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Gulf Coast Resiliency:

Nature-Based Solutions to Mitigate Toxic Flooding

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Toxic Flooding

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Project Goals

- Understand toxic releases due to flooding
- Where and how nature-based solutions (NBS) can be used to reduce risks of chemical release and exposure

Agenda

- Contaminants in fish
- Chemical facility sources & vulnerable communities
- NBS case studies
- NBS guide

Contaminants in Fish

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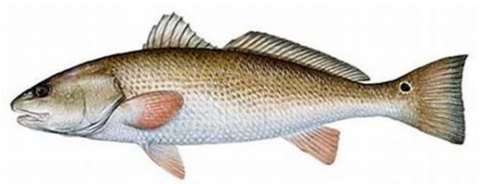
Environmental Contaminants in Fish: An Analysis of PFAS and Heavy Metal Concentrations

Speckled Trout



Red Drum

Black Drum

Sampled 64 fish which were taken from Galveston and Trinity Bay to assess for the concentration of:

- Heavy Metals | Arsenic (As), Cadmium (Cd), Copper (Cu), Mercury (Hg), Lead (Pb), and Selenium (Se)
- Per- and polyfluoroalkyl substances (PFAS)

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How have chemical releases in the environment contaminated marine organisms?

Heavy Metal Concentration (mg/kg) in Fish Samples

Analyte	Mean (µ)	Median	Range
As*	0.0773	0.0639	0.018 to 0.321
Cd	0.0125	0.0099	0.000 to 0.096
Cu	0.9353	0.8510	0.163 to 3.990
Hg	0.2633	0.2334	0.067 to 0.641
Pb	0.0709	0.0000	0.000 to 0.647
Se	3.7809	3.4250	1.990 to 7.110

* Estimated inorganic arsenic present in samples

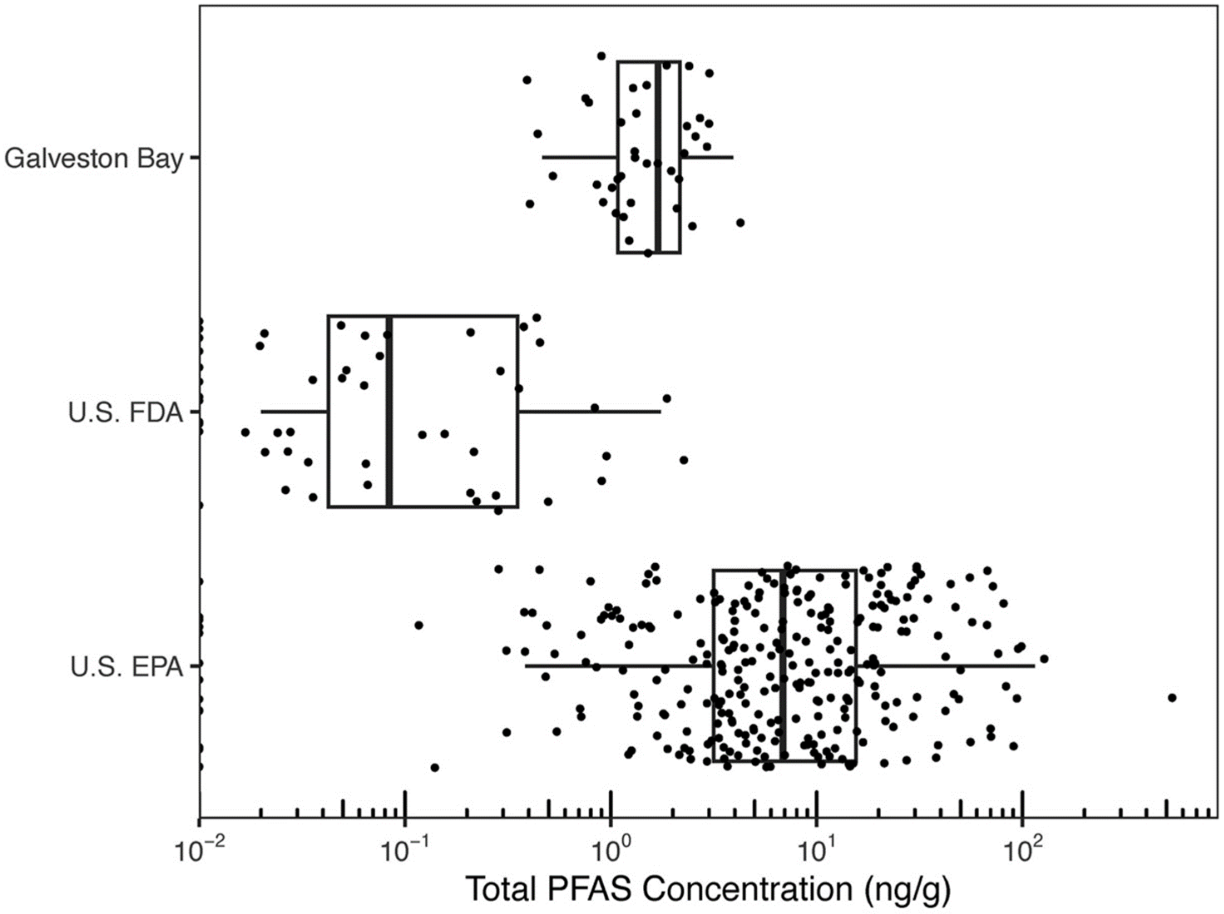
How have chemical releases in the environment contaminated marine organisms?

Target Hazard Quotient For Each Metal by Quantity of Ingested Fish

Analyte	**THQ** (Average Consumption)	**THQ** Weekly	**THQ** bimonthly	**THQ** Twice Yearly
As*	3.33	13.32	6.66	0.56
Cd	0.20	0.80	0.40	0.03
Cu	0.31	1.24	0.62	0.05
Pb	0.23	0.92	0.46	0.04
Se	10.12	40.48	20.24	1.69

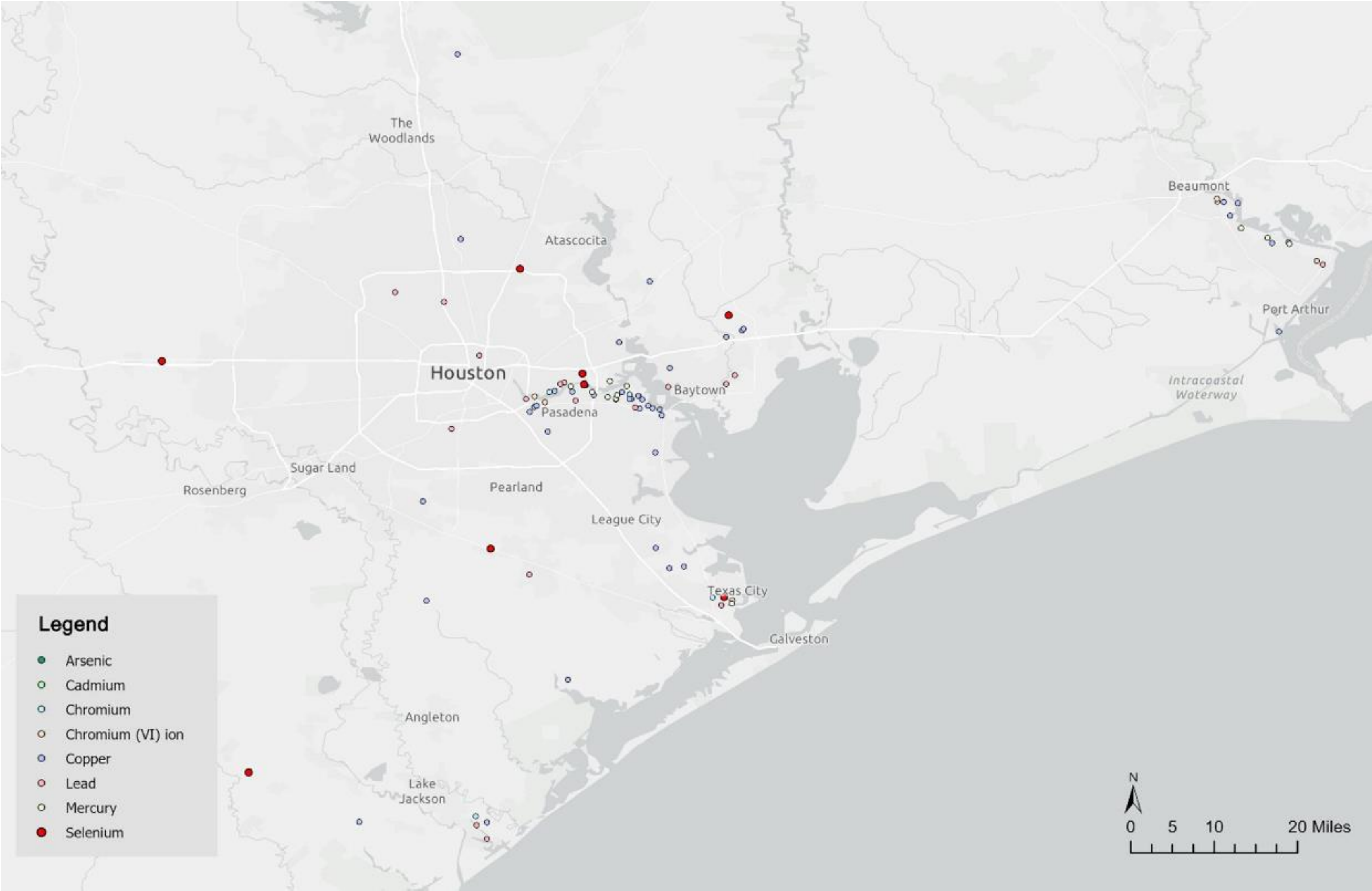
* Estimated inorganic arsenic present in samples

PFAS in Fish



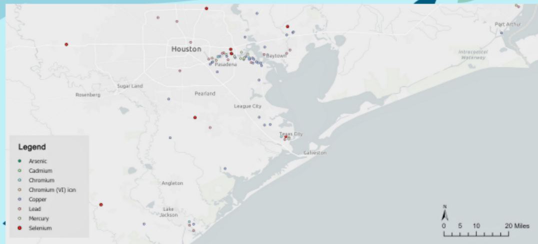
- Perfluorinated and polyfluorinated substances, collectively known as PFASs, are widely used, long lasting chemicals, many of which break down very slowly over time.
- We found total PFAS concentrations on average lower than EPA national freshwater survey, but higher than FDA retail fish survey.
- EPA recently finalized drinking water regulations for six PFAS.

Potential Causes for this Contamination



Under the Surface: Assessing Heavy Metals in Fish

We analyzed **64** fish from the Houston Ship Channel and Trinity Bay for heavy metals.



- Type of fish collected:
  - Black Drum
  - Red Drum
  - Speckled Trout

To analyze the potential health risks we used an assessment tool called the Target Hazard Quotient (THQ). The THQ is calculated by comparing the estimated dose of a substance that an individual is exposed to with the reference dose.

- Results show that the THQ for Cadmium, Copper, and Lead are below 1 suggesting their consumption is within safer ranges. However, the THQ levels for Arsenic and Selenium are above 1 resulting in a higher risk. This is assuming these fish are being consumed regularly as a main source of protein.

THQ For Each Heavy Metal Based On Quantity Consumed

Metal	THQ Weekly	THQ Bimonthly	THQ Monthly	THQ Twice a Year
Arsenic	13	7	3	1
Cadmium	<1	<1	<1	<1
Copper	1	1	<1	<1
Lead	1	<1	<1	<1
Selenium	40	20	10	2

- If THQ is **<1** this indicates that there is unlikely to be any significant risk of adverse health effects
- If THQ is **>1** this indicates a potential risk of adverse health effects. The higher the THQ, the greater the potential risk

If you want to know more about the effects of heavy metals please visit the FDA website: https://www.fda.gov/food/chemical-contaminants-pesticides/environmental-contaminants-food

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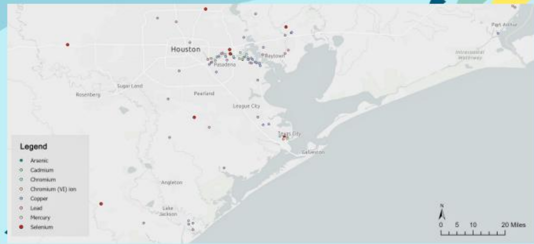
Bajo la superficie: Evaluación de metales pesados en peces

Analizamos **64** peces del Houston Ship Channel y Trinity Bay en busca de metales pesados.



- Especie de pescado colectado
  - Tambor Negro
  - Tambor Rojo
  - Trucha Punteada

Para analizar los posibles riesgos para la salud utilizamos una herramienta llamada Target Hazard Quotient (THQ). El THQ se calcula comparando la dosis estimada de una sustancia a la que está expuesto un individuo con la dosis de referencia.

- Los resultados muestran que el THQ para el cadmio, el cobre y el plomo son menores que 1, lo que sugiere que su consumo se encuentra dentro de unos niveles más seguros. Sin embargo, los niveles de THQ para el arsénico y el selenio son más altos que 1, lo que implica un mayor riesgo. Todo esto suponiendo que estos peces se consuman regularmente como fuente principal de proteínas.

THQ para cada metal pesado basado en la cantidad consumida

Metal	THQ Semanal	THQ Bimensual	THQ Mensual	THQ Dos veces al año
Arsénico	13	7	3	1
Cadmio	<1	<1	<1	<1
Cobre	1	1	<1	<1
Plomo	1	<1	<1	<1
Selenio	40	20	10	2

- Si THQ es <1, indica que es poco probable que exista un riesgo significativo de efectos negativos para la salud.
- Si THQ es >1, indica un riesgo probable de efectos negativos para la salud. Entre más alto sea el THQ, mayor será el riesgo.

Si desea saber más sobre los efectos de los metales pesados, visite el sitio web de la FDA: https://www.fda.gov/food/chemical-contaminants-pesticides/environmental-contaminants-food

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Chemical Facilities & Vulnerable Communities

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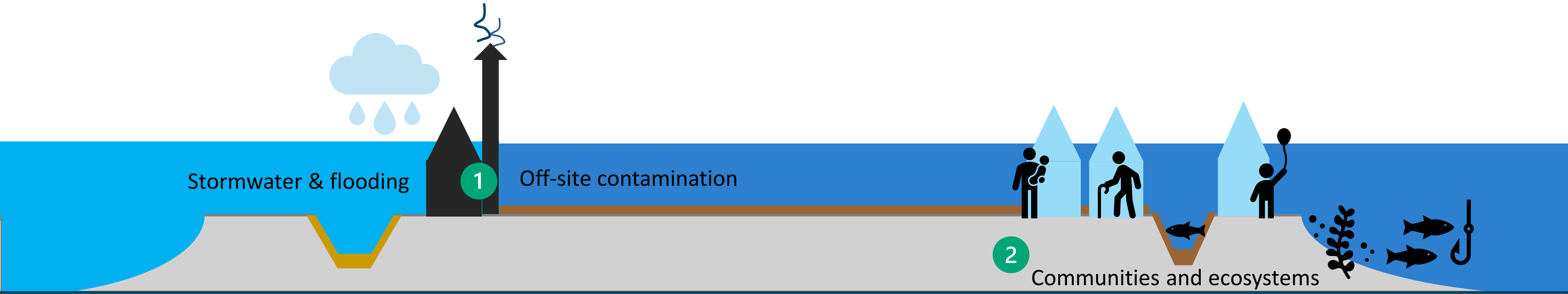
Vulnerability assessment

1 **Facility scoring:** Ranks facilities by their vulnerabilities that create the potential for water to carry contamination off-site

