

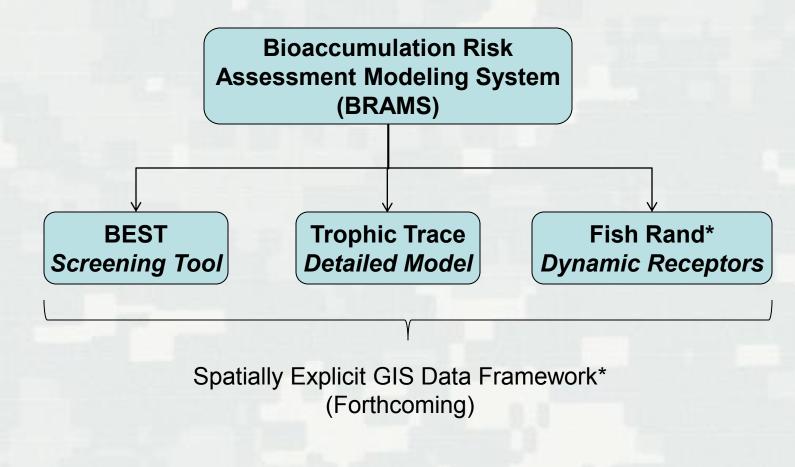
### Bioaccumulation Risk Assessment Modeling System Software Presentation and Demonstration

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# **Outline: BRAMS**

### Scope

- Dredged Material Disposal Regulations
- Bioaccumulation
- Introduction to BRAMS

BEST

- Technical Approach
- Software Demonstration
- Trophic Trace
  - Technical Approach
  - Software Demonstration









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## **Dredged Material Management**

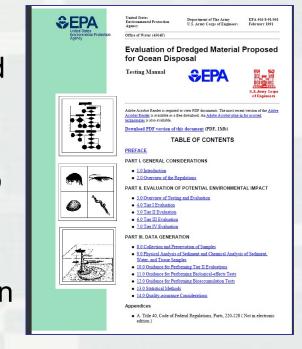
- Over 200 million cubic yards of sediment are dredged from U.S. waters each year.
- The Marine Protection Research and Sanctuaries Act (MPSA, 1972) prohibits ocean dumping of material that would unreasonably degrade or endanger human health or the marine environment.
- EPA and USACE share the responsibility for regulation of this dredged material.
- The Corps issues permits for dredged material disposal which are subject to EPA review and concurrence before ocean disposal can occur.





# Dredged Material Disposal Requirements

- The tiered approach to evaluation of potential environmental impacts of ocean dumping is outlined in the Ocean and Inland Testing Manuals (OTM & ITM)
- BRAMS can be used in Tiers I through IV to provide information about potential risks
- Specific guidance for sampling and testing in accordance with the OTM and ITM is provided in Regional Implementation Manuals







# **Environmental Impact and Bioaccumulation**

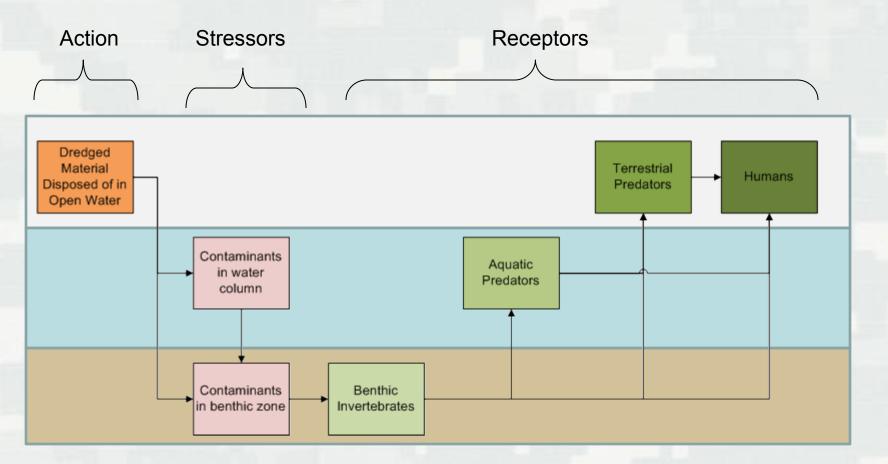
- Primary source of environmental risk associated with dredged sediment disposal:
  - Sediment-associated contaminants
  - Partially due to bioaccumulation and biomagnification in aquatic food chains



