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The Nebraska Department of Roads Roadway Design Manual Chapter Fourteen, "Traffic", October 2016, has been approved for use.

Approved by: ______________________ / 10-19-16
Mike Owen, Roadway Design Engineer, P.E. Date

Approved by: ______________________ / 10/19/2016
Pritesh Mehta, FHWA Date

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The information contained in Chapter Fourteen: Traffic, dated October 2016, has been updated to reflect the December 2018 Errata. The errata addresses errors, changes in procedure, changes in NDOT department titles, changes in other Roadway Design Manual chapters and other reference material citations occurring since the latest publication of this chapter.

Chapter Fourteen presents guidance for the design of new and reconstructed projects; design guidance for 3R projects is provided in Chapter Seventeen. This chapter replaces Chapter Fourteen: Traffic Engineering, dated July 2006. The Nebraska Division of the FHWA approved this chapter for use on the National Highway System and other federal projects on October 19, 2016.

Chapter Fourteen
Traffic

1. TRAFFIC ENGINEERING STUDIES

The **Traffic Engineering Division** (**Traffic Engineering**) is responsible for conducting a variety of studies, which are summarized in the following sections. The roadway designer is responsible for requesting information from **Traffic Engineering**.

1.A Capacity Analysis

The principal objective of capacity analysis is to estimate the amount of traffic that can be accommodated by a given set of geometric features and to provide metrics for comparison of alternatives while maintaining a desired level of service. For example, this information can be used to determine whether improvements are needed or not. If so, the information can be further utilized to evaluate alternative geometric configurations. The designer should confirm with **Traffic Engineering** that the design typical section and alignment contained in the Planning Document provides the intended capacity and level of service for the project (See Chapter One: Design Standards, Section 12.A, and Chapter Four: Intersections, Driveways and Channelization, Section 1.C.1).

1.B Safety Analysis

A safety analysis uses factors such as crash history, traffic volume data and roadway configuration to predict the future performance of the roadway in terms of crash frequency and severity. A safety analysis may be used to determine the extent of project improvements, which may include:

- Roadway geometry
- Intersection improvements
- Shoulder width
- Rumble strips/ stripes
- Superelevation rates
- Roadside improvements
- Roadside barrier installation/ retention
- Speed limits
- Auxiliary lanes

A safety analysis may be used in evaluating the expected average crash frequency under both existing and proposed conditions. This evaluation may be assessed with other considerations such as, but not limited to, capacity, right-of-way costs and environmental impacts, aiding the designer in focusing project resources in areas which are in the greatest need of improvement thereby maximizing the efficient expenditure of **Nebraska Department of Transportation**, federal, and local funding.

1.C Volume Studies

Traffic volume studies are conducted to determine the levels of traffic along highways or at intersections during specified time periods (e.g. annual average daily traffic (ADT), peak hour traffic). Traffic study results are used to recommend the appropriate design standard and for planning, capacity analysis, accident rate analysis, and for other studies as needed.

1.D At-Grade vs. Interchange Recommendations

Traffic Engineering assists in the development of recommended interchange types and designs to be considered where two or more roadways intersect (at-grade intersection, interchange, roundabout or other alternatives). For additional information see Chapter Four: Intersections, Driveways and Channelization, Section 1.

1.E Weaving Section Analysis

Traffic Engineering analyzes weaving sections where traffic entering and exiting a roadway facility will cross paths. The length and number of lanes necessary in a weaving section are determined using capacity analysis techniques.

1.F Lane Configuration

Auxiliary lanes may be provided for left turns, right turns, or free flow right turns as recommended by **Traffic Engineering**. The length of the turn lane is typically determined by a combination of storage length and deceleration/ taper requirements. Storage needs are often developed through a capacity analysis while deceleration/ taper is typically obtained from design guidance documents. Turn lane length should be verified with **Traffic Engineering** (See Chapter Four: Intersections, Driveways and Channelization, Section1.D).

