CHAPER 8 METRIC CONVERSIONS

Metric	Imperial Equivalent
50 mm	2 inch
2 cm	0.8 Inch
10 cm	4 inch
50 cm	20 inch
100 m	330 feet
1,300 kg/ha	1,150 pounds/acre
1,700 kg/ha	1515 pounds/acre
5 mm/hr	0.2 in/hr
10 mm/hr	0.4 in/hr
0.4 m/day	1.3 feet/day
1.2 m/day	4 feet/day
2 ds/m	2 mmho/cm
4 ds/m	4 mmho/cm
8 ds/m	8 mmho/cm
1 µg/ml	1 ppm
1 µg/g	1 ppm

Conversions in this table are rounded to a convenient number.
See Appendix E for exact conversion factor.

Values from tables and examples are not included in Metric Conversions

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CHAPTER **8**

SOILS

INTRODUCTION

This chapter discusses soil management practices for protection of the environment. It contains introductory information on soil quality. It also contains information on environmental concerns, legislation and beneficial management practices related to:

- soil management

SOIL QUALITY FACTORS

The following soil quality factors are listed in alphabetical order. While these factors can be influenced by agricultural production, they also may be influenced by other human activities and natural phenomenon.

Carbon to Nitrogen Ratio

Applications of soil amendments high in carbon or nitrogen can alter the carbon-nitrogen (C:N) ratio of soils. The median C:N ratio of soils in equilibrium are in the order of 12:1. Wood residue, by comparison, has a C:N ratio near 300:1. The application of materials with a C:N ratio greater than 25:1 will tie up available nitrogen in the soil. Repeated application of high-carbon materials will continue to lower the level of available nitrogen in the soil until a new soil equilibrium is attained. Soils with high C:N ratios will have less nitrogen available for plant use.

Compaction

Soil compaction is the compression of a soil, usually caused by heavy equipment traffic on the site. It results in a loss of soil structure and aggregate stability, and therefore a reduction in soil porosity. Compaction reduces the movement of water, air, nutrients, and soil microbes through the soil. Farm traffic and tillage can result in compaction, particularly when the soil is wet, at either the soil surface or the plow layer. Soils left bare during wet periods, particularly during winter on the South Coast, often have a thin compacted or "puddled" layer at the surface which significantly reduces air and water movement into and out of the soil.

Cover cropping and the incorporation of organic matter in the form of crop residue, mulches, compost, or manure can help to prevent compaction and may actually restore compacted soils. Timely and appropriate tillage and traffic on fields will also reduce the risk of compaction. Livestock may also impact soil structure. Poaching, which is the destruction of structure in the upper layers of the soil, is caused by livestock hoof action in poorly drained conditions.

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Drainage

Soil drainage addresses the challenge of cold and wet soils, which in turn controls the number of workable days in a field. The drainage class of a soil depends partly on the soil texture in the soil profile: coarser-textured soil (e.g., sand) is usually more efficiently drained than finer-textured soil (e.g., silt or clay). Drainage class also reflects the landscape: a deep and coarse permeable soil in a depression, with a high water table, could be an imperfectly drained or poorly drained soil.

FIGURE 8.1 Screen shot of the information that can be obtained from the on-line BC Soil Information Finder Tool (SIFT) tool.

To find information regarding drainage and surface soil texture, the BC Soil Information Finder Tool (SIFT) is a useful resource

- Soil Information Finder Tool (SIFT)

Organic Matter

Soil organic matter refers to organic matter that has become part of the humus portion of the soil. It does not refer to plant residue or organic matter which is applied to or remains near the soil surface, and which may be recognizable. Soil organic matter is involved in nutrient cycling by supplying and holding nutrients. Soils high in organic matter are also more efficient in holding water and contribute to aggregate stability or resistance against different types of topsoil loss (erosion). Levels of soil organic matter change relatively slowly over time but are strongly influenced by farming activities and climate.

Potential Soil Contaminants

Agricultural By-Products. Agricultural by-products as defined in the Code of Practices for Agricultural Environmental Management are generally safe to be applied to soil. However, they may sometimes contain elevated levels of metals and nutrients, salt content and pathogens. Examples of agricultural by-products which may be applied to the soil are vegetative debris, such as crop residue, spent mushroom-growing media, manure which may be mixed with bedding or feed.

Non-Agricultural By-Products. Materials that are not agricultural by-products may contain metals, nutrients, pathogens, salts, organic matter, other contaminants, and petroleum products. These are materials such as drywall, glass, biosolids, anaerobic digestate or wood residue. They may be applied to soils as amendments or for other specific purposes.

Nutrients. Spills, improper storage, and over-application of chemical fertilizers or manure may lead to excess nutrient concentrations in soil. An overabundance of particular nutrients can result in toxicity to plants, soil and water pollution, and reduction of crop yield. Excess nutrients not utilized by plants can leach out of the root zone to groundwater or be carried into surface waters.

Pathogens. Most pathogens, such as bacteria, viruses, and parasites die off rapidly when exposed to sunlight and the biological processes which occur in soils. However, there are some that can remain infectious in soils for many years. Some pathogens can be transferred between plants, soils, and animals.

Pesticides. Soils can be polluted with pesticides as a result of excessive application rates, inappropriate application methods, improper disposal, and spills. The extent of contamination depends largely on the characteristics of the pesticide, particularly its persistence and solubility. Soil contamination can result in the elimination of beneficial insects, the inhibition of crop growth, and a reduction in viable crop varieties. In addition, domestic animals and wildlife may be harmed when feeding on contaminated crops or when ingesting soil particles that contain pesticides. A particular risk to humans is that pesticide accumulations in plant and animal products can make foods unfit for consumption.

Petroleum Products. Petroleum products, such as gasoline, diesel, and kerosene, and petroleum byproducts, such as oils, greases, paints, and solvents, are complex organic compounds that may contain metals and other contaminants. Petroleum products that loosely adhere to soil particles are easily washed or leached into surface or groundwater, while petroleum products that firmly bind to soil particles may restrict the growth of plants.

Wood residue. Wood residue leachate is acidic and will cause metals and nutrients to be released from the soil. High application rates of wood residue, either onto the soil surface or by incorporation, will increase the soil carbon-to-nitrogen (C:N) ratio because wood residue is high in carbon.

Leachate. can be generated when soluble materials are dissolved by water passing through them. Soil leachate normally contains soluble nutrients such as nitrates which have not been used by crops. The soil pH is reduced by strongly acidic leachate such as from silage or wood residue. Low pH makes some metals soluble, allowing them to be leached from the soil.

Micro-Elements and Metals

Metals that are beneficial to the soil-crop system are often referred to as trace metals or micronutrients. The application of materials or fertilizers containing excess metals may result in an unwanted accumulation of metals in the soil. Mineral supplements in feed or mineral licks can result in elevated concentrations of micronutrients or metals in soils from manure, typically boron, copper, zinc, and selenium. Crop uptake of metals is generally in low amounts due to the relative immobility of metals in soils, but metal buildup should be avoided to prevent reduced crop production and/or toxicity to plants or animals. Because metal solubility is pH dependent, changing the soil pH will change the potential for metal leaching. Refer to pH and **Figure 8.3, page 8-5**.

Nitrogen (N)

Nitrogen. The nitrogen cycle in agricultural soils is illustrated in **Figure 8.2**, next page. Nitrogen exists in two forms, inorganic and organic. The sum of these two forms of nitrogen is referred to as 'Total Nitrogen.' The inorganic forms (ammonium/ammonia and nitrate/nitrite) are the simple soluble forms that plants use. Inorganic nitrogen represents 2 to 5% of the total nitrogen in soil. The organic forms are complex insoluble forms.

Inorganic Nitrogen – Ammonium (NH_4^+). Ammonium is a common form of inorganic nitrogen used by plants, and it is found in soil, fertilizer, manure, and compost. After application to land, ammonium is converted by soil bacteria to nitrate (NO_3-). Because ammonium and nitrate are soluble, it is found in the liquid fraction of the soil.

