.W. and Ibrahim, S.A. 1993. *Radioecological Investigations at Rocky Flats.* Rocky Flats Plant. April 30, 1993.

TABLE 3-1
VEGETATION SPECIES BY HABITAT

<u>HABITAT</u>	<u>VEGETATION SPECIES</u>
Disturbed (annual/forb)	Sunflower, Russian-Thistle, Klamath Weed, Curlycup Gumweed, Western Ragweed, Burning Bush, Diffuse Knapweed, Cheat-grass, Japanese Brome, Canada Thistle, Musk Thistle, Bull Thistle
Mesic Grassland (mixed grassland)	Needle-and-Threadgrass, Prairie Junegrass, Big Bluestem, Canada Bluegrass, Kentucky Bluegrass, Sideoats Grama, Blue Grama, Mountain Muhly
Xeric Grassland (short grass)	Red Three-Awn, Fendler Three-Awn, Buffalo Grass, Hairy Grama, Ring Muhly, Aster, Mountain Bladder-Pod, Prairie Sage, Golden Aster, Filaree, Green Milkweed, Goldenrod, Winged Eriogonum, Sego-Lily, Sagewort, Broom Snakeweed, Spanish Bayonet, Prickly Pear
Short Marsh	Spike Rush, Rush, Baltic Rush, Soft Rush, Redtop Bentgrass, Timothy, Meadow Fescue, Nebraska Sedge, Foxtail Barley, Water Cress, Cress, Horseweed, Common Evening-Primrose, Violet, Lady's Thumb
Tall Marsh	Common Cattail, Common Evening Primrose, Catnip, Field Mint, Foxtail, Houndstongue, Plains Cottonwood, Russian-Olive, Peach-Leaved Willow
Deciduous Woodland (Woodland)	Plains Cottonwood, Russian-Olive, Peach-Leaved Willow, Creek Willow, Choke Cherry, Coyote Willow, Leadplant, Sandbar Willow
Reclaimed Grassland	Smooth Brome, Crested Wheatgrass, Intermediate Wheatgrass, Hybrid Native Side-Oats Grama, Alfalfa, White Sweet Clover, Yellow Sweet Clover, Wild Licorice
Ornamental Plantings	Ponderosa Pine, Russian-Olive, Plains Cottonwood, Juniper, Sheep Fescue

TABLE 3-2
 RESULTS OF SMALL MAMMAL LIVE TRAPPING AT
 THE EAST DRAINAGE STUDY AREA, OCTOBER 14 THROUGH 16, 1993

Small Mammal Species

White-footed deer mouse (*Peromyscus maniculatus*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	3	2	3
Females	0	0	0
Number of Age Classes:			
Juveniles	8	8	8
Number of Reproductives:	0	0	0
Number of Recaptures:	-	1	1

Western harvest mouse (*Reithrodontomys megalotis*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	2	0
Females	0	1	1
Number of Age Classes:			
Subadults	2	2	2
Juveniles	2	2	2
Number of Reproductives:	0	0	1
Number of Recaptures:	-	0	0

Prairie vole (*Microtus ochrogaster*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	1	3	0
Females	0	0	1
Number of Age Classes:			
Adults	4	4	4
Juveniles	1	1	1
Number of Reproductives:	0	0	0
Number of Recaptures:	-	1	0

TABLE 3-3
RESULTS OF SMALL MAMMAL LIVE TRAPPING AT THE NORTH POND
AND SEEP STUDY AREA, OCTOBER 14 THROUGH 16, 1993

Small Mammal Species

White-footed deer mouse (*Peromyscus maniculatus*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	1
Females	0	0	0
Number of Age Classes:			
Subadults	1	1	1
Number of Reproductives:	0	0	1
Number of Recaptures:	-	0	0

Western harvest mouse (*Reithrodontomys megalotis*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	1	0	0
Females	0	0	0
Number of Age Classes:			
Adults	1	1	1
Number of Reproductives:	0	0	0
Number of Recaptures:	-	0	0

Prairie vole (*Microtus ochrogaster*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	2	2
Number of Age Classes:			
Adults	3	3	3
Subadults	1	1	1
Number of Reproductives:	-	0	0
Number of Recaptures:	-	0	0

TABLE 3-4
RESULTS OF SMALL MAMMAL LIVE TRAPPING AT
THE NORTHWEST DRAINAGE STUDY AREA, OCTOBER 14 THROUGH 16, 1993

Small Mammal Species

White-footed deer mouse (*Peromyscus maniculatus*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	1	1	0
Females	2	1	0
Number of Age Classes:			
Adults	2	2	2
Juveniles	2	2	2
Number of Reproductives:	0	0	0
Number of Recaptures:	-	1	0

Western harvest mouse (*Reithrodontomys megalotis*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	1	0
Females	0	0	1
Number of Age Classes:			
Juveniles	2	2	2
Number of Reproductives:	0	0	0
Number of Recaptures:	-	0	0

Prairie vole (*Microtus ochrogaster*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	1
Females	0	2	1
Number of Age Classes:			
Adults	2	2	2
Subadults:	2	2	2
Number of Reproductives:	0	1	0
Number of Recaptures:	-	0	0

TABLE 3-5
RESULTS OF SMALL MAMMAL LIVE TRAPPING AT THE
WEST RAILROAD STUDY AREA, OCTOBER 14 THROUGH 16, 1993

Small Mammal Species

White-footed deer mouse (*Peromyscus maniculatus*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	0	0
Number of Age Classes:	None		
Number of Reproductives:	None		
Number of Recaptures:	None		

Western harvest mouse (*Reithrodontomys megalotis*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	0	1
Number of Age Classes:			
Juveniles	0	1	0
Number of Reproductives:	0	0	0
Number of Recaptures:	-	0	0

Prairie vole (*Microtus ochrogaster*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	0	0
Number of Age Classes:	None		
Number of Reproductives:	None		
Number of Recaptures:	None		

TABLE 3-6
RESULTS OF SMALL MAMMAL LIVE TRAPPING AT THE
WEST AREA STUDY AREA, OCTOBER 14 THROUGH 16, 1993

Small Mammal Species

White-footed deer mouse (*Peromyscus maniculatus*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	1	0
Females	0	1	0
Number of Age Classes:			
Subadults	0	2	0
Number of Reproductives:	0	0	0
Number of Recaptures:	-	0	0

Western harvest mouse (*Reithrodontomys megalotis*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	0	0
Number of Age Classes:	None		
Number of Reproductives:	None		
Number of Recaptures:	None		

Prairie vole (*Microtus ochrogaster*)

Number Caught:	Oct 14	Oct 15	Oct 16
Males	0	0	0
Females	0	0	0
Number of Age Classes:	None		
Number of Reproductives:	None		
Number of Recaptures:	None		

TABLE 3-7
BIRD SPECIES OBSERVED IN THE INDUSTRIAL AREA
DURING A THREE DAY SURVEY -- OCTOBER 28 TO NOVEMBER 8, 1993

SPECIES	EAST DRAINAGE	NO. POND & SEEP	NORTHWEST DRAINAGE	WEST RAILROAD	WEST AREA
Raven	4	0	0	0	2
Rock Dove	2	3	3	0	0
House Finch	5	0	6	0	0
Cassin's Finch	0	0	1	0	0
Starling	9	4	0	0	20
American Robin	0	0	0	0	2
House Sparrow	2	3	0	0	0
Vesper Sparrow	0	1	8	0	3
Dark-eyed Junco (slate-colored race)	0	0	8	0	3
Rosey Finch (Brown-capped race)	0	0	3	0	0
Unknown Sparrows*	0	0	11	0	0
American Kestrel	1	0	0	0	1
Ferruginous Hawk	0	0	1	0	0
Herring Gull	1	0	1	0	0
TOTAL BIRDS	24	11	41	0	30
TOTAL SPECIES	7	4	9	0	6
SPECIES USING HABITAT AND NOT FLYING OVERHEAD	3	2	6	0	5

* These sparrows were deep into the willows and could not be identified with certainty.