1.G Traffic Control Studies

Traffic control determination is the responsibility of **Traffic Engineering**. Recommendations for traffic control devices at intersections are made with regard to the type of traffic control necessary (none, yield sign, stop sign, or traffic signal) (See the Manual on Uniform Traffic Control Devices for Streets and Highways (*MUTCD*), Ref. 14.1, and the State of Nebraska, Supplement to the Manual on Uniform Traffic Control Devices, Ref. 14.2, http://www.roads.nebraska.gov/business-center/contractor/mutcd/). If traffic signalization is recommended, **Traffic Engineering** will also develop the traffic signal design. For additional information, see Section 4 of this chapter and Chapter Four: Intersections, Driveways and Channelization, Section 1.E.

1.H Pedestrian Crossings

Pedestrian crossings are used to facilitate the movement of the walking public and/ or bicyclists across highways, railroad tracks, and rivers or streams. Warrant analysis for mid-block pedestrian crossings are the responsibility of **Traffic Engineering**. The roadway designer will coordinate the design of the pedestrian crossing with the design of the highway, sidewalk/ bikeway/ shared-use path, railroad crossing, or bridge. For additional information, see Section 4.A of this chapter, Chapter Four: Intersections, Driveways and Channelization, Section 1.C.10, and Chapter Sixteen: Pedestrian and Bicycle Facilities, Section 7.

2. ROADWAY SIGNS

Roadway signs are used to regulate traffic operations by advising/ informing motorists of roadway rules, hazards, or function. These signs are provided to promote efficient vehicle operation on highways. Signing should be considered as an integral part of design and should be designed concurrently with the geometry of the roadway. The designer will submit a preliminary alignment design to **Traffic Engineering** at "Preliminary Roadway Design", Activity 5300, Clarity Task Code 5336 (See the Design Process Outline (*DPO*), Ref. 14.3) (http://www.roads.nebraska.gov/business-center/design-consultant/).

Supports for highway signs are considered as obstacles to motorists. The supports should be crashworthy or shielded if they are inside the horizontal clear zone or they should be located outside of the horizontal clear zone (See Chapter Six: The Typical Roadway Cross-Section, Section 9.A).

Traffic Engineering determines the need for overhead signs. Although the roadway designer does not design the signs, the designer will confirm that overhead signs are included in the cost estimate for the project and will verify that the locations of overhead signs meet horizontal and vertical clearances as defined in the Nebraska Minimum Design Standards (*MDS*), Ref. 14.4 (http://www.roads.nebraska.gov/media/5593/nac-428-rules-regs-nbcs.pdf) and in Chapter Three: Roadway Alignment, Section 3.D.

3. MARKINGS

Markings are an integral part of roadway design and should be designed concurrently with the geometry of the roadway. There are three general classifications of markings: pavement markings, object markers, and delineators.

Pavement markings are line markings such as center lines, edge lines, lane lines, parking lines, cross walk lines and other symbols and legends. The designer will consider the location of pavement markings when creating pavement jointing diagrams for Portland Cement Concrete pavement (See Chapter Eight: Surfacing, Section 2.A.2); the joints should be in the same location where the markings will be to provide positive guidance to the driver when the markings may be difficult to see. The roadway designer will submit a preliminary jointing diagram to **Traffic Engineering** for review as soon as the alignment and roadway geometry are designed during “Functional Design”, Activity 5400, Clarity Task Code 5428 (See the *DPO*, Ref. 14.3).

Object markers warn of physical obstructions within or adjacent to the roadway that pose an obstacle to motorists such as piers, bridge abutments, flumes, and culvert headwalls. Object markers may warn of roadside conditions, such as abrupt changes in alignment or the end of a roadway.

