APPENDIX

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Transportation *integrated* Storm Water Management (TriSWM)

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Transportation *integrated* Storm Water Management (TriSWM)

Introduction

Appendix J has been developed as a supplement to the *integrated* Storm Water Management (iSWM™) Design Manual for Site Development for use by cities, counties, and transportation agencies in the planning and design of storm water management systems for streets, roads, and highways. The table below indicates the sections or subsections of the iSWM™ Design Manual for Site Development that are modified when used in the planning and design of storm water management facilities for transportation projects. Most notably, all of Chapter 1 in the iSWM™ Design Manual for Site Development is replaced by sections of this Appendix. Chapters, sections, or subsections of the iSWM™ Design Manual for Site Development not referenced in the table are to be used "as is."

Note: Storm water runoff from residential streets should be managed as part of the overall storm water management system for the entire site. Chapter 1 of the iSWM™ Design Manual for Site Development should be used for the planning and design of storm water management facilities for residential subdivisions and internal residential streets. Appendix J does not apply to streets within residential subdivisions, unless required by the local jurisdiction.

Affected Section of the iSWM Design Manual for Site Development	Replacement Section in Appendix J	Comments
Section 1.1, Storm Water Site Planning	Section J1.1, TriSWM Planning	The planning process for public facilities is significantly different than for private projects.
Section 1.2, *integrated* Planning and Design Approach	Section J1.2, TriSWM Planning and Design Approach	The Water Quality Protection Criteria has been modified due to the nature of linear facilities.
Section 1.3, *integrated* Site Design Practices	Section J1.3 is not used (it is retained as a placeholder for organization purposes)	This section is omitted. *integrated* Site Design Practices that apply to streets and highways are generally covered in Subsection J1.1.3
Section 1.4, *integrated* Storm Water Controls	Section J1.4, *integrated* Storm Water Controls	*integrated* Storm Water Controls associated with buildings (i.e. Planter Boxes, Rain Barrels) have been removed. Water Quality Protection designations in Table J1.4.3-1 reflect TriSWM classifications.
Subsection 5.1.1, Storm Water Controls Overview	Subsection J5.1.1, Storm Water Controls Overview	This subsection has been modified to reflect the difference in terminology with regard to the TriSWM Water Quality Protection Criteria. Storm Water Controls associated with buildings have been removed from Table J5.1.1-1.

<table>
<tr><th>Affected Section of the iSWM Design Manual for Site Development</th><th>Replacement Section in Appendix J</th><th>Comments</th></tr>
<tr><td>Subsection 5.1.2, Suitability of Storm Water Controls</td><td>Subsection J5.1.2, Suitability of Storm Water Controls</td><td>Storm Water Controls associated with buildings have been removed from Table J5.1.2-1.</td></tr>
<tr><td>Subsection 5.1.3, Storm Water Control Selection</td><td>Subsection J5.1.3, Storm Water Control Selection</td><td>This subsection has been modified to reflect the difference in terminology with regard to the TriSWM Water Quality Protection Criteria. Storm Water Controls associated with buildings have been removed from Table J5.1.3-1 and water Quality Protection designations were changed to reflect TriSWM classifications.</td></tr>
<tr><td colspan="3">Note that the information sheets for the individual structural controls in Section 5.2 of the iSWM™ Design Manual for Site Development have not been changed to reflect the TriSWM Water Quality Protection Criteria classifications. Please refer to Tables J1.4.3-1 and J5.1.3-1 for the TriSWM Water Quality Protection Criteria designations for the controls.</td></tr>
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Section J1.1
TriSWM Planning

J1.1.1 Project Development Goals

In order to most effectively and efficiently manage storm water on new roadway, street, and highway projects, as well as significant expansion projects, consideration of storm water runoff needs to be fully integrated into the project planning and design process. This involves a comprehensive planning approach and a thorough understanding of the physical characteristics and natural resources in proximity to the proposed route. In addition, the management of the quantity and the quality of storm water should be addressed in an integrated approach. The purpose of this manual is to provide design guidance and a framework for incorporating effective and environmentally sensitive storm water management into the street and highway project development process and to encourage a greater uniformity in developing plans for storm water management systems that meet the following goals:

- Provide safe driving conditions
- Minimize the downstream flood risk to people and properties
- Minimize downstream bank and channel erosion
- Reduce pollutants in storm water runoff to protect water quality

J1.1.2 Storm Water Management Planning

J1.1.2.1 Applicability

The criteria within Appendix J, Transportation *integrated* Storm Water Management, is applicable to projects that disturb 1 acre or more, including projects less than one acre that are part of a larger common project plan or scope that will disturb 1 acre or more.

Projects located in or near critical or sensitive areas, or as identified through a watershed study or plan, may be subject to additional performance and/or regulatory criteria. Furthermore, these sites may need to utilize certain structural controls in order to protect a special resource or address certain water quality or drainage problems identified for a drainage area or watershed.

For some projects, particularly expansion projects, practical limitations may present obstacles to fully meeting storm water management requirements within the project right-of-way (ROW). Limitations could include lack of land availability, engineering constraints, health and safety issues associated with operations and maintenance activities, or low benefit/cost ratio. If the project planning, assessment, and design process reveals that storm water requirements for a project cannot be met because it is not feasible to do so, an explanation must be provided in the planning documents for the project. The explanation must include the reasons why the requirements cannot be met for the site and the provisions for storm water management that can be provided.

J1.1.2.2 Conditions for Accepting Off-Site Flows

Local governments and the Texas Department of Transportation (TxDOT) must provide for the passage of off-site flows through street and highway right-of-way to maintain natural drainage paths. If a private developer's project discharges off-site flow to public right-of-way, local governments designated as

Municipal Separate Storm Sewer Systems (MS4s) must require the private development project to comply with the requirements of the *integrated* Storm Water Management (iSWM™) Design Manual for Site Development (or other local government post construction storm water quality management requirements). Once the local government MS4 accepts discharge of water onto its right-of-way, the jurisdiction becomes liable for the quality of that discharge under National Pollutant Discharge Elimination System (NPDES) regulations.

TxDOT lacks statutory authority to prohibit or control post-construction discharges of storm water from development projects outside the right-of-way. TxDOT should coordinate with local governments to the extent possible to ensure that private development projects meet the jurisdiction's post construction storm water management requirements.

J1.1.2.3 Planning Process

Storm water management practices must be programmed at the earliest stages of project development so that sufficient right-of-way may be preserved to accommodate the facilities. This would generally be at the site assessment and preliminary design phases of a city/county street project or the preliminary design phase of a TxDOT project.

<u>City / County Project Development Process</u>
Local governments plan for the preservation and creation of transportation corridors through master thoroughfare plans and/or comprehensive plans. The function of these planning tools is to establish the future roadway network and design guidelines to provide an adequate level of service. Thoroughfare planning is used by local government to proactively prepare for future traffic conditions, accommodate growth and development and identify projects for the capital improvements program (CIP), determine roadway right-of-way requirements, and improve community aesthetics and safety. Conventional thoroughfare planning should be expanded to include avoidance of sensitive natural features where possible and to accommodate storm water management best management practices (BMPs).

Planning for individual projects typically starts with identification in the capital improvement program, which is a long-range financial planning tool to address community needs in the long-term future for improving streets, drainage, parks, public facilities, utilities and other city functions. Projects selected for funding in the CIP would proceed through various stages of development including Site Assessment, Preliminary Design, Right-of-Way Acquisition, Final Design, and Drawings & Specifications.

The Site Assessment phase consists of identifying physical and environmental constraints on the potential alignment of the project. The Preliminary Design phase incorporates information from the site assessment and identifies the vertical alignment for the street or roadway. Typically, preliminary design drawings are reviewed by the local government at a point where the engineering design is approximately 30 to 50 percent complete. Once the preliminary plans and vertical alignment are approved, activities to acquire the right-of-way are initiated. While right-of-way acquisition efforts are in progress, the final design drawings and specifications for the project are completed and reviewed by the local government.

Since many storm water management best management practices require additional space beyond the typical right-of-way (50' two-lane streets, 120 – 130' for 6-lane divided with median), storm water management practices must be identified during the Preliminary Design phase. Once storm water management controls are identified, the right-of-way acquisition process and development of the final design may proceed accordingly.

<u>TxDOT Project Development Process</u>
The TxDOT project development process is laid out in detail in the Project Development Process Manual, which may be downloaded at ftp://ftp.dot.state.tx.us/pub/txdot-info/gsd/manuals/pdp.pdf. A general characterization of the process is outlined below:

- Planning and Programming

Consists of needs identification, site visit, project authorization, compliance with planning requirements, determination of study requirements, and construction funding identification.

- Preliminary Design
  Consists of data collection and preliminary design preparation, public meetings, preliminary schematic preparation, geometric schematic preparation (including determination of right-of-way needs), and value engineering.
- Environmental
  Consists of environmental issues determination and data collection, interagency coordination and permitting, environmental documentation, public hearing, and environmental clearance. This process is further described below.
- Right-of-Way and Utilities
  Consists of right-of-way and utility data collection, mapping, appraisals and acquisition, and utility adjustments.
- Plans, Specifications, and Engineering Development
  Consists of the design conference, design of bridges, final vertical and horizontal alignment design, roadway design, drainage design, and final review.
- Letting
  Consists of final funding approval and bidding and award of construction contract.

The environmental review process is coordinated by the District Environmental Quality Coordinator (DEQC). The DEQC is aided by the Storm Water Advisory Team (SWAT), which includes multiple disciplines drawn from several TxDOT Divisions. The SWAT provides the subject matter expertise particular to storm water regulations and best management practices. The DEQC, SWAT, and divisional and central management are aided by the Environmental Tracking System (ETS), a database system that tracks the environmental process for projects generated by TxDOT's 25 Districts. The ETS tracks and facilitates coordination throughout the TxDOT system concerning:

- Project environmental clearance
- Environmental Permits, Issues and Commitments (EPIC)
- Public involvement
- Cultural resources protection
- Hazardous material avoidance or removal
- Corps of Engineers permits
- Biological resource protection
- Water quality protection
- Coordination with other regulatory agencies as necessary

<u>Determine/Confirm Local Requirements</u>
The consultant or project designer should determine the storm water management requirements of the jurisdiction(s) that the project will be located in. For local governments that have adopted the iSWM™ Design Manual for Site Development, much of this information is available in the jurisdiction’s Local Criteria section of the Design Manual for Site Development. These requirements may include:

- Design storm frequencies
- Conveyance design criteria
- Floodplain criteria

- Buffer/setback criteria
- Watershed-based criteria
- Need for physical site evaluations such as infiltration tests, geotechnical evaluations, etc.

Defining and Avoiding Potential Impacts

The planning phase offers the greatest opportunity to avoid adverse water quality impacts as alignments and right-of-way requirements are developed and refined. Conducting natural and cultural resource studies concurrently with early project planning provides timely information to assist in identifying and avoiding potential impacts. Sections J1.1.2.4, Site Analysis and Inventory, and J1.1.3, Special Planning and Design Considerations, describe the features that should be considered and avoided if possible. Avoiding impacts may reduce or eliminate the need for higher level water quality treatment controls.

Once the alignment has been determined, planning and design of storm water management controls should be performed early in the preliminary design phase of the project so that adequate right-of-way may be acquired. The proposed alignment should include sufficient reserved land to construct and maintain all required BMPs at appropriate locations.

