# B.C. Agricultural Drainage Manual

## Chapter 4


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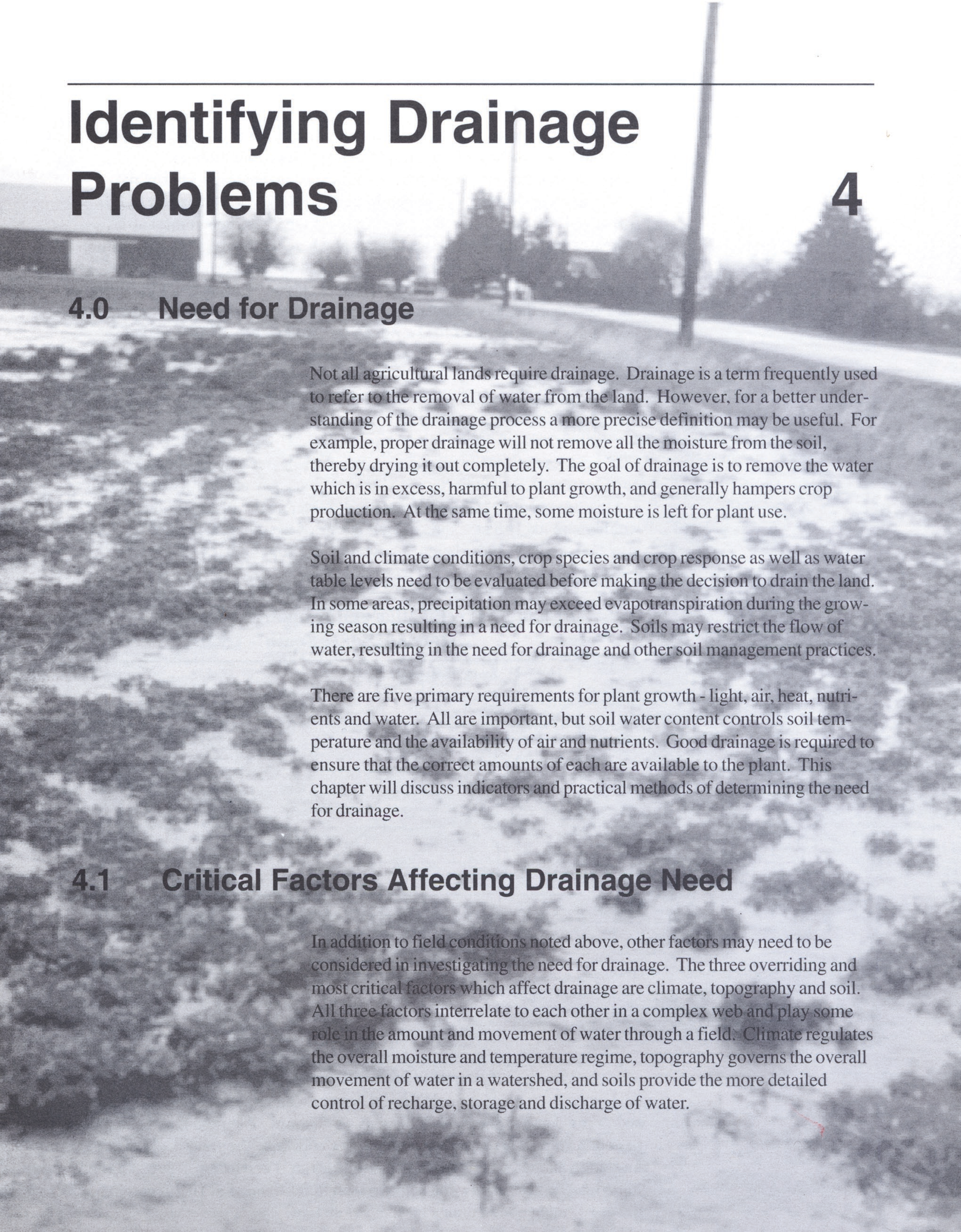

# Identifying Drainage Problems 4

## 4.0 Need for Drainage

Not all agricultural lands require drainage. Drainage is a term frequently used to refer to the removal of water from the land. However, for a better understanding of the drainage process a more precise definition may be useful. For example, proper drainage will not remove all the moisture from the soil, thereby drying it out completely. The goal of drainage is to remove the water which is in excess, harmful to plant growth, and generally hampers crop production. At the same time, some moisture is left for plant use.

Soil and climate conditions, crop species and crop response as well as water table levels need to be evaluated before making the decision to drain the land. In some areas, precipitation may exceed evapotranspiration during the growing season resulting in a need for drainage. Soils may restrict the flow of water, resulting in the need for drainage and other soil management practices.

There are five primary requirements for plant growth - light, air, heat, nutrients and water. All are important, but soil water content controls soil temperature and the availability of air and nutrients. Good drainage is required to ensure that the correct amounts of each are available to the plant. This chapter will discuss indicators and practical methods of determining the need for drainage.

## 4.1 Critical Factors Affecting Drainage Need

In addition to field conditions noted above, other factors may need to be considered in investigating the need for drainage. The three overriding and most critical factors which affect drainage are climate, topography and soil. All three factors interrelate to each other in a complex web and play some role in the amount and movement of water through a field. Climate regulates the overall moisture and temperature regime, topography governs the overall movement of water in a watershed, and soils provide the more detailed control of recharge, storage and discharge of water.

