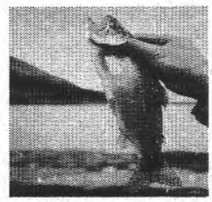
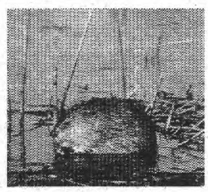
Canada Alberta Northwest Territories

Northern River Basins Study







NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 113

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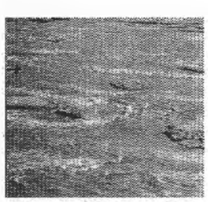

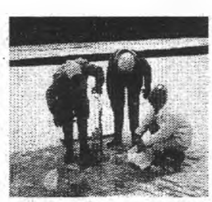


Prepared for the
Northern River Basins Study
under Project 2381-E2

by

Mary Ellen Starodub and Glenn Ferguson
CanTox Inc.

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

This report contains referenced data obtained from sources external to the Northern River Basins Study. Individuals interested in using external data must obtain permission to do so from the donor agency.

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Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

F J Wrona — 14 May 96
(Dr. Fred J. Wrona, Science Director) — (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No

P A Larkin — 24 May 96
(Dr. P. A. Larkin, Ph.D., Chair) — (Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

Lucille Partington — May 29/96
(Lucille Partington, Co-chair) — (Date)

Robert McLeod. — May 21/96
(Robert McLeod, Co-chair) — (Date)

A BIOENERGETIC MODEL OF FOOD CHAIN UPTAKE AND ACCUMULATION OF ORGANIC CHEMICALS, ATHABASCA RIVER: STOCHASTIC AND TIME VARIABLE VERSION

STUDY PERSPECTIVE

> ***Related Study Questions***
>
> *13a) What predictive tools are required to determine the cumulative effects of man made discharges on the water and aquatic environment?*
>
> *14) What long term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems. These programs must ensure that all stake holders hove the opportunity for input.*

Environments are constantly changing; that the aquatic environments contained within the Northern River Basins Study (NRBS) area were being changed as a result of development was not challenged. However, the ability to describe and predict those changes likely to arise from development continued to be a challenge to resource managers at the onset of the Study.

Typically, the change that occurs within the environment like those found in the Peace, Athabasca and Slave rivers, take place over an extended period of time. Although not as evident or dramatic, the change and its effects can be just as substantive as those occurring within a shorter time frame; the changes are so subtle as to go unnoticed. A major difficulty for aquatic scientists working with these large aquatic systems is the lack of documented information covering a long period of time. The monitoring that was underway or done prior to the onset of the NRBS Study was disparate and information gaps existed.

For large, complex aquatic ecosystems like the Peace, Athabasca and Slave rivers, subjected to significant seasonal variation, scientists use tools like models to help them assess the consequence of changing one or many parameters. Models offer researchers and managers with the capability of being better able to understand and predict changes arising from development. NRBS undertook to investigate the potential use of models. A decision was made to utilize WASP IV, Thomann/Connolly and Gobas food chain models, to assess the fate and bioaccumulation of point-source contaminants entering the upper Athabasca River.

The modelling effort by NRBS was a multi-faceted initiative involving review and interpretation of sediment transport dynamics, contaminant distribution and concentration in sediment, water and biota and the refinement of existing models. This report describes Phase II of the initiative; to develop a model to simulate the uptake and accumulation of selected organic chemicals in selected species of the Athabasca River food web in response to changes in environmental concentrations as a function of time. The selection of a model, Phase I, was described in NRBS Project Report No. 137.

Researchers utilized data acquired in the upper Athabasca River for sediment, water and biota to input into a model selected as being best suited for the river system and data available. Results using the model underestimated observed concentrations of dioxins and furans in mountain whitefish, longnose sucker and northern pike tissues. Researchers concluded that improvements were likely if more representative data of environmental concentrations, including values assigned to fish tissue and the excretion rate variability among the fish species, were obtained. Although use of the model is limited to the area of study, the potential to refine a model to simulate contaminant uptake and accumulation within the food chain of the upper Athabasca River is possible. Additional time and data precludes NRBS being able to bring this work to a conclusion but researchers have indicated an interest to pursue this work independently and to publish the results.

Complementary work is reported in Northern River Basins Study Project Reports No. 136 (*Contaminant Fate Modelling for the Athabasca River: Implementation of New Sediment Flux Routines*), No. 137 (*A Bioenergetic Model of Food Chain Uptake and Accumulation of Organic Chemicals, Athabasca River*), No. 129 (*Environmental Contaminants In Fish: Spatial and Temporal Trends of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans, Peace, Athabasca and Slave River Basins, 1992 to 1994*), and No. 101 (*Environmental Contaminants in Fish: Polychlorinated Biphenyls, Organochlorine Pesticides and Chlorinated Phenols, Peace and Athabasca Rivers, 1992 to 1994*).

REPORT SUMMARY

Objective

The objective of Phase II is to develop for the Northern River Basins Study a stochastic and time variable food chain model to simulate the uptake and bioaccumulation of organic chemicals in the mountain whitefish, longnose sucker and northern pike of the Athabasca River food web. The Monte Carlo based exposure model will predict the variation in tissue concentrations in mountain whitefish, longnose sucker and northern pike corresponding to user specified distributions in environmental concentrations and biological parameters that are reflective of observed trends in site-specific environmental data.

Model Theory

The kinetic model of Thomann and Connolly (1984) used in Phase I was selected as the theoretical basis of the stochastic model. This model was selected in Phase I since observed trends in chemical concentrations in three different species of fish collected within one km downstream of a BKM could not be explained solely on the basis of equilibrium-lipid partitioning. For a discussion of the general theory of the Thomann and Connolly model see: the Northern River Basins Study Report entitled, A Bioenergetic Model of Food Chain Uptake and Accumulation of Organic Chemicals. Athabasca River and Wapiti-Smoky Rivers: Phase I. by M.E. Starodub and G. Ferguson (CanTox Inc., 1995).

Phase II: Stochastic and Time Variable Version

The stochastic model accepts input in the form of mean and standard deviations for model parameters, such as environmental concentrations and biological data describing the species selected for modelling. For each stochastic parameter a probability distribution is assigned on the basis of observed distribution of the field data. When operated under the time variable mode, the user must also specify the duration corresponding to entered environmental concentrations.

Model Configuration

The Athabasca River food web configuration used in the Phase II stochastic version is identical to that derived in Phase I and is based on the NRBS results of gut contents analysis of mountain whitefish, longnose sucker and northern pike. Predator-prey relationships which result in distinct exposure pathways for fish inhabiting the river are described by the model. Two distinct exposure pathways are considered by including bottom-feeding invertebrate (BFI) and filter-feeding invertebrate (FFI) at the lower trophic level.

Example of Stochastic and Time Variable Simulation: 2,3,7,8-TCDF

To illustrate the stochastic and time variable features of the Monte Carlo based food chain model a food chain simulation was conducted for the Athabasca River food web for 2,3,7,8-tetrachlorodibenzofuran (TCDF) based on NRBS 1992 field data, loading rate data and effluent concentrations of 2,3,7,8-TCDF in the Athabasca River for 1991 to 1993.

Means and standard deviations for biological parameters describing the growth rate, respiration rate, lipid content, weight, fraction dry weight, food assimilation efficiency of each species modelled were determined on the basis of site-specific field data and modelled assuming normal distribution of the data.

Mean environmental concentrations input to the model were determined from the NRBS analytical data summarized in "Table 6: Environmental Chemical Concentrations and Species Data from NRBs Data Set" of the Phase I report (CanTox Inc., 1995) . Standard deviations of the water column dissolved and suspended sediment adsorbed 2,3,7,8-TCDF were based on the relative standard deviation (RSD) of the mill effluent loading rates, since it was concluded that the water column concentrations would respond directly to changes in environmental loading rates. However, since the response of the Athabasca River sediments to changes in environmental loadings would be expected to occur more slowly, the standard deviation for 2,3,7,8-TCDF concentrations in Athabasca R. sediments was based on the RSD for total PCDDs/PCDFs collected at the Emerson lake site in May, 1995 (Crosley, 1995). For the purpose of the food chain simulation the concentration of 2,3,7,8-TCDF in porewater was assumed to be 10-fold greater than that of the water column dissolved *in lieu* of measured data.

Stochastic and Time Variable Model Results 2,3,7,8-TCDF

2,3,7,8-Tetrachlorodibenzofuran is a hydrophobic chemical which when introduced to aquatic systems readily adsorbs to organic carbon of suspended solids and accumulates in biological tissues. As noted in the Phase I report (CanTox Inc., 1995), predicted tissue concentrations of TCDF were directly proportional to the percent diet comprised of filter-feeding invertebrates. These modelling results support the theory that consumption of filter-feeding invertebrates and suspended solids represent the primary exposure pathway for mountain whitefish to TCDF and likely to other chlorinated dioxins and furans downstream of pulp mills. The model was able to simulate the trend in TCDF contamination of whitefish> longnose sucker> northern pike, observed within 1 km downstream of the BKM at Weldwood Haul. Maximum predicted concentrations in mountain whitefish were about three-fold less than the observed concentrations assuming an initial tissue concentration of 0.00 ppt and exposure duration of 5 years. Maximum predicted concentrations in longnose sucker and northern pike were about eight- to ten-fold less than observed tissue concentrations, assuming initial tissue concentrations of 0.00 ppt and exposure duration of 5 years.

Conclusions

Variations in environmental loading rates of 2,3,7,8-TCDF by mills discharging to the Athabasca River have been documented over the period from 1991 to 1993 (Golder, 1995). In general, chlorine dioxide substitution for elemental chlorine in the bleaching process and implementation of secondary treatment of effluents by Canadian pulp mills has resulted in non-detectable concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF. Corresponding to these changes in environmental loading rates, variations in concentrations of these substances in the water column and underlying bed sediments will also occur hence steady-state would not be expected to prevail in the Athabasca River. To address the influence of environmental variation in ambient concentrations on chemical residues in fish a stochastic food chain model was developed.

The model best predicted TCDF concentrations in invertebrate species which were assumed to be at steady state with ambient environmental concentrations. The 95th percentile predicted TCDF concentrations for filter-feeding invertebrates was 23.7 ppt and for bottom-feeding invertebrates was 8.4 ppt. These concentrations are directly related to the concentration of TCDF in the suspended solids and bottom sediments, respectively. Concentrations in the bed sediments and suspended sediments were selected randomly by the model using Monte Carlo sampling techniques according to the assumed triangular distribution and the relative standard deviation corresponding to effluent loading rates for suspended solids and that of data for bottom sediments of Emerson lake (Crosley, 1995). Differences between predicted and observed concentrations of TCDF in invertebrates is likely attributed to the assumed relative standard deviations. Agreement between model predicted and observed values would require more site specific environmental concentration data for TCDF in the water column dissolved, suspended solids, pore water and bed sediments.

The 95th percentile predicted TCDF concentration in mountain whitefish was 5.0 ppt , in longnose sucker was 0.25 ppt and in northern pike was 0.07. The model underestimated observed concentrations in these three species. This discrepancy between the model predicted and observed values is likely due to the following assumptions included in the input data: (1) an initial tissue concentration of 0.00 ppt; (2) the large relative standard deviation in environmental concentrations; and (3) constant excretion rate of 0.003 (d^{-1}) for all fish species. Better agreement between model predicted concentrations of TCDF in fish tissues would likely be obtained by using more representative data for environmental concentrations, assigning an initial tissue concentration greater than 0.00 ppt for fish, and inputting species-specific excretion rates for TCDF which could be experimentally determined.

Use of the current Stochastic Food Chain Model is restricted to the Northern River Basins Study. Application of the Athabasca River model to other ecosystems is subject to modifications of the food web configuration and biological data representative of the aquatic ecosystem of study, by contacting Mary Ellen Starodub and Glenn Ferguson of CanTox Inc.

ACKNOWLEDGEMENTS

This work was conducted by Mary Ellen Starodub, M.Sc. and Glenn Ferguson, Grad. Dip., B.Sc., of CanTox Inc. Funding for this study was provided by the Northern River Basins Study, Edmonton, Alberta. Brian Brownlee, Coordinator of the Contaminants Modelling Sub-Committee, provided advice regarding data input for relative standard deviations and distributions of environmental concentrations data.

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1.0 INTRODUCTION

The Phase II Athabasca River Food Chain Modelling study builds on the results of the Phase I Steady-State Food Chain Modelling Study by enhancing the food chain models capability through the development of a probabilistic or stochastic model based on Monte Carlo Sampling Techniques. Detailed in the NRBS Phase I report entitled, A Bioenergetic Model of Food Chain Uptake and Accumulation of Organic Chemicals. Athabasca River and Wapiti-Smoky Rivers: Phase I. by M.E. Starodub and G. Ferguson (August 31, 1995), is the general the methodology and results of the site-specific food chain model simulation of the uptake and accumulation of a variety of organic chemicals in the Athabasca River ecosystem. In Phase I, CanTox was contracted by the Contaminants Working Group of the Northern Rivers Basin to construct and calibrate a site-specific steady-state food chain model for the Athabasca River ecosystem, downstream of Weldwood Haul using NRBS field data. In Phase II, CanTox was contracted to develop a stochastic version of the food chain model that can be used to predicted the variability in concentrations of contaminants in selected aquatic species of the Athabasca River food web.

As noted in the Phase I report (CanTox Inc., 1995), the impetus for the food chain modelling component stemmed partially from observations downstream of BKMs of greater concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) in mountain whitefish (*Prosopium williamsoni*) compared to longnose sucker (Mah et al., 1989; Whittle et al., 1990; Owens et al., 1994), including NRBS data that reported significantly greater concentrations of TCDF in fillets of mountain whitefish than longnose sucker and northern pike (*Esox lucius*), sampled 1 km downstream of a BKM (Pastershank and Muir, 1995). These differences could not be attributed solely to lipid-partitioning (Owens et al., 1994; Pastershank and Muir, 1995).

The results of the Phase I Food Chain Modelling Study support the hypothesis that observed differences in tissue concentrations may be attributed to differences in feeding habits of mountain whitefish and longnose sucker (Owens et al., 1994). From gut contents analysis, longnose sucker (Catostomus catostomus) of the Athabasca River were found to consume greater relative dietary proportions of bottom feeding invertebrates and detritus in comparison to mountain whitefish that appeared to preferentially consume filter-feeding Trichoptera, caddisfly larvae, despite the fact that these were not the most abundant invertebrates (CanTox Inc., 1995).

Another major incentive for conducting the food chain modelling study is the need for proactive watershed management tools to assess the potential environmental impacts of chemical loadings to the Northern River Basins. Environmental impacts include the potential accumulation of organic chemicals in aquatic species and potential health risks to piscivorous wildlife and humans. The Athabasca River is a dynamic ecosystem that experiences considerable variation in environmental concentrations related to variations in chemical loading rates, flowrates and other prevailing environmental conditions. In order to address the influence of environmental variation in ambient concentrations on chemical residues in fish a stochastic food chain model was developed.

