RPS ASA
Modeling Crude-by-Rail Releases Overland and into Aquatic Environments to Assess Risk

November 2016

Matthew Horn, Ph.D.
Senior Scientist
Matt.Horn@rpsgroup.com

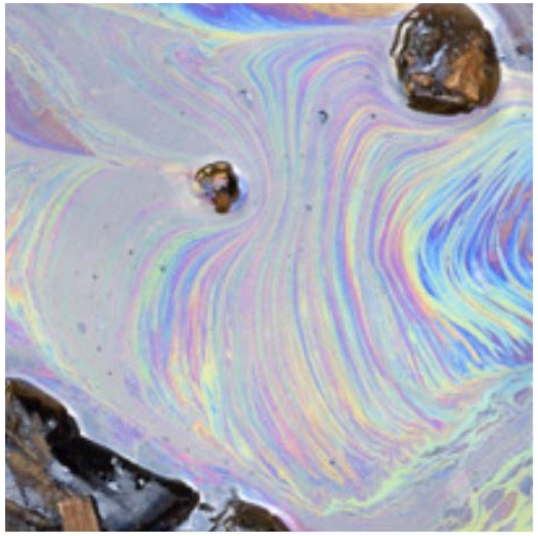
RPS ASA
South Kingstown, RI 02874, USA
+1 (401) 789 - 6224

asascience.com
rpsgroup.com

Secure & Stable
ADDING VALUE

Overview

- Introduction to RPS ASA
- Selected Projects of Interest
- Framing the Situation
  - Why we model
  - Regulations
- OILMAP Land
- SIMAP



RPS ASA Overview

- Formally known as Applied Science Associates, now member of the RPS Group plc.
- RPS ASA is a global science and technology solutions company. Through consulting, environmental modeling, and application development, ASA helps a diverse range of clients solve their issues of concern.
- Since 1979 and in over 100 countries, ASA has been providing services and custom solutions to sectors including energy, environment, construction, defense, security, emergency management, transportation, and shipping.
- Developer of commercially available oil spill and contaminant models for nearly 30 years OILMAP, SIMAP, CHEMMAP, OILMAP Land, OILMAP Deep, as well as other software (EDS, SARMAP)

- **Provide:** Expert Modeling / Technical Reporting / Testimony ...and more

Selected Projects of Interest

Rail Projects

- Shell Puget Sound Refinery - Anacortes Refinery Unloading Facility
- Tesoro Savage Rail Risk Assessment

Pipeline Projects

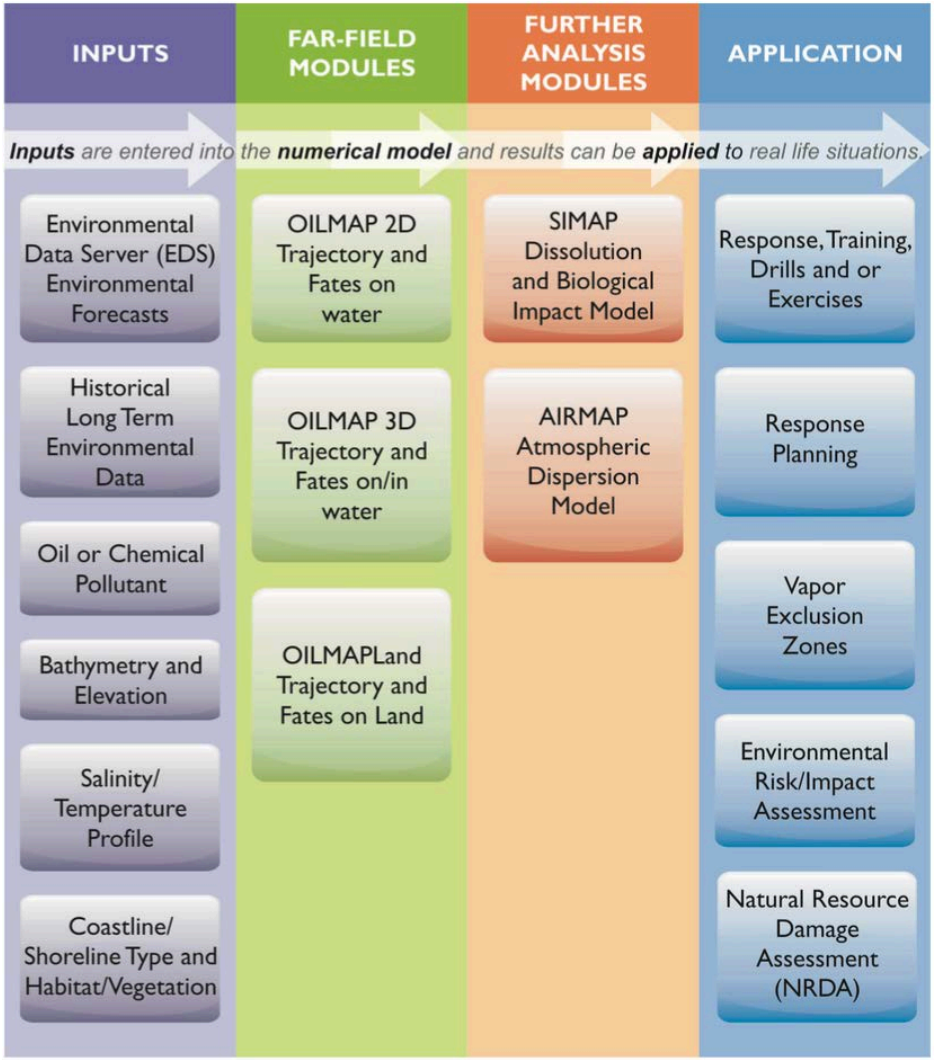
- Enbridge – Northern Gateway Pipeline
- Enbridge – Line 3 Replacement Program (U.S. and Canada)
- Kinder Morgan – Trans Mountain Pipeline System
- TransCanada – Energy East Pipeline
- Energy Transfer – Dakota Access Pipeline

Offshore Projects

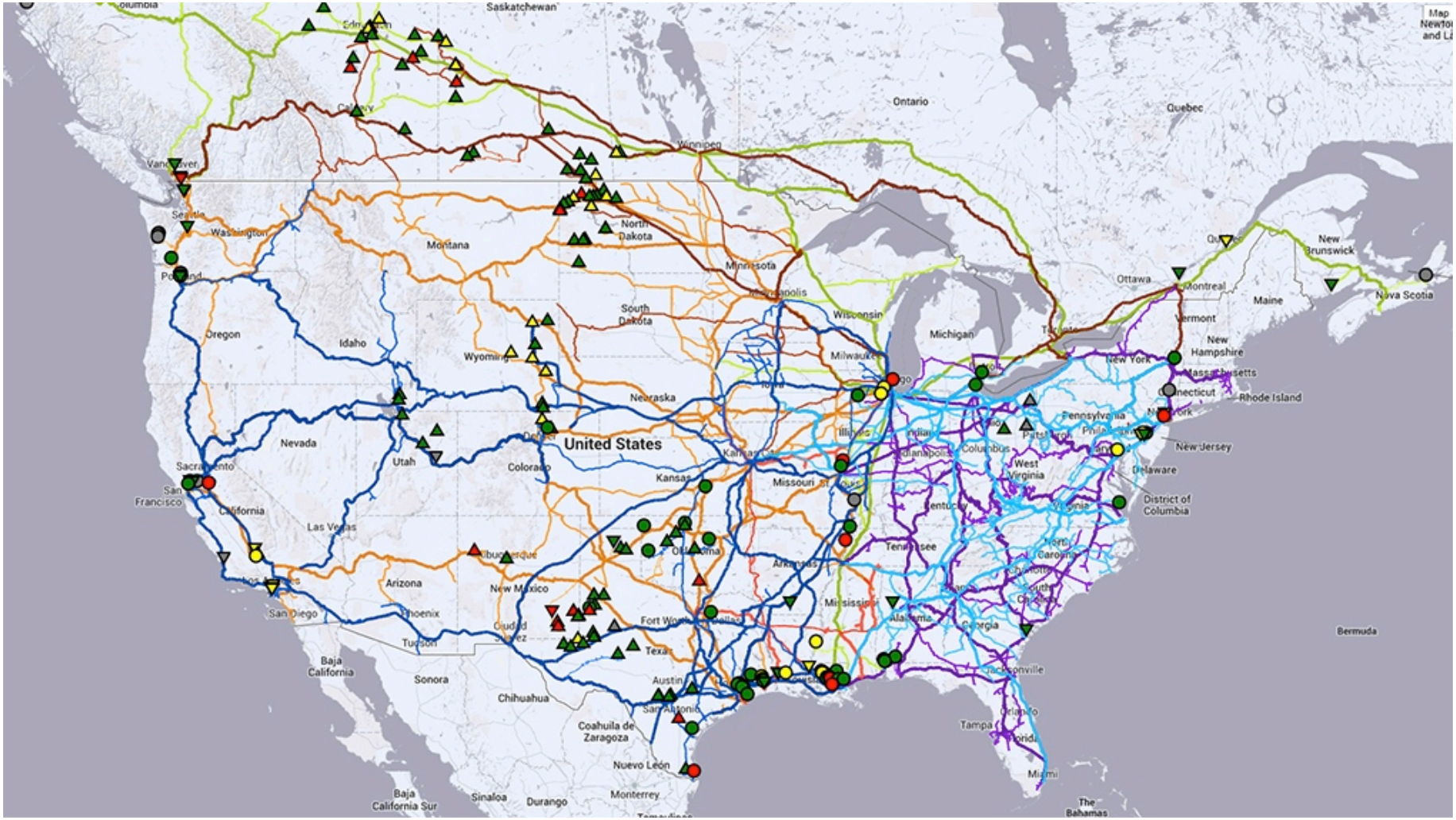
- Deepwater Horizon Natural Resource Damage Assessment (NRDA)
- Shell Shelburne Basin Exploration Drilling Program

