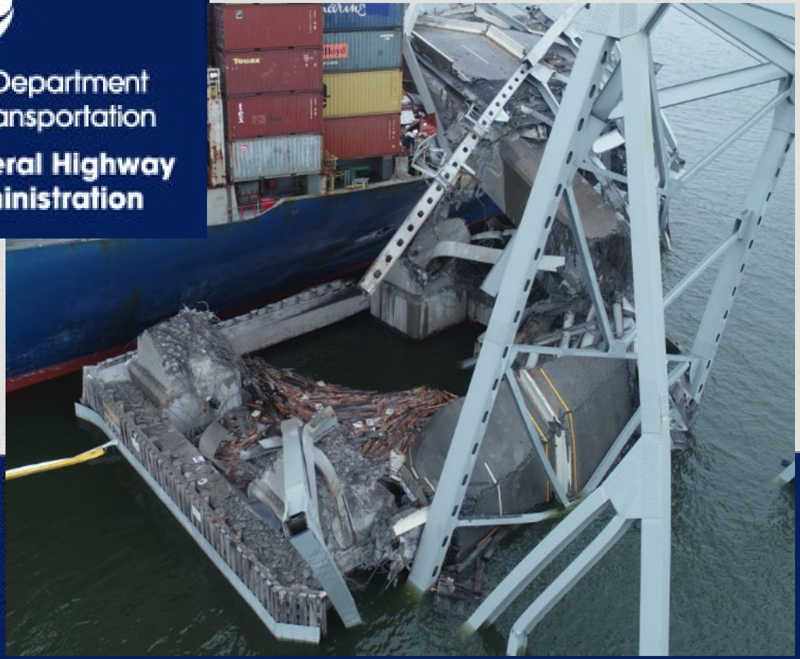
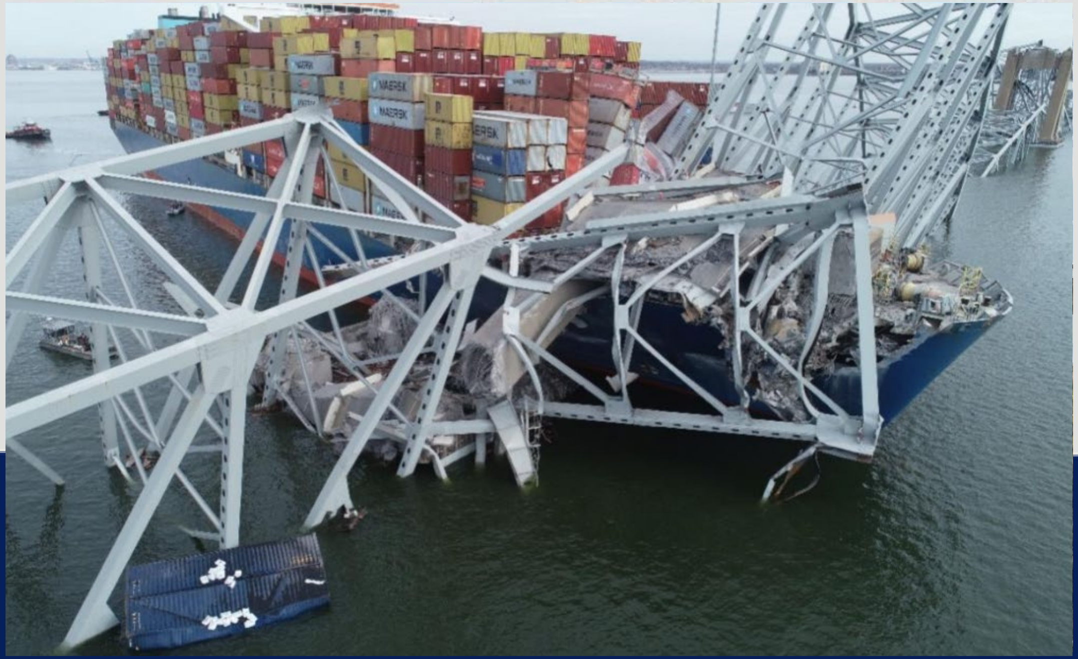




NTSB Francis Scott Key Bridge Investigation Urgent Recommendations

Francis Scott Key Bridge
Source: NTSB

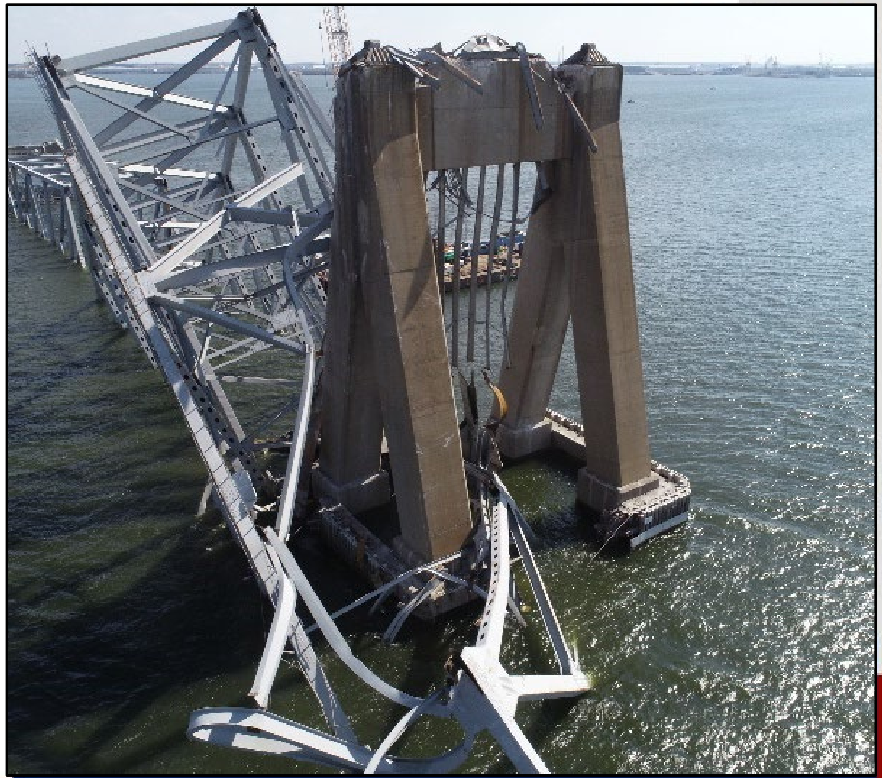
Disclaimer

Except for the statutes and regulations cited, the contents of this presentation do not have the force and effect of law and are not meant to bind the States or the public in any way. This presentation is intended only to provide information regarding existing requirements under the law or agency policies.

Unless otherwise noted, FHWA is the source for all images in this presentation.