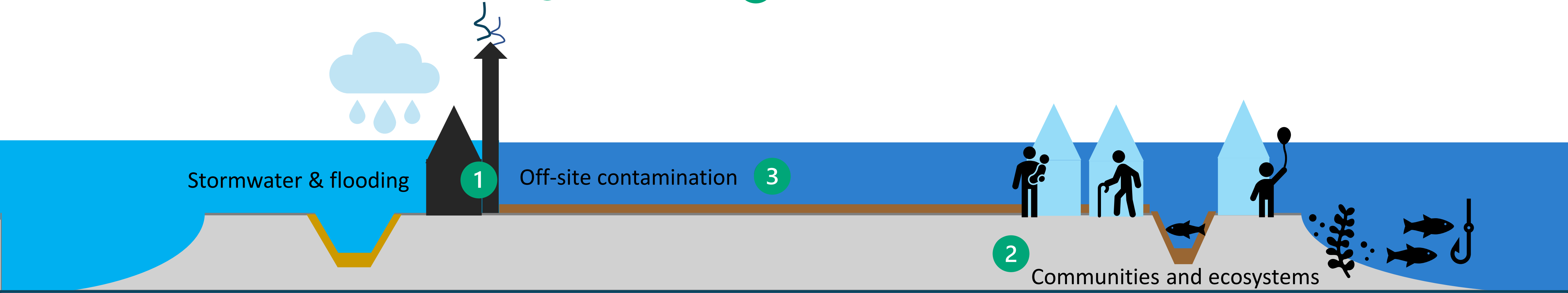
2 **Community scoring:** Ranks communities and ecosystems by factors that make them vulnerable to this contamination

100+ environmental, health, social, economic, industry indicators



Vulnerability assessment

1. **Facility scoring:** Ranks facilities by their vulnerabilities that create the potential for water to carry contamination off-site
2. **Community scoring:** Ranks communities and ecosystems by factors that make them vulnerable to this contamination
3. **Flood Modeling:** Estimates flood and off-site contamination potential and physically links 1 facility and 2 community scores



Vulnerability assessment

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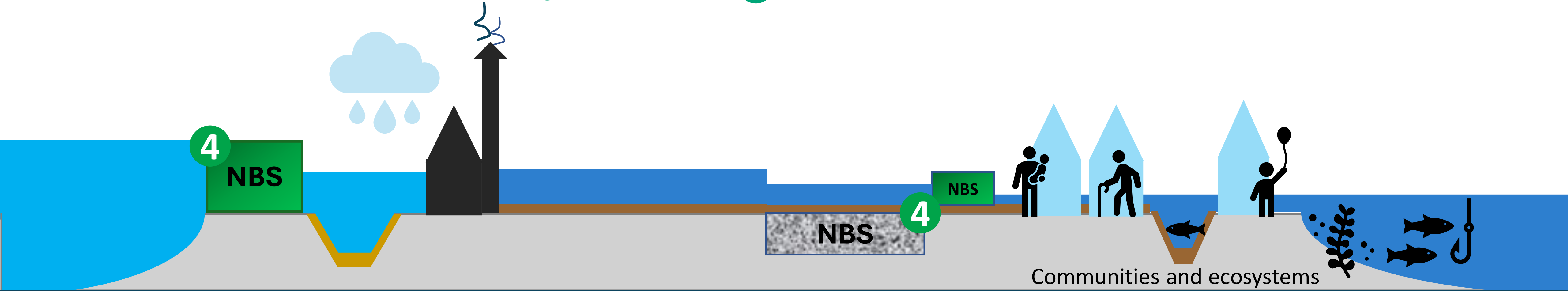
Nature-based solutions 4 mitigate these vulnerabilities



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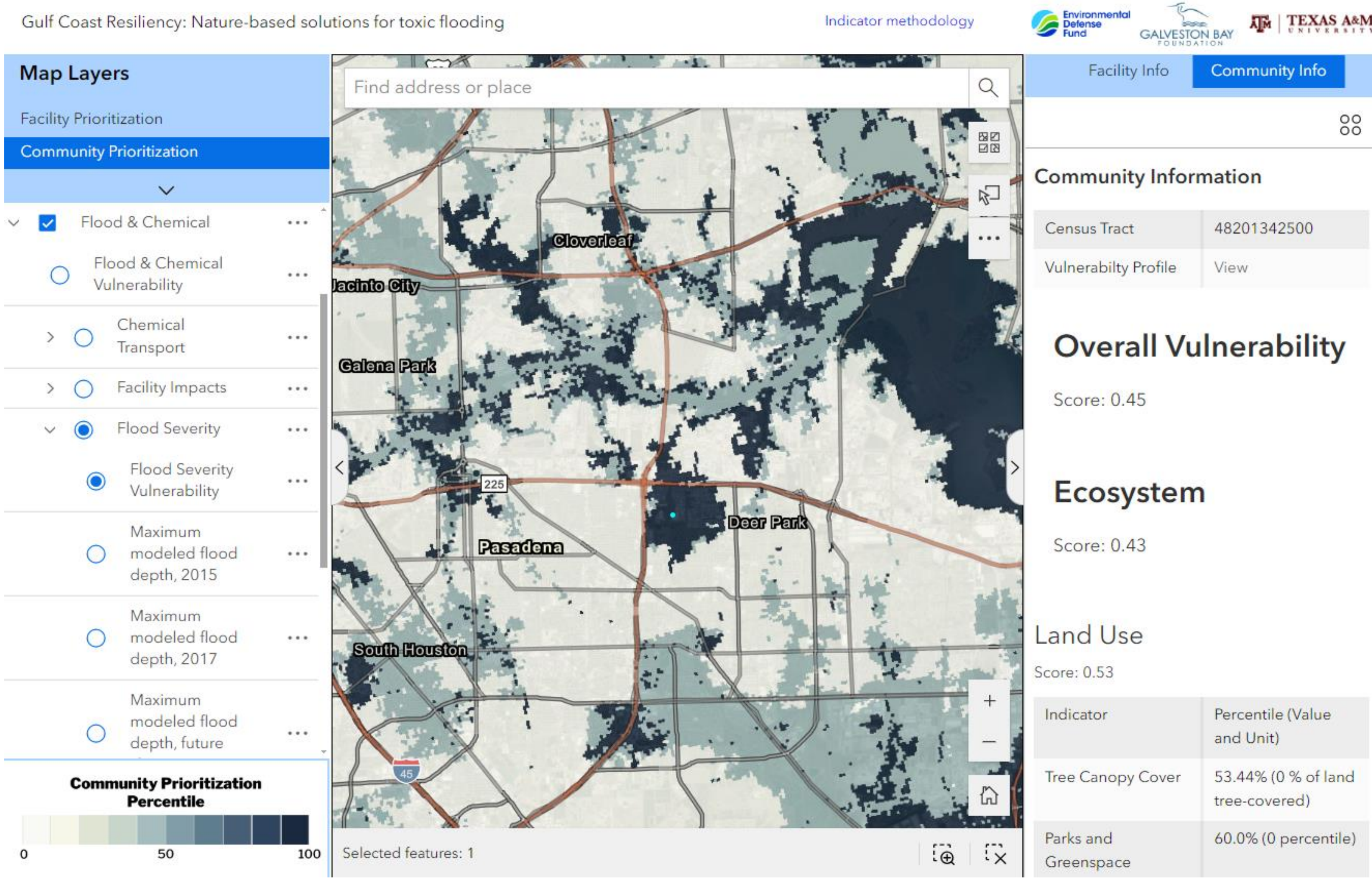
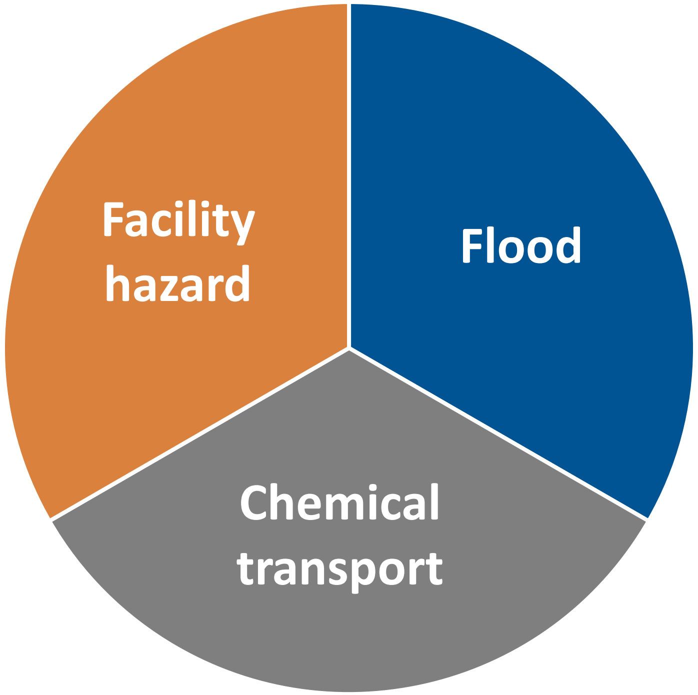
Look ahead

