DEN

DENVER INTERNATIONAL AIRPORT

DESIGN STANDARDS MANUAL

Civil

Design, Engineering and Construction

Revised: Q4 2025

Printed in the United States of America

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Summary of Revisions

The following tables list the revision to the Civil DSM.

2025 Revisions

Fourth Quarter

Reference	Revision Description
2.1.Geometry	Reference update
2.2.1.Pavement Design Criteria and Standard Pavement Sections	Updated design criteria
2.2.1.1.Runway/Taxiway/Apron Pavement Areas	Added descriptions for each pavement layer along with specification reference
2.2.1.3.Gate Apron Pavement Areas	Updated description
2.2.1.4.Paved Shoulder Pavement Areas	FAARFIELD software to be used for design per FAA AC 150/5320-6G
2.10.FAA Review	Include FAA PM to be included during design

Second Quarter

Reference	Revision Description
2.0.2.Criteria	Included link to FAA Airport Design Guidance Link
2.2.1.Pavement Design Criteria and Standard Pavement Sections	Combined Standard Pavement Section and included FAA Requirements to use FAARFIELD software for pavement design
2.7.1.Fencing	Updated for fence skirting to prevent wildlife from burrowing beneath
2.8.1.Recycling	Materials to be evaluated for PFAS prior to utilizing recycle yards
3.0.Overview	Updated description
3.9.Traffic Signals	Requirement for any new equipment to be approved by DEN to maintain continuity
5.2.2.Criteria	Clarified Xcel/DEN delineation point

2024 Revisions

Fourth Quarter

Reference	Revision Description
1.6 ORAT Requirements	New ORAT Requirements section
Throughout	Accessibility improvements

2023 Revisions

Fourth Quarter

Reference	Revision Description
4.1.1 Design Requirements	Re-formated section and added information
4.2 Structured Piping	Added design standards for DEN structured parking

Second Quarter

Reference	Revision Description
1.0 General	Added Figure 1-1: DEN Property Map
1.3 Parking Facilities	Added description of Parking Facilities Chapter
1.4 Utility Distribution	Added references to Electrical and Mechanical DSMs
2.0.1 Scope	Added Figure 2-1: Fence and Airfield Area Map
2.0.3 History	Added Figure 2-2: Taxiway Design Groups
2.4 Vehicle Service Roads (VSRs)	Added Figure 2-5: Airfield Roads Map
2.5 Airfield Lighting, Signage, Markings and Navigational Aids (NAVAIDS)	Taxiway and Runway lighting has been con- verted to LEDs
2.12 Aircraft De-Icing Facilities	Moved content and added reference to Water Systems Chapter
3.1 Criteria	Consolidated and organized design criteria sec- tion
Table 3-1: Roadway Design Criteria	Updated values per AASHTO
Chapter 4- Parking Facilities	New criteria and design requirements for entire chapter
5.0.2 Guiding Principles	Consolidated language and removed redundancies
5.2 Utility Systems	Updated utility distribution systems and Jet Fuel Criteria
5.5 Water Systems and Storm Drainage	Removed Chapter 5- Water Systems and included content in Utilities Chapter
Figure 5-1: Overall DIW System Plan	Updated Overall DIW System Drawing

Revision Notation: Revisions made to this Manual during this revision cycle are annotated as shown in the example below:

A vertical line in the left-hand margin is used to annotate paragraphs that have been added or revised in the current publication. Revisions may include items such as new requirements, clarifications of existing requirements, or removal of requirements that no longer apply to projects. Revision annotation is applied to each publication individually; revisions made in past publications are not annotated in subsequent publications.

Purpose of Design Standards Manuals

The DEN Design Standards have been developed to ensure a unified and consistent approach to the thematic and technical design for DEN. These standards are for use and strict implementation by all consultants under contract to DEN, to tenants, and all other consultants under contract to any other entity for the design of projects at DEN.

The Standards Manuals are working documents, which will be revised and updated, as required, to address the general, conceptual, design, and technical standards for all areas of design for DEN.

This Design Standards Manuals (DSM) for DEN has been prepared for use by competent, professionally licensed architectural and engineering consultants under the direction of DEN Maintenance and Engineering or tenants of DEN.

The Design Standards shall not be quoted, copied, or referenced in any bidding or construction contract documents. Content contained in this Manual shall not be copied in any bidding or construction documents, except where specifically instructed to do so. All information contained in these standards must be fully explained and shown in all bidding and contract documents.

The Design Standards Manuals are intended to be used as a whole, as each manual is complimentary to the other DSMs. To understand the overall thematic and design standards for DEN, the applicable manuals must be utilized together and not separated from the Design Standards Manuals.

The Consultant shall not reproduce, duplicate in any manner, transmit to other consultants or other entities, or use in conjunction with other projects without the express written consent of DEN.

NOTE: This document is optimized for duplex (double-sided) printing.

VARIANCE FROM DEN DESIGN STANDARDS MANUALS

Requests for non-conformance or variance from DEN Design Standards manuals, for any DEN or Tenant Projects, must be formally submitted using the online DSM Variance Request form at the following website:

DEN DSM Variance Request

Variance requests may or may not be approved by DEN and response will be communicated to the requestor.

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Chapter 1 - General

1.0 General

This DSM has been prepared for use by Consultants and Designers of Record (DORs) in the design of civil infrastructure systems at DEN. The design criteria herein must be adhered to on all designs whether they are sponsored by DEN, tenants, airlines, concessionaries, operating contractors, or any other entity preparing designs for projects on DEN property, which may also include DEN-owned infrastructure and systems that exist off-Airport.

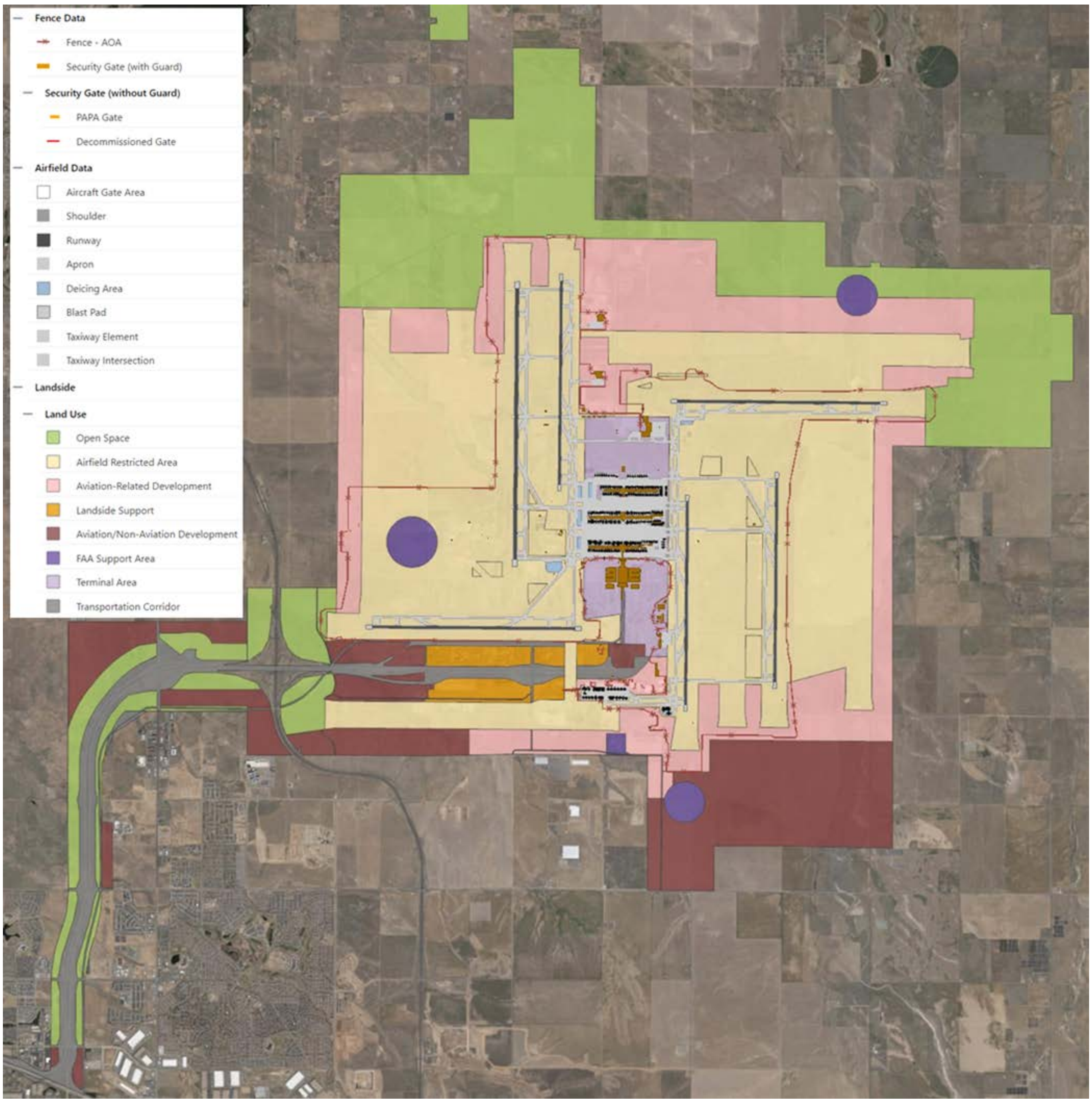

Figure 1-1: DEN Overall Property Map

1.1 Airfield

Chapter 2- Airfield covers the area within the security fence excluding building structures. Different areas of the airfield are referred to as the west airfield, east airfield, commercial apron, cargo apron and Signature apron.

1.2 Landside Roadways and Bridges

Chapter 3- Landside Roadways and Bridges covers the area outside of the airfield security fence and excludes building structures. The following areas are considered Landside: Peña Boulevard, East 74th Avenue, East 75th Avenue, East 78th Avenue, Jackson Gap Street, Gun Club Road, New Castle Street, East 71st Avenue, Valleyhead Street, East 68th Avenue, Quency Street, Quency Way, Queensburg Street, and East 114th Avenue.

1.3 Parking Facilities

Chapter 4- Parking Facilities provides design standards for all parking facilities at DEN including DEN-operated pay parking (Economy, Garage, Shuttle, Short Term, and 61st and Peña), employee parking, and other select parking facilities as determined by DEN such as tenant development and rental car

1.4 Utility Distribution

Chapter 5- Utility Distribution focuses primarily on the routing of utilities throughout DEN property and the general relationship between the various utilities servicing the airport. Details related to power distribution and electrical design can be found in the DEN Electrical DSM. Details related to water and natural gas piping and other mechanical systems can be found in the DEN Mechanical DSM.

1.5 Geotechnical

Chapter 6- Geotechnical references the latest edition of the Colorado Department of Transportation (CDOT) Geo-technical Design Manual for preliminary criteria on subsurface investigations of bridges, interchanges, culverts, and roadways.

1.6 ORAT Requirements

The Operational Readiness, Activation, and Transition (ORAT) team at DEN plays a critical role in ensuring that DEN’s Design Standards Manuals integrate operational requirements throughout the design and construction phases. By collaborating closely with project teams, architects, and engineers, ORAT ensures that the DSMs align with the airport’s functional and operational needs. This alignment is achieved by gathering feedback based on operational expertise, identifying potential challenges in facility layouts, and ensuring that the final design facilitates a seamless transition to full-scale operations. Program and project design teams are expected to be familiar with the DEN ORAT Standards Manual (OSM) and actively participate in ORAT-led meetings, charrettes, workshops, trials, and testing at the request of the DEN Project Manager.

End of Chapter

Chapter 2 - Airfield

2.0 Airfield Overview

2.0.1 Scope

The airfield is considered the area within the security fence excluding building structures. Different areas of the airfield are referred to as the west airfield, east airfield, commercial apron, cargo apron and Signature apron.

Figure 2-1: Fence and Airfield Area Map

2.0.2 Criteria

The main criteria for designing airfield infrastructure can be found in the Federal Aviation Admiration's (FAA) Series 150 Advisory Circulars (AC). Additional information for airfield engineering, design and construction can be found in the Airport Engineering Briefs from the FAA's Airport Engineering Division. The FAA regularly updates the AC's and engineering briefs which should be periodically checked during the define, development and design phases of the project.

Any new improvements on the airfield needs to follow the current AC including any revisions for Modifications of Standards previously approved by the FAA and any discrepancies identified in the annual Part 139 inspections. FAA guidance on taxiway design and other airfield design considerations can be found at the following site:

FAA Airport Design Technical Videos

General design criteria for roadways on the airfield should follow CDOT apart from criteria in this DSM outlined in Chapter 3- Landside Roadways and Bridges.

2.1 Geometry

Any new improvements on the airfield needs to follow the current FAA AC 150/5300-13b series geometry including any revisions for Modifications of Standards previously approved by the FAA and any discrepancies identified in the annual Part 139 inspections.

Conflicts may arise between existing and new geometry in current AC. In this situation, the designer should develop several alternatives to best resolve the conflict while maintaining the intent of the AC. Exhibits of the alternatives along with cost and schedule estimates should be included in the project Design Analysis Report (DAR). The DEN project manager should select the preferred alternative with applicable stakeholders' engagement and review with the FAA ADO. The FAA ADO should provide a recommendation before proceeding with final design.

2.2 Pavement Evaluations and Design

2.2.1 Pavement Design Criteria and Standard Pavement Sections

Airfield pavement shall be designed to support fleet mix, current and future, for 20 year life. Planning group should be consulted to verify current future fleet mix and volume.

FAARFIELD software shall be used for designing new pavement sections as per FAA AC 150/5320-6G. DEN has developed standard pavement sections to be used for the airfield. These have been developed over time and are standardized to keep aircraft pavement consistent throughout the airfield. FAARFIELD analyses should be compared to standard pavement sections. At a minimum Standard pavement sections should comply with FAA AC 150/5320-6G. If standard pavement sections exceed AC 150/5320-6G, project teams may determine whether deviating from standard pavement sections is acceptable, based on cost and application.

The standard pavement sections identified below should be utilized for all new airfield pavements to be constructed unless otherwise directed by the DEN Project Manager. Specifications for materials that make up the pavement section will be developed by the Designer of Record (DOR) but generally will meet the requirements of FAA AC 150. Standard pavement sections should be verified for compliance with FAA AC 150/5320-6G

2.2.1.1 Runway/Taxiway/Apron Pavement Areas

Pavement Layers:

A. Subgrade (P-152): To be designed by geotechnical contractor to account for swelling, frost layer, compaction, etc. Standard pavement design utilizes 5' of select fill, but this may be reduced with justification.

B. Cement Treated Soil Base Course (P-220): Not considered a 'stabilize base'

C. Cement Treated Aggregate Base Course (P-304):

D. Bondbreaker Geotextile Fabric

E. Portland Cement Concrete Pavement (P501): Flexural strength 650-700psi. Excessive cementation material can lead to brittleness and durability issues in concrete due to issues like thermal cracking from the heat of hydration and increased brittleness with age. While a proper cement content is crucial for strength, an excess can cause the concrete to become more fragile, reducing its ability to withstand stress, especially in applications requiring toughness like airport pavements.

