

Designing Positive Protection Systems for Work Zones

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Learning Objectives for This Module

- Define terms associated with positive protection and attributes.
- Provide alternatives to positive protection and assist designers in considering whether they are appropriate for site conditions.
- Describe barrier crashworthiness concepts and performance characteristics.
- Distinguish between various types of barrier systems.
- Discuss criteria for selecting appropriate work zone positive protection systems for site conditions.
- Discuss the decision making process on whether positive protection should be incorporated in the work zone design.

What is Work Zone Positive Protection?



Source: FHWA

Work Zone Hardware Barrier Systems that:

- Decelerates, stops or safely redirects errant vehicles from entering work area.
- Reduces risk of serious injury or death to occupants of errant vehicles.
- Successfully passed crash test standards for site conditions where barrier system is installed.

Positive Protection vs Drums, Cones, & Barricades

Positive Protection

- Physical containment or redirection of errant vehicles
- Relatively expensive
- Repositioning usually requires lifting equipment
- Requires considerable width for device and room for deflection.

Drums, Barricades, & Cones

- Visually guide road users
- Relatively inexpensive
- Quick to reposition as work progresses
- Requires only width of device



Barrier vs Channelizer Devices

Barrier

- Crash-tested to provide positive protection
- Requires end treatments
- Often heavy and difficult to move



Source: [SafeRoads](#)

Channelizer

- Crashworthy
- Used mainly on urban streets to:
 - Delineate travelled way
 - Designate road space allocated to non-motorized traffic
 - Discourage bystanders from entering work areas
- Light weight and portable



Source: [Wikimedia Commons/Jean Housen](#)

Positive Protection Work Zone Benefits



Source: Wisconsin DOT

- Can prevent traffic from reaching steep drop-offs or fixed objects close to the travelled way.
- Separates workers, pedestrians, or bicyclists from motorized vehicles.
- Separates traffic streams moving in opposite directions or different speeds.
- Can help shield partially completed work from traffic.

Negative Aspects of Positive Protection

- Barrier itself is a fixed object obstacle.
- Often significant deployment cost.
- Installation and removal time expose installers to traffic hazards.
- Some systems are difficult to reposition.
- Requires space that may narrow travel lanes which can reduce traffic capacity.
- Requires breaks in barrier runs to provide access to cross-roads and driveways.



Source: [BenAveling](#)/ Wikimedia Commons



Source: [Des Moines Register](#)

Typical Concrete Barrier Installation Process

The logo for J-J Hooks Highway Safety Barrier. It features the text "J-J Hooks" in a large, bold, white sans-serif font. The "J"s are stylized and connected. A horizontal white bar is positioned below the "Hooks" portion of the text. Below this bar, the words "Highway Safety Barrier" are written in a smaller, white sans-serif font. The entire logo is set against a black background.

J-J Hooks[®]
Highway Safety Barrier

Barrier Installation

Haymarket, Virginia - Precaster: Smith-Midland Corporation

Video from J-J Hooks, Co.

Methods to Eliminate Need for Barrier Systems (Exposure Control Measures)

- Detour all traffic to another route.
- Use ramp closures or other system configuration changes to redirect a significant portion of the traffic to other routes.
- Complete the work at a time with lower traffic volumes.
- Use speed reduction techniques such as pilot cars, pace vehicles, point-to-point automated speed enforcement, or intensive police presence.
- Use temporary backfill or wedging material to eliminate abrupt vertical drop-offs.
- Remove roadside obstacles to increase the available clear zone.
- Revise construction method or work sequence to eliminate the need for positive protection.
- Combinations of the above.

Crashworthiness

Crashworthiness : NCHRP 350 & MASH

- 1993: NCHRP Report #350 standardizes crashworthiness testing procedures and acceptance criteria.
- 2009 & 2016: AASHTO Manual for Assessing Safety Hardware (MASH) updates protocols and criteria.
 - Reflects changes in vehicle fleet, *e.g.* increased prevalence of SUVs
 - Updated criteria generally more stringent than NCHRP 350
- 2016: AASHTO/FHWA issue Joint Implementation Agreement for Implementing MASH (and phase out NCHRP 350 devices.)
- 2020: All newly manufactured temporary work zone devices, including portable barriers, must have been successfully tested to 2016 edition of MASH.
- 2020: Existing NCHRP 350 temporary work zone devices, including portable barriers can be used until they wear out.

MASH Test Levels

MASH Test Level	Test Vehicle(s)	Test Speed
TL-1	Automobile (2420 pounds) Pick-up Truck (5000 pounds)	31 mph
TL-2	Automobile (2420 pounds) Pick-up Truck (5000 pounds)	43 mph
TL-3	Automobile (2420 pounds) Pick-up Truck (5000 pounds)	62 mph
TL-4	Single unit truck (22,000 pounds)	56 mph
TL-5	Semi-tractor with van trailer (36,000 pounds)	50 mph
TL-6	Semi-tractor with tanker trailer (36,000 pounds)	50 mph

What's a Good Test Result?

Ideally:

- Redirect vehicle away from hazard within a narrow angle.
- Vehicle follows barrier and decelerates within a fairly short distance.
- Deceleration rates well within human tolerance and comfort levels.
- No hindrance to driver's recovery process.
- No impediments to interventions by first responders.

Barrier Deflection and Working Width

- Barriers deflect laterally when struck.
- Amount of deflection varies depending on barrier type, shape, and mass.
- *Working Width: The distance between the traffic face of the barrier before impact and the farthest lateral position of any major part of the barrier after impact with a test vehicle.*
- Must be kept clear of construction materials, equipment, etc. (except items actively being used).
- Can be reduced by anchoring barrier to road/bridge surface, but this can increase consequences of barrier strikes.

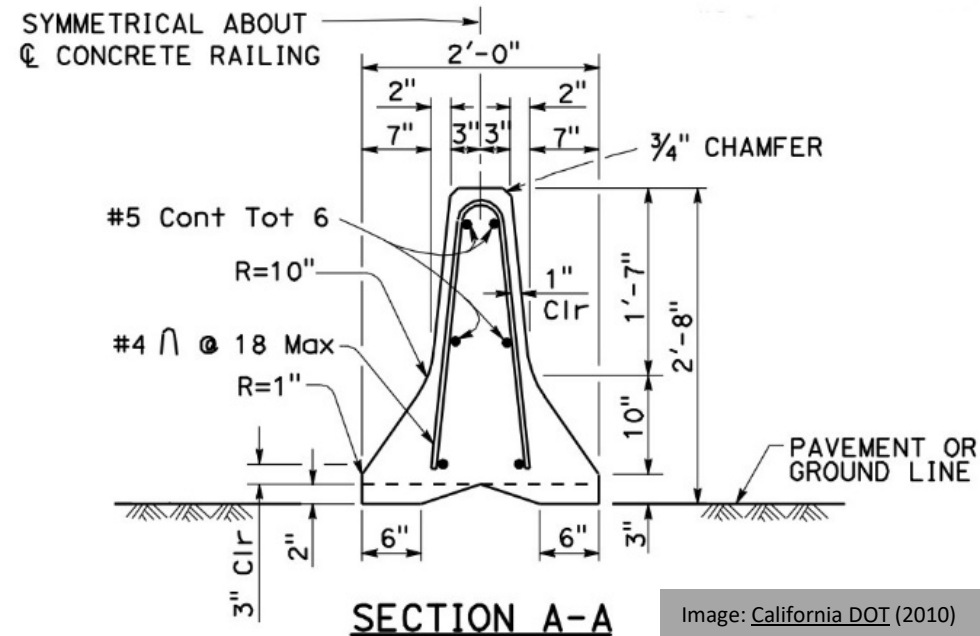
Anchored Barrier Performance



<https://vimeo.com/116895165> start at 0:30

Barrier Types

Temporary Portable Concrete Barrier (TPCB)



- TPCB are the most widely used positive protection system.
- Numerous public domain & proprietary NCHRP 350 approved designs.
- Most systems have been updated to obtain MASH approval.
- Most designs crash tested and approved at TL-3, a few at TL-4
- Typical TPCB are 390 to 720 pounds per lineal foot depending on height, geometry, etc.
- Heavier systems are more resistant to movement when struck by trucks, but are more expensive to ship and install.

TPCB Successful Proprietary Design NCHRP 350 Test



video courtesy of J-J Hooks Co.

TPCB J-J Hooks Successful F-Shape MASH TL-3



Photo courtesy of J-J Hooks Co.

Portable Steel Barrier Systems



Source: Hill & Smith



Source: Barrier Systems, Inc.

- Most systems are proprietary.
- Non-proprietary system for temporary bridge rail.
- Some systems tested at TL-3, others at TL-4.
- Manufacturers claim a crew can install 1000 to 1500 lineal feet per hour.

Portable Steel Barrier Systems



Source: Barrier Systems Inc.



Source: Hshighway.com

- Lighter than concrete, so more barrier can be hauled per truck load.
- Sections typically are 26 to 50 feet long, weighing 3000 to 3300 lb (60 to 115 lb/ft.)
- May be available for rental in some markets.

Portable Steel Barrier System Crash Tests



Video courtesy of Hill & Smith Inc

Water-Filled Barrier Systems



Source: TrafFix Devices



Source: WikiMedia Commons.

- Plastic shells moved empty and filled with water at the site.
- When empty, they are light enough to be picked up by 1 or 2 people without lifting equipment.
- Proprietary systems available with TL-1, TL-2, and TL-3 acceptances.
- TL-3 systems have internal/external steel reinforcement.
- Some systems can serve as their own end treatments.
- Usually drained onto pavement for repositioning/removal.
- Can also be filled with sand for long-term deployment.

Low-Profile Barriers



Source: Klam & Ivey, Texas DOT system



Source: Florida DOT

- Less than 24" tall
- Improves visibility of traffic approaching from side streets and driveways compared to other barrier types.
- Crash tested to TL-2.
- Low deflection.
- Relatively easy and inexpensive to install.

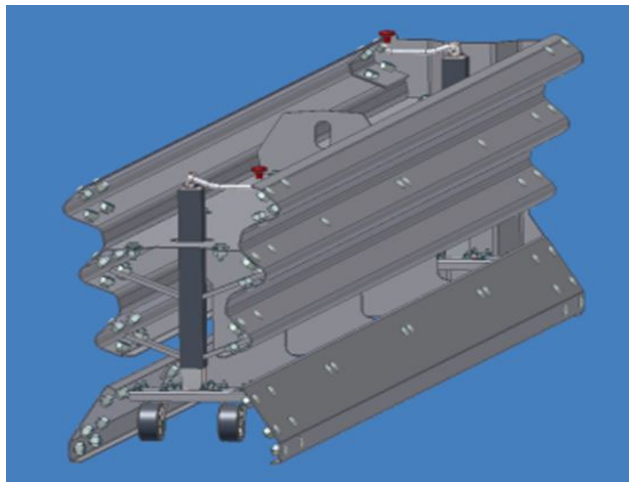
Moveable Barrier



Source: [Anonymous/WikiMedia Commons](#)



Source: [Eekim/WikiMedia Commons](#)



Source: [Trinity Highway Products, LLC](#)



Source: [Barrier Systems, Inc.](#)

- Specialty systems for rapid barrier repositioning.
- All systems are proprietary.
- Concrete system mainly used on roads with heavy directional commuter flows.
- More expensive than standard concrete barriers.

Mobile Barrier System



Source : Mobile Barriers, LLC

- Worker protection device to shield workforce from live traffic.
- Used primarily on short duration maintenance projects.

Group Discussion

All other things being equal, which barrier types would be most suitable for each of the following applications:

- Long-term reconstruction of a rural freeway with high volumes of heavy truck traffic?
- A 45-mph suburban arterial with many commercial driveways?
- An urban freeway bridge deck replacement that must be completed in one weekend?
- A bridge deck replacement on a long-span urban freeway bridge with heavy flows into downtown in the morning, and heavy flows away from downtown in the afternoon?
- Emergency repairs on a remote two-lane rural highway with no availability of skilled workers or heavy lifting equipment?

End Treatments and Transitions

Why specify crashworthy end treatments?



Source: DeChant Consulting Services

Chevrolet Lumina vs Blunt End of Concrete Barrier

Impact Attenuators



Source: Wikimedia Commons



Source: Energy Absorption Systems, Inc.



