The City of Calgary

Water Resources

Erosion and Sediment Control Guidelines

2022

Objectives

Successful erosion and sediment control (ESC) ultimately results from the combined efforts of all stakeholders partnering to develop site-specific design and innovation, combined with timely implementation, inspection, and maintenance of ESC measures.

The objectives of these guidelines are to provide an ESC framework that:

Meets an overall goal of reducing ESC impacts to infrastructure and the environment.

Achieves a high degree of compliance with ESC requirements as laid out in the *Standard Specifications – ESC.*

Fosters a greater understanding of ESC issues in Calgary.

Facilitates an efficient and effective submission process.

Supports The City's goal to meet our environmental regulatory requirements.

To meet these objectives, the Erosion and Sediment Control (ESC) Guidelines:

- Identify the people responsible for ensuring good ESC practices and their roles in the process.
- Highlight the most common ESC regulatory requirements applicable to construction projects or other soil-disturbing activities within Calgary.
- Describe the physical processes that influence erosion and the movement of eroded sediment that ESC designers and construction people need to know about.
- Describe the planning and design of ESC measures and submissions of ESC plans to The City of Calgary (The City).

These guidelines were prepared to help customers and stakeholders understand, evaluate, and implement effective ESC measures during construction.

Note: These ***Erosion and Sediment Control Guidelines*** are intended to provide an overview of erosion and sediment control and support the planning and design stages of projects in Calgary. For more information on the regulations for ESC in Calgary, refer to the *Standard Specifications – ESC*.

For information on how to submit an ESC Application, follow the *ESC Plan Application Instruction Manual* which requires alignment with the *Standard Specifications – Erosion and Sediment Control*. Both documents are available on the stormwater pollution prevention web page at calgary.ca/StmPP

EROSION AND SEDIMENT CONTROL CONTACT INFORMATION

CONTACTING THE CITY OF CALGARY:

General ESC questions: Call - 311 or email ESC@calgary.ca

Drainage Permits:

To obtain permission to dewater a site, contact 311 or visit calgary.ca/StmPP.

Information on Drainage Permits is available at calgary.ca/StmPP.

Key 311 phrases to ensure that you are promptly connected with ESC staff are:

Erosion and Sediment Control
Stormwater Pollution Prevention
Erosion and Sediment Control Inspection
Erosion and Sediment Control Approval
Drainage Permit
Drainage Permit Self-Assessment
Environmental Compliance Specialist, Stormwater Pollution Prevention

EMERGENCIES:

Immediate response required from Police, Fire and/or Emergency Medical Services: **9-1-1**

RELEASE REPORTING:

Reports of releases (including sediment) must be made to:

311 (The City of Calgary)
1-800-222-6514 (Alberta Environment and Parks) 24-hour release reporting line

Publication information

LEGAL DISCLAIMER

Construction activities, including the operations, maintenance, and repair of infrastructure and utilities, commonly disturb soil or sediments and create the potential for erosion, sedimentation, and offsite releases of sediment and associated contaminants. The design, implementation, and management of stormwater and erosion and sediment control practices require detailed knowledge and practical expertise.

Guidance in this document is solely provided to assist users with basic information on requirements, processes, and practices. While believed to be accurate, content is provided strictly as is and without warranty of any kind.

The City of Calgary, its agents, and its consultants are not responsible for the accuracy of the contents, and do not accept any liability for the results of any action taken on the basis of the information provided in this document. In addition, information in this document must not be construed as legal advice.

TITLE:	Erosion and Sediment Control Guidelines
INTENT:	This document provides information on control of erosion and sediment during urban construction, and operations and maintenance activities that disturb soil or sediments.
PREPARED FOR:	The City of Calgary, Water Resources
VERSION:	2022 Edition
ADDITIONAL COPIES:	To download an electronic copy: calgary.ca/StmPP
INFORMATION:	Corporate Call Centre: 311 (within Calgary)

NOTE: Due to changing regulations and technology, The City of Calgary may periodically update this manual. Please ensure you have a current version by visiting our website at: calgary.ca/StmPP

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Commonly used acronyms and abbreviations

°C	degree Celsius
AEP	Alberta Environment and Parks
ASTM	ASTM International
CEPA	*Canadian Environmental Protection Act*
Can-CISEC	Canadian Certified Inspector of Sediment and Erosion Control
CPESC	Certified Professional in Erosion and Sediment Control
DFO	Department of Fisheries and Oceans - Canada
EI	Erosivity Index
EPEA	*Environmental Protection and Enhancement Act* (Alberta)
ESC	erosion and sediment control
ha	hectare
LID	low-impact development
m	metre
m/s	metre per second
MGA	Alberta *Municipal Government Act*
mm	millimetre
NPA	*Navigation Protection Act*
NPP	Navigation Protection Program
P.Ag.	Professional Agrologist
P.Eng.	Professional Engineer
P.L.Eng.	Professional Licensed Engineer
PAM	Polyacrylamides
RECP	Rolled erosion control product
RUSLE	Revised Universal Soil Loss Equation
RUSLEFAC	Revised Universal Soil Loss Equation for Application in Canada
t/ha/y	tonne per hectare per year
The City	The City of Calgary
U.S.	United States
USDA	U.S. Department of Agriculture

1.0 Introduction

1.1 Why control erosion and sediment?

Natural and geologically dynamic processes (including weathering, erosion, and plate tectonics) can occur at very slow rates and are a vital factor in maintaining environmental balance. Human activities, including the removal of vegetation and topsoil during construction, can expose highly erodible subsoil and can lead to accelerated rates of erosion and magnified volumes of sediment released from site. The removal of soil-stabilizing vegetation, and the exposure and compaction of fine-grained soils, can result in stormwater run-off and soil erosion rates that are orders of magnitude greater than natural rates. Disturbed sediment can be transported from sites into the surrounding storm infrastructure where they settle out, reducing the stormwater systems capacity to convey stormwater. Removal of this sediment is costly and time consuming. Sediments may also contain deleterious substances like silt, hydrocarbons, metals, and fertilizers which can adversely impact waterways. Half of the trace metals carried in run-off water are attached to sediment (Caltrans, 1996). These substances can negatively impact water quality and aquatic habitat, and by extension the quality of life in Calgary and the broader watershed.

The following common terms and definitions are used in this guideline:

City ESC Inspector refers to the Environmental Compliance Specialist, Stormwater Pollution Prevention who attend construction sites to assess compliance with Approved ESC Plans.

Erosion refers to the physical detachment, entrainment, and transportation of soil particles by erosive agents, usually wind and water.

Sediment refers to soil particles that have been detached and mobilized by soil erosion agents.

Sedimentation occurs when the energy of wind or moving water is less than the force of gravity on soil particles, resulting in their deposition.

Stormwater refers to rain or melt water.

Drainage refers to the flow of collected rain or melt water on a site.

Stormwater system/Stormwater infrastructure are used synonymously and refer to engineered conveyance systems for stormwater.

1.1.1 Source control philosophy

The management of eroded fine sediment can be very challenging, ineffective, and expensive, so ESC efforts must be primarily directed at reducing soil loss at the source.

Many subsoils in the Calgary area contain high proportions of fine silt and clay-sized particles, which can limit the effectiveness of filtration and settling practices proposed on construction sites.

Fine sediment may settle out in the stormwater system; damage public and private property; and negatively impact fish and fish habitat, water supply, flood control, navigation, and recreation.

Practices that focus on reducing soil loss through the control of run-on and run-off, and temporary and permanent stabilization of exposed soils, are collectively known as *source control practices.*

Controlling erosion at the source is the most effective and economical strategy in most situations. Well-planned and implemented source control practices are best when complemented with sediment control practices (ideally placed close to the source).

1.1.2 Erosion and sediment on construction sites

Construction site stormwater management, dust control, and erosion control are critical parts of any construction activity that disturbs soil. Operational activities like site dewatering are a potential source of sediment loading into the stormwater system. Dust caused by disturbance of exposed, dry subsoils by wind and equipment is also a significant problem in Calgary.

Even small construction sites and operations (such as underground utility repairs) need to implement practices to minimize or control mud tracking, wind-blown dust, and water-borne sediment transfer.

1.1.3 Erosion and sediment control design and planning objectives:

ESC designers on a construction site must consider the following objectives:

Limit soil loss for all exposed slopes below acceptable **tonnes per hectare per year** (t/ha/y) or less as outlined in Section 100.6 of the *Standard Specifications – ESC*.

Identify and recognize the high value of environmental resources, infrastructure, human health and safety, and property within, and adjacent to, construction sites. Protect them accordingly.

Assist stakeholders in gaining a good understanding of erosion and sedimentation processes.

Consider the importance of soil texture, site topography, and seasonal variations in climate.

Plan and implement practices to control erosion at the source (this requires control of run-on and run-off, and provision of timely and effective soil cover and stabilization).

Ensure plans are tailored to the unique requirements that will vary from site to site.

Clearly understand the purposes and limitations of specific ESC practices.

Include specifications and requirements for ESC in pre-tender documents and contracts. Use clear writing and plain language for ESC Plans so they will be easily understood by contractors.

Hold preconstruction meetings and invite the appropriate stakeholders, including regulatory agencies.

Recognize that the ESC Plan is a living document and may require amendments during the construction process.

1.2 Erosion and sediment control responsibilities

This section provides a brief outline of ESC stakeholder responsibilities.

The successful planning, implementation, inspection, and maintenance practices to control run-on, run-off, erosion, and sedimentation requires the cooperation of many project stakeholders (landowners, consultants, project managers, homebuilders, contractors and trades, regulators, and City of Calgary staff).

1.2.1 Parcel owner

During development, the property owner is responsible for ensuring:

- That an ESC Plan is created for the property.
- The approved ESC Plan for the property they own is being followed.
- Deficiencies noted during ESC Inspections are remedied.
- All legislation relevant to ESC is being adhered to.

- The timely removal and proper disposal of all temporary ESC measures when they are no longer required to ensure compliance with the approved ESC Plan.
- If they sell all or part of the land, that the land is stabilized against erosion in compliance with the *Standard Specifications – ESC* (Specifications) and the approved ESC Plan and the next owner(s) receive(s) a copy of the approved ESC Plan.

1.2.2 Developer

In the case of a subdivision development, the Developer, who is the interim guardian of the stormwater system until all Final Acceptance Certificates have been received, is responsible for ensuring:

- That homebuilders receive a copy of the approved ESC Plan.
- ESC inspections related to the development area covered in the ESC Plan are continued at the frequency outlined in Section 100.13 of the *Specifications* by a Qualified Inspector as outlined in Section 100.14 of the *Specifications*. This is to ensure properties in the development area, which may or may not be owned by others, do not cause adverse effects to the stormwater system or public property.
- That work in the development area adheres to the approved ESC Plan.

1.2.3 Homebuilder

A Homebuilder is responsible for following the ESC Plan tied to the property they purchased. This includes ensuring that lot-level good housekeeping practices are followed. These practices will include installation of:

- a construction entrance/exit control to prevent mud tracking;
- perimeter controls to manage run-on and run-off;
- controls to protect the stormwater system including but not limited to swales, catchbasins, and LIDs; and
- if stockpiles are present, stockpile controls.

1.2.4 Designer (ESC consultant)

The City requires that ESC Plans be prepared by a Qualified Designer. A Qualified Designer must hold a CPESC (Certified Professional in Erosion and Sediment Control), Alberta P.Eng. (Professional Engineer), Alberta P.L.Eng. (Professional Licensed Engineer; called a Limited Licence in other jurisdictions), or a P.Ag. (Professional Agrologist).

The ESC designer must develop ESC Plans that meet regulatory requirements and adhere to the *Specifications*, can be integrated with project scheduling, and can be clearly understood and implemented by staff on site.

During the development of the ESC Plan, the designer must visit the project site to conduct a thorough site evaluation and risk assessment and gather information that will be required for the creation of the ESC Plan.

The ESC designer must emphasize, to the owner and those who will be using the plan, that the ESC Plan is a legally binding document which is approved by The City prior to commencement of the project construction and will need to be frequently reviewed. The ESC Plan must be updated as necessary to accommodate potential changes throughout the construction stage of the project. Amendments to the approved ESC Plan must be submitted to The City for approval.

1.2.5 Responsible site contact (e.g. contractor, site superintendent)

The responsible site contact is either the property owner or the owner's primary representative on the site. This is the person whose job it is to ensure the ESC Plan is physically present on the site and that it is being properly implemented and inspected. This person is responsible for knowing and communicating what ESC drawing must be followed for each area with the relevant people at the site.

The responsible site contact must understand and follow the approved ESC Plan.

They must ensure the implementation of the practices prescribed in the ESC Plan (including amendments), and accommodate a defined inspection and maintenance program.

Where practices do not function as intended, the site contact must communicate observations to the person responsible for submitting ESC amendments.

When the site contact has concerns or wishes to propose alternate ESC measures, they must discuss them with the owner and ESC designer. The owner is responsible for ensuring the amendment process and requirements are met and that the City ESC Inspector has approved the amendment prior to implementation.

The site contact will also ensure temporary ESC practices are removed once the contributing area is stabilized.

1.2.6 Site ESC Inspector

To ensure compliance with the ESC Plan and identify concerns before they become a problem, an ESC inspector must evaluate the site on a regular basis.

Site ESC inspectors must meet the definition of a Qualified Inspector as defined in Section 100.14 of the *Specifications*. This is a person with the education and experience necessary to inspect a construction site to ensure the ESC measures prescribed in the ESC Plan are being employed and are effective. Designation as a Canadian Certified Inspector of Sediment and Erosion Control (Can-CISEC) is one method of attaining the qualifications of a Qualified Inspector.

Site ESC inspectors must clearly understand the ESC Plan; be able to recognize the effective application of controls and communicate concerns to the responsible site contact.

Site ESC inspectors must understand the need to document ESC practices (photos, inspection and maintenance records, and amendments to the ESC Plan), and follow documentation requirements.

The site ESC inspector may highlight deficiencies and indicate actions required which exist in the ESC Plan (e.g. clean out sediment from silt fence as per Section 200.2.6.4 Inspection and Maintenance of the *Specifications* which outlines maintenance requirements for silt fence, forms part of the ESC Plan) but they may not propose actions that do not reside in the approved ESC Plan (e.g. dig a new sediment pond where one is not shown on the drawing). Their role is to inspect, assess compliance with, and communicate deficiencies with the ESC Plan.

1.2.7 The City of Calgary

The City is responsible for the protection of the stormwater system from discharges that could impact the integrity of the system or the quality of stormwater.

ESC approvals

The City accepts, reviews, negotiates, and approves ESC Plans and ESC Plan amendments associated with Development Permits, Development Liaisons, Airport Developments, Development Agreements, Construction Drawings and City Projects where there is an earth moving component on a site and the site is equal to or greater than 0.4ha.

City ESC Inspections

The City ESC Inspectors conduct ESC inspections on sites to assess compliance with Approved ESC Plans.

The City ESC Inspector communicates inspection outcomes by emailing the owner and other relevant contacts identified at the inspection.

In the event of non-compliance with the approved ESC Plan, the City ESC Inspector will communicate the deficiencies noted and outline what actions must be taken for the site to resume compliance and by which date this must occur.

If compliance is not achieved, the City ESC Inspector will coordinate enforcement actions, including but not limited to:

- engaging Bylaw for enforcement responses under City of Calgary bylaws;
- engaging the Development Inspector to pursue non-compliance with land use permits and/or agreements; and/or
- arranging to have City crews or a third-party contractor complete the work needed to move a site into compliance. The cost for this would be recovered from the site owner.

City management and City ESC Inspectors are responsible for confirming inspections and enforcement are thorough and fair, and that any enforcement for non-compliance follows established compliance assurance principles.

2.0 Regulatory Requirements

Disclaimer: This section provides an overview of the common regulatory requirements that may apply to projects and activities that could result in erosion and sedimentation. This information is NOT offered, or intended to be used, as legal advice. Always obtain specific legal advice and contact all relevant regulatory agencies when planning a construction project.

2.1 Overview

This section provides a summary of some of the federal, provincial, and municipal statutes, regulations, codes of practice, and bylaws containing provisions addressing (or inferring the requirements for) the control and management of erosion, sedimentation, and water discharged from construction sites. Although requirements are outlined in the following subsections, the list is not intended to be all-encompassing.

2.2 Municipal legislation (The City of Calgary)

The Alberta *Municipal Government Act* (*MGA*) grants municipalities in Alberta the authority to create and enforce bylaws, and regulate private land use through planning and zoning. Under the act, Council has the power to regulate a system of licences, permits, or approvals, and has the right to control drainage to water bodies and watercourses in their jurisdiction.

The following City bylaws and standards are applicable to the design and implementation of ESC Plans and their impacts on the stormwater system, the wastewater systems, and stormwater management practices in Calgary. Copies of all City bylaws are available on calgary.ca).

2.2.1 Stormwater Bylaw

The *Stormwater Bylaw, 37M2005*, regulates stormwater within Calgary and contains provisions aimed at protecting stormwater systems, and private and public property from adverse effects.