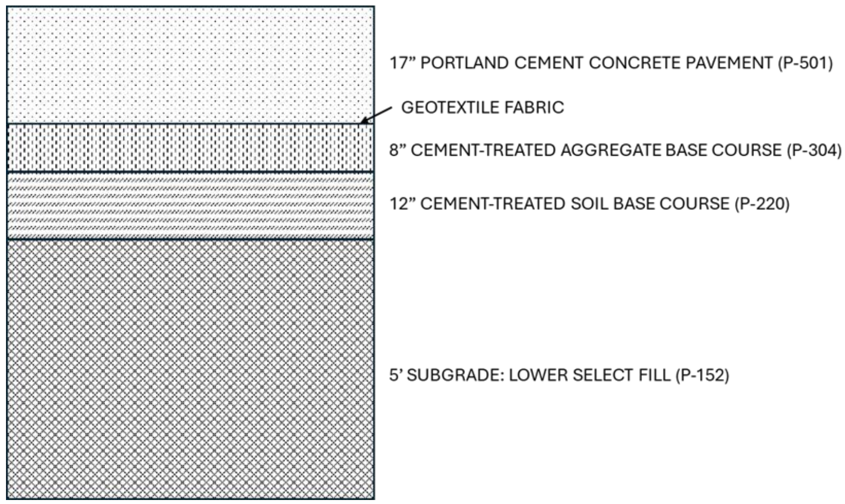

Figure 2-2: 17" Portland Cement Concrete Pavement

2.2.1.2 Standard Pavement Section for Taxiways, Runways and Aprons

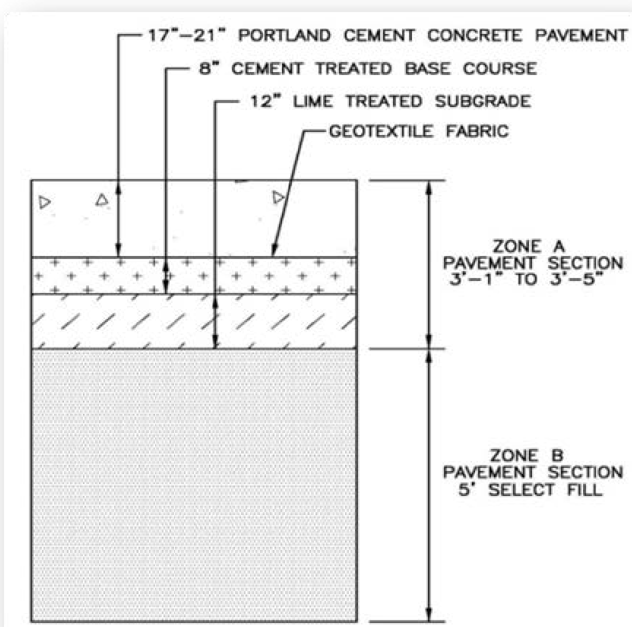

Figure 2-3: Standard Pavement — Runways/Taxiways/Aprons

The design of this standard pavement section was developed during the original construction of the airport and can be provided by DEN if required. This is the pavement section that is currently found on the airfield and should be utilized for all new Runway, Taxiway and Apron aircraft pavement unless otherwise directed by the DEN PM. The standard thickness of PCCP is 17-inches. Any thickened edge pavement will have a PCCP thickness of 21- inches.

2.2.1.3 Gate Apron Pavement Areas

Gate apron pavement areas utilize a standard pavement section design as shown in Figure 2-4. This standardized pavement design was developed as part of the GARDI Program (Gate Apron Rehabilitation and Drainage Improvement), which is a long-term project to systematically replace all apron pavement areas as they degrade. Historically, the pavement section at the gate apron was the same as the pavement section listed in the previous section (Runways/Taxiways/Aprons). The standard thickness of PCCP is 17-inches. Any thickened edge pavement shall have a PCCP thickness of 21-inches.

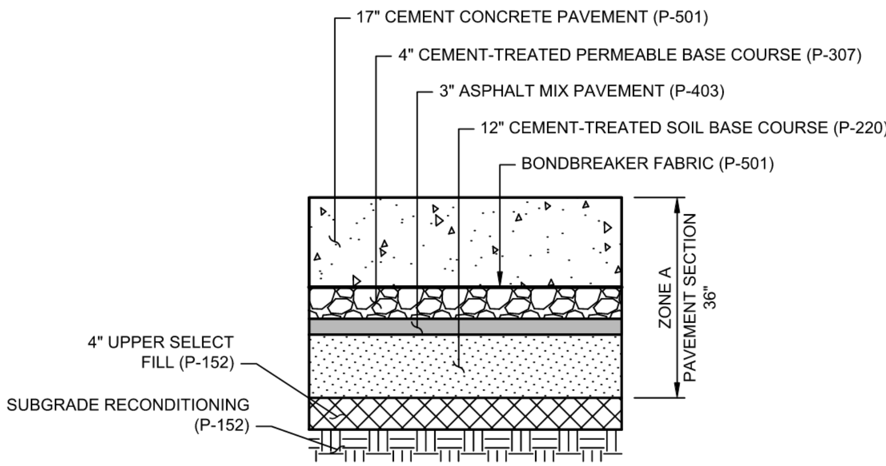

Figure 2-4: Standard Pavement Section - Gate Apron

2.2.1.4 Paved Shoulder Pavement Areas

Paved shoulders shall be designed using FAARFIELD software in accordance with Chapter 6 of FAA AC 150/5320-6G.

2.3 Utilities

Refer to Chapter 5- Utility Distribution.

2.4 Vehicle Service Roads (VSRs)

2.4.1 Introduction

There are approximately 68 lane miles of paved roadways located on the airfield and several miles of unpaved roadways which are located primarily along the perimeter fence. The two arterial VSRs with the heaviest trafficare Oakhill Street and Vandriver Street which each run north-south. Oakhill Street is located to the west of the concourses and Vandriver Street is located to the east of the concourses. The VSRs located in the non-movement area receive the heaviest amounts of traffic. Limited Access Roads (LARs) are VSRs restricted to certain airport personnel with a special badge designation and are located mostly near the movement area taxiways and runways.

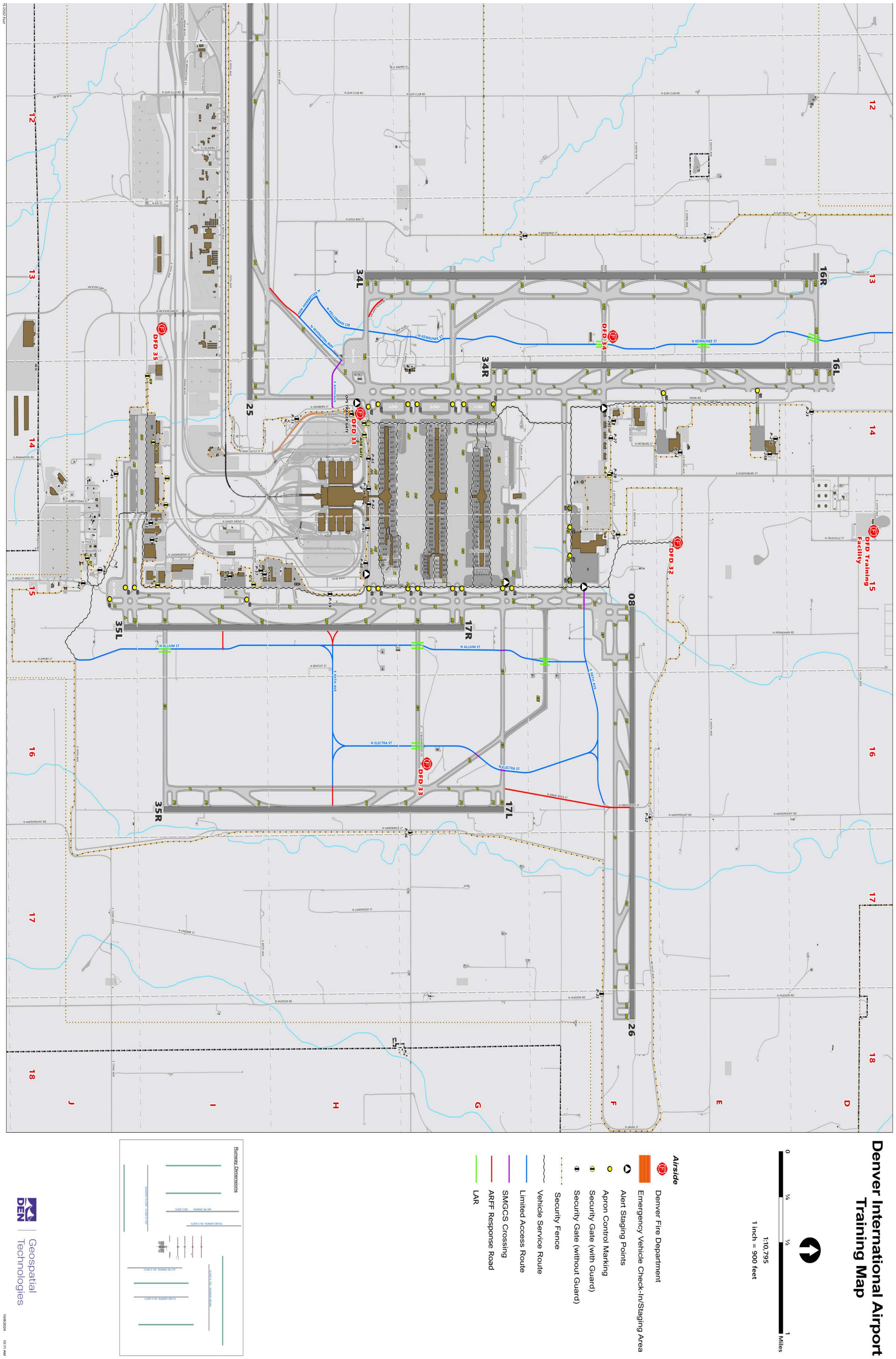

Figure 2-5: Airfield Roads Map

2.4.2 History

Many of the VSRs at DEN were built during original construction of DEN and the construction of VSRs was occasionally bundled with larger apron, taxiway, or runway projects during original construction. There have been a few VSR rehabilitation or improvement projects since the original roads were constructed. As-built record drawings are generally available for VSRs. In 2017, DEN hired a consultant to perform a pavement condition assessment of all paved VSRs and compiled this information into a final report and into the DEN PAVER database (See Pavement Assessment: Airside Vehicle Service Roads Volumes I and II dated April 20, 2018).

2.4.3 VSR Criteria

VSRs shall comply with all local, state, and national design criteria for roadways and more specifically those pre-scribed by AASHTO (American Association of State Highway and Transportation Officials) and CDOT. Either CDOT or FAA Technical Specifications may be used for roadway construction with concurrence from the DEN Project Manager.

VSRs and LARs have distinct striping and signage characteristics which are unique to DEN. In general, the DEN Graphics Shop has established standards for VSR/LAR signage and DEN Paint has established standards for striping which should be utilized on projects.

There are several VSRs that cross taxiways at DEN. These taxiway crossings shall comply with all applicable FAA Airport design standards including but not limited to Airport Design AC 150/5300-13, current edition.

2.4.4 Standard Pavement Sections

DEN does not currently utilize a standard pavement section for VSRs and the pavement section varies for each VSR. VSR Pavement design should be based upon localized traffic conditions, anticipated lifecycle costs, and under- lying soil conditions.

2.5 Airfield Lighting, Signage, Markings and Navigational Aids (NAVAIDS)

2.5.1 Introduction

The DEN airfield utilizes an extensive network of lighting and signage to guide aircraft engaging in operations both on the ground and in the air. These systems have been designed and maintained in accordance with FAA regulations, ACs, and related requirements.

DEN conducts periodic condition evaluations of the airfield lighting and signage system, along with continuously monitoring the circuit loads and cable megger data. The airfield lighting system is divided into four areas based on the lighting vaults; East Airfield, West Airfield, WC, and Concourses. All centerline taxiway lights and four of the six runways in-pavement lights have been converted to LED. Elevated edge lights for 3 of 6 runways and taxiways have been converted to LEDs.

2.5.2 Airfield Lighting Design Criteria

The DEN airfield utilizes an extensive network of lighting and signage to guide aircraft engaging in operations both on the ground and in the air. These systems have been designed and maintained in accordance with FAA regulations, ACs, and related requirements.

Applicable FAA ACs include, but are not limited to:

A. AC 150/5300-13 – Standards and Recommendations for Airport Design
B. AC 150/5340-30 – Design and Installation Details for Airport Visual Aids
C. AC 150/5000-13 – Guidance and Recommended Requirements for Surface Movement Guidance and Control System (SMGCS)

D. AC 150/5340-5 – Standards for Airport Marking Systems

E. AC 150/5340-18 – Standards for Siting and Installation of Signs on Airport Runways and Taxiways

F. AC 150/5340-26 – Guidelines for Maintenance of Airport Visual Aid Facilities

G. AC 150/5345-3 – Manufacturing Standards for Airport Lighting Control Panels

H. AC 150/5345-5 – Specifications for Airport Lighting Circuit Selector Switches

I. AC 150/5345-7 – Specifications for L-824 Underground Electrical Cable for Airport Lighting

J. AC 150/5345-10 – Specification for Constant-Current Regulators (CCRs) and Monitors for use with Airport Lighting Circuits

K. AC 150/5345-12 – Specifications for Airport and Heliport Beacons

L. AC 150/5345-26 – Specification for L-823 Plus and Receptacle for Use with Underground Power Cables, Isolation Transformer Leads, and Light Fixture Leads for Airport Lighting Systems

M. AC 150/5345-27 – Specifications for Airport Wind Cone Assemblies

N. AC 150/5345 -43– Specifications for Obstruction Lighting Equipment

O. AC 150/5345-44 – Specifications for Unlighted and Lighted Signs to be Used on Runways and Taxiways

P. AC 150/5345-45 – Specifications for Low-Impact-Resistant (LIR) Structures to Support Approach Lighting Systems (ALS)

Q. AC 150/5345-46 – Specification for Light Fixtures to be used on Airport Runways and Taxiways

R. AC 150/5345-55 – Guidance in Design of a Lighted Visual Aid to Indicate Temporary Runway Closure

S. AC 150/5345-53 – Airport Lighting Equipment Certification Program

T. AC 150/5345-42 – Specifications for Light Bases, Transformer Housings, Junction Boxes and Accessories

U. AC 150/5345-47 – Specifications for Series to Series Isolation Transformers for Airport Lighting

V. AC 150/5345-56 – Requirements for Airport Lighting Control and Monitoring System (ALCMS

Designs shall also comply with other applicable standards:

A. Illumination Engineering Society (IES) Recommended Practice RP-37 – Outdoor Lighting for the Airport Environment

B. DEN Design Standards Manuals

C. American Society for Testing and Materials (ASTM)

D. National Fire Protection Agency (NFPA) 70 – National Electrical Code

2.6 Grassing (Turfing)

A. DEN currently is under a Wildlife Hazard Mitigation Plan approved annually by the FAA as part of the Part 139 inspection. The USDA Wildlife Service staff should be consulted in the later stages of the design for the appropriate seed mix for all projects on airport property.

B. DEN routinely performs research with Colorado State University Agricultural Cooperative Extension Office for recommendations on seed mix, weed control and fertilizers. Please check with DEN's sustainability and environmental groups for the current recommendations.

