NEVADA DEPARTMENT OF TRANSPORTATION

NEVADA DOT

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DRAINAGE MANUAL

NDOT HYDRAULICS

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2nd Edition

December 2006

NEVADA DEPARTMENT OF TRANSPORTATION

DRAINAGE MANUAL

Procedure for Manual Revisions

This manual was developed to reflect current Nevada Department of Transportation drainage policies, procedures, and practices. The manual will be periodically revised or updated. For edits or updates, contact the Hydraulics Section at (775) 888-7619. All updates will be available on the NDOT website which should be visited regularly for updated information.

Temporary Revisions:

Temporary revisions will be issued by the Hydraulics Section to reflect new policies, procedures and directives. These will be reflected on dated errata sheet(s) posted on the NDOT website.

Scheduled Revisions:

In October of each year, the Principal Hydraulic Engineers and the Chief Hydraulic Engineer will review the manual and errata sheets to determine if a revised edition of the Manual is required. New editions will incorporate all errata sheets.

Summary of Revisions included in the Second Edition		
Page # of 1st edition	**Section # of 1st edition**	**Revision Description**
i	Table of Contents	Corrected typos – page #s for Section 2 (corrected page 1-1 to 2-1) and Section 3 (corrected page 2-1 to 3-1)
Entire manual	Entire manual	FEMA changed their website – corrected all hyperlinks and references to new websites
Entire manual	Entire manual	Updated numerous hyperlinks and their corresponding website references in Section 3.3.12.6
Entire manual	Entire Manual	All references to "permanent erosion" were changed to add "and sediment" (Sections 2.1, 2.3.1, 2.9.2, Appendix A, B.1, Table B-1, Table B-2, and Table B-3)
Entire manual	Entire Manual	All references to "temporary erosion control" were changed to "temporary pollution control" (Sections 2.9.2, Appendix A, Table B-1, Table B-2, Table B-3, Table B-4, and Table B-5)
1-1 3-21	1.1 3.3.12.6	Corrected from FHWA computer programs to FHWA publications
3-4	3.2.2.1	Reworded 6th bullet
3-6	3.3.2.2	8th bullet - increased the minimum cross slope from 1% to 1.5%
3-7	3.3.2.2.1	4th bullet – clarified inlet spacing at reversed super elevations
3-7	3.3.2.2.1	Added 5th bullet - coordination with Roadway Designer regarding super elevation transitions
3-10	3.3.2.2.6	5th bullet - increased minimum bridge deck cross from 1% to 1.5%
3-12	3.3.41	Corrected typo "Highway" Design Series to "Hydraulic"
3-21 3-25	3.3.12.1 3.3.12.6	Deleted reference 7 (HEC 12) and website link.
3-21	3.3.12.1	Updated reference 5 (HEC 9) and reference 8 (corrected HDS 13 to HEC 13)
3-22	3.3.12.4	Deleted website link for #6, HCDDM Washoe County website link no longer exists. (FYI -Washoe County updating Manual)
3-24	3.3.12.6	Deleted NDOT references to 3.3.10 and 33.11.3 (wrong Sections). Corrected to Section 3.3.11 and 3.3.12.3.
3-24 3-25 3-26	3.3.12.6 3.3.12.6	Typos – incorrectly references 3.3.11.1. Corrected to 3.3.**12**.1. Typos – incorrectly references 3.3.11.1. Corrected to 3.3.**12**.1.

Summary of Revisions included in the Second Edition		
Page # of 1st edition	**Section # of 1st edition**	**Revision Description**
3-24	3.3.12.6	Added website references for: Section 2.3 – "Flood zones, flood maps" Tables 3.1. 3.2 – "Functional Classification Maps" Section 3.2.2.4 – "Clark County Land Use" Section 3.2.2.4 – "Washoe County Land Use" Section 3.2.2.4 – "Soil Types" Section 3.3.12.1 – "IP-86-2 Culvert Inspection Manual"
3-25	3.3.12.6	Deleted FHWA reference to 3.3.8.3 (wrong Section)
3-25	3.3.12.6	Deleted USDOT (HDS 6) reference to 3.3.11.1 (wrong Section). Changed to FHWA for consistency. Corrected to Sections 3.3.9 and 3.3.12.1.
3-26	3.3.12.6	Typos – incorrectly references 3.3.11.3. Corrected to 3.3.**12**.3.
3-26	3.3.12.6	Typos – incorrectly references 3.3.11.4. Corrected to 3.3.**12**.4.
3-26	3.3.12.6	Typos – incorrectly references 3.3.11.5. Corrected to 3.3.**12**.5.
A-2	Appendix A	Reworded Section II.b.ii to add "Title 23"
A-7	Appendix A	Corrected numbering for Appendix D
A-8	Appendix A	Reworded and relocated the electronic format note from check list table Appendix H to bottom of page
B-3	Appendix B	Modified plan sheet designations in Table B-6
B-4	Section B.3	Added a sentence regarding drainage cut sheet limits
B-5	Section B.3.2	7th bullet - added cut off walls
B-5	Section B.3.2	Added a section for channel profile
C-2	C.1.3	Relocated footnote from bottom of page to corresponding Section C.1.3.
C-6	C.1.4.4	Corrected typo to add sheet number "EC-1" to Silt Fence Section.

TABLE OF CONTENTS **PAGE**

TABLES **PAGE**

Section 1

1. Hydraulics Section Overview

1.1 Introduction

This document provides a summary of the Nevada Department of Transportation (NDOT) policies and criteria pertaining to hydrology and hydraulics. Technical information is generally not provided and only technical references are cited.

References to specific computer programs, Federal Highway Administration (FHWA) publications, American Association of State Highways and Transportation Officials (AASHTO) guidelines, NDOT, and other agency manuals and regulations will be noted within this document. It is expected that the Hydraulic Engineer will be knowledgeable in the use of the referenced items.

The policies and procedures set forth in this document are intended to be followed to the fullest extent possible. It is recognized however, that no manual or design guide can provide entirely complete and practical guidance applicable to all drainage design situations, nor can it take the place of experience and sound engineering judgment. As such, deviations from the guidelines of this document may, in some cases, be unavoidable or otherwise justifiable. Any deviation to policy or procedure must be pre-approved in writing by the NDOT Chief Hydraulic Engineer (CHE).

Questions regarding NDOT drainage policies and procedures are encouraged, and should be directed to the NDOT Hydraulics Section at (775) 888-7619.

Please refer to Section 3.3.12 (Design References) for other accepted discipline manuals and references.

1.2 Hydraulic Section Responsibilities

Hydraulics is a Section of the Design Division. For a detailed account of Design's responsibilities refer to the Roadway Design Project Development Design Manual (PDDM). A brief overview of the Hydraulics Section functions and responsibilities follows:

1.2.1 Design and Review

The Hydraulics Section provides drainage design support necessary for in-house design projects (projects coordinated by Roadway Design, Project Management, Traffic/Safety and Bridge). Typically, the Hydraulics Section provides design information for storm drains, culverts, ditches, channels, energy dissipators, bridges, detention and retention basins, water quality facilities, erosion control measures, etc. The Hydraulics Section also coordinates design activities, provides direction and performs reviews of drainage designs completed for NDOT by consultants.

1.2.2 Certification and Coordination

The Hydraulics Section is responsible to ensure designs comply with all relevant drainage design criteria and related policy, such as Federal Highway Administration (FHWA) Policy & Memos, Code of Federal Regulations Title 23 Part 650 Subparts A and B, Federal Emergency Management Agency (FEMA), and regulatory agencies (for example US Army Corps of Engineers (USACE), Nevada Division of Environmental Protection (NDEP), Environmental Protection Agency (EPA), etc), appropriate local agency criteria (Cities, Counties, General Improvement Districts, Irrigation Districts), and to ensure the drainage design is compatible with other criteria and design from other NDOT Divisions (Legal, Right-of-way, Materials, Bridge, Traffic/Safety, etc.). The Hydraulics Section also coordinates with the State Floodplain Coordinator when a project will affect regulatory floodplains, and with the State Engineer for those projects with facilities that require a Dam Safety permit.

1.2.3 Programs

The Hydraulics Section is responsible for the following programs:

1.2.3.1 Bridge Scour

The Statewide Bridge Scour Program includes scour vulnerability evaluation of existing bridges, development and implementation of scour mitigation plans for bridges determined to be at risk, and design of new bridges to satisfy current scour criteria.

1.2.3.2 Lake Tahoe Environmental Improvement Program

Managing the Lake Tahoe Environmental Improvement Program (EIP), the Hydraulics Section is responsible for planning, designing, scheduling, and implementing EIP projects within the Lake Tahoe Basin. The Hydraulics Section oversees planning, budgeting and usage of legislatively approved bonds for NDOT EIP projects. Hydraulics Section acts as NDOT's liaison with all federal, state, and local agencies in the Tahoe Basin. The Hydraulics Section obtains construction and grading permits from the Tahoe Regional Planning Agency (TRPA).

1.2.3.3 Water Quality and Erosion Control Program

The Hydraulics Section implements NDOT's Water Quality and Erosion Control Program. This program addresses policies, procedures and guidelines for NDOT and contractor compliance with federal and state water quality and erosion control requirements. Refer to NDOT's Water Quality Manuals for additional information.

1.2.4 Support Services

Support services include: review of encroachment permits, drainage studies, and surplus property requests; investigation of drainage complaints; performance of hydrologic and hydraulic research and monitoring; participation in cooperative agreements including the USGS stream flow gaging program; and, development of agreements with local agencies and consultants.

1.3 Legal Aspects

1.3.1 General

With any project, the hydraulic engineer must determine what hydrologic and hydraulic effect the project will have on other properties. If there will be substantial interference with the use of the property, NDOT may be responsible for damages. Conversely, if other projects will adversely impact NDOT property, NDOT needs to protect its interests. In difficult cases, NDOT legal counsel should be consulted.

1.3.2 Reasonable Use

Under the reasonable use doctrine, the courts judge the reasonableness of the landowner's dealings with the surface waters on his or her land in light of all relevant circumstances. If the landowner acts reasonably in modifying the natural flow of water across his or her land, the courts will allow a landowner to modify the flow of surface water onto or away from neighboring lands. Nevada follows the reasonable use rule. The Nevada Supreme Court adopted the reasonable use rule in County of Clark v. Powers, 96 Nev. 497, 502, 611 P.2d 1072, 1075 (1980):

This rule of reason provides that in effecting a reasonable use of land for a legitimate purpose, a landowner or user, acting in good faith, may drain surface waters and cast them on a neighbor's land if: (a) the injurious flow of waters is reasonably necessary for drainage; (b) reasonable care is taken to avoid unnecessary injury; (c) the benefit to the drained land outweighs the gravity of harm inflicted upon the flooded land; (d) the drainage is accompanied, where practicable, by the reasonable improvement and aiding of normal and natural systems of drainage in accordance with their reasonable carrying capacity; and (e) where no natural systems of drainage are available, the drainage is accomplished by the use of a reasonable, artificial system of drainage.

Id. at 503. Various factors for consideration of each case enunciated by the court are: the nature of the land, soil and terrain; the types of surface water involved; the availability of natural drainage ways; the feasibility of artificial drainage systems; the uses to which the land has been and will be put; the benefit and the harm produced by the drainage; and a host of environmental and social concerns. The reasonable use rule allows for the careful consideration of each of these public and private concerns; growth and urbanization are not unduly restricted, but merely tempered with elements of order, planning and reasonableness.

1.3.3 Guidelines

For every design project, the following should be evaluated:

- What are the historic drainage patterns, and will the project cause a change in the natural flow patterns of surface waters in the area (path of flow, velocity, depth, concentration, etc.)?

- If there is a change in the natural or historic flow patterns of surface water, will it cause an adverse impact to an adjacent property?
- Is there damage to an adjacent property owner(s)? Is the change in the flow patterns of water reasonably necessary? Has care been taken to avoid unnecessary damage to adjacent landowners? Are there any feasible alternatives that would prevent the damage?

Attention should also be paid to developers' projects adjacent to NDOT right-of-way. The hydraulic engineer must be diligent in efforts to ensure that these projects will not adversely impact NDOT right-of-way. The following actions, coordinated with the appropriate NDOT District Office, should be taken:

- Contact the appropriate local agency and/or developer (developers engineer) adjacent to NDOT right-of-way to discuss potential hydrologic/hydraulic issues.
- A developer's construction plans should be examined to determine the drainage effects of the proposed development.

Every effort should be made to protect NDOT from injury due to either change of flow patterns into or within NDOT right-of-way, or potential liability if a project adversely affects property owners adjacent to NDOT right-of-way.

1.4 Policy

1.4.1 General

The purpose of this section is to outline specific policies which, when carried out, will provide an appropriate level of consideration for the multitude of variables which influence drainage design. These policies are intended to be followed to the fullest extent possible. Specific information contained in this manual supersedes any conflicting information in the listed references. Any policy exceptions require prior written approval from the CHE.

The design of all NDOT drainage facilities must be completed to meet or exceed standard engineering practice, and be consistent with what a reasonably competent and prudent engineer would do under similar circumstances.

1.4.2 Drainage Policies

- The drainage design of roadway drainage facilities shall conform to established NDOT criteria, standard plans and specifications to the extent practicable.
- With adequate justification, it may be acceptable to follow locally developed and adopted drainage design criteria in lieu of NDOT criteria. Local community criteria may be used for NDOT roadways classified as "Other Principal Arterial" or lower and with the approval of the CHE.
- All NDOT drainage facilities shall be designed consistent with the legal aspects outlined in Section 1.3 (Legal Aspects) of this manual.

- Drainage improvements outside NDOT right-of-way shall not be considered unless there is a direct benefit to the Department, or the cost is borne by others.
- Drainage improvements proposed by others shall not be constructed within NDOT right-of-way unless they can be shown to be a direct benefit to NDOT and the general public.
- Roadway encroachment or development within a designated FEMA floodplain or floodway shall be consistent with regulations established by FEMA.
- Federally funded projects must be in compliance with Code of Federal Regulations Title 23 Part 650 Subparts A and B.
- Whenever practicable, NDOT will participate in design and construction of local flood control facilities (Nevada Revised Statue 543.547).

Section 2

2. Project Development and Documentation

2.1 Introduction

This section provides a general guideline for the hydraulic engineer to develop and document the drainage design at each developmental phase. Drainage design elements progressed through the various design phases include, but are not limited to: storm drain systems, channels, ditches, permanent erosion and sediment control features, water quality features, energy dissipators, culverts, detention and retention basins, etc. The procedures in this section are for typical major transportation projects. For many projects, it will not be necessary to follow all steps outlined in this section. Conversely, other projects such as bridges over waterways, river training systems, and water quality projects, may require more detailed information to be developed earlier in the design process. The Principal Hydraulic Engineer (PHE) will determine the appropriate design submittal requirements for each project. The hydraulic engineer is ultimately responsible to apply the appropriate level of design, select appropriate design methods, and provide complete project products.

2.2 Procedures and Documentation

2.2.1 General

NDOT projects are developed following the National Environmental Policy Act (NEPA) process. The following section is a brief overview of the major milestones in the NDOT project design process. This section is followed by a more detailed description of each phase.

The procedures in this manual are intended to be consistent with and supplement to the NDOT Project Design Development Manual (PDDM). Refer to the PDDM to ensure consistency in the design process.

Where appropriate, approval/verification from the NDOT Chief Hydraulic Engineer (CHE) or PHE will be required at various project milestones. These approvals must be documented in writing. The minimum approvals are outlined in the detailed description of each phase.

Completed Drainage Report Contents and Project Progress Checklist shall be included with each design submittal. Refer to Appendix A .

Drainage report and plan sheet submittal requirements are outlined in detail in Appendices A and B respectively. This information must be shared with the design team throughout project development.

Smaller, simpler projects may not need all the milestones/submittals as described below. Regardless of submittals required, all appropriate design steps outlined in this Section must be addressed.

Conceptual Design **-** In this phase, major project elements are considered. There may be several viable roadway alignment corridors, interchange types, etc., each with conceptual drainage alternatives. The main purpose of the conceptual design phase is to determine the most viable alternatives that warrant additional consideration.

Alternative Development - The viable alternatives from the Conceptual Design effort are evaluated further, with the goal of determining the preferred design alternative. The design for each alternative must be progressed equally to a level sufficient to determine the preferred alternative. This may be as detailed as the preliminary design level. Several drainage alternatives may be considered for each project alternative. These alternatives must be developed to an adequate level to determine the preferred drainage alternative for each roadway alternative, and to determine if drainage will be a significant factor in selecting the preferred roadway alternative.

Preliminary Design - In this phase, the selected design has progressed and is refined. Major design decisions including roadway geometrics and drainage concepts are determined.

Intermediate Design – During this phase, all design decisions are completed. The major goal of this phase is to develop the design to a level adequate to determine all right-of-way needs.

Discipline Review **-** This milestone may be required for complex projects designed by consultants as determined by the PHE. The submittal must include finalized drainage and erosion control related plan sheets. The plan submittal is sent to the Hydraulics Section to ensure the comments from the intermediate design are fully addressed and incorporated correctly. If necessary, final review of drainage related structural details will also be completed at this phase. **Note**: This manual does not include any additional information regarding this submittal. Please contact the PHE regarding questions or additional guidance.