J1.1.2.4 Site Analysis and Inventory

Using approved field and mapping techniques, the project designer shall collect and review information on the existing site conditions and map the following site features:

- Topography
- Drainage patterns and basins
- Intermittent and perennial streams / receiving waters
- Stream flow data
- Soils
- Ground cover and vegetation
- Wetlands
- Critical habitat areas
- Boundaries of wooded areas
- Floodplain boundaries
- Steep slopes
- Required buffers
- Other required protection areas (e.g., well setbacks)
- Clean Water Act Section 303(d) listed impaired stream segments
- Proposed stream crossing locations
- Existing storm water facilities (open channels & enclosed)
- Existing development
- Utilities
- Adjacent areas
- Property lines and easements

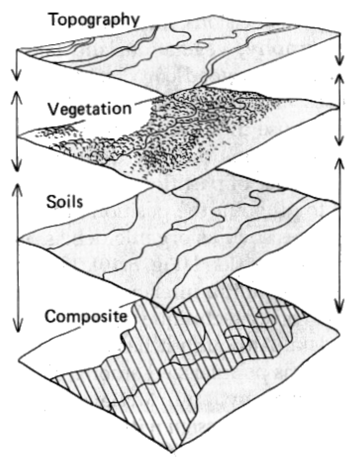

Figure J1.1.2.4-1
Composite Analysis
(Source: Marsh, 1983)

Some of this information may be available from previously performed studies or from a feasibility study. For example, some of the resource protection features may have been mapped as part of erosion and sediment control activities. Other recommended site information to map or obtain includes utilities information, seasonal groundwater levels, and geologic data.

Individual map or geographic information system (GIS) layers can be designed to facilitate an analysis of the site through what is known as map overlay or composite analysis. Each layer (or group of related information layers) is placed on the map in such a way as to facilitate comparison and contrast with other layers. A composite layer is often developed to show all the layers at once (see Figure 1.12.4-1).

J1.1.3 Special Planning and Design Considerations

This section discusses several environmental features that should be identified and assessed during the earliest stages of planning for a project, as well as design considerations for bridges and right-of-way. Proposed alignments for a project should avoid sensitive natural resources to the greatest extent practicable. In cases where avoidance is not possible, providing an undisturbed buffer and additional practices or structural controls to minimize impact should be considered.

Preserving natural conservation areas such as undisturbed forested and vegetated areas, floodplains, stream corridors and wetlands helps to preserve the original hydrology and avoids the impact of storm water runoff and pollutants. Undisturbed vegetated areas also stabilize soils, provide for filtering and infiltration, decreases evaporation, and increases transpiration.

Buffer areas and sensitive features in proximity to project alignments should be clearly marked on all construction and grading plans to ensure equipment is kept out of these areas and native vegetation is kept in an undisturbed state. The boundaries of each conservation area should be mapped by carefully determining the limit that should not be crossed by construction activity.

J1.1.3.1 Sensitive Areas

Stream segments classified by the Texas Commission on Environmental Quality (TCEQ) as Exceptionally-High quality should be avoided if possible when considering potential alignments. These are waters that have been designated “Exceptional Quality Aquatic Habitat” by the TCEQ or “Endangered/Protected Species Habitat” by the Texas Parks and Wildlife Department.

- Exceptional Quality Aquatic Habitat – segments that are significant due to unique or critical habitats and exceptional aquatic life uses dependent on or associated with high water quality
- Endangered/Protected Species Habitat – sites along segments where water development projects would have significant detrimental effects on state or federally listed threatened and endangered species, and sites along segments that are significant due to the presence of unique, exemplary, or unusually extensive natural communities

J1.1.3.2 Wetlands

Because the alteration of ground cover and drainage patterns will almost always affect the hydrology of wetlands, and because hydrologic changes strongly impact vegetation and amphibian communities, it is always preferable to avoid wetland areas when determining road or street alignments if possible.

An important measure to maintain the health of a natural wetland is the protection and control of the wetland’s hydroperiod. The hydroperiod is the pattern of fluctuation of water depth and the frequency and duration of drying in the summer. A hydrological assessment is performed to determine pre-project hydroperiod characteristics and to model the post-project conditions. Coordination with the TCEQ is necessary to properly assess the impact of hydroperiod changes.

The design of facilities adjacent to wetlands should maximize natural water storage and infiltration opportunities within the project area. Natural wetlands may not be used in lieu of runoff treatment BMPs.

Any construction of storm water treatment or flow control facilities is discouraged within natural wetland areas, with the exception of the following situations, which involve additional permitting:

- Necessary conveyance systems with applicable permits
- Lower quality wetland approved for hydrologic modification

J1.1.3.3 Floodplains

Development in floodplain areas can reduce the ability of the floodplain to convey storm water, potentially causing safety problems or significant damage to the site in question, as well as to both upstream and downstream properties. Ideally, the entire 100-year full-buildout floodplain should be avoided for clearing or building activities, and should be preserved in a natural undisturbed state where possible. Floodplain protection is complementary to riparian buffer preservation.

Roadway construction can displace hydrologic storage, resulting in increased stream flows, erosion, and decreased infiltration. Loss of hydrologic storage may require creation of additional hydrologic storage elsewhere in the watershed. Design for management of storm water runoff from transportation facilities in floodplains differs from parcel based BMPs primarily in the increased influence of off-site storm water entering the facility, space limitations of a linear facility, and the likelihood that roadways will cross jurisdictional boundaries.

J1.1.3.4 Aquifers and Wellhead Protection Areas

Pollutants can enter aquifers through storm water runoff treatment and storage systems. Local ordinances may specify minimum setbacks or buffers between wellheads and roadway construction. In Texas, the TCEQ's Source Water Assessment Program (SWAP), Source Water Protection Program (SWP) and Wellhead Protection Program (WHP) may also impact BMP selection and implementation for transportation projects. Aquifer recharge zones may also have state or local restrictions. See Appendix C, Section 3.8.

J1.1.3.5 Streams and Riparian Areas

Roadway alignments should cross streams and riparian areas as few times as possible and should be located a sufficient distance from the stream when the alignment is parallel. Maintaining riparian buffers is important for the protection of stream banks and stream ecosystems.

Forested riparian buffers should be maintained and reforestation should be encouraged where no wooded buffer exists. Proper restoration should include all layers of the forest plant community, including understory, shrubs and groundcover, not just trees. A riparian buffer can be of fixed or variable width, but should be continuous and not interrupted by impervious areas that would allow storm water to concentrate and flow into the stream without first flowing through the buffer.

Ideally, riparian buffers should be sized to include the 100-year floodplain as well as steep banks and wetlands. The buffer depth needed to perform properly will depend on the size of the stream and the surrounding conditions, but a minimum 25-foot undisturbed vegetative buffer is needed for even the smallest perennial streams and a 50-foot or larger undisturbed buffer is ideal. Any structural controls for management of storm water should be located outside the riparian buffer if possible.

Generally, the riparian buffer should remain in its natural state. However, some maintenance is periodically necessary, such as planting to minimize concentrated flow, the removal of exotic plant species when these species are detrimental to the vegetated buffer and the removal of diseased or damaged trees.

J1.1.3.6 Bridges

The portion of bridge storm water runoff associated with the part of the bridge over water is the same volume as would have fallen in the water body without the presence of the bridge. The water quality, however, is impacted by material deposited on the road surface. Furthermore, the bridge itself doesn't offer an opportunity for treatment or infiltration. Although bridges have traditionally been built with gutters routing storm water directly into the receiving waters, this is no longer the preferred alternative. It is recommended that runoff be collected and conveyed to the ends of the bridge and directed to the selected treatment facility as necessary. Collection and conveyance systems must be designed to prevent backup of storm water onto the bridge surface in the event of clogging by trash and debris.

J1.1.3.7 Right-of-Way

After the storm water treatment requirements of the project are determined, and the hydrology of the site is known, the area required for storm water treatment facilities can be estimated. Availability and cost of right-of-way may influence treatment selection. Placement of the roadway and storm water treatment facilities within the right-of-way can be adjusted and additional right-of-way requirements may be identified.

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Section J1.2
TriSWM Planning and Design Approach

J1.2.1 Introduction

This section presents an integrated approach for meeting the storm water runoff quality and quantity management goals by addressing the key adverse impacts of development on storm water runoff. The purpose is to provide guidance for designing a comprehensive storm water management system to:

- Remove pollutants in storm water runoff to protect water quality
- Assess discharge from the site to minimize downstream bank and channel erosion
- Control conveyance of runoff within and from the site to minimize flood risk to people and property

The TriSWM Planning and Design Approach is a coordinated set of design standards that allow the site engineer to design and size storm water controls to address these goals. Each of the TriSWM Planning and Design Steps should be used in conjunction with the others to address the overall storm water impacts from a transportation project. When used as a set, the TriSWM Planning and Design Approach controls the entire range of hydrologic events, from the smallest runoff-producing rainfalls up to the 100-year, 24-hour storm.

The design approach for each of the goals above is summarized in Table J1.2.1-1 below:

Table J1.2.1-1 Steps for TriSWM Planning and Design Approach for Storm Water Control

Steps	Approach
Step 1: Downstream Assessment	Conduct a downstream assessment to the point at which the discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system. The assessment shall analyze downstream impacts from a development for three (3) storm events based on Local Criteria: (1) a "Streambank Protection" storm, either the 1- or 2-year, 24-hour event; (2) a "Conveyance" storm, either the 5-, 10-, or 25-year, 24-hour event; and (3) the "100-year" storm, a 100-year 24-hour storm event.
Step 2: Water Quality Protection	Water Quality Protection requirements are determined based on the quality of receiving waters, proximity of project discharge to any wetlands and/or drinking water supply intakes, and projected traffic volume for the project. Refer to Section J1.2.3 to determine the Water Quality Treatment Level required (Treatment Level I, II, or III).
Step 3: Streambank Protection	Provide streambank protection from erosion due to increased storm water volumes and velocities caused by development using one or more of the following options: (1) Determine acceptable downstream conditions; (2) Reinforce/stabilize downstream conditions; (3) Install storm water controls to maintain existing downstream conditions; (4) Provide on-site controlled release of the 1-year, 24-hour storm event over a period of 24 hours (Streambank Protection Volume, SP_V).

Table J1.2.1-1	Steps for TriSWM Planning and Design Approach for Storm Water Control
Step 4: Flood Control	Flood impact reduction may be achieved by a combination of on-site control, downstream protection, floodplain management, and/or other mitigation measures. Onsite: Minimize localized site flooding of streets, sidewalks, and properties by a combination of on-site storm water controls and conveyance systems. These systems will be designed for the "Streambank Protection" and "Conveyance" storm event frequencies. Depending upon their location, function, and the requirements of the local jurisdiction, the full build-out "100-year" storm event is to be conveyed on-site such that no resulting habitable structural flooding occurs. Downstream: Based on the downstream assessment, manage downstream flood impacts caused by the increase of storm water discharges from the development using one or more of following options: (1) Determine acceptable downstream conditions; (2) Provide adequate downstream conveyance systems, (3) Install storm water controls on-site to maintain existing downstream conditions; (4) In lieu of a downstream assessment, maintain existing on-site runoff conditions.

Figure J1.2.1-1 graphically illustrates the relative volume requirements of each of the TriSWM Planning and Design Steps and demonstrates that the pieces typically overlay one another. If the downstream assessment for flood control indicated upstream detention was needed to limit the discharge from a project, the volume requirement to achieve the downstream flood control requirement could also contain the volume needed to provide for Streambank Protection and, if required, Water Quality Protection. The appropriate type of detention facility could be designed with outlet controls to address each of the steps of the Design Approach. Obviously, detention may not be required in all situations, but consideration of site design practices and storm water controls that work together to meet all the requirements is what is important. The following sections describe the TriSWM Planning and Design Approach in more detail.