- The City and site owners must verify that the stormwater system receives only water of the quality and quantity for which it was designed. By reviewing, approving, and inspecting ESC Plans, The City helps ensure that stormwater systems are protected from prohibited materials such as soil and sediment.
- Certain materials and contaminants defined under the bylaw are prohibited from entering the stormwater system. These materials and contaminants may be defined by their ability to obstruct the flow of water directly or indirectly within the stormwater system, or they may have an adverse effect on the stormwater system, stormwater quality, human health or safety, property, or the environment.
- The *Stormwater Bylaw* requires the responsible party to report and mitigate any unauthorized discharge of prohibited materials, whether accidental or intentional. Reporting of unauthorized discharges is mandatory.

Photo 1 Sediment laden water flowing off a construction site

Authorization requirements related to ESC under the *Stormwater Bylaw*

- An approved **ESC Plan** is legally required before commencing soil movement on any construction site equal to or greater than 0.4 hectare (ha).
    - The ESC Plan outlines the owner's commitment to reduce soil losses from their site that can cause an adverse effect on the stormwater system and the surrounding and receiving environment.
    - ESC Plans are often triggered under the *Land Use Bylaw*; however, they are always approved under the *Stormwater Bylaw*.

A **Stormwater Drainage Permit** is required before allowing any impounded water from a parcel of land to be directed into The City's stormwater system. This includes draining ponds on private land and draining excavations during construction.

- To obtain a Stormwater Drainage Permit phone 311 or visit calgary.ca/StmPP.
- Information on Drainage Permits is available at calgary.ca/StmPP.

2.2.1.1 Community Standards Bylaw

The *Community Standards Bylaw, 5M2004*, regulates neighbourhood nuisances, and safety and liability issues. This bylaw requires owners or occupiers of property to take precautions to prevent dust or other airborne matter from escaping the premises and ensures responsibilities around ponding water.

- Dust control measures must be implemented at all construction sites, regardless of size.
- It is important to keep in mind when planning and constructing sediment traps or ponds on construction sites (especially locations accessible to the public), that they are not considered nuisances or pose a danger to public safety.
- An owner or occupier of a property must not allow an excavation, drain, ditch, or other depression in the ground to become or remain a danger to public safety. A trap or pond may be declared a nuisance and the owner or occupier of the property will be required to eliminate the nuisance or danger.

Photo 2 Dust blowing into an intersection off a construction site with no control

2.2.1.2 Wastewater Bylaw

The *Wastewater Bylaw, 14M2012*, regulates the quality of wastewater discharge streams to protect Calgary's wastewater system and treatment plants. Designers of ESC Plans must not rely on discharging site storm and/or groundwater into the sanitary (wastewater) system but must dispose of it at an approved location with an approved permit.

- Discharge of stormwater or groundwater coming off a construction site cannot be directed into a wastewater (sanitary) system.

2.2.1.3 Streets Bylaw

The purpose of the *Streets Bylaw, 20M88*, is to control and regulate the use of streets; and to restrict and regulate activities on, adjacent, or near to streets. In ESC Plans this bylaw relates to soil stockpiling activities and sediment control (especially tracking mud onto City streets).

- Under the *Streets Bylaw*, no person will place, dispose, direct, or allow any material belonging to that person on a portion of a street unless authorized to do so by the Traffic Engineer pursuant to this bylaw or pursuant to the Calgary *Traffic Bylaw, 26M96*; or by any other bylaw.
    - Material includes sand, gravel, earth, refuse, and building products.
- Any person authorized under permit to develop private or public land adjacent to a street, or other person acting on their behalf, must not allow mud, dirt, or other construction debris to be tracked by motor vehicles from these lands onto a street.

Photo 3 Mud tracked onto roadway and over a catch basin

- **Note:** The *Streets Bylaw* definition of a street is broad, and it includes, to name a few, highways, roads, trails, lanes, alleys, sidewalks, and ditches which lie adjacent to or parallel with the roadway.

2.2.1.4 Riparian Strategy

The City's *Riparian Strategy* provides direction for the protection, restoration, and management of riparian areas in Calgary (The City, 2014). Five riparian management categories (Conservation, Restoration, Recreation, Flood and Erosion Control, and Developed) have been mapped along the riparian areas of major rivers and streams in Calgary.

The City encourages the use of bioengineering design that focus on reducing environmental impacts within these areas. Bioengineering designs incorporate both structural and vegetative practices which can enhance the aesthetics and habitat value of a project.

- Under The City's *Riparian Decision Matrix for River Engineering Projects* (The City, 2015), traditional (hard) engineering techniques (like riprap slope reinforcement) are prohibited or discouraged for bank stabilization projects located within Riparian Management Zones.

2.2.2 Duty to Report Releases

Provincial requirements associated with the *Release Reporting Regulation* under the Alberta *Environmental Protection and Enhancement Act* (*EPEA*) addresses the release of substances into the environment and sets requirements for reporting releases to Alberta Environment and Parks (AEP) and any other regulatory authority with jurisdiction.

In the *Release Reporting Regulation*, any release, including sediment, into any watercourse or surface water body requires immediate notification to AEP. After immediate reporting, submission of written reports are required within seven days.

The City of Calgary, as per the current *Stormwater Bylaw, 37M2005*, Release of Prohibited Substances, Section 5. (1), requires that any person who releases, or causes or allows to be released, any prohibited material into the stormwater system in contravention to the Bylaw must take all reasonable measures to immediately notify:

(a) the 9-1-1 emergency telephone number if there is any damage or immediate danger to:

(i) human health or safety;

(ii) property;

(iii) the environment; or

(iv) the stormwater system;

(b) The City, by calling the 24-hour 311 telephone number;

(c) the owner of the premises where the release occurred; and

(d) any other person that may be affected by the release.

Note: Releases must be reported **as soon as a person knows or ought to have known** of the release. A person "ought to have known" a release has occurred when, based on the information available, it is possible a release has occurred. That person will then confirm whether a release has occurred and report accordingly.

2.3 Provincial and Federal regulations

2.3.1 Provincial regulatory requirements

Current versions of all provincial acts, regulations, and codes of practice, including those listed in this section, are available online from the Alberta Queen's Printer (qp.alberta.ca).

2.3.1.1 Environmental Protection and Enhancement Act

The purpose of the *EPEA* is to support and promote the protection, enhancement, and wise use of the environment. Under the act, it is prohibited to knowingly release or permit the release of a substance into the environment in an amount, concentration, or level, or at a rate of release, that is in excess of an approval or a regulation, or causes or may cause an adverse effect. The act also creates a **duty to report** that includes all persons who release or cause a release of a substance into the environment that may cause, is causing, or has caused an adverse effect.

An employee of a local authority or other public authority who discovers, is informed of or who investigates a release of a substance into the environment must ensure AEP has been notified. If the employee is unable to confirm release reporting to AEP has occurred, they have a legal obligation under *EPEA* to report the release.

2.3.1.2 Wastewater and Storm Drainage Regulation

The *Wastewater and Storm Drainage Regulation* is also part of *EPEA* and sets out requirements for design and construction, substance release, extensions and replacement, and operations of municipal, industrial, and privately owned wastewater and stormwater systems.

This regulation prohibits the disposal of a substance into a wastewater or stormwater system that is in an amount, concentration, or level, or rate of release, that may impair the integrity of the wastewater or storm drainage collection system, impair the operation or performance of a storm drainage treatment facility or wastewater treatment plant, or impair the quality of storm drainage or treated wastewater and the gases and sludge produced in the treatment process.

2.3.1.3 Water Act

The Alberta *Water Act* focusses on managing and protecting Alberta's water, while streamlining administrative processes through various regulations, codes of practice, and guidelines. Under the act, AEP regulates work in and around water bodies, including lakes, rivers, streams, and wetlands. The *Water Act* prohibits the alteration of water flow, water level, and location of water for the purpose of removing an ice jam, or water drainage, flood control, erosion control, or channel realignment infrastructure. Approval under the act is required for activities related to placing, constructing, operating, maintaining, removing, or disturbing ground, vegetation, or other material in or on any land, water, or water body that may cause or may become capable of causing the siltation of water or the erosion of any bed or shore of a water body.

2.3.1.4 Water (Ministerial) Regulation

This regulation relates to site stormwater management. The *Water (Ministerial) Regulation,* lists activities that are exempt from the approval requirement. Included in this list is landscaping that is not in a watercourse, lake, or wetland if the landscaping does not result in an adverse effect on the aquatic environment on any parcel of land, or does not change the flow or volume of water on an adjacent parcel of land.

This regulation also outlines exemptions for the requirement of a license when dewatering construction sites.

2.3.1.5 Water Act Codes of Practice

Under the *Water Act* are several Codes of Practice, including the:

- *Code of Practice for Outfall Structures,*
- *Code of Practice for Watercourse Crossings*,
- *Code of Practice for Pipelines and Telecommunications Lines Crossing a Water Body*.

Measures to prevent or control erosion and sedimentation when undertaking these activities are included in the requirements found in these codes.

2.3.1.6 Public Lands Act

The Alberta *Public Lands Act* manages the access and work conducted on Alberta public lands through written authorizations or dispositions that specify requirements for activities. For work on public land, approval to undertake an activity in or near a water body or watercourse may be required.

The act prohibits any activities involving the accumulation of waste material, debris, refuse, or garbage on public land; injuriously affecting watershed capacity; disturbance that results or is likely to result in injury to the bed or shore of any river, stream, watercourse, lake, or other body of water or land; and the creation of any condition on public land that is likely to result in soil erosion.

2.3.1.7 Soil Conservation Act

The intent of the Alberta *Soil Conservation Act* is to protect soils for agricultural purposes. In some cases, uncontrolled erosion and sedimentation on construction projects within Calgary may lead to loss or deterioration of soil on adjacent agricultural land.

2.3.2 Federal Regulatory Requirements

Current versions of all federal legislation, including those listed in this section, are available online from Justice Canada (justice.gc.ca).

2.3.2.1 Fisheries Act

The *Fisheries Act* was established to manage and protect fish and fish habitat and is binding in all Canadian provinces and territories. The act is administered by Fisheries and Oceans Canada (DFO), although Environment Canada may also enforce sections of the *Fisheries Act*.

The *Fisheries Act* prohibits the deposition of deleterious substances into waters frequented by fish. Sediment is considered a deleterious substance; therefore, the erosion of exposed soils and offsite transport of sediment into natural water bodies can violate the pollution prevention provisions of this act.

2.3.2.2 Navigation Protection Act

The *Navigation Protection Act* (*NPA*) (formerly, the *Navigable Waters Protection Act*) is a federal law administered by Transport Canada that came into effect April 1, 2014. The *NPA* is designed to protect the public's right of navigation, and applies to works constructed or placed in, on, over, under, though, or across scheduled navigable waters. The Navigation Protection Program (*NPP*) ensures that works constructed in navigable waterways are reviewed and regulated to reduce the risks to navigation. The *NPP* administers and enforces the provisions of the *NPA*. This act applies to sediment and debris releases that may affect the navigability of a waterway

2.3.2.3 Canadian Environmental Protection Act

The *Canadian Environmental Protection Act*, *1999* (CEPA) is jointly administered by Environment Canada and Health Canada. Under the act, it is prohibited to release or permit the release of a toxic substance into the environment in an amount, concentration, or level that is in excess of an approval or a regulation that may cause significant adverse effects to the environment, and human life and health.

With respect to ESC, this act applies to the release of sediment-laden water, as well as dust from construction sites. The act includes requirements for reporting releases and the duty to take reasonable remedial measures.

3.0 Erosion and Sediment Control (ESC) Plans

3.1 Overview

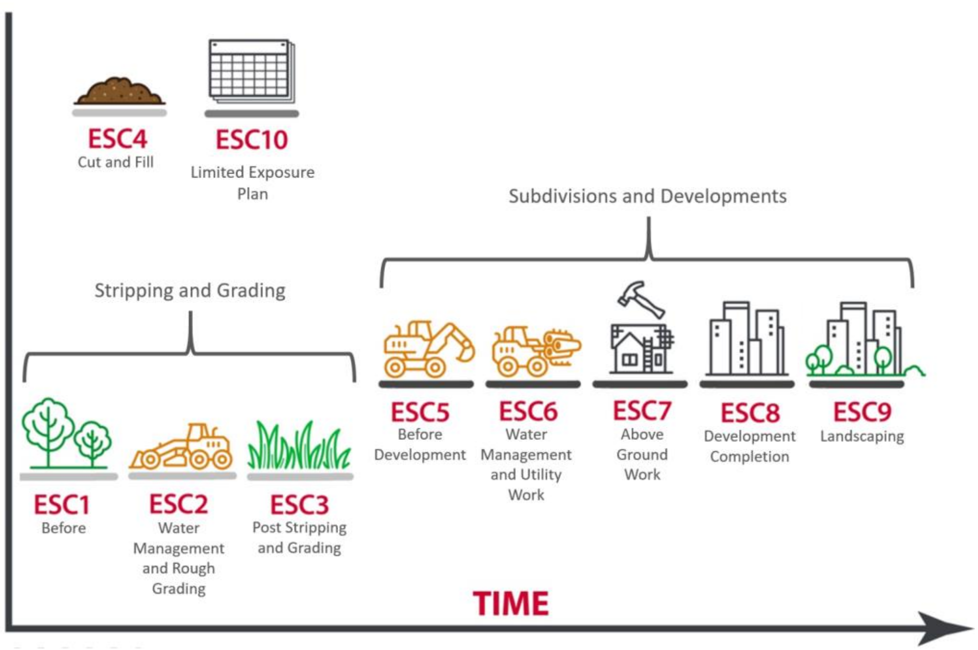
The owner is responsible for ensuring an ESC Plan is created, and if required, obtaining approval from The City under Section 16(1) of the *Stormwater Bylaw, 37M2005*. The ESC Plan must indicate what measures will be employed to prevent soil erosion and the release of a substance into the stormwater system or into the environment that may cause an adverse effect.

ESC Plans consist of:

- ESC Application;
- ESC Drawings;
- The City of Calgary's *Standard Specifications - Erosion and Sediment Control* [current edition]; and
- Supplementary Documents, as outlined in the *ESC Application* which may include but are not limited to sieve analysis, nomograph, site photos, and manufacturer's specifications.

The ESC Application, sample drawings, and Standard Specifications ESC can be found at calgary.ca/StmPP.

ESC Plans must identify the location, design, and timing of appropriate ESC practices throughout all stages of construction. Figure 3-1 shows the typical progression of development and ESC drawings required. Depending on the stages in your project, you will only be required to submit a selection of these drawing types along with your application. See Section 3.2 below for more details on submission requirements for specific project types. After initial approval, amendments to the plan may be required over the course of a development project where there is a change to the approved ESC Plan or ownership of the property.



FFigure 3 1 Erosion and sediment control drawings for stages of construction

3.1.1 New projects

While all soil disturbing projects need an ESC Plan and should follow good housekeeping requirements as outlined in the *Standard Specifications – ESC*, the need to have the ESC Plan reviewed and approved by The City is determined by the size of the proposed *soil disturbance area*.

Site less than 0.4ha:

- Project sites where soil is being disturbed and with a project site less than 0.4ha must create an ESC Plan that incorporates good housekeeping practices. These are outlined in Section 100.26 of the *Standard Specifications – ESC.*

Sites 0.4ha or greater with soil disturbance less than 0.4ha:

- Depending on conditions set out through the permitting process, project sites may not require submission of an ESC Plan if their soil disturbance area:
    a. is less than 0.4 ha;
    b. has low erosion potential; and is
    c. not in close proximity to critical areas

In these cases, an ESC Good Housekeeping letter will be issued **if** there is a prior to release conditions that needs to be lifted, or written documentation is required to support permission to construct undergrounds.

Sites equal to or greater than 0.4ha:

- Project sites with a soil disturbance area equal to or greater than 0.4 ha will require an ESC Plan be submitted for review and approval.
    a. The ESC Plan must consist of an application, drawings, *Specifications,* and supporting documents. These documents are meant to provide a *comprehensive* plan for ESC implementation, inspection, and maintenance practitioner(s) to follow during construction.

Sites greater than 10ha:

- Project sites with a total soil disturbance area greater than 10 ha require:
    - an ESC Plan; and
    - a Limited Exposure Plan (ESC10) which clearly shows how the soil disturbance area is to be limited to 10 ha at any one time during development of the site.

Sites greater than 65ha:

- Project sites with a total soil disturbance area of greater than 65 ha require:
    - an ESC Plan;
    - a Limited Exposure Plan (ESC10) which clearly shows how the soil disturbance area is to be limited to 10 ha at any one-time during development of the site; and
    - a Large Site Management Plan.

For detailed information on ESC Plans and for a complete and up-to-date list of ESC Plan requirements and templates, please visit calgary.ca/StmPP

> **Note:** ESC Plans must be easily understood by contractors. Drawings will clearly identify where, when, and how to implement controls and practices to manage water, erosion, and sedimentation. Effective planning and implementation require the cooperation of the engineering consultant, ESC designer, project manager, contractors, regulators, and other project stakeholders.

3.1.2 Amendments

Approved ESC Plans must be updated to account for any changes that may occur onsite that affect the staging of work, location, or type of practices that were originally approved.

- Sites must submit an amendment prior to making changes to a construction site in order to stay in compliance with their approved ESC Plan.
- The project owner or owner's designate is responsible for submitting amendment documentation to The City prior to implementing any proposed changes.