### 4.1.1 Climate

The most important of the three factors is climate. In South Coastal British Columbia, sometimes referred to as the "Wet Coast", rainfall and evapotranspiration (ET) characteristics must be understood. During the winter months (November through March) rainfall is well in excess of ET. The reverse is true during the growing season (May to September) as ET increases and rainfall decreases to a point where there is a climatic moisture deficit. On the margins of the growing season (March and October), the potential for saturated soil conditions is high. Figure 4.1 illustrates the difference between the 30 year average monthly evapotranspiration and precipitation in the western end of the Lower Fraser Valley. Most locations in the South Coastal Region have a similar annual pattern of precipitation and evapotranspiration. Most other regions of the province do not experience this peak of rainfall in the winter months, but rather have more uniform monthly precipitation rates over the entire year.

Climate does not usually play as significant a role in drainage need in areas outside Coastal British Columbia. Some regions may experience poor drainage that is apparently climate induced. However, many of these situations would more likely be the direct result of one of the other two critical factors affecting drainage, those being, topography and soil.

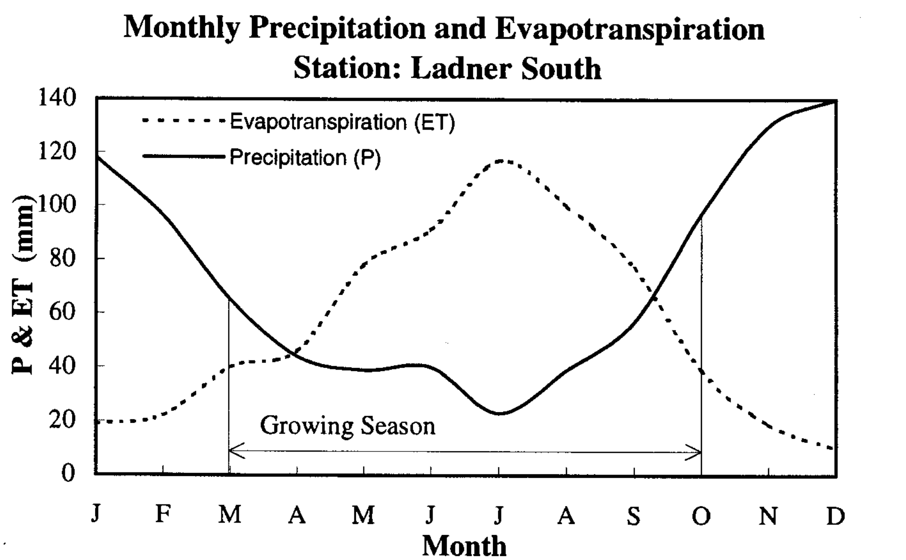


Figure 4.1 Annual Precipitation vs. Evapotranspiration at Ladner

### 4.1.2 Topography

Topography or slope is the second critical factor. Where the field lies, in relation to the surrounding landscape, will impact drainage. If the field is at the lowest slope position in the region, water will tend to collect on the field and/or the depth to the water table may be shallow. The field may be at the base of a slope where surface runoff water collects. The field could also be located in an area where groundwater discharge is occurring as a result of an impermeable layer below the soil surface. Refer to Section 10.2 regarding the use of interception drains for these situations.

Where this kind of topography is found, based on soil texture, the soils may not always be poorly drained. The field may be poorly drained simply because of excessive water and poor regional drainage. Figure 4.2 is an example of a valley with poor regional drainage which is restricting the discharge of drainage water, resulting in ponding at the base of the slope.