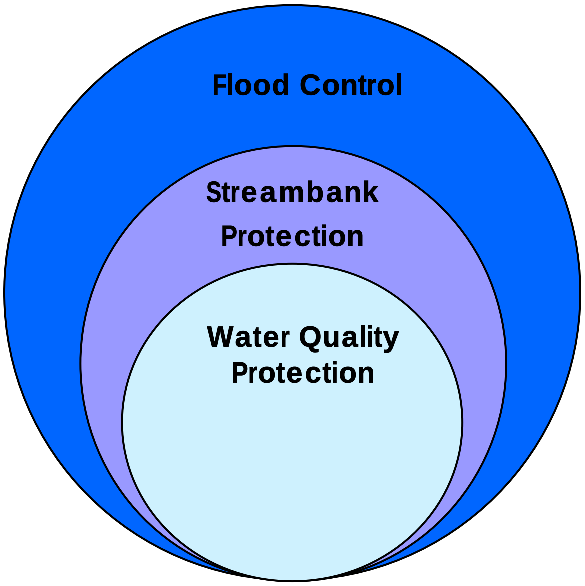

Figure J1.2.1-1 Representation of the TriSWM Planning and Design Approach

J1.2.2 Downstream Assessment

As part of the TriSWM planning process, the downstream impacts of development must be carefully evaluated. The purpose of the downstream assessment is to protect downstream properties from increased flooding and downstream channels from increased erosion potential due to upstream development. The importance of the downstream assessment is particularly evident for larger sites or developments that have the potential to dramatically impact downstream areas. The cumulative effect of smaller sites, however, can be just as dramatic and, as such, following the TriSWM Planning and Design Approach is just as important for the smaller sites as it is for the larger sites.

The assessment should extend from the outfall of a proposed development to a point downstream where the discharge from a proposed development no longer has a significant impact on the receiving stream or storm drainage system. The assessment should be a part of the preliminary and final design plans, and should include the following properties:

- Hydrologic analysis of the pre- and post-development on-site conditions
- Drainage path that defines the extent of the analysis
- Capacity analysis of all existing constraint points along the drainage path, such as existing floodplain developments, underground storm drainage systems culverts, bridges, tributary confluences, or channels
- Offsite undeveloped areas are considered as “full build-out” for both the pre- and post-development analyses
- Evaluation of peak discharges and velocities for three (3) 24-hour storm events
    - Small-frequency storm for “Streambank Protection”, either the 1- or 2-year event
    - A “Conveyance” storm of either the 5-, 10-, or 25-year event
    - A “100-year” storm event
- Separate analysis for each major outfall from the proposed development

Once the analysis is complete, the designer should ask the following three questions at each determined junction downstream:

- Are the post-development discharges greater than the pre-development discharges?
- Are the post-development velocities greater than the pre-development velocities?
- Are the post-development velocities greater than the velocities allowed for the receiving system?

These questions should be answered for each of the three storm events. The answers to these questions will determine the necessity, type, and size of non-structural and structural controls to be placed on-site or downstream of the proposed development. Section 2.1, Estimating Runoff, gives additional guidance on calculating the discharges and velocities, as well as determining the downstream extent of the assessment.

J1.2.3 Water Quality Protection

J1.2.3.1 Water Quality Treatment Level Criteria

In assessing the need to incorporate post-construction water quality control measures into street and highway construction projects, the quality of receiving waters is to be considered along with projected traffic volume for the facility. Of many variables that affect the quality of runoff from a roadway (rainfall characteristics, traffic type, surrounding land use, etc.), average daily traffic volume (ADT) is a determining factor for which data is readily available.

Various studies and reports published by the Federal Highway Administration have concluded that greater pollutant levels in storm water runoff could be anticipated where traffic volume exceeds 30,000 ADT. Therefore, 30,000 vehicles per day (VPD) is used as the threshold between low volume and high volume roadways and the corresponding level of post-construction storm water quality treatment required.

The water quality of streams or reservoirs and existence of downstream critical areas are used to classify receiving waters and riparian environments. The classification is based on the susceptibility of the receiving waters and riparian areas to negative impact from pollutants in storm water runoff from the proposed project. The classification of receiving waters is as follows:

1. **High**: These are receiving waters that meet one or more of the following criteria:
   - Designated as “Exceptional Quality Aquatic Habitat” by the TCEQ
   - Identified as Endangered/Protected Species Habitat by the Texas Parks and Wildlife Department
   - Proximity and potential impact to drinking water supply reservoir (as determined by water treatment provider)

2. **Moderate**: These are receiving waters that meet one or more of the following criteria:
   - Three or more designated uses on the Texas Surface Water Quality Standards, or any perennial stream not having a segment designation
   - Wetlands that would receive more than 10% of total flow from the project

3. **Minimal**: Receiving waters listed with two or less designated uses on the Texas Surface Water Quality Standards

Table J1.2.3-1 shows the level of post-construction storm water management measures required for street and highway projects based on the previously discussed factors of traffic volume and quality of receiving waters. The levels should be considered during project planning and design for construction of new streets and highways and major reconstruction projects. The ADT will be based on a 20-year design projection.

Table J1.2.3-1 Post-Construction Water Quality Treatment Levels

Traffic Volume	**Receiving Water / Riparian Area Susceptibility**		
	Minimal	**Moderate**	**High**
Low (<30,000 VPD)	Level I	Level I	Level II
High (>30,000 VPD)	Level I	Level II	Level III

Treatment Level I

Select from the following practices and/or structural controls (Section J1.4 and Chapter 5 contain selection, pollutant removal effectiveness, and design information for structural controls):

- Program of Scheduled Pollution Prevention Practices
  Municipal pollution prevention/good housekeeping practices such as street sweeping, storm drain inlet cleaning, and proper application of landscape chemicals

- Off-site Pollution Prevention Activities/Programs
  Route storm water runoff to new or existing watershed-level BMPs (i.e. regional detention, Dallas CBD sumps, etc.) identified in the entity’s MS4 Permit / Storm Water Management Program

- Grass Channels

- Filter Strips

- Gravity (Oil-Grit) Separator

- Proprietary Structural Controls

- Porous Concrete / Modular Porous Paver Systems

Treatment Level II

Select from the following practices and/or structural controls:

- Enhanced Swales
- Bioretention Areas
- Dry Detention / Extended Detention Dry Basins
- Supplement with any BMPs identified in Level I

Treatment Level III

Select from the following practices and/or structural controls:

- Organic Filter
- Sand Filter
- Underground Sand Filter
- Infiltration Trenches
- Storm Water (Wet) Ponds
- Storm Water Wetlands
- Alum Treatment Systems (used as pretreatment in conjunction with wet pond)
- Supplement with any BMPs identified in Levels I and II

Once the treatment level is established and potential practices and structural controls are identified, the volume of runoff to be treated must be calculated in accordance with the following section for some controls. Refer to Chapter 5, Storm Water Controls, for each of the proposed controls to determine whether the water quality protection volume is applicable. Structural controls or practices from a higher Treatment Level category may be used to meet lower Treatment Level requirements if desired. Combinations of practices and controls may also be implemented.

J1.2.3.2 Water Quality Protection Volume

Hydrologic studies show smaller, frequently occurring storms account for the majority of rainfall events. Consequently, the runoff from the many smaller storms also accounts for a major portion of the annual pollutant loadings. By treating these frequently occurring, smaller rainfall events and the initial portion of the storm water runoff from larger events, it is possible to effectively mitigate the water quality impacts from a developed area.

Studies have shown the 85^{th} percentile storm event (i.e., the storm event that is greater than 85% of the storms that occur) is a reasonable target event to address the vast majority of smaller, pollutant-loaded storms. Based on a rainfall analysis, 1.5 inches of rainfall has been identified as the average depth corresponding to the 85^{th} percentile storm for the North Central Texas Council of Governments (NCTCOG) region. The runoff from these 1.5 inches of rainfall is referred to as the Water Quality Protection Volume (WQ_v). Thus, a storm water management system designed for the WQ_v will treat the runoff from all storm events of 1.5 inches or less, as well as a portion of the runoff for all larger storm events. The Water Quality Protection Volume is directly related to the amount of impervious cover and is calculated using the formula below:

$$WQ_V = \frac{1.5 R_V A}{12}$$

where:

WQ_v = Water Quality Protection Volume (in acre-feet)

R_v = 0.05 + 0.009(I) where I is percent impervious cover

A = site area in acres remaining after reduction

Determining the Water Quality Protection Volume (WQ_v)

- *Measuring Impervious Area*: The area of impervious cover can be taken directly off a set of plans or appropriate mapping. Where this is impractical, Natural Resources Conservation Service (NRCS) TR-55 land use/impervious cover relationships can be used to estimate impervious cover. I is expressed as a percent value not a fraction (e.g., I = 30 for 30% impervious cover)
- *Multiple Drainage Areas*: When a development project contains or is divided into multiple outfalls, WQ_v should be calculated and addressed separately for each outfall.
- *Determining the Peak Discharge for the Water Quality Storm:* When designing off-line structural control facilities, the peak discharge of the water quality storm (Q_{wq}) can be determined using the method provided in Section 2.1.10.2.
- *Extended Detention of the Water Quality Volume:* The water quality treatment requirement can be met by providing a 24-hour drawdown of a portion of WQ_v in a storm water pond or wetland system (as described in Chapter 5). Referred to as water quality extended detention (ED), it is different than providing extended detention of the 1-year storm for the streambank protection volume (SP_v). The ED portion of the WQ_v may be included when routing the SP_v.
- *Permanent Pool:* Wet ponds and wetlands will have permanent pools, the volume of which may be used to account for up to 50% of the WQ_v.
- WQ_v can be expressed in cubic feet by multiplying by 43,560. WQ_v can also be expressed in watershed-inches by removing the area (A) and the "12" in the denominator.

This approach to control pollution from storm water runoff treats the WQ_v from a site to reduce a target percentage of post-development total suspended solids (TSS). TSS was chosen as the representative storm water pollutant for measuring treatment effectiveness for several reasons:

- The measurement standard of using TSS as an "indicator" pollutant is well established.
- Suspended sediment and turbidity, as well as other pollutants of concern adhere to suspended solids, and are a major source of water quality impairment due to urban development in the region's watersheds.
- A large fraction of many other pollutants of concern are removed either along with TSS, or at rates proportional to the TSS removal.

Even though TSS is a good indicator for many storm water pollutants, there are special cases that warrant further consideration including:

- The removal performance for pollutants that are soluble or that cannot be removed by settling must be specifically designed for. For pollutants of specific concern, individual analyses of specific pollutant sources should be performed and the appropriate removal mechanisms implemented.
- Runoff, which is atypical in terms of normal TSS concentrations, will be treated to a higher or lesser degree. For example, treatment of highly turbid waters would attain a higher removal percentage but still may not attain acceptable water quality without additional controls or a higher level of BMP maintenance.
- Bed and bank-material sediment loads not accurately measured by the TSS standard are also typically removed using this approach.

- Site, stream, or watershed specific criteria, different from the TSS standard, may be developed through a state or federal regulatory program necessitating a tailored approach to pollution prevention.

J1.2.4 Streambank Protection

The increase in the frequency and duration of bankfull flow conditions in stream channels due to urban development is the primary cause of accelerated streambank erosion and the widening and downcutting of stream channels. Therefore, streambank protection criterion applies to all development sites for which there is an increase in the natural flows to downstream feeder streams, channels, ditches, and small streams.

