DOCKETED	
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Impacts of climate change for California's Interdependent Transportation Fuel Sector

John Radke

Research Workshop on Energy Impacts of Climate Change

August 30, 2018
Rosenfeld Hearing Room
California Energy Commission
1516 Ninth Street Sacramento, CA

Center for Catastrophic Risk Management
University of California, Berkeley

FED-15-001

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Center for Catastrophic Risk Management
University of California, Berkeley

FED-15-001

Climate change Impacts for California's Interdependent Transportation Fuel Sector

- What is the California Transportation Fuel Sector (TFS)?
- Modeling exposure of the TFS to Flooding and Wildfire (under Climate Change)
  - Exposure to Flooding
  - Exposure to Wildfire

- Stakeholder engagement

- What have we learned?

- What are implications of our findings?

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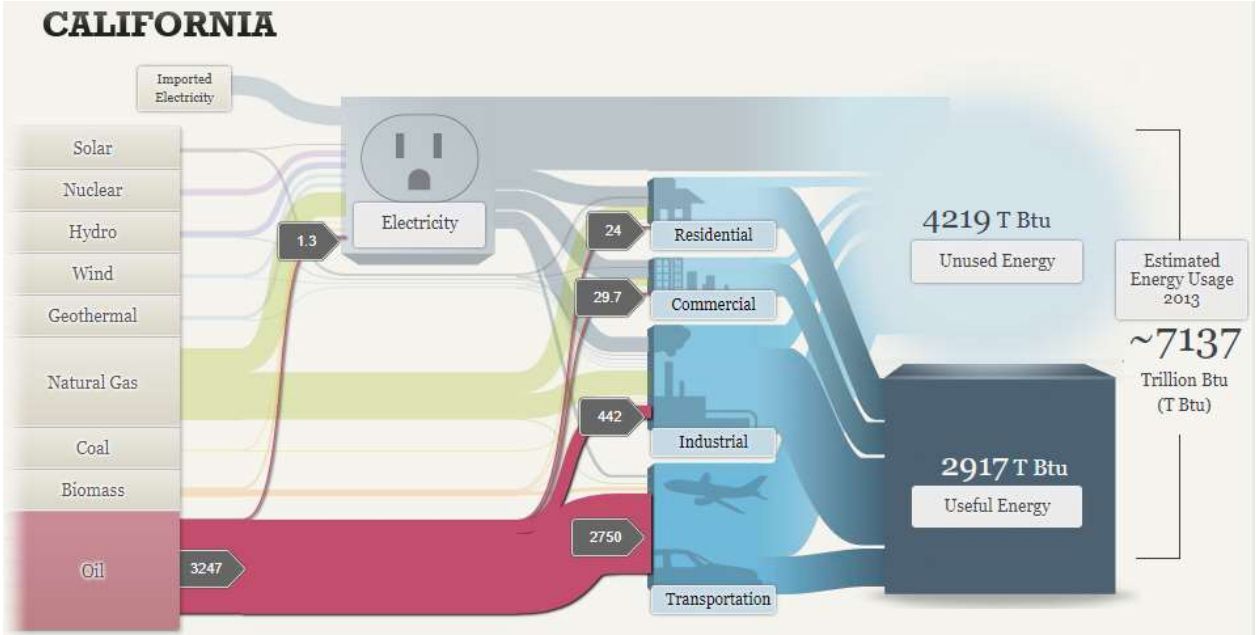
The TFS is the interconnected infrastructure that enables the reliable supply and distribution of transportation fuels.

...In California



TFS Processes

PRE - REFINERY
(FEEDSTOCK)

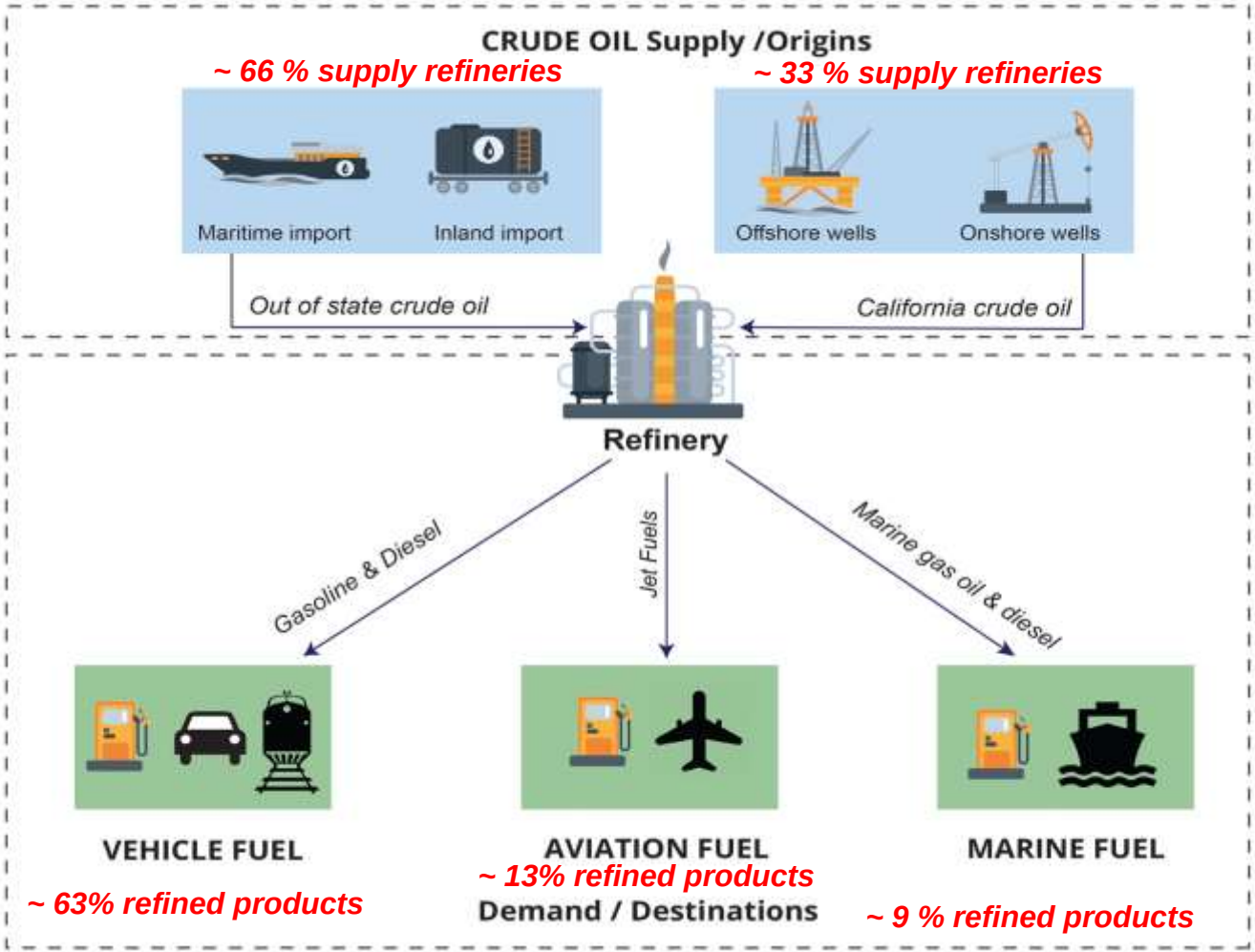
Refinery

POST - REFINERY
(PRODUCTS)

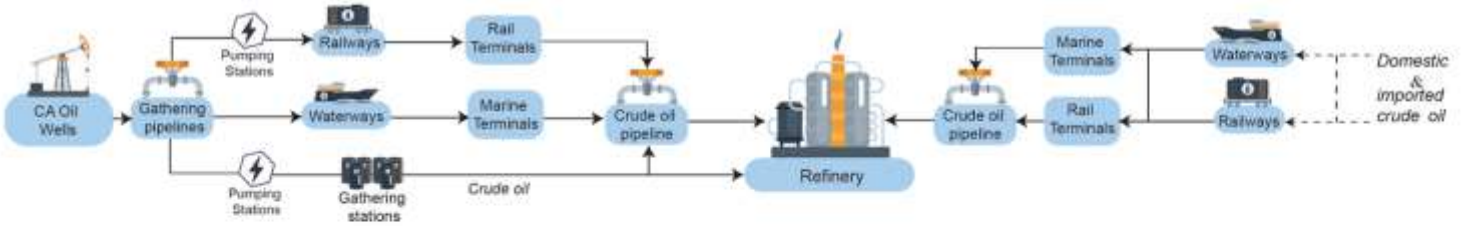
TFS Processes

PRE

POST



Nodes & Links :PRE-REFINERY



Pre-refinery assets comprised in our model

Post-refinery assets comprised in our model

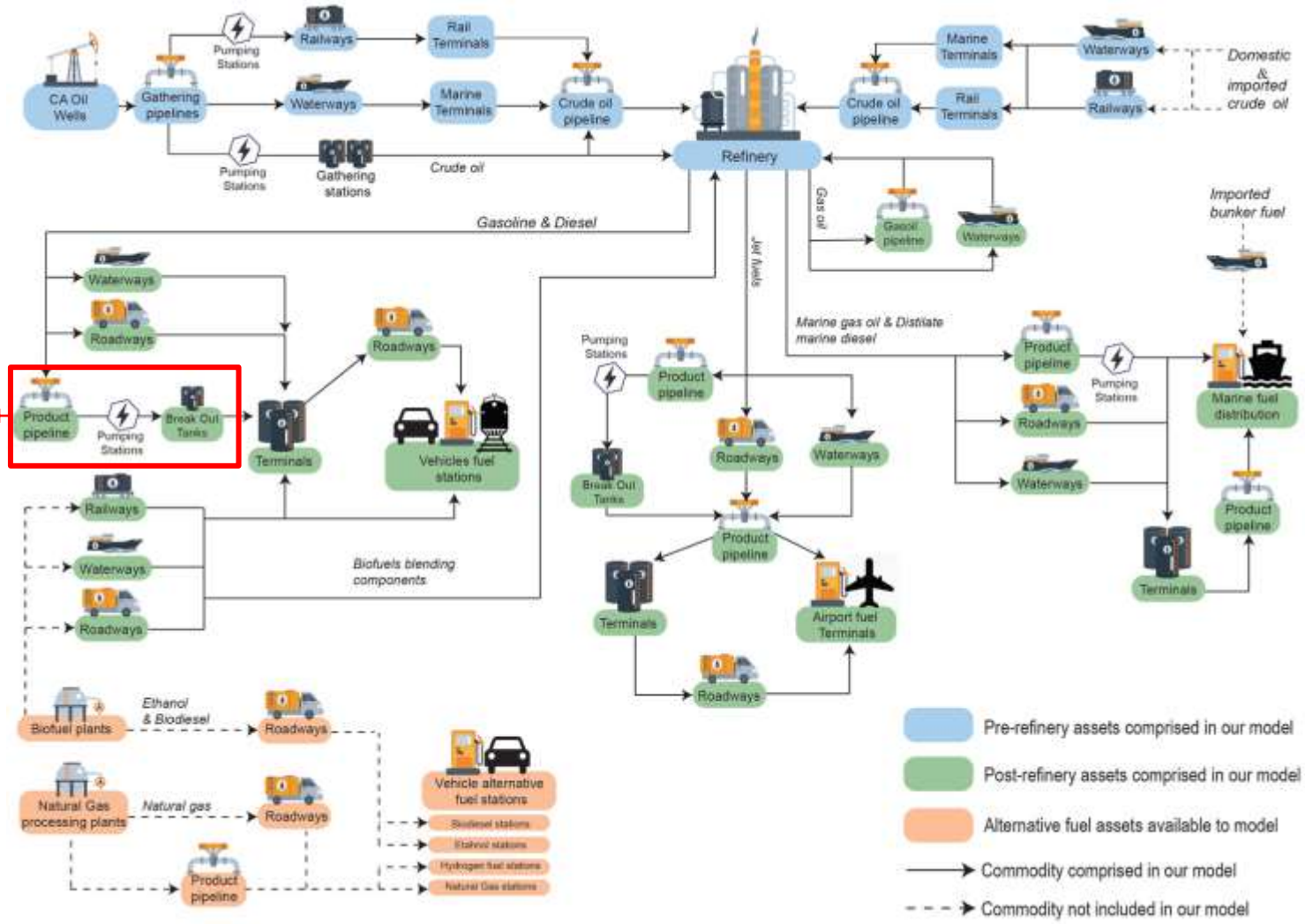
Alternative fuel assets available to model