2.0 OBJECTIVE

The objective of Phase II is to develop a stochastic version of the food chain model used in Phase I to predict the variability in concentrations of contaminants in selected species of the aquatic food web of the Athabasca River. In addition, to include a time-variable feature in the stochastic model which will enable the user to simulate the uptake and accumulation of organic chemicals in selected species of the Athabasca food web in response to changes in environmental concentrations as a function of time.

3.0 MODEL THEORY

As noted in the Phase I report (CanTox Inc., 1995) a major consideration in the prediction of the food chain transfer and accumulation of chemicals in the environment is the theoretical basis of the food chain model with respect to the mathematical relationships designed to simulate the exposure pathways of concern at both lower and upper trophic levels and the pharmacokinetics of the selected chemicals in different species or trophic links within the food web. Since simple lipid-equilibrium partitioning could not explain the observed differences in tissue concentrations in mountain whitefish, longnose sucker and northern pike, the Thomann and Connolly (1984) kinetic based food chain model was selected as the theoretical framework for the steady-state model used in Phase I and for the stochastic version developed in Phase II. For a discussion of the general theory of the Thomann and Connolly model the reader is referred to the Phase I report (CanTox Inc., 1995).

The general equation for the model is:

$$dv_i / dt = K_{ui}c + \Sigma\, a_{ij}C_{ij}v_j - K'_i v_i \qquad (1)$$

where,

K'_i	=	loss due to excretion and dilution due to growth
	=	$K_i + (dw_i/dt)/w_i$
K_i	=	excretion rate of the organism i (d^{-1})
w_i	=	weight of organism i (g)
t	=	time (d)
K_{ui}	=	uptake of organism i (L/d/g)
a_{ij}	=	chemical assimilation efficiency of organism i on organism j
C_{ij}	=	consumption rate of organism i on organism j [g(prey)/g (pred)/d]
v	=	concentration of chemical in a given organism i or j (µg/g)
c	=	dissolved chemical concentration
n	=	total number of organisms preyed on by organism i

3.1 Stochastic Version

The stochastic version of the Athabasca River Food Chain model is designed to predict the variability of chemical concentrations in aquatic species corresponding to user specified environmental concentrations. The predicted variability is representative of field data and is considered to be a more realistic simulation than single value point estimates of tissue concentrations computed by deterministic models. The stochastic model accepts input in the form of mean and standard deviations for model parameters, such as environmental concentrations and biological data describing the species selected for modelling. For each stochastic parameter a probability distribution is assigned on the basis of observed distribution of the field data. By assigning a distribution to the various parameters, the stochastic model enables the model to select representative values for each parameter according to Monte Carlo sampling techniques. This readily facilitates full sensitivity analysis of model outcomes to the various model parameters without time-consuming re-entry of individual values for each input parameter and scenario to be tested. Refer to the Food Chain Manager Manual in "**APPENDIX B: STOCHASTIC FOOD CHAIN MODEL USER'S MANUAL**" for further information.

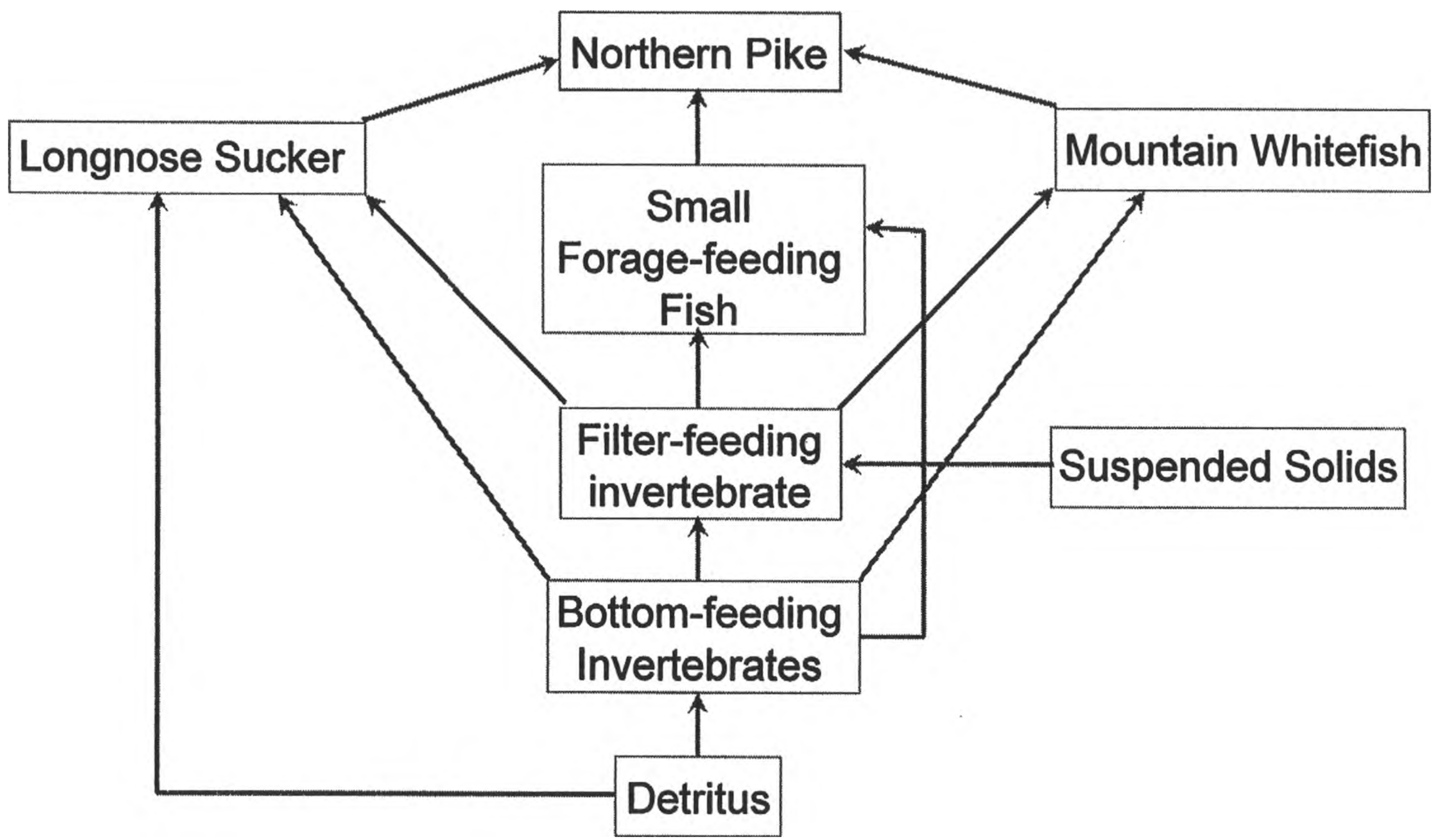
3.2 Time Variable Feature

The incorporation of a time variable feature allows the simulation of the uptake and accumulation of organic chemicals by selected species in response to changes in environmental concentrations as a function of time.

4.0 ATHABASCA FOOD WEB CONFIGURATION

The food web configuration of the Phase II model is identical to that developed in Phase I. Three fish species, mountain whitefish, longnose sucker and northern pike were selected for the food chain simulation. The food web was identified for the Athabasca River ecosystem on the basis of NRBS 1992 monitoring data and data from the Smoky/Wapiti Ecosystem Study (Swanson, 1992). Feeding interactions selected to simulate the Athabasca River food web is illustrated in "Figure 1: Feeding Interaction Modelled for Athabasca River Ecosystem." These feeding interactions are based on the frequency of occurrence of various prey items identified through stomach contents analysis for fish collected from the Athabasca R. and Smoky/Wapiti rivers, respectively. These data are detailed in the Phase I report (CanTox Inc., 1995).

Figure 1: Feeding Interactions Modelled for Athabasca River Ecosystem



For each species modelled the relative dietary compositions of food items as input to the model are listed in "Table 1: Dietary Composition of Athabasca R. Food Web Model."

Table 1: Dietary Composition of Athabasca R. Food Web Model

	Consumer[a]					
Food item	BI	FFI	MWF	NP	LNS	SFF
Bottom substrate[b]	100%				45%	
Suspended solids[c]		100%				
Bottom-feeding invertebrate (BI)			39%		49%	95%
Filter-feeding invertebrate (FFI)			61%		6%	5%
Mountain whitefish (MWF)				31%		
Longnose sucker (LNS)				39%		
Small forage-feeding fish (SFF)				30%		

a BFI= bottom-feeding invertebrate; FFI= filter-feeding invertebrate; MWF= mountain whitefish; LNS=longnose sucker; SFF= small foraging fish.
b Bottom substrate consists of detritus (e.g., includes biofilm and depositional sediments).
c Suspended solids consists of all suspended particulate material (e.g., may include phytoplankton, microinvertebrates, organic/inorganic solids).

5.0 STOCHASTIC AND TIME VARIABLE SIMULATION: 2.3.7.8-TCDF

To illustrate the stochastic and time variable feature of the Athabasca River food chain model, a simulation of the uptake and accumulation of 2,3,7,8-TCDF in mountain whitefish, longnose sucker and northern pike was conducted. The environmental concentrations in the water column and bed sediments corresponding to the 1992 NRBS field data for the Weldwood Haul reach were used in the simulation.

5.1 Input Data

Data input to the stochastic model for the simulation of 2,3,7,8-TCDF uptake and accumulation in selected species of the Athabasca Food web are outlined below. The model requires chemical, biological and environmental data to be specified by the user.

5.1.1 Chemical

Chemical dependent parameters used in the calculation of the rate of uptake of 2,3,7,8-TCDF through respiration and food consumption and the rate of loss due to excretion are presented in "Table 2: Chemical Dependent Parameters used in Stochastic Food Chain Model." The stochastic model will accept either single values or means and standard deviations with user specified distributions for these parameters.

Table 2: Chemical Dependent Parameters used in Stochastic Food Chain Model

Chemical	Parameter							
	log Kow	PRatio	E_{BFI}	E_{FFI}	E_{fish}	$k_{2\ BFI}$ (d^{-1})	$k_{2\ FFI}$ (d^{-1})	k_2 fish (d^{-1})
2,3,7,8-TCDF	6.1[a]	0.20[b]	0.15[c]	0.017 to 0.092[d]	0.54[e]	0.015[c]	0.025 to 0.070[c]	0.003[f]

a Mackay et al. 1992.
b McKim et al., 1989.
c Muir et al., 1992a
d Pastershank, 1994
e Muir et al., 1992b.
f Data estimated from a study by Kuehl et al., 1986.

5.1.2 Biological

Input data for the biological parameters used in the stochastic model are listed in Table 3a: Biological Data for Stochastic Athabasca Food Chain Model - Invertebrates" and "Table 3b: Biological Data for Fish", respectively.

The model will accept either point estimates or established distributions for these parameters. These values were based on the NRBS 1992 field data and represent the mean and standard deviations in biological data. For each of these parameters a normal distribution was assumed on the basis of the observed distribution of the field data. For several parameters distributions were automatically truncated at or approaching zero so as to prevent negative values being selected by the model. For example respiration and growth rates could not be less than zero.

Table 3a: Biological Data for Stochastic Athabasca Food Chain Model - Invertebrates

	Species Modelled	
Parameter	BFI[a]	FFI[b]
Respiration Rate (g/g/d)	0.109±0.00874	0.0658±0.0106
Growth Rate (l/d)	0.0337±0.00299	0.0194±0.0034
Food Assimilation Efficiency	0.06	0.06
Fraction Dry Weight	0.180±0.032	0.180±0.029
Percent Lipid	5%	5%

[a] Based of Chiranomidae data, Athabasca River Study.
[b] Based on Trichoptera data, Athabasca River Study.

Table 3b: Biological Data for Fish

	Species Modelled			
Parameter	MWF[a]	LNS[a]	NP[a]	SFF[b]
Initial Weight (g)	800	1000	2000	200
Growth Rate (l/d)	0.00259±0.00254	0.0004±0.00016	0.0004±0.00016	0.00343
Food Assimilation Efficiency	0.82	0.82	0.82	0.82
Percent Lipid	5.22%	4.6%	1.0%	3.0%

[a] Based on NRBS 1992 data, Athabasca River.
[b] Based on brookstickleback: percent lipid of yellow perch.

5.1.3 Environmental Concentrations

Variations in environmental loading rates of 2,3,7,8-TCDF by mills discharging to the Athabasca River over the period from 1991 to 1993 are summarized in "Table 4: Effluent Concentrations and Loading Rates of 2,3,7,8-TCDF." In general, chlorine dioxide substitution for elemental chlorine in the bleaching process and implementation of secondary treatment of effluents by Canadian pulp mills has resulted in non-detectable concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF. Concentrations of 2,3,7,8-TCDF in the water column (both dissolved and adsorbed) forms would be directly related to the changes in environmental loading rates. Hence for the purpose of conducting the stochastic food chain simulations, the standard deviation of the water column dissolved and suspended sediment adsorbed 2,3,7,8-TCDF were estimated based on the relative standard deviation (RSD) of the mill effluent loading rates.

Table 4: Effluent Concentrations and Loading Rates of 2,3,7,8-TCDF

Time Period	Concentration (pg/L)			Loading (mg/day)		
	mean	std.dev.	n	mean	std.dev.	n
1991-1993	11.4	8.2	34	1.21	0.94	36
1991	11.5	3.6	13	1.23	0.33	13
1992	12.2	12.0	12	1.34	1.43	13
1993	10.2	7.5	9	1.00	0.72	10
1992- 1st half	14.2	15.7	6	1.49	1.81	7
1992-2nd half	10.2	7.8	6	1.17	0.95	6

Source: (Golder, 1995).

Therefore, for loadings in the first half of 1992 the relative standard deviation (RSD) was assumed to be 0.99, since RSDs greater than 1.00 would result in negative concentrations. For loadings in the second half of 1992 the RSD was assumed to be 0.80. Environmental concentrations input to the model for the first half of 1992 were based on NRBS field data, April 1992 as summarized in "Table 6: Environmental Chemical Concentrations and Species Data from NRBs Data Set" of Phase I report (CanTox Inc., 1995). For the second half of 1992, the environmental concentrations were estimated from these values on the basis of the ratio of mean loadings for the two time periods (i.e., 1.17/1.49 = 0.79).

Since 2,3,7,8-TCDF is relatively persistent in riverine sediments, the response of the Athabasca River sediments to changes in environmental loadings would be expected to occur more slowly than the response of the overlying water column. Therefore, the standard deviation for 2,3,7,8-TCDF concentrations in Athabasca R. sediments was based on the RSD for total PCDDs/PCDFs collected at the Emerson lake site in May, 1995 (Crosley, 1995). For the purpose of the food chain simulation the concentration of 2,3,7,8-TCDF in porewater was assumed to be 10-fold greater than that of the water column dissolved *in lieu* of measured data.