There are four options by which the local government/agency can provide adequate streambank protection downstream of a proposed project. The entity should specify in their Local Criteria which of these options are acceptable, as well as any other alternatives for streambank protection. If on-site or downstream improvements are required for streambank protection, easements or right-of-entry agreements may need to be obtained in accordance with the Local Criteria.

Option 1: Determine Acceptable Downstream Conditions

The designer should first determine if existing downstream streambank protection is adequate to convey storm water velocities for post-development conditions. This is accomplished by first obtaining post-developed velocities for the "Streambank Protection" storm event from the downstream assessment, as described in Section J1.2.2. These velocities are then compared to the allowable velocity of the downstream receiving system. Allowable velocities can be found in Chapter 4 in Tables 4.4-2 and 4.4-3. If the downstream system is designed to handle the increase in velocity, the developer should provide all supporting calculations and/or documentation to show that the stream integrity will not be compromised.

Option 2: Reinforce/Stabilize Downstream Conditions

If the increased velocities are higher than the allowable velocity of the downstream receiving system, then the developer may choose to reinforce/stabilize the downstream conveyance system. The proposed modifications must be designed so that the downstream post-development velocities (for the 3 storm events described in Section J1.2.2) are less than or equal to either the allowable velocity of the downstream receiving system or the pre-development velocities, whichever is higher. The designer must provide supporting calculations and/or documentation that the downstream velocities do not exceed the allowable range once the downstream modifications are installed. (See Tables 4.4-2 and 4.4-3 for allowable velocities.)

Option 3: Install Storm Water Controls On-site to Maintain Existing Downstream Conditions

The designer may also choose to use on-site controls to keep downstream post-development discharges at or below allowable velocity limits described in Option 2. The designer must provide supporting calculations and/or documentation that the on-site controls will be designed such that downstream velocities for the three (3) storm events described in Section J1.2.2 are within an allowable range once the controls are installed.

Option 4: Provide On-site Controlled Release of the Streambank Protection Volume

Another approach to streambank protection is to specify that 24 hours of extended detention be provided for on-site, post-developed runoff generated by the 1-year, 24-hour rainfall event to protect downstream channels. The required volume for extended detention is referred to as the Streambank Protection Volume (SP_v). The reduction in the frequency and duration of bankfull flows through the controlled release provided by extended detention of the SP_v will reduce the bank scour rate and severity.

<u>Determining the Streambank Protection Volume</u>

- *SP_v Calculation Methods:* Several methods can be used to calculate the SP_v storage volume required for a site. Subsection 2.1.11 illustrates the recommended average outflow method for volume calculation.
- *Hydrograph Generation:* The SCS TR-55 hydrograph methods provided in Section 2.1.5 can be used to compute the runoff hydrograph for the 1-year, 24-hour storm.
- *Rainfall Depths:* The rainfall depth of the 1-year, 24-hour storm will vary depending on location and can be determined from the rainfall tables included in Appendix A for various locations across North Central Texas.
- *Multiple Drainage Areas*: When a development project contains or is divided into multiple outfalls, SP_v should be calculated and addressed separately for each outfall.
- *Off-site Drainage Areas:* A structural storm water control located "on-line" will need to safely bypass any off-site flows. Maintenance agreements may be required.
- *Routing/Storage Requirements:* The required storage volume for the SP_v must lie above the permanent pool elevation in storm water ponds. Wet ponds and wetlands will have permanent pools. The portion of the WQ_v above the permanent pool may be included when routing the SP_v.
- Hydraulic control structures appropriate for each storage requirement may be needed.
- *Control Orifices*: Orifice diameters for SP_v control of less than 3 inches are not recommended without adequate clogging protection (see Section 4.6). Clogging protection must be provided on all orifices.

J1.2.5 Flood Control

Flood control analyses are based on the following three (3) storm events. The storm frequencies for each event shall be established in the Local Criteria section.

- *"Streambank Protection":* Either the 1- or 2-year, 24-hour storm event
- *"Conveyance"*: Either the 5-, 10-, or 25-year, 24-hour storm event
- "100-year" the 100-year, 24-hour storm event

The intent of the flood control criteria is to provide for public safety; minimize on-site and downstream flood impacts from the "Streambank Protection", "Conveyance", and "100-year" storm events; maintain the boundaries of the mapped 100-year floodplain; and protect the physical integrity of the on-site storm water controls and the downstream storm water and flood control facilities.

Flood control must be provided for on-site conveyance, as well as downstream outfalls as described in the following sections.

J1.2.5.1 On-Site Conveyance

The "Conveyance" storm event is used to design standard levels of flood protection for streets, sidewalks, structures, and properties within and adjacent to the project. This is typically handled by a combination of conveyance systems including street and roadway gutters, inlets and drains, storm drain pipe systems, culverts, and open channels. Other storm water controls may affect the design of these systems.

The design storms used to size the various on-site conveyance systems will vary depending upon their location and function. For example, open channels, culverts, and street rights-of-way are generally designed for larger events (25- to 100-year storm), whereas inlets and storm drain pipes are designed for smaller events (5- to 25-year storm). The requirements of the entity should be obtained and utilized as shown in the Local Criteria section of this manual.

It is recommended that once the initial set of controls are selected in the project design, the full build-out 100-year, 24-hour storm be routed through the on-site conveyance system and storm water controls to determine the effects on the systems, adjacent property, and downstream areas. Even though the conveyance systems may be designed for smaller storm events, overall, the site should be designed appropriately to safely pass the resulting flows from the full build-out 100-year storm event with no flood waters entering habitable structures.

On-site flood control has many considerations for the safeguarding of people and property. On residential streets, for the "Conveyance" storm event, the safe passage of vehicular traffic is an important concern. For the 100-year storm events, traffic may be limited in order to utilize all or portions of the right-of-way for storm water conveyance in order to protect properties. As such, the effective management of storm water throughout the development for the full range of storm events is needed.

J1.2.5.2 Downstream Flood Control

The downstream assessment is the first step in the process to determine if a specific development will have a flooding impact on downstream properties, structures, bridges, roadways, or other facilities. This assessment should be conducted downstream of a development to the point where the discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system. Hydrologic and hydraulic evaluations must be conducted to determine if there are areas of concerns, i.e. an increase of the Base Flood Elevations. The local jurisdiction should be consulted to obtain records and maps related to the National Flood Insurance Program and the availability of Flood Insurance Studies and Flood Insurance Rate Maps (FIRMs) that will be helpful in this assessment.

The downstream flood control criterion is based on an analysis of the "Streambank Protection" and "Conveyance" storm events, as well as the "100-year", defined as the 100-year, 24-hour storm event (denoted Q_{p100}). The local jurisdiction should quantify the frequency of the "Streambank Protection" and "Conveyance" storm events, as well as other events that may be required based on local policy or site-specific conditions, as identified in the Local Criteria section of this manual. If on-site or downstream modifications are required for downstream flood control, easements or right-of-entry agreements may need to be obtained in accordance with the Local Criteria.

Initially, the assessment will determine if the downstream receiving system has adequate capacity in its "full build-out" floodplain. To make this determination, Q_f, the runoff that the stream can handle without having an impact on downstream properties, structures, bridges, roadways, or other facilities, must be determined. There are four options by which a community can address downstream flood control. The local jurisdiction should specify in their Local Criteria which of these options are acceptable, as well as any other alternatives for downstream flood control. These options closely follow the four options for Streambank Protection.

<u>Option 1: Determine Acceptable Downstream Conditions</u>

The designer should provide all supporting calculations and/or documentation to show that the existing downstream conveyance system has capacity (Q_f) to safely pass the full build-out Q_{p100} discharge (peak rate of discharge for the 100 year storm). Systems shown to be adequate are reflective of areas where attempts have been made to keep flood-susceptible development out of the "full build-out" floodplain through a combination of regulatory controls, storm water master planning, and incentives. This includes communities that have regulated floodplains for fully-developed conditions. This approach recognizes that the impacts of new development might not be completely mitigated at the extreme flood level and provides a much greater assurance that local flooding will not be a problem because people and structures are kept out of harm's way.

<u>Option 2: Provide Adequate Downstream Conveyance Systems</u>

If the downstream receiving system does not have adequate capacity, then the designer may choose to provide modifications to the off-site, downstream conveyance system. If this option is chosen the proposed modifications must be designed to adequately convey the full build-out storm water peak discharges for the three (3) storm events. The modifications must also extend to the point at which the discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system. The developer must provide supporting calculations and/or documentation that the downstream peak discharges and water surface elevations are safely conveyed by the proposed system, without endangering downstream properties, structures, bridges, roadways, or other facilities.

Option 3: Install Storm Water Controls to Maintain Existing Downstream Conditions

If the downstream receiving system does not have adequate capacity, then the designer may also choose to provide storm water controls to reduce downstream flood impacts. These controls include on-site controls such as detention, regional controls, and, as a last resort, local flood protection such as levees, floodwalls, floodproofing, etc. Storm water master plans are a necessity to attempt to ensure public safety for the extreme storm event. The developer must provide supporting calculations and/or documentation that the controls will be designed and constructed so that there is no increase in downstream peak discharges or water surface elevations due to development.

Option 4: In lieu of a Downstream Assessment, Maintain Existing On-Site Runoff Conditions

Lastly, on-site controls may be used to maintain the pre-development peak discharges from the site. The designer must provide supporting calculations and/or documentation that the on-site controls will be designed and constructed to maintain on-site existing conditions.

It is important to note that Option 4 does not require a downstream assessment; it is a detention-based approach to addressing downstream flood control. For many developments however, the results of a downstream assessment may show that significantly less flood control is required than “detaining to pre-development conditions”. This method may also exacerbate downstream flooding problems due to timing of flows as discussed in Section 2.1.9. Therefore, it is strongly recommended that a downstream assessment be performed for all projects, and that Option 4 only be used when Options 1, 2, and 3 are not feasible.

The following items should be considered when providing downstream flood control.

- *Peak-Discharge and Hydrograph Generation:* Hydrograph methods provided in Section 2.1 can be used to compute the peak discharge rate and runoff for the three (3) storm events (“Streambank Protection”, “Conveyance”, and 100-year).
- *Rainfall Depths:* The rainfall depth of the three storm events will vary depending on location and can be determined from rainfall tables included in Appendix A for various locations across North Central Texas.
- *Off-site Drainage Areas:* Off-site drainage areas should be modeled as “full build-out” for the three storm events to ensure safe passage of future flows.
- *Downstream Assessment:* If flow is being detained on-site, downstream areas should be checked to ensure there is no peak flow or water surface increase above pre-development conditions to the point where the undetained discharge from the proposed development no longer has a significant impact upon the receiving stream or storm drainage system. More detail on Downstream Assessments is given in Section 2.1.9.

Section J1.3

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Section J1.4
integrated Storm Water Controls

J1.4.1 Introduction

The impacts of storm water runoff resulting from development cannot always be completely mitigated by land use and nonstructural approaches. Therefore, the use of appropriate structural storm water controls is sometimes necessary as an integrated part of the storm water management system. Storm water controls (sometimes referred to as best management practices or BMPs) are constructed storm water management facilities designed to treat storm water runoff and/or mitigate the effects of increased storm water runoff peak rate, volume, and velocity due to urbanization.