Commodity comprised in our model

Commodity not included in our model

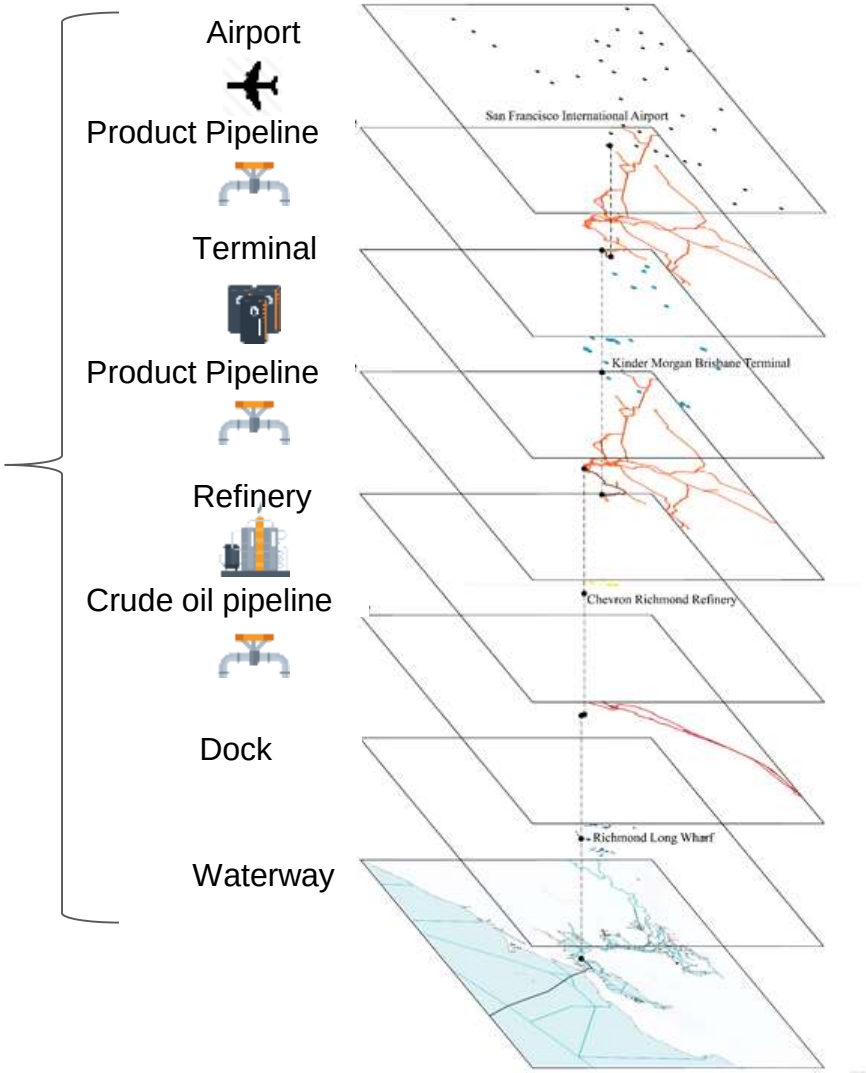
Nodes & Links : POST-REFINERY

75-85% of vol.

