MODJESKI and MASTERS

NSBA Uncoated Weathering Steel Manual

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Uncoated Weathering Steel (UWS) Manual Background

- Sponsored by AISC/NSBA
- Research team:

U of Delaware

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Modjeski and Masters

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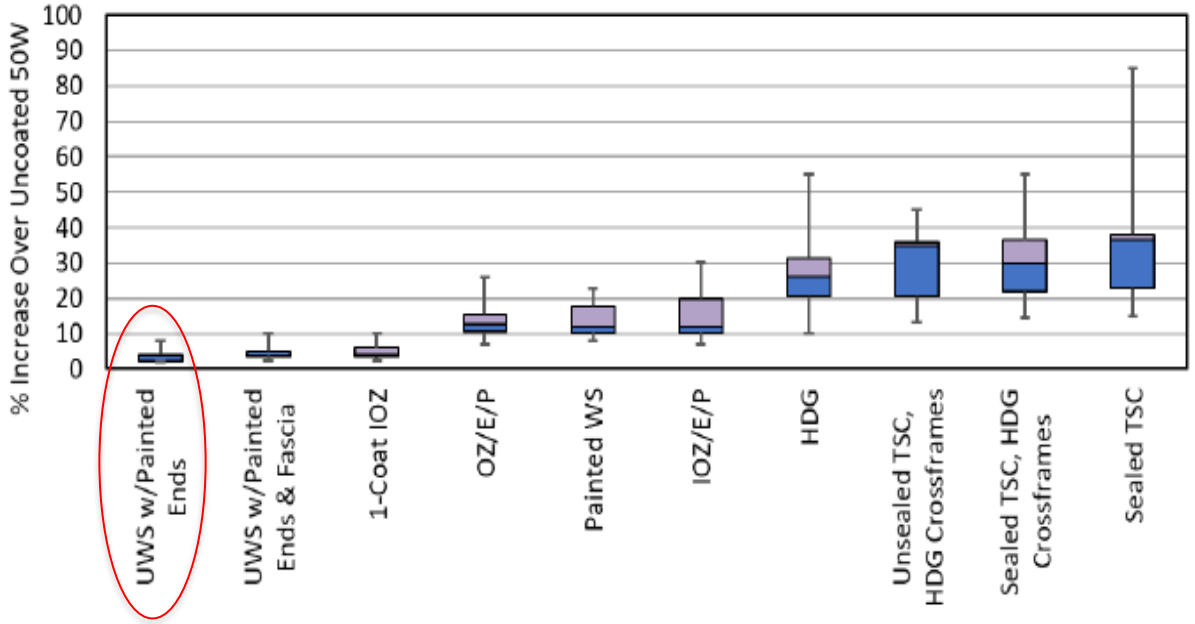
UWS Manual Scope

- Chapter 1 – Introduction
- Chapter 2 – Design Recommendations
- Chapter 3 – Fabrication and Construction
- Chapter 4 – In-Service Inspection
- Chapter 5 – Maintenance
- Chapter 6 – Repair and Rehabilitation

- Recommendations given as minimum requirements, and improved performance

Context for Use of UWS



- UWS provides:
  - Minimal 1st cost
  - Minimal life cycle cost
  - When properly detailed, fabricated, etc.
  - In most environments

Purpose of the Manual

- Need for broad guidance and collection of best practices
- Little published guidance on when and how to use Uncoated Weathering Steel
- FHWA Technical Advisory is long-in-the-tooth (1989)
- Owners and designers need basis for determining when use of UWS is appropriate
- FHWA is planning on updating the TA, Manual will serve as a more detailed companion guide

DESIGN RECOMMENDATIONS: PART 1 – SITE SELECTION

Design Recommendations

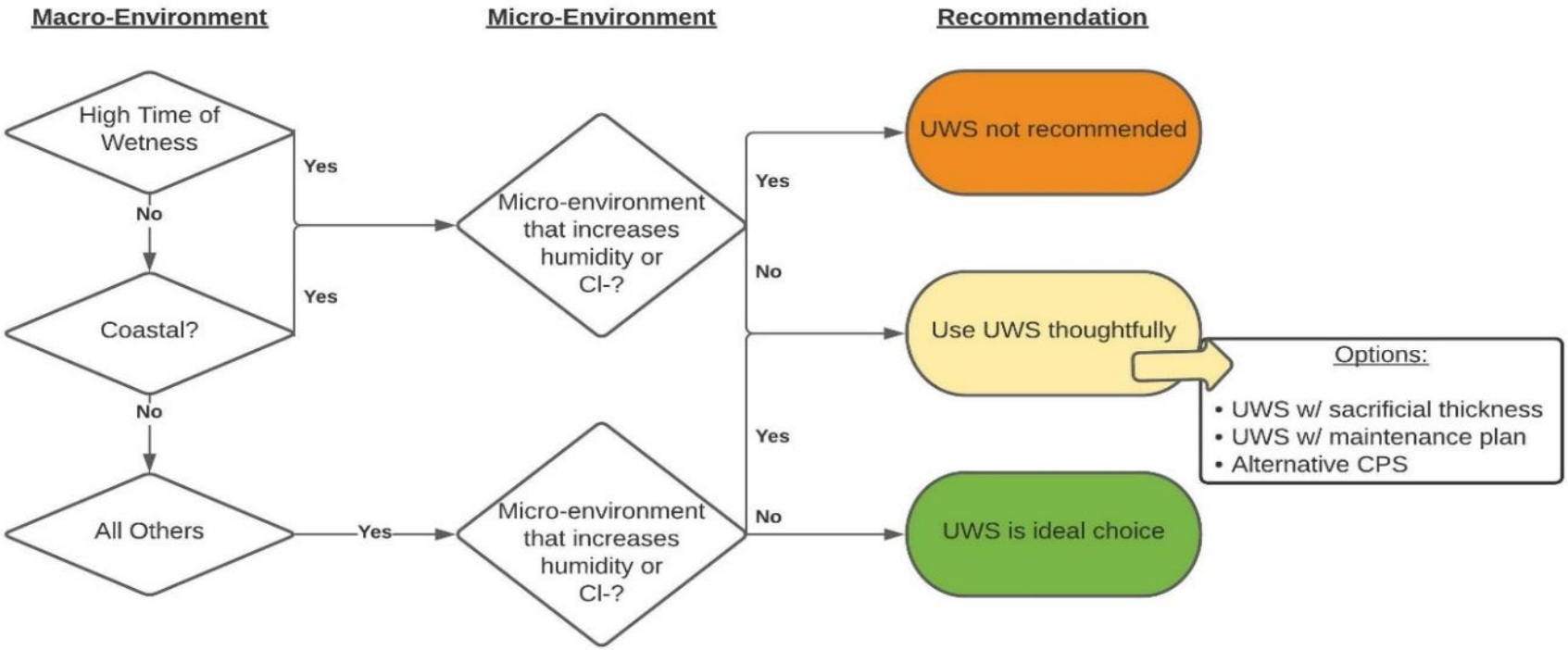
- When to use UWS, and when to proceed cautiously
- Macro-environment
  - High Time of Wetness environments
  - Coastal environments
- Micro-environment
  - Deicing salt / tunnel-like situation
  - Low vertical clearance over water
  - Vegetation / shelter

Site Selection – UWS

Circa 1989 → 2018

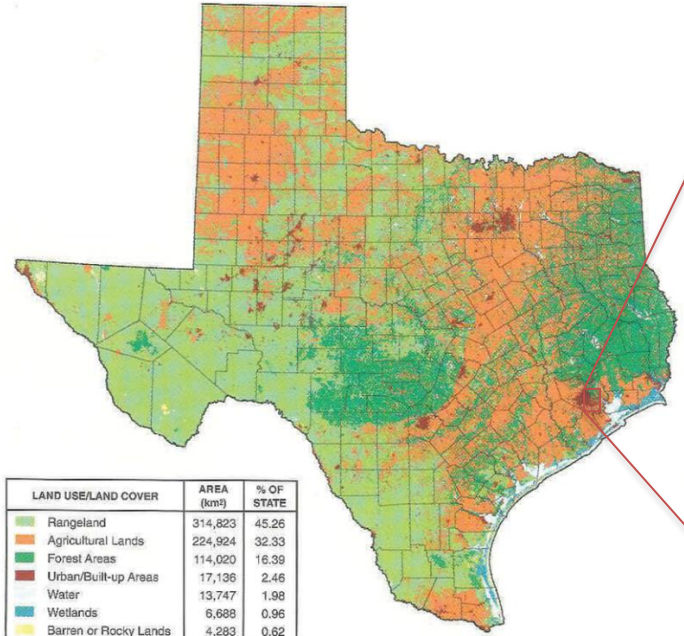
- Consider UWS “with caution” if:
  - Environment:
    1. Marine coastal areas. — *How far?*
    2. Frequent high rainfall, high humidity or persistent fog (condensing conditions). — *How much?*
    3. Industrial areas where concentrated chemical fumes may drift directly onto the structure. — *How much?*
  - Location:
    1. Grade separations in “tunnel-like" conditions. — *How high/wide? Salt use?*
    2. Low level water crossings. — *How often?*
       a. ≤ 10 ft. over stagnant, sheltered water.
       b. ≤ 8 ft. over moving water.

When to use UWS



Macro-Environments and Micro-Environments: Overview of Concept

Macro-Environment = Regional Geography



LAND USE/LAND COVER	AREA (km²)	% OF STATE
Rangeland	314,823	45.26
Agricultural Lands	224,924	32.33
Forest Areas	114,020	16.39
Urban/Built-up Areas	17,136	2.46
Water	13,747	1.98
Wetlands	6,688	0.96
Barren or Rocky Lands	4,283	0.62
TOTAL	695,624	100.00

Micro-Environment = Site Features

MACRO-ENVIRONMENT

Key Concepts

- **Chlorides and Humidity**

Overview of Qualitative Macro-Environments

- Rural → Benign
- Urban → Deicing Agents (Extreme) → Micro-environment
- Industrial → Mitigated
- Coastal →

Coastal Macro-Environment: How to Define It?

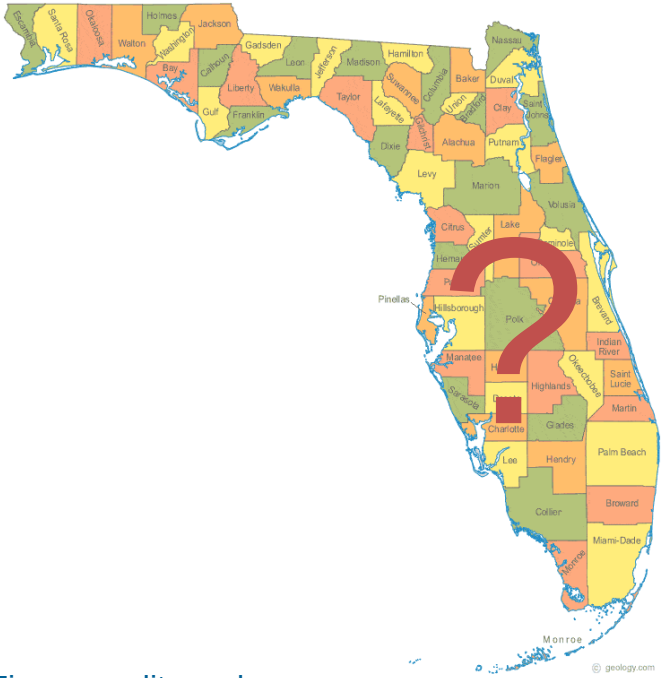


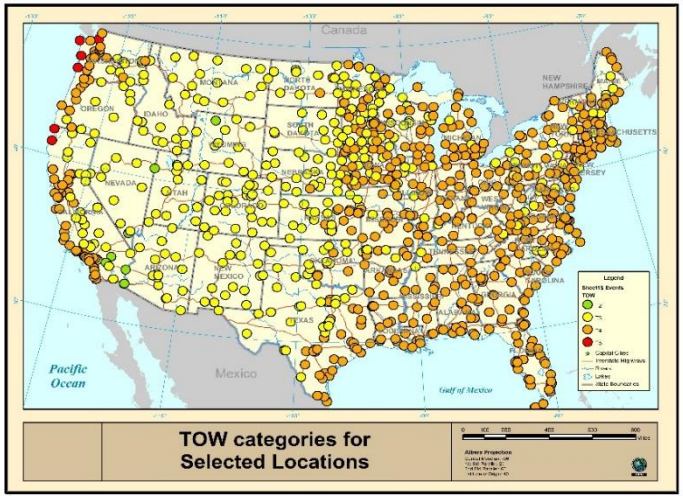
Figure credit: geology.com

Photo credit: valleycentral.com

Coastal Macro-Environment: Metrics to Quantify It?
v1: Time of Wetness

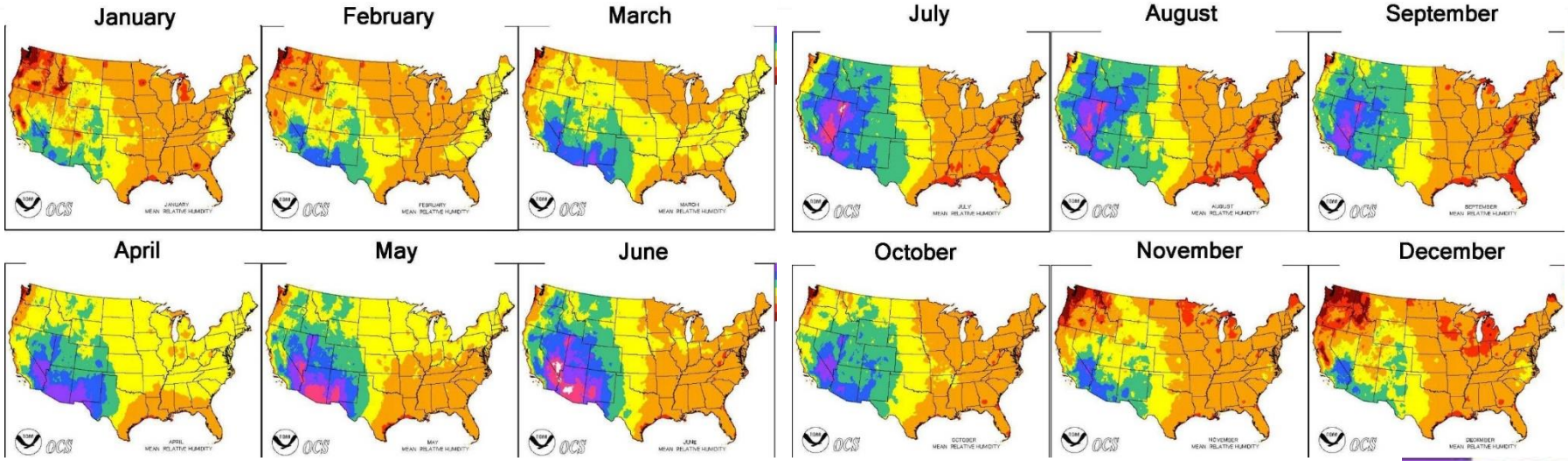
- Time of Wetness (TOW): # of hours per year that RH exceeds 80% and temperature is above freezing

ISO Category	Time of Wetness, Upper Bound Limit (hr / year)
1	10
2	250
3	2500
4	5500
5	>5500



- **Recommendations:**
  - **High TOW + Good Micro-environment → Use UWS**
  - **High TOW + Humid Micro-environment → UWS not recommended**

Coastal Macro-Environment: Metrics to Quantify It?
v2: Relative Humidity



Source: NOAA Climate Atlas of the United States

- **Recommendations: Thoughtful use of UWS when at least 8 months of year literally “in the red” AND high chlorides**

Coastal Macro-Environment: Metrics to Quantify It?

Chlorides

- **Background:**
  - The amount of chloride that is problematic is uncertain, and likely variable
  - More readily available data: =f(distance to coast)
  - Ongoing FHWA research…
  - FL study…

- **Recommendations:**
  - **2 miles from coast + not high humidity → Use UWS**
  - **2 miles from coast + high humidity + good micro-environment → Thoughtful use of UWS**
  - **2 miles from coast + high humidity + humid or high chloride micro-environment →**

MICRO-ENVIRONMENT

Micro-Environments Overview

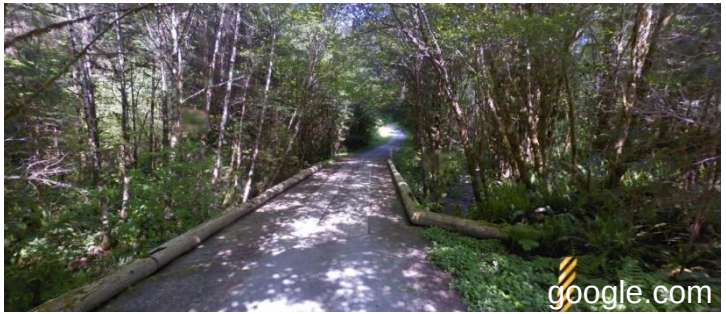
- Micro-environment should be assessed to screen for features that:
  - Increase **humidity**
  - Increase **chloride** exposure
- Such consideration can be made by assessing:
  - Crossing type
  - Site vegetation
  - Shelter from sunlight at site

Micro-Environment: Consideration of Crossing Types

Crossing Type	Concern	Conclusion
Grade Separations		
Over HEAVILY salted roadways	Chloride	Use UWS thoughtfully
Other	Benign	UWS is ideal choice
Rail Crossings	Benign	UWS is ideal choice
Water Crossings		
Most water crossings	Benign	UWS is ideal choice
w/ low clearance over water	Humidity, Flooding	Depending on macro-environment, use UWS or use thoughtfully
Over salt water	Chloride + Humidity	Do not use if wave action present

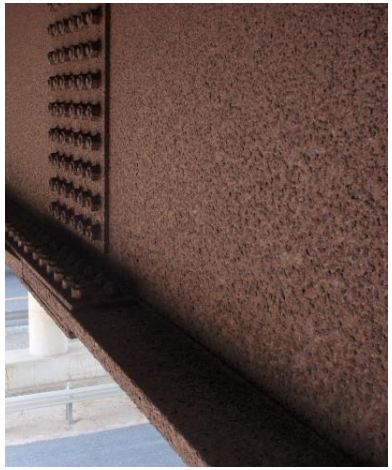
Micro-Environment: Other Considerations

Site Feature	Concern	Conclusion
Dense Vegetation	Humidity	TOW 1 – 4 + not low clearance :→Use UWS High TOW or low clearance → Do not use UWS
Rough definition: vegetation in, or nearly in, contact with UWS		
Excessive Shelter	Humidity	TOW 1 – 4 + not low clearance :→Use UWS High TOW or low clearance → Do not use UWS
Rough definition: in shadow for at least 6 hours per day		



Micro-Environment: More Specifics

- "Heavily salted roadways" = f(…
  - High ADT (and travel speeds) **AND**
  - Average annual snowfall >= 20 inches **AND**
  - Vertical clearance <= 20 feet **AND**
  - Possibly: bridge width, number of travel lanes)
- Tunnel-like environments – understanding is evolving
- Low clearance waterways – current guidance thought to be conservative



When to Use UWS

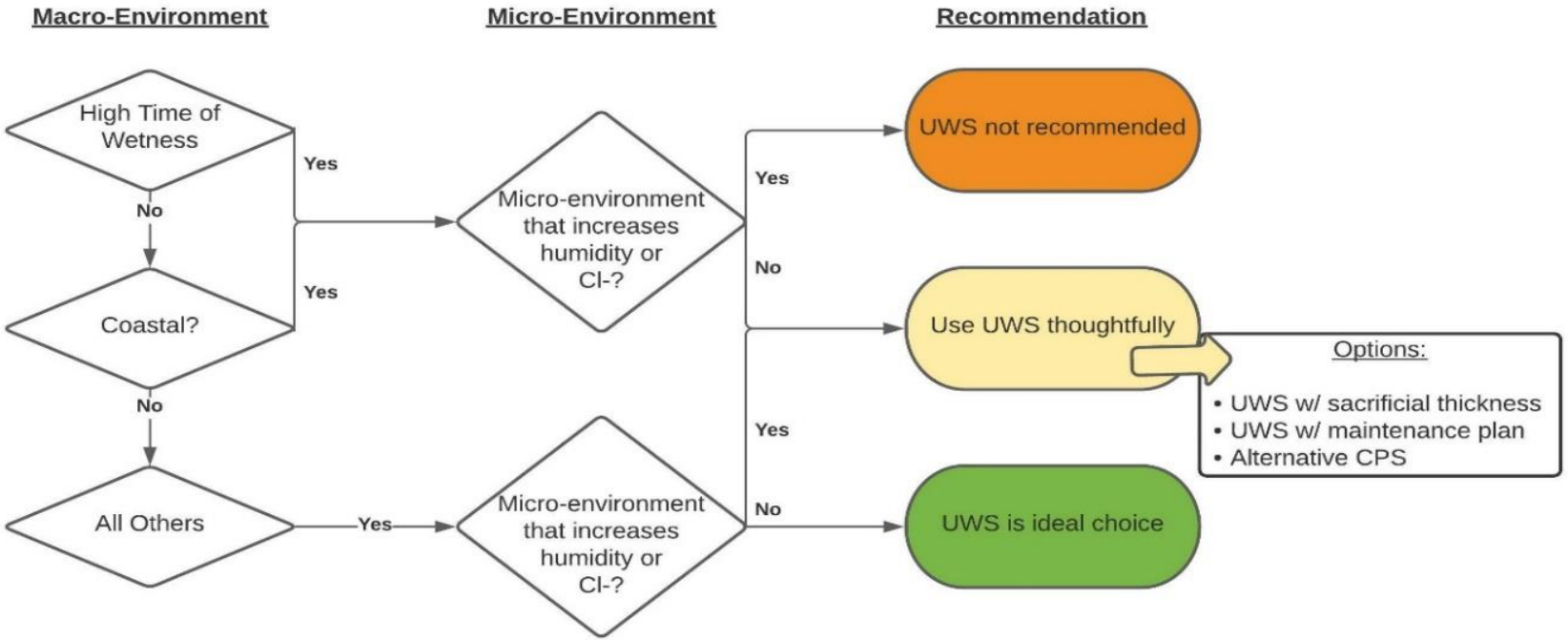


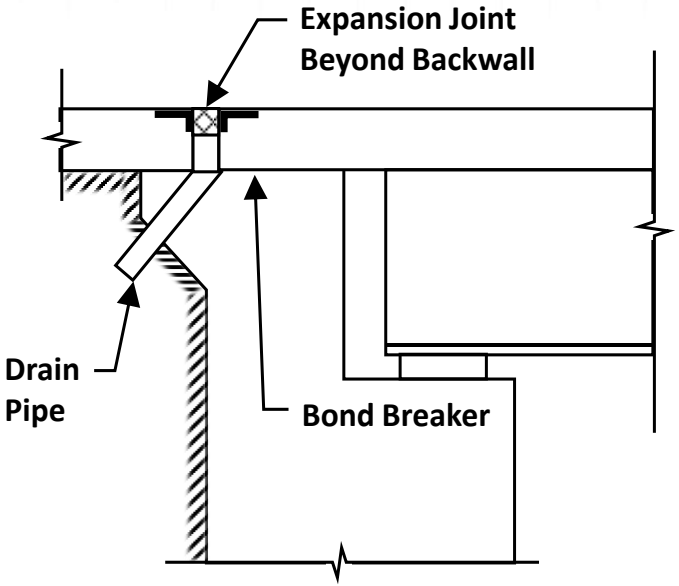
Table of UWS Use

Micro-Environment	Macro-Environment		
	All Others	High Time of Wetness	Coastal
All Others	UWS is ideal choice	Use UWS thoughtfully	Use UWS thoughtfully
Highway Crossings with Extreme Salt Use	Use UWS thoughtfully	Use UWS thoughtfully	Use UWS thoughtfully
Water Crossings with Low Vertical Clearance	If minimal vegetation, use UWS thoughtfully; if dense vegetation, UWS not recommended	UWS not recommended	UWS not recommended
Sites with Dense Vegetation or Shelter	UWS is ideal choice, if vegetation can be maintained and, for water crossings, adequate vertical clearance over water provided	UWS not recommended	Depending on severity, UWS not recommended or UWS with sacrificial thickness recommended

DESIGN RECOMMENDATIONS: PART 2 – STRUCTURAL DESIGN

Design Recommendations

- Eliminate joints wherever possible!
- Integral abutment jointless, semi-integral abutments, moving joints behind the back walls, link slabs, etc.
- Attention needs to be paid to the drainage system
- Experience is clear – water directly discharging on steel is bad!



Detailing to Avoid Corrosion

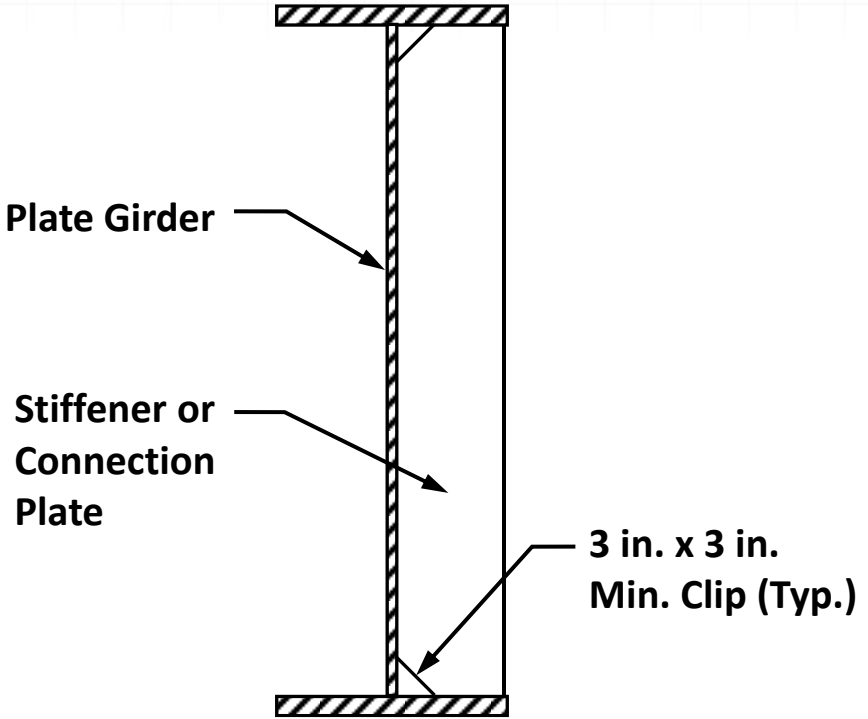
- UWS needs dry cycles to function properly
- Trapped debris retains moisture
- Continuous moisture prevents patina formation

Haunched Girders

- Haunches can trap debris and moisture
- Clips and drain holes needed

Stiffener Clips

- The larger the clip, the better for drainage control
- Many states use 2” clips
- 3” is better to avoid clogging with debris

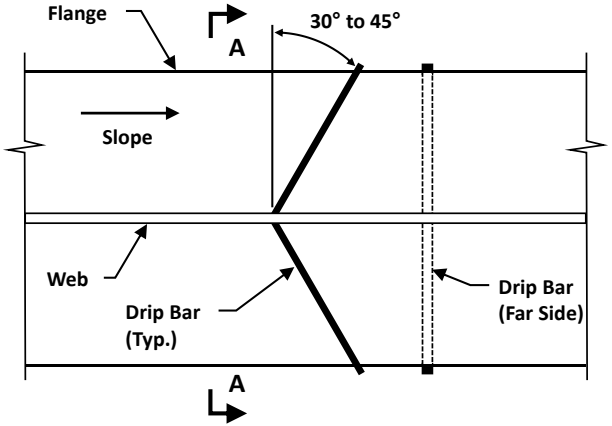


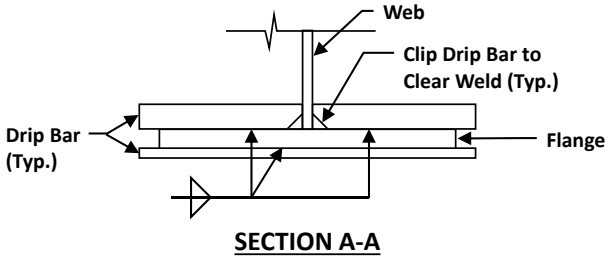
Tactical Painting

- Painting beam ends near joints is a common practice that has proven to be successful
- Painting over interior piers sometimes performed
- Beam ends encases in concrete should be painted – condensation and capillary action

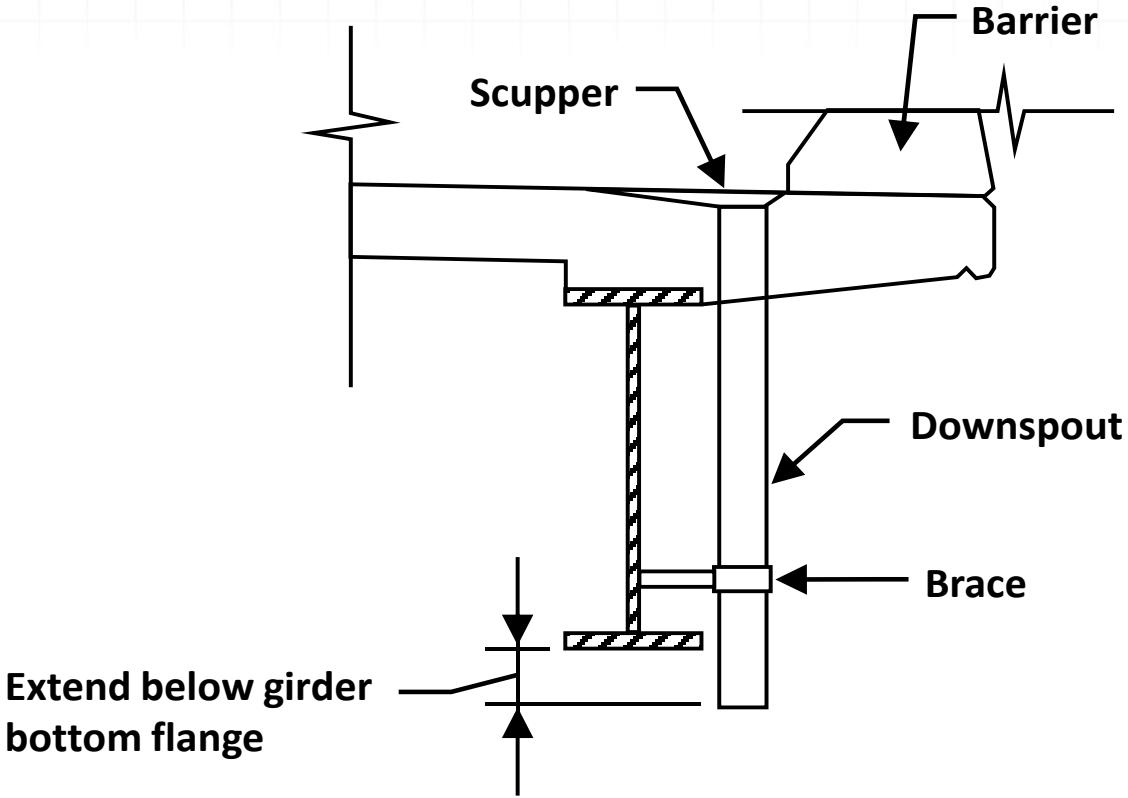
Drainage control

- Water flowing down flanges can collect and cause damage, staining
- Drip bars are one way of controlling this drainage
- Welded, or bonded with epoxy



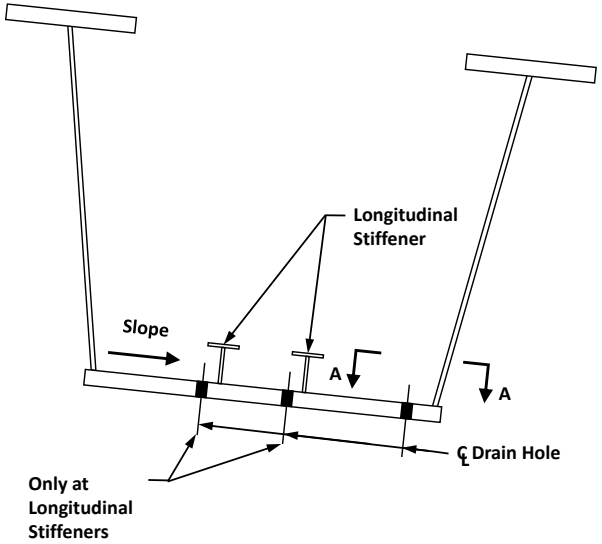


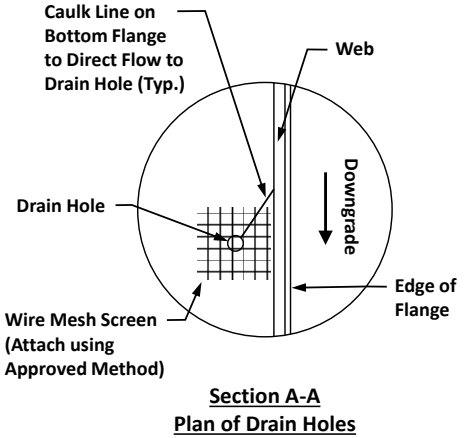
Drainage details



Box Girders

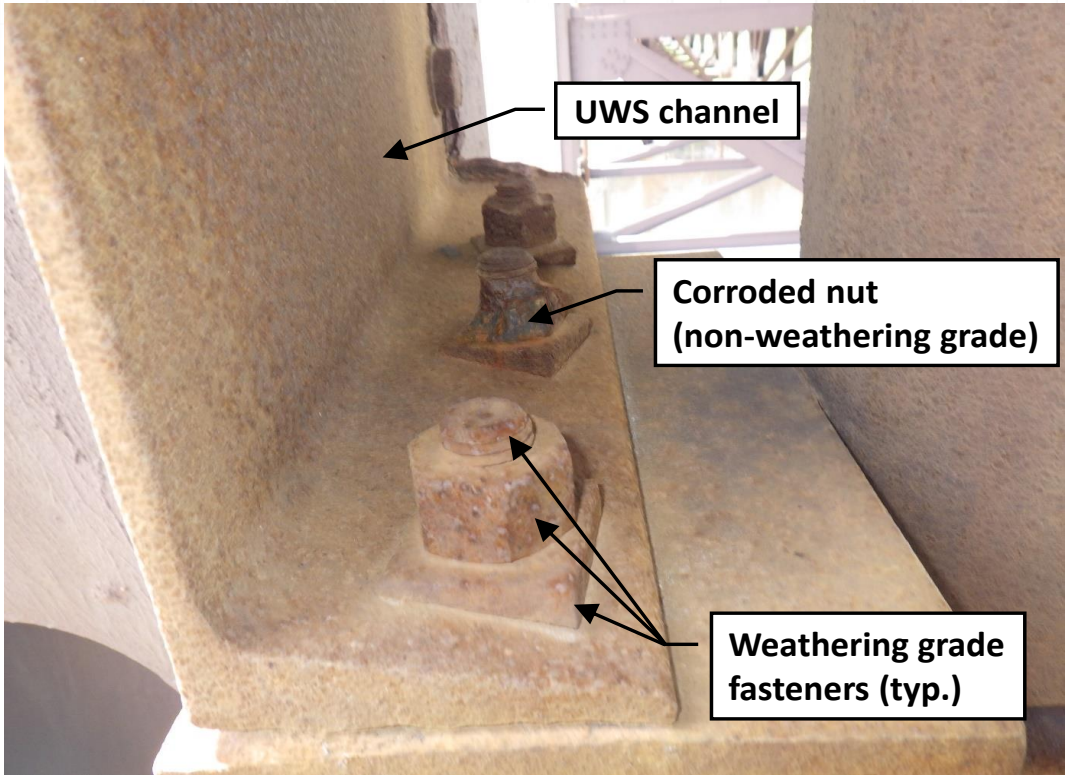
- Interior of closed shapes can be problematic
- Efforts to eliminate water ingress often not successful
- Need to provide drainage to allow water a way out
- Water can sit for long periods of time if not appropriately drained





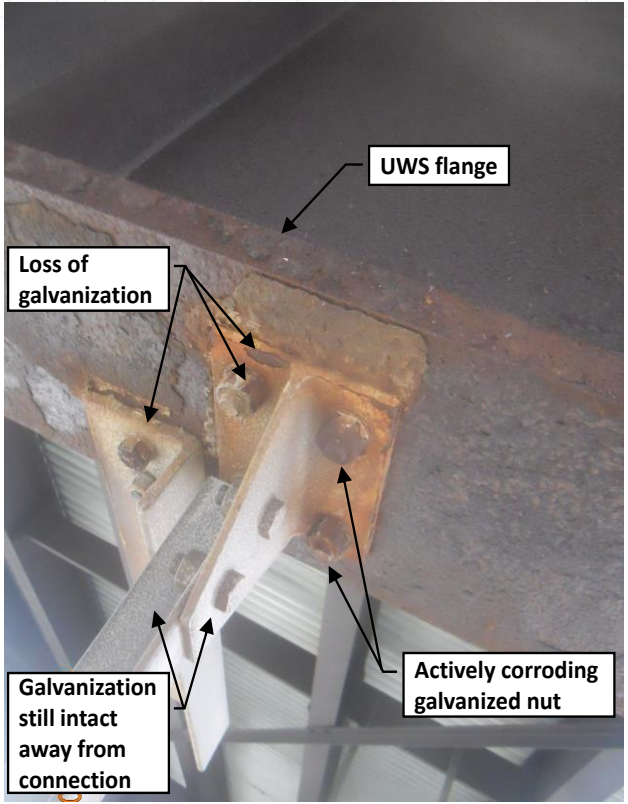
Dissimilar Metals - Fasteners

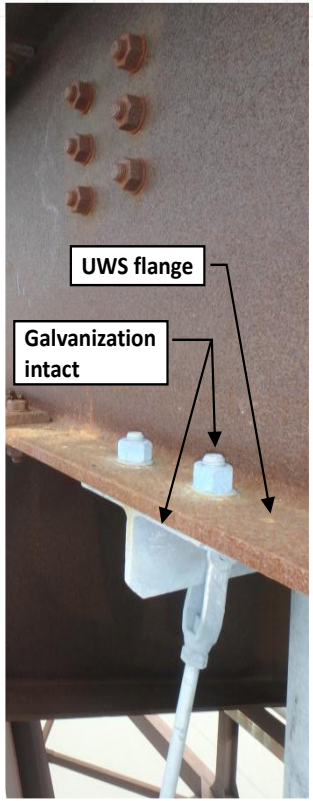
- Make sure the appropriate fasteners are specified and used
- Non-weathering grades of fasteners can quickly corrode
- Area ratios important



Galvanized Components

- Weathering action will drive corrosion in galvanized components
- Stops when patina fully forms
- Use depends on specific conditions
- Consider electrical isolation





Fabrication Considerations

- Weathering steel appearance can be a major advantage
- Patina formation takes time
- Uniform shop blasting ensures a consistent appearance during lifespan
- Leaving mill scale can lead to mottled appearance
- Markings left in place can stain surface
- Material handling considerations

Construction Considerations

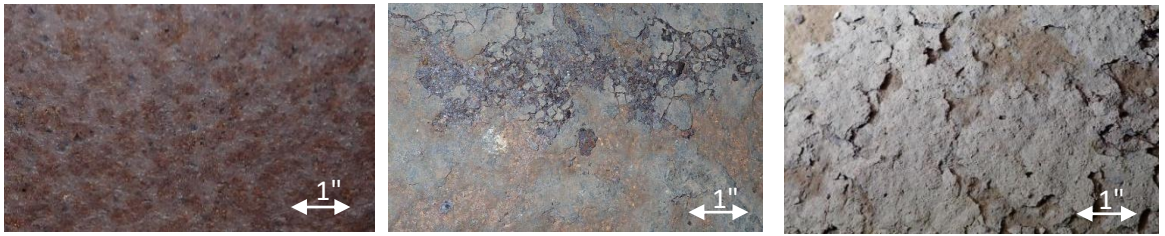
- Run-off from girders can stain concrete surfaces
- Greatest risk is during initial patina formation
- Solutions
  - Wrapping concrete substructures during construction
  - Drip pans
  - Concrete coatings
  - Zone painting near piers
- Do not neglect storage requirements

Inspection of Weathering Steel Bridges

- Guidance provided on evaluating the patina on existing bridges
- Information on the “Tape Test” is provided
- Examples of good performing patina and poor performance provided

Good performance

Poor performance



Maintenance Practices

- Joint sealing
- Drainage system clearing
- Girder washing

Maintenance Best Practices

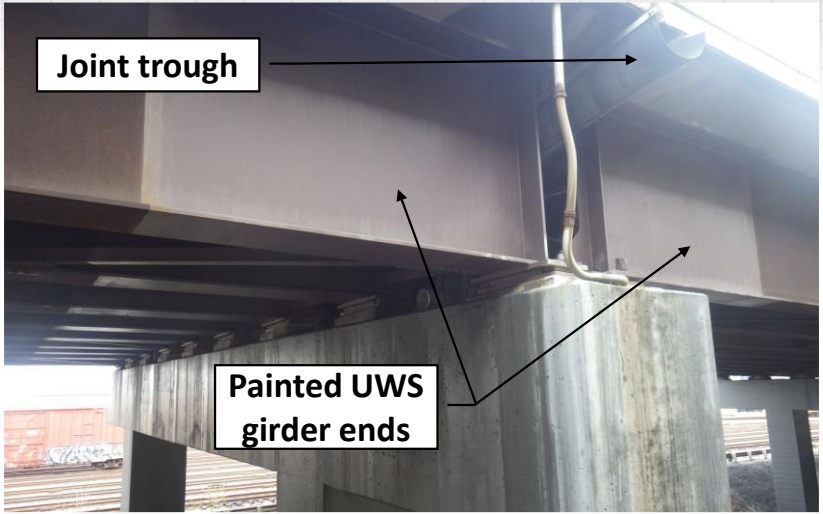
Region	Component/Element	Activity	Description	Interval (Years)
Deck	• Roadway and shoulders • Expansion joints and drainage troughs • Drainage grates, scuppers, and pipes • Sidewalks, medians, curbs • Rails and parapets	Sweep / Compressed Air Blow	Remove and dispose of dirt, salt, and other debris using dry methods.	1-2
		Wash / Flush	Remove residual material after sweeping/blowing by washing. Flush all deck drainage systems.	1-2
Super-structure	• Bearings • Bottom flanges of beams and girders above roadways • Ends of beams and girders under deck joints within a distance of 1 to 1.5 times the girder depth on each side of the joint • End diaphragms and cross frames • Truss members in the Splash Zone; truss members at or below the road level	Compressed Air Blow / Brush / Dry Clean	Remove and dispose of dirt, salt, and other debris using dry methods.	1-2
		Wash	Remove and dispose of dirt, salt, and other debris by washing.	2-4
Sub-structure	• Abutment seats, backwalls, and pier seats • Pier and abutment regions in the Splash Zone	Compressed Air Blow / Brush / Dry Clean	Remove and dispose of dirt, salt, and other debris using dry methods.	1-2
		Wash	Remove and dispose of dirt, salt, and other debris by washing.	2-4
All	• As applicable	Vegetation Removal	Cut, remove, and dispose of vegetation that is in, or nearly in, contact with structure	1-2

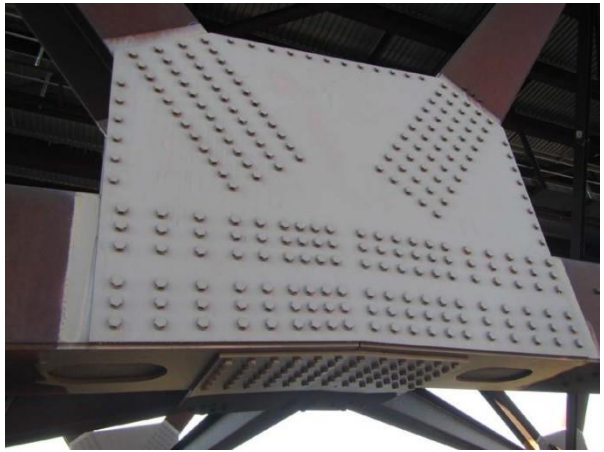
Drainage system health

- Drainage systems often a neglected bridge component
- Key system for obtaining desired service life
- Needs regular maintenance and repair

Repair and Rehabilitation

- If UWS not performing as expected, can be painted
- Need only paint those areas with poor performance





Repair

- Coating the entire structure also a viable option
- Primer coat quantities will be higher due to uneven surface
- Successful examples of coating weathering steel after years of exposure
- Even if coated in the field, still a success on initial and life cycle costs

QUESTIONS?