At a minimum, an amendment request must contain the:

a) Project name;

b) Project reference number (Development Permit, Development Agreement, Development Liaison, Airport Development or Construction Drawing number);

c) Municipal site address;

d) Notification that it is an amendment to a previous ESC approval;

e) A detailed description of what is being amended; and

f) Applicable amended drawing and details portions of the ESC Plan.

For detailed information and the most up-to-date ESC Plan amendment requirements and process, please visit calgary.ca/StmPP.

3.2 ESC Plan submission process

3.2.1 Overview

Site development within Calgary may take place under different authorizations (e.g. Development Permits, Development Agreements).

Conditions set out in the authorization will outline ESC requirements for the site. If it is determined that an ESC submission is required, one of the four different process categories outlined in this section must be followed for submitting your ESC application and drawing set to The City for review. Submission process categories are based on development types noted in the following subsections. Please refer to the detailed submission process and requirement charts located on calgary.ca/StmPP for up-to-date information.

3.2.2 Stripping and grading

Stripping and grading development involves removing existing vegetation (grubbing) and topsoil, followed by cutting, filling, and grading of subsoils to create an appropriate base for future development (e.g. utilities, roadways, and buildings).

Photo 4 Stripping and grading using earth movers

3.2.3 Subdivision

Subdivision development takes place after stripping and grading is complete and typically consists of final grading of land, delineation of individual building lots, installation of deep and shallow utilities and surface improvements (e.g. installation of sidewalks, curbs and gutters, homebuilding, and asphalt).

Offsite utility installation

Offsites utilities, often referred to as ‘offsites’, typically include deep sanitary, water and storm installation. This work typically occurs in parallel with subdivision works but may be submitted separately.

Row housing/bareland condos

Row housing developments are single-family attached units. These types of developments will have ESC drawings that are prepared and submitted during the larger subdivision approval process by the developer and are governed by the associated subdivision development agreement standard terms and conditions. Copies of the ESC Plan should be supplied by the developer to each individual builder who is working on the subdivision. If the builder wants to amend the original ESC plans for their specific lots, they will follow the existing ESC amendment process. For additional details on the ESC submission process, please refer to calgary.ca/StmPP for up-to-date information.

3.2.4 Multi-family/industrial/commercial/institutional

These types of developments take place after stripping and grading is completed, and lots have been delineated. They may also take place on land that was developed previously and is being redeveloped. These developments involve lot-level deep and shallow utility installation and building construction.

3.2.5 City capital projects

City capital projects involve any project that is funded by The City and managed by a business unit or civic partner. These projects can vary from roadway widening to redevelopment of a City park.

4.0 ESC Plan design considerations

4.1 Erosion and sediment control design

Appropriate and effective erosion and sediment control will vary according to:

- Project type (e.g. linear, industrial, or residential)
- Duration of construction (e.g. how long between stripping of topsoils and a permanent cover being established)
- Size of site (scale)

When developing ESC Plans, the Qualified Designer must carefully consider the project schedule in selecting, designing, and laying out ESC practices. This will require communication between all parties.

At a minimum, the following steps should be followed when creating ESC Plans and selecting ESC practices:

1. **Identify project scope and proposed activities:**

    Project description. Identify the work to be completed as part of the project and the extent of construction disturbance expected.

    Identify the area to be controlled. In addition to the construction site, identify adjacent areas that could be adversely impacted by construction activities (existing vegetation to be preserved, existing watercourses and/or wetlands and ponds, and residential areas), and plan to put adequate measures in place to protect these sensitive areas.

    Establish construction phasing (if needed). The construction stage of a project or development is usually considered a temporary condition, which is normally replaced by permanent structures and facilities. However, the construction work may take place over an extended period. Make sure management practices and controls are of sufficient size, strength, and durability to outlast the expected construction schedule until the site is permanently stabilized.

2. **Characterize existing site conditions:**

    Conduct a site visit. A trip to site is required to get the best understanding of site conditions and areas that will require ESC attention.

    Determine soil characteristics. Soil texture, soil structure, permeability, and chemistry can affect the performance of many erosion control practices. Site-specific soil characterization using sieve analysis and the development of K-values is a required component of any ESC Plan (see Appendix A for more information on K-value determination).

    Establish topographic contours. The selection and success of erosion control practices are dependent on slope length and gradient. The ease or difficulty of diverting clean run-off around the site is dependent on the terrain and drainage patterns. Therefore, a site topographic survey is essential to determine how water will run off.

    Identify and define drainage areas and patterns. (Based on preconstruction topography and construction design). Linear projects may have numerous drainage areas that must be addressed. Large, relatively flat grades may only generate sheet flow and will also be suitable areas for locating detention facilities. Steeper slopes may be prone to concentrated flows, especially at the toe of slopes.

Identify climate and season impacts. Using vegetation as an erosion control depends on local climatic conditions (because they affect, for example, seed mix selection and timing requirements). Soils that thaw in spring and have been left exposed prior to winter freeze-up are particularly susceptible to erosion; therefore, it is essential to implement erosion controls as part of pre-winter practices.

Consider accessibility. Some ESC practices require access for specialized equipment (e.g. hydroseeding).

Evaluate costs. Choose the most cost-effective practices that provide the necessary level of control for the required length of time. Controls and practices that can be implemented using equipment and personnel available on the construction site, such as sediment containment systems and surface roughening, are good examples of practical and cost-effective options.

3. **Select ESC practices, and consider the following for implementation:**

Divert clean run-on and run-off around the site and away from disturbed areas. It may be necessary to construct or install temporary diversion measures to divert water away from exposed slopes or to safely convey water down exposed slopes.

Determine temporary and permanent erosion control needs for all drainage channels and sensitive areas. Some erosion control practices are intended as permanent measures (e.g. rock or grass lining, turf reinforcement mats, and check dams); while others are temporary (e.g. mulch and tackifiers). Identify existing vegetation to be preserved, existing watercourses to be protected from sediment, and existing residential areas that require dust control.

Determine areas and stages suitable for erosion control using vegetative or non-vegetative measures, or a combination of measures. Until suitable vegetation cover can be established, it may be necessary to implement additional practices, such as mulch, tackifiers, and rolled erosion control products (RECPs). See *Standard Specifications - Erosion and Sediment Control* [current edition] for examples of common erosion controls.

Determine appropriate sediment control requirements for detaining and treating sediment-laden run-off. Large drainage areas can produce a significant amount of run-off, resulting in a need for large detention or retention structures. The size of structures required can be reduced by splitting up the large drainage areas or by phasing activities that cause soil disturbance.

Consult manufacturer specifications. When selecting some ESC practices, manufacturer's specifications provide valuable information on application, C-values, P-values, performance, installation, inspection, and maintenance.

4.2 Design considerations for small sites

4.2.1 Overview

This section is intended to assist small parcel owners, developers, and contractors in designing and planning ESC on small sites.

Small sites are defined as sites with an overall disturbed area less than 0.4 ha (1 acre), including single-family residential and duplex developments, commercial, industrial, and multi-family sites.

Note: Although small sites may not require a formal ESC Plan submission and approval through The City, an ESC Plan must still be created and available for construction contractors to reference on site. This plan must follow *Standard Specifications - Erosion and Sediment Control* [current edition]. Sections of note are Section 100.23 Development Responsibilities and Section 100.26 Good Housekeeping Practices.

Controlling dust and sediment and managing stormwater onsite are critical tasks on small sites. Uncontrolled construction activity can result in large quantities of sediment and other stormwater pollutants moving offsite and into the stormwater system and water bodies.

Every small site is unique and poses its own constraints and potential erosion risks. Even on small sites it is the responsibility of the site developers and contractors to comply with all federal, provincial, and municipal regulations.

Additional measures and/or regulatory permits may be required in some circumstances. Some examples include sites:

adjacent to, or within, 100 m upstream of a water body or other critical areas that are hard to rehabilitate;

containing steep slopes;

with highly erosive soils;

with little or no protection from wind;

receiving significant run-on from adjacent upstream areas.

ESC practices for small construction sites (including single-family lots) must be proposed and, where applicable, in place before contractors and homebuilders commence any grading activities, utility installation, or building construction, and the ESC practices must remain in place until the site is permanently stabilized.

4.2.2 Erosion and sediment control practices for small sites

The following four general categories are practices for controlling erosion and sediment during development and construction activities on small sites:

1. Site preparation
2. Stormwater management
3. Erosion control
4. Sediment control

4.2.2.1 Site preparation

Construction scheduling and staging: Construction must be scheduled to minimize the potential for erosion and offsite transport of sediment and other pollutants. Additional controls may be required during periods of high erosion potential (e.g. heavy rainfall events in summer and rapid snowmelt).

Perimeter protection: Perimeter ESC measures, as described in the ESC Plan, must be installed at this stage.

Existing vegetation or vegetative strip preservation: Preserving vegetation during site preparation, and correctly placing and protecting soil stockpiles are critical. Where possible, preserve a vegetative buffer strip around the perimeter of the construction site, as this will help reduce run-off velocity and trap sediment before run-off reaches perimeter controls.

Topsoil salvage and placement: Long-term stockpiles (in place for more than 30 days) must be covered or stabilized with mulch and tackifier, vegetative cover, or other suitable measures.

Topsoil is a living resource full of beneficial microorganisms, native seed bank, and organic material. In addition, topsoil slowly forms over thousands of years, including the development of micro- and macro-aggregates (structure). These topsoil structures (called peds) are vital to viable biological, chemical, and physical processes provided by topsoil (e.g., plant nutrient availability and uptake, plant establishment and drainage). Poor handling and stockpiling of topsoil typically result in a rapid decline of all these valuable properties, losing an important resource.

The ESC Plan must incorporate practices that maintain the integrity of topsoil. Examples include:

1) minimizing stockpile height and width,
2) minimizing stockpiling duration,
3) ensuring topsoil and subsoil are not mixed during stripping and handling,
4) topsoil sampling and testing prior to reclamation / revegetation work,
5) careful placement of topsoil to avoid excessive handling,
6) avoiding unnecessary compaction and undertaking de-compaction operations, and
7) when required, incorporating an aeration system.

- **Site access and egress:** Construction entrances and exits must be stabilized (e.g. with gravel pads, coarse woody slash, or plywood sheeting).

Note: Except in special cases approved by The City’s Roads business unit, storage of stockpiles on streets (including back lanes and sidewalks) is not permitted. This material may be eroded and washed into offsite areas and the stormwater system. Likewise, material must not be stockpiled such that it could leave a site and enter a City street (e.g. on driveways). Where possible, locate stockpiles on a pervious surface, away from driveways, sidewalks, or other drainage features. Where it is necessary to store piles of gravel or soil on streets, obtain a City Street Use Permit (contact 311).

4.2.2.2 Stormwater Management

Erosion caused by concentrated discharge of stormwater from downspouts onto exposed soils is a common problem on small sites, especially residential lots prior to landscaping. Options to manage this include installing dissipaters at downspouts to get water back to a sheet flow format or collecting water on site in sediment containment systems.

If water is impounded on site, a stormwater drainage permit must be obtained from The City prior to discharging any water to the stormwater system (including swales) or offsite.

4.2.2.3 Erosion Control

Small site construction projects in Calgary typically last from 12 to 18 months, with additional time required for permanent stabilization. During this time, it is critical that exposed soils be stabilized with an appropriate erosion control. Where feasible, permanent erosion control is recommended for areas that can be brought to grade relatively quickly.

4.2.2.4 Sediment Control

Sediment-laden run-off, dust, and sediment tracking must be contained onsite for all small sites. Use of adjacent streets for sediment trapping and deposition is not permitted.

The following should be considered for smaller sites:

Identify all perimeter areas and onsite stormwater inlets where sediment-laden run-off could leave the construction site.

Consider onsite perimeter controls (e.g. sediment, silt fence, or lot logs, such as compost socks or straw or fibre wattles) to minimize the potential for offsite sedimentation.

Perimeter controls must be in place before any other grading or soil-disturbing activities commence. Perimeter protection is also required around stockpiles in cases where material could migrate offsite.

For more information on suitable ESC practices see the *Standard Specifications - Erosion and Sediment Control* [current edition].

4.3 Erosion and sediment control design requirements and considerations for stormwater low-impact developments

4.3.1 Overview

Low-impact development (LID) ESC measures are part of the stormwater system and must be protected from sedimentation to function as designed.

If an existing LID is on the construction site, it must be identified as such on all drawings. The ESC Plan must outline how the LID will be protected for the duration of the project.

LID is a philosophy that focusses on maintaining the functional relationship between terrestrial and aquatic ecosystems. From a stormwater perspective, LID matches the post-development hydrological regime with the predevelopment regime in:

Discharge rate

Run-off volume

Water quality

LIDs work with natural systems to manage stormwater run-off by preserving and recreating natural landscape features, and by minimizing hard surfaces (like asphalt and concrete) to create functional and appealing site drainage (The City, 2016). Constructed systems, like cisterns and water reuse systems, are also forms of LIDs.

LID practices typically rely on filtering stormwater run-off through a soil and vegetation complex or storing run-off in a retention system to be used at a later date or be discharged slowly over time.

Options for LID facilities include a variety of landscaping and design practices that ultimately improve the quality and decrease the volume of stormwater entering waterways (Photo 1).

Examples of LIDs include:

Rain gardens – These small landscape depression features use a soil and vegetation complex to detain and filter run-off from an upstream catchment area. As run-off filters through the soil and vegetation complex, pollutants and contaminates are removed through biodegration, root absorption, and plant uptake. Rain gardens are more likely to be used in residential applications, such as a single-family lot.

Bioretention facilities – Similar to rain gardens, but these facilities are larger and typically service a larger catchment area. Bioretention facilities are more likely found in commercial and industrial sites and multi-family developments.

Green roofs – Also known as a living roof, the primary purpose of a green roof is to manage flow rates and discharge volumes at the source prior to discharging into the offsite drainage course. A green roof is a roof partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. It may also include additional layers, such as a root barrier, and drainage and irrigation systems.

Bioswales – These landscape elements are designed to remove silt and pollutants from surface run-off water. Bioswales are gently sloping drainage swales comprising a soil and vegetation complex that is used to infiltrate and treat run-off prior to discharging into the receiving drainage course.

Absorbent landscapes – These landscapes consist of typical landscape features that use a thicker, less-compacted layer of topsoil below to maximize the water-holding potential of the feature. Absorbent landscaping typically consists of flatter slopes that slow incoming run-off and allow it to infiltrate through the vegetation and soil complex.

Water recycling and reuse – This process involves retaining and storing excess run-off during a rainfall event, typically by using cisterns or underground storage tanks to store and retain peak stormwater flows and reusing the stored water at a later date for irrigation or other grey water uses.

Photo 5 Landscaping design and low-impact development

If proper ESC measures are not employed upstream of the LID, sediment-laden run-off can enter the LID, clogging the soil and vegetation complex, thereby reducing, or eliminating its filtration capacity. Sediment-laden run-off entering cisterns or storage tanks can cause operational problems by silting up mechanical equipment used to discharge run-off. For these reasons, it is imperative that that LID measures be protected until the upstream catchment area has been fully stabilized, or proper ESC measures have been installed.

Note: Whether an LID practice has been in place for years or is currently under construction, it is considered a critical area. Critical areas must be clearly identified in ESC documentation and applications, and the application must outline how the critical area will be protected for the duration of the project and until final stabilization.

4.3.2 LID construction planning

The primary consideration when planning LID construction planning is to ensure peak performance of the LID at the construction completion stage. The timing of installation for the LID relative to other activity is critical for long-term success. The first step is to identify the construction method that will be used, followed by selecting the most suitable ESC practices that align with the construction method.

4.3.2.1 Identify construction methods

LID construction methods are project stage specific. There may be more than one construction method for the same LID, based on the stage it is constructed within. Although one construction method may apply for all stages of construction, consider each stage separately when evaluating the following LID construction methods.

Photo 6 Installing low-impact developments last is the preferred construction method

1. **Construction phasing – install LID last**

The preferred method of establishing an LID is to construct it after the upstream catchment area has been fully stabilized (Photo 6).

2. **Isolation measures**

If upstream areas can’t be stabilized prior to installation of LIDs, the next preference is full isolation. To fully isolate LIDs that have been constructed, use temporary protection measures such as poly sheeting, and separation and diversion barriers, (Photo 7).

Use signage to alert those working on the site, as well as the public, to the importance of protecting the LID.

Photo 7 Isolation measures, poly sheeting

3. Sacrificial measures

If the LID can't be fully isolated from the construction site, use temporary sacrificial measures such as poly sheeting, sod, sand, or aggregate, with a separation barrier, such as a geotextile fabric (Photo 8).

4. Structurally designed protection

Structurally designed protections are temporary or permanent controls placed to either prevent the deposition of sediment into a source control practice or ensure deposited sediment is easily cleaned out. Though good ESC practices must still be followed onsite, there is an extra level of control that ensures the ESC practice is working the way it was designed. Good practices include:

Photo 8 Temporary sod cover

- Diversion of run-on around the LID(s)
- Adding barriers around the LID(s)
- Worker awareness of the importance of the LID(s) and frequent inspections to ensure ESC measures are working as planned.

4.3.2.2 Select erosion and sediment control practices for LID protection

Once the appropriate construction method has been selected for the proposed LID by construction stage, ESC practices required to adequately protect the proposed LID will be selected.