### Bioaccumulation is included in the required evaluations to:

- Indicate biological availability of contaminants in dredged material
- Assess potential for long-term accumulation of contaminants in aquatic food webs and to levels harmful to consumers
- Material is potentially unacceptable if:
  - Animals exposed to dredged material bioaccumulate statistically greater amounts of contaminants than those exposed to reference sediments or higher concentrations than FDA action levels

## **Bioaccumulation Conceptual Model**



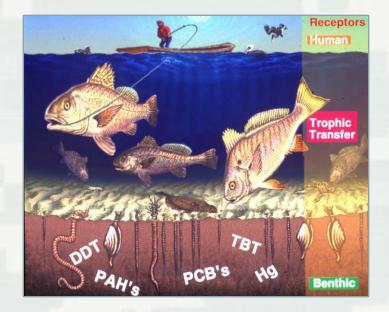


ERDC

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# **Bioaccumulation Modeling**

- Designed to estimate bioaccumulation, trophic transfer and risk associated with contaminants in sediment
- Model Components
  - Contaminant concentration in water, sediment, and/or tissue
  - Site Food Web
  - Receptor Exposure Scenarios
  - Contaminant uptake, transfer, and toxicity factors
  - Environmental conditions







# **Risk Assessment Process**

### 1. Problem Formulation/Hazard Identification

- General site characterization
- Exposure pathway definition (links between contaminant sources and receptors)
- 2. Exposure Assessment
  - Quantify exposure characteristics of human and ecological receptors
- 3. Effects or Toxicity Assessment
  - Potential toxicity of contaminants (RfDs, CSFs, TRVs)
- 4. Risk Characterization
  - Use information from previous steps to calculate dose and risks and compare to established thresholds:



(ADD, LCR, HI, NOAEL TQ, LOAEL TQ)



# **Interpreting Results**

### No Potential Risk

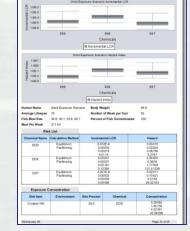
- Risks below EPA thresholds of concern
- Conservative, health protective assumptions and bioaccumulation test data used
- With uncertainty, lowest portion of range of risks still below thresholds of concern

### Potential Risk

- Predicted risks greatly exceed EPA thresholds of concern
- ► With uncertainty, lowest portion of range of risks still exceed thresholds
- Site-specific data and sediment or bioaccumulation test data used

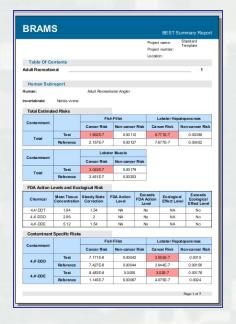
### Equivocal Risk

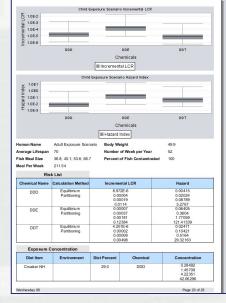
- Predicted cancer and non-cancer risks above thresholds of concern and NOAEL TQ >1, while LOAEL <1.</p>
- With uncertainty, lowest portion of range of risks below thresholds
- Conservative, health protective assumptions and sediment or bioaccumulation test data used

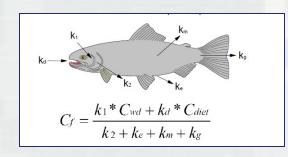


# Bioaccumulation Risk Assessment Modeling System (BRAMS)

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Plankton NSHR Plankton HBR Plankton CNYN Fishes Glivits Glivits Fishes Glivits Glivits Fishes Glivits Fishes Fish	Plankton CNYN	Canyon Slope	0.98; 1.24; 1.88	Water		