Chapter 5 recommends a number of structural storm water controls that can be used for meeting the TriSWM Planning and Design Approach including very specific performance and design criteria. The next several pages provide a brief overview of the range of storm water controls recommended for use in North Central Texas communities.

J1.4.2 Recommended Storm Water Control Practices for North Central Texas

Bioretention Areas

- Bioretention areas are shallow storm water basins or landscaped areas that utilize engineered soils and vegetation to capture and treat storm water runoff. Runoff may be returned to the conveyance system, or allowed to fully or partially infiltrate into the soil.

Channels

- Enhanced Swale: A vegetated open channel that is explicitly designed and constructed to capture and treat storm water runoff within wet or dry cells formed by check dams or other means.
- Grass Channel: A vegetated open channel designed to filter storm water runoff and meet velocity targets for the water quality and streambank protection design storm events.
- Open Conveyance Channel: Includes such conveyance systems as drainage ditches, grass channels, dry and wet enhanced swales, riprap channels, and concrete channels.

Chemical Treatment

- Alum Treatment System: This chemical treatment provides for the injection of liquid alum into storm water runoff on a flow-weighted basis during rain events as it enters a settling basin. The alum precipitate or ‘floc’ that is formed during coagulation combines with nutrients, suspended solids, and heavy metals and settles in the settling basin.

Conveyance Components

- Culverts: Typically, short, closed (covered) conduits that convey storm water runoff under an embankment, usually a roadway. The primary purpose of a culvert is to convey surface water, but it may also be used to restrict flow and reduce downstream peak flows.

- Energy Dissipaters: Energy dissipaters are engineered devices such as riprap or concrete baffles placed at the outlet of a storm water conveyance for the purpose of reducing the velocity, energy, and turbulence of the discharged flow.
- Inlets/Street Gutters: Drainage elements that remove runoff from sidewalks, streets, and sumps for public safety purposes and function to input storm water to the storm drain pipe systems.
- Pipe Systems: A branching system of closed conduits that accumulate storm water runoff and convey it to an open channel, natural stream, or storage facility.

Detention

- Dry Detention: Dry detention basins are surface storage basins or facilities typically designed to provide water quantity control through detention or extended detention of storm water runoff.
- Extended Dry Detention Basins: Extended dry detention basins are surface storage basins or facilities that can be designed to provide water quality and quantity control through extended detention of storm water runoff.
- Multi-Purpose Detention Areas: Multi-purpose detention areas are facilities designed primarily for another purpose, such as parking lots and rooftops, that can provide water quantity control through detention of storm water runoff.
- Underground Detention: Underground detention storage is provided by underground tanks or vaults designed to provide water quantity control through detention and/or extended detention of storm water runoff.

Filtration

- Filter Strip: Filter strips are uniformly graded and densely vegetated sections of land engineered and designed to treat runoff and remove pollutants through vegetative filtering and infiltration.
- Organic Filter: Organic filters are design variant of the surface sand filter using organic materials such as peat or compost in the filter media.
- Sand Filter: Sand filters are multi-chamber structures designed to treat storm water runoff through filtration, using a sand bed as the primary filter media. Filtered runoff may be returned to the conveyance system, or allowed to fully or partially infiltrate into the soil.
- Underground Sand Filter: The underground sand filter is a design variant of the surface sand filter located in an underground vault designed for high density land use where there is not enough space for a surface sand filter or other storm water controls.

Hydrodynamic Devices

- Gravity (Oil-Grit) Separator: The gravity (oil-grit) separator is a hydrodynamic separation device designed to remove settleable solids, oil, grease, debris, and floatables from storm water runoff through gravitational settling and trapping of pollutants.

Infiltration

- Infiltration Trench: Infiltration trenches are excavated trenches filled with stone aggregate used to capture and allow infiltration of storm water runoff into the surrounding soils from the bottom and sides of the trench.

Ponds

There are two storm water storage functions: detention and retention. Detention ponds are designed to store water and release it over time to empty the basin. Retention basins have a permanent pool (or micropool) of water. Some basins are designed to include both detention and retention. Runoff from each rain event is detained and treated in the pool. Pond design variants include:

- Micropool Extended Detention Pond
- Multiple Pond Systems
- Wet Extended Detention Pond
- Wet Pond

Porous Surfaces

- *Modular Porous Paver Systems:* Modular porous paver systems are pavement surfaces composed of structural units with void areas that are filled with pervious materials such as sand or grass turf. Porous pavers are installed over a gravel base course to provide storage as runoff infiltrates through the porous paver system into underlying permeable soils.
- *Porous Concrete:* Porous concrete is the term for a mixture of coarse aggregate, Portland cement, and water that allows for rapid infiltration of water and overlays a stone aggregate reservoir. The reservoir provides temporary storage as runoff infiltrates into underlying permeable soils and/or out through an underdrain system.

Proprietary Structural Controls

There are numerous manufactured structural control systems available from commercial vendors designed to treat storm water runoff and/or provide water quantity control.

Wetlands

- *Storm Water Wetlands:* Storm water wetlands are constructed wetland systems used for storm water management. Storm water wetlands consist of a combination of shallow marsh areas, open water areas, and semi-wet areas above the permanent water surface. Wetland design variants include:
  - Extended Detention Shallow Wetland
  - Pocket Wetland
  - Pond/Wetland Systems
  - Shallow Wetland
- *Submerged Gravel Wetlands:* Submerged gravel wetlands are also known as subsurface flow wetlands and consist of one or more cells filled with crushed rock designed to support wetland plants. Storm water runoff flows subsurface through the root zone of the constructed wetland where pollutant removal takes place.

Note: Consideration must be given in the design of storm water ponds, wetlands, and detention basins to minimize potential mosquito breeding areas. This can be accomplished in a variety of ways including aquatic and chemical techniques that should be utilized as appropriate for the situation.

J1.4.3 Suitability of Storm Water Controls to Meet Storm Water Management Goals

Table J1.4.3-1 summarizes the storm water management suitability of the various storm water controls in addressing the TriSWM Planning and Design Approach. Given that some storm water controls cannot alone meet all of the design requirements, typically two or more controls are used in series to form what is known as a storm water "treatment train." Chapter 5 provides guidance on the use of a treatment train as well as how to calculate the pollutant removal efficiency for storm water controls in series. Chapter 5 also provides guidance for choosing the appropriate storm water control(s) for a site as well as the basic considerations and limitations on the use of a particular storm water control. Note that Chapter 5 includes additional storm water controls for parcel-based development that are not included in the following table since they are not typically appropriate for linear projects such as streets and highways.

Table J1.4.3-1 Suitability of Storm Water Controls to Meet TriSWM Planning and Design Approach

Category	Storm Water Controls	Water Quality Protection#	Streambank Protection	On-Site Flood Control	Downstream Flood Control
Bioretention Areas	Bioretention Areas	Level II	S	S	-
Channels	Enhanced Swales	Level II	S	S	S
	Channels, Grass	Level I	S	P	S
	Channels, Open	-	-	P	S
Chemical Treatment	Alum Treatment System	Level III	-	-	-
Conveyance Components	Culverts	-	-	P	P
	Energy Dissipation	-	P	S	S
	Inlets/Street Gutters	-	-	P	-
	Pipe Systems	-	P	P	P
Detention	Detention, Dry	Level II	P	P	P
	Detention, Extended Dry	Level II	P	P	P
	Detention, Multi-purpose Areas	-	P	P	P
	Detention, Underground	-	P	P	P
Filtration	Filter Strips	Level I	-	-	-
	Organic Filters	Level III	-	-	-
	Sand Filters, Surface/Perimeter	Level III	S	-	-
	Sand Filters, Underground	Level III	-	-	-
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	Level I	-	-	-
Infiltration	Infiltration Trenches	Level III	S	-	-
Ponds	Ponds, Storm Water	Level III	P	P	P
Porous Surfaces	Modular Porous Paver Systems	Level I	S	-	-
	Porous Concrete	Level I	S	-	-
Proprietary Systems	Proprietary Systems*	Level I	S	S	S
Wetlands	Wetlands, Storm Water	Level III	P	P	P
	Wetlands, Submerged Gravel	Level III	P	S	-

P = **Primary Control:** Able to meet design criterion if properly designed, constructed, and maintained.

S = **Secondary Control:** May partially meet design criteria. May be a Primary Control but designated as a Secondary due to other considerations.

= Applicability of controls to meet Water Quality Treatment Level Criteria (see Section J1.2.3.1).

- = Not typically used or able to meet design criterion.

***** = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data.

Section J5.1
Storm Water Controls Overview

J5.1.1 Storm Water Controls - Categories and Applicability

J5.1.1.1 Introduction

Structural storm water controls are engineered facilities intended to treat storm water runoff and/or mitigate the effects of increased storm water runoff peak rate, volume, and velocity due to urbanization. This section provides an overview of structural storm water controls that can be used to address the minimum storm water management standards outlined in Section J1.2.

In terms of the TriSWM Planning and Design Approach, a structural storm water control, or set of structural controls, must:

- **Water Quality:** Remove pollutants in storm water runoff to protect water quality in accordance with the required Treatment Level classification ;
- **Streambank Protection:** Regulate discharge from the site to minimize downstream bank and channel erosion; and
- **Flood Control:** Control conveyance of runoff within and from the site to minimize flood risk to people and properties.

J5.1.1.2 Control Categories

The storm water control practices recommended in this Manual vary in their applicability and ability to meet storm water management goals.

Water Quality Protection
Storm Water Controls are classified as Level I, Level II, or Level III depending on the ability of the control to achieve the desired reduction in pollutants. When designed to treat the required Water Quality Volume (WQ_v) and constructed and maintained in accordance with recommended specifications, the desired level of protection is presumed to be provided to the receiving waters.

Streambank Protection and Flood Control

Storm Water Controls designated as "Primary" controls have the ability to fully address one or more of the Steps in the TriSWM Planning and Design Approach if designed appropriately. Several of these structural controls can be designed to provide primary control for downstream streambank protection (SP_v) and flood control (Q_f). These structural controls are recommended storm water management facilities for a site wherever feasible and practical.

Storm Water Controls designated as "Secondary" controls are recommended only for limited use or for special site or design conditions. Generally, these practices either: (1) do not have the ability on their own to fully address one or more of the Steps in the TriSWM Planning and Design Approach, (2) are intended to address hotspot or specific land use constraints or conditions, and/or (3) may have high or special maintenance requirements that may preclude their use.

Table J5.1.1-1 lists the structural storm water control practices. These structural controls are recommended for use in a wide variety of applications. A detailed discussion of each of the controls, as well as design criteria and procedures can be found in Section 5.2.