C. Seeding and turfing may be seasonal based on manufacturer's recommendations. This needs to be considered based on the anticipated construction phasing and performance schedule to establish substantial growth for erosion control permit requirements.

D. Plans should show the limits of the project to be seeded and the quantities for each area identified. Small areas can be measured in square feet instead of acres. However, units of measurement for seeding should be consistent throughout the project including in the schedule of values.

E. Refer to the following items for additional information on wildlife hazards at airports:

a. AC 150/5200-33, Hazardous Wildlife Attractants on or near Airports
b. Airport Safety Wildlife Management, see link below:

Airport Safety Wildlife Management

2.7 Fencing and Blast Fencing

2.7.1 Fencing

A. For any permanently installed perimeter or security fencing, refer to FAA AC 150/5370-10H (or most current) Part 10 – Fencing.

B. Fence skirting shall comply with FAA Part 139 CertAlert #16-03 to mitigate wildlife from burrowing under perimeter security fence.

C. Temporary facilities on the airfield provided to a contractor for use during an airside project are required to be fenced in and secured using temporary, 6' chain-link fencing.

2.7.2 Blast Fencing

DEN has a limited supply of portable, temporary blast fencing available for use by the contractor for purposes of protecting their work site from excessive and potentially harmful jet blast. Blast fencing is available on a firstcome, first served basis, and there is no guarantee of availability. DEN Airside Engineering is the P.O.C. for requesting use of the blast fencing. It is the responsibility of the contractor to load, transport, set, maintain, and return to the designated storage area any blast fencing requested for use on a project.

2.8 Recycling, Disposal, and Decommissioning

2.8.1 Recycling

A. All removed asphalt and concrete pavements shall be delivered to a DEN Recycle Yard in accordance with Division 01 – General Requirements, Section 017419 – Construction Waste Management.

B. DEN operates two Concrete and Asphalt Recycling Yards for stockpiling and processing concrete and asphalt materials generated on the DEN projects. The recycle yards will be used as a staging area for the sizing and crushing of asphalt and concrete removed from DEN construction projects. Only material coming from an approved DEN construction project will be accepted into the recycle yards.

C. DEN has developed and utilizes technical specification P-159 Concrete and Asphalt Crushing.

D. Refer to the DEN Concrete and Asphalt Recycle Yards Standard Operating Procedures (SOP) document for more information.

E. Materials should be evaluated and if necessary tested for PFAS prior to utilizing recycling yards.

2.8.2 Disposal

City and County of Denver Executive Order 115 requires the direction of all non-hazardous waste to the Denver Arapahoe Disposal Site (DADS) Landfill located on Gun Club Road.

2.9 Site and Yard Preparation and Layout

Temporary facilities for purposes of laydown yard, batch plant site, staging, etc., are project specific and must be indicated on the record drawings. Coordination and planning for these sites is accomplished during planning and design by DEN Airside or Landside Engineering, DEN Airside Operations and DEN Tactical Planning.

2.10 FAA Review

The Denver ADO FAA PM may attend pre-design meeting and design progress meetings to review and comment on all design deliverables for projects receiving FAA funding.

2.11 Hall Routes and Traffic Control

Haul routes to/from project sites within the AOA must be planned and coordinated during design with DEN Airside Operations, DEN Tactical Planning, DEN Safety, DEN Security, and the DEN Project Manager.

2.12 Aircraft De-Icing Facilities

2.12.1 Overview

Aircraft deicing may be located at concourse gates or fixed aprons (pads) remote from the terminal complex.

Facility and equipment shall be standardized and developed for joint use by all carriers, thus creating more cost-effective and efficient development, and operations.

Dedicated, fixed deicing aprons (pads) and facilities shall be planned and located in accordance with the Airport Layout Plan. The size and number of deicing positions shall be based on the projected peak hour departure capacity of the respective runways served.

Each runway end does not need a deicing apron; only those planned or existing preferred winter departure runway ends that are normally used in adverse winter weather.

Deicing aprons shall be located to permit all facilities and aircraft to clear FAR Part 77 and TERPS (Terminal Instrument Procedures Manual) imaginary surfaces and Instrument Landing System (ILS) critical area. They shall be close enough to the departure runway end to accommodate immediate departure +/- 5 minutes.

2.12.2 Deicing and Industrial Waste Water (DIW) Drainage

The DIW system is designed to handle spent Airport Deicing Fluid (ADF) prior to discharge to the Metro Wastewater Reclamation District (Metro) and/or for recycling of high-concentration spent ADF. The DIW collection system is comprised of a network of trench drains, drainage pipes, and underdrains that convey surface water runoff from aircraft deicing pads and apron areas, in combination with spent ADF, to six (6) on-site retention ponds (Ponds 001, 002, 003A, 004, 005, and 009) and several storage tanks. Temporary storage for runoff from these areas is provided by interconnected Ponds 001, 002, and 009, and above-ground tanks at the Recycling Facility. Figure 1-1: DEN Overall Property Map shows an overall plan of the DIW system facilities.

Full deicing and anti-icing operations for the East and West concourse areas occur at dedicated Deicing Pads (A, B, C, J, WA). Runoff from these dedicated Deicing Pads is collected in above-ground storage tanks and/or Pond 300A to be processed at the glycol Recycling Facility.

2.13 Construction Administration and Field Engineering Services

2.13.1 Construction Administration (CA)

Services during construction by a consultant are intended to assist DEN in administering the contract for construction in responding to events during the construction phase. During the construction phase, the consultant will be required to perform CA duties outlined below, but not limited to:

A. Attend pre-construction conference

B. Prepare a submittal register

C. Attend weekly construction, pre-work, and all other required meetings

D. Provide monthly written reports of project progress

E. Provide daily field observation reports

F. Assist with interpreting the requirements of design deliverables

G. Review submittals

H. Review and reply to Requests for Information (RFIs)

I. Review deficiencies and Non-Conformance Requests (NCRs)

J. Review and analyze contract revisions

K. Provide updated plan sheets for any changes

L. Prepare any schematic drawings or exhibits for distribution

M. Maintain and update the BIM Models

N. Review all survey and test results reports

O. Assist in identifying punch list and warranty items

P. Assist in the Consultant Project Closure process

Q. Prepare Record Drawings based on marked up drawings from the Contractor

R. Incorporate all changes and deviations between the IFC specifications and actual work performed.

S. Provide an updated final DAR

2.13.2 Field Engineering Services

Field Engineering Services during construction by a Consultant are intended to assist DEN in observing construction related activities in the field in order to ensure the Contractor is following all construction documents as intended by the designer, including the most current plans, specifications, guidelines, and general requirements. During the construction phase, the Consultant will be required to perform duties outlined below, but not limited to:

A. Attend Pre-Construction Conference

B. Attend Weekly Construction, Pre-Work, and all other required meetings

C. Provide monthly written reports of project progress

D. Report any obstacles and safety concerns

E. Provide daily field observation reports

F. Review submittals

G. Review and reply to RFIs

H. Review deficiencies and NCRs

I. Provide recommendations for any field change items

J. Assist in identifying punch list and warranty items

2.14 Closeout and Lessons Learned

2.14.1 Closeout

The Consultant shall meet all requirements as detailed in the Contract/Task Order prior to the acceptance of the Consultant's work. The closeout requirements can be found in the most current Standards and Criteria Design Standards Manual, Chapter 10 – Design Contract Closeout/Task Closeout.

2.14.2 Lessons Learned

Lessons Learned meetings provide feedback from all parties associated with or affected by a project. This feedback provides information which can increase effectiveness and efficiencies, and to build on the experience which has been earned for future projects. The Consultant shall attend a minimum of one Lessons Learned meeting with the DEN team, Contractor, and all other necessary parties at the conclusion of the project. Any intermittent Lessons Learned meetings shall also be attended by the Consultant, as directed by the DEN.

End of Chapter

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Chapter 3 - Landside Roadways and Bridges

3.0 Overview

This chapter provides guidance to design standards for all primary and secondary roadways and bridges, outside the airfield security fence, and excludes building structures. Landside areas include Peña Boulevard, East 74th Avenue, East 75th Avenue, East 78th Avenue, Jackson Gap Street, Gun Club Road, New Castle Street, East 71st Avenue, Valleyhead Street, East 68th Avenue, Quency Street, Quency Way, Queensburg Street, and East 114th Avenue. It is understood that design requirements change and are updated over time. The designer shall notify DEN if information in this chapter is out of date or conflicting with standard industry practice. Deviations to these guidelines can be discussed with DEN on a case-by-case scenario and will need to be approved by DEN prior to making any changes. DEN will update these manuals as necessary.

3.1 Criteria

The Consultant shall use the latest version of CDOT M and S Standards, Standard Specifications, Standard Special Provisions, Project Special Provisions, Roadway Design Guide, and Bridge Design Guide for all specifications and design. Additional resources may include, but are not limited to, the latest version of the Manual on Uniform Traffic Control Devices, AASHTO A Geometric Design of Highways and Streets (Green Book), AASHTO Roadside Design Guide, and AASHTO LRFD Bridge Design Specifications, or any other AASHTO publication for the design of roadways and bridges.

All horizontal and vertical geometry for Roadways shall meet all requirements of the latest edition of the AASHTO A Policy on Geometric Design of Highways and Streets (The Green Book).

Stopping sight distances and decision sight distances shall meet or exceed the requirements described in Table 3-1: Roadway Design Criteria. Stopping sight distances shall be determined in accordance with the AASHTO A Policy on Geometric Design of Highways and Streets.

Application of Roadway sight distance triangles required for the Design of Roadway intersections shall be in accordance with the AASHTO A Policy on Geometric Design of Highways and Streets.

3.2 Intersection Design

Curb Ramps shall be constructed in accordance with City and County of Denver Transportation Standards and Details.

Curb returns shall be constructed to meet the design vehicle requirements. Turning movement and curb return designs shall account for:

A. Where constraints require, the design vehicle turning movements may utilize receiving lanes;
B. Where double left turns are implemented, simultaneous turning movements of the design vehicle are required; and
C. Consideration of best practices for pedestrian/bike/handicap designs shall be implemented.

Note: Design items not listed shall meet criteria as shown in the AASHTO Green Book.

Table 3-1: Roadway Design Criteria

Design Data	Peña Blvd (IB/OB)		Ramps Jackson Gap and Gun Club	New Castle Direct Connect Ramps	Return to Terminal Jackson Gap	71st Ave, 75th Ave, 78th Ave	Jackson Gap, Gun Club, 74th Elk, New Castle
	Jackson Gap to Curve	Curve to Terminal					
Design Speed (mPH)	60	50	55/45/30	25	20	50	35
Posted Speed (mPH)	55	45	-	-		45	30
Roadway Classi-fication	Expressway	Expressway	Ramp	Ramp	Ramp	Aterial	Arterial
Design Vehicle	WB-62	WB-62	WB-62	WB-62	WB-62	WB-62	WB-62
RADIUS (Ft) (Min)	1330'	833'	1060'/ 643'/340'	1644'	81'	833'	408'
Emax (%)	6%	6%	6%	4%	6%	6%	NC
Normal Cross Slope	2%	2%	2%	2%	2%	2%	2%
Superelevation Rate	AASHTO 2011- TABLE 3-10b						
Terrain Classification	Level	Level	Level	Level	Level	Level	Level
Max Grade	3%	3%	4%	4%	4%	3%	3%
Min Grade	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%
Min. Length of Horizontal Curve (Ft)	15 X Design Speed						
Min. Length of Vertical Curve (Ft)	3 X Design Speed						
Min Vert Clearance (Ft)	16.5'	16.5'	16.5'	16.5'	16.5'	16.5'	16.5'
Min Lane Width (Ft)	12'	12'	12'/15'	12'/15'	12'/15'	12'	12'

Table 3-1: Roadway Design Criteria (Continued)

Design Data	Peña Blvd (IB/OB)		Ramps Jackson Gap and Gun Club	New Castle Direct Connect Ramps	Return to Terminal Jackson Gap	71st Ave, 75th Ave, 78th Ave	Jackson Gap, Gun Club, 74th Elk, New Castle
	Jackson Gap to Curve	Curve to Terminal					
Rt Shoulder Width (Paved) (Ft)	12'	12'	8'	8'	8'	4'	4'NA, CURB & GUTTER
Lt Shoulder Width (Paved) (Ft)	12'	12'	4'	4'	4'	4'	4'NA, CURB & GUTTER

3.3 Pavement Design

Roadway pavements shall be designed in accordance with the latest version of CDOT M-E Pavement Design Manual, utilizing AASHTOWare Pavement M-E Design software (M-E Design software).

The material properties of the pavement, base, sub-base, and subgrade shall also follow the CDOT M-E Pavement Design Manual.

Concrete mixes from CDOT's material databases shall be used in all M-E Design analysis. Generic, nationwide, or similar, samples of concrete shall not be utilized in the analysis.

Pavement Designs shall use the parameters listed in Table 3-2: Minimum M-E Design Parameters.

Table 3-2: Minimum M-E Design Parameters

Parameter	Input
Reliability	95%
Two Way average annual daily truck traffic (AADTT)	Per Traffic study and CDOT M-E Pavement Design Manual
Number of Lanes in Design Direction	Based on Design
Percent of Trucks in Design Direction	Per CDOT M-E Pavement Design Manual
Percent of Trucks in Design Lane	Per CDOT M-E Pavement Design Manual
Operational speed (in miles per hour [mph])	Based on Design
Vehicle Class Distribution (CDOT)	Based on Traffic Study used to determine AADTT
Growth rate %	Based on Traffic Study used to determine AADTT
Growth function	Compound
Climate station	DEN

Table 3-2: Minimum M-E Design Parameters (Continued)

Parameter	Input
Depth of Water Table	Based on Geotechnical Report
Design life (Rigid) (New Construction)	30-year minimum
Performance criteria thresholds	Per CDOT M-E Pavement Design Manual

Note: All M-E designs shall use 12-foot design lane width. Modification of the design lane width will require appropriate modification of the traffic wander deviation and supporting justification for the modification. All PCCP designs shall be based on a 15-foot joint spacing.

3.3.1 Pavement Smoothness

Roadway smoothness requirement are set forth in Table 3-3: Smoothness Requirements.

Table 3-3: Smoothness Requirements

Location	Pavement Smoothness Category
Rigid Pavement	MRI Category II (Inches/mile)
Flexible (HMA) Pavement	MRI Category II (Inches/mile)
Structures	MRI Category II (Inches/mile)

3.4 Clearances

Overhead signs and future message display boards should be designed with a minimum vertical clearance of 17.5 feet, measured from the high point on the roadway surface.

Minimum vertical clearance of 16 feet, 6 inches (from Traveled Way and outside edge of Shoulder) shall be provided for all grade separations.

3.5 Lanes and Shoulders (Typical Sections)

3.5.1 Roadside Clear Zones

Clear zones shall be designed in accordance with the recommendations of the latest edition of the AASHTO Road-side Design Guide and to avoid the need for guardrail wherever possible. Where clear zones cannot be obtained, guardrail shall be required.

3.5.2 Roadside Slopes Adjacent to Pavement

Note: All slopes stated herein are in terms of horizontal: vertical.

The Point of Slope Selection (POSS) is defined as the location at which the roadside slope adjacent to the pavement ends, and the cut, or fill slope begins.