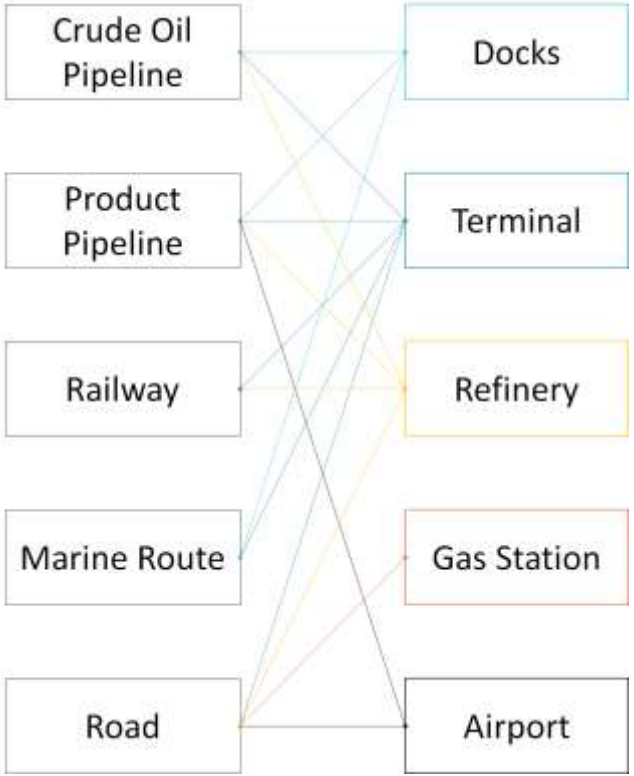


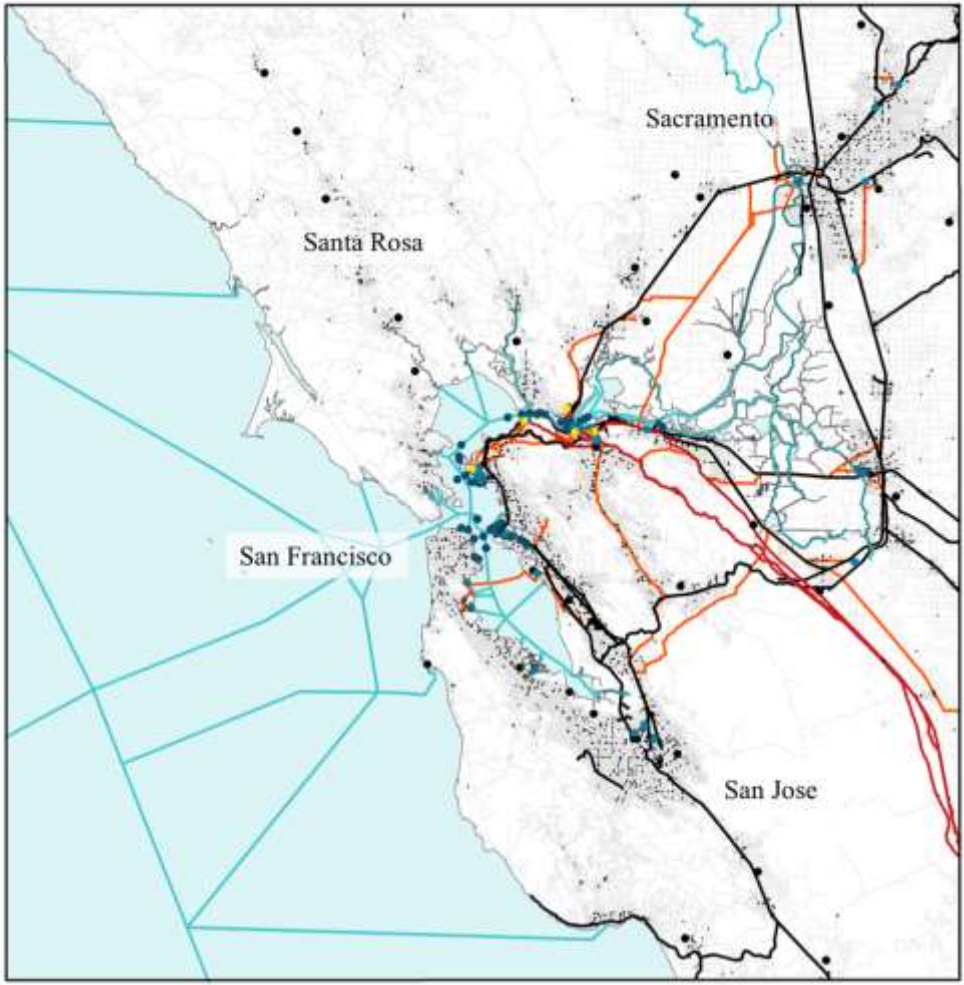
Topological Model of the TFS

Follow the oil molecule from crude oil to end fuel consumer

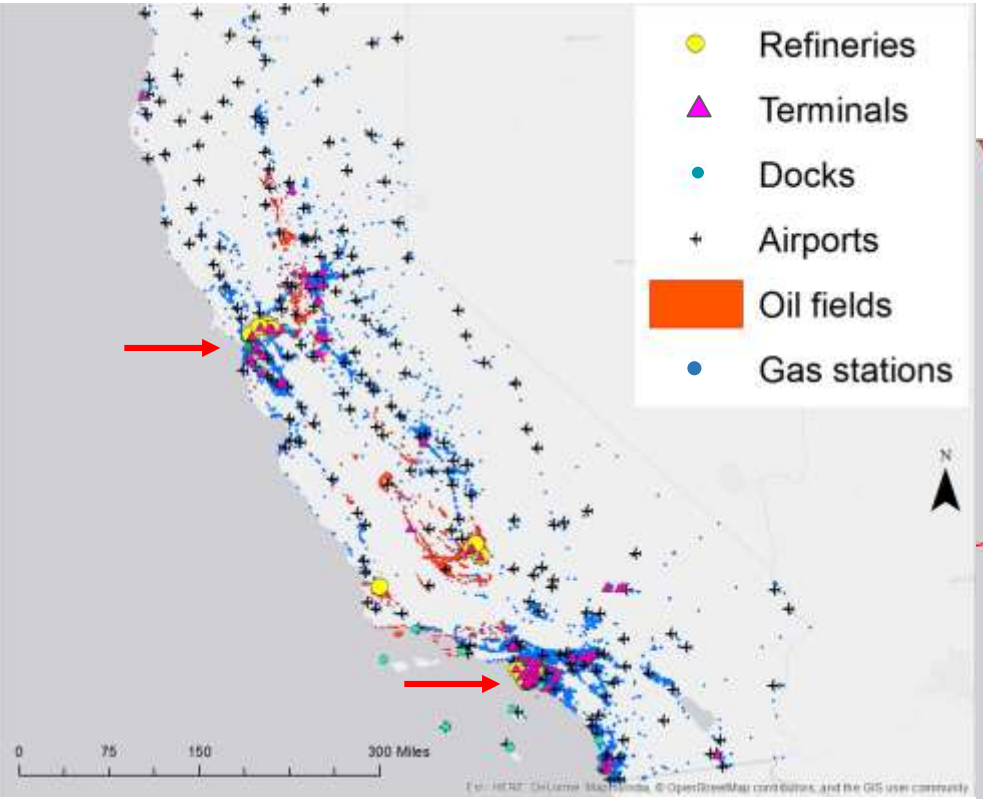


Intra-connectivity

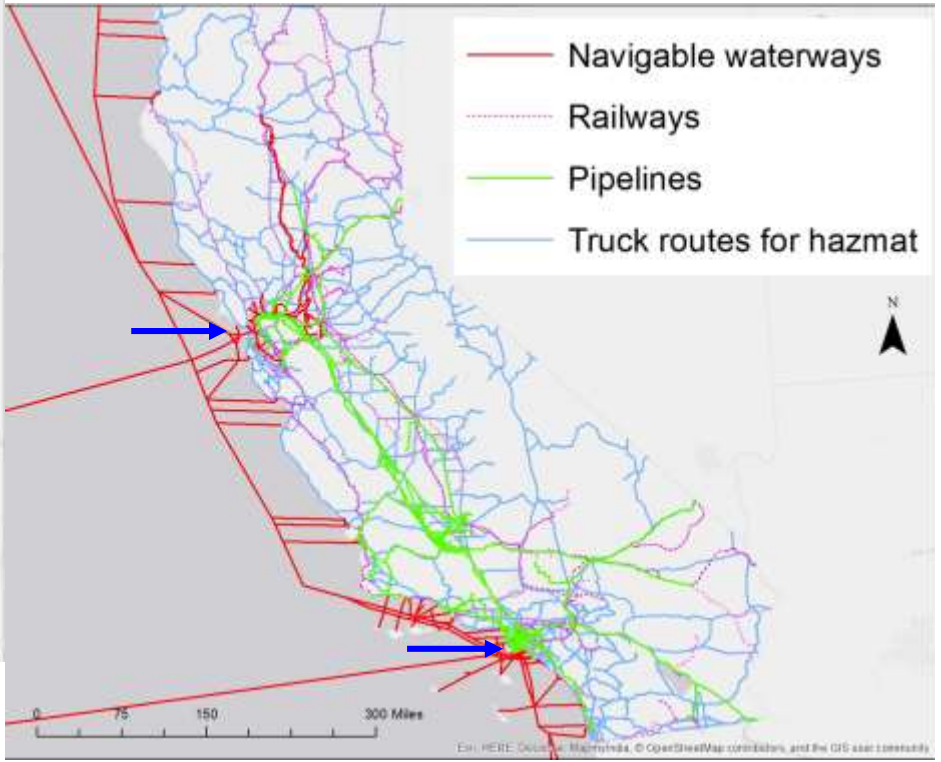




TFS Nodes

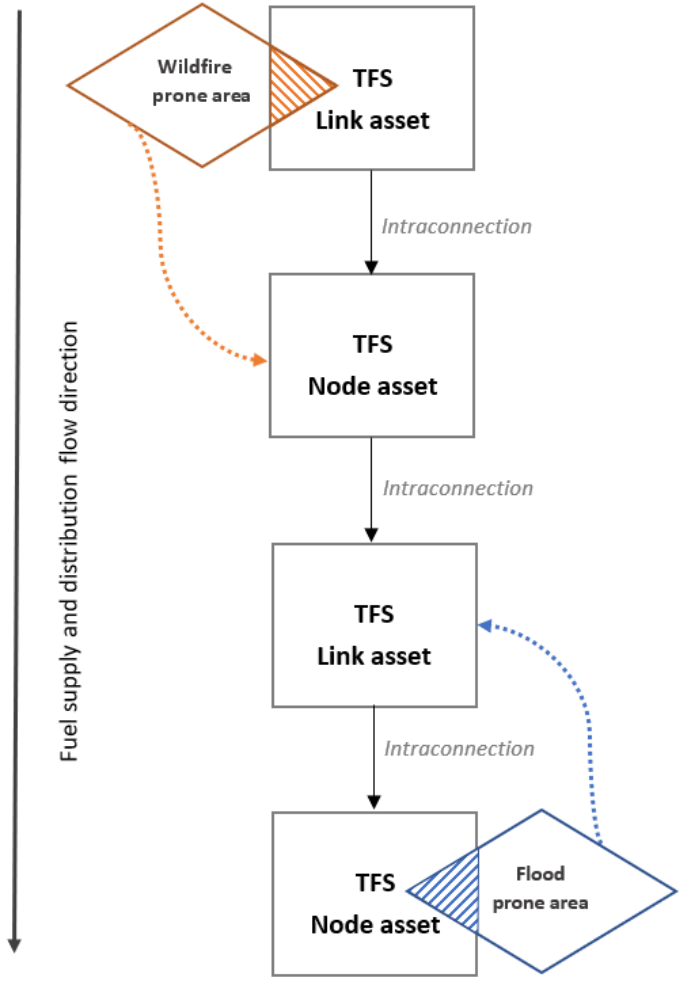


TFS Links



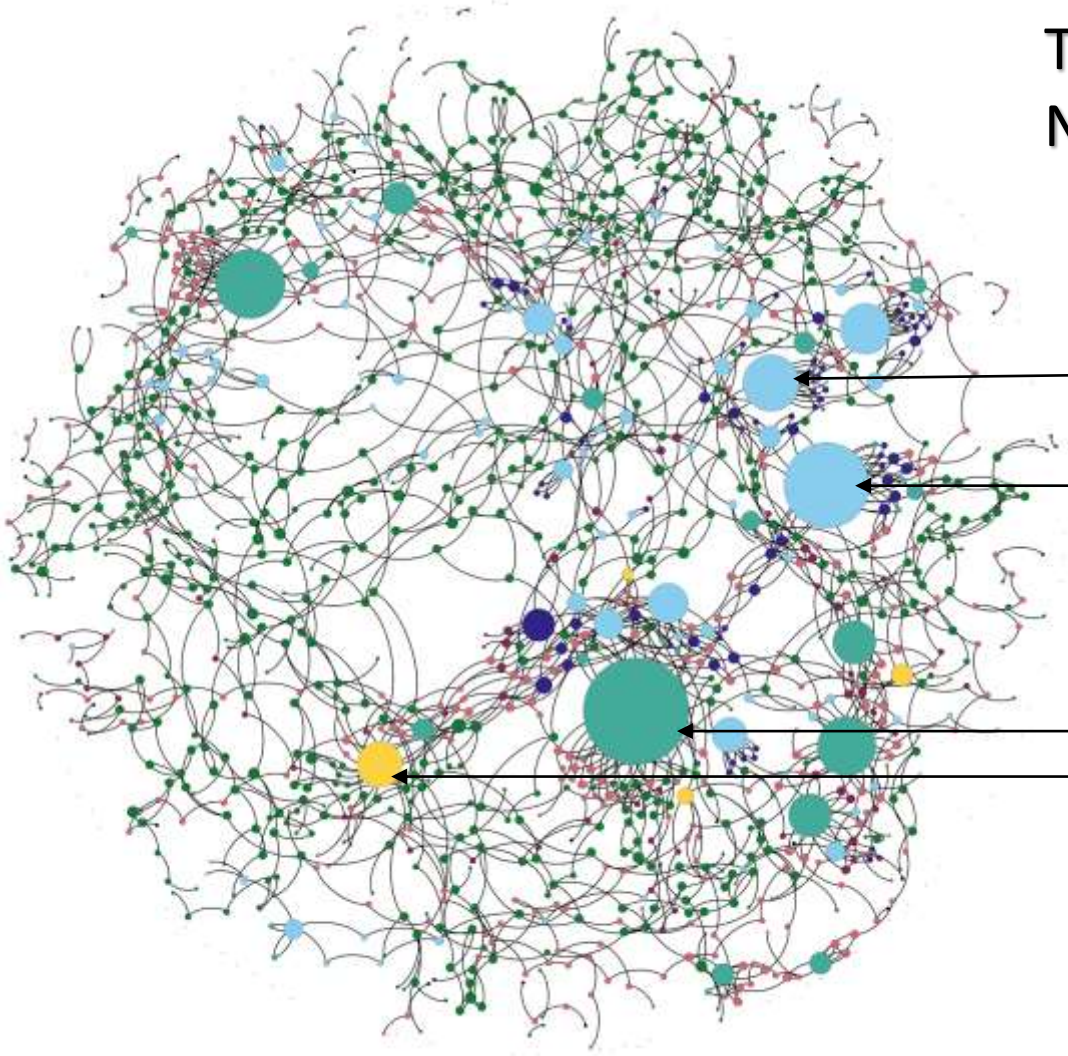
Direct and Indirect Exposure

- Direct exposure = intersect TFS + hazard;
- Not all exposure results in damage or disruption;
- Exposure leading to disruption is location + asset + organizational specific;
- Indirect exposure is relevant because of the high level on interconnectedness of the system

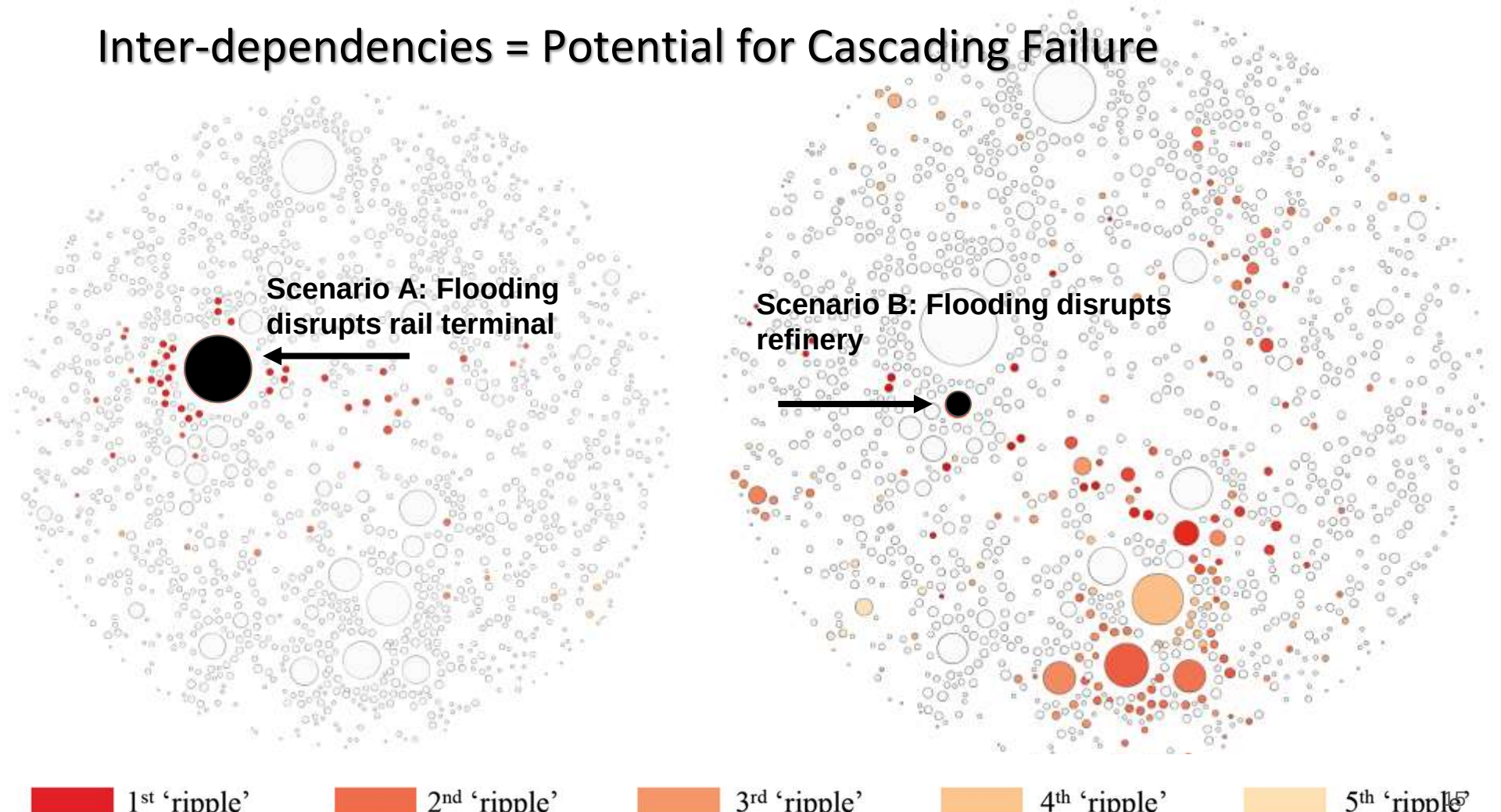


Direct flood exposure – can cause direct damage that can lead to disruptions
Direct wildfire exposure – can cause direct damage that can lead to disruptions
Indirect flood exposure – network connectivity effects that can lead to disruptions
Indirect wildfire exposure – network connectivity effects that can lead to disruptions