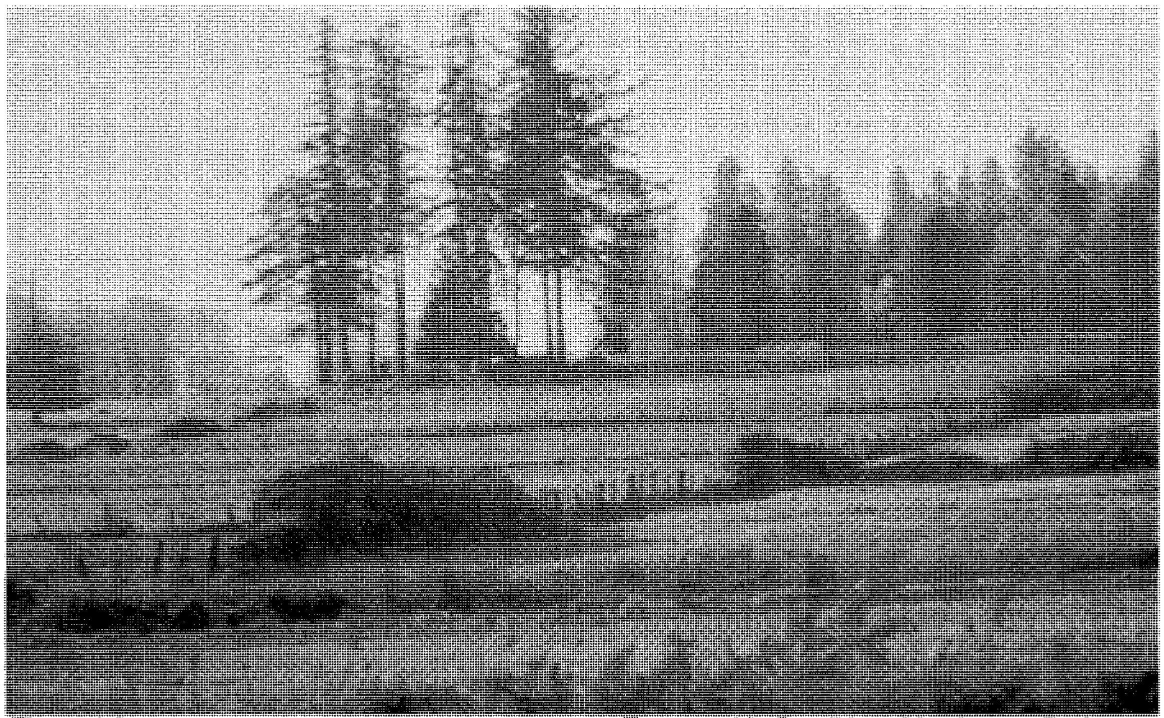

Figure 4.2 Topographic Conditions May Impact Drainage

### 4.1.3 Soil

The third critical factor is the physical characteristics of the soil within the field. Chapter 2 introduced soil and its many characteristics. Chapter 3 introduced water and its movement through soil, providing the basics of why water flows into, through, and out of a soil. Soil plays a significant role in drainage. A soil's texture and structure will either restrict or enhance the movement of water within the field scale watershed, which is discussed here.

A well drained soil, such as a sandy loam will have a rapid infiltration rate and high hydraulic conductivity. If the soil is in a well drained landscape, good drainage is expected year round. If the same soil is subject to poor regional drainage, such as a field that is adjacent to a water body and is subject to high water levels during freshet, then it is expected that poor drainage will be the result during these periods. An example of a well drained soil in a poorly drained landscape may be found on an island or along the banks of a river during freshet. These soils are usually gravelly sandy loams. Figure 4.3 shows a gravely sandy loam Iltcoola soil in poorly drained landscape along the Similkameen River.

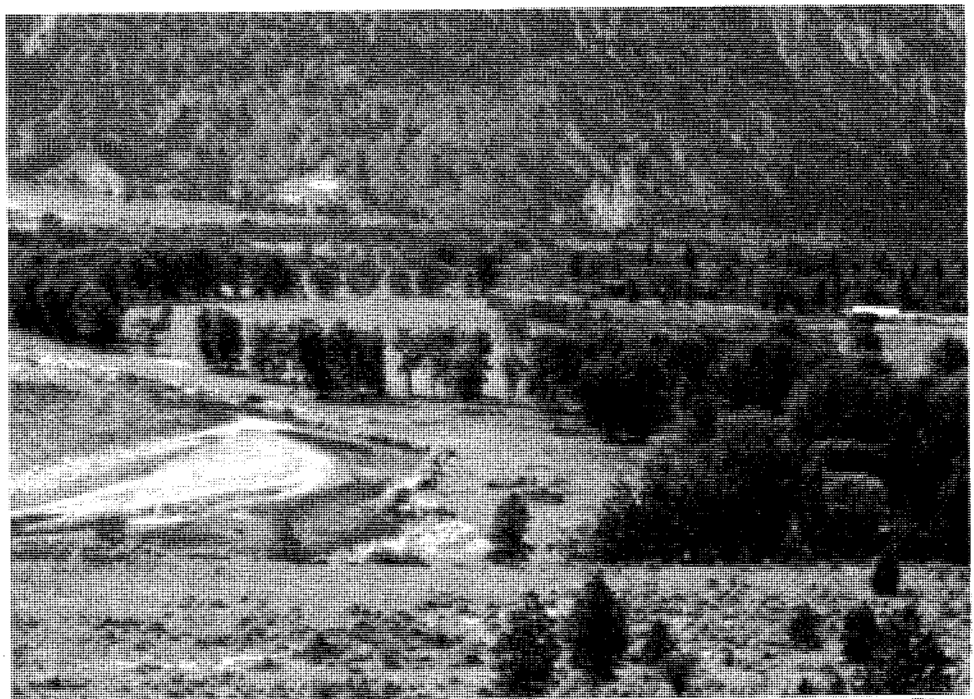

Figure 4.3 Well Drained Gravelly Soils Adjacent to Similkameen River

The opposite situation may occur where a silty clay soil with compact subsoil is present in a well drained landscape. Water flows rapidly off the field but the soil tends to remain saturated due to its high water holding capacity and low hydraulic conductivity. A drainage system can remove excess winter rainfall and control erosion in cultivated situations. An example of this situation is the Whatcom-Scat soils found in the uplands of the Langley/West Abbotsford area. These are silty clay loam soils formed in areas with slopes ranging from 5 to 25%. The soils remain moist for long periods of time and become saturated during the winter, leaving them vulnerable to surface runoff and water erosion. Figure 4.4 shows water ponding on Whatcom soils in a strawberry field with slopes of about 10 %.