Inorganic Nitrogen – Ammonia (NH_3). Ammonia is a gaseous compound of nitrogen and hydrogen that is predominant at high pH and easily volatilizes into the air. The transition between ammonium and ammonia is affected by both pH and temperature. Fertilizer and manure application practices, cultivation, irrigation, and drainage can all affect ammonia movement.

Inorganic Nitrogen – Nitrate (NO_3^-) and Nitrite (NO_2^-). Nitrate is another common form of inorganic nitrogen found in soil, fertilizer, manure, and compost. Nitrate does not generally bind to soil particles and is therefore prone to leaching. This is particularly true in areas such as the Lower Mainland where mild temperatures, intense rainfall events, and wet winters promote the formation and movement of nitrate through the soil. Nitrate leaching also occurs readily in coarse-textured soils that receive high rates of irrigation. The leaching of nitrates into domestic water sources is a significant health concern. Nitrite is an unstable transitional form of nitrate. Both nitrates and nitrites can be toxic to aquatic life.

Soil bacteria, under certain conditions, convert nitrate and nitrite to gaseous nitrogen or oxides of nitrogen, a process called denitrification. This conversion results in the movement of nitrogen from the soil to the air.

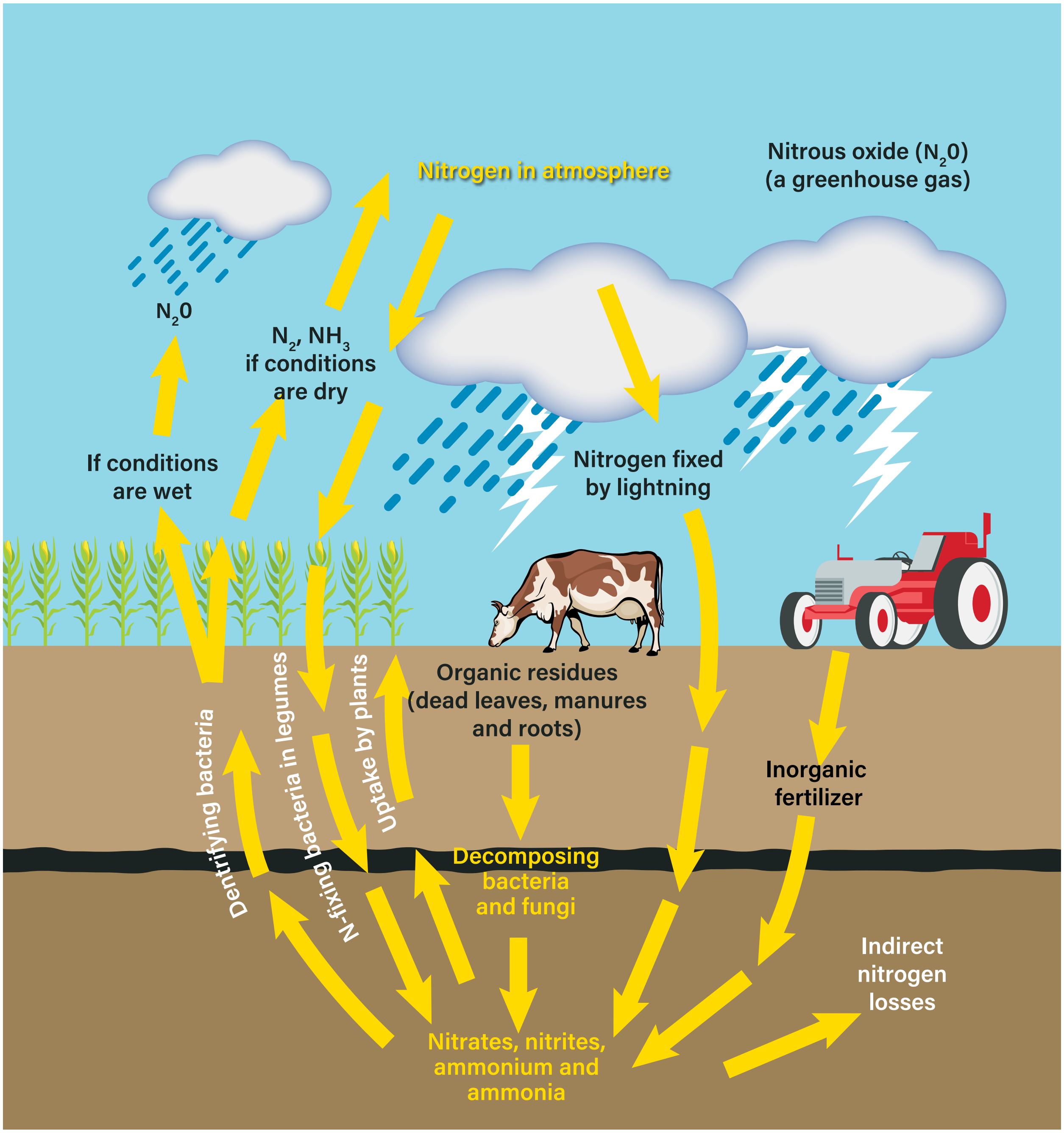


FIGURE 8.2 Simplified Nitrogen Cycle

Organic Nitrogen. The largest pool of nitrogen in soils is in the form of organic nitrogen. As organic matter is broken down by bacteria and other soil organisms, the nitrogen is either converted to the two common inorganic forms of ammonia or nitrate, or returned back to the nitrogen pool as new organic matter in the form of plant or soil microbial biomass.

Additions of manure, crop residue, compost, and other organic nutrient sources can change the size of the pool of organic nitrogen held in the soil. In contrast, cultivation and other cultural practices cause oxidation of organic matter and will result in the loss of nitrogen from the pool

Phosphorus (P)

Phosphorus has a low potential to leach into groundwater because it is normally strongly bound to soil particles. However, in coarse soils and in fields that have experienced repeated phosphorus fertilizer or manure applications over several years, the ability of soils to bind phosphorus can be low. Phosphorus availability is very dependent on soil pH (refer to Figure 8.3) and the presence of mycorrhizal fungi. Aggressive tillage can destroy these valuable fungi resulting in a reduction of immediately available phosphorus. Cultivation can be of value, as it aerates and warms the soil resulting in microbial activity that releases organic phosphorus into available phosphorus forms. Artificial drainage of poorly-drained soils also increases this microbial activity and phosphorus availability, by allowing soils to warm more quickly than if the soil was not drained.

Potassium (K)

Potassium leaches slowly, particularly as the clay content increases in soils that shrink and swell. Potassium is therefore subject to building up in soils similar to phosphorus, if the additions of potassium to soil exceed the removal of potassium in crop harvests, erosion or both. Soil that regularly receives manure is rarely deficient in this nutrient.

pH

pH is a measure of the acidity or alkalinity of a soil. Soil pH has a significant impact on the availability of plant nutrients and micro-elements. It also impacts the activity of soil micro-organisms, and therefore the decomposition of organic soil amendments, such as manure. The impact of pH on nutrient availability varies with the type of soil, with the optimum for mineral soils ranging from 6.0 to 7.0 and for organic soils between 5.0 and 6.0. Optimum soil pH for specific crops may fall outside of these ranges. Figure 8.3, shows the effect of pH on the availability of nutrients in both types of soil.

As pH drops, the availability of many metals increases. A low pH can create a toxic metal environment within the soil that can impact plants negatively or can cause the metals to be more susceptible to leaching. As pH rises to levels above 7.5, certain nutrients such as boron become less available to plants.