Agenda

- March 2025 NTSB Urgent Recommendations
- FHWA/USCG/USACE Interdisciplinary Team
- Previous Bridge Collisions and NTSB Recommendations
- Vessel Collision Evaluation



Francis Scott Key Bridge

Source: NTSB

March 2025 Urgent NTSB Recommendation to FHWA

Recommendation H-25-1 (Urgent)

In coordination with the US Coast Guard and US Army Corps of Engineers, establish an interdisciplinary team—including representatives from the Federal Highway Administration, US Coast Guard, and US Army Corps of Engineers—and ***provide guidance and assistance*** *to bridge owners on evaluating and reducing the risk of a bridge collapse from a vessel collision.*

- Similar recommendations sent to the U.S. Coast Guard and U.S. Army Corps of Engineers (H-25-2)

March 2025 Urgent NTSB Recommendation to Bridge Owners

U.S. Department of Transportation
Federal Highway Administration

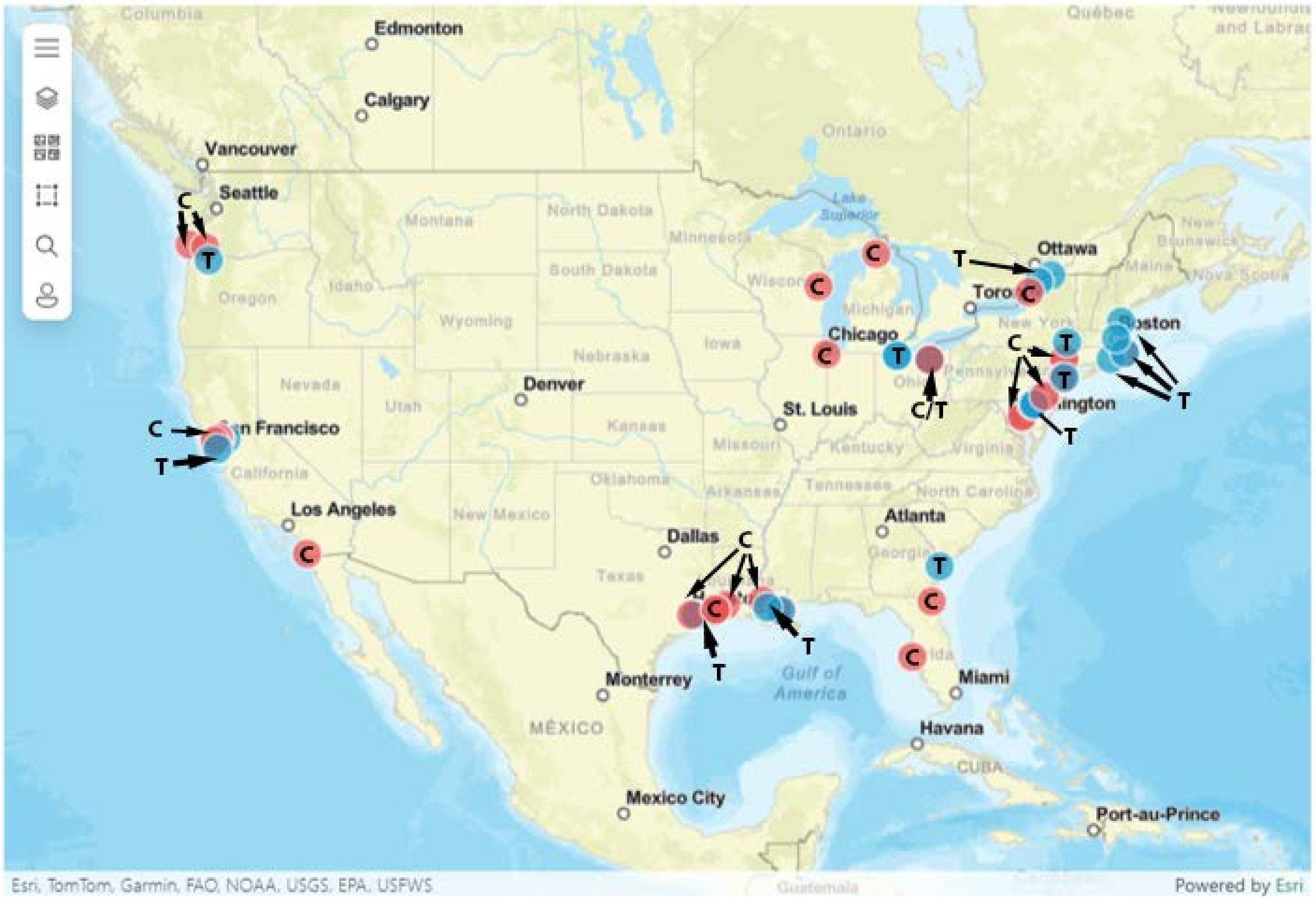
- Recommendations H-25-3 and H-25-4(Urgent)
    - *Calculate the American Association of State Highway and Transportation Officials (AASHTO) Method II annual frequency of collapse for the bridge(s) identified in appendix B of this report for which you are responsible and inform the National Transportation Safety Board whether the probability of collapse is above the AASHTO threshold. (H-25-3) (Urgent) (See section 2.4 and appendix B)*
    - *If the calculations that you performed in response to Safety Recommendation H-25-3 indicate that a bridge has an annual frequency of collapse greater than the American Association of State Highway and Transportation Officials threshold, develop and implement a comprehensive risk reduction plan that includes, at a minimum:*
        - *guidance and assistance from the Federal Highway Administration, US Coast Guard, and US Army Corps of Engineers Interdisciplinary Team identified in Safety Recommendations H-25-1 and -2, and*
        - *short- and long-term strategies to reduce the probability of a potential bridge collapse from a vessel collision. (H-25-4) (Urgent)*

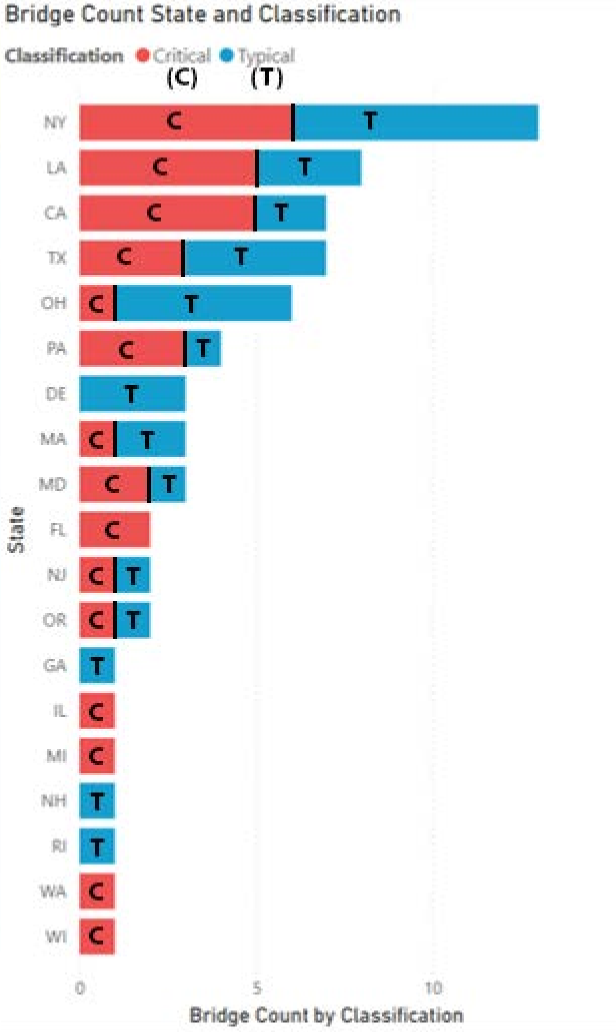
Interdisciplinary Team

Agency Leads

- Derek Soden
  - Federal Highway Administration (FHWA), Principal Structural Engineer
- Captain Paul Mangini
  - United States Coast Guard, Senior Maritime Safety and Security Advisor, USCG/USDOT Liaison Offic
- James Moore
  - United States Coast Guard Office of Bridge Programs
- Thomas North
  - United States Army Corps of Engineers, Bridge Safety Program Manager

Bridges Identified by NTSB





Previous Bridge Allision Accidents

- 1978 – Benjamin Harrison Bridge (Virginia)
- 1980 - Sunshine Skyway Bridge (Florida)
- 1993 – Big Bayou Canot Bridge (Alabama - Railroad)
    - William Seeber Bridge (Louisiana)
- 2002 – Interstate 40 Arkansas River Bridge (Oklahoma)

Sunshine Skyway Bridge
AP Photo/St. Petersburg Times, Weaver Tripp

Previous NTSB Recommendations to FHWA

U.S. Department of Transportation
Federal Highway Administration

- Recommendation M-81-20 (Sunshine Skyway)
  In cooperation with the U.S. Coast Guard, develop standards for the design, performance, and location of structural bridge pier protection systems which consider that the impact from an off course vessel can occur significantly above as well as below the water surface.
  - Result – AASHTO Guide Specifications and Commentary for Vessel Collision Design of Highway Bridges
- Recommendation M-81-21 (Sunshine Skyway)
  In cooperation with the U.S. Coast Guard, conduct a study to determine which existing bridges over the navigable waterways of U.S. ports and harbors are not equipped with adequate structural pier protection.
  - Results – 23 CFR 650.807(f), Technical Advisory 5140.19, National Bridge Inventory Item 111 – Pier or Abutment Protection (for Navigation)

Previous NTSB Recommendations to FHWA

U.S. Department of Transportation
Federal Highway Administration

- Recommendation H-04-29 (Interstate 40)
  Revise your sufficiency rating system, which prioritizes bridges for rehabilitation and replacement, to include the probability of extreme events, such as vessel impact.
  - Result: 2009 Edition of the Guide Specifications with addition of Pier Protection effectiveness measure

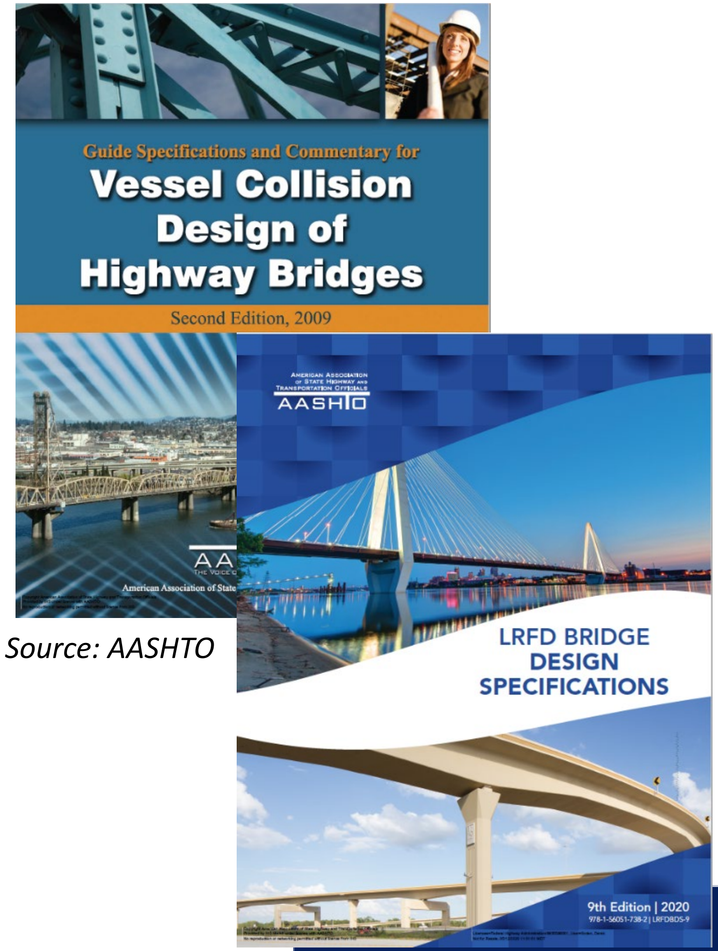
I-40 Arkansas River Bridge
Source: NTSB/ODOT

U.S. Department of Transportation
Federal Highway Administration

Vessel Collision Evaluations

How are Bridges Designed (and Evaluated) for Vessel Collision

- Guide Specifications and Commentary for Vessel Collision Design of Bridges (GSVC) first issued in 1991, updated 2009
  - Developed via FHWA-led pooled fund study
  - Portions incorporated* into LRFD Bridge Design Specifications (LRFD BDS) in 1994
- Three Methods
  - Method I – Semi-deterministic $Demand < Capacity$
  - Method II – Probabilistic, produces Annual Frequency of Collapse considering probability of:
    - Vessel aberrancy
    - Geometric probability of allision
    - Bridge collapse due to allision $(D < C)$ - *2010 interim*
    - Effectiveness of pier protection
  - Method III – Method II plus Cost/Benefit Analysis



Source: AASHTO

** - 23 CFR 625.4(d)(1)(v)*

Operational Classification

- LRFD Article 3.14.3 and GSVC Article 3.3
- Assigned by the owner to establish risk acceptance and determine design vessels (new bridges)
- Two operational classifications considered
  - Critical/Essential Bridges

    Shall continue to function after an impact (LRFD and GSVC)

    STRAHNET, and other social and economic considerations (GSVC only)
  - Typical Bridges

    Not meeting critical/essential criteria

** - 23 CFR 625.4(d)(1)(v)*

Operational Classification, cont'd.

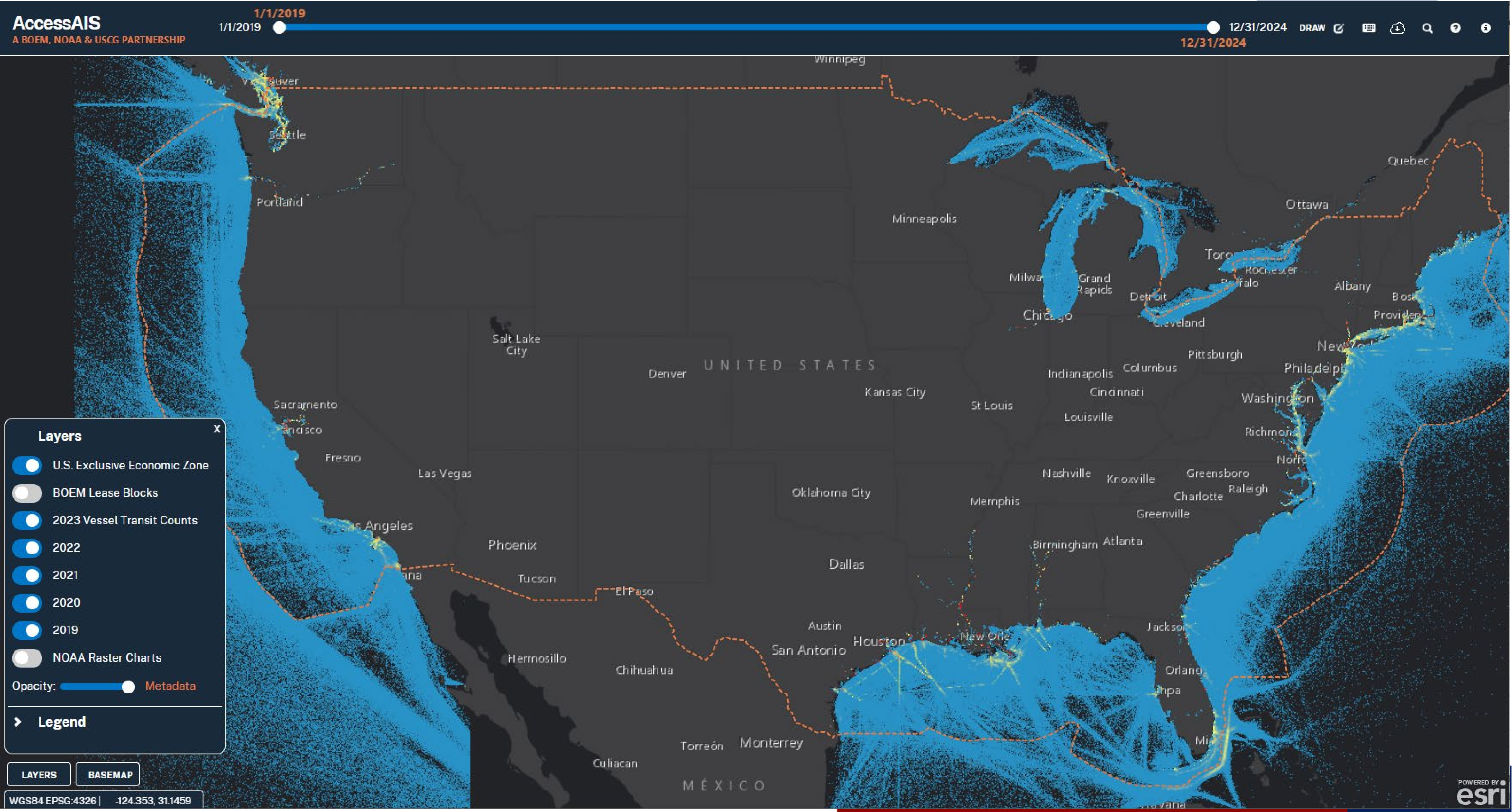
- Discussions with other stakeholders (fire/EMS, police, local agencies) may inform the operational classification
- Other considerations:
  - Lack of, or limited, alternate detour routes
  - Access for civil defense, police, fire department or public health agencies
  - Access to essential facilities such as hospitals, police and fire stations, and communications centers
  - Bridge carries high volumes of traffic
  - Closure has a large economic impact
  - Bridge provides routes to facilities such as schools, arenas, power installations, water treatment plants, etc.

Navigation Studies

U.S. Department of Transportation
Federal Highway Administration

- Necessary regardless of method used
- Data sources
  - Automatic Identification System (AIS) – vessel location data
    - BOEM, NOAA, and USCG
  - Data sets available at: https://marinecadastre.gov/accessais/

- Lat/Long
- Heading (inbound/outbound)
- Vessel Type (bulk cargo, tanker, etc.)
- Length (LOA), Width, Draft
- Cargo Type
- MMSI/IMO/Official Number (Identification)



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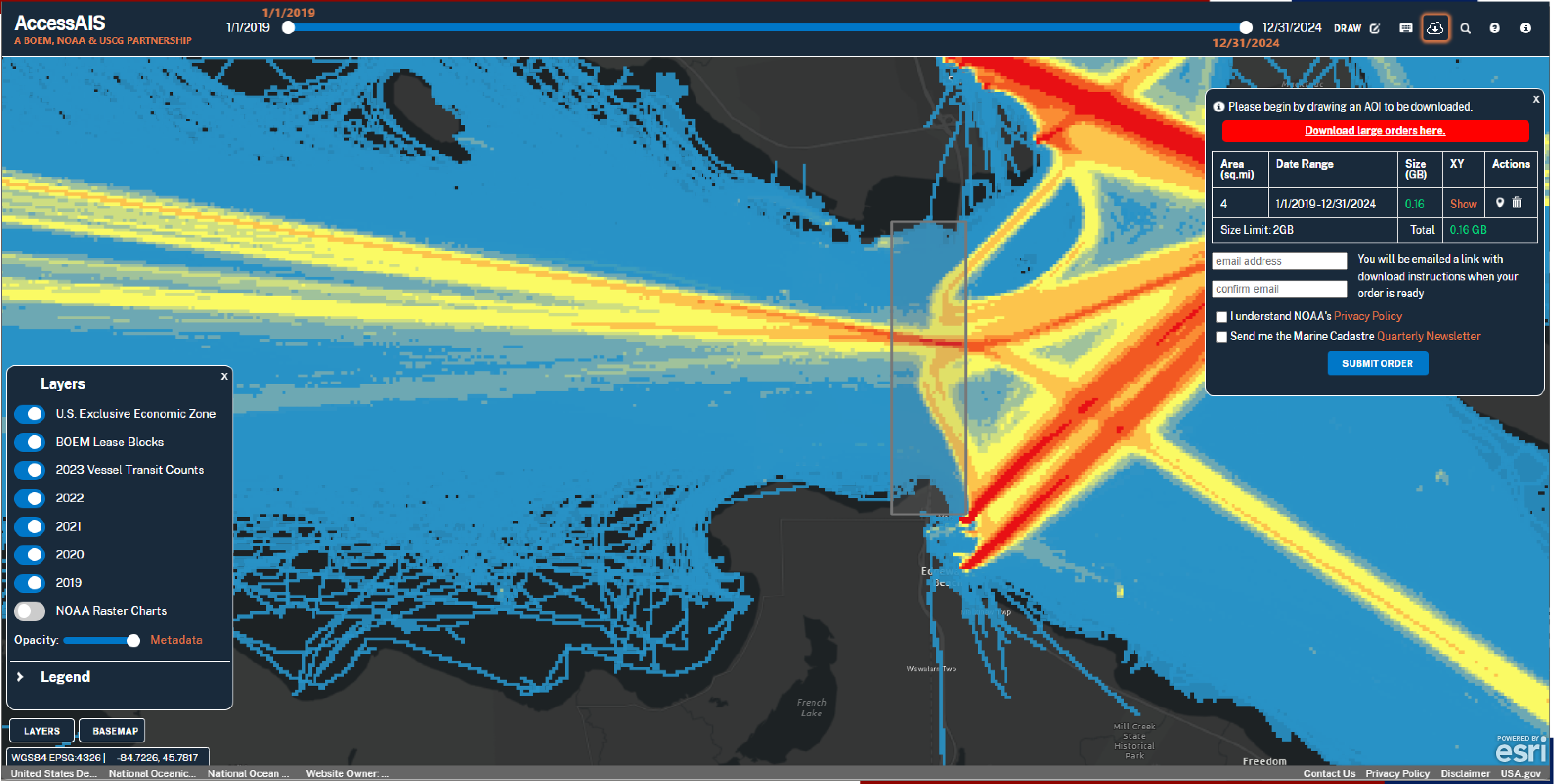


Source: https://marinecadastre.gov/accessais/

Navigation Studies

U.S. Department of Transportation
Federal Highway Administration

- Information not available from AIS
  - Deadweight Tonnage (DWT) – characteristic information
  - Bow depth
  - Displacement
- Potential Data Sources
  - USCG National Vessel Movement Center
  - USCG Marine Information for Safety and Law Enforcement (MISLE – USCG access only)
  - USCG Aids to Navigation Information Management System (USAIMS – USCG access only)
  - USCG Port State Information Exchange (PSIE) and free services on commercial websites
    - Search individually by IMO
    - Not ideal for navigation studies
  - Commercial Databases
    - Query-able
    - Cost to access
  - USCG PSIE API

Example Study Results

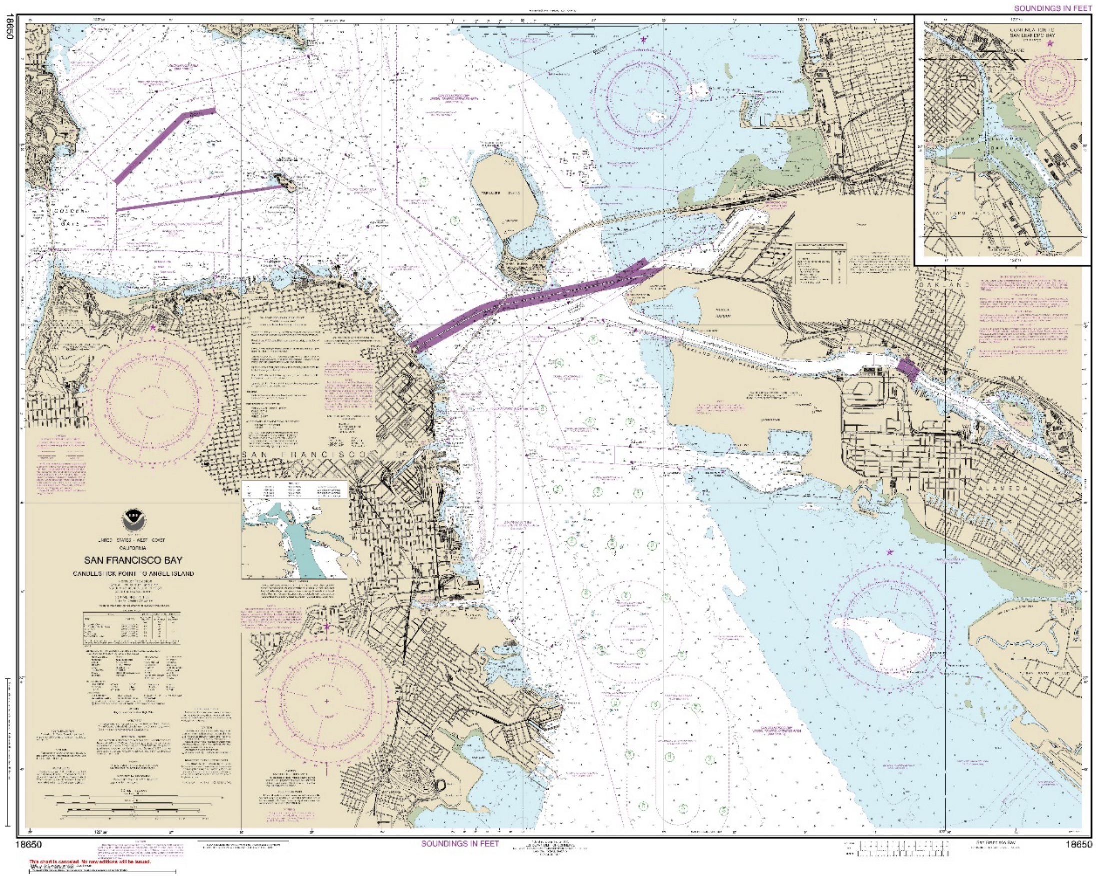
U.S. Department of Transportation
Federal Highway Administration

By vessel type

DWT (ton)	2019	2020	2021	2022	2023	2024
0 - 10,000	42	24	71	61	83	19
10 - 20,000	426	301	417	510	593	146
20 - 30,000	13	11	36	38	36	18
30 - 40,000	9	8	32	27	27	5
40 - 50,000	4	1	12	8	21	10
50 - 60,000	21	25	24	25	30	3
60 - 70,000	19	15	12	15	21	0
70 - 80,000	17	11	13	16	15	2
80 - 90,000	17	26	27	9	20	2
90 - 100,000	3	1	6	6	0	0
100 - 110,000	0	0	0	0	0	0
110 - 120,000	0	1	0	0	0	0
120 - 130,000	0	0	0	0	0	0
130 - 140,000	0	2	0	0	1	0
140 - 150,000	6	5	1	6	3	0
150 - 160,000	16	8	15	10	23	0
160 - 170,000	0	0	0	0	0	0
170 - 180,000	0	0	1	0	0	0
>180,000	0	0	1	0	0	0
Total	**593**	**439**	**668**	**731**	**873**	**205**

Waterway Characteristics

- Method II Assessments
  - Federal Navigation Projects
    - Maintained navigation channel width and depth
  - Navigation channels
  - Channel alignment
    - Turning movements
  - Waterway depths
    - Grounding assessments
  - Currents



Source: NOAA

AASHTO Method I – Ship vs. Substructure

- Demand (collision with substructure)

$$P_s = 8.15V\sqrt{DWT}$$ (LRFD BDS* Eq. 3.14.8-1)

$$P_s = 220(DWT)^{\frac{1}{2}}\left(\frac{V}{27}\right)$$ (LRFD GSVC Eq. 3.9-1)

- Equations for vessel collision energy, (KE), and ship bow damage depth, (a_s)

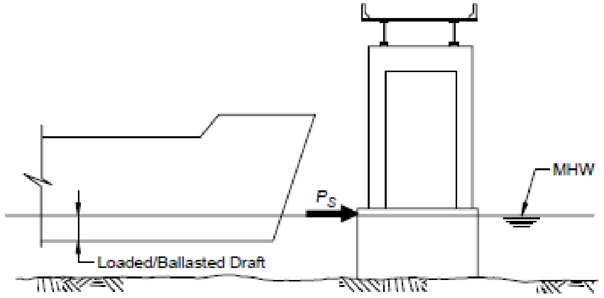


Figure 3.15.1-1—Ship Impact Concentrated Force on Pier (for Foundation Design and Overall Stability)

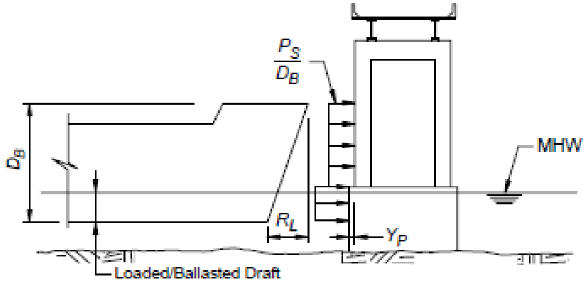


Figure 3.15.1-2—Ship Impact Line Load for Local Collision Force on Pier (for Structure Check and Design)

Source: AASHTO

** - 23 CFR 625.4(d)(1)(v)*

AASHTO Method II

- Risk-based (risk comparison) assessment
- Establishes an Annual Frequency of Collapse

$$AF = (N)(PA)(PG)(PC)(PF)$$

(LRFD BDS* Eq. 3.14.5-1) and GSVC Eq. 4.8.3-1)

Where: $N =$ Number of vessels, by type and size

$PA =$ Probability of aberrancy

$PG =$ Geometric probability

$PC =$ Probability of collapse

$PF =$ Protection factor

- Cumulative

$$\sum_{\substack{Ship\ Class \\ DWT\ category \\ Bridge\ Element \\ inbound/outbound}} (N)(PA)(PG)(PC)(PF)$$

** - 23 CFR 625.4(d)(1)(v)*

PA – Probability of Aberrancy

U.S. Department of Transportation
Federal Highway Administration

- Probability of a vessel straying off course
- Determined by either statistical or approximate method
- Approximate method:

$$PA = (BR)(R_B)(R_C)(R_{XC})(R_D)$$

(LRFD BDS* Eq. 3.14.5.2.3-1 and GSVC Eq. 4.8.3.2-1)

Where: $BR =$ Aberrancy base rate (0.6×10^{-4} for ships, or by statistics)

$R_B =$ Bridge location factor (straight, transition, or turn/bend region)

$R_C =$ Current parallel to transit path correction

$R_{XC} =$ Current perpendicular to transit path correction

$R_D =$ Vessel traffic density correction

** - 23 CFR 625.4(d)(1)(v)*

PG – Geometric Probability

- AASHTO LRFD BDS Article 3.14.5.3 and GSVC Article 4.8.3.3
- Probability that an aberrant vessel will strike a substructure unit
- Based on a normal distribution centered on the navigation path
  - $\mu = 0$
  - $\sigma = LOA$
- Area under the distribution
- Cumulative distribution functions are useful
  - In Excel, NORM.DIST with "Cumulative" = TRUE

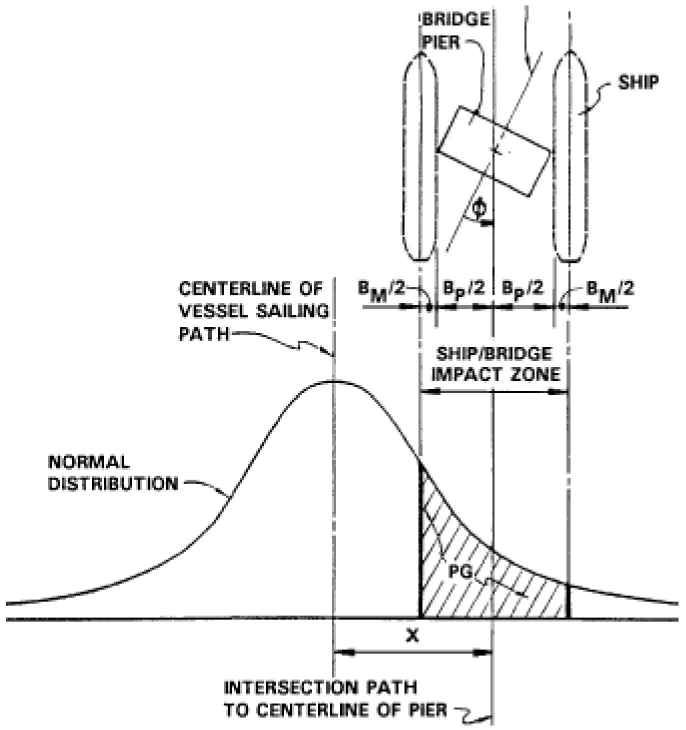


Figure 3.14.5.3-1—Geometric Probability of Pier Collision

*Source: AASHTO LRFD BDS**

** - 23 CFR 625.4(d)(1)(v)*

PC – Probability of Collapse

- AASHTO LRFD BDS* Art. 3.14.5.4 and GSVC Art. 4.8.3.4
- Computed based on capacity (H) to demand (P) ratio
- For $0.0 \leq H/P < 0.1$,

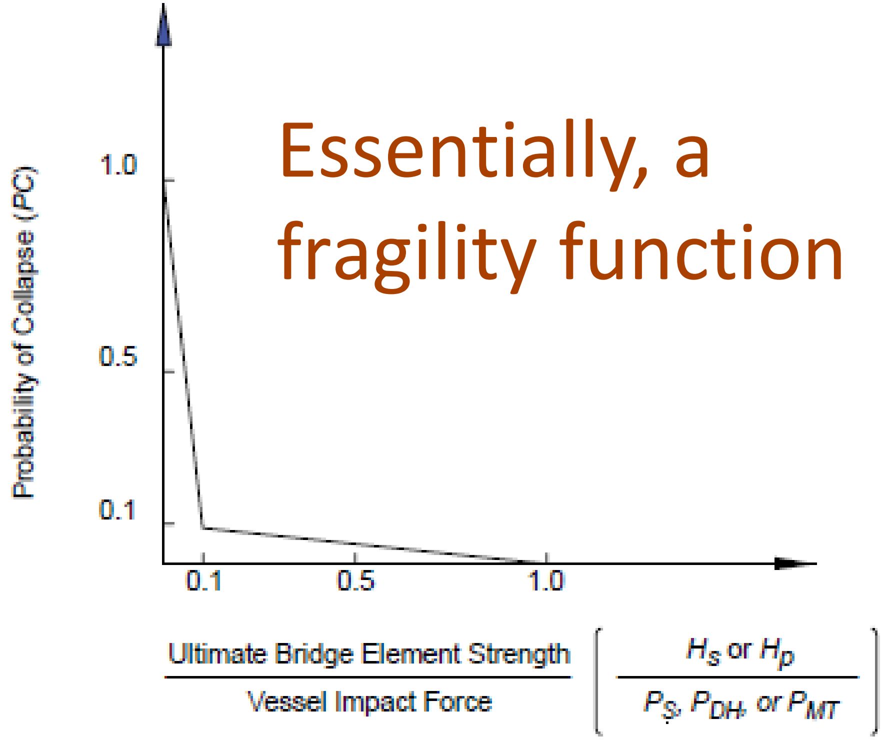
$$PC = 0.1 + 9\left(0.1 - \frac{H}{P}\right)$$

- For $0.1 \leq H/P < 1.0$,

$$PC = \left(1 - \frac{H}{P}\right)(0.111)^{**}$$

- For $H/P > 1.0$,

$$PC = 0.0$$



Essentially, a fragility function

Figure 4.8.3.4-1—Probability of Collapse Distribution

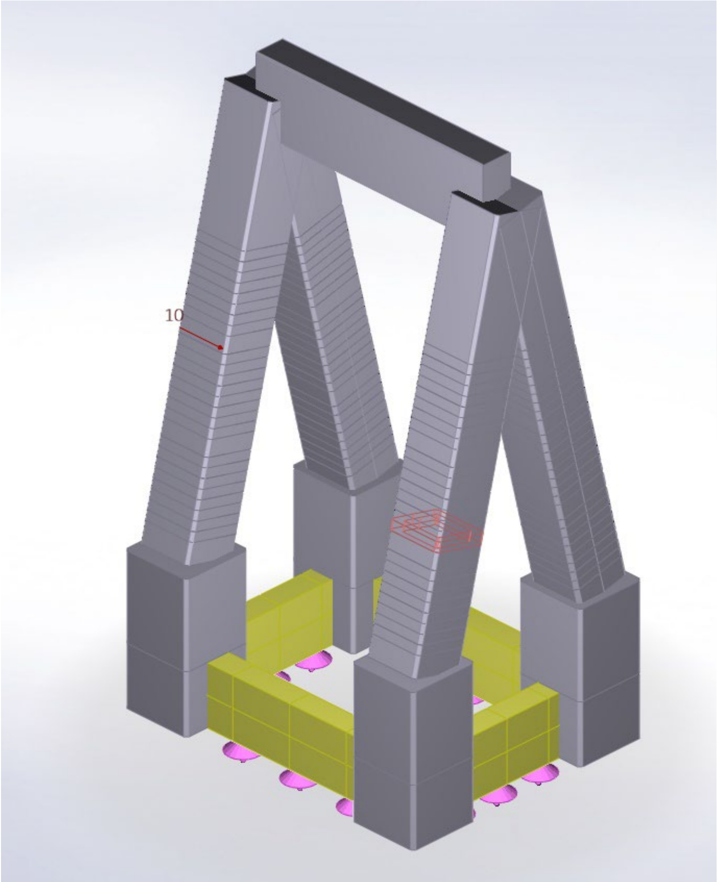
*Source: AASHTO LRFD BDS**

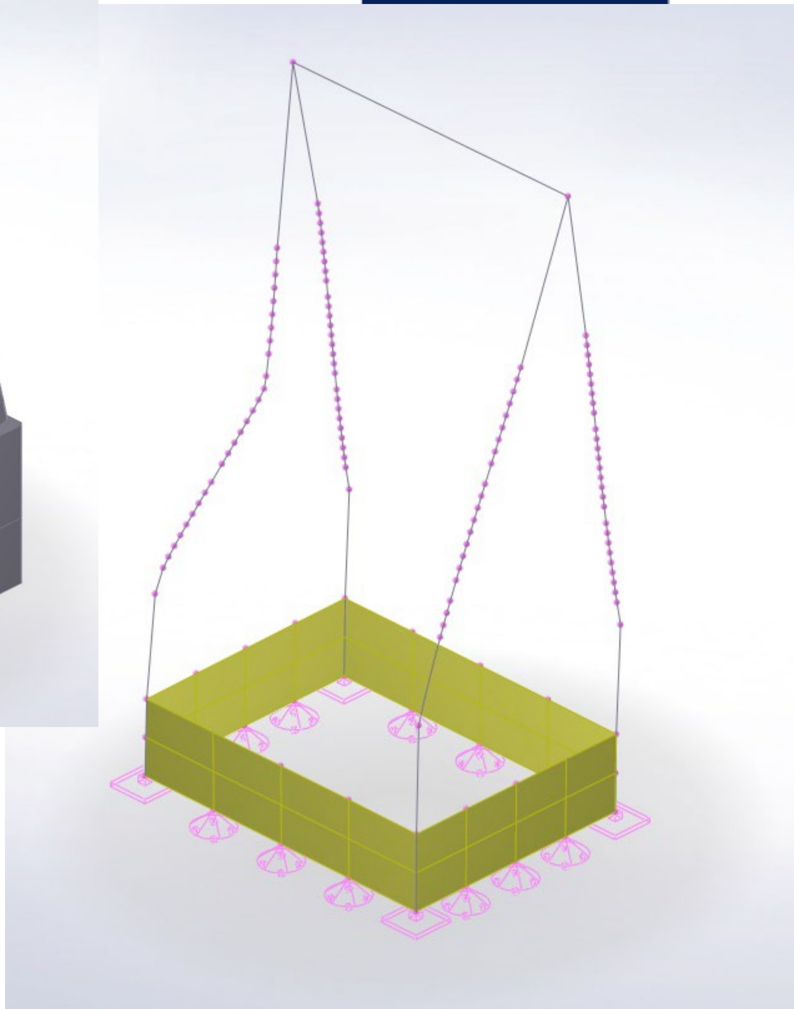
* - *23 CFR 625.4(d)(1)(v)*

** - 2010 GSVC interims made this correction

PC Calculation

- Demand (P) - P_s from slide 18
- Capacity – Ultimate capacity of the pier
  - Foundation
  - Pier columns
  - Linear-elastic
  - Nonlinear



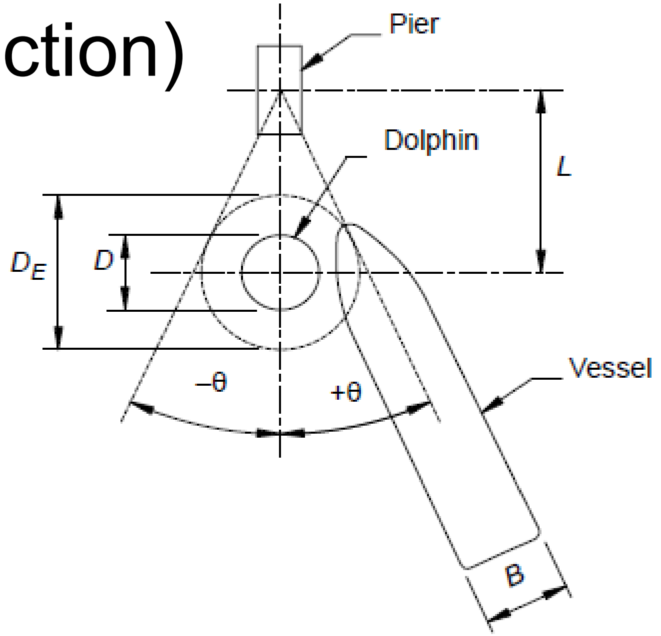


PF – Protection Factor

- AASHTO LFRD BDS* Art. 3.14.5.5 and GSVC Art. 4.8.3.5
- Varies from 0 (full protection) to 1.0 (no protection)

$$PF = 1 - (\%\,\text{Protection Provided}/100)$$

- Protection in terms of
  - Geometry
  - Capacity (energy dissipation)



Source: AASHTO LRFD BDS* Figure C3.14.5.5-1

* - 23 CFR 625.4(d)(1)(v)

AASHTO Acceptance Criteria*

- For Critical/Essential Bridges: $AF \leq 0.0001$
- For Typical Bridges: $AF \leq 0.001$

- In design, used to select the design vessel
  - Not to be exceeded when considering vessels larger than the design vessel
  - Assumption being that for smaller vessels, PC and/or PF is zero
- In evaluation, all vessel sizes considered
  - PC and PF will still remove ship classes and DWTs from consideration

** - AASHTO LRFD BDS Art. 4.8.3 - 23 CFR 625.4(d)(1)(v)*
AASHTO GSVC Art. 4.8.2

AF For Asset Management

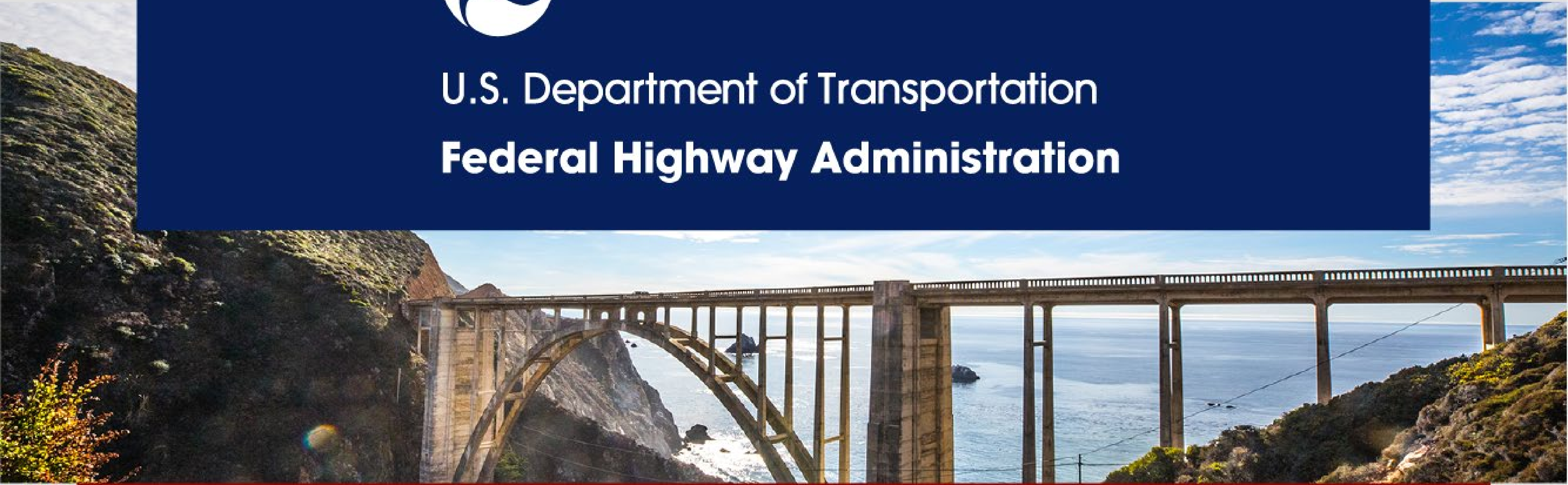
- Method III of the AASHTO GSVC Art. 4.9.2
- Annual risk cost: $AF \cdot DC$
  - Where: $DC =$ Disruption cost (capital, user – vehicular and vessel, casualty)
- Net benefit realized by reducing AF

$$B = PV_{n,i}(AF \cdot DC)_{Base} - PV_{n,i}\,(AF \cdot DC)_{Protected}$$

Interdisciplinary Team Assistance

U.S. Department of Transportation
Federal Highway Administration

- Contact your state's FHWA Division Bridge Engineer or Derek Soden (derek.soden@dot.gov)



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