Environmental concentrations entered into the model for the stochastic simulation of 2,3,7,8-TCDF uptake and accumulation in the Athabasca Food Web are listed in "Table 5: 2,3,7,8-TCDF Environmental Concentration Data Using Triangular Distribution." A triangular distribution of the environmental concentrations was entered into the model.

Table 5: 2,3,7,8-TCDF Environmental Concentration Data Using Triangular Distribution

Environmental Media	Concentration	
	mean	std. dev
January to June, 1992		
Water Column Dissolved (µg/L)	3.5 x 10^{-8}	3.4 x 10^{-8}
Water Column Particulate (µg/g)	2.2 x 10^{-6}	2.18 x 10^{-6}
Sediment Porewater (µg/L)	3.5 x 10^{-7}	2.1 x 10^{-7}
Sediment Particulate (µg/g C)	5.43 x 10^{-6}	3.3 x 10^{-6}
July to December, 1992		
Water Column Dissolved (µg/L)	2.7 x 10^{-8}	2.2 x 10^{-8}
Water Column Particulate (µg/g)	1.738 x 10^{-6}	1.39 x 10^{-6}
Sediment Porewater (µg/L)	3.5 x 10^{-7}	2.1 x 10^{-7}
Sediment Particulate (µg/g C)	5.43 x 10^{-6}	3.3 x 10^{-6}

6.0 MODEL RESULTS

2,3,7,8-Tetrachlorodibenzofuran is a hydrophobic chemical which when introduced to aquatic systems readily adsorbs to organic carbon of suspended solids and accumulates in biological tissues. As noted in the Phase I report (CanTox Inc., 1995), predicted tissue concentrations of TCDF were directly proportional to the percent diet comprised of filter-feeding invertebrates. These modelling results support the theory that consumption of filter-feeding invertebrates and suspended solids represent the primary exposure pathway for mountain whitefish to TCDF and likely to other chlorinated dioxins and furans downstream of pulp mills. The model was able to simulate the trend in TCDF contamination of whitefish> longnose sucker> northern pike, observed within 1 km downstream of the BKM at Weldwood Haul. The model predicted tissue concentrations of TCDF (ppt) in selected aquatic species for the first half of 1992 are presented in "Figure 2: Comparison of 2,3,7,8-TCDF Concentrations at the Weldwood Site - Field Data and Predicted (Day 1460)". These predicted tissue concentrations were entered into the model as initial concentrations using the time variable feature of the model and tissue concentrations in aquatic species related to changes in environmental concentrations for the second half of 1992 were computed. These results are presented in "Figure 3: Comparison of 2,3,7,8-TCDF Concentrations at the Weldwood Site - Field Data and Predicted (Day 2555).

To simulate the results of the reduction in environmental TCDF concentrations over time, the July to December 1992 data set was entered as a time variable concentration occurring at the 6 year mark (day 2190) within the model simulation. Simulation data indicates that chemical concentrations within the fish species reach their highest point at approximately 5 years. Therefore, time series simulation of the effect of declining environmental concentrations (based on the second-half of 1992) on predicted tissue concentrations was initiated following a 5 year exposure period assuming environmental concentrations corresponding to the first half of 1992. The results of the time variable analysis are presented in "Figure 4: Time Variable Model Results for 2,3,7,8-TCDF at the Weldwood Site using January-June and July-December 1992 Environmental Concentration Data".

For comparative purposes each figure includes observed concentrations in biota collected from the Weldwood Haul reach in 1992. These figures illustrate the ability of the model to simulate the observed variability in tissue concentrations in various aquatic species. The model most closely predicted 2,3,7,8-TCDF concentrations in the invertebrate species and the mountain whitefish.

Figure 2: Comparison of 2,3,7,8-TCDF Concentrations at the Weldwood Site Field Data and Predicted

(Day 1460)

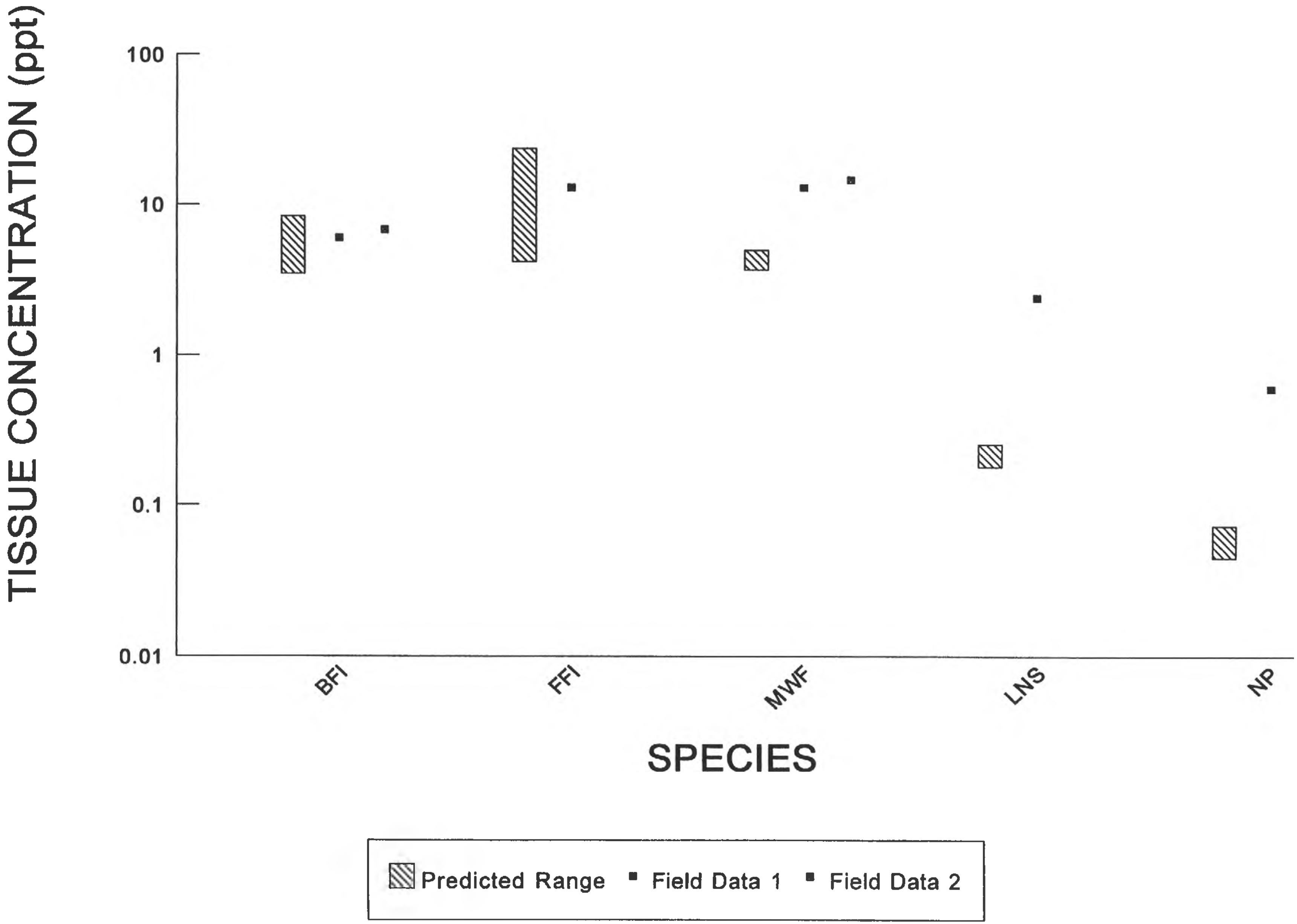


Figure 3: Comparison of 2,3,7,8-TCDF Concentrations at the Weldwood Site Field Data and Predicted

(Day 2555)

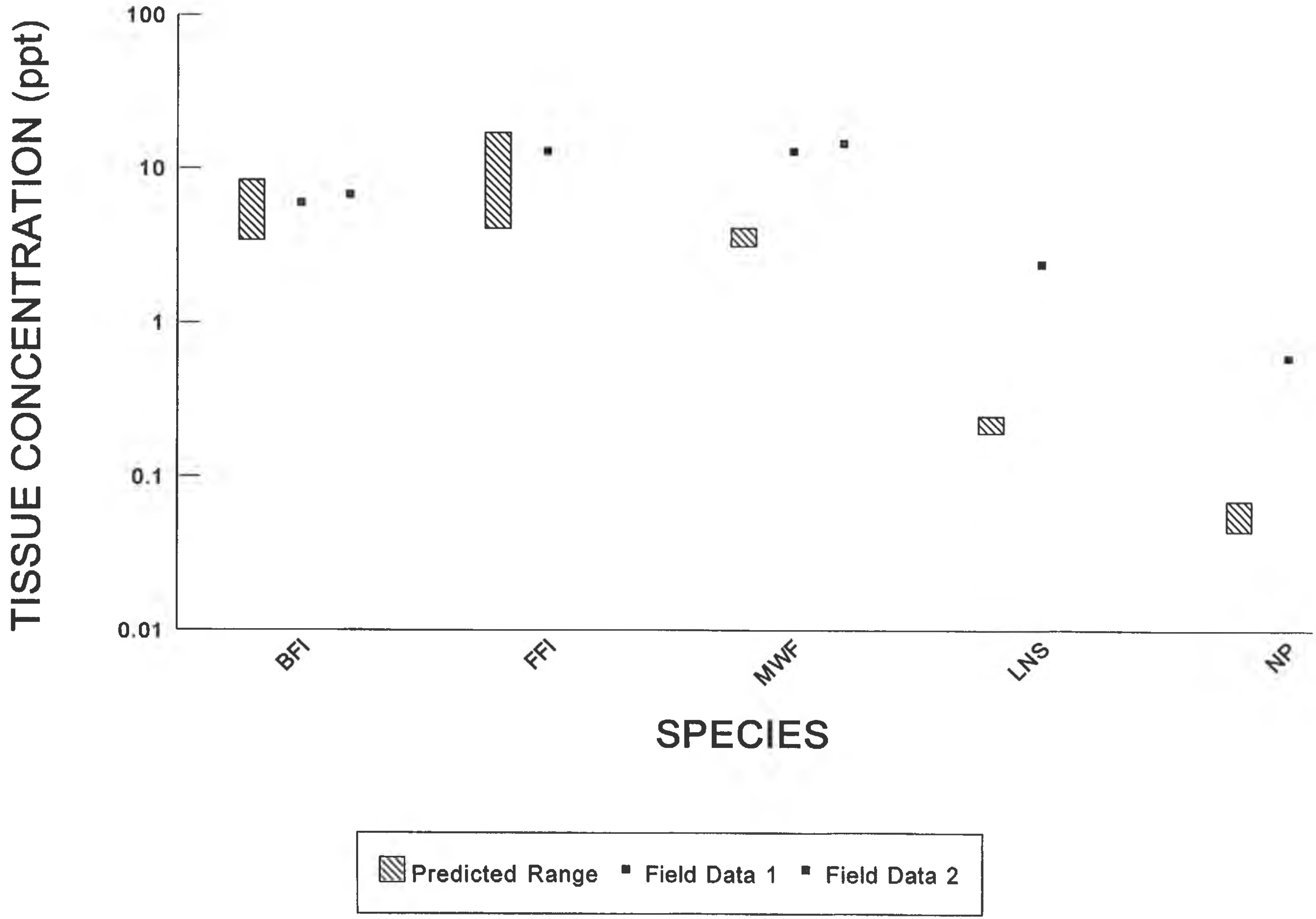
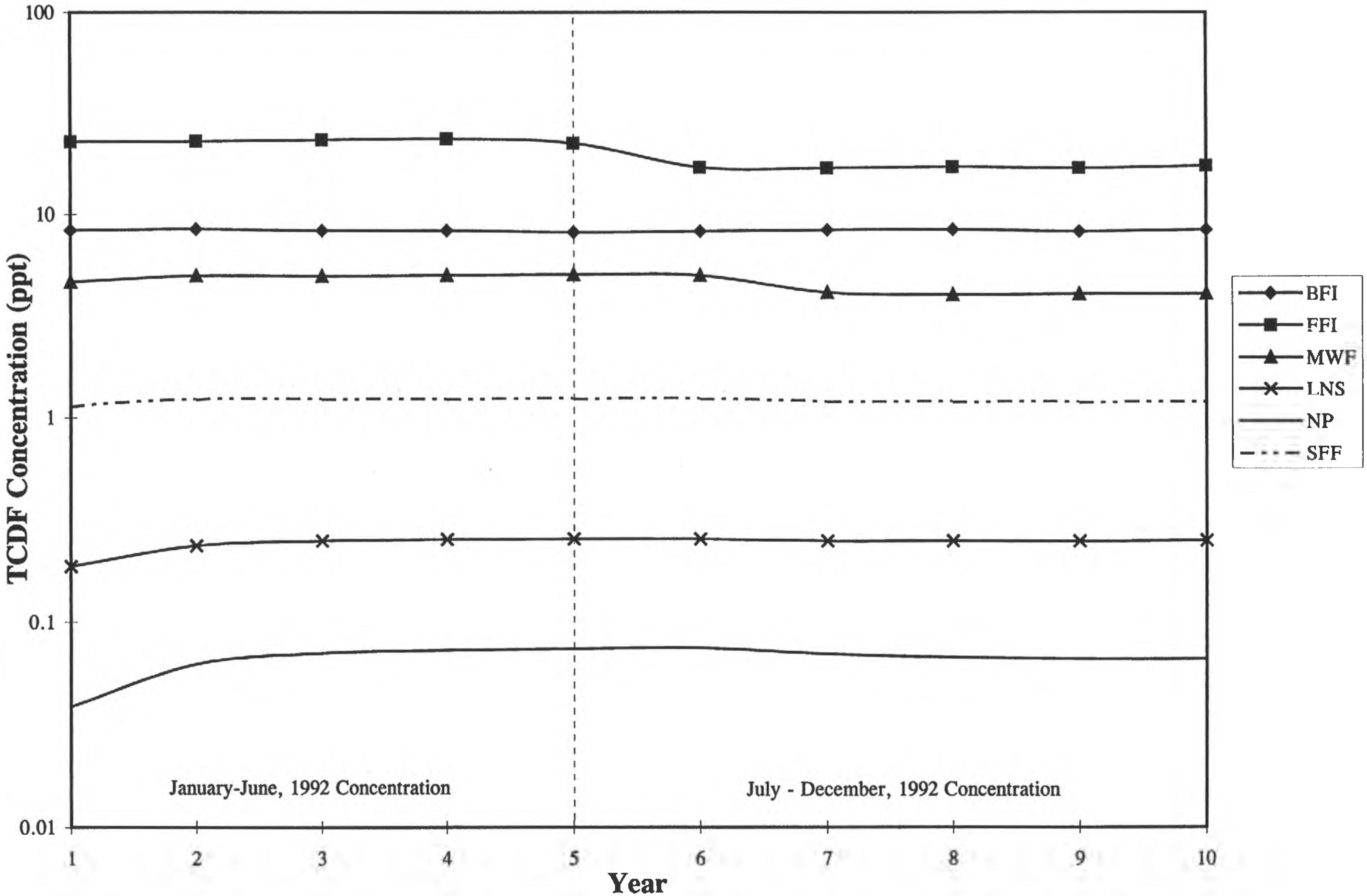


Figure 4: Time Variable Model Results for 2,3,7,8-TCDF at the Weldwood Site using January-June and July-December 1992 Environmental Concentration Sets



7.0 CONCLUSIONS

The model best predicted TCDF concentrations in invertebrate species which were assumed to be at steady state with ambient environmental concentrations. The 95th percentile predicted TCDF concentrations for filter-feeding invertebrates was 23.7 ppt and for bottom-feeding invertebrates was 8.4 ppt. These concentrations are directly related to the concentration of TCDF in the suspended solids and bottom sediments, respectively. Concentrations in the bed sediments and suspended sediments were selected randomly by the model using Monte Carlo sampling techniques according to the assumed triangular distribution and the relative standard deviation corresponding to effluent loading rates for suspended solids and that of data for bottom sediments of Emerson lake (Crosley, 1995). Differences between predicted and observed concentrations of TCDF in invertebrates is likely attributed to the assumed relative standard deviations. Agreement between model predicted and observed values would require more site specific environmental concentration data for TCDF in the water column dissolved, suspended solids, pore water and bed sediments.