**TABLE 4-1
Rocky Flats Industrial Area Environmental Evaluation
Potential Contaminants of Concern**

Contaminant of Concern	Toxicity Information	Concentration Ranges from OU4	Applicable or Relevant and Appropriate Requirements (ARAR)	Carcinogen Classification
INORGANICS				
Beryllium	LD ₅₀ : Intravenous - rat 496 mg/kg NOAEL: 0.95 mg/kg/day	1.1 - 9.6 mg/kg	0.2 mg/kg ¹	B2; probable human carcinogen
Cadmium	LD ₅₀ : Ingestion - mouse 790 mcmol Cd/kg NOAEL: 0.005 mg/kg/day	1.1 - 380 mg/kg	40 mg/kg ¹	B1; probable human carcinogen
Chromium	Chronic toxicity studies with rats showed no significant adverse effects	4.2 - 48.4 mg/kg	400 mg/kg ¹	A; human carcinogen
Mercury	Rats were injected with metallic mercury and observed for their lifetimes, sarcomas were seen only in those tissues that had been in direct contact with the metal	0.05 - 18 mg/kg	20 mg/kg ¹	D; not classifiable as to human carcinogenicity
Nickel	LD ₅₀ : Ingestion - Rat 2.0 g/kg NOAEL: 5 mg/kg/day	10 - 180 mg/kg	2000 mg/kg ¹	EPA has not evaluated for potential human carcinogenicity
Silicon	LD ₅₀ : Ingestion - Rat 3160 mg/kg	463 - 11300 mg/kg		
Strontium	NOAEL: 375 mg/kg/day	22 - 510 mg/kg	8 pCi/l ²	EPA has not evaluated for potential human carcinogenicity
RADIONUCLIDES				
Americium-241		0 - 6.1 pCi/g	0.05 pCi/l ³	
Plutonium-230/240		0 - 25 pCi/g	0.05 pCi/l ³	
Thorium			500 pCi/l ³	
Tritium		0.11 - 62 pCi/ml	20,000 pCi/l ²	
Uranium-233/234		0 - 21 pCi/g		
Uranium-235		0 - 0.87 pCi/g		
Uranium-238		0 - 11 pCi/g	5 pCi/l ³	

**TABLE 4-1
Rocky Flats Industrial Area Environmental Evaluation
Potential Contaminants of Concern**

Contaminant of Concern	Toxicity Information	Concentration Ranges from OU4	Applicable or Relevant and Appropriate Requirements (ARAR)	Carcinogen Classification
VOLATILE ORGANICS				
Carbon Tetrachloride	LD ₅₀ : Ingestion - Rat 2350 mg/kg NOAEL: 1 mg/kg/day	6 - 29 µg/l	5 mg/kg ¹	B2; probable human carcinogen
Chloroform	LD ₅₀ : Ingestion - rat 300 mg/kg LOAEL: 12.9 mg/kg/day	6 - 29 µg/l	100 mg/kg ¹	B2; probable human carcinogen
Methylene Chloride	NOAEL: 5 mg/kg/day	0 - 6000 µg/kg	90 mg/kg ¹	B2; probable human carcinogen
Tetrachloroethylene	LD ₅₀ : Ingestion - rat 2629 mg/kg NOEL: 14 mg/kg/day	6 - 29 µg/kg	10 mg/kg ¹	The evaluation for this chemical is under review by an EPA inter-office agency work group.
1,1,1-Trichloroethane	LD ₅₀ : Ingestion - human estimation 500 mg/kg	6 - 29 µg/kg	200 µg/l ²	D; not classifiable as to human carcinogenicity
1,1,2,2-Tetrachloroethane		6 - 29 µg/kg	30 mg/kg ¹	C; possible human carcinogen

LD₅₀: Lethal dose to 50% of the population
 NOAEL: No observed adverse effect level
 LOAEL: Lowest observed adverse effect level
 NOEL: No observed effect level

¹ Values from the Corrective Action for Solid Waste Management Units (SWMUs) at Hazardous Waste Management Facilities, Proposed Rule, Vol. 55, No. 145, Friday, July 27, 1990

² Maximum Contaminant Level

³ Colorado Department of Health Standard

TABLE 6-1
FOOD CONSUMPTION AND FOOD ITEM PERCENTAGES
USED TO ESTIMATE BIOACCUMULATION FACTORS

SPECIES	DAILY FOOD CONSUMPTION (g/kg bw/day) ^a	AVERAGE WEIGHT (grams)	FOOD ITEMS	PERCENT IN DIET
Great Horned Owl	202.5	1500 ¹	Invertebrates Birds Mammals	8.1 ¹ 29.7 ¹ 62.1 ¹
American Kestrel	30	115 ¹	Insects Small Birds Reptiles Mammals	51.8 ² 16.4 ² 4.5 ² 27.3 ²
Feral Cat	50	1250	Insects Mammals	50 ³ 50 ³
Cottontail Rabbit	120	1450	Insects Plants	50 ³ 50 ³
Song Bird	40	40	Plants Insects Earthworms	50 ⁴ 25 ⁴ 25 ⁴
Prairie Vole	70	50 ⁵	Insects Plants	50 ³ 50 ³
Harvest Mouse	20	15 ⁵	Insects Plants	50 ³ 50 ³
Deer Mouse	25	20 ⁵	Insects Plants	50 ³ 50 ³

^a g/kg bw/day = grams/kilogram body weight/day

¹ Craighead and Craighead, 1969

² Sherrod, 1978

³ Jones et. al, 1985
 Hall, 1981

⁴ ESE, 1988

⁵ DOE, 1993b

TABLE 6-2
RATES OF WATER AND SOIL INGESTION
FOR SELECTED SPECIES

Species	Weight of Animal (grams)	Water (l/kg bw/day) ^a	Soil (g/kg bw/day) ^a
Cotton Rat	160	0.125	0.00028
White-footed Mouse	17.5	0.02	0.00074
Rabbit	1450	0.165	0.0613
Cat	1250	0.05	0.0022
Raptor	1500	0.10	---
Chipmunk	90	---	0.0016

^a l/kg bw/day = liters/kilogram body weight/day
g/kg bw/day = grams/kilogram body weight/day

**TABLE 6-3
 SUMMARY OF BIOACCUMULATION FACTORS
 FOR KEY SPECIES IN INDUSTRIAL AREA FOOD WEB PATHWAYS**

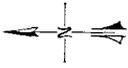
Pathway*	Cottontail Rabbit	Deer Mouse	Bird	Feral Cat	Kestrel	Great Horned Owl
1			4.5	7.85		13.7
2		5.05		8.35		28.58
3	2.19			5.77		16.80
4		5.05				28.58
5	2.19					16.80
6			4.5			13.7
7		5.05			24.63	
8			4.5		14.52	
9			4.5	7.85		
10		5.05		8.35		
11	2.19			5.77		

* Pathways include the following:

- Pathway #1: Soil → Plants → Bird → Feral Cat → Great-horned Owl
- Pathway #2: Soil → Plants → Deer Mouse → Feral Cat → Great-horned Owl
- Pathway #3: Soil → Plants → Cottontail Rabbit → Feral Cat → Great-horned Owl
- Pathway #4: Soil → Plants → Deer Mouse → Great-horned Owl
- Pathway #5: Soil → Plants → Cottontail Rabbit → Great-horned Owl
- Pathway #6: Soil → Plants → Bird → Great-horned Owl
- Pathway #7: Soil → Plants → Deer Mouse → American Kestrel
- Pathway #8: Soil → Plants → Bird → American Kestrel
- Pathway #9: Soil → Plants → Bird → Feral Cat
- Pathway #10: Soil → Plants → Deer Mouse → Feral Cat
- Pathway #11: Soil → Plants → Cottontail Rabbit → Feral Cat

TABLE 6-4
SOIL AND WATER CRITERIA ESTIMATED FROM
BIOMAGNIFICATION FACTORS FOR FERAL CAT

Potential COCs	NOEL/LOAEL (mg/kg)	Soil/Water Criteria NOEL/LOAEL BMF Cat mg/kg	Soil Daily Dose to Feral Cat mg/l	Water Daily Dose (Feral Cat) mg/l	Concentration Range at OU4
Beryllium	0.95	0.133	2.9×10^{-4}	0.007	1.1 - 9.6 mg/kg
Cadmium	0.005	0.0007	1.5×10^{-6}	3.5×10^{-5}	1.1 - 380 mg/kg
Nickel	5.0	0.698	1.5×10^{-3}	0.035	10 - 180 mg/kg
Silicon	3160.0	441.34	0.97	22.07	463- 11,300mg/kg
Strontium	375.0	52.37	0.115	2.62	22 - 510 mg/kg
Carbon Tetrachloride	1.0	0.14	$3.1 \times 10^{-4} \mu\text{g/l}$	$0.007 \mu\text{g/l}$	6 - 29 $\mu\text{g/l}$
Chloroform	12.9	1.8	$3.96 \times 10^{-3} \mu\text{l}$	$0.09 \mu\text{g/l}$	6 - 29 $\mu\text{g/l}$
Methylene Chloride	5.0	0.698	1.5×10^{-6}	0.035	0 - 6 mg/kg
Tetrachloroethylene	14.0	1.96	4.3×10^{-3}	0.098	.006-.029 mg/kg