Source: WikiMedia Commons



Source: Wikimedia Commons/JPG

- Attenuator length varies based on operating speed
- Attenuator angle should match most likely direction of approaching (errant) vehicles

Sand Barrel Crash Test



QuadGuard[®]

- Proprietary “Family” of devices
- QuadGuard[®] CZ mounted on 3/8” steel plate
- Requires bolts w/ adhesive to anchor system to concrete or asphalt pad
- CZ model crash tested currently to MASH
- FHWA Eligibility Letter CC-112B



QuadGuard[®] M10 Shown

Flared End Treatments



Source: Wisconsin DOT

Flared system terminated beyond clear zone with adequate taper length.

Transitions



Source: [Poudou99/WikiMedia Commons](#)

Non Crash Tested transition from steel to concrete barrier.

Specify Crashworthy Transitions



Source: University of Nebraska - Lincoln

Crashworthy transition from temporary PTCB to permanent barrier.

Upstream & Downstream Transitions

← 100 ft min →



Attenuator required.

← 100 ft min →



Attenuator not required.

TPCB – 5000# TL-3 Test with insufficient # of barrier sections needed for crashworthy anchorage



Video courtesy of University of Nebraska-Midwest Roadside Safety Facility

Barrier Accessories

Barrier Gates



Source: Lindsay Corporation

- Provides emergency or worker access to opposite side of lengthy barrier runs.
- Proprietary system compatible with some barrier types.
- Can simplify stage/phase transitions in some cases.

Glare & Visibility Screens



Source: [Beilharz Road Equipment Systems](#)



Source: [Coral Sales](#)



Source: [New Zealand Transport Agency](#)

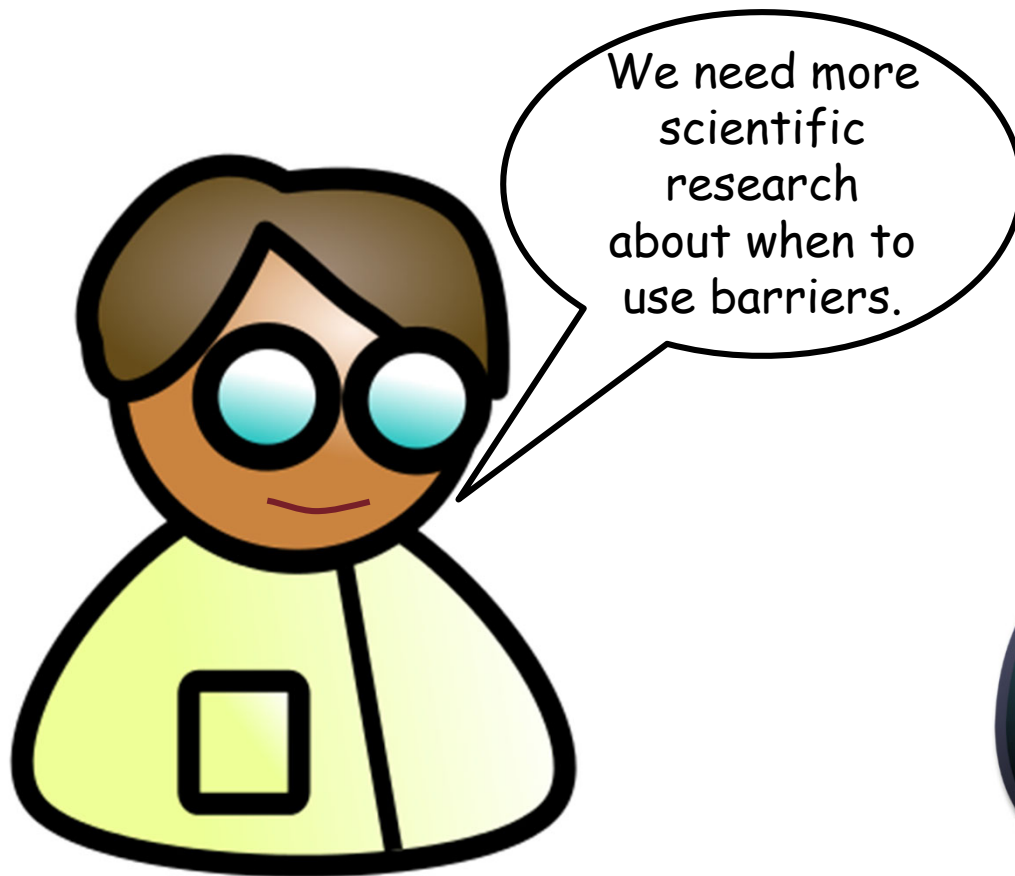
- If correctly positioned, can reduce glare from headlights and construction vehicles.
- Visibility screens block view of construction to reduce driver distraction.
- Currently no crash test protocol has been established.
- Recommend not specifying questionable designs using plywood and water pipe.
- Recommend specifying light, deformable materials, *e.g.* fabric on thin-wall tubing.
- If traffic on one side: recommend specifying attachment on back side.
- If traffic on both sides: recommend specifying breakaway fasteners on top of barrier.
- *Recommend specifying sight distance field verification required if used near ramp terminals or intersections.*

Consider Drainage Around Barrier Systems

- Drainage is accomplished by having adequate slots (scuppers) built into barriers and at connection points.
- Stormwater flow is most often present near bottom of sag sections.
- If construction site is in an area prone to heavy rainfall, provide additional barrier set back from travel lanes for use as temporary rain storage area until water can be dissipated through barrier scuppers.
- If temporary ponding is still anticipated, specify appropriate MUTCD signage, *e.g.*:
 - SLIPPERY WHEN WET
 - ROAD MAY FLOOD
 - WET PVMT (on PCMS)

Barrier Design Process

When to Specify Barrier?



Recommended Design Approach

- Currently only limited scientific research has been completed on the risks of using (or not using) positive protection.
- It is not yet possible to establish numerical warrants that cover all situations.
- Many barrier deployment decisions require a degree of engineering judgment.
- The rationale for agency barrier use policies are often undocumented.



- Mandatory use of barriers in high-risk situations.
- Guided discretionary use of barriers based on site conditions.
- Independent review/appeal if designers/managers disagree about use (or non-use) of barriers for a specific site.

Recommended Design Process

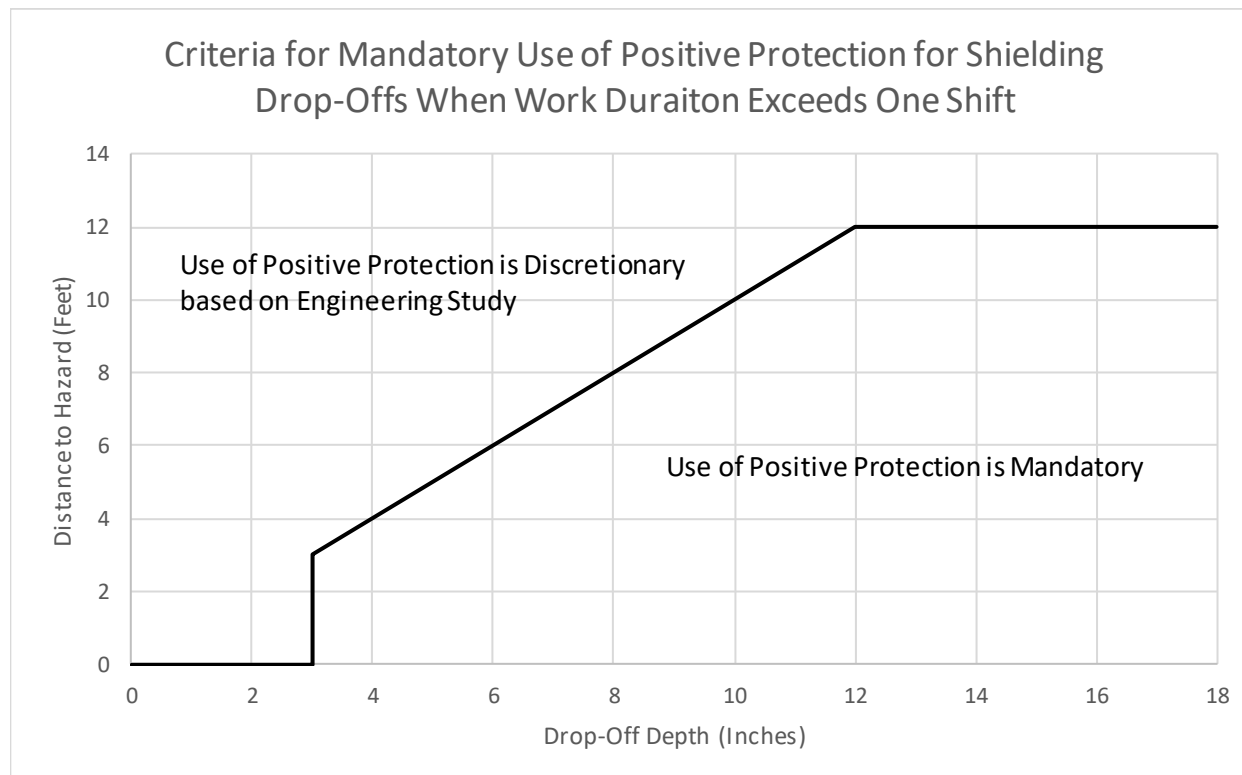
- Gather site data (geometrics, traffic volume, etc.)
- Identify high-risk situations that point toward the mandatory use of barriers.
- Determine work area clear zone widths and evaluate vertical edge drops.
- Evaluate need to shield workers.
- Evaluate combined worker and edge drop shielding.
- Identify potential exposure control measures that could potentially eliminate need for positive protection. Note: this step can be considered in conjunction as part of earlier steps.
- Select and specify the most appropriate positive protection system, if positive protection is best available option.

Mandatory Use of Barrier – High Risk Sites

Examples – Each agency establishes their own policy.

- Bridges without parapets.
- High-speed roadways with contraflow operation, significant traffic volume, and multi-day work duration.
- High-speed roadways with significant edge drops.

Example



Mandatory Use of Barrier – High Risk Sites

Examples – Each agency establishes their own policy.

- High-speed roadways* with fixed objects at less than 50% of minimum clear zone width*.
- Sites with scaffolding or lifting equipment near* the travelled way.
- Sites with workers very close to high-speed roadways*, and no escape path*, such as in tunnels and on bridges.
- Waiver process suggested for sites where problem can be mitigated by exposure control methods without using barrier.

**Conditions are established by agency and may differ for each project.*

Engineering Study – Moderate Risk Sites

Step 1: Gather site data (geometrics, traffic volume, etc.)

Step 2: Determine clear zone width (distance to fixed objects)

Example: Vermont DOT*		
Roadway Type	Work Zone Speed Limit (mph)	Distance from Travelled Way (ft)
State/US Routes	All	10
Interstates	30-40	13
	45-50	16
	55	23
	60-70	30

* Vermont follows the criteria in Table 9-1 of the AASHTO Roadside Design Guide.

Engineering Study – Moderate Risk Sites

Step 3: Check distances to drop-offs



Source: Wisconsin DOT

Examples

Agency	Criteria
California DOT	Drop-off depth > 6 inches, located within 8 feet of travel way; special engineering consideration for all drop-offs > 2.5 feet.
Iowa DOT	Drop-off depth > 10 inches, located with 10 feet of travel way.
Maryland DOT	Drop-off depth > 2.5 inches, located adjacent to travel way
Minnesota DOT	Optional for drop-off depth > 4 inches, if no wedge, located adjacent to travel way, speed > 30 mph, project duration > 3 days, length < 50 feet; if 12 inches, recommended.
North Dakota DOT	Drop-off depth > 5 inches located between travel lanes, drop-off depth > 12 inches, located adjacent to travel way speed; when speed limit > 30 mph, project duration > 7 days, work area length > 50 feet
Ohio DOT	Drop-off depth > 5 inches located between travel lanes, drop-off depth > 2 feet located within 30 feet of travel way, overnight exposure
Virginia DOT	Drop-off depth > 12 inches located 4 to 5 feet from travel way
Wisconsin DOT	On freeways/expressways when drop-off expected > 3 days and length > 100 feet drop-off > 6 inches located 2 feet or less from travel way; drop-off > 12 inches located < 4 feet or less from travel way; drop-off > 24 inches located < 12 feet or less from travel way; or drop-off > 37 inches located < 20 feet or less from travel way.

Engineering Study – Moderate Risk Sites

Step 4: Evaluate need for barriers to protect workers*

Federal rule requires determination based on an engineering study.

Typical variables used in the engineering study:

- Project duration
- Distance from travelled way to workforce
- Traffic volume and speed
- Type of positive protection proposed and estimated cost.

Consideration of exposure control measures if decision is leading toward need for positive protection.