Poor permeability or impervious soil structural layers may also contribute to poor drainage in a field. Downward water movement is restricted by zones of low permeability in the soil profile resulting in poorly drained conditions. Low permeability or impervious layers result in perched water tables (see Section 3.2). As in the case of soil textural, topographic or climate induced poor drainage, this kind of situation may result in temporary or long term saturated conditions in the soil profile.

Figure 4.4 Ponded Water on a Well Drained Landscape

## 4.2 When is drainage required?

To determine the need for drainage, field conditions must be assessed. The following are indicators of poor soil or regional drainage conditions:

1. Presence of water-loving plants such as reeds, hardhack, willow, sedges, horsetail, rushes or coarse grasses.

2. Land owner's experience with:
   - difficulties in working the field,
   - obtaining unsatisfactory crop yields, or
   - poor crop quality.

3. Surface appearance of:
   - ponded surface water,
   - high ditch or creek water levels,
   - wet spots or flowing water at the soil surface (i.e. springs),
   - boggy conditions,
   - poor crop response, damage or crop loss,
   - cloddy surface conditions after tillage operations, or
   - ruts or damage to fields produced by livestock or machinery.

4. Subsurface indicators of a high water table in the soil, such as mottled soil colour, shallow crop roots, or high water levels.

The presence of coarse grasses and reeds shown in Figure 4.5 indicate poorly drained conditions in this field. Figure 4.6 illustrates poorly drained conditions that resulted in soil compaction and rutting in a nursery operation.

Figure 4.5 Coarse Grasses and Reeds Indicate Poor Drainage

Figure 4.6 Compaction & Rutting – Indicators of Poor Drainage

# 4.3 Indicators of the Need for Drainage

There are many indicators of "drainage need" as illustrated in Section 4.2. The following sections will expand on those factors, such as, how to distinguish them from one another, and the potential causes for the poor drainage. The presence of water on the soil surface may be the result of three distinctly different conditions: ponding, a high water table or flooding. Figure 4.8 illustrates the differences between these three conditions. Other indicators of the need for drainage manifest themselves within the soil profile or as specific crop responses.

## 4.3.1 Surface Ponding

Surface ponding is often the result of impoundment of water in depressions at the surface resulting from 'puddled soils'. Ponded water at the soil surface may also be the result of a high water table. In some cases, both a high water table and surface ponding from puddled conditions may be present. Water table position is discussed further in Section 4.3.2.

Water on the soil surface may also be the result of flooding. Flooding is distinguished from ponding or a high water table by the source of the water. In general, flooding is the result of runoff or inflow of water onto a field from a source outside the field. Section 4.3.3 discusses flooding in more detail.

Puddling is the destruction of the soil structure at or near the soil surface. Puddling results primarily from the impact of raindrops on bare soil, however, improper irrigation, excessive cultivation, traffic on wet soils, deletion of soil organic matter and freeze-thaw weather conditions all can lead to puddled soil. Puddling is best defined as a change in orientation of clay size particles from random in an undisturbed soil to parallel or stacked in a puddled soil, as illustrated in Figure 4.7. Puddling is most likely to occur when the soil is above the plastic limit (as described in Section 2.6).

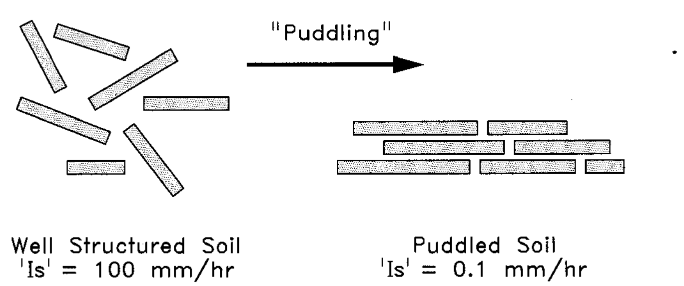


Figure 4.7 Puddling Schematic

Once a soil is puddled, the steady state infiltration rate "$I_s$" is significantly reduced. Infiltration rate controls the movement of water through the soil surface. If the rainfall rate or snow melt runoff rate is higher than the infiltration rate, then ponding will occur. This ponding can occur regardless of where the water table is in relation to the soil surface. In most cases, surface ponding from puddled conditions results when the soil within the plow layer is well below saturation and the water table is below the root zone.

| CONDITION | Ponding | High Water Table | Flooding |
|---|---|---|---|
| water on surface | yes | possibly | yes |
| soil surface | puddled | pervious | slowly pervious |
| subsurface soil | unsaturated | saturated | saturated or unsaturated |
| Soil Surface | $\nabla^{P}$ / $\nabla^{WT}$ | $\nabla^{WT}$ | $\nabla^{WT}$ / $\nabla^{WT}$ |
| **RATES** | | | |
| Rainfall Rate | ≥ 0 | ≥ 0 | = 0 |
| Infiltration Rate | = 0 | ≥ 0 | ≥ 0 |
| Percolation Rate | ≥ 0 | ≥ 0 | ≥ 0 |
| Description | • soil surface is "sealed" due to puddling of the soil particles restricting flow of water into the soil<br>• soil is unsaturated below the surface<br>• water table may be high but remains below the soil surface<br>• water source is precipitation | • water table has risen to or above the soil surface<br>• soil is saturated<br>• infiltration and percolation rates remain above zero<br>• water source is precipitation or a rising regional water table | • soil may or may not be saturated<br>• as flooding continues soil will become saturated<br>• infiltration and percolation rates remain above zero<br>• water source is from outside the field and generally results from overland flow |