- Scoring system details
- Example results
- Vulnerability map

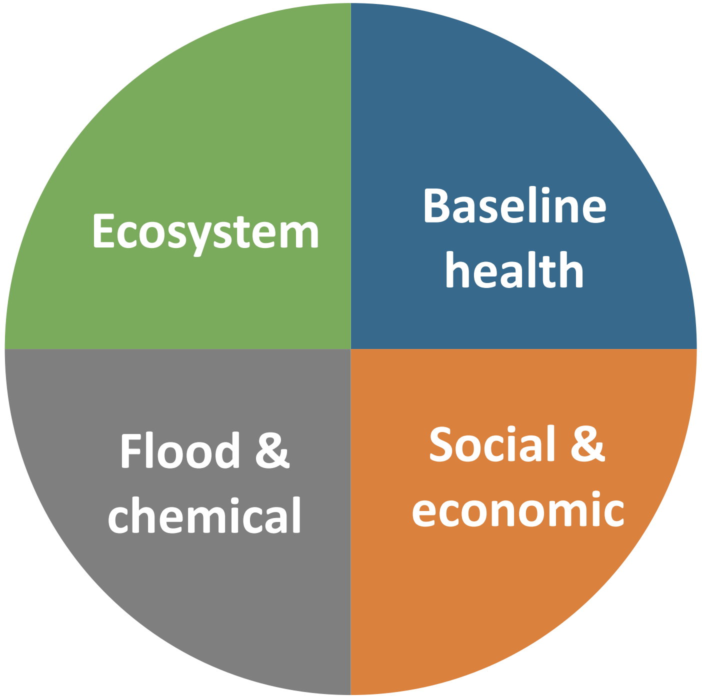


Vulnerability assessment

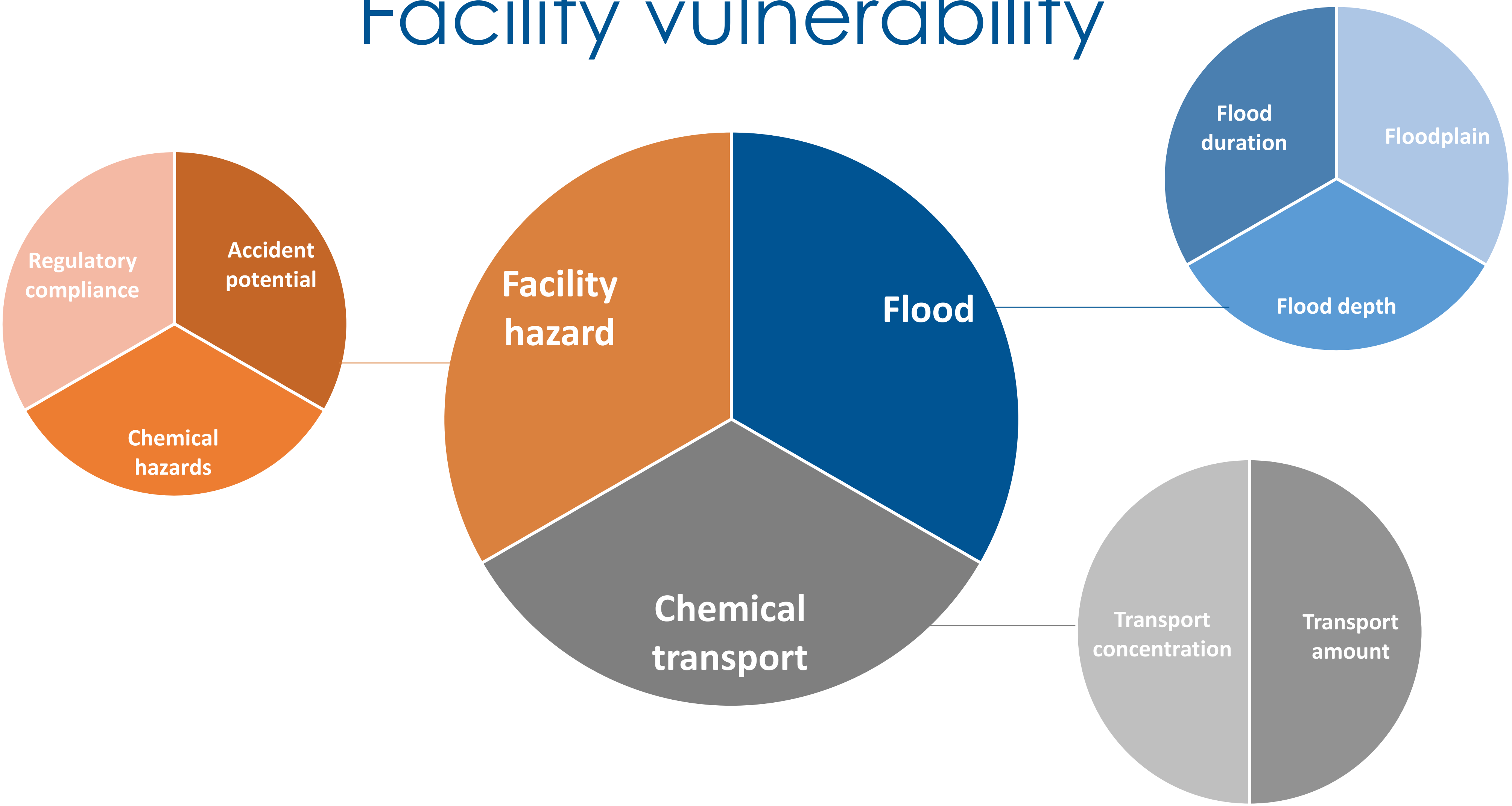
Facility vulnerability



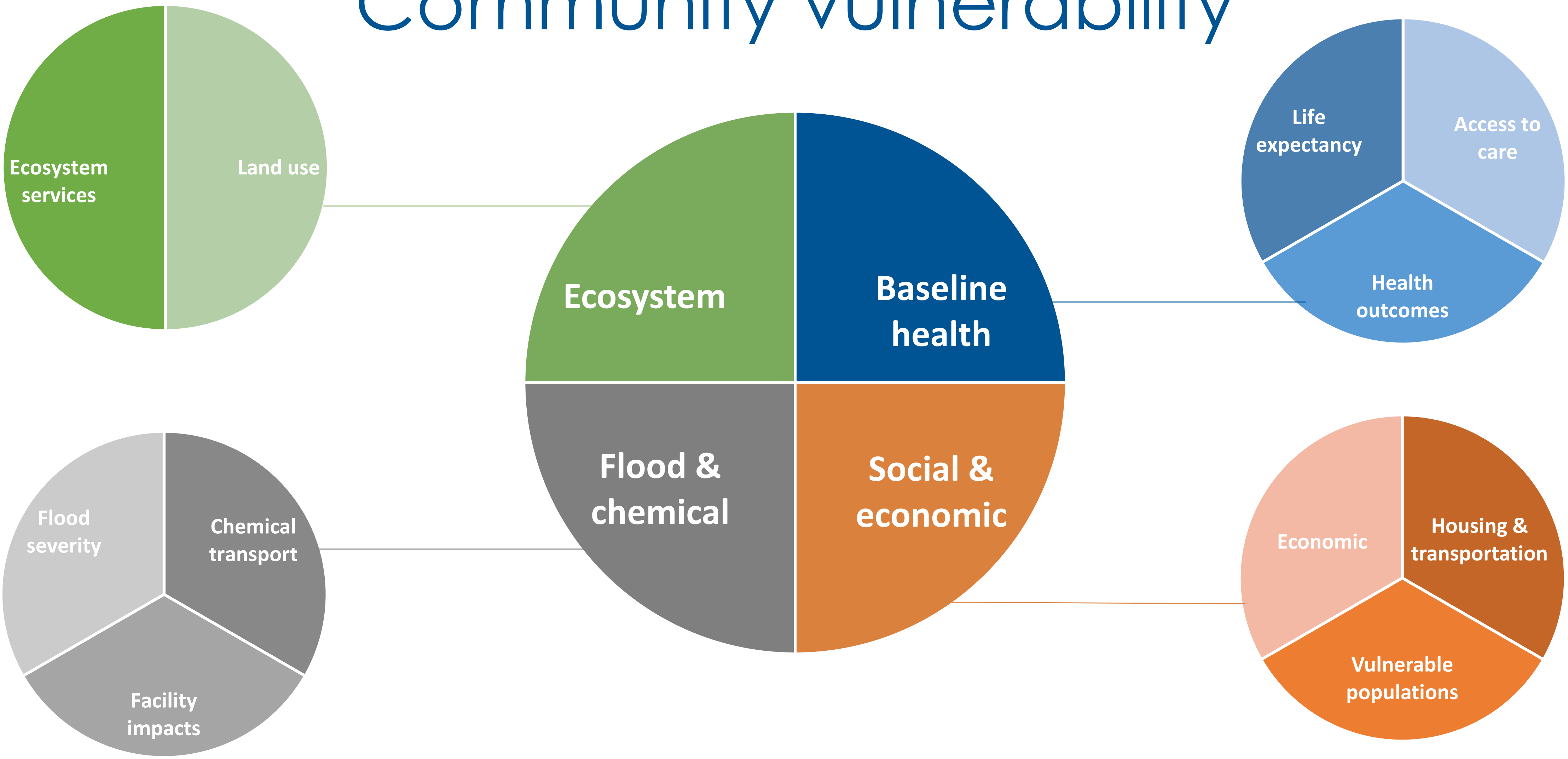
Community vulnerability



Facility vulnerability



Community vulnerability

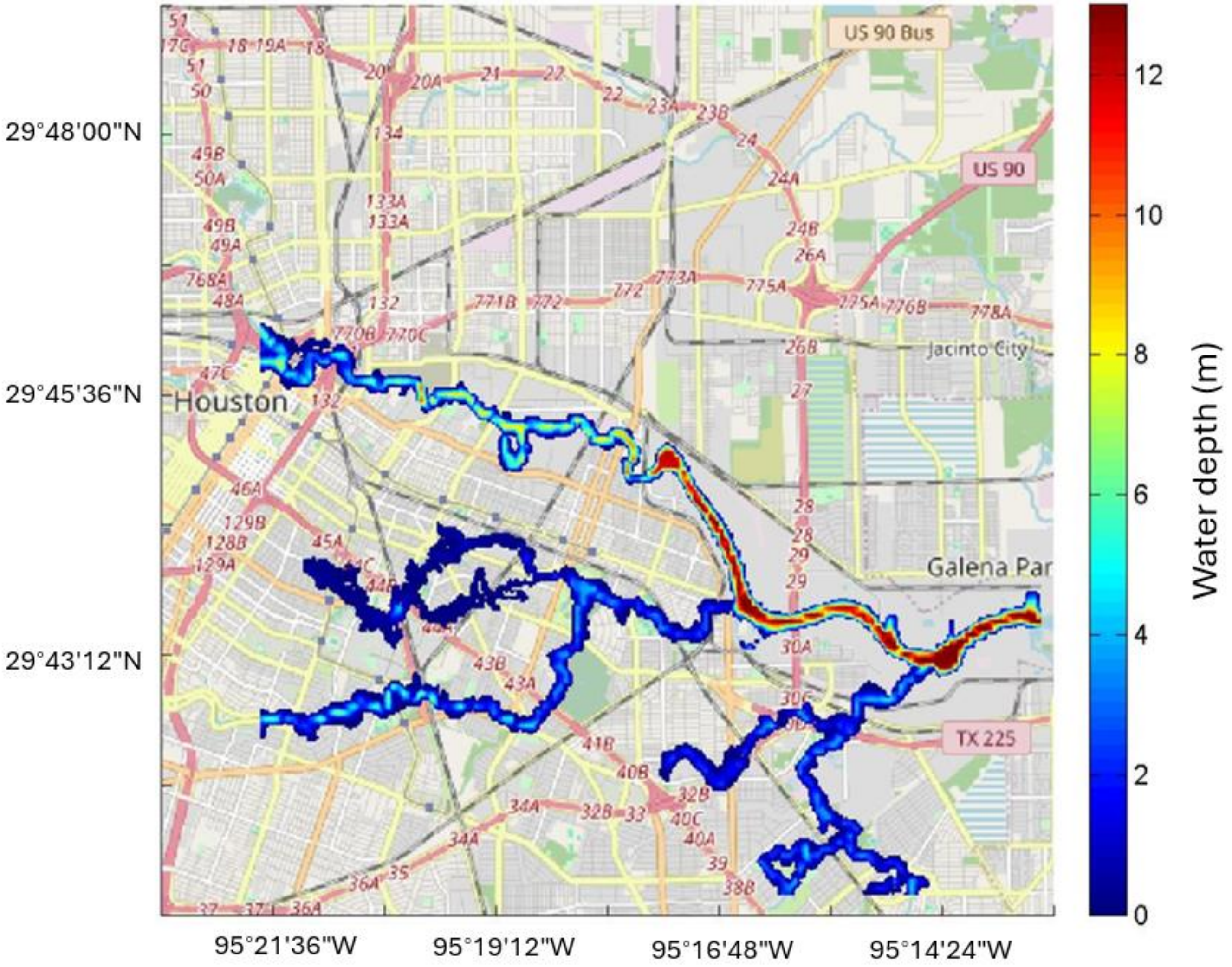


Modeling

- Coupled flood modeling system
- Combined effects of stormwater and storm surge
- Where and how potential contamination may move for facilities and communities

SWAT Soil & Water Assessment Tool

Delft3D

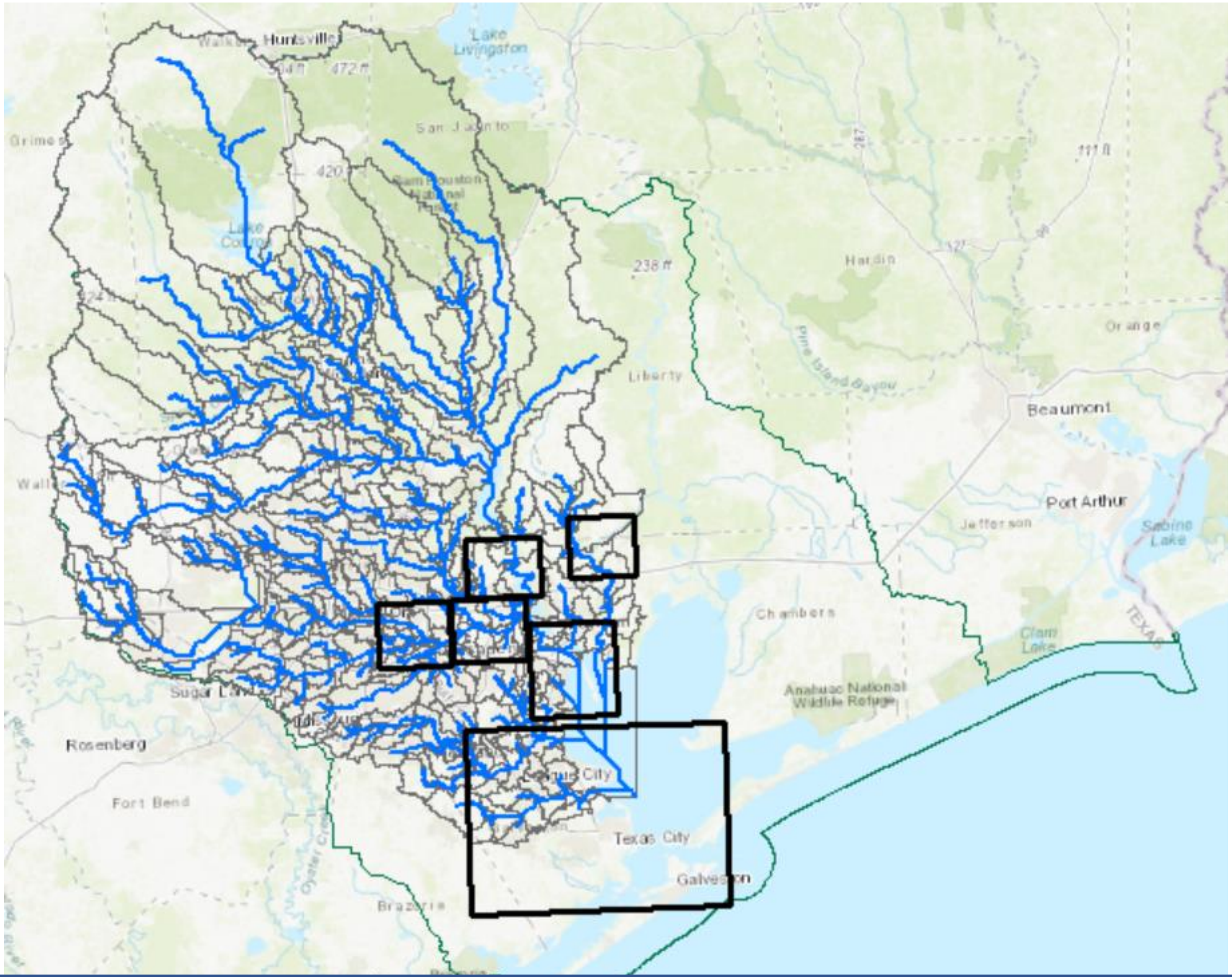


Where we modeled

Hydrology model watersheds

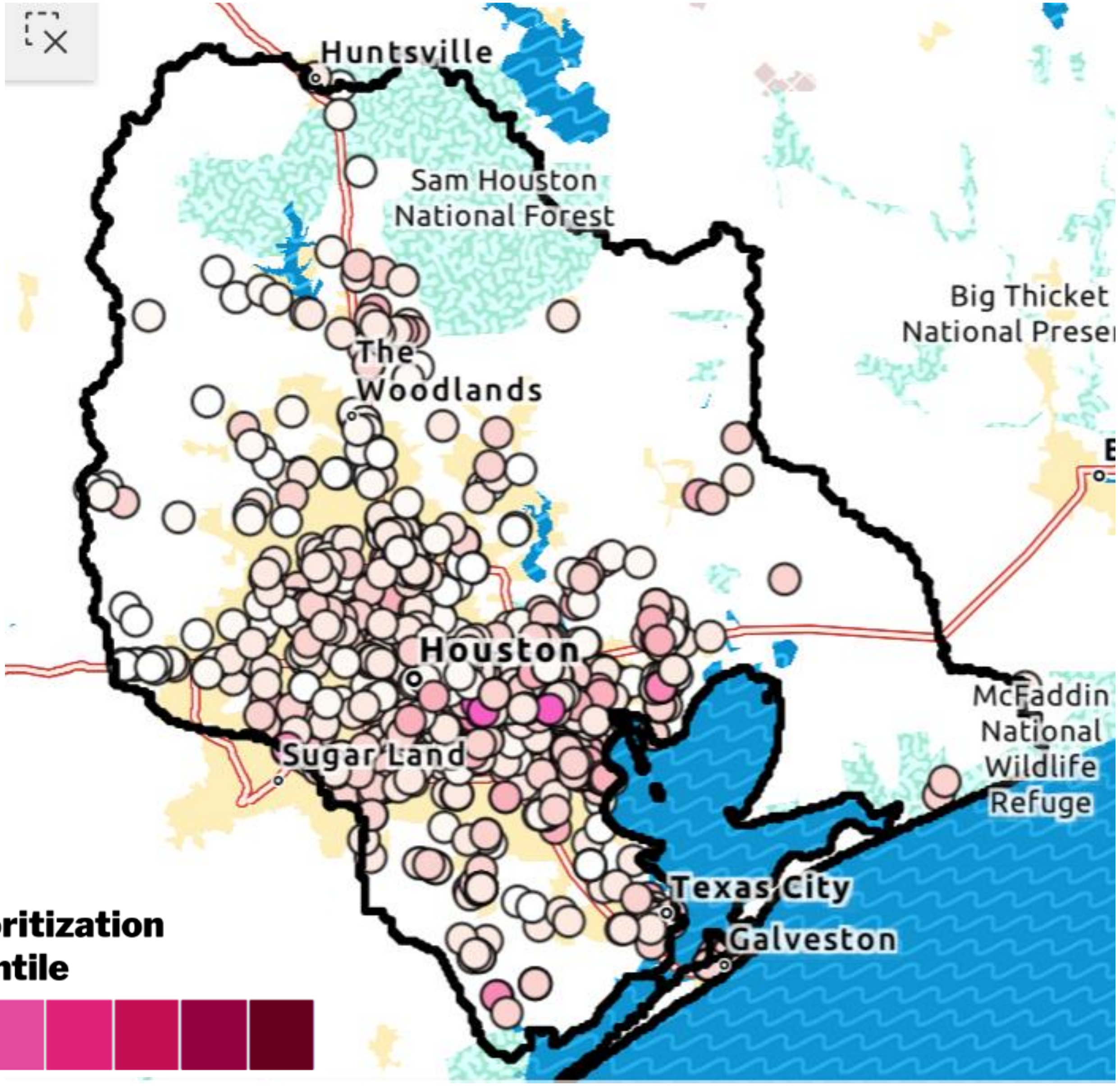
Coupled hydrologic-hydraulic model area

Study area



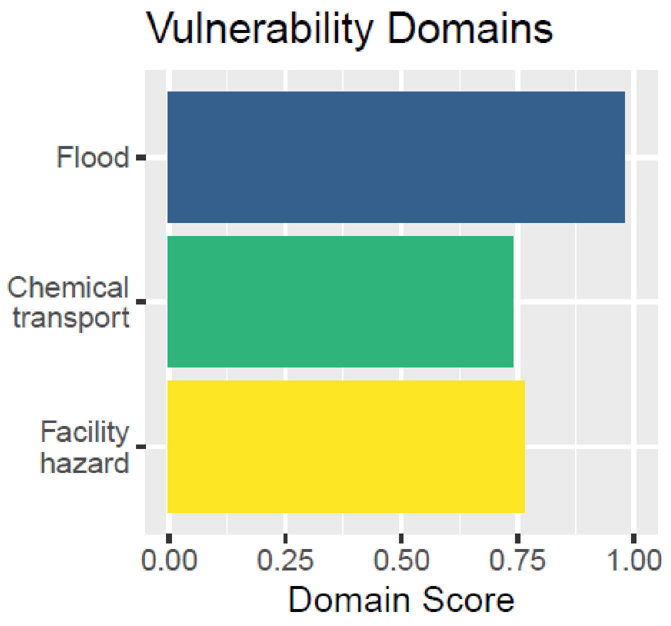
Facility vulnerability results

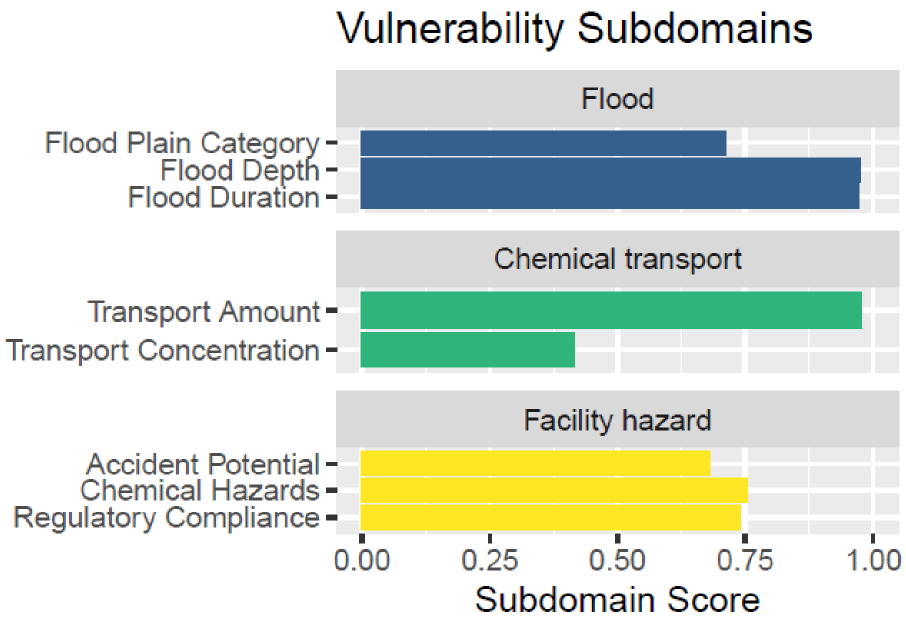
- Flood plain, riverine and/or coastal flooding
- High runoff/soil erosion
- Mobile, hazardous, toxic chemicals
- Past safety violations