The 95th percentile predicted TCDF concentration in mountain whitefish was 5.0 ppt, in longnose sucker was 0.25 ppt and in northern pike was 0.07. Maximum predicted concentrations in mountain whitefish were about three-fold less than the observed concentrations assuming an initial tissue concentration of 0.00 ppt and exposure duration of 5 years. Maximum predicted concentrations in longnose sucker and northern pike were about 10-fold less than observed tissue concentrations, assuming initial tissue concentrations of 0.00 ppt and exposure duration of 5 years.

The model underestimated observed concentrations of TCDF in the three fish species. This discrepancy between the model predicted and observed values is likely due to the following assumptions included in the input data: (1) an initial tissue concentration of 0.00 ppt; (2) the large relative standard deviation in environmental concentrations; and (3) constant excretion rate of 0.003 (d^{-1}) for all fish species. Better agreement between model predicted concentrations of TCDF in fish tissues would likely be obtained by using more representative data for environmental concentrations, assigning an initial tissue concentration greater than 0.00 ppt for fish, and inputting species-specific excretion rates for TCDF which could be experimentally determined.

Use of the current Stochastic Food Chain Model is restricted to the Northern River Basins Study. The model may be used to simulate the uptake of organic chemicals within the Athabasca Food web as characterized in the NRBS Web. Should there be a need to investigate chemical uptake and bioaccumulation in other species or food webs the Athabasca Food Web can be modified with respect to predator prey interactions and biological data. Application of the Athabasca River model to other ecosystems is subject to modifications of the food web configuration and biological data representative of the aquatic ecosystem of study. For further information or modifications to the existing model contact Mary Ellen Starodub and Glenn Ferguson of CanTox Inc., Mississauga ON.

A user manual and printout of the applied 2,3,7,8-TCDF scenario presented in Phase II is included in "**APPENDIX B: STOCHASTIC FOOD CHAIN MODEL USER'S MANUAL**".

8.0 REFERENCES

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APPENDIX A: TERMS OF REFERENCE

Project 2381-E2: Food Chain Model - Time Variable and Stochastic Version

A.1. Background and Objectives

One of the major objectives of the Northern River Basins Study (NRBS) is to develop predictive tools to determine the cumulative effects of man-made discharges on the aquatic environment (Study Board Question 13a) and predictive models to provide an ongoing assessment of the state of the aquatic ecosystem (Study Board Question 14). The Contaminants Component of the NRBS assumed the task of modelling the fate, accumulation and effects of contaminants released into the aquatic environment. A modelling sub-committee was formed and, in April 1993, the sub-committee hosted a contaminant fate and food chain modelling workshop (NRBS Projects 2381-C1-C4) to provide direction for future modelling initiatives (Brownlee and Muir, 1994). The workshop was attended by government representatives, members of the academic community, environmental consultants, representative from resource-based industries in the northern river basins and NRBS-affiliated research scientists. Based on presentations and discussions at the workshop, the sub-committee decided to utilize the WASP IV model, developed by the U.S. Environmental Protection Agency, and the Thomann/Connolly and Gobas food chain models to model the fate and bioaccumulation of point-source contaminants entering the Athabasca River system.

During Phase I of this project, CanTox Inc. was sub-contracted by Golder Associates and the Contaminants Working Group of NRBS to develop a food chain model for the Athabasca River ecosystem downstream of Hinton. The objective of this study was to construct and calibrate a steady-state food chain model to simulate the uptake and bioaccumulation of selected organic compounds, with different physical-chemical properties, in the mountain whitefish, longnose sucker and northern pike food web of the Athabasca River. Additionally, the contractor was to identify the primary exposure pathway through a sensitivity analysis of each chemical modelled. To supplement the Athabasca River database, field data for the Wapiti-Smoky River system was incorporated to fill data gaps describing food web relationships.

A bioenergetic model based on Thomann and Connolly (1984) was selected to simulate the uptake and accumulation of selected chemicals in the Athabasca River food web. This model was selected because observed trends of chemical concentrations in fish tissues collected within 1.0 km downstream of the Hinton combined effluent could not be explained solely on the basis of equilibrium-lipid partitioning. Results from this phase of the study indicate that the Athabasca River ecosystem bioenergetics based steady-state food chain model has the predictive capability to simulate chemical uptake and accumulation of a variety of compounds with a wide range in physical chemical and pharmacokinetic characteristics (CanTox Inc., 1995). The bioenergetics based model is able to simulate multiple exposure pathways simultaneously.

Phase II of this study will address the variation in observed tissue concentrations in mountain whitefish, longnose sucker and northern pike through the development of a time variable and stochastic version of the bioenergetics model and application of the Monte Carlo based exposure model to simulate the 1992-1993 NRBS data for the Athabasca River.

A.2 General Requirements

The contractor is required to develop a stochastic version of the food chain model that can be used to predict the variability in concentrations of contaminants in aquatic species. The predicted variability would be representative of field data, rather than estimating a single value of tissue concentration as is computed by deterministic models. The proposed stochastic model would be able to accept the geometric mean and the standard deviation for model parameters, such as environmental concentration, species weight and lipid content, on the basis of field data. Additionally, a probability distribution would be assigned to the various parameters on the basis of the observed distribution of field data. By assigning a distribution to the various parameters, the stochastic model would enable the user to select representative values for each parameter using Monte Carlo sampling techniques based on a range of values and distribution specified by the user. One of the advantages of having these computations incorporated into a stochastic model is to allow full sensitivity analysis of the various model parameters to model outcomes without time-consuming re-entry of individual values for each input parameter and each scenario to be tested.

The contractor is also required to add a time variable feature to the stochastic food chain model which will enable the user to simulate the uptake and accumulation of organic chemicals in aquatic species in response to changes in environmental concentrations as a function of time. As part of the stochastic runs, under time variable conditions, simulate the change in uptake and accumulation of 2,3,7,8-tetrachlorodibenzofuran in longnose sucker, northern pike and mountain whitefish from the Athabasca River. The Phase II Food Chain model will include a parameter for time step dependent on the computational limitations of the model. This portion of the project will make use of NRBS data from 1992 and 1993, and output from the *WASPIV* Contaminant Fate Model being developed by Golder Associates.

A.3 Reporting Requirements

1. A progress report, in the form of a letter, is to be submitted to the Component Coordinator by **October 1, 1995.**

2. Ten bound copies of a Draft Report which incorporates the new food chain model with time variable and stochastic capability is to be submitted to the Component Coordinator, including an electronic disk version, by **October 15, 1995.**

Five copies of the computer software and User's Manual to be distributed as follows:

a) Dr. B. Brownlee - National Water Research Centre;
b) Dr. D. Muir - Freshwater Institute;
c) Mr. L. Noton - Alberta Environmental Protection;
d) Mr. R. Crosley - Environment Canada; and
e) Northern River Basins Study.

3. Three weeks after receipt of the review comments, the contractor is to submit ten cerlox bound copies, two unbound camera ready copies, and an electronic disk version of the final project report to the Component Coordinator.

4. The Contractor is to provide draft and final reports in the style and format outlined in the NRBS document, "A Guide for the Preparation of Reports," which will be supplied upon execution of the contract.

The final report is to include the following: an acknowledgement section that indicates any local involvement in the project, Report Summary, Table of Contents, List of Tables, List of Figures and an Appendix with the Terms of Reference for this project.

Text for the report should be set up in the following format:

a) Times Roman 12 point (Pro) or Times New Roman (WPWIN 6.0) font.
b) Margins; are 1 " at top and bottom, 7/8" on left and right.
c) Headings; in the report body are labelled with hierarchical decimal Arabic numbers.
d) Text; is presented with full justification; that is, the text aligns on both left and right margins.
e) Page numbers; are Arabic numerals for the body of the report, centred at the bottom of each page and bold.

- If photographs are to be included in the report text they should be high contrast black and white.
- All tables and figures in the report should be clearly reproducible by a black and white photocopier.
- Along with copies of the final report, the Contractor is to supply an electronic version of the report in Word Perfect 5.1 or Word Perfect for Windows Version 6.0 format.
- Electronic copies of tables, figures and data appendices in the report are also to be submitted to the Project Liaison Officer along with the final report. These should be submitted in a spreadsheet (Quattro Pro preferred, but also Excel or Lotus) or database (dBase IV) format. Where appropriate, data in tables, figures and appendices should be geo-referenced.

5. All figures and maps are to be delivered in both hard copy (paper) and digital formats. Acceptable formats include: DXF, uncompressed E??, VEC/VEH, Atlas and ISIF. All digital maps must be properly geo-referenced.

6. All sampling locations presented in report and electronic format should be geo-referenced. This is to include decimal latitudes and longitudes (to six decimal places) and UTM coordinates. The first field for decimal latitudes / longitudes should be latitudes (10 spaces wide). The second field should be longitude (11 spaces wide).

A.4 Deliverables

1. A draft report submitted to the Study Office by October 15, 1995.
2. An electronic program for the re-simulated version of the bioenergetics model of food chain in the Athabasca River, and installation instructions and user's manual for the model.
3. A final project report.

A.5 Contract Administration

This project is being coordinated by the modelling sub-committee of the Contaminants Component of the Northern River Basins Study. The Scientific Authorities for this project are:

Dr. Brian Brownlee
National Water Research Institute
867 Lakeshore Road,
P.O. Box 5050
Burlington, Ontario L7R 4A6
phone: (905) 336-4706
fax: (905) 336-4972

Dr. Derek Muir
Fisheries and Oceans Canada
Freshwater Institute
501 University Cresent
Winnipeg, Manitoba R3T 2N6
phone: (204) 983-5168
fax: (204) 984-2403

Questions of a scientific nature should be directed to them.

Members of the modelling sub-committee include:
Dr. Brian Brownlee, National Water Research Institute, Burlington - Contaminant fate
Dr. Anne-Marie Anderson, Alberta Environmental Protection, Edmonton - Benthos
Bob Crosley, Environment Canada, Calgary - Water and sediment
Dr. Mike MacKinnon, Syncrude Research, Edmonton - Oil sands
Dr. Derek Muir, Fisheries and Oceans Canada, Winnipeg - Food chain
Leigh Noton, Alberta Environmental Protection, Edmonton - Pulp mills

They will have direct input with the contractor in the development of the model.

The Component Coordinator for this project is:

Richard Chabaylo
Northern River Basins Study
690 Standard Life Centre
10405 Jasper Avenue
Edmonton, Alberta T5J 3M4
phone: (403) 427-1742
fax: (403) 422-3055

Questions of an administrative nature should be directed to him.

A.6 Literature Cited

Brownlee, B., and D. Muir. 1994. Proceedings of the Contaminants Fate and Food Chain Modelling Workshop. Draft report submitted to the Northern River Basins Study.

CanTox Inc. 1995. A Bioenergetic Model of Food Chain Uptake and Bioaccumulation of Organic Chemicals in the Athabasca River: Phase I. Draft Report Prepared for the Northern River Basins Study. Prepared by M.E. Starodub and G.F. Ferguson. Mississauga, ON.

Thomann, R.V., and J.P. Connolly. 1984. Model of PCB in the Lake Michigan lake trout food chain. Environ Sci Technol 18:65-71.

APPENDIX B: STOCHASTIC FOOD CHAIN MODEL USER'S MANUAL

FOOD CHAIN MANAGER
For Windows®

Version 2.0

Quick Start Guide

CanTox Inc.
2233 Argentia Road, Suite 308
Mississauga, Ontario, Canada
L5N 2S6

Food Chain Manager for Windows, Version 2.0, was programmed using Borland Delphi 1.0 for Windows.

The Thomann and Connolly Bioenergetic model is an aquatic food chain analysis methodology (Thomann, R.V. and Connolly, J.P. 1984).

For technical assistance regarding the *FCM* software, contact:

Glenn Ferguson
CanTox Inc.
2233 Argentia Road, Suite 308
Mississauga, Ontario, Canada
L5N 2X7
Phone: (905) 542-2900
Fax: (905) 542-1011

PROGRAM REQUIREMENTS

Computer: any 386 (with math coprocessor), 486, Pentium™ or PS/2 computer that will run Microsoft Windows 3.1 or higher in 386 Enhanced mode.

Software: an installed copy of Microsoft Windows, version 3.1 or higher.

Disk Drives: a hard drive with at least 1 megabyte of free storage space; model run data files will require additional free storage space.

RAM: 4 megabytes minimum, 8 or more is recommended.

Display: any video system of VGA or better resolution supported by Windows.

Mouse: any pointing device supported by Windows. Although the program can be operated entirely from the keyboard, use of a mouse is recommended for optimum convenience and speed.

INSTALLATION

The *FCM* SETUP program will automatically copy the required files to your hard drive and configure your system. You MUST install **FCM for Windows** with the SETUP program. Simply copying the files from the distribution diskette to your hard drive will NOT work.

To begin, run Windows and insert the *FCM* distribution diskette into any floppy drive on your system. From inside Windows, pull down the File menu from the Program Manager menu and select Run. Windows will then prompt you for the name of an application to run. Type the following command:

a:setup
and press Enter. If you're loading SETUP from drive B, instead of drive A, type:

b:setup
and press Enter.

FCM SETUP will lead you through the installation process. When **FCM for Windows** has been successfully installed, SETUP will display a confirmation message. The installation procedure will have created a new program group for the **FCM for Windows** program.