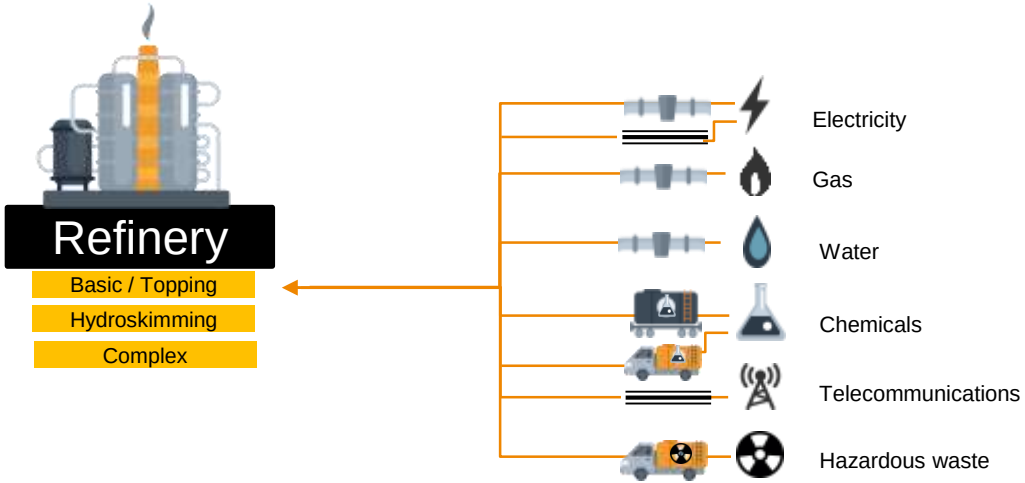
Topological Model: NorCal TFS



Inter-dependencies = Potential for Cascading Failure



Add to that …
California's TFS is Interconnected and Dependent on other Critical Infrastructures



Climate change Impacts for California's Interdependent Transportation Fuel Sector

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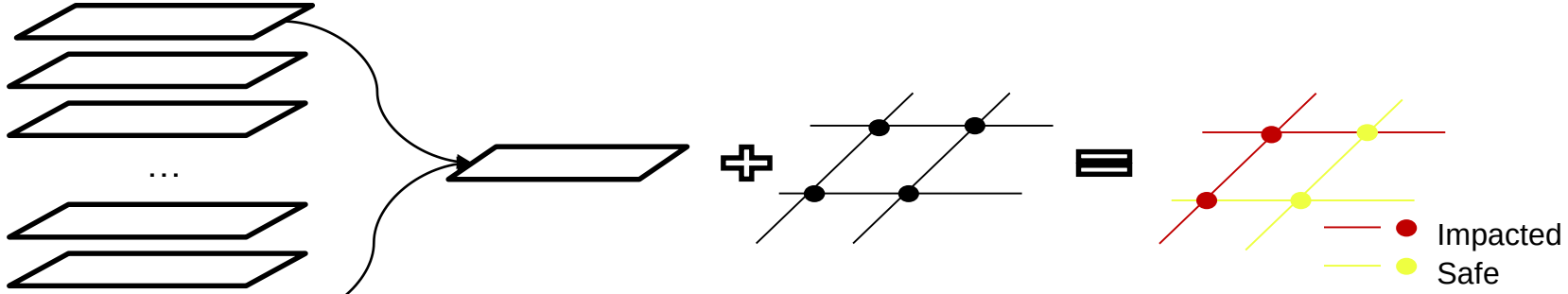
Modeling Logic



Science-based possible future scenarios → Synthesis → Physical infrastructure network → Vulnerability assessment

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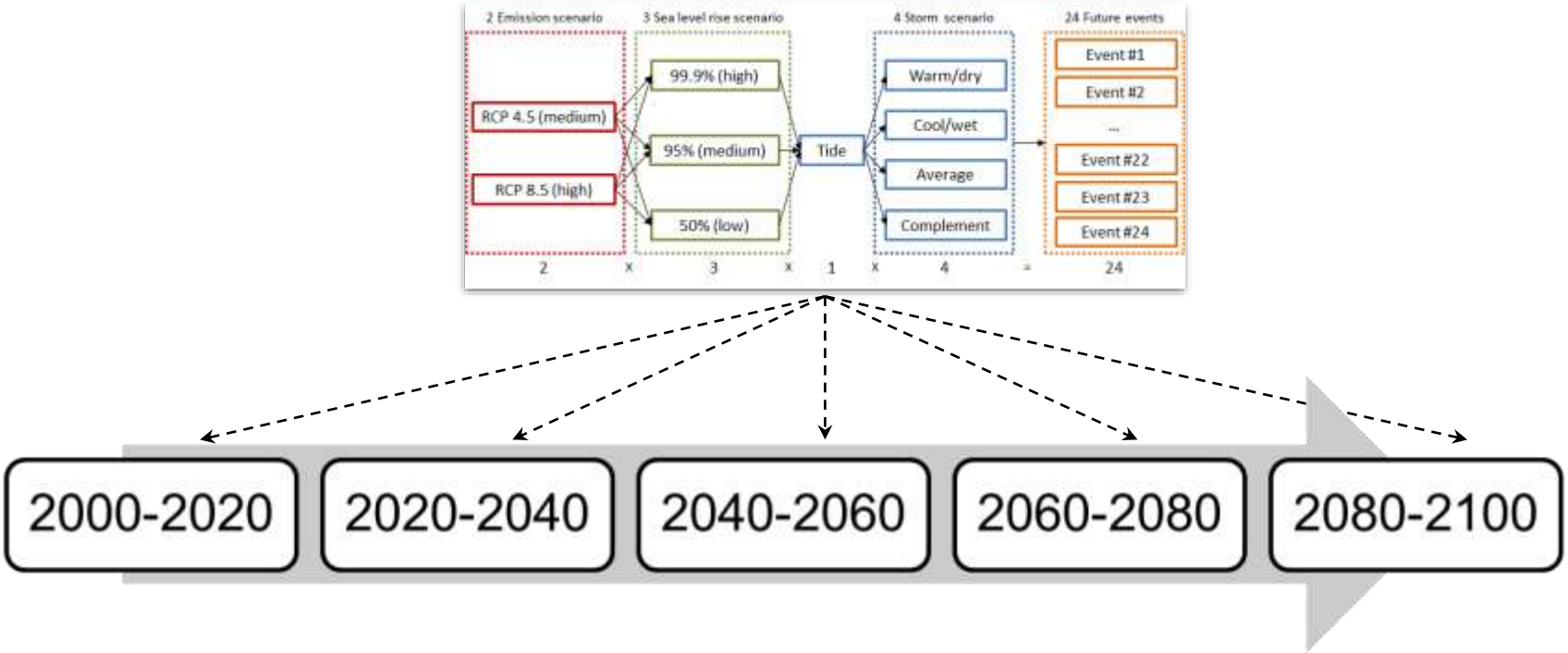
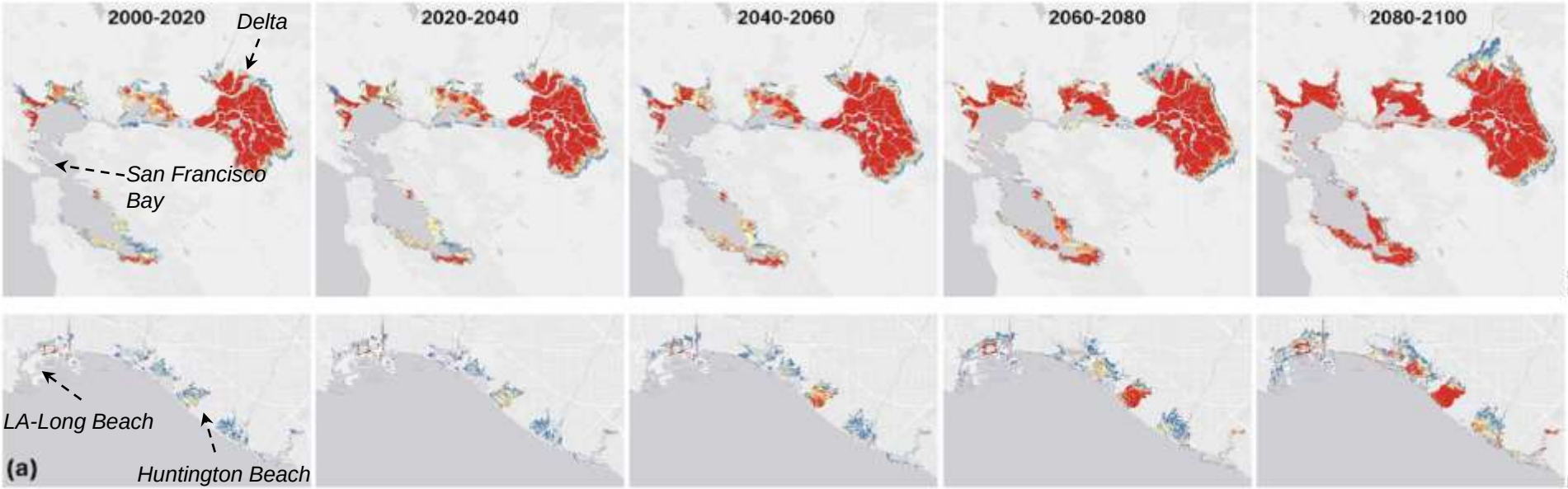
Multi-scenario & Multi-temporal Flooding Model



Five 20-year planning horizons

Statewide Exposure to Coastal Flooding



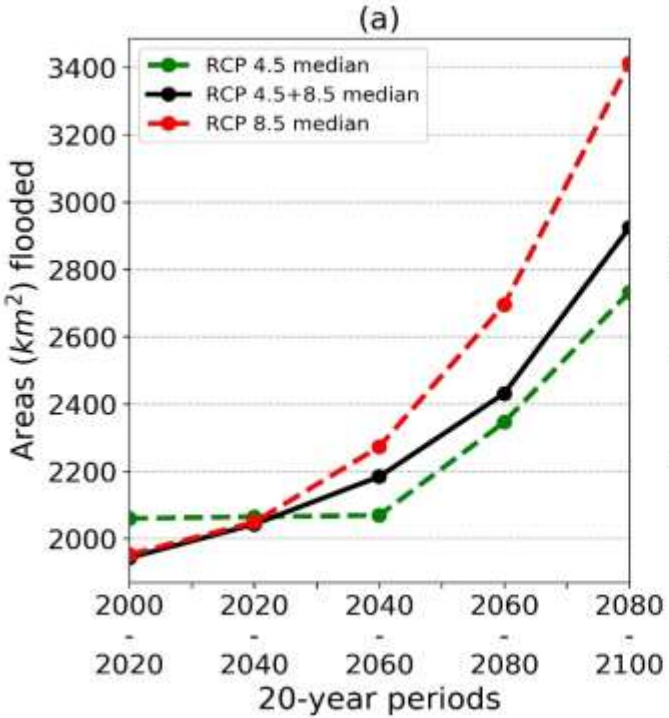
Modeled Flood Exposure

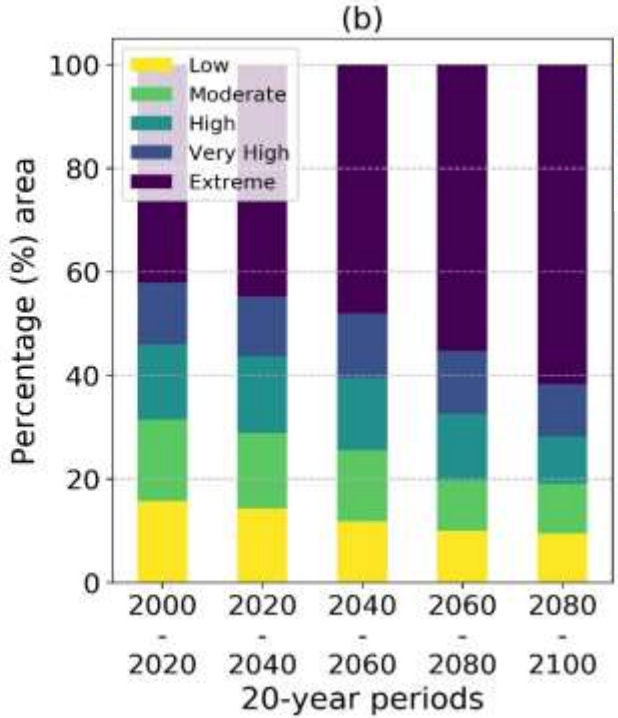
- LOW (0 m – 0.5 m (1.64ft) depth)
- MODERATE (0.5 m (1.64ft) – 1.0 m (3.28 ft) depth)
- HIGH (1.0 m (3.28 ft) – 1.5 m (4.92 ft) depth)
- VERY HIGH (1.5 m (4.92 ft) – 2.0 m (6.56 ft) depth)
- EXTREME (>2.0 m (6.56 ft) depth)