Facility vulnerability results

Chemical complex south of Manchester along Sims Bayou





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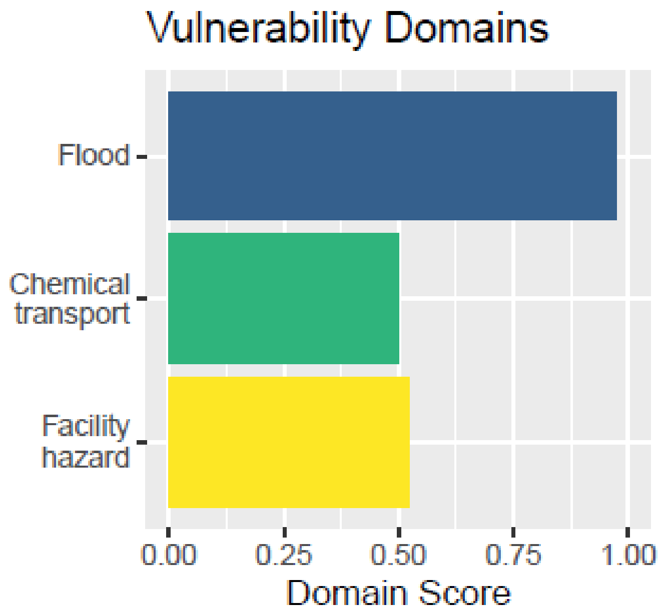
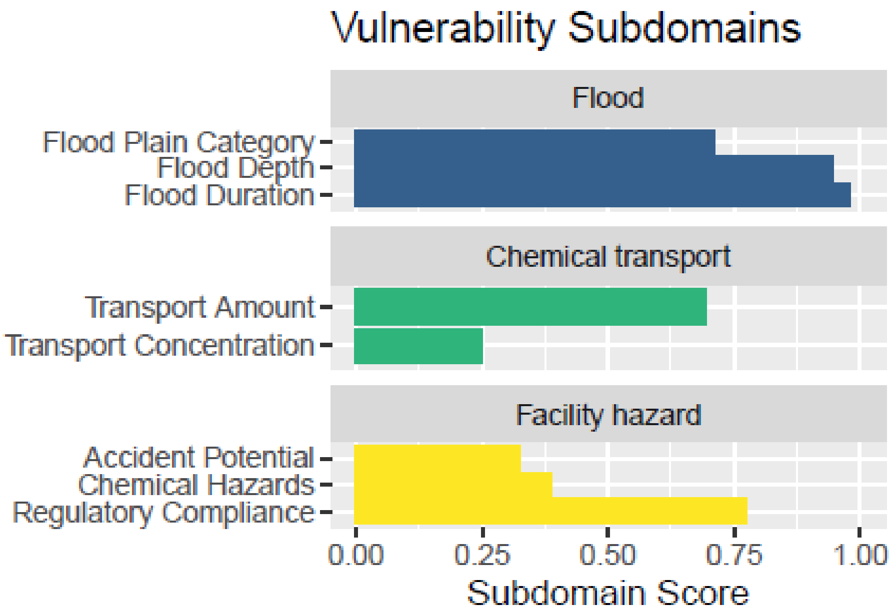
Facility vulnerability results

Chemical complex at confluence of Carpenter and Buffalo Bayous



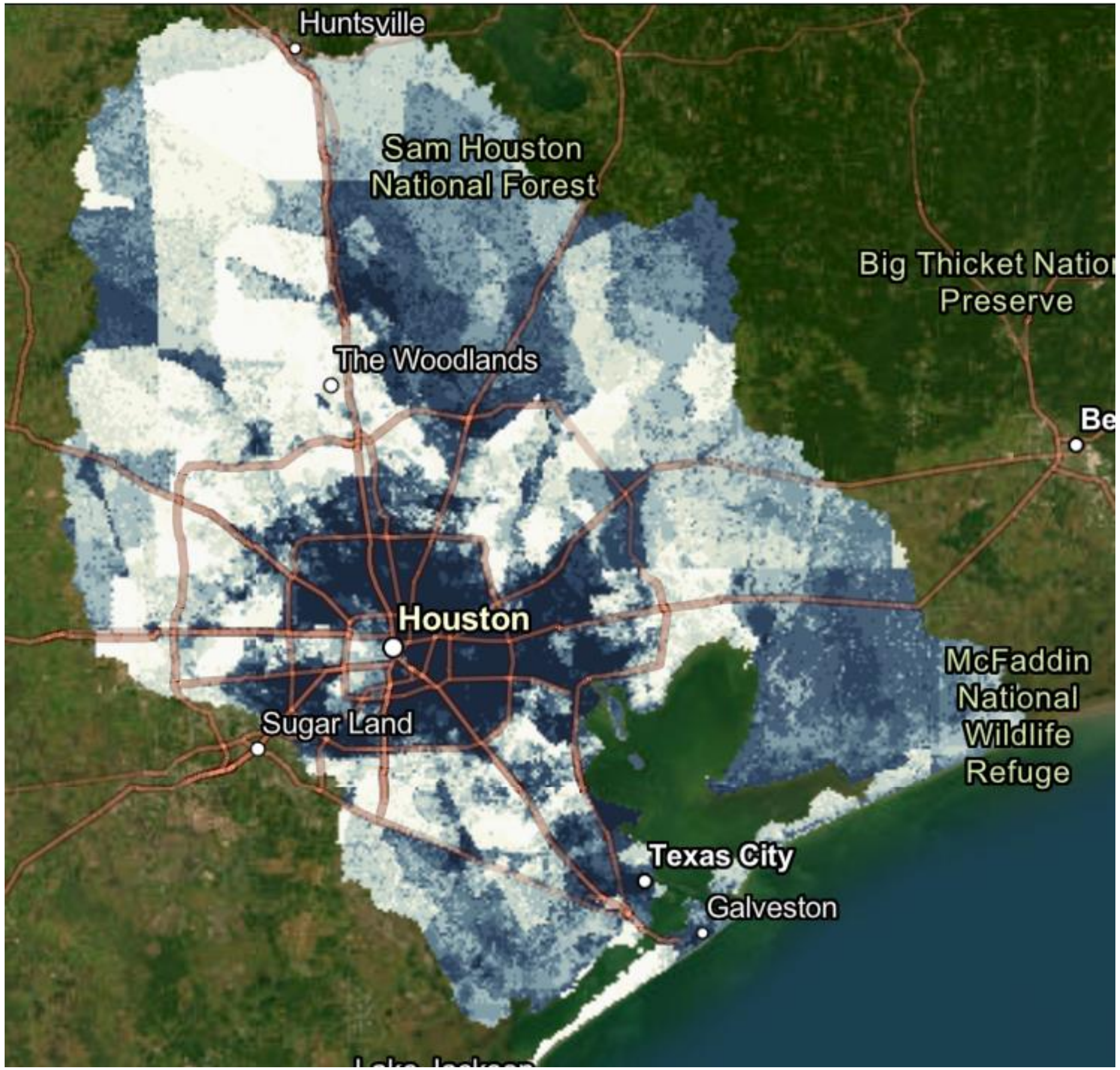


Community vulnerability results

- Impacted by multiple facilities
- Locations with potential to flood
- Lack natural infrastructure and green spaces
- Lower baseline socioeconomic condition

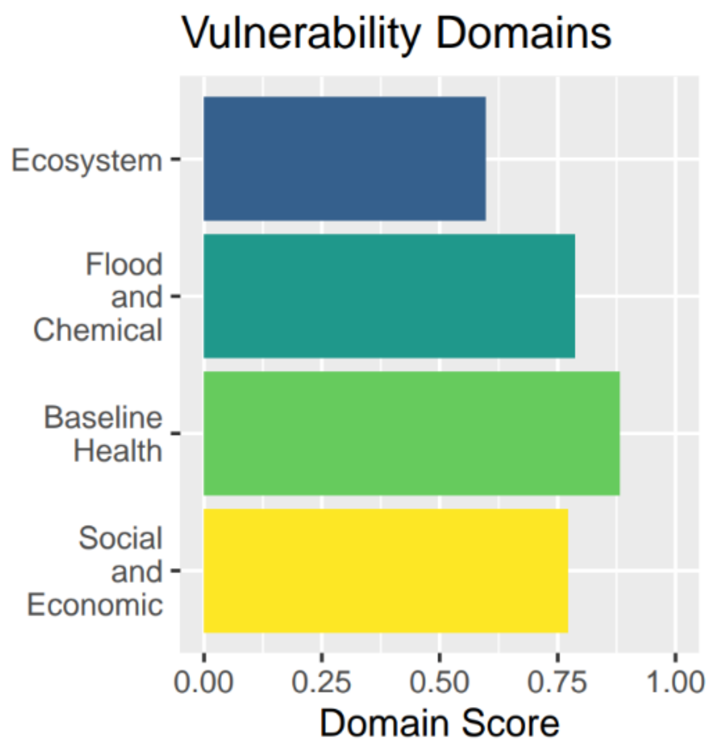
Community Prioritization Percentile

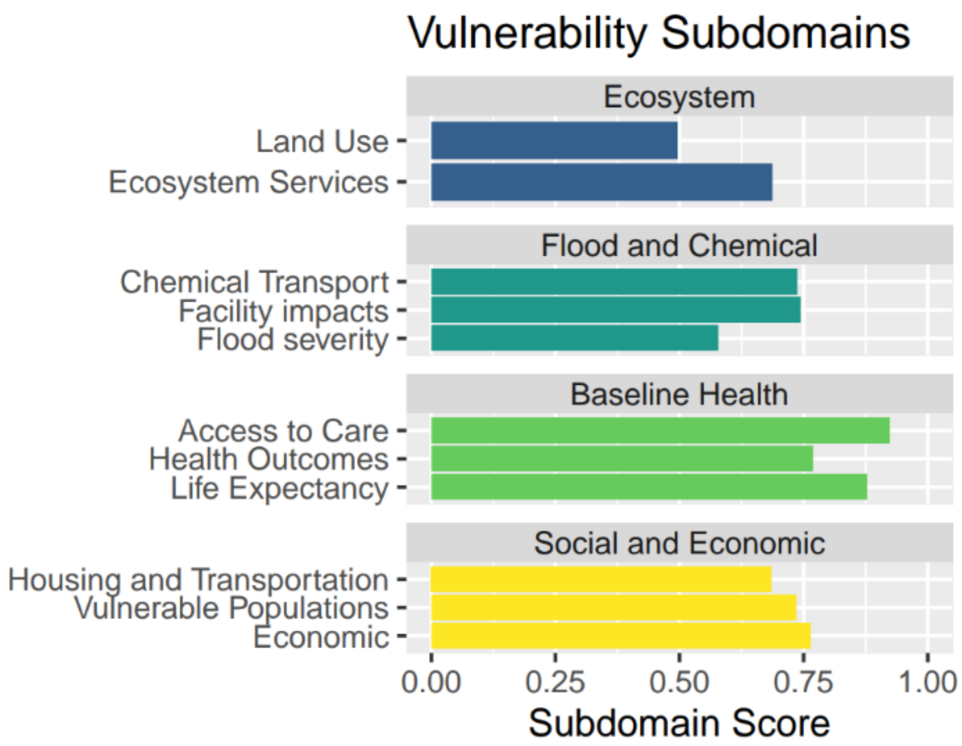
0 50 100

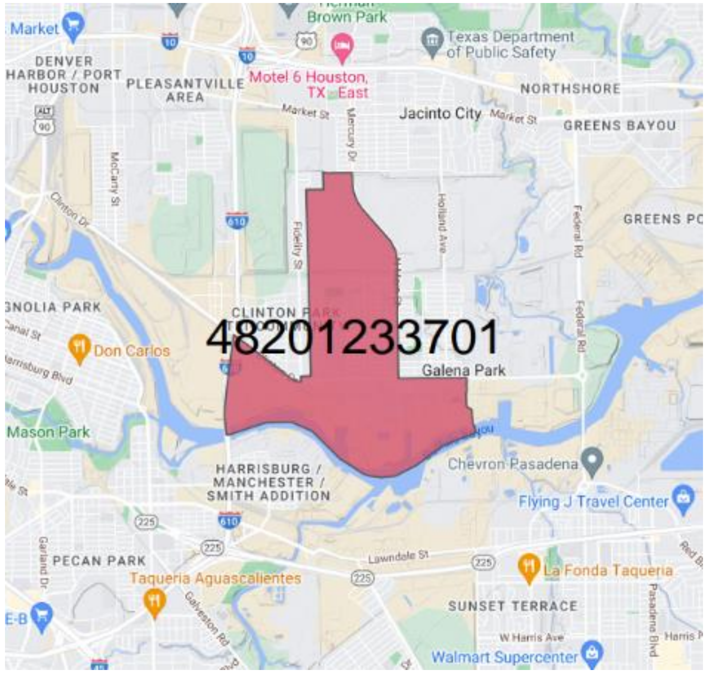


Community vulnerability results

Galena Park (Tract 48201233701)