Quality Assurance/Specifications- This submittal is intended to be 100% complete and will be used for the checking and specifications review. All drainage QA/QC review is to be completed prior to this submittal. NDOT's Specifications Section will perform a checking review, and finalize the Special Provisions (Specials). The Specials and plans will be distributed to provide a complete package for the entire review team. Approximately three weeks after distribution of the Specials, a Specifications review meeting will be held. Review comments for this submittal should generally be very minor and cosmetic in nature (comments from this review are expected to be incorporated into the plans in a matter of days).

Advertising Set – This plan set incorporates comments from the specifications review, and is then reproduced for advertising.

2.3 Conceptual Design

The conceptual design phase is used to develop the most viable design alternatives, and to identify any fatal flaws that result in less desirable alternatives being dropped from consideration. The level of effort should also identify preferred alternatives based on drainage impacts, i.e., impacts such as Federal Emergency Management Agency (FEMA) flood zones, environmentally sensitive areas, etc.

Drainage analysis and design is only developed to a level to determine if options are feasible, i.e., this is an order of magnitude evaluation to identify fatal flaws or obvious undesirable drainage impacts. Feasible design alternatives should be discussed with the project team and affected agencies. An order of magnitude cost estimate may be necessary to determine if any options can be eliminated from further consideration.

2.3.1 Coordination

Coordination between affected disciplines at the conceptual level is essential to development of the project. The hydraulic engineer must coordinate closely with the affected disciplines and project manager/coordinator.

General project criteria and design approach must be verified and approved in writing by the PHE. Selection of viable alternatives must be verified by the CHE and PHE. Verify that all local agency and FEMA requirements can be met.

At this stage, the hydraulic engineer will provide drainage concepts for review and comment from the design team. The hydraulic engineer typically provides the following during this design phase:

- Identification of project design constraints due to drainage issues (flood plain impacts, regional flood control facilities, water quality, etc.)
- Identification of conceptual project limits and potential impacts to right-of-way.
- Conceptual drainage design alternatives.
- Plan View - Schematic layout of major drainage facilities (channels, culverts, bridges, major storm drains, detention basins, permanent erosion and sediment control elements, water quality basins, etc.)
- Profile view - Major channel profiles and major cross drainage features.

The following coordination summary is intended to provide general guidance for typical situations only. It is not intended to be comprehensive. Additional coordination will likely be needed depending on project specific issues or complexity.

- **Project Manager / Coordinator** regarding project scope, schedule and budget.

- **Roadway Design Division** for initial roadway alignments, profiles, typical sections, barrier rail and sound wall locations. Limits of requested mapping must be coordinated with Roadway Design and verified with the PHE. Coordinate with Roadway Design Division to develop conceptual cost estimates.
- **Right-of-Way Division** for available right-of-way limit information, and to coordinate right-of-entry requests. Conceptual right-of-way needs should be identified during this phase. Coordinate with the **Utility Section** of the Right-of-Way Division to identify any known major utilities that may be difficult to relocate (fiber optic lines, high pressure gas, etc.).
- **Environmental Services Division** to identify fundamental environmental concerns and permitting requirements (wetlands, cultural sites, etc.). Identify areas/regions with special regulations or requirements, i.e., Tahoe Basin, etc. Coordination may be necessary to assist in the development of the project environmental documents.
- **Structures Division** for consultation on conceptual bridge dimensions.
- **Geotechnical Section** to identify regional geological conditions.
- **District Maintenance** for known flooding problems.

2.3.2 Design Methods and Procedures

2.3.2.1 Hydrology

Use of available hydrologic data is typically acceptable and encouraged for conceptual design. Sources for cross drainage peak flow information may include FEMA Flood Insurance Studies (FIS), Flood Control Master Plans, or studies prepared for other projects in the area.

If no existing information is available, regression equations, simple models, or statistical analyses are generally acceptable.

Typically, detailed on-site analysis is not required at this level. In those cases where an on-site evaluation is necessary, use of Rational Method and normal depth calculations are appropriate.

A preliminary conservative volume of an on-site basin can be estimated by determining the total run-off depth (rainfall minus losses) and multiplying by the contributing area. For off-site basins, a preliminary volume can be estimated by comparing existing basins with similar watershed characteristics, and modifying the size proportionally.

2.3.2.2 Hydraulics

Simple hydraulic calculations are typically adequate for the conceptual design level. Normal depth calculations using available topographic data are generally used for channel, ditch, and bridge opening sizing. Standard culvert calculations are used for culvert sizing. If necessary, storm drain trunk line sizing can be estimated using normal depth. Feasible storm drain outfall locations are identified.

2.4 Alternative Development

The alternative development phase is used to develop drainage alternatives for each viable roadway concept identified in the conceptual study. If a conceptual study is not required, all design and coordination outlined in that section must be completed as part of this phase.

Viable drainage alternatives are developed to the point that a preferred drainage option can be selected. The level of detail will be dependent on the complexity of the roadway design and drainage options. In many cases, the roadway alternatives will have similar drainage impacts, and will not require significantly different drainage solutions. The level of detail for drainage alternatives will be lower in these cases. For more complex roadway alternatives with varied drainage alternatives, this level could be as high as the preliminary design level. This is especially important if the preferred drainage alternative will influence the selection of the preferred roadway alternative. The hydraulic engineer and PHE must discuss the alternative development phase in detail and determine the required level of analysis.

At this stage, the hydraulic engineer will provide drainage alternatives for review and comment from the design team. The hydraulic engineer typically provides the following during this design phase:

- Input on relative drainage impacts for each project alternative.
- Alternative drainage designs and relative costs for the project alternatives.
- Plan view - Refined conceptual sketches of feasible drainage systems
- Profile view - Refined conceptual drawings, typically for major channel profiles and major cross-drainage features
- Identification of potential drainage right-of-way needs.

2.4.1 Coordination

The recommended drainage alternative must be approved in writing by CHE. Confirm that all local agency and FEMA requirements are met.

Coordinate all design elements and issues with the following affected disciplines, with the understanding that all listed information may not be fully available:

- **Project Manager/Coordinator** regarding project scope, schedule and budget.
- **Roadway Design Division** for available information including updated roadway alignments, profiles, typical sections, barrier rail, guardrail and sound wall locations, etc. Coordinate with the Roadway Design team to incorporate appropriate features into the typical sections (approximate locations and size of roadside ditches, curb and gutter, etc.). Provide the Roadway Design team with any known hydraulic design information and flexibility (culvert sizes, dip section geometry, etc.) to help advance the roadway design.

- **Right-of-Way Division** to verify existing right-of-way limits. Preliminary (order of magnitude) drainage easements and right-of-way needs should be identified by this time, with approximate dimensions, and reviewed by the PHE. All utility designation must be complete by the end of this phase. Coordinate with the **Utility Section** to determine desired clearances (horizontal and vertical) for utilities and identify those utilities that have prior rights.
- **Environmental Services Division** to finalize the project environmental documents.
- **Structures Division** for potential bridge types, location, and preliminary geometry (pier and abutment information, etc).
- **Geotechnical Section** to identify any known fundamental geotechnical conditions in the vicinity of potential major drainage facilities that may affect the drainage design alternative development (high groundwater, unsuitable foundation material, material where excavation may be difficult, etc.). Request needed geotechnical testing (percolation test, etc.)
- **Construction Division** for general constructability of proposed drainage features.
- **District Maintenance** to identify maintenance issues of existing drainage facilities (poor draining areas, facility condition, sediment/erosion prone areas, etc.) and concerns regarding proposed facilities.
- **Local government agencies** to coordinate drainage design alternatives and to discuss possible agency cooperation (funding, maintenance responsibilities, etc.).

2.4.2 Design Methods and Procedures

2.4.2.1 Hydrology

The hydrologic level of detail needed for alternative analysis will vary depending on the complexity and potential impacts of the project. The hydrologic results generated from the conceptual analysis may be refined using more detailed techniques and guidelines as necessary. The level of analysis must be determined in writing and approved by the PHE.

Hydrology for the alternative development design should usually be developed using the same methodology that will be carried through final design, especially for the more complex cases. This will typically be done with regression equations, synthetic models, or statistical analyses. Please see Section 3.2 (Hydrology) for a discussion of method applicability. For projects that do not require comprehensive drainage analysis, hydrologic methods outlined in Section 2.3 (Conceptual design) may be more appropriate. For projects where the drainage design may influence the selected alternative, refer to the hydrologic analysis requirements in Section 2.5.2 (Preliminary Design-Design Methods & Procedures). The methods and level of detail must be approved by the PHE.

If the on-site system will be a factor in determining the preferred alternative, preliminary flows can be determined using the Rational Method.

2.4.2.2 Hydraulics

More sophisticated hydraulic calculations for off-site flows may be required for the alternative development phase. Normal depth calculations are acceptable where appropriate. For sensitive areas that may experience backwater, a water surface profile model may be required. All culverts must be evaluated using standard culvert calculations (HDS 5). Water surface profile modeling programs are used for major bridge and culvert sizing. Roadway surface systems (on-site systems) are only evaluated as necessary to determine major impacts associated with each alternative, and to determine if the on-site system will be a significant factor in selecting a preferred alternative.

On-site systems at this level are designed only to determine if there are fatal flaws or if there are significant on-site system issues that will affect the alternative selection. This may be done by developing a conceptual layout, and determining viable storm drain outfall locations.

2.5 Preliminary Design

The preliminary design phase is used to develop the selected drainage alternatives for the selected roadway alternative. All major roadway and drainage concepts and elements have been selected through the alternative development phase.

At this stage, the hydraulic engineer will provide drainage alternatives for review and comment from the design team. The hydraulic engineer typically provides the following during this design phase:

- Preliminary drainage design requirements developed based on applicable local, state, and federal agency criteria.
- Preliminary drainage designs for the selected project alternative.
- Plan view - preliminary drawings of selected drainage alternative
- Profile view - refined conceptual drawings, typically for major channel profiles and major cross drainage features
- Identification of preliminary drainage right-of-way needs.
- Preliminary scour depths and bridge opening size.

2.5.1 Coordination

Coordinate all design elements and issues with the following affected disciplines, with the understanding that all listed information may not be fully available:

- **Project Manager / Coordinator** regarding project scope, schedule and budget.
- **Roadway Design Division** for preliminary roadway alignments, profiles, typical sections, barrier rail and sound wall locations, etc. Coordinate with the Roadway Design team to incorporate appropriate features into the typical sections (roadside

ditches, curb and gutter, etc.). Provide Roadway Design team with any necessary hydraulic information (culvert sizes, dip section geometry, etc.) to finalize the roadway profiles. Coordinate with the **Specifications Section** to initiate a procedure for inclusion of any proprietary items. Coordinate with the **Landscaping Section** regarding compatibility of landscape components with drainage design.

- **Right-of-way Division** to identify preliminary drainage easements and right-of-way needs. All right-of-way needs must be reviewed by the PHE. Coordinate with the **Utility Section** of the Right-of-Way Division to identify any apparent or potential utility conflicts. Identify potential costly utility relocations. All utility designation must be completed by the beginning of this phase. Once drainage facilities are determined, pothole locations must be identified, and reviewed by the PHE.
- **Environmental Services Division** to formulate mitigation measures for issues identified in the projects environmental documents.
- **Structures Division** for refinements to bridge design. Coordinate the need for on-site drainage facilities within the bridge structure, including size, material, and location. Notify the Structures Division of the need for any anticipated drainage special detail designs (transitions, energy dissipators, connections, etc.).
- **Geotechnical Section** to obtain drainage related geotechnical information such as anticipated settlement, potential filter blanket design, percolation rates of detention/retention basins, problematic foundation material, high groundwater, etc.
- **Construction Division** for constructability of proposed drainage features, preliminary construction phasing, and potential detour impacts. Coordinate construction constraints pertaining to the drainage facility construction, e.g., construction windows, and river diversion requirements.
- **Traffic/Safety Division** to coordinate sign, signal, and lighting locations, as well as traffic control.
- **District Maintenance** to resolve maintenance needs for proposed facilities.
- **Local government agencies** to ensure they are fully aware of design issues and drainage impacts, to gain consensus on flows and criteria, and to define terms of cooperation.

2.5.2 Design Methods and Procedures

2.5.2.1 Hydrology

The hydrologic results generated from the conceptual or alternative development phase may be refined using more detailed techniques and guidelines as necessary. Hydrology for the preliminary design will be developed using the same methods that will be carried through final design. This will typically be done with regression equations, synthetic models, or statistical analyses. Please see Section 3.2 (Hydrology) for a discussion of method applicability.

All off-site hydrology must be completed to a level as high as possible given the availability of off-site information, i.e., zoning information, soils maps, etc. Modifications to the hydrology from this point forward should be limited to minor adjustments and refinements. Off-site flows shall be compared to existing available data such as local Flood Control Master Plans, existing studies, and existing Flood Insurance Studies (FIS). Any major discrepancies shall be addressed and resolved by the hydraulic engineer.

Preliminary flows for on-site systems can be determined using the Rational Method.

2.5.2.2 Hydraulics

More sophisticated hydraulic calculations for off-site flows are typically required for the preliminary design phase. Normal depth calculations are acceptable where appropriate. For sensitive areas that may experience backwater, a water surface profile model is typically required. All culverts must be evaluated using standard culvert calculations (HDS 5). Water surface profile modeling programs are used for major bridge and culvert sizing.

On-site systems at this level are designed by placing inlets at mandatory locations (end of barrier rails, reverse super elevations, sags, etc.) and at locations determined by approximate spacing needed to meet spread criteria (determined with Rational Method and normal depth). More detailed discussion on inlet spacing can be found in Section 3.3.2.2.1 (Inlets-Roadway Surface and Infield). The on-site trunk line sizing can be estimated using normal depth. Potential storm drain outfall locations must be verified to be feasible.

2.6 Intermediate Design

At this stage, the hydraulic engineer will provide the drainage design for review and comment to the design team. The hydraulic engineer typically provides the following during this design phase:

- Substantially complete drainage designs for the project (refer to Appendix A, Drainage Report Contents and Project Progress Checklist, for required level of completion) including:
    - ♦ Drainage designs plan view drawings.
    - ♦ Drainage profile drawings, typically for major channels and cross drainage features.
    - ♦ Construction notes.
    - ♦ Inroads files for major channels and cross drainage features including horizontal and vertical alignments and templates.
- Dimensioned special details.
- Preliminary erosion control plans.
- Identification of final drainage right-of-way needs.

2.6.1 Coordination

Coordination involves reviewing approaches and design methods with the PHE, as well as obtaining approval from the PHE for all proposed facility locations, peak flows, etc. Final right-of-way, temporary and permanent easements, and permissions to construct must be verified by the CHE prior to the right-of-way setting. Any necessary design exceptions must be fully discussed and approved in writing by the CHE.

Continued coordination must include the following at a minimum:

- **Project Manager / Coordinator** regarding project scope, schedule and budget.
- **Roadway Design Division** for final alignments, profiles, typical sections, barrier rail and sound wall locations, construction phasing (including detours). **Landscaping Section** to verify compatibility of landscape components with drainage design and erosion control elements. Provide notes to **Specifications Section** for drainage related special provisions. Obtain approval for use of proprietary items during the early stage of this phase.
- **Right-of-Way Division** to finalize right-of-way, easements, and permissions to construct for drainage purposes. The final right-of-way setting will occur after the intermediate submittal. All right-of-way needs must be verified by the PHE and CHE prior to the final right-of-way setting. Coordinate with **Utilities Section** to obtain final pothole information and resolve utilities conflicts. Necessary drainage related utility issues must be resolved and approved by the PHE by the end of this phase.
- **Environmental Services Division** to coordinate drainage design refinements that minimize environmental impacts, and finalize mitigation plans.
- **Structures Division** for final location and size of bridge piers and abutments, and bridge deck information. Provide design for on-site drainage facilities that may affect bridge structures, including size, material, and location. Provide information to the Structures Division necessary to develop special structural designs and details. Provide final scour depths and false-work opening size.
- **Geotechnical Section** to verify that the drainage design has properly incorporated geotechnical issues.
- **Construction Division** to resolve constructability issues. Ensure adequate right-of-way or easements are established for construction of drainage facilities.
- **Traffic/Safety Division** to resolve sign, signal, and lighting location conflicts with drainage facilities, and to resolve traffic control issues.

- **District Maintenance** to verify maintenance needs have been properly addressed, and adequate right-of-way or easements have been established for long-term maintenance access.

- **Local governmental agencies** to finalize terms of cooperation.

2.6.2 Design Methods and Procedures

2.6.2.1 Hydrology

Hydrology for the intermediate level will involve refining the analysis developed for the preliminary design. All off-site and on-site hydrology must be essentially completed at this level. Consensus for design flows must be obtained by all affected agencies and the PHE.

2.6.2.2 Hydraulics

More sophisticated hydraulic calculations are required for the intermediate design phase. Normal depth calculations are acceptable where appropriate. For sensitive areas that may experience backwater, a water surface profile model is required. All culverts and bridges must be evaluated using standard culvert calculations and/or water surface profile modeling programs. Stability calculations are required for any hydraulic feature that may be susceptible to erosion.

The on-site system must be completed at this level to determine all facility locations. More detailed discussion on storm drain design can be found in Section 3.3.2 (Roadway Surface Systems).

All storm drain inlet and pipe locations must be determined and verified that no unresolved conflicts exist. Storm drain models that generate standard hydraulic grade line information must be used. Sizes of all laterals, trunk lines, down drains, etc. must be determined, optimized, and supported with hydraulic calculations. All outlet locations and water quality treatment areas must be established.

