B.C. Agricultural Drainage Manual

Chapter 5

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Drainage Solutions 5

5.0 Improving Drainage

The previous chapters have discussed soil, water and methods of identifying a drainage problem. This chapter will discuss methods of improving drainage. Solutions range from changes in cropping or tillage practices to installation of subsurface drainage systems. These systems may require sophisticated design procedures. Some sites may require the use of a multi-faceted approach like: using cover crops, surface grading and subsurface drainpipe installation. Often, improvements to drainage can be achieved without subsurface drainage, for example some soils may only require the use of special cropping or tillage practices such as periodic subsoiling.

An "all or nothing" approach to managing drainage problems on a farm through drainage improvement should be avoided. It is better to take a step by step approach to implementing improvements. Some methods have high capital costs while others have high maintenance and operating costs. The first drainage improvement considered should be the method that will provide the greatest benefit compared to its cost (benefit/cost ratio). The impact of some methods given in this chapter will vary and some will take longer to provide better drainage than others.

As an example of a step by step approach, it may be appropriate to look at a scenario where conditions have resulted in surface ponding, poor growth of the crop, compacted soil and surface runoff. In this case, the improvement with the greatest benefit/cost ratio may be the installation of surface drainage structures such as ditches and grassed waterways. These will carry excess surface water away from the site. Once the benefit of surface drainage is realized there may be other incremental improvements that can be made to further improve drainage. Additional improvements can be achieved by altering cropping practices, such as cover cropping and subsoiling. If these improvements do not provide the desired drainage improvement then high capital cost methods such as subsurface drainage systems should be considered.

Table 5.1 is a matrix of soil and water management issues that may occur on a particular site. In each case, a slightly different approach in terms of drainage solutions can be used to improve drainage. The sections following the table contain a brief discussion of the methods.

Table 5.1 Investigating Drainage Methods

Improvement Methods	Section	Soil and Water Management Issues: Surface Ponding								
		Puddling	High WT	Flooding	Poor Soil Structure	Poor Root Development or Compaction	Soil Erosion Control	Peat Soils	Acid Soils Toxicity	Salinity
Cropping Practice	5.1									
Cover Crop	5.1.1	✔		✔	✔		✔	✔		
Soil Amendment	5.1.2				✔				✔	✔
Subsoiling	5.1.3		✔		✔	✔	✘			✘
Surface Drainage	5.2									
Ditch	5.2.1	✔	✔	✔				✔	✔	
Grassed Waterway	5.2.2			✔			✔			
Land Grading	5.2.3	✔	✔				✔	✘	✘	
Dyking	5.2.4			✔						
Subsurface Drainage	5.3		✔		✔	✔	✔		✘	✔

✘ = caution should be used when using these methods. See Section 5.4.

✔ = methods are useful for dealing with soil/water management issue.

5.1 Cropping Practice Based Drainage Improvements

This type of improvement includes, but would not be limited to, the use of cover crops, soil amendments and tillage. In terms of tillage only subsoiling or soil loosening will be discussed. When surface drainage is required, some improvements will aid in reducing the risk of erosion or soil structure degradation. If a high water table exists subsurface drainage should be used in conjunction with the crop management based improvements listed below.

5.1.1 Cover Crops

Cover crops are plant species that are planted in a gap of either time or space between the cash crop. Of the many uses and benefits provided by cover crops the one most critical to drainage is their use as a means of protecting the soil surface from water erosion. The above ground plant or plant residue protects the soil from the impact of raindrops which can cause puddling. The root system of the cover crop improves soil structure and aids in improving infiltration. Refer to Section 2.5.1 on the effect of plant roots on aggregate stability.