Any ESC practice can be used to protect or to work in conjunction with an LID facility. Selecting ESC practices for LIDs follows a similar approach to the steps defined in Section 5, and as LIDs are very sensitive to any sediment, the ESC practices selected must provide greater protection than 2 t/ha/yr.

Detailed information related to LID installation and protection must be clearly documented and included in the ESC Plan submitted to The City.

For more information on LIDs, refer to the *Standard Specifications - Erosion and Sediment Control* [current edition].

5.0 Site assessment and erosion potential evaluation

This section provides details on ESC processes and methods to assess the erosion potential of construction sites in Calgary.

5.1 Overview

There are several key reasons for reducing sediment loss from sites. These include:

stopping sediments from entering the stormwater system (where it is very costly to remove);

preventing eroded sediments from discharging into watercourses (and impacting fish and fish habitat and water quality in general);

preventing the loss of valuable organic soil materials (that provide mineral support, moisture, and rooting medium for plant growth);

maintaining regulatory compliance and protecting human health and safety.

Understanding the ESC processes and assessing erosion potential during the planning stage of a project is essential to determining the degree to which ESC practices will need to be integrated into development.

5.2 Erosion and sediment control processes

Erosion, sediment transport, and sedimentation can be characterized by the four processes of **detachment, entrainment, transport**, and **deposition/sedimentation**. The intensity and duration of each of these processes determine, to a large degree, the severity of erosion events. This section describes each of the four processes.

5.2.1 Detachment

Detachment refers to the breaking of bonds that hold a material together. Drag or tractive forces exerted by soil erosion agents are resisted by inertia or cohesive forces between soil particles. The forces are measured by velocity, discharge, soil particle shape, and roughness. Erosion is initiated by drag, impact (raindrop impact), or tractive forces acting on soil particles.

The texture, structure, and organic matter content of exposed soils affect detachment (erodibility) of soil particles. Soil can primarily be considered a mixture of different-sized inorganic materials formed from parent material and influenced by several physical, chemical, and biological variables over time.

Based on the U.S. Department of Agriculture (USDA) classification, mineral soils (inorganic materials) are classified based on particle size, as follows:

Gravels and cobbles (>2.0 mm in diameter)

Sand (0.05- to 2.0 mm diameter),

Silt (0.002- to 0.05 mm diameter),

Clay (less than 0.002 mm diameter).

The cohesion and texture of soils have a major influence on detachment. Clay-sized particles typically have a much higher resistance to detachment than larger soil particles like sand and coarse silt, generally due to greater cohesive forces at the molecular level. Other factors influencing soil cohesion are organic matter content (stabilized organic matter in the soil acts like glue to bind particles together, increasing cohesive strength) and soil moisture (moisture improves cohesion up to a point, then when the soil is saturated it decreases cohesion).

The majority of organic surface soils in the Calgary area are characterized as Black Chernozems (see Appendix A for more information), with textures typically ranging from silty clay loam to fine sandy loam. Much of the subsoil exposed during construction activities contains high proportions of fine silt and clay-sized material with minimal organic matter. These fine materials can limit the effectiveness of filtration and settling practices when trying to manage ESC issues.

Additional details about Calgary-specific soil characteristics and erodibility are provided in Appendix A.

The two basic detachment mechanisms in soil erosion are ***raindrop impact*** and ***abrasion***, which are described as follows:

- Raindrop impact: The force of falling raindrops (rainfall impact) is a function of raindrop mass and velocity. High-intensity rainfall events result in increased mass and velocity of raindrops impacting the ground and result in increasing particle displacement.
- Abrasion: Soil particles transported by water or wind can exert impact and friction on other soil particles, resulting in additional detachment by rubbing (abrading) against them.

> **Note:** Protecting exposed soil from raindrop impact by providing cover is the principal means of controlling erosion. Implementing erosion control measures and inspection prior to, during, and after high-intensity and long-duration rainfall events will effectively reduce the potential for erosion. For more information on implementation and inspection of erosion control measures reference *Standard Specifications - Erosion and Sediment Control* [current edition]

5.2.2 Entrainment

Entrainment refers to the picking up of particles detached by erosive agents, such as wind and water (Briggs et al., 1989). It generally takes much more energy to detach particles than to entrain them, so entrainment usually automatically follows detachment. Entrainment is caused by:

- Gravity: As a slope increases, an increasing proportion of the gravitational force operates down the slope, and detached particles begin to lose resistance to entrainment. Detached particles can be entrained by gravity as they are airborne or exposed to moving water.
- Fluid forces: Run-off and wind exert horizontal drag on particles. The density of the fluid is also critical in determining horizontal drag.

5.2.3 Transport

In addition to material that becomes dissolved in flowing water, detached soil particles that are entrained by air or water are transported in the following three ways:

- Suspension: Suspended particles move in the water or air column without touching the bottom. The smallest particles (clays and silts) are easily transported in suspension.
- Saltation: Larger, denser particles are somewhat resistant to entrainment and fall in and out of suspension. Falling particles can also dislodge other particles, setting them in motion.
- Traction: Detached particles that are partially entrained by flowing air or water are not suspended, but slowly move along at the surface. Particles transported by traction move much more slowly than flow velocity.

5.2.4 Deposition and sedimentation

Deposition and sedimentation occurs when there is insufficient energy to keep eroded particles entrained in air or water. This is typically caused by a . Large particles are very sensitive to changes in flow velocity. A very small reduction in flow velocity may be sufficient to change the entrainment and transport of large particles into deposition. (See Appendix A: Particulate sedimentation times, for a discussion on how particle size impacts the rate of deposition).

5.3 Run-off-induced erosion

Precipitation hitting the ground is either stored (for example, snow and ice), absorbed (if the ground is dry), or runs off (if the ground is saturated). Run-off over exposed soils occurs when the quantity of water reaching the soil surface is greater than the ability of the soil to store it.

The amount of water a soil can absorb is based on the type of soil, how much water it is already storing, the time it has to absorb the water, and whether the soil is frozen or not.

Rainfall-induced erosion occurs mainly when ambient temperatures are above 0 degrees Celsius (°C); therefore, these guidelines focus on rainfall precipitation. However, melting snowfall must also be managed on a construction site, especially in the early spring when large amounts of snow may be in place above frozen ground. Note that RUSLEFAC applies for unfrozen soil only and it remains the ESC designer's responsibility to also ensure the construction site is protected during the frequent freeze-thaw cycles likely to occur every winter.

The amount of run-off an area receives is governed by the following three factors:

1. Storm intensity: As storm intensity increases, the volume of water reaching the exposed soil may exceed the soil's ability to absorb water, resulting in surface ponding, run-off, or both.
2. Storm duration and pre-existing soil moisture conditions: Saturated soils recharge the groundwater system, but they do so at very slow rates. As the duration of a storm event lengthens, soils become increasingly saturated, increasing the potential for ponding, run-off, or both. If the soil is dry before the storm, it may be capable of absorbing large amounts of water. If, however, the soil recently experienced a weather event it may already be partially or completely saturated, so any further moisture may readily run off and carry soil with it.
3. Soil permeability and infiltration capacity: Fine-grained soils are generally more compact and have smaller pore spaces than coarse-grained soils, resulting in reduced permeability and water infiltration. Working a soil (e.g. scarifying or ripping) can increase permeability and infiltration. Compaction of soils by heavy construction equipment, on the other hand, decreases soil porosity, reduces infiltration, and can cause a marked increase in overland flow.

The first two factors are particularly variable across Calgary, with different parts of the city experiencing different storm intensities and durations.

5.3.1 Types of run-off Induced erosion

Erosion caused by run-off can be classified into four types:

1. Sheet erosion (Photo 9)**:** Diffuse sheets of water moving across a soil surface (run-off) can result in the entrainment and transport of soil particles detached by raindrop erosion, and to a lesser degree, cause additional detachment of soil particles.

Photo 9 Sheet erosion

2. Rill erosion (Photo 10): Rills are long, narrow depressions or soil incisions, 75 millimetres (mm) or less in depth. On hill slopes, run-off generally only occurs as sheet flow for a small distance before surface irregularities or turbulence cause run-off to concentrate. Water concentrates into the path of least physical resistance, resulting in micro-channels called rills. As the flow of run-off concentrates into channels, the friction between the flowing water and the soil surface is reduced and velocity increases. The resulting increase in flow velocities increases the erosion rate and the quantity of sediment transported. Road cuts and fills are particularly susceptible to rill erosion. Once the depth of a rill exceeds 75 mm, formation of gullies occurs (Fifield, 2005).

Photo 10 Rill erosion

3. Gully erosion (Photo11): Deep, large channels called gullies can develop as an extension of the process of rill development, resulting from further concentration of run-off over erodible soils and a dramatic increase in erosion rates. Gullies can be very costly and time-consuming to repair.

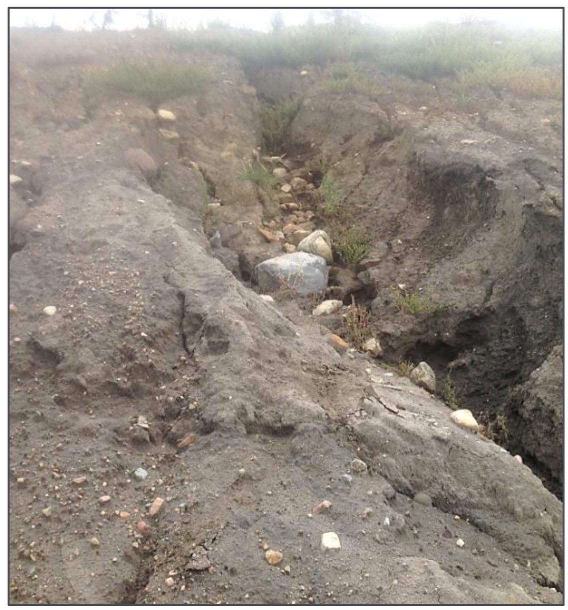


Photo 11 Gully erosion

4. Channel erosion (Photo12): The erosion of the beds and banks of defined stream channels is often caused by increased run-off volumes, longer-duration peak flows, and altered channel base flow. Increased impervious cover and reduced infiltration resulting from soil compaction and urbanization (asphalt roads and parking lots) are common causes of increased run-off and peak discharges. Uncontrolled release of stormwater run-off in urbanized environments can result in significant scour and undercutting of stream channels. Sediment deposits can further alter stream channel characteristics and flow patterns.

Photo 12 Channel erosion

5.4 Assessing soil erosion potential

5.4.1 Erosion and sediment control design goals:

The design goals are to:

- Limit soil erosion during site development by ensuring soils are stabilized where exposed.
  - Limit soil loss for all slopes to approved **tonnes per hectare per year** (t/ha/y) or less as outlined in the table below:

Soil loss tolerance	Requirements for drainage divide
2 tonnes/hectare/year (t/ha/y) using the Revised Universal Soil Loss Equation for Application in Canada (RUSLE-FAC)	Run off may go to: • *Surface waters (e.g. river, lake, stream, wetland); • Storm system (e.g. catch basins, pipes, storm pond, gutter, concrete or grass swale); • Environmentally sensitive area (e.g. environmental reserve); or • Private or public property.
4 tonnes/hectare/year (t/ha/y) using the Revised Universal Soil Loss Equation for Application in Canada (RUSLE-FAC)	Run off must go to: Properly sized sediment containment system, or Be contained in the drainage area where it will not flow off site to a surface water, storm system, environmentally sensitive area or private or public property.

- Look for innovative ways to reduce soil loss from the site.
- Locate sediment controls as close to the source of erosion as possible (when erosion controls cannot be implemented).

> **Note:** While The City has previously accepted professional justification for an increased soil loss tolerance, the addition of 4 tonnes/ha/yr to the 2022 *Standard Specifications – ESC* formalizes a higher soil loss on slopes where 100% of the water and sediments will remain on the construction site.

5.4.2 Revised Universal Soil Loss Equation for Application in Canada

Soil loss can be estimated using the mathematical equation defined as the Revised Universal Soil Loss Equation for Application in Canada (RUSLEFAC). RUSLEFAC is also used to assess proposed mitigation practices. With RUSLEFAC, the designer can estimate the rate of soil loss based on site-specific environmental factors, and then select and design ESC systems to address those factors.

The City uses RUSLEFAC during the review of ESC Plans to verify that estimated soil loss during the proposed project will not exceed the tolerable annual soil loss limits either of 2 t/ha/y or 4t/ha/yr depending on the slope location. This does not mean sites are permitted to discharge up to this amount of soil; RUSLEFAC is only used to confirm that the ESC Plan will reduce sediment losses and justify that the selected ESC measures are adequate.

In addition, as construction sites are dynamic, and not all ESC practices are in place for the entire duration of the project, erosion prediction calculations are required for each drawing, stage of construction, submitted as part of the ESC Plan (see Section 3).

The RUSLEFAC equation is defined as:

$$A = R * K * LS * C * P$$

Where:

A = Annual soil loss due to erosion (t/ha/y)
R = Erosivity index at a specific climatic location
K = Index for soil erodibility based on a specific soil's susceptibility to erosion
L = Topographic factor specific to length of the overland flow path
S = Topographic factor specific to steepness or slope of the overland flow path length
C = Cover and management factor
P = Support practices factor

Note: RUSLEFAC only provides soil loss estimates rather than absolute soil loss data, and does not determine when soil loss is excessive at a site or when erosion control systems have failed (like during major weather events). The ESC designer makes these decisions based upon numerous criteria, of which soil-loss and sediment-yield estimates are only two important components.

Exercise caution when using RUSLEFAC, as calculations are only as accurate as the accuracy of the input data.

Other limitations for RUSLEFAC include:

1. The component RUSLEFAC equations have not been verified for certain hill slope-length and gradient limits.
2. RUSLEFAC does not produce watershed-scale sediment yields, and it is inappropriate to input average watershed values for the computation of the RUSLE factors.
3. RUSLEFAC is limited to an estimation of erosion rates due to sheet and rill erosion. RUSLEFAC cannot be used to estimate erosion rates caused by gully or channel erosion.
4. RUSLEFAC is based on average storm erosivity values and not individual short, high-intensity rainfalls.

5.4.3 Annual Soil Loss (A-value)

For construction sites in Calgary, the soil loss tolerance of either 2 t/ha/yr or 4 t/ya/yr, as outlined in Section 5.4.1, must be achieved using suitable ESC practices applied within the site.

5.4.4 Climate (R-value)

The R-value is derived from probability statistics resulting from analyzing rainfall records of individual storms. Rainfall produces the erosive agents of raindrop impact and overland flow. Rainfall amount and intensity determine erosivity. Rainfall erosivity varies by location; therefore, the R-value describes erosivity at a location. The Erosivity Index (EI) for a single storm event is the product of a storm's energy (related to storm amount and intensity) and maximum 30-minute intensity.

Note: Calgary construction sites presently use **320** as an annual R-value but with climate change this rainfall intensity is increasing.

5.4.5 Soil Erodibility Factor (K-value)

Soil susceptibility to erosion is the opposite of resistance of erosion. This susceptibility is known as soil erodibility, and the index for erodibility is the K-value. The K-value represents the rate of soil loss per unit area as measured on a 3.7-metre (m) by 22-m plot (Agriculture and Agri-Food Canada, 2002). The lower the K-value, the better a soil is at resisting erosion.

Erosion assessment begins with a review of the types of soils that will be disturbed during construction, as well as soil materials that may be brought onto the site as fill. Although estimates of soil texture, structure, and permeability can be made from geotechnical reports, The City requires that project sites have quantitative information on soil texture, obtained from soil sampling and laboratory particle size distribution data (to determine texture). The number of samples needed to get a rough soil texture assessment of the site is normally at the discretion of the geotechnical engineer (see Appendix A: Variables that Affect K-value).

The single most important factor affecting soil erodibility is soil texture (see Appendix A: Soil Types in the Calgary Area). Determination of a soil's texture is the first step in determining its K-value.

Detailed geotechnical investigations are used to determine a soil's texture by assessing particle size distribution in a sample, as reported by percent weight of:

- Silt,
- Very fine sand,
- Sand greater than 0.10 mm
- Organic matter

Soil structure, soil permeability, and then K-values are determined once these size distributions are known using design charts (see Appendix A).

A City of Calgary evaluation of 170 soil samples representing projects across Calgary had average K-values of 0.042 but they **could** range from 0.01 to 0.079.

Photo 13 Silty clay soil common in Calgary

A summary of typical K-values based on soil textural class is shown in Table 5-1.

Note: If quantitative soil information is not available for your site and you are unable to determine a K-value, The City will accept a K-value of 0.079 for the purpose of RUSLE calculations.

Table 5-1 Soil erodibility values (K) for common surface textures

Textural class	Organic matter content		
	< 2%	> 2%	Average
Clay	0.032	0.028	0.029
Clay loam	0.044	0.037	0.040
Coarse sandy loam	-	0.009	0.009
Fine sand	0.012	0.008	0.011
Fine sandy loam	0.029	0.022	0.024
Heavy clay	0.025	0.020	0.022
Loam	0.045	0.038	0.040
Loamy fine sand	0.020	0.012	0.015
Loamy sand	0.007	0.005	0.005
Loamy very fine sand	0.058	0.033	0.051
Sand	**0.001**	0.003	0.001
Sandy clay loam	-	0.026	0.026
Sandy loam	0.018	0.016	0.017
Silt loam	0.054	0.049	0.050
Silty clay	0.036	0.034	0.034
Silty clay loam	0.046	0.040	0.042
Very fine sand	**0.061**	0.049	0.057
Very fine sandy loam	0.054	0.044	0.046

Based on *Revised Universal Soil Loss Equation for Application in Canada:* 1997, Wall et al.