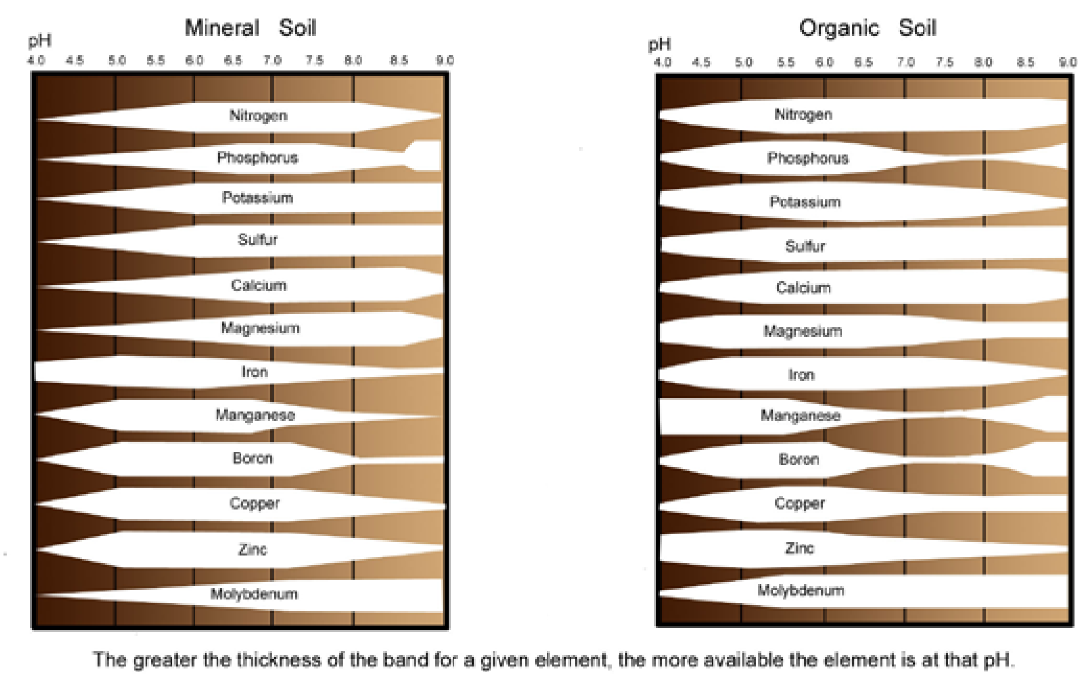


FIGURE 8.3 Effect of pH on Availability of Nutrients in Soil

Salts

Soluble salts in soil, which can impact crops, are measured by electrical conductivity (i.e., EC in units of dS/m). Crop species and varieties vary with respect to the levels of salts that they can tolerate. When the electrical conductivity of soils is above 2 dS/m, the soils are considered to be salt affected. Crops are generally broken into three sensitivity groupings based on how well they perform for given ranges of salt concentration: sensitive (0 to 4 dS/m), high tolerance (above 4 to 8 dS/m), and very high tolerance (greater than 8 dS/m). Soils above 4 dS/m are considered saline and will begin to cause a reduction in the yield potential of a wide range of crops. In some coastal areas of B.C. such as Delta, the projected rise in sea level would mean increasing challenges with soil salinity.

Sodicity is characterized by the sodium adsorption ratio (SAR). When the sodium adsorption ratio exceeds 13:1, soil structure is generally degraded, evidenced by a hard cloddy or crusted surface and reduced water infiltration due to loss of soil particle aggregation. In addition, sodium levels begin to become toxic to plants. Farms in Interior BC should be aware of the SAR levels of their soils and SAR levels of irrigation water when used on susceptible fields.

Secondary Nutrients and Micronutrients

Calcium (Ca). Calcium is an essential part of plant cell wall formation. Calcium is not readily mobile and is very important in soil structure formation.

Magnesium (Mg). Magnesium is essential to the formation of the chlorophyll molecule in plants. Magnesium is not readily mobile in soils.

Sulphur (S). Sulphur (also spelled as sulfur) is absorbed by plants in the sulphate (SO_4^{2-}) form, much the same way as nitrogen is absorbed as nitrate (NO_3-). Like nitrate, the plant-available form of sulphur is released by decomposition of organic matter by soil microbes. Traditionally, sulphur has been considered to be mobile like nitrate. However, sulphur adsorption can occur in acidic soils, such as those in the Lower Fraser Valley.

Micronutrients. These include elements like Boron (B), Copper (Cu) and Zinc (Zn). They are required for enzymes and other substances in plants that regulate important functions like photosynthesis, growth and respiration. In general, the range between deficiency and toxicity is narrow; the potential for toxicity to plants (and other organisms) is quite real.

Soil Texture and Structure

Soil texture is the relative proportion of sand, silt, and clay and cannot be easily changed. Soil texture describes the fineness or coarseness of soil (e.g., "sandy loam," or "silty clay"). It is influenced by the level of soil organic matter and activity of soil organisms. It influences drainage and nutrient adsorption and release, amongst other factors. Soil structure is the arrangement of the particles or aggregates in soil and is usually changed slowly by soil management practices, such as cultivation, amendment additions, type of crops grown, and water management.

Soil Texture Calculator

SOIL MANAGEMENT

Soil is a receiving environment just as air and water are. Good soil management promotes healthy plant growth, overall crop quality, and high productivity while preserving soil health. Productive soil depends on the appropriate integration of various field practices such as management of water, crop tillage and nutrient application. Excess water or nutrients will not only create problems associated with crop quality and yield, but will cause environmental degradation as well.

SOIL MANAGEMENT ENVIRONMENTAL CONCERNS

Primary environmental concerns related to soil management are:

- Soil loss through erosion by water or wind that results in air or water pollution.
- Excess soil removal with harvested crops, such as turf grass, nursery plants, and field vegetables, that results in loss of topsoil and eventual reduced crop yield.
- Soil compaction or structure degradation that results in decreased crop yield and increased runoff.
- Loss of soil organic matter that decreases an important sink for carbon and lowers the resilience of soils to adapt to climate change.
- Excess application of nutrients, micronutrients, metals, and contaminants that results in soil or water pollution.

For detailed information on these concerns:

➔ see Soil Quality Factors, **page 8-1**, and refer to Compaction, and to Potential Soil Contaminants

➔ see Nutrient Application, **page 6-1**

➔ see Water Quality and Quantity Factors, **page 9-1**, refer to Contaminants, and to Overland Flow

➔ see Air Contaminants, **page 10-1**

➔ see Impacts of Agricultural Activities on Greenhouse Gas Emissions, **page 12-6**

SOIL MANAGEMENT LEGISLATION

The following is a brief outline of the main legislation that applies to soil management.

➔ see **page A-1** for a summary of these and other Acts and Regulations

Agricultural Land Commission Act

The *Agricultural Land Commission (ALC) Act S.B.C. 2002, c. 36*, and *Agricultural Land Reserve (ALR) Regulations* are the legislative framework for the establishment, administration, and procedures of BC's agricultural land preservation program. The ALC Act takes precedence over, but does not replace other legislation and bylaws that may apply to the land. Local and regional governments, as well as other provincial agencies are expected to plan in accordance with the provincial policy of preserving agricultural land.

The *ALR General Regulation, B.C. Reg. 171/2002*, identifies the procedures for submitting applications and notices of intent.

The *ALR Use Regulation, B.C. Reg. 30/2019* specifies land uses permitted in the ALR.

- SECTION 7(2): the storage and application of soil amendments (fertilizers, manures, mulches and soil conditioners), other than compost
- SECTION 7(3):
  - (a) The production, storage and application of Class A compost in compliance with the *Organic Matter Recycling Regulation, B.C. Reg. 18/2002*, if all the compost produced, stored and applied is used on the agricultural land on which it was produced.
  - (b) The production, storage and application of any other compost that is from agricultural by-products that were produced for a farm use.
- SECTION 35: permitted soil or fill uses on agricultural land
- SECTION 36: prohibited fill materials

The ALC's Policy L-23 provides further information reflecting the regulations regarding the placement of fill for soil-bound agricultural activities.

Placement of Fill for Soil Bound Agricultural Activities

Bylaw No 2: Placement of Fill in the ALR, outlines the conditions under which an application for Non-Farm Use must be made, and which exemptions exist.

Information Bulletin regarding Bylaw No. 2: Placement of Fill in the ALR

Drinking Water Protection Act

The *Drinking Water Protection Act* and its Regulations have requirements to protect drinking water quality and regulate domestic water systems (those serving more than one single-family residence).