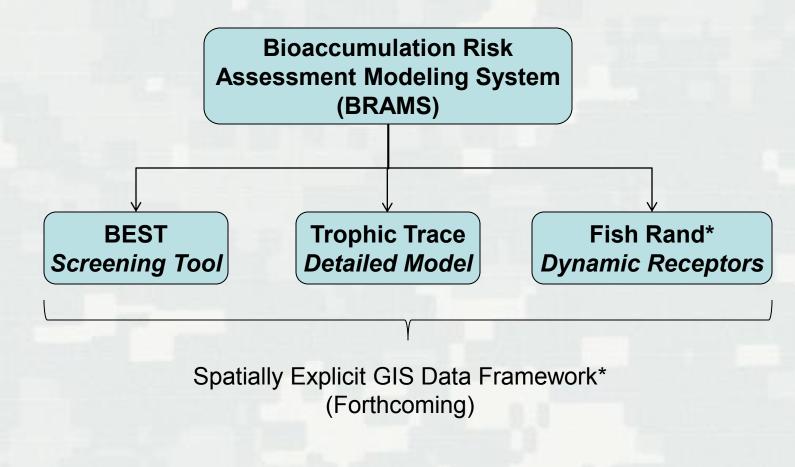
	A	B	C	D
1	28-days Bioaccumulation Test Results			
2	Project Name:	pname1		
3	Project Number:	pnumber1		
4	Location	11		
5				
6	Organism	Contaminant	Mean Tissue Concentration ([Tissue]/Normalization Factor = µg/g)	Max Tissue Concentration [[Tissue]/Normalization Factor = µg/g]
7				
8	01	c1	1.00	1.00
	01	c2	1.00	
10	01	c3	1.00	1.00
	01	c4	1.00	1.00
	02	c1	1.00	
	02	c2	1.00	1.00
	02	c3	1.00	1.00
15	02	c4	1.00	1.00
16				
17				
18				
19				
20				



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# **BRAMS History**

### BEST:

- 1999 EPA Region 1 develops and begins using MS Excel-based risk model to estimate risks of open water disposal from results of bioaccumulation testing
- 2012 ERDC moves model framework into BRAMS Java application and adds flexibility to tailor model to specific projects

### Trophic Trace:

- 1999 Originally developed (as TrophicTrace) by Menzie-Cura & Associates, Inc.
- ► 2003 MS Excel add-in created for the USACE
- 2004 Implemented as a desktop application using Adobe (former Macromedia) Flash technology
- 2012 Updated by USACE ERDC to a stand-alone Java-based tool that can run on any Java-enabled operating system



# **Trophic Trace vs. BEST**

### Trophic Trace

- Mechanistic Bioaccumulation Model
- Tiers I-III, IV (partially)
- Required Input:
  - Sediment, Water, or Tissue Concentrations
- Uncertainty:
- Interval Analysis or "fuzzy math" Food Chain:
  - Invertebrates
  - ► Fish
  - Mammals
  - Birds
  - Humans
  - Trophic Transfer:
    - Equilibrium Partitioning + Gobas Model or BCF
    - 28-bioaccumulation test results (+ TTF)
       + Gobas Model
- Risk Receptors:
  - Humans
  - Ecological

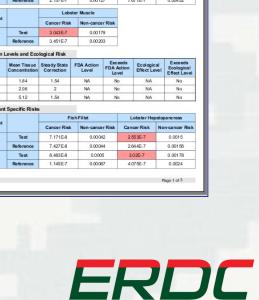
### <u>BEST</u>

- Empirical Screening Tool
- Tier III
- Required Input:
  - ► Tissue Concentrations
- Uncertainty:
  - ► None
- Food Chain:
  - Invertebrates
  - Aquatic Predators
  - Humans
- Trophic transfer:
  - ► 28-day bioaccumulation test results + BMFs
- Risk Receptors:
  - Humans