From Table 5-1 it can be seen that the **best** soil at resisting erosion is sand (K= 0.001, highlighted in green) but the **worst** soil is very fine sand (K=0.061, highlighted in red).

This example illustrates the need to have a geotechnical professional quantify the soils based on particles size, as the same general types of soils (sands) can have very different K-values and subsequent impacts on soil erosion.

Note: Soil characteristics provided in these guidelines are meant only to provide general information on soils and are not acceptable for ESC submissions. The developer must attain K-values through site soil quantification by a geotechnical professional.

5.4.6 Topographical assessment (LS-value)

The effect of topography on erosion is accounted for by the LS-value, which combines the effects of **steepness** of the overland flow path, the **length** of the path, and the **profile** shape of the flow path (how steepness varies along the path).

Photo 14 Steep slope created to facilitate infrastructure installation

A site may have many different slopes, each of which may contribute differently to potential erosion. If more than a single slope or overland flow path exists, then each flow path must be analyzed separately.

The overland flow path on many natural landscapes follows a complex hillslope profile, where the upper part of the slope is convex (humped) and the lower part of the slope is concave (cupped). If the lower portion of the slope is sufficiently flat, then deposition may actually occur.

As hillslope length and hillslope gradient increase, soil loss increases. As hillslope length increases, total soil loss and soil loss per unit area increases due to the progressive accumulation of run-off in the downslope direction. As the hillslope gradient increases, the velocity and erosivity of run-off increases.

5.4.6.1 Interaction of hillslope length and gradient

The hill-slope length (L) and gradient (S) terms are combined into a single topographic factor (LS), representing the ratio of soil loss from a given hill-slope length and gradient to soil loss from a defined unit plot. (See Appendix A: LS-values for more information.)

5.4.6.2 Non-uniform hillslope profiles

LS-values emphasize the importance of correctly identifying the configuration of the hillslope profile in question. Accurate measurements of the field characteristics will produce the most accurate estimates of the LS-value.

In many cases hillslope profiles are non-uniform, consisting of several segments of differing lengths, gradients, and shapes, which necessitate special handling in RUSLEFAC. The hillslope profile is divided into segments of uniform length and gradient characteristics, and the segments are calculated individually.

See Appendix A for more information on assessing LS-values.

5.4.7 Erosion control (C-value)

Soil stabilization practices are the single most effective method to control erosion.

Fine sediment is difficult and expensive to manage; therefore, planning and implementing practices designed to **control stormwater, run-on, and run-off** and **stabilize exposed soils** must be the primary objectives on all construction projects (See Appendix A for more information on C-values).

The C-value is one of the most influential variables in RUSLEFAC and represents a combined effect of surface cover (plants), soil biomass, and cover management practices implemented to reduce erosion. The purpose of source control is to prevent or minimize the detachment, entrainment, and transport of sediment. Good planning and implementation of temporary and permanent erosion control practices reduces the need for expensive, high-maintenance sediment control, and delivers significant cost savings and better compliance with regulations.

As with other RUSLEFAC factors, the C-value is a ratio comparing the existing surface conditions at the site to the standard conditions of a unit plot.

The C-value for construction sites is affected by the following:

Surface covers (e.g. temporary or permanent vegetation, hydromulching, aggregate cover, and rolled erosion control products)

Soil biomass (all vegetative matter within the soil; residue helps to improve the flow of water into the soil and the soil water-holding capacity)

C-values are important during and immediately following construction because the topsoil is often stripped and stockpiled, causing a decrease in the incorporated biomass. Soil disturbance makes the soil more erodible because the soil is less consolidated, and stable aggregates are broken up. Vegetation cover on long-term topsoil stockpiles helps maintain the biological integrity of the topsoil, which will help provide an improved erosion control and growing medium when the topsoil is replaced during final site stabilization.

> **Note:** C-values will vary based on slope, application rate, material, construction details, and percent coverage, among other variables. The ESC designer must provide supporting information for any C-value used (references from peer-reviewed journal or manufacturer’s specifications with ASTM International [ASTM] testing completed) for practices and technologies in the ESC documentation. Refer to product manufacturer’s specifications for product-specific C-values.

5.4.8 Sediment control (P-value)

As stated, the first goal of an ESC practice is to **avoid** having to manage sediment in the first place by applying proper erosion control techniques. However, when sediment must be managed, the techniques described in this section are applicable.

The support practice value (P) in RUSLEFAC is the ratio of soil loss, with a specific support practice to the corresponding loss for slopes freshly tilled up and down the slope. The P factor is applied to proposed sediment control techniques with the RUSLEFAC equation.

Sediment controls can be divided into two categories:

1. Filtering controls: Water is filtered through a porous filter media, allowing sediment to be trapped on the filter. However, it is very difficult to filter fine sediment while providing

adequate flow rate. Soils in the Calgary area are not easily filtered once they are entrained in water because of their size and electrical charge.

2. Settling and impoundment: Water is retained or detained, or velocity is slowed sufficiently, to allow sediment to settle out of suspension (through gravity). Settling of fine sediment can often be improved by the controlled addition and mixing of chemicals known as flocculants or coagulants.

Photo 15 Straw wattle

Supporting structural practices include buffer strips of close-growing vegetation, surface roughening, sediment containment systems, and other soil management practices orientated on or near the contour that result in the collection and storage of moisture and reduction of run-off. In addition, many structures, such as gravel filters, silt fences, and bench terraces are used on construction sites to control or minimize sediment transport.

The effectiveness of sediment control depends on:

- Soil texture;
- Sediment concentration in run-off;
- Practices selected; and
- Installation, inspection, and maintenance of the practices.

Sediment controls are generally only useful for retaining larger particles in low-volume, low-velocity run-off. The effectiveness of sediment control decreases rapidly with decreasing particle size, increasing run-off volumes and sediment loadings in run-off.

Sediment control is generally least effective when the need for sediment control is highest (e.g. during intense rain events with high rates of run-off and sediment transport.)

Note: The P-value may be the least accurate and most subject to error of all the factors in RUSLEFAC. The ESC designer must provide supporting information (such P-value references, and field and laboratory data) for practices and technologies in the ESC documentation. Refer to product manufacturer’s specifications for product-specific P-values.

Appendix A: RUSLE values determination

Particulate sedimentation times

Particulates in a solution settle out according to Stokes Law.

The settling velocity (v) of a particle in metres per second is described as:

$$v = gd^2 \frac{(\gamma_s - \gamma_f)}{18\vartheta\gamma_f}$$

Where:

g = gravitational acceleration

d = particle diameter

γ_s and γ_f are specific gravity of solid and fluid, respectively

ϑ = kinematic viscosity of fluid

For example, by doubling the size of the particle, the settling velocity is increased by a factor of 4, or the time needed to settle out the particle is reduced by ¾. This is important because the amount of time needed for a soil to completely settle out depends very much on the sizes of the particles within the soil. Some of the particles might settle quickly (gravels and sands), while others may take days to settle (fine silts and clays).

Table A-1 is based on the time it takes a certain sized particle to settle 0.5 m; the minimum design depth for sediment ponds in Calgary. From Table A-1 you can see that it would be impractical to assume that a pond would settle out clay particles, as the particles would take 285 hours (11.9 days) to settle out. A pond might be effective for certain sized silts, however, as it would take from 0.25 to 2.8 hours for silts to settle out. Clay soil erosion is much better mitigated using cover techniques rather than sediment control.

Table A-1 Soil particulate settling times (based on Alberta Transportation Appendix G Sediment Containment System Design Rationale (March 18, 2003)

Particle size	Settling velocity	Time to settle 0.5 m
Clay: dia. <0.002 mm	4.87×10^{-5} cm/s	285 hours
Silt (fine) dia.= 0.01 mm	4.9×10^{-3} cm/s	2.83 hours
Silt (coarse): dia. = 0.05 mm	1.22×10^{-1} cm/s	13.6 minutes
Sand (fine): dia. = 0.1 mm	4.76×10^{-1} cm/s	3.5 minutes

Soil types in the Calgary area

Soils may be broadly defined as organic or mineral.

The dominant organic soil classification in Calgary is Black Chernozemic. Alberta Agriculture and Forestry describes (1994) Black Chernozemic soils as:

> *"…associated with grassland areas with the most available moisture and cooler temperatures. These soils are characterized by the presence of a black surface horizon that is 12 to 20 cm thick with organic matter generally in the range of 6 to 10 percent."*

The Calgary area also has many types of mineral soils ranging from small, colloidal clays, all the way up to large, glacial erratics of 2-3 metres (m) in width or larger (like the Big Rock in Okotoks, Alberta). A developer in the Calgary area might find any of the following mineral soils on their site:

Clays

Silts

Sands

Gravels

Loess (wind deposited silts)

Variables that affect K-value

Soils have different characteristics that impact erodibility. Mineral soils may be described in different ways by different experts. Referring to Figure A-1, there are at least four different classifications systems commonly in use today. They share some similarities around:

What they call different soils; broadly, they describe cobbles and gravels, sands, silts, and clays

Use of particle size as the delineator between one type of soil and another

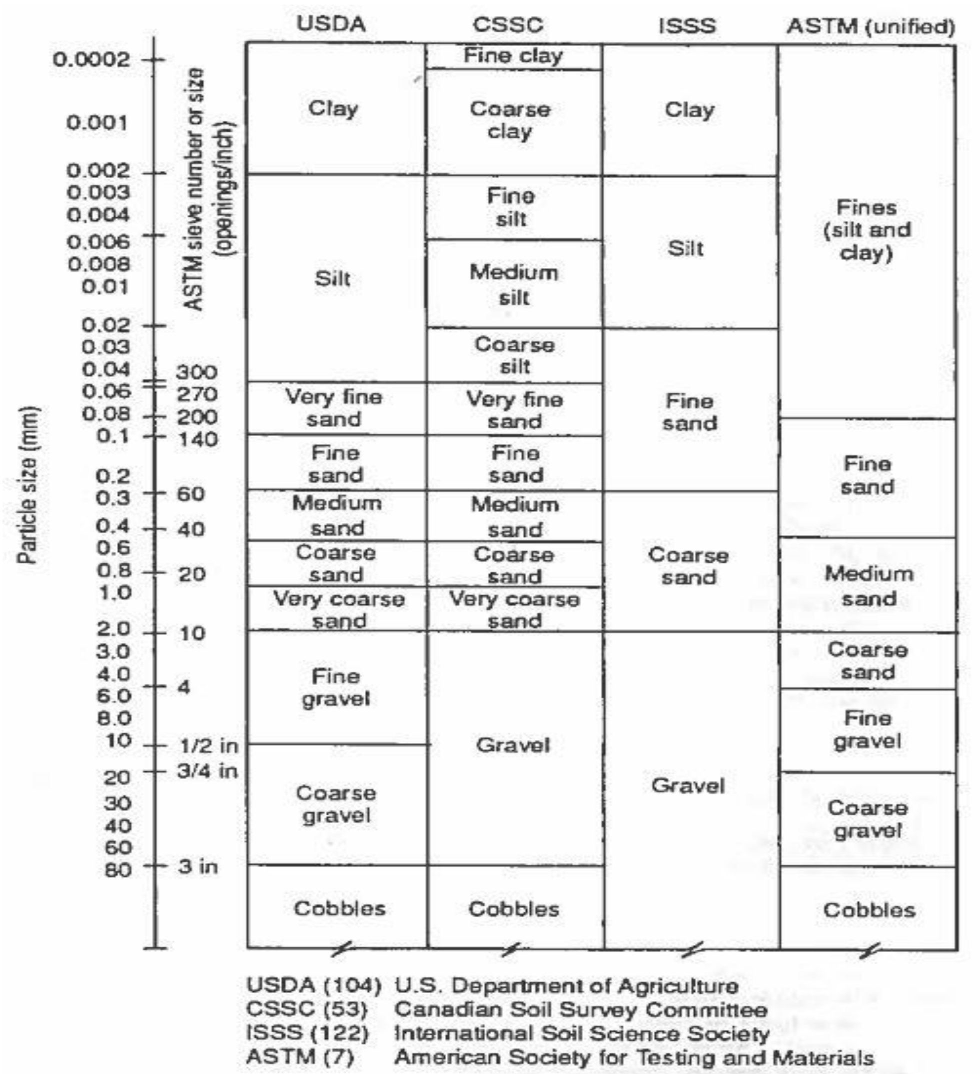


Figure A-1 Soil classification systems (Handbook of Hydrology, David R. Maidment, 1992)

The RUSLE equation was designed for agricultural purposes and subscribes to the U.S. Department of Agriculture (USDA) soil classification system. The USDA soil system is concerned with soil characteristics that impact soil erodibility.

The system often used for construction however, is based on ASTM International standards. The ASTM system is not designed to quantify the potential of a soil to erode, but it is the one used by geotechnical consultants. The ASTM system looks at soil characteristics from a construction point of view. A soil report from a geotechnical consultant, therefore, would most likely discuss the site soils in terms of ASTM and not USDA definitions.

What's important to realize is that both the USDA and ASTM systems collect the same particle size information but package it differently for the client. A client that is aware of this can therefore proactively ask for the same information to be presented in different manners. This might be just asking to ensure that the right sized soil sieves are used to ensure a certain fraction of particles is captured.

When the erosion and sediment control (ESC) designer is ready to classify a soil from an ESC perspective, the ESC designer must translate the ASTM information into USDA information to use RUSLEFAC. The most important difference is in quantifying the amount of **very fine sand**, which is a key variable in soil texture and soil erodibility. Delineating very fine sand means ensuring that ASTM 40, 60, and 140 size sieves are utilized in the particle analysis (see Figure A-1) so that the percentage of very fine sand can be found.

Other factors that impact soil erodibility are listed in Figure A-2.

Variable	Description and Function	Effect on Erosion	Management Implications
Soil texture	- size and distribution of the available soil particles - smaller particles, once detached, are easily transported - texture of a soil influences runoff amount and rate	- erodibility increases with silt plus very fine sand content (particles easily detached, readily form crusts which decrease infiltration, increase runoff	- type of soil may limit: - agricultural uses - crops that can be grown - management systems
Organic matter content	- amount of humus present - organic material helps to bind the soil particles together - affects water-holding capacity of soil, influences infiltration/runoff amounts	- soil with high organic matter content more erosion resistant, hold more water - low organic matter = low erosion resistance	- maintenance of adequate organic matter levels (through residue and/or manure management) reduces erosion risk, increases fertility (which can increase crop vigour/cover, increase soil protection…)
Structure	- the arrangement of soil particles and aggregates - gives an indication of how strongly the soil particles “bind” together to resist erosion	- soils which do not break down easily yet allow infiltration more erosion-resistant	
Permeability	- affects the amount of water that will infiltrate into the soil as opposed to flowing downslope or ponding on the surface	- better infiltration = less runoff, less erosion (e.g. medium and course sand)	- practices which lead to the development of consolidated, impermeable layers or ploughpans increase the risk of soil erosion
Seasonality	- soil characteristics that may vary on a seasonal basis and affect erodibility including water content, bulk density, structure, permeability, biological activity, and drainage	- soil tend to be most susceptible in spring (especially during thaw conditions – saturated, less dense soils over frozen soils with low permeability) - least erodible in fall (dry, consolidated after growing season)	- better cover (standing and/or residue), rough surfaces in spring can help stabilize soil, reduce erosion

Figure A-2 Variables That affect K-value Source: Agriculture and Agri-Food Canada, 2002

Determination of K-values

The physical makeup of a soil determines its propensity to erode. A soil may be made of many different sized particles, and those particles may have become stuck together into larger aggregate particles called peds. Both the size of the individual particles and the size of the aggregate peds are important in determining K-values.

Step 1: Determine the size of the particles for every soil type on the proposed site:

The size of all the particles can be determined by using a sieve analysis or by manual methods used by trained ESC professionals. The following percentages are required:

Percent (%) silt and very fine sand in a sample by weight (0.002 - to 0.10 mm diameter), Percent (%) sand by weight (0.10 - to 2.0 mm diameter)

Percent (%) clay (less than 0.002 mm diameter)

Percent (%) organic matter (by weight)

Based on the percent clay and percent sand (as defined above) the ESC designer can quickly find the soil texture class.

The soil texture triangle allows determination of soil properties using lab results (objective) rather than field observations which should only be done by qualified ESC specialists.

Step 2: Determine the soil structure

Soil structure defines the frequency and shape of gaps between the soil aggregate peds. These gaps can encourage water to flow through cracks and crevices and increase the rate of erosion.