3.5.3 Roadside Fill Slopes

Fill slopes beyond the POSS shall be Designed and Constructed in accordance with the following:

A. Use 6:1 slopes where fill heights are less than four-feet;

B. Use 4:1 slopes or flatter where fill heights are greater than four-feet and match existing surface conditions. Where existing surface conditions cannot be matched, use retaining walls;

C. All fill slopes shall be rounded at their tops and toes or ties to existing ground to provide for a pleasing appearance.

3.5.4 Roadside Cut Slopes

Cut slopes beyond the POSS shall be Designed and Constructed in accordance with the following:

A. Use 4:1 maximum front slopes and 4:1 maximum back slopes for all roadside cut slopes. Where existing surface conditions cannot be matched within Project Limits, or as practical, use retaining walls.

B. All cut slopes shall be rounded at their connection to existing ground to provide for a pleasing appearance.

C. Cut slope areas shall be designed with ditches or closed storm sewer systems, as necessary.

3.5.5 Safety Edge and Shouldering

Safety edge for pavement shall be designed in accordance with the latest edition of the CDOT Standard Specifications for Road and Bridge Construction and the CDOT M-Standard Project Special Details, detail D-614-1 Safety Edge for Pavement. All roadways without curbs shall have four feet of shouldering material placed to a minimum depth of four inches from the outside edge of pavement consisting of Aggregate Base Course Class 6 or other approved material.

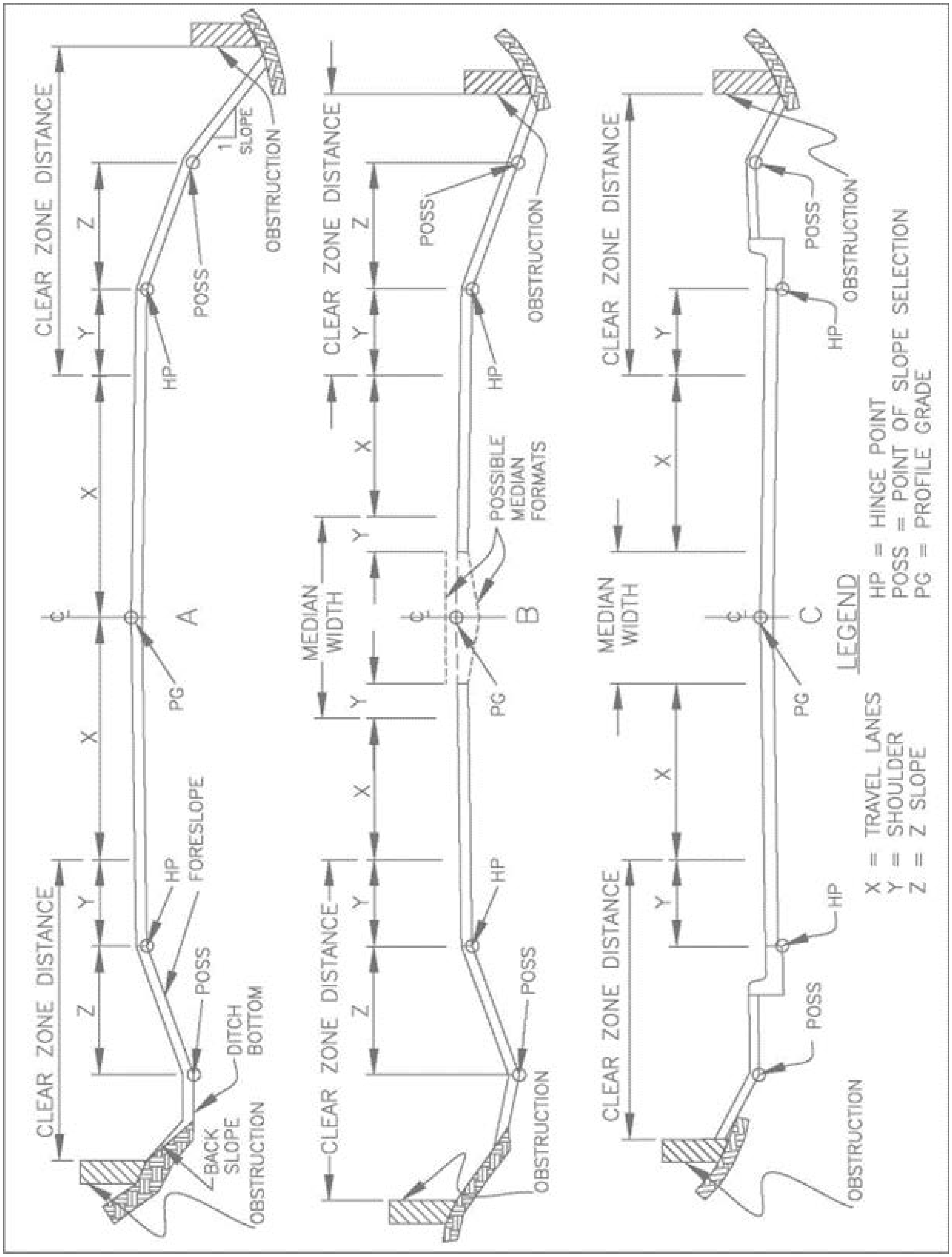

Figure 3-1: General Cross-Sectional Information

3.6 Pavement Markings and Roadway Signs

Table 3-4: Pavement Marking Materials

Location	Pavement Marking Type
Edge lines and channelization lines	Modified Epoxy Pavement Marking
Broken lines of any type on Portland concrete cement pavement (PCCP)	Preformed Plastic Pavement Marking (Type II) (Inlaid) (contrast)
Broken lines of any type on Hot Mix Asphalt (HMA)	Preformed Plastic Pavement Marking (Type II)
Word/symbols/cross walks/stop lines with contrasting border or shield	Preformed Plastic Pavement Marking (Type 1)

Signing, striping, and pavement markings are in accordance with Federal Highway Administration (FHWA) Manual on Uniform Traffic Control Devices (MUTCD). Peña Boulevard should be considered an urban freeway and all MUTCD Standards and Guidance for such should be applied.

Terminal designations, and other major destinations, will require elongated route shields and/or terminal designations.

All guide signs for IB Peña Boulevard shall include both wording for Peña Boulevard and an airplane symbol.

Mile posts on Peña Boulevard should be installed at a minimum of every even mile.

Exit numbers should be established consistent with MUTCD standards and Peña Boulevard mile posts. Exit numbers should be applied to guide signs per MUTCD standards.

No signs are to be installed on roadway Bridge structures.

Sign structures shall be Designed in accordance with the latest edition of CDOT Standard Plan S-614-50 and S-614-60.

Sign lighting and walkways shall not be used on overhead sign structures except for the overhead airline message sign/display board locations.

All signs must meet CDOT and AASHTO retro-reflectivity standards.

All ground mounted signage, delineators, etc., shall be installed within a full depth polyvinyl chloride (PVC) sleeve at locations where the device is installed within concrete sidewalk, median cover material, concrete pavement, slope paving, etc.

Wood posts for mounting permanent ground signs shall not be used.

Delineators shall be steel post or Shur Tite for flexible post applications.

Sheeting shall be Type IV and Type XI, as defined in the CDOT Retroreflective Sheeting Materials Guide, and shall conform to subsections 713 when applicable. For all permanent signs, the legend, borders, and background shall be Type XI.

3.7 Bridges and Structures

All new bridges and bridge widenings shall maintain a consistent appearance with the existing structures. All new walls shall maintain a consistent appearance with the existing structures.

Drainage systems for inlets on bridges shall limit flow across the expansion device to less than one cubic feet per second (cfs) for the 10-year storm.

Bridge deck drainage systems shall be designed in accordance with the FHWA HEC-21 Design of Bridge Deck Drainage.

No signs are to be installed on roadway bridge structures.

The use of lightweight concrete will not be allowed.

Minimum design concrete strengths shall meet the requirements of Section 601 of the CDOT Standard Specifications for Road and Bridge Construction.

Maximum design concrete strengths used for design shall be in accordance with CDOT's Bridge Design Manual (BDM).

All design is to be completed in accordance with AASHTO Load Resistance Factor Design (LRFD) Bridge Design Specifications, latest edition, with current interim revisions, except as otherwise noted.

All Design calculations and plans shall be performed in English (standard) units.

Bridges shall be Designed in accordance with all provisions of CDOT's current interim edition BDM.

Bridge superstructure types that require temporary falsework or shoring for construction and require a full closure of Peña Boulevard or any other roadway are not allowed. All falsework shall be designed in accordance with the AASHTO Guide Design Specifications for Bridge Temporary Works, First Edition with current interim revisions.

A safety railing shall be provided at the top of all new and extended culvert ends greater than four feet of exposed height

3.7.1 Loads and Forces

All structures, except as otherwise noted in this section will be designed for loads and forces in accordance with the current interim edition of the AASHTO LRFD Bridge Design Specifications and CDOT's BDM, or as stated herein.

Architectural elements and components to be constructed as part of bridges, retaining walls, and sign structures shall be designed using the appropriate current AASHTO specifications.

3.7.1.1 Live Loads

All new highway bridges, box culverts, retaining walls, and new bridge elements for highway bridge widenings shall be designed using the live loads defined in the current interim edition of the AASHTO LRFD Bridge Design Specifications and CDOT's BDM. All highway bridges shall also be designed for the Colorado Permit Vehicle at Strength II. Impact loads (dynamic load allowance) for highway bridges shall be as per the AASHTO LRFD Bridge Design Specifications. Existing bridge elements for widenings shall satisfy the live load requirements they were originally designed for.

3.7.1.2 Dead Loads

All highway bridges shall be designed to account for future loads of a three-inch asphalt overlay wearing surface and waterproofing membrane.

3.7.1.3 Uplift

All bridge spans shall be proportioned to avoid uplift at supports due to non-seismic loads.

3.7.1.4 Thermal Forces

All new bridges shall be designed using temperature ranges as indicated in Section 14 of CDOT BDM for moderate climates per the AASHTO LRFD Bridge Design Specifications.

3.7.1.5 Seismic

All new bridges shall be designed for seismic requirements in accordance with the AASHTO LRFD Bridge Design Specifications.

3.7.1.6 Load Rating

All new highway bridges, box culverts and extended portions of existing box culverts, and bridge widenings shall be rated in accordance with the AASHTO Manual for Bridge Evaluation, Second Edition with current interim revisions and the CDOT Bridge Rating Manual. New structures designed in accordance with the LRFD Design Specification shall be rated by the Load and Resistance Factor Rating (LRFR) method. Structures that are not designed in accordance with the AASHTO LRFD Bridge Design Specification shall also be rated using LRFR. However, should the LRFR rating be insufficient, the Structure shall be rated by the Load Factor Rating (LFR) method. Both the LRFR rating and the LFR ratings shall be submitted to DEN.

The following software shall be used to load rate all major and minor Structures: AASHTOWare Bridge Rating (BrR).

Any temporary Bridges shall be load rated for HL93 and CDOT Permit Vehicles.

3.7.1.7 Wind Loads

All highway bridges, and other structures shall be designed for the wind loads specified in the AASHTO LRFD Bridge Design Specifications. Design wind speed shall be 100 mph.

3.7.1.8 Collision Loads

All bridges shall be designed for the collision loads specified in AASHTO LRFD Bridge Design Specifications unless specified otherwise.

All new bridges and bridge widenings shall maintain a consistent appearance with the existing structures. The superstructure shall match existing and the bottom elevation of girders shall be matched for visual appearance. Girders, on an individual bridge, shall have a consistent depth along the bridge to the greatest extent possible.

All new walls shall maintain a consistent appearance with the existing structures.

3.7.1.9 Geometry

All fill and cut slopes along the longitudinal axis of bridges with spill-through abutments shall not be steeper than 2:1 (H:V) perpendicular to abutment. There shall be a 2-foot minimum width berm at the top of the slopes at the front face of abutments and a 2-foot minimum vertical dimension from the top of this berm to the bottom of girder. Minimum vertical clearance of 16 feet, 6 inches (from traveled way and outside edge of shoulder) shall be provided for all grade separations. For bridge widenings, new slope paving shall be required.

3.7.1.10 Structure Type

All bridge and retaining wall types shall follow the guidelines in the CDOT BDM unless otherwise specified. Other types will be allowed, but only if they have been Accepted for general use by other state or federal transportation authorities and Approved by DEN. Bridge types shall allow for and facilitate future bridge widening unless Approved by DEN. Avoid the use of fracture critical bridges.

3.7.1.11 Inspection Access

All bridge superstructures, joints, and steel reinforced elastomeric bearing pads with sliding surfaces and high load multi-rotational (HLMR) bearings shall be made accessible for long-term Inspections and maintenance and shall be designed and detailed for ease of replacement.

All concrete box girders with an inside depth of four feet or more shall be made accessible for interior Inspection. All pretensioned precast concrete box or tub girders with access shall be provided with low-point Drainage through the bottom slab.

Access doors shall be placed at locations that do not impact traffic under the bridge and shall be accessible with ladders from the ground and shall not require access by use of an inspection truck. Where access doors are provided above tiered MSE walls, cleats to support a ladder shall be provided in the slope paving and on steel girders. CDOT Standard Structural Worksheet B-618-2 shows typical bottom-slab access-door details. The doors shall swing into the box girder. Box girders shall be protected from access by vermin. The minimum opening for access doors shall be two feet by three feet and door shall be secured by a single padlock. Access holes through diaphragms shall be two feet, six inches in diameter, minimum. Access doors shall include lock protectors.

3.7.1.12 Bridge Rails and Pedestrian Fencing

Bridge rails shall be designed to match the face, color, and overall shape of existing barriers. Bridge rail shall be used on approach slabs. Railing shall be designed in accordance with AASHTO LRFD Bridge Design Specifications. Bridge rails subject to vehicular impact shall be designed to meet TL-4 loading in accordance with AASHTO LRFD Bridge Design Specifications. Current CDOT bridge rails that meet the above criteria, such as Type 10M bridge rails, are Acceptable and do not have to be designed or crash tested. Only 10M bridge rails will be used on new bridges unless Approved.

Structures over railroads shall include chain link fence (special) (120-inch) attached to the Type 10M bridge rail posts.

3.7.1.13 Approach Slabs

An approach slab shall be designed for each end of all bridges. All approach slabs shall be a minimum of 20 feet in length measured along the centerline of the bridge, except when other physical features preclude this minimum length. For bridges that are less than 50 feet wide (i.e., edge of deck to edge of deck), the end of the approach slab (i.e., adjacent to pavement), including expansion joint, shall be placed normal to centerline of roadway. Approach slabs shall be separate from, and fit between, cantilevered wingwalls or retaining wall wingwalls so that the approach slab can freely rotate about the abutment. The approach slab for highway bridges shall be at least the same width as the bridge deck and provide for expansion and contraction at the approach pavement interface where required. Approach slabs shall be anchored to the abutment. Design shall include an underdrain system beneath the entire approach slab to remove water at bridge abutments. Backfill behind the abutments shall be as shown in the CDOT Bridge Structural Worksheets Backfill Drawings B-206-F1 or B-206-M1. Bridge approach slab drains shall be located so as to minimize the amount of water flowing across all joints.