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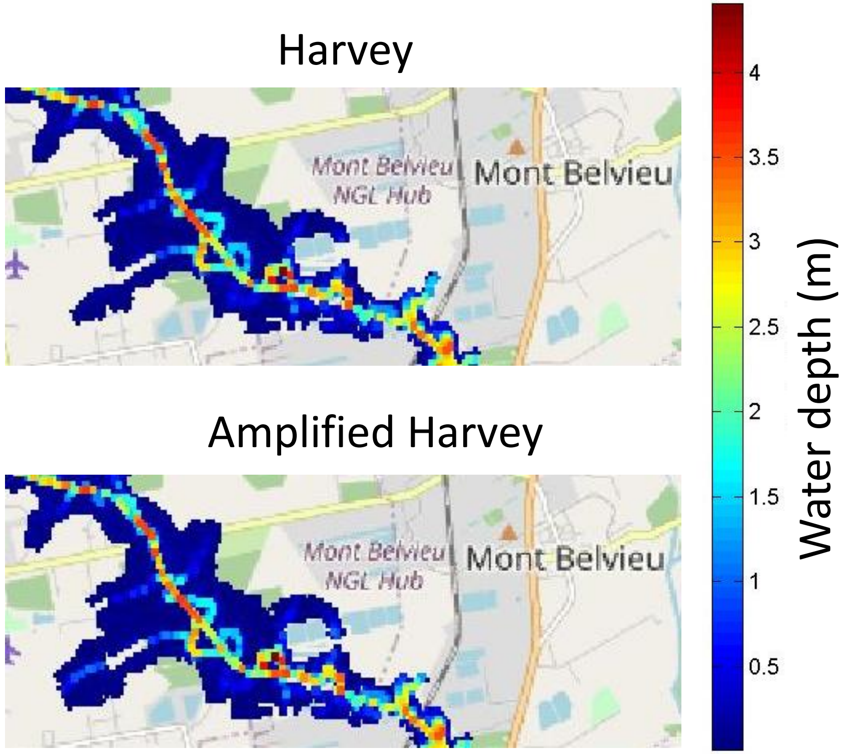
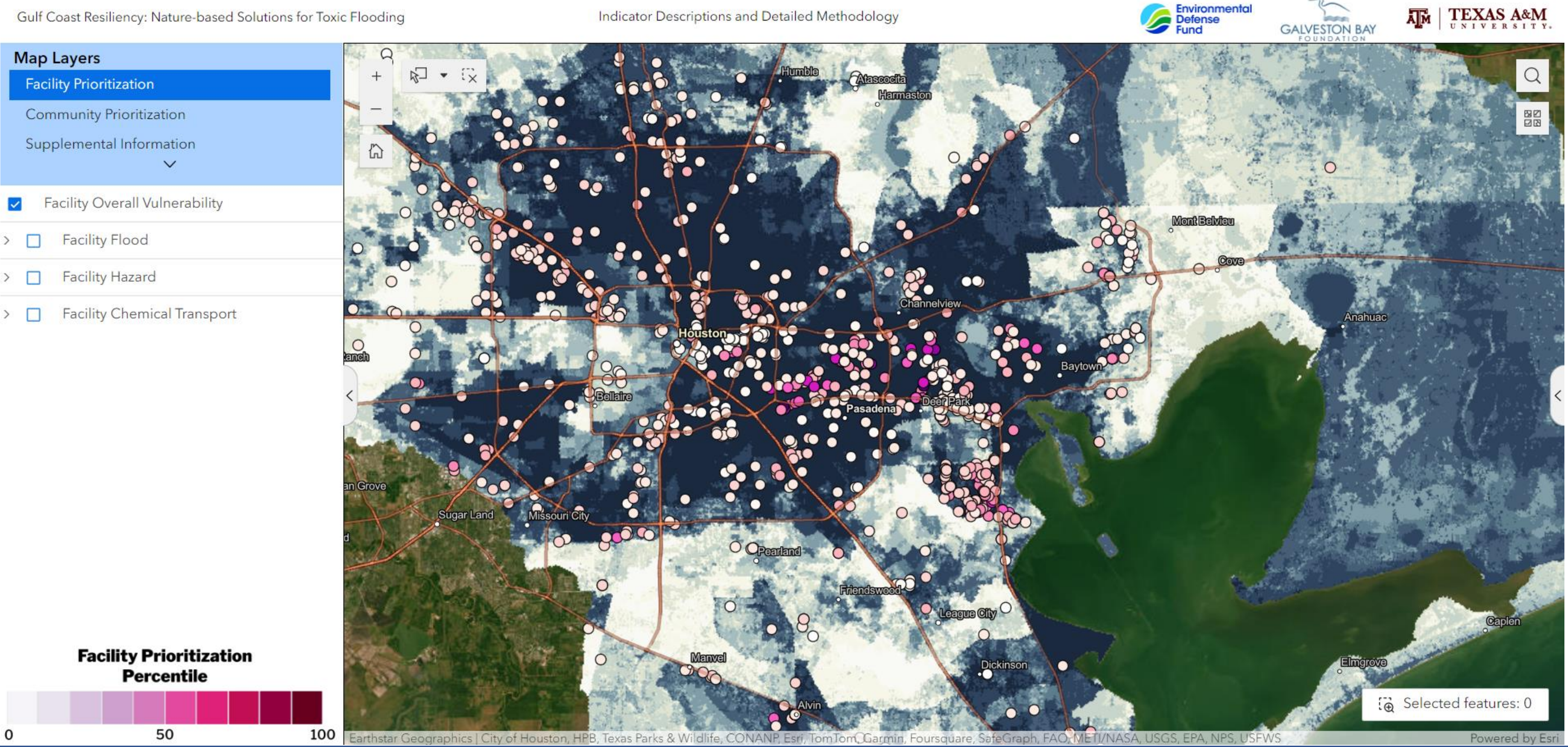
Future climate considerations

- Downscaled climate model ensemble for future precipitation
- Resulted in 7% increase in future (2040-2059) peak streamflow compared to baseline (2000-2019)
- Coupled simulation with amplified streamflow and hurricane Harvey winds and tides



Vulnerability map

https://createnbs.org/toxic-flooding/vulnerability-map/



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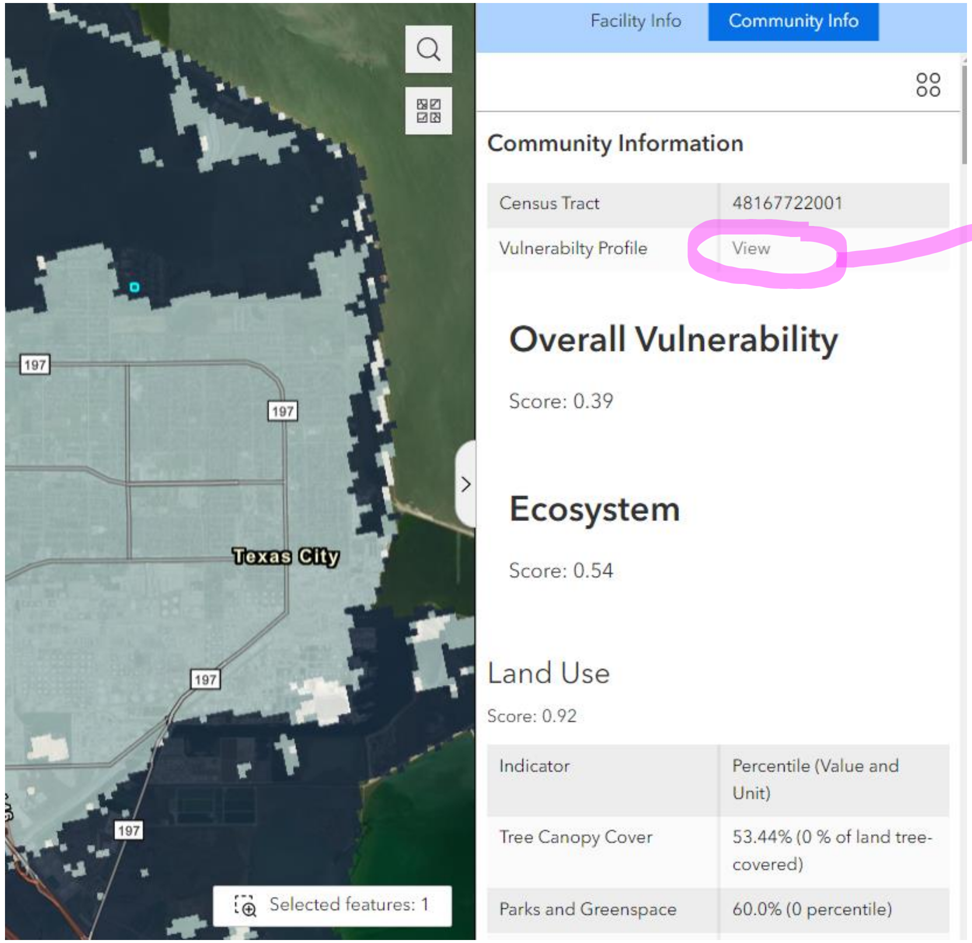
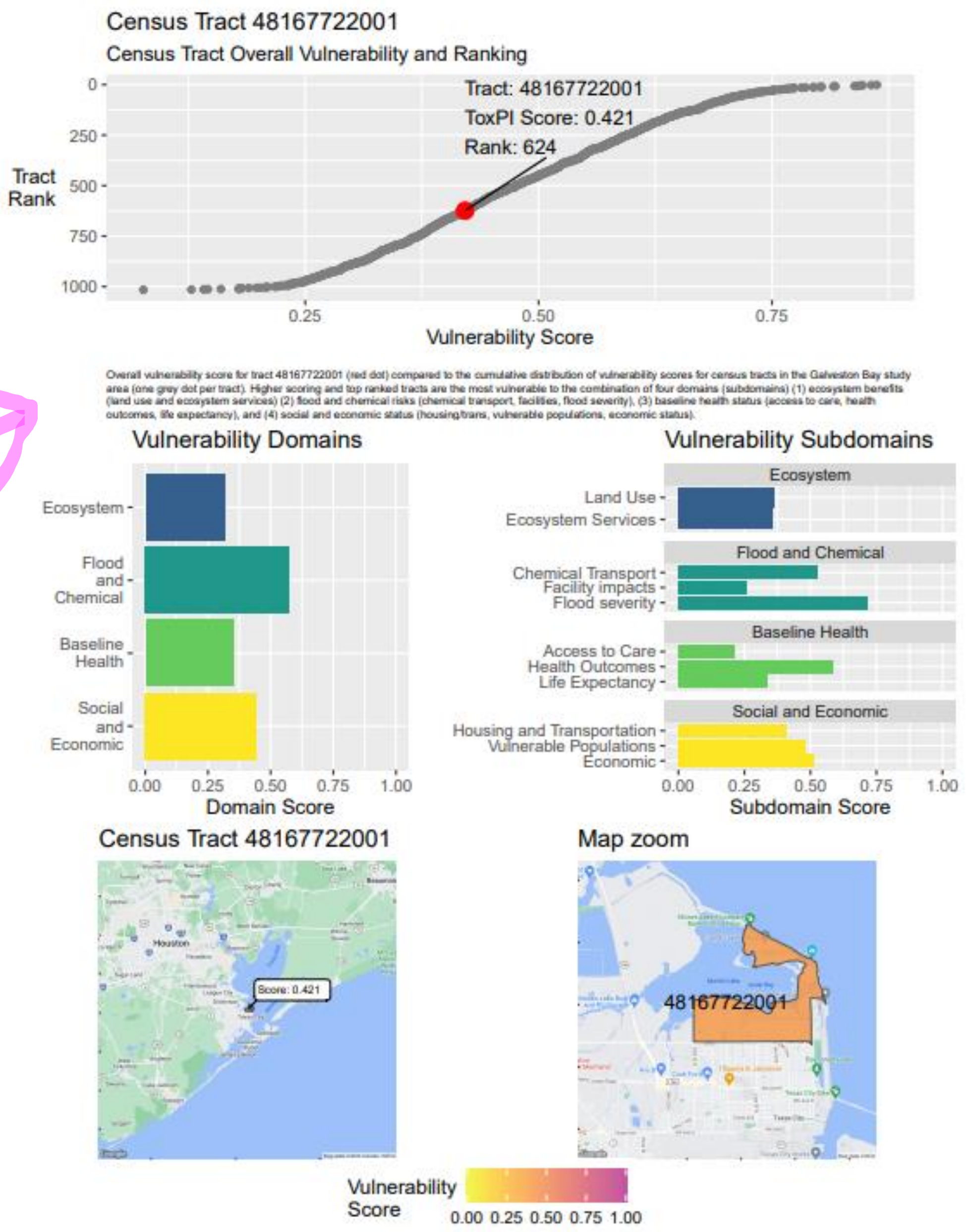
Vulnerability map





Nature Based Solutions Case Studies

Galena Park & Texas City

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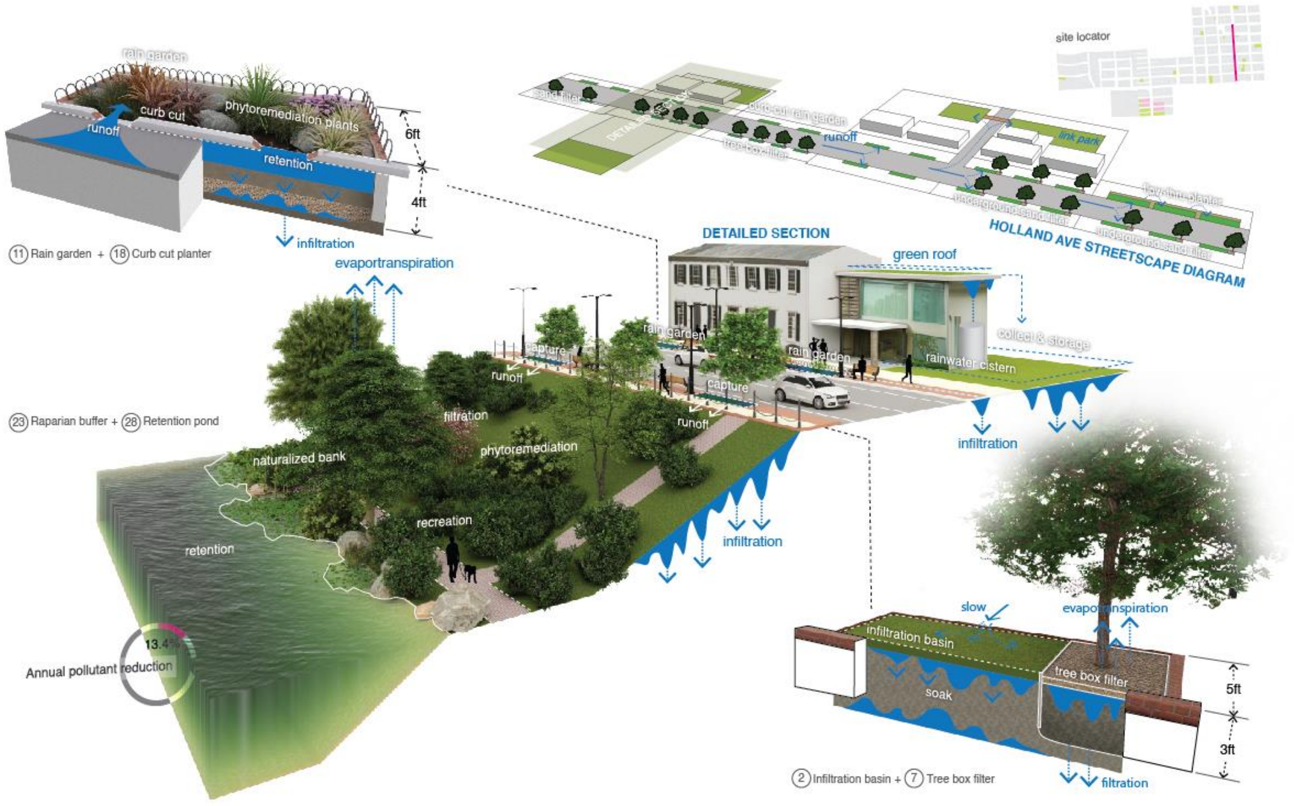
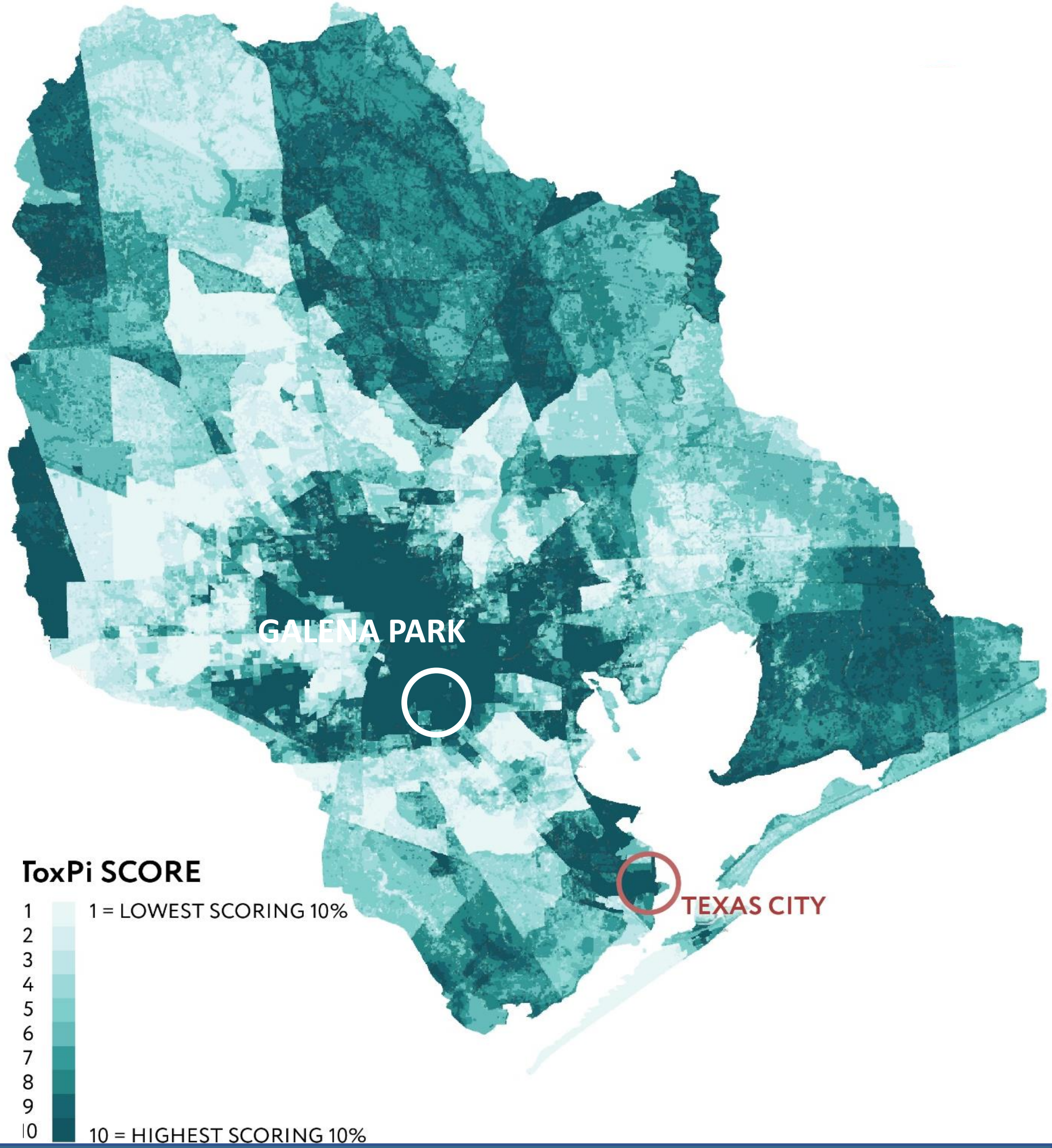