Delineators are retroreflective devices mounted at the side of the roadway. They are used to guide traffic, especially at night. The units are installed at specified heights and spacing to delineate changes in the roadway. Designers are responsible for determining the locations, spacing, and quantity of the delineators for a project and should refer to the Standard/Special Plans Book (*Standard Plans*) (Ref. 14.5) (http://www.roads.nebraska.gov/business-center/design-consultant/stand-spec-manual/) for information concerning location and spacing of delineators. The designer should discuss the lateral offset distance of the delineators with **District** on the plan-in-hand; the offset determines the length of the delineator post which impacts the item cost.

4. TRAFFIC SIGNALS

Traffic signals are used to direct conflicting movements of vehicles and/ or pedestrians by assigning the right-of-way to various movements at different times. The design of traffic signals and signal timing is the responsibility of **Traffic Engineering** and should be coordinated with the design of the intersection geometry. **Traffic Engineering** may recommend the installation of conduits and loops for future work. Refer to Chapter Four: Intersections, Driveways and Channelization, Section 1.E.2, for additional information concerning the coordination of signal design with intersection design.

4.A Pedestrian Signals

Warrant analysis for pedestrian crossing signals, as outlined in the *MUTCD* (Ref. 14.1), is the responsibility of **Traffic Engineering**. For further information, see Section 1.H of this chapter.

Accessible pedestrian signals are devices that provide non-visual guidance for those with visual disabilities. They are not routinely installed on signal projects, but can be installed upon request and the completion of an engineering study determining their need. The engineering study generally includes a discussion of need and locations with the requesting party. If pedestrian signals are installed on a project the designer should account for any project impacts such as the need for additional right-of-way for signal poles and pavement sawing, removal and replacement for the installation of detection conduits.

5. INTELLIGENT TRANSPORTATION SYSTEM

An Intelligent Transportation System (ITS) uses technology (e.g. traffic sensors, traffic cameras, computers, modern communications) to collect and analyze transportation data such as traffic flow, traffic speed, crashes, and other information. This information is sent to a control center where traffic control and enhancement strategies (such as anti-icing systems, signal timing or alternate routes) may be developed using real-time data. The strategy may then be transmitted to the driving public through such methods as message boards, radio announcements, GPS systems, self-driving cars, and other communication methods. The effective use of ITS may enhance the transportation system in many ways including reduced congestion, improved traffic flow, reduced crash potential, drivers alerted to adverse road conditions, improved efficiency of public transportation, a reduction in fuel usage and a reduction in air pollution. An efficient transportation system may also negate or delay the need for the expensive construction of additional traffic lanes.

In accordance with 23 CFR 940.11, “Project Implementation”, (http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=23:1.0.1.11.50) (Ref. 14.6) all ITS projects funded with highway trust funds shall be based on an engineering systems analysis. This analysis should be on a scale commensurate with the project scope.

When a project impacts existing ITS elements (e.g. cutting the power, moving the device, damaging the system), the designer will coordinate with the **Operations Division** to verify that the project includes sufficient plans, provisions, and right-of-way to place the elements back to working order. This may include in-pavement systems into new pavement construction and/or sawing pavement for a retro-fit of the system. New ITS deployments are the responsibility of the **Operations Division**. For additional information see Intelligent Transportation Systems and Systems Engineering Process Document (Ref. 14.7).

6. WORK ZONE TRAFFIC CONTROL

Traffic Engineering is responsible for developing a traffic control plan (TCP) consisting of warning signs, markings, channelization devices or other methods. The roadway designer will address construction-sequencing issues and coordinate the development of the traffic control plan with **Traffic Engineering** as early as possible in the design process.

When preparing roadway and construction phasing plans, the roadway designer should consider:

- The use of a detour versus construction under traffic
- The delay cost of a detour
- The capacity of a detour or temporary road to handle the expected traffic around or through the construction zone
- If the detour/ temporary roadway geometry will meet or exceed minimum guidelines
- Roadside safety and clear zone requirements
- The constructability of the phasing
- The economic costs to users and adjacent property owners and businesses
- Community and social impacts, local festivals
- The maintenance of access to adjacent property owners

6.A <u>Construction Under Traffic</u>

The majority of projects will be built under traffic, when practicable. It may be necessary to encroach upon travel lanes, shift lanes, or even close lanes during construction. The frequency and length of time that traffic must be routed through the construction zone should be kept to a minimum and adequate warning will be provided to motorists.