3.7.1.14 Bridge Decks

Minimum concrete deck thickness shall be eight inches. Refer to CDOT BDM Section 9 for additional requirements. Full depth precast deck slabs shall require cast-in-place joint closures, post-tensioning across joints and an overlay. Pretensioned, precast concrete deck forms shall be a minimum of three inches thick and have a full grout or concrete bearing. Full grout is defined as a one-inch minimum thickness by two-inch wide grout pad. Stay-in- place metal deck forms are permitted.

If stay-in-place metal forms are used, the superstructure, substructure, and foundation shall be designed for an extra five psf minimum dead load applied to the Superstructure. Permanent deck forms will not be allowed for cast-in-place post-tensioned box girders, T-girder deck slabs, or cantilevered portions of decks. Cast-in-place con- crete placed on top of a precast double tee or precast box girders shall be considered composite with the precast top flange if the minimum total laminated deck thickness is eight-inches, the minimum cast-in-place thickness is five-inches and the top surface of the precast top flange is roughened. Precast double tees or precast box girders without a cast-in-place deck placed on top will not be allowed. Minimum longitudinal steel in the top mat of cast- in-place decks shall be #4s at six-inch spacing spliced to the negative-moment steel reinforcing over piers. Expos- ure factor shall be 0.75.

3.7.1.15 Deck Joints

Deck design shall avoid or minimize joints wherever possible. Bridges shall be jointless between the ends of approach slabs, wherever possible, according to guidelines given in CDOT's BDM Section 14, except that for Bridges less than 250 feet, expansion joints at the ends of approach slabs are still required. A minimum zero to four-inch joint shall be placed at the end of approach slabs. Only strip seals for joints as reflected in CDOT Bridge Structural Worksheet - Bridge Expansion Device (zero two four-inch) B-518-1, or DEN Approved equal, with expected maximum 4-inch movement or modular joints for expected movements of 4 inches or greater shall be allowed. Design and location of joints shall provide for maintenance accessibility and future replacement.

Aluminum joints will not be permitted. Modular joints shall be designed by LRFD and shall include LRFD fatigue requirements. Modular joints shall be tested for fatigue loading according to National Cooperative Highway Research Program (NCHRP) Report 402, Fatigue Design of Modular Bridge Expansion Joints (1997) Appendix A and Appendix B. All expansion devices shall be set to provide a smooth surface between the final grade into the device and the final grade out from the device. A smooth surface is defined as a maximum grade break, at or 30 feet either side of the device, of 0.2%. To facilitate the proper placement of expansion devices, the tabular bridge geo- metry shall include a bent line for the expansion devices on a bridge or approach slab. Asphaltic expansion devices and asphaltic plug joints shall not be used for any new construction.

End dam on approach slab shall be designed to accommodate wearing surface provided on the bridge.

3.7.1.16 Overlays

All new bridge decks will be designed with an initial overlay system. Bridge deck overlays shall be a minimum ¾-inch thin-bonded overlay (polyester concrete) on the bridge deck and approach slabs. The overlay shall be used on both the bridge deck and associated approach slabs.

3.7.1.17 Superstructure

All new Superstructure elements must be designed to meet the requirements for redundancy, fatigue, crack control, and deflection as specified in the AASHTO LRFD Bridge Design Specifications and CDOT's current interim edition BDM.

Utilities to be supported by structures shall be submitted to DEN for Approval no later than 30 days prior to construction. Utility supports and other details shall be designed by a Professional Engineer licensed in the State of Colorado. Utilities shall be hidden from view in superstructure elevation. Bridge deck drainage or anti-icing pipes shall not be allowed inside of box girders or embedded within concrete structural members.

The design of cast-in-place concrete box girders shall include the weight of any stay in place the deck forms in the design of the superstructure, substructure, and foundation.

The maximum shear reinforcement spacing for cast-in-place mildly reinforced or post-tensioned concrete bridges shall be 18 inches. The minimum amount of shear reinforcing per web for prestressed concrete girders shall be at least $A_v=135 \times b'/f_y$, with b' the web width in inches, and fy the yield strength of the shear reinforcing in pounds per square inch (psi). Webs shall have at least double this minimum reinforcement for a distance d in front of anchorages. The minimum spacing of the skin reinforcement shall be 1.5 times the minimum shear steel for areas more than the depth of girder from the supports and shall be spaced at 12 inches maximum. All reinforcing steel shall have a minimum two-inch clearance between parallel bars including spirals.

Under full dead load, without live load and after all losses, no part of the top or bottom girder fiber which resists moments using post-tensioning shall be in tension. Under full loads, after losses, tension due to live load will not be permitted if well distributed fully bonded reinforcing is not provided in these areas. For girders spliced between supports, no tension is permitted at the interfaces between the precast and cast-in-place concrete splice under Service III load conditions.

Girder camber for pre-tensioned, precast concrete box girders and BT girders shall be designed in accordance with CDOT's current interim edition BDM. Girder sag is not permitted in precast concrete members. Refer to CDOT's current interim edition BDM for additional design requirements and allowable stresses, except that ten- sion is permitted in the tops of precast, pre-tensioned concrete girders in pre-compressed tensile zones in accord- ance with AASHTO LRFD Bridge Design Specifications.

The minimum concrete strength (f'c) shall be 4.5 ksi for any cast-in-place concrete member which forms part of a deck.

When utilizing continuity for design of precast prestressed girders, the effects of differential shrinkage, differential temperature, and any redistribution of moments due to creep shall be investigated. The transverse steel area in precast box girder flanges shall, at a minimum, be equal to the minimum required shear reinforcing steel for one web.

Precast girders used in segmental or spliced girder construction shall be bonded with epoxy or concrete closure pours. The top surface of precast deck panels shall be roughened perpendicular to the longitudinal axis of the bridge to ensure composite action between the precast and cast-in-place slab. The minimum amount of non-prestressed longitudinal steel required in the cast-in-place portion of the slab shall be 0.2 square inch per foot width of slab.

3.7.1.18 Bearings

Design shall locate bearings to allow Inspection, maintenance accessibility, and future replacement. Substructure drawings shall show locations for lifting when removing bearings. Elastomeric pads and steel reinforced elast-omeric bearings, with or without sliding surfaces, are the preferred bearing types. Sliding surfaces shall be poly-tetrafluoroethylene (PTFE) with a stainless-steel mating surface. Bearings shall be either elastomeric pads (CDOT Type I), steel reinforced elastomeric bearings with or without PTFE and stainless-steel sliding surfaces (CDOT Type I or Type II), or HLMR bearings (CDOT Type III). The thickness of Type II bearings shall be designed so that the acceptable shear deflection limits of the pad are not exceeded if slip does not occur. The design of elastomeric pads and steel reinforced elastomeric bearings shall be such that pad walk-out will not occur by including pad- walkout restraints.

Sole plates shall have a 3/4-inch minimum thickness. At expansion bearings, the edge of the sole plate shall not slide past the edge of the elastomeric pad by the use of a positive stop. Bearing design shall provide at least three inches of cover between anchor bolt centerlines and the edge of the concrete pedestal and shall provide rein-forcement for pedestals greater than three inches high. For new bridges, only one bearing type shall be used across the width of the bridge at any given substructure location. Elastomeric pads and steel reinforced elast- omeric bearing devices shall not be mixed with HLMR bearings at any one particular bridge. The maximum bearing height for Type I bearings shall be seven (7") inches. Thermal movements shall be calculated using AASHTO LRFD Bridge Specifications Procedure B and CDOT's current interim edition BDM Section 14. Design of leveling pads for integral Bridges are excluded.

3.7.1.19 Piers and Pier Caps

The design of all pier and pier caps will be of a type that will be consistent with the existing bridge piers. Drop caps or integral caps are acceptable. Integral caps are preferred with cast-in-place concrete box Superstructures. Integral steel pier caps are not allowed. Aesthetic treatments on piers shall extend below existing grade and be considered for ultimate template as necessary to accommodate future construction. Concrete guardrails shall not be cast monolithically with integral pier caps.

3.7.1.20 Abutments

The design shall provide for integral, or semi-integral, end diaphragm-type abutments for bridges whenever pos-sible. The bottom of the abutment cap shall extend a minimum of 18-inches below the bottom of riprap or slope protection. Mechanically Stabilized Earth (MSE) walls, will not be allowed for abutment support. Geosynthetic Reinforced Soil (GRS) abutments are not be permitted. Retaining wall wingwalls may be used in lieu of cantilevered wingwalls at abutments for all categories of bridges. Cantilevered wingwalls and/or retaining walls shall extend four-feet beyond the point of intersection of the embankment slope with the roadway finished grade. Wingwalls and/or retaining walls adjacent to the abutments shall be supported on deep foundations to eliminate/minimize any differential settlement between the abutment and the walls. Bridge monuments shall be sup- ported on separate foundations.

3.7.1.21 Slope Protection

The design shall include modification of existing concrete slope protection for all slopes under Bridges to be widened. Slope protection on slopes between tiered walls and any slopes shall use a similar detail, aesthetic appearance and shall be concrete slope and ditch paving per the CDOT Bridge Structural Worksheets Slope Paving Drawings B-507-1. All structures shall maintain a hard surface between the roadway and face of abutment.

3.7.1.22 Foundations

The design shall ensure that differential settlement shall be designed for and considered in the foundation design. Differential settlements shall be included in the design as referenced by AASHTO and in the geotechnical design report recommendations. Spread footings are not Acceptable at water crossings. Spread footings are acceptable if the bottom of the footing is located below frost heave, scour elevation, and are an accepted foundation type in the Foundation Design Report. Foundations of integral abutments with skews between the axis of the abutment and the direction of allowed movement shall be designed to resist the unbalanced earth pressures behind the abutments.

3.7.1.23 Drainage and Scour

The bridge deck drainage systems shall be designed in accordance with the FHWA Hydraulic Engineering (HEC)-21, Bridge Deck Drainage Systems. Bridge deck drainage systems are required for highway bridges when the flow across expansion joints exceeds 1.0 cubic foot per second (cfs) for the 10-year frequency peak discharge. Spread limits (defined as to the edge of travelled lane) shall be designed to the lesser intensity of the ten-year frequency or four inches per hour. Gutter flow at both ends of bridges shall be intercepted. Stormwater flowing toward the bridge shall be intercepted prior to the approach slab. Stormwater flowing away from the bridge shall be intercepted prior to leaving the approach slab. This stormwater shall be directed to an appropriate outfall.

All bridge drain inlets shall be grated. The bridge deck drainage system shall be compatible with the structural reinforcement, components, and aesthetics of the bridge. Outfalls shall be positioned to avoid corrosion of structural members, and splash on vehicular traffic and pedestrian areas below the bridge. adequate erosion protection shall be constructed at all outfalls. Downspouts for bridge drains are not allowed.

Bridge drain systems with horizontal runs are not allowed.

The drain system shall be Designed and constructed to be easily modified to accommodate future changes to the width on the Bridge.

Scour analyses shall be based on the procedures in the FHWA HEC-18, Scour at Bridges, and HEC-20, Stream Stability at Highways. Scour countermeasures shall be designed in accordance with the FHWA HEC-23, Design of Countermeasures.

Approach slab inlets are preferred and should allow for thermal expansion.

3.7.1.24 Utilities (On Structures)

Hanging of electrical conduits, telephone conduits, or other utilities shall not be permitted under deck overhangs or on bridge rail. Protection of conduits from the settlement of the abutment backfill shall be provided. Utilities shall be hidden from view within the superstructure elevation.

3.7.1.25 Wildlife Mitigation

The top surfaces of substructures for new bridges and/or the widened portions of the bridges to be rehabilitated shall be designed with no more than a 3-inch exposed ledge to prevent and/or limit access for birds under bridges. Portions of the pier or abutment caps that require Inspection and/or bridge maintenance access will require alternative mitigations (netting, spikes, 45 degrees instead of flat, etc.) to make it less desirable for bird access. Bottom flanges of bridge girders with a slope flatter than 30 degrees off horizontal shall also apply to this pro- vision.

3.7.1.26 Finished Concrete Surfaces

All formed surfaces shall be finished with a Class 1 finish in accordance with the CDOT Standards and Specifications.

For bridges, structural concrete coating (or paint for steel structures) shall be the final finish and applied to surfaces for each particular structure and applied to exposed surfaces of bridge rails, exterior edges of sidewalks and decks, deck overhangs and soffits, exterior girder outside and exposed flanges, exposed bottom flanges on exterior/ interior girders, abutments to one-foot below grade, pier columns to one foot below grade and wingwalls to one-foot below grade. Coating limits on bridge rails shall apply to railings on approach slabs. All other visible, exposed, and accessible concrete surfaces shall have a surface treatment of structural concrete coating. Retaining walls shall also receive structural concrete coating unless otherwise Approved by DEN. The existing bridge piers, bridge girders and abutments of widened and non-widened bridges shall also be coated to provide a consistent color and texture between the existing and widened portions of the bridge.

Concrete coating color shall be equivalent to the light tan, Federal Standard Color No. 33531 for curbs, walls, slope paving and abutments, and dark brown, Federal Standard Color No. 30108 for girders. Sample coating colors shall be submitted in advance to DEN for approval.

3.7.1.27 Retaining Wall

The retaining wall layout shall address slope maintenance above and below the wall and provide returns into the retained fill or cut at retaining wall ends. Final tolerances shall be 1 to 240 for level and plumb. Any residual wall batter shall be into the fill.

Design shall consider surface and subsurface drainage. Walls which support soil and loads from outside ROW, and are built with MSE soil reinforcements, shall require an appropriate setback from ROW line for the construction of the wall system. A system shall be provided to intercept or prevent surface water from entering behind walls.Lengths of wall without relief joints shall be limited to lengths which control the differential settlement or a maximum of 100 ft. Walls over 30-inches high may require a railing or barrier at the top of the wall meeting current AASHTO and Occupational Safety and Health Administration (OSHA) requirements.

Metal walls, including bin and sheet pile walls, recycled material walls, MSE (block) walls, and timber walls shall not be permitted for permanent retaining walls.

All permanent retaining walls and their associated structural support elements, constructed for the project, shall be designed to resist corrosion or deterioration for a minimum service life of 75 years. Fencing on walls shall satisfy OSHA, and/or DEN Maintenance requirements. Outlets for backfill drainage for any retaining wall type shall be detailed on the plans.

All walls near irrigation lines for landscaping shall account for any additional hydrostatic load due to a waterline break. The use of free draining backfill material and/or leak detection devices to reduce hydrostatic loads on retaining walls may be considered during design. All retaining walls shall be designed in according to the seismic criteria from AASHTO LRFD Bridge Design Specifications.

3.7.1.28 Mechanically Stabilized Earth (MSE) Panel Walls

MSE Panel walls shall be designed in accordance with the requirements of AASHTO LRFD Bridge Design Specifications and per CDOT Bridge Structure Worksheets for MSE walls. Global stability, overturning, sliding, and settlement calculations shall be performed on all retaining wall systems. All retaining wall installations shall provide for a positive drainage system of the backfill. Additionally, the wall shall be designed for hydrostatic pressure or be constructed using a free draining material to account for water fluctuations including rapid drawdown after flooding conditions to prevent failure.