Table J5.1.1-1 Structural Controls

Structural Control	**Description**
Bioretention Areas	*Bioretention areas* are shallow storm water basins or landscaped areas which utilize engineered soils and vegetation to capture and treat storm water runoff. Runoff may be returned to the conveyance system, or allowed to partially exfiltrate into the soil.
Channels • Enhanced Swale (Dry, Wet, or Wetland) • Grass Channel (biofilter)	• *Enhanced swales* are vegetated open channels that are explicitly designed and constructed to capture and treat storm water runoff within dry or wet cells formed by check dams or other means • *Grass channels* provide "biofiltering" of storm water runoff as it flows across the grass surface.
Chemical Treatment • Alum Treatment	• *Alum treatment* provides for the removal of suspended solids from storm water runoff entering a wet pond by injecting liquid alum into storm sewer lines on a flow-weighted basis during rain events. Alum treatment should only be considered for large-scale projects where high water quality is desired.
Conveyance Components • Culvert • Inlet • Pipe Systems • Energy Dissipators • Open Conveyance Channel	• *A culvert is a short, closed (covered) conduit that conveys storm water runoff under an embankment, usually a roadway.* • *Inlets are drainage structures used to collect surface water through grate or curb openings and convey it to storm drains or direct outlet to culverts.* • *Pipe systems are used for transporting runoff from roadway and other inlets to outfalls at structural storm water controls and receiving waters.* • *Culverts, inlets, and pipe systems alone do not provide water quality treatment.*
Detention • Dry Detention / Dry Extended Detention Basins • Multi-Purpose Detention Areas • Underground Detention	• *Dry detention basins and dry extended detention (ED) basins* are surface facilities intended to provide for the temporary storage of storm water runoff to reduce downstream water quantity impacts. • *Multi-purpose detention areas* are site areas used for one or more specific activities, such as parking lots and rooftops, which are also designed for the temporary storage of runoff. • *Underground detention tanks and vaults* are an alternative to surface dry detention for space-limited areas where there is not adequate land for a dry detention basin or multi-purpose detention area.

Table J5.1.1-1 Structural Controls	
Structural Control	**Description**
Filtration • Filter Strip • Organic Filter • Surface Sand Filter/ Perimeter Sand Filter • Underground Sand Filter	• *Filter strips* provide "biofiltering" of storm water runoff as it flows across the grass surface. • *Organic filters* are surface sand filters where organic materials such as a leaf compost or peat/sand mixture are used as the filter media. These media may be able to provide enhanced removal of some contaminants, such as heavy metals. Given their potentially high maintenance requirements, they should only be used in environments that warrant their use. • *Sand filters* are multi-chamber structures designed to treat storm water runoff through filtration, using a sand bed as its primary filter media. Filtered runoff may be returned to the conveyance system, or allowed to partially exfiltrate into the soil. • *Underground sand filters* are sand filter systems located in an underground vault. These systems should only be considered for extremely high density or space-limited sites.
Hydrodynamic Devices • Gravity (Oil-Grit) Separator	• Hydrodynamic controls use the movement of storm water runoff through a specially designed structure to remove target pollutants. They are typically used on smaller impervious commercial sites and urban hotspots.
Infiltration • Infiltration Trench	• An *infiltration trench* is an excavated trench filled with stone aggregate used to capture and allow infiltration of storm water runoff into the surrounding soils from the bottom and sides of the trench.
Storm Water Ponds • Micropool Extended Detention Pond • Multiple Pond Systems • Wet Extended Detention Pond • Wet Pond	• Storm water ponds are constructed storm water retention basins that have a permanent pool (or micropool) of water. Runoff from each rain event is detained and treated in the pool.
Porous Surfaces • Modular Porous Paver Systems • Porous Concrete	• *Modular porous paver systems* consist of open void paver units laid on a gravel subgrade. Both porous concrete and porous paver systems provide water quality and quantity benefits, but have high workmanship and maintenance requirements, as well as high failure rates. • *Porous surfaces* are permeable pavement surfaces with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil. *Porous concrete* is the term for a mixture of course aggregate, Portland cement, and water that allows for rapid infiltration of water.

Table J5.1.1-1 Structural Controls	
Structural Control	**Description**
Proprietary Systems • Commercial Storm Water Controls	• Proprietary controls are manufactured structural control systems available from commercial vendors designed to treat storm water runoff and/or provide water quantity control. Proprietary systems often can be used on small sites and in space-limited areas, as well as in pretreatment applications. However, proprietary systems are often more costly than other alternatives, may have high maintenance requirements, and often lack adequate independent performance data.
Storm Water Wetlands • Extended Detention Shallow Wetland • Pocket Wetland • Pond/Wetland Systems • Shallow Wetland • Submerged Gravel Wetlands	• *Storm water wetlands* are constructed wetland systems used for storm water management. Storm water wetlands consist of a combination of shallow marsh areas, open water, and semi-wet areas above the permanent water surface. • *Submerged gravel wetland systems* use wetland plants in submerged gravel or crushed rock media to remove storm water pollutants. These systems should only be used in mid- to high-density environments where the use of other structural controls may be precluded. The long-term maintenance burden of these systems is uncertain.

J5.1.1.3 Using Other or New Structural Storm Water Controls

Innovative technologies should be allowed and encouraged providing there is sufficient documentation as to their effectiveness and reliability. Communities can allow controls not included in this Manual at their discretion, but should not do so without independently derived information concerning performance, maintenance, application requirements, and limitations.

More specifically, new structural storm water control designs will not be accepted for inclusion in the manual until independent performance data shows that the structural control conforms to local and/or State criteria for treatment, conveyance, maintenance, and environmental impact.

J5.1.2 Suitability of Storm Water Controls

Some structural storm water controls are intended to provide water quality treatment for storm water runoff. Though most of these structural controls provides pollutant removal capabilities, the relative capabilities vary between structural control practices and for different pollutant types.

J5.1.2.1 Water Quality

Pollutant removal capabilities for a given structural storm water control practice are based on a number of factors including the physical, chemical, and/or biological processes that take place in the structural control and the design and sizing of the facility. In addition, pollutant removal efficiencies for the same structural control type and facility design can vary widely depending on the tributary land use and area, incoming pollutant concentration, flow rate, volume, pollutant loads, rainfall pattern, time of year, maintenance frequency, and numerous other factors.

To assist the designer in evaluating the relative pollutant removal performance of the various structural control options, Table J5.1.2-1 provides design removal efficiencies for each of the control practices. It should be noted that these values are *conservative* average pollutant reduction percentages for design purposes derived from sampling data, modeling, and professional judgment. A structural control design may be capable of exceeding these performances, however the values in the table are minimum reasonable values that can be assumed to be achieved when the structural control is sized, designed, constructed, and maintained in accordance with recommended specifications in this Manual.

Where the pollutant removal capabilities of an individual structural storm water control are not deemed sufficient for a given site application, additional controls may be used in series in a "treatment train" approach. More detail on using structural storm water controls in series is provided in subsection 5.1.6.

For additional information and data on the range of pollutant removal capabilities for various structural storm water controls, the reader is referred to the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the International Storm Water Best Management Practices (BMP) Database at www.bmpdatabase.org

Table J5.1.2-1 Design Pollutant Removal Efficiencies for Storm Water Controls (Percentage)

Structural Control	Total Suspended Solids	Total Phosphorus	Total Nitrogen	Fecal Coliform	Metals
Bioretention Areas	80	60	50	---	80
Grass Channel	50	25	20	---	30
Enhanced Dry Swale	80	50	50	---	40
Enhanced Wet Swale	80	25	40	---	20
Alum Treatment	80	80	60	90	75

Table J5.1.2-1 Design Pollutant Removal Efficiencies for Storm Water Controls (Percentage)					
Structural Control	**Total Suspended Solids**	**Total Phosphorus**	**Total Nitrogen**	**Fecal Coliform**	**Metals**
Filter Strip	50	20	20	---	40
Dry Detention	65	50	30	70	---
Organic Filter	80	60	40	50	75
Sand Filters	80	50	25	40	50
Underground Sand Filter	80	50	25	40	50
Gravity (Oil-Grit) Separator	40	5	5	---	---
Infiltration Trench	80	60	60	90	90
Storm Water Ponds	80	50	30	70*	50
Modular Porous Paver Systems with infiltration	**	80	80	---	90
Porous Concrete with infiltration	**	50	65	---	60
Proprietary Systems	***	***	***	***	***
Storm Water Wetlands	80	40	30	70*	50
Submerged Gravel Wetland	80	50	20	70	50

* If no resident waterfowl population present

** Due to the potential for clogging, porous concrete and modular block paver systems should not be used for the removal of sediment or other coarse particulate pollutants

*** The performance of specific proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data

--- Insufficient data to provide design removal efficiency

J5.1.2.2 Streambank Protection

These controls have the ability to detain the volume and regulate the discharge of the 1-year, 24-hour storm event to protect natural waterways downstream of the development. Controls that provide streambank protection include detention, energy dissipation, storm water ponds, storm water wetlands, and pipe systems.

J5.1.2.3 Flood Control

- **On-Site:** These controls have the ability to safely convey storm water through a development to minimize the flood risk to persons and property on-site. On-site flood control structures include channels, culverts, detentions, enhanced swales, open conveyance channels, storm water ponds, conveyance components (inlets and pipe systems), and storm water wetlands.
- **Downstream:** These controls have the ability to detain the volume and regulate the discharge from the controlling storm event, as determined by downstream assessment, and to minimize flood risk to persons and property downstream of the development. Downstream flood controls include open channels, pipe systems, detention, storm water ponds, and storm water wetlands.

J5.1.3 Storm Water Control Selection

J5.1.3.1 Control Screening Process

Outlined below is a screening process for structural storm water controls which can effectively treat the water quality volume as well as provide water quantity control. This process is intended to assist the site designer and design engineer in the selection of the most appropriate structural controls for a development site, and provides guidance on factors to consider in their location.

In general the following four criteria should be evaluated in order to select the appropriate structural control(s) or group of controls for a development:

- Storm Water Treatment Suitability – Ability to meet TriSWM Planning and Design Approach criteria (Water Quality Protection, Streambank Protection, On-Site and Downstream Flood Control)
- Water Quality Performance – Provides additional infomation when pollutant reduction information is needed to address specific pollutant concerns (TSS, nutrients, bacteria)
- Site Applicability
- Implementation Considerations

In addition, for a given site, the following factors should be considered and any specific design criteria or restrictions need to be evaluated:

- Physiographic Factors
- Soils
- Special Watershed or Stream Considerations

Finally, environmental regulations should be considered as they may influence the location of a structural control on site, or may require a permit.

The following pages provide a selection process for comparing and evaluating various structural storm water controls using a screening matrix and a list of location and permitting factors. These tools are provided to assist the design engineer in selecting the subset of structural controls that will meet the storm water management and design objectives for a development site or project.

Step 1 Overall Applicability

Through the use of the first four screening categories in Table J5.1.3-1, Structural Control Screening Matrix, the site designer evaluates and screens the overall applicability of the full set of structural controls as well as the constraints of the site in question. The following are the details of the various screening categories and individual characteristics used to evaluate the structural controls.

<u>Storm Water Management Suitability</u>

The first category in the matrix examines the capability of each structural control option to provide water quality treatment, downstream streambank protection, and flood control. A blank entry means that the structural control cannot or is not typically used to meet that aspect of the TriSWM Planning and Design Approach. This does not necessarily mean that it should be eliminated from consideration, but rather is a reminder that more than one structural control may be needed at a site (e.g., a bioretention area used in conjunction with dry detention storage).

Ability to meet Water Quality Protection Criteria. This indicates the designated water quality protection level for the structural control.

Ability to provide Streambank Protection (SP_v). This indicates whether the structural control can be used to provide the extended detention of the streambank protection volume (SP_v). The presence of a “P” indicates that the structural control can be used to meet SP_v requirements. An “S” indicates that the structural control may be sized to provide streambank protection in certain situations, for instance on small sites.

Ability to provide Flood Control (Q_f). This indicates whether a structural control can be used to meet the flood control criteria. The presence of a “P” indicates that the structural control can be used to provide peak reduction of the 100-year storm event.

<u>Relative Water Quality Performance</u>

The second category of the matrix provides an overview of the pollutant removal performance of each structural control option, when designed, constructed, and maintained according to the criteria and specifications in this Manual. This information may be used to meet additional pollutant removal requirements should the receiving waters be particularly susceptible to or already contain high levels of particular pollutants.