Case Projects:

Galena Park, TX and Texas City, TX



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Example Project: Adaptive Stormbox

Flexible Green Infrastructure Assemblage Units for Galena Park, TX

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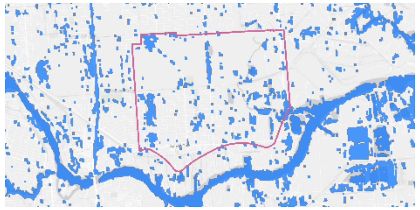
Severe Flood Events in Galena Park

2017 — Hurricane Harvey 2017

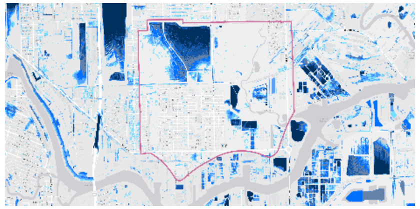


Overall Impact	Overall Impact	Impact to Galena Park
Total Economic Loss: **125 billion**	Residents Relocation: 60,049	Inundation Percent: 17.3%
Storm Surge: 12-19 ft	Flooded Homes: 154,170	Inundated Industrial Sites: 58.3 Acre

2016 — Spring Floods 2016

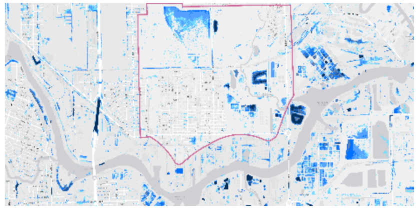
Overall Impact	Overall Impact	Impact to Galena Park
Total Economic Loss: **65 million**	Residents Relocation: 300	Inundation Percent: 1.2%
Storm Surge: 13-17 inch	Flooded Homes: 9,820	Inundated Industrial Sites: 2.1 Acre

2008 — Hurricane Ike 2008



Overall Impact	Overall Impact	Impact to Galena Park
Total Economic Loss: **351 million**	Residents Relocation: 1.2-1.5 million	Inundation Percent: 9.2%
Storm Surge: 12-15 ft	Flooded Homes: 2,550	Inundated Industrial Sites: 67.5 Acre

2001 — Tropical Storm Allison 2001

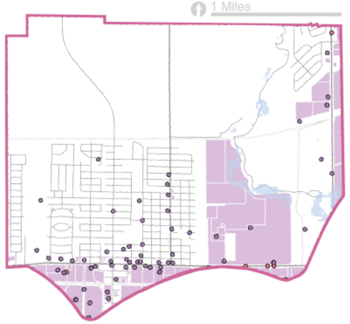


Overall Impact	Overall Impact	Impact to Galena Park
Total Economic Loss: **5 billion**	Residents Relocation: 30,000	Inundation Percent: 3.4%
Storm Surge: 20-30 inch	Flooded Homes: 73,000	Inundated Industrial Sites: 28.1 Acre

Projected Future Storm Surge

Category 1

Hurricane Inundation Area: 53.9 Acre
Inundated Industrial Zone: 40.2 Acre
Inundated TCEQ Facilities: 0
Inundated TRI Facilities: 0



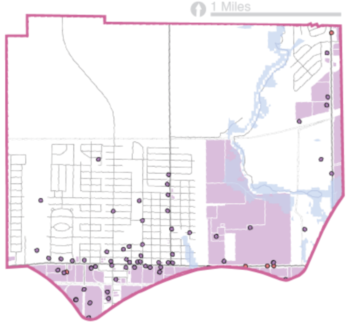
Inundation Percent | Industrial Percent

Inundated Facility Types

Petroleum, Chemical

Category 2

Hurricane Inundation Area: 152.8 Acre
Inundated Industrial Zone: 81.5 Acre
Inundated TCEQ Facilities: 0
Inundated TRI Facilities: 0



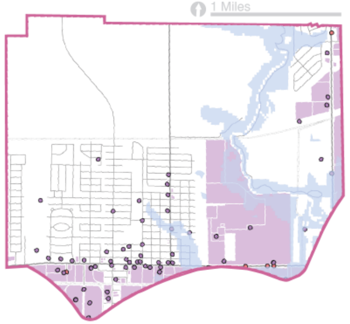
Inundation Percent | Industrial Percent

Inundated Facility Types

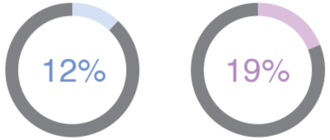
Petroleum, Chemical

Category 3

Hurricane Inundation Area: 396.8 Acre
Inundated Industrial Zone: 152.7 Acre
Inundated TCEQ Facilities: 4
Inundated TRI Facilities: 0



Inundation Percent | Industrial Percent

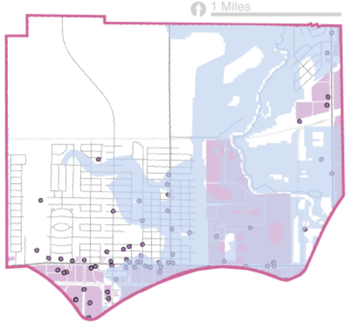


Inundated Facility Types

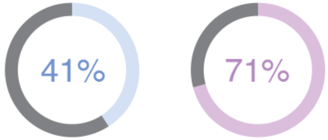
Petroleum, Stormwater, Air, Sewage, Chemical, Toxicity

Category 4

Hurricane Inundation Area: 1314.9 Acre
Inundated Industrial Zone: 568.9 Acre
Inundated TCEQ Facilities: 36
Inundated TRI Facilities: 4



Inundation Percent | Industrial Percent

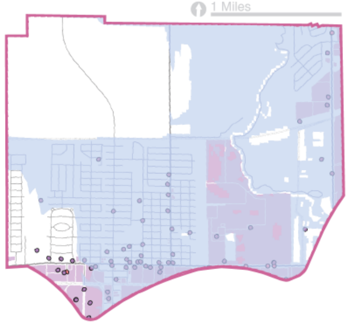


Inundated Facility Types

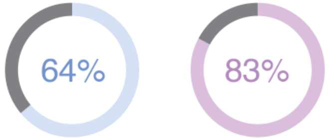
Petroleum, Stormwater, Air, Sewage, Chemical, Toxicity

Category 5

Hurricane Inundation Area: 2045.4 Acre
Inundated Industrial Zone: 668.2 Acre
Inundated TCEQ Facilities: 57
Inundated TRI Facilities: 4