3.7.1.29 Cast-In-Place Walls

Cast-in-place walls shall be designed and constructed in accordance with AASHTO LRFD Bridge Design Specifications. Construction joint spacing shall accommodate or limit differential settlement. Foundations shall be Designed per the geotechnical Design requirements and recommendations.

3.7.1.30 Anchored Walls

Wall design and construction shall use FHWA DP-90-068, FHWA RD-82-046, FHWA RD-82-047, Design Manual for Permanent Ground Anchor Walls FHWA RD-97-130, Geotechnical Engineering Circular No. 4- Ground Anchors and Anchored Systems FHWA IF-99-015 as guidelines. Anchors shall be encapsulated with plastic sheathing. Proof load tests for anchors shall be provided in accordance with the above FHWA guidelines.

3.7.1.31 Soil Nail Walls

Soil nail walls may only be used when top-down construction is warranted. Soil nail walls shall not be used if groundwater seepage will occur. Design and construction shall use FHWA GEC 007, FHWA Publication No. FHWA-NHI-14-007 Soil Nail Walls Reference Manual. Load testing for nails shall be provided in accordance with the above FHWA guidelines.

3.7.1.32 Soil Reinforcement for Walls

Soil reinforcement for MSE and modular walls shall be galvanized (or epoxy) coated steel, geogrids, or fabrics meeting creep requirements of AASHTO LRFD Bridge Specifications. The design shall account for any items projecting through the soil reinforcement. The design shall avoid placing culverts and utilities perpendicular to soil reinforcement within the reinforced soil mass.

3.7.1.33 Retaining Wall Aesthetics

All wall facing shall be of a consistent type (i.e., cast-in- place, precast facing, etc.) This includes surface treatment, pattern, texture, color, and jointing layout. An overall negative batter (wall face leaning outward away from fill) between the bottom and the top of the wall is not allowed. Wall facing shall be installed vertically (plus or minus ½ inch in ten feet or as defined in the CDOT Bridge Structure Worksheets for MSE walls) and shall be capped with a cast-in- place or precast concrete cap. Wall facing and cap shall be colored with pigmented sealer.

For project consistency, retaining walls within a common viewshed shall incorporate similar visual aesthetics. Retaining walls for parallel bridges shall have similar structure types and aesthetic treatments.

3.7.1.34 Sign Structures

Major sign structures and supports for Intelligent Transportation System (ITS) equipment shall be designed and constructed in accordance with AASHTO LRFD Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 1st Edition with current interim revisions. Loadings shall consider natural period of vibration from vortex shedding and upward wind pressures from passing trucks. Sign structures shall be galvanized structural steel (single) tubing, painted in accordance with the revision of Section 522 – Duplex Coating System. Draft structural Worksheets for single-tube sign supports are available from CDOT, Standard Plans S-614- 50 and S-614-60 worksheets.

Variable Message Signs (VMSs) shall be mounted on a sign structure in accordance CDOT S Standard 614-60. Minor sign structures and supports shall be constructed in accordance with CDOT M and S Standard Plans.

3.7.1.35 Sign Components

Section in Development

3.7.1.36 Foundations

Drilled caissons shall be used to support overhead and cantilever sign structures as well as ground mounted VMS structures. See Standard Plans S-614-50 and S-614-60 worksheets.

3.7.1.37 Connections

Connections shall be made with high strength A325 bolts. Shop splices shall be made with full penetration butt welds. Base connections shall be made with full penetration shop butt welds. All sign connection hardware shall be galvanized with strengthened structural tubing at electrical connection openings. See Standard Plans S-614-50 and S-614-60 worksheets.

3.8 Roadway Lighting

Design to include average, maximum, minimum foot-candles and average to minimum and maximum to minimum luminance on the horizontal roadway plane. The lighting design shall include iso-foot-candle curve plots showing foot-candle levels at 1.0, 0.5, 0.2, and 0.1. The design and plans shall also include circuit layouts showing underground circuits alongside and under the roadway and through retaining wall and bridge structures.

3.9 Traffic Signals

All traffic signal poles shall be approved by DEN. This includes wiring, luminaires, luminaire lengths, luminaire heads, conduit sizes, and all other materials for the signals. All lighting fixtures and signal heads shall be LED.

Span wire type installations are permitted for temporary signals only.

All temporary and permanent traffic signals shall be designed in conformance to the CDOT Standard Specifications for Road and Bridge Construction. Traffic signal controllers shall be an ATC eX2 NEMA with standard-size ATC cabinet, uninterruptable power supply (UPS) and all necessary auxiliary equipment to provide full operational, signalization control and coordinated corridor operations between interconnected signals. Radar detection shall be required for all permanent traffic signals. Permanent traffic signalization appurtenances will not be allowed to hang from or be attached to any part of a bridge.

Signal equipment clear zones shall be in accordance with City and County of Denver Transportation Standards and Details Sheet 7.9. All new equipment shall be reviewed and approved by the CCD to ensure continuity with existing systems. CCD intends to maintain all signal equipment at DEN.

3.10 Vehicular Barriers and Guardrails

Roadside and center barriers shall be four strand tensioned cable barrier test level 4 (TL-4) with 10.5-foot post spacing where dictated by the AASHTO Roadside Design Guide and per the deflection specifications of the barrier.

CDOT Type 3 guardrail is to be used when warranted by design when it is not possible to use cable barrier, per the AASHTO Roadside Design Guide and per the deflection specifications of the barrier.

Cut retaining walls adjacent to pavement shall be protected with CDOT Type 9 – single slope concrete barrier rail. Fill retaining walls at the road edge shall be capped with CDOT bridge rail type 9 and utilize a moment slab. Type 9 guardrail is to be used when cable barrier and type 3 rail cannot be used per the AASHTO Roadside Design Guide and per the deflection specifications of the barrier.

All concrete barrier shall be cast-in-place. Precast barrier will not be accepted for permanent installations.

All bridges shall use CDOT bridge rail type 10M.

Crash attenuators and rail end treatments shall be provided at all required locations where barrier/guardrail begins or ends in accordance with the CDOT Safety Guide, Standards M-606-1 and M-606-13 and Chapter 8 of the AASHTO Roadside Design Guide.

End of Chapter

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Chapter 4 - Parking Facilities

4.0 Overview

This chapter provides guidance to design standards for all parking facilities at DEN. Parking facilities at DEN include DEN-operated pay parking (Economy, Garage, Shuttle, Short Term, and 61st and Peña), employee parking, and other select parking as determined by DEN, such as tenant development and rental car.

4.1 Criteria

Parking design shall be in accordance with the City and County of Denver Zoning Code Article 10. Additional resources include the City and County of Denver Transportation Standards and Details. Modifications to these standards that are specific to DEN are specified herein.

4.1.1 Design Requirements

A. Parking Stall dimensions: The minimum dimensions of a parking stall are 9 feet wide by 18 feet long. However, larger stalls may be required for certain types of vehicles, such as SUVs and vans.

B. Aisle widths: The minimum width of one-way and two-way aisles is 24 feet. Additional consideration may be necessary for the turning movements of shuttles or other non-standard vehicles dependent on facility usage and intent.

Parking layout: Parking spaces should be perpendicular to aisles (90 degree layout). However, other angles may be proposed due to space constraints and/or efficiency of the layout. Aisle width may be reduced to go with non-perpendicular layout, pending DEN approval.

C. Accessibility: Parking facilities must be ADA compliant. This includes providing accessible parking stalls, ramps, and elevators per ADA Standards.

D. Electric Vehicle requirements per Denver Building Code are generally applicable to all surface parking facilities at DEN but must be confirmed by the DEN Project Manager on a case-by-case basis, in accordance with the DEN EV Master Plan.

E. Pavement designs and markings: Refer to sections 3.3.Pavement Design and 3.6.Pavement Markings and Roadway Signs; these standards apply to surface parking facilities as well.

4.1.2 High Density Vehicle Storage

For surface parking facilities designated as “high-density vehicle storage” areas, additional criteria for fire access must be considered in accordance with Denver Fire Code and approval by DFD Fire Code Official.

A. Minimum 25-ft/50-ft (inside/outside) turning radii at all drive aisle intersections.

B. Stacked parking blocks shall not exceed 500-ft x 500-ft and shall be separated by drive aisles.

C. Any gate across a fire access road shall be a minimum of 16-ft wide and shall be provided with one or more of the following features:

   a. Key box
   b. An approved lock
   c. Chains used to secure gate shall be 1/4-inch maximum, non-case hardened steel
   d. Other emergency operation approved by Fire Code Official

D. Unobstructed vertical clearance of not less than 13.5 feet, and open to sky.

E. Fire lane pavement marking must meet the following criteria:

   a. 6-inch red stripe, with 4-inch white reflective lettering stating "No Parking / Fire Lane"
   b. Lettering spaced every 25 feet

4.2 Structured Parking

4.2.1 Criteria

Civil contractors and engineers must coordinate with architects and structural engineers when designing Parking Structures: DEN Structured Parking Design shall comply with the following codes and standards:

A. DEN Structural Design Standards Manual

B. International Building Code (IBC)

C. American Concrete Institute (ACI) 318-19

D. Building Code Requirements for Structural Concrete

E. American Institute of Steel Construction (AISC) 360-16 Specifications for Structural Steel Buildings

4.2.2 Design Considerations

A. Site selection: The site should be large enough to accommodate the desired number of parking spaces, as well as access and egress ramps and other necessary features. The site should also be relatively level, to minimize the need for grading and excavation.

B. Structural design: The parking structure must be designed to support the weight of the vehicles parked within it, as well as any other loads, such as snow, wind, and seismic forces. The structure must also be able to withstand the dynamic loads caused by vehicles entering and exiting the structure. Refer to the DEN Structural DSM for details related to structural design of parking structures.

C. Access and egress: The parking structure should have adequate access and egress points, to minimize traffic congestion and delays. The access and egress ramps should be designed to accommodate the largest vehicles that will be using the structure.

D. Circulation: The interior circulation pattern of the parking structure should be designed to minimize traffic congestion and delays. The aisles should be wide enough to allow vehicles to maneuver safely, and the parking spaces should be clearly marled.

E. Safety: The parking structure should be designed with safety in mind. This includes features such as adequate lighting, ventilation, and drainage. The structure should also be designed to minimize the risk of accidents, such as by providing guardrails and impact protection at the edges of ramps and levels

F. Drainage: Proper drainage design required to ensure that contaminated water from the parking structure does not enter waterways.

4.2.3 Specific Design Standards

A. Ramp slopes: The maximum slope for a ‘non-parking’ ramp is 8% grade. A ramp slope that includes park- ing may not exceed 6.67%.

B. Floor-to-ceiling height: Minimum height between floor and ceiling of parking structures is 8' 4". This allows for an 8' clearance height with 4" tolerance.

4.2.4 Additional Considerations

A. Sustainability: Parking structures can be designed to be more sustainable by incorporating features such as rainwater harvesting, solar panels, and green roofs.

B. Security: Parking structures should be designed with security in mind. This includes features such as security cameras, lighting, and fencing as required by DEN security.

End of Chapter

Chapter 5 - Utility Distribution

5.0 General

5.0.1 Overview

This chapter focuses on the routing of utilities throughout DEN property and the general relationship between the various utilities servicing the Airport. Design criteria for specific utilities are provided in more detail in other chapters and other DSMs.

5.0.2 Guiding Principles

The utility distribution systems are a critical component of the foundational infrastructure underlying DEN. Utilities, whether water, sewer, power, or telecommunications, accommodate the most basic of necessities for DEN's operations and for the travelling public. DEN is one of the busiest airline hubs in the world's largest aviation market – North America; therefore, the continuity and reliability of those utilities must be the primary goal of any installation to be integrated into the Airport.

DEN is committed to sustainability through its ongoing development projects. Sustainability principles that must be incorporated into utility distribution designs include, at a minimum:

A. An ability to maintain and enhance DEN's system of asset management and preventative maintenance.

B. Features that are maintenance friendly.

C. Measurable reductions in carbon emissions with each design.

D. Leave no trace behind on grounds and surrounding waterways including, but not limited to, visible water/ recycling solutions.

E. Visibility and integration of renewable energy systems.

F. Innovations in MEP systems and digital control to reduce loads and carbon footprint.

5.0.3 Standard Design Level Requirements

This DSM presumes a minimum adherence to governing rules, regulations, and building codes in the design of all utility distribution systems. Specific utilities may also need to meet the design standards of public utility companies that service the Airport. In addition, design criteria contained in this and other DSMs must be complied with in all designs. If criteria or requirements from the varying sources conflict, the more stringent criteria must be used.

Additional design requirements for all projects, including required submittals and DOR responsibilities, are detailed in the General Standards and Criteria DSM and DFI DSM.

5.1 Key Considerations and Opportunities

The utility distribution systems for all facilities at DEN must be based upon the use of proven design techniques. These techniques must utilize readily available equipment and components. Designs must conform to the criteria listed herein, with the highest priorities being the safety, convenience, and comfort of the traveling public and airport personnel.

5.1.1 Serviceability

Utility distribution systems must be serviceable, maintainable, and provide flexibility for future addition or modification. All utility distribution installations, including equipment and components, must be accessible for inspection, adjustment, and maintenance. Adequate provisions must be included for the future removal and replacement of any or all components of a utility distribution system including, but not limited to:

A. Adequate access to all equipment and components for periodic condition assessment, preventative maintenance, and eventual replacement.

B. Redundancy or bypass, or both, to allow work to be done with minimal disruption to normal operations.

5.1.2 Excess Capacity

Airport facilities by their very nature are dynamic in that changes, additions, and modifications are to be anticipated to adapt to ever-changing business needs. Flexibility in utility distribution design will be the key to allow for the sometimes-rapid changes and expansion that are now an integral part of a modern airport facility. As a result, all utility distribution systems must be designed to provide a minimum excess capacity of 25% to allow for future growth without the need for continuous modifications or additions to the systems that would be unnecessarily disruptive to Airport operations

5.1.3 Sensitive Security Information

Pursuant to 49 CFR Part 1520 and Part 15, SSI is information that if publicly released would be detrimental to transportation security. Such information encountered during design and construction projects may include, but not be limited to:

A. Critical aviation infrastructure or asset information.

B. Security measures such as specific operational or technical details of aviation security.

C. Performance specifications including any description of a test object or procedure.

All utility systems at DEN may, in part or entirety, include SSI on a project-specific basis. Refer to DEN rules, regulations, and policies for additional criteria,

DEN Rules and Regulations

5.2 Utility Systems

5.2.1 Scope

The Airport's utility distribution systems at DEN include, but are not limited to:

A. Power

B. Renewable energy

C. Natural Gas

D. Central utility plant (heating/chilled water)

E. Water

F. Sanitary

G. Stormwater/drainage

H. Groundwater

I. DIW and Glycol Supply

J. Aircraft Fuel

K. Non-aircraft fuel

L. Oil and gas production

M. Telecommunications

N. Cathodic protection

5.2.2 Criteria

Specific design criteria for each of the above-listed utilities are detailed in separate DSMs identified by system.

The Airport's utility distribution systems are wholly owned, operated, and maintained by DEN or its Operating Contractors, except for the following:

A. Power

Xcel Energy owns, operates, and maintains power transmission and distribution infrastructure up to the utility transformer or switch (for medium voltage distributions); beyond which infrastructure responsibility belongs to DEN.