Use of cover crops is particularly critical to soil management and drainage in the South Coastal Region of B.C.. From investigations carried out on cover crops, late summer planted annual ryegrass or fall rye grown on a silt loam soil, may increase the formation of water stable aggregates by as much as 20 percent over a winter growing season. With the same cover cropping practice, infiltration rates under the cover crop were over 300% greater than those on the same soil left bare over the winter. The key role of cover crops in drainage improvements is this protection of the soil surface and enhancement of water movement into the soil. Figure 5.1 shows the root development of a winter cover crop after about four months of growth between September and January

Cover crops are important tools in protecting the soil surface from the impacts of flooding. Although flooding may drown a cover crop, the crop itself will reduce the risk of soil erosion and surface puddling. Cover crop use is important for all soils, however it is particularly useful in the management of peat soils, providing protection against erosion and holding the surface layers in place if they have become hydrophobic.

Figure 5.1 Cover Crop Roots Improve Soil Structure

5.1.2 Soil Amendment Use

Although not commonly used to directly improve drainage, soil amendments can play a significant role in improving infiltration. It is the soil conditioning aspects of amendments which can aid in improving soil structure and reducing the incidence of surface puddling. Amendments, as with other crop management based improvements, will not lower the water table in a field. Amendments which are most likely to improve soil structure are solid manure, compost and mulch. Manure and compost should be used in conjunction with a cover cropping program and in such a way as to prevent loss of nutrients that would cause pollution. Pollution can be reduced by slowing run off, reducing erosion or trapping nutrients in the crop root system.

Other amendments may be used to alter the chemistry of the soil to reduce the impact of naturally occurring hardpans that are soil chemistry induced. These would include the use of lime or gypsum to alter a sodium-clay based hardpan which may appear after the installation of drainage to control a saline seep. If acid sulfate soils are encountered during installation of a drainage system, soil amendments such as lime and organic matter may be required to reduce the acidity and improve the soil structure.

5.1.3 Subsoiling

Implementation of a subsoiling program may improve percolation of water through the soil profile. Subsoiling is the practice of loosening the soil below the surface. The practice of soil loosening should be used when soil compaction, poor soil structure or poor root development are encountered. Hardpans, compacted layers or root restrictive zones that have reduced porosity or permeability can be physically altered by the use of a subsoiler. In some soils, the hardpan or root restrictive layer is the result of chemical cementation during the natural formation of the soil. Subsoiling may have an impact on the chemistry of these soils, by mixing minerals into the hardpan layer from under lying layers, or by mixing amendments added to the surface. Figure 5.2 illustrates the impact on drainage from the use of a subsoiler. The left side of the field shown in Figure 5.2 was subsoiled. In this case a "Para-till" implement was used to break a traffic pan and create an open surface for water to flow to the subsoil, under an organic soil prior to the winter. As a result of the pan layer, surface ponding is present on the field on the right side of the photo.

Many factors influence soil structure, and soil loosening is only one of many practices used to improve soil structure. Soil loosening is not a replacement for good management practices, including crop rotation and avoiding tillage when the soil is wet and easily compacted. Practices such as cover cropping, which adds organic matter and improves the soil structure, will tend to increase the effectiveness of subsoiling by stabilizing the aggregates formed.

Figure 5.2 Impact of Subsoiling on Drainage

Subsoiling should be used in conjunction with subsurface drainage when high water tables are present. If a high water table is the result of the water perching on layers with reduced permeability, both subsurface drainage and subsoiling practices are required to control the water table.

Salt affected soils can be subsoiled, but extreme caution and an understanding of the source of the salts is important. See Section 5.4.1 for more detail on salt affected soils and the implementation of drainage and subsoiling.

Subsoiling can be implemented on sloping land, but certain cautions must be used to ensure that the practice does not increase the risk of water erosion. Section 5.4.4 discusses this issue in more detail.

Critical Working Depth

Whenever subsoiling is to be used, the critical working depth of the soil and implement must be determined. Attempting to improve drainage without consideration of the critical working depth of the subsoiling implement may be detrimental to the drainage of the site. Optimal working depth is a function of soil texture, moisture content and the tractor/implement configuration. Research data indicates that subsoiling operations should be designed to work at a depth just below the compacted layer or near the desired rooting depth of the crop.