The roadway designer should consider construction sequencing and the maintenance of traffic during construction throughout the entire design process. The following items should be considered and provided for in the design of a project that is to be built under traffic:

- Provide a minimum of four feet for worker protection (two feet for barrier width and a two feet clear space behind the barrier). Consult with **Traffic Engineering** regarding the barrier layout.
- Taper lengths for lateral lane transitions and lane drops should meet or exceed the minimums set by the *MUTCD* (Ref. 14.1).
- Day and night sight distances should meet or exceed the minimums presented in **AASHTO's** <u>A Policy on Geometric Design of Highways and Streets</u> (*Green Book*) (Ref. 14.8).

Often road improvements such as milling, armor coat, asphalt surfacing, and shoulder work will require the closing or partial closing of travel lanes on highways during construction. On highways of four lanes or more this may simply involve reducing the number of lanes in each direction so construction work can be completed or in the closing of two of the directional lanes (e.g. the eastbound lanes), shifting the traffic to the other lanes in an opposing traffic configuration by the construction of crossovers (See Section 6.A.1 of this chapter). On two-lane highways this may involve such methods as closing one lane and using a flagger to direct traffic through the construction, the use of stop signs, yield signs, temporary signals, or other methods as the situation allows. **Traffic Engineering** will recommend the type of traffic control that is suitable. On roadways with high traffic volumes it may be practicable to schedule construction at night, closing the roadway and detouring traffic to another route. The roadway designer will coordinate with the **Construction Division** and with **Traffic Engineering** regarding the construction schedule (day or night) and the number of lanes that will be open to traffic.

6.A.1 Crossovers

Crossovers are used on multi-lane divided highways to temporarily route traffic across the median to the opposite lanes so that construction can progress on the vacated side. Additional earthwork needed to construct the crossovers will be included in the earthwork quantities (See Chapter Seven: Earthwork, Section 2). Single lane crossovers should be designed with 16 feet lane widths. The crossover pavement quantities will be included in the cost estimate and paid for separately (See Chapter Twelve: Cost Estimating & Funding, EXHIBIT 12.8).

6.A.2 Temporary Surfacing

Additional temporary surfacing may be needed during different phases of construction for lane or shoulder widening, property entrances, etc. These surfacing quantities will be included in the cost estimate and paid for separately (See Chapter Twelve: Cost Estimating & Funding).

On new and reconstructed projects with major grading involving disrupted accesses the designer should discuss the use of gravel, crushed rock, or millings with the **District** on the plan-in-hand field inspection. These materials may be used to provide temporary access to adjacent properties during construction (See Chapter Twelve: Cost Estimating & Funding, EXHIBITS 12.5 & 12.8).

6.B Temporary Roads

In certain situations, (e.g. the construction of culverts) it may be more practicable to construct a short route around the work zone than to build the project under traffic or to utilize a detour (See EXHIBIT 14.1). The following considerations apply in the design of a temporary road:

Right-of-Way - Right-of-way should be adequate to construct the temporary road or an easement will be acquired.

Design Vehicle – The temporary road should be designed using the same design vehicle as the project (See Chapter Four: Intersections, Driveways and Channelization, Section 1.C.5).

Design Speed – As a rule-of-thumb, the design speed for the temporary road should be 10 mph less than the existing posted speed.

Sight Distance – Stopping sight distance and intersection sight distance will be based on the design speed of the temporary road. The designer should pay particular attention to sight distance where there is a combination of horizontal and vertical curves. For additional information see Chapters 3 and 9 of the *Green Book* (Ref. 14.8).

Typical Section - Typical temporary road sections are shown in EXHIBIT 14.2.

