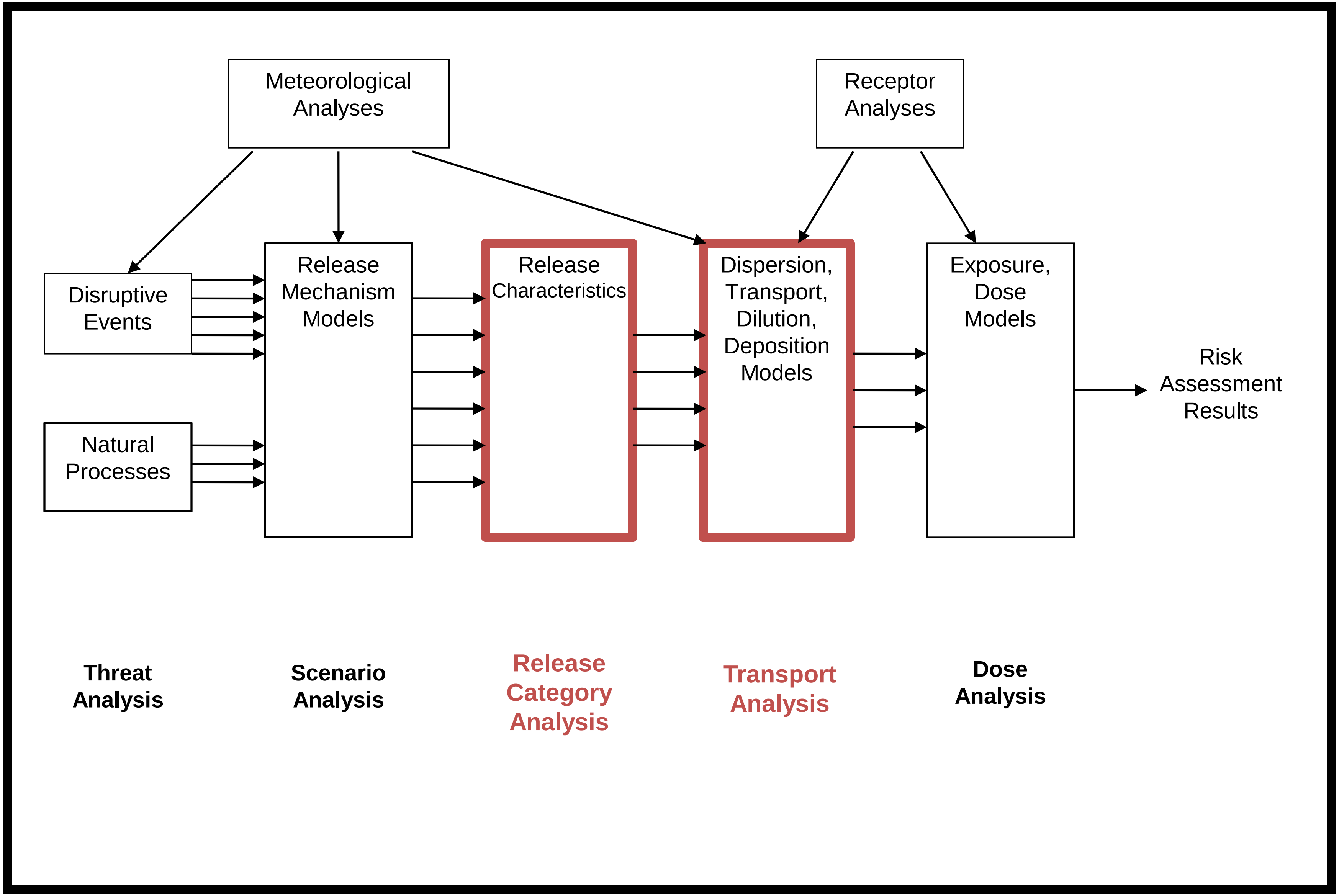
QUANTITATIVE RISK ASSESSMENT

Release and Transport Estimation

Steve Wampler, P.E., P.G.
Consultant – Hydrogeology and Geotechnical Engineering

Presented to the
U.S. Nuclear Waste Technical Review Board
Buffalo, New York
April 27, 2011