The critical depth generally occurs at a depth corresponding to an aspect ratio (tine depth/tine thickness) in the order of 5 to 7, although, it becomes shallower as the soils become more plastic (i.e., wetter) or the surface confining layers become harder and drier. The critical depth is defined as the depth at which maximum soil disturbance occurs. Tine spacing is usually equal to the working depth which gives a considerable overlap of soil disturbance in the upper soil layer and adequate disturbance in the lower layer. For subsoiling to be effective, the actual working depth should always be less than the critical depth of the soil implement combination. If the working depth exceeds the critical depth, draught will increase, compaction on the bottom of the furrow will occur and the volume of disturbed soil will not be maximized. Also, flow fracture, rather than brittle fracture will occur.

The Six Cases for Subsoiling

When subsoiling or soil loosening has been found to be economically viable or beneficial for drainage there is also an associated increase in crop yield. Subsoiling or loosening all soils is not wise. The key is to determine under what conditions soil loosening will improve drainage or increase yield. Consideration of the soil conditions is required. Many soils conditions can be grouped into six categories. Details on the recommendations for these six cases are given in the Soil Management Handbooks for the Lower Fraser Valley and the Okanagan and Similkameen Valleys, from BCMAFF. Table 5.1 summarizes those cases and some information on implementation.

Table 5.2 Six Cases for Subsoiling				
Soil Condition	**Use A Subsoiling Program**	**Cautions**	**Implementation Requirements**	**Implement**
Well structured	No	May damage soil	-	-
Salt Affected	No/yes	Salts in subsoil must be dealt with first	1. Drain 2. Add soluble calcium 3. Leach	Fracture only above drains
Poorly drained with high water table	No/yes	No benefit unless drained	1. Drain 2. Improve surface management	"Para-till" (*1) or v-ripper (*2) perpendicular and above drains
Traffic or tillage pans	Yes	Critical working depth should be greater than pan depth	Change tillage and traffic practices	"Para-till" or deep chisel cultivator or alter tillage depth to below pan
Compact fine subsoil	Yes	Work to shallow depth or into the restrictive layer, install drainage	Add organic matter, avoid working when wet	Frequent shallow subsoiling or deep chisel cultivation
Compact coarse subsoil	Yes	Be aware of depth to coarse material and the amount of rocks or sones	Subsoil at a high speed to create more disturbance	Use a "V"-ripper with deep working depth or "Para-till" if stones are a concern

*1 "Para-till" is the trade name for a particular style of subsoiling implement that has a characteristic dog-leg shape.
*2 "V"-ripper indicates a subsoiler with parabolic curved shanks in a V configuration.

Implementation of Soil Loosening

The success of soil loosening depends on many factors, some of which are hard to quantify in advance. It is recommended that test strips be established before a soil loosening operation is carried out on a whole farm. One way of accomplishing this is to put subsoiling, where appropriate, into a normal crop rotation pattern. In this way, only a portion of the farm would be subsoiled each year. Problems, such as movement of salt into the root zone, would be detected and practices could be changed before the entire area is affected. Rotating subsoiling throughout a farm also aids in scheduling operations when the soil is as dry as possible.

5.2 Surface Drainage

Surface water can only be removed in 3 ways: conveyance by natural or constructed channels, infiltration, and evapotranspiration from soil and plants (ET). During winter and spring months ET is very low and does not provide significant drainage benefits. Infiltration for these months will provide minimal relief because of frozen ground or soils that are saturated due to long periods of rain. The only option left to remove excess water is to convey it by surface drainage to a proper outlet. Surface drainage systems remove water from the soil surface and are not usually designed to lower the water table in the soil profile. During summer months, heavy rainfall can often have an intensity that is greater than the soil infiltration rate. When this happens, proper surface drainage will reduce the amount of water that will pond and will keep the water table from rising excessively.