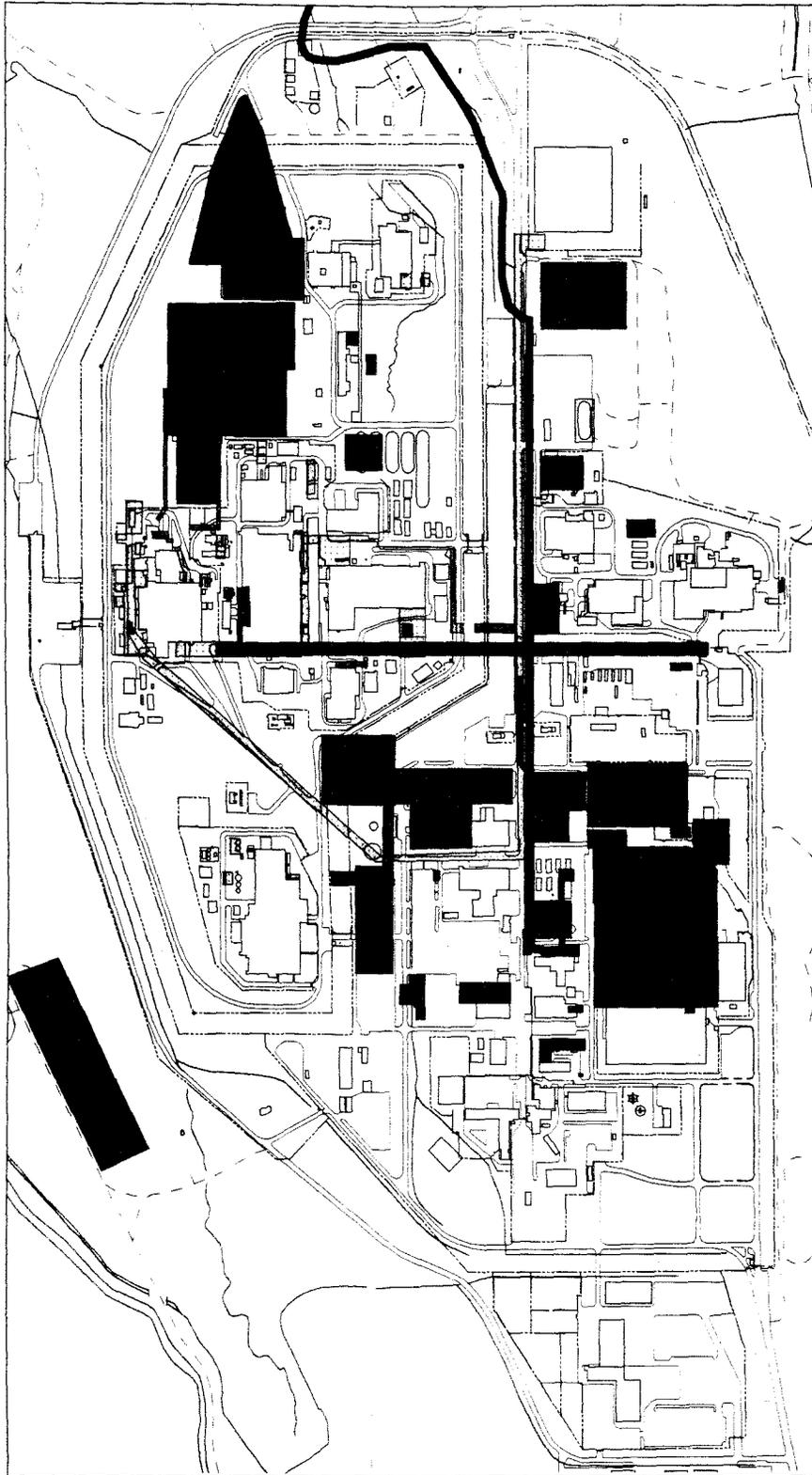


- Drainage
- Pond
- Buildings
- Fence
- Paved Road
- Dirt Road
- OU14
- OU6
- OU8
- OU9
- OU10
- OU12
- OU13
- OU14

250 0 250 500 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 1
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
INDIVIDUAL HAZARDOUS
SUBSTANCE SITES



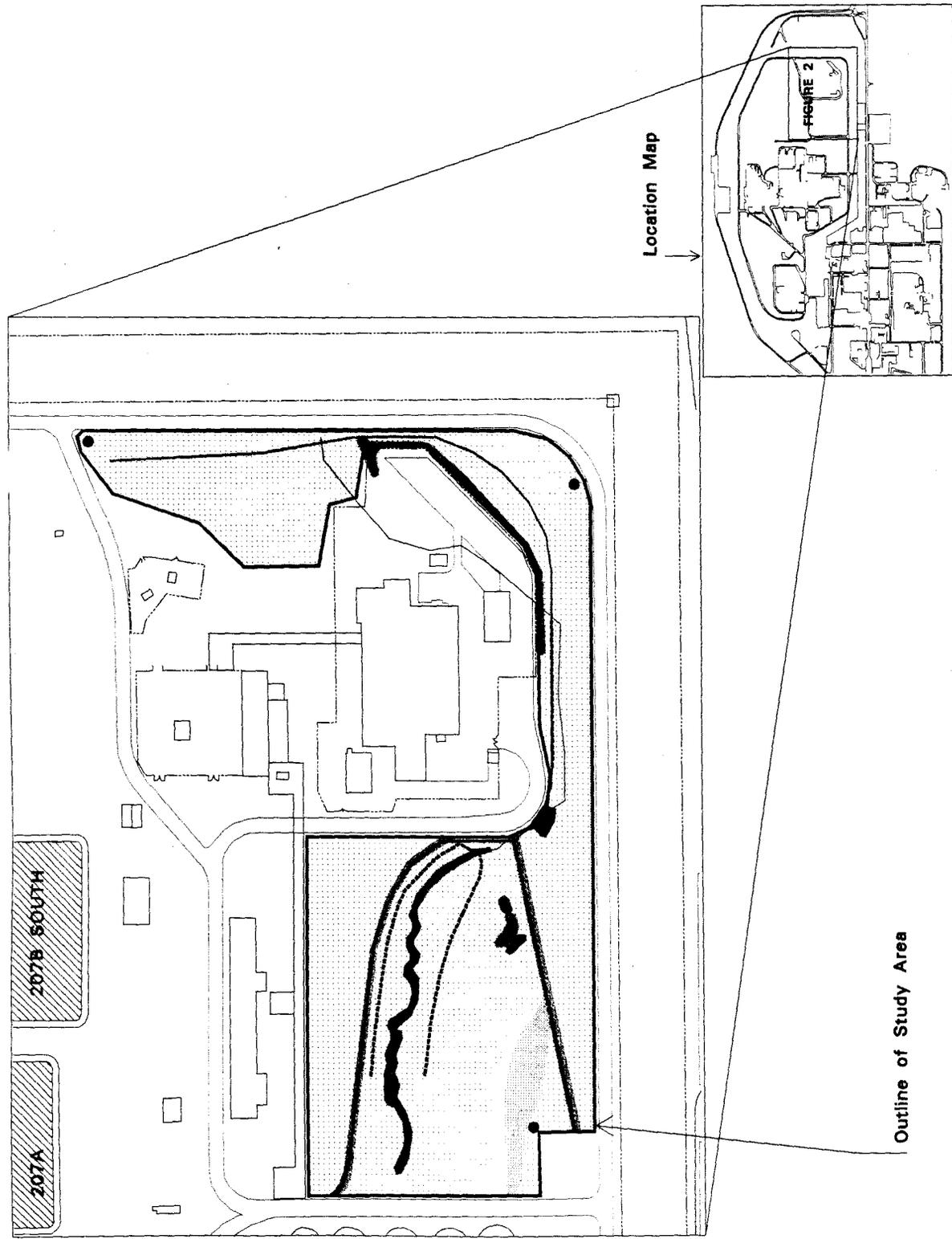


- Drainage
- ▨ Pond
- Buildings
- Fence
- Paved Road
- ▨ Sidewalk
- ▨ Rock
- ▨ Reclaimed Grassland
- ▨ Short Marsh
- ▨ Tall Marsh
- ▨ Disturbed
- ▨ Bare Ground
- ▨ Deciduous Woodland
- ▨ Disturbed/Reclaimed
- Outline of Study Area
- Small Mammal Trap Lines
- Bird Observation Points
- Traverse Route

Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 2
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
EAST DRAINAGE



Location Map

Outline of Study Area



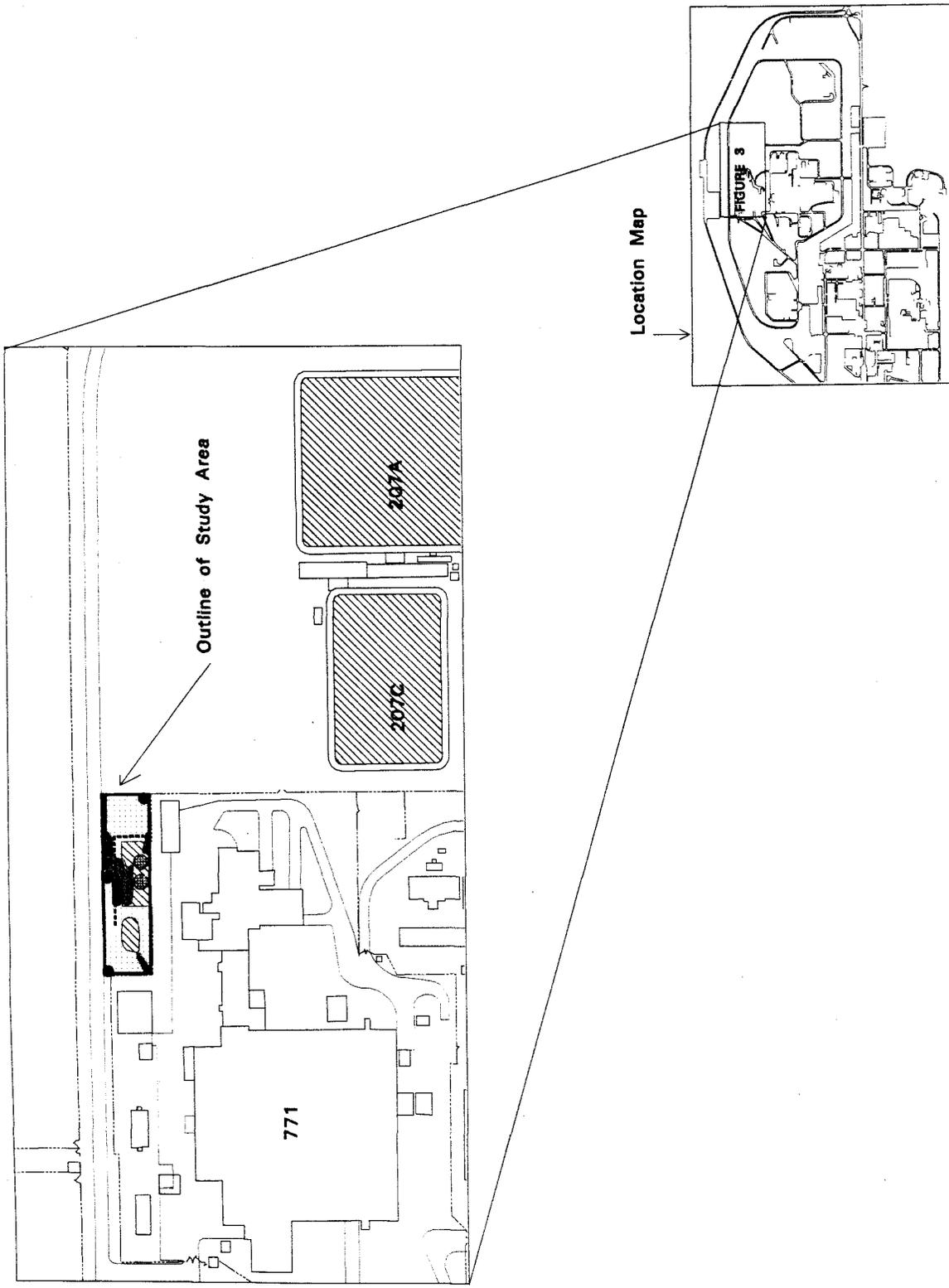
- Drainage
- ▨ Pond
- Buildings
- - - Fence
- Paved Road
- Tank
- Short Marsh
- Tall Marsh
- Disturbed/Reclaimed

- Outline of Study Area
- Small Mammal Trap Lines
- Bird Observation Points

Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 3
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
NORTH POND AND SEEP



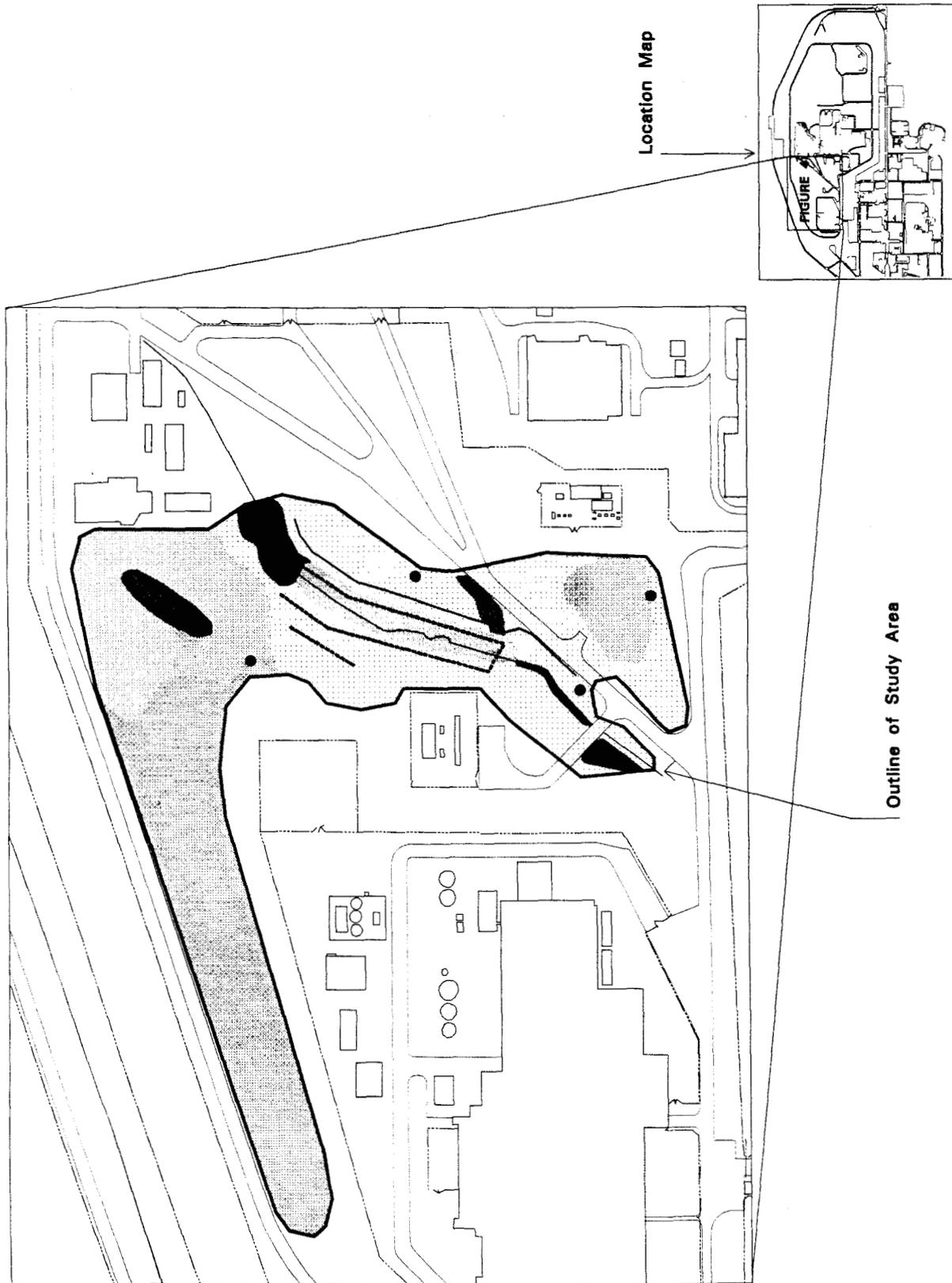


- Drainage
- ▭ Buildings
- Fence
- Paved Road
- ▨ Disturbed
- Bare
- ▨ Reclaimed Grassland
- ▨ Reclaimed/Disturbed
- ▨ Reclaimed/Mesic Grass
- ▨ Mesic Grassland
- ▨ Short Marsh
- ▨ Tall Marsh
- ▨ Deciduous Woodland
- ▨ Riparian Shrub
- ▨ Xeric/Mesic Grass