$\nabla^{P}$ Ponded Water Level
$\nabla^{WT}$ Water Table

(shaded) Soil Surface
→ Indicates Movement of Water

Figure 4.8 Three Conditions: Ponding, High Water Table, Flooding

When surface ponding occurs as a result of puddled conditions, crop and soil management practices need to be altered to protect the soil surface from further compaction or structural degradation. High water tables need to be controlled by subsurface drainage practices to reduce the potential for ponding. Flooding requires control of water sources external to the field.

Ponded water is harmful to most soils and it worsens the drainage situation by causing layers of fine soil particles, which have a much lower permeability than the original soil, to be deposited on the surface. In some cases, surface drainage by land smoothing, cover cropping, reduced tillage and reduced traffic can be used to eliminate surface ponding. Control of surface ponding can be achieved more effectively by using subsurface drainage, along with soil and crop management practices that improve structure and increase infiltration such as cover cropping and reduced tillage.

## 4.3.2 High Water Table

As mentioned above, ponded water on the soil surface may also be the result of high water tables. If the water table of the field is at the soil surface, water will pond in depressions, along rows, or randomly within the field. When ponding results from a high water table, the permeability of the soil surface is not usually affected by puddling. However, long term exposure to high water tables and saturated conditions may adversely affect soil structure and lead to puddled conditions. This is especially true when the soil surface is left bare and exposed to high water tables. High water tables within a field may occur as a result of a rise in the regional water table during the winter, or during the freshet if the field is adjacent to a large watercourse. In the Lower Fraser River Valley, fields adjacent to the river may experience high water tables during the winter rainy season and the June freshet.

Section 3.5 discusses water movement and position of the water table. Position is an indicator of poor or restricted drainage. The preceding section referred to water on or at the soil surface. Water tables may also occur at various positions further down in the soil profile over the course of a year. If the water table is present within the root zone of a crop during the growing season, crop yield and quality will be impacted. Knowing the water table position in relation to both the effective rooting depth and the time of year will indicate whether the water table will impact the crop.

Water table position may be indicated by the presence of free water which can be observed from a pit dug in the field. In order to effectively determine the location of the water table the pit should be dug to a depth of greater than 1 m. It should then be left for a day to allow the water level to equilibrate. Once this has occurred, the depth to water table can be measured. Other signs in the soil profile may also show the presence of a high water table (refer to Section 4.3.4). A high water table which has resulted in surface ponding indicates a drainage need in the strawberry field shown in Figure 4.9.

Figure 4.9 High Water Table Causes Surface Ponding

A well drained soil or site can be defined as one with a water table that does not come within 0.30 m of the soil surface, or does so briefly, receding quickly to a depth of 0.50 m upon cessation of a storm event. Poorly or imperfectly drained soils or sites would have a water table that remains above the 0.30 m depth for long periods of the growing season.

### 4.3.3 Flooding

As indicated from the discussion above, ponded water in a field may result from several causes. Flooding may be one of the most difficult problems for a land owner to deal with as the water source is from outside the field rather than from precipitation that falls on the site. In the South Coastal Region of British Columbia flooding often results from stormwater flows or during the snowmelt runoff freshet.

Rainfall driven stormwater flows that result in flooding are difficult to predict and very difficult to manage from an individual farm standpoint. As they tend to be "flashy" in nature. To determine a drainage need based on storm water flooding the land owner must have a good understanding of the watershed the field is situated in. A good question to ask is: Are the upland reaches of the watercourse in urban areas, in logged areas, or in areas with restricted infiltrability? In these cases, rainfall will tend to runoff rather than infiltrate and slowly percolate through the soil. When rain falls in a watershed that has significant areas of restricted infiltrability runoff water moves quickly over the watershed resulting in high flow rates for a short period. These flows can overwhelm watercourses resulting in flooding. The best protection against this type of flow is to maintain dykes and reduce the amount of water retained in farm ditches. Maintaining some space in farm ditches may provide a buffer against the peak flow.

Flooding which results from a freshet tends to be less "flashy" in nature. Rivers or lakes tend to rise and fall at a lower rate during the spring thaw. Water volumes from freshet flows are normally higher than storm water flows. Higher dyking and pumping costs may be required to handle freshet flooding. Freshet flows are more predictable than storm water flows, so drainage system design and crop management can be planned around the flooding potential.

Storm water flows in Willband Creek in the Clayburn area of Abbotsford are shown in Figure 4.10. This is one example where, in general, these flows overwhelm the well defined creek channel in the foreground and spill into the adjoining blueberry and forage fields in the background.

Figure 4.10 Flooding Resulting from Storm Water Runoff

### 4.3.4 Soil Profile

Within the soil profile there are several direct signs of poor or restricted drainage. These are: colour, structure, odour and the presence of free water. A one meter deep pit with an exposed face will provide a good frame work and enable investigation of the soil profile.