Grades – Grades will be designed based on the temporary road design speed, the maximum allowable grade is 10% (See Chapter Three: Roadway Alignment, Section 3.A).

Transitions – Traffic may be moved between the main roadway and the temporary road by the use of tapers, curves, or a combination of the two.

1. CURVES – Horizontal curves should be designed according to the design speed of the temporary road. High-speed temporary roads ($V \geq 50$ mph) should be designed according to the e_{max} = 6% superelevation table found in Chapter Three: Roadway Alignment, EXHIBIT 3.4c. Low-speed temporary roads ($V \leq 45$ mph) should be designed in accordance with **FIGURE 3-14** of the *Green Book* (Ref. 14.8), using a relative gradient of 185:1.

   See Chapter Three: Roadway Alignment, Section 2.A, for information on the design of horizontal curvature.

2. TAPERS – Taper rates between 29:1 (2°) and 11:1 (5°) are allowed. A 20:1 taper rate is recommended.

Lateral Clearance to the Work Zone (Buffer Space) - The distance required between the centerline of a temporary road section and the project centerline will be determined on a case-by-case basis. Factors affecting the required width of this space include construction clearances, side slope geometry, and temporary drainage requirements.

When a temporary road is required adjacent to bridge construction/ reconstruction, the highway designer will coordinate with the **Bridge Division** (**Bridge**) regarding the lateral offset of the temporary road to the bridge (See EXHIBIT 14.2) and the required size of the drainage structure(s) needed to handle the water flow or the use of a temporary bridge structure.

Drainage - Existing drainage patterns will be maintained to prevent flooding of the existing roadway and surrounding properties. Drainage structures needed to construct the temporary road will be included in the cost estimate and any required connection bands will be added to the build notes and cost estimates. If temporary drainage pipe is to be retained by the **District** they should be consulted regarding the pipe lengths and diameters that can be used when the pipe is salvaged.

The designer should pay particular attention to the drainage of the temporary road surface where there is a combination of horizontal and vertical curves.

Earthwork - Earthwork quantities for temporary roads will be included in the project earthwork calculations. Temporary road material will be placed as embankment and removed as excavation, specified for the temporary road. Construction phasing and material location should be considered in the earthwork quantities, verify that material is available for the construction of the temporary road.

Surfacing - The **District** will determine the type of surfacing for each temporary road at the plan-in-hand inspection. The following considerations should be kept in mind:

- Pavement used to construct the temporary road will be structurally adequate to handle expected traffic.
- Pavement used to construct the temporary road will be estimated for the same quantity items as for the main roadway (See Chapter Twelve: Cost Estimating & Funding, EXHIBIT 12.8) and will be included in the pavement quantities.
- If gravel surfacing is used, gravel embedment is required.

The roadway designer will do the preliminary calculations. The following individuals will calculate the final quantities, depending on the type of temporary road surfacing to be used:

Temporary Road Surfacing Type	Final Quantity Calculations by:
Concrete	Roadway Designer
Asphaltic Concrete	**M&R**
Gravel & Gravel for Embedment	Roadway Designer
Embedment of Gravel	**M&R**
Calcium Chloride	**M&R**

Traffic Engineering – The designer will submit the temporary road design, including design speed, to **Traffic Engineering**. Pavement markings and signals needed to construct the temporary road will be determined by **Traffic Engineering** and included in the cost estimate.

Erosion Control – Temporary erosion control measures will be required for temporary road construction. Temporary erosion control methods may be found in Chapter Two: Erosion and Sediment Control, Section 5, of the Drainage Design and Erosion Control Manual (*Drainage Manual*) (Ref. 14.9) (http://roads.nebraska.gov/business-center/design-consultant/rd-manuals/). The designer will review the temporary road design with the **Roadside Stabilization Unit** in the **Project Development Division**.