**Required step on Federally-aided projects per 23 CFR 630 Subpart K, which was established in 2007.*

Engineering Study – Moderate Risk Sites

Alternative Step 4: Experimental methodology for evaluating barriers to shield workers*

- Benefit/Cost method based on the value of statistical life (currently \$9.2 to \$9.8 million per fatality).
- Uses Roadside Safety Analysis Program (RSAP) version 3 software package.
- Variables in program besides cost of fatality include:
 - Barrier cost, project duration, active work area length, directional daily traffic volume, roadway daily traffic volume, lateral buffer space, and work zone traffic speed.

**Derived from research done by TTI for Idaho DOT – RP228, Dec. 2014*

Engineering Study – Moderate Risk Sites

Step 6: Identify situations justifying the use of barriers based on engineering judgment

Examples:

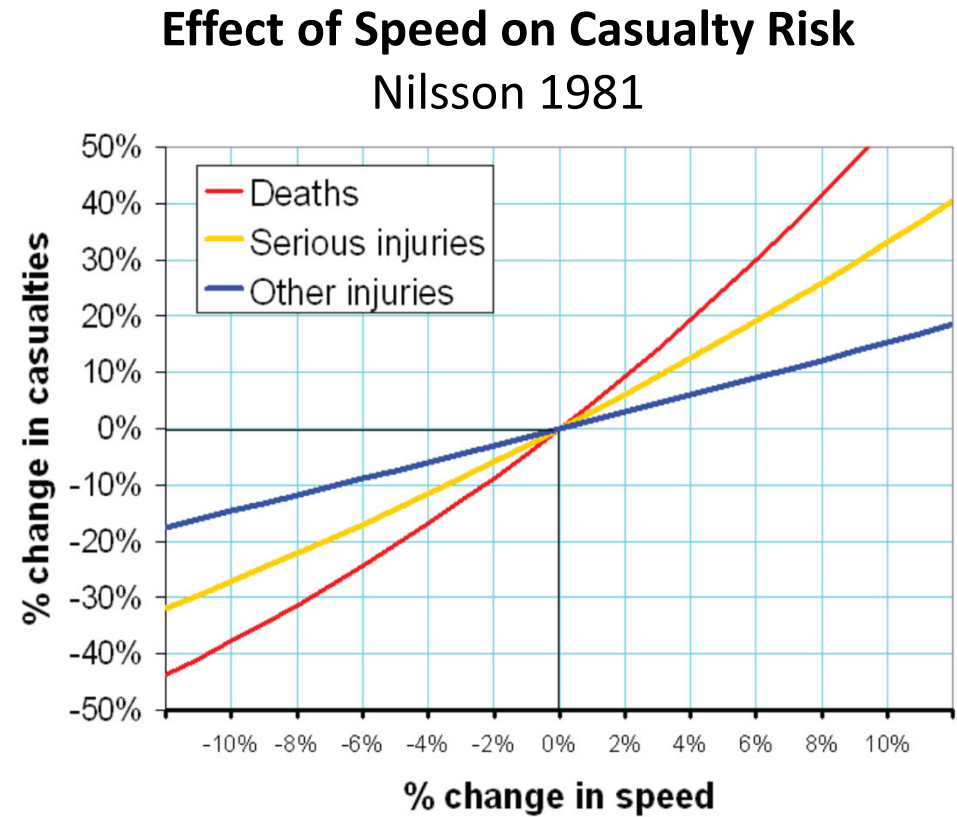
- Two-way traffic running on one side of what is ordinarily a divided freeway
- Substantial speed differential between adjacent lanes
- Non-motorized users in close proximity to high-speed traffic.
- Sites with severe non-conformance to geometric standards
- Sites with no worker escape path for (e.g. tunnels, long bridges, “urban canyons”) and moderate to long work duration
- Sites with very high traffic speeds (e.g., 80 mph Texas freeways)

Engineering Study – Moderate Risk Sites

Step 7: Identify viable/potential exposure control measures

Examples:

- Full closure
- Speed reduction
- Increased lateral buffer space
- Hazard severity reduction
- Traffic volume reduction
- Hazard length reduction
- Hazard duration reduction
- Workforce size reduction



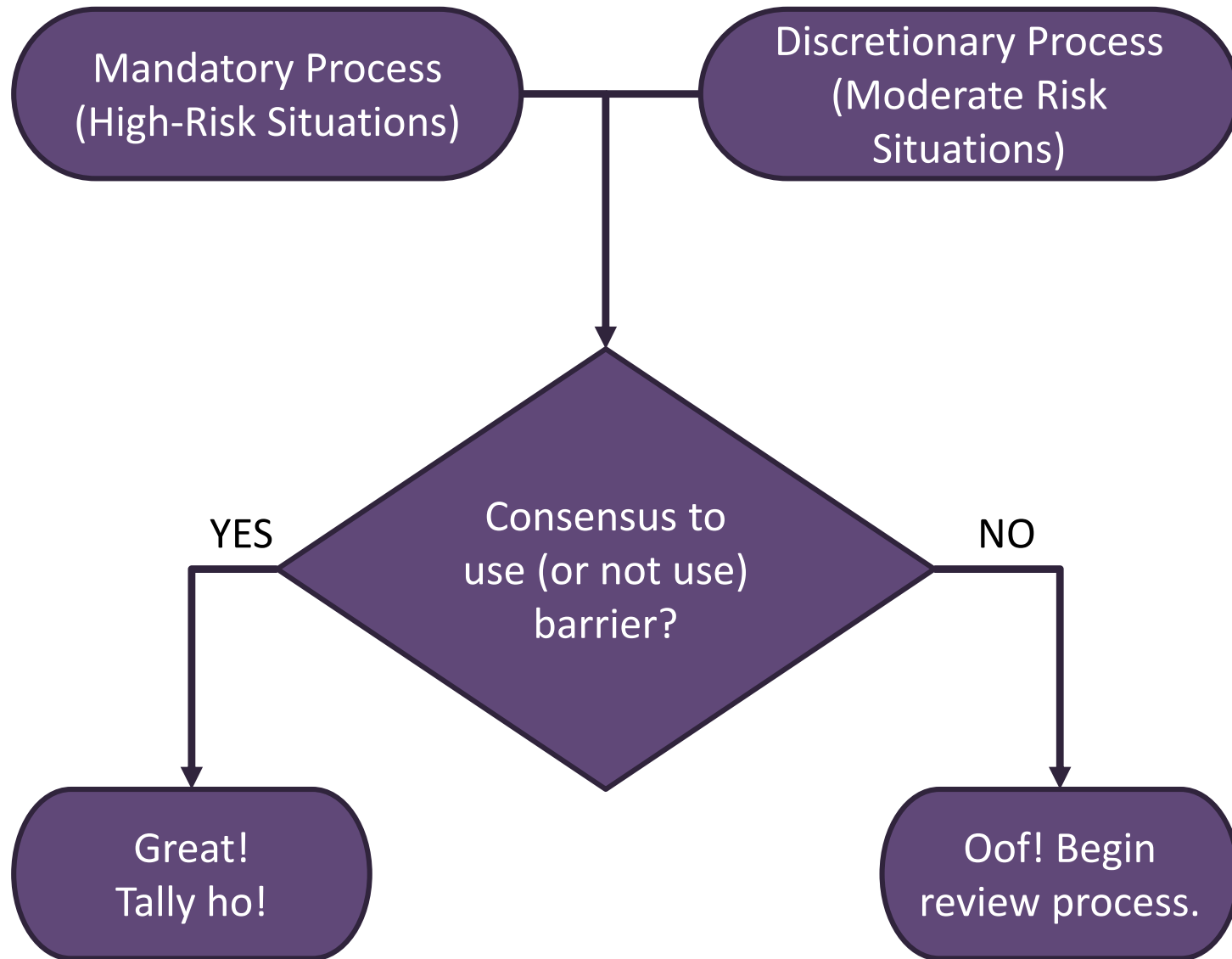
Engineering Study – Moderate Risk Sites

Step 8: Document Decisions



Appeal Process





Appeal Process

- Could be patterned on other successful agency review processes, such as design exceptions.
- Could include provisions for independent evaluation by a neutral party with positive protection expertise.

Discussion

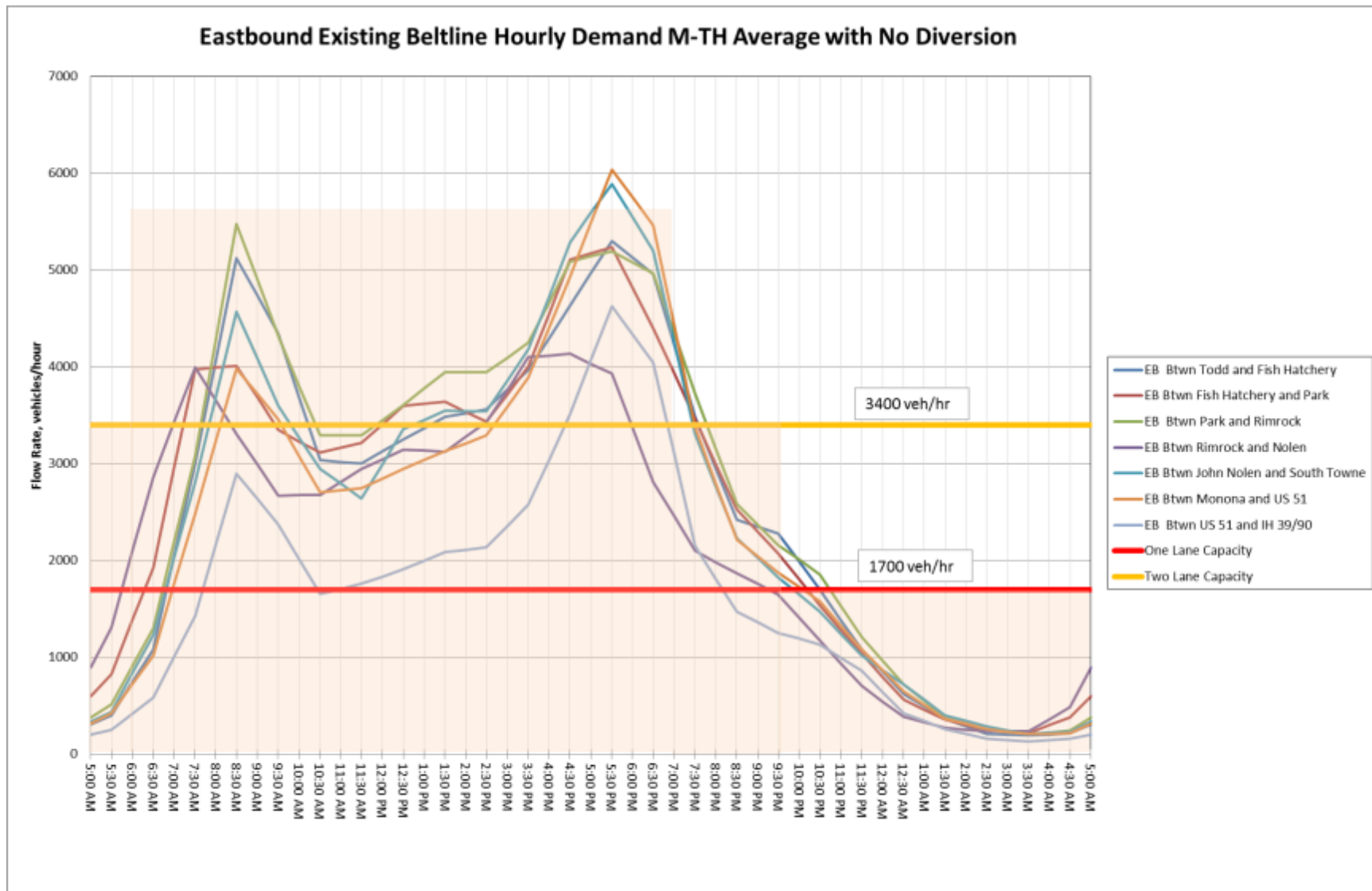
- What are the implications of under-specifying positive protection systems?
- What are the implications of over-specifying positive protection systems?
- Have you observed situations where an alternative to barrier would have been safer and more cost-effective?
- Have there been situations where you felt your organization should have used (or not used) barriers? What did you do?