**Signs of Restricted Drainage:**

***Colour*** – Blue, blue grey, blackish and grey (gley) tones as opposed to brown or brownish tones are good, though not infallible, indicators of poor drainage. Spots of grey, brown, black, yellow and particularly rust coloured blotches (mottles) in mineral soils also indicate poor drainage conditions that are usually caused by a fluctuating water table.

***Structure*** – Under poorly drained conditions, development of structure within the soil profile is usually weak or absent causing the soil to be more or less massive. Tillage operations that break the soil into large, coarse clods leave the field in a rough condition making proper seed bed preparation more difficult. In a well structured soil, air and water move freely in cracks, fissures and pores. A poorly structured soil may exhibit structureless or compacted layers such as plow pans or rust coloured iron pans.

***Organic Matter Content*** – Organic matter levels in poorly drained mineral soils are generally higher in the surface layer if they have not been exposed to cultivation. Poorly drained soils that have been cultivated tend to have very low organic matter contents. Organic soils, those that have greater than 30% organic matter, are developed under poorly drained conditions. The rate of water movement in organic soils is generally very high if they are in a partially or undecomposed condition. This is opposed to the very low rate of water movement in the underlying mineral soil that is often associated with organic soils.

***Odour*** – Under poorly drained conditions, soils will impart an anaerobic, swampy, stale or even putrid odour. This is a result of reduced or anaerobic conditions and the decay of organic matter or reduction of minerals as well as the presence of sulfur compounds.

***Free Water*** – Upon excavation of a hole or pit within the soil, free water appears indicating the presence of a water table. Over a short period of time the water level will equilibrate showing the depth to the water table. Observation over an extended period will show the extent of fluctuation of the water table near or within the root zone.

***Root Development*** – Roots reach their maximum extent in soils that have good drainage and well developed structure. On poorly drained or poorly structured soils, they will tend to die back and form a mass of fine roots in a layer that indicates the high water table level or the abrupt change in soil structure.

In addition, poorly drained soils do not provide the right amounts of air, nutrients, warmth and water required for proper plant growth. The soil may portray the following additional signs of not meeting these basic needs in many ways:

***Soil pH*** – In humid regions, a low pH is usually associated with inadequate drainage. Poorly drained soils of arid regions often have a high pH as well as a high conductivity (salt content). Salt crusts showing on soil surface indicate alkali formation, often associated with poor drainage.

***Temperature*** – Reduction of the water content allows the soil to warm more rapidly. Since the specific heat of water is approximately 4.2 joules per gram and that of dry mineral soil is about 0.8 joules per gram, five times as much heat is required to raise the temperature of wet soil than that of dry soil. Evaporation of water from a saturated soil also has a marked cooling effect due to the requirement of approximately 2.4 kilojoules of heat to transform one gram of water from a liquid to the gaseous state.

***Toxicity*** – In humid regions, chemical reactions in the soil which occur in the absence of oxygen (anaerobic) cause micronutrients and other compounds such as iron, manganese and hydrogen sulfide, to be transformed into a reduced state which may reach toxic levels. In arid regions, high evaporation causes gradual accumulation of salts near the soil surface that could build up to toxic levels.

***Aeration*** – Restricted or completely blocked aeration in high moisture level soils results in reduced gas exchanges. Accumulation of carbon dioxide in the soil pores and a subsequent reduced oxygen supply, adversely affect the uptake of water and nutrients by plant roots. Plant roots need to breathe.

*Fertility* – Availability of many plant nutrients is restricted by changes in pH and high moisture. The process of denitrification which alters plant available nitrogen and releases it to the atmosphere as a gas is increased. Other previously listed factors, which are detrimental to the growth of high yield domestic crops, contribute to a general state of low relative fertility.

Saturation of the soil for extended periods of time is harmful to most soils and generally causes reduction of crop yields. In addition, it causes trafficability problems, reducing land access and use. It is for these reasons that saturation of the soil should be avoided by means of appropriate drainage systems and other measures described below.

### 4.3.5 Crop Response

The growth of agricultural crops is adversely affected by continued saturation of the root system or by ponded water on the soil surface. Poorly drained soils exhibit many of the following features:

*Germination* – Seed germination is delayed and sometimes prevented due to high moisture levels, low soil temperature, reduced aeration and other associated factors which may cause the seed to rot. Also, rough condition of the seedbed reduces seed soil contact.

*Development* – Growth of crops is usually restricted, resulting in non-uniform development due to a variety of drainage conditions. High groundwater results in damaged soil structure which inhibits root development and causes shallow root systems.

*Colour* – The colour of annual crops is usually lighter than normal, similar to that caused by nitrogen deficiency, and is particularly evident when poor drainage conditions exist during the growing season. However, in grasses and other perennials, poor drainage is characterized by dark discoloration of dying or decaying plant matter and the predominance of coarse, dark coloured plant species such as sedges and rushes. Both colour impacts relate to the reduced availability of nutrients to the crop from changes in soil chemistry.

*Yield* – Most agriculturally significant crop species will generally have lower yields. The degree to which yields are depressed depends on the type of crop and the severity of the drainage problem.