- Outline of Study Area
 - - - Small Mammal Trap Lines
 - Bird Observation Points
 - Traverse Route
- Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 4
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
NORTHWEST DRAINAGE



Location Map

Outline of Study Area

FIGURE



- Drainage
- Buildings
- Fence
- Paved Road

- Short Marsh
- Disturbed

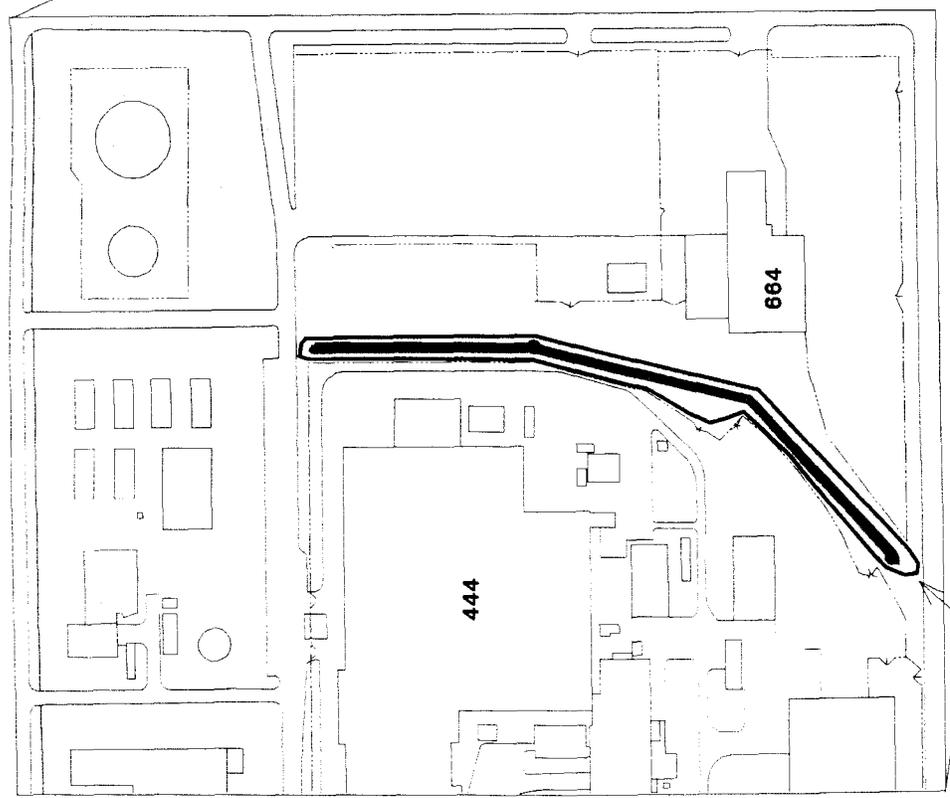
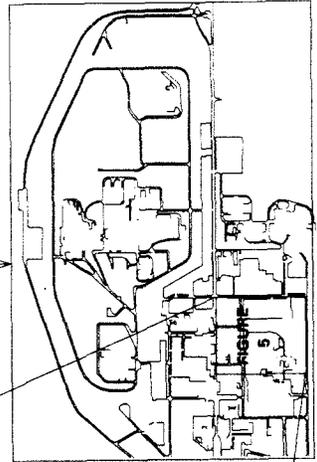
- Outline of Study Area
- Small Mammal Trap Lines
- Bird Observation Points
- Traverse Route

Scale: 1 inch = 150 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 6
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
WEST RAILROAD

Location Map



Outline of Study Area



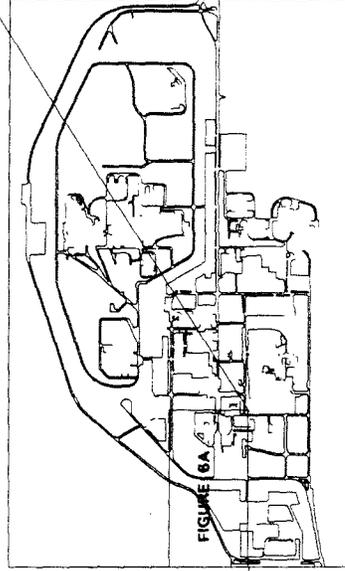
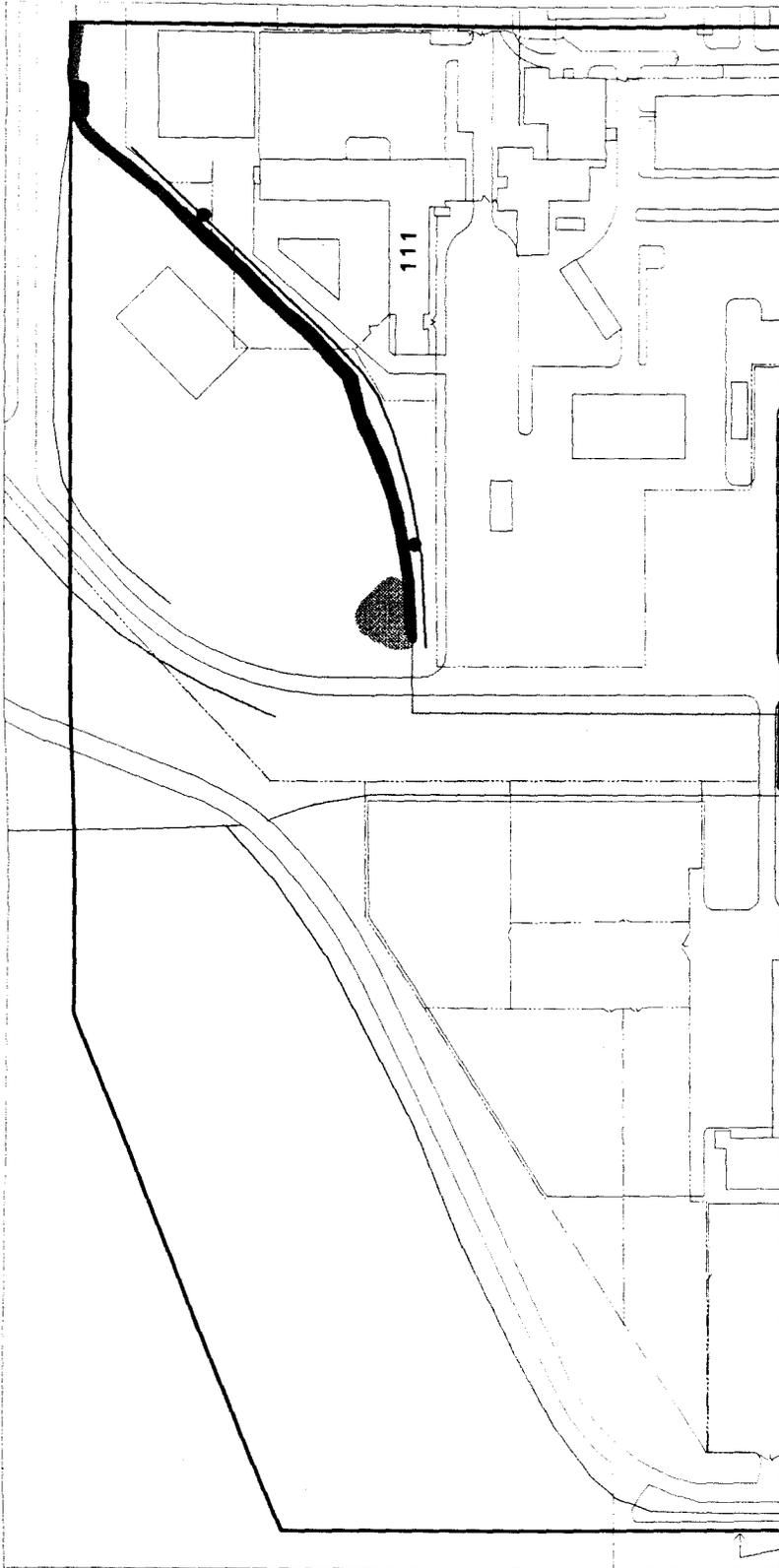
- Drainage
- Buildings
- - - Fence
- - - Paved Road
- Ornamental Trees
- Disturbed/Mosaic Grass
- Short Marsh
- Tall Marsh

- Outline of Study Area
- Bird Observation Points
- Traverse Route

Scale: 1 inch = 150 feet

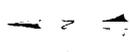
PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 6A
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
WEST AREA