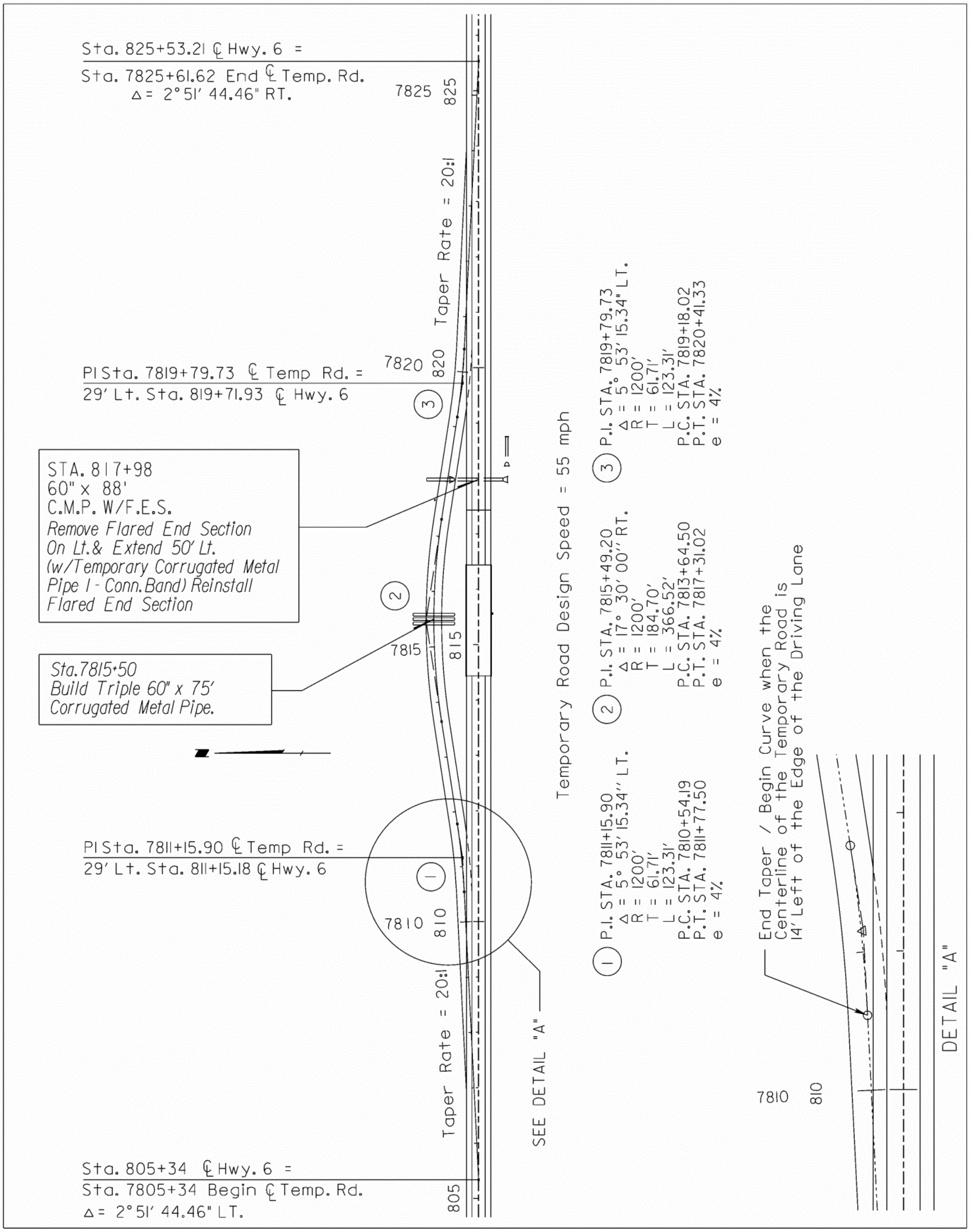