*Uniformity* – Crop growth is often very uneven in fields that have restricted drainage. Due to the variability of soils, the impact of a high water table may result in the accumulation of water in areas of finer textured soils or in depressions in the field.

*Drought* – Crops are more susceptible to drought when poorly drained conditions exist. Rooting depth is reduced due to the high water table. When the water table drops in drought conditions, the crop is unable to respond by developing a good root system to extend to the new, lower water table level.

***Weeds*** – There are several weedy species which are common to wet, swampy land including: rushes, sedges, horsetail, silverweed, mosses, smartweed, water timothy, skunk cabbage, buttercup, chickweed, cattails, duckweed, reed canary grass, water foxtail and red sorrel.

***Diseases*** – Many diseases such as root or crown rot of grasses, cereals, alfalfa, clover, beans, peas, raspberries and strawberries may develop under poorly drained conditions. Blueberries, apples and potatoes may show signs of collar rot, crown rot and other diseases.

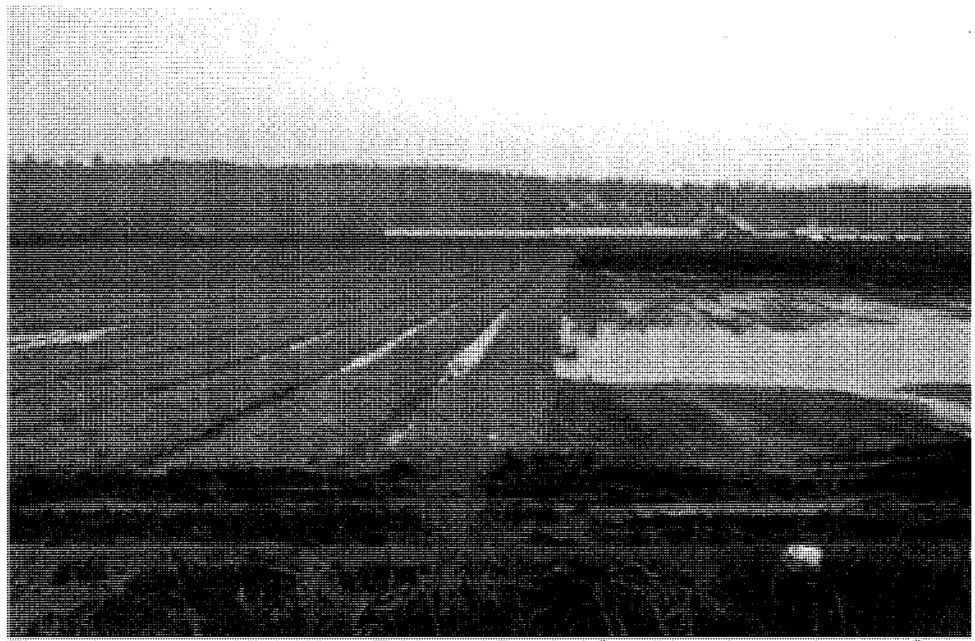

Figure 4.11 High Water Table and Ponded Conditions Impact Lettuce Crop

### 4.3.6 Animal Indicators

Wildlife and domestic livestock can impact drainage as well as act as indicators of poor drainage. Indications of poor drainage may also become apparent from an increased incidence of animal diseases or insect infestations such as foot rot, worms and flies. Poaching, which is the destruction of structure in the upper layers of the soil, is caused by cattle or horses trampling in poorly drained conditions. Livestock activity on wet soils may also result in a reduction in the infiltrability of the soil surface. In Figure 4.12, unrestricted cattle access has resulted in damage to a shallow dyke along the creek and caused the stream banks to slough into the channel. Reduced flows in the channel along with flooding and erosion in the field during freshet are the result.

Figure 4.12 Cattle Can Cause Stream Bank Degradation

Grazing on wet soils will cause damage to the grass sward by trampling on weakened or diseased plants, poaching, and tearing out of plants which have poorly developed root systems. Long term damage to soils and the forage swards will result from attempting to graze livestock on poorly drained sites. Poorly drained sites will also have a lower suitability for grazing as the range and palatability of species will be reduced.

Livestock can also impact on drainage by damaging drainage structures such as outlet pipes. Unrestricted access to watercourses by cattle, horses or sheep can result in stream and ditch bank slump or erosion. Access or damage to a watercourse may reduce flows in the watercourse or create areas where flood flows can spill out of the watercourse.

Wildlife, in particular beavers, can cause a serious impact on a site in terms of water management. Beaver, muskrats, otters, rats and other rodents can create dams, divert streams, burrow and erode banks or dykes, chew drainage pipes and generally wreak havoc on a drainage system. This type of wildlife activity, although not widespread in British Columbia, can be devastating when it does occur. Beaver impacts are common in the Cariboo, and in isolated locations in the south Coastal Region.

Rodents may also chew drainage pipes creating the risk of leaks or blowouts. Nests may be built in the system when it is dry, causing drainlines to stop flowing during wet weather. Rodent protection for outlet pipes, as shown in Figure 10.22, should always be used.