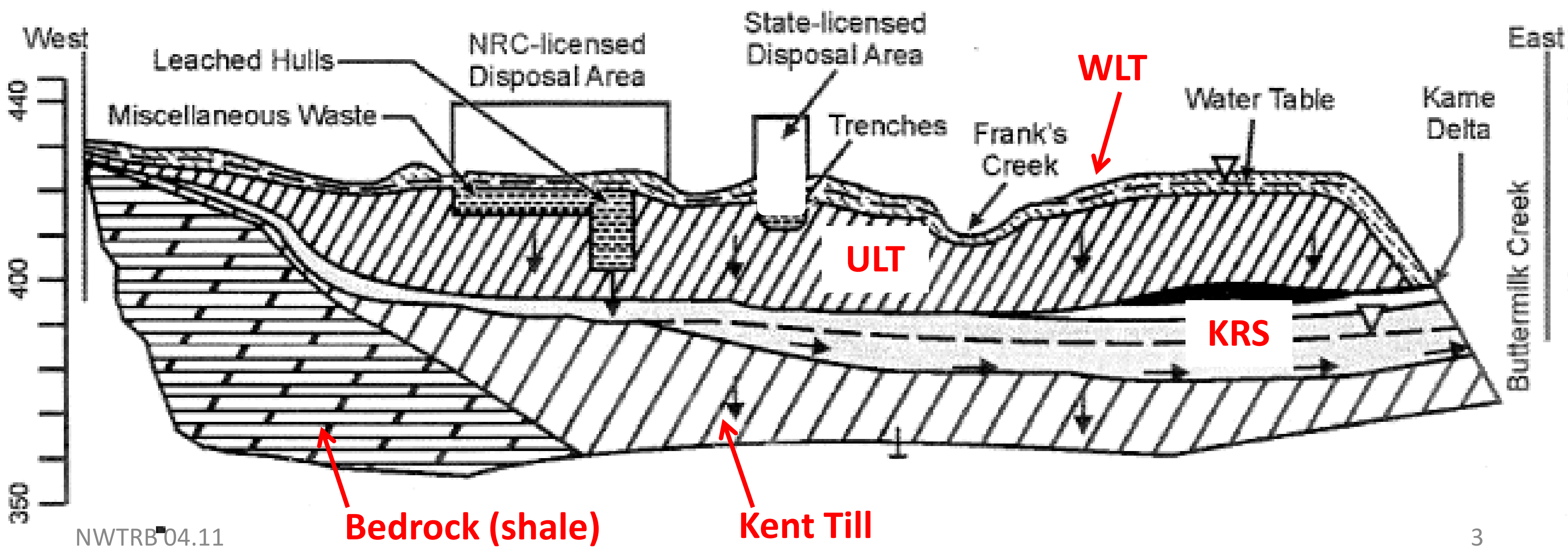

Meteorological Analyses
Receptor Analyses
Disruptive Events
Natural Processes
Release Mechanism Models
Release Characteristics
Dispersion, Transport, Dilution, Deposition Models
Exposure, Dose Models
Risk Assessment Results
Threat Analysis
Scenario Analysis
Release Category Analysis
Transport Analysis
Dose Analysis

SDA HYDROGEOLOGY

The 15-acre SDA is located on Glacial Till Plain the west side of the Buttermilk Creek valley, a 31.4 square mile drainage basin.

Subsurface materials important to shallow groundwater flow include a sequence of glacial (Pleistocene) deposits that is up to 500 feet thick overlying Devonian shale bedrock.