RPS ASA Services

- Trajectory Modeling Services
- Area Risk Assessments (ARA)
- Environmental Risk Assessments (ERA)
- Consequence Analysis
- Environmental Assessments (EA's)
- Environmental Impact Assessments (EIA)
- Net Environmental Benefit Analysis (NEBA)
- Natural Resource Damage Assessment (NRDA)
- Cost / Benefit Analysis
- Biological Services
- Oil Spill Response Planning (OSRP)
- MetOcean, Environmental Data Services (EDS), Environmental Data Connector (EDC)
- Data Management (GIS & Integration)



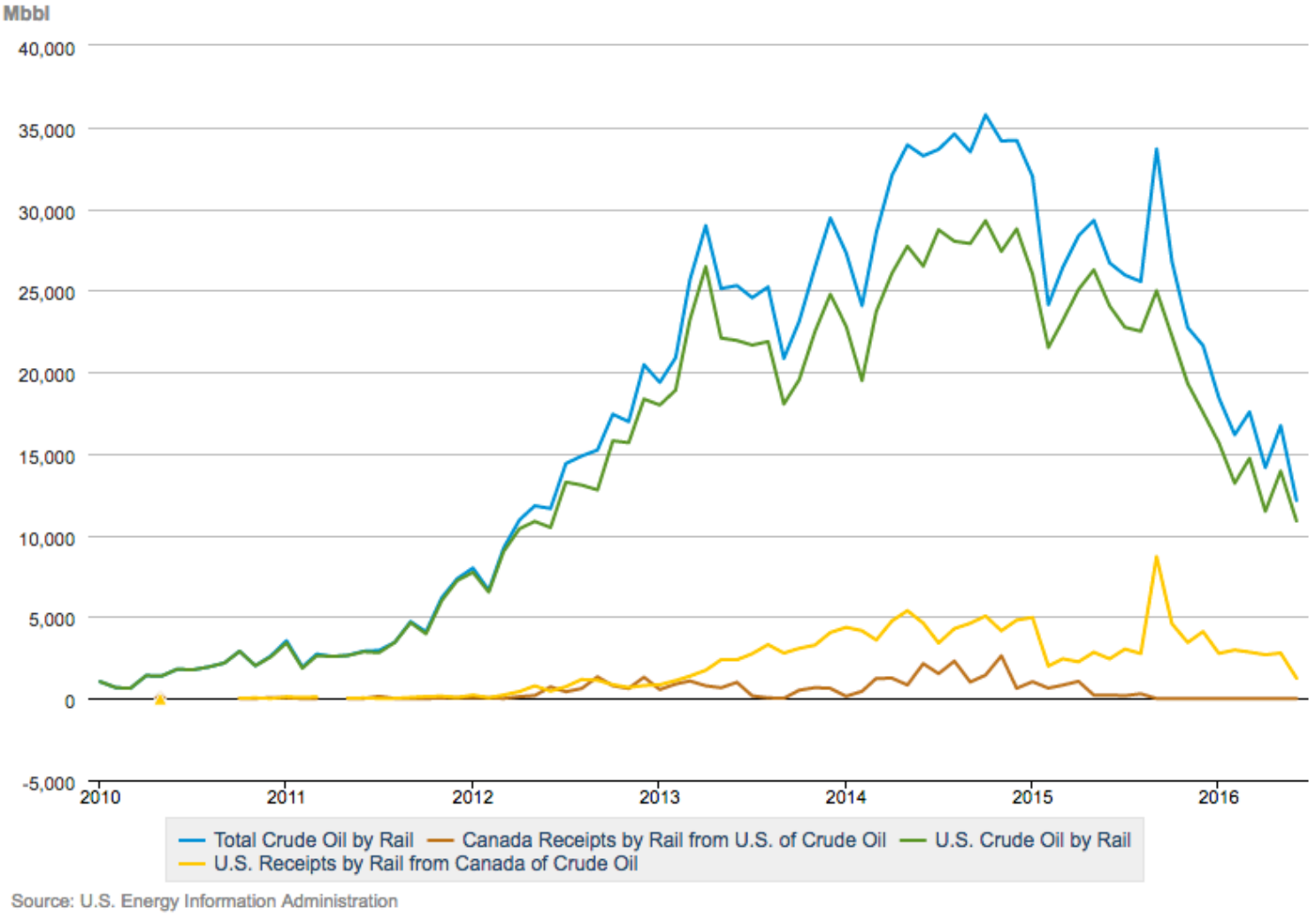
North American Rail Network and Crude-by-Rail Facilities



Source: http://priceofoil.org/rail-map/

Movements of Crude Oil and Selected Products by Rail

- Large increase in the volume of crude oil shipped by rail between 2011-2015



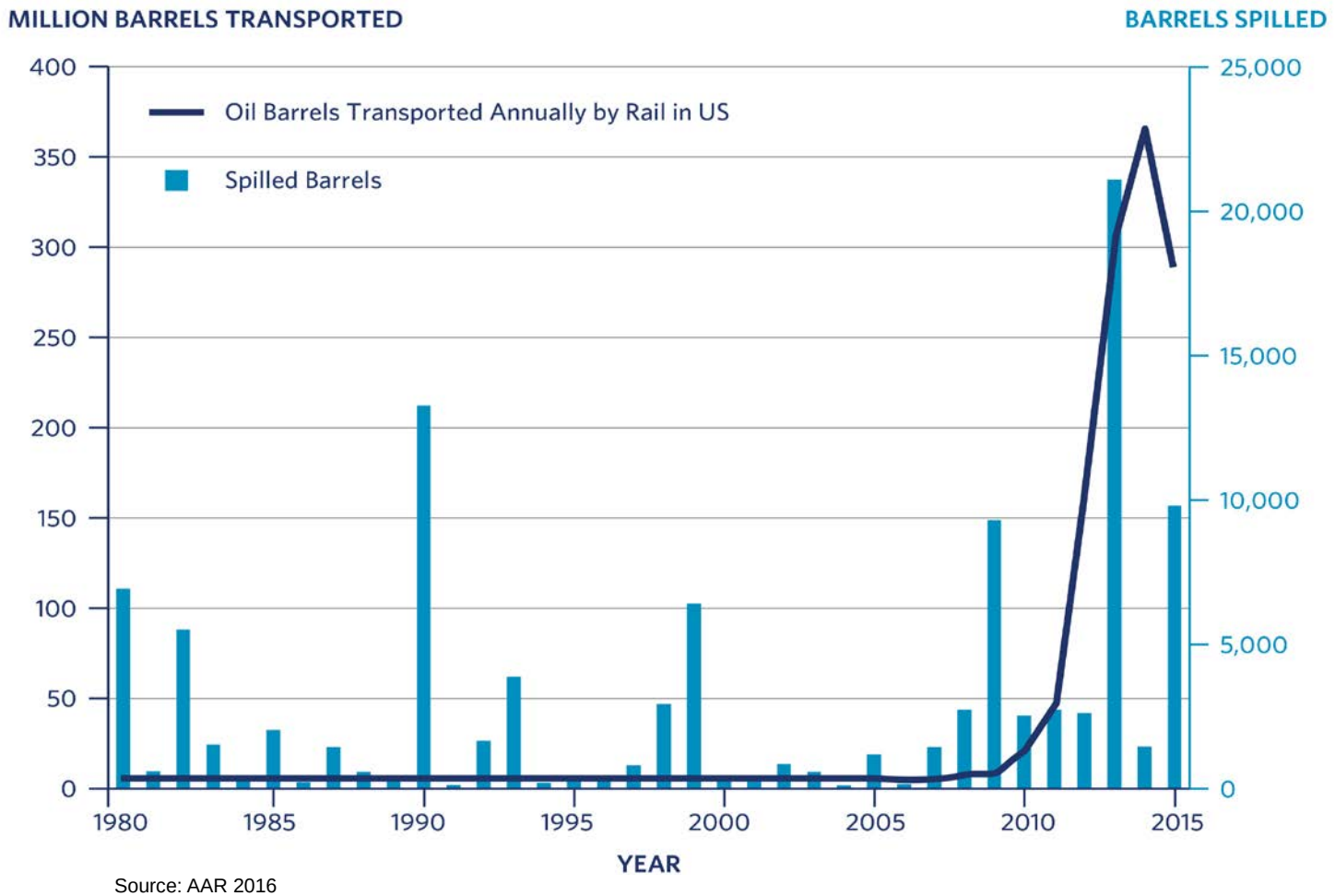
Source: U.S. Energy Information Administration