Location Map

Outline of Study Area



- Drainage
- Buildings
- - - Fence
- Paved Road

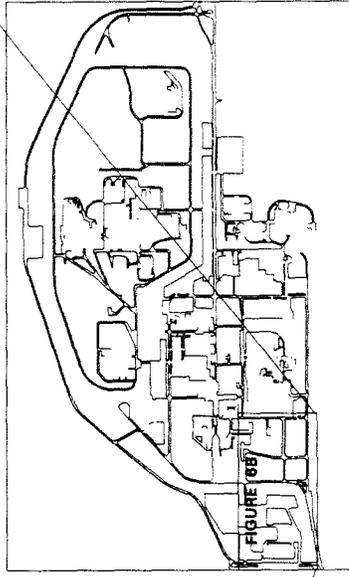
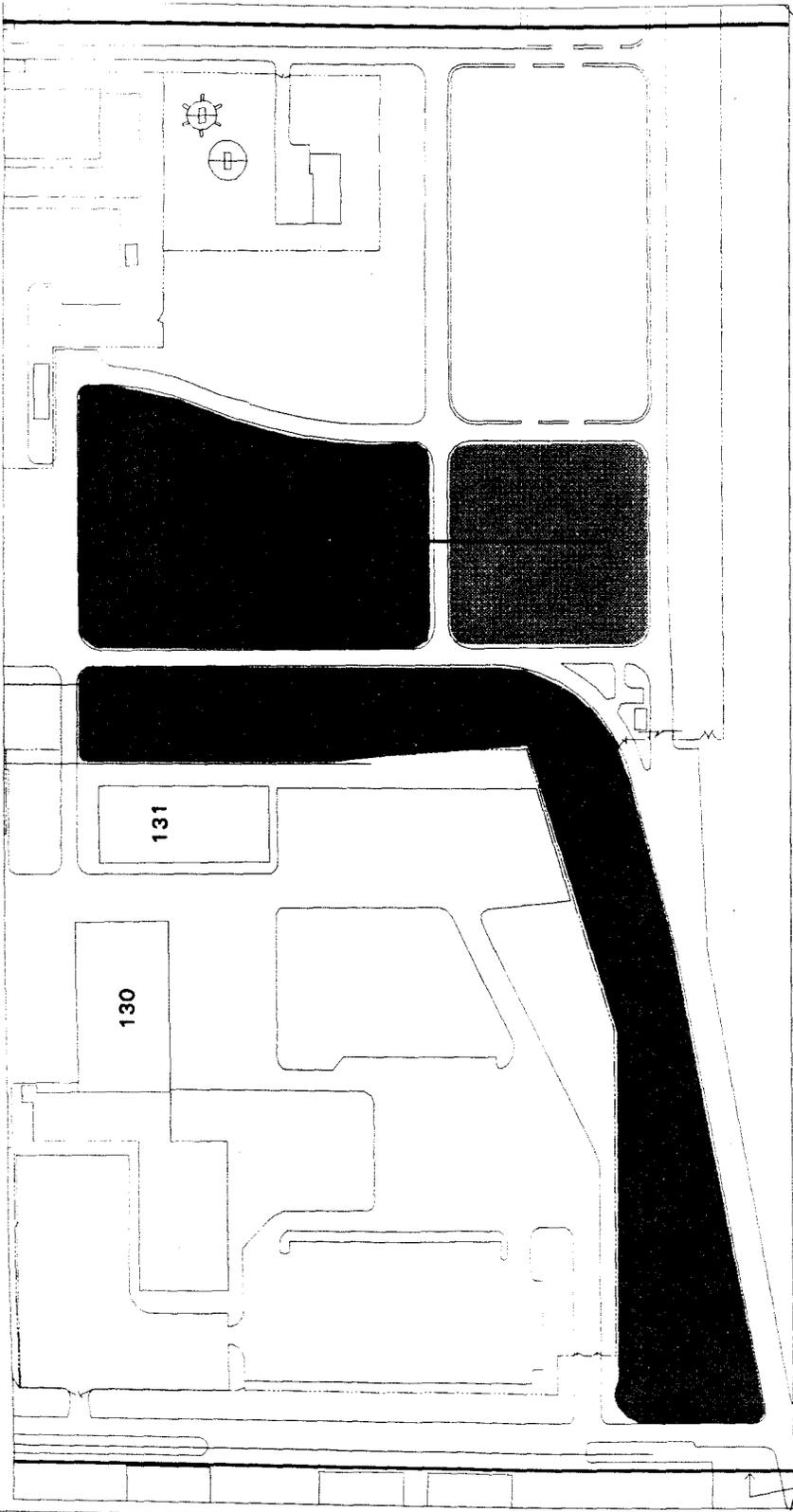
- Xeric Grassland
- Xeric/Mesic Grass
- Disturbed/Mesic Grass

- Outline of Study Area
- - - Small Mammal Trap Lines
- Bird Observation Points
- Traverse Route

Scale: 1 inch = 300 feet

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 86
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
WEST AREA