- SECTION 23(1): subject to subsection (3), a person must not (a) introduce anything or cause or allow anything to be introduced into a domestic water system, a drinking water source, a well recharge zone or an area adjacent to a drinking water source, or (b) do or cause any other thing to be done or to occur if this will result or is likely to result in a drinking water health hazard in relation to a domestic water system

Environmental Management Act

The Code of Practice for Agricultural Environmental Management requires persons to use environmentally responsible and sustainable agricultural practices when carrying out agricultural operations, for the purpose of minimizing the introduction of waste into the environment and preventing adverse impacts to the environment and human health.

Other regulations under the Act address soil quality parameters to protect human and soil health, including the following regulations:

The Contaminated Site Regulation (CSR) outlines the identification, investigation, and remediation of contaminated sites. Contaminated sites are areas where hazardous waste or organic and inorganic substances are in soil or groundwater at levels potentially toxic to humans, animals and the environment. Contaminated sites are typically the result of past industrial and commercial uses. They are unlikely to be found in areas located in the natural environment or where land uses, and the use of adjacent land, has exclusively been farming or forestry.

The CSR may also be relevant when landowners import soil onto their property as they may be liable for the remediation of the land if the soil that has been deposited turns out to be contaminated.

The CSR is administered by the Ministry of Environment and Climate Change Strategy.

SCHEDULE 2 of the CSR contains a list of activities at a site that may trigger an investigation and remediation. Agricultural and forest activities are not included.

SCHEDULES 3.1 TO 3.3 of the CRS contain standards (threshold) for soil and water to protect humans, livestock and the environment. Where those standards are exceeded, a site remediation may be required. It is unlikely that those limits are exceeded in the natural environment or where land, and the adjacent land, has been exclusively under agricultural and/or forestry production.

The Organic Matter Recycling Regulation and *Soil Amendment Code of Practice* govern the land application of particular residual materials, and these regulations refer to the *Contaminated Sites Regulation* to limit the accumulation of contaminants in soils.

Public Health Act

Administered by the Ministry of Health, this Act has a specific prohibition that "a person must not willingly cause a health hazard, or act in a manner that the person knows, or ought to know, will cause a health hazard". This prohibition would apply to farm practices that may result in a health hazard, such as when nutrients, contaminants or pathogens are discharged to land, water or air to pose a public health problem. Any situation that entails a health hazard will enable health officers to investigate using their powers under the Act. Under the *Public Health Act*, the local Health Authority must investigate any health hazard and has authority to order that a person prevent or stop a health hazard, or mitigate the harm or prevent further harm from a health hazard amongst other powers. Similar regulatory provisions exist for addressing health hazards to drinking water supplies under the *Drinking Water Protection Act*.

The Act has conditions under the *Health Hazards Regulation*:

- SECTION 8(1): provides separation distance from wells to be at least.
- 30 m from any probable source of contamination (probable source of contamination could include nutrients from agricultural by-products).
- 120 m from any dumping ground.

Wildlife Act

The provincial *Wildlife Act* protects wildlife designated under the Act from direct harm, except as allowed by regulation (e.g., hunting or trapping), or under permit. Legal designation as Endangered or Threatened under the Act increases the penalties for harming a species. The Act also enables the protection of habitat in a Critical Wildlife Management Area.

Fisheries Act

Administered by both Fisheries and Oceans Canada and Environment and Climate Change Canada, this Act is established to manage Canada's fisheries resources, including fish habitat. The Act can also be administered provincially by FLNRORD and ENV. The Act applies to all Canadian waters that contain fish, including ditches, channelized streams, creeks, rivers, marshes, lakes, estuaries, coastal waters and marine offshore areas. It also applies to seasonally wetted areas that provide fish habitat such as shorelines, stream banks, floodplains, intermittent tributaries and privately owned land. The Act includes provisions for stiff fines and imprisonment to ensure compliance.

The purpose of this Act is to provide a framework for (a) the proper management and control of fisheries; and (b) the conservation and protection of fish and fish habitat, including by preventing pollution.

This Act was updated in 2019 and now empowers the Minister to make regulations for the purposes of the conservation and protection of biodiversity.

The definition of fish habitat is:"water frequented by fish and any other areas on which fish depend directly or indirectly to carry out their life processes, including spawning grounds and nursery, rearing, food supply and migration areas". The quantity, timing and quality of the water flow that are necessary to sustain fish habitat are also deemed to be a fish habitat. Furthermore, serious harm to fish includes the death of fish or any permanent alteration to, or destruction of, fish habitat.

Provisions of the *Fisheries Act* relevant to agricultural operations include:

- Protection for all fish and fish habitats;
- Prohibition against the death of fish or the 'harmful alteration, disruption or destruction of fish habitat';
- A permitting framework and codes of practice to improve management of large and small projects impacting fish and fish habitat;
- Protection of fish and/or fish habitats that are sensitive, highly productive, rare or unique; and
- Consideration for the cumulative effects of development activities on fish and fish habitat.

Specific SECTIONS of the Act include:

- SECTION 34.2 (1) The Minister may establish standards and codes of practice for:
  - (a) The avoidance of death to fish and harmful alteration, disruption or destruction of fish habitat;
  - (b) The conservation and protection of fish or fish habitat; and
  - (c) The prevention of pollution.
- SECTION 34.4 (1) No person shall carry on any work, undertaking or activity, other than fishing, that results in the death of fish.
- SECTION 35 (1) No person shall carry on any work, undertaking or activity that results in the harmful alteration, disruption or destruction of fish habitat.

Every person who contravenes subsection 34.4(1) or 35(1) is guilty of an offence and liable.

Notifying authorities about serious harm to fish or deposit of a deleterious substance:

- SECTION 38 (4.1) Every person shall without delay notify an inspector, a fishery officer, a fishery guardian or an authority prescribed by the regulations of a harmful alteration, disruption or destruction of fish habitat that is not authorized under this Act, or of a serious and imminent danger of such an occurrence, if the person at any material time
  - (a) Owns or has the charge, management or control of the work, undertaking or activity that resulted in the occurrence or the danger of the occurrence; or
  - (b) Causes or contributes to the occurrence or the danger of the occurrence.
- SECTION 38 (5) If there occurs a deposit of a deleterious substance in water frequented by fish that is not authorized under this Act, or if there is a serious and imminent danger of such an occurrence, and detriment to fish habitat or fish or to the use by humans of fish results or may reasonably be expected to result from the occurrence, then every person shall without delay notify an inspector, a fishery officer, a fishery guardian or an authority prescribed by the regulations.
- SECTION 38 (7) As soon as feasible after the occurrence or after learning of the danger of the occurrence, the person shall provide an inspector, a fishery officer, a fishery guardian or an authority prescribed by the regulations with a written report on the occurrence or danger of the occurrence.

Species at Risk Act

The *Species at Risk Act* has sections that protect listed species, their residence, and critical habitat. It applies to federal lands, internal waters (i.e., all watercourses), territorial sea of Canada, and the air space above them.

The provisions of the *Species at Risk Act* (known as the "safety net") could be invoked on BC Crown and private lands using a federal order under the Act if provincial action is not sufficient to protect listed species.

On private land, unless an order is made by the government, the Act prohibitions apply only to:

- Aquatic species at risk.
- Migratory birds listed in the *Migratory Birds Convention Act, 1994* and also listed as Endangered, Threatened, or Extirpated in Schedule 1 of the Act.

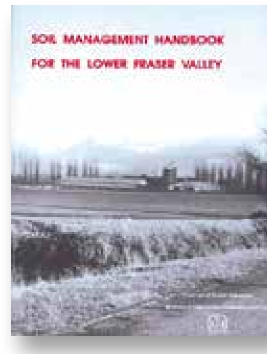
SOIL MANAGEMENT BENEFICIAL MANAGEMENT PRACTICES

Comply with applicable soil related legislation, including the above, and where appropriate, implement the following beneficial management practices to protect the environment.

Soil Cultivation

Cultivation plays a critical role in crop management and environmental protection. Implement the following practices:

To reduce the risk of erosion and compaction, cultivate fields only when testing has shown that soils are at the correct moisture content, such that when soil is squeezed by hand:



- Soils should be dry enough to easily crumble.
- If too dry, they will be either very hard or very powdery.
- If too wet, they will smear and compact more easily.
- Cultivate fields if the chance of significant rain in the forecast that could cause erosion is not expected.