# BEST – Bioaccumulation Evaluation Screening Tool

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		V Vs									Project number:	Template
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eis virens	is virens	0.0146	1000	Туре	Invertebrate		Human Subr	eport				
	oma nasuta	0.0124	1000	Name	Nereis viren:		Human:		Adult Recreati	ional Angler		
				Specific			Invertebrate:	Nereis virens				
Muscle				Lipid (g lipid/g ti	ssue: 0.0146 🛨	the second se						
r Hepatopanci let				Normalization	1000 🕒		Total Estimate	ed Risks				
-met					ccumulation Test		Contaminant		10.759	h Fillet		epatopa no reas
creational Ar				Bioaccumulation	n Tes   4,4'-DDT; 🛨				Cancer Risk	Non-cancer		Non-cancer Ris
are duoridi / u							Total	Test	1.902E-7	0.00112		0.00398
								Reference	2.157E-7	0.00123	7.677E-7	0.00452
							Contaminant		Lobste	er Muscle		
ie i i i							Contaminant		Cancer Risk	Non-cancer	Risk	
							Total	Test	3.043E-7	0.00179		
ene							Total	Reference	3.451E-7	0.00203	i	
							FDA Action L	evels and Eco	logical Risk			
o)fluoranthene								Mean Tissue	-	FDA Action	Exceeds FDA Action	Exceeds
h,i)perylene						the second s	Chemical	Concentration	Correction	Level	FDA Action Level Effect I	evel Ecologica Effect Lev
(k)fluoranthene						and the second sec	4,4'-DDT	1.84	1.54	NA	No NA	
thylhexyl) Phtl ne							4,4'-DDD	2.06	2	NA	No NA	No
							4,4-DDE	5.12	1.54	NA	Na NA	No
(a,h)anthrace thene							Contaminant	Specific Risks				
ie line				-	7.		Contaminant		Fis	h Fillet	Lobster H	epatopancreas
(1.2.2.o.d)pure							Contaminant		Cancer Risk	Non-cancer	Risk Cancer Risk	Non-cancer R
alene	otes						4.4-DDD	Test	7.171E-8	0.00042	2.553E-7	0.0015
nthrene					A		4,4-000	Reference	7.427E-8	0.00044	2.644E-7	0.00156
anthrene							4.4-DDE	Test	8.483E-8	0.0005		0.00178
ie 🗧							SA-DOL	Reference	1.145E-7	0.00067	4.075E-7	0.0024
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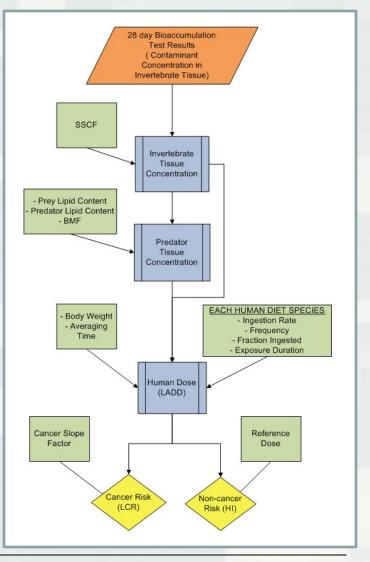




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# **BEST - Technical Approach**

- Invertebrate and Predator Body Burdens
  - 28-day Bioaccumulation Test Results
  - ► SSCF, BMF, Lipid Content
- Human Dose
  - Prey Body Burden
  - Exposure Scenario
- Human Cancer and Non-Cancer Risk
  - LCR = Dose x CSF
  - ► HI = Dose/ RfD





## **BEST Model Inputs**

### Food Web

- Invertebrates
  - Lipid Content
  - 28-day Bioaccumulation Test Results (mean and maximum tissue concentration)
- Predators
  - Lipid Content
  - Diet

### Human Exposure

- Body Weight
- Averaging Time
- Each Diet Species
  - Fraction Ingested
  - Frequency
  - Ingestion rate
  - Exposure Duration

### <u>Chemicals</u>

- ▶ Туре
- \*Cancer Slope Factor
- \*Reference Dose
- Steady State Correction Factor
- Biomagnification Factor
- \*Human Toxicity Equivalence Factor
- \*FDA Action Level
- \*Ecological Effects Level

### **Project**

- Name
- \*Number
- \*Location
- Risk Thresholds
- \*Reference Project

\*Optional Input



### **Invertebrate Tissue Concentration**

 $[EdibleTissue_{Invertebrate}] = [C_{Prey}] \times SSCF$ 

#### Where:

 [Edible Tissue <sub>Invertebrate</sub>] = Concentration of contaminant in edible tissue of invertebrate species (mg/kg)
 [C<sub>Prey</sub>] = Maximum tissue concentration of contaminant in the invertebrate out of five replicates from the 28-day bioaccumulation test data (mg/kg)

SSCF = Steady state correction factor (unitless)







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### **Predator Tissue Concentration**

 $[EdibleTissue_{Predator}] = [EdibleTissue_{Invertebrate}] \times BMF \times \left(\frac{Lipid_{Pred}}{Lipid_{Prev}}\right)$ 

#### Where:

[Edible Tissue<sub>Predator</sub>]

[Edible Tissue Invertebrate]

Lipid<sub>Pred</sub> Lipid<sub>Prev</sub> BMF

- = Concentration of contaminant in edible tissue of predator (mg/kg)
- = Concentration of contaminant in edible tissue of invertebrate species (mg/kg)
- = Predator mean lipid fraction (g lipid/g tissue)
- = Invertebrate mean lipid fraction (g lipid/g tissue)
- = Biomagnification factor (unitless)