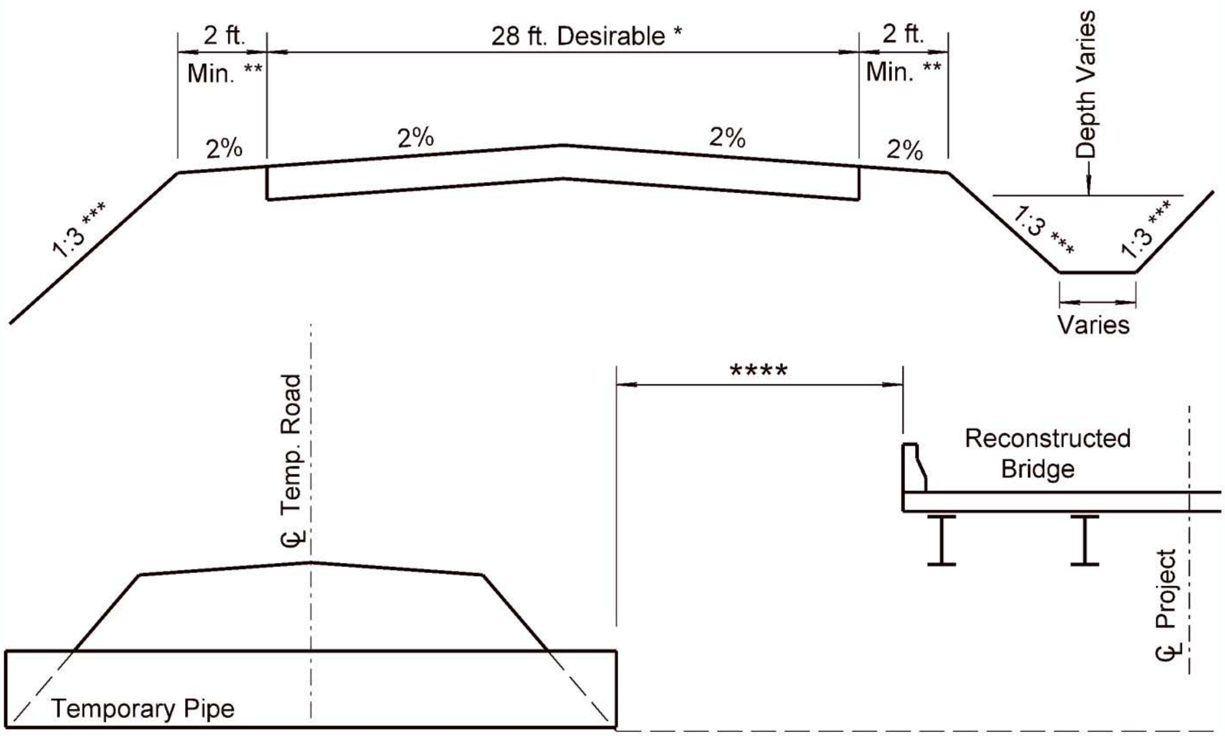