Management of livestock to reduce impacts on drainage may be easy to achieve through effective use of fencing and timing of grazing periods. On the other hand, management of wildlife, in particular beavers, may be more difficult. Where required, trapping of rodents, by professionals, can be used as a management tool to reduce the impacts of flooding or damage to a drainage system.

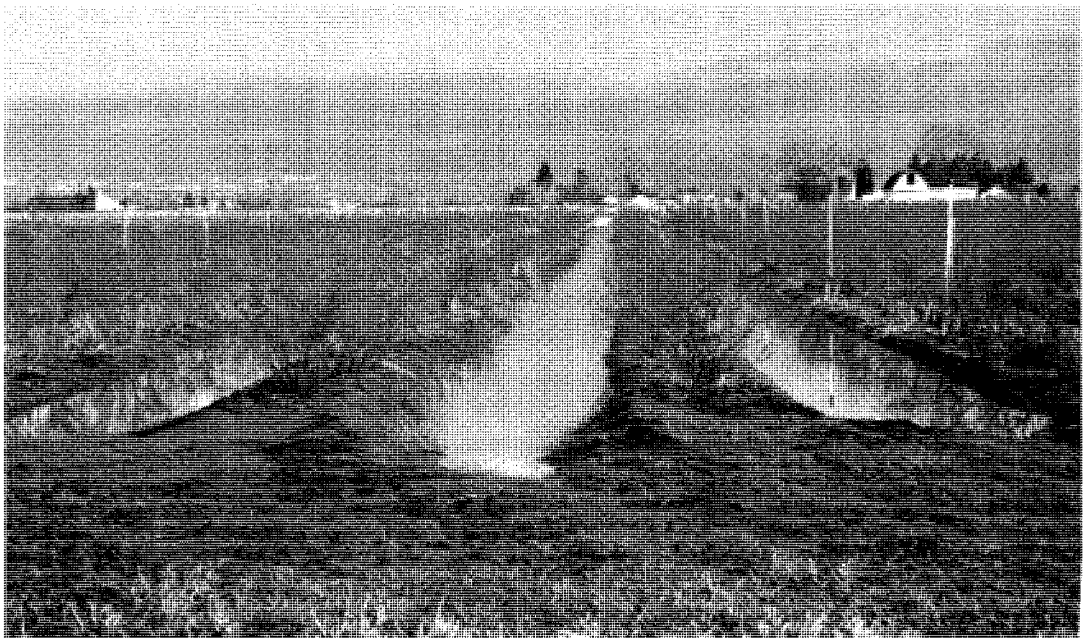

Figure 4.13 Impacts of Poor Drainage on Blueberry Crop

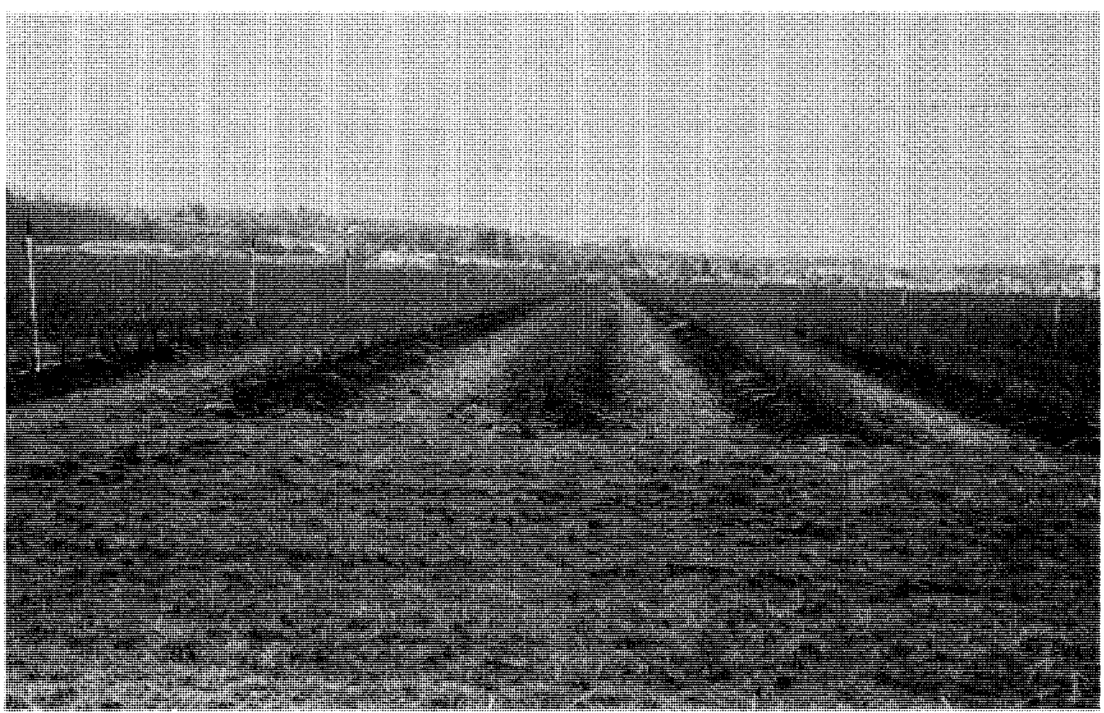

Figure 4.5 Impact of Well Drained Conditions on Blueberry Crop