With surface drainage, land surfaces are modified as necessary to allow the flow of water to an outlet. Design of surface drainage systems is largely dependent upon topography. The selection of a surface drainage system for a field or area also depends on soil characteristics, climate, type of crop, value of land and the availability of a suitable outlet. Ditches, grassed waterways, land grading and dyking can all be integral parts of surface drainage. Refer to Chapter 9 for details on the design and construction of surface drainage systems.

5.2.1 Ditches

An open ditch is an integral part of a farm drainage system. It usually forms the backbone of farm drainage systems and is the main outlet for other drainage methods. Ditches are often used to intercept surface runoff from higher ground and hill sides, to drain surface water and to act as an outlet for subsurface drainage. Refer to Section 9.1 for details on the design and construction of ditches.

Ditches can be an effective means of lowering water tables, but the amount of land lost is very significant in comparison to similarly spaced subsurface drainage system. Ditches can lower a water table if they are strategically located.

The main advantages of open ditches are:
1. Low initial cost,
2. Provide capacity for large volumes of water,
3. Rapid removal of surface water,
4. Easy to construct, and
5. May provide riparian habitat for beneficial birds, insects or animals.

The main disadvantages are:
1. Loss of useable land area,
2. High maintenance requirements,
3. Subject to soil erosion,
4. More susceptible to accidental escape of pollutants (manure and pesticides), and
5. May create habitat that is unfavorable to the farm operation.

For areas that tend to pond during fallow, surface water is sometimes collected and directed off a field in shallow seasonal ditches. Care must be taken to use cover cropping and limit the velocity of the water to reduce soil loss from field by these shallow ditches. It is preferable to use surface inlets if the field has a subsurface drainage system (see Section 10.4).

5.2.2 Grassed Waterways

Grassed waterways can be natural or constructed and should be vegetated for stable conveyance of runoff away from cultivated fields. Grassed waterways dissipate part of the energy from the flowing water to a level that will not cause erosion, thus preventing the formation of gullies. Figure 5.3 illustrates a grassed waterway within a forage field. Since the primary purpose of a grassed waterway is the removal of surplus water, consideration of forage production should be secondary. Grassed waterways require a proper shape and vegetative cover in order to provide satisfactory performance. These waterways are NOT suitable for continuous flow. The geometry of the channel also varies with the stage of growth of the grass cover. Refer to section 9.2 for details on the design and construction of grassed waterways.

The main advantages of a properly designed grassed waterway are:

- Allows farm machinery to cross,
- Waterway grass can be harvested as forage,
- Low maintenance once grass is established,
- Will convey large quantities of water,
- Will remove excess water collected off hard surfaced roadways, and
- Can act as outlet for surface drainage systems on sloping land.

The main disadvantages are:

- Not suitable for subsurface drainage outlet,
- Vegetation establishment can be difficult, and
- Requires maintenance.

Figure 5.3 Grassed Waterway Within a Forage Field

5.2.3 Land Grading

Land grading consists of shaping the soil surface within a field to improve drainage and eliminate areas where surface water may pond. This is usually done by cutting high spots and filling in low spots . The general slope of the field usually stays the same. There are different types of land grading techniques that can improve drainage. These operations include land levelling and re-contouring. A more extensive alteration of the site in the form of terracing may be used when the site is steep and intensive soil and water conservation management is required.

Land levelling and re-contouring are useful in dealing with surface ponding. However, care should be taken when implementing a land grading operation on soils with acid sulfate subsoil conditions or on peat soils with underlying mineral ridges. Sections 5.4 provides more discussion on these topics.

Improper soil management practices during and following landgrading, leveling, clearing and re-contouring operations, can result in severe soil degradation either due to excessive compaction and/or erosion of the topsoil. Refer to Section 9.3 for details on the design and implementation of land leveling and grading. Figure 5.4 shows land levelling equipment in operation on an intensive horticulture operation on the Sumas Prairie.