2.7 Quality Assurance / Specifications Submittal (QA / Specs)

This submittal is used as a last check for quality assurance and should simply be a verification that the information in the plans and specifications represents all intended design objectives. The Hydraulic Engineer shall verify that all previous review comments have been fully addressed.

NDOT's Specification Section will perform an overall quality assurance review, and prepare the Special Provisions (Specials). After the Specials have been prepared, they are distributed to the entire team. The team will have approximately three weeks to review the complete package, and then a Specifications review meeting is held to go over any final comments. Only very minor cosmetic revisions to the plans as well as minor revisions to the Specials are expected at this level.

2.7.1 Coordination

Continued coordination between the intermediate and QA/Specs submittals is critical, as there is very little opportunity to incorporate changes after the QA/Specs submittal.

The coordination effort must include the following at a minimum:

- **Project Manager / Coordinator** regarding project scope, schedule and budget.
- **Roadway Design Division** to verify that all drainage design elements are accounted for in the PS&E package. Coordinate with **Specifications Section** to finalize drainage related special provisions.
- **Structures Division** to finalize drainage special details.

2.7.2 Design Methods and Procedures

2.7.2.1 Hydrology

Hydrology for the QA/Specs submittal will involve incorporating any comments from affected agencies, and refining the analysis to reflect any modifications to the roadway or drainage designs that may have occurred since the intermediate submittal. Only minimal changes should be needed at this level.

2.7.2.2 Hydraulics

Minor refinements to the hydraulics are made at this submittal to reflect comments or modifications since the intermediate submittal.

2.8 Advertising Submittal

The Advertising Submittal is the final opportunity to incorporate minor comments received from the QA/Specs review. The team will have approximately two (2) weeks to incorporate comments from the Specifications review meeting. The plans will then be reproduced and used to advertise for bidding.

2.8.1 Coordination

Continued coordination with project manager and all affected Sections, Divisions, or agencies is required to ensure comments resulting from the QA/Specs review are adequately addressed and resolved.

For federally funded projects, the Hydraulics Section will certify that the drainage design was completed in accordance with the Code of Federal Regulations Title 23 Part 650 Subparts A and B.

2.9 QA/QC Process

The following are minimum guidelines for Quality Assurance and Quality Control (QA/QC) of design submittals.

2.9.1 Definitions

- **Quality Assurance (QA):** The process that establishes design requirements (policies, standards and guidelines) and verifies design products conform to specified requirements. QA is the responsibility of the PHE or the consultant's principal hydraulic engineer/manager.
- **Quality Control (QC):** The process by which design quality is ensured which includes checking calculations and following established procedures and guidelines. QC is the responsibility of the entire drainage design team.
- **Chief Hydraulic Engineer (CHE):** Hydraulics Section Chief, Registered Professional Engineer (RPE).
- **Principal Hydraulic Engineer (PHE)**: Hydraulics Section Manager, Registered Professional Engineer (RPE).
- **Hydraulic Engineer:** Hydraulics Section Staff III, Registered Professional Engineer (RPE) and consultant hydraulic engineer that are registered in Nevada.

2.9.2 Responsibilities and Required Approvals

The following is a summary of roles and responsibilities of Hydraulics Section staff and consultants that work on drainage projects. Please note that drainage designs include, but are not limited to: storm drain systems, channels, ditches, permanent erosion and sediment control features, temporary pollution control features, water quality features, energy dissipators, culverts, detention and retention basins, etc. All required approvals listed below must be in writing.

2.9.2.1 Chief Hydraulic Engineer (CHE)

2.9.2.1.1 Responsibilities

1. Establishing drainage polices, procedures, guidelines and standard plan drawings.
2. Directing Hydraulic Section programs.

2.9.2.1.2 Required Approvals

1. Deviation from drainage policies, standards and guidelines.
2. Modifications to Hydraulic Section program elements.
3. Consultant scope of work and engineering costs.
4. Drainage inter-local and cooperative agreements.
5. Grants and funding applications.

6. Final drainage alternative for new construction projects.
7. Final drainage right-of-way, temporary and permanent easements, and permissions to construct.
8. FEMA flood plain modifications.
9. Use of proprietary drainage and erosion control products.
10. Research proposals.
11. Technical publications and presentations.
12. Supplemental notices to contractors initiated by Hydraulics Section.
13. Construction contract change orders initiated by Hydraulics Section.
14. Modifications and changes to existing drainage facilities proposed by NDOT Districts.

2.9.2.2 Principal Hydraulic Engineer (PHE)

2.9.2.2.1 Responsibilities

1. Managing one or more of the Hydraulics Section's programs.
2. Programming projects and ensuring inclusion of programs' elements in the STIP and NDOT annual work program.
3. Determining the appropriate design effort, required design products and submittals for each project.
4. Developing project schedules and managing resources (in-house staff and consultants).
5. Coordinating design activities with internal divisions and external agencies.
6. Providing expertise and technical leadership in solving complex engineering problems.
7. Preparing inter-local agreements.
8. Managing and directing the development of drainage designs to include plans, specifications and estimates.
9. Managing design consultant agreements to include preparing consultant requests for proposals; evaluating proposals and selecting consultants; negotiating and preparing consultant agreements; monitoring design efforts of consultants to ensure compliance to project scope; reviewing invoices; appraisal of consultants, and handling contract disputes, appeals and terminations.

10. Certifying that all standards, specifications, codes regulations have been met in the design of projects.

11. Overseeing research and monitoring activities.

2.9.2.2.2 Required Approvals

1. Project criteria, design approaches, methods, use of hydraulic modeling software, major facility locations and sizes, design flows, and major design assumptions.

2. Drainage project scope, cost and schedule.

3. Design submittal elements including but not limited to reports, plans, and specifications.

4. Limits of required mapping.

5. Pothole location requests.

6. Utility relocation requests.

7. Project related written communication with federal, state, and local agencies.

2.9.2.3 Hydraulic Engineer

2.9.2.3.1 Responsibilities

1. Planning, organizing and conducting drainage studies.

2. Identifying feasible drainage alternatives and recommending viable alternative(s).

3. Selecting the most appropriate design approach, method, assumptions and hydraulic model for a project.

4. Ensuring minimum design standards and guidelines established in this manual are followed.

5. Optimizing design elements based on economic considerations, impact to adjacent properties, legal issues, constructability, and maintenance needs.

6. Preparing accurate plans, reports, and specifications.

7. Coordinating design activities with internal divisions and external agencies.

8. Reviewing plans, reports, specifications, and recommendations prepared by in-house staff and consultants.

9. Reviewing occupancy permit applications, surplus property request and drainage studies.

10. Providing engineering assistance to internal divisions.

11. Investigating, resolving and answering flooding complaints from the public.

2.9.3 QA / QC Procedures and Documentation

The following procedures must be followed for all NDOT design projects conducted internally or through consultants:

1. The hydraulic engineer must perform and/or check design calculations, assumptions, spreadsheets, and computer program input and output.

2. For all design submittals, the PHE or consultant principal engineer/manager must certify to the CHE in writing that the design products including the reports, plans, details, and specifications were developed according to minimum standards established in this manual. For federally funded projects, the certification must include compliance with Code of Federal Regulations Title 23 Part 650 Subparts A and B. Any exceptions must be justified and require prior written approval of the CHE.

3. Project criteria, methodology, and guidelines are established by the hydraulic engineer and must be approved in writing by the PHE.

4. Form 1 (Review Comments) (Appendix A) must be completed by the reviewer and the project hydraulic engineer. The hydraulic engineer must address all comments to a level that is satisfactory to the hydraulic reviewer. **Note:** For consultant projects Form 1 will be completed by the consultant reviewer and then by the Hydraulics Section reviewer for each submittal.

5. All project worksheets, spreadsheets and computer program input and output must be signed and dated by the hydraulic engineer and a hydraulic reviewer.

6. The Drainage Report Contents and Project Progress Checklist (Appendix A) must be signed and dated by the hydraulic engineer and PHE or consultant principal engineer/manager.

7. For in-house projects, the hydraulic engineer and PHE must sign the drainage report. For consultant projects, the hydraulic engineer or consultant principal engineer/manager must seal the report.

8. All required PHE and CHE approvals must be obtained in advance of performing the work.

Section 3

3. Design Guidelines

3.1 Introduction

This section is intended to provide technical guidance and criteria for use in developing drainage designs, including a brief overview of available methods, and NDOT's interpretation of their applicability and limitations. The following are general hydraulic design guidelines:

- The level of design studies should be commensurate with the risk associated with the improvement and with other economic, engineering, social, or environmental concerns.
- Established drainage patterns within NDOT right-of-way shall be perpetuated and/or improved through the roadway prism to the extent practicable, up to the 100-year event.
- The design must be assessed to verify no adverse drainage effects have been created up to the 100-year event.
- Design of local regional flood control facilities within NDOT right-of-way shall conform to established local policies, criteria, and standards to the extent practicable.
- For impoundments and diversions, consideration should be given to water rights impacts.
- Consideration should be given to public safety when designing hydraulic facilities.
- The use of drainage systems (channels, detention basins, etc.) as multi-use facilities (parks, bike paths, etc) is not supported, unless all liability, maintenance, and ownership are assumed by a local entity. The CHE must be notified of any proposed multi-use facility.

3.2 Hydrology

3.2.1 General

For a complete discussion of hydrologic analysis, the reader is referred to Hydraulic Design Series No. 2 (HDS 2): Highway Hydrology, by FHWA, and Guidelines for Hydrology – Volume II, Highway Drainage Guidelines, prepared by AASHTO.

A design storm frequency shall be selected based on the facility to be designed and the roadway classification. Design storm frequency tables for various facilities are as follows:

Table 3-1
Roadway Surface Drainage Facilities

Roadway Classification [1]	Minimum Design Return Frequency (Years)	Maximum Allowable Spread Into Adjacent Travel Lane [3]
Interstate Highways [2]	25	0
Principal Arterials & Other Freeways and Expressways [2]	25	0
Other Principal Arterial	25	½ lane
Minor Arterial	10	½ lane
Rural Major Collector	10	½ lane
Urban or Rural Minor Collector	10	½ lane
Frontage Roads (if not classified)	10	½ lane

(1) Contact the NDOT Planning Division for the latest roadway functional classification maps.
(2) Including ramps
(3) Spread limits specified are as measured into the traveled lane beyond any available parking lanes, bike lanes, and shoulder widths. Turn pockets and bus turnouts are not considered as the travel lane. Auxiliary lanes are considered as travel lane.

Table 3-2
Design Storm Selection Guidelines for Off-Site Flow Facilities (Culverts, Channels, Bridges)

Roadway Classification [1]	Minimum Design Return Frequency (years) [2]
Interstate Highways [3]	50
Principal Arterials & Other Freeways and Expressways [3]	50
Other Principal Arterial	25
Minor Arterial	25
Rural Major Collector	25
Urban or Rural Minor Collector	10
Frontage Roads (if not classified)	10

(1) Contact the NDOT Planning Division for the latest roadway functional classification maps.
(2) If an existing roadway is known to have been designed for a higher return frequency than indicated in the above table, the higher return frequency shall be used for design.
(3) Including ramps.

The hydrologic analysis shall consider the existing and future 20-year development or ultimate build-out condition in the contributing watershed. Verify assumptions with the Principal Hydraulic Engineer (PHE). The existing conditions shall be evaluated based on current development and current flood control facilities in place. If proposed flood control facilities are imminent or will be constructed within the same time frame as the project, they can be considered as existing (discuss with local agencies and PHE). The developed or future conditions of the watershed shall be modeled by assuming the upstream area has been developed in accordance with available land use planning information, judgment, and the assumption that all proposed master planned flood control facilities are in place. Typically the larger flow condition will be used for design.

3.2.2 Acceptable Methods

Several available hydrologic methods acceptable to NDOT and the circumstances and limitations of their use are listed below. Upon approval by the PHE, other appropriate methods may be used. Where possible, the hydrologic method used should be calibrated to local conditions and tested for accuracy and reliability. It is good practice to compare the results of other hydrologic methods to the chosen method. The hydraulic engineer must select the most appropriate hydrologic method for the watershed to be analyzed. The appropriate method is typically dependent on considerations such as available data, project complexity, required level of effort and accuracy, etc., and must be approved by the PHE. All hydrologic analyses shall include research of the flood history of the area (including maintenance records), available storm run-off data, and the effect these historical flows have had on existing structures.

The following provides a guide to hydrologic methods and their appropriate applications and limitations:

3.2.2.1 Rational Method

- The Rational Method shall be used only for drainage areas up to 200 acres.
- The Rational Method is typically used to determine design discharge rates for all storm drain system elements. However, for complex storm drain systems or where a hydrograph is needed (for peak timing or run-off volume), it is preferred to design the inlets and laterals using peak flows estimated by the Rational Method, and design the storm drain mainline, and/or detention basin using a synthetic hydrograph model, such as HEC-1. The two methods will often produce varied results, and therefore should be adjusted to produce reasonably consistent peak flows.
- For Clark County, rainfall intensities shall be developed in accordance with the Clark County Regional Flood Control District (CCRFCD) Hydrologic Criteria and Drainage Design Manual (HCDDM). Rainfall intensities for the remainder of the state shall be developed using the procedure outlined in National Oceanic and Atmospheric Administration (NOAA) Atlas 14, Precipitation-Frequency Atlas of the Western United States, Nevada.
- A minimum time of concentration (T_c) of 5 minutes is used for directly connected impervious drainage basins, such as on-site roadway surface basins. A minimum T_c of 10 minutes is used for basins including pervious areas. Subdivide basins into areas of similar hydrologic characteristics in order to develop an appropriate T_c.

- The hydrograph produced by the Rational Method is not appropriate for detention basin design due to the hydrograph time base. NDOT requires detention basins to be based on the 6 or 24-hour storm as appropriate.
- NDOT does not accept the use of the "Modified Rational Method" as defined in the CCRFD Manual in which a reduction factor is applied to the calculated flow rate.
- Depending on the terrain, the sheet flow component of the T_c generally occurs over distances much less than 300 feet (flat terrain), and typically less than 100 feet (steep terrain).

3.2.2.2 Regression Equations

- Regression equations are generally used to estimate peak flows for watersheds with limited data for which other hydrologic methods are impractical or infeasible.
- Regression equations may be used at sites within the limitations of the equations, and where the required accuracy of the analysis is commensurate with the equations.

3.2.2.3 Statistical Analysis

- Statistical analyses are used to estimate peak flows using recorded data. Where stream flow gage data is available, the Log Pearson III analysis shall be used provided there are at least 10 years of continuous or synthesized gage data for 10-year or more frequent discharge estimates and 25 years for 100-year discharge estimates (Reference WRC Bulletin 17b). Consider drought periods, watershed development and condition, facility construction or removal, type of run-off event, and other factors that may affect the statistical distribution.
- Statistical analysis results from hydrologically similar basins may be transferred to adjacent basins.
- For NDOT projects, statistical analysis of gage data is available from the USGS upon request. Real time and historical data is available online from USGS. Gage data may also be available from local entities.

3.2.2.4 Synthetic Modeling

- Synthetic modeling is used to develop peak flows or where a run-off hydrograph is required.
- Synthetic models using a unit hydrograph should not be used for watersheds over 100 square miles.
- The SCS (NRCS) unit hydrograph method shall be used to develop a unit hydrograph.
- Within Clark County, rainfall distribution shall be developed in accordance with the CCRFCD manual. Rainfall distribution for the remainder of the state shall be developed using the procedure outlined in NOAA Atlas 14, Precipitation-Frequency Atlas of the Western United States, Nevada, referred to as the "Balanced Storm." With sufficient justification, alternate storm distributions may be used with approval of the PHE.

- Watershed T_c and Lag Time shall be computed using SCS TR-55 (1986), United States Bureau of Reclamation (USBR) Flood Hydrology Manual, (1989), of Federal Aviation Administration (FAA) equations (1970). Refer to the CCRFCD manual and the Washoe County manual for usage guidelines and limitations.
- Additional information regarding land use (Clark County, Washoe County) and soil types (Natural Resources Conservation Service) can be found online.
- Within Clark County, routing methods shall be developed in accordance with the CCRFCD Manual. Use the Muskingum, Muskingum-Cunge or Kinematic Wave channel routing for the remainder of the state. The Modified-Puls method shall be used for reservoir routing.

3.2.2.5 Other Methods

- Local published hydrologic methods may be used with prior written approval by the PHE.
- The 100-year discharges specified in FEMA Flood Insurance Studies shall be used to analyze impacts of proposed projects in regulatory floodways and floodplains. If the published flows appear to be outdated, values based on current hydrologic methods may be used subject to approval from necessary regulatory agencies. Verification that the published discharges are reasonable must be completed prior to using the flow values for design.
- Locally accepted flows presented in local flood control master plans may be used with concurrence of the PHE.

3.3 Hydraulic Design Guidelines

3.3.1 General

Following are hydraulic design guidelines and criteria. For more detailed information, refer to the appropriate references listed in Section 3.3.12 (Design References).

3.3.2 Roadway Surface Systems

3.3.2.1 General

Roadway surface drainage facilities collect storm water run-off from the pavement and contributing adjacent area and convey it through the roadway right-of-way to an appropriate outlet. Roadway surface drainage facilities, a.k.a. on-site systems, consist of curbs, gutters, drop inlets, storm drains, median ditches, and roadside ditches.