### **Lifetime Average Daily Dose Equation**

# $LADD = \frac{ETC \times FI \times F \times IR \times ED}{BW \times AT}$

#### Where:

ETC

FI

F

IR

FD

BW

- LADD = Lifetime Average Daily Dose (mg/kg-day)
  - Edible Tissue Concentration of diet species (mg/kg)
    - = Fraction Ingested (unitless)
    - = Frequency (days/year)
    - = Fish/shellfish Ingestion Rate (kg/day)
    - = Exposure Duration (years)
    - = Body Weight (kg)
    - = Averaging Time (days)







AT

### **Standard Risk Equations**

### Cancer Risk = $LADD \times CSF$

Where: LADD = Lifetime Average Daily Dose (mg/kg-day) CSF = Oral Cancer Slope Factor (mg/kg)

### Non-cancer Risk = LADD/RfD

Where: ADD = Lifetime Average Daily Dose (mg/kg-day) RfD = Oral Reference Dose (mg/kg-day)





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### **Excel Input Templates - Bioaccumulation**

4	A	В	С	D
1	28-days Bioaccumulation Test Results			
2	Project Name:	pname1		
3	Project Number:	pnumber1		
4	Location	11		
5				
6	Organism	Contaminant	Mean Tissue Concentration (Organics = ng/g; Metals = µg/g)	Max Tissue Concentration (Organics = ng/g; Metals = μg/g)
7				
8	01	c1	1	1
9	01	c2	1	1
10	01	c3	1	1
11	01	c4	1	1 1
12	o2	c1	1	1
13	o2	c2	1	1
14	02	c3	1	1 1
15	02	c4	1	1
16				
17				
18				
19				





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### **Excel Input Templates - Chemicals**

	A	В	С	D	E	F	G	Н		J	К
1	Chemicals										
2											
		Chemical	Oral Cancer Slope	Oral Reference	Biomagnification		<b>TEF Reference</b>		Steady State	FDA Action	Ecological Effects
3	Name	Туре	Factor (mg/kg-day)-1	Dose (mg/kg-day)	Factor	Equivalence Factor	Chemical	TEF Relation	Correction Factor	Level (ppm)	Level (ppm)
4											
	c1	Organic	1.00					NA	1.00		
6	c2	Organic	1.00		1.00	0.01	N	c1	1.00		
7	c3	Metal	1.00	1.00	1.00	NIA NIA	N	NA	1.00	1.00	) 1.0(
8	c4	Organic	1.00	NA	1.00	NIA NIA	N	NIA	1.00	1.00	) 1.00
9											
10											
11		-									
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### **BEST Reports**

### Full Report

Table Of Co dult Recreatio General uman Name ancer Risk on-Cancer Risk Diet Report	nal		Adult Recreational 2.842E-6 0.01672	F	roject nan roject nun ocation :		Standard Template	
dult Recreatio General uman Name ancer Risk on-Cancer Risk	nal		2.842E-6	L		mber:	2005.00 • C.2006	
dult Recreatio General uman Name ancer Risk on-Cancer Risk	nal		2.842E-6		ocation:		1	
dult Recreatio General uman Name ancer Risk on-Cancer Risk	nal		2.842E-6	Angler	_		1	
General uman Name ancer Risk on-Cancer Risk			2.842E-6	Angler			1	
uman Name ancer Risk on-Cancer Risk			2.842E-6	Angler				
ancer Risk on-Cancer Risk			2.842E-6	Angler				
on-Cancer Risk								
			0.01672					
Diet Report								
			8-11		-			
Diet	Name		Cance	er Risk		Non-Ca	ncer Risk	
Fish	n Fillet		3.84	2E-7		0.0	0226	
Lobste	er Muscle		6.14	7E-7		0.0	0362	
Lobster He	patopanc	reas	1.36	8E-6		0.0	0805	
Macon	na nasuta	8	4.75	8E-7		0.0	0028	
Prey Report								
Prey Nam	e	D	iet Name	Cancer Ris	sk	No	n-Cancer Risk	
Nereis vire	ns	F	ish Fillet	1.902E-7		0.00112		
Macoma nas	suta	F	ish Fillet	1.94E-7		0.00114		
Nereis vire	ns	Lob	ster Muscle	3.043E-7	3E-7		0.00179	
Macoma nas	suta	Lob	ster Muscle	3.104E-7	8		0.00183	
Nereis vire	ns	Lobster I	Hepatopancreas	6.771E-7			0.00398	
Macoma nas			Hepatopancreas	6.906E-7			0.00406	
Macoma nas	suta	Mac	oma nasuta	4.758E-7			0.0028	
Chemical Re	eport							
Chemical Name	Diet N	ame	Edible Tissue Concentration	Average Daily Dose	Cance	r Risk	Non-Cancer Risk	
4,4'-DDT	Fish F Nereis		0.00032	9.901E-8	3.36	6E-8	0.0002	
4,4'-DDD	Fish F Nereis		0.00069	2.109E-7	7.17	1E-8	0.00042	
4,4'-DDE	Fish Fish Fish Fish Fish Fish Fish Fish	Fillet	0.00082	2.495E-7	8.48	3E-8	0.0005	