AN OVERVIEW OF THE FCM SYSTEM

The **FOOD CHAIN MANAGER for Windows** program, or *FCM* for short, is a user-friendly Windows application incorporating the Thomann and Connolly Bioenergetics methodology. The application allows the user to quickly and easily modify chemical or scenario parameters, and view the resulting impact on chemical concentrations within the modelled aquatic organisms.

The Thomann and Connolly Bioenergetics Model is an age-dependent food chain methodology that considers species bioenergetics and toxicant exposure through water and food sources. Detailed model theory and application is not within the scope of this guide and is outlined elsewhere (Thomann and Connolly, 1984; CanTox Inc., 1995).

The basis of the *FCM* system is the Web descriptor file. This file, usually having a .WEB file extension (*i.e.,* NRBS.WEB), holds the calibrated model data describing the food web interactions at the specific site being modelled. This data is the foundation on which the model simulations are built. It contains such data as the species being modelled, their physiological data (*i.e.*, respiration rate, growth rate, fraction of weight lipid, *etc.*), and other site specific data.

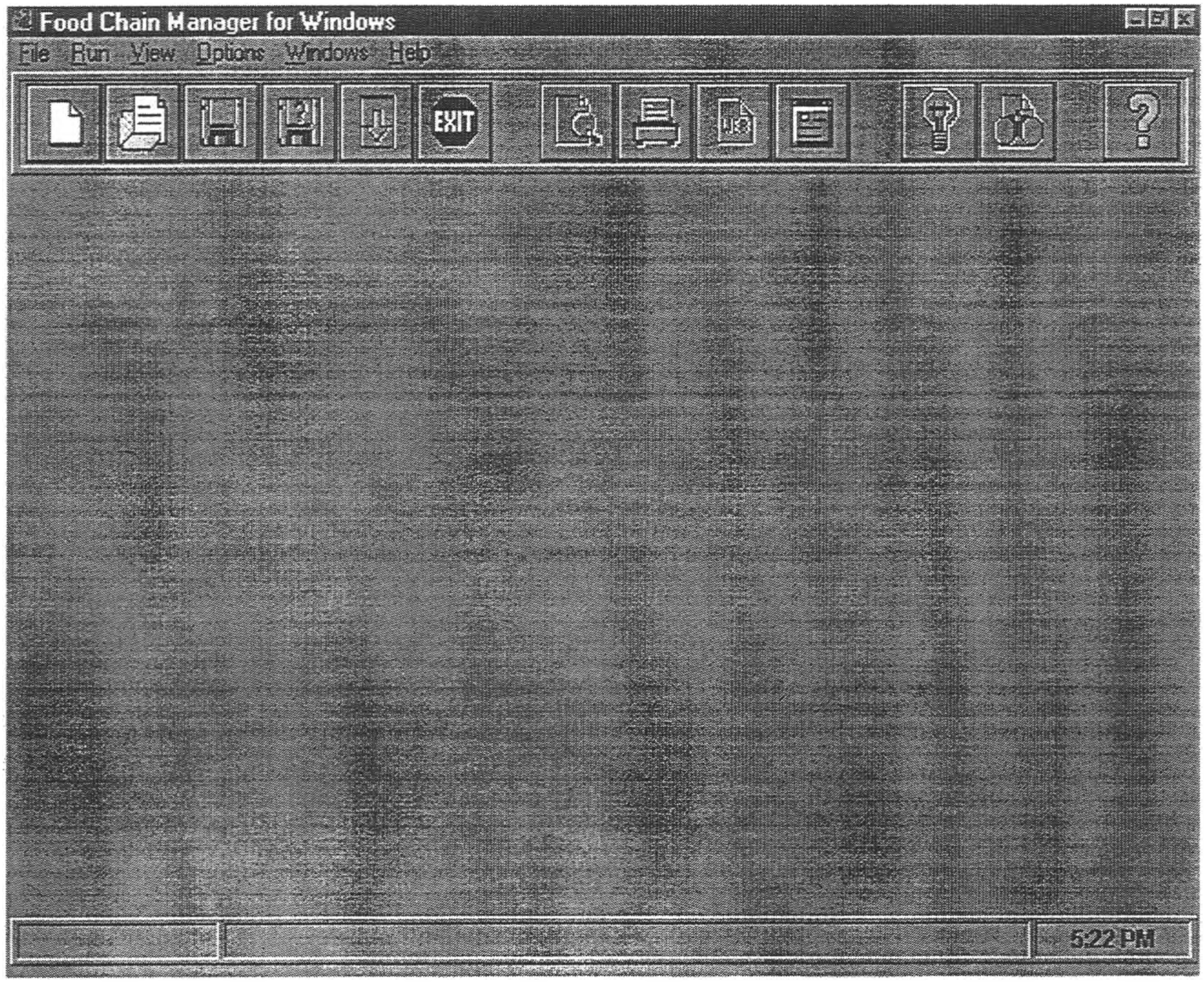
The *FCM* system allows the user to enter chemical-specific data to model on the food web environment specified by the selected Web file. In the current version of the *FCM* system, only the chemical and related data can be altered by the user; most food web interaction data described in the Web file are locked in their site-specific form. Thus, each new site requires a new Web descriptor file to update for the new site-specific web interactions.

Version 2.0 of the *FCM* system allows the use of probabilistic (*i.e.*, stochastic) risk analysis methodology to calculate the resulting chemical body burden within each food chain organism. Probabilistic frequency distributions, rather than deterministic or point estimate values, can be entered for each food chain variable. This approach avoids the unrealistic estimates of potential exposure that can result from the combination of a myriad of worst-case assumptions for the various model parameters. Further, it allows the use of the full range of accumulated data, rather than a single point value. Probabilistic calculation methodologies were obtained from the US EPA published Modular Oriented Uncertainty System statistical package (EPA, 1992), abbreviated MOUSE, and supplemented by other published peer-reviewed methodologies (Press *et al.*, 1992).

The *FCM* stochastic system currently allows the use of seven distribution formats: continuous uniform, triangular, trapezoidal, normal, lognormal, bounded normal, and bounded lognormal. Depending of the variable in question, the distribution may be automatically bounded by zero to prevent impossible value selection.

STARTING FCM For Windows

When you start **FCM for Windows** by clicking on the *FCM* program icon, the *FCM* program main window appears, similar to the one shown below.



The window has four main features:

Menu Bar

"Pull-down" menus are a familiar part of any Windows application. They appear at the top of the application window, and each one usually displays a "family" of commands when you click on it (a family contains menu items with similar functions).

You can also pull down the menu from the keyboard - hold down the Alt key while you press the underlined letter in the family name. For example, to pull down the File menu with the keyboard, you'd press Alt-F. While you're using the menus, you can move between the different menu families with the left and right arrow keys.

The *FCM* menu system has six main menu headings: File, Run, View, Options, Windows and Help. The File menu heading holds file processing menu commands. These include:

New Scenario (Ctrl-N)
This command initiates a new model scenario by requesting a site-specific Web file on which to base the scenario simulations. If a default Web file has been specified in the System Options, this file will be automatically loaded. Otherwise, the user will be prompted for a Web filename.

Open Scenario (Ctrl-O)
This command opens a pre-existing model scenario.

Save Scenario (Ctrl-S)
This command attempts to save the currently active scenario file under the specified filename.

Save As Scenario (Ctrl-A)
This command requests a new filename under which to save the currently active scenario file.

Close Scenario (Ctrl-C)
This command closes the currently active scenario file and clears the Workspace area. If the current scenario file has been changed, the user will prompted with the option to save the scenario file.

Load New Food Web Information
This command allows the user to replace an existing Web configuration with a new Web configuration in the currently active scenario. This will cause any existing Watch Points and species-specific data to be lost.

Display Current Food Web Information (Ctrl-D)
This command displays information on the currently active Web descriptor file.

Preview Current Scenario
This command allows the user to preview the current scenario data, including the site-specific data stipulated by the Web interaction file.

Print Current Scenario (Ctrl-P)
This command prints the current scenario data to a Windows-compatible printer or similar output device.

Printer Setup
This command allows the user to change the settings of the existing Windows-compatible printer or similar output device.

Exit (Ctrl-X)
This command closes the currently active scenario file and exits the *FCM* system. If the current scenario file has been changed, the user will prompted with the option to save the scenario file prior to exiting.

The Run menu heading holds the following menu commands:

Current Scenario (Ctrl-R)
This command initiates a model run simulation using the current scenario information.

Other Scenarios
This command displays the Run Selection box which allows the user to select multiple scenario sets for model simulation runs.

The View menu heading holds the following menu command:

Current Run Results (Ctrl-V)
This command allows the user to view the results of a model simulation. If the *Automatically Display Results after Run* option has been selected by the user (see below), the results will automatically be displayed after a model simulation run.

The Options menu heading holds the following menu commands:

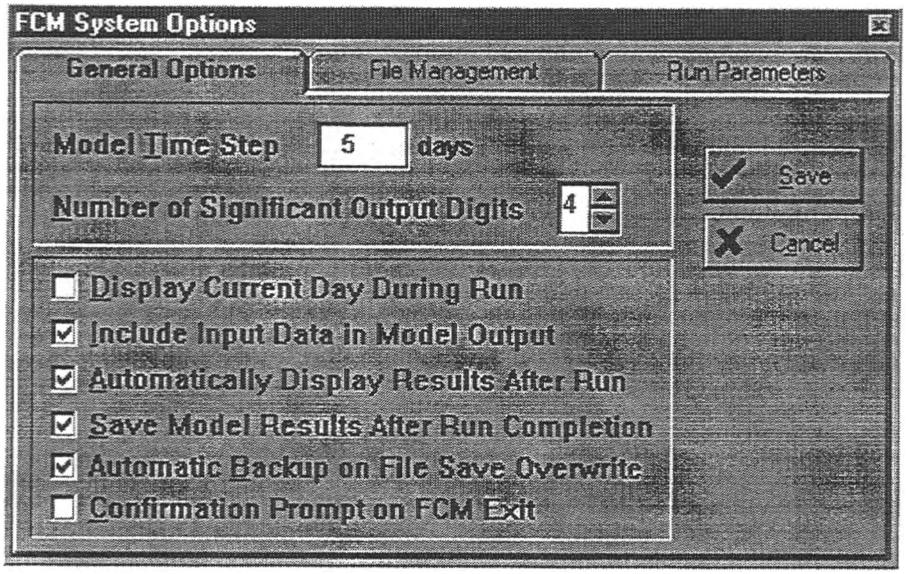
Update Monthly Temperature Ranges (Ctrl-T)
This command allows the user to set stochastic temperature ranges for each month, or one range for the entire year.

Clear All Current Watch Points
This command clears all existing Watch Points.

Clear All Current Time Series
This command clears all existing Time Series Sets.

Set System Options
This command allows the user to change certain application settings under the headings of *General Options*, *File Management*, and *Run Parameters*.

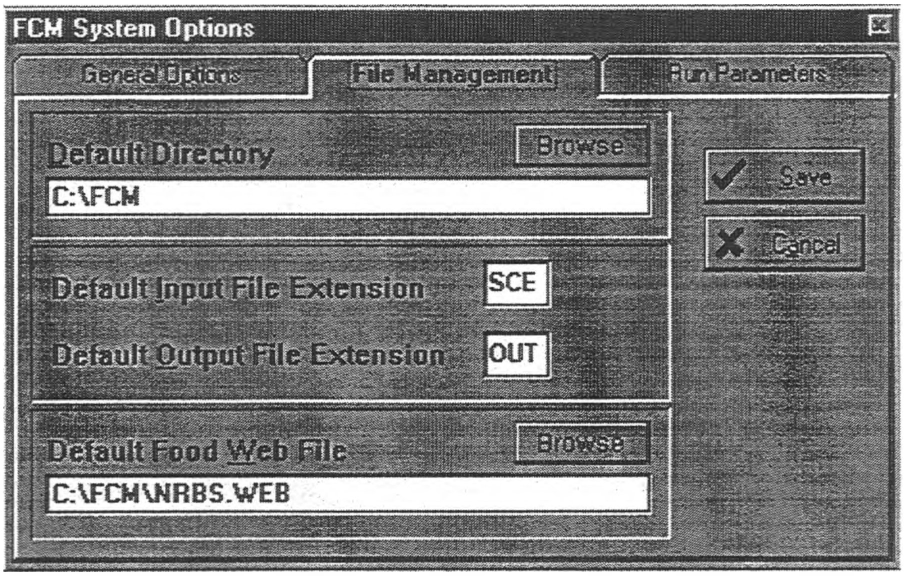
General Options



Under General Options, the user can adjust the following items:

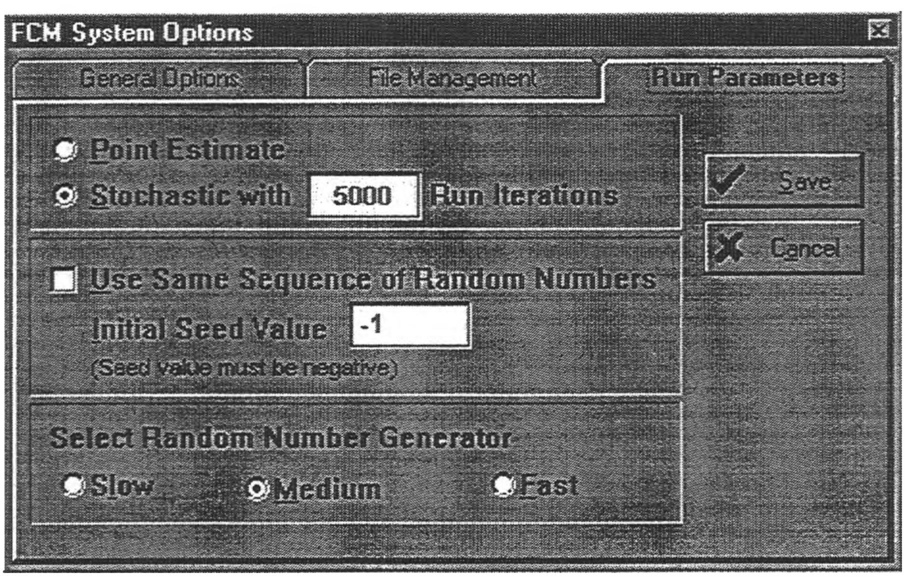
- number of days elapsed in each model time step (model results lose resolution as the number of days in the time step increase; time steps of 5 days or less are highly recommended);
- number of digits used in all numerical values displayed in scientific notation;
- display of the current simulated day and year in the progress box during a model run (the model will generally run twice as quickly if this option is turned off);
- inclusion of input data with all model run output;
- automatic display of model results after model run completion;
- automatic saving of model results after model run completion;
- automatic backup of all overwritten scenario save files, and;
- confirmation prompt on application exit.

File Management



Under File Management, the user can adjust the default file access directory, the file extensions used for the scenario and output files, as well as the default Web file used. If specified, the default Web file will be automatically loaded when the application is started.