Small Group Workshop Exercises

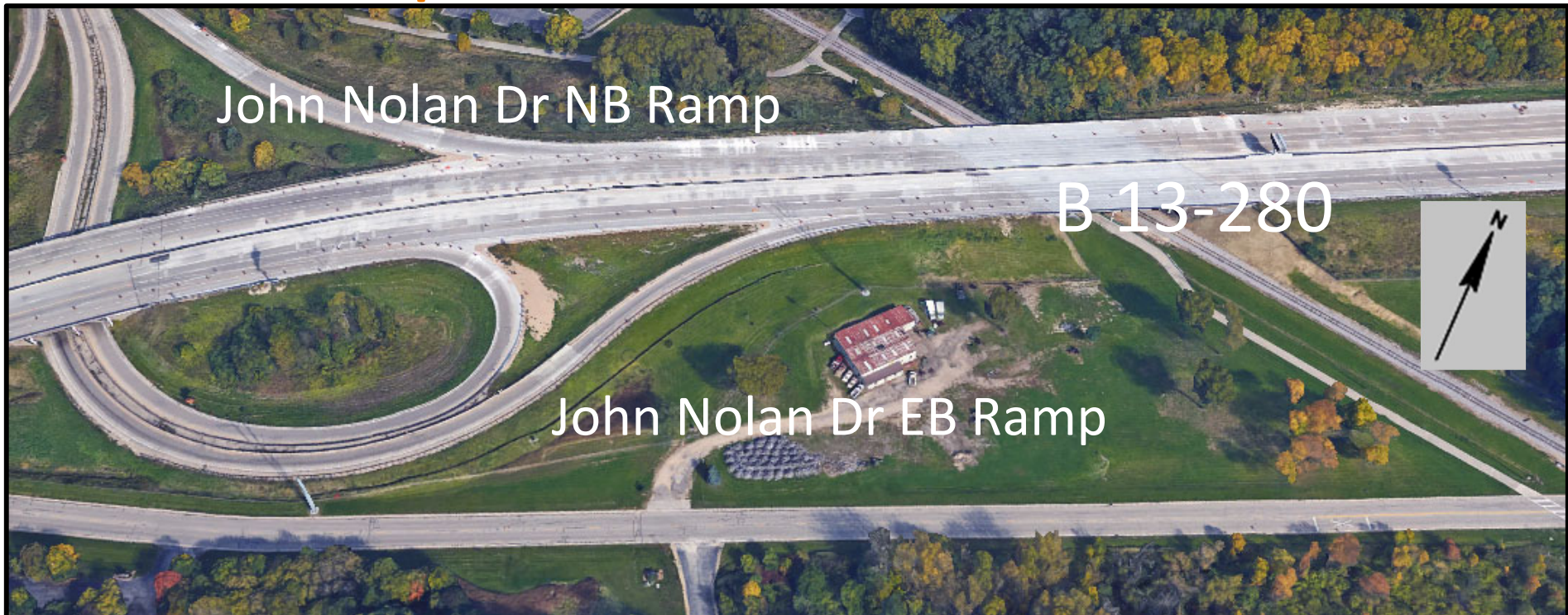
Madison, WI South Belt Line

- 8.2 mile preventive maintenance project
- 6 lane urban freeway with some auxiliary lanes
- Speed Limit is 55 mph
- 123,000 – average daily traffic (ADT)
- State policy prohibits any edge drop-offs greater than 3 inches within 4 feet of driving lane without shielding by TPCB
- State policy allows a maximum 15-minute delay increase caused by work zone
- Maximum hourly volumes – 6000 westbound vehicles per hour and 6000 eastbound vehicles per hour.

Madison South Belt Line Weekday Hourly Volume Data



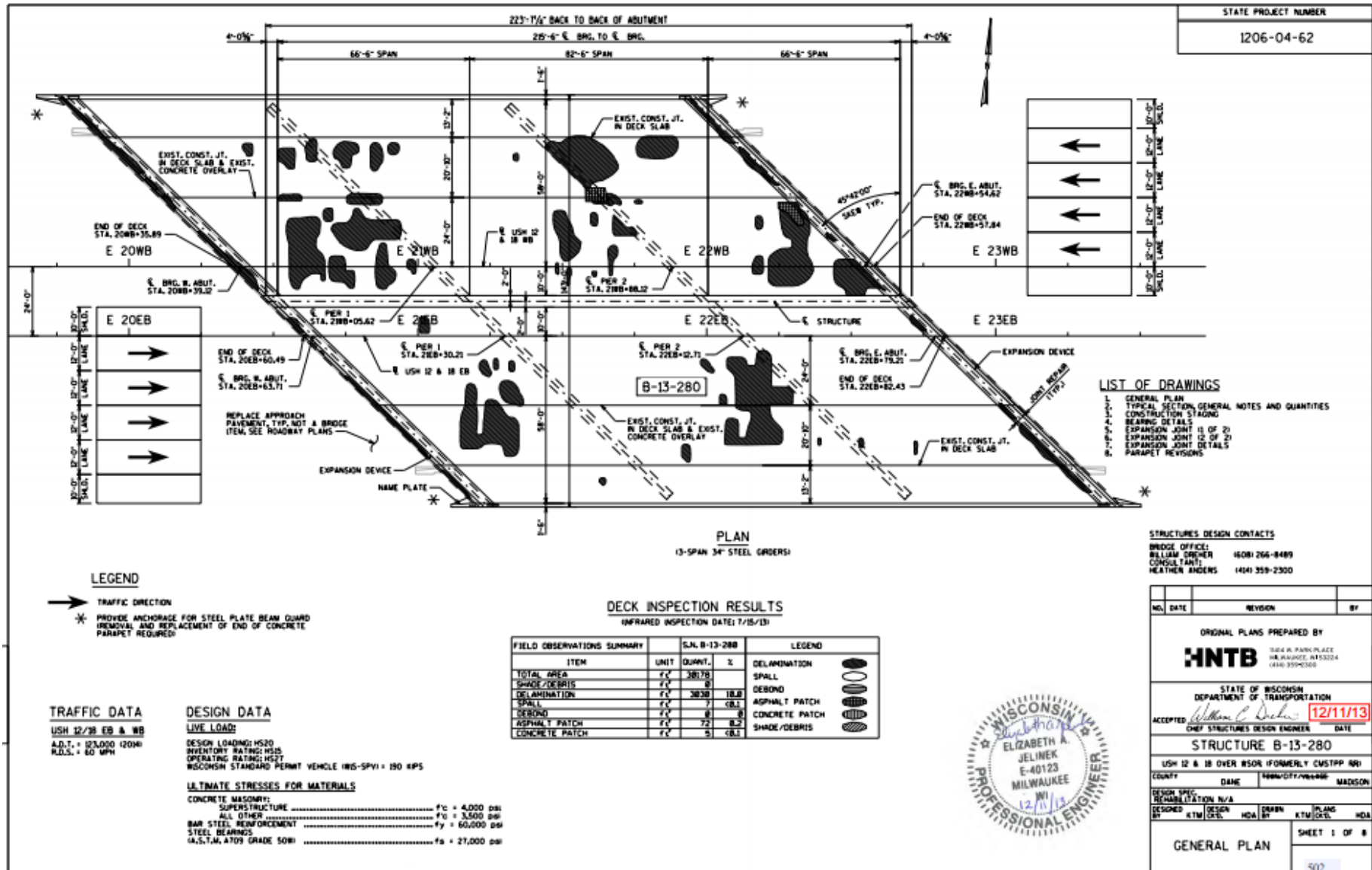
Workshop Exercise 1: Structure B 13-280



Source: Google Maps

- B 13-280 is 140 feet wide with a 4 foot wide concrete median barrier that separates 4 - 12 foot lanes and 2 - 10 foot wide shoulders in each direction.
- Bridge work will include removing old 1.5" concrete overlay, spall/delamination repairs to deck, new 1.5" concrete overlay, replacing expansion joints, replacing approach slabs on each end, and some bridge bearing assemblies.
- All John Nolan Drive ramps must remain open.

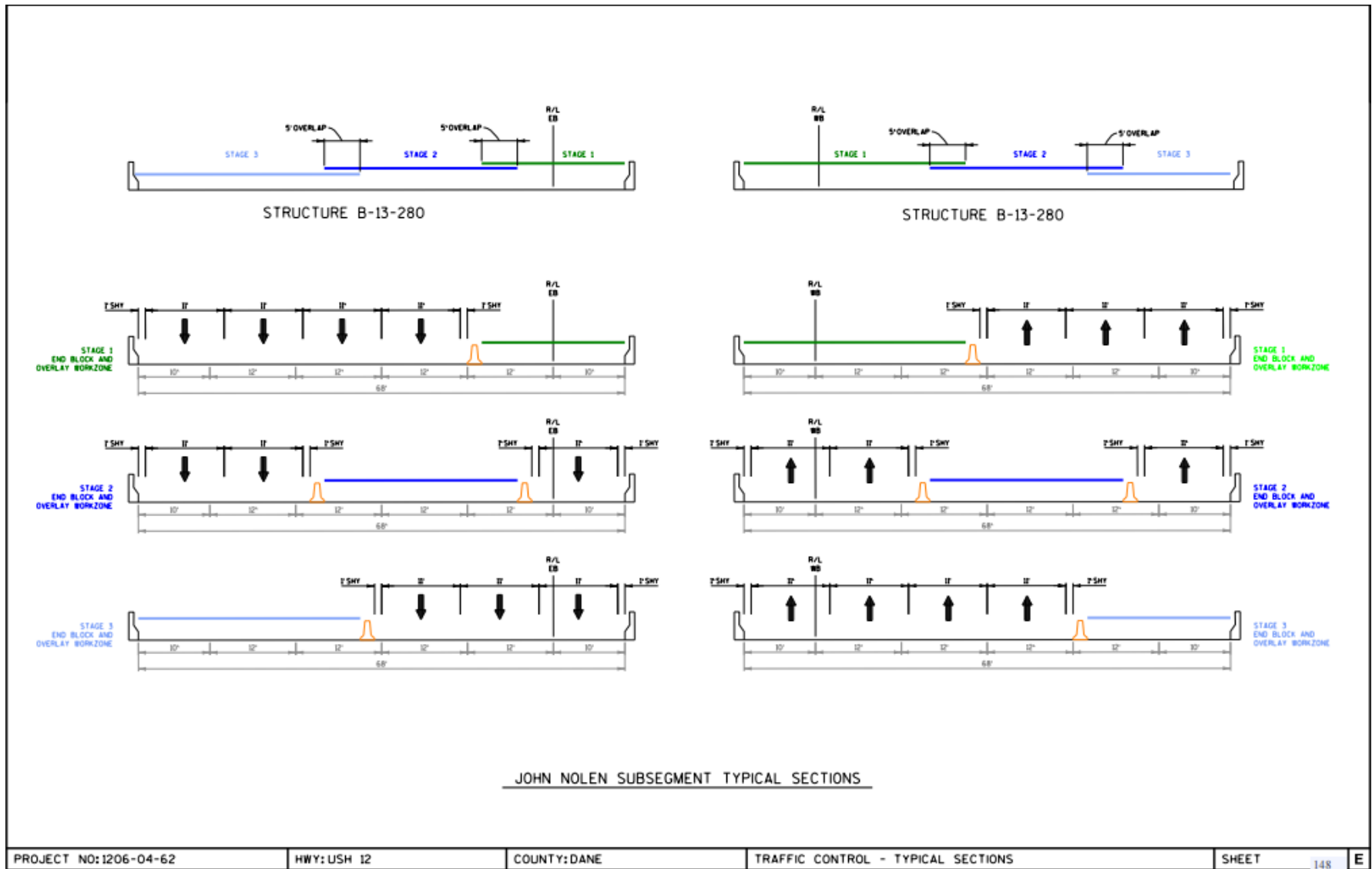
Workshop Exercise 1: Structure B-13-280



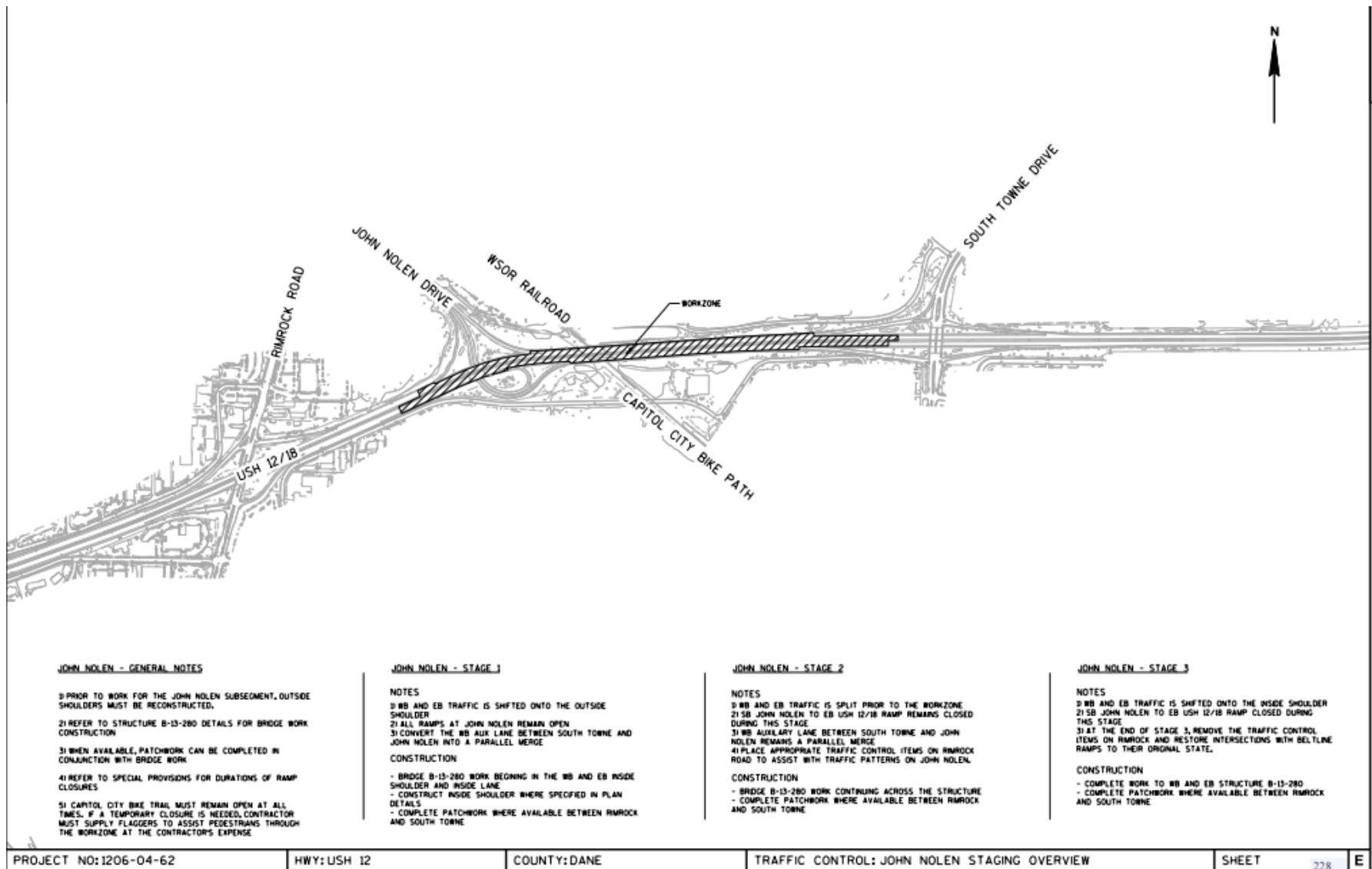
Exercise 1: Traffic Control Questions

- Number of lanes required open during rush hour periods?
- Can structure repair work only be done during off-peak periods with temporary traffic control devices (TTCDs)?
- If not, justify using positive protection (PP):
 - Drop offs?
 - Shield workers?
 - Separate opposing traffic?
 - Combination?
- Number of work zone stages required?
- If PP justified, develop possible staging plans. For exercise only develop cross section sketch showing lane widths and TCD/barrier placement on bridge for each stage.
- What type of PP would you use?

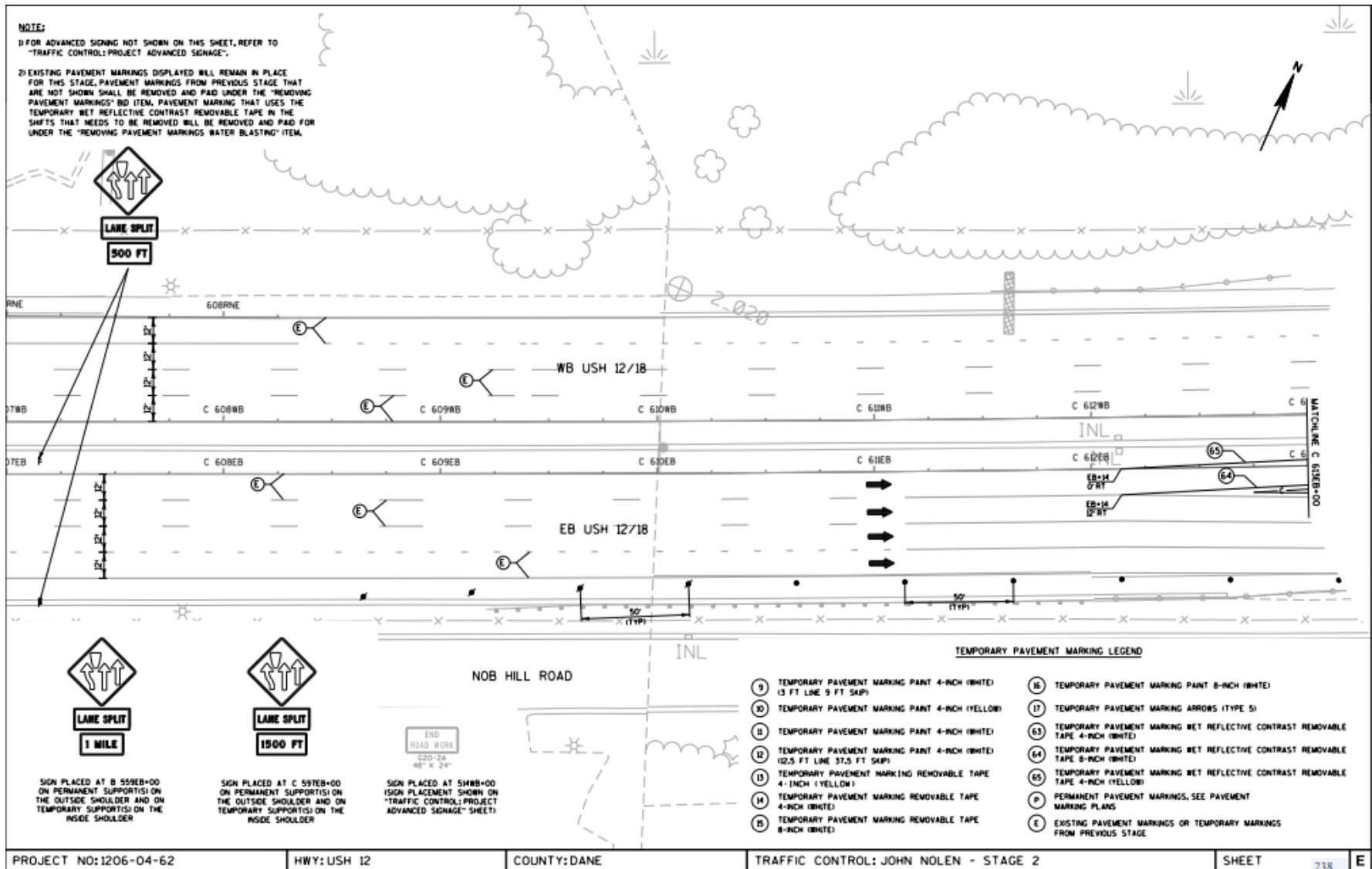
Exercise 1 Solution B 13-280



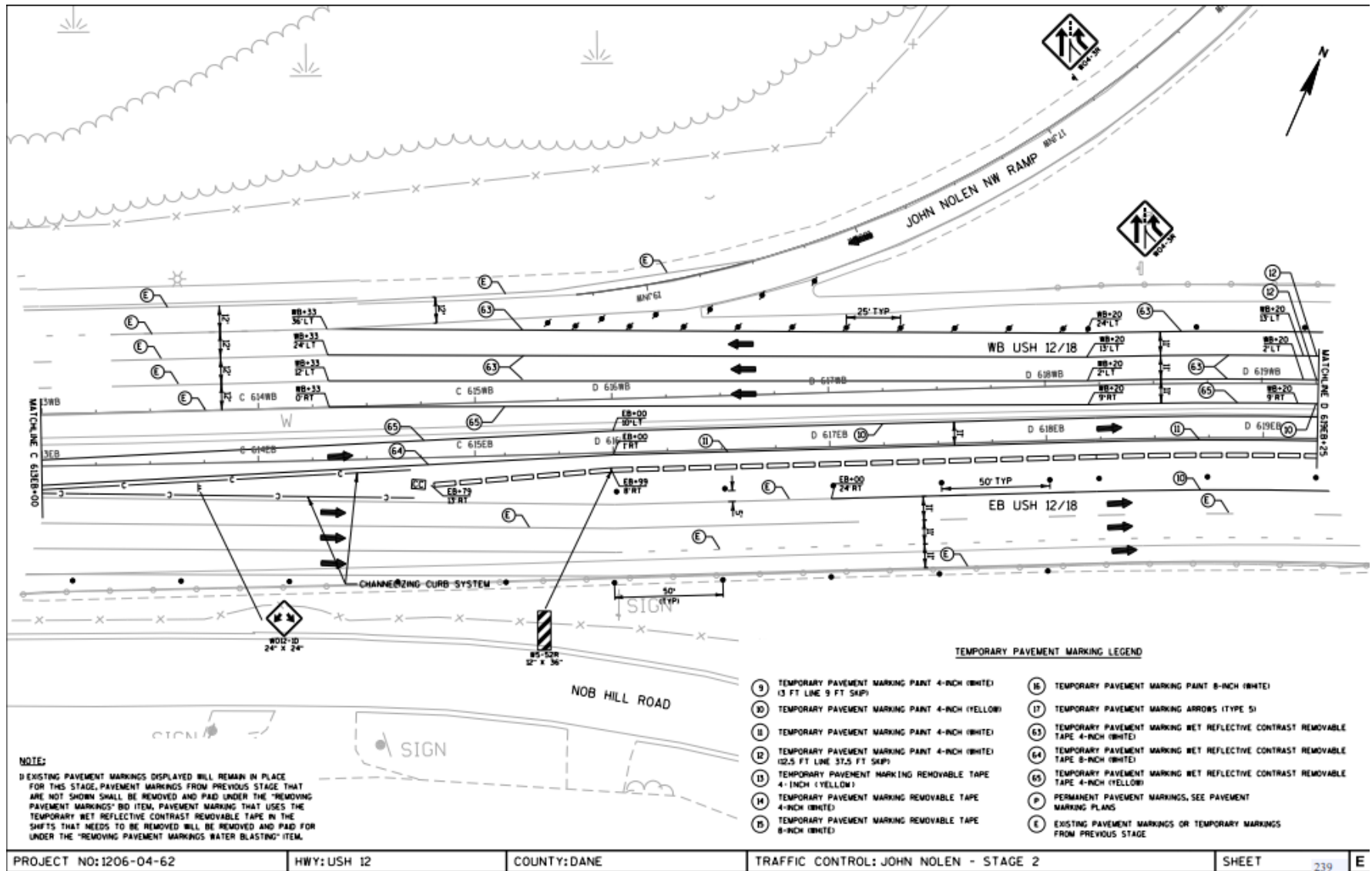
Exercise 1 Solution Work Zone Plan Overview



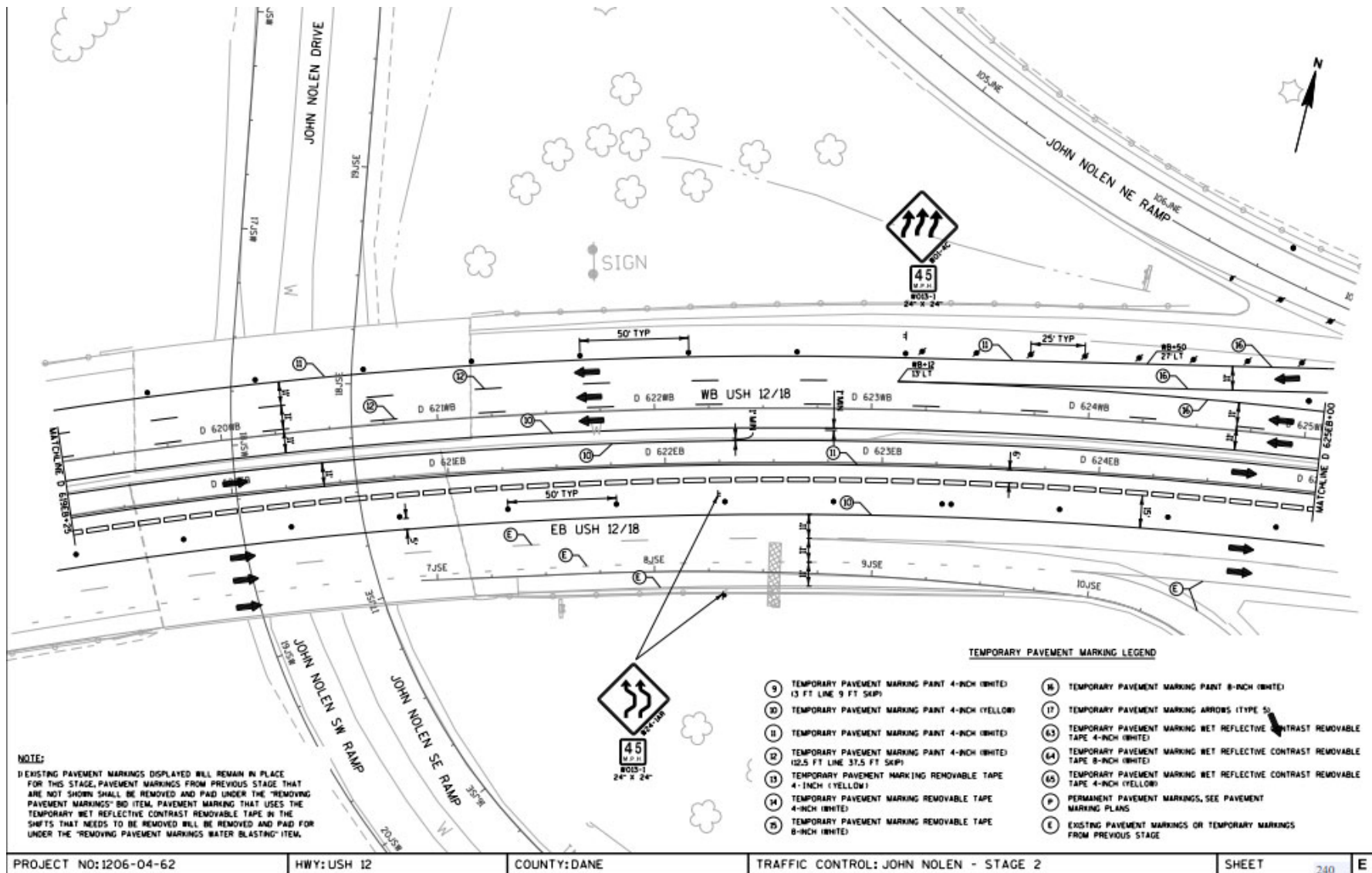
Solution Stage 2 Plan Sheet 1 for B 13-280



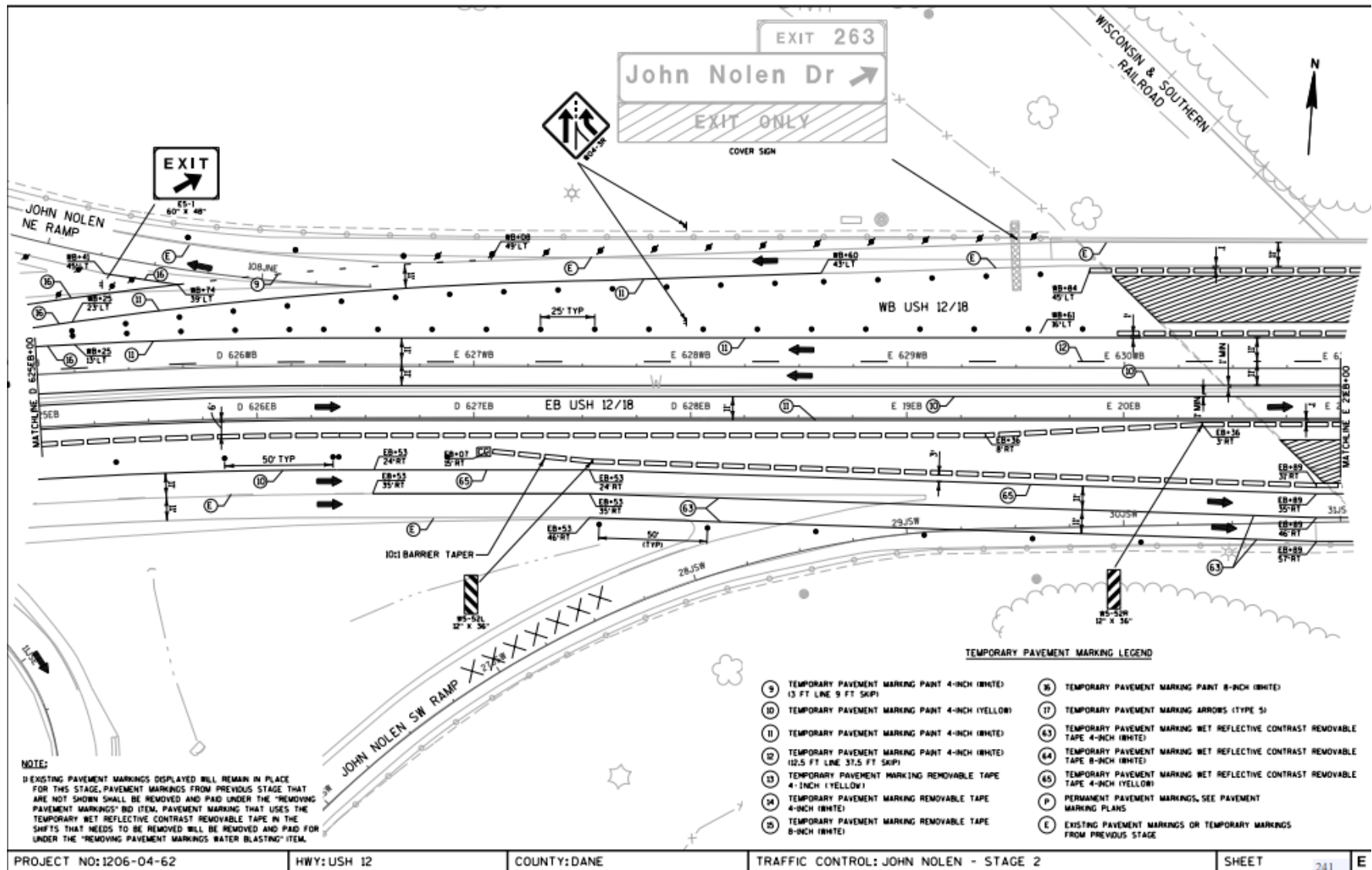
Solution Stage 2 Plan Sheet 2 for B 13-280



Solution Stage 2 Plan Sheet 3 for B 13-280



Solution Stage 2 Plan Sheet 4 for B 13-280



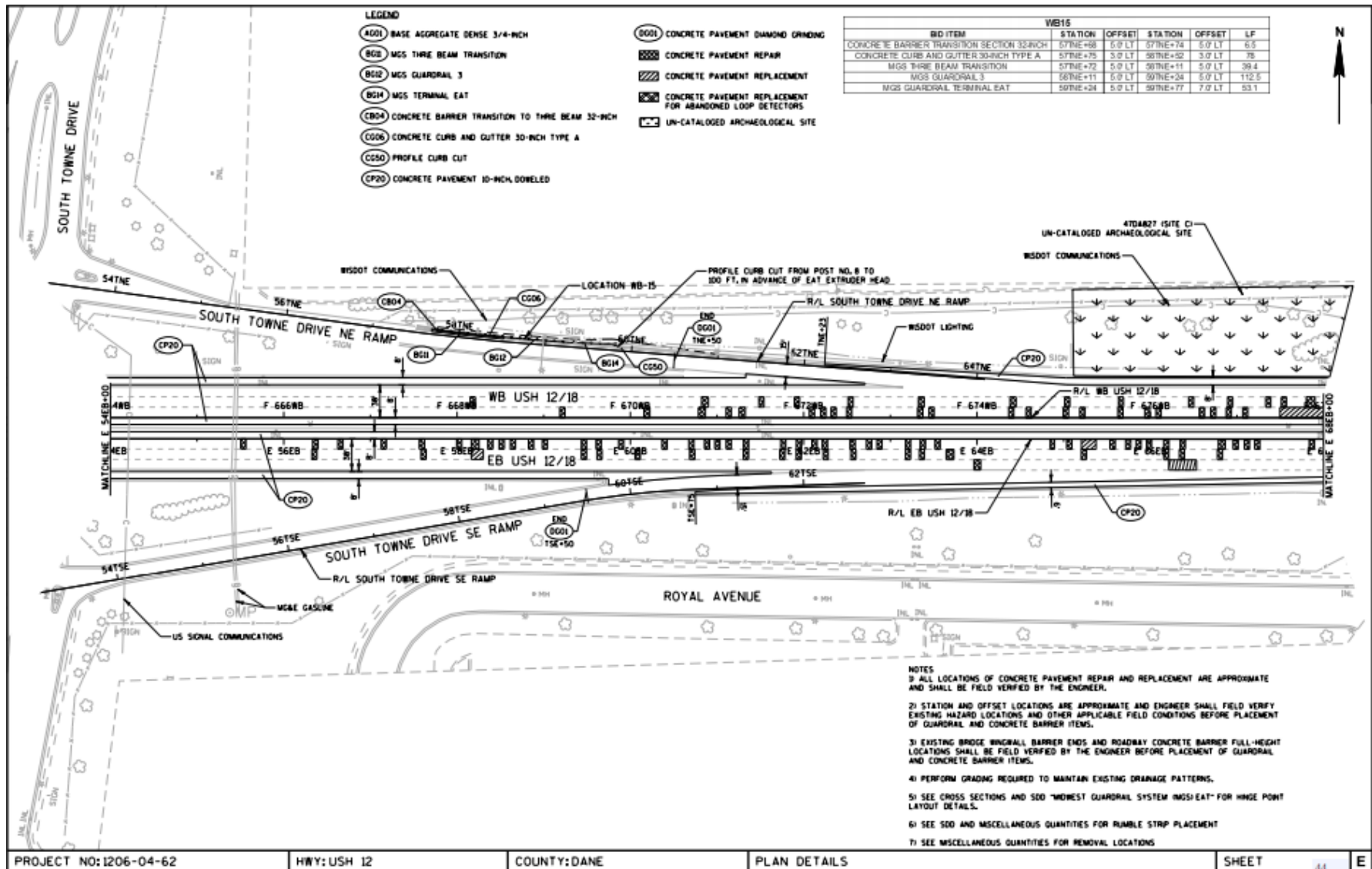
Workshop Exercise 2: Pavement Repairs



Source: Google Maps

- Beltline highway eastbound and westbound lanes divided by a concrete median barrier that separates 2 - 12 foot lanes, 1- 14 foot lane (outside lane) and typically 2 -10 foot wide shoulders plus periodic varying width auxiliary lane in each direction.
- Repair work includes: reconstruct inside and outside shoulders, install outside guardrails, concrete pavement repairs, and pavement diamond grinding.
- All interchange ramps must remain open.

Workshop Exercise 2: Pavement Repairs

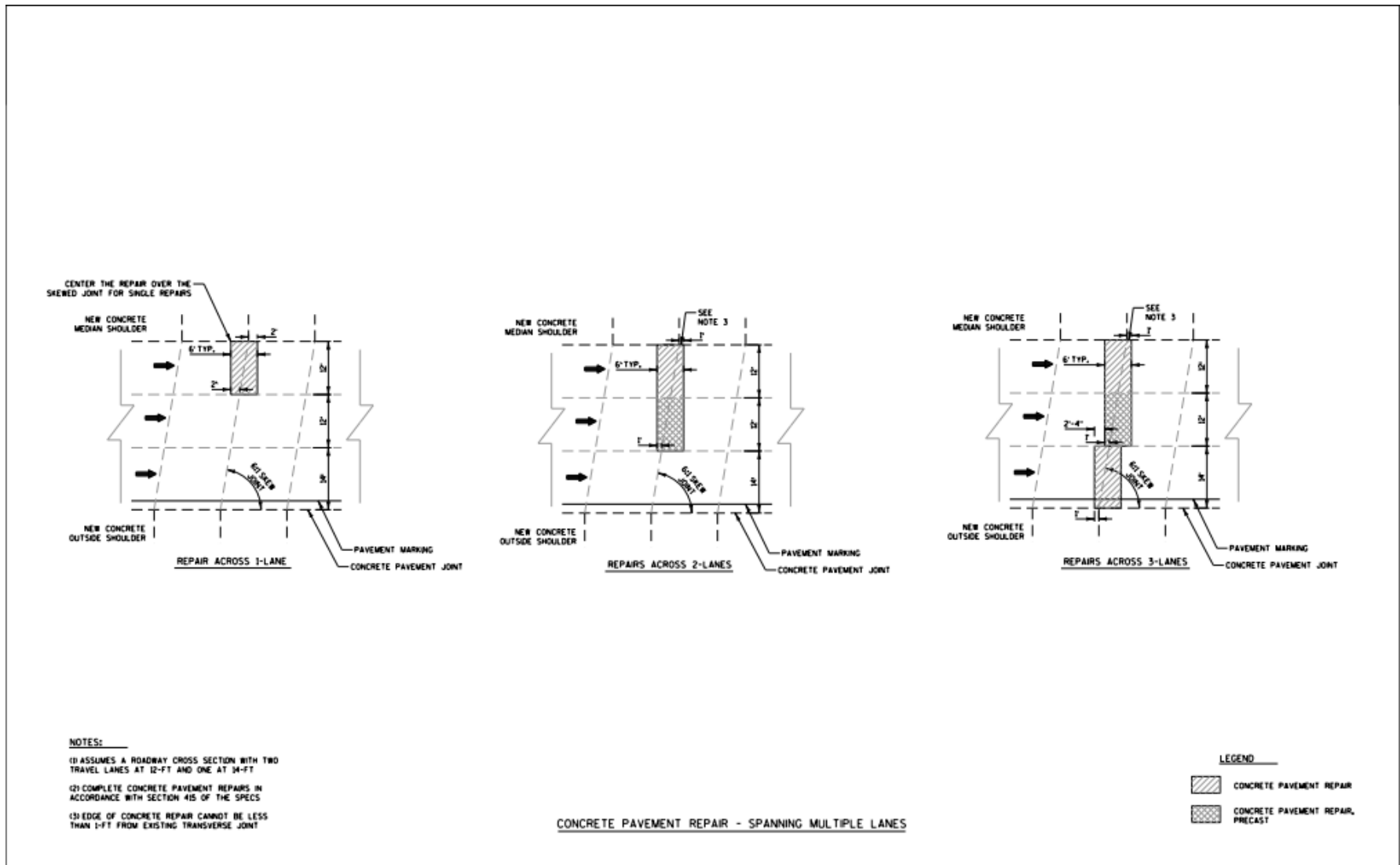


Traffic Control Questions for Pavement Repairs

- Number of lanes required to be open during rush hour periods?
- Is PP justified?
- Can pavement repair work only be done during off-peak periods?
- If so, when does it appear work can begin at night?
- What time must lane(s) be opened in the morning?
- What TTCD(s) do you recommend to separate workers from traffic?
- What construction repair technique(s) should be examined for possible use to accelerate completion?
- Number of work zone stages required?
- For exercise only develop cross section(s) showing lane widths and TTCD/barrier placement for work on inside lane(s) next to median barrier.

Workshop Exercise 2 Solution

Pavement Repair w/Full Depth Concrete



Workshop Exercise 2 Solution

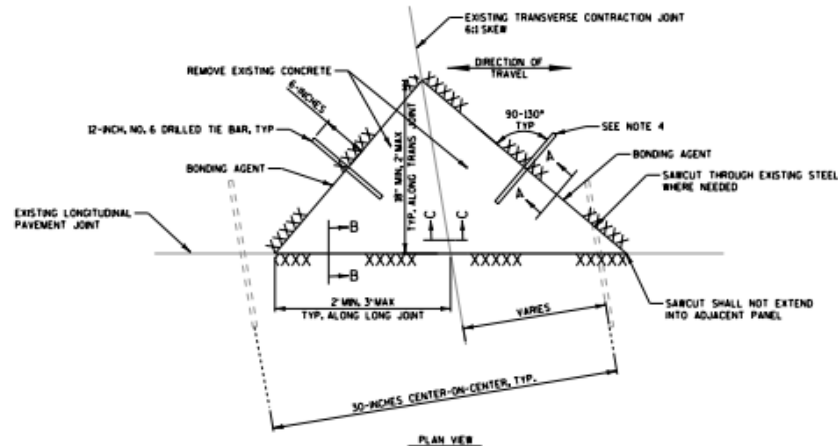
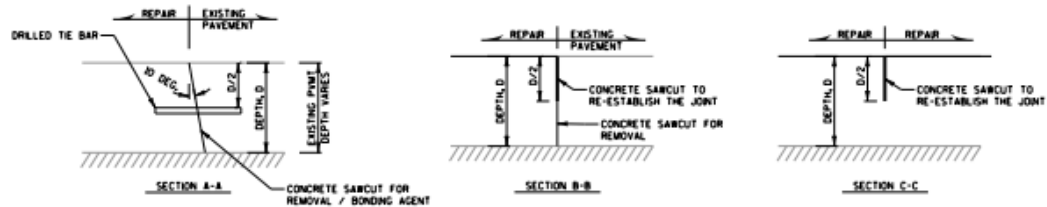
Pavement Repair w/Full Depth Concrete

NOTES:

- (1) NUMBER 6 DRILLED TIE BARS AND ALL SAWCUTS INCIDENTAL TO THE BID ITEM "CONCRETE PAVEMENT CORNER REPAIR FULL DEPTH"
- (2) RE-ESTABLISH EXISTING JOINTS (AS SHOWN IN SECTION B-B & C-C) WITH HALF-DEPTH SAWCUT
- (3) TAKE ALL MEASURES NECESSARY TO NOT EXTEND SAWCUTS BEYOND THE EXISTING PAVEMENT JOINTS
- (4) TIE BAR CAN BE ROTATED UP TO 20-DEGREES OFF OF PERPENDICULAR RELATIVE TO THE SAWCUT ON THE X-Y PLANE, TIE BAR MUST BE DRILLED PARALLEL TO THE FINISH SURFACE AS SHOWN IN SECTION A-A.
- (5) NO SPECIAL HIGH EARLY STRENGTH MIX DESIGNS ARE ALLOWED FOR CONSTRUCTING FULL DEPTH CORNER CRACK REPAIRS.
- (6) HAND TAMP SUBGRADE AFTER REMOVING THE EXISTING PAVEMENT.
- (7) THE DEPTH OF THE REPAIR MUST BE NO SHALLOWER THAN THE DEPTH OF THE EXISTING ADJACENT PAVEMENT.
- (8) SAWCUTTING FOR REMOVAL AND RE-ESTABLISHING EXISTING JOINTS INCIDENTAL TO BID ITEM "FULL DEPTH CONCRETE CORNER CRACK REPAIR"
- (9) TIE BARS USED MUST BE A MINIMUM OF 12-INCHES IN LENGTH

LEGEND:

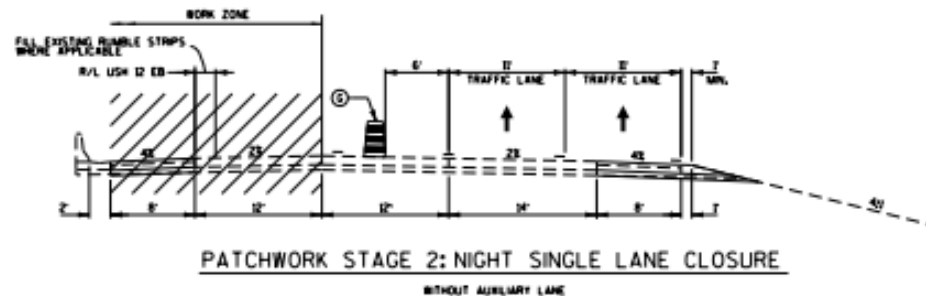
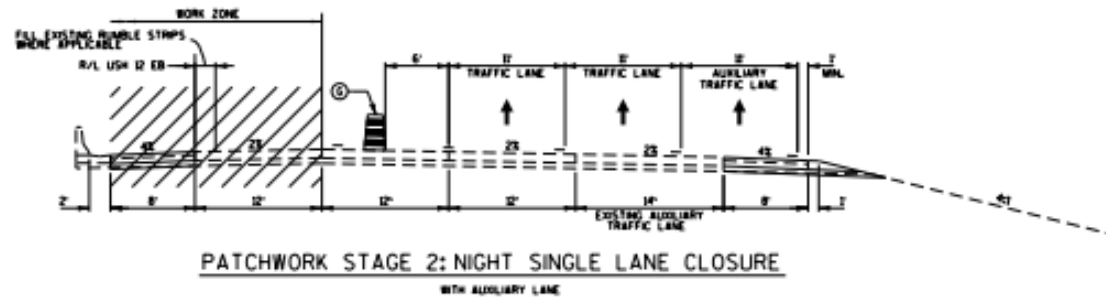
XXXXX SAWING PAVEMENT



CONCRETE PAVEMENT CORNER REPAIR FULL DEPTH

Workshop Exercise 2– Solution

Stage 2 - Inside Lane and Shoulder Closed



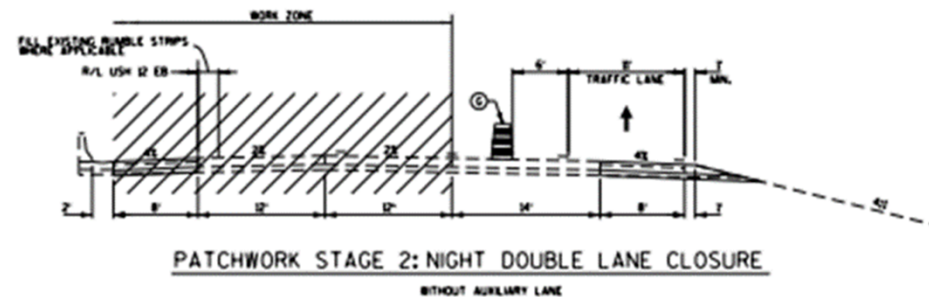
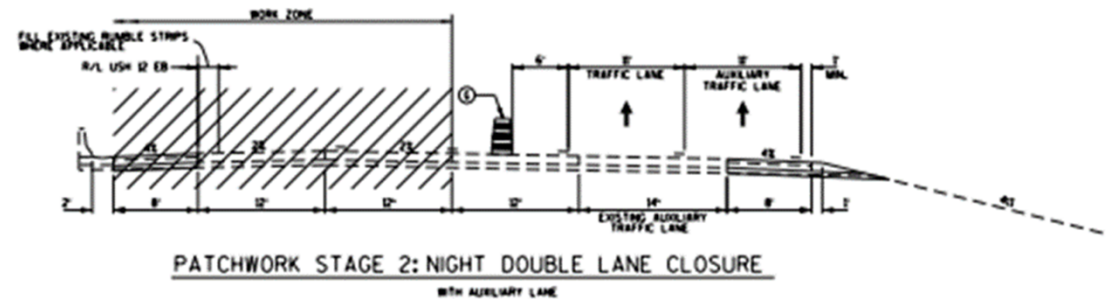
LEGEND

- Ⓐ TEMPORARY PAVEMENT MARKING 4-INCH (YELLOW EDGE LINE)
- Ⓑ TEMPORARY PAVEMENT MARKING 4-INCH (WHITE DASHES)
- Ⓒ TEMPORARY PAVEMENT MARKING 4-INCH (WHITE EDGE LINE)
- Ⓓ PROPOSED FINAL PAVEMENT MARKINGS
- Ⓔ EXISTING PAVEMENT MARKING FROM PREVIOUS STAGE
- Ⓕ PROPOSED PAVEMENT MARKINGS (SAME DAY EPOXY)
- Ⓖ DRUMS AT 50' SPACING

↑ TRAFFIC FLOW

Workshop Exercise 2: Solution

Stage 2: Inside lane and shoulder closed



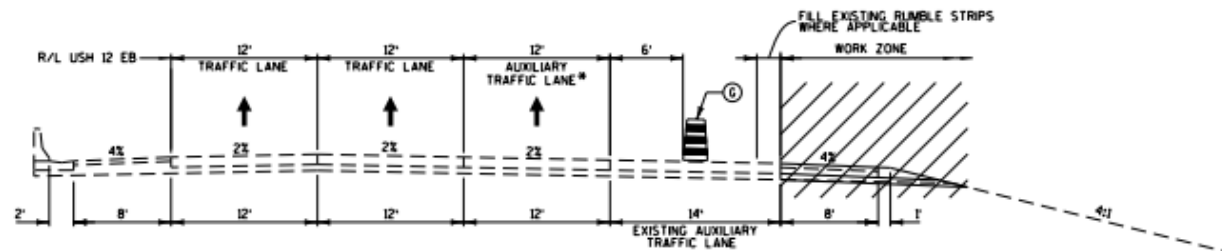
LEGEND

- ① TEMPORARY PAVEMENT MARKING 4-INCH (YELLOW EDGE LINE)
- ② TEMPORARY PAVEMENT MARKING 4-INCH (WHITE DASHES)
- ③ TEMPORARY PAVEMENT MARKING 4-INCH (WHITE EDGE LINE)
- ④ PROPOSED FINAL PAVEMENT MARKINGS
- ⑤ EXISTING PAVEMENT MARKING FROM PREVIOUS STAGE
- ⑥ PROPOSED PAVEMENT MARKINGS (SAME DAY EPOXY)
- ⑦ DRAINS AT 50' SPACING

↑ TRAFFIC FLOW

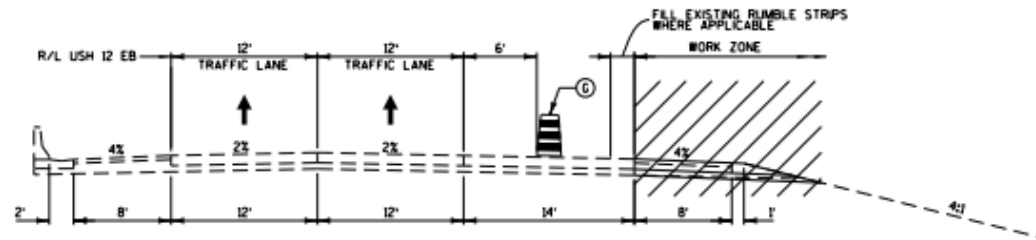
Workshop Exercise 2: Other Stage Solutions

Stage 1: Outside lanes and shoulder closed



PATCHWORK STAGE 1: NIGHT SINGLE LANE CLOSURE
WITH AUXILIARY LANE
(NIGHTTIME CLOSURE ONLY)

* UPSTREAM ON-RAMP MAY BE CONVERTED TO YIELD CONDITION DURING NIGHTTIME OPERATIONS. SHIFT DRUM 12-FEET TOWARD THE MEDIAN TO ALLOW FOR LARGER WORKZONE BUFFER



PATCHWORK STAGE 1: NIGHT SINGLE LANE CLOSURE
WITHOUT AUXILIARY LANE
(NIGHTTIME CLOSURE ONLY)

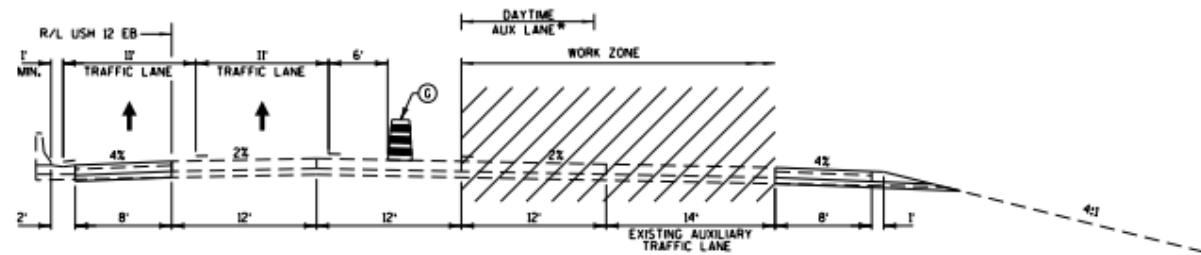
LEGEND

- ① TEMPORARY PAVEMENT MARKING 4-INCH (YELLOW EDGELINE)
- ② TEMPORARY PAVEMENT MARKING 4-INCH (WHITE DASHES)
- ③ TEMPORARY PAVEMENT MARKING 4-INCH (WHITE EDGELINE)
- ④ PROPOSED FINAL PAVEMENT MARKINGS
- ⑤ EXISTING PAVEMENT MARKING FROM PREVIOUS STAGE
- ⑥ PROPOSED PAVEMENT MARKINGS (SAME DAY EPOXY)
- ⑦ DRUMS AT 50' SPACING

↑ TRAFFIC FLOW

Workshop Exercise 2: Other Stage Solutions

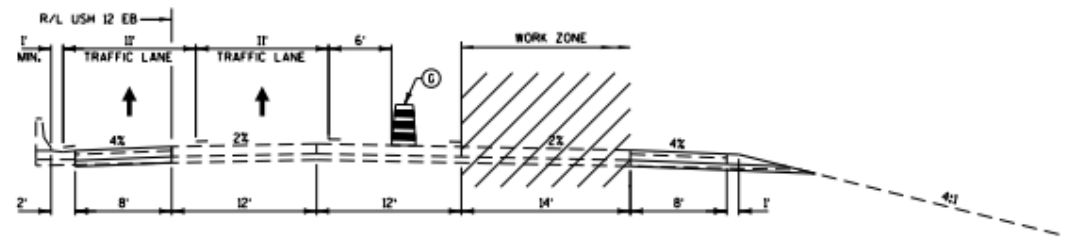
Stage 1: Outside lanes and shoulder closed



PATCHWORK STAGE 3: NIGHT SINGLE LANE CLOSURE

WITH AUXILIARY LANE

* AUXILIARY LANE NOT IN USE WHILE UPSTREAM ON-RAMP IS SWITCHED TO A YIELD CONDITION. THE CONTRACTOR MAY ALSO CLOSE THE UPSTREAM ON-RAMP TO COMPLETE REPAIRS ON THE RAMP. REFER TO SPECIAL PROVISIONS FOR DETAILS REGARDING RAMP CLOSURES.



PATCHWORK STAGE 3: NIGHT SINGLE LANE CLOSURE

WITHOUT AUXILIARY LANE

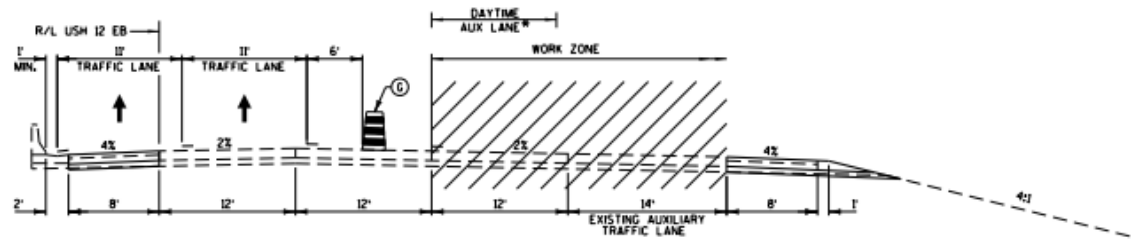
LEGEND

- (A) TEMPORARY PAVEMENT MARKING 4-INCH (YELLOW EDGELINE)
- (B) TEMPORARY PAVEMENT MARKING 4-INCH (WHITE DASHES)
- (C) TEMPORARY PAVEMENT MARKING 4-INCH (WHITE EDGELINE)
- (D) PROPOSED FINAL PAVEMENT MARKINGS
- (E) EXISTING PAVEMENT MARKING FROM PREVIOUS STAGE
- (F) PROPOSED PAVEMENT MARKINGS (SAME DAY EPOXY)
- (G) DRUMS AT 50' SPACING

↑ TRAFFIC FLOW

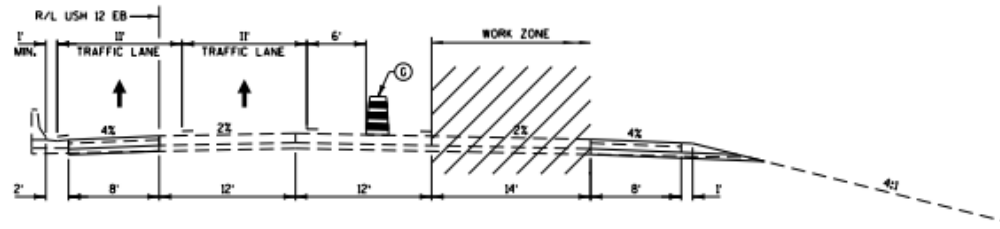
Workshop Exercise 2: Other Stage Solutions

Stage 3: Shoulder & outside lane closed



PATCHWORK STAGE 3: NIGHT SINGLE LANE CLOSURE
WITH AUXILIARY LANE

* AUXILIARY LANE NOT IN USE WHILE UPSTREAM ON-RAMP IS SWITCHED TO A YIELD CONDITION. THE CONTRACTOR MAY ALSO CLOSE THE UPSTREAM ON-RAMP TO COMPLETE REPAIRS ON THE RAMP, REFER TO SPECIAL PROVISIONS FOR DETAILS REGARDING RAMP CLOSURES.



PATCHWORK STAGE 3: NIGHT SINGLE LANE CLOSURE
WITHOUT AUXILIARY LANE

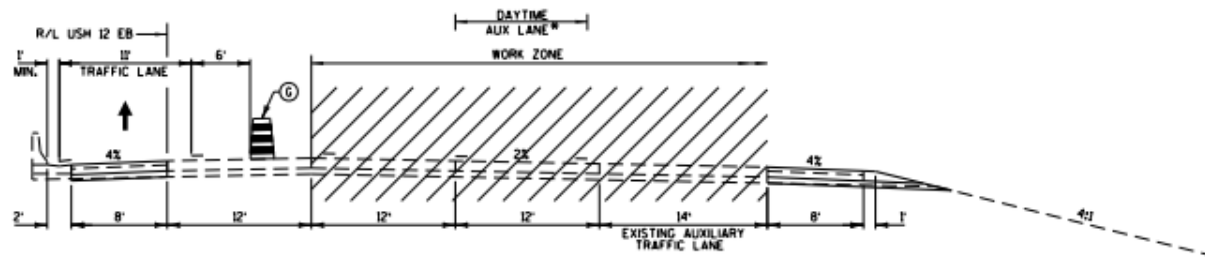
LEGEND

- Ⓐ TEMPORARY PAVEMENT MARKING 4-INCH (YELLOW EDGELINE)
- Ⓑ TEMPORARY PAVEMENT MARKING 4-INCH (WHITE DASHES)
- Ⓒ TEMPORARY PAVEMENT MARKING 4-INCH (WHITE EDGELINE)
- Ⓓ PROPOSED FINAL PAVEMENT MARKINGS
- Ⓔ EXISTING PAVEMENT MARKING FROM PREVIOUS STAGE
- Ⓕ PROPOSED PAVEMENT MARKINGS (SAME DAY EPOXY)
- Ⓖ DRUMS AT 50' SPACING

↑ TRAFFIC FLOW

Workshop Exercise 2 – Other Stage Solutions

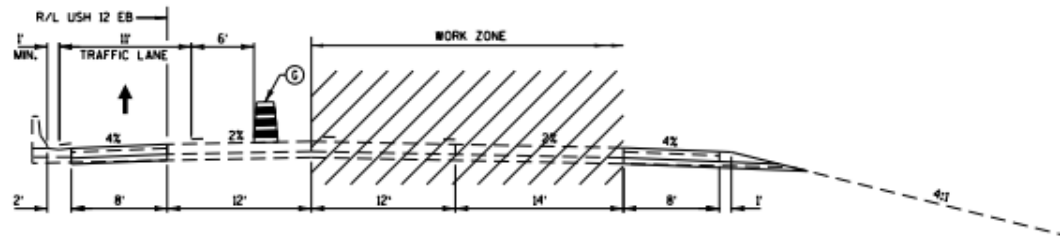
Stage 3 – Shoulder, Outside, & Center lane Closed



PATCHWORK STAGE 3: NIGHT DOUBLE LANE CLOSURE

WITH AUXILIARY LANE

* AUXILIARY LANE NOT IN USE WHILE UPSTREAM ON-RAMP IS SWITCHED TO A YIELD CONDITION. THE CONTRACTOR MAY ALSO CLOSE THE UPSTREAM ON-RAMP TO COMPLETE REPAIRS ON THE RAMP. REFER TO SPECIAL PROVISIONS FOR DETAILS REGARDING RAMP CLOSURES.



PATCHWORK STAGE 3: NIGHT DOUBLE LANE CLOSURE

WITHOUT AUXILIARY LANE

LEGEND

- (A) TEMPORARY PAVEMENT MARKING 4-INCH (YELLOW EDGELINE)
- (B) TEMPORARY PAVEMENT MARKING 4-INCH (WHITE DASHES)
- (C) TEMPORARY PAVEMENT MARKING 4-INCH (WHITE EDGELINE)
- (D) PROPOSED FINAL PAVEMENT MARKINGS
- (E) EXISTING PAVEMENT MARKING FROM PREVIOUS STAGE
- (F) PROPOSED PAVEMENT MARKINGS (SAME DAY EPOXY)
- (G) DRUMS AT 50' SPACING

↑ TRAFFIC FLOW