Figure 5.4 Land Levelling Equipment in Action

5.2.4 Land Clearing

Although not directly related to land grading, land clearing may involve grading of the site. When land clearing takes place it is critical to think of drainage and soil conservation needs during the clearing process. Land clearing is any operation which includes the removal of excess undesirable vegetation or debris from a site, such as trees, shrubs, stumps, logs or rocks. Land clearing must be carried out in several phases to reduce soil degradation.

The site should be mapped to identify intermittent streams, surface water runoff channels and steep slopes such as ravines. Land at the edges of ravines, river banks or other steeply sloping areas are subject to erosion and should not be cleared. Intermittent streams or surface water runoff channels should also be left uncleared unless provision is made to keep water from entering them. If these areas are cleared and cultivated without some means of controlling runoff, they will soon develop into gullies. By identifying water courses and severe slopes, a drainage plan can be prepared and installation take place prior to clearing. This will reduce the risk of soil saturation and erosion in the first and subsequent winters following clearing. The plan may entail the construction of ditches or grassed waterways.

Every attempt should be made to clear land only during the dry season in order to reduce water runoff and soil erosion. Newly cleared land could be cover cropped with cereals, grasses and/or legumes in order to prevent surface soil degradation from erosion and help rebuild the soil structure.

5.2.5 Dyking

Dyking is the development of soil ridges or berms along streams, ditches or field margins to prevent surface flow of flood water from entering an area. Regardless of whether the water is from freshet driven flood events, stormwater or adjacent upland sources, dyking may be necessary to prevent flooding. Dykes must be constructed in conjunction with other on-farm and regional drainage system components.

Dykes should be constructed to withstand the hydraulic pressure and the erosive force of the flood waters. They should be seeded to form a permanent grass cover to minimize erosion risk. In addition to designing for stability some consideration must be given to how water from precipitation or seepage will be removed from inside the dyked area. This is usually provided by flood boxes or pumping systems unless a gravity outlet is available. The construction of dykes or berms around a field may also impact the land surrounding the farm. Investigations should be carried out to determine the effect of dyking on the local drainage patterns.

5.3 Subsurface Drainage

The objective of a subsurface drainage system is to lower the water table to improve crop production. With a subsurface drainage system, perforated drains are installed below the soil surface to collect excess ground water and convey it to a gravity or pumped outlet. Surface drainage methods (e.g. open ditches and land grading) are often be used in conjunction with subsurface drainage systems. The subsurface system must account for hydrologic characteristics of the soil, including soil texture and structure, required drainage rate, flood tolerance of specific crops, climate, environmental issue and economics. Proper design of a subsurface drainage system includes the layout and arrangement of the drain lines, the spacing, size, depth and grade of drainage pipes, the selection of good quality materials and the design of special features such as outlets, surface inlets, water table control devices. Where regional drainage systems do not provide an adequate outlet, on-farm ditches, dykes and pumps may be required, in conjunction with the subsurface drainage system, to prevent flooding and the resulting soil and crop damage.

There are three basic methods used to install subsurface drainage systems. They are the trenchless plow, the trencher and the backhoe. Each one designed to place the drainpipe below the soil surface.

Trenchless Plow

In recent years, the trenchless plow has become the most common installation technique. This installation method uses principles similar to those of a subsoiler. In this case, a large single shank is pulled through the soil at the installation depth. The shank is equipped with a chute that delivers the drain tubing down the back of the shank and lays it through a shoe on the bottom of the trench or slot. A relatively dry working surface is required in order to effectively install drains. Grade control is usually achieved by using a laser control system.