Coastal areas exposed to coastal flooding

**Evaluated using the median-scenario extreme sea level events, every 20 years.*

Statewide Exposed to Coastal Flooding



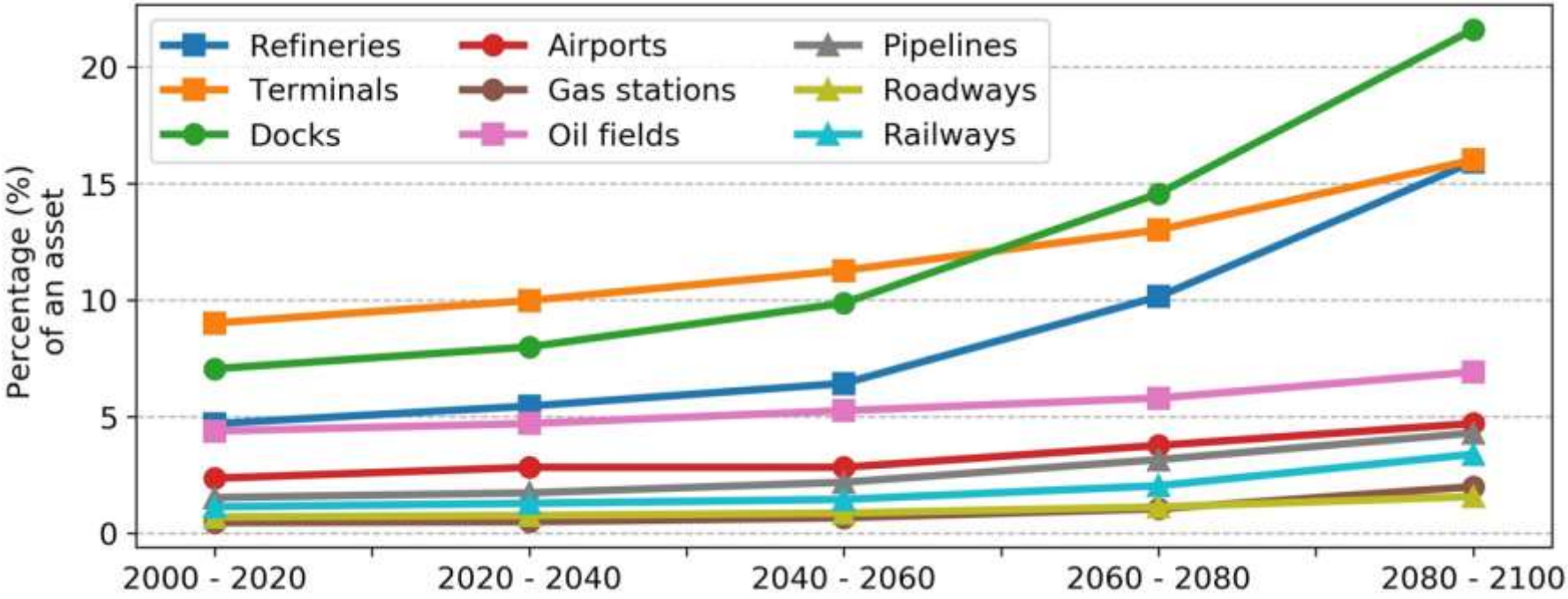


Low exposure (0 m – 0.5 m (1.64ft) depth)
Moderate exposure (0.5 m (1.64ft) – 1.0 m (3.28 ft) depth)
High exposure (1.0 m (3.28 ft) – 1.5 m (4.92 ft) depth)
Very high exposure (1.5 m (4.92 ft) – 2.0 m (6.56 ft) depth)
Extreme exposure (>2.0 m (6.56 ft) depth)

Land area exposed to coastal flooding

**Evaluated using the median-scenario extreme sea level events, every 20 years.*

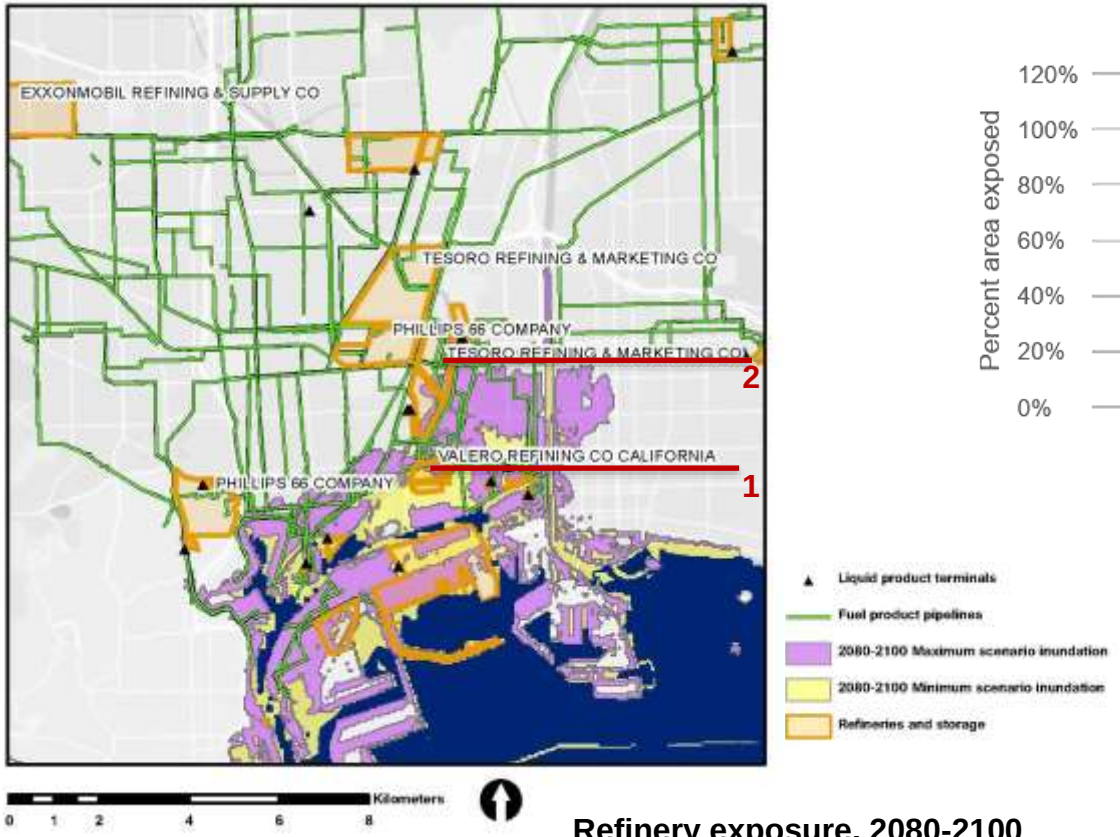
Statewide TFS Exposure to Coastal Flooding



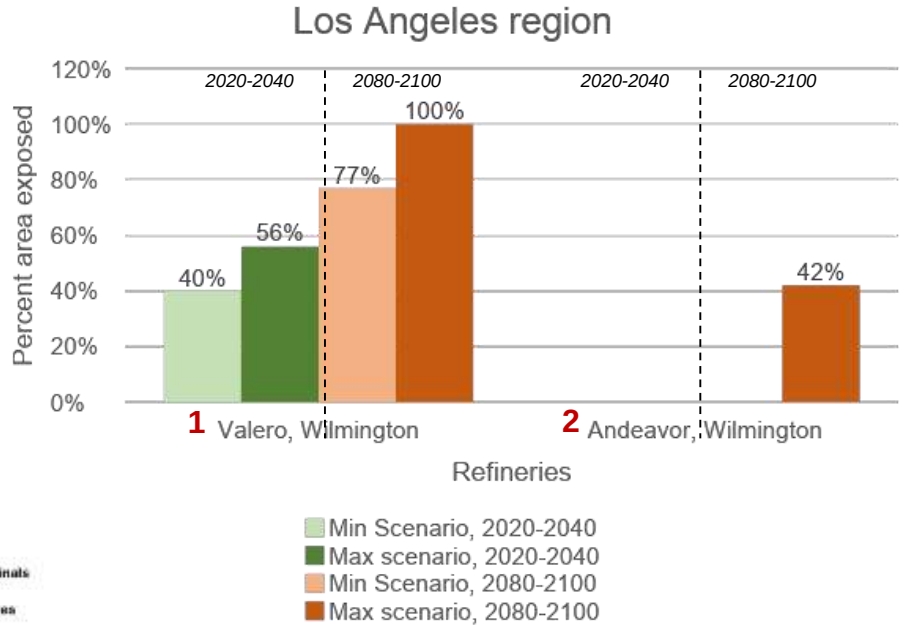
TFS assets exposed to coastal flooding

**Evaluated using the median-scenario extreme sea level events, every 20 years.*

Refineries: Exposure to Coastal Flooding



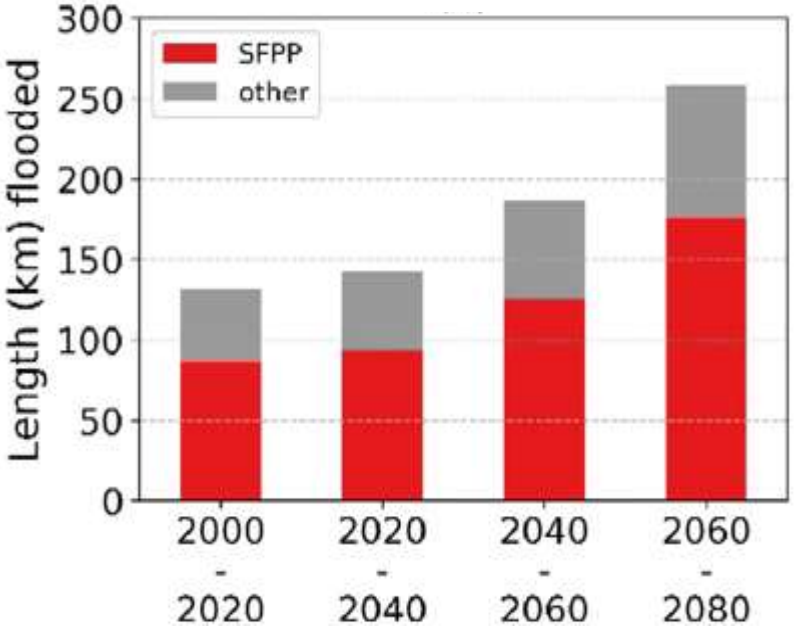
Refinery exposure, 2080-2100



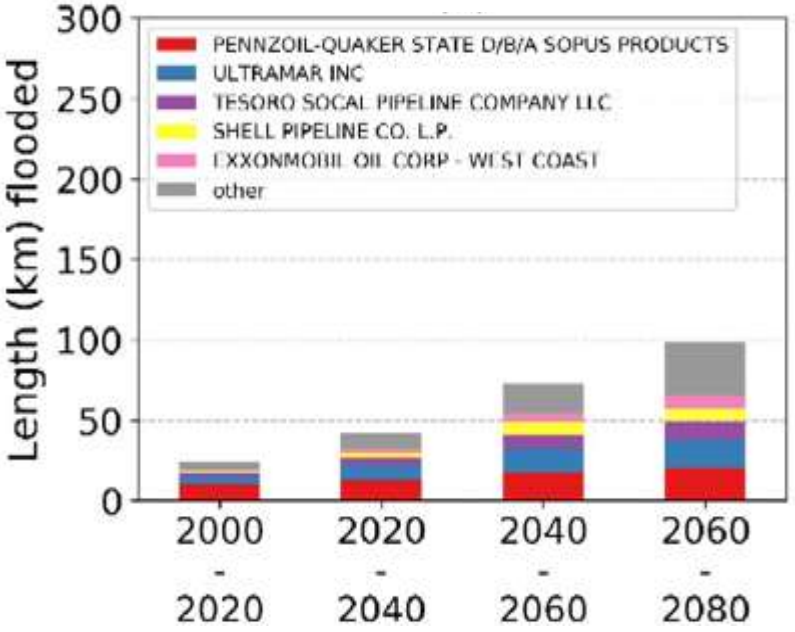
Refinery exposure under the maximum and minimum scenario high sea level event, 2020-2040 and 2080-2100