Run Parameters



Under Run Parameters, the user can adjust the various settings controlling stochastic assessment procedures within the model. If a point estimate assessment is selected, the model will use the point estimate value entered for each variable, and ignore any stochastic distributions provided. Alternatively, if a stochastic assessment is selected, the model will use any stochastic distributions provided, and conduct the entered number of model run iterations. The user can also specify the methodology for random-number generation. The use of the same sequence of random numbers, the initial seed, and the speed of the random generator can be selected in this menu. The slowest speed setting uses the most thorough random number generator of the three methodologies available with the application, while the fastest generator uses a less thorough (though adequate) methodology.

Finally, the Help menu heading holds *FCM*-specific and Windows help access, as well as the *About...* credits. Detailed online help is not available in the current version of the *FCM* system.

Button Bar

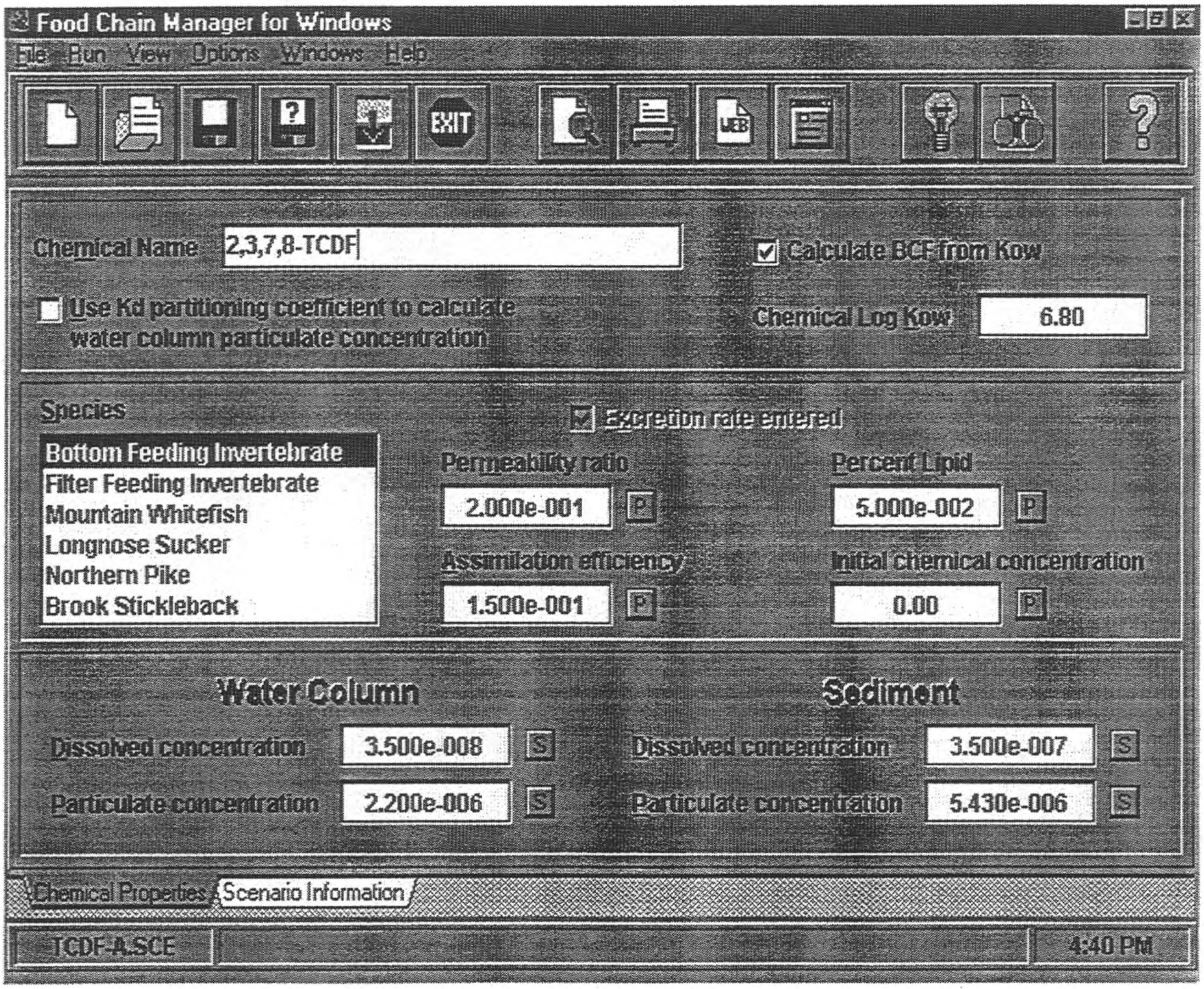
Along the top of the Workspace area, beneath the Menu Bar, you'll see a horizontal strip containing several controls. This is the *FCM* Button Bar, the important graphical "control centre" of *FCM for Windows*. It offers the most commonly-used functions from the menu as icon buttons. Although these buttons perform the same function as their menu counterparts, they're far more convenient. When you point at an individual button with your mouse, a description of the button will be displayed in the second segment of the Status Bar.

The buttons, from left to right, perform the following functions: New Scenario, Open Scenario, Save Scenario, Save As Scenario, Close Scenario, Exit, Preview Current Scenario, Print Current Scenario, Display Food Web Information, System Options, Run Current Scenario, View Model Run Results, and Online Help.

Workspace

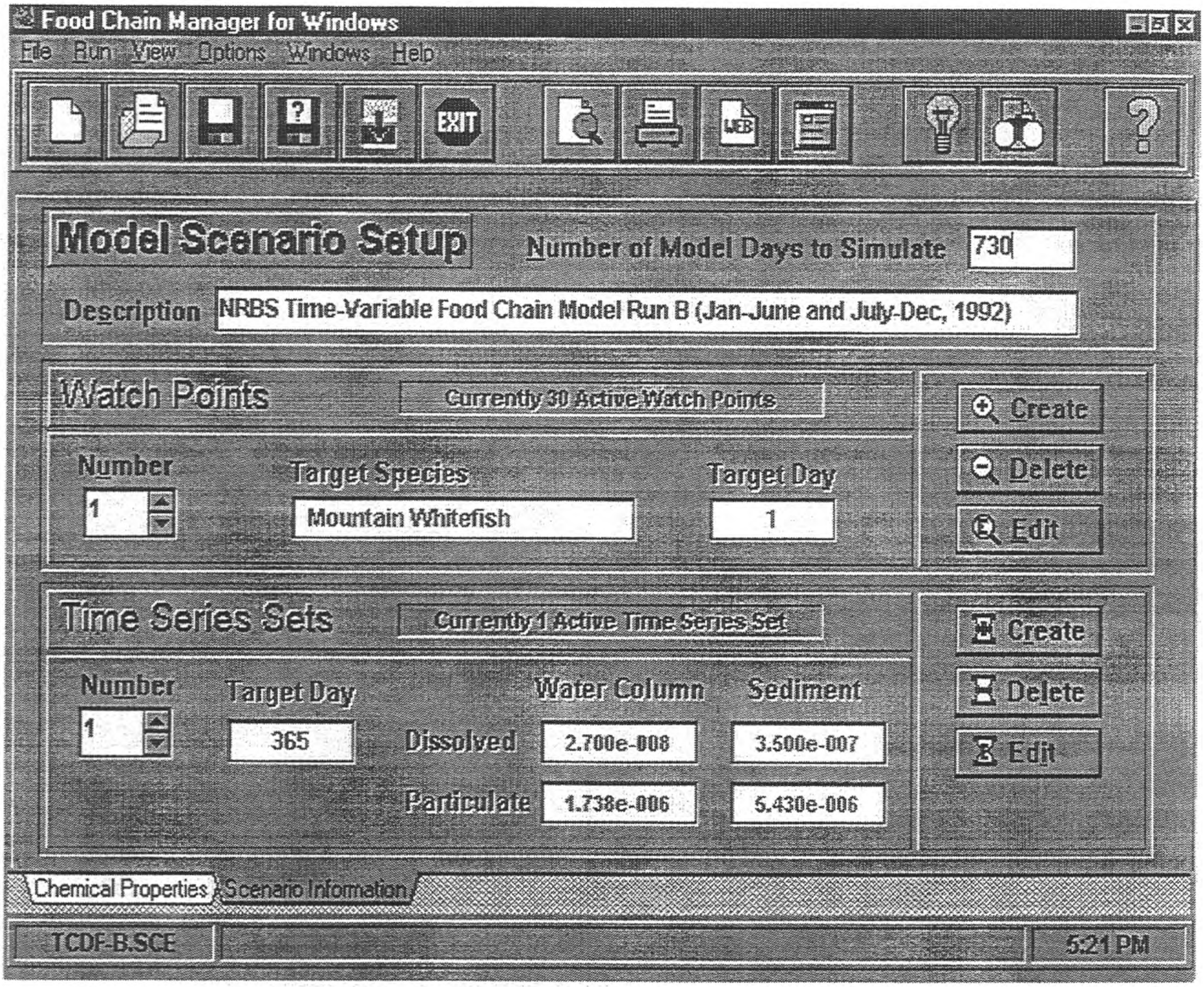
Unless you began **FCM for Windows** with a scenario file as a command-line argument, the workspace region will begin blank (as shown in the first figure above). If a default Web file has been entered in the options settings, a new scenario workplace using this Web information will be presented instead of a blank workspace region. It is in this region where you will enter or modify the data required by the food chain model for its simulation runs. A scenario workspace is composed of two windows: *Chemical Properties*, and *Scenario Information*.

Chemical Properties



The Chemical Properties window allows the user to enter in chemical-specific data for the food chain analysis based on the previously designated Web configuration.

Scenario Information



The Scenario Information window allows the user to specify scenario-specific settings, such as the number of model days to simulate, and a description of the current scenario. The user can also specify target Watch Points and Time Series sets in this window.

A Watch Point is a flag that can be assigned to record the stochastic range of values obtained for a specified species on a particular day. For example, in the above illustration, Watch Point number 1 is set to record the values for the Mountain Whitefish species on day 1 for each model iteration. The number of Watch Points you are allowed is entirely dependent on the memory and speed constraints of the user's computer.

A Time Series set is a setting that will change the environmental chemical concentrations to a new specified set of stochastic values on a particular day. For example, in the above illustration, Time Series set number 1 is set to change the environmental chemical concentrations on day 365. The number of Time Series sets you are allowed is entirely dependent on the memory and speed constraints of the user's computer.

Stochastic Input Buttons

Another important feature of *FCM*, version 2.0, is the stochastic input buttons. These buttons are placed beside each data entry field, and allow the user to access the stochastic range data for that particular variable. If the button is displaying a "P" (), then no stochastic data has been provided for this variable and will only use the value in point estimate form. However, if the button is displaying a "S" (), the variable has stochastic data in addition to its point estimate value. By clicking a particular button (or pressing the spacebar while focussed on the button), the stochastic entry dialog form will be displayed for data entry.

Status Bar

The Status Bar is displayed at the bottom of the application window, and is used to display messages and program information to the user. The first segment displays the filename of the current scenario file being processed. If you double-click on the first segment, the full filename will be displayed in a system infobox. The second segment provides information describing either the currently highlighted information box or the object at which the mouse is pointing. The third segment of the Status Bar displays the current time, as stored in your computer. By double-clicking on the third segment, the full date and time will be displayed in a system infobox.

CONFIGURING A FOOD CHAIN SCENARIO

After a new scenario has been initiated, the user may then setup the model simulation by entering the required data in their respective information boxes. The user can move from one data box to the next by pressing ENTER or TAB. After all the data has been entered, the user must first save the newly created scenario file with a unique name, using the save command. This completed, the scenario is now ready to be processed through the food chain model. The simulation run can be initiated with either the Run Button, the Run Current Scenario command (or Ctrl-R), or the Run Other Scenarios command.

VIEWING SCENARIO SIMULATION RESULTS

The results of the model simulation run can be viewed (if the *Automatically Display Results after Run* option is not selected) by selecting the View Button, or the View Current Model Results menu command. A viewing window will be displayed, providing the user with a scrolling display of the simulation results. The results will contain a list of all the scenario configuration parameters (if selected by the *Include Input Data with Model Run Output* option), as well as the simulated chemical concentration data for each of the modelled food web species.

REFERENCES

CanTox Inc. 1995. A Bioenergetic Model of Food Chain Uptake and Accumulation of Organic Chemicals in the Athabasca River: Phase I. Prepared for: Northern River Basin Study, Contaminants Modelling Subcommittee. Prepared by M.E., Starodub and G.M., Ferguson. Mississauga, Ontario.

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Press, W.H., Teukolsky, S.A., Vetterling, W.T., and Flannery, B.P. 1992. Numerical Recipes in Fortran: The Art of Scientific Computing. Second Edition. Cambridge University Press, New York.

Thomann, R.V., and Connolly, J.P. 1984. (Manhattan College, Environmental Engineering and Science, Bronx, NY) Age Dependent Model of PCB in a Lake Michigan Food Chain. Environmental Protection Agency, U.S. (EPA), Office of Research and Development, Duluth, MN. EPA-600/3-84-024.