The soil structure modification brought about by the installation of drains with a trenchless plow will influence the performance of the drainage system. The shank will fracture the soil much like a subsoiler tine if the soil moisture conditions are appropriate. The trenchless plow blade is designed to lift and fracture the soil in its path. The slot should be loosened and fractured not smeared and compacted. Compaction and smearing of the plow slot can occur depending on the design of the plow shoe, the soil type and the soil moisture content. Soils with sandy to clay loam textures usually fracture when subsoiled in many conditions. On the other hand, soils with moderate to high clay contents are highly affected by moisture content and should only be plowed when relatively dry. This will result in fracturing and cracking which will increase water movement to the drains. Although drains installed in clay can function efficiently, the recommendations of Section 10.10.6 should be followed.

Trencher

Trenching involves the use of either a chain or wheel trencher to open a channel in the soil. These implements can be used in a range of soils and conditions. However, for stony fields or when a high percentage of coarse fragments are present, it may be more appropriate to use a backhoe. Trenching can provide advantages over plowing when used to install collectors with several lateral connections. In areas where the trench bottom is below the water table the drainpipe must be partially backfilled or anchored or the pipe will float and proper grade establishment will be impossible (see Section 10.10.4). Trenching also provides an opportunity to install porous back fill when a blind inlet is required (see Section 10.4.2).

Backhoe

Backhoes can be used for installation of small amounts of drain tubing or in cases where other installation methods are not suited or available. They are more expensive per linear meter than a plow or trencher for large projects. Backhoes are particularly useful for providing access to lateral and mainline connections or for installing outlets and special structures. Care must be taken when using a backhoe to stay on grade and not over excavate. Usually grade tolerances are small, so constant grade checking is required (see Section 10.9.1).

5.4 Simplified Soil Profile Based Drain Spacing Guide for B.C.

This simplified soil profile based drain spacing guide for B.C. is designed to provide a quick estimate of required subsurface drainage pipe spacing. It is a supplementary to the detailed design procedures provided in Chapter 8 of this manual. The guide presents estimates for drain spacing based upon many years of practical experience. The aim is to help estimate the drainage requirements prior to going through detailed investigations.

The basis of this guide is a set of seventeen generalized soil profiles or soil categories which are distinctly different in regard to drainage and soil management requirements. Drainage requirements were formulated for each soil category. Recommendations given in this guide are based on information contained in soil survey reports or information obtained by many years of field investigations. The guide describes average conditions over larger areas and on generalized soil categories. It is possible, that on occasion, site specific conditions are at variance with those for which the guidelines were formulated. For this reason that caution must be used in applying the recommendations. Only by through on-site investigation, and detailed design procedures, can the necessary information for completely accurate drainage recommendations be provided.

Drainage may not be required on all soils. However, the drain spacing requirements could be applied to imperfect or moderately well drained soils where water erosion control is desired.

5.4.1 Generalized Soil Profile Descriptions

In order to establish an approximate drainage spacing without doing a detailed design investigation, generalized soil profile descriptions are provided in Table 5.3. These descriptions are based on the typical soil profiles found in B.C. Seventeen categories were established using soil texture and subsoil density as the most readily available criteria. The soil profile description uses three broad textural groups. Detail on these groups and information on how to determine soil texture in the field is provided in Section 2.4.

Once the texture and depth of the soil layers has been established, the soil category can be determined. This category can then be used to determine estimated drainage spacing and depth. Some specialized requirements such as filters and subsoiling are also provided.