For more design and engineering guidance, refer to the Federal Highway Administration publication, "Urban Drainage Design Manual" (HEC 22). On-site systems should be evaluated for unanticipated impacts (areas of ponding, flow diversion, etc.) resulting from 100-year rainfall. Consult with PHE to assess the level of effort needed for evaluation and mitigation.

3.3.2.2 Design Criteria and Guidelines

- The on-site system design frequency shall be based on Table 3-1 (Roadway Surface Drainage Facilities).
- For all roadway surface flow spread calculations use a Manning's "n" value of 0.015.
- When practicable, roadway surface drainage facilities shall be designed to collect all flows reaching the roadway surface. This would include run-off generated both on the roadway itself, and flows reaching the roadway prism from upstream and adjacent basins such as parking lots or cross streets that direct flows onto the roadway surface. If significant off-site flows are directed into the on-site system, that system must be designed to accommodate those flows. Consult with the PHE for these cases.
- The outlets of storm drains shall be designed considering the potential for flow diversion, outlet erosion, safety, etc.
- Where roadway widening is expected in the future, the onsite system shall be designed to be compatible with the ultimate roadway configuration to the extent possible. At a minimum, consideration shall be given to drop inlet and manhole location, storm drain trunk line capacity and location, and impacts of increased peak flow at storm drain outlet.
- The 100-year event (developed conditions flows) must be evaluated to the extent necessary to ensure no adverse impacts are created. For example, at sag locations or where a long system is bordered by barrier rail and cumulative bypass flow could become significant, or where storm drain outlets discharge to detention structures or other facilities susceptible to failure.
- Gutter grades should not be less than 0.3 percent for curbed pavements (not less than 0.2 percent in very flat terrain). Minimum grades can be maintained in very flat terrain by use of a "saw tooth" profile. Special care must be taken when roadway surfaces are created from vertical curves and/or super elevations that reduce the available gutter slopes.
- A minimum two (2%) percent typical cross slope is desirable for all roadway surfaces. The typical roadway cross slope shall not be less than 1.5 percent without CHE approval.
- The on-site system shall be designed to minimize flows across the traveled way, such as at reverse super elevations and gore locations. Flows directed onto bridges should also be minimized, especially in areas where freezing temperatures are expected. Concentrated flows across the traveled way or onto bridges shall be limited to a maximum of 0.25 cfs (this is measured as the bypass at the last inlet, which is usually at the point of 1% cross slope).
- Bituminous shoulder dike heights greater than three inches require the approval of the CHE. Use of six inch high dike requires approval of the Chief Road Design Engineer.

3.3.2.2.1 Inlets (Roadway Surface and Infield)

- Inlets shall be placed to intercept flows to meet the spread criteria as shown in Table 3-1 (Roadway Surface Drainage Facilities), and designed in accordance with HEC-22, Urban Drainage Design Manual, FHWA. Larger inlets, i.e., inlets collecting off-site flows, may require additional design consideration. Coordinate these instances with the PHE.
- Bicycle/Pedestrian safe grates shall be used for all areas where bicycle/pedestrian traffic is expected.
- Infield grates, such as the NDOT Standard Type 2A, can be used where debris is expected or high efficiency is required, however, this type of grate shall not be used where pedestrian traffic is expected.
- At super elevation reversals, place inlets where the cross-slope reduces to approximately 1% and limit design flow bypass to 0.25 cfs. On a case-by-case basis and in long transitions, especially where the distance between the last inlet and the reverse super elevation exceeds 100 ft, the hydraulic engineer and the roadway designer shall work closely to minimize risks associated with bypass flow. Placing an additional drop inlet at approximately 0.5% and minimizing the bypass flow to 0.1 cfs should be considered.
- Coordinate with Roadway Design to avoid cross slope reversals near vertical curve high or low points. This creates flat areas on the roadway surface that accumulate water and cannot efficiently be drained.
- Sag locations are determined by the roadway profile, super elevation, and gore details. Super elevation transitions in sag locations should be avoided, however, if unavoidable, ensure the true low point is accurately located by considering both the profile grade and cross slope.
- If special details are provided in the plans, i.e., gore details, intersection grading, etc., the elevation information included in these details will generally supersede the plan and profile sheets (coordinate with Roadway Design team).
- For capacity calculations, longitudinal and transverse slopes at inlets must be consistent with the roadway profile and super elevation plans. If a Digital Terrain Model (DTM) is used, the hydraulic engineer must verify the DTM accurately portrays the profile information.
- For inlets in a vertical curve and/or a super elevation transition, determine the instantaneous longitudinal slope at the grate by determining the elevation at the grate, and at 10 feet upstream. The slope between these two points will be considered the instantaneous slope at the grate.
- It is not necessary to include a clogging factor for inlets on grade, unless debris is known to be a problem. Use a minimum 25% clogging factor for inlets on grade that are expected to be subject to debris. Use of a larger clogging factor requires the approval of the PHE. Apply a clogging factor by reducing the actual grate front and side dimensions by 25% in capacity calculations.

- In sag locations, a 50% clogging factor shall be applied by providing double the required inlet capacity (If in orifice flow, assume half of the open area is clogged, if in weir condition, assume half of the weir length is ineffective).
- For sag locations where a clogged inlet could result in ponding depths greater than one foot, design the sag inlet as described above and provide two (2) additional flanker inlets. Each flanker inlet shall have the same effective perimeter as required for the sag inlet prior to application of the 50% clogging factor. The flanker inlets should be placed at an elevation of 0.37 times the allowable ponding depth (as determined by the allowable spread) above the sag inlet. This design approach will provide the required inlet capacity at the allowable ponding depth if the sag inlet should become fully clogged and assumes that the sag and flanker inlets operate as weirs. The same general design philosophy shall be used for the rare cases in which the sag inlet operates as an orifice at the allowable ponding depth. Orifice situations shall be designed on a case-by-case basis. The design must also be checked for 100-year flows.

3.3.2.2.2 Suggested inlet spacing procedure

Optimizing the placement of roadway surface inlets in terms of function and cost is an iterative process. Any reasonable, logical approach is acceptable, as long as the design is easily followed and the resulting system is optimized. The following is a brief summary of the preferred approach:

1. Place inlets at all necessary locations (sags, reverse super elevations, ends of barrier rail, major intersection, etc.)
2. Determine allowable spread widths.
3. Determine approximate spacing needed to meet spread widths, and tentatively locate inlets.
4. The next steps are iterative. Connect the system with a preliminary storm drain layout. Optimize the layout considering manhole spacing, inlet interception and bypass, lateral locations, outfall locations, etc. Use of trench drains or larger inlets may help optimize spacing.

3.3.2.2.3 Storm Drains

- Storm drain systems shall be analyzed using hydraulic grade line computations. Refer to HEC-22 for design guidance. Grade line computations are not required for a single inlet down drain.
- Storm drains should normally be sized on the assumption that they will flow full or partially full under the design discharge but will not be placed under pressure head. If pressure flow is unavoidable, the hydraulic gradient shall remain at least one (1) foot below the ground surface for the design flow. The intent is to ensure trunk line flows do not exit the system through inlets or manholes.

- Maintain a minimum flow velocity in storm drain trunk lines (more than 2 upstream inlets) of 3 feet per second at the design flow, modeled with standard hydraulic grade line computations. For laterals (2 or less upstream inlets), a minimum of 3 feet per second shall be maintained at the design flow under normal depth conditions.
- Design pipes with a minimum slope of 0.3 percent. Where necessary, this slope can be less, but in no cases less than 0.2 percent.
- Minimum pipe diameters for storm drains are 18 inches for trunk lines, 15 inches for lateral connectors, and 12 inches for down drains.
- Conduit cross section shall not decrease in the downstream direction.
- Select appropriate conduit "n" values according to HEC-22 guidance.
- Debris blockage potential, maintenance issues, cost implications, and physical constraints influence the number of inlets that can be connected in series.
- Alignments of storm drains should be set using tangent sections and angle points as opposed to radii, for constructability reasons.

3.3.2.2.4 Manholes

Manholes are utilized to provide access to continuous underground storm drains for inspection and cleanout.

- Manholes are required where two (2) or more storm drains converge, at a maximum spacing along tangent sections, where pipe size changes, where vertical or horizontal alignment changes more than 10 degrees, and at the intersection of laterals to trunk lines. Exceptions to the above are allowed based on site conditions and maintenance accessibility. For example, a manhole may not be required at the junction of a short, shallow lateral and a storm drain trunk line.
- Manholes should not be located in traffic lanes. However, when it is impossible to avoid locating a manhole in a traffic lane, care should be taken to ensure it is not in the normal vehicle wheel path. Locating manholes in intersections is to be specifically avoided.
- A minimum difference of 0.1'shall be provided between the inlet and outlet pipe invert elevations in a manhole or drop inlet.
- Allow a minimum of six inches separation between pipe penetrations in manholes.
- For storm drains with diameters 24" or less, the maximum spacing for manholes is 300'. For pipes over 24" in diameter, a 400' maximum is required for manhole spacing.

3.3.2.2.5 Roadside and Median Ditches

- For ditches that collect significant off-site flows, refer to Section 3.3.3 (Channels - off-site flow).

- Roadside and median ditches shall be designed to the recurrence interval specified in Table 3.1 (Roadway Surface Drainage Facilities).

- Judgment must be applied to determine appropriate freeboard. Consider freeboard requirements based on depth, velocity and amount of flow, maintenance, constructability, and consequence of flow breakout. Generally, appropriate freeboard will be between 0 and 1 foot.

- All ditches must be designed to be stable (non-erosive) during the design event (refer to HEC-15 for design guidance).

- For ditches within clear zone limits, refer to AASHTO Roadside Design Guide and consult with Roadway Design personnel for traversable geometry guidance.

3.3.2.2.6 Bridge Deck Drainage

- Attempt to collect 100% of the roadway surface water prior to flowing onto the bridge deck. If this is not feasible, flow onto the bridge shall be limited to 0.25 cfs. Avoid placing inlets in the approach slab.

- Longitudinal drainage on long bridges should be provided by scuppers or inlets sufficient in size and number to meet the spread criteria refer to Table 3-1 (Roadway Surface Drainage Facilities).

- Downspouts, where required, should be made of rigid corrosion-resistant material not less than six inches in diameter and should be provided with cleanouts.

- Deck drains and downspouts shall be designed to prevent the discharge of drainage water against any portion of the structure, embankments, slope pavement, slope protection, onto moving traffic below, railroad tracks, onto private property or into environmentally sensitive areas. Prevent erosion at the outlet of the downspout.

- Zero gradients and sag vertical curves should be avoided on bridges. The minimum typical bridge deck cross slope and longitudinal slope shall be 1.5 percent and 0.5 percent, respectively. Use of lesser typical slopes requires CHE approval.

3.3.3 Channels (off-site flow)

3.3.3.1 General

Channelization may be required to mitigate encroachment of roadway improvements into natural watercourses, or to protect the roadway facilities from natural flood hazards. Roadside channels may be necessary to collect and convey off-site and on-site run-off to appropriate outfall locations. Follow design guidance in HEC-15 for flows equal to or less than 50 cfs, and HEC-11 for flows greater than 50 cfs. Median ditches and roadside ditches that do not collect significant off-site flows are covered under Section 3.3.2.2.5 (Roadside and Median Ditches).

3.3.3.2 Design Criteria & Guidelines

3.3.3.2.1 Engineered Channels

- The channel size and capacity shall be designed based on roadway classification, consequences of traffic interruption, flood hazard risks, economics, and local site conditions. Table 3-2 (Design Storm Selection Guidelines for Off-Site Flow Facilities) shall be used to select the design frequency for channel design.
- In addition to the design storm, flow conditions for channels shall be analyzed for the 100-year event. Mitigation must be provided if the 100-year flow conditions within or outside of NDOT right-of-way are unreasonably aggravated.
- Safety of the general public shall be an important consideration in the selection of cross-sectional geometry and channel lining.
- Channels, where public access is not prohibited, should be designed considering the hazards presented by the channel and flood flows.
- The design of channels shall consider the frequency and type of maintenance expected and to make allowance for access of maintenance equipment. When needed, a 15 feet wide access road shall be provided. Wide channels, if they cannot be maintained from only one side, will require maintenance roads on both sides.
- All new channels are to be designed to be non-erosive and horizontally and vertically stable for the design event. Stream bank stabilization shall be provided when appropriate. Impacts to channel stability upstream and downstream of the project site shall also be evaluated.
- Earthen channel side slopes shall be 3:1 or flatter and riprap-lined channels shall have 2:1 or flatter side slopes.
- Channel freeboard shall be a minimum of 1 foot for the design storm. Higher freeboard may be required for high velocity channels or for varying flow regimes.
- The minimum radius for channel bends shall be 50 feet.

- Channel design incorporating curves must account for flow super elevation.

- For channels within clear zone limits, refer to AASHTO Roadside Design Guide for traversable geometry guidance.

3.3.3.2.2 Natural Channels

- Environmental impacts of channel modifications, including disturbance of fish habitat, wetlands, riparian vegetation, and stream bank stability shall be assessed. The channel design shall minimize these impacts, and mitigation shall be provided as appropriate.

- If relocation of a stream channel is unavoidable, the cross-sectional shape, meander, pattern, roughness, sediment transport, and slope shall conform to the existing conditions insofar as practicable.

3.3.4 Culverts

3.3.4.1 General

In-depth culvert design guidance can be found in the FHWA publication Hydraulic Design Series Number 5 (HDS 5), "Hydraulic Design of Highway Culverts".

3.3.4.2 Design Criteria & Guidelines

- The design flow selected shall be consistent with the class of highway and commensurate with the risk at the site. Table 3-2 (Design Storm Selection Guidelines for Off-Site Flow Facilities) shall be used to establish the minimum design event for all culverts.

- Flow conditions for culverts must be analyzed for the existing and future conditions 100-year event. Mitigation must be provided if the 100-year flow conditions within or outside of NDOT right-of-way are unreasonably aggravated.

- When necessary culverts shall be designed to accommodate debris or proper provisions shall be made for debris maintenance, i.e., debris rack (refer to Section 3.3.4.3 and HEC-9 for guidance).

- Culvert plan and profile layout shall be designed to avoid sediment accumulation in culvert barrels. Detailed sediment transport analysis may be required where significant sedimentation issues are anticipated. When determining which sediment transport analysis method should be used, consideration should be given to the final channel geometry, channel bed stability (aggradation, degradation) debris potential, design stage, backwater magnitude resulting from the structure, median sediment size and overall watershed condition.

- Depending on District maintenance requirements, access for personnel and equipment shall be provided to facilitate culvert maintenance.

- The minimum culvert diameters shall be 24″ on interstate systems and 18″ elsewhere.
- Follow manhole placement guidelines as described in Section 3.3.2.2.4 (Manholes).
- Use arch or oval shapes only if required by hydraulic limitations, site characteristics, structural criteria, or environmental criteria.
- The culvert skew shall not exceed 45 degrees as measured from a line perpendicular to the roadway centerline without the approval of the PHE.
- Outlet protection shall be considered for all culverts with erosive outlet velocities (see HEC-11, HEC-14). Judgment must be applied in all cases, considering site conditions (soils, slope, existing conditions velocity, existing conditions erosion, etc.), when evaluating the need for outlet protection.
- Flotation potential of flexible culverts shall be evaluated by comparing the vertical hydrostatic uplift force with the combined weight of the culvert and soil overburden. Anchorage and other methods shall be used to prevent flotation.
- Select appropriate conduit "n" values according to HDS-5 guidance.
- The maximum allowable ponding elevation for the design flow is the edge of the roadway pavement. Additional consideration (seepage /piping, buoyancy, etc.) should be given if the headwater is over 1.5 times the diameter of the culvert.

3.3.4.3 Debris Racks and Grates

- Racks and grates should be considered as part of design in areas with high debris load, where the culvert is long, and for culverts that present an "attractive nuisance". Provide a minimum net open area of two times the culvert entrance.
- In urban areas, consider using access control grates for culverts with smallest dimension of 4 ft and longer than 1000 ft. Use of access control grates must be based on an economic analysis that considers flooding impacts, cost of grate, right of way impacts, and long term maintenance costs (20 - years).
- Selection of rack or grate type must be based on cost and available maintenance equipment.

3.3.4.4 Traffic and Safety Considerations

- The AASHTO Roadside Design Guide establishes a "clear zone" in which obstructions to the traveling public should be avoided or mitigated. Coordinate drainage design clear zone issues with the Roadway Design Engineer. Refer to the AASHTO Roadside Design Guide for roadside safety considerations relative to drainage facilities.
- Consider fencing where drainage facilities present an "attractive nuisance," or safety hazard.

- Typically, infield grates can be used in areas within NDOT control of access, and locations where a minimum of 10 feet is maintained away from expected pedestrian traffic areas.

3.3.5 Bridges

3.3.5.1 General

Bridges are hydraulically defined as structures that operate in a free water surface condition for the design flow rate. Bridges ordinarily lack an integrated floor and typically span drainage ways as well as manmade structures. Structures designed as described above are treated in this section.

3.3.5.2 Design Criteria & Guidelines

Table 3-2 (Design Storm Selection Guidelines for Off-Site Flow Facilities) shall be used to establish the minimum design flood. See Section 3.3.2.2.6 (Bridge Deck Drainage) and Table 3-1 (Roadway Surface Drainage Facilities) for bridge surface drainage considerations. Table 3-2 (Design Storm Selection Guidelines for Off-Site Flow Facilities) relates the minimum required flood design frequency to functional classifications of roadways. Deviations from this Table may be warranted based on local site conditions, economic consideration, and/or risk analysis. Revisions will require prior (written) approval of the Chief Bridge Engineer and Chief Hydraulic Engineer.