- Weathered Lavery Till (WLT)
- Unweathered Lavery Till (ULT)
- Kent Recessional Sequence (KRS)



SHALLOW HYDROGEOLOGIC UNITS IMPORTANT TO THE QRA

Unit	Thickness	Description	Hydraulic conductivity and Porosity
Weathered Lavery Till	**Ground surface to 10 feet deep**	**Weathered clay and silt** **Fractured and moderately porous throughout**	**$K = 1 \times 10^{-5}$ to 1×10^{-8} m/s** **$N_e = 0.001$ to 0.32**
Unweathered Lavery Till	**15 to 90 feet**	**Dense, clayey and silty till with some sand lenses** **Fracturing in the upper portion**	**$K = 1 \times 10^{-5}$ to 1×10^{-11} m/s** **$N_e = 0.01$ to 0.32**
Kent Recessional Sequence	**40 feet**	**Possible meltwater or lake deposit, gravel comprised of pebbles, small cobbles, and sand**	**$K = 1.0 \times 10^{-6}$ to 5.5×10^{-9} m/s** **$N_{e\,=}$ 0.19 to 0.27**

SIGNIFICANCE OF TRENCH CONTENTS ESTIMATION TO THE QRA

Trench contents are assumed to be:

- **75% solids**, a mix of disposed solids (about 67%) and soil (about 33%)
- **25% void space** filled with liquid or air (gas), with the differentiation between liquid and gas filling void space dependent upon fluid level in the trenches

Trench contents will be partly or fully exposed or fully or partly released to the environment depending upon the Release Mechanism and Scenario under consideration

The volume of solids and liquids released under different mechanisms and scenarios is important to the Transport Analysis and Dose Analysis aspects of the QRA

- **Overflow** - liquid-only releases resulting from rainfall following a cap breach
- **Groundwater movement** - liquid-only release via the groundwater pathway
- **Catastrophic failure** - liquid & solid releases resulting from slope instability

TRENCH OVERFLOW

- **Liquid-only releases result from rainfall following a cap breach**
- **Four initial trench fluid levels were considered**
- **The trench requiring the least precipitation to become filled is assumed to be representative of all SDA trenches.**

Trench Fluid Level	Precipitation Amount to Fill the Trench
Initial fluid levels at trench bottoms	47.1 inches
Initial fluid levels at March 2008 levels	24.7 inches
Initial fluid levels at WLT / ULT transition	8.7 inches
Initial fluid levels at trench tops	0.0 inches

EVALUATION OF RELEASE ALONG THE GROUNDWATER PATHWAY

The methodology and analytical models used were developed by Dr. Shlomo P. Neuman as part of the expert elicitation process.

The one-dimensional groundwater flow and contaminant transport estimation method suggested by Dr. Neuman are "highly simplified" models intended to provide reasonable characterization of a "relatively complex and heterogeneous three-dimensional saturated-unsaturated domain."

Deterministic properties:

Soil density, flow dimensions, head levels

Conservative assumptions:

Radioactive decay – set at a sufficiently high value to be essentially ignored, R = 1
Retardation coefficient - all contaminants considered to be non-sorbing, Kd = 0

Model properties varied probabilistically:

Hydraulic conductivity (Kh and Kv)
Advective porosity

GROUNDWATER FLOW AND RADIONUCLIDE TRANSPORT PATHWAYS EVALUATED

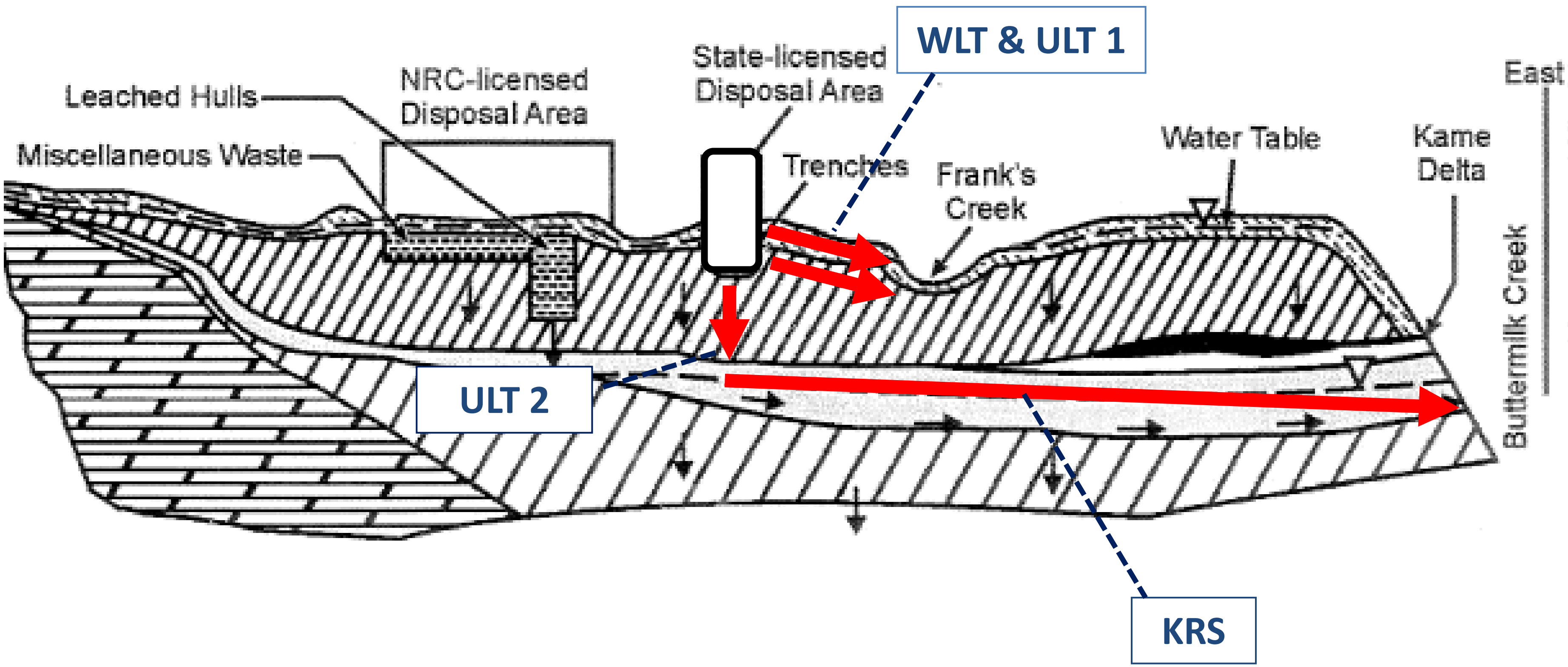
WLT Pathway: Horizontal flow through the WLT from trenches to surface environment

ULT Pathway 1: Horizontal flow through the ULT from trenches to surface environment

ULT Pathway 2: Vertical flow through the ULT and the unsaturated zone of the KRS from trenches to the saturated KRS

KRS Pathway: Horizontal flow through the KRS from point beneath trenches to the surface environment.

GROUNDWATER PATHWAYS EVALUATED



SLOPE STABILITY EVALUATION

The actual topography of three slope cross-sections were evaluated using WinSTABL

North	slope between northern limits of Trenches 2, 3, 4, and 5 and Erdman Brook
East (N)	slope between Trenches 1 and 2 and Frank's Creek
East (S)	slope between Trench 8 and Frank's Creek.

Circular failure surfaces were generated between a low point at the base of slope and high points varying from 100 to 500 feet away on top of disposal trench caps

Each WinSTABL analysis run considered 200 potential slip surfaces, ranging from:

- **shallow-seated surfaces** that extended only into the uppermost soil layers (and not into trench waste)
- **deep-seated surfaces** that extended relatively deeply into the tills and penetrated trench waste

SLOPE STABILITY EVALUATION

Soil properties, groundwater levels, and seismic loading were varied to provide a wide range of conditions to be modeled by WinSTABL.

For each of the 3 slope configurations modeled, the following variations on conditions were considered:

3 soil property parameter sets **3 water levels** **5 seismic accelerations**	**For 3 different slope configurations, this provided 135 separate models**

Probabilities of occurrence were assigned to each variation of soil properties, water levels, and seismic accelerations.