B. Natural Gas

Xcel Energy owns, operates, and maintains natural gas transmission and distribution infrastructure up to the meter; beyond which infrastructure responsibility belongs to DEN

C. Water

Denver Water Department owns, operates, and maintains water system transmission and distribution infrastructure up to the meter; beyond which infrastructure responsibility belongs to DEN.

D. Jet Fuel

DEN owns and leases the jet fuel storage facility and hydrant system to DEN Fuel Company LLC, which consists of participating member airlines based on consumption. The LLC is responsible for maintaining and upgrading the system with appropriate approvals from DEN. Refer to the Fueling DSM for additional requirements regarding fuel systems.

The specific utility companies listed above must be contacted before starting any design that would modify or alter their respective utility systems to obtain project-specific requirements

5.3 Utility Corridors

A network of designated utility corridors has been established to efficiently distribute utilities throughout the Airport. These utility corridors must be utilized in all design projects for utility system routing, additions, modifications, or alterations, to the maximum extent practicable.

The routing of utility distribution systems through designated corridors offers the following advantages:

A. Dedicates or reserves space for existing and future utilities in an orderly and controlled manner.

B. Minimizes utility crossings as wells as potential interference with airfield pavements, roads, and other infrastructure.

C. Provides an orderly and more easily accessible utility arrangement that increases efficiency of operations and maintenance.

D. Provides compatibility throughout the phased development of the Airport.

5.3.1 Corridor Designations

In general, utility corridors are easily observed on DEN Maps when the utility GIS layers are on. Descriptively, these corridors can be summarized, as shown in the following sections.

North-South Utility Corridors (listed from west to east)

A. Buckley Road

B. Tower Road (within Denver Public Works ROW)

C. Himalaya Road

D. Picadilly Road
E. Gun Club Road
F. Jackson Gap Road
G. Oak Hill Street
H. Terminal Complex Center Axis (typically within Utility Tunnel)
I. Van Driver Street

East-West Utility Corridors (listed from south to north)

A. 40th Avenue (within Denver Public Works ROW)
B. 48th Avenue (within Denver Public Works ROW)
C. 56th Avenue (within Denver Public Works ROW)
D. 61st Avenue (Aviation Station)
E. 64th Avenue (within Denver Public Works ROW)
F. 68th Avenue
G. 72nd Avenue
H. 75th Avenue
I. 78th Avenue
J. 80th Avenue
K. 84th Avenue
L. 99th Avenue
M. 109th Avenue
N. 114th Avenue

Concourse Utility Corridors (looped around each concourse extending from center core)

A. Concourse A
B. Concourse B
C. Concourse C
D. Concourse D
E. Concourse E
F. Concourse F
G. Concourse G

Airfield Utility Corridors

A. Looped throughout the runway/taxiway complexes per FAA design standards and requirements.
B. Typically, only power distribution.

5.3.2 Corridor Access

Full access to the utilities located in the utility corridors must be assured to always maintain safety and operational continuity. No operational activity or structure, whether temporary or permanent, is permitted within a utility corridor if it might damage or restrict full access to the utilities located within it or reduce access for the full use of the corridor for the placement of future utilities.

5.3.3 Runway Crossings

The utility corridor system was originally designed to avoid all runway crossings thereby providing an ideal situation for operations and maintenance of the utilities. During design development of the Airport, it became evident that much shorter routings of some utilities could be achieved by running those utilities under portions of the run- ways while having minimal impact on the reliability of the utility distribution system. In certain cases, utilities werelooped back under the runway to ensure reliability of critical services (i.e., life safety, power). Such runway crossings have always been, and must be in the future, kept to a minimum.

5.3.4 Utility Tunnel

The Utility Tunnel is used primarily to distribute certain utilities from the Central Utility Plant to the Terminal and Concourses. These utilities include:

A. Chilled water
B. Heating water
C. Steam
D. Telecommunications
E. Control and instrumentation devices

Specific criteria for utilities distributed through the Utility Tunnel are detailed in the Mechanical DSM

5.4 Utility Distribution within Corridors

The utility corridors were originally designed to accommodate the utility distribution systems appropriately sized and arranged for full development of the Airport. Space within some of the utility corridors was also provided to accommodate the addition of one or two future utilities whose needs may be unforeseen at present.

5.4.1 Utility Placement

The location and arrangement of utilities within the utility corridors, both vertically and horizontally, should be determined by the following criteria:

A. Utility installations must conform to applicable governing codes and public utility requirements.
B. Utility depths should be minimized to the extent practicable to reduce excavation requirements.
C. Utility lines should be located, where possible, on the side of the utility corridor that minimizes the number of connecting crossings.
D. Spare conduits in duct banks must be installed to provide additional space for future development.
E. All utilities and corridor boundaries must be identified with buried warning tape, tracer wire, and standard surface markers placed at regular intervals along the alignment.
F. Access roads for servicing utilities may be contained within the utility corridors only if other local service roads cannot be used for this purpose.
G. Utilities must be routed to minimize crossings of paved roads and airfield pavement and should cross open areas to the extent practicable.
H. Sleeves and casings must be provided for all utility crossings under roads, airfield pavement, including in areas that are presently known to require sleeves and casings in the future and where future access may be limited.
I. Manholes, valve pits, and other in-line features must be located within the utility corridors to the maximum extent practicable.
J. Wet utilities must be arranged with adequate space to allow future maintenance excavation of individual lines by means of supported trenches (i.e., trench boxes).
K. Electrical manhole spacing should be approximately 800 feet nominal and 1,000 feet maximum.

L. A minimum cover of 3'-0" should be maintained below finished grade for all wet utilities, except for water, which has a minimum cover of 4'-6". A minimum cover of 3'-0" should be provided for all electrical and telecommunications ductbanks. Cover depth may be increased if added protection is necessary (i.e., under drainage crossings) on a project-specific basis. Cover depth may only be decreased if additional protection, such as a pipe sleeve or concrete encasement, is provided in lieu of the required cover depth on a project-specific basis.

M. Sanitary sewers within the utility corridors must have a 10-foot minimum horizontal separation and an 18-inch minimum vertical separation below water lines to prevent potential cross contamination per code. All other wet utilities that may have similar potentials for contaminating the potable water lines (fuel,non-potable water, deicing, etc.) must also observe this same horizontal and vertical separation.

N. Power and telecommunications cables are contained within conduits. Conduits must be concrete encased under all roads, airfield pavement, other paved areas, and load-bearing structures as further detailed in other related DSMs. These utilities are typically adjacent but separate to avoid induction influence in the telecommunication cables. The minimum separation distance between the very low voltage (6- to 40-volt) control cables and the medium voltage (3.8- to 34.5-kV) transmission power cables must be 4 feet. If fiber optic or other interference-protected cables are utilized, a separation of 3 inches of concrete is sufficient between ducts. If power and telecommunications cables run parallel for 3,000 feet or more, a 10-foot separation is required. A 6-foot separation from the nearest water or sewer line is required both horizontally and vertically.

5.4.2 Utility Terminations

Utility distribution systems must terminate at the following locations:

Table 5-1: Utility Terminations

Utilities	Termination Location
Sanitary Sewer	5'-0" from building or structure
Hazardous Waste	5'-0" from building or structure
Water (Potable/Fire/Irrigations)	5'-0" from building or structure
Natural Gas	At outlet of gas meter/regulator at building or structure
Aircraft Fuel	At fuel hydrant pit outlet
Automotive Fuel	At fuel dispenser/pump outlet
Power	At the load side of the transformer
Telecommunications	At the service pedestal or pole as specified

Specific criteria for utility distribution beyond these termination points and within building envelopes are detailed in the Mechanical, Electrical, Life Safety, and Architectural DSMs.

5.5 Water Systems and Storm Drainage

5.5.1 Scope

This section applies to routing, transmission, and distribution of water systems throughout DEN property outside of the building and structure envelopes. Design criteria for other utilities are provided in other chapters or other DSMs. Design criteria for water systems plumbing within buildings or structures is provided in Mechanical DSM.

5.5.2 Criteria

All water distribution and transmission infrastructure constructed at DEN must be designed in conformance with the current edition of Denver Water's Engineering Standards. The Denver Water Engineering Standards are being updated to include specific variances applicable to the water systems at DEN.

5.5.3 Storm Drainage on the Airfield

Conveying stormwater through the airport requires significant drainage infrastructure, including storm drains, pipes and box culverts, bridges, and natural and engineered channels. Online and offline detention/retention basins are located throughout the airport to meet Urban Drainage and Flood Control District (UDFCD) and FAA standards while reducing potentially adverse downstream impacts. These basins range in size from regional scale facilities along the periphery of the airport to small scale basins designed to capture pavement runoff. Many of these basins also function as water quality ponds and were sized to provide capacity for water quality capture volumes.

The airfield drainage system consists of a series of trench drains at the concourses with pipes conveying runoff to either clean storm water conveyances such as open channels or to the DIW ponds. Runway and taxiway drainage from pavement is collected primarily in open channels running parallel to the complex and then moving off the air-field via culverts under paved areas ultimately to storm basins.

5.5.4 Airfield Drainage Design Criteria

A. FAA AC 150/5320-5C, Surface Drainage Design
B. City and County of Denver, Strom Drainage Design and Technical Criteria Manual
C. Urban Drainage and Flood Control District, Urban Storm Drainage Criteria Manual
D. DEN WQMP Oct 2017 and DEN Drainage Masterplan May 2014

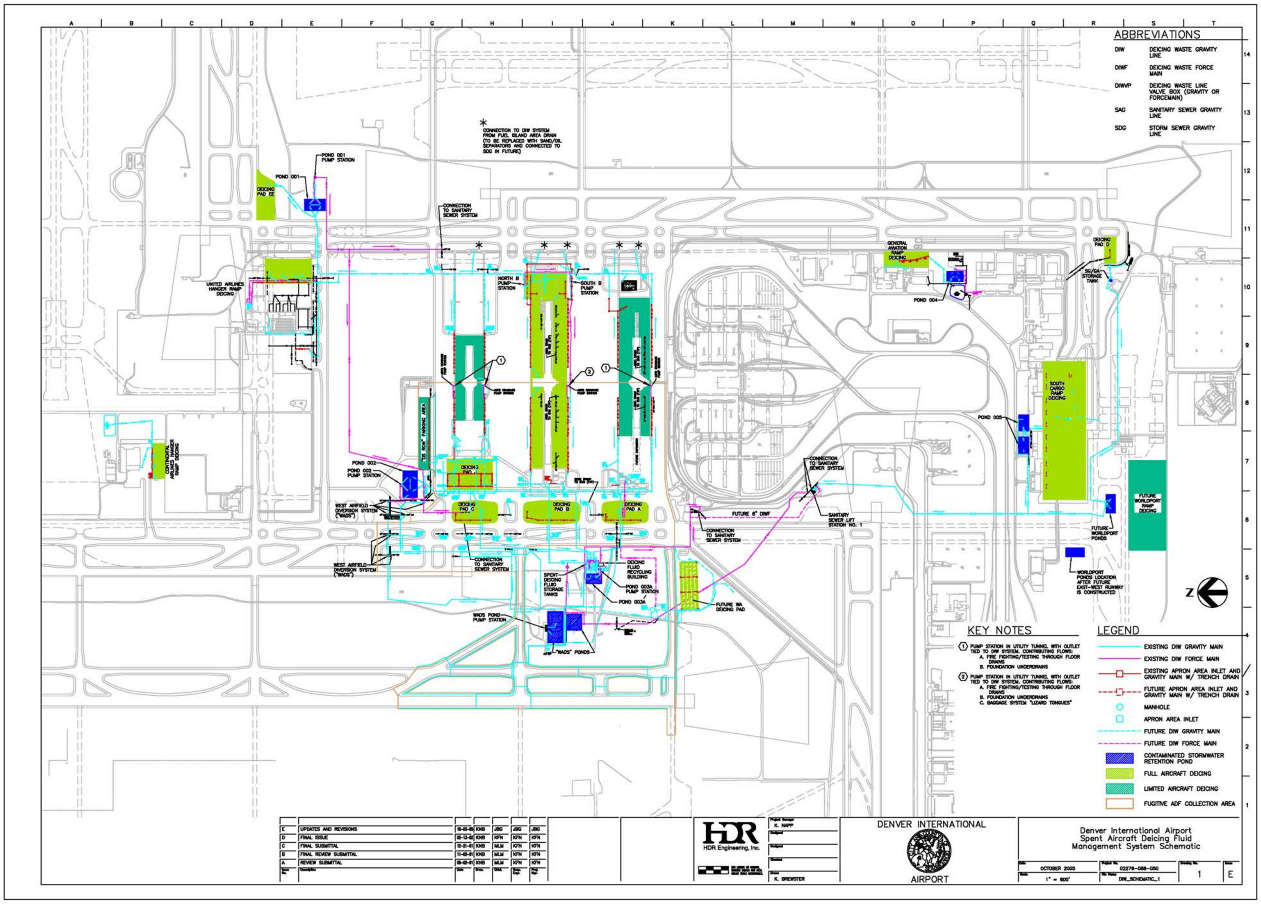

Figure 5-1: Overall DIW System Plan

End of Chapter

Chapter 6 - Geotechnical

6.0 General Geotechnical Criteria

6.0.1 General Criteria for Subsurface Investigations by Design Consultants

Reference the latest edition of the CDOT Geotechnical Design Manual for preliminary criteria on subsurface investigations of bridges, interchanges, culverts, and roadways.

6.0.2 AGTS Tunnel

6.0.2.1 Preliminary Investigations

One sampled boring every 800 feet along tunnel centerline extending at least 30 feet below the proposed sub-grade level, sampling intervals five foot minimum. Some continuous coring should be performed in moderately weathered or unweathered bedrock.

6.0.2.2 Final Investigations

Borings at 200-foot intervals on alternate sides of the centerline. Borings should be sampled at intervals of at least five feet in soils and highly weathered bedrock. Some continuous coring should be performed in moderately weathered to unweathered bedrock.

6.1 Laboratory Tests, Analysis, and Reports

Reference the latest edition of the CDOT Geotechnical Design Manual.

All relevant boring data must be entered into the Geodatabase Entry Template and submitted with all reports.

6.2 Preliminary Geotechnical Criteria for Airside Runway, Taxiway, and Apron Pavements

6.2.1 Preliminary Geotechnical Criteria for Airside Runway, Taxiway, and Apron Pavements

Airport pavements are constructed to provide adequate support for the loads imposed by aircraft and support vehicles using the airport. The purpose of the pavement is to provide a firm, stable, smooth all-year, all weather surface free from dust or other particles which may be picked up by propeller wash or jet blast.

To satisfactorily fulfill these requirements, the pavement must be of such quality and thickness that it will not fail under the imposed airplane and support vehicle traffic loads. In addition, it must possess sufficient inherent stability to withstand the abrasive action of traffic, adverse weather conditions and other deteriorating influences. To produce such pavement requires a coordination of many design factors, construction and inspection to assure the best possible pavement structure. The criteria for subsurface investigation, presented in 6.3.Criteria for Subsurface Investigations by Design Consultants, will provide general guidelines for investigations for airside pavement structures at DEN.