Cultivate to incorporate nutrients in order to:

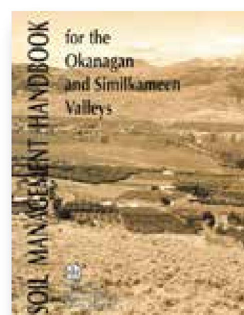
- Maximize nutrient retention.
- Improve infiltration and thereby reduce the risk of runoff flow.
- Interrupt excessive subsurface percolation.

Cultivate prior to liquid manure application to:

- Break macropores (macropores are formed by soil cracks, worm holes, and animal burrows and can lead to direct discharge of manure to surface water via subsurface drainage tiles).

Cultivate for weed control to maximize crop yield and crop nutrient use by reducing competition

- Effectiveness is dependent on timeliness, since even small weeds can cause significant crop growth reduction.



Cultivate after harvest to:

- Incorporate crop residue if the risk of being carried off by wind or runoff is present.
- Break traffic or cultivation pans for improved water infiltration.

Time cultivation for renovation of perennial forages to:

- Minimize risk of erosion;
- Minimize nutrient loss;
- Maximize germination and crop cover.

Cultivate the subsoil to improve aeration, to remove compacted layers, and to improve water management for:

- Better crop growth and nutrient use.
- Increased infiltration of water.

Soil Management Handbooks for BC

Soil Management Handbook for the Lower Fraser Valley

Soil Management Handbook for the Okanagan & Similkameen Valleys

Soil Management Handbook for Vancouver Island

Precautions. Consider the following precautions when cultivating:

- Do not over-cultivate since soil with reduced structure will have an increased risk of soil erosion.
- Do not use a conventional rototiller for repeated cultivation, residue incorporation, and/or weed control since too much cultivation with a rototiller will pulverize the soil and compact the subsoil over time.
- Establish and maintain adequate buffers between cultivated fields and sensitive areas to keep soil erosion and dust from causing a nuisance or pollution.

➔ see Buffers, **page 11-4**

Soil Erosion Risk

Erosion refers to the loss of soil due to water, wind or tillage. Erosion risk depends not only on management practices, but on the topography and climate of a region. Water erosion can be the result of surface runoff caused by rapid snowmelt, heavy rainfall, or excessive irrigation. Wind and water erosion occurs if soils are allowed to remain bare for extended periods of time. Wind and water erosion can each lead to loss of soil productivity and environmental problems. Eroded soil nutrients or fine-grained materials, such as silt or clay, can impact watercourses. Wind-blown soil can cause dust nuisance and respiratory health problems. Wind-blown sand in particular causes physical damage to stems and leaves. The damaged plants are then susceptible to diseases and other pests.

The susceptibility of a site to soil erosion depends on several factors, some of which apply to both wind and water, and others to wind or water alone. The following list may help to assess the site for its erosion risk.

Soil Texture and Structure. Soil texture and structure play a role in both wind and water erosion. Medium-textured soils, such as very fine sand, silt, and silt loam, are highly susceptible to erosion. Soils with good structure (arrangement and stability of soil particles and pores) are more resistant to erosion than are individual particles. Organic matter helps to create good structure, with the result that soils high in organic content are more resistant to erosion.

Soil Condition. Saturated or compacted soil conditions facilitate erosion because excess water will flow over the soil surface rather than seep into the ground. Similarly, very dry soil conditions create an environment where wind erosion is more probable.

Topography. Topographic conditions play a major role in whether a site is prone to water erosion. In general, the greater the slope, the greater the risk that erosion may occur. Erosion potential increases at a rate of more than 2.5 times for each twofold increase in slope. Slopes of greater than 2% are considered to present a moderate risk of soil loss if left bare, while slopes of more than 5% are considered to have high risk of eroding. Erosion potential increases by 1.5 times for each twofold increase in slope length. If slopes are longer than 100 m, the erosion risk is considered high.

Rainfall Intensity. Sites subject to high-intensity rainfall events or subject to rapid snowmelt runoff over frozen soils require extra management to prevent severe erosion. With predicted changes in rainfall intensity as a result of climate change, it is becoming increasingly important to address an increasing risk of soil erosion.

Wind Exposure. Winds with sufficient velocity and of high frequency can contribute to the movement of significant amounts of soil if low soil moisture is coupled with the absence of surface cover or wind barriers.

💻 An Introduction to Wind Erosion Control

Surface Cover. Bare and exposed soils increase both water and wind erosion potential. Bare soils are susceptible to a hundredfold increase in erosion potential when compared with grass-covered soils.

Detailed Assessment of Erosion Risk. Producers who wish to do a more complete water and wind erosion risk assessment on their sites can use a tool known as the Revised Universal Soil Loss Equation (RUSLE). This is a mathematical equation that predicts annual soil loss.

💻 The RUSLEFAC - Revised Universal Soil Loss Equation for Application in Canada

Field Soil Erosion by Water

Orientation of Rows. Crop rows that are planted up and down slopes facilitate the overland flow of water and therefore promote soil erosion. Similarly, crop rows planted in the direction of prevailing winds promote wind channeling effects that increase erosive forces.

The potential for soil erosion due to runoff flow varies between operations depending on the risk factors discussed above. To reduce the erosion potential, implement the following practices:

- Establish cover crops or maintain crop residue between plant rows, along headlands, and on fields during non-cropping periods to reduce the destructive impact of rain drops (Figure 8.4).
- Maintain a suggested minimum 30%–50% cover crop foliage on the soil surface during high rainfall or runoff periods.
- Plant crop rows along contours instead of up and down slopes to slow down and filter runoff flow.
- Install and manage drainage systems to maintain unsaturated soil conditions.
- If cover crops are impractical or result in too much competition for water, cover the soil with organic mulches, such as straw. In areas where frequent winds are expected, the straw will need to be anchored by disking or crimping.
- Establish and maintain adequate vegetated buffers between fields and watercourses to protect ditch and stream banks, and to filter and slow down runoff flow.

➔ see Buffers, **page 11-4**

- Modify tillage practices to keep crop residue on the surface for greatly reduced erosion potential.
  - Practice conservation tillage in all regions of the province.
  - Maintain a suggested minimum of 30%–50% anchored cover crop residue on the soil surface when crops are not growing.

Estimating Crop Residue Cover for Soil Erosion Control

- Use grassed waterways, drop structures, lined channels, or terraces to control more severe water erosion problems (technical advice may be needed to implement some of these special measures).

Soil Erosion Control BC

Minimizing the Effects of Runoff Flow. Runoff flow results from rainfall events, snowmelt or excess irrigation water. Controlling rainfall-generated stormwater on the farm can be a critical factor in reducing soil erosion in areas around buildings, yards, roadways, ditches, and fields. Uncontrolled stormwater flow is very erosive to soil, as it tends to be high in intensity. Such flow readily carries soil, crop residue, and agricultural by-products by virtue of its high velocity and turbulence. Minimizing runoff flow effects will have added importance with projected increased frequency and intensity of precipitation events occurring with climate change.

Stormwater from roofs should be collected and diverted into ponds or grassed waterways. Stormwater from roadways and yards should be collected and filtered to remove suspended solids, nutrients, and other contaminants. Clean water can be diverted directly into drainage systems if they have been designed to handle the peak flows characteristic of stormwater events.

➔ see Runoff, **page 9-50**

The interception of surface and subsurface flow from adjacent properties can reduce soil erosion:

- Drain areas on hillsides with shallow soils overlying compact subsoil, or areas subject to saturation, with tile lines placed across the slope and backfilled with a porous medium.
- Use porous interceptors, also know as French drains, to capture runoff.
- Maintain the land surface above such drains in a porous, open condition by establishing permanent vegetation directly over the drain line or by growing a winter cover crop.

➔ see Drainage, **page 9-42**

Grassed Waterways. Grassed waterways are designed to collect and transport water from fields while protecting the soil from the erosive force of rapidly-moving concentrated water flow. Grassed waterways may be integrated into fields from which forage may be directly harvested; however, they are usually designed to contain different species, and are subject to different management practices than the rest of the field.