For each set of properties (parameters, water levels, and accelerations) WinSTABL was used to determine failure slope configurations and factors of safety (against failure) for **200 different surfaces.**

For 135 different models, this was 27,000 different failure surfaces

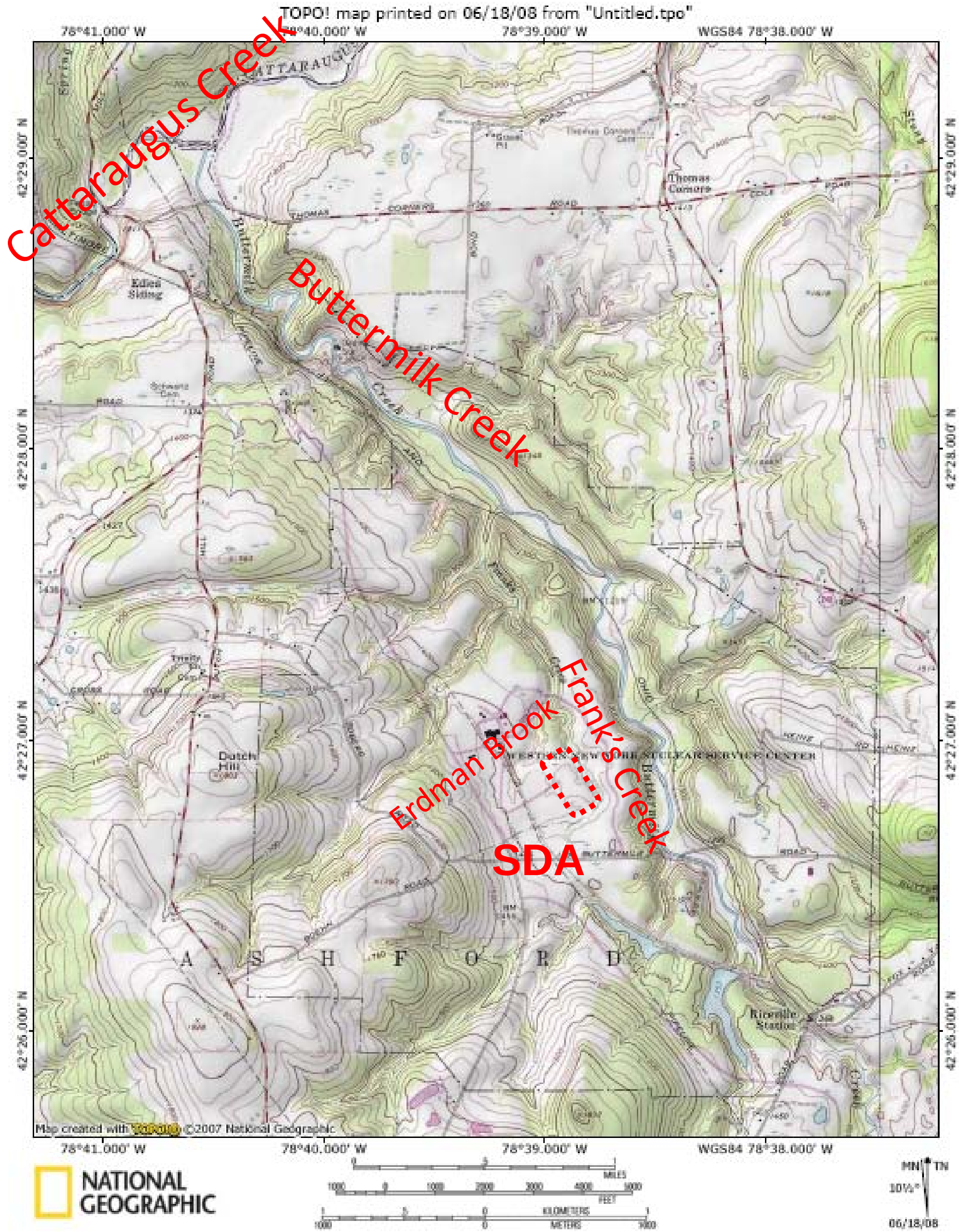
SOLID AND FLUID TRANSPORT IN SURFACE WATER

The "environment" for this evaluation was considered to be:

- stream channel areas in the valleys of Erdman Brook and Frank's Creek downstream from the SDA, and
- stream channel area in the valley of Buttermilk Creek from near the SDA to Cattaraugus Creek

Transport analyses considered two mechanisms by which a human receptor could experience exposure as a result of releases from SDA trenches

- **Transport of impacted liquids** (containing radionuclides) as a portion of surface-water flow moving downstream under various flow conditions, and
- **Transport of impacted solids, or sediment,** (containing radionuclides) as suspended sediment or bed load by surface-water flow moving downstream under various flow conditions.