Product Pipelines: Exposure to Coastal Flooding

Northern California



Southern California



Product pipeline exposure

**Evaluated using the median-scenario extreme sea level events, every 20 years.*

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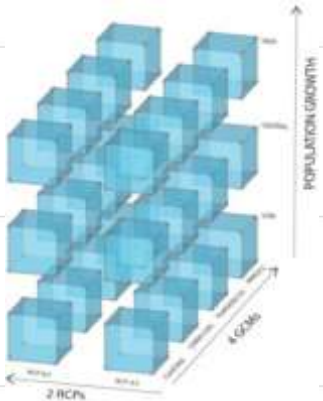
State Level Projections of Area Burned by Large Wildfire Over Time



Area Burned by Wildfire (hectares)

350000
300000
250000
200000
150000
100000

1960's 1970's 1980's 1990's 2000's 2010's 2020's 2030's 2040's 2050's 2060's 2070's 2080's 2090's

Data Source: *Westerling, Anthony Leroy. (University of California, Merced). 2018. Wildfire Simulations for the Fourth California Climate Assessment: Projecting Changes in Extreme Wildfire Events with a Warming Climate. California's Fourth Climate Change Assessment, California Energy Commission. Publication number: CEC-XXX-2018-XXX.*

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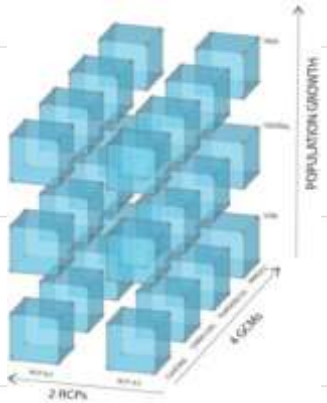

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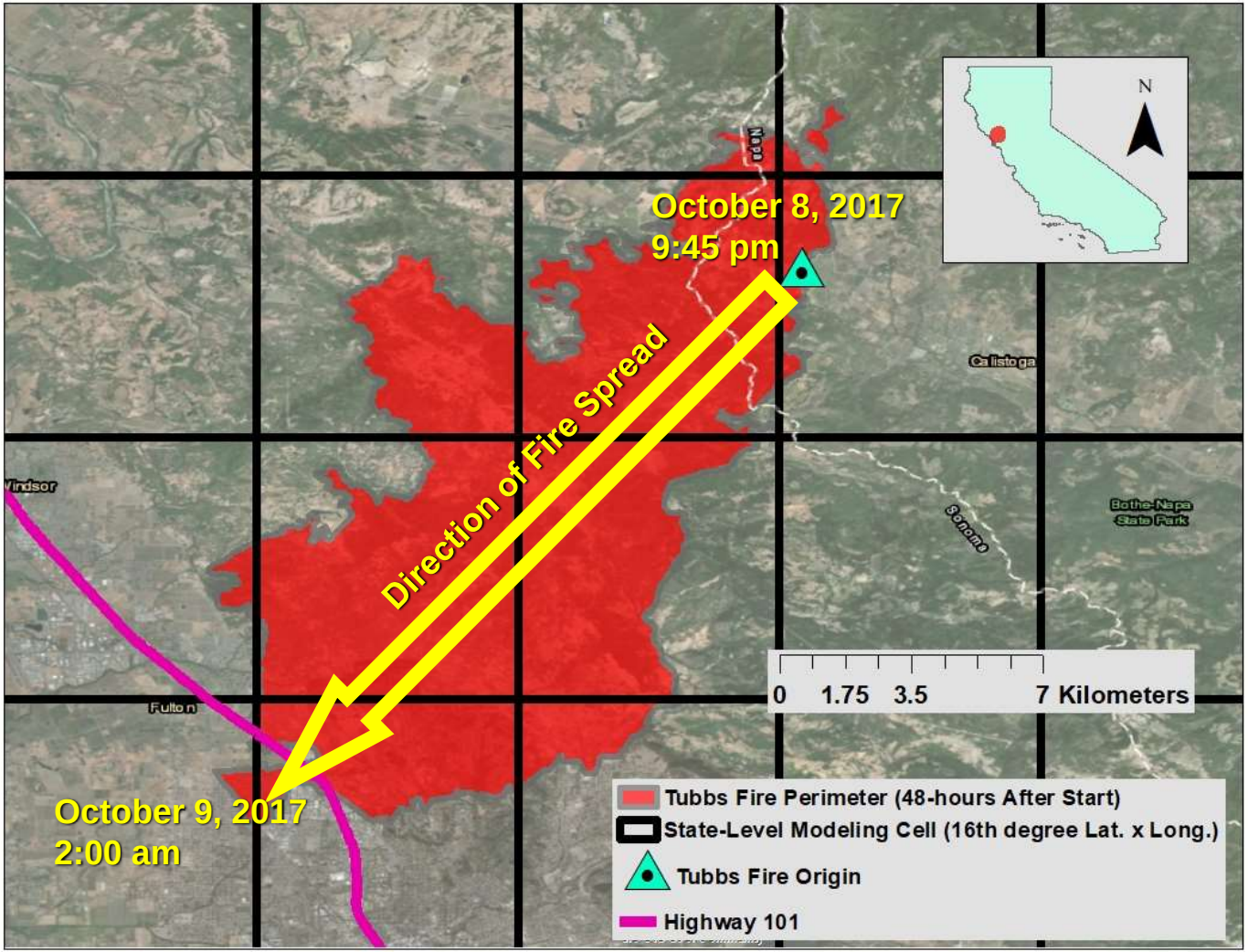
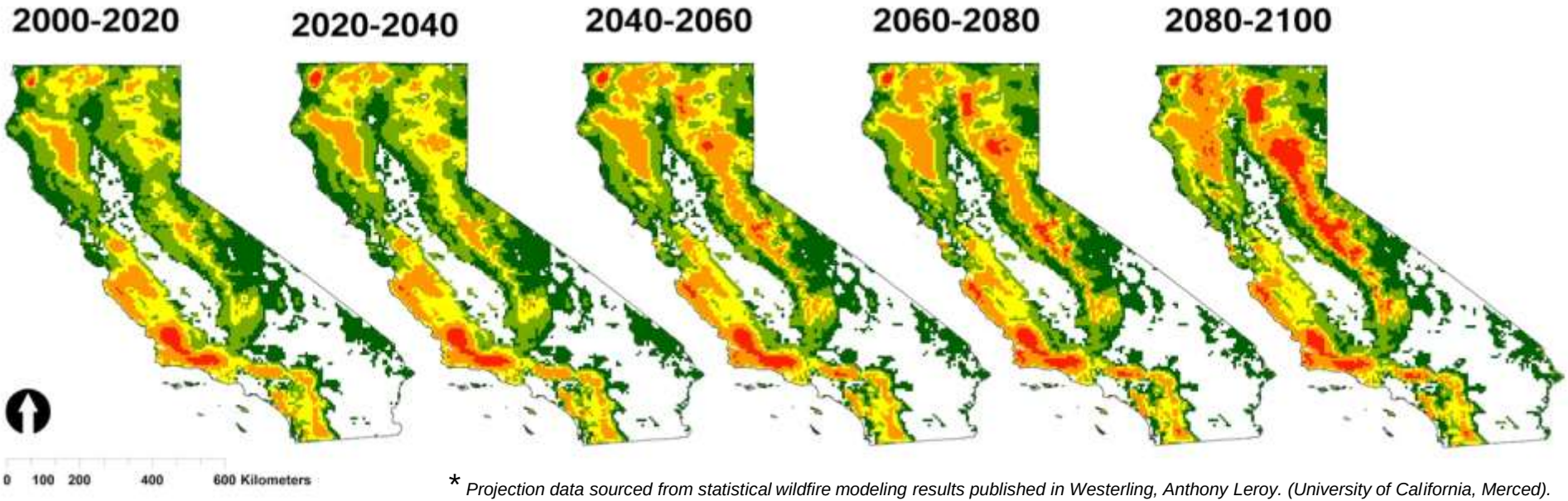

October 8, 2017
9:45 pm
Direction of Fire Spread
October 9, 2017
2:00 am
N
Calistoga
Bothe-Napa State Park
Fulton
0 1.75 3.5 7 Kilometers
Tubbs Fire Perimeter (48-hours After Start)
State-Level Modeling Cell (16th degree Lat. x Long.)
Tubbs Fire Origin
Highway 101

Projected* Statewide Changes in Wildfire Over Time

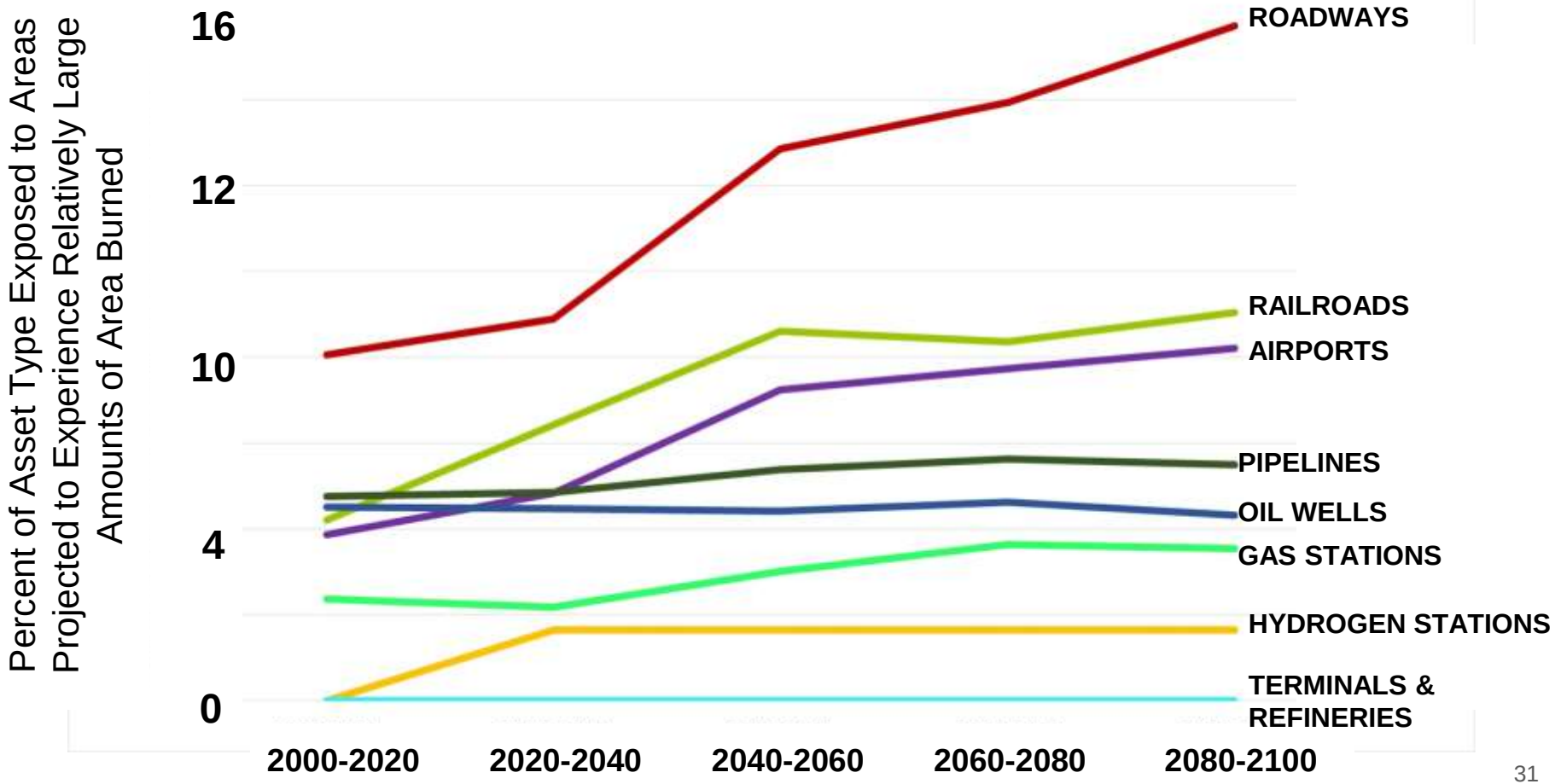
Relative Amount of Area Burned by Large Wildfires During 20-Year Period*