Location Map

Outline of Study Area

REVISION NO. 5

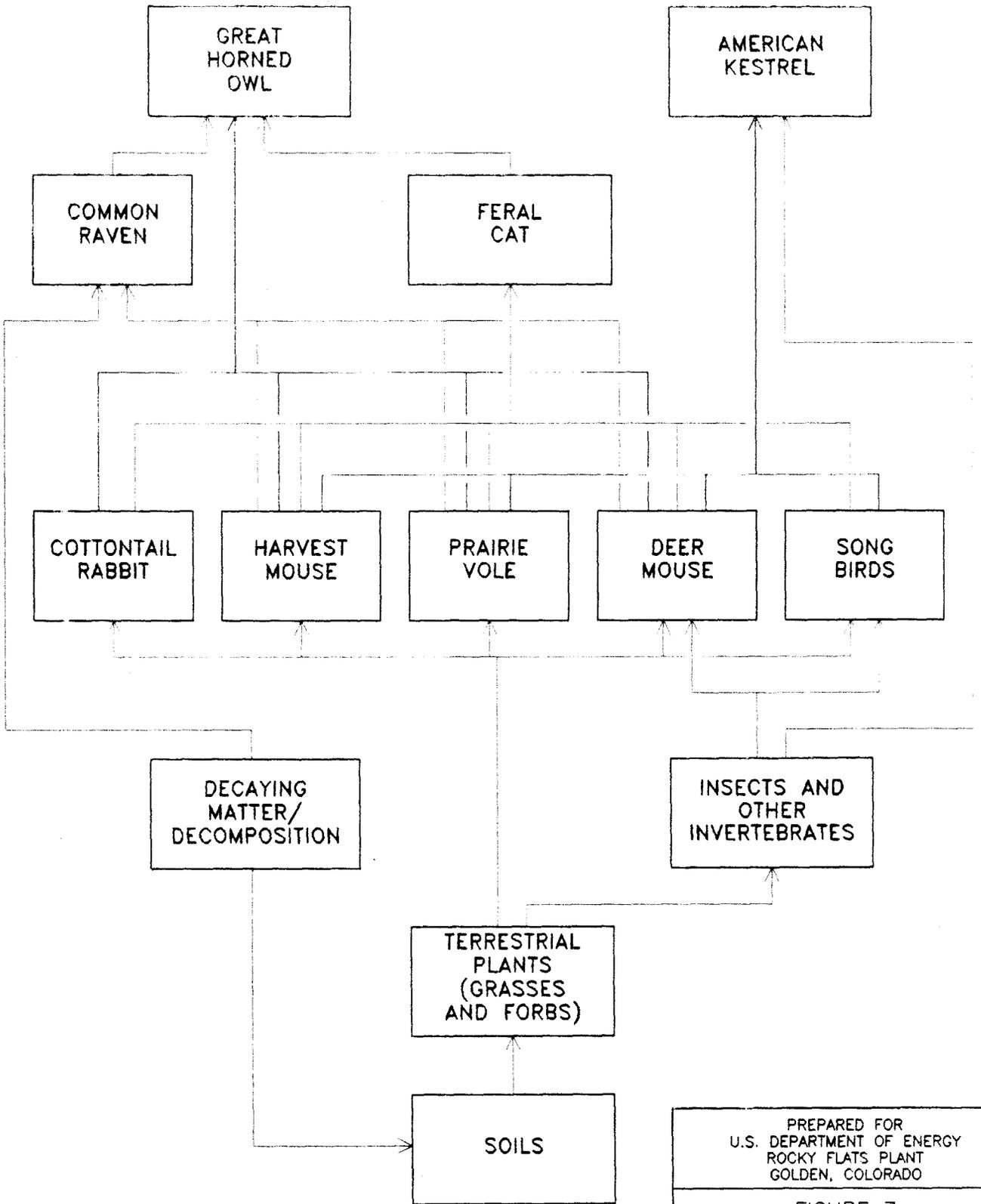
FILE NAME C:\KJS\FWAGENTM

DATE 12/6/93

DRAWN BY KJS

APPROVED BY *UCF*

CHECKED BY *WR*



PREPARED FOR
 U.S. DEPARTMENT OF ENERGY
 ROCKY FLATS PLANT
 GOLDEN, COLORADO

FIGURE 7
 INDUSTRIAL AREA
 ENVIRONMENTAL EVALUATION
 GENERALIZED FOOD WEB

REVISION NO. 5

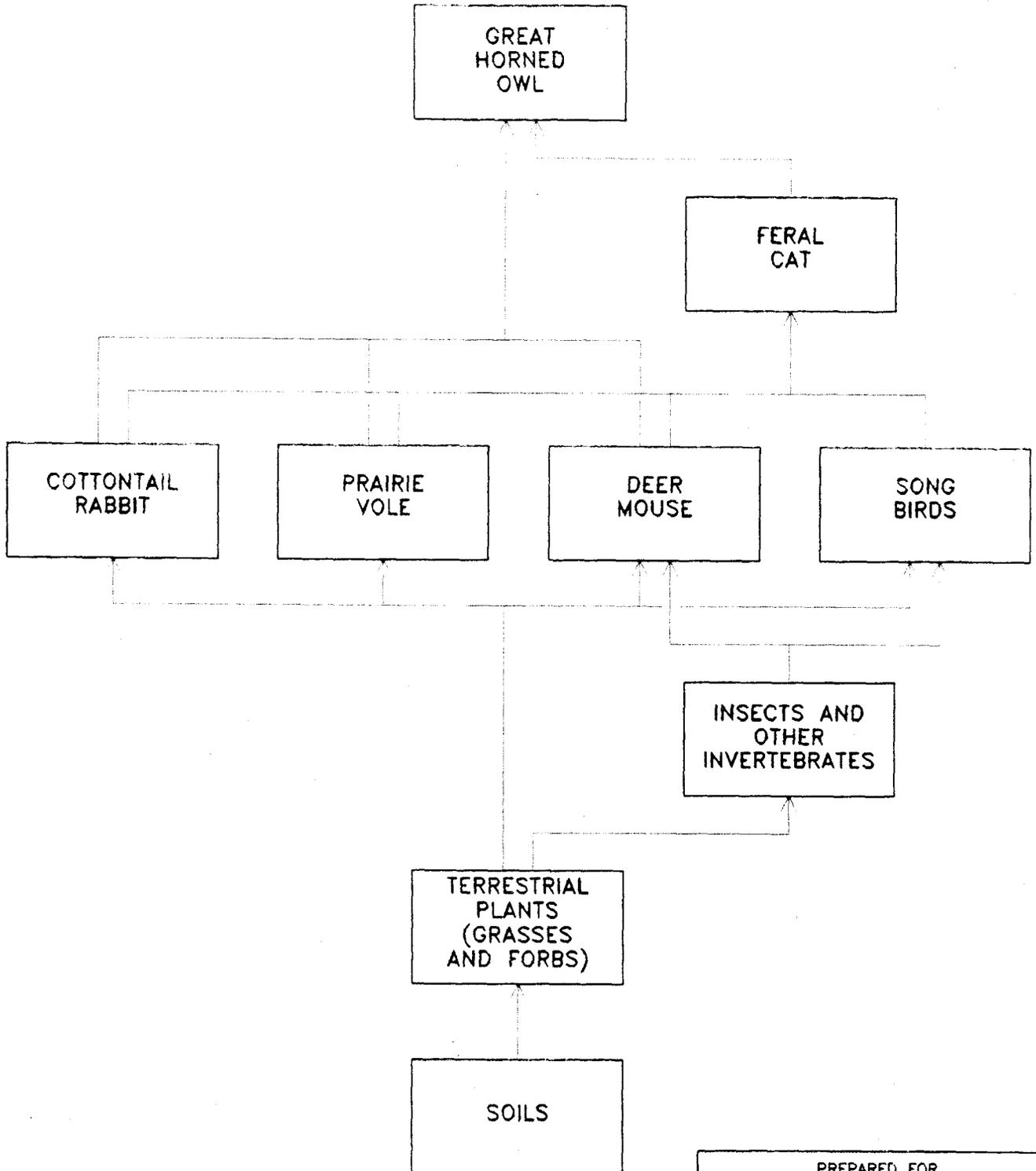
FILE NAME C:\KUS\FWGHOTM

DATE 12/6/93

DRAWN BY KJS

APPROVED BY VEF

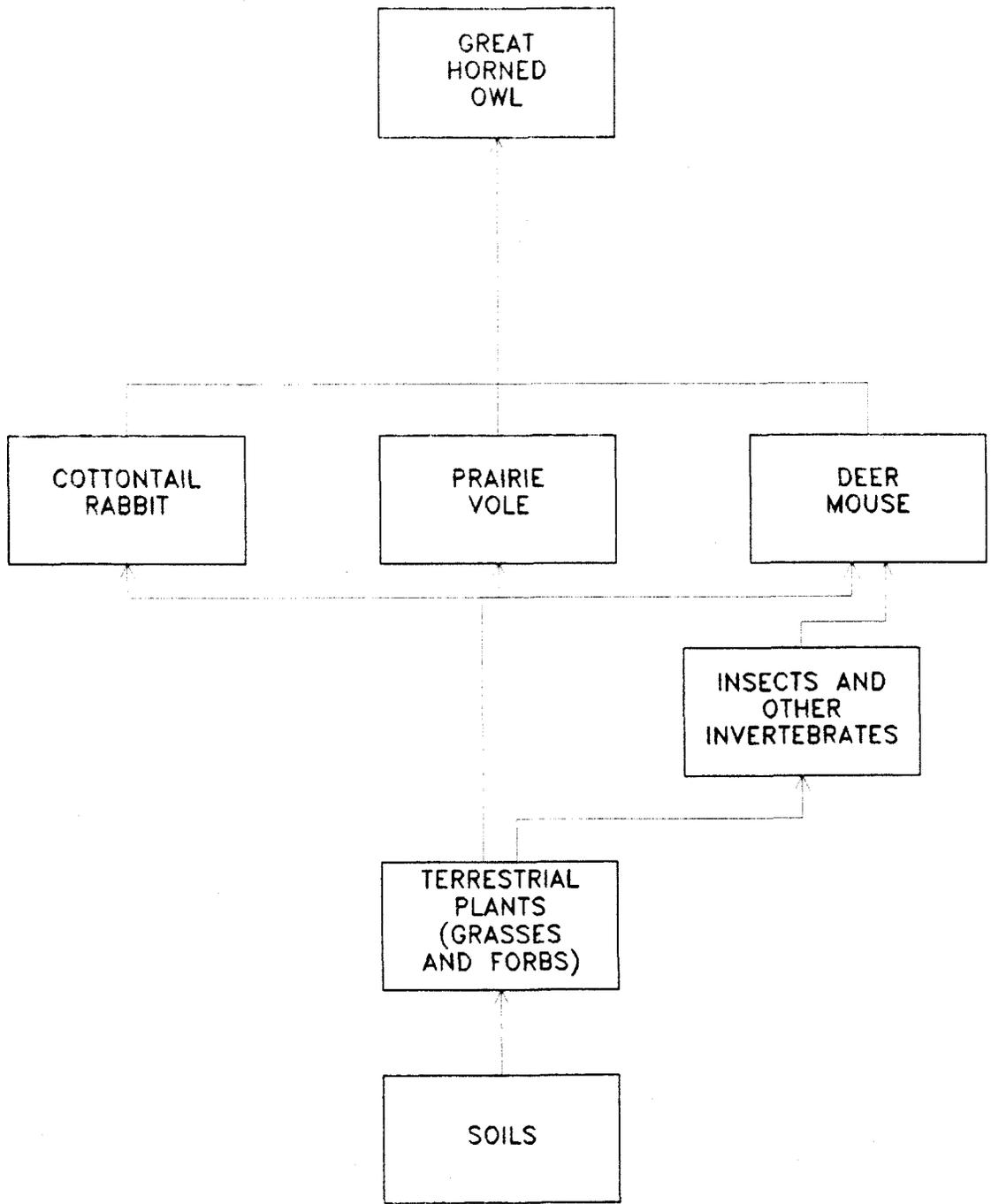
CHECKED BY 48



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

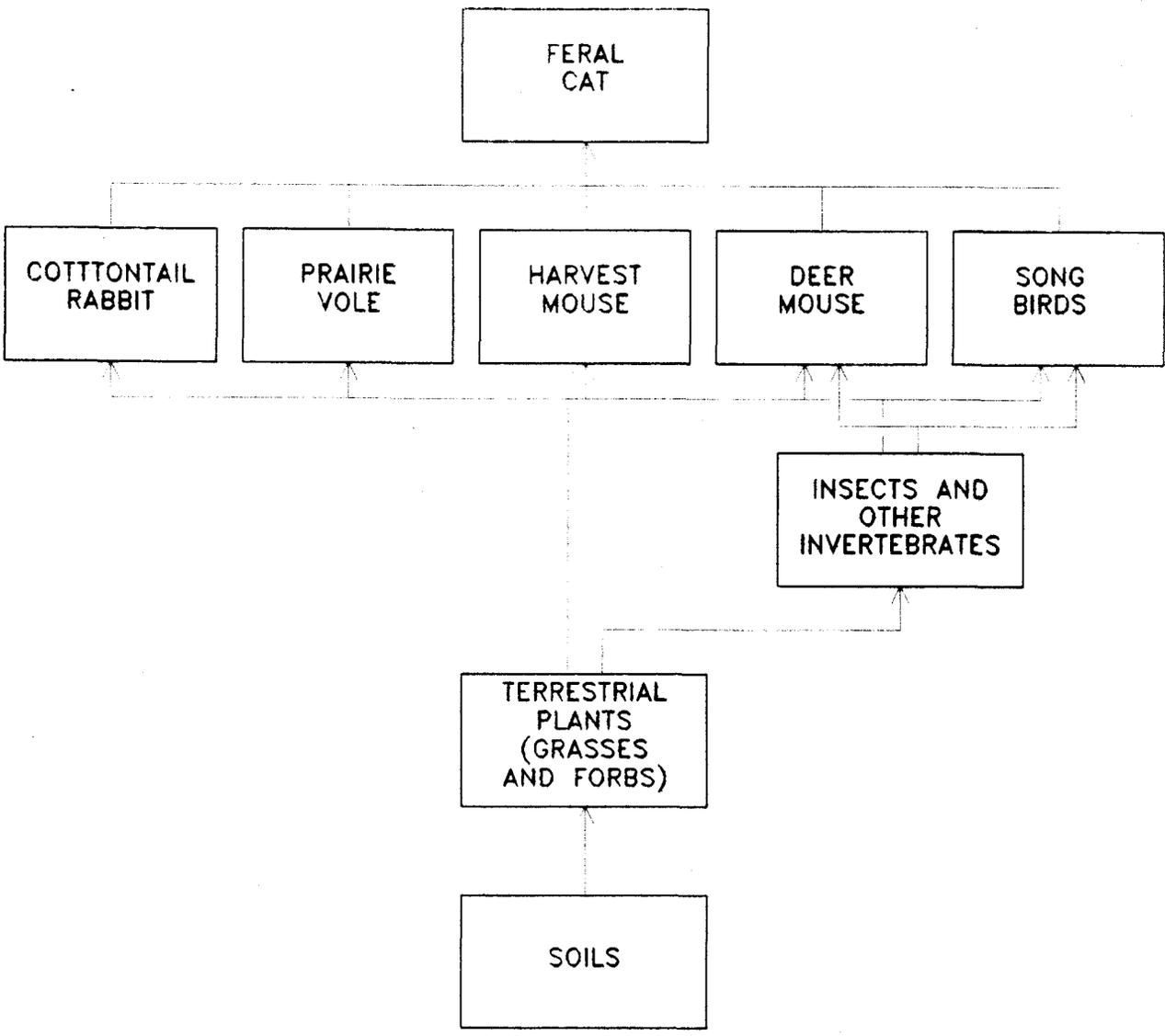
FIGURE 8
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR GREAT HORNED OWL