Soil structure is determined by using the information in Figure A-3 to describe the soil as:

Very fine granular = 1

Fine granular = 2

Medium or coarse granular = 3

Blocky, platy, or massive =4

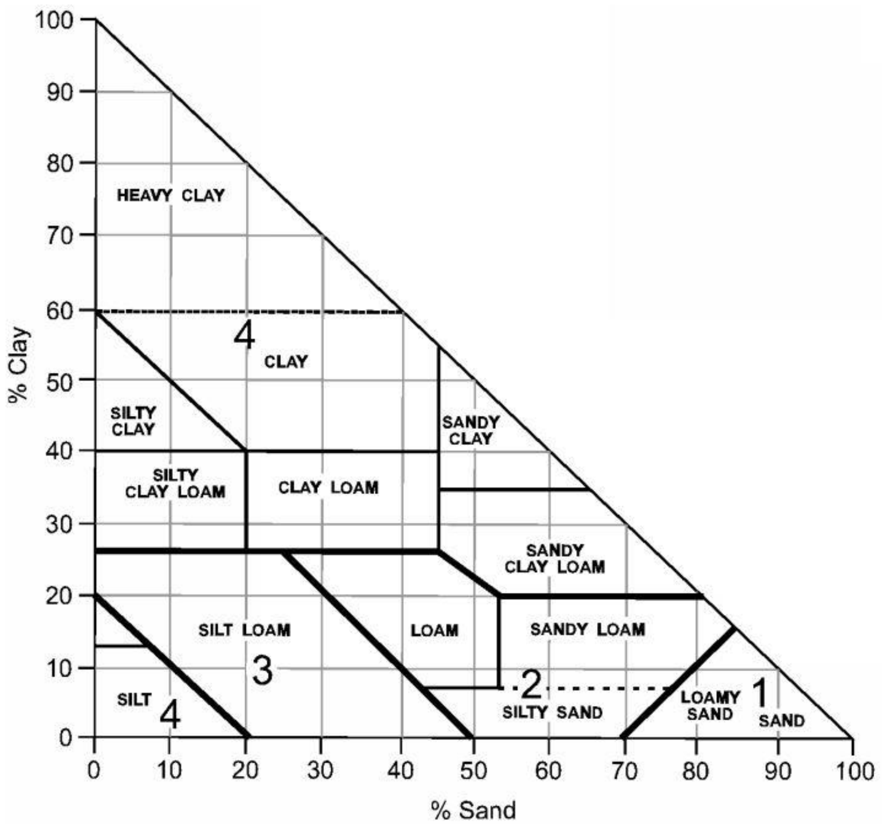


Figure A-3 Soil structure based on soil texture (RUSLEFAC)

Step 3: Determine the soil permeability

Related to soil structure is permeability which describes how easily water would flow through the soil.

Soil permeability is determined by using the information in Figure A-4 to describe the soil's permeability as:

Rapid = 1

Moderate to rapid = 2

Moderate = 3

Slow to moderate = 4

Slow = 5

Very slow =6

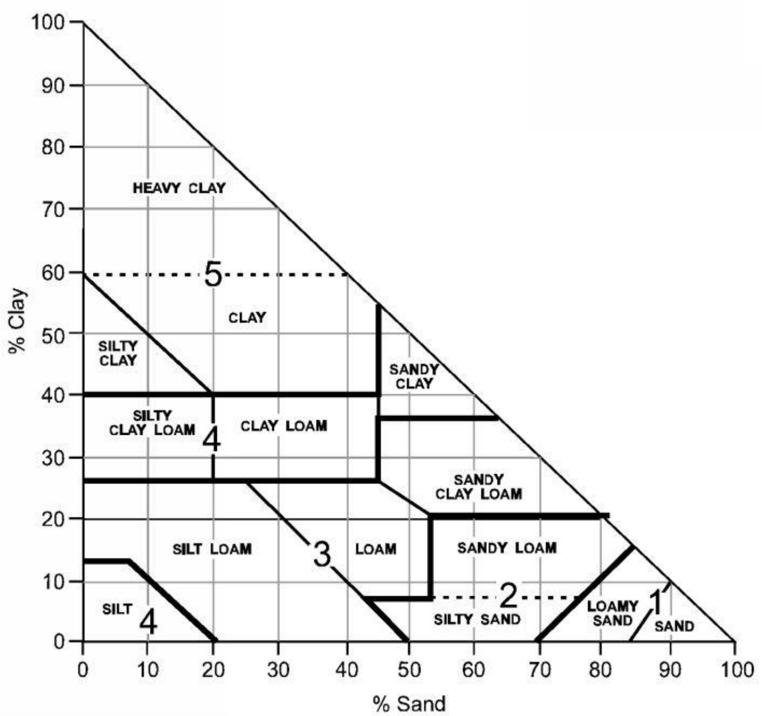


Figure A-4 Soil permeability based on soil texture (RUSLEFAC)

Step 4: Record the K-value

Example: A soil sample is run through a number of sieves and the following particle size distribution is reported as:

- Percent silt and very fine sand: 45%
- Percent sand: 25%

- Percent clay: (by calculation) = 100% -45%-25%= 30%

Percent sand: Starting at the bottom of the Soil Texture Triangle (see Figure A-5), the ESC designer finds the value for 25% sand and then strikes a line diagonally up (blue line)

Percent clay: The ESC designer then finds the value for 30% clay on the left side of the triangle and strikes a line to the right (green line). The green line crosses the blue line in the area marked "clay loam".

This soil is defined as having a clay loam texture. This definition is used to find soil structure and permeability.

Organic matter: the geotechnical report determined that there is no organic material in the soil.

Soil Structure: Knowing the soil texture is clay loam, the ESC designer finds the clay loam section on Figure A-5 to determine soil structure. In this case it is region 4 (contained within the orange border), indicating that the soil has Type 4 structure, and is described as "blocky, platy, massive".

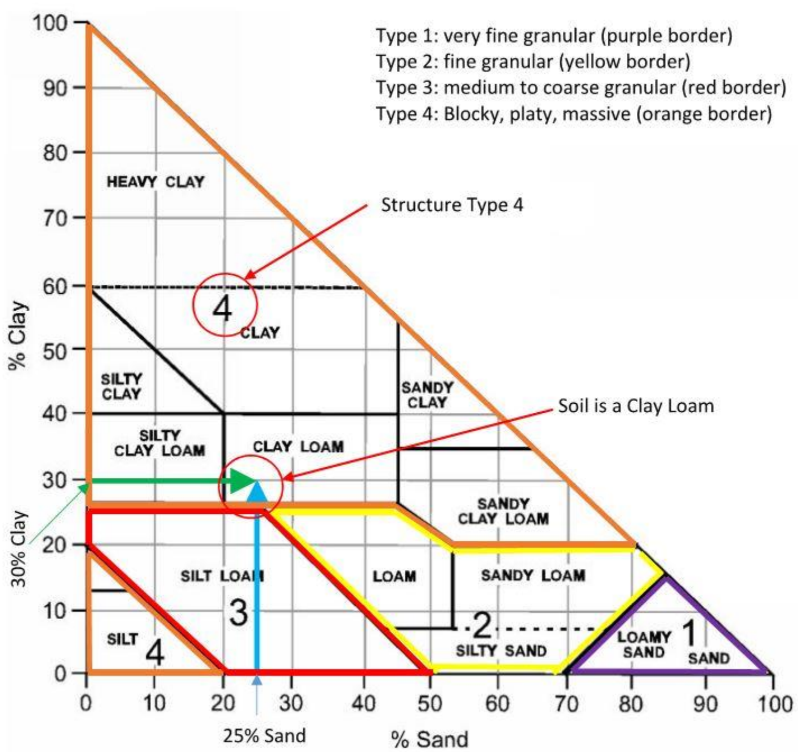


Figure A-5 Soil structure determination (Based on RUSLEFAC, 1997, Wall et al)

Soil Permeability: The soil **permeability** is determined knowing that the soil **texture** is clay loam. In Figure A-6, the ESC designer finds the area marked "CLAY LOAM". The ESC designer then confirms the region of the graph that the soil permeability is located in. In this case it is type 4 (contained within the orange border), indicating that the soil has slow to moderate permeability.

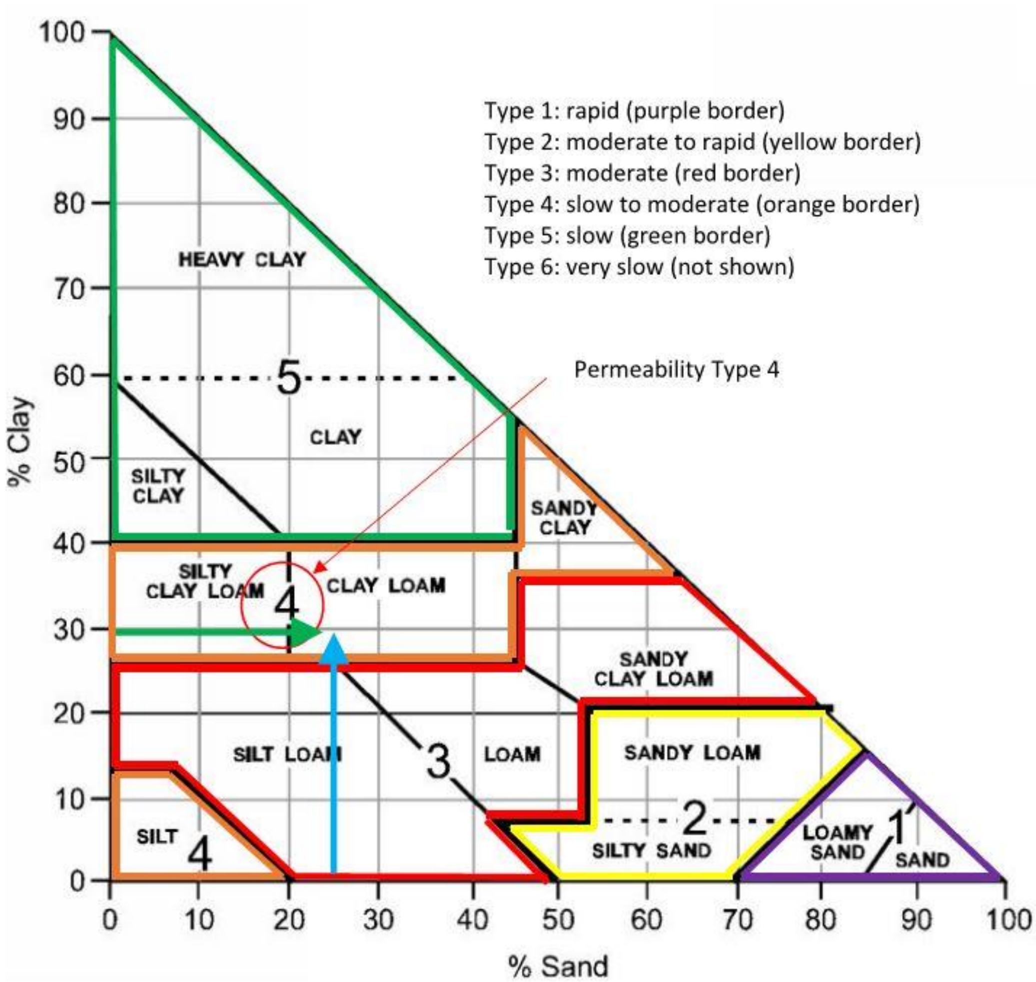


Figure A-6 Soil permeability determination (Based on RUSLEFAC, 1997, Wall et al)

The permeability is defined as Type 4, slow to moderate.

Determining K-values:

Using the Foster Nomograph (Figure A-7), do the following:

1. Starting at the left of the page, find the **PERCENT SILT AND VERY FINE SAND** mark (45%).
2. Move right horizontally across the nomograph until you intersect the **PERCENT SAND** mark (25%). Interpolation between curves is allowed.
3. Move up vertically until you intersect the % OM (Organic Matter) (0% in this case).
4. Move horizontally to the right now until you intersect the **SOIL STRUCTURE** mark (Type 4, blocky, platy).
5. Move directly down until you hit the **PERMEABILITY** mark (4, slow to moderate).
6. Move to the left horizontally to find the **SOIL ERODIBILITY FACTOR** (final K-value) (0.49).
7. In summary, the K-value for this soil is 0.049.

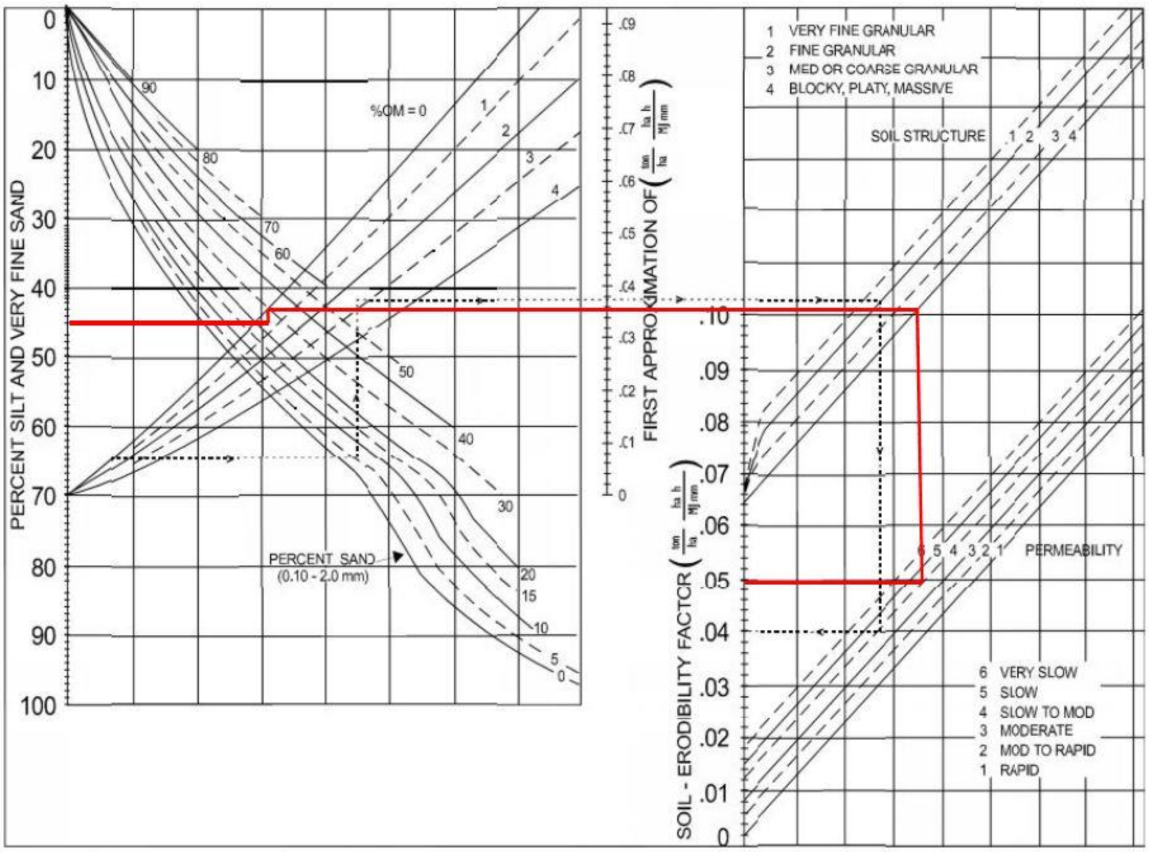


Figure A-7 Soil erodibility Nomograph (Foster et al. 1981)

The Qualified Designer must not rely on historical values. The K-value for the different soil types that will be encountered during construction must be defined for each site.

LS-value determination

Information provided in this section comes from *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation Agricultural Handbook No. 703,* (K.G. Renard et al., 1997).

Once the ESC designer has determined the potential for a soil to erode, the topography of the soil is assessed. The effect of topography on erosion in RUSLEFAC is accounted for by the LS-value.

Soils erode when exposed soil comes into contact with water droplets. The energy of the falling water breaks bonds between the particles (described by the K-value), and the water medium provides a transport mechanism to carry the soil particles away. As the water flows down the slope, it gains more kinetic energy that can lead to even more erosion. Finally, the water gains enough energy to form rills and gullies.

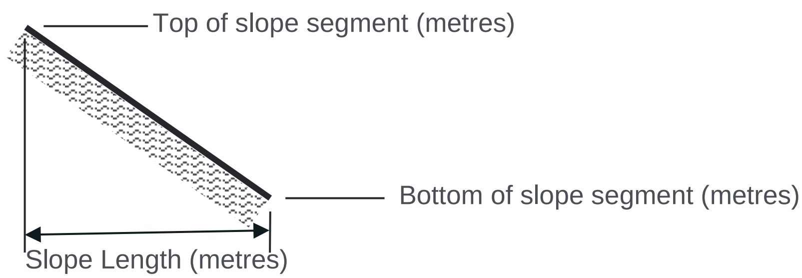
Soils located on long, steep slopes will tend to erode more than comparable soils on short, flatter slopes or in level areas.

The topography of the construction site, including lengths and gradients of slopes, must be documented both pre and post-development.

Definitions

Slope Length is the **horizontal** distance of a segment of slope to be analyzed.

Slope Gradient (also just called “grade” or “slope”) equals the change in vertical elevation over a slope segment divided by the horizontal slope length of the same segment (Figure A-8), given in percent (e.g. a 45° slope is defined as 100%.)



$$\text{Slope (\%)} = \frac{\text{Top elevation – bottom elevation (metres)}}{\text{Slope Length (metres)}} \times 100$$

Figure A-8 Definition of slope length and slope grade

Choosing a slope length (uniform slopes)

A uniform slope is one where the steepness (slope), soil type, and cover management conditions are comparable everywhere along the slope. A uniform slope is assumed in many RUSLEFAC applications.