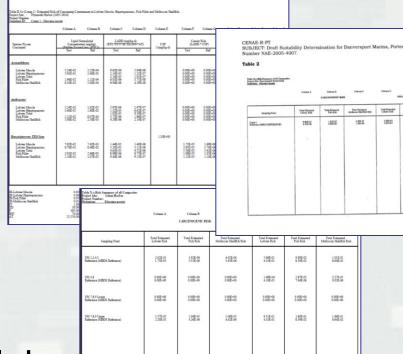
### Summary Report

BRAM	s						BESTS	Sum	mary Repor
						Project Project Locatio	number:		andard mplate
Table Of Co	ntents								
dult Recreatio	nai								_ 1
Human Sub	report								
luman:		Adult Recres	ation	al Angler					
vertebrate:	Nereis virens								
Total Estimat	ed Risks							102	
Contaminant				fillet			obster Hep	-	
		Cancer Risk		Non-cance			cer Risk	No	n-cancer Risk
Total	Test	1.902E-7		0.0011	-		71E-7	-	0.00398
	Reference	2.157E-7		0.0012	7	7.6	77E-7		0.00452
Contaminant		Lobs	ster	Muscle					
conamiant		Cancer Risk		Non-cance	r Risk				
Total	Test	3.043E-7		0.0017	9				
	Reference	3.451E-7		0.0020	3				
FDA Action L	evels and Eco	logical Risk							
Chemical	Mean Tissue Concentration	Steady State Correction	FD	A Action Level	Exc FDA /		Ecologic Effect Le		Exceeds Ecological Effect Level
4,4'-DDT	1.84	1.54		NA	N		NA		Na
4,4'-DDD	2.06	2		NA	N		NA		Na
4,4'-DDE	5.12	1.54	-	NA	N	0	NA		Na
Contaminant	Specific Risks								
Contaminant		F	ish F	fillet		L	obster Hep	patop	ancreas
o o manimalit		Cancer Risk		Non-cance	r Risk	Can	cer Risk	No	n-cancer Risk
4.4°-DDD	Test	7.171E-8		0.0004	2	2.5	63E-7	-	0.0015
4,4-000	Reference	7.427E-8		0.0004	4	2.6	44E-7		0.00156
	Test	8.483E-8		0.0005	5	3)	02E-7		0.00178
4.4-DDE							75E-7	1	

### Validation

### Plymouth Harbor

Salem Harbor



Danversport Yacht Club



Internet.

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# **Trophic Trace**

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File Edit View Run Tools Help						_
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🛛 Explorer 🛛 🗖 🗙	🗋 Table				Properties	
🔻 🚞 TTModel					- +	
🔻 📄 Invertebrates	Name	Environment	Lipid	Diet Pathway	🖯 General	
Ep Inv CNYN	Ep Inv CNYN	Canyon Slope	1.08; 1.38; 2.7;		Туре	Invertebrate
📄 Plankton SHLF	Plankton SHLF	Continental Sh	0.98; 1.24; 1.88		Name	Ep Inv CNYN
📄 Inf Inv HCNYN	Inf Inv HCNYN	Head of Canyon	0.98; 1.24; 1.88		Environment	Canyon 💌
📄 Ep Inv HCNYN	Ep Inv HCNYN	Head of Canyon	1.08; 1.38; 2.7;	Sediment	Specific	Canyon
📄 Plankton HCNYN	Plankton HCNYN		0.98; 1.24; 1.88		Lipid	1.08; 1.38 🛨
Inf Inv SHLF	Inf Inv SHLF	Continental Sh	0.98; 1.24; 1.88			
Ep Inv SHLF	Ep Inv SHLF Ep Inv NSHR	Continental Sh Nearshore	1.08; 1.38; 2.7;		Diet Pathway	Sedimer 💌
Ep Inv NSHR	Inf Inv CNYN	Canyon Slope	1.08; 1.38; 2.7; 0.98; 1.24; 1.88		28-days Bioaccum	
Inf Inv CNYN	Inf Inv HBR	Harbor	0.98; 1.24; 1.88		Bioaccumulation Tes	. E
Inf Inv HBR	Inf Inv NSHR	Nearshore	0.98; 1.24; 1.88			
inf Inv NSHR	Ep Inv HBR	Harbor	1.08; 1.38; 2.7;	Sediment		
Ep Inv HBR	Plankton NSHR	Nearshore	0.98; 1.24; 1.88			
Plankton NSHR	Plankton HBR	Harbor	0.98; 1.24; 1.88			
Plankton HBR	Plankton CNYN	Canyon Slope	0.98; 1.24; 1.88	Water		
Plankton CNYN						
_						
Fishes						
▶ 💼 Birds						
Mammals						
🕨 📄 Human	Notes					
Chemicals						
Environment						