Grassed Waterways

Soil Erosion Along Watercourses

Soil erosion along watercourses often occurs when the vegetation surrounding the watercourse, known as the riparian area, is in poor condition. Healthy riparian areas are critical in protecting stream banks from erosion, and, by extension, farmland. Well-vegetated riparian areas have a root mass that binds the soil together for good erosion resistance. If a watercourse starts eroding, especially if water flow volumes and velocities are high, soil loss can be dramatic and every difficult to stop. ➔ see Riparian Areas, **page 11-17**

Field Soil Erosion by Wind

Susceptibility to wind erosion is greatest when the ground is bare, when plants are young, or when land is unprotected from the effects of wind. Options for the control of wind erosion include reduced tillage, strip cropping, crop residue cover, mulches, windbreaks, shelterbelts, and wind barriers such as fences.

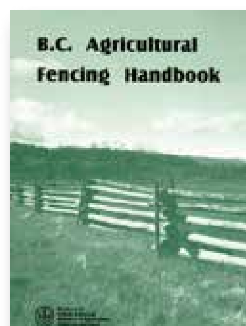
Strip Cropping. This management-intensive practice involves planting strips of crops with varying growth characteristics (e.g., alternate rows of grain and forage).

Cover Crops. Cover crops are useful for protecting the soil surface from erosion by wind. The taller and denser the crop, the better protected the soil will be. Planting cover crops provides additional benefits such as tying up nutrients until productive crops can utilize them. Most soils require a minimum 30% ground cover to prevent wind erosion. This means that choice of species, seeding rates, and planting dates are critical for cover crops to be effective. Suitable cover crops for early summer planting are cereal/legume mixes or annual ryegrass. Appropriate cover crops to follow late harvested annual crops include fall rye, winter wheat or winter barley.

Fences. Fences can provide protection from wind erosion where vegetative windbreaks are impractical. Fencing is a management tool which will be most successful when properly planned as part of an overall system for a farm or ranch.

B.C. Agricultural Fencing Handbook (series of Factsheets)

Mulches. The most effective mulches to reduce or control wind erosion are straw, coarse wood chips or larger pieces of crop residue. In order to be an effective erosion control practice the mulch must be anchored.



Crop Residue Cover. Crop residue left on the fields after harvest also provides erosion protection. To be effective, at least 30% of the soil surface needs to be covered by residue. Crop residue protects soil from wind erosion by reducing wind speeds at the soil surface. Residues can take the form of standing stubble or post harvest crop waste. In the case of cereal crops, a 30% cover is equivalent to about 1,300 to 1,700 kg/ha of residue. Highly erodible soils may require double this amount of residue to effectively reduce erosion.

Estimating Crop Residue Cover for Soil Erosion Control

Reduced Tillage. The risk of both wind and water erosion is decreased by reduced tillage practices. These include minimizing or eliminating cultivated fallow, decreasing the number of tillage events, and choosing implements and methods that minimize soil and residue disturbance. In areas where erosive winds are expected but field preparation requires bare soil for a limited time, try to leave a rough surface as opposed to smooth surface.

Protecting Pastures. Overgrazing reduces long-term pasture productivity and leaves soil prone to erosion. Manage grazing to leave adequate plant cover at all times.

Windbreaks. Establish and maintain adequate vegetative buffers in strategic locations around the farm to minimize soil erosion by wind and to prevent dust from creating a nuisance or causing pollution. Agroforestry practices, including shelterbelts, timber belts, and alley cropping can also be implemented to provide windbreak functions. All vegetative buffers and agroforestry practices improve carbon sequestration in farming systems, providing an important means to mitigate climate change.

➔ see Buffers, **page 11-4**

Soil Loss by Harvest

The degree of soil loss caused by certain harvest practices is dependent on the type of crop grown and the soil moisture conditions at harvest. Harvesting of balled and burlapped nursery stock, turf, and field vegetable crops commonly remove soil from fields. In the case of field vegetables, most of this soil remains on the farm after crop washing and eventually should be returned to the field. In cases where soil loss is unavoidable, rebuild the soil by adding amendments, such as sand, and by implementing practices that improve soil organic matter content, such as cover cropping.

➔ see **Chapter 6**, Nutrient Application

FIGURE 8.4 Relay Cover Crop in Corn Stubble

The following practices are recommended to reduce soil loss.

Field-Grown Nursery Stock. Prune roots, use large pot sizes when planting out stock, market bare root plants in place of ball & burlapped when possible, and avoid wet soils during harvest.

Turf Nursery. Reduce the depth of cut, use ground netting, and avoid wet soils during harvest.

Field Vegetables. Avoid cultivation activities on wet soils which causes clodding. Avoid harvesting in wet soils. Use soil eliminators on mechanized harvesting equipment.

Nutrient Management

Nutrient requirements are likely to be different for each field and crop. It is important to understand specific nutrient requirements to minimize excess soil nutrients and their losses from the field. This is best accomplished by following a Nutrient Management Plan.

➔ see **Chapter 6**, Nutrient Application, for general information on nutrient management

Leachate Formation in Soil

Leaching is the removal or transfer of soluble compounds by water from soils or other materials such as manure, silage, compost or wood residues which have been incorporated into or placed on the soil. The primary concern is the potential for leachate nutrients or metals reaching surface or groundwater.

➔ see Leachate, **page 9-58** for information on leachate management

Leaching of metals from soils occurs when soil pH decreases, causing metals in the soil to become more soluble, contributing to a greater risk of toxic leachate formation. In order to reduce the risk of leachate generation containing metals, implement the following practices:

- Know the effect of various soil amendments and mulches on soil pH and maintain soil pH above 4.5.
- Wood residue added to soil will lower soil pH.

➔ see Wood Residue, **page 2-40**

Contaminant Movement in Soil

The movement of contaminants in soil, such as petroleum, nutrients, pesticides, or leachate, is affected by:

- The amount of water moving through the soil, such as from rainfall, irrigation or runoff.
- The infiltration and permeability of the soil, in particular the presence of preferential soil paths caused by cracks or macro-pores.
- The ability of the soil to bind contaminants.
- The breakdown of contaminants by soil microbes.

The rate at which contaminants on the soil surface enter the soil is controlled by the soil's infiltration rate. Permeability is a measure of the rate at which water moves through the soil. The size and continuity of soil pores control both permeability and infiltration, and thus the risk of contaminant leaching. Factors which influence infiltration and permeability are shown in **Table 8.1**. Soil texture and structure have the highest weighting with respect to the risk of leaching.

There is generally an inverse relationship between the risk of leaching and the risk of runoff. For example, a fine textured clay or silt soil with large pores or cracks will have a higher risk of leaching, at least to the depth of a dense compacted layer or to subsurface tile drains. If this same soil was cultivated to eliminate macropores, the risk of leaching, would be low. Soils with a low risk of leaching generally contribute to a higher risk of runoff. **Table 8.1,** describes the factors which contribute to increased risk of leaching and in reduced risk of runoff. Soils that are moderately to well drained are generally most desirable for cropping, also have an inherent, yet manageable risk of leaching.

Coarse-textured soil has a specific meaning in the *Code of Practice for Agricultural Environmental Management*. The term refers to soils with a saturated hydraulic conductivity (K_{sat}) of more than 10^{-3} cm per second. **Table 8.2** lists the soils in B.C. that have been mapped and can be expected to have K_{sat} values greater than 10^{-3} cm per second. This list is meant to be used with the BC Soil Information Finder Tool, (SIFT) can be used as guidance to avoid sites of coarse-textured soil if required by the *Code of Practice for Agricultural Environmental Management*.