Table 5.3 Generalized Soil Profile Descriptions

Soil Category	Generalized Soil Profile Description and Comments
1	**0-150 cm medium coarse texture.** Water infiltration and movement through the soil is good. This allows for easy water table control. There is little likelihood of surface ponding to occur. Drainage is most effective by means of surface drainage. There is no need for special surface drainage provisions, but land smoothing should not be ruled out to eliminate problems in low areas. The water holding capacity is low making provisions for irrigation desirable. Subirrigation can be very effective in this category of soil provided an impervious layer is within 3 meters of the surface. Drains should be wrapped with a synthetic fabric filter. Iron ochre hazard is high.
2	**0-150 cm medium texture (well structured).** Water infiltration and transmission through the soil is moderately high, but surface ponding can be a problem. Water table control is effective with underdrains. Surface drainage provisions are not normally required, but land smoothing is recommended. The soil holds water quite well and irrigation needs are, therefore, not high. Suitability for subirrigation is moderately high.
3	**0-150 cm fine texture (well structured).** Water infiltration and transmission through the soil is low with a fairly high surface ponding hazard. Water table control is difficult. Underdrains are suitable, but a close spacing is necessary. Surface or blind inlets should be considered in troublesome depressions particularly under sloping conditions. Soils in this category respond well to subsoiling and careful soil management is a prerequisite for effective water control. Land smoothing is strongly recommended. Subirrigation may not effective in these soils. Controlled drainage gives good responses.
4	**0-100 cm coarse texture (well structured) // 100-150 cm fine texture, moderately dense.** Water infiltration and transmission through the soil is high. Ponding hazard is low. Underdrains are the most effective way of controlling the water table and there is no need for special surface drainage provisions. Irrigation requirements are high and subirrigation systems are well suited to this soil. Filters are not needed if the drains can be placed sufficiently deep into the subsoil. Iron ochre hazard is high.
5	**0-100 cm medium texture (well structured) // 100-150 cm fine texture, moderately dense.** The capacity of the soil to accept and transmit water is moderate to low requiring a relatively close drain spacing for good water table control. Where the dense subsoil is less than 100 cm deep, porous soil material or gravel should be used to blind the drains. Underdrains are most appropriate for drainage and land smoothing is a good measure to eliminate depressions and the likelihood of surface ponding. Under sloping conditions, there is a high hazard of water erosion. Water holding capacity is high and there is a moderate to moderately high suitability for subirrigation.
6	**0-100 cm fine texture (well structured) // 100-150+ cm fine texture, moderately dense.** Control of excess water in this soil is difficult. A close drain spacing must be used for adequate control. Considerable emphasis must be placed on proper soil management to achieve satisfactory results. Land smoothing and judicious use of surface inlets in depressions is recommended. Irrigation requirements are not high due to the high water holding capacity and subirrigation suitability is low or moderately low. This soil responds well to subsoiling. When the land slopes there is a high risk of water erosion.

Table 5.3 Generalized Soil Profile Descriptions (Continued)	
Soil Category	**Generalized Soil Profile Description and Comments**
7	**0-50 cm coarse texture // 50-150 cm fine texture, moderately dense.** This soil accepts water readily, but transmission of water is hampered by the dense subsoil. Drains are well suited to control the water table and filters are not necessary provided drains are placed at the recommended depth. There is little danger of surface ponding, and except for land smoothing, there is no need for surface drainage provisions. Irrigation need is relatively high and subirrigation suitability is high. Effective rooting depth can be improved through the use of subsoiling. Iron ochre is high.
8	**0-50 cm medium texture // 50-150 cm fine texture, moderately dense.** Managing excess water poses difficulties because of the shallow soil. Drains must be placed close together and at a shallower depth than normal. Blinding with porous soil or gravel is recommended. This soil requires emphasis on drainage measures related to the surface. Land smoothing and the use of surface inlets in depressions and in other strategic locations is needed for optimum water control. With slope, surface interceptors are necessary to stop erosion. Irrigation needs are normal and the suitability for subirrigation is moderate. Subsoiling will deepen effective soil depth and aid water movement and should be done prior to drain installation. Iron ochre hazard is low.
9	**0-50 cm fine textured // 50-150 cm fine texture, moderately dense.** Water management requirements of this soil are high. Extra effort is needed to deal with excess water. Closely spaced drains with provisions for surface inlets may be necessary. Where such surface provisions are not possible, the use of surface ditches may be unavoidable. Soil structure must be amended by using a subsoiler and additions of organic matter. Permanent cover crops are recommended, but if not possible, a careful crop rotation must be selected to prevent soil structure damaged. Iron ochre hazard is low. Under sloping conditions, erosion potential is high and surface interceptor drains are required. This soil is not suitable for subirrigation.
10	**0-50 cm medium fine texture // 50-150 cm coarse texture.** Water table control of this soil is not difficult. Subsurface drains are very effective, but filters are required. Efforts must be directed towards keeping the surface soil in an open well structured condition, use organic matter applications and sensitive management practices. Subirrigation suitability is high. Iron ochre hazard is fairly high.
11	**0-100 cm medium fine texture // 100-150 cm coarse texture.** Although water table control of this soil is moderately good, surface conditions are poor. Land smoothing and surface drainage oriented provisions are desirable as are subsoiling, organic matter applications and sensitive management practices. Filters are generally required around drain pipes and the ochre hazard is moderately high. Suitability for subirrigation is moderate.
12	**0-40 cm organic material moderately well to well decomposed // 40-150 cm fine texture, medium high density.** Water movement into and through the soil is restricted. Fairly intensive drainage is required for satisfactory control. Use of watertable control to inhibit decomposition of the peat soil has relatively little effect and is not recommeded due to the adverse effect on the subsoil structure. Potential for subirrigation is low. Subsoiling will be of help in enhancing subsoil porosity and water movement.