- The 100-year event must be checked in all cases to ensure that no adverse flooding impacts are created to adjacent properties.

- Backwater increases over existing conditions shall conform to FEMA regulations for sites covered by the National Flood Insurance Program (NFIP). In general, a backwater increase of no more than 1 foot is allowed during the passage of the 100-year flood, if practicable, for sites not covered by NFIP. All increases in backwater must be assessed for upstream impacts. Mitigation must be provided if the 100-year flow conditions within or outside of NDOT right-of-way are unreasonably aggravated.

- Where feasible, a minimum freeboard of two (2) feet shall be provided between the design water surface elevation and the low chord of the bridge to allow for passage of debris. Where this is not feasible (depending on type of structure, site conditions and economic considerations), the freeboard should be based on the type of stream and level of protection desired as approved by the PHE.

- The proposed facility shall not cause unreasonable change in the existing flow distribution.

- When needed, channel and abutment protection measures through bridge crossings shall be designed for the lesser of the 100-year or overtopping event. Additional abutment protection for scour design may be required as per Section 3.3.5.4.3 (Abutment Scour Notes).

3.3.5.3 Scour

Bridge foundations must be designed by an interdisciplinary team of hydraulic, geotechnical and structural engineers to withstand the effects of estimated total scour including local scour at piers and abutments, contraction scour and long-term channel aggradation or degradation. The bridge foundation must not fail or be damaged for the scour design event of the 100-year flood. The overtopping flood is used as the design event if less than the 100-year flood and is defined as the event at which flow just begins to overtop the approach embankment(s), the bridge or both. Lesser flood events should be checked if there are indications they may produce deeper scour than the 100-year or overtopping flood. The bridge foundation must also be checked using estimated total scour for the lesser of the 500-year (1.7 multiplied by the 100-year flood unless better data is available) or overtopping event. The foundation must not fail while maintaining a minimum geotechnical factor of safety of 1.0 under the check flood scour conditions. Bridge scour design should be accomplished according to procedures and guidance contained in the latest editions of HEC-18 and HEC-20.

3.3.5.4 HEC-18 Supplemental Notes:

3.3.5.4.1 Pier Scour Notes

When debris potential exists at a bridge, the potential shall be classified as low, moderate or high. The potential for debris accumulation at a bridge foundation can be estimated by assessing the type and availability of upstream debris material, the potential for the debris to be washed into the river, the shape of the bridge foundations, etc. Scour calculations for piers with debris shall be as per HEC-18 with the following debris widths added to each side and the front of the pier: one (1.0) foot for low debris potential, one and a half (1.5) feet for moderate debris potential and two (2.0) feet for high debris potential. Limiting maximum scour depths shall be based on a multiple of the pier width (adjusted for debris and angle of attack) according to HEC-18 guidance.

3.3.5.4.2 Contraction Scour Notes

A contraction scour analysis can be essentially reduced to the proper selection of the width values, W_1 and W_2 (refer to HEC-18 for definitions). Once these values are selected, all other necessary hydraulic parameters are subsequently determined by the hydraulic model and soil properties.

The uncontracted section width (W_1) should be selected as the width over which sediment transport occurs. The contracted section width (W_2) should be selected as the width over which contraction scour takes place. This width (W_2) should not include pier widths or non-scourable surfaces. Several factors can affect whether transport occurs, including vegetation, soil cohesion, material gradation and size, and flow velocity and depth.

The first step to determine the width (W_1) is a visual inspection of the floodplain. If the over banks and channel banks are moderately to heavily vegetated, it is probably safe to assume there will not be significant transport over these areas. If the channel is relatively clean (little or no vegetation), with sandy banks and over bank areas, the entire floodplain width may be transporting sediment. To check this, compare the flow velocity distribution from the hydraulic model with a table of permissible velocities for various soil types.

Using the widths as defined above, the note in HEC-18 that states to consistently use top width or bottom width for both W_1 and W_2 should be disregarded. Additionally, the bottom width of a channel will rarely be used as W_1 in the analysis. The width associated with ordinary high water is often a reasonable selection, because vegetation will usually stabilize the floodplain above this line, and the channel is relatively clean below this elevation.

The two cross sections used to develop parameters in the contraction scour analysis should be located to represent the uncontracted and contracted conditions of the channel. Two approaches are recommended:

- The first approach is consistent with HEC-18, with an upstream section to represent the uncontracted channel, and a section at the bridge location to model contracted conditions. This approach is acceptable if a section can be located upstream of the bridge that is representative of the channel reach, i.e., the channel is fairly prismatic, and over bank flow distribution is not changing rapidly. The approach section must be placed beyond the immediate effects of the bridge, specifically beyond any ineffective flow areas created by bridge abutments.

- The second approach is to model the uncontracted condition with a section located at the bridge site, without the bridge and abutments in place, i.e., the channel is modeled in a pre-bridge condition. The contracted section would be located at the same place and would reflect the bridge in place.

3.3.5.4.3 Abutment Scour Notes

Due to the uncertain nature of current equations for prediction of local scour at bridge abutments, these equations should not be used other than to develop insight as to the scour potential at an abutment. The abutment foundation scour design approach to follow depends on the assessed stability of the channel crossing relative to the abutments:

- If there is a reasonable chance of failure of the material surrounding the abutment (due to sudden channel migration, undermining resulting from channel contraction or pier scour, etc.), the abutment foundation should be designed as a pier. That is, the abutment foundation scour design should assume that the channel has migrated through the abutment and that local foundation scour will occur below the thalweg elevation according to pier scour calculation procedures.

- If, due to natural or engineered conditions, there is not a reasonable chance of failure of the material surrounding the abutment, it is not necessary to design the bridge abutment foundation for a specifically calculated local scour depth. In this case, however, protection of the abutment must be provided for flows up to the 500-year or overtopping event as defined in Section 3.3.5.3 (Scour) earlier in this Subsection. It will generally be prudent to design the foundation assuming that material has been removed around the abutment at least to the channel thalweg elevation following predicted contraction scour and long term degradation.

Many factors must be considered when assessing channel stability and developing appropriate abutment foundation scour design recommendations. These include the type of material on or in which the foundation will be located, ability to protect the abutment, setback distance of the abutment from the channel bank, undermining effects from any predicted pier scour, contraction scour or channel degradation, return frequency of the bridge or approach roadway overtopping flow, importance of the bridge, etc. The abutment foundation scour design approach requires approval of the CHE.

3.3.6 Energy Dissipators

3.3.6.1 General

Energy dissipators are used to reduce culvert and storm drain outlet velocities to a non-erosive level. In general, it is desirable to reduce outlet velocities to natural stream flow velocity or lower. Refer to HEC-11 and HEC-14 for additional design guidance.

Riprap apron protection is typically adequate for outlet velocities up to 12 feet per second. Structural energy dissipators are generally used when outlet velocities exceed 12 feet per second. Apply engineering judgment, considering site conditions for all cases, to determine the level of outlet protection needed.

3.3.7 Detention Basins

3.3.7.1 General

Detention basins are used to attenuate peak flow rates to acceptable levels. Basins are commonly used to mitigate the increase in peak flows due to development (increased impervious area), or to lower flow rates due to downstream conveyance limitations.

3.3.7.2 Design Criteria and Guidelines

- The detention basin design event and appropriate freeboard shall be determined by evaluating downstream impacts, risks, available downstream conveyance, etc. The design event must be approved by the CHE.

- Larger detention basins (over 20-acre feet volume above original ground or embankment height over 20-feet above original ground) must be designed according to Nevada Division of Water Resources Laws Pertaining to Dam Safety.

- Detention basins shall be designed to convey the design flow through the principal or low flow outlet without overtopping of the emergency spillway.

- An emergency spillway is required for all detention basins. Emergency spillways shall have a minimum conveyance capacity of a 100-year event plus freeboard, neglecting the capacity of the principal spillway /outlet. The emergency spillway may be designed for a more infrequent event if failure to the embankment would result in unacceptable downstream flood hazards.

- Basins shall be designed to accommodate the anticipated sediment load. At a minimum, the basin must accommodate the anticipated sediment volume from the design storm. The method used to quantify sediment loads must be approved by PHE.

- Where the potential for debris is high, a debris basin located upstream of the detention basin shall be considered. Trash racks for low flow outlets may be required.

- Detention basins must be designed to drain 90% of the design storage volume within 48 hours to allow for the possibility of multiple events within a short period of time. The 48-hour drain time requirement begins at the time of maximum stage.

- Detention basins shall accommodate the design storm with a duration of 24 hours, with the exception of basins in Clark County which are to be designed for a 6-hour duration storm.

- Using the Rational Method or "triangular" hydrograph is not acceptable due to the inappropriate time base of the hydrograph.

- Design basins to provide for maintenance access and with stable floors if necessary, to facilitate maintenance activities.

- If necessary, provide markers and/or structural elements to maintain original basin geometry.

- Provide low flow channels as appropriate.

3.3.8 Pedestrian and Bicycle Paths

3.3.8.1 General

The following guidelines should be followed for design of Pedestrian and Bicycle paths:

3.3.8.2 Design Guidelines

- All existing drainage patterns in the vicinity of the proposed path should be perpetuated.

- Drainage facilities (side ditches, culverts, etc.) should be designed for nuisance flows and should not adversely affect the hydraulic design of the adjacent highway facility.

- Placement of a "dip section" downstream and /or upstream of an existing hydraulic structure (culvert) is encouraged. However, if not practicable, existing roadway hydraulic facilities should be extended in kind under the bike path.

- HEC-2, HEC-RAS or WSPRO Water Surface Profile Models shall be developed for proposed bridge(s) over rivers, channels or any other identified location where water surface profile computation is required.

3.3.8.3 Pedestrian and Bicycle Bridges

The following criteria shall be followed for Pedestrian and Bicycle path bridge structures over channels within 1,000 ft upstream of an existing roadway structure:

- The proposed bridge shall be designed according to Section 3.3.5 (Bridges). The design storm shall be equal to the adjacent downstream roadway bridge structure (use Table 3-2 (Design Storm Selection Guidelines for Off-Site Flow Facilities)). Exceptions will require prior written approval of the Chief Bridge Engineer and Chief Hydraulic Engineer.

3.3.9 Sediment and Stream Stability Considerations

The Hydraulic Engineer is referred to River Engineering for Highway Encroachments (HDS-6) for guidance related to sediment and stream stability. Manmade changes to natural channel hydraulics can result in local or regional geomorphic instability. These instabilities can result in excessive maintenance costs, property damage and decreased system functionality. To minimize these impacts, the Hydraulic Engineer shall consider the following:

- Sediment issues are generally examined based on dominant flow, defined as the 5-10 year (bank full) flood event in arid regions.

- Consider upstream and downstream natural instability of channels. This may extend several thousand feet upstream and downstream of the drainage facility.

- When changes in channel alignment are necessary, design hydraulically efficient transitions between culvert and dominant (bank full) channel section geometry. Make every reasonable attempt to match upstream and downstream stage/discharge relationships and horizontal channel alignment for the bank full condition. Horizontal transition rates should generally vary from 1:1 to 4:1 depending on site conditions.

- When a culvert inlet must be placed below natural channel grade, address impacts at the inlet. Mitigate any introduced upstream instability as necessary (e.g., paved sump, drop structures, rip rap placement, grade control structures, etc.).
- Discuss appropriate level of effort and methodology with the PHE. When a detailed sediment transport analysis is necessary, available methods may include Yang, Ackers-White, Brownlie, Engelund-Hansen, and Einstein.
- For small watersheds use Universal Soil Loss Equation (USLE) or Revised Universal Soil Loss Equation (RUSLE) when sediment yield calculations are necessary. For large watersheds, consult with the PHE.

3.3.10 Drainage Design During Construction

The following are general guidelines to determine drainage requirements during construction. These must be evaluated on a case-by-case basis, considering risk, construction time and phasing, seasonal considerations, etc.:

- Use a minimum 5-year design frequency for design of bridge false work openings. The hydraulic engineer will typically provide the minimum false work opening information (size, dimensions, elevations, etc).
- Typically, the contractor will be responsible for temporary drainage design during construction. For temporary systems identified in the contract plans, a minimum 2-year design frequency shall be used.
- For detours included in the contract plans, use a minimum 2-year design event if in place for less than one year and minimum 5-year design event if in place for one year or more.
- Typically, the contractor will be responsible for temporary river diversion design. For river diversions identified in the contract plans, a minimum 5-year design frequency shall be used.

3.3.11 Water Quality and Erosion Control

Refer to NDOT Storm Water Quality Manuals for guidance. The NDOT Drainage Manual shall take precedence for hydrologic and hydraulic issues should discrepancies be noted.

3.3.12 Design References

The following is a list of acceptable design references. The hydraulic engineer is responsible to use the latest version of the publications listed.

3.3.12.1 FHWA Publications:

1. Highway Hydrology, HDS 2
2. Introduction to Highway Hydraulics, HDS 4
3. Hydraulic Design of Highway Culverts, HDS 5
4. River Engineering for Highway Encroachments, HDS 6
5. Debris Control Structures Evaluation and Countermeasures, HEC 9
6. Design of Riprap Revetment, HEC 11
7. Hydraulic Design of Improved Inlets for Culverts, HEC 13
8. Hydraulic Design of Energy Dissipators for Culverts and Channels, HEC 14
9. Design of Roadside Channels with Flexible Linings, HEC 15
10. The Design of Encroachments on Flood Plains using Risk Analysis, HEC 17
11. Evaluating Scour at Bridges, HEC 18
12. Stream Stability at Highway Structures, HEC 20
13. Bridge Deck Drainage Systems, HEC 21
14. Urban Drainage Design Manual, HEC 22
15. Bridge Scour and Stream Instability Countermeasures, HEC 23
16. Highway Storm Water Pump Station Design, HEC 24
17. Tidal Hydrology, Hydraulics, and Scour at Bridges, HEC 25
18. Best Management Practices for Erosion and Sediment Control, Report No. FHWA-FLP 94-005
19. Culvert Repair Practices Manual Volume I, FHWA – RD-94-096
20. Culvert Repair Practices Manual Volume II, FHWA – RD-95-089
21. Culvert Inspection Manual, IP-86-2

3.3.12.2 AASHTO Publications:

1. Highway Drainage Guidelines
2. A Policy on Geometric Design of Highways and Streets
3. Model Drainage Manual
4. Standard Specifications for Highway Bridges
5. LRFD Bridge Design Specifications
6. Roadside Design Guide

3.3.12.3 NDOT Publications:

1. Standard Specifications for Road and Bridge Construction
2. Standard Plans for Road and Bridge Construction
3. Project Design Development Manual
4. Bridge Design Manual
5. Computer-Aided Design and Drafting Standards Manual
6. Construction Site Best Management Practices (BMP's) Field Manual
7. Construction Manual
8. Storm Water Quality Manuals
9. Maintenance Manual
10. Special Instructions for Survey, Mapping or GIS Consultants
11. Design Drafting Guide

3.3.12.4 Other Publications:

1. Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States, U.S.G.S. Open-File Report 93-419.
2. Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains, U.S.G.S. Water Supply Paper 2339.
3. Flood Hydrology Manual, United States Bureau of Reclamation, 1989.
4. Guidelines for Determining Flood Flow Frequencies, Water Resource Council (WRC), Bulletin 17B.
5. Hydrological Criteria and Drainage Design Manual (HCDDM), Clark County Regional Flood Control District (CCRFCD) .
6. Hydrologic Criteria and Drainage Design Manual (HCDDM), Washoe County Regional Flood Control District.
7. SCS National Engineering Handbook, Section 4.
8. US Dept. of Interior, BOR, 1987 - Design of Small Dams, A Water Resources Technical Publication.
9. FAA, 1970 – Airport Drainage, Advisory Circular 150/5320-5B, U.S. Department of Transportation, Federal Aviation Administration, Washington, D.C., 1970.

3.3.12.5 Computer Programs:

It is the responsibility of the hydraulic engineer to verify the limits and applicability of any computer program used.

1. Flood Hydrograph Package, HEC-1, or HEC-HMS, United States Army Corps of Engineers (USACE).
2. Water Surface Profiles, HEC-2, or HEC-RAS, United States Army Corps of Engineers (USACE).
3. Watershed Modeling System (WMS), Environmental Modeling System, Inc.
4. HY 8 Culvert Analysis, FHWA.
5. The Finite Element Surface Water Modeling System (FESWMS), FHWA.
6. SCS (NRCS) Urban Hydrology for Small Watersheds, TR-55.
7. Integrated Drainage Design Computer System, HYDRAIN.
8. Water Surface Profile Gradient (WSPG).

Other appropriate references may be accepted with prior approval of the CHE. The above-listed references may be revised, updated, or superseded by future references. In this event, the most current publication shall be used.