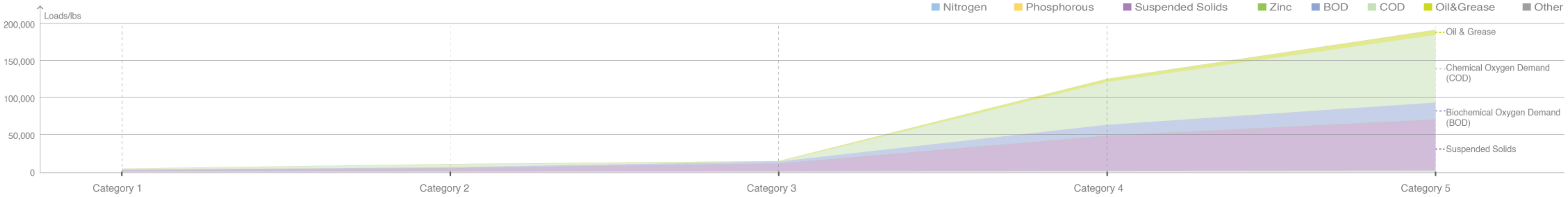
Inundation Percent | Industrial Percent



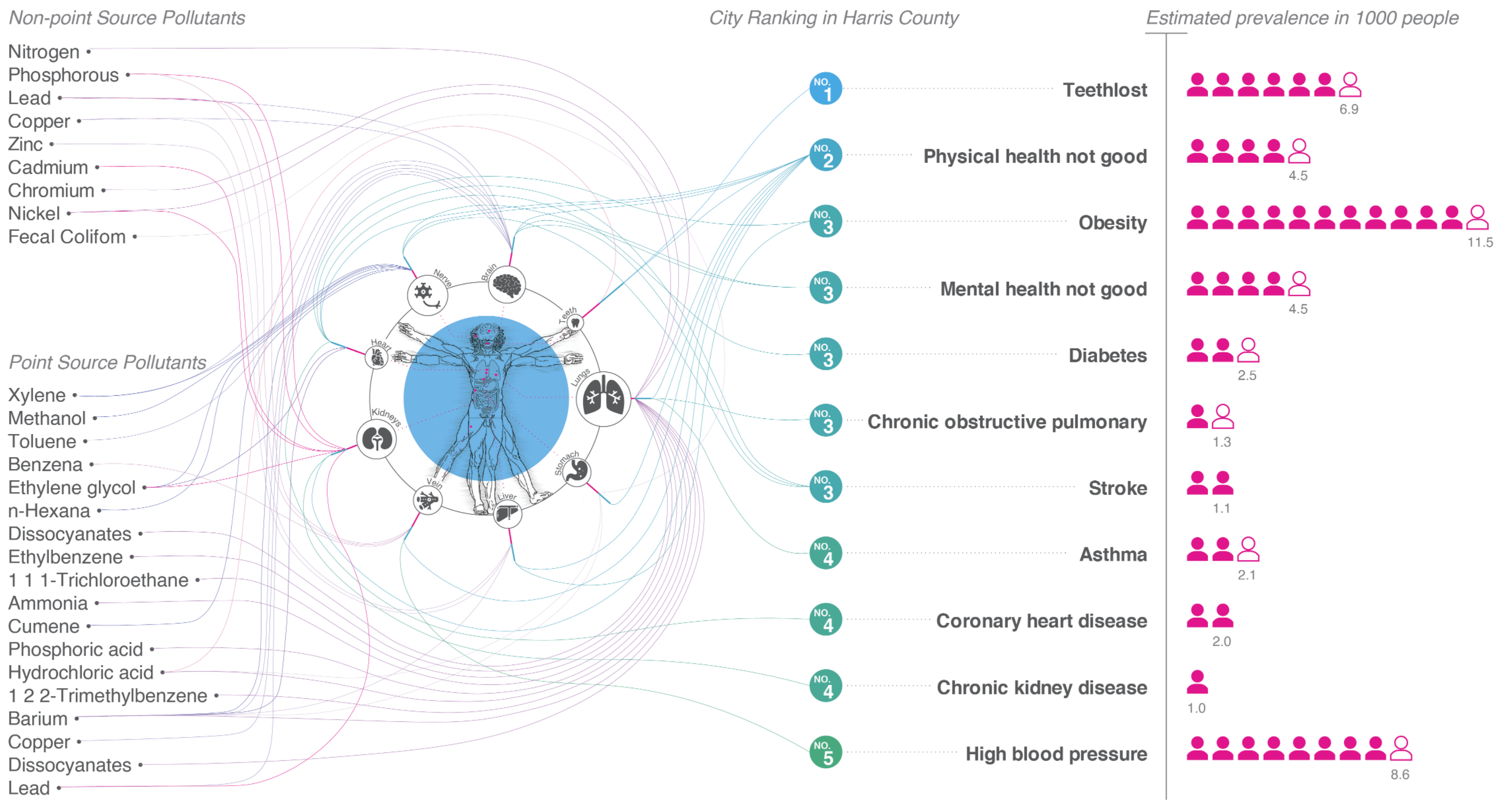
Inundated Facility Types

Petroleum, Stormwater, Air, Sewage, Chemical, Toxicity

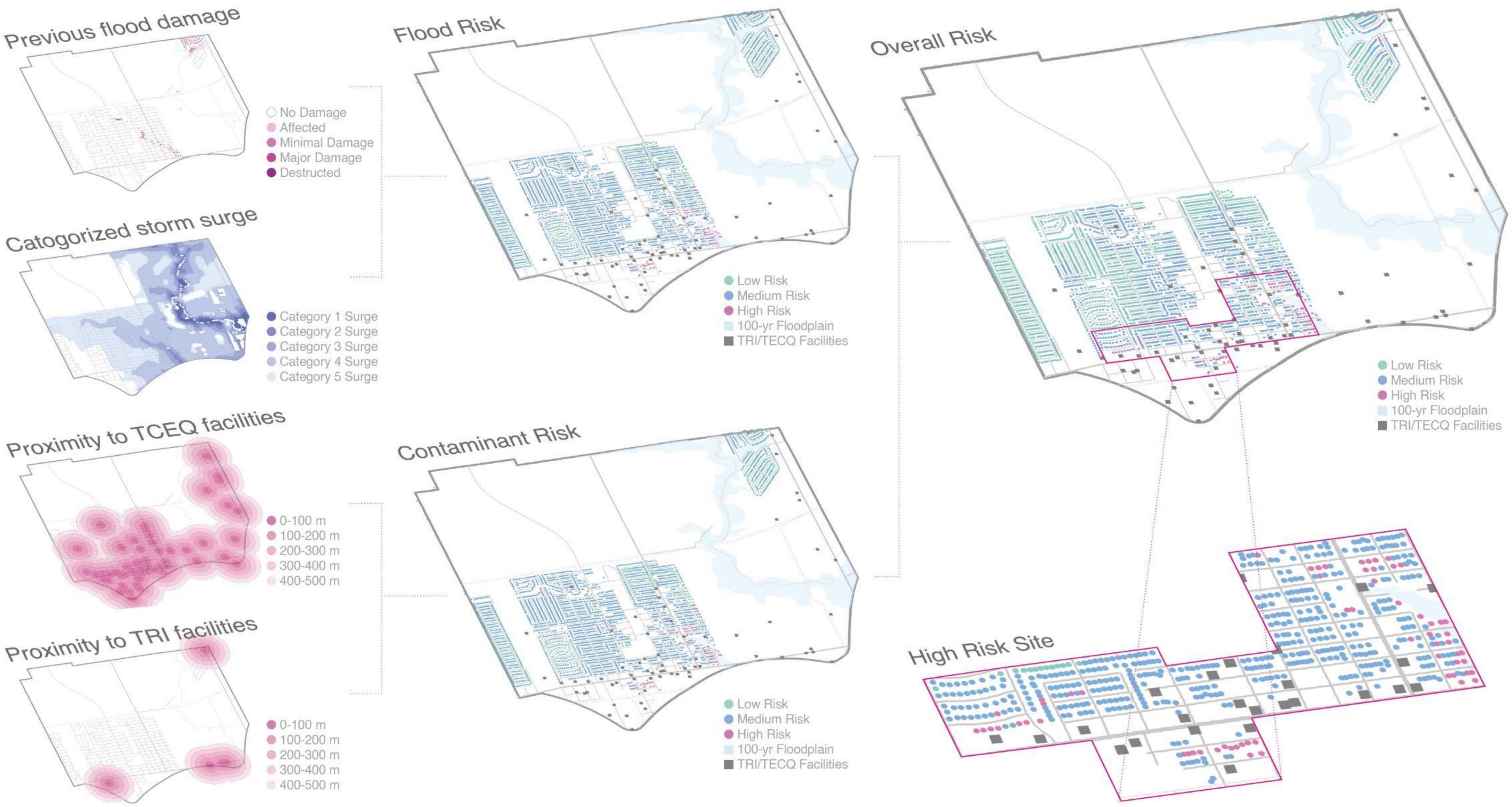
Chemical Contaminations

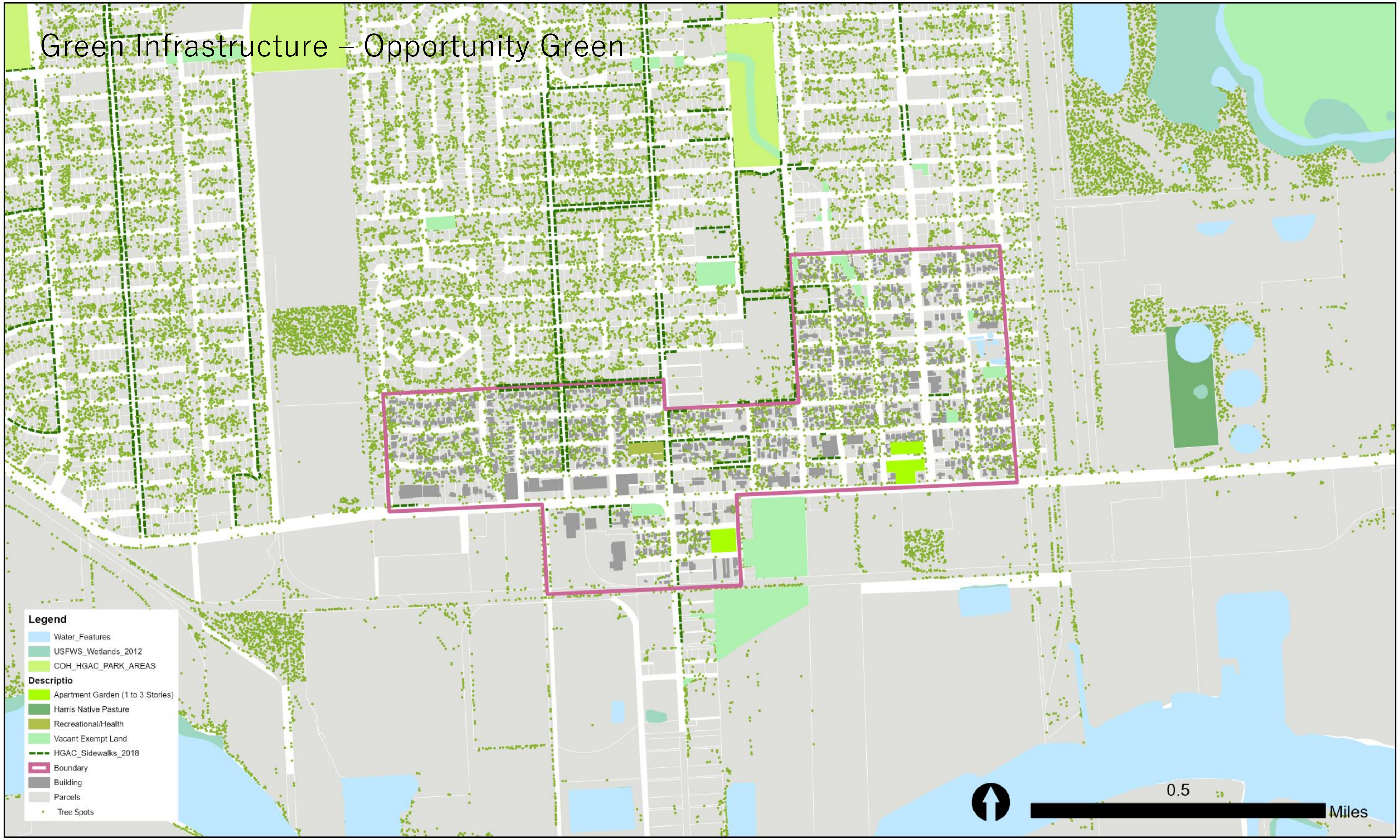


Pollution-Related Disease Prevalence (Source: CDC 2019)



Flood and Contaminant Risk Maps





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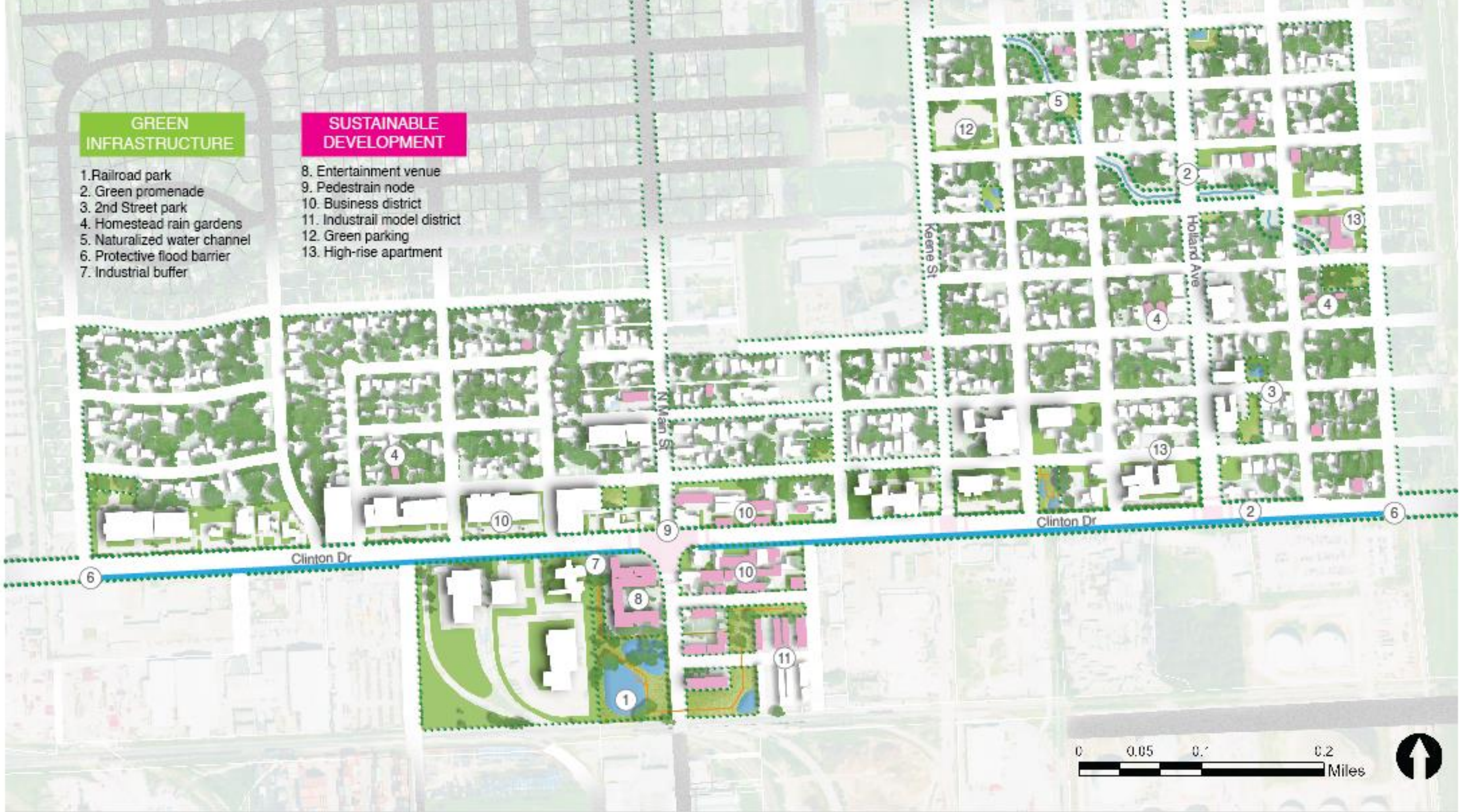
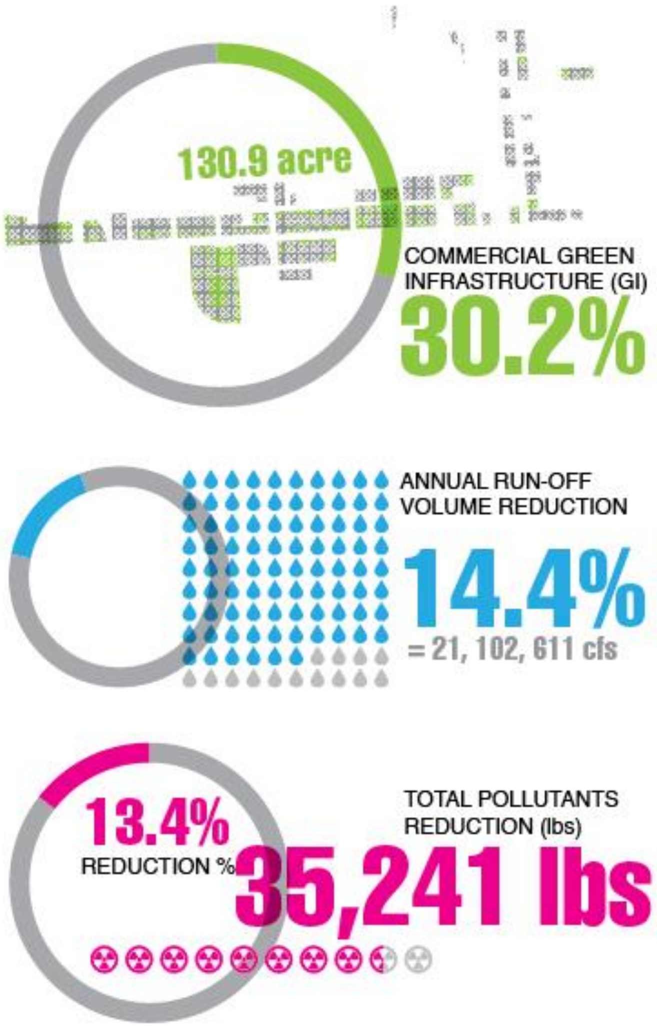
Right-of-Way (ROW) Offset Distance

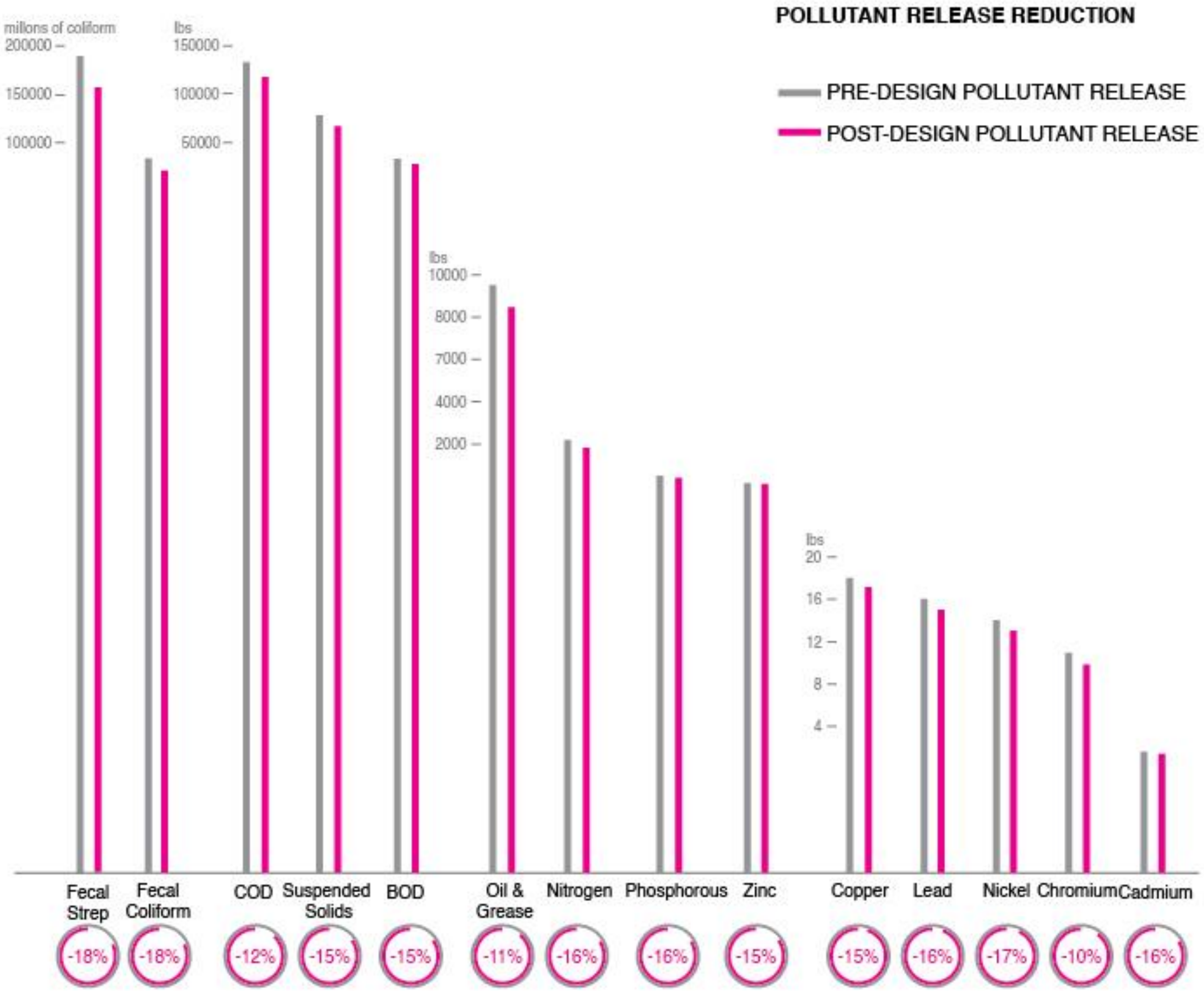
Master Plan


GREEN INFRASTRUCTURE
1.Railroad park
2. Green promenade
3. 2nd Street park
4. Homestead rain gardens
5. Naturalized water channel
6. Protective flood barrier
7. Industrial buffer
SUSTAINABLE DEVELOPMENT
8. Entertainment venue
9. Pedestrain node
10. Business district
11. Industrail model district
12. Green parking
13. High-rise apartment
Keene St
Holland Ave
N Main St
Clinton Dr
Clinton Dr
0
0.05
0.2
Miles

Green Infrastructure Stormbox
Toolbox: Pipe Depth vs. ROW Width

Design Impact (Basic L-THIA Model)





Source: [Low-Impact Development L-THIA (purdue.edu)]

Green Infrastructure “Assemblage Units”