TOPO! map printed on 06/18/08 from "Untitled.tpo"
78°41.000' W
78°40.000' W
78°39.000' W
WGS84 78°38.000' W
42°29.000' N
42°28.000' N
42°27.000' N
42°26.000' N
Cattaraugus Creek
Buttermilk Creek
Frank's Creek
Erdman Brook
SDA
Thomas Corners
Edies Siding
Dutch Hill
WESTERN NEW YORK NUCLEAR SERVICE CENTER
A S H F O R D
Riceville Station
Map created with TOPO! ©2007 National Geographic
NATIONAL GEOGRAPHIC
MILES
FEET
KILOMETERS
METERS
MN
TN
06/18/08

SOLID AND FLUID TRANSPORT IN SURFACE WATER

Transport of fluids and solids originating at SDA release points was analyzed using surface-water modeling methods under a range of precipitation events

- **Hydrologic Modeling System (HEC-HMS)** was used to determine stream hydrographs for the selected precipitation events

- **River Analysis System (HEC-RAS)** was used to model flooding potential resulting from the selected precipitation events and quantify potential solids mobilization, transport, and deposition

SOLID AND FLUID TRANSPORT IN SURFACE WATER

Six precipitation conditions were considered in the HEC models to determine the range of stream flows within the watershed that could mobilize and transport liquids or solids

- These precipitation conditions, and the duration of resultant peak flows, included:

Precipitation Condition	Duration of Peak Flow (hours)
Normal flow	NA
2-in / 24-hr Storm	162
4-in / 24-hr Storm	158
8-in / 24-hr Storm	160
12-in / 24-hr Storm	161
16-in / 24-hr Storm	158
24.9-in / 24-hr Storm	150

FLUID TRANSPORT IN SURFACE WATER

Fluid transport considered introduction of various SDA trench fluids volumes into surface-water, with the release volume dependent upon the nature of the release under consideration.

The releases to surface water considered included:

- **Slow continuous discharge of groundwater mixed with trench fluids** *(such as by overflow or groundwater discharge)*
- **Rapid release of the entire fluid contents of one or more SDA trenches** *(such as by catastrophic trench failure)*

Release volume and timing were considered with stream flow to estimate the dilution of trench fluids at potential points of exposure.

SOLID TRANSPORT IN SURFACE WATER

- **Solids (sediment) originating at the SDA is mobilized, transported and deposited under all 7 of the stream flow conditions considered**
- **Flow volume influences where SDA-originated sediment is deposited, but SDA sediment is deposited along some stream segments under each flow condition**

For example

- ✓ **Along Frank's Creek segments**, SDA-originated sediment comprises 20% to 40% of the deposited sediment under five of the seven flow conditions considered
- ✓ **Along Buttermilk Creek segments**, SDA-originated sediment comprises between 1% and 5% of the deposited sediment under six of the seven flow conditions considered

SOLID TRANSPORT IN SURFACE WATER

Considering the modeled sediment deposition estimates for the Frank's and Buttermilk Creek stream segments considered, conservative assumptions were made with regard to the deposition of "diluted sediment" originating at the SDA source

- **Human receptors in the Frank's Creek stream segments were assumed to encounter sediment** <u>consisting of 50% SDA source solids and 50% sediment not originating at the SDA</u>

- **Human receptors in the Buttermilk Creek stream segments were assumed to encounter sediment** <u>consisting of 10% SDA source solids and 90% sediment not originating at the SDA</u>