6.2.2 Range of Design Parameters

Based on limited boring information and laboratory test results presented in AAE’s report and AEI’s experience with similar soils has been prepared which summarizes the general engineering properties of potential subgrade materials expected to be encountered at DEN. It should be noted that this table is based on very limited data and should only be used for planning and cost estimating purposes

The major portion of natural soils, as encountered by AAE's borings, consisted of sandy clays to clays. These materials, in general, provide fair to poor subgrade support for pavement structures. Furthermore, these soils may exhibit swell potential, have poor drainage characteristics and are generally considered to be not suitable as base material directly under pavement wearing surfaces.

The clayey sands and sands are limited to thin veneer of surficial material over major portions of DEN and to greater depths near drainageways and creeks. These materials, in general, provide fair to good subgrade support for pavement structures. Furthermore, these soils generally do not exhibit expansion, have poor to excellent drainage characteristics and are generally considered to be poor to not suitable as base material directly under wearing surface.

Excavations for the proposed runways and taxiways at many of the cut locations will be into weathered bedrock consisting mainly of weathered claystone bedrock. This material may have high swell potential, have very poor drainage characteristics (including potential for perched water tables) and not be acceptable as base directly under pavement wearing surfaces.

Due to potentially varying subsurface conditions, detailed subsurface investigations will be necessary to further define the subsurface conditions at the proposed runway and taxiway locations.

6.3 Criteria for Subsurface Investigations by Design Consultants

6.3.1 Criteria for Subsurface Investigations by Design Consultants

Due to varying subsurface conditions at DEN, the investigation for runways and taxiways should be conducted in two phases:

A. Preliminary subsurface investigations should be performed prior to rough grading operations to determine subgrade soil types, soil type boundaries and preliminary pavement design parameters. The information developed during the preliminary subsurface investigation can be used for earthwork planning, preliminary cost estimating and preliminary design of pavement types and thicknesses.

B. Final subsurface investigations should be carried out after completion of rough grading at the proposed runway and taxiway locations. The data obtained during the final investigation phase should be used to design the actual pavement structure.

The requirements for each investigation phase are presented in the following sections.

6.3.2 Field Investigations

6.3.2.1 Preliminary Subsurface Investigations

Preliminary subsurface investigations must consist of drilling a series of borings to determine the quantity and extent of different types of soils and bedrock, the arrangement of soil and bedrock layers and the depth to the groundwater table. Coordinate recommended criteria with the DEN Project Manager.

6.3.2.2 Final Subsurface Investigation

Final subsurface investigations must consist of drilling a series of borings to determine the engineering characteristics of subgrade materials after completion of grading operations. The criteria for boring frequencies and depths for final subsurface investigations shall be coordinated with the DEN Project Manager.

Field investigations must be performed in accordance with ASTM D 420, Standard Guide for Site Characterization for Engineering Design and Construction Purposes. The borings must be drilled with solid or hollow stem auger equipment. Bulk samples of auger cuttings must be obtained of the different subgrade materials for soil support testing.

Drive sampling must be performed at regular intervals in the borings, but in no case must be less than five feet on centers and at significant changes of soil types. Sampling must include both disturbed and relatively undisturbed sampling. The preferred sampling method must be relatively undisturbed sampling using California Split Spoon samplers at a minimum.

If standard penetration testing is preferred, frequent Shelby tube or other relatively undisturbed sampling attempts must be made.

In each boring, the various layers of compacted fill, natural soils and weathered bedrock must be identified and sufficient representative samples of each obtained so that appropriate laboratory testing can be performed. The depth and elevation of the water table should be recorded and the presence of any water bearing strata noted. If there is frozen ground at the time of drilling, the depth of frost penetration must be recorded.

6.3.2.3 Borehole Abandonment

Restore borehole locations in accordance with the CDOT Geotechnical Design Manual criteria: when borings extend through existing concrete pavement, properly patch the surface of the hold with asphalt, grout, or concrete to maintain public safety. Borings through existing asphalt pavement shall be patched with asphalt.

When borings are in unimproved, vegetated or rock/gravel areas, restore locations to its preexisting condition with the use of in-situ materials or new materials that match the surrounding area. Restore the area to conditions that are equal to or better than the original condition.

6.3.3 Laboratory Tests

All soil and bedrock samples recovered must be visually inspected and classified in the laboratory by the Project Geotechnical Engineer. The materials must be classified in accordance with the following standards:

A. Classification of Soils for Engineering Purposes, ASTM Designation D 2487. This method is usually referredto as the Unified Soil Classification System (USCS).

B. The Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes, AmericanAssociation of State Highway and Transportation Officials (AASHTO) Designation M 145-92.

In addition, the following supplemental tests may be performed when appropriate to determine the physical and engineering properties of subgrade materials.

Table 6-1: Supplemental Tests for Subgrade Materials

Subgrade Material	Supplemental Test
Moisture-Density Relations of Soils	ASTM D 698/or ASTM D 1557
Permeability of Granular Soils	ASTM D 2434
Determination of Organic Material in Soils by West Combustion	AASHTO T-194
Swell/Consolidation	ASTM D-4545 (modified according to local practices)
Consolidation	ASTEM D 4546 or local practice-The Denver Swell Method

6.3.4 Soil Grouping

To facilitate subgrade support testing, soil samples collected in the field investigation must be combined to form soil groups. The soil grouping must be limited to a maximum of six individual samples. These groups must be based upon the AASHTO Classification, Group Index (GI) and location within the investigation area. Groups must not consist of samples with different AASHTO classification. (NOTE: There may be more than one soil group within a given classification.) Composite samples must be manufactured by combining small portions of each subgrade sample contained within the group and mixing to provide a uniform composite sample of the soil group. Coordinate with the DEN Project Manager for classification of composite samples.

6.3.5 Soil Support Testing

6.3.5.1 Field Tests

Plate Bearing Tests (PBTs) should be performed in accordance with the procedures established in AASHTO T-22 using a 30-inch diameter plate. At least two to three tests should be performed for each pavement feature, for each significant subgrade condition (i.e. compacted fill, natural soils, weathered bedrock, etc.).

6.3.5.2 Laboratory Tests

Laboratory soil support testing should be performed to supplement the field tests and to allow a correlation of field and laboratory data so that appropriate soil support values can be selected at locations other than PBT locations.

Individual subgrade or composite samples must be tested to determine the subgrade support value using R-Value Tests for rigid pavements and California Bearing Ratio (CBR) tests for flexible pavements. CBR tests must be conducted in accordance with ASTM D-1883, Bearing Ratio of Laboratory-Compacted Soils, with the following modifications:

A minimum three-point CBR evaluation is required.

A. Where samples to be tested classify as A-1 through A-5, the requirement for compaction should be inaccordance with ASTM D 1557.
B. Surcharges must be calculated using a unit weight of 140 pcf for hot bituminous pavement (HBP) and 135pcf for treated or untreated aggregate base course (ABC).
C. The design CBR value must be determined from the CBR-Dry Density curve and must be the CBR value at95% compaction.

6.3.6 Subsurface Investigation

All relevant boring data must be entered into the Geodatabase Entry Template and submitted with all reports.

6.3.6.1 Preliminary Subsurface

Reports should be prepared for the preliminary subsurface investigations and should include at least the following items:

Graphic presentation of boring locations in relation to runways and taxiways.

A. Graphic logs of borings, indicating soil stratification and proposed cut and/or fill elevations. Logs of borings should include the date performed, surface elevation, USCS classifications of the various soil and weathered bedrock layers and the water table elevation, if encountered.
B. Graphic presentation of lateral distribution of different soil groups.
C. Preliminary subgrade support values for each soil group.
D. Swell/collapsibility potentials of subgrade and fill materials.
E. Frost susceptibility of subgrade and fill materials.
F. Suitability of on-site subsurface materials as fill material.

6.4 Borrow Area Investigations

6.4.1 Scope

Borrow sources of appropriate fill material should be located and approved prior to the start of grading at the subject site.

Two general fill material types will be considered:

A. Structural fill, including structural backfill
B. Non-structural fill

The investigations indicated in the next subsections will be required to identify borrow sites for fill materials.

6.4.2 Structural Fill

Further investigation will be required to locate and delineate borrow areas for structural fill material. Borrow area investigations should follow the three general strategies as follows:

A. The first strategy will be to utilize, to the extent possible, materials from planned excavation areas. However, much of the material from excavation areas may be cohesive soils with low to medium swell potentials not meeting structural fill specifications. Careful planning and subsurface investigations will be required to delineate appropriate fill sources within planned cut areas.
B. The second strategy will be to locate and delineate localized deposits of appropriate fill material near fill sites. However, most surficial soils within the DEN site are clay to fine sand and may not meet structural fill requirements. Pockets of relatively clean sand meeting the requirements may be limited to areas along Second Creek, Third Creek, Box Elder Creek or Barr Lake Tributary drainages. Borrow sources investigations should concentrate in these areas.
C. The third strategy will be to locate and delineate a large deposit of appropriate fill material within the DEN site. A possible location of a major deposit of structural fill and backfill material occurs in the ancient Box Elder Creek floodplain as described in Chapter 7. This potential aggregate resource occurs as a linear north-south band west of the present Box Elder Creek floodplain and beneath the present Box Elder Creek tributary. Because the potential borrow source is offset from Box Elder Creek, excavation of this resource may not disturb the Box Elder Creek floodplain or associated wetlands. The excavation site could also be used to dispose of poor quality materials.

This three- strategy borrow site exploration approach may provide an adequate quantity of borrow material for development of proposed facilities at DEN. If adequate quantities of appropriate borrow materials are not identified within the site, explorations may be required off-site. However, off-site borrow areas are undesirable due to additional land acquisition requirements and greater haul distances.

Location and delineation of borrow sources will require additional geologic review and subsurface investigations. Requirements for investigation of localized borrow sources near fill areas and a large borrow source within the DEN site are outlined in the following sections.

6.4.3 Surficial Geology Study

Surficial geology studies should include review of USGS, CGS, and SCS maps and documents to locate probable sources of appropriate fill material. Site reconnaissance will be necessary to confirm local conditions.

6.4.4 Subsurface Investigation

Subsurface investigation, including geotechnical borings and/or test pits and laboratory testing, will be required to confirm and delineate borrow sources.

Boring and test pit spacing will vary depending on lateral continuity of the deposit. Maximum spacing will be a 400- by 400-foot grid. Boring or test pits should extend to at least five feet below the bottom of the proposed borrow strata or 25 feet, whichever is greater. Samples and penetration test values will be obtained at five-foot intervals throughout the entire boring or test pit depth. Depth to groundwater should be recorded.

6.4.4.1 Laboratory Tests

Laboratory tests should be performed on representative samples obtained from borings or test pits. All samples from borings or test pits within the proposed borrow area must be subjected to the following tests:

A. Gradation Analysis

B. Atterberg Limits

C. Swell/Consolidation

6.4.4.2 Representative Composite or Select Sample Tests

In addition, representative composite or select samples must be subjected to the following tests:

A. Moisture Density Relationship

B. CBR or R-Value

C. Strength tests such as direct shear strength tests and/or triaxial compression test.

Potential borrow source reports must include citation of source documents leading to exploration of a site and a summary of field observations- laboratory test results.

A plan view of the DEN site must be prepared identifying the proposed borrow site location. A plan view of the borrow site should be included showing boring locations and proposed borrow site boundaries. Boring logs must be presented showing elevations of strata encountered during boring, sample depths, penetration test results and depth to groundwater.

All laboratory test results should be included showing boring identification and sample depth. Borrow source depth interval and volume should be estimated and reported. Overburden depth and volume should be estimated and reported. Borrow source reports should be submitted to the Airport Engineers. All borrow sources must be approved by the Airport Engineer before excavation begins.

Consult with the DEN Project Manager for access to DEN Maps – Soils, a GIS viewer illustrating historic and current soil analysis inventory at DEN.

All relevant boring data must be entered into the Geodatabase Entry Template and submitted with all reports.

6.4.5 Non-Structural Fill

Investigation for non-structural fill borrow sites can occur in conjunction with structural fill borrow site investigations. Non-structural fill material can be any material discovered during the investigation that does not meet requirements for structural fill and backfill.

Non-structural fill may need to meet certain other criteria specified in plans such as permeability rate or swell potential. Sufficient laboratory testing will be performed and reported to verify that a non-structural fill meets requisite design criteria.

End of Chapter

Chapter 7 - Technical Specification Requirements

7.0 General

Designers are required to provide project specifications on all DEN projects in accordance with the Standards and Criteria DSM, Chapter 11. The project specifications should encompass all aspects of the project and be based on industry-standard construction methods and products, with content based on the DEN Standard Specifications (where available) or from an industry-standard guide specification.

7.0.1 How to Use DEN Standard Specifications

7.0.1.1 DEN Technical Requirements

The DEN Standard Specifications listed in this chapter have been developed to ensure project consistency and compliance with DEN policy and procedure. For sections available as DEN Standard Specifications, the designer must obtain and use these sections for their project.

7.0.1.2 DEN Technical Requirements

This provides DEN-specific requirements that must be included in nonstandard specifications for all DEN projects. An itemized list of DEN-specific technical specification requirements is provided, which may include general requirements, product requirements, and execution requirements. The designer shall incorporate these requirements into their project specification content as appropriate for the project scope. Requirements are provided in an outline format similar to construction specifications for ease of incorporation. Content may be copied directly from this chapter, with article/paragraph numbering and structure modifications as needed to ensure a cohesive document.

Note: This chapter is intended to be used as an aid to the development of a project specification and is not intended to represent a complete specification as presented.

The designer is responsible for developing a complete specification, incorporating the requirements, which encompasses all aspects of the project and complies with general specification requirements outlined in the Standards & Criteria DSM, Chapter 11. After incorporating the requirements listed herein, the project specification should be reviewed to ensure it is free of redundant and/or conflicting information.

7.0.1.3 Notes to the Designer

Notes to the designer are included throughout the chapter, shown in red highlighted text. These are provided for guidance and clarification of requirements and are intended for use only by the designer in development of their specification.

Notes to the designer shall not be incorporated into the final project specifications.

7.0.2 Specification Numbering

7.0.2.1 Numbering of Deliverables

Project deliverables should utilize Section names and numbers contained in the latest edition of MasterFormat Numbers & Titles at the time of project kickoff, which may vary from those in this chapter. It is the designer's responsibility to ensure that all applicable DEN requirements are reflected accurately in the appropriate sections of the project specifications.

7.0.2.2 Numbering Provided in this Chapter

Specification section names and numbers provided in this chapter are based on MasterFormat Numbers & Titles, 2014 edition.

7.0.2.3 Product and Manufacturer Listings

Where manufacturers and products are listed in this chapter, they represent approved manufacturers and/or products. Do not include additional manufacturers and/or products for that Article or paragraph without written permission from the DEN Project Manager.

For sections without manufacturer and/or products listed in this chapter, the designer shall select a basis of design based on current industry standards which comply with all applicable requirements in this and other DEN DSMs, the DEN Standard Specifications, and the Denver Building Code. Provide at least (2) acceptable alternatives to the basis of design for all products, for a total of (3) or more acceptable products, except where a sole-source selection has been approved in writing by the DEN Project Manager.

7.1 DEN Standard Specifications

Please contact the DEN Project Manager.

7.2 DEN Technical Requirements

Please contact the DEN Project Manager.

End of Chapter