Exhibit 14.1 Example Temporary Road



* Check Chapter 3 of A Policy on Geometric Design of Highways and Streets (Ref. 14.5) for width vs. radius of curve.

** 4 ft. desirable in the Sandhills.

*** 1:2 slope may be used with concrete barriers (except in the Sandhills). Unit Head approval is required.

**** Verify/coordinate offset with the Bridge and Construction Divisions on a case by case basis. See EXHIBIT E of the DPO for factors to be considered.

Exhibit 14.2 Typical Temporary Road Section

6.C Detours

Detours may guide traffic around construction zones outside of the project limits. A detour is a signed route within an existing roadway system that is appropriate for the intended traffic and the intended duration. The detour route(s) should be determined prior to the plan-in-hand for NEPA review and processing.

The following items should be considered in determining if a detour route is feasible and should be verified at the plan-in-hand:

- The delay cost of the detour; the designer should coordinate with the **Final Plans Coordinator** in the **Construction Division**.
- Existing road(s) will be able to handle the expected volumes of traffic generated by the proposed detour. The roadway designer will design any required improvements to the detour roadway and/ or intersection geometry.
- The bridges on the detour route shall be structurally adequate for the expected traffic composition. The roadway designer will coordinate bridge/ bridge size structures on the detour route with **Bridge**.
- The existing pavement(s) shall be structurally adequate to handle the expected traffic volumes; the roadway designer will coordinate with the pavement engineer in the **Materials and Research Division** regarding necessary surfacing improvements.
- Environmental considerations/ impacts along the detour route.
- The detour route should be a reasonable length, not requiring the motorist to travel too far from the normal route.
- The impact of the detour route on the operation of businesses, both along the project route and the detour.
- Local access will be provided to residents and businesses.
- The impact of the detour route on emergency vehicle operations.
- The impact of the detour route on school bus routes and schedules.
- Railroad crossings on the detour route; railroad crossing upgrades, crossing signals, and agreements with the railroad company will be coordinated with the **Intermodal Planning Division**.

The **District Operations & Maintenance Manager** should be consulted at the plan-in-hand about the feasibility of maintaining the detour during construction.

The roadway designer will coordinate the detour route selection and any improvements with the **District** and with all impacted **Divisions**/ **Units** (e.g. **Bridge**, **Project Development**, **Construction**). The roadway designer will submit the proposed detour route to **Traffic Engineering** for review.

The selected route may require temporary geometric and surfacing improvements to handle the intended detour traffic. Pavement needed for detour improvements is paid for under a separate pay item group; the designer will compute quantities of surfacing and other construction items required for the detour improvements (See Chapter Twelve: Cost Estimating and Funding, EXHIBIT 12.5).

If roads other than state highways are proposed for use as a detour a signed agreement must be obtained from the appropriate governing agencies. The agreement will outline the surfacing, geometric, and other improvements to be accomplished and will depict the detour route. The **City/ County** should be contacted early in the design process, informing them about the proposed detour route(s) and requesting information regarding local construction projects or special events (e.g. parades, local festivals) that will affect the choice and/ or allowable time frame of a detour route. Proposed detour routes will be addressed at public meetings. See the *DPO* (Ref. 14.3), Activity 5300, Clarity Task Code 5350 and **EXHIBIT C** and Chapter Thirteen: Planning and Project Development, Section 5.A, for additional information.

7. REFERENCES

14.1 United States Department of Transportation Federal Highway Administration, Manual on Uniform Traffic Control Devices for Streets and Highways (*MUTCD*), Washington, D.C., 2009. (http://www.roads.nebraska.gov/business-center/contractor/mutcd/)

14.2 State of Nebraska, Supplement to the Manual on Uniform Traffic Control Devices, 2011 (http://www.roads.nebraska.gov/business-center/contractor/mutcd/)

14.3 Nebraska Department of Transportation, Design Process Outline (*DPO*), Current Edition. (http://www.roads.nebraska.gov/business-center/design-consultant/)

14.4 Board of Public Roads Classifications and Standards, Nebraska Minimum Design Standards (*MDS*), Current Edition. (http://www.roads.nebraska.gov/media/5593/nac-428-rules-regs-nbcs.pdf)

14.5 Nebraska Department of Transportation, Standard/Special Plans Book (*Standard Plans*), Current Edition. (http://www.roads.nebraska.gov/business-center/design-consultant/stand-spec-manual/)

14.6 Title 23 of the "Code of Federal Regulations", Chapter I – Subchapter K – Part 940 (23 CFR 940.11) (http://www.ecfr.gov/cgi-bin/text-idx?rgn=div5&node=23:1.0.1.11.50)

14.7 Nebraska Department of Transportation, Intelligent Transportation Systems and Systems Engineering Process Document, May 18, 2015

14.8 American Association of State Highway and Transportation Officials, A Policy on Geometric Design of Highways and Streets (*Green Book*), Washington, D.C., 2011.

14.9 Nebraska Department of Transportation, Drainage Design and Erosion Control Manual, Current Edition (http://roads.nebraska.gov/business-center/design-consultant/rd-manuals/)