Food Chain Manager for Windows
Stochastic Food Chain Model Results

2,3,7,8-TCDF
NRBS Time-Variable Food Chain Model Run - Weldwood Data Set

MODEL RUN SUMMARY
Scenario file: C:\FCM\TCDF.SCE
Food Web file: NRBS.WEB
Run Began December 7, 1995 at 1:55:44 pm
Run ended December 7, 1995 at 2:31:16 pm

Total Run Iterations Completed: 1000 of 1000
Number of Days Per Model Run: 3650
Model Time Step: 5 days
Random Number seed: -1 (Random series selection)
Randomizing Speed: Medium

WATCH POINT SUMMARIES

Watch Point 1
Species: Bottom Feeding Invertebrate
Day: 365

Mean	5.621E-006 ug/g wet weight
Standard Deviation	1.534E-006
Variance	2.353E-012
Skewness	4.936E-001
Kurtosis	3.060E-001
5th Percentile	3.320E-006
50th Percentile	5.497E-006
95th Percentile	8.359E-006

Watch Point 2
Species: Filter Feeding Invertebrate
Day: 365

Mean	1.271E-005 ug/g wet weight
Standard Deviation	5.636E-006
Variance	3.177E-011
Skewness	4.997E-001
Kurtosis	1.544E-001
5th Percentile	4.174E-006
50th Percentile	1.222E-005
95th Percentile	2.291E-005

Watch Point 3
Species: Mountain Whitefish
Day: 365

Mean	3.968E-006 ug/g wet weight
Standard Deviation	4.736E-007
Variance	2.243E-013
Skewness	-2.087E+000
Kurtosis	1.355E+001
5th Percentile	3.368E-006
50th Percentile	3.984E-006
95th Percentile	4.640E-006

Watch Point 4

Species: Longnose Sucker
Day: 365

Mean	1.685E-007	ug/g wet weight
Standard Deviation	1.755E-008	
Variance	3.080E-016	
Skewness	-4.585E+000	
Kurtosis	3.264E+001	
5th Percentile	1.512E-007	
50th Percentile	1.701E-007	
95th Percentile	1.862E-007	

Watch Point 5
Species: Northern Pike
Day: 365

Mean	3.305E-008	ug/g wet weight
Standard Deviation	4.459E-009	
Variance	1.989E-017	
Skewness	-3.318E+000	
Kurtosis	1.904E+001	
5th Percentile	2.786E-008	
50th Percentile	3.337E-008	
95th Percentile	3.849E-008	

Watch Point 6
Species: Brook Stickleback
Day: 365

Mean	1.033E-006	ug/g wet weight
Standard Deviation	1.236E-007	
Variance	1.526E-014	
Skewness	-4.734E+000	
Kurtosis	2.741E+001	
5th Percentile	9.517E-007	
50th Percentile	1.051E-006	
95th Percentile	1.131E-006	

Watch Point 7
Species: Bottom Feeding Invertebrate
Day: 730

Mean	5.675E-006	ug/g wet weight
Standard Deviation	1.484E-006	
Variance	2.201E-012	
Skewness	4.449E-001	
Kurtosis	8.379E-002	
5th Percentile	3.509E-006	
50th Percentile	5.549E-006	
95th Percentile	8.486E-006	

Watch Point 8
Species: Filter Feeding Invertebrate
Day: 730

Mean	1.265E-005	ug/g wet weight
Standard Deviation	5.898E-006	
Variance	3.479E-011	
Skewness	5.790E-001	
Kurtosis	5.579E-001	

5th Percentile	3.607E-006
50th Percentile	1.224E-005
95th Percentile	2.302E-005

Watch Point 9
Species: Mountain Whitefish
Day: 730

Mean	4.299E-006	ug/g wet weight
Standard Deviation	5.442E-007	
Variance	2.961E-013	
Skewness	-2.830E+000	
Kurtosis	1.590E+001	
5th Percentile	3.680E-006	
50th Percentile	4.340E-006	
95th Percentile	4.973E-006	

Watch Point 10
Species: Longnose Sucker
Day: 730

Mean	2.135E-007	ug/g wet weight
Standard Deviation	2.752E-008	
Variance	7.572E-016	
Skewness	-4.514E+000	
Kurtosis	2.441E+001	
5th Percentile	1.925E-007	
50th Percentile	2.179E-007	
95th Percentile	2.348E-007	

Watch Point 11
Species: Northern Pike
Day: 730

Mean	5.499E-008	ug/g wet weight
Standard Deviation	8.945E-009	
Variance	8.002E-017	
Skewness	-3.774E+000	
Kurtosis	1.665E+001	
5th Percentile	4.494E-008	
50th Percentile	5.666E-008	
95th Percentile	6.230E-008	

Watch Point 12
Species: Brook Stickleback
Day: 730

Mean	1.119E-006	ug/g wet weight
Standard Deviation	1.416E-007	
Variance	2.005E-014	
Skewness	-4.499E+000	
Kurtosis	2.396E+001	
5th Percentile	9.400E-007	
50th Percentile	1.145E-006	
95th Percentile	1.220E-006	

Watch Point 13
Species: Bottom Feeding Invertebrate
Day: 1095

Mean	5.656E-006 ug/g wet weight
Standard Deviation	1.484E-006
Variance	2.203E-012
Skewness	4.033E-001
Kurtosis	-7.354E-002
5th Percentile	3.512E-006
50th Percentile	5.499E-006
95th Percentile	8.336E-006

Watch Point 14
Species: Filter Feeding Invertebrate
Day: 1095

Mean	1.294E-005 ug/g wet weight
Standard Deviation	5.828E-006
Variance	3.397E-011
Skewness	4.520E-001
Kurtosis	-2.387E-001
5th Percentile	4.099E-006
50th Percentile	1.219E-005
95th Percentile	2.342E-005

Watch Point 15
Species: Mountain Whitefish
Day: 1095

Mean	4.328E-006 ug/g wet weight
Standard Deviation	5.228E-007
Variance	2.733E-013
Skewness	-3.007E+000
Kurtosis	1.694E+001
5th Percentile	3.720E-006
50th Percentile	4.369E-006
95th Percentile	4.962E-006

Watch Point 16
Species: Longnose Sucker
Day: 1095

Mean	2.248E-007 ug/g wet weight
Standard Deviation	3.106E-008
Variance	9.649E-016
Skewness	-4.170E+000
Kurtosis	2.039E+001
5th Percentile	1.855E-007
50th Percentile	2.309E-007
95th Percentile	2.484E-007

Watch Point 17
Species: Northern Pike
Day: 1095

Mean	6.202E-008 ug/g wet weight
Standard Deviation	1.077E-008
Variance	1.160E-016
Skewness	-3.513E+000
Kurtosis	1.393E+001
5th Percentile	4.104E-008
50th Percentile	6.437E-008

95th Percentile	7.032E-008

Watch Point 18
Species: Brook Stickleback
Day: 1095

Mean	1.123E-006 ug/g wet weight
Standard Deviation	1.440E-007
Variance	2.073E-014
Skewness	-4.434E+000
Kurtosis	2.310E+001
5th Percentile	9.248E-007
50th Percentile	1.150E-006
95th Percentile	1.226E-006

Watch Point 19
Species: Bottom Feeding Invertebrate
Day: 1460

Mean	5.777E-006 ug/g wet weight
Standard Deviation	1.532E-006
Variance	2.348E-012
Skewness	3.479E-001
Kurtosis	-9.914E-002
5th Percentile	3.486E-006
50th Percentile	5.708E-006
95th Percentile	8.346E-006

Watch Point 20
Species: Filter Feeding Invertebrate
Day: 1460

Mean	1.286E-005 ug/g wet weight
Standard Deviation	5.756E-006
Variance	3.313E-011
Skewness	4.300E-001
Kurtosis	-7.606E-003
5th Percentile	4.180E-006
50th Percentile	1.251E-005
95th Percentile	2.368E-005

Watch Point 21
Species: Mountain Whitefish
Day: 1460

Mean	4.342E-006 ug/g wet weight
Standard Deviation	5.252E-007
Variance	2.758E-013
Skewness	-2.597E+000
Kurtosis	1.454E+001
5th Percentile	3.710E-006
50th Percentile	4.376E-006
95th Percentile	4.992E-006

Watch Point 22
Species: Longnose Sucker
Day: 1460

Mean	2.288E-007 ug/g wet weight

Standard Deviation	3.091E-008
Variance	9.555E-016
Skewness	-4.050E+000
Kurtosis	1.958E+001
5th Percentile	1.787E-007
50th Percentile	2.347E-007
95th Percentile	2.529E-007

Watch Point 23
Species: Northern Pike
Day: 1460

Mean	6.428E-008 ug/g wet weight
Standard Deviation	1.112E-008
Variance	1.236E-016
Skewness	-3.457E+000
Kurtosis	1.343E+001
5th Percentile	4.448E-008
50th Percentile	6.688E-008
95th Percentile	7.277E-008

Watch Point 24
Species: Brook Stickleback
Day: 1460

Mean	1.125E-006 ug/g wet weight
Standard Deviation	1.413E-007
Variance	1.996E-014
Skewness	-4.560E+000
Kurtosis	2.438E+001
5th Percentile	9.367E-007
50th Percentile	1.153E-006
95th Percentile	1.224E-006

Watch Point 25
Species: Bottom Feeding Invertebrate
Day: 1825

Mean	5.671E-006 ug/g wet weight
Standard Deviation	1.420E-006
Variance	2.016E-012
Skewness	3.701E-001
Kurtosis	2.734E-002
5th Percentile	3.535E-006
50th Percentile	5.587E-006
95th Percentile	8.166E-006

Watch Point 26
Species: Filter Feeding Invertebrate
Day: 1825

Mean	1.281E-005 ug/g wet weight
Standard Deviation	5.768E-006
Variance	3.327E-011
Skewness	3.842E-001
Kurtosis	-1.595E-001
5th Percentile	3.820E-006
50th Percentile	1.217E-005
95th Percentile	2.257E-005

Watch Point 27
Species: Mountain Whitefish
Day: 1825

Mean	4.360E-006 ug/g wet weight
Standard Deviation	5.602E-007
Variance	3.138E-013
Skewness	-2.848E+000
Kurtosis	1.587E+001
5th Percentile	3.737E-006
50th Percentile	4.395E-006
95th Percentile	5.037E-006

Watch Point 28
Species: Longnose Sucker
Day: 1825

Mean	2.294E-007 ug/g wet weight
Standard Deviation	3.142E-008
Variance	9.873E-016
Skewness	-3.955E+000
Kurtosis	1.872E+001
5th Percentile	1.794E-007
50th Percentile	2.353E-007
95th Percentile	2.538E-007

Watch Point 29
Species: Northern Pike
Day: 1825

Mean	6.497E-008 ug/g wet weight
Standard Deviation	1.140E-008
Variance	1.299E-016
Skewness	-3.461E+000
Kurtosis	1.334E+001
5th Percentile	4.461E-008
50th Percentile	6.768E-008
95th Percentile	7.377E-008

Watch Point 30
Species: Brook Stickleback
Day: 1825

Mean	1.125E-006 ug/g wet weight
Standard Deviation	1.438E-007
Variance	2.068E-014
Skewness	-4.392E+000
Kurtosis	2.281E+001
5th Percentile	9.348E-007
50th Percentile	1.151E-006
95th Percentile	1.232E-006

Watch Point 31
Species: Bottom Feeding Invertebrate
Day: 2190

Mean	5.741E-006 ug/g wet weight
Standard Deviation	1.496E-006
Variance	2.238E-012

Skewness	4.597E-001
Kurtosis	4.724E-001
5th Percentile	3.531E-006
50th Percentile	5.674E-006
95th Percentile	8.260E-006

Watch Point 32
Species: Filter Feeding Invertebrate
Day: 2190

Mean	1.029E-005 ug/g wet weight
Standard Deviation	3.906E-006
Variance	1.525E-011
Skewness	6.211E-001
Kurtosis	9.130E-001
5th Percentile	4.429E-006
50th Percentile	9.998E-006
95th Percentile	1.713E-005

Watch Point 33
Species: Mountain Whitefish
Day: 2190

Mean	4.346E-006 ug/g wet weight
Standard Deviation	4.809E-007
Variance	2.313E-013
Skewness	-2.529E+000
Kurtosis	1.655E+001
5th Percentile	3.797E-006
50th Percentile	4.358E-006
95th Percentile	4.982E-006

Watch Point 34
Species: Longnose Sucker
Day: 2190

Mean	2.313E-007 ug/g wet weight
Standard Deviation	2.679E-008
Variance	7.178E-016
Skewness	-4.501E+000
Kurtosis	2.622E+001
5th Percentile	2.016E-007
50th Percentile	2.355E-007
95th Percentile	2.537E-007

Watch Point 35
Species: Northern Pike
Day: 2190

Mean	6.588E-008 ug/g wet weight
Standard Deviation	9.941E-009
Variance	9.882E-017
Skewness	-3.793E+000
Kurtosis	1.773E+001
5th Percentile	5.155E-008
50th Percentile	6.788E-008
95th Percentile	7.429E-008

Watch Point 36

Species: Brook Stickleback
Day: 2190

Mean	1.126E-006 ug/g wet weight
Standard Deviation	1.437E-007
Variance	2.064E-014
Skewness	-4.413E+000
Kurtosis	2.308E+001
5th Percentile	9.185E-007
50th Percentile	1.151E-006
95th Percentile	1.231E-006

Watch Point 37
Species: Bottom Feeding Invertebrate
Day: 2555

Mean	5.662E-006 ug/g wet weight
Standard Deviation	1.524E-006
Variance	2.323E-012
Skewness	5.153E-001
Kurtosis	2.206E-001
5th Percentile	3.446E-006
50th Percentile	5.588E-006
95th Percentile	8.376E-006

Watch Point 38
Species: Filter Feeding Invertebrate
Day: 2555

Mean	9.995E-006 ug/g wet weight
Standard Deviation	3.952E-006
Variance	1.562E-011
Skewness	4.865E-001
Kurtosis	2.023E-003
5th Percentile	4.094E-006
50th Percentile	9.653E-006
95th Percentile	1.697E-005

Watch Point 39
Species: Mountain Whitefish
Day: 2555

Mean	3.634E-006 ug/g wet weight
Standard Deviation	4.246E-007
Variance	1.802E-013
Skewness	-3.359E+000
Kurtosis	1.985E+001
5th Percentile	3.157E-006
50th Percentile	3.674E-006
95th Percentile	4.126E-006

Watch Point 40
Species: Longnose Sucker
Day: 2555

Mean	2.262E-007 ug/g wet weight
Standard Deviation	3.041E-008
Variance	9.250E-016
Skewness	-4.344E+000
Kurtosis	2.184E+001

5th Percentile	1.929E-007
50th Percentile	2.324E-007
95th Percentile	2.480E-007

Watch Point 41
Species: Northern Pike
Day: 2555

Mean	6.158E-008 ug/g wet weight
Standard Deviation	1.098E-008
Variance	1.206E-016
Skewness	-3.645E+000
Kurtosis	1.470E+001
5th Percentile	4.478E-008
50th Percentile	6.401E-008
95th Percentile	6.965E-008

Watch Point 42
Species: Brook Stickleback
Day: 2555

Mean	1.061E-006 ug/g wet weight
Standard Deviation	1.852E-007
Variance	3.431E-014
Skewness	-3.266E+000
Kurtosis	1.122E+001
5th Percentile	6.460E-007
50th Percentile	1.110E-006
95th Percentile	1.188E-006

Watch Point 43
Species: Bottom Feeding Invertebrate
Day: 2920

Mean	5.704E-006 ug/g wet weight
Standard Deviation	1.509E-006
Variance	2.278E-012
Skewness	4.056E-001
Kurtosis	8.458E-002
5th Percentile	3.399E-006
50th Percentile	5.587E-006
95th Percentile	8.433E-006

Watch Point 44
Species: Filter Feeding Invertebrate
Day: 2920

Mean	1.020E-005 ug/g wet weight
Standard Deviation	3.968E-006
Variance	1.574E-011
Skewness	4.741E-001
Kurtosis	-8.300E-002
5th Percentile	4.244E-006
50th Percentile	9.751E-006
95th Percentile	1.721E-005

Watch Point 45
Species: Mountain Whitefish
Day: 2920

Mean	3.561E-006	ug/g wet weight
Standard Deviation	4.269E-007	
Variance	1.822E-013	
Skewness	-3.392E+000	
Kurtosis	1.978E+001	
5th Percentile	3.090E-006	
50th Percentile	3.612E-006	
95th Percentile	4.025E-006	

Watch Point 46
Species: Longnose Sucker
Day: 2920

Mean	2.246E-007	ug/g wet weight
Standard Deviation	3.113E-008	
Variance	9.688E-016	
Skewness	-4.124E+000	
Kurtosis	2.007E+001	
5th Percentile	1.763E-007	
50th Percentile	2.309E-007	
95th Percentile	2.481E-007	