#### BRAMS

Fishes	1
Anchovy NRSHR	1
Sole NRSHR	3
Halibut NRSHR	5
Croaker NH	7
Leop Shk NH	9
Rock NH	11
Flat NH	13
Scul NH	15
Surf NH	
Croaker SH	15
Humans	2
Child Exposure	21
Adult Exposure	23

Trophic Trace Model Report

Fishes	
Fish Name	Anchovy NRSHR
Body Weight	20
Lipid	3.5; 10.7; 24.6
Site Use Factor	1

Ris	k List	-			
Chemical Name	Calculation Method	NOAELTQ	LOAELTQ	NOAELTQ Eggs	LOAELTQ Eggs
DDD	Equilibrium Partitioning	0	0	2.798E-6 0.00002 0.00003 0.0002	1.735E-6 0.00001 0.00002 0.00013
DDE	Equilibrium Partitioning	0	0	0.00003 0.00011 0.00018 0.00126	0.00002 0.00007 0.00011 0.00078
DDT	Equilibrium Partitioning	0	0	2.054E-6 3.216E-6 4.812E-6 0.00002	1.273E-6 1.994E-6 2.983E-6 0.00001
Exposure 0	Concentration				
DietItem	Environment	Diet Percent	Chemi	cal Co	oncentration
Plankton NRSHR	Nearshore	100.0	DDD		0.00016 0.00079 0.00119 0.00304
uesday 31 July 2012					Page 1 of 25

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# **Technical Approach Overview**

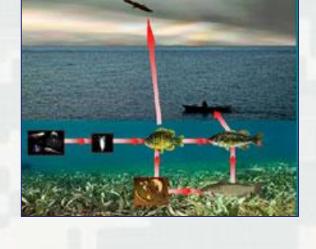
Depending on inputs, several modeling choices are available:

- Freely Dissolved Water Concentration
  - User specified from site specific data
  - Calculated from a subroutine based on whole water concentration
  - Calculated using equilibrium partitioning from a sediment concentration
- Hydrophobic organics
  - Invertebrates Tissue Concentration:
    - BSAF (hydrophobic organics)
    - 28-day Bioaccumulation Testing
  - Fish Burdens:
    - Gobas steady state uptake model
- Inorganic and hydrophilic organics
  - ► Fish Burdens:
    - BCF Approach



• TTF Approach



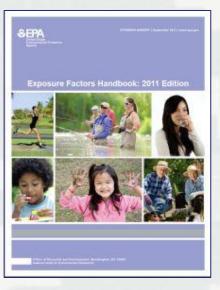




### **Technical Approach Overview Continued**

- Daily dose:
  - Fish tissue concentrations
  - Exposure assumptions
- Human Health Risk:
  - Incremental Lifetime Cancer Risk (Dose x CSF)
  - Hazard index (Dose/RfD)
- Ecological Risk:
  - NOAEL and LOAEL TQs (Dose/TRV)
- Implements Uncertainty Analysis using Fuzzy Mathematics





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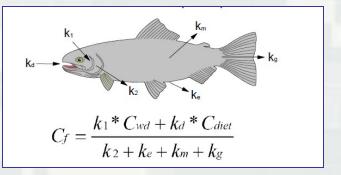
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### **Model Structure: Gobas Model**

 $= \frac{k_1 \times C_{wd} + k_d \times C_{diet}}{k_2 + k_e + k_m + k_g}$  $C_f =$ 