Steady:
West Coast

Declining:
East Coast
Gulf of Mexico

Movements of Crude Oil and Selected Products by Rail

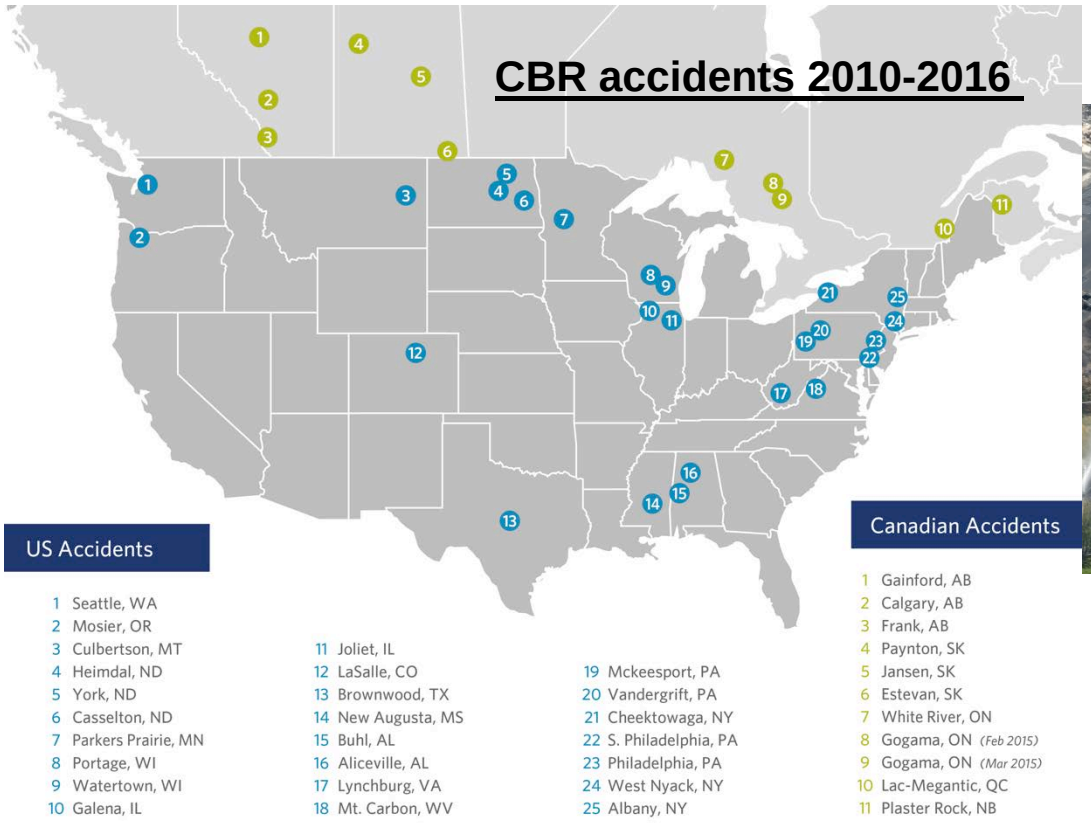
- Along with the increase in volume of crude oil shipped by rail, there has also been an increase in the number of barrels spilled (1980-2015).



Source: AAR 2016

Movements of Crude Oil and Selected Products by Rail

- Despite >99.9% of cargo arriving safely, the public perception of crude by rail shipments is skewed to a handful of unlikely but catastrophic events



US Accidents

1 Seattle, WA
2 Mosier, OR
3 Culbertson, MT
4 Heimdal, ND
5 York, ND
6 Casselton, ND
7 Parkers Prairie, MN
8 Portage, WI
9 Watertown, WI
10 Galena, IL
11 Joliet, IL
12 LaSalle, CO
13 Brownwood, TX
14 New Augusta, MS
15 Buhl, AL
16 Aliceville, AL
17 Lynchburg, VA
18 Mt. Carbon, WV
19 Mckeesport, PA
20 Vandergrift, PA
21 Cheektowaga, NY
22 S. Philadelphia, PA
23 Philadelphia, PA
24 West Nyack, NY
25 Albany, NY

Canadian Accidents

1 Gainford, AB
2 Calgary, AB
3 Frank, AB
4 Paynton, SK
5 Jansen, SK
6 Estevan, SK
7 White River, ON
8 Gogama, ON *(Feb 2015)*
9 Gogama, ON *(Mar 2015)*
10 Lac-Megantic, QC
11 Plaster Rock, NB

Based on a review of the Pipeline and Hazardous Materials Safety Administration (PHMSA) database of accidents involving crude-by-rail shipments (USDOT 2016).

Pipeline Regulations

Code of Federal Regulations, Title 49, Parts 190 – 199
Hazardous Liquid Integrity Management
HCA Analysis provides predictions of intersection of HCA "could affect" areas and oil released from the pipeline

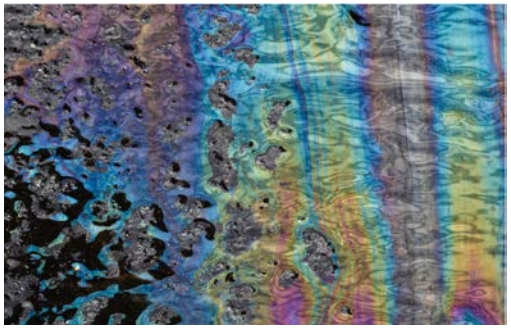
- High Consequence Area (HCA)
  - Drinking water
  - Commercially navigable waterway
  - Urbanized areas and other populated areas
  - Unusually sensitive environmental areas
- Determining Affect
  - Direct – HCA crossed by pipeline centerline
  - Indirect –HCA reached by oil spill plume
- HCA boundaries change and new HCAs must be incorporated into the Baseline Assessment Plan within one year

Offshore and Inland Water Regulations

- Canadian Waters - CEAA and Transport Canada oversees regulatory requirements and are advised by ECCC (previously EC) and DFO

- Offshore (seaward of coastline) - BSEE oversees regulatory requirements for pollution control for offshore.
  - 30 CFR 254 requires worst case trajectory modeling

- Inland Waters - EPA and ACOE oversees regulatory requirements for pollution control for all inland waters
  - Spill Prevention, Control, and Countermeasure (SPCC) Rule
  - Facility Response Plan (FRP) Rule



Rail Regulations

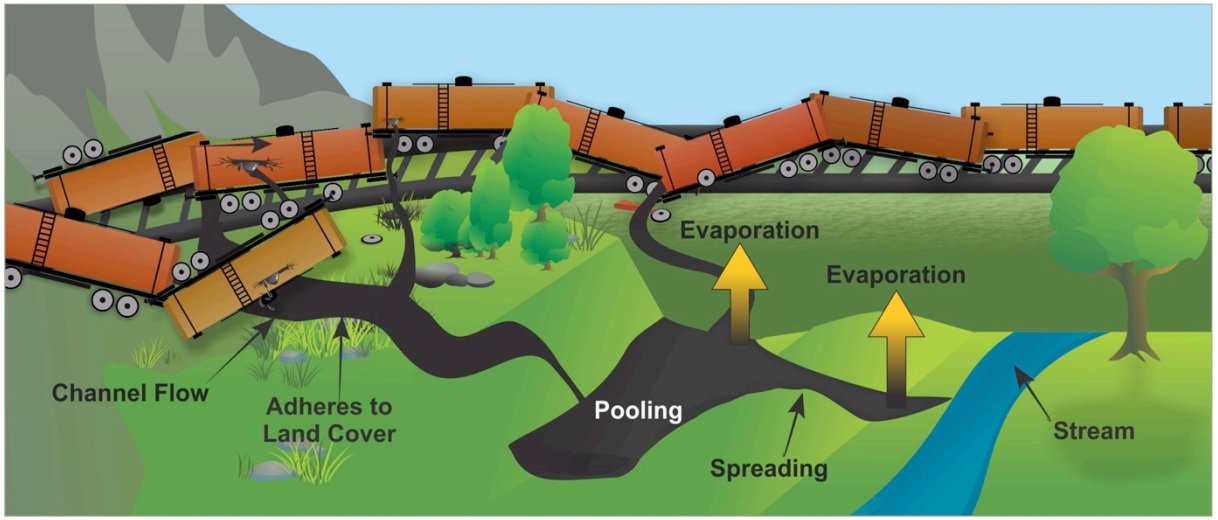
Key Players:

1. Transport Canada (TC)
2. Canadian Transportation Agency (CTA)
3. Railway Association of Canada (RAC)
4. U.S. DOT Federal Railroad Administration (FRA)
5. Pipeline and Hazardous Materials Safety Administration (PHMSA)
6. National Transportation Safety Board (NTSB)
7. Transportation Security Administration (TSA)
8. Federal Emergency Management Agency (FEMA)

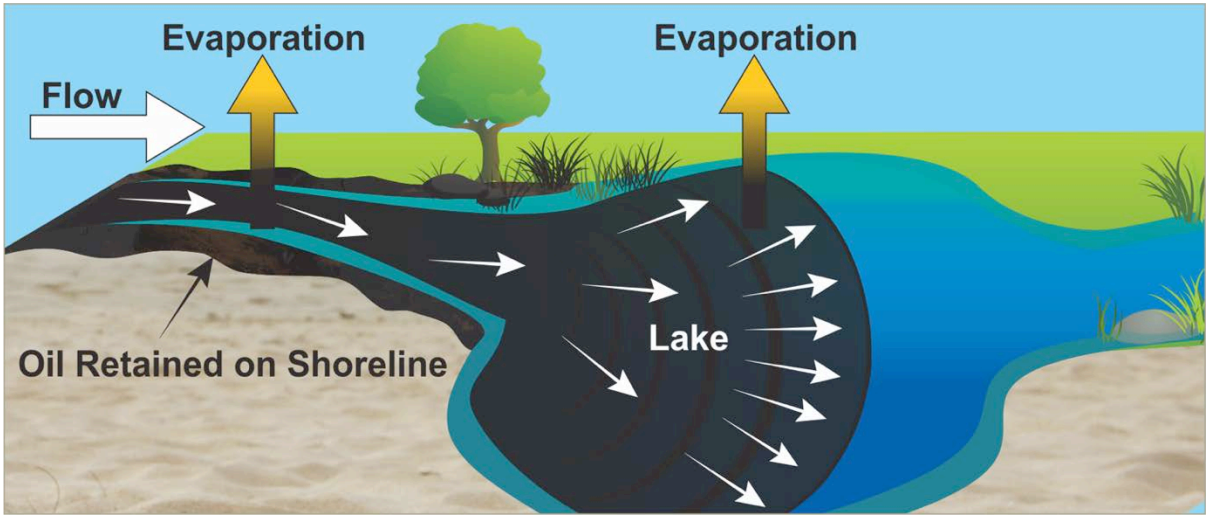
Selected Regulations:

1. Enhanced tank car design
2. Braking controls and speed restrictions
3. Proper classification and treatment (conditioning) of transported crude (Bakken)
4. Technical information for local officials and first responders (State Emergency Response Commissions - SERCs)
5. First responder training
6. **Risk Assessments – need for <u>Quantitative Analyses</u>**

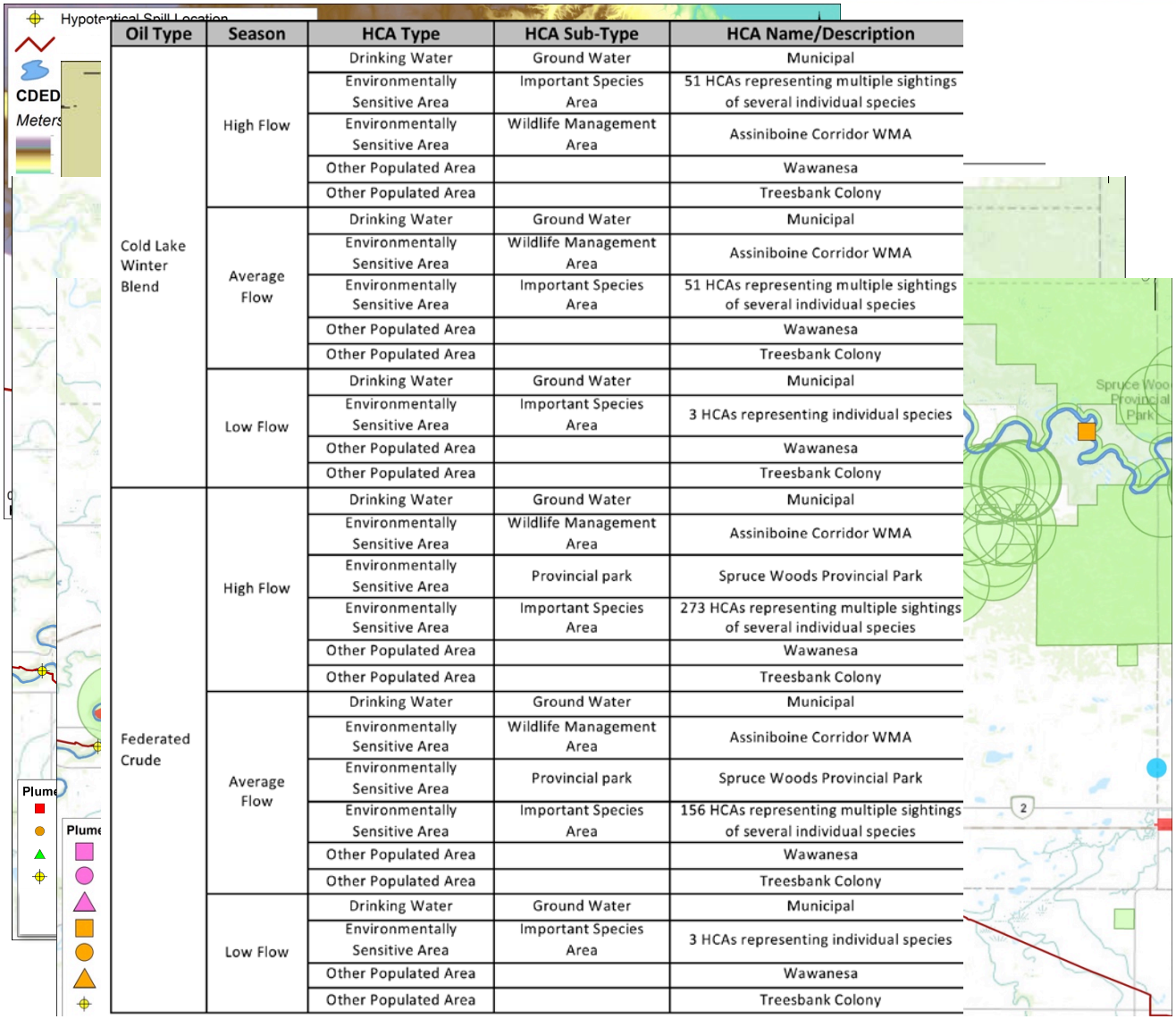
Modeled Processes – Overland Flow



Modeled Processes – Surface Water Network



OILMAP Land - 2D Trajectory and Fates

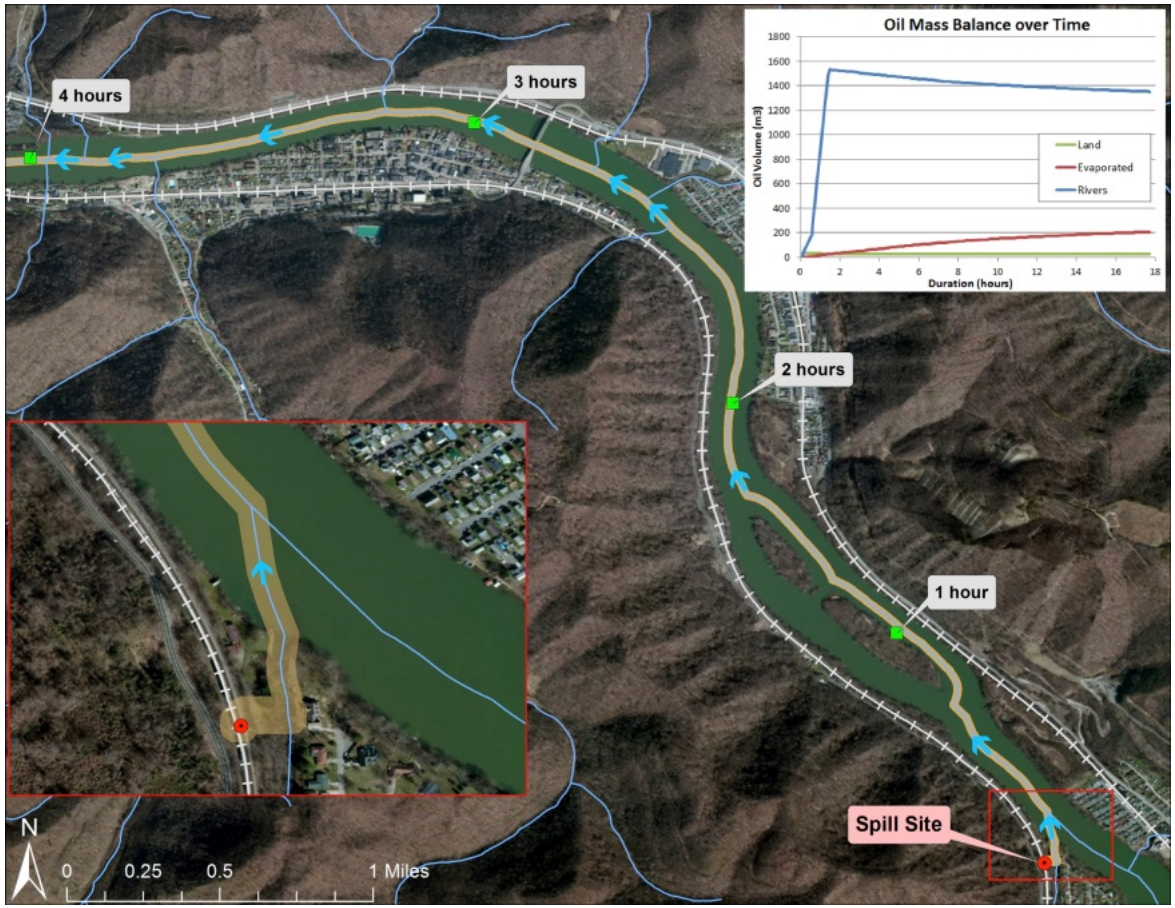


Oil Type	Season	HCA Type	HCA Sub-Type	HCA Name/Description
Cold Lake Winter Blend	High Flow	Drinking Water	Ground Water	Municipal
		Environmentally Sensitive Area	Important Species Area	51 HCAs representing multiple sightings of several individual species
		Environmentally Sensitive Area	Wildlife Management Area	Assiniboine Corridor WMA
		Other Populated Area		Wawanesa
		Other Populated Area		Treesbank Colony
	Average Flow	Drinking Water	Ground Water	Municipal
		Environmentally Sensitive Area	Wildlife Management Area	Assiniboine Corridor WMA
		Environmentally Sensitive Area	Important Species Area	51 HCAs representing multiple sightings of several individual species
		Other Populated Area		Wawanesa
		Other Populated Area		Treesbank Colony
	Low Flow	Drinking Water	Ground Water	Municipal
		Environmentally Sensitive Area	Important Species Area	3 HCAs representing individual species
		Other Populated Area		Wawanesa
		Other Populated Area		Treesbank Colony
Federated Crude	High Flow	Drinking Water	Ground Water	Municipal
		Environmentally Sensitive Area	Wildlife Management Area	Assiniboine Corridor WMA
		Environmentally Sensitive Area	Provincial park	Spruce Woods Provincial Park
		Environmentally Sensitive Area	Important Species Area	273 HCAs representing multiple sightings of several individual species
		Other Populated Area		Wawanesa
		Other Populated Area		Treesbank Colony
	Average Flow	Drinking Water	Ground Water	Municipal
		Environmentally Sensitive Area	Wildlife Management Area	Assiniboine Corridor WMA
		Environmentally Sensitive Area	Provincial park	Spruce Woods Provincial Park
		Environmentally Sensitive Area	Important Species Area	156 HCAs representing multiple sightings of several individual species
		Other Populated Area		Wawanesa
		Other Populated Area		Treesbank Colony
	Low Flow	Drinking Water	Ground Water	Municipal
		Environmentally Sensitive Area	Important Species Area	3 HCAs representing individual species
		Other Populated Area		Wawanesa
		Other Populated Area		Treesbank Colony

- **Site Specific Inputs**
  - Elevation
  - Land Cover
  - Shore Type
  - River Width
  - River Flow
  - Temperature
  - Wind Speed
- **Site Specific Outputs**
  - Trajectory (pathway)
  - Travel Time
  - Spatial Extent
  - Mass Balance
  - HCA's

Response and Preparedness with OILMAP Land: Downstream Travel Time and Mass Balance

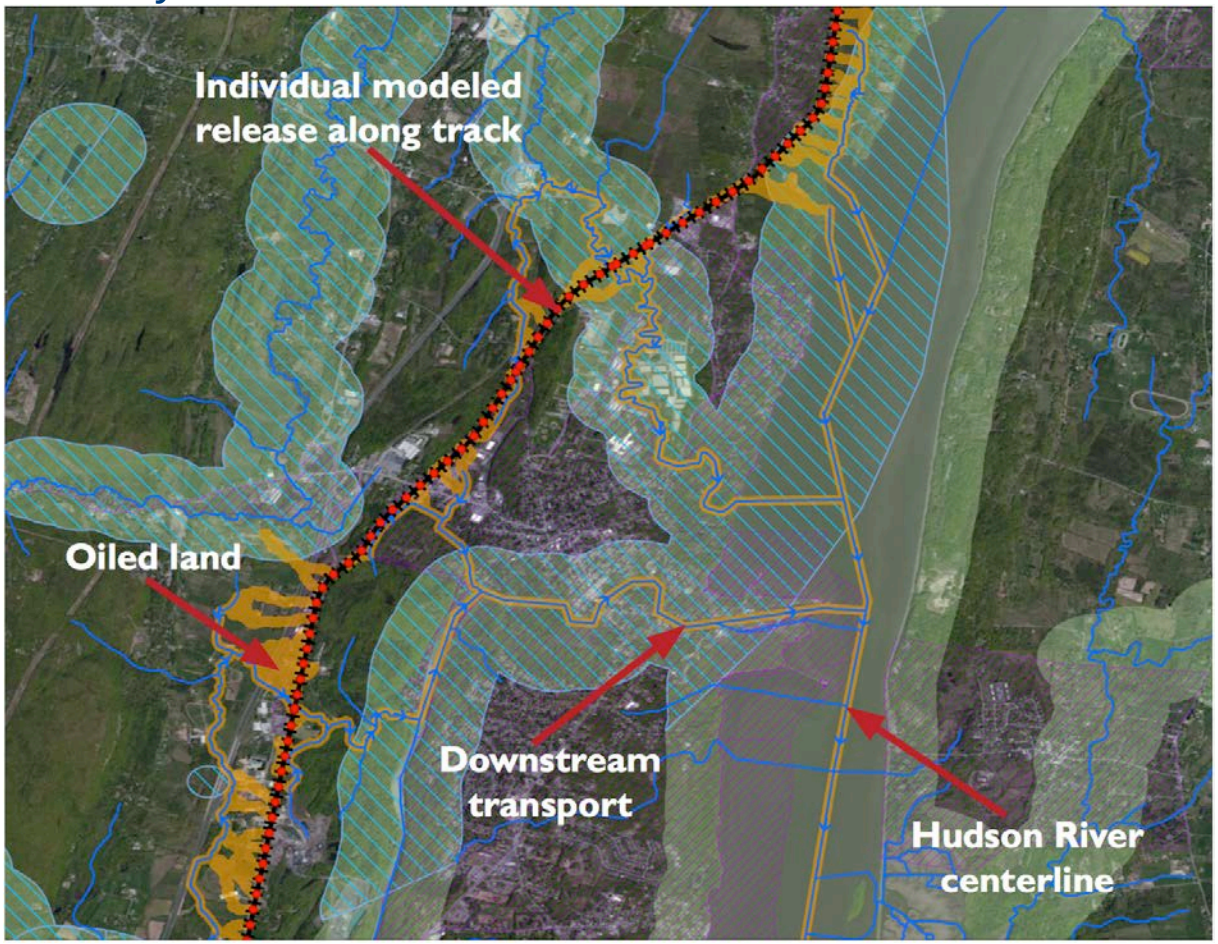
- Predict the overland and downstream trajectory and fate to provide conservative estimates of the extent (where) and timing (when) of potential oiling to better focus response activities.



Hypothetical release at Mt. Carbon, WV in spring

Response and Preparedness with OILMAP Land: Spatial Extent

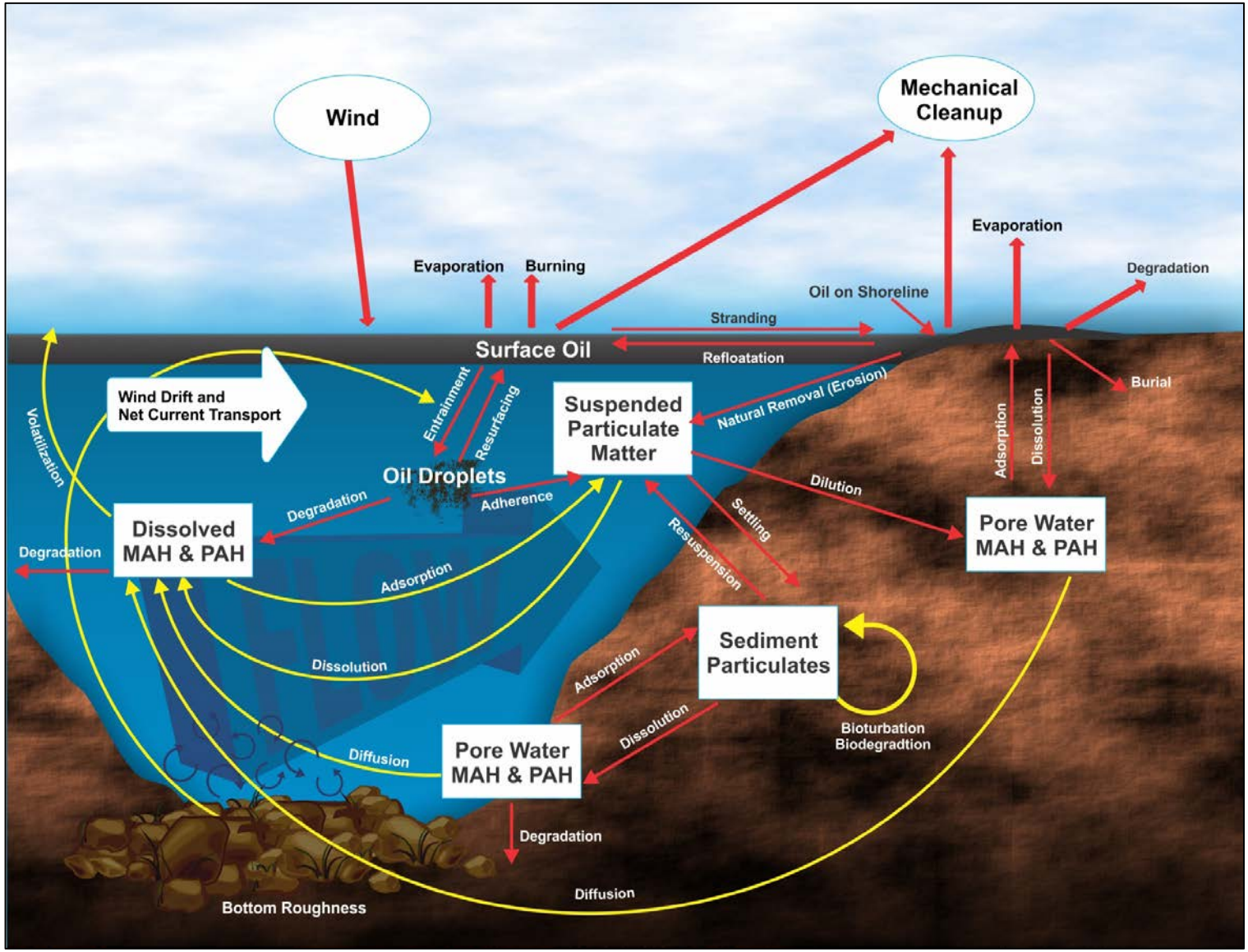
- Provide overland and downstream trajectory and fate predictions to identify the spatial extent and possible high consequence areas (HCAs) along the rail corridor that may be affected in the event of a release.



Hypothetical release on the Hudson River

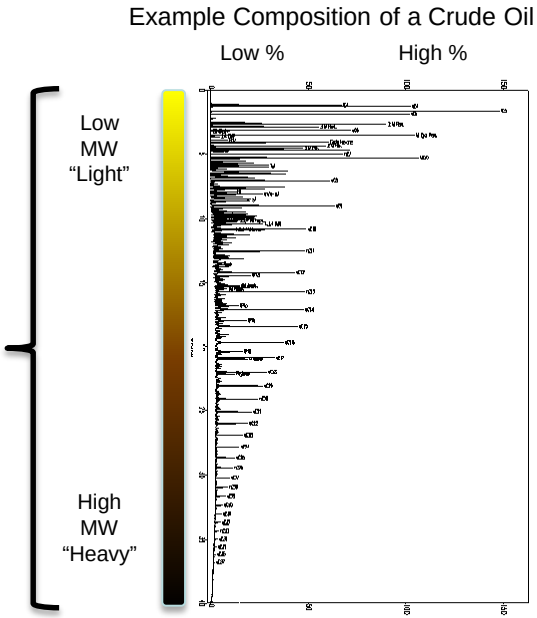
- Watercourse
- Oil
- Water Supply
- Populated Area
- Environmental Sensitivity

SIMAP - 3D Oil Fate Processes Along Shorelines



Chemical Parameters

***Each* oil has a *different* composition**



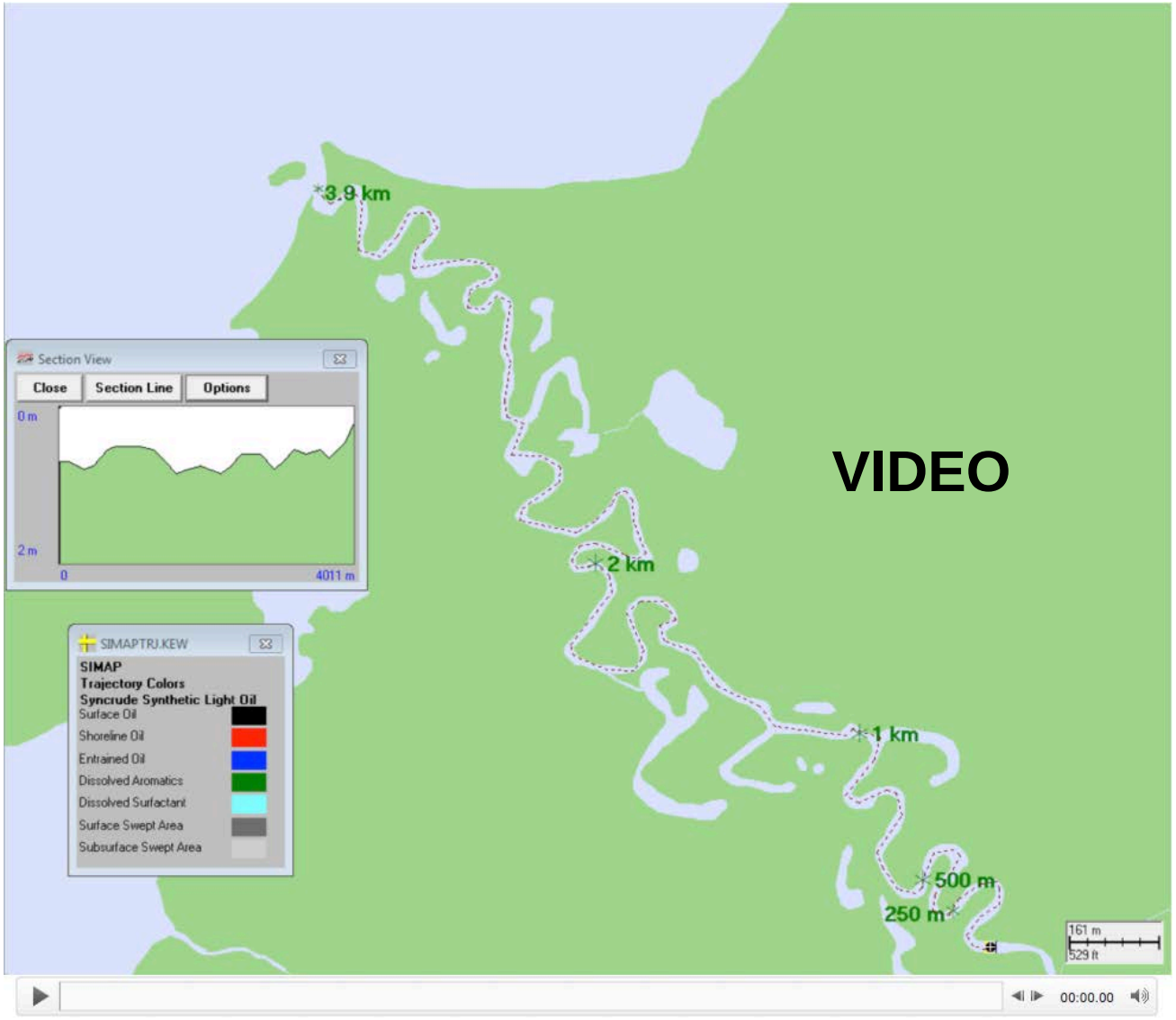
***Each* line is a *different* chemical**

***Each* chemical has *different* properties**

- Simplify each oil by grouping like-compounds (pseudo-component approach):

Characteristic	Volatile and Highly Soluble	Semi-volatile and Soluble	Low Volatility and Slightly Soluble	Residual (non-volatile and very low solubility)
Distillation cut	1	2	3	4
Boiling Point (°C)	< 180	180 - 265	265 - 380	>380
Molecular Weight	50 - 125	125 - 168	152 - 215	> 215
Log(K_{ow})	2.1-3.7	3.7-4.4	3.9-5.6	>5.6
Aliphatic pseudo-components: Number of Carbons	volatile aliphatics: C4 – C10	semi-volatile aliphatics: C10 – C15	low-volatility aliphatics: C15 – C20	non-volatile aliphatics: > C20
Aromatic pseudo-component name: included compounds	MAHs: BTEX, MAHs to C3-benzenes	2 ring PAHs: C4-benzenes, naphthalene, C1-, C2-naphthalenes	3 ring PAHs: C3-, C4-naphthalenes, 3-4 ring PAHs with log(K_{ow}) < 5.6	>4 ring aromatics: PAHs with log(K_{ow}) > 5.6 (**very low solubility**)

Trajectory in A Small River and Lake



VIDEO

Each point is an individual Lagrangian Element (LE) representing a portion of the total volume of released oil.

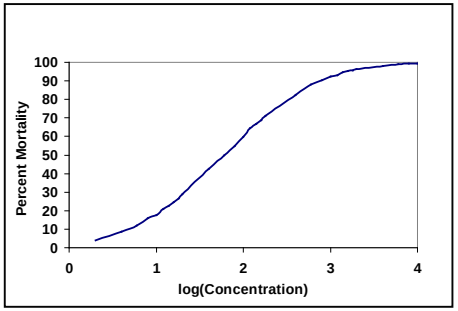
The trajectory (movement) of each LE is calculated *individually* using site-specific and location-specific wind and current data.

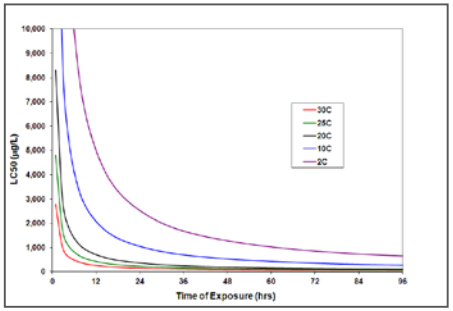
The fate (behavior) of each LE is calculated *individually* for each chemical and physical parameter as well as for various pseudo-components of the oil.

Biological Impact Analysis

- Use spatially and temporally varying oil concentration, thickness, and mass throughout the modeled domain
- Estimate the short term (acute) exposure of biota to floating oil and subsurface oil contaminants (in-water and sediments).

Exposure is a function of Concentration & Duration

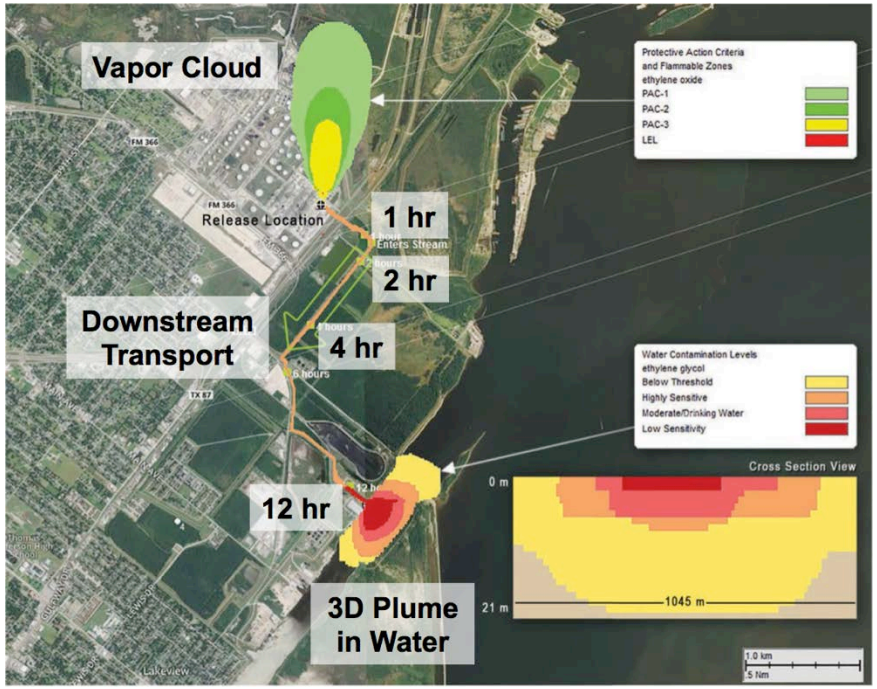




- Determine the acute toxicity (mortality) for multiple sensitivity thresholds (e.g. 5 µg/L and 50 µg/L)
- Present predicted mortality
  - Volume of water affected
  - Area of water affected
  - Length of shoreline affected
  - % mortality

Model results have been used to inform

- Emergency Preparedness
- Response Planning
- Contingency Plans
- Environmental / Ecological Assessments
- Risk Assessments
- Regional and Site Specific Assessments
- Net Environmental Benefits Analysis
- Natural Resource Damage Assessments
- ...and more



Hypothetical Release from a Chemical Plant
Potential Effects: Air, Land and Estuary

Let us know how we can best help you.

Thank You

Matthew Horn, Ph.D.
Senior Scientist &
Project Manager
Matt.Horn@rpsgroup.com

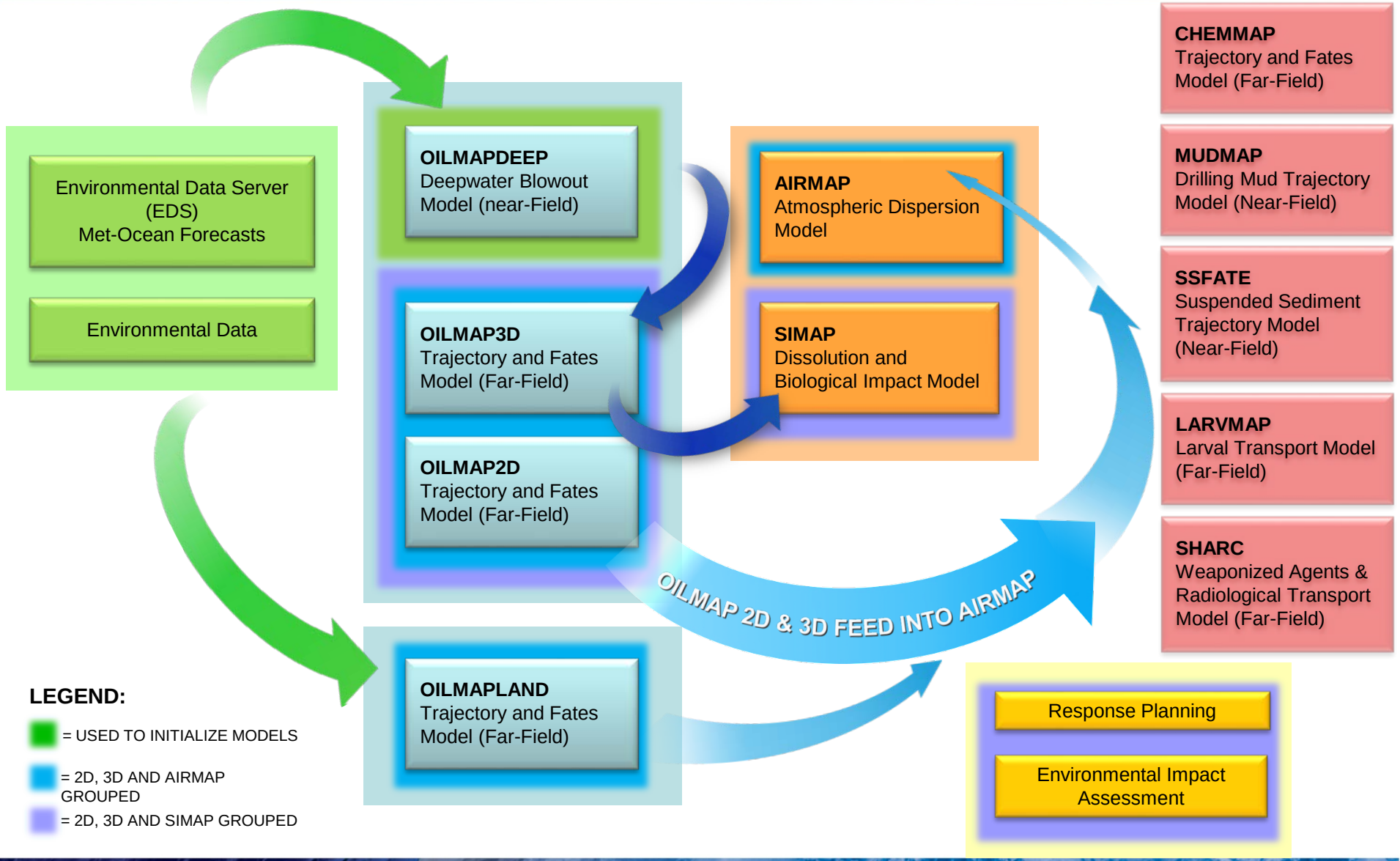
RPS ASA
South Kingstown, RI 02874, USA
+1 (401) 789 - 6224

rpsgroup.com
asascience.com

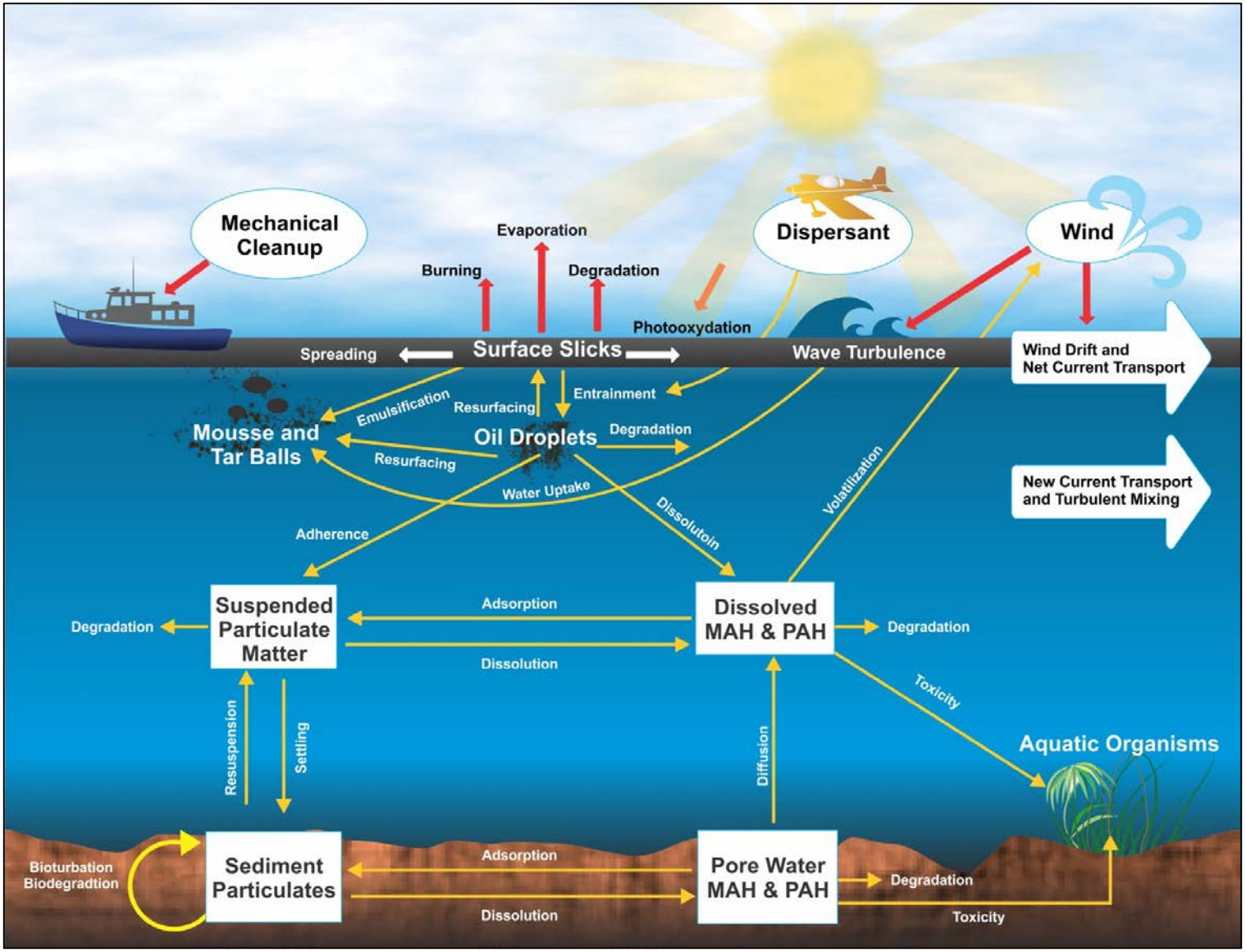
Secure & Stable
ADDING VALUE

Additional Slides

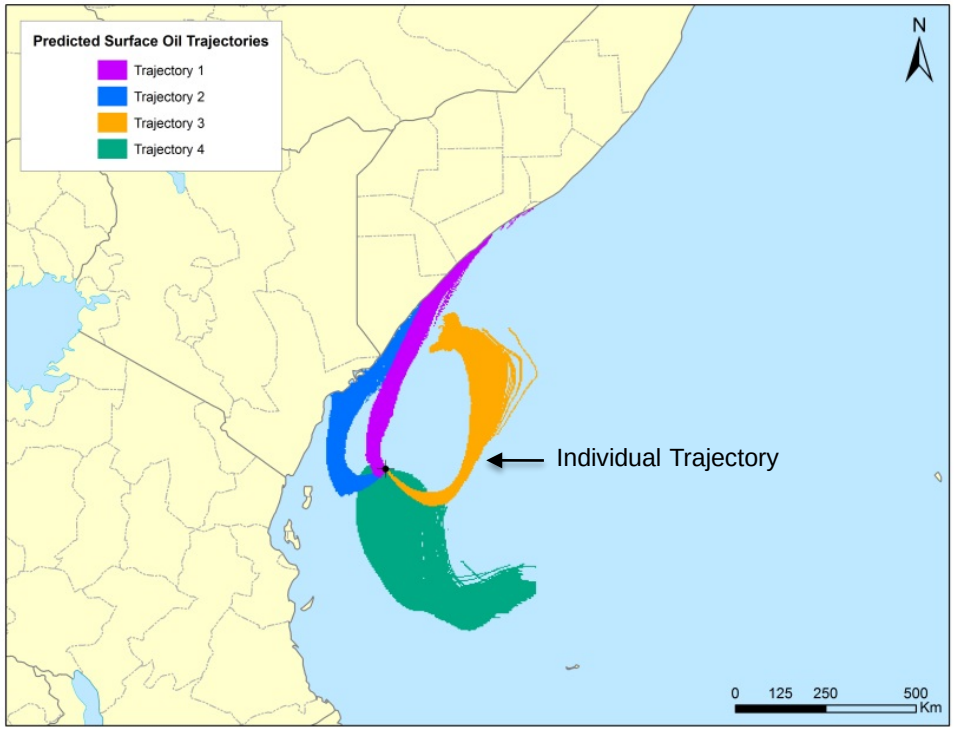
The OILMAP Family ...and a few relatives

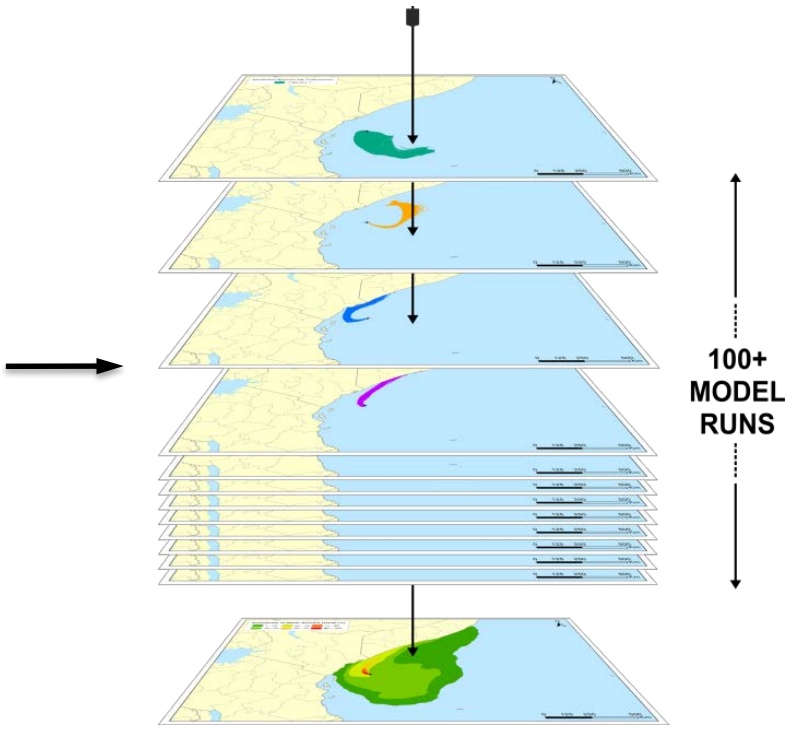


SIMAP Oil Fate Processes in Open Water



Stochastic Modeling





- Multiple 3D deterministic model trajectories (>100) are run for one scenario to characterize the consequences of spills under various environmental conditions
- Long term wind and currents records (5-10+ years)
- Randomly selected start date
- **Statistical analysis** of all trajectories generates maps of overall **oiling probability** and minimum travel time
- Areas and concentrations affected over prescribed minimum cut-off values or thresholds are evaluated
- Individual worst case and/or representative trajectories are identified and examined in more detail (95th percentile)

Potential Biological Effects of Oil

- **Smothering / Coating** (floating and shoreline oil)
  - Thermal Regulation (birds and mammals)
  - Mechanical (smothering, prevention of uptake and depuration, interference with motility, etc.)
  - Adsorption of toxic compounds (via skin or gut)
- **Toxicity** (dissolved aromatics)
  - Requires uptake into tissues
  - Dissolved components
  - Acute and chronic
- **Mechanical Interference** (subsurface oil droplets)
  - Clogging of feeding appendages and gills
  - Impeding movements
- **Behavioral Interference** (floating and shoreline oil)
  - Avoidance (leave area or shut down)
  - Attraction (more exposure)