3.3.12.6 Web Sites:

Section	Agency / Description	Web Site Address
1.1	**FHWA /** Publications	http://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm?sort=Pub_abbrevation
1.2.2	**FHWA /** Policy & Memos	http://www.fhwa.dot.gov/engineering/hydraulics/policymemos.cfm
1.2.2	**Federal Government (GPO Access) /** (23 CFR 650 A and B) Code of Federal Regulations, Title 23, Part 650, Subparts A and B	http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=4326b3462801c075d9d260366f1f811e&rgn=div5&view=text&node=23:1.0.1.7.27&idno=23
1.2.2	**FEMA /** Flood Insurance Laws and Regulations	http://www.fema.gov/business/nfip/laws1.shtm
1.2.2	**USACE /** Statutory, Administrative and Judicial Materials	http://www.usace.army.mil/inet/functions/cw/cecwo/reg/sadmin3.htm
1.2.2	**NDEP /** State of Nevada - Bureau of Water Pollution Control	http://ndep.nv.gov/bwpc/bwpc01.htm
1.2.2	**EPA /** Federal Laws & Regulations – Clean Water Act	http://www.epa.gov/region5/water/cwa.htm
1.2.2	**NDWR /** Nevada Floodplain Management Program	http://water.nv.gov/Flood/page1.htm
1.2.2	**NDWR /** Dam Safety	http://water.nv.gov/Engineering/Dams/index.htm

Section	Agency / Description	Web Site Address
1.2.3.1	**FHWA /** Bridge Scour Program	http://www.fhwa.dot.gov/engineering/hydraulics/scourtech/scour_memos.cfm
1.2.3.2	**NDOT /** Lake Tahoe Environmental Improvement Program	http://www.nevadadot.com/projects/tahoe/
1.2.3.2	**TRPA /** Tahoe Regional Planning Agency	http://www.trpa.org/
1.2.3.3	**EPA /** Federal Laws & Regulations – Clean Water Act	http://www.epa.gov/region5/water/cwa.htm
1.2.3.3	**NDEP /** State of Nevada – Bureau of Water Pollution Control	http://ndep.nv.gov/bwpc/bwpc01.htm
1.2.3.3	**NDOT /** NDOT's Water Quality Manuals	http://www.nevadadot.com/reports_pubs/Water_Quality/
1.2.4	**USGS /** Flood Investigations of Nevada Streams	http://nevada.usgs.gov/activities/nv036.cfm
1.4.2	**FEMA /** Flood Insurance Laws and Regulations	http://www.fema.gov/business/nfip/laws1.shtm
1.4.2	**Federal Government (GPO Access) /** (23 CFR 650 A and B) Code of Federal Regulations, Title 23, Part 650, Subparts A and B	http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=4326b3462801c075d9d260366f1f811e&rgn=div5&view=text&node=23:1.0.1.7.27&idno=23
1.4.2	**State of NV /** Nevada Revised Statute Chapter 543 - Floods	http://leg.state.nv.us/NRS/NRS-543.html
2.2.1	**FHWA /** National Environmental Policy Act (NEPA)	http://environment.fhwa.dot.gov/index.htm
2.3	**FEMA /** Flood zones, flood maps	http://msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1
2.3.1 **2.4.1**	**FEMA /** Flood Insurance Laws and Regulations	http://www.fema.gov/business/nfip/laws1.shtm
2.3.2.1	**FEMA /** National Flood Insurance Program	http://www.fema.gov/business/nfip/
2.4.2.2 **2.5.2.2**	**FHWA /** (HDS 5) Hydraulic Design of Highway Culverts	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=7&id=13
2.8.1 **2.9.3**	**Federal Government (GPO Access) /** (23 CFR 650 A and B) Code of Federal Regulations, Title 23, Part 650, Subparts A and B	http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=4326b3462801c075d9d260366f1f811e&rgn=div5&view=text&node=23:1.0.1.7.27&idno=23
3.2.1	**FHWA /** (HDS 2) Highway Hydrology	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=2&id=6
Table 3-1 **Table 3-2**	**NDOT /** Functional Classification Maps	http://www.nevadadot.com/reports_pubs/class_maps/
3.2.2.1	**USACE /** Hydrologic Engineering Center (HEC 1)	http://www.hec.usace.army.mil/
3.2.2.1 **3.2.2.4**	**CCRFCD /** Clark Co. (HCDDM)	http://www.ccrfcd.org/hcddm.htm

Section	Agency / Description	Web Site Address
3.2.2.1	**NOAA /** Hydrometeorological Design Studies Center – Atlas 14	http://hdsc.nws.noaa.gov/hdsc/pfds/sa/nv_pfds.html
3.2.2.3	**USGS /** Real-time Data for Nevada Stream Flow	http://waterdata.usgs.gov/nv/nwis/current/?type=flow
3.2.2.4	**Clark Co. /** Clark County Land Use	http://gisgate.co.clark.nv.us/openweb/asp/openweb.asp
3.2.2.4	**Washoe Co. /** Washoe County Land Use	http://lnxgisweb.washoecounty.us/website/Map_Warehouse/viewer.htm
3.2.2.4	**NRCS /** Soil types	http://www.nv.nrcs.usda.gov/technical/soils.html
3.3.2.1 3.3.2.2.1 3.3.2.2.3	**FHWA /** (HEC 22) Urban Drainage Design	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=22&id=47
3.3.2.2.5 3.3.3.1	**FHWA /** (HEC 15) Design of Road-side Channels with Flexible Linings	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=15&id=32
3.3.3.1 3.3.4.2	**FHWA /** (HEC 11) Design of Riprap Revetment	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=11&id=27
3.3.4.1 3.3.4.2	**FHWA /** (HDS 5) Hydraulic Design of Highway Culverts	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=7&id=13
3.3.4.2	**FHWA /** (HEC 9) Debris Control Structures Evaluation and Countermeasures	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=9&id=23
3.3.4.2	**FHWA /** (HEC 14) Hydraulic Design of Energy Dissipators for Culverts and Channels	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=13&id=129
3.3.5.2	**FEMA /** Flood Insurance Laws and Regulations	http://www.fema.gov/business/nfip/laws1.shtm
3.3.5.2	**FEMA /** National Flood Insurance Program	http://www.fema.gov/business/nfip/
3.3.5.3 3.3.5.4.1 3.3.5.4.2	**FHWA /** (HEC 18) Evaluating Scour at Bridges	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=17&id=37
3.3.5.3	**FHWA /** (HEC 20) Stream Stability at Highway Structures	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=19&id=43
3.3.6.1	**FHWA /** (HEC 11) Design of Riprap Revetment	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=11&id=27
3.3.6.1	**FHWA /** (HEC 14) Hydraulic Design of Energy Dissipators for Culverts and Channels	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=13&id=129
3.3.7.2	**NDWR /** Dam Safety	http://water.nv.gov/Engineering/Dams/index.htm
3.3.9	**FHWA /** (HDS-6) River Engineering for Hwy Encroachments	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=8&id=20

Section	Agency / Description	Web Site Address
3.3.11	**NDOT /** NDOT's Water Quality Manuals	http://www.nevadadot.com/reports_pubs/Water_Quality/
3.3.12.1	**FHWA /** (HDS 2) Highway Hydrology	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=2&id=6
3.3.12.1	**FHWA /** (HDS 4) Intro to Highway Hydraulics	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=47&id=10
3.3.12.1	**FHWA /** (HDS 5) Hydraulic Design of Highway Culverts	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=7&id=13
3.3.12.1	**FHWA /** (HDS-6) River Engineering for Hwy Encroachments	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=8&id=20
3.3.12.1	**FHWA /** (HEC 9) Debris Control Structures Evaluation and Countermeasures	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=9&id=23
3.3.12.1	**FHWA /** (HEC 11) Design of Riprap Revetment	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=11&id=27
3.3.12.1	**FHWA /** (HEC 13) Hydraulic Design of Improved Inlets for Culverts	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=53&id=29
3.3.12.1	**FHWA /** (HEC 14) Hydraulic Design of Energy Dissipators for Culverts and Channels	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=13&id=129
3.3.12.1	**FHWA /** (HEC 15) Design of Roadside Channels with Flexible Linings	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=15&id=32
3.3.12.1	**FHWA /** (HEC 17) The Design of Encroachments on Flood Plains using Risk Analysis	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=16&id=36
3.3.12.1	**FHWA /** (HEC 18) Evaluating Scour at Bridges	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=17&id=37
3.3.12.1	**FHWA /** (HEC 20) Stream Stability at Highway Structures	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=19&id=43
3.3.12.1	**FHWA /** (HEC 21) Bridge Deck Drainage Systems	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=21&id=46
3.3.12.1	**FHWA /** (HEC 22) Urban Drainage Design Manual	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=22&id=47
3.3.12.1	**FHWA /** (HEC 23) Bridge Scour and Stream Instability Countermeasures	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=23&id=49
3.3.12.1	**FHWA /** (HEC 24) Highway Storm Water Pump Station Design	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=25&id=53
3.3.12.1	**FHWA /** (HEC 25) Tidal Hydrology, Hydraulics, and Scour at Bridges	http://www.fhwa.dot.gov/engineering/hydraulics/hydrology/hec25.cfm
3.3.12.1	**FHWA /** Best Management Practices for Erosion and Sediment Control Report (FLP 94-005)	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=29&id=4
3.3.12.1	**FHWA /** Culvert Repair Practices Manual, Vol I, FHWA (RD-94-096)	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=36&id=94

Section	Agency / Description	Web Site Address
3.3.12.1	**FHWA /** Culvert Repair Practices Manual, Vol II, FHWA (RD-95-089)	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=37&id=90
3.3.12.1	**FHWA /** Culvert Inspection Manual, (IP-86-2)	http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=31&id=57
3.3.12.3	**NDOT /** Standard Specifications for Road and Bridge Construction	http://www.nevadadot.com/business/contractor/standards/
3.3.12.3	**NDOT /** Standard Plans for Road and Bridge Construction	http://www.nevadadot.com/business/contractor/standards/
3.3.12.3	**NDOT /** Computer-Aided Design and Drafting Standards Manual	http://www.nevadadot.com/business/contractor/CaddInfo/
3.3.12.3	**NDOT /** NDOT's Water Quality Manuals	http://www.nevadadot.com/reports_pubs/Water_Quality/
3.3.12.3	**NDOT /** Special Instructions for Survey, Mapping or GIS Consultants	http://www.nevadadot.com/business/contractor/GIS_Manual/
3.3.12.4	**CCRFCD** /HCDDM Clark County	http://www.ccrfcd.org/hcddm.htm
3.3.12.4	**NRCS /** SCS National Engineering Handbook, Section 4	http://www.wcc.nrcs.usda.gov/hydro/hydro-techref-neh-630.html
3.3.12.4	**USBR /** Design of Small Dams	http://www.usbr.gov/pmts/hydraulics_lab/pubs/manuals/SmallDams.pdf
3.3.12.4	**FAA /** Airport Drainage	http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/f26314836c9a516a86256c750060f2fe/$FILE/150-5320-5b.pdf
3.3.12.5	**USACE /** Flood Hydro Package (HEC-1 or HEC-HMS)	http://www.hec.usace.army.mil/publications/pub_download.html
3.3.12.5	**USACE /** Water Surface Profiles (HEC-2 or HEC-RAS)	http://www.hec.usace.army.mil/publications/pub_download.html
3.3.12.5	**FHWA /** HY 8 Culvert Analysis	http://www.fhwa.dot.gov/engineering/hydraulics/software.cfm
3.3.12.5	**FHWA /** FESWMS	http://www.fhwa.dot.gov/engineering/hydraulics/software.cfm

Appendix A

A.1. Drainage Report Contents and Project Progress Checklist

The following table is intended as a guide to develop consistent report contents. It is also to be used as a progress checklist to be completed and submitted at each design submittal level. The expected percent completion of work (i.e., 30, 60, etc.) at the end of each submittal is also presented.

Each square is to be checked (✓) or marked "N/A" by the hydraulic engineer and/or principal hydraulic engineer (or consultant manager). Depending on project type and complexity, the report contents, submittal requirements and percent completion requirements can be modified with prior written approval of the PHE.

DRAINAGE REPORT CONTENTS AND PROJECT PROGRESS CHECKLIST						
Report Contents	**Project Progress Checklist**					
	Conceptual	**Alternative**	**Preliminary**	**Intermediate**	**QA/Specs**	**Advertise**
Title Page						
Project Name, Project ID Number, Type of Study, Study Date, Preparer's Name, Company Name						
Table of Contents						
Executive Summary						
I. Introduction & Purpose	**30**	**60**	**90**	**100**	**100**	**100**
a. Project location & description [Location of project, city, county, route number, project limits, location map (8 ½" x 11")]						
b. Overall project scope summary						
c. Drainage design scope summary						
d. Drainage design team (name, title, responsibility)						
II. Design Procedures and Criteria	**30**	**60**	**90**	**100**	**100**	**100**
a. Drainage criteria - Summarize design criteria						
i. Hydrologic procedures and criteria (provide explanation for methods used)						
ii. Hydraulic procedures and criteria (provide explanation for methods used)						
iii. Design assumptions and issues (special design issues that influenced design, i.e., geotechnical, environmental, utilities, right-of-way, etc.)						
b. Agency Regulations - Federal, State and Local Regulations (summarize applicable regulations including but not limited to the following:)						
i. Drainage Manual Section 1.3 – Legal Aspects						
ii. Code of Federal Regulations Title 23 Part 650 subparts A & B						
iii. Federal Emergency Management Agency (National Flood Insurance Program) requirements						
iv. Regulatory agency requirements (NDEP, Corps of Engineers, Fish and Wildlife, etc.)						
v. Regional flood control requirements						
c. Compliance - Statement of compliance with NDOT drainage policies and criteria, and all applicable federal, state, and local regulations. List of any approved design and regulatory exceptions.						

DRAINAGE REPORT CONTENTS AND PROJECT PROGRESS CHECKLIST						
Report Contents	Project Progress Checklist					
	Conceptual	Alternative	Preliminary	Intermediate	QA/Specs	Advertise
III. Existing Conditions	**30**	**90**	**100**	**100**	**100**	**100**
a. Existing conditions - general description of the contributing watersheds and sub-basins, and offsite and onsite drainage facilities						
i. List and provide a brief discussion of previous reports in the project vicinity. Confirm applicability of information used. Copy appropriate information in Appendix F.						
ii. Drainage basin characteristics (sub basins, areas, slopes, hydrologic condition, etc.)						
iii. Established/historic design frequency and 100-year flow patterns, flow splits, diversions, etc.						
iv. FEMA information including established and ongoing studies.						
v. General discussion of existing facilities (flood control master plan elements, irrigation ditches, storm drain systems, water quality facilities, etc) including capacity, condition, maintenance problems, etc.						
vi. General discussion of stability issues such as aggradation, degradation, erosion, scour, etc.						
vii. General discussion of existing environmental issues such as wetlands, impaired waters, fisheries, etc., and permanent water quality and erosion control facilities						
b. Figures & Summary Tables	**30**	**60**	**90**	**100**	**100**	**100**
i. Existing facility summary table - including station, facility type (culvert, channel, inlet, etc,), size, material, capacity, condition (new, good, fair, poor), deficiency (corroded, failed, flaking, damaged, etc.), other issues (scour, erosion, etc.) potential repair strategy (replace, repair, etc.), comments						
ii. Existing watershed summary table - including pertinent information such as basin number, area, curve number or Rational C, time of concentration, design frequency peak flow, 100-year flow						

DRAINAGE REPORT CONTENTS AND PROJECT PROGRESS CHECKLIST						
Report Contents	Project Progress Checklist					
	Conceptual	Alternative	Preliminary	Intermediate	QA/Specs	Advertise
iii. Existing watershed basin map showing contours, design and 100-year flow patterns, sub basins, nodes and flow direction, and existing facilities (storm drain facilities, channels, dikes, culverts, bridges, etc.), and the flow rates at each point of interest.						
IV. Design Recommendations	**15**	**30**	**80**	**100**	**100**	**100**
a. General (discuss overall project approach and summarize benefits, accomplishments, etc.)						
b. Design alternatives (discuss concepts, major features, pros and cons, opportunities, constraints, etc.)						
i. Project and drainage cost estimates						
ii. Effects to existing drainage patterns and conditions						
iii. Regional flood control facilities						
iv. Developer local drainage facilities						
v. Temporary drainage facilities						
vi. Roadway geometrics constraints						
vii. Geotechnical (percolation rates, settlement, soil types, chemistry, etc.)						
viii. Utility conflicts						
ix. Constructability						
x. Traffic control (detour, phasing, etc.)						
xi. Environmental issues						
xii. Water quality, erosion and sediment control (temporary & permanent)						
xiii. Special maintenance needs (access, equipment, etc.)						
xiv. Right-of-way impacts						
xv. Structural issues						
c. Proposed/Selected alternative (discuss major features)						
i. On-site facilities						
ii. Off-site facilities						
iii. Water quality, erosion control and sediment (temporary and permanent)						
(1). Temporary Pollution Control Project Categorization Score Sheet						
iv. Proprietary items						
v. Drainage cost estimates						

DRAINAGE REPORT CONTENTS AND PROJECT PROGRESS CHECKLIST

Report Contents	Project Progress Checklist					
	Conceptual	Alternative	Preliminary	Intermediate	QA/Specs	Advertise
vi. Right-of-way impacts						
vii. Utility relocations						
viii. Special provisions issues						
ix. Maintenance plan (refer to appendix or separate report)						
d. Figures & Summary Tables						
i. Proposed facility summary table - including station, facility type (culvert, channel, inlet, protection, etc.), size, material, capacity, velocity, comments.						
ii. Proposed watershed flow summary table - including pertinent information such as basin number, area, curve number or Rational C, time of concentration, design frequency peak flow, 100-year flow, etc.						
iii. Proposed watershed basin map showing revised sub-basins, design and 100-year flow patterns, nodes and flow direction, and proposed facilities (storm drain facilities, channels, dikes, culverts, bridges, etc.), and the flow rates at each point of interest.						
iv. On-site drainage summary table including; basin number, basin discharge, upstream bypass flow, total flow, inlet number and type, station/offset, calculated spread, allowable spread, intercepted flow, bypass flow and receiving inlet number, etc.						
v. On-site drainage basin map, superimposed on roadway plans, showing contour (if available), sub basins, nodes and flow direction, roadway low & high points, location of all drainage ditches, facilities, etc.						
vi. FEMA floodplain map showing project limits						
vii. Master plan and neighborhood plan flood control facilities map (if available), with pertinent facility information and the projects limits identified						
References	**30**	**90**	**100**	**100**	**100**	**100**
Appendix A* - Hydrologic Information and Computations	**30**	**60**	**90**	**100**	**100**	**100**
I. Backup hydrologic data and calculations including but not limited to:						
a. Soils map with hydrologic group information with project limits and watershed boundaries						

DRAINAGE REPORT CONTENTS AND PROJECT PROGRESS CHECKLIST						
Report Contents	**Project Progress Checklist**					
	Conceptual	**Alternative**	**Preliminary**	**Intermediate**	**QA/Specs**	**Advertise**
b. Land use information map with project limits and watershed boundaries						
c. Curve number/precipitation loss parameter						
d. Precipitation data and calculations						
e. Time of concentration calculations						
f. Routing parameter calculations						
g. HEC-1, Regression, Rational, Statistical, etc. (Input and summary output data listing for all computerized hydrologic calculations)						
Appendix B* - Hydraulic Calculations – Off-site facilities	**30**	**60**	**90**	**100**	**100**	**100**
I. Backup hydraulic data and calculations including but not limited to:						
a. Sizing (bridges, culverts, etc.)						
b. Documentation/discussion on starting water surface elevation						
c. Scour / mitigation						
d. River training						
e. Transition structures						
f. Energy dissipators						
g. Existing and proposed ponding elevations and limits						
h. Hydraulic work map showing cross-sections, water surface elevations, Manning's 'n' value, bank stations, right-of-way limits, etc.						
i. Channel sizing and lining/stability calculations with summary table showing stationing, proposed dimensions, flow rate, depth, velocities, super elevation etc.						
j. Detention basins						
i. Basin relationships (stage-storage, stage-discharge)						
ii. Sediment calculations						
iii. Principal and emergency spillway calculations						
iv. Outfall						
k. Temporary facilities (during construction)						
l. Pipe material selection and strength calculations						
m. HEC-RAS, HEC-2, WSPG, etc. (Input and summary output printout of computerized hydraulic calculations)						

DRAINAGE REPORT CONTENTS AND PROJECT PROGRESS CHECKLIST						
Report Contents	Project Progress Checklist					
	Conceptual	Alternative	Preliminary	Intermediate	QA/Specs	Advertise
Appendix C* – Hydraulic Calculations – On-site facilities	**10**	**30**	**60**	**100**	**100**	**100**
I. Backup hydraulic data & calculations including but not limited to:						
a. Inlet interception, spread calculations, bypass, etc.						
b. Storm drain calculations including hydraulic and energy grade lines						
c. Roadside ditch and median ditch sizing and stability calculations, with summary table showing stationing, proposed dimensions, flow rate, depth, velocities, etc.						
d. Documentation on starting water surface elevation						
e. Water quality facilities/sand-oil separators, sediment traps, etc.						
f. Target pollutants, TMDLs, pollutant load reduction, etc.						
g. Detention/infiltration basins						
i. Basin relationships (stage-storage, stage-discharge)						
ii. Sediment calculations						
iii. Principal and emergency spillway calculations						
iv. Infiltration rates						
v. Outfall						
h. Temporary facilities (during construction)						
i. Pipe material selection and strength calculations						
j. WSPG, MicroStation Storm and Sanitary, Hydrain, etc. (Input and summary output printout of computerized hydraulic calculations)						
Appendix D – Erosion control and calculations	**15**	**15**	**30**	**60**	**100**	**100**
I. Permanent Erosion and Sediment Control (Refer to NDOT Storm Water Quality Planning and Design Guide)						
a. Supporting calculations and related information for all facilities (Refer to Appendices A, B, and C above)						
II. Temporary Pollution Control (Refer to NDOT Storm Water Quality Planning and Design Guide)						
a. Supporting calculations and related information for all facilities (Refer to Appendices A, B, and C above)						
Appendix E- Cost Estimates	**30**	**60**	**90**	**100**	**100**	**100**
I. Supporting drainage cost estimate calculations, including summary table showing; bid item number, bid item description, quantity, cost per unit, total cost per item, etc.						

DRAINAGE REPORT CONTENTS AND PROJECT PROGRESS CHECKLIST						
Report Contents	**Project Progress Checklist**					
	Conceptual	**Alternative**	**Preliminary**	**Intermediate**	**QA/Specs**	**Advertise**
Appendix F - Previous Reports / Historic Information						
I. Pertinent excerpts/copies from referenced reports						
II. Historic information (Maintenance reports, news articles, observations)						
Appendix G – Photo Log						
I. Aerial photographs						
II. Pre-project photographs (with location key)						
Appendix H - QA/QC Items						
I. Design exceptions						
II. Review comments and responses (Form 1)						
III. Updated Report Content, Progress Report and QA/QC Check List						
IV. Updated Documentation Check List						
Coordination Checklist						
I. Coordination with disciplines and agencies						

Project Name: ______________________ Date: ______________________
Project No./EA: ______________________ Submittal Level: ______________________
Principal Engineer: ______________________ Hyd. Engineer: ______________________
Consultant: ______________________ Agreement No.: ______________________

NOTE: Appendices A, B, and C – *Provide information in electronic format in lieu of hard copy where possible (check with PHE).

FORM 1
REVIEW COMMENTS

Project Name:	______________________	Date:	______________
Project No./EA:	______________________	Submittal Level:	______________
Reviewer:	______________________	Hyd. Engineer:	______________
Consultant:	______________________	Agreement No.:	______________

Comment #	Report (R) or Plan (P) sheet #	REVIEW COMMENTS	*TYPE	HYD. ENGINEER'S RESPONSE
Example 1	(R) General	Please ensure all off-site flows entering the project are collected or perpetuated.	S	
Example 2	(R) 3	Please ensure all watersheds contributing to the project are represented on figures and tables.	S	
Example 3	(P) DD-1	Construction note 24: A detail will be needed for the plug where the manhole is to be removed.	N	

*TYPE:

- 'F' = FATAL FLAW REVISION MANDATORY.
- 'S' = SERIOUS PROBLEM ADDRESS IMMEDIATELY. COULD RISE TO AN 'F' IF DISREGARDED.
- 'C' = COORDINATION PROBLEM. DISCIPLINE NEEDS TO TALK.
- 'N' = NOTE TO DESIGNER. NOT MANDATORY TO INCORPORATE, BUT COULD RESULT IN AN IMPROVED PRODUCT.

A.1.1 Helpful Hints / Common Mistakes to Avoid

The following are miscellaneous notes, intended to help the hydraulic engineer develop a quality submittal.

A.1.1.1 Drainage Report:

- Thoroughly describe all drainage elements and assumptions in the drainage report, to the level an engineer with no project history can understand what has been completed and why. Document all design decisions.

- Provide quality work maps that can be reviewed with the associated model.

A.1.1.2 Design:

- Verify proposed drainage systems have been optimized for cost effectiveness (alignments, layout, profile depth, etc.), construction (phasing, conflicts with utilities and structural section, pipe class and minimum and maximum cover, etc.), maintenance (minimize locations needed to be maintained, adequate maintenance access), etc.

- If spreadsheets are used for calculations, include a summary of the equations used in the table formula.

- Drainage cost estimates shall include mobilization, contingencies, engineering, and construction engineering (discuss percentages for these items with PHE), unless otherwise noted.

A.1.1.3 Plans, Profiles & Details:

- Verify all roadway plans match the drainage design/plans, including horizontal and vertical profiles, barrier rail and retaining wall locations, gore details, super elevations, striping, etc.

- For high embankments (over 15 feet), design storm drain outlets and embankment protectors similar to the layout for embankment protectors as shown in the standard plans. Provide elbows (or mitered sections with concrete collars) at the necessary hinge points to parallel the embankment slope. Provide a manhole (or inlet as appropriate) near the hinge point when a storm drain crosses lanes before the downdrain section.

A.1.1.4 Specifications and Pay Items:

- Verify all construction elements are covered and paid for either with a bid item and quantity, or through the specifications (included in another bid item, no direct payment, etc.). Ensure all contract elements to be constructed are included in a construction note or the special provisions, and are somehow paid for or noted as “no direct payment”.

- Verify special provisions are written for any non-standard item, and are written in the format of the Standard Specifications for Road and Bridge Construction. Request new bid items if necessary.

A.1.1.5 Constructability:

- Verify drop inlets and manholes can properly accommodate the storm drain pipe(s). Design inlets to accommodate pipes without impacting the corner of the inlet structure.

- Where proposed drainage elements are close together, consider how the contractor will be able to backfill and compact, and design accordingly.

A.1.1.6 Coordination:

- Verify all coordination as outlined in this manual has occurred. Verify all appropriate information requests have been made, and all appropriate drainage information has been disseminated.

A.1.1.7 Consultant Agreements:

- Do not perform any out of scope work without prior authorization of PHE or CHE.

Appendix B

B.1 Drainage Plan Sheet Submittal Requirements

The following tables include the typical sheets and information required at each design submittal. Drainage design elements progressed through the various design phases include, but are not limited to: storm drain systems, channels, ditches, permanent erosion and sediment control features, water quality features, energy dissipators, culverts, detention and retention basins, etc. **Note**: Some information described in these tables may be incorporated on sheets prepared by other engineering disciplines.

Conceptual Plan Submittal

Table B - 1
Conceptual Plan Submittal

Item Description	Notes
Drainage Plan view	Conceptual sketches of on-site system as necessary. Schematic locations and sizes of channels, culverts, bridges, and permanent erosion and sediment control features, etc., with general labeling (no construction notes, elevations or sheet references). Show existing right-of-way limits (if available). Identify proposed conceptual drainage right-of-way needs.
Drainage Profile view	Conceptual drawings, typically for major channel profiles and major cross-drainage features. On-site profiles typically not required.
Special Details	Typically not required.
Temporary Pollution Control Plans	Typically not required.
Structure List	Not required.

Alternative Development

Table B – 2 Alternative Development	
Item Description	Notes
Drainage Plan view	Refined conceptual sketches of feasible on-site systems (if necessary to influence selection of preferred alternative). Refined schematics indicating location and size of channels, culverts, bridges, detention basins, permanent erosion and sediment control features, etc., with general labeling (no construction notes, elevations or sheet references). Identify potential drainage right-of-way needs.
Drainage Profile view	Refined conceptual drawings, typically for major channel profiles and major cross-drainage features. On-site profiles typically not required.
Special Details	Typically not required.
Temporary Pollution Control Plans	Typically not required.
Structure List	Not required.

Preliminary Design

Table B-3 Preliminary Design	
Item Description	Notes
Drainage plan view	Preliminary layout of on-site and off-site drainage system elements (drop inlets, trunk lines, culverts, channels, ditches, detention basins, permanent erosion and sediment control features, water quality features, etc.). Preliminary construction notes (location and sizes of facilities, approximate stations and elevations, no sheet references). Preliminary easements and right-of-way included and dimensioned on plan sheets.
Drainage profile view	Preliminary profiles of cross-drainage features, trunk lines, channels, etc. Indicate existing and proposed ground profiles and utility locations if available. Label design components. Provide profiles of storm drain laterals where utility conflicts are anticipated. Show known utility information.
Special Details	Preliminary drawings with major dimensions and features shown.
Temporary Pollution Control Plans	Conceptual drawings as necessary.
Structure List	Preliminary structure list.

Intermediate Design

Table B – 4 **Intermediate Design**	
Item Description	Notes
Drainage plan view	Substantially complete layout of on-site and off-site systems (Complete construction notes, refer to Appendix C). Final drainage easements and right-of-way.
Drainage profile view	Substantially complete profiles of all on and off-site systems, (draft all features including existing and proposed ground profiles, labels, symbols for manholes drop inlets, headwalls, end sections, transitions, riprap, all utilities, etc.)
Special Details	Major dimensions and features shown.
Temporary Pollution Control Plans	Preliminary layout.
Structure List	Preliminary structure list.

QA/QC Plan Submittal

Table B – 5 **QA/QC Plan Submittal**	
Item Description	Notes
Drainage plan view	Complete layout of on-site and off-site systems
Drainage profile view	Complete profiles.
Special Details	Complete details.
Temporary Pollution Control Plans	Complete plans and details.
Structure List	Complete.

B.2 Drainage Plan Sheet Numbering Designation

The following designations (Table B-6) are used when independent drainage sheets are prepared. For minor drainage involvement, drainage information may be combined with other disciplines' plan sheets.

Table B – 6 **Plan Sheet Designation**	
D-1	Drainage Plans
DP-1	Drainage Profiles
DD-1	Drainage Details
DS-1	Drainage Structure List
TPC-1	Drainage Temporary Pollution Control

B.3 Drainage Sheet Format Guidelines

All contract drainage sheets shall be complete, clear, concise and as easy to read and understand as possible. Information must be presented in a manner such that bidding on, and construction of, all drainage improvements is facilitated to the fullest extent practicable. Drafting of drainage sheets must be in compliance with the NDOT Design Drafting Guide as applicable. General drainage sheet content and format guidelines follow. These guidelines are generally written for the case when drainage plan sheets are separated from roadway plan sheets. Ensure the cut sheet limits match the Roadway Design plans. When drainage items are incorporated into the roadway sheets, follow applicable roadway plan sheet development guidelines as presented in the Project Design Development Manual (PDDM).

B.3.1 Drainage Plans ("D" Sheets)

- Include a north arrow.
- Identify items of work with a leader line and circled number tag.
- List notes with circled number identifiers in a logical sequence.
- For sheets that would otherwise be too cluttered, list notes on a separate sheet. Use the same sheet number for the note sheet as the associated plan sheet, but add the letter "A" (e.g., D-1 & D-1A).
- Generally depict cut/fill limits and use slope indicators to identify sloped drainage features. Use contours for complex grading areas.
- Use Station/Offset/Flow Line Elevation tags on minor ditch and grading elements ("Grade to Drain" can be used for miscellaneous non-critical areas).
- Include flow direction arrows on storm drains, ditch flow lines and grade to drain areas.
- Create separate alignments for major channels and storm drainage systems.
- Only show ditches that will be paid as drainage items (drainage excavation, channel excavation, etc.) on the drainage plans. Do not show roadside and median ditches to be constructed as part of the roadway prism for which work is included in the earthwork items.
- Unless separate utility sheets are included in contract plans, use the best available information to depict locations of existing or proposed utilities that will be in place at the time of construction. Do not show existing utilities that will be relocated. Include a note on each plan sheet stating "Depicted utility locations are approximate only. Contractor to verify existence and location of underground utilities prior to construction."
- Provide legends to define area patterning (stipple) and symbols when appropriate.
- For large projects with multiple plan sheets, include a graphic sheet index on each plan sheet.

B.3.2 Drainage Profiles ("DP" Sheets)

Culvert Profiles:

- Title the profile using the beginning and ending station limits of the depicted culvert (e.g. "A" 14+00 to "A" 14+50).
- Include a divided circle identifier indicating the plan sheet (top) and note number (bottom) corresponding with the culvert.
- Use a scale sufficient for adequate clarity (ordinarily with a 5:1 or 10:1 vertical exaggeration). Do not label the horizontal axis unless the culvert has it's own alignment.
- Show both original ground and proposed finished grade along the centerline of the culvert and ditch in/ditch-out flow lines.
- Label culvert ends with station/offset tags.
- Indicate culvert size, length and material type (e.g. 36" X 128' CMP).
- Include depictions of end sections, headwalls, riprap, cut off walls, etc.
- Indicate interior and exterior limits of culverts and appurtenant structures.
- Label upper and lower invert elevations.
- Identify culvert slope in percent to two decimal places (e.g., S = 2.14%).
- Show ditch-in/ditch-out flow lines to point of daylight.
- Include an HGL for the design flow with the flow frequency and rate indicated. Round flow rates to the nearest one cfs.
- Using the best available information, depict locations of existing or proposed utilities that will be in place at the time of construction. Do not show existing utilities that will be relocated. Include a note on each profile sheet stating "Depicted utility locations are approximate only. Contractor to verify existence and location of underground utilities prior to construction."
- Indicate right-of-way limits when close to limits of proposed work.

Storm Drain Profiles:

- Title the profile using the beginning and ending station limits of the depicted storm drain (e.g. "B" 7+00 to "B" 14+00).
- Use a scale sufficient for adequate clarity (ordinarily with a 5:1 or 10:1 vertical exaggeration). Do not label the horizontal axis unless the storm drain has it's own alignment.
- Show both original and proposed finished grade.