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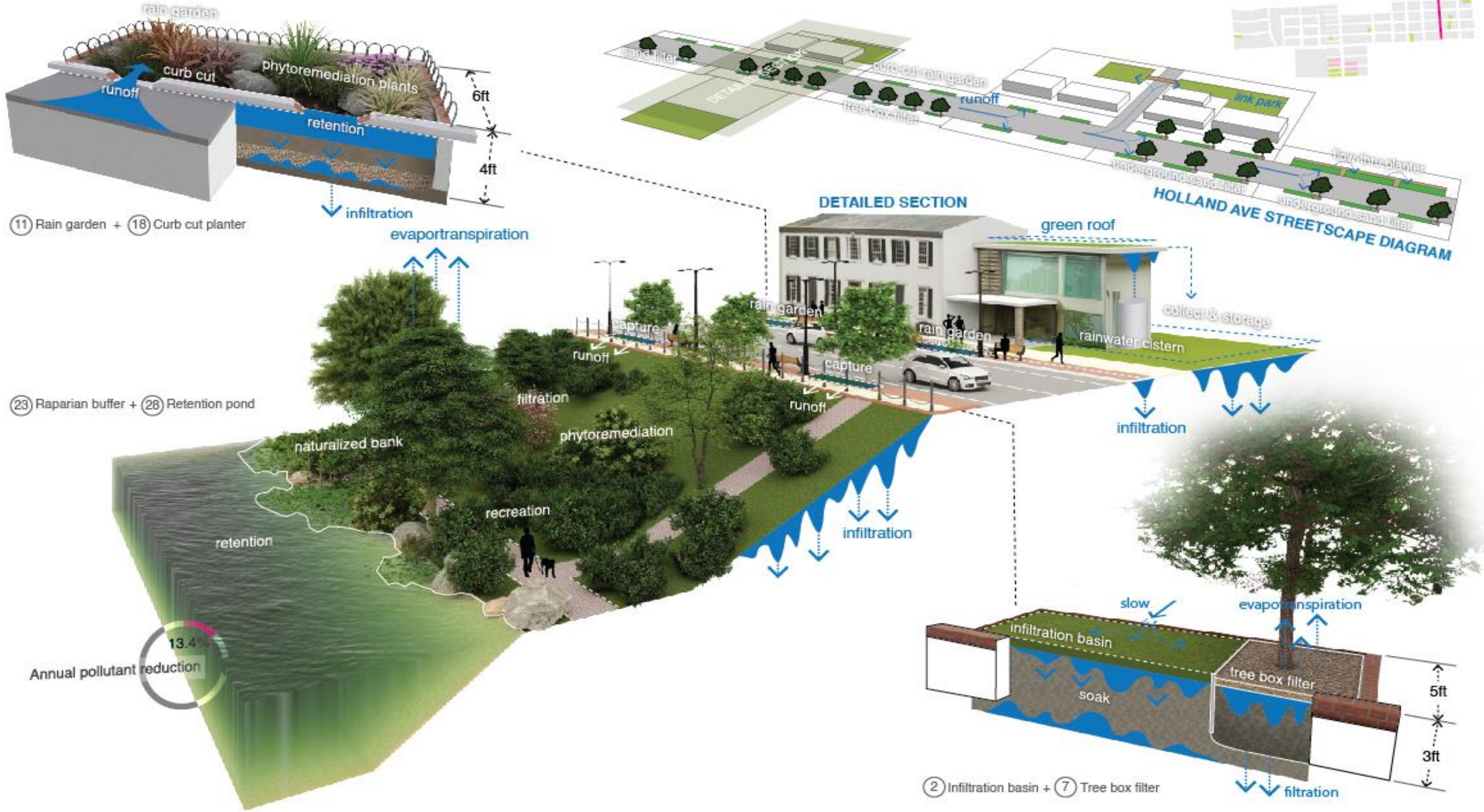
Assemblage Unit: Streetscape & Retention System



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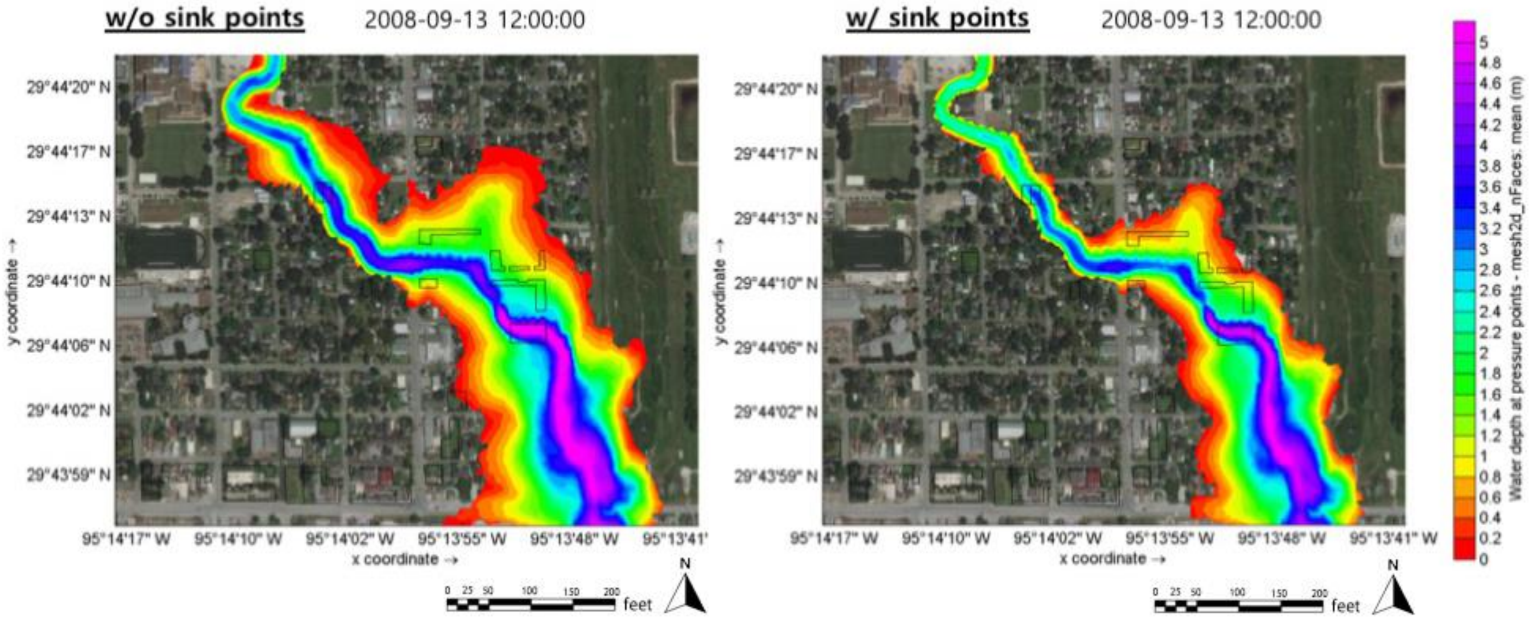
Delft 3D Mesh Modeling for Impact

The master plan reduces areal extent and total water volume of flooding at peak inundation by 30%

The duration of the flood reduced from approximately 38 hours to approximately 10 hours due to the master plan

Scenario	Inundation Volume at Maximum Surge (m^3)	Areal Extent at Maximum Surge (m^2)
Without Master Plan	449,493	270,029
With Master Plan	315, 312	191,018



APPLYING THE 3|30|300 METHOD FOR REMEDIATION IN TEXAS CITY, TX

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Nature Based Solution Guide

Why a decision guide

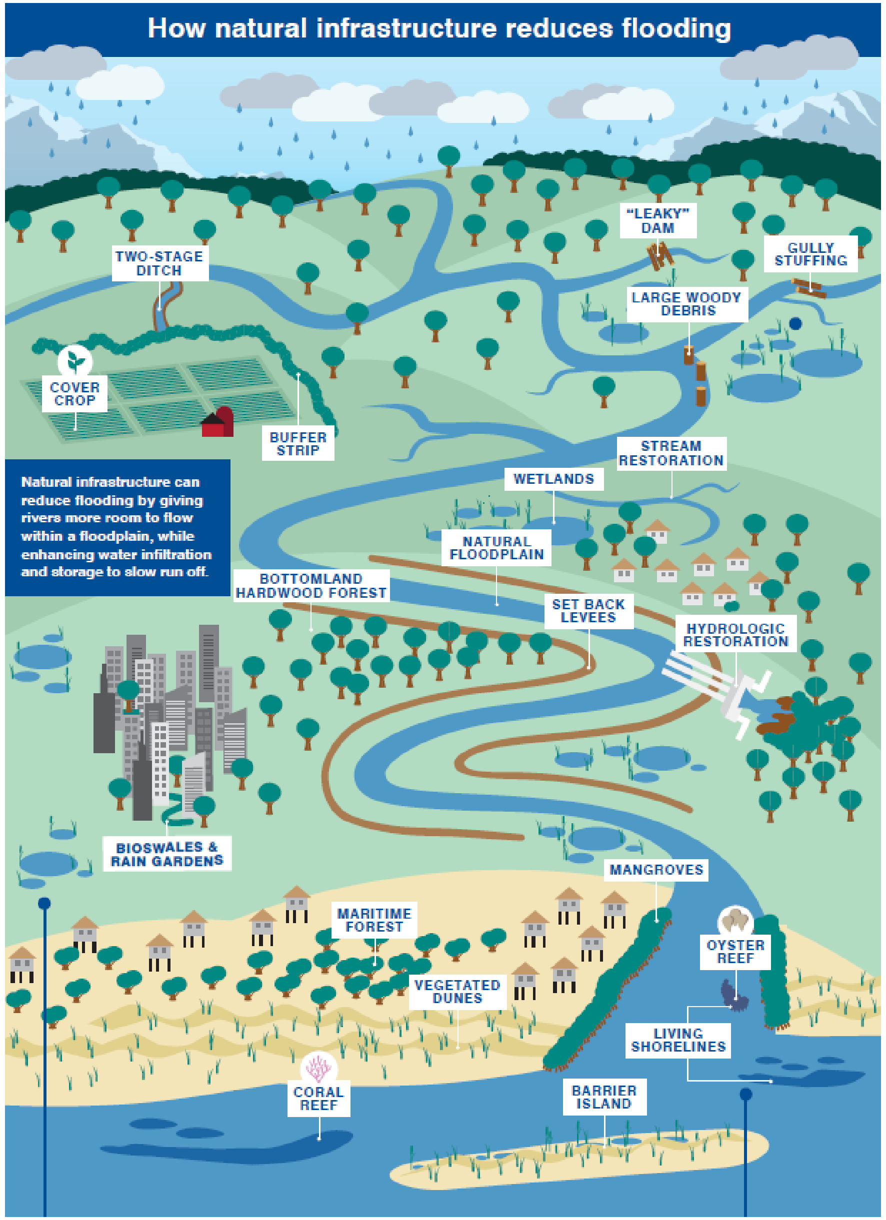
- Explore flood risk
- Assess conditions affecting damages and vulnerability
- Reduce exposure
- Evaluate opportunities for community–desired outcomes
- Flexible decision-making
- Connective tissue linking information from this initiative

Who is the decision guide for

- Facility managers
- Non-profits
- Engineers
- Hazard risk managers
- Consultants
- Municipalities/local government
- Community groups/orgs

What does the decision guide do

- Identifies NBS options for flooding with chemical risks
- Identifies NBS options for flooding not associate with chemical risks
- Guides acquisition of expertise & data
- Provides a basis for dialogue on community needs, desires, opportunities
- Positions the community to secure funding and permits



How do you use the decision guide

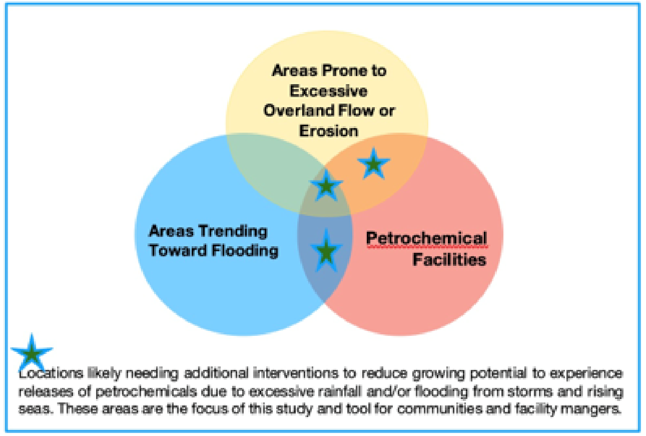
A Decision Tool for Identifying Potential Nature-Based Solutions (NBS) to Reduce Flood Damages and Petrochemical Pollution in the Gulf of Mexico, based on an Evaluation of Galveston Bay

The aim of implementing Nature-Based Solutions (NBS) is to address the inherently dynamic aspects of flooding and provide multifunctional solutions (e.g., flood and contamination mitigation) for communities. Natural infrastructure and NBS have been shown to reduce flood heights, speed, and volume, assist in the sequestration and reduction of stormwater runoff as well as the natural filtration of contaminants associated with floodwaters.

There are two means to reduce the threat of chemical exposure from flooding: measures that lower the risk of flooding within a petrochemical facility and measures that restrain, redirect, and/or contain contaminated waters and sediment. See Tables 1 and 2.

Identifying the appropriate NBS or combinations of NBS necessitates broad (a.k.a. systems) thinking to identify and consider hazards and their likelihood; assess the interplay of physical, ecological, social, and economic influences affecting damages and vulnerability; and evaluate opportunities and identify desirable outcomes. Consideration of these many systems will help reveal the root causes, changing conditions, and trends to identify plausible solutions that can address multiple issues.

Figure 1. Schematic on the focus of this study and tool.



Reduction in flood risk depends on several factors such as topography, sediment and vegetation characteristics, and the characteristics of the incoming events (e.g., precipitation intensity and duration, antecedent soil moisture, water level, wave height, and wave period, etc.) as well as sea level rise (and subsidence). NBS proposed for flood-risk reduction depend on raising the cross-shore profile, increasing the distance between water and structures, and offering greater frictional resistance to the movement of water to reduce waves, slow water speed, decrease erosion, lower water levels, and manage storm runoff. This is done via:

- creating space for less damaging flooding to occur (e.g., broadening floodplains);
- recreating topographic and bathymetric complexity (e.g., using features such as dunes, islands, strategically placed logs and sticks, and shellfish reefs) to store, restrain, or redirect flows;

- Online tool and downloadable guide
- Data/Input guidance
  - Flood and chemical risk
  - Community benefits from NBS
  - Ecosystem needs
- Iterative process
- Diverse stakeholder engagement

How do you use the decision guide

Table 4b. Example showing only top 10 community priorities.

Goal	Objective	Top 10 (*)	Possible Nature Based Solution (s): Increase pervious surfaces	Riparian buffer/Urban forest	Shellfish Reef	Park lands	Retention pond/water director	Bioswales/Filter strips	Freshwater wetlands	Offshore barrier islands
Improves resilience to coastal storms, sea level rise,	Benefits vulnerable populations	*	1	5	1	5	5	3	3	3
	Mitigates multiple flood hazards	*	1	5	1	3	4	1	3	1
	Complements other flood risk reduction solutions	*	Y	Y	Y	Y	Y	Y	Y	Y
	Reduces chemical exposure	*	1	3	3	1	5	3	4	3
	Reduces storm damage	*	3	4	3	4	4	3	5	4
Increases ecological resilience	Improves stormwater runoff quality or coastal/riverine water quality	*	Y	Y	Y	Y	Y	Y	Y	N
Improves social and economic resilience	Creates recreational opportunity	*	N	Y	N	Y	N	N	Y	Y
	Minimized industrial operations impact	*	L	H	L	M	L	L	M	L
	Aligns with community goals	*	Y	Y	N	Y	Y	Y	Y	N
	Affordability	*	M	M	H	M	L	M	L	L

Summary

- Fill critical gaps in our understanding of toxic releases due to flooding
- Highlight how nature-based solutions can be used to reduce risks of chemical release and exposure
- Provide stakeholders with data and guidance to inform deployment of NBS in their own communities

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Createnbs.org

HOME | TOXIC FLOODING VULNERABILITY | NATURE BASED SOLUTIONS | RESOURCES | ABOUT

Climate change increases the likelihood of floods causing health-harming chemical releases at petrochemical manufacturing and storage sites. New research from Environmental Defense Fund, Texas A&M University and Galveston Bay Foundation improves understanding of this toxic flooding vulnerability and proposes nature-based solutions to protect people and ecosystems.

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Special Thanks

Research reported in this presentation was supported by the Gulf Research Program of the National Academy of Sciences, Engineering, and Medicine under award number SCON-10000841 and VoLo Foundation.

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Shannon Cunniff
Former Director for Coastal Resilience

Lauren Padilla, PhD
Project Director and VoLo Senior Environmental Data Scientist

Rachel Rhode
Manager for Climate Resilient Coasts & Watersheds

TEXAS A&M UNIVERSITY

Weihsueh Chiu, PhD
Professor in the Department of Veterinary Physiology and Pharmacology

James Kaihatu, PhD
Professor in the Zachry Department of Civil & Environmental Engineering

Galen Newman, PhD
Professor and Department Head - Landscape Architecture and Urban Planning

Garett Sansom, PhD
Environmental & Occupational Health Assistant Professor and NIH-P42 investigator

Thomas McDonald, PhD
Regent's Professor in the School of Public Health - Department of Environmental and Occupational Health

GALVESTON BAY FOUNDATION

Lisa Scobel, MS
Marine Debris Programs Manager

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