VERY LITTLE **EXTREMELY LARGE**



* *Projection data sourced from statistical wildfire modeling results published in Westerling, Anthony Leroy. (University of California, Merced). 2018. Wildfire Simulations for the Fourth California Climate Assessment: Projecting Changes in Extreme Wildfire Events with a Warming Climate. California's Fourth Climate Change Assessment, California Energy Commission. Publication number: CEC-XXX-2018-XXX.*

Exposure of TFS Nodes and Links to Large Wildfire



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Organizations involved

Andeavor
Buck Oil Trucking Company
Cal Fire
Cal OES
California Energy Commission
California Fuel Cell Partnership
California Independent System Operator (CalISO)
California Office of Spill, Prevention, and Response (OSPR)
California Public Utilities Commission (CPUC)
California State Lands Commission
California Utilities Emergency Association
CIOMA
County of LA
Crimson
Dewitt Petroleum
Downs Energy
Engineering, Procurement, and Construction
California Fire Marshals
Fiedler Group
Interstate Oil Company
Jacobsen Pilots
Kinder Morgan
Los Angeles Department of Water and Power
Los Angeles Emergency Preparedness Foundation
Luxfer-GTM
Nexant, Inc.
Nustar Energy
PG&E
Phillips 66
Plains All American Pipeline
San Diego Law Enforcement Coordination Center
San Francisco International Airport
San Jose Water Company
SF Department of Emergency Management
Shell Oil Products
Southern California Edison
Travis Air Force
United Hydrogen
US Coast Guard Sector San Francisco
US Defense Logistics Agency
US Department of Energy
US Department of Homeland Security
US Department of Transportation
US Geological Survey
US Navy

Stakeholder engagement lead to …

1. Fine-resolution better captures the exposure at the asset scale;
2. Stakeholders are more interested in the near-term: 2020-2040;
1. Stakeholders identified several locations for fine-resolution modeling.

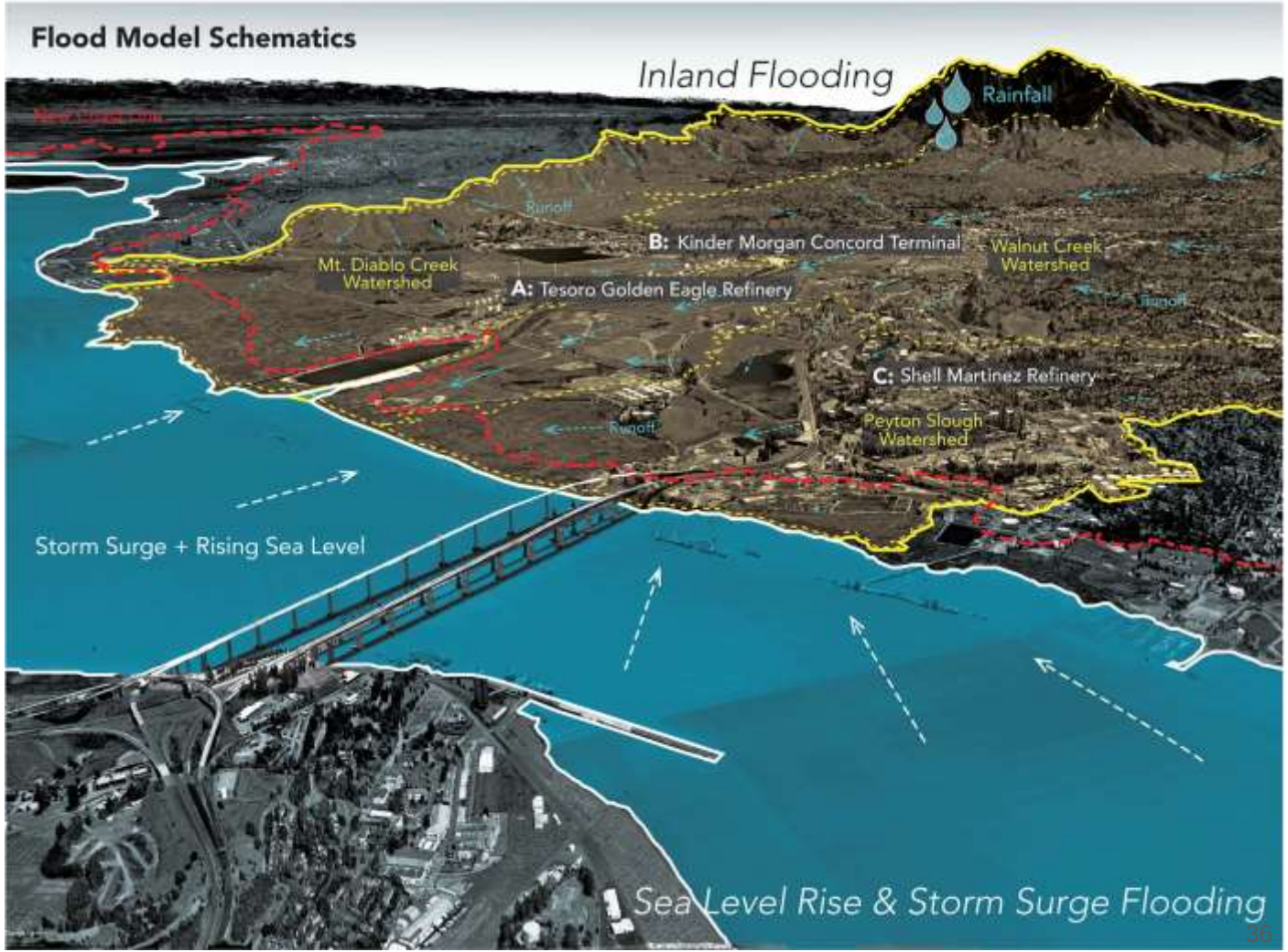
Areas of Interest - Flooding

- Terminal

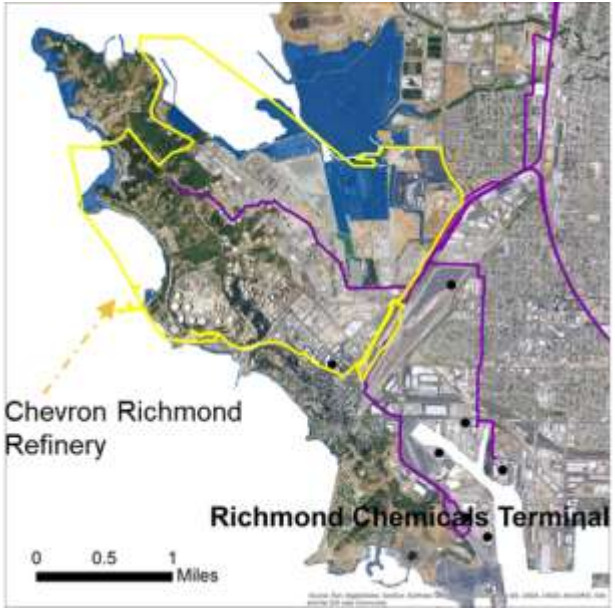
NPMS piplelines

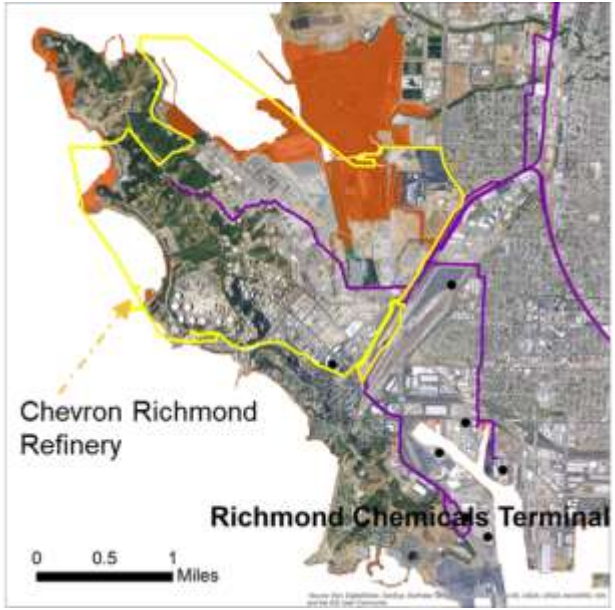
- SFPP Northern region
- Refinery boundary (tax parcel)
- Flooding, medium scenario

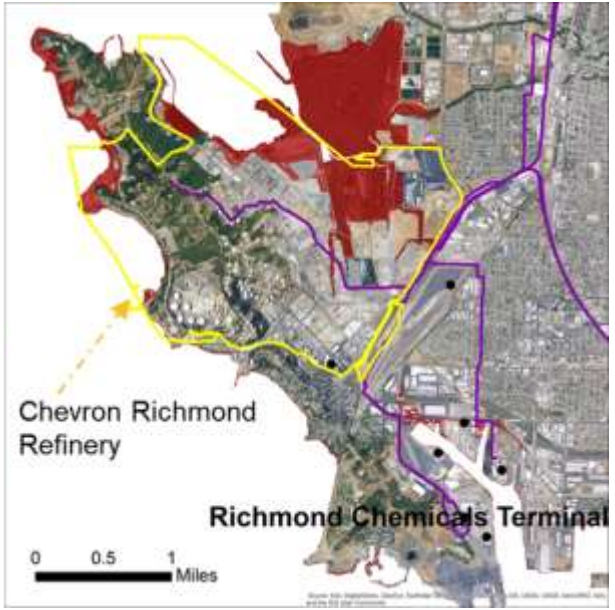
Fine Spatial Resolution Coastal and Inland Flooding



Nearer-term Flood Exposure (2020-2040)



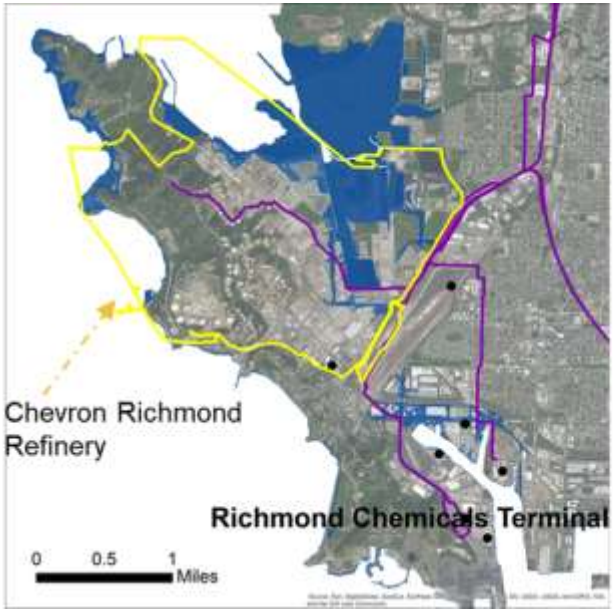


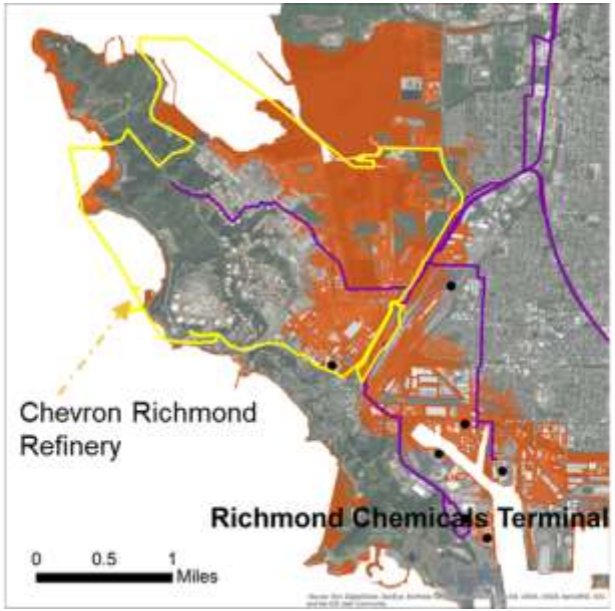


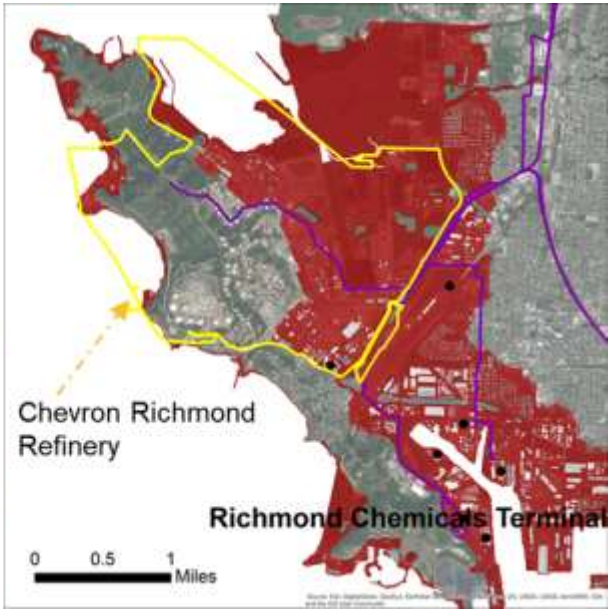
Low SLR scenario
Medium SLR scenario
High SLR scenario