Slope length is defined as the horizontal length from the origin of overland flow (often, the top of a hill or break in grade) to the point where either:

The slope gradient decreases enough to allow deposition of soil.

The run-off becomes concentrated in a defined channel.

The minimum and maximum lengths of a slope are defined by the slope’s ability, when hit by rainfall, to form rills and then consolidate those rills into full channel flow.

L_{min}= 4.6 m (15 feet), below this length, sheet flow is expected and will normally only form rills after 4.6 m

L_{max}= 122 m (400 feet), above this length, the rills are expected to consolidate into channels (gullies)

Once the slope length of a uniform slope is determined and the slope gradient calculated, the LS-value is selected from Table LS-3.

Table LS-3 assumes the land being assessed is a freshly prepared construction site (stripped of organic soils).

Table LS-3. Values for topographic factor (LS-value) for a high ratio of rill: inter-rill erosion

	Slope Length in metres													
Slope %	1	2	4.57	5	10	15	25	50	75	100	150	200	250	300
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.08	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.13
1	0.09	0.09	0.09	0.09	0.11	0.12	0.14	0.17	0.19	0.20	0.23	0.24	0.26	0.27
2	0.13	0.13	0.13	0.14	0.18	0.21	0.26	0.34	0.40	0.44	0.52	0.58	0.64	0.68
3	0.17	0.17	0.17	0.17	0.24	0.29	0.37	0.52	0.63	0.72	0.88	1.01	1.12	1.22
4	0.20	0.20	0.20	0.21	0.30	0.38	0.49	0.71	0.88	1.03	1.28	1.49	1.67	1.84
5	0.23	0.23	0.23	0.24	0.36	0.46	0.61	0.91	1.14	1.35	1.70	2.01	2.28	2.53
6	0.26	0.26	0.26	0.28	0.42	0.54	0.73	1.11	1.42	1.68	2.15	2.56	2.93	3.27
7	0.29	0.29	0.29	0.31	0.48	0.61	0.85	1.31	1.69	2.03	2.62	3.14	3.61	4.05
8	0.32	0.32	0.32	0.34	0.53	0.69	0.96	1.51	1.97	2.38	3.09	3.73	4.31	4.86
9	0.35	0.35	0.35	0.37	0.59	0.78	1.09	1.73	2.27	2.75	3.61	4.37	5.08	5.73
10	0.35	0.36	0.40	0.42	0.68	0.90	1.27	2.04	2.69	3.28	4.32	5.26	6.13	6.94
12	0.36	0.40	0.49	0.53	0.86	1.14	1.64	2.67	3.56	4.36	5.80	7.11	8.32	9.46
14	0.38	0.44	0.58	0.62	1.03	1.38	2.00	3.30	4.43	5.45	7.32	9.01	10.59	12.09
16	0.39	0.47	0.67	0.72	1.20	1.62	2.36	3.93	5.31	6.57	8.86	10.96	12.92	14.79
20	0.41	0.53	0.84	0.90	1.53	2.08	3.07	5.20	7.07	8.81	11.99	14.92	17.69	20.32
22	0.43	0.57	0.92	0.99	1.69	2.31	3.42	5.82	7.95	9.93	13.56	16.92	20.09	23.11
25	0.45	0.62	1.04	1.12	1.92	2.64	3.93	6.75	9.26	11.59	15.91	19.91	23.70	27.32
30	0.48	0.69	1.24	1.33	2.30	3.18	4.77	8.26	11.40	14.33	19.77	24.84	29.65	34.27
40	0.53	0.83	1.59	1.71	3.01	4.19	6.34	11.13	15.46	19.53	27.15	34.30	41.11	47.67
50	0.58	0.95	1.91	2.06	3.65	5.09	7.75	13.72	19.17	24.29	33.93	43.00	51.68	60.05
60	0.63	1.07	2.19	2.36	4.21	5.89	9.01	16.04	22.48	28.55	40.00	50.82	61.18	71.20

Source: RUSLEFAC Handbook, Agriculture Canada (modified by: Joe Buchner, CPESC)

Example: A slope drops a distance of 7 m over a slope length of 87 m. The slope gradient is calculated as:

Slope (%) = *(7/87) x 100% = 8.05 %*

Looking at Table LS-3 and extrapolating gives us an LS-value of 2.17 for an 8% slope of 87 m in length.

LS-values for Thawing Ground

When the RUSLEFAC analysis period includes a time of year when the soil will be frozen, Table LS-4 is used for determining the LS-value.

Table LS-4. Values for topographic factor (LS-value) for thawing soils where most of the erosion is caused by surface flow (using m=0.5).

	Slope Length in metres											
Slope %	2	5	10	15	25	50	75	100	150	200	250	300
0.2	0.01	0.02	0.03	0.04	0.05	0.06	0.08	0.09	0.11	0.13	0.14	0.16
0.5	0.02	0.04	0.06	0.07	0.09	0.12	0.15	0.18	0.21	0.25	0.28	0.30
1	0.04	0.07	0.09	0.11	0.15	0.21	0.25	0.29	0.36	0.41	0.46	0.50
2	0.07	0.12	0.17	0.20	0.26	0.37	0.45	0.52	0.64	0.74	0.83	0.90
3	0.11	0.17	0.24	0.29	0.37	0.53	0.65	0.75	0.92	1.06	1.18	1.30
4	0.14	0.22	0.31	0.38	0.49	0.69	0.84	0.97	1.19	1.38	1.54	1.68
5	0.17	0.27	0.38	0.47	0.60	0.85	1.05	1.21	1.48	1.71	1.91	2.09
6	0.20	0.32	0.45	0.55	0.72	1.01	1.24	1.43	1.75	2.02	2.26	2.48
8	0.27	0.42	0.90	0.73	0.94	1.33	1.63	1.88	2.31	2.66	2.98	3.26
10	0.33	0.52	0.74	0.91	1.17	1.66	2.03	2.34	2.87	3.31	3.70	4.05
12	0.36	0.56	0.79	0.97	1.26	1.78	2.18	2.51	3.08	3.55	3.97	4.35
14	0.39	0.61	0.87	1.06	1.37	1.94	2.38	2.75	3.37	3.89	4.35	4.76
16	0.42	0.66	0.94	1.15	1.49	2.10	2.57	2.97	3.64	4.20	4.70	5.15
20	0.48	0.76	1.07	1.31	1.69	2.39	2.93	3.39	4.15	4.79	5.36	5.87
25	0.54	0.86	1.22	1.49	1.92	2.72	3.33	3.84	4.71	5.44	6.08	6.66
30	0.60	0.95	1.35	1.65	2.13	3.01	3.69	4.26	5.21	6.02	6.73	7.37
40	0.70	1.11	1.57	1.92	2.48	3.51	4.30	4.97	6.08	7.02	7.85	8.60
50	0.79	1.24	1.76	2.15	2.78	3.93	4.81	5.55	6.80	7.85	8.78	9.62
60	0.85	1.35	1.91	2.34	3.02	4.27	5.23	6.04	7.40	8.54	9.55	10.46

Source: RUSLEFAC Handbook, Agriculture Canada

Using the same example for a uniform slope but now with the ground frozen and thawing produces:

Slope gradient = 8.05 %, slope length = 87 m

Looking at Table LS-4, we now get an LS-value of 1.76.

LS-values for complex slopes

Complex slopes

A complex slope is one where the slope is not uniform, or the soil type(s) and land use conditions change along it. These factors can all lead to erosion rates many times higher than on comparable constant-slope hillsides.

Complex slopes may have both convex and concave sections. A convex slope is one where the slope becomes steeper the further downhill you go. Erosion rates at the end of a convex slope can be extremely high. A concave slope is one where the steepness decreases along the slope. Concave slopes can become so flat that soil deposition may occur, which can reduce the amount of sediment leaving the slope.

The overland flow path on many natural landscapes follows a complex hillslope profile, where the upper part of the slope is convex and the lower part of the slope is concave. The slope must then be divided into two parts, an eroding portion and a depositional portion (Figure A-10). The RUSLEFAC equation is only applied to the eroding portion of the slope.

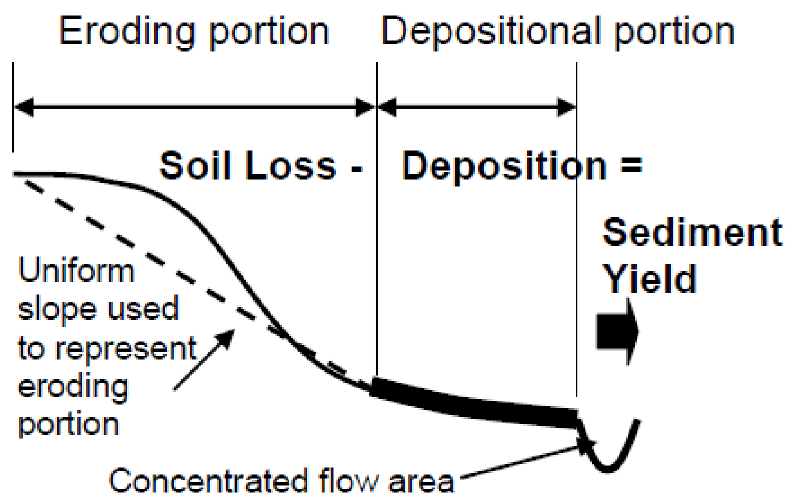


Figure A-9 Soil loss, deposition and sediment yield from complex slope, concave-convex shape
Source: USDA, May 2008, RUSLE2 User's Reference Guide

Non-uniform/ complex hillslope profiles

In many cases, hillslope profiles are complex, consisting of several segments of differing lengths, gradients (slopes), and shapes, which necessitate special handling in RUSLEFAC. The hillslope profile is divided into segments of uniform length and gradient characteristics, and the segments are calculated individually.

LS-values emphasize the importance of correctly identifying the configuration of the hillslope profile in question. Accurate measurements of the field characteristics will produce the most accurate estimates of the LS-value, especially for non-uniform hillslope profiles consisting of more than one segment.

The simplest irregular slope case is for soil and cover to be consistent along the slope. To apply the irregular slope procedure, the following steps are taken:

1. Divide the convex, concave, and complex slopes into **three to five equal-length** segments.
2. Determine the average slope for each segment
    a. List the segments in the order in which they occur on the slope, beginning at the top of the slope
3. From Table LS-3 determine the original LS-value for each segment ($LS_{init.}$)
4. From Table LS-5 determine the slope length exponent (for high rill /interill ratios) (m)
5. From Table LS-6 determine the slope loss factor (SLF) based on sequence of the slope (1,2,3)
6. Multiply each segment's revised LS-value by its slope length factor divided by the number of segments. This is the revised LS-value for each segment $LS_{rev.}$

a. $LS_{rev.} = (LS_{init.}$ X SLF)/ number of segments

7. Add all the revised LS-values to determine the cumulative total LS-value for the entire slope
   a. LStotal = Σ (LSrev.)

Example: the ESC designer is presented with the following slope (Figure A-10):

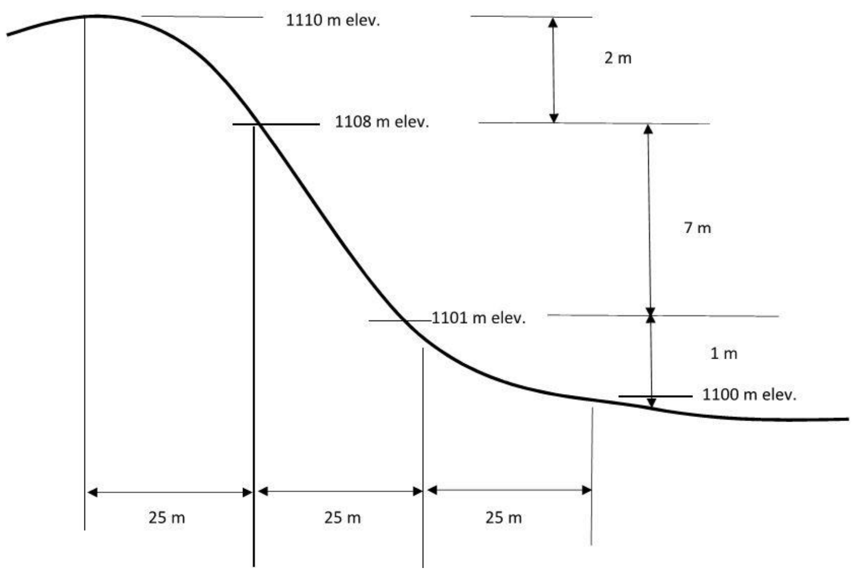


Figure A-10 LS determination for an irregular slope example

The slope is flat (concave) at the top, then becomes very steep before ending in a convex depositional area.

1. Divide the 75 m slope into equal sections. In this case the ESC designer chose to divide the slope into three, 25 m sections
2. Determine the slopes for each 25 m section
   - Segment 1: Slope (%) = [(1110 m – 1108 m)/ 25 m] x 100= 8%
   - Segment 2: Slope (%) = [(1108 m – 1101 m)/25 m] = 28%
   - Segment 3: Slope (%) = [(1101 m – 1100 m)/25 m] = 4%
   - Segment 1: 8% slope and 25 m length, LS = 0.96
   - Segment 2: 28% slope and 25 m length, LS = 4.44(extrapolated)
   - Segment 3: 4% slope and 25 m length, LS= 0.42
3. Using Table LS-3, find the original LS-value for each segment
4. Using Table LS-5 determine the slope length exponent (m) for each segment, assuming high Rill/ Interrill Ratios (exposed slopes)
   - Segment 1: Slope = 8%, m = 0.65
   - Segment 2: Slope =28%, m = 0.79
   - Segment 3: Slope = 4%, m = 0.53

Table LS-5. Slope length exponents for a range of slopes and rill/interrill erosion classes.

Slope Steepness (%)	Slope Length Exponent, m Rill/Interill Ratio ã Low*	Moderate**	High***
0.2	0.02	0.04	0.07
0.5	0.04	0.08	0.16
1	0.08	0.15	0.26
2	0.14	0.24	0.39
3	0.18	0.31	0.47
4	0.22	0.36	0.53
5	0.25	0.40	0.57
6	0.28	0.43	0.60
8	0.32	0.48	0.65
10	0.35	0.52	0.68
12	0.37	0.55	0.71
14	0.40	0.57	0.71
16	0.41	0.59	0.74
20	0.44	0.61	0.76
25	0.47	0.64	0.78
30	0.49	0.66	0.79
40	0.52	0.68	0.81
50	0.54	0.70	0.82
60	0.55	0.71	0.83

*conditions where rill erosion is slight with respect to rill erosion; generally C factor would be less than 0.15

**conditions where rill and interill erosion would be about equal on a 22.1m long slope in seedbed conditions on a 9% slope

***conditions where rill erosion is greater with respect to interill erosion; generally C factors would be greater than 7.0

(Source: McCool et al., 1989)

5. Using the m values obtained in Step 4, and using Table LS-6, determine the soil loss factor (SLF) for each segment
   - Segment 1: m = 0.65, SLF = 0.50
   - Segment 2: m = 0.79, SLF = 1.03
   - Segment 3: m = 0.53, SLF = 1.39
6. For each segment, multiply it’s original LS-value by its SLF factor, then divide by the total number of segments to determine the revised LS-value for each slope segment

– Segment 1: (0.96 x 0.50)/ 3 = 0.16
– Segment 2: (4.65 x 1.03)/3 = 1.597
– Segment 3: (0.49 x 1.39)/3 = 0.23

Table LS-6. Soil loss factors for irregular slopes

# of Segments	Sequence # of Segment (i)	Soil Loss Factor (SLF) Value of m																		
		0.02	0.06	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.64	0.7	0.75	0.8	0.85	0.9
2	1	0.99	0.96	0.93	0.90	0.87	0.84	0.81	0.78	0.76	0.73	0.71	0.68	0.66	0.64	0.62	0.59	0.57	0.55	0.54
	2	1.01	1.04	1.07	1.10	1.13	1.16	1.19	1.22	1.24	1.27	1.29	1.32	1.34	1.36	1.38	1.41	1.43	1.45	1.46
3	1	0.98	0.94	0.90	0.85	0.80	0.76	0.72	0.68	0.64	0.61	0.58	0.55	0.52	0.50	0.46	0.44	0.42	0.39	0.37
	2	1.01	1.02	1.02	1.03	1.04	1.05	1.05	1.05	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.03	1.02	1.02
	3	1.02	1.05	1.08	1.12	1.16	1.19	1.23	1.26	1.30	1.33	1.37	1.40	1.43	1.46	1.49	1.52	1.55	1.58	1.61
4	1	0.97	0.92	0.87	0.81	0.76	0.71	0.66	0.62	0.57	0.54	0.50	0.47	0.44	0.41	0.38	0.35	0.33	0.31	0.29
	2	1.00	1.00	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.91	0.90	0.88	0.87	0.85	0.84	0.82	0.80	0.78
	3	1.01	1.03	1.05	1.07	1.09	1.11	1.13	1.14	1.16	1.17	1.18	1.19	1.20	1.21	1.22	1.23	1.23	1.24	1.24
	4	1.02	1.05	1.09	1.13	1.17	1.21	1.25	1.29	1.33	1.36	1.40	1.44	1.48	1.50	1.55	1.58	1.62	1.65	1.68
5	1	0.97	0.91	0.85	0.07	0.72	0.67	0.62	0.57	0.53	0.48	0.45	0.41	0.38	0.36	0.32	0.30	0.28	0.25	0.23
	2	1.00	0.99	0.97	0.96	0.94	0.92	0.90	0.88	0.86	0.84	0.82	0.80	0.77	0.76	0.73	0.71	0.69	0.66	0.64
	3	1.01	1.02	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.06	1.06	1.06	1.05	1.05	1.05	1.04	1.03	1.03	1.02
	4	1.01	1.04	1.06	1.09	1.12	1.14	1.17	1.19	1.21	1.23	1.25	1.27	1.29	1.30	1.32	1.34	1.35	1.37	1.38
	5	1.02	1.05	1.09	1.13	1.17	1.22	1.26	1.30	1.34	1.38	1.42	1.46	1.50	1.53	1.58	1.62	1.65	1.69	1.73

Source: RUSLEFAC Handbook, Agriculture Canada

Step 7: add all the revised slope segment LS's together to determine the total LS for the irregular slope

– LS total = LS1 + LS2 + LS3= 0.16+1.597+0.23 = 1.98

Table A-3 Summarizes the process:

Table A-3 Irregular slope example calculation

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Segment n = 3	Slope (Gradient)	LS-value LS-3	Slope length exponent (m) LS-5	Soil loss Factor (SLF) LS-6	LS*SLF/n n = 3
1	(2/25)*100= 8%	0.96	m = 0.65	SLF= 0.50	(0.96 x 0.50)/3 = 0.16
2	(7/25)*100= 8%	4.65	m = 0.79	SLF= 1.03	(4.65 x 1.03)/3 = 1.59
3	(1/25)*100= 4%	0.49	m = 0.53	SLF= 1.39	(0.49 x 1.39)/3 = 0.23
3 segments total				LS Total	**1.98**

Erosion control: C-value determination

The Qualified Designer must provide supporting information for any C-value used (references from peer-reviewed journal or manufacturer's specifications with ASTM International [ASTM] testing completed) for practices and technologies in the ESC documentation. Refer to product manufacturer's specifications for product-specific C-values. C-values will vary based on slope, application rate, material, construction details, and percent cover, among other variables.