TSS and Sediment Removal Rate. This column indicates the capability of a structural control to remove sediment in runoff.

Nutrient Removal Rate. This column indicates the capability of a structural control to remove the nutrients nitrogen and phosphorus in runoff, which may be of particular concern with certain downstream receiving waters.

Bacteria Removal Rate. This column indicates the capability of a structural control to remove bacteria in runoff. This capability may be of particular focus in areas with public beaches, shellfish beds, or to meet water regulatory quality criteria under the Total Maximum Daily Load (TMDL) program.

<u>Site Applicability</u>

The third category of the matrix provides an overview of the specific site conditions or criteria that must be met for a particular structural control to be suitable. In some cases, these values are recommended values or limits and can be exceeded or reduced with proper design or depending on specific circumstances. Please see the specific criteria section of the structural control for more details.

Drainage Area. This column indicates the approximate minimum or maximum drainage area considered suitable for the structural control practice. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway can be permitted if more than one practice can be installed. The minimum drainage areas indicated for ponds and wetlands should not be considered inflexible limits, and may be increased or decreased depending on water availability (baseflow or groundwater), the mechanisms employed to prevent outlet clogging, or design variations used to maintain a permanent pool (e.g., liners).

Space Required (Space Consumed). This comparative index expresses how much space a structural control typically consumes at a site in terms of the approximate area required as a percentage of the impervious area draining to the control.

Slope. This column evaluates the effect of slope on the structural control practice. Specifically, the slope restrictions refer to how flat the area where the facility is installed must be and/or how steep the contributing drainage area or flow length can be.

Minimum Head. This column provides an estimate of the minimum elevation difference needed at a site (from the inflow to the outflow) to allow for gravity operation within the structural control.

Water Table. This column indicates the minimum depth to the seasonally high water table from the bottom or floor of a structural control.

<u>Implementation Considerations</u>

The fourth category in the matrix provides additional considerations for the applicability of each structural control option.

Ultra-Urban. This column identifies those structural controls appropriate for use in very high-density (ultra-urban) areas, or areas where space is a premium.

Construction Cost. The structural controls are ranked according to their relative construction cost per impervious acre treated, as determined from cost surveys.

Maintenance. This column assesses the relative maintenance effort needed for a structural storm water control, in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging), and reported failure rates. It should be noted that **all structural controls** require routine inspection and maintenance.

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Table J5.1.3-1 Structural Control Screening Matrix

Category	On-Site Storm Water Controls	STORM WATER TREATMENT SUITABILITY				WATER QUALITY PERFORMANCE			SITE APPLICABILITY					IMPLEMENTATION CONSIDERATIONS		
		Water Quality Protection	Streambank Protection	On-Site Flood Control	Downstream Flood Control	TSS/ Sediment Removal Rate	Nutrient Removal Rate (TP/TN)	Bacteria Removal Rate	Drainage Area (acres)	Space Req'd (% of tributary imp. Area)	Site Slope	Minimum Head Required	Depth to Water Table	High Density/Ultra Urban	Capital Cost	Maintenance Burden
Bioretention Areas	Bioretention Areas	**Level II**	**S**	**S**	**-**	**80%**	**60%/50%**	**-**	5 max***	5-7%	6% max	5 ft	2 feet	✓	Moderate	Low
Channels	Enhanced Swales	**Level II**	**S**	**S**	**S**	**80%**	**25%/40%**	**-**	5 max	10-20%	4% max	1 ft	below WT		High	Low
	Channels, Grass	**Level I**	**S**	**P**	**S**	**50%**	**25%/20%**	**-**							Low	Moderate
	Channels, Open	**-**	**-**	**P**	**S**	**-**	**-**	**-**							Low	Low
Chemical Treatment	Alum Treatment System	**Level III**	**-**	**-**	**-**	**90%**	**80%/60%**	**90%**	25 min	None				✓	High	High
Conveyance Components	Culverts	**-**	**-**	**P**	**P**	**-**	**-**	**-**						✓	Low	Low
	Energy Dissipation	**-**	**P**	**S**	**S**	**-**	**-**	**-**						✓	Low	Low
	Inlets/Street Gutters	**-**	**-**	**P**	**-**	**-**	**-**	**-**						✓	Low	Low
	Pipe Systems	**-**	**P**	**P**	**P**	**-**	**-**	**-**						✓	Low	Low
Detention	Detention, Dry	**Level II**	**P**	**P**	**P**	**65%**	**50%/30%**	**70%**		2 - 3%	15% across pond	6 to 8 ft	2 feet		Low	Moderate to High
	Detention, Extended Dry	**Level II**	**P**	**P**	**P**	**65%**	**50%/30%**	**70%**		2 - 3%	15% across pond	6 to 8 ft	2 feet		Low	Moderate to High
	Detention, Multi-purpose Areas	**-**	**P**	**P**	**P**	**-**	**-**	**-**	200 max		1% for Parking Lot; 0.25 in/ft for Rooftop			✓	Low	Low
	Detention, Underground	**-**	**P**	**P**	**P**	**-**	**-**	**-**	200 max					✓	High	Moderate
Filtration	Filter Strips	**Level I**	**-**	**-**	**-**	**50%**	**20%/20%**	**-**	2 max***	20-25%	2-6%				Low	Moderate
	Organic Filters	**Level III**	**-**	**-**	**-**	**80%**	**60%/40%**	**50%**	10 max***	2-3%		5 to 8 ft		✓	High	High
	Sand Filters, Surface/ Perimeter	**Level III**	**S**	**-**	**-**	**80%**	**50%/25%**	**40%**	10 max***/ 2 max***	2-3%	6% max	5 ft/ 2 to 3 ft	2 feet	✓	High	High
	Sand Filters, Underground	**Level III**	**-**	**-**	**-**	**80%**	**50%/25%**	**40%**	5 max	None				✓	High	High
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	**Level I**	**-**	**-**	**-**	**40%**	**5%/5%**	**-**	1 max***	None				✓	High	High
Infiltration	Infiltration Trenches	**Level III**	**S**	**-**	**-**	**80%**	**60%/60%**	**90%**	5 max	2-3%	6% max	1 ft	4 feet	✓	High	High
Ponds	Wet Pond	**Level III**	**P**	**P**	**P**	**80%**	**50%/30%**	**70%**		2-3%	15% max	6 to 8 ft	2 feet, if hotspot or aquifer		Low	Low
	Wet ED Pond	**Level III**	**P**	**P**	**P**	**80%**	**50%/30%**	**70%**	25 min**						Low	Low
	Micropool ED Pond	**Level III**	**P**	**P**	**P**	**80%**	**50%/30%**	**70%**	10 min**						Low	Moderate
	Multiple ponds	**Level III**	**P**	**P**	**P**	**80%**	**50%/30%**	**70%**	25 min**						Low	Low
Porous Surfaces	Modular Porous Paver Systems	**Level I**	**S**	**-**	**-**	**	**80%/80%**	**-**	5 max	Varies				✓	Moderate	High
	Porous Concrete	**Level I**	**S**	**-**	**-**	**	**50%/65%**	**-**	5 max	Varies				✓	High	High
Proprietary Systems	Proprietary Systems ****	**Level I**	**S**	**S**	**S**	****	****	****	****	****				✓	High	High
Wetlands	Wetlands, Storm Water	**Level III**	**P**	**P**	**P**	**80%**	**40%/30%**	**70%**	25 min	3-5%	8% max	3 to 5 ft (shallow) 6 to 8 ft (pond)	2 feet, if hotspot or aquifer		Moderate	Moderate
	Wetlands, Submerged Gravel	**Level III**	**P**	**S**	**-**	**80%**	**50%/20%**	**70%**	5 min			2 to 3 ft	below WT	✓	Moderate	High

✓ **-** Meets suitability criteria

P - Primary Control, meets suitability criteria

S - Secondary Control, can be incorporated into the structural control in certain situations

** Smaller area acceptable with adequate water balance and anti-clogging device

*** Drainage area can be larger in some instances

**** The application and performance of specific commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data

1 Porous surfaces provide water quantity benefits by reducing the effective impervious area

2 Due to the potential for clogging, porous surfaces should not be used for the removal of sediment or other coarse particulate pollutants

Table J5.1.3-1 Structural Control Screening Matrix

Category	On-Site Storm Water Controls	PHYSIOGRAPHIC FACTORS			Soils	SPECIAL WATERSHED CONSIDERATIONS		
		Low Relief	High Relief	Karst		High Quality Stream	Aquifer Protection	Reservior Protection
Bioretention Areas	Bioretention Areas	Several design variations will likely be limited by low head		Use poly-liner or impermeable membrane to seal bottom	Clay or silty soils may require pretreatment	Evaluate for stream warming	Needs to be designed with no exfiltration (i.e. outflow to groundwater)	
Channels	Enhanced Swales	Generally feasible however slope <1% may lead to standing water in dry swales	Often infeasible if slopes are 4% or greater				Hotspot runoff must be adequately treated	Hotspot runoff must be adequately treated
	Channels, Grass							
	Channels, Open							
Chemical Treatment	Alum Treatment System							
Conveyance Components	Culverts							
	Energy Dissipation							
	Inlets/Street Gutters							
	Pipe Systems							
Detention	Detention, Dry		Embankment heights restricted	Require poly or clay liner, Max ponding depth, Geotechnical tests	Underlying soils of hydrologic group "C" or "D" should be adequate to maintain a permanent pool. Most group "A" soils and some group "B" soils will require a pond liner.			
	Detention, Extended Dry							
	Detention, Multi-purpose Areas							
	Detention, Underground			GENERALLY NOT ALLOWED				
Filtration	Filter Strips							
	Organic Filters							
	Sand Filters, Surface/ Perimeter	Several design variations will likely be limited by low head		Use poly-liner or impermeable membrane to seal bottom	Clay or silty soils may require pretreatment	Evaluate for stream warming	Needs to be designed with no exfiltration (i.e. outflow to groundwater)	
	Sand Filters, Underground							
Hydrodynamic Devices	Gravity (Oil-Grit) Separator							
Infiltration	Infiltration Trenches	Minimum distance to water table of 2 feet	Maximum slope of 6% Trenches must have flat bottom	GENERALLY NOT ALLOWED	Infiltration rate > 0.5 inch/hr		Maintain safe distance from wells and water table. No hotspot runoff	Maintain safe distance from bedrock and water table. Pretreat runoff
Ponds	Wet Pond	Limit maximum normal pool depth to about 4 feet (dugout) Providing pond drain can be problematic	Embankment heights restricted	Require poly or clay liner Max ponding depth Geotechnical tests	"A" soils may require pond liner "B" soils may require infiltration testing	Evaluate for stream warming	May require liner if "A" soils are present Pretreat hotspots 2 to 4 ft separation distance from water table	
	Wet ED Pond							
	Micropool ED Pond							
	Multiple ponds							
Porous Surfaces	Paver Systems							
	Porous Concrete							
Proprietary Systems	Proprietary Systems ****							
Wetlands	Wetlands, Storm Water		Embankment heights restricted	Require poly-liner Geotechnical tests	"A" soils may require pond liner	Evaluate for stream warming	May require liner if "A" soils are present Pretreat hotspots 2 to 4 ft separation distance from water table	
	Wetlands, Submerged Gravel							

✓ **-** Meets suitability criteria

P - Primary Control, meets suitability criteria

S - Secondary Control, can be incorporated into the structural control in certain situations

****** Smaller area acceptable with adequate water balance and anti-clogging device

******* Drainage area can be larger in some instances

******** The application and performance of specific commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data

1 Porous surfaces provide water quantity benefits by reducing the effective impervious area

2 Due to the potential for clogging, porous surfaces should not be used for the removal of sediment or other coarse particulate pollutants

Step 2 Specific Criteria

The last three categories in the Structural Control Screening Matrix provides an overview of various specific design criteria and specifications, or exclusions for a structural control that may be present due to a site's general physiographic character, soils, or location in a watershed with special water resources considerations.