- Hydrologic Soil Groups, United States Department of Agriculture
- Soil Information Finder Tool (SIFT)

TABLE 8.1 Factors that Affect Risk of Contaminant[a] Leaching — Worksheet 1

Factor	Soils with High Leaching Risk [b]	Soils with Low Leaching Risk [c]
Soil Texture	▪ Coarse textured sandy or gravelly. ▪ Fine-textured soil that shrinks and cracks during drying, if cracks connect with subsurface tile drains, bedrock, or the water table.	▪ Fine-textured, silty or clay, with low potential for shrinking and swelling. ▪ Greater than 15% clay. ▪ Homogeneous texture throughout the profile.
Soil Structure/ Pores	▪ Well structured, blocky or large crumbs with large or abundant pores (macropores) and/or column structures.	▪ Poorly structured, platey or smeared with few or fine pores (micropores). ▪ The presence of a self-sealing layer below the soil surface that forms in animal feedlots.
Soil Organic Matter Content	▪ Organic matter in well-structured mineral soil, resulting in significant large pores. ▪ Poorly decomposed organic soils (peat soils).	▪ Poorly structured mineral soil. ▪ Well decomposed organic soils (muck soils).
Soil Bulk Density	▪ Loose, with large lumps that do not easily break into smaller lumps.	▪ Dense, compacted or cemented.
Animals	▪ Abundant soil animals or burrowing insects.	▪ Soil animal or burrowing insects channels are absent.
Roots	▪ Abundant coarse roots and root channels.	▪ Few root channels and many fine roots.
Soil Depth to a Restrictive Layer or Water Table	▪ Shallow soils over gravel or fractured bedrock. ▪ Soils with shallow water tables.	▪ Deep, well defined topsoil and subsoil over slowly pervious rock or clay.

[a] Contaminants, such as manure, pesticides, petroleum, leachate, etc.
[b] High Risk of contaminant movement = infiltration more than 10 mm/hr & permeability more than 1.2 m/day
[c] Low Risk of contaminant movement = infiltration less than 5 mm/hr & permeability less than 0.04 m/day
Note - there is an inverse relationship between risk of leachate and risks of runoff:

- soils with a low risk of contaminant (leachate) movement generally contribute to a higher risk of runoff
- soils with a high risk of contaminant (leachate) movement are generally most desirable for cropping

TABLE 8.2	Soils[a] with saturated hydraulic conductivity of more than 10^{-3} cm/second			
Abbotsford	Debeck	Haynes	Onyx	Skaha
Abbot	Dub Lake	Isar	Paradise	Skins
Alix	Eena	Kammat	Parkill	Sitkum
Allison	Ellison	Kaslo	Peta	Stemwinder
Asp	Errington	Kaleden	Pillar	Snodgrass
Avis	Fishertown	Kitsumgallum	Pope	Stolle
Badshot	Fleet Creek	Kuhushan	Pari	Sprucebark
Beddis	Frog	Kinkade	Purjue	Stepney
Brennan	Galena	Kinert	Quamichan	Squally
Big Fish	Granite Creek	Kluk	Qualicum	Shass
Bohan Creek	Giscome	Kenneth	Quennell	Steepland 2
Banshee	Godey	Kennedy	Ragbark	Steepland 1
Barkerville	Gisborne	Kruger	Rainbowl	Succour
Bellhouse	Glade	Kiwigana	Ramsey	Suskwa
Burtontown	Gillis	Kwikoit	Rockface	Shuswap
Beaufort	Gammil	Kye	Roaring	Swift
Beaverdell	Glimpse	Larch Hill	Rockbluff	Solly
Cavanaugh	Gang	Layton	Rouke	Talus
Celista	Henning	Mapes	Rossland	Tamihi
Colony	Hellroarer	Malakwa	Rosewall	Trehearne
Canyonview	Hiller	Miner	Ruault	Trurans
Comiaken	Hooligan	Morice	Rutland	Tatton
Corporation	Haney	Moulton	Ryanier	Trewitt
Cassidy	Honeymoon	Neilson	Salalakim	Tzuhalem
Cultus	Holden	Nissen	Salmo	Vermelin
Dragon	Hester	Nighthawk	Saunier	Valemount
Dahl	Hastings	O'keefe	Sawtooth	Vedan Meadow
Decker	Huffer	Oona	Shepherd	Whipsaw
Dog Creek	Hupel	Ormond	Seaton	
Dil Dil	Hawks	Oyama	Shegunia	
Desperation	Hawarth	Osoyoos	Sechelt	

[a] The following soil series are described as rapidly drained in soil surveys. Rapid drainage is often associated with coarse-textured soils, many of which can have a saturated hydraulic conductivity exceeding 10-3 cm/sec. However, the user should be aware that drainage at a specific may substantially vary from the general description. This table must, therefore, be used with some caution and can only be considered as guide. Canadian Soil Information Service http://sis.agr.gc.ca/cansis/soils/bc/soils.html

Use the Soil Information Finder Tool to determine the soils most likely to be found at a given location based on soil maps. At any point on a soil map, up to three different named soils are likely to be present. The presence of any of these soils at a particular point is not guaranteed. One or more soil pits may need to be evaluated to confirm soil characteristics, including saturated hydraulic conductivity.

Soil Contamination

Contaminants may include non-organic compounds (e.g., salts, metals, pesticides, excessive nutrients) and organic compounds (e.g., hydrocarbons, oils, dioxins, furans, weed seeds, pathogenic organisms). To prevent soil contamination it is necessary to know the chemical characteristics of all materials used on the farm, including pesticides, fertilizers, manure, compost, and other soil amendments. Off-farm organic materials must be fully identified before use as well. Numerous beneficial off-farm organics are identified in Schedule 12 of the *Organic Matter Recycling Regulation*.

Implement the following practices to monitor and prevent soil contamination.

➔ see Farm Waste, **page 2-19**

➔ see Petroleum , **page 2-32**

➔ see Pesticides, **page 5-15**

➔ see Chapter 6, Soil Amendments, **page 6-4**

If contamination is suspected or does occur, consult ENV and a qualified environmental professional for remediation procedures.

pH Check. pH levels in soil may be affected by application of soil amendments or cultivation. Implement the following practice:

- Check pH levels every three to six years, or more frequently if soil pH levels are suspected of restricting crop growth and adjust pH in the soil as required.
- When soil pH is lower than 5.5 or higher than 7.5 on mineral soils special management is required to adjust pH, such as liming or acidifying the soil.
- Blueberries and cranberries are notable exceptions among crops with respect to soil pH tolerance; these crops thrive in low pH (4.5 to 5.5) conditions that are typical in bog soils, although these crops may be grown in mineral soils as well.

Soil pH Resources

Soil pH

Liming Acid Soils in Central B.C.

Understanding Different Soil Test Methods

Acidifying Soils

Salt Check. Salt levels in soil may be affected by application of farm nutrients, chemical fertilizers, or irrigation water. Monitor the salt level by measuring electrical conductivity (EC) and sodium adsorption ratio (SAR) on a regular basis. Implement the following practices:

- Check electrical conductivity every three to six years, or more frequently if soil salts are suspected of restricting crop growth.
- In the Interior of BC, check the sodium adsorption ratio of the soil every three to six years, or more frequently if levels are suspected of negatively affecting soil structure.
- Reduce salt and sodium levels in soil amendments as required.
- Check irrigation water quality.

➔ see Irrigation Water Quality, **page 9-25**

If salt levels within the soil are found to be high (when soil salt level exceeds 2 dS/m or when the sodium adsorption ratio exceeds 5:1), and if leached salts have been determined to not cause an environmental impact:

- remove the salt from the crop root zone by applying irrigation water at a rate that causes leaching to occur and/or improve drainage
- if the sodium adsorption ratio is found to be high, apply gypsum to the soil prior to applying water to cause leaching

Soil Management Handbook for the Okanagan and Similkameen Valley

Micronutrients and Metals Check. Micronutrient and metal levels in soil may be affected by the application of farm nutrients or chemical fertilizers. Implement the following practices:

- Check concentrations of micronutrients and metals in both soils and soil amendments:
  - In soils every three to six years, or more frequently if the soil tests indicate levels greater than soil limits shown in Table 8.3.
  - In manure every three to six years, or more frequently if the manure tests indicate levels greater than organic nutrient limits shown in Table 8.3.
- Reduce metal levels in farm nutrient sources as required by:
  - Changing to feeds with lower metal levels.
  - Altering soil pH to reduce metal uptake in crops.
- Reduce metal build-up in soil where required by moving manure applications to fields with low metal levels.