Terminal
NPMS piplelines
SFPP Northern region
Refinery boundary (tax parcel)

Longer-term Flood Exposure (2080-2100)







Low SLR scenario
Medium SLR scenario
High SLR scenario

Terminal
NPMS piplelines
SFPP Northern region
Refinery boundary (tax parcel)

Areas of Interest - Fire

1. Increases in the likelihood of large wildfire expected in mountainous regions of California including the Sierra Nevada, the southern Cascades, and the inland ranges of the central Coast;

1. TFS asset types (e.g. roads, railways, and pipelines) dispersed throughout the State are more exposed to large wildfire hazards;

2. Fine spatial resolution modeling wildfire allows for more accurate exposure evaluation for specific TFS assets at a local scale and is more effective for engaging stakeholders in discussions of asset vulnerability.

Wildfire Behavior Modeling

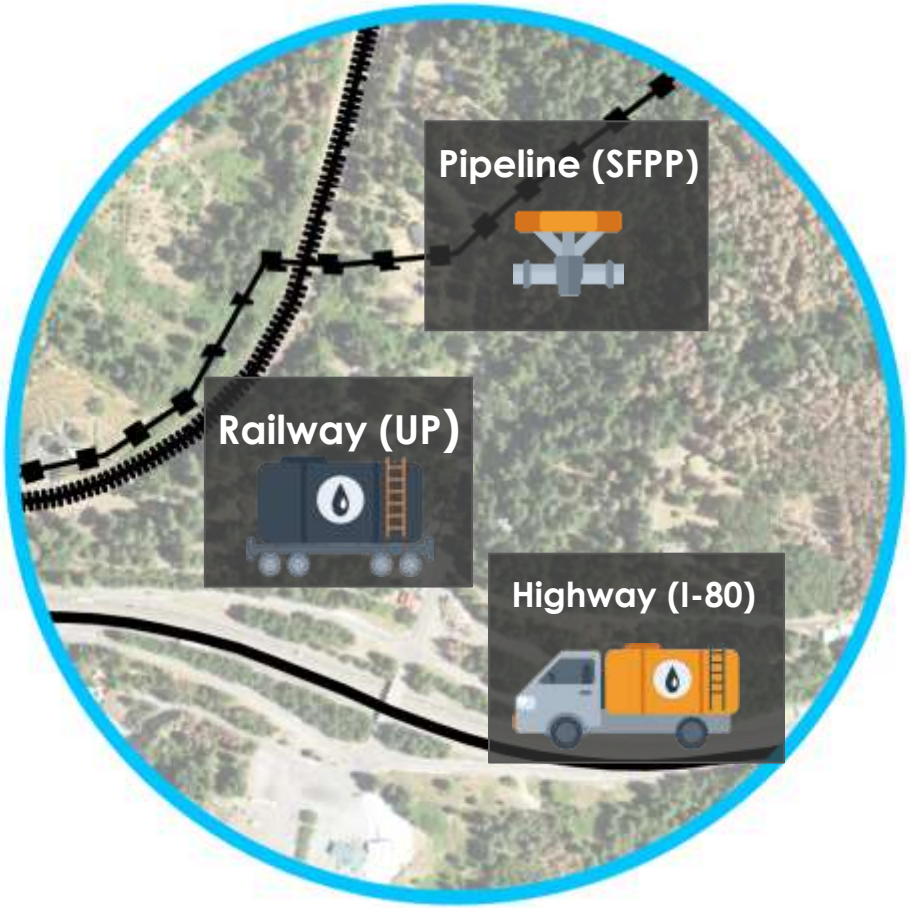
High Resolution Data

675 meters

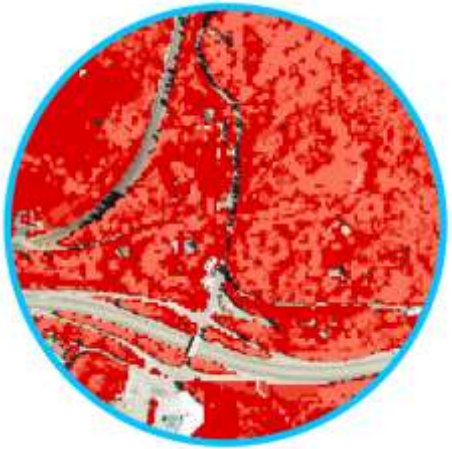
0.5 miles

Wildfire Behavior Modeling

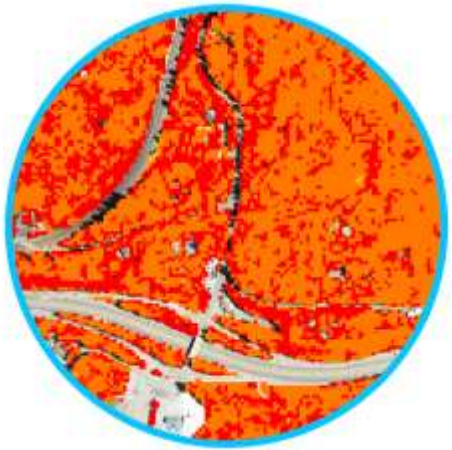
TFS Infrastructure



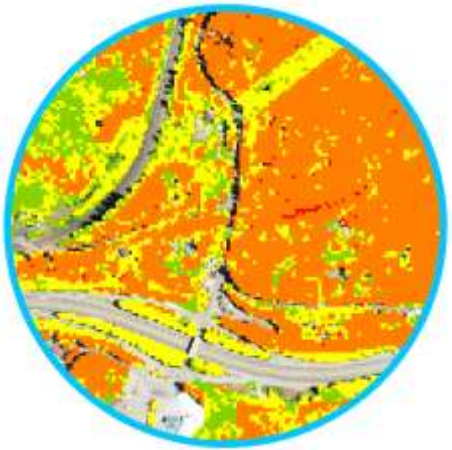
High Res Wildfire Modeling Products



Rate of Spread
Speed of wildfire spread

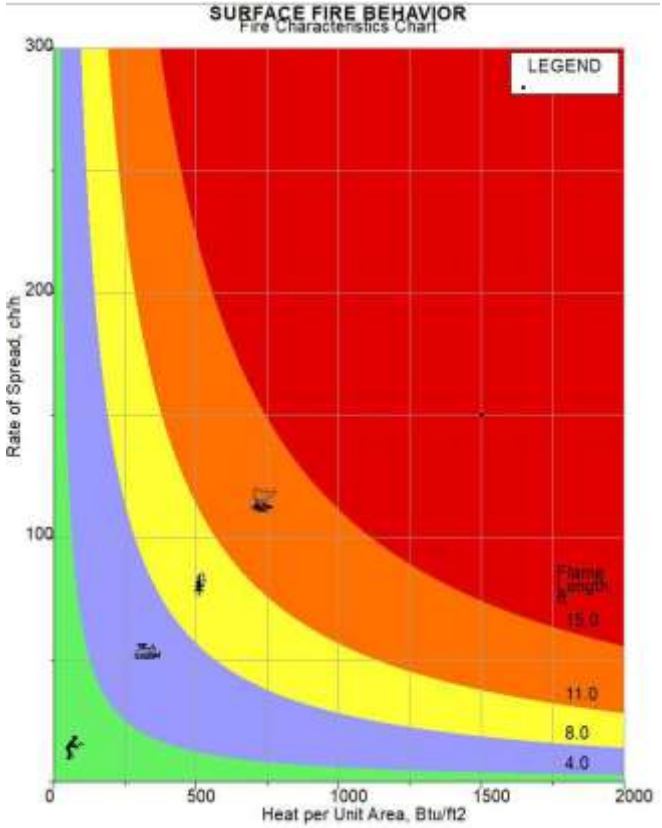


Flame Length
Length of flame emitted



Fire Intensity
Heat per Unit Area

Wildfire Behavior and Suppression Options – Lead to Mitigation Strategies



Increasing Control Difficulty

Metric Classes		Rate of Spread (ft/min)	Flame Length (ft)	Fire Intensity (BTU/ft^2)
Very Low/ None		0 - 5	0 - 4	0 - 100
Moderate		5 - 20	4 - 8	100-500
High		21 - 50	8 - 12	500 - 1,000
Extreme		50+	12+	1,000+

Climate change Impacts for California's Interdependent Transportation Fuel Sector

- What is the California Transportation Fuel Sector (TFS)?
- Modeling exposure of the TFS to Flooding and Wildfire (under Climate Change)
  - Exposure to Flooding
  - Exposure to Wildfire
- Stakeholder engagement
- What have we learned?
- What are implications of our findings?

TFS is extremely complex

- Physically, but also organizationally;
- The sector functions because of contracts and agreements between all stakeholders.

- No one stakeholder or group
  - Has comprehensive overview of all of TFS;
  - Or has ability to respond reliably to all exposure risks and uncertainties.

TFS is Interconnected with the Energy Sector

- The energy sector is interconnected with the TFS, energy (and the same holds for water and refineries) is critical and integral to TFS assets;

- TFS stakeholders underscore the importance of interconnected external industry infrastructures that are critical to the their successful operation;

- The necessity and added value of finer resolution modeling, help indicate the necessity to also look at exposure of key interconnected infrastructure that the TFS depends on.

Critical TFS Assets

- Refined product pipelines are critical assets in the TFS;
- Central distribution terminals are critical assets in the TFS;
- Refineries in Northern California are predicted to be flooded as early as the 2020-2040 period;
- Uncertainty in hazard modeling and asset exposure increase further in the Future.

TFS Stakeholder Engagement

- Most stakeholders do not exceed 10 years for their current planning and investment cycles, with 20 years as the limit for their strategic planning;

- Stakeholders suggest that research studies should look at the life-cycle of the TFS assets and to relate those to projections of exposure;

- Throughout the stakeholder engagement process, stakeholders express difficulty in utilizing the proliferating climate-related projection models;

- Downscaling each exposure potential to the asset level at finer resolutions is effective in addressing the uncertainty surrounding the use of larger scale climate hazard modeling.

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Potential policy implications

1. Long term planning requires inclusion of scientific and modeling uncertainties + organizational/institutional uncertainties;
2. Multiple extreme weather events have different impacts on TFS assets due to distribution (or lack thereof) throughout the state;
3. Ability to focus at finer resolution allows for better alignment with existing depreciation, investment and other planning cycles;
4. TFS entities face a certain future where measures to harden or make more resilient their key assets are unavoidable for many different reasons, including climate change;
5. The TFS needs to be viewed as a system that is part of a greater system.