CHECKED BY *WJ* APPROVED BY *JEF* DRAWN BY KJS DATE 12/6/93 FILE NAME C:\KJS\F\WGH3TM REVISION NO. 2



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

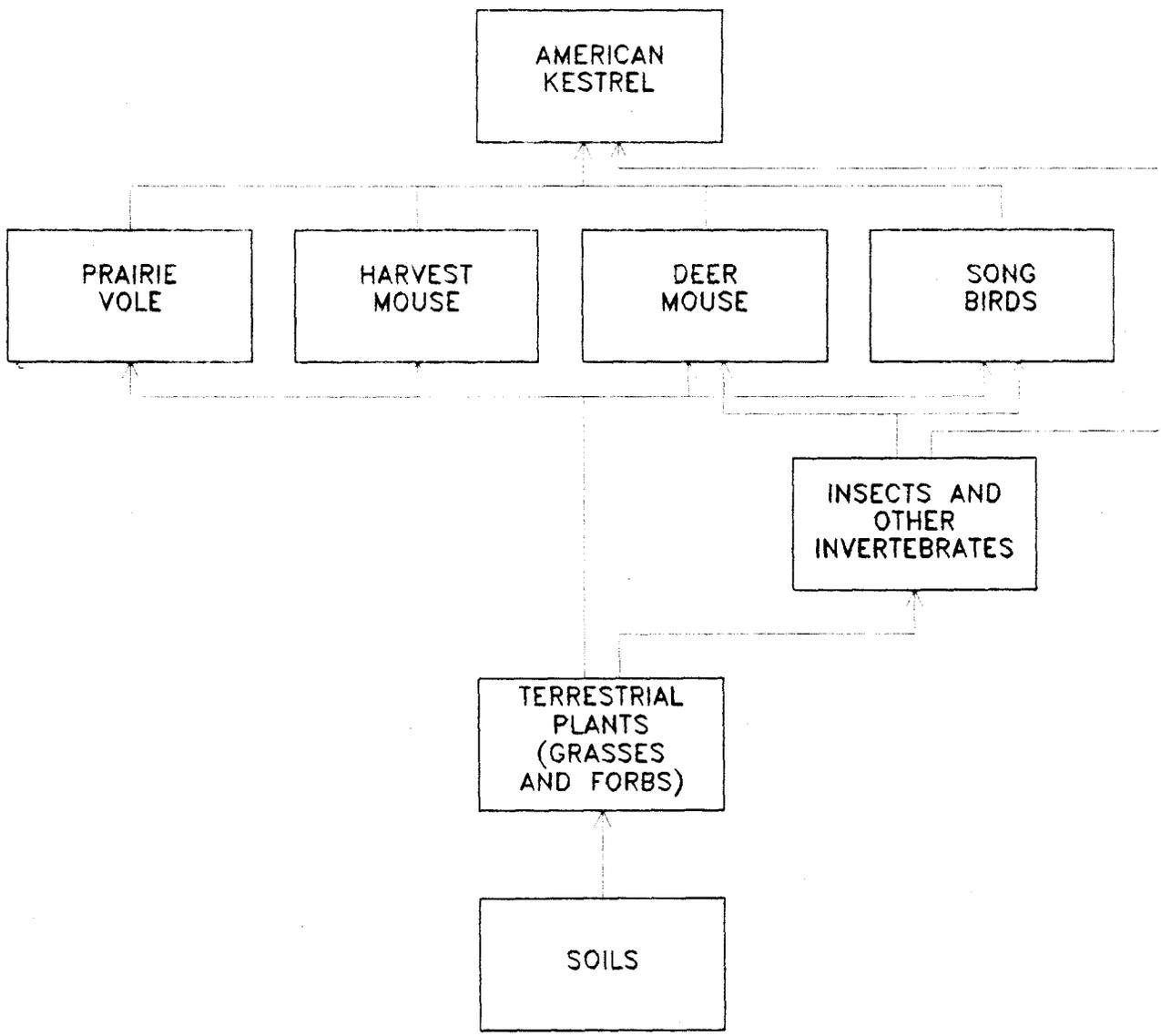
FIGURE 9
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR GREAT HORNED OWL
WITHOUT FERAL CAT PATHWAY



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 10
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR FERAL CAT

CHECKED BY *WJ* APPROVED BY *JEF* DRAWN BY KJS DATE 12/6/93 FILE NAME C:\KJS\FWAKTM REVISION NO. 4



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 11
INDUSTRIAL AREA
ENVIRONMENTAL EVALUATION
SINK FOOD WEB
FOR AMERICAN KESTREL