- Indicate size, length, material and class as appropriate for all storm drain segments (e.g. 24" X 128′ RCP, Class III). Use pipe lengths as measured along the design slope from center to center of connected round manholes and to the inside wall of drop inlets, rectangular manholes, and box culverts.
- Indicate interior and exterior limits of pipes and structures.
- Label invert elevations into and out of all storm drain elements as well as at any grade breaks.
- Identify storm drain slopes in percent to two decimal places (e.g., S = 1.28%).
- Label connected storm drain elements (drop inlets, manholes, intersecting laterals, etc.) with station/offset tags. Include element description (e.g., Type 1 MH), appropriate elevation data (e.g., Cover Elev = 4500.14′, H = 5.28′), and a divided circle identifier indicating the plan sheet (top) and note number (bottom) corresponding with the element.
- Include an HGL for the design flow with the flow frequency and rate indicated.
- Include depictions of slotted drain and trench drain as appropriate.
- Include depictions of end sections, headwalls, riprap, ditch flow lines, etc. at storm drain outlets.
- Using the best available information, depict locations of existing or proposed utilities that will be in place at the time of construction. Do not show existing utilities that will be relocated. Include a note on each profile sheet stating "Depicted utility locations are approximate only. Contractor to verify existence and location of underground utilities prior to construction."
- Do not include profiles for standard embankment protectors.
- Do not break profiles for horizontal direction changes.

Channel Profiles:

- Include applicable corresponding information as listed above for culvert and storm drain profiles.
- Add left and right top of bank/wall profiles as necessary.

B.3.3 Details ("DD" Sheets)

- Draw details at a scale that will clearly depict the information on 11-inch by 17-inch sheets.
- Provide an appropriate title for each detail. Identify the location of each detail with station and offset.

- Special detail sheets should reflect the same drafting standards and level of detail as the standard construction details. Incorporate all dimensioning and other information necessary for quantity calculation and construction of the detailed feature.
- When details are applicable to multiple locations, use tables to list the various locations as well as any variable location-specific information (dimensions, etc.) of the detail.
- Provide legends to define area patterning (stipple) and symbols when appropriate.
- Provide borders encompassing individual details and associated notes, sections, etc. as necessary for clarity.

B.3.4 Structure List ("DS" Sheets)

- Produce structure lists according to guidance presented in the PDDM.
- For construction notes including a manhole and downstream pipe, break out quantities for the manhole and the pipe on two separate rows on the structure list (two rows for a single construction note). This is necessary as the quantity for the manhole is "each" (which includes excavation and backfill) and the pipe quantities are broken out into individual pay items.

B.3.5 Temporary Pollution Control ("TPC" Sheets)

- Develop using the same general guidelines as listed above for other sheets.

Appendix C

C.1. Standard Construction Notes

C.1.1 General

The following is provided as a general guideline for the development of consistent drainage construction notes. The sample notes presented are not all-inclusive and may be modified to reflect specific design requirements.

C.1.2 Abbreviations/Acronyms:

The Table A-1 is a list of typical abbreviations common to drainage related construction notes including pipe materials, reference elevations, etc.:

Table C – 1
Abbreviations & Acronyms

CMP	Corrugated Metal Pipe
CMAP	Corrugated Metal Arch Pipe
RCP	Reinforced Concrete Pipe
RCB	Reinforced Concrete Box
HE-RCP	Horizontal Elliptical Reinforced Concrete Pipe
VE-RCP	Vertical Elliptical Reinforced Concrete Pipe
HDPE	High Density Polyethylene
SD	Storm Drain
C & G	Curb and Gutter
DI	Drop Inlet
MH	Manhole
UIE	Upper Invert Elevation
LIE	Lower Invert Elevation
BMP	Best Management Practices
RT	Right
LT	Left
ELEV	Elevation
W	Width
H	Height
L	Length

C.1.3 Accuracy:

Table C-2 presents accuracy typically used for data contained in drainage construction notes. Special cases may require changes to the level of accuracy.

Table C – 2 Accuracy	
Stations	1 ft
Offsets	0.1 ft
Elevation data (UIE, LIE, H, etc.)	0.01ft
Pipe Lengths[1]	1 ft

[1] Pipe lengths are measured from center to center of connected round manholes. Pipe lengths are measured to the inside wall of drop inlets, rectangular manholes, and box culverts. All pipe lengths are measured along the design slope.

C.1.4 Drainage Note Format

[BRACKETS] indicate typical alternate or optional information.

C.1.4.1 Culverts

Culvert Pipe

"A" 14+00
<u>"A" 14+50</u>

INSTALL 24" X 100′ CMP **[RCP, etc.]** FROM"A" 14+00, 34.6′ LT (UIE = 4000.00′) TO "A" 14+50, 52.0′ RT (LIE = 3999.00′). INSTALL **[CONSTRUCT]** METAL **[PRECAST]** END SECTIONS **[CULVERT HEADWALLS]** LT AND RT.

Notes:

- No mention of Gage or Class indicates the use of 16 Gage CMP or Class III RCP. Only include CMP Gage (14, 12, etc.) and RCP Class ([HE-, VE-] IV, V) in the construction note if other than 16 Gage or Class III. Per the Standard Specifications (Section 601.03.01), Class C bedding (Standard Sheet R-1.1.6) is used unless otherwise specified.
- For multiple culvert installations, reference station and offset to the centerline of the installation.

Extension

<u>"B" 14+00</u>

EXISTING 24" X 100′ CMP **[RCP, etc.]**. REMOVE EXISTING END SECTIONS **[HEADWALLS]** LT AND RT. EXTEND 4′ LT AND 6′ RT (24" X 110′ CMP **[RCP, etc.]**). INSTALL **[CONSTRUCT]** METAL **[PRECAST]** END SECTIONS **[CULVERT HEADWALLS]** LT AND RT.

Roadway Approach Culvert

"C" 14+00
<u>"C" 14+50</u>

INSTALL 24" X 50′ CMP **[RCP, etc.]** FROM "C" 14+00, 52.0′ RT (UIE = 4000.00′) TO "C" 14+50, 52.0′ RT (LIE = 3999.00′). INSTALL **[CONSTRUCT]** METAL **[PRECAST]** END SECTIONS **[CULVERT HEADWALLS]** AT INLET AND OUTLET.

RCB	
"D" 14+00 "D" 14+50	CONSTRUCT **[DOUBLE, TRIPLE]** 10′ X 4′ X 100′ *(span x height x length)* RCB FROM "D" 14+00, 34.6′ LT (UIE = 4000.00′) TO "D" 14+50, 52.0′ RT (LIE = 3999.00′). TYPE II **[TYPE I]** HEADWALLS **[(30 DEGREE SKEW)]** LT AND RT.

Notes:

- If possible, set RCB skews at 0, 15, 30 or 45 degrees in order to accommodate the Standard RCB headwalls.
- For multiple culvert installations, reference station and offset to the centerline of the installation.

Example Culvert Note Add-ons

- CLASS 300 **[400, etc.]** RIPRAP APRON AT OUTLET. *(refers to standard Riprap Apron detail, standard plan sheet R-3.1.4)*
- DITCH IN **[OUT]** FROM **[TO]** ELEV. 4500.00′, "A" 14+00, 34.6′ LT (W = 4′). *(refers to standard Inlet, Outlet and Median Ditch Details, standard plan sheet R-1.4.1) "Minor" ditch in/ditch out situations can be handled with "Grade to drain. No direct payment.")*
- CLASS B CULVERT BEDDING. *(Only included if other than Class C. Per Standard Specifications, Class C is used unless otherwise noted. Refer to standard plan sheet R-1.1.6)*
- CONSTRUCT RIPRAP BASIN AT OUTLET. SEE SHEET DD-1.
- CONSTRUCT ENERGY DISSIPATOR AT OUTLET. SEE SHEET DD-1.
- CONSTRUCT SPECIAL HEADWALL AT INLET. SEE SHEET DD-1.
- CONSTRUCT SPECIAL CULVERT INLET. SEE SHEET DD-1.
- CONSTRUCT TRASH RACK AT INLET. SEE SHEET DD-1.

C.1.4.2 Storm Drain Elements (Drop Inlets, Manholes, and Connecting Pipes)

In general, each storm drain construction note includes a structure (drop inlet, manhole) and the downstream pipe.

Type 2 Drop Inlet	
"A" 14+00	CONSTRUCT TYPE 2 DROP INLET 28.0′ RT (GRATE ELEV. = 4500.00′, H = 3.75′, **[A = 3′-8″]**) **[WITH 18″ X 30′ SLOTTED DRAIN AHEAD [BACK] ON LINE]**. INSTALL 24″ X 100′ RCP **[CMP, etc.]** (UIE = 4496.25′, LIE = 4495.00′), CONNECT TO **[TYPE 2 DROP INLET, TYPE 1 MANHOLE, etc.]** "A" 15+00, 28.0′ RT. SEE SHEET DP-1.

Type 2A Drop Inlet

“B” 14+00	CONSTRUCT TYPE 2A DROP INLET 28.0′ LT (GRATE ELEV. = 4500.00′, H = 4.00′). INSTALL 24″ X 100′ RCP **[CMP, etc.]** (UIE = 4496.00′, LIE = 4495.00′), CONNECT TO **[TYPE 2A DROP INLET, TYPE 1 MANHOLE, etc.]** “B” 15+00, 28.0′ LT. SEE SHEET DP-1.

Type 3 Drop Inlet

“C” 14+00	CONSTRUCT TYPE 3 DROP INLET 28.0′ RT (GRATE ELEV. = 4500.00′, H = 4.00′, **[A = 4′-0″]**). INSTALL 24″ X 100′ RCP **[CMP, etc.]** (UIE = 4496.00′, LIE = 4495.00′), CONNECT TO **[TYPE 3 DROP INLET, TYPE 1 MANHOLE, etc.]** “C” 15+00, 28.0′ RT. SEE SHEET DP-1.

Note:

- Be aware that the invert elevation added to the “H” dimension does not equal the grate elevation.

Type 7 or 8 Drop Inlet

“D” 14+00	CONSTRUCT TYPE 7 **[8]** DROP INLET 28.0′ RT (GRATE ELEV. = 4500.00′). INSTALL 24″ X 100′ RCP **[CMP, etc.]** (UIE = 4497.00′, LIE = 4495.00′), CONNECT TO **[TYPE 2 DROP INLET, TYPE 1 MANHOLE, etc.]** “D” 14+00, 72.0′ LT. SEE SHEET DP-1.

Type 10 Drop Inlet

“A” 14+00	CONSTRUCT TYPE 10 DROP INLET 28.0′ RT (COVER ELEV. = 4500.00′, H = 6.00′). INSTALL 24″ X 100′ RCP **[CMP, etc.]** (UIE = 4495.00′, LIE = 4494.00′), CONNECT TO **[TYPE 10 DROP INLET, TYPE 1 MANHOLE, etc.]** “A” 15+00, 28.0′ RT. SEE SHEET DP-1.

Type 11 Drop Inlet

“B” 14+00	CONSTRUCT TYPE 11 DROP INLET 28.0′ LT (GRATE ELEV. = 4500.00′, H = 4.00′, L = 12′, **[A = 4′-0″]**). INSTALL 24″ X 100′ RCP **[CMP, etc.]** (UIE = 4496.00′, LIE = 4495.00′), CONNECT TO **[TYPE 3 DROP INLET, TYPE 1 MANHOLE, etc.]** “B” 15+00, 28.0′ LT. SEE SHEET DP-1.

Note:

- Be aware that the invert elevation added to the “H” dimension does not equal the grate elevation.

Pipe Riser Inlet

“C” 14+00	CONSTRUCT PIPE RISER INLET 28.0′ RT (GRATE ELEV. = 4500.00′). INSTALL 24″ X 100′ RCP **[CMP]**, CONNECT TO **[36″ CMP, 8′ X 4′ RCB, etc.]**.

Modified Drop Inlet

<u>"D" 14+00</u>	CONSTRUCT MODIFIED TYPE **[2, 2A, 3, etc.]** DROP INLET 28.0′ RT (GRATE ELEV. = 4500.00′, H = 5.00′). INSTALL 24" X 100′ RCP **[CMP, etc.]** (UIE = 4495.00′, LIE = 4493.00′), CONNECT TO **[TYPE 2 DROP INLET, TYPE 1 MANHOLE, etc.]** "D" 15+00, 28.0′ RT. SEE SHEETS DD-1, DP-1.

Manholes

<u>"A" 14+00</u>	CONSTRUCT TYPE **[1, 1 MODIFIED, 2, 2 MODIFIED,4]** ECCENTRIC MANHOLE 28.0′ LT (COVER ELEV. = 4500.00′, H = 7.00′). INSTALL 24" X 100′ RCP **[CMP, etc.]** (UIE = 4493.00′, LIE = 4491.00′). CONNECT TO **[TYPE 2 DROP INLET, TYPE 1 MANHOLE, etc.]** "A" 15+00, 28.0′ LT. SEE SHEET DP-1.

Storm Drain Outlet

<u>"B" 14+00</u>	CONSTRUCT [Drop Inlet, Manhole as above] … INSTALL 24" X 100′ RCP **[CMP, etc.]** OUTLETTING TO "B" 15+00, 56.0′ RT (UIE = 4000.00′, LIE = 3999.00′). INSTALL **[CONSTRUCT]** PRECAST **[METAL]** END SECTION **[CULVERT HEADWALL]**. SEE SHEET DP-1.

Embankment Protectors

<u>"C" 14+00</u>	CONSTRUCT TYPE **[5, 5-2G]** EMBANKMENT PROTECTOR 28.0′ RT **[WITH 12" X 20′ SLOTTED DRAIN AHEAD [BACK] ON LINE]**.

Note:

- If embankment protector outlet location is not clearly identifiable according to the Standard Plans, include outlet information in note [OUTLET TO "A" 14+00, 28.0′ RT (FLOWLINE ELEV. = 4500.00′)]. Measure length of downdrain pipe along pipe slope.

C.1.4.3 Channels, Ditches and Dikes

General Channel

"CH1" 14+00 <u>"CH1" 21+00</u>	CONSTRUCT **[RIPRAP, CONCRETE LINED]** CHANNEL. SEE SHEETS DP-1, DD-1.

Notes:

- Stationing is along independent channel alignment defined on survey control sheet.
- Detail sheets shall include sections, dimensions, etc.
- Use separate construction notes for changes in channel geometry, transitions, confluence structures, maintenance access ramps, etc.

General Ditch

"D" 14+00 "D" 14+00	CONSTRUCT DITCH FROM "D" 14+00, 28.0' LT, TO "D" 14+00, 28.0' LT. **[LT SIDE SLOPE = 3:1, RT SIDE SLOPE = 4:1, W = 4'] [SEE SHEET DD-1]**.

Notes:

- Include station, offset, and elevation tags on plans at locations of horizontal and vertical changes.
- Detail sheets, if used, may include sections, details, etc.

Bituminous Turnout and V-Ditch

"A" 14+00 "A" 14+00	CONSTRUCT BITUMINOUS TURNOUT DITCH **[V-DITCH]** FROM "A" 14+00, 28.0' LT T O "A" 14+00, 28.0' LT.

Flat Bottom Ditch and Dike

"B" 14+00 "B" 14+00	CONSTRUCT FLAT BOTTOM DITCH AND DIKE FROM "B" 14+00, 28.0' RT TO "B" 14+00, 28.0' RT. **[H=3.0', W=6'.]**

Bituminous Shoulder Dike

"C" 14+00 "C" 15+00	CONSTRUCT BITUMINOUS SHOULDER DIKE RT.

C.1.4.4 Pollution Control Items

Pretreatment Vaults (Sand / Oil Interceptors)

"D" 14+00	INSTALL PRETREATMENT VAULT 28.0' RT. SEE SHEET DD-2.

Silt Fence

"A" 14+00 "A" 28+00	INSTALL SILT FENCE **[10" SEDIMENT LOG, etc.]** FROM "A" 14+00, 50.0' LT, TO "A" 28+00, 75.0' LT, TOTAL LENGTH 1600'. SEE SHEET EC-1.

Note:

- The "TOTAL LENGTH" is used since silt fence, sediment logs, etc. typically follow a constant contour, not a straight line, so scaling or otherwise determining the length from the plans is difficult.

Sediment Log

"B" 14+00 "B" 21+00	INSTALL 10" SEDIMENT LOG BETWEEN "B" 14+00 AND "B" 21+00, 10' VERTICAL SPACING, TOTAL LENGTH 2800'. SEE SHEET EC-1.

Note:

- This format is appropriate where sediment logs are placed at a set spacing over an entire slope, for a linear disturbed area where a culvert was installed down a slope, etc.

Check Dam	
“C” 14+00	INSTALL CHECK DAM **[DI PROTECTION TYPE x, etc.]** 28.0′ LT. SEE SHEET DD-2.

Sediment Basin	
“D” 14+00	CONSTRUCT SEDIMENT BASIN **[SEDIMENT TRAP, INFILTRATION BASIN]** 100.0′ LT. SEE SHEET DD-2.

Surface Treatment	
“A”14+00 “A” 21+00	APPLY 2 ACRES **[SQ YARDS]** SURFACE TREATMENT **[(TYPE A)]** LT.

Note:

- Treatment may include mulching, stabilizers, seeding, etc. Treatment area should be hatched or otherwise shown on the plans and described in special provisions.

C.1.4.5 Miscellaneous Non-Standard Items

Special Drop Inlet, Transition Structure, Inlet Grading, Median Dike	
“B” 14+00	CONSTRUCT **[SPECIAL DROP INLET, TRANSITION STRUCTURE, INLET GRADING, MEDIAN DIKE, etc.]** LT. SEE SHEET DD-1.