Physiographic Factors

Three key factors to consider are low-relief, high-relief, and karst terrain. In the North Central Texas, low relief (very flat) areas are primarily located east of the Dallas metropolitan area. High relief (steep and hilly) areas are primarily located west of the Fort Worth metropolitan area. Karst and major carbonaceous rock areas are limited to portions of Palo Pinto, Erath, Hood, Johnson, and Somerveil counties. Special geotechnical testing requirements may be needed in karst areas. The local reviewing authority should be consulted to determine if a project is subject to terrain constraints.

- Low relief areas need special consideration because many structural controls require a hydraulic head to move storm water runoff through the facility.
- High relief may limit the use of some structural controls that need flat or gently sloping areas to settle out sediment or to reduce velocities. In other cases, high relief may impact dam heights to the point that a structural control becomes infeasible.
- Karst terrain can limit the use of some structural controls as the infiltration of polluted waters directly into underground streams found in karst areas may be prohibited. In addition, ponding areas may not reliably hold water in karst areas.

Soils

The key evaluation factors are based on an initial investigation of the NRCS hydrologic soils groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors.

Special Watershed or Stream Considerations

The design of structural storm water controls is fundamentally influenced by the nature of the downstream water body that will be receiving the storm water discharge. In addition, the designer should consult with the appropriate review authority to determine if their development project is subject to additional structural control criteria as a result of an adopted local watershed plan or special provision.

In some cases, higher pollutant removal or environmental performance is needed to fully protect aquatic resources and/or human health and safety within a particular watershed or receiving water. Therefore, special design criteria for a particular structural control or the exclusion of one or more controls may need to be considered within these watersheds or areas. Examples of important watershed factors to consider include:

High Quality Streams (Streams with a watershed impervious cover less than approximately 15%). These streams may also possess high quality cool water or warm water aquatic resources or endangered species. The design objectives are to maintain habitat quality through the same techniques used for cold-water streams, with the exception that stream warming is not as severe of a design constraint. These streams may also be specially designated by local authorities.

Wellhead Protection. Areas that recharge existing public water supply wells present a unique management challenge. The key design constraint is to prevent possible groundwater contamination by preventing infiltration of hotspot runoff. At the same time, recharge of unpolluted storm water is encouraged to maintain flow in streams and wells during dry weather.

Reservoir or Drinking Water Protection. Watersheds that deliver surface runoff to a public water supply reservoir or impoundment are a special concern. Depending on the treatment available, it may be necessary to achieve a greater level of pollutant removal for the pollutants of concern, such as bacteria pathogens, nutrients, sediment, or metals. One particular management concern for reservoirs is ensuring storm water hotspots are adequately treated so they do not contaminate drinking water.

Step 3 Location and Permitting Considerations

In the last step, a site designer assesses the physical and environmental features at the site to determine the optimal location for the selected structural control or group of controls. The checklist below (Table J5.1.3-2) provides a condensed summary of current restrictions as they relate to common site features that may be regulated under local, state, or federal law. These restrictions fall into one of three general categories:

- Locating a structural control within an area when expressly prohibited by law.
- Locating a structural control within an area that is strongly discouraged, and is only allowed on a case by case basis. Local, state, and/or federal permits shall be obtained, and the applicant will need to supply additional documentation to justify locating the storm water control within the regulated area.
- Structural storm water controls must be setback a fixed distance from a site feature.

This checklist is only intended as a general guide to location and permitting requirements as they relate to siting of storm water structural controls. Consultation with the appropriate regulatory agency is the best strategy.

Table J5.1.3-2 Location and Permitting Checklist

Site Feature	Location and Permitting Guidance
Jurisdictional Wetland (Waters of the U.S) U.S. Army Corps of Engineers Regulattory Permit	• Jurisdictional wetlands should be delineated prior to siting structural control. • Use of natural wetlands for storm water quality treatment is contrary to the goals of the Clean Water Act and should be avoided. • Storm water should be treated prior to discharge into a natural wetland. • Structural controls may also be *restricted* in local buffer zones. Buffer zones may be utilized as a non-structural filter strip (i.e., accept sheet flow). • Should justify that no practical upland treatment alternatives exist. • Where practical, excess storm water flows should be conveyed away from jurisdictional wetlands.
Stream Channel (Waters of the U.S) U.S. Army Corps of Engineers Section 404 Permit	• All Waters of the U.S. (streams, ponds, lakes, etc.) should be delineated prior to design. • Use of any Waters of the U.S. for storm water quality treatment is contrary to the goals of the Clean Water Act and should be avoided. • Storm water should be treated prior to discharge into Waters of the U.S. • In-stream ponds for storm water quality treatment are highly discouraged. • Must justify that no practical upland treatment alternatives exist. • Temporary runoff storage preferred over permanent pools. • Implement measures that reduce downstream warming.

Table J5.1.3-2 Location and Permitting Checklist

Site Feature	Location and Permitting Guidance
Texas Commission on Environmental Quality Groundwater Management Areas	• Conserve, preserve, protect, recharge, and prevent waste of groundwater resources through Groundwater Conservation Districts • Groundwater Conservation District pending for Middle Trinity. • Detailed mapping available from Texas Alliance of Groundwater Districts.
Texas Commission on Environmental Quality Surface Water Quality Standards	• Specific stream and reservoir buffer requirements. • May be imperviousness limitations • May be specific structural control requirements. • TCEQ provides water quality certification – in conjunction with 404 permit • Mitigation will be required for imparts to existing aquatic and terrestrial habitat.
100 Year Floodplain Local Storm water review Authority	• Grading and fill for structural control construction is generally discouraged within the 100 year floodplain, as delineated by FEMA flood insurance rate maps, FEMA flood boundary and floodway maps, or more stringent local floodplain maps. • Floodplain fill cannot raise the floodplain water surface elevation by more than limits set by the appropriate jurisdiction.
Stream Buffer Check with appropriate review authority whether stream buffers are required	• Consult local authority for storm water policy. • Structural controls are discouraged in the streamside zone (within 25 feet or more of streambank, depending on the specific regulations).
Utilities Local Review Authority	• Call appropriate agency to locate existing utilities prior to design. • Note the location of proposed utilities to serve development. • Structural controls are discouraged within utility easements or rights of way for public or private utilities.
Roads TxDOT or DPW	• Consult TxDOT for any setback requirement from local roads. • Consult DOT for setbacks from State maintained roads. • Approval must also be obtained for any storm water discharges to a local or state-owned conveyance channel.
Structures Local Review Authority	• Consult local review authority for structural control setbacks from structures. • Recommended setbacks for each structural control group are provided in the performance criteria in this manual.
Septic Drain fields Local Health Authority	• Consult local health authority. • Recommended setback is a minimum of 50 feet from drain field edge or spray area.
Water Wells Local Health Authority	• 100-foot setback for storm water infiltration. • 50-foot setback for all other structural controls.

J5.1.3.2 Example Application

A 2-mile existing 2 lane roadway is being expanded to a 4 lane divided roadway with a 15 foot median in an urban area within the Dallas/Fort Worth metropolitan area. The roadway will exceed a traffic count of 30,000 vehicles per day. The impervious coverage of the approximate 20 acre site will be 80%. The site drains to two receiving waters, 75% to an urban river with two designated uses on the Texas Surface Water Quality Standards and 25% to an unclassified urban stream. There is a small city park adjacent to the roadway. Low permeability soils limit infiltration practices.

Table J5.1.3-3 lists the results of the selection analysis using the screening matrix described previously. The shaded rows indicate the controls that used alone or in combination may be considered for managing storm water quality and/or quantity for portions of the site. The **X**'s indicate inadequacies in the control and ✓'s indicate adequate control capabilities for the particular category when considered for this site.

The receiving waters must be evaluated to determine the level of treatment required. The 15 acre area that drains to the urban river will require Level I treatment, while the 5 acre area that drains to the urban stream will require Level II treatment. The level designations are based on the definitions of "Minimal" and "Moderate" receiving water classifications located in Section J1.2.3.1 and on Table J1.2.3-1.

There are no special watershed factors or physiographic factors to preclude the use of any of the practices from the structural control list. Other limiting factors of the site might include limited space within the right of way to include non-pipe storm water conveyance necessary for many Level I treatment options; limited space for detention facilities; downstream condition of the urban river and stream; offsite drainage; and large storm water volumes.

A traditional roadway cross section for the 15 acre roadway section will only require good housekeeping practices such as street sweeping, storm drain inlet cleaning, and proper application of landscape chemicals for Level I treatment as long as the downstream assessment does not show need for additional flood and streambank protection. In order to provide secondary flood control and/or streambank protection for the 15 acres draining to the urban river, a series of grass channels can be placed in the median with the roadway draining towards the median rather than the edges of the right of way. This series of grass channels can be connected to the overall storm drainage system flowing to the urban river. The downstream conveyance system may need to be improved if downstream assessment shows need for additional flood control and/or streambank protection.

Level II treatment for the 5 acre roadway section will require the use of bioretention facilities, an enhanced swale or a detention facility which would all connect to the storm drainage system draining to the urban stream. The additional width of the right of way beyond the roadway limits determines the placement of the bioretention facilities or enhanced swale. These can either be placed in the median or on the edges of the roadway in lieu of curb and gutter with the roadway draining to the location of the storm water facility. The dry/extended dry detention pond could be placed in the public park adjacent to the roadway and would be better suited to provide flood control and streambank protection if a downstream assessment shows that they are necessary.

Table J5.1.3-3 Sample Structural Control Selection Matrix

Structural Control Alternative	Treatment Level	Streambank Protection and Flood Control	Site Applicability	Implementation Considerations	Other Issues
Bioretention	Level II	✓[1]	✓[2]	✓	
Enhanced Swale	Level II	✓[1]	✓[2]	✓[3]	
Channels, Grass	Level I	✓[1]	✓[2]	✓[3]	
Dry Detention Pond	Level II	✓	✓	✓[3]	
Extended Dry Detention Pond	Level II	✓	✓	✓[3]	
Filter Strips	Level I	**X**	✓[2]	✓[3]	
Gravity (Oil-Grit) Separator	Level I	**X**	✓[2]	✓	Typically only for drainage areas less than 1 acre
Modular Porous Paver Systems	Level I	**X**	**X**	✓	Not used for travelled lane applications
Porous Concrete	Level I	**X**	**X**	✓	Typically used for low traffic applications
Proprietary Systems[4]	Level I	✓[1]	**UNK**	✓	High cost and maintenance requirements
Scheduled Pollution Prevention Practices	Level I	**X**	**NA**	✓	
Off-Site Pollution Prevention Activities	Level I	**UNK[5]**	**UNK[5]**	**UNK[5]**	

Notes:
1. Only when used with another structural control that provides onsite and downstream flood control
2. Can treat a portion of the site
3. Typically not used in high density / ultra urban settings; however conditions on this site are favorable for this control
4. The application and performance of specific commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data
5. Must be determined by the jurisdiction or agency on a case-by-case basis depending on the type of proposed off-site activity

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