TABLE 8.3 Suggested Concentration Limits of Metals in Nutrient Sources and Soils

Metal		Organic Nutrient Limit [1] (total µg/g dry weight) [3]	Soil Limit [2] (total µg/g dry weight)
Name	Symbol		
Arsenic	(As)	13	25 [4]
Cadmium	(Cd)	3	10 [4]
Chromium	(Cr)	100	150 [4, 5]
Cobalt	(Co)	34	45
Copper	(Cu)	400	150 [6]
Lead	(Pb)	150	350 [4]
Mercury	(Hg)	2	0.6 [4]
Molybdenum	(Mo)	5	80
Nickel	(Ni)	62	150
Selenium	(Se)	2	1.5
Zinc	(Zn)	500	200 [4]

[1] Organic nutrient source limit (Class A Compost) from *Organic Matter Recycling Regulation, Schedule 4*
[2] Soil limit from *Organic Matter Recycling Regulation, Schedules 10.1* (Agricultural Land). Specific soil standards for environmental protection based on toxicity to soil invertebrates and plants.
[3] 1 µg/g is one part per million, or 1 ppm
[4] Specific soil standards for environmental protection based on livestock ingesting soil and fodder.
[5] Specific soil standard for Chromium +6
[6] Recommend lowering the standard to 40 µg/g for land which sheep are grazing and 150 µg/g for all other livestock

Soil Compaction

Soil compaction reduces pore spaces between soil particles, resulting in decreased air and water movement through the soil, deteriorated drainage conditions, and slower warming of the soil. The effects of severe soil compaction on crops include insufficient nutrient uptake, root damage, and premature aging. Environmental concerns caused by compaction are the excessive runoff flow due to the low infiltration rate of compacted soil and the associated discharge of nutrients to watercourses, and some metals will become mobile and susceptible to leaching.

Compaction is often caused by the operation of heavy machinery on wet soils and by inappropriate tillage techniques, such as those producing plow pan. Excessive tillage breaks soil aggregates, disrupts structure, and encourages quick decomposition of organic matter, all leading to a low organic matter content. The resulting low organic matter, in turn, contributes to the soil being even more susceptible to compaction.

Examine the sides of a constructed soil pit to determine if compaction is present. Check for soil layers, including thin crusts near the surface, which restrict root or water movement.

Surface Soil Compaction. It is difficult to reverse surface soil compaction. Freeze-thaw cycles, root activity, and soil animal activity are not sufficient to overcome annual compaction events. To prevent surface soil compaction, implement the following practices:

- Avoid working with equipment on wet soils.
- Keep livestock off wet soils.
- Ensure that fields are well drained during the growing season.
- Reduce the number of trips over a field with equipment.
- Minimize tillage, particularly operations which pulverize the soil.
- Use a wide variety of tillage implements including chisel plows or subsoilers, and vary tillage depth.
- Limit the weight on an individual axle to less than five tonnes.
- Install flotation or radial tires on equipment to better distribute weight.
- Ensure that tires are properly inflated following manufacturer's instructions.
- Use four-wheel-drive tractors for better weight distribution between axles.
- Ensure wheels are aligned with implement and follow the same tracks.
- Limit equipment and foot traffic to the same areas in a field (e.g., establish lanes and roadways).
- Employ good crop rotation practices with deep-rooted crops and cover crops.
- Delay entry into fields until the water table is 50 cm (suggested) below the soil surface.

Subsoil Compaction. Compaction of soils below the plow layer is more difficult to deal with than surface compaction. To prevent subsoil compaction, implement the following practices:

- Follow the steps outlined above for preventing surface soil compaction.
- Work soils only if they are dry within the tillage zone.
- Plant deep-rooted cover crops.
- Use a crop rotation program.
- Install a subsurface drainage system.

If subsoil compaction has occurred, subsoilers may provide some relief. However, this equipment may create other problems such as unwanted root pruning or increased compaction at the working level if the soil is too wet or if subsoiling occurs below the critical depth. Critical depth is the maximum working depth at which the soil can be cracked and lifted upwards rather than being laterally compressed. Below this depth, the subsoilers compact the soil and smearing occurs along the channels they create. Considering that much can go wrong when subsoiling, test subsoiling in a small area first to check whether it works for your specific case. Only use subsoiling equipment when the soil below the normal tillage layer is dry enough to fracture rather than smear.

Soil Compaction – A Review of its Origin and Characteristics

Soil Organic Matter Content

Soil organic matter is generated from the decomposition of crop residue and other organic materials. Soil organisms and microorganisms digest plant residues to form humus, the earthy, dark coloured material, often associated with topsoil. Humus breaks down very slowly, and provides fertility to the soil. In addition it binds mineral soil particles together, resulting in increased stability when the soil is wetted or cultivated. The impact of higher levels of organic matter in the soil not only improves soil fertility, but contributes to soil structure and plant vitality by:

- Holding essential nutrients for plant growth.
- Increasing resistance to erosion, crusting and compaction.
- Facilitating water and air movement through the soil.
- Increasing water retention capacity.
- Improving conditions for beneficial soil microbes.

Maintaining a high organic matter content in soils may reduce the amount of irrigation water, fertilizers and pesticides required. Soils with higher organic matter content are generally characterized by better tilth and are therefore less susceptible to damage caused by improper tillage. Soil organic matter is also a very important store of carbon in farms and ranches, mitigating greenhouse gas emissions and helping to adapt to changing climate conditions.

Cover Crops. Increasing the organic content of a soil by utilizing a "green manure" requires the growing of a legume or grass crop for deliberate incorporation into the soil before seeding or planting a new cash crop.

Mulches. Mulches are generally recognized as a tool for soil moisture conservation, weed suppression and soil temperature modification. Mind, however, that it may delay drying of the soil in spring and harbor diseases. Suitable mulch materials include straw, leaves, hay, grass clippings, crop residues, compost and wood residues. Mulch depths range from 2 to 10 cm. Mulches will decay over time and become part of the stable organic matter pool in soil. If high carbon-nitrogen ratios mulches, such as straw or wood residue, are incorporated by cultivation the amount of available nitrogen in the soil may be reduced.

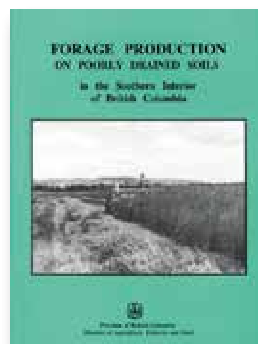
Wood Residues. Wood residues can be used as a soil conditioner to increase organic matter levels. Fine particle material or material that has been partially decomposed or composted is most appropriate. The amount of wood residues incorporated into the soil should not raise the carbon-nitrogen ratio above 50. If the carbon-nitrogen ratio is taken above this level, available nitrogen will be tied up for two to three years. The nitrogen will be released over time as the wood residue continues to decompose.

➔ see Wood Residue, **page 2-37**

Livestock Manure. Manure may be utilized as a source of organic matter; however, do not apply at rates higher than required for its fertilizer value. If manure is used as an organic amendment, it is recommended that its use be in conjunction with a cover cropping program to trap excess nutrients.

➔ see Chapter 6, Soil Amendments

Organic Soil Subsidence



Organic soil subsidence is the loss of organic material through erosion or decomposition. Subsidence can be prevented through effective water management, cultivation practices, nutrient management, and cropping.

An effective water management program will balance the drainage required to provide soil strength and aeration, with the supply of sufficient water to both promote crop growth and minimize organic soil decomposition.

Maintain waterlogged soil conditions to retard decomposition of some organic soils. Use caution when flooding organic soils, particularly muck soils that are highly decomposed or soil with shallow organic layers; flooding can create restrictive layers near the surface that reduce the effectiveness of drainage systems.

Drainage systems in wetland areas should be managed to regulate water table levels in response to changing crop and habitat requirements. Do not allow organic soils to dry out since excessive drying may discourage re-wetting and may result in the loss of the surface layers from erosion.

Avoid tillage practices that pulverize and leave organic soils exposed to air as this promotes rapid decomposition. Use minimum tillage practices for all organic soils.

Forage Production on Poorly Drained Soils - in the Southern Interior of British Columbia