Table 5.3 Generalized Soil Profile Descriptions (Continued)	
Soil Category	**Generalized Soil Profile Description and Comments**
13	**0-40 cm organic material, moderately well to well decomposed // 40-150 cm medium to medium-coarse texture.** Watertable control is high in these soils. They are well suited to use of underdrains. Filters are recommended where sand is present at drain depth. Accelerated decomposition of the organic material is a consequence of improved drainage. Decomposition can be reduced by keeping the water table high whenever possible through controlled drainage or water control facilities. Effectiveness of these measures diminishes as the depth of the organic material is reduced. Subirrigation potential is moderately high.
14	**0-150 cm organic material.** Movement of water through this soil material is variable, but in general, it is moderately good. Subsurface drains control excess water effectively, but accelerated decomposition is a consequence. Drains must be placed at maximum depth and installed with a water control system to raise water levels when possible. Suitability for subirrigation is moderate, but the drought hazard is low due to a high water holding capability.
15	**0-100 cm organic material, well to moderately well decomposed // 100-150 cm medium texture.** Movement of water through this soil material is variable, but generally it is moderately good. Subsurface drains control excess water well, but accelerated decomposition is a consequence. Drains must be placed at maximum depth and provided with a water control system to raise water levels when possible. The suitability for subirrigation is low, but the drought hazard is low due to a high water holding capability.
16	**0-50 cm organic material, well to moderately well decomposed // 50-100 cm coarse-texture // 100-150 cm fine texture, moderately dense.** Movement of water through this soil material is variable, but generally rapid in the upper 100 cm. Water tables tend to perch on the fine-dense layers. Subsurface drains control excess water effectively, but accelerated decomposition of the surface organic layers may be a consequence. Drains must be placed at or near the interface between the coarse and fine-dense layers to provide adequate water control. Suitability for subirrigation is moderate, but the drought hazard is high due to a low water holding capability of the coarse textured layer. Filter requirements are high as the drains will be placed in the coarse layer. Possibility of encountering iron ochre is relatively high.
17	**0-50 cm medium to medium coarse texture // 50-100 cm fine-texture, medium high density, moderately compact // 100-150 cm medium to medium coarse texture.** Movement of water through this soil material is variable, but generally restricted. Subsurface drains may not control excess water. Watertables tend to perch on the 50 - 100 cm fine textured soil layer. Drains may be placed within the fine textured layer . Drains may need to be fitted with a filter material. Suitability for subirrigation is low. Possibility of encountering ochre is quite moderate. Increasing the permeable soil depth through the use of subsoiling into the fine layer is recommended.

5.4.2 Estimated Drain Spacing Recommendations

Table 5.4 was developