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NeBC northwest environmental business council

Asphalt Spill Modeling for Facility Response Plan Determinations

PIPER ROELEN, PE, CHMM // DECEMBER 11, 2024

// Presentation Outline

- Background – Regulations and Industry Requirements for Facility Response Plans (FRPs)
- Spill Modeling to Evaluate Need for FRP
  - Simple Calculation-Based Model
  - Comprehensive Analytical Software-Based Model
- Case Studies

Background – FRP Regulations

40 CFR 112 – OIL POLLUTION PREVENTION

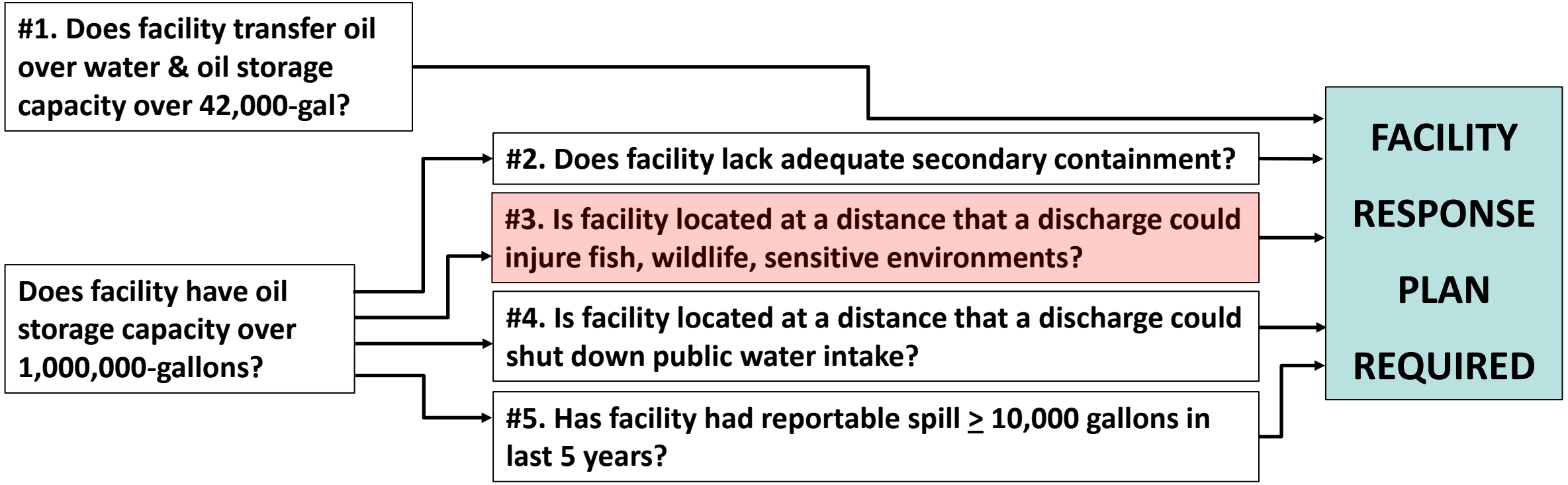
- 40 CFR 112.1 to 112.12 - Spill Prevention, Control, and Countermeasures (SPCC):
  - >1,320 gal of oil → SPCC Plan required

- 40 CFR 112.20 to 112.21 - Facility Response Plan (FRP):
  - "the owner or operator of any non-transportation-related onshore facility that, because of its location, could reasonably be expected to cause **substantial harm** to the environment by discharging oil into or on the navigable waters or adjoining shorelines shall prepare and submit a facility response plan…"

// Background – SPCC/FRP Regulations

SUBSTANTIAL HARM CRITERIA

§112.20 - Facility Response Plan (FRP): Facility meets "substantial harm criteria" → **FRP Required**



PROBLEM → **often rely on a judgement call from operators or regulators that may be based on overly conservative or unrealistic "worst case" scenarios**

// Solution – Spill Modeling

40 CFR 112, Appendix C allows for the use of a "comparable formula" for determining whether the substantial harm criteria is met.

- Simple Calculation Based Model
  - Guo Model + Roche Model
- Comprehensive Analytical Software-Based Model
  - OilFlow2D (Finite-Volume Viscous Flow Model)

// Guo Model

Guo, James C.Y. (2005). "*Overland Flow Model for Hot Asphalt Oil Spill*", J. of Environmental Management, October, 2005.

ASPHALT OIL SPILL MODELED BY VISCOUS FLOW

James C.Y. Guo, P.E. and Professor,
Department of Civil Engineering, University of Colorado at Denver, Denver, Colorado 80217, USA.
Email james.guo@cudenver.edu

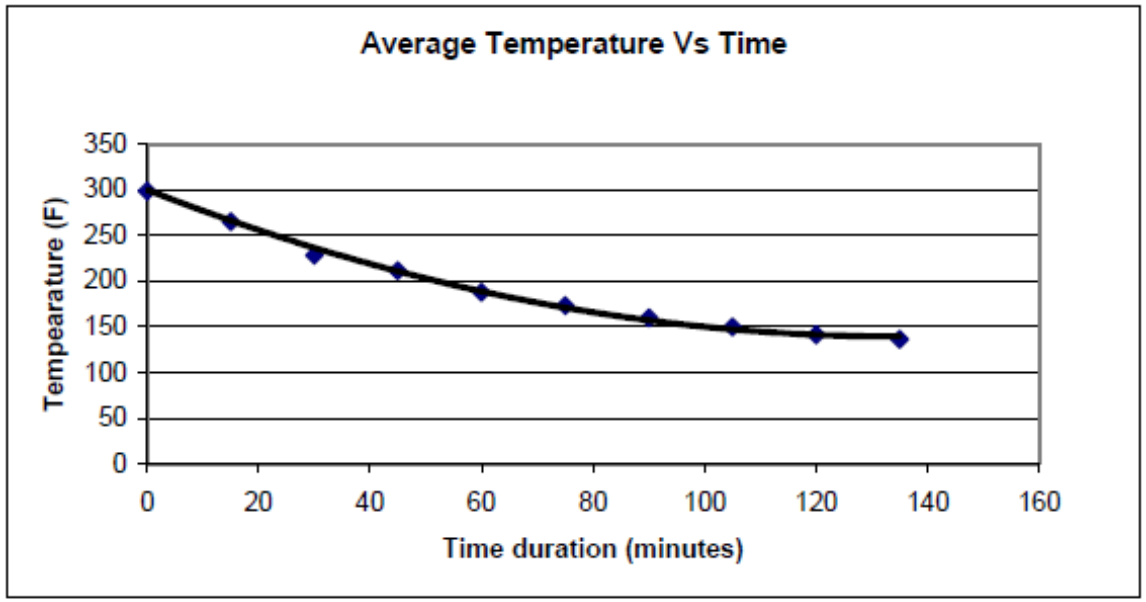


Figure 1. Temperature Variation of Hot Asphalt Oil during a Cooling Process

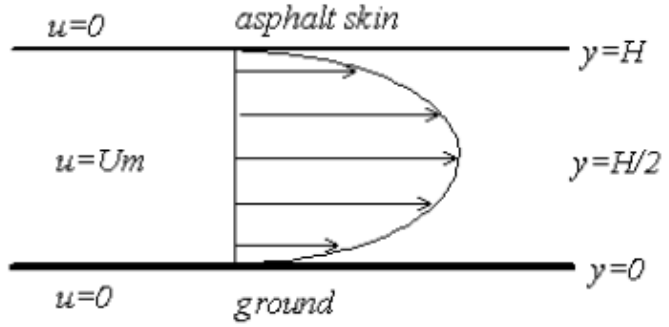
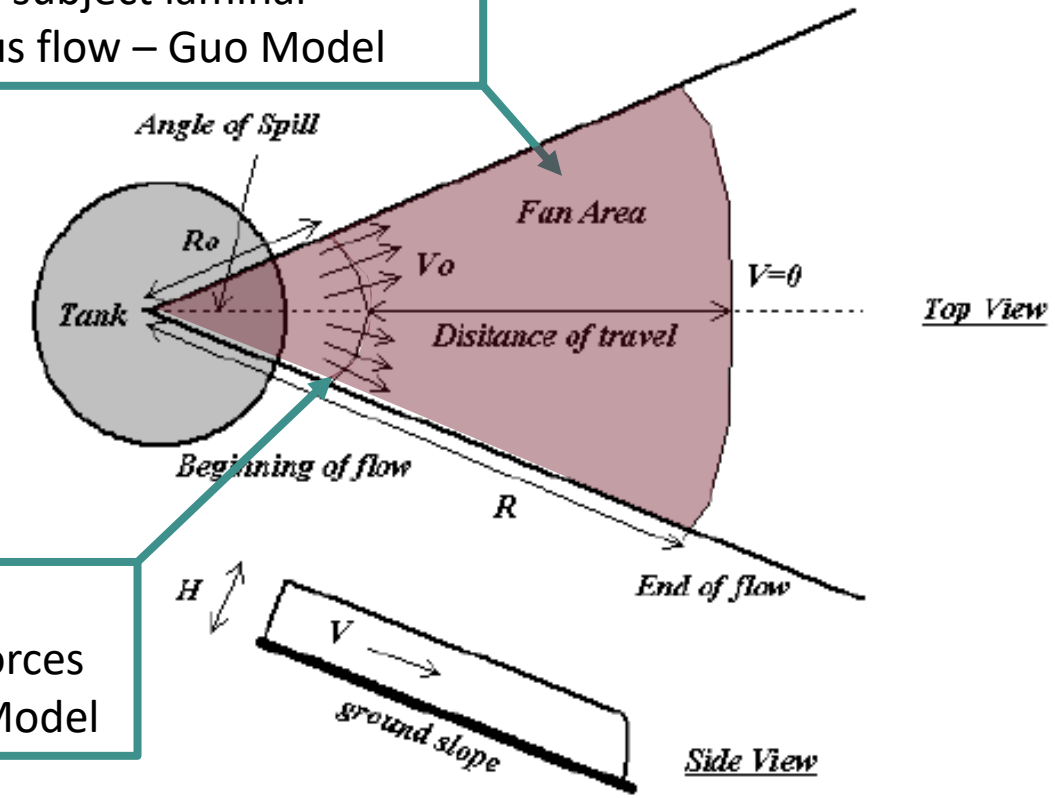


Figure 3 Laminar flow velocity profile

2) Subsequent "sheet flow" phase subject laminar viscous flow – Guo Model



1) Initial "splash phase" subject to gravitational forces – determined by Roche Model

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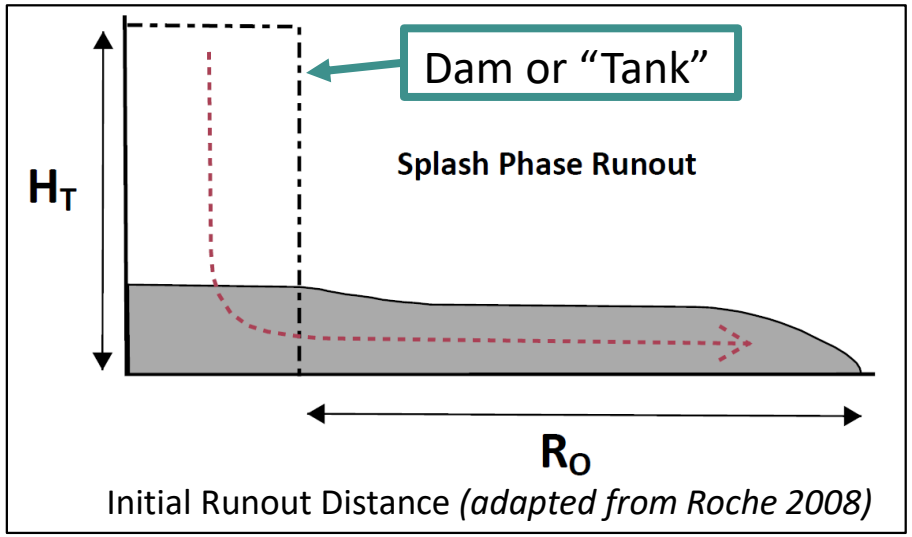
// Roche Model

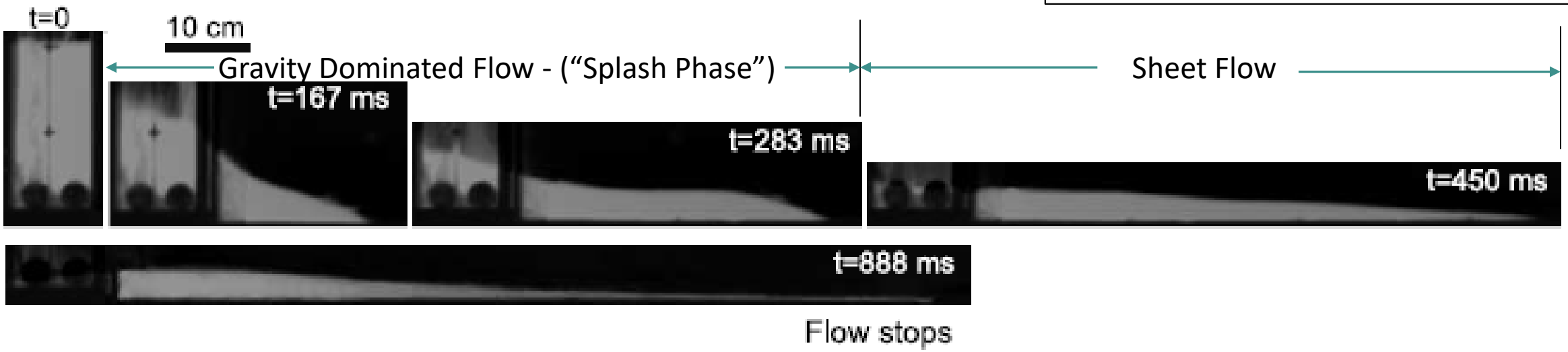
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, B12203, doi:10.1029/2008JB005664, 2008

Experimental observations of water-like behavior of initially fluidized, dam break granular flows and their relevance for the propagation of ash-rich pyroclastic flows

O. Roche,[1] S. Montserrat,[2] Y. Niño,[2] and A. Tamburrino[2]



Initial Runout Distance *(adapted from Roche 2008)*



→ **Runout distance of splash phase is roughly correlates to the initial fluid height in tank**

// Guo/Roche Model

SIMPLE CALCULATION-BASED SOLUTION

- **Inputs**
  - Tank volume
  - Tank height
  - Ground elevation at tank
  - Ground elevation at shoreline
  - Distance to shoreline
  - Product specific kinematic viscosity (or use literature values)
- **Output**
  - Total flow distance of release

If flow distance < distance to shoreline → No FRP required
(theoretically)

// Guo/Roche Model

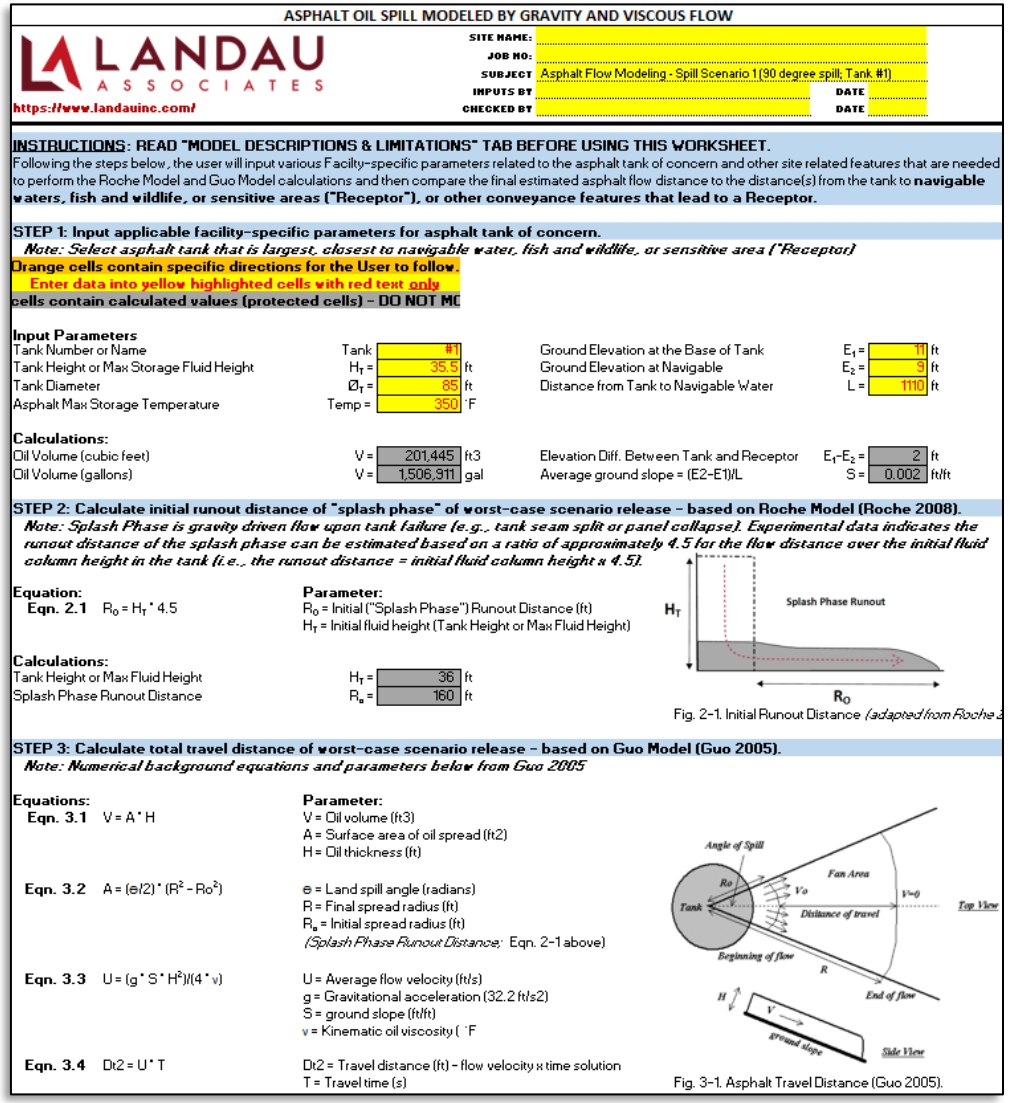
PROS/CONS

Pros

- Performed with simple spreadsheet
- Facility can self perform
- Accounts for cooling of asphalt → flow endpoint
- Based on conservative simplifying assumptions
  - Flat ground
  - Constant slope
- Built-in conservatism → if 'no FRP required' indicated should provide solid basis for determination

Cons

- Unrealistically conservative worst-case scenario
  - Does not consider terrain/obstacles
  - Does not consider ground surface/roughness
- Undetermined if EPA will accept results



ASPHALT OIL SPILL MODELED BY GRAVITY AND VISCOUS FLOW

LANDAU ASSOCIATES — https://www.landauinc.com/

SITE NAME:
JOB NO:
SUBJECT: Asphalt Flow Modeling - Spill Scenario 1 (90 degree spill, Tank #1)
INPUTS BY: DATE:
CHECKED BY: DATE:

INSTRUCTIONS: READ "MODEL DESCRIPTIONS & LIMITATIONS" TAB BEFORE USING THIS WORKSHEET.

Following the steps below, the user will input various Facilty-specific parameters related to the asphalt tank of concern and other site related features that are needed to perform the Roche Model and Guo Model calculations and then compare the final estimated asphalt flow distance to the distance(s) from the tank to **navigable waters, fish and wildlife, or sensitive areas ("Receptor"), or other conveyance features that lead to a Receptor.**

STEP 1: Input applicable facility-specific parameters for asphalt tank of concern.

Note: Select asphalt tank that is largest, closest to navigable water, fish and wildlife, or sensitive area ("Receptor)

Orange cells contain specific directions for the User to follow.
Enter data into yellow highlighted cells with red text only
cells contain calculated values (protected cells) - DO NOT MC

Input Parameters

Tank Number or Name	Tank	#1	Ground Elevation at the Base of Tank	E_1 =	11 ft
Tank Height or Max Storage Fluid Height	H_T =	35.5 ft	Ground Elevation at Navigable	E_2 =	9 ft
Tank Diameter	$Ø_T$ =	85 ft	Distance from Tank to Navigable Water	L =	1110 ft
Asphalt Max Storage Temperature	Temp =	350 °F			

Calculations:

Oil Volume (cubic feet)	V =	201,445 ft3	Elevation Diff. Between Tank and Receptor	E_1-E_2 =	2 ft
Oil Volume (gallons)	V =	1,506,911 gal	Average ground slope = (E2-E1)/L	S =	0.002 ft/ft

STEP 2: Calculate initial runout distance of "splash phase" of worst-case scenario release - based on Roche Model (Roche 2008).

Note: Splash Phase is gravity driven flow upon tank failure (e.g., tank seam split or panel collapse). Experimental data indicates the runout distance of the splash phase can be estimated based on a ratio of approximately 4.5 for the flow distance over the initial fluid column height in the tank (i.e., the runout distance = initial fluid column height x 4.5).

Equation:
Eqn. 2.1 $R_0 = H_T * 4.5$

Parameter:
R_0 = Initial ("Splash Phase") Runout Distance (ft)
H_T = Initial fluid height (Tank Height or Max Fluid Height)

Calculations:

Tank Height or Max Fluid Height	H_T =	36 ft
Splash Phase Runout Distance	R_o =	160 ft

Fig. 2-1. Initial Runout Distance *(adapted from Roche 2*

STEP 3: Calculate total travel distance of worst-case scenario release - based on Guo Model (Guo 2005).

Note: Numerical background equations and parameters below from Guo 2005

Equations:

Eqn. 3.1 $V = A * H$

Eqn. 3.2 $A = (\theta/2) * (R^2 - Ro^2)$

Eqn. 3.3 $U = (g * S * H^2)/(4 * \nu)$

Eqn. 3.4 $Dt2 = U * T$

Parameter:
V = Oil volume (ft3)
A = Surface area of oil spread (ft2)
H = Oil thickness (ft)

θ = Land spill angle (radians)
R = Final spread radius (ft)
R_o = Initial spread radius (ft)
(Splash Phase Runout Distance; Eqn. 2-1 above)

U = Average flow velocity (ft/s)
g = Gravitational acceleration (32.2 ft/s2)
S = ground slope (ft/ft)
ν = Kinematic oil viscosity (°F

Dt2 = Travel distance (ft) - flow velocity x time solution
T = Travel time (s)

Fig. 3-1. Asphalt Travel Distance (Guo 2005).

→ May yield false positive for FRP requirement

// OilFlow2D Finite-Volume Viscous Flow Modeling

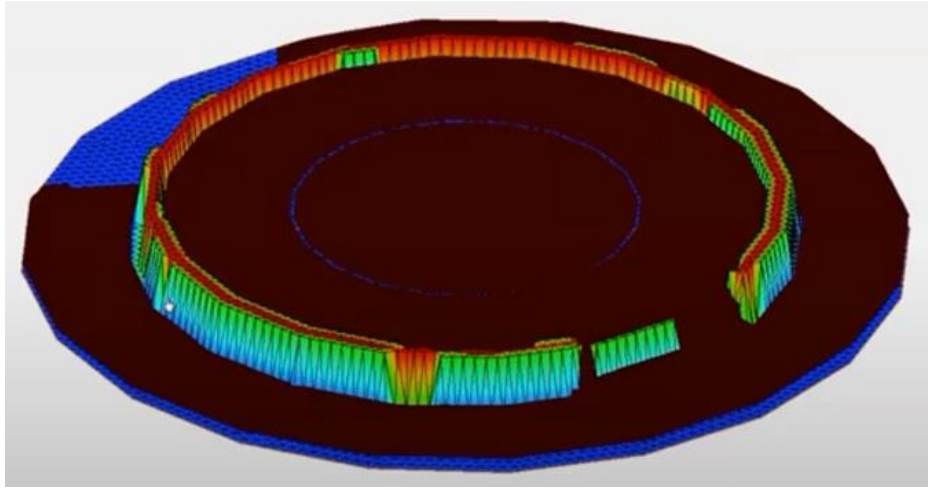
COMPREHENSIVE ANALYTICAL SOFTWARE

- OilFlow2D (Hydronia LLC) is a finite-volume, viscous flow model integrated with QGIS, for simulation of on-land oil spills from tank (or pipeline) breaks
- Utilizes unstructured and flexible mesh grid to capture small-scale terrain features, inputs on surface texture, temperature relationships with material density and viscosity, and simulation of discrete tank failure

HYDRONIA

OilFlow2D

THE SOLUTION FOR OIL SPILLS ON LAND AND WATER



// OilFlow2D Model

ADDRESSES REGULATORY REQUIREMENTS

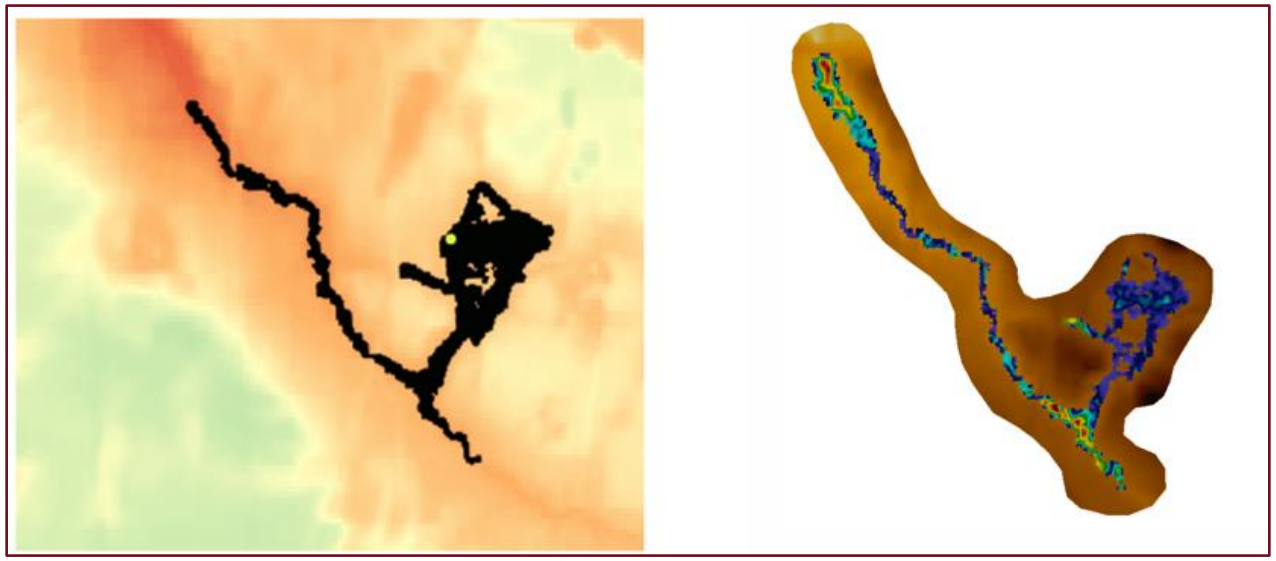
40 CFR 112, Appendix C:

- Owners or operations "must evaluate the likelihood that portions of a worst-case discharge would reach navigable waters via open channel flow or from sheet flow across the land **or be prevented from reaching navigable waters when trapped in natural or man-made depressions, excluding secondary containment structures**."
- Factors to consider for assessing oil transport over land "**shall include the topography of the surrounding area, drainage patterns, man-made barriers** (excluding secondary containment structures), **and soil distribution and porosity**."

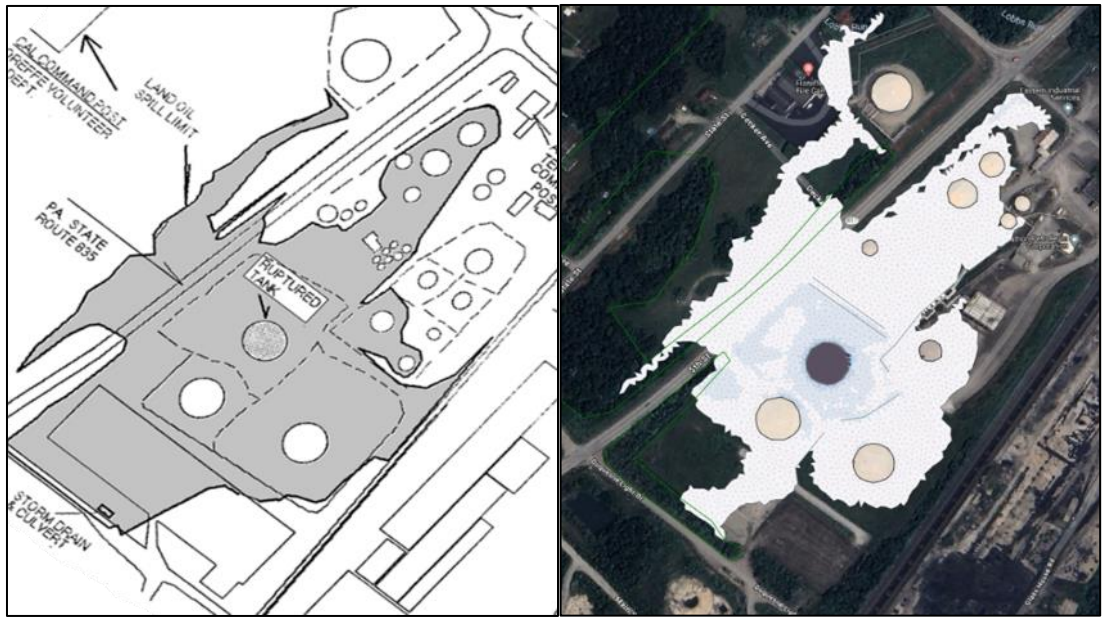
OilFlow2D → addresses these factors and more

// OilFlow2D Model DEMONSTRATED ACCURACY

- EPA requires owner/operator to demonstrate reliability and analytical soundness of “comparable formulas”
- Hydronia has validated OilFlow2D model against actual release events
  - Model results compared with surveys of the affected area to demonstrate reliability of the model generate realistic depiction of actual catastrophic failure events



Observed extent of oil pipeline release (left) and OilFlow2D (right); (Courtesy of Hydronia)
Kalamazoo, MI



Observed extent of tank collapse release (left; Miklaucic & Saseen, 1988) and OilFlow2D (right; Hydronia)
Ashland, PA

// OilFlow2D Model PROS/CONS

Pros

- Highly accurate/reliable results
- Results accepted by EPA at multiple sites
- Considers site-specific conditions/info:
  - Topography/terrain
  - Product-specific properties
  - Variable slopes/grades/channels
- Can use available topo data (ft) or high-resolution survey data for topography (mm)
- Simulate different tank failure modes planning purposes if FRP is needed
- Can be used for different materials/products

Cons

- Proprietary software; experienced modelers needed
- Relative expense (but << than FRP preparation and implementation)
- Requires multiple site and product inputs parameters which may or may not be available:
  - Viscosity
  - Density
  - Yield stress
  - Product starting temperature
  - Ambient conditions
  - Land surface roughness coefficients

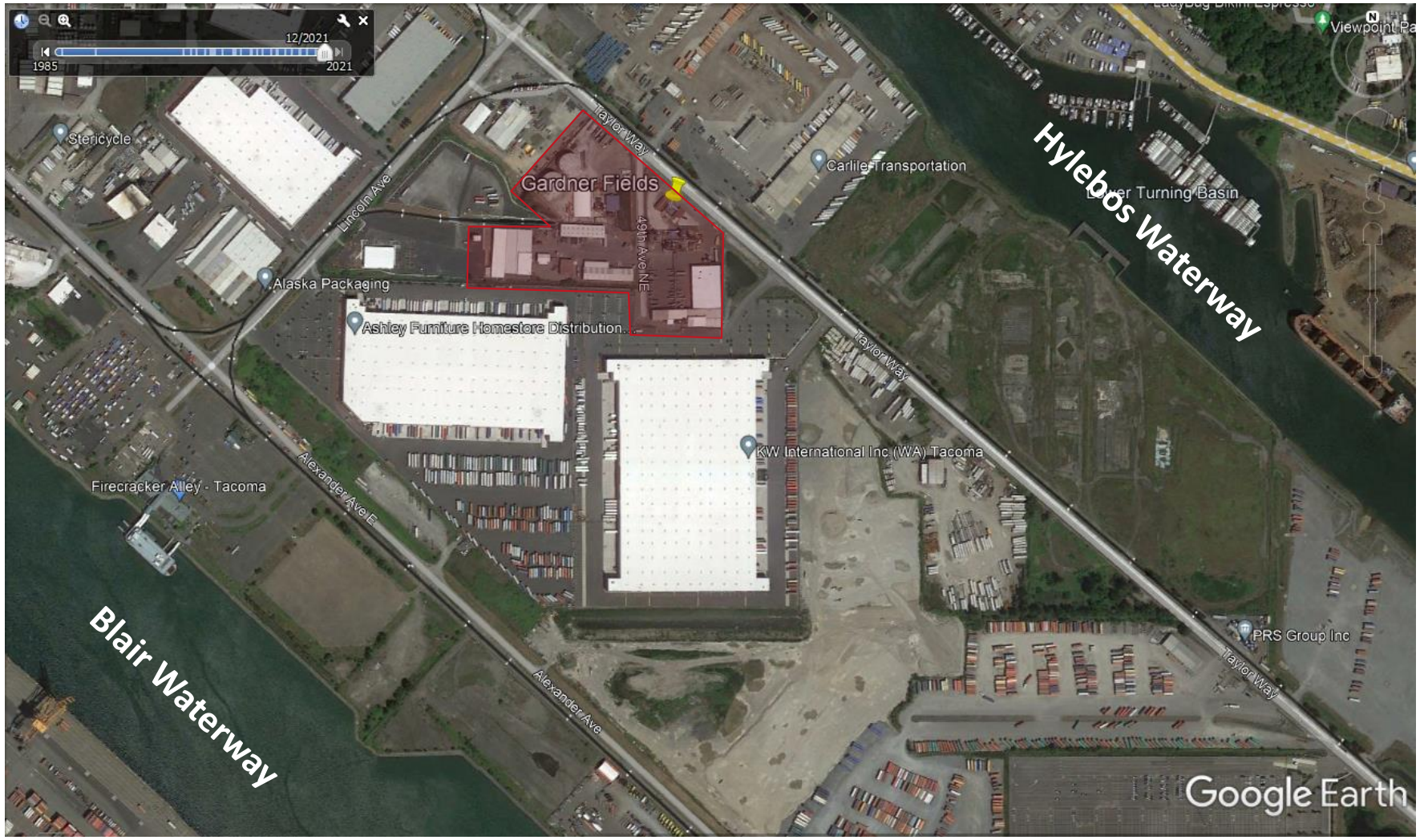
// Case Studies

- Asphalt Plant - Tacoma, Washington
  - Guo Model
  - OilFlow2D
- Asphalt Plant – Delaware
  - OilFlow2D
- Asphalt & Roofing Plant – Georgia
  - OilFlow2D

// Case Study #1 – Gardner Fields Asphalt Plant

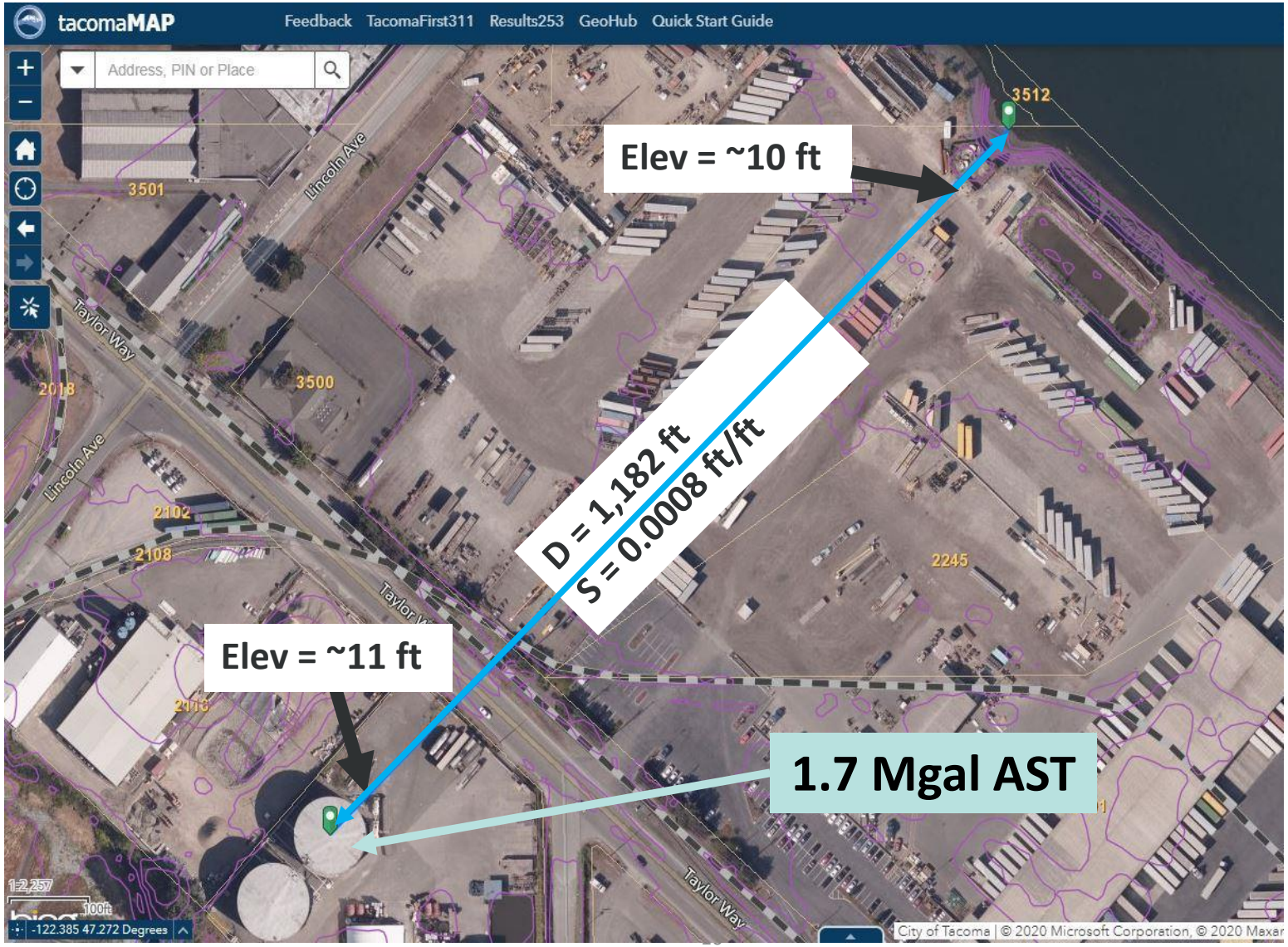
TACOMA, WA

- On Hylebos Peninsula
- 60K-gal release reached stormwater ditch
- EPA/DOJ alleged SPCC and FRP violations
- Facility had no FRP



// Gardner Fields Asphalt Plant

SITE DETAILS



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// Guo/Roche Model

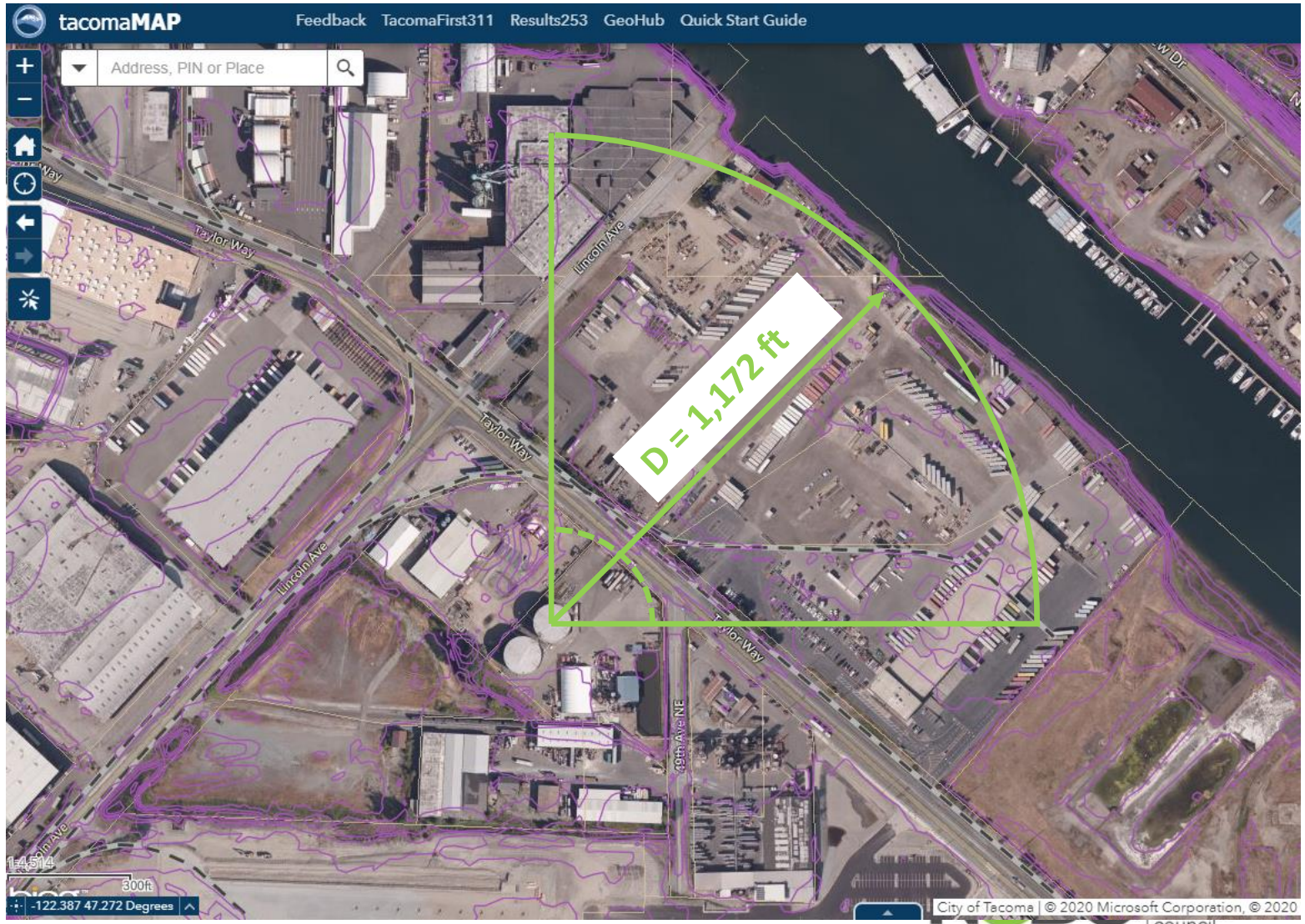
CALCULATED RESULTS (LANDAU)

Model results for 90-degree spill angle

- Initial splash distance = 240 ft
- Max spill distance = 1,172 ft
- Distance to Hylebos = 1,182 ft
- ***Model is conservative because it does not take terrain into consideration***

→ **Facility does not meet substantial harm criteria, no Facility Response Plan required**

EPA did not accept Landau's findings



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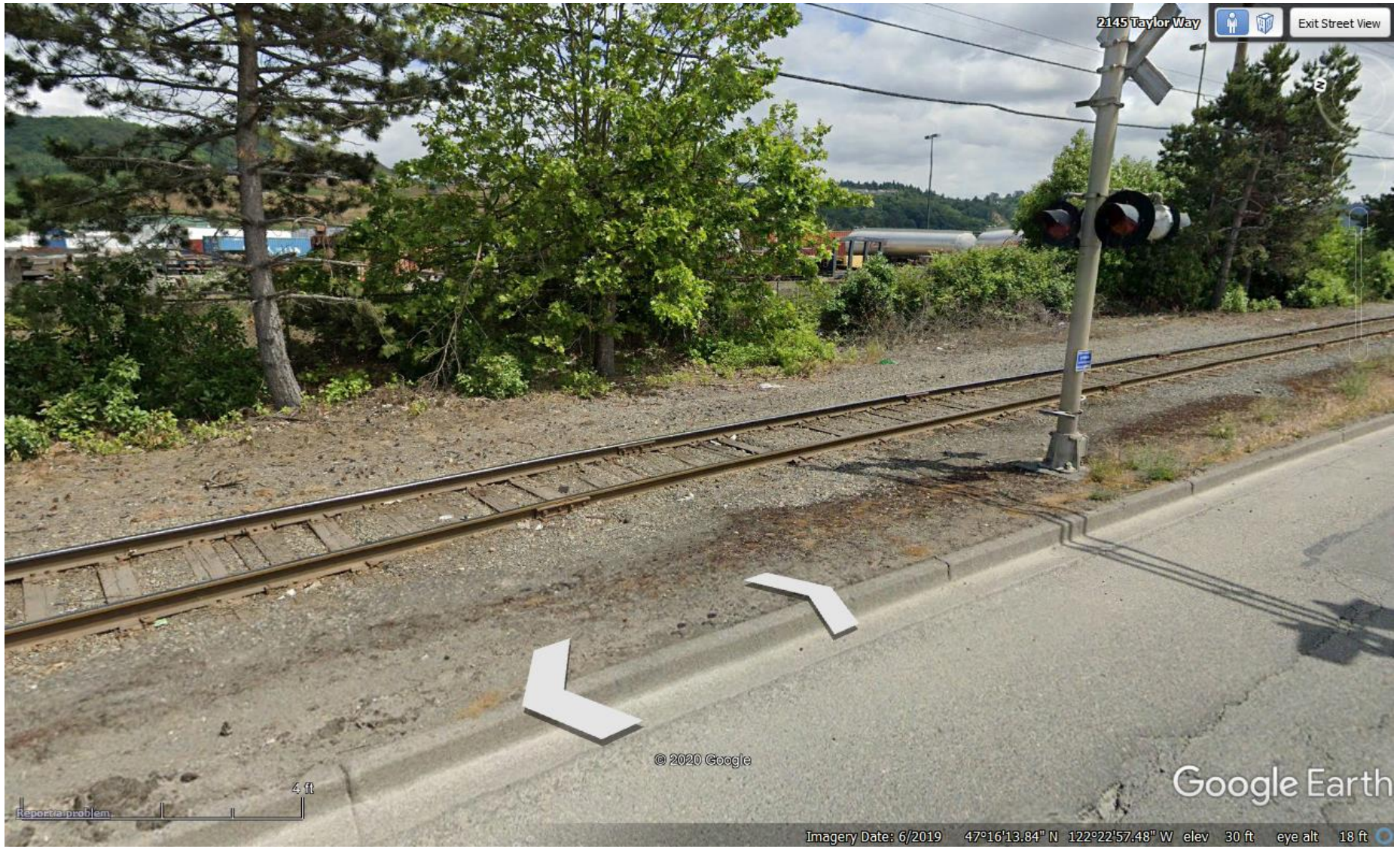
// Guo/Roche Model Conservatism

DOES NOT ACCOUNT FOR TERRAIN/TOPOGRAPHIC FEATURES



Terrain between tank and Hylebos Waterway

- **Curbs/roadway camber**
- **Railroad tracks (ballast and gravel)**
- **Vegetated Strip (brush, trees, grass – elevated/mound)**

Secondary containment ignored *for the substantial harm evaluation as required by regulation*

→ **OilFlow2D Model**

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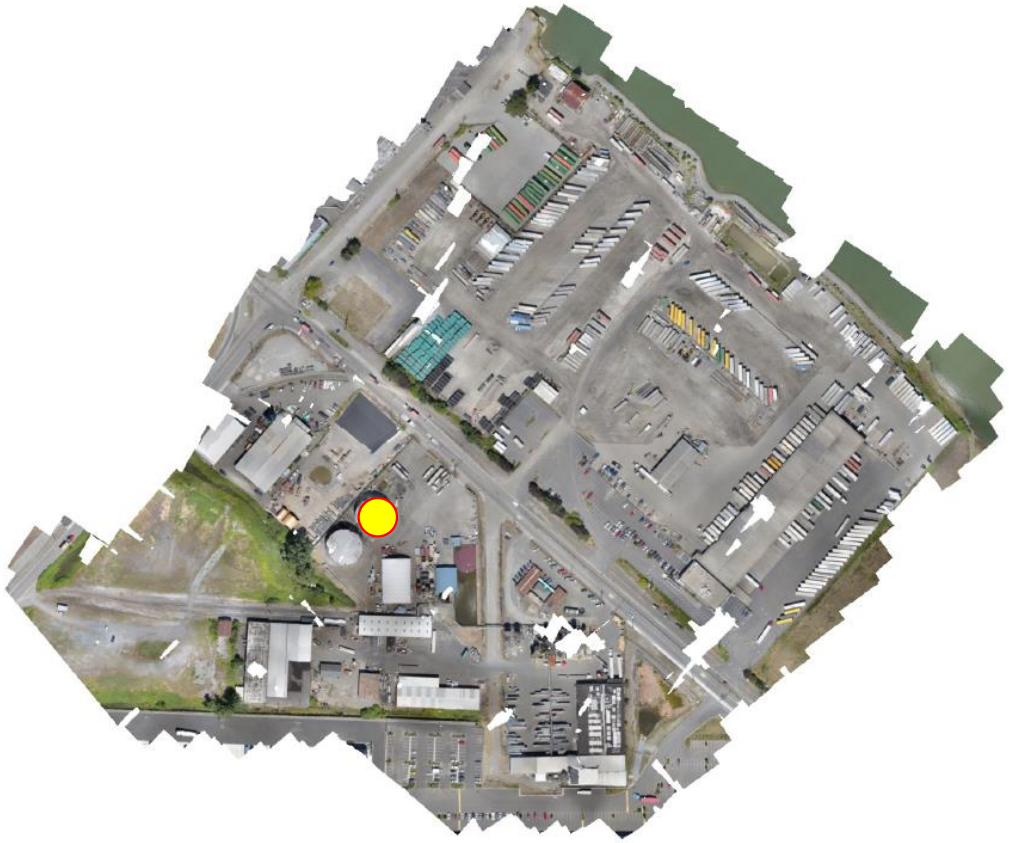
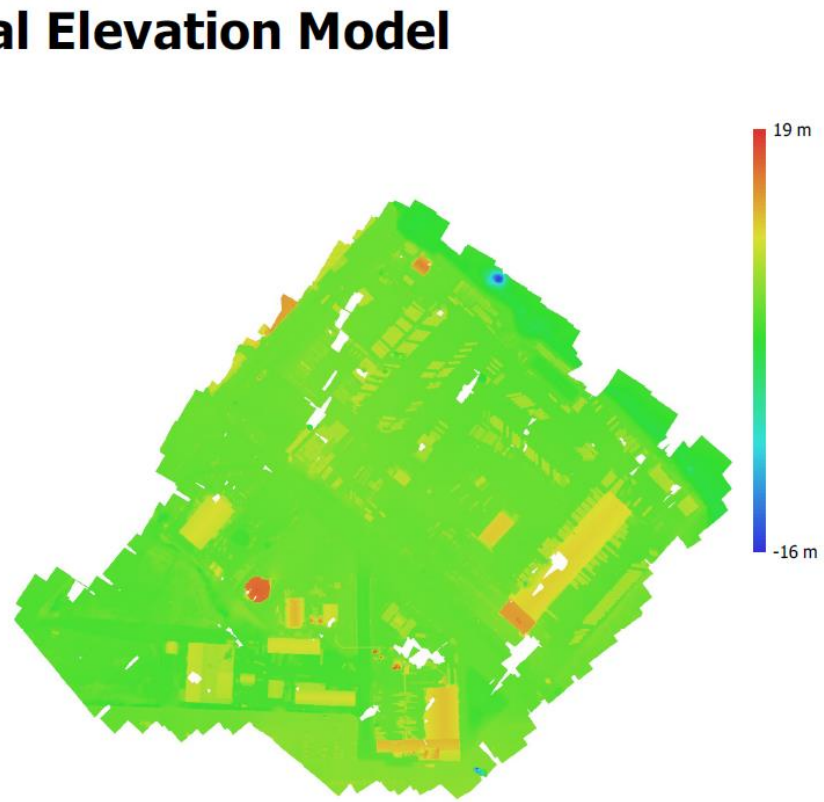
// OilFlow2D – Setup

TOPOGRAPHY/DIGITAL ELEVATION MODEL (DEM)

Model simulations run using a high resolution (10 centimeter) DEM created w/drone survey

Secondary containment manually removed from the DEM

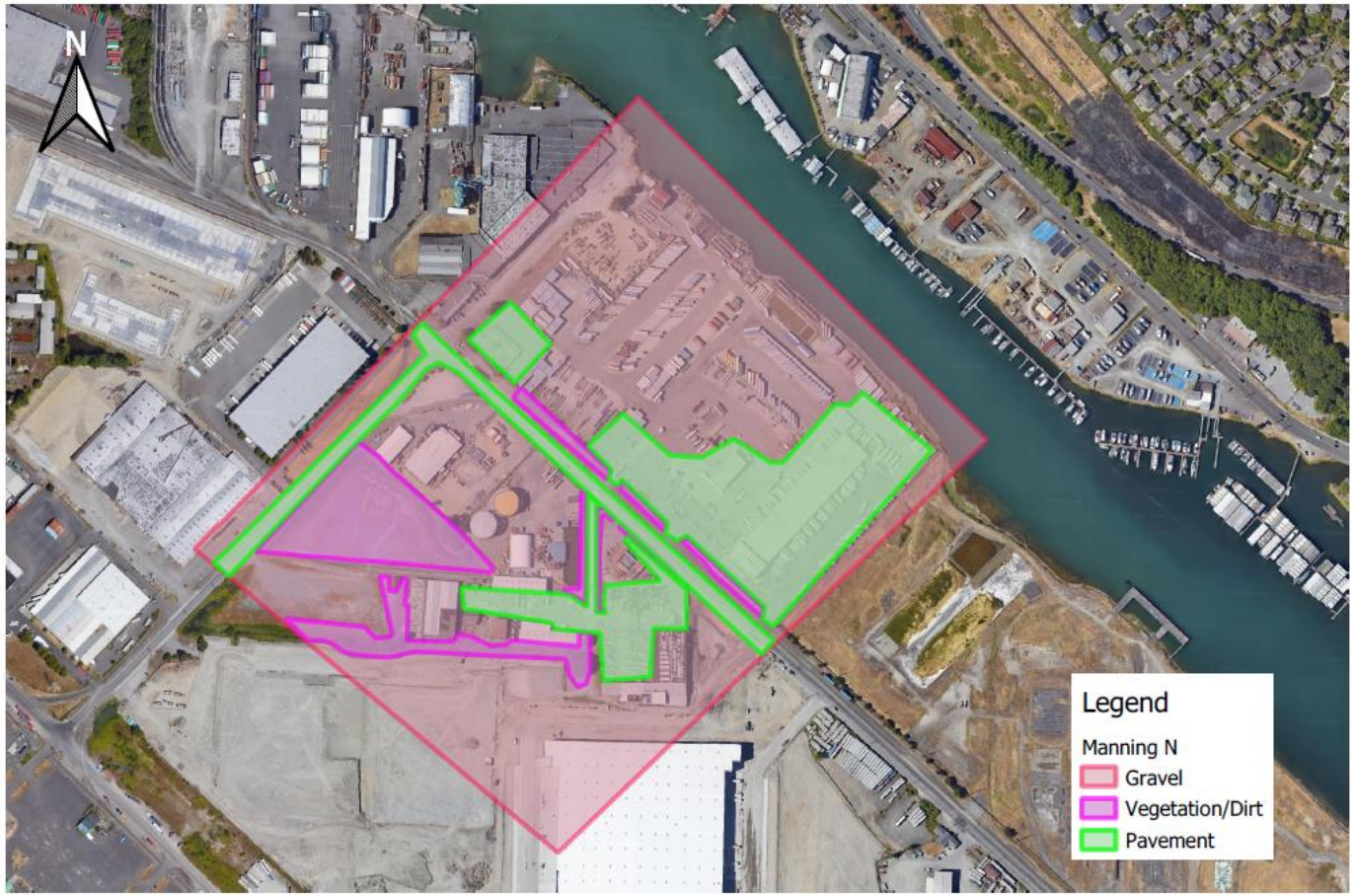




// OilFlow2D – Setup

INPUT PARAMETERS

Surface Roughness – Manning N Values



Facility Material-Specific or Literature Values

Temperature °F	Viscosity cPs	Viscosity lb - s/in^2	Correction Factor	Density [1] lbs/gal	Density [1] lbs/ft^3
350	72.5	1.1E-05	0.9024	7.670	57.38
300	160.0	2.3E-05	0.9187	7.809	58.42
250	562.5	8.2E-05	0.9352	7.949	59.46
200	3,300.0	4.8E-04	0.9520	8.092	60.53
150	50,000.0	7.3E-03	0.9689	8.236	61.61

Notes:

1. Assuming a density of 8.5 lbs/gal at 60 °F and correction factors based on ASTM guidance D4311

// OilFlow2D – Results

MODELED THREE SCENARIOS:

- Scenario 1: 90-degree panel rupture/failure
- Scenario 2: 1-meter vertical seam split
- Scenario 3: 45-degree panel rupture/failure

➢ **Results Similar for All**

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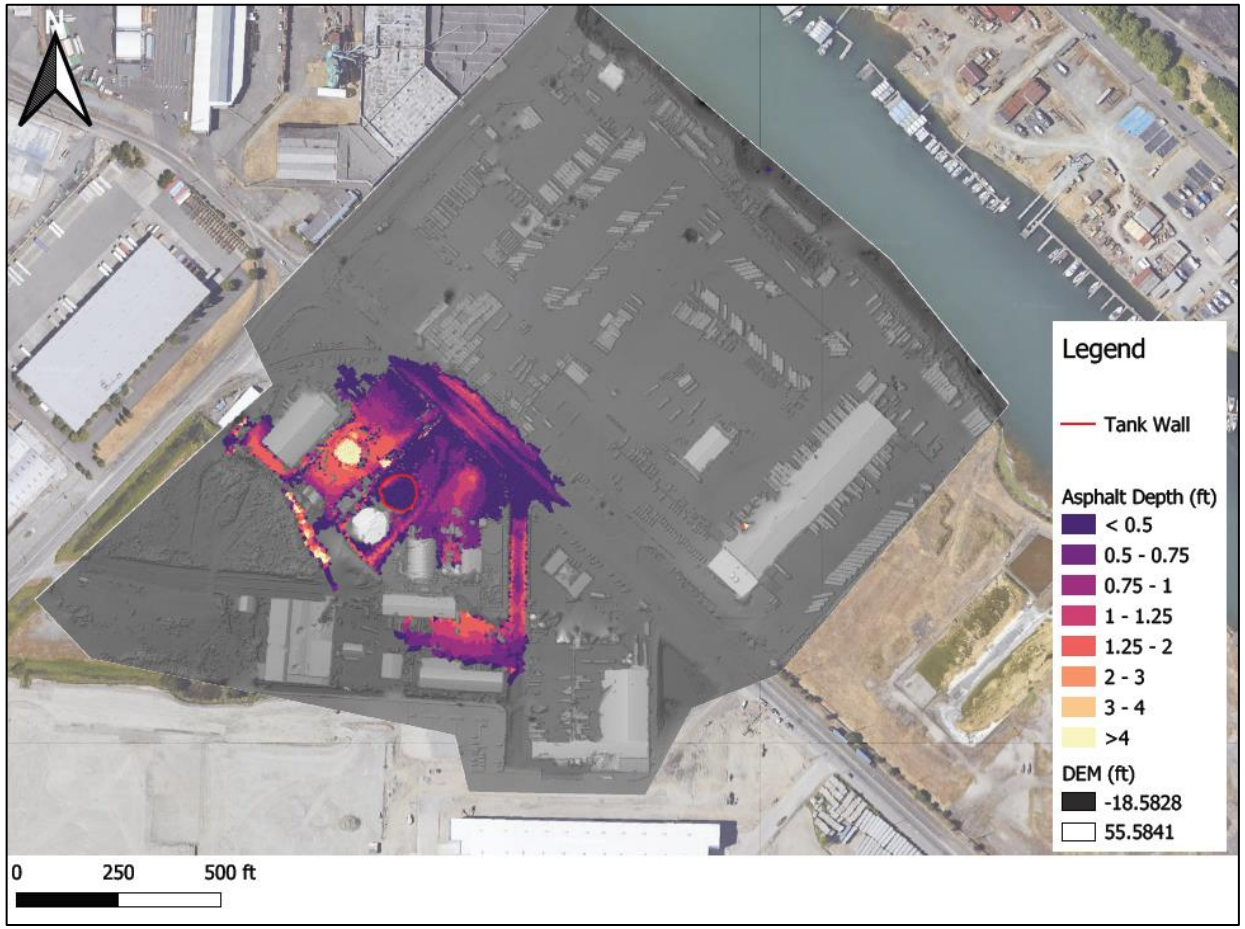
// OilFlow2D – Comparison of Splash Phase

SCENARIO 3: 45-DEGREE PANEL FAILURE

45-degree tank breach
(30-seconds after start of release)

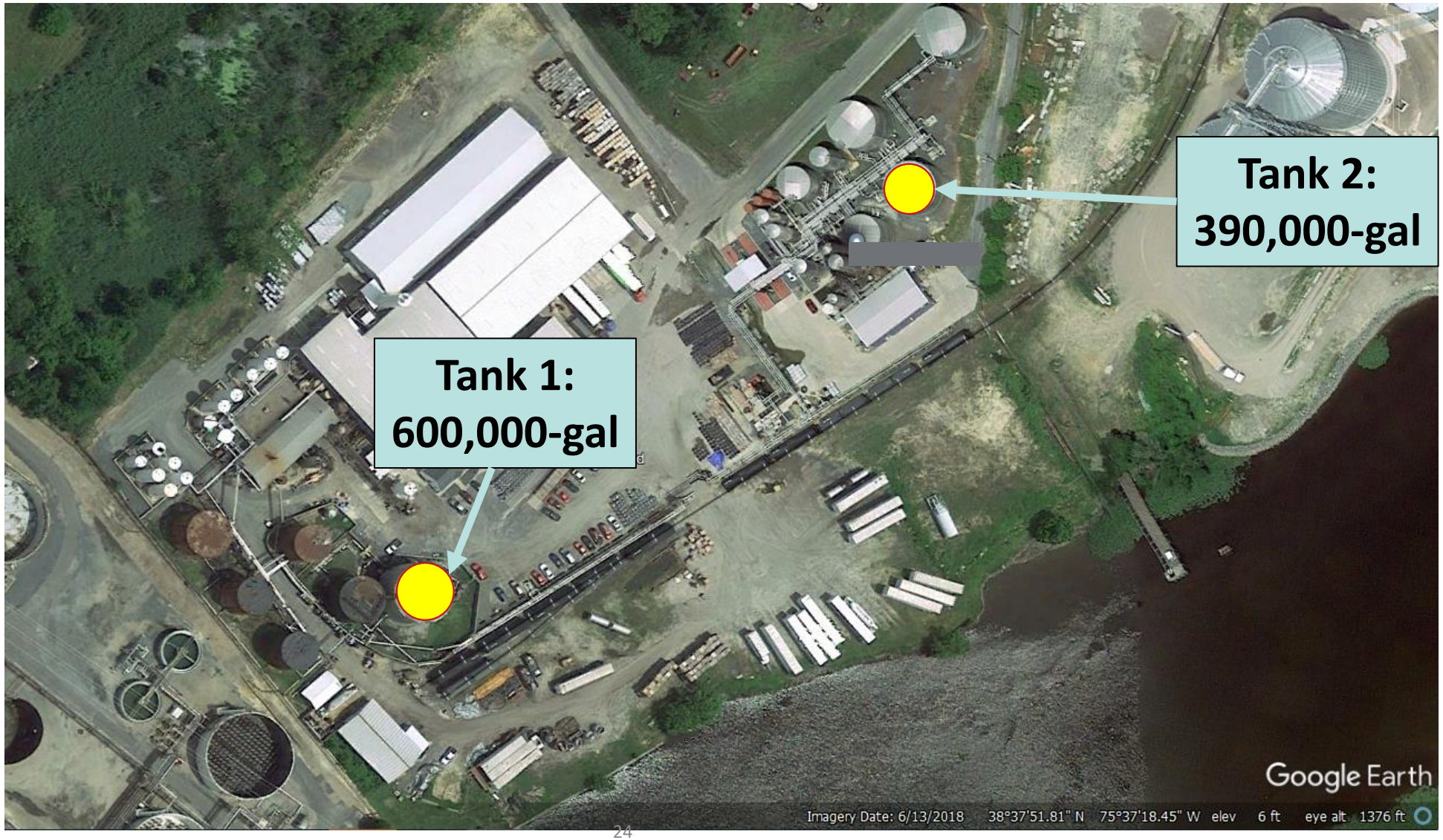
// Case Study #1 – Conclusion

- Based on OilFlow2D modeling results, EPA agreed that no FRP required for the facility
- EPA/DOJ dropped all FRP-related violations/fines



// Case Study #2: Confidential Client - Asphalt Plant

DELAWARE



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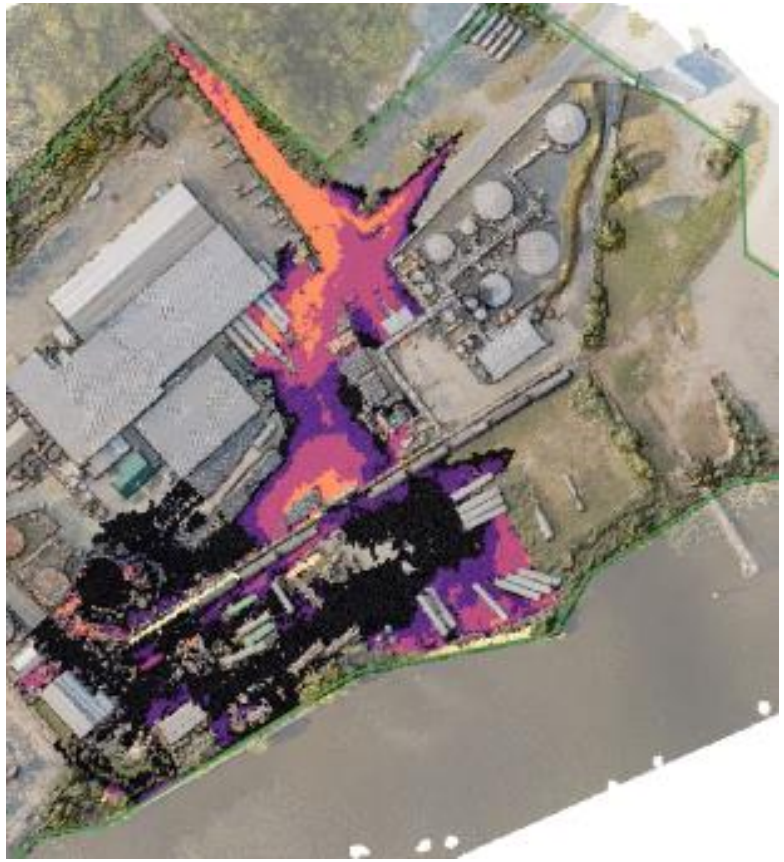
// Case Study #2: Conclusion
OILFLOW2D → PLANNING TOOL

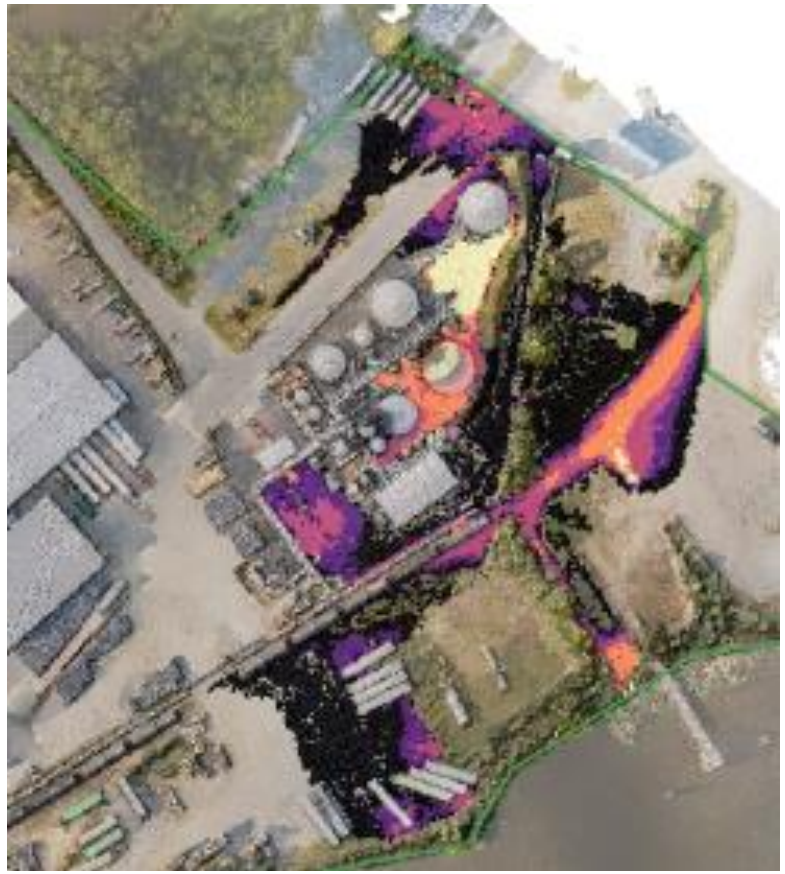
Results as expected:

Based on OilFlow2D modeling results:

- Confirmed that FRP is required for the facility
- FRP can be tailored to focus resources on primary flow paths and discharge areas identified by model



Tank 1



Tank 2

// Case Study #3: Confidential Client – Asphalt Plant

GEORGIA

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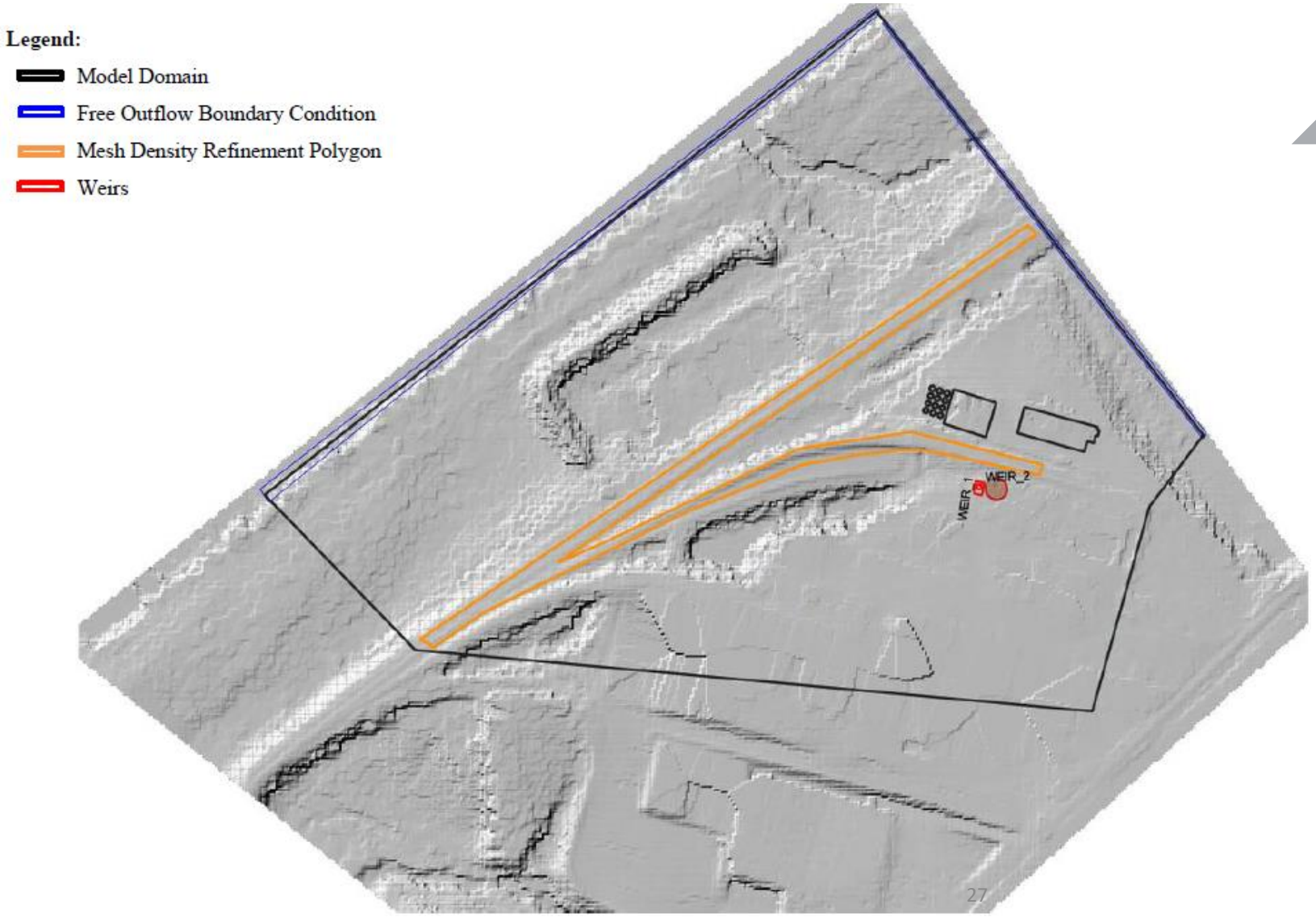
// OilFlow2D - Setup

DRONE SURVEY/DIGITAL ELEVATION MODEL (DEM)



- High-resolution (2-in) DEM generated from drone elevation survey

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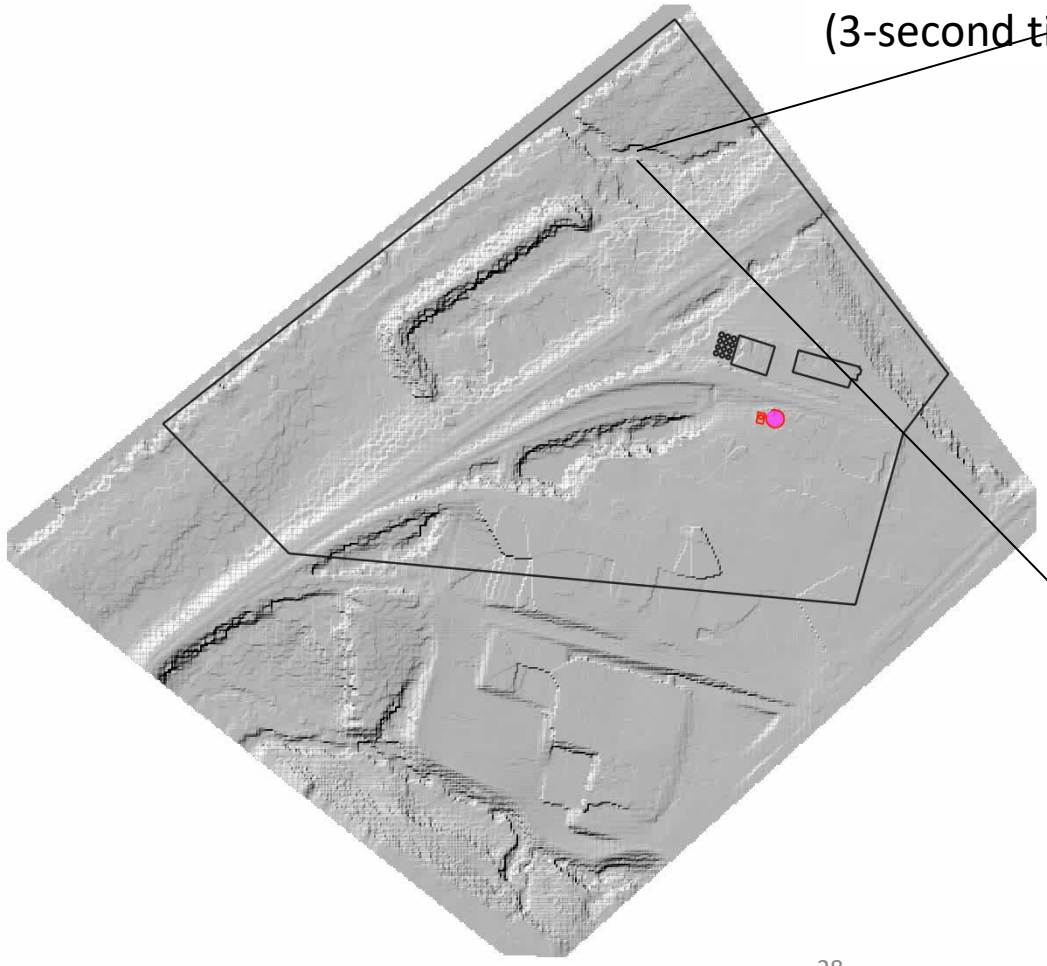
OilFlow2D - Results

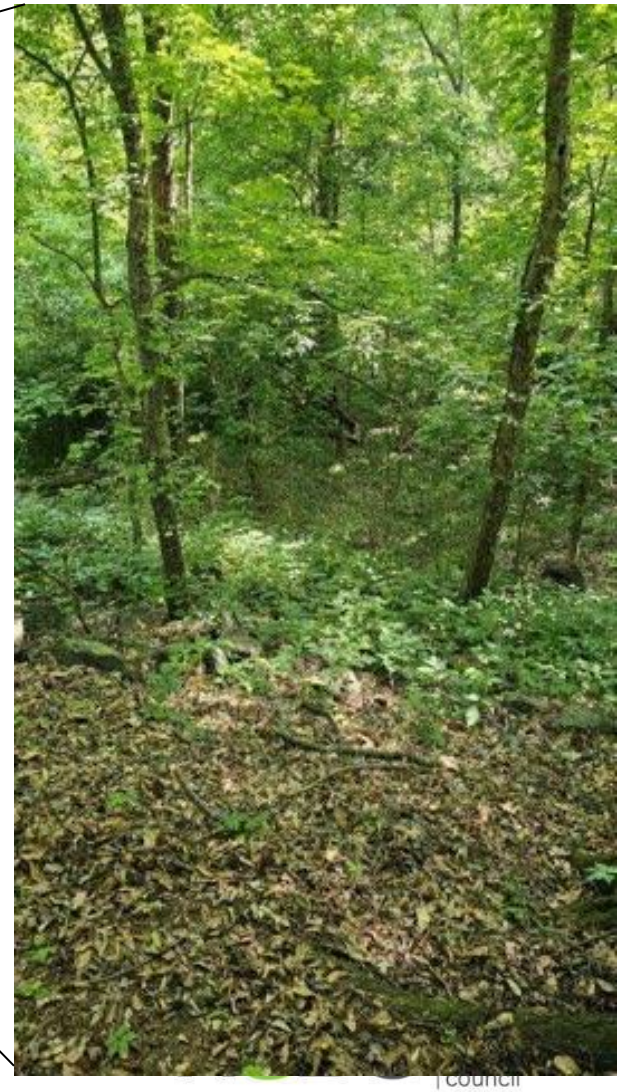
SPILL SIMULATION: 90-DEGREE PANEL FAILURE

Depth (ft)

- 0 – 0.01
- 0.01 – 0.1
- 0.01 – 0.02
- 0.02 – 0.03
- 0.03 – 0.04
- 0.04 – 0.05
- 0.05 – 0.75
- 0.75 – 1
- 1 – 2
- 2 – 5
- 5 – 10
- 10 - 40



Model Animation:
5-minute elapse time
(3-second time steps)

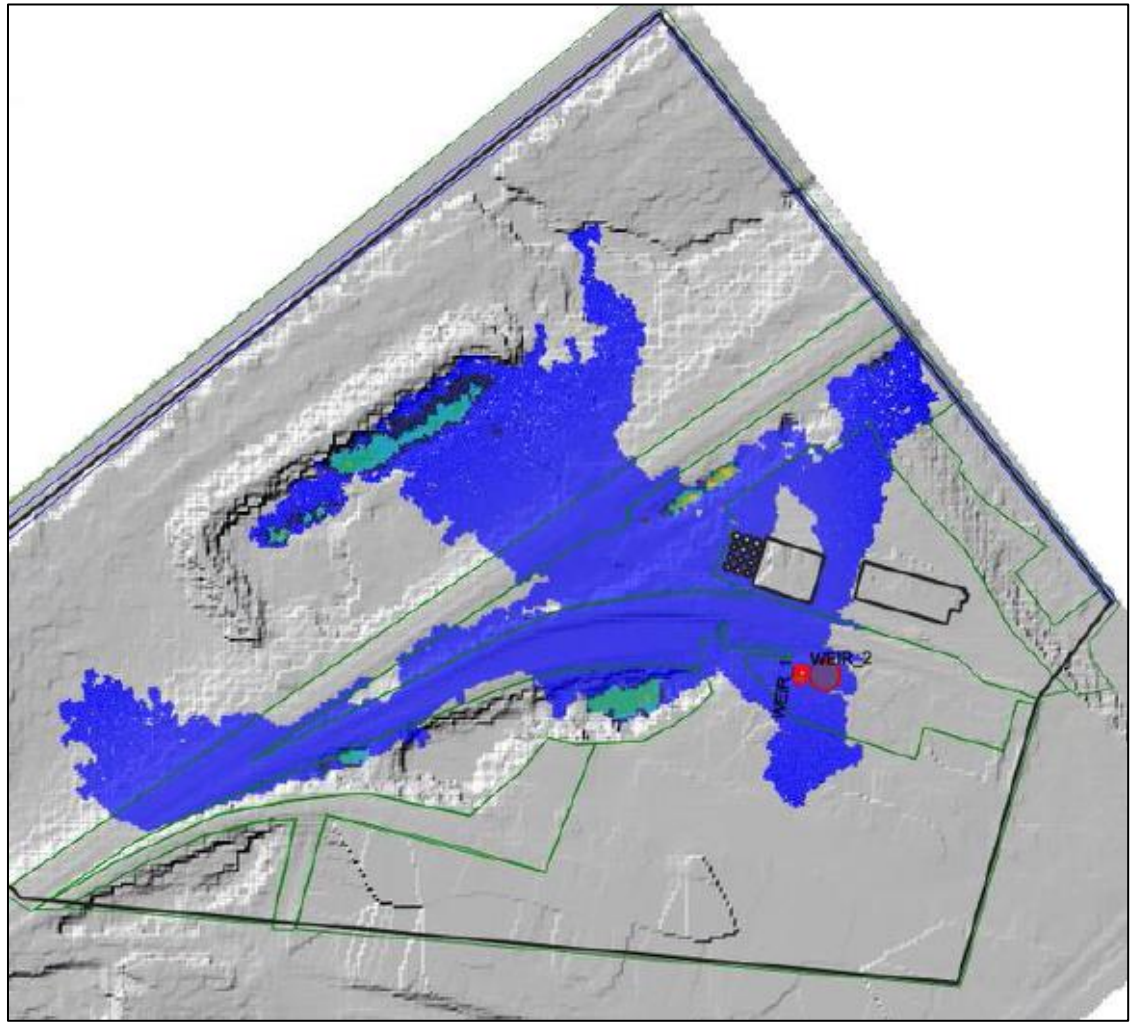


// Case Study #3: Conclusion
SUCCESSFUL OUTCOME

Based on the OilFlow2D modeling results (and wildlife and critical habitat search performed by client):

- **No FRP required** for the facility
- Terrain matters!

EPA reviewed and agreed with the finding!



// Summary and Conclusions

DETERMINING FRP APPLICABILITY

- No easy solutions
- Regulations allow for use of “comparable formulas”
- Simplified conservative model (e.g., Guo/Roche Model) is a good first step to the evaluation process (may be enough)
- For more complicated situations, complex terrains, complicated sites, or where a definitive answer is required, robust software models (e.g., OilFlow2D) provide comprehensive and defensible results
  - ***Has earned EPA approval!***

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Questions?

THANK YOU!!!

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