For example, per Table C-5 of the RUSLEFAC Handbook, a ground cover of 80 per cent or more of established grass with no appreciable canopy corresponds to a C-value of 0.01; whereas, a 20 per cent grass ground cover corresponds to a C-value of 0.2 (Wischmeier and Smith, 1978).

Table A-4. C Values for permanent pasture, range, and idle land (based on RUSLEFAC 1997)

Vegetative canopy type and height	Percent cover	Type	Cover that contacts the soil surface					
			Percent ground cover					
			0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.04	0.01	0.00
		W	0.45	0.24	0.15	0.09	0.04	0.01
Tall weeds or short brush with average drop fall height of 20 inches	25	G	0.36	0.17	0.09	0.04	0.01	0.00
		W	0.36	0.20	0.13	0.08	0.04	0.01
	50	G	0.26	0.13	0.07	0.35	0.01	0.00
		W	0.26	0.16	0.11	0.08	0.04	0.01
	75	G	0.17	0.10	0.06	0.03	0.01	0.00
		W	0.17	0.12	0.09	0.07	0.04	0.01
	25	G	0.40	0.18	0.09	0.04	0.01	0.00

Appreciable brush or bushes, with average drop fall height of 6 ½ feet		W	0.40	0.22	0.14	0.09	0.04	0.01
	50	G	0.34	0.16	0.08	0.08	0.04	0.00
		W	0.34	0.19	0.13	0.04	0.01	0.01
	75	G	0.28	0.14	0.08	0.04	0.01	0.00
		W	0.28	0.17	0.13	0.08	0.04	0.01
Trees, but no appreciable low brush. Average drop fall of 13 feet.	25	G	0.42	0.19	0.10	0.04	0.01	0.00
		W	0.42	0.23	0.14	0.09	0.04	0.01
	50	G	0.39	0.18	0.09	0.04	0.01	0.00
		W	0.39	0.21	0.14	0.09	0.04	0.01
	75	G	0.36	0.17	0.09	0.04	0.01	0.00
		W	0.36	0.20	0.13	0.08	0.04	0.01

Vegetation and mulch randomly distributed over area; G-grasses, W-broadleaf weeds; Canopy height – average drop fall height of water falling from canopy to ground (negligible in height greater than 33 feet)

Figure A-11 represents different coverage of an area and can help to visually confirm per cent ground cover by grass or mulch.

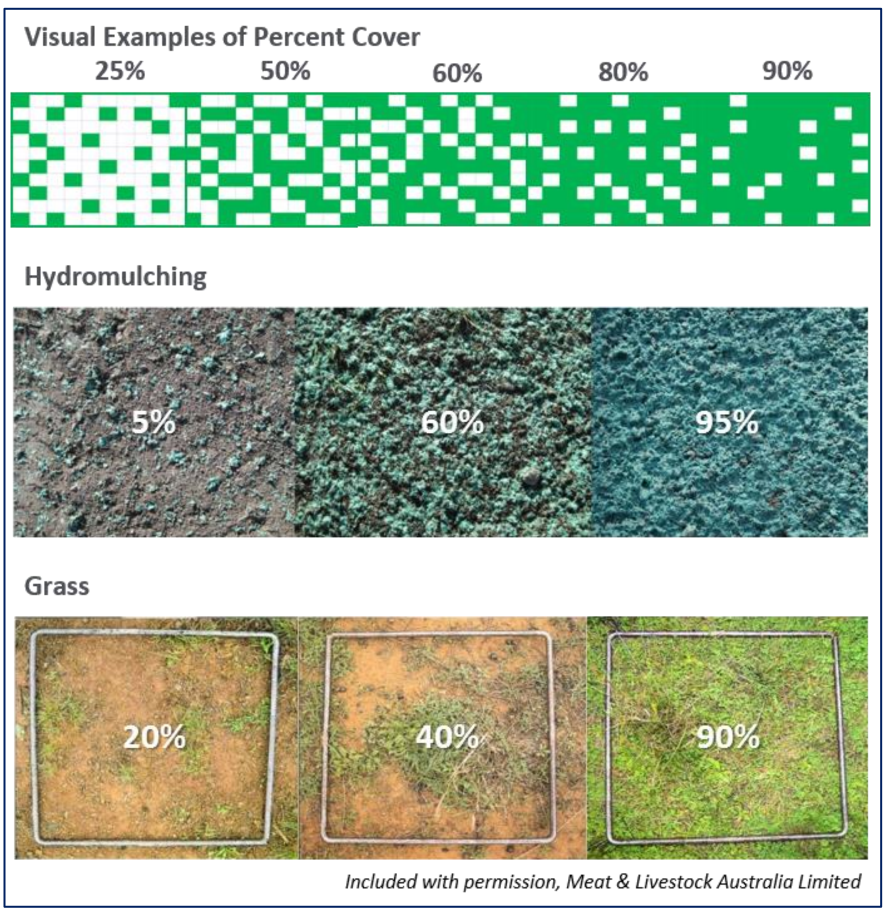


Figure A-11 Per cent ground cover by grass or mulch

Appendix B: Glossary

The following words and terms are used in this document when discussing erosion and sediment control (ESC) and stormwater management. Some definitions are adapted from *Erosion & Sediment Control on Construction Sites* (Spring, 2002). Some definitions were also adapted from the *Erosion & Sediment Control Participant's Handbook* (Malaspina University College, 2005).

Abrasion	Erosion caused by particles carried by wind or water.
Accretion	The outward growth of a bank or shoreline caused by sedimentation.
Base flow	Stream flow during dry periods, predominantly due to groundwater recharge.
Berm	A structure (generally compacted earthen material) built to contain or divert run-off or, in the case of a compost berm, to detain and filter run-off through stabilized organic material.
Best management practice	Control or practice implemented to protect water quality and reduce the potential for pollution associated with stormwater run-off. Often abbreviated as *BMP*.
Capacity	The effective carrying ability of a drainage structure (cubic metres per second).
Channel erosion	Erosion of the bed or banks of a defined channel.
Check dams	Small dams constructed in channels subject to periodic run-off, with the purpose of reducing water velocity, channel gradient, and erosion.
Clay	Inorganic particles 0.0002 to 0.004 millimetres (mm) in diameter.
Cohesion	The ability of individual soil particles to stick together.
Conveyance	Any natural or constructed channel or pipe in which concentrated water flows.
Culvert	A closed conduit that allows water to pass under a road.
Deleterious	Deleterious substances, as defined in the *Fisheries Act*, are substances (or water containing a substance) that degrade or alter water quality so that it is, or is likely to be, rendered dangerous to fish, fish habitat, or the use of fish by humans. Water that is treated, processed, or changed from a natural state and introduced into fish habitat could also harm fish, fish habitat, or consumers of fish.
Deposition	The settling of material due to gravity.
Detachment	The breaking of bonds holding a material together (i.e., by raindrop impact).

Detention	The temporary detention of stormwater for later release. This practice is often used in sedimentation traps and basins to promote the settling of sediment.
Discharge	A volume of water flowing out of a drainage structure or facility (measured in cubic metres per second or United States [U.S.] gallons per minute). May also refer to a discharge of water from an excavation as a result of dewatering.
Disturbed areas	Areas that have been purposefully cleared, grubbed, excavated, or graded. Ground surface that has been disrupted by construction activities, including construction access and roads, and staging and storage sites, producing significant areas of exposed soil and stockpiles.
Ditch	A small, artificial channel, usually unlined.
Diversion	The interception and conveyance of run-off into an unnatural channel (usually to protect a disturbed area).
Drainage area	A defined area of the land surface that run-off flows off of to a given location.
Due diligence	The legal expectation or requirement that individuals and companies will maintain a reasonable standard of care to protect worker safety and the environment.
Entrainment	The picking up of soil particles after they are detached by erosive agents.
Erosion	The physical removal or detachment of soil particles, followed by the entrainment and transport of the particles to another location.
Erosion control	The stabilization of soils using controls and practices, such as vegetation cover, mulches, protective blankets, wattles, fascines, or engineered materials.
Fascine	A long bundle of live, woody material bound together and used for biotechnical stabilization of river banks and slopes.
Grade	The slope of a roadway, channel, slope, or natural ground.
Grading	Earth-disturbing activities, including excavation, cutting, filling, stockpiling, or any combination thereof.
Groundwater	Sub-surface water within a zone of saturated material (aquifer).
Grubbing	Removing stumps, roots, or brush.
Gully erosion	Results when numerous rills join to cut deeper, wider channels. In turn, gullying dramatically concentrates run-off and erosion rates.

Hydromulching	Application of water-based slurry containing mulch (and tackifier) to the soil.
Hydroseeding	Similar to hydromulching, but with the addition of seed, fertilizer, and other specialized soil amendments.
Impoundment	A natural or constructed containment for surface water.
Infiltration	The movement of water through the soil surface into the ground.
Inlet	The entrance into a ditch, culvert, storm drain, or other water conveyance.
Lining	Protective covering installed over a channel substrate or, in the case of a pond, to prevent the infiltration of water.
Loading	Usually refers to the total contribution of sediment and other pollutants into stormwater and receiving waters from all sources.
Mulch	A natural or artificial layer of plant residue or other material that covers the land, preventing surface crusting, reducing erosion caused by wind and raindrop impact, and, in many cases, aiding in establishing vegetation by preserving moisture and reducing temperature fluctuations.
Non-point source pollution	Diffuse sources of contaminants (i.e. streets and driveways in a residential subdivision). These sources can add to a cumulative problem with serious health or environmental consequences.
Permeability	The capacity for transmitting water through a material or into the soil.
Permit	An authorization, licence, or a similar control document issued by The City of Calgary (The City) or another regulatory body to conform to the requirements of an environmental regulation or bylaw. Permits are usually issued based on the review of a written application and other information, and have conditions that must be adhered to.
Piping	Seepage or sub-surface flow often causing removal of soil, eroding larger and larger pathways or “pipes.”
Precipitation	The falling to ground of atmospheric moisture as rain, snow, or hail, measured in depth or intensity.
Qualified Designer	A person with designation as a Professional Agrologist (P.Ag.), Professional Engineer (P.Eng.), Certified Professional in Erosion and Sediment Control (CPESC), or Professional Licensee Engineer (P.L.Eng). Also called the Project Designer.
Qualified Inspector	A person with the education and experience necessary to inspect a construction site to ensure the ESC measures prescribed in the ESC Plan are being employed and are effective. Designation as a Canadian

	Certified Inspector of Sediment and Erosion Control (Can-CISEC) is one method of attaining the qualifications of a Qualified Inspector.
Raindrop erosion	The dislodging of soil particles caused by the impact of raindrops.
Retention	The holding of run-off in a basin without release, except by means of evaporation, infiltration, or emergency bypass.
Revegetation	The planting of indigenous plants to replace natural vegetation that is damaged or removed as a result of construction activity or other forces.
Rill erosion	The formation of numerous, closely spaced streamlets due to the increased concentration and velocity of sheet run-off on slopes.
Riparian	The land area around a body of water that is critical in supporting aquatic habitat (e.g. cover, filtration, and adsorption of pollutants, or soil stabilization with roots).
Riprap	Angular, durable rock meeting a design size gradation. Riprap is used to control erosion in high-energy environments.
Rolled erosion control products (RECPs)	Biodegradable or synthetic soil coverings used to protect exposed soils from erosion. Classes of RECPs included erosion control blankets, turf reinforcement mats, and composite turf reinforcement mats.
Run-off	A volume of surface water that exceeds the soil's infiltration rate and depression storage; thereby, running over the land surface and off the construction site.
Sand	Inorganic soil particles 0.06 to 2 mm in diameter.
Scheduling	A document identifying major construction and soil-disturbing activities and the time allotted to each activity for completion.
Scour	Erosion caused by concentrated water flow, carrying away material by abrasive action. Scour can commonly occur at the toe of stream banks, often resulting in bank undercutting. Unprotected inlets and outlets at stormwater conveyances are also prone to scour if not adequately protected.
Sediment control	Capture (by settling or filtration) of sediment produced by erosion.
Sediment	Soil particles detached and mobilized by erosion.
Sedimentation	The gravitational deposit of transported material from flowing or standing water or air. Sedimentation occurs when the energy of the transport agent is less than gravitational forces acting on material.
Seepage	The percolation of underground water through slopes, river banks, or at the base of slopes. Seepage can often cause erosion or make the stabilization of seepage-prone areas difficult.

Sequencing	An orderly list of all major land-disturbing activities and the proposed ESC measures associated with each.
Sheet erosion	The removal (entrainment) of thin layers of soil by sheets of flowing water.
Sheet flow	The movement of water in broad, thin sheets across a surface.
Silt	Soil particles 0.004 to 0.06 mm in diameter.
Slope texturing	Roughening, tracking, furrowing, grooving, or benching of slope surfaces to reduce flow path length; thus, controlling run-off and reducing erosion potential.
Soil disturbance area	The area of land stripped of vegetation and exposed to erosion.
Soil stabilization	Vegetative or structural soil cover used to control erosion (e.g. permanent, and temporary seed, mulch, sod, and pavement).
Source control	An effort to control pollutants (such as sediment at the source). Controlling run-on and run-off, and quickly stabilizing exposed soils during construction activities are all examples of source control.
Storm sewer	A system of structures (such as catch basins, underground pipes, manholes, and outfalls) that collect and convey stormwater run-off to treatment structures (such as storm ponds) or receiving water bodies. In many areas of Calgary, storm sewers connect directly to receiving water bodies; therefore, it is especially important that controls and practices are developed and implemented to control point source and non-point source pollution in such drainage areas.
Stormwater	Run-off and ponded water resulting from precipitation, snowmelt, and seepage.
Suspended solids	Organic or inorganic particles suspended in the water column (including sand, silt, and clay particles).
Temporary cover	A shallow channel intended to collect and convey water during run-off events.
Tackifiers	Non-toxic, organic or polymer glues that bind mulch and other materials.
Topography	The physical features (natural and constructed) of a land surface (i.e., flat, rolling, mountainous).
Total suspended solids (TSS)	Usually expressed as mg/L, TSS represents the mass of suspended material in a given volume of water.
Turbidity	Turbidity is the ability of particles in water to reflect light. The higher the amount of reflection, the more *turbid* a water is. High turbidity can negatively impact fish habitat and makes drinking water sources difficult

	and expensive to treat. Turbidity can easily be measured in the field using a handheld turbidity meter (measures light scattering). Results are expressed in nephelometric turbidity units (NTU).
Turbulence	Turbulence reflects an energy state of water where the flow regime is chaotic. Turbulence occurs in flowing water that has a high velocity and can be initiated by cross-currents; uneven, shallow substrates; and eddies.
Water body	Surface waters, including rivers, streams, lakes, and wetlands.
Wetland	An area that is inundated with surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation adapted to saturated conditions (swamps, marshes, bogs, and similar areas).

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