Watch Point 47
Species: Northern Pike
Day: 2920

Mean	5.862E-008	ug/g wet weight
Standard Deviation	1.088E-008	
Variance	1.184E-016	
Skewness	-3.316E+000	
Kurtosis	1.214E+001	
5th Percentile	3.572E-008	
50th Percentile	6.116E-008	
95th Percentile	6.711E-008	

Watch Point 48
Species: Brook Stickleback
Day: 2920

Mean	1.052E-006	ug/g wet weight
Standard Deviation	1.885E-007	
Variance	3.552E-014	
Skewness	-3.120E+000	
Kurtosis	1.039E+001	
5th Percentile	6.066E-007	
50th Percentile	1.104E-006	
95th Percentile	1.188E-006	

Watch Point 49
Species: Bottom Feeding Invertebrate
Day: 3285

Mean	5.661E-006	ug/g wet weight
Standard Deviation	1.541E-006	
Variance	2.375E-012	
Skewness	4.297E-001	
Kurtosis	2.010E-001	
5th Percentile	3.284E-006	
50th Percentile	5.616E-006	

95th Percentile	8.251E-006

Watch Point 50
Species: Filter Feeding Invertebrate
Day: 3285

Mean	1.015E-005 ug/g wet weight
Standard Deviation	3.918E-006
Variance	1.535E-011
Skewness	4.049E-001
Kurtosis	-5.307E-002
5th Percentile	4.283E-006
50th Percentile	9.980E-006
95th Percentile	1.699E-005

Watch Point 51
Species: Mountain Whitefish
Day: 3285

Mean	3.563E-006 ug/g wet weight
Standard Deviation	4.279E-007
Variance	1.831E-013
Skewness	-3.535E+000
Kurtosis	2.116E+001
5th Percentile	3.104E-006
50th Percentile	3.590E-006
95th Percentile	4.060E-006

Watch Point 52
Species: Longnose Sucker
Day: 3285

Mean	2.241E-007 ug/g wet weight
Standard Deviation	3.109E-008
Variance	9.667E-016
Skewness	-4.156E+000
Kurtosis	2.029E+001
5th Percentile	1.735E-007
50th Percentile	2.304E-007
95th Percentile	2.470E-007

Watch Point 53
Species: Northern Pike
Day: 3285

Mean	5.777E-008 ug/g wet weight
Standard Deviation	1.064E-008
Variance	1.133E-016
Skewness	-3.346E+000
Kurtosis	1.251E+001
5th Percentile	3.684E-008
50th Percentile	6.035E-008
95th Percentile	6.593E-008

Watch Point 54
Species: Brook Stickleback
Day: 3285

Mean	1.050E-006 ug/g wet weight

Standard Deviation	1.838E-007
Variance	3.379E-014
Skewness	-3.183E+000
Kurtosis	1.078E+001
5th Percentile	6.340E-007
50th Percentile	1.101E-006
95th Percentile	1.183E-006

Watch Point 55
Species: Bottom Feeding Invertebrate
Day: 3650

Mean	5.689E-006 ug/g wet weight
Standard Deviation	1.500E-006
Variance	2.251E-012
Skewness	4.765E-001
Kurtosis	2.911E-001
5th Percentile	3.460E-006
50th Percentile	5.593E-006
95th Percentile	8.394E-006

Watch Point 56
Species: Filter Feeding Invertebrate
Day: 3650

Mean	1.013E-005 ug/g wet weight
Standard Deviation	4.059E-006
Variance	1.647E-011
Skewness	5.399E-001
Kurtosis	3.072E-001
5th Percentile	4.014E-006
50th Percentile	9.833E-006
95th Percentile	1.739E-005

Watch Point 57
Species: Mountain Whitefish
Day: 3650

Mean	3.562E-006 ug/g wet weight
Standard Deviation	4.139E-007
Variance	1.713E-013
Skewness	-3.178E+000
Kurtosis	1.857E+001
5th Percentile	3.092E-006
50th Percentile	3.601E-006
95th Percentile	4.070E-006

Watch Point 58
Species: Longnose Sucker
Day: 3650

Mean	2.244E-007 ug/g wet weight
Standard Deviation	3.086E-008
Variance	9.521E-016
Skewness	-4.058E+000
Kurtosis	1.942E+001
5th Percentile	1.806E-007
50th Percentile	2.305E-007
95th Percentile	2.489E-007

Watch Point 59
Species: Northern Pike
Day: 3650

Mean	5.750E-008 ug/g wet weight
Standard Deviation	1.044E-008
Variance	1.089E-016
Skewness	-3.340E+000
Kurtosis	1.250E+001
5th Percentile	3.658E-008
50th Percentile	6.006E-008
95th Percentile	6.589E-008

Watch Point 60
Species: Brook Stickleback
Day: 3650

Mean	1.050E-006 ug/g wet weight
Standard Deviation	1.839E-007
Variance	3.381E-014
Skewness	-3.189E+000
Kurtosis	1.094E+001
5th Percentile	6.477E-007
50th Percentile	1.101E-006
95th Percentile	1.180E-006

==== FOOD CHAIN MODEL INPUT DATA ====

NRBS Time-Variable Food Chain Model Run - Weldwood Data Set

CHEMICAL: 2,3,7,8-TCDF

Log Kow (unitless) 6.80

ENVIRONMENTAL DATA

Water Column Dissolved Chemical Concentration (ug/L) 3.500E-008
[Triangular] Minimum: 1.000E-009 Most Likely: 3.500E-008 Maximum: 6.900E-008

Water Column Particulate Chemical Concentration (ug/g C) 2.200E-006
[Triangular] Minimum: 2.000E-008 Most Likely: 2.200E-006 Maximum: 4.380E-006

Sediment Pore Water Chemical Concentration (ug/L) 3.500E-007
[Triangular] Minimum: 1.400E-007 Most Likely: 3.500E-007 Maximum: 5.600E-007

Sediment Particulate Chemical Concentration (ug/g C) 5.430E-006
[Triangular] Minimum: 2.130E-006 Most Likely: 5.430E-006 Maximum: 8.730E-006

Mean Monthly Temperature (degrees Celsius)

January	1.000E+001
February	1.000E+001
March	1.000E+001
April	1.000E+001
May	1.000E+001
June	1.000E+001
July	1.000E+001

August	1.000E+001
September	1.000E+001
October	1.000E+001
November	1.000E+001
December	1.000E+001

Species 1 [Steady-State Benthic Species] Bottom Feeding Invertebrate

Respiration Rate (g/g/d)	1.080E-001
[Normal] Mean: 1.090E-001 Standard Deviation: 8.740E-003	
Growth Rate (1/d)	3.300E-002
[Normal] Mean: 3.370E-002 Standard Deviation: 2.990E-003	
Food Assimilation Efficiency (unitless)	6.000E-002
Fraction Dry Weight (unitless)	1.900E-001
[Normal] Mean: 1.800E-001 Standard Deviation: 3.200E-002	
Respiration Temperature Coefficient [Rho] (1/degrees Celsius)	0.000E+000
Fraction of Weight Lipid (unitless)	5.000E-002
Permeability Ratio (unitless)	2.000E-001
Chemical Assimilation Efficiency (unitless)	1.500E-001
Excretion Rate (1/d)	1.500E-002
Initial Chemical Concentration (ug/g)	0.000E+000

DIETARY CONSUMPTION

Detritus	100.0%

Species 2 [Steady-State Pelagic Species] Filter Feeding Invertebrate

Respiration Rate (g/g/d)	7.000E-002
[Normal] Mean: 6.580E-002 Standard Deviation: 1.060E-002	
Growth Rate (1/d)	2.100E-002
[Normal] Mean: 1.940E-002 Standard Deviation: 3.400E-003	
Food Assimilation Efficiency (unitless)	6.000E-002
Fraction Dry Weight (unitless)	1.900E-001
[Normal] Mean: 1.800E-001 Standard Deviation: 2.900E-002	
Respiration Temperature Coefficient [Rho] (1/degrees Celsius)	0.000E+000
Fraction of Weight Lipid (unitless)	5.000E-002
Permeability Ratio (unitless)	2.000E-001
Chemical Assimilation Efficiency (unitless)	1.500E-001
Excretion Rate (1/d)	4.750E-002
Initial Chemical Concentration (ug/g)	0.000E+000

DIETARY CONSUMPTION

Phytoplankton/Suspended Solids	100.0%

Species 3 [Age-Dependent Pelagic Species] Mountain Whitefish

Duration of Age Class (days)	1825.0
Initial Weight (g)	8.000E+002
Growth Rate (1/d)	2.600E-004
[Normal] Mean: 2.590E-003 Standard Deviation: 2.540E-003	

Food Assimilation Eff. (unitless)	8.200E-001
Chemical Assimilation Eff. (unitless)	5.400E-001
Fraction Dry Weight (unitless)	2.400E-001
[Normal] Mean: 2.500E-001 Standard Deviation: 3.400E-002	
Permeability Ratio (unitless)	2.000E-001
Fraction of Weight Lipid (unitless)	5.220E-002
Respiration Coefficient [Beta] (unitless)	4.600E-003
Swimming Speed Weight Coefficient [Delta] (unitless)	0.000E+000
Respiration Weight Exponent [Gamma] (unitless)	2.400E-001
Swimming Speed coefficient [Omega] (cm/s)	0.000E+000
Swimming Speed Temperature Coefficient [Phi] (1/degree Celsius)	0.000E+000
Respiration Temperature Coefficient [Rho] (1/degrees Celsius)	6.700E-002
Coefficient for Swimming Speed [Xnu] (s/cm)	0.000E+000
Excretion Rate (1/d)	3.000E-003
Initial Chemical Concentration (ug/g)	0.000E+000

DIETARY CONSUMPTION

Bottom Feeding Invertebrate	39.0%
Filter Feeding Invertebrate	61.0%

Species 4 [Age-Dependent Pelagic Species] Longnose Sucker

Duration of Age Class (days)	1825.0
Initial Weight (g)	1.000E+003
Growth Rate (1/d)	9.300E-004
[Normal] Mean: 4.000E-004 Standard Deviation: 1.600E-004	
Food Assimilation Eff. (unitless)	8.200E-001
Chemical Assimilation Eff. (unitless)	5.400E-001
Fraction Dry Weight (unitless)	2.800E-001
Permeability Ratio (unitless)	2.000E-001
Fraction of Weight Lipid (unitless)	4.620E-002
Respiration Coefficient [Beta] (unitless)	4.600E-003
Swimming Speed Weight Coefficient [Delta] (unitless)	0.000E+000
Respiration Weight Exponent [Gamma] (unitless)	2.400E-001
Swimming Speed coefficient [Omega] (cm/s)	0.000E+000
Swimming Speed Temperature Coefficient [Phi] (1/degree Celsius)	0.000E+000
Respiration Temperature Coefficient [Rho] (1/degrees Celsius)	6.700E-002
Coefficient for Swimming Speed [Xnu] (s/cm)	0.000E+000
Excretion Rate (1/d)	3.000E-003
Initial Chemical Concentration (ug/g)	0.000E+000

DIETARY CONSUMPTION

Filter Feeding Invertebrate	6.0%
Bottom Feeding Invertebrate	49.0%
Detritus	45.0%

Species 5 [Age-Dependent Pelagic Species] Northern Pike

Duration of Age Class (days)	1825.0
Initial Weight (g)	2.000E+003
Growth Rate (1/d)	9.900E-004
[Normal] Mean: 4.000E-004 Standard Deviation: 1.600E-004	
Food Assimilation Eff. (unitless)	8.200E-001
Chemical Assimilation Eff. (unitless)	5.400E-001

Fraction Dry Weight (unitless)	2.200E-001
[Normal] Mean: 2.400E-001 Standard Deviation: 4.200E-002	
Permeability Ratio (unitless)	2.000E-001
Fraction of Weight Lipid (unitless)	1.000E-002
Respiration Coefficient [Beta] (unitless)	4.600E-003
Swimming Speed Weight Coefficient [Delta] (unitless)	0.000E+000
Respiration Weight Exponent [Gamma] (unitless)	2.400E-001
Swimming Speed coefficient [Omega] (cm/s)	0.000E+000
Swimming Speed Temperature Coefficient [Phi] (1/degree Celsius)	0.000E+000
Respiration Temperature Coefficient [Rho] (1/degrees Celsius)	6.700E-002
Coefficient for Swimming Speed [Xnu] (s/cm)	0.000E+000
Excretion Rate (1/d)	3.000E-003
Initial Chemical Concentration (ug/g)	0.000E+000

DIETARY CONSUMPTION

Mountain Whitefish	34.0%
Longnose Sucker	42.0%
Brook Stickleback	24.0%

Species 6 [Age-Dependent Pelagic Species] Brook Stickleback

Duration of Age Class (days)	730.0
Initial Weight (g)	2.000E+002
Growth Rate (1/d)	3.430E-003
Food Assimilation Eff. (unitless)	8.200E-001
Chemical Assimilation Eff. (unitless)	5.400E-001
Fraction Dry Weight (unitless)	1.620E-001
Permeability Ratio (unitless)	2.000E-001
Fraction of Weight Lipid (unitless)	3.000E-002
Respiration Coefficient [Beta] (unitless)	4.600E-003
Swimming Speed Weight Coefficient [Delta] (unitless)	0.000E+000
Respiration Weight Exponent [Gamma] (unitless)	2.400E-001
Swimming Speed coefficient [Omega] (cm/s)	0.000E+000
Swimming Speed Temperature Coefficient [Phi] (1/degree Celsius)	0.000E+000
Respiration Temperature Coefficient [Rho] (1/degrees Celsius)	6.700E-002
Coefficient for Swimming Speed [Xnu] (s/cm)	0.000E+000
Excretion Rate (1/d)	3.000E-003
Initial Chemical Concentration (ug/g)	0.000E+000

DIETARY CONSUMPTION

Bottom Feeding Invertebrate	95.0%
Filter Feeding Invertebrate	5.0%

TIME SERIES DATA SETS

Time Series Set 1

Adjustment Day	2190
Water Column Dissolved Chemical Concentration (ug/L)	2.700E-008
[Triangular] Minimum: 5.000E-009 Most Likely: 2.700E-008 Maximum:	7.900E-008
Water Column Particulate Chemical Concentration (ug/g C)	1.738E-006
[Triangular] Minimum: 3.480E-007 Most Likely: 1.738E-006 Maximum:	3.128E-006
Sediment Pore Water Chemical Concentration (ug/L)	3.500E-007
[Triangular] Minimum: 1.400E-007 Most Likely: 3.500E-007 Maximum:	5.600E-007

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Sediment Particulate Chemical Concentration (ug/g C)                 5.430E-006
[Triangular] Minimum: 2.130E-006  Most Likely: 5.430E-006  Maximum: 8.730E-006

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