#### Where:

- $k_1$  = gill uptake rate (L/Kg/d)
- C<sub>wd</sub> = freely dissolved concentration in water (ng/L)
- $k_d$  = dietary uptake rate (d<sup>-1</sup>)
- $C_{diet}$  = concentration in the diet (µg/kg)
  - $k_2$  = gill elimination rate (d<sup>-1</sup>)
  - $k_e$  = fecal egestion rate (d<sup>-1</sup>)
    - = metabolic rate (d<sup>-1</sup>)
    - = growth rate  $(d^{-1})$
    - = concentration in fish ( $\mu$ g/kg)







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k<sub>m</sub>

## **Gobas Model**

- Estimates fish body burdens for hydrophobic organic compounds
- Relies on a steady-state uptake model based on the approach of Gobas (1993 and 1995)
- Several sources provide equations for the rate constants (k<sub>2</sub>, k<sub>e</sub>, k<sub>m</sub> and k<sub>g</sub>) detailed in von Stackelberg et al. (2002)





# Human Health - Cancer Risk Calculation

# $CancerRisk = \frac{CSF \times IR_f \times C_f \times ED}{BW \times 1000000 \times AT}$

#### Where:

CSF

 $IR_{f}$ 

ED

BW

AT

C<sub>f</sub>

- Cancer Risk = incremental lifetime cancer risk
  - = cancer slope factor (mg/kg-day)<sup>-1</sup>
    - = annualized fish ingestion rate (g/day)
  - = concentration in fish ( $\mu$ g/kg)
  - = exposure duration (days)
    - = body weight (kg)
    - = averaging time (days)





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# Human Health - Non-Cancer Risk Calculation

HazardIndex =

 $RfD \times BW \times 1000000 \times AT$ 

 $IR_f \times C_f \times ED$ 

#### Where:

- HI = hazard index
- $IR_f$  = annualized fish ingestion rate (g/day)
- $C_f$  = concentration in fish (µg/kg)
- RfD = Reference dose (mg/kg-day)
- ED = exposure duration (days)
- BW = body weight (kg)
- AT = averaging time (days)







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# Ecological Risk - Toxicity Quotient Calculations

 $TQ = \frac{\sum (IR_f \times C_f \times Frac)}{TRV \times BW}$ 

Where:

TQ = Toxicity Quotient

 $IR_f$  = annualized ingestion rate (kg/day)

 $C_f$  = concentration in prey (mg/kg)

Frac = fraction in diet

TRV = toxicity reference value (mg/kg/day)

BW = body weight (kg)







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## **Toxicity Quotient Calculations**

- Compare predicted contaminant concentrations in tissue and/or daily dose estimates to appropriate toxicity reference values (TRVs).
- TRVs are levels of exposure associated with:
  - Lowest Observed Adverse Effects Levels (LOAELs)
  - No Observed Adverse Effects Levels (NOAELs)
- TRVs are contaminant- and species-specific and are developed based on laboratory or field studies.







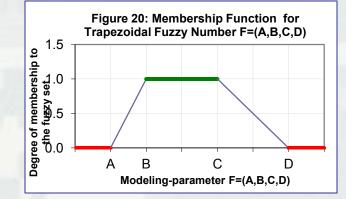
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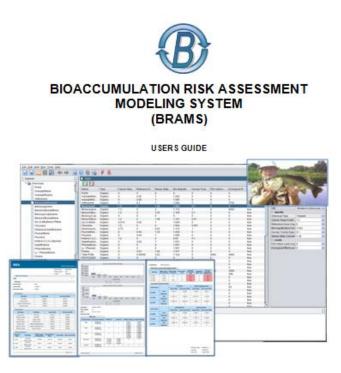
### Characterizing Parameter Uncertainty Through Interval Analysis or "Fuzzy Math"

- Four numerical values [A, B, C, D] represent the possible and probable range of a parameter.
- The interval [A,D] represents the possible range of the parameter.
  - A is the minimum possible value
  - D is the maximum possible value
- The range [B,C] is the probable range of the parameter.
  - ► A is the minimum plausible value
  - ► D is the maximum plausible value
- Fuzzy results yield both "worst case" and
  - "best estimates" simultaneously.





### **User Manual**



Prepared By: Kelsie Baker and John Thomas Vogel II U.S. Army Engineer Research and Development Center, Environmental Lab

Prepared For: U.S. Environmental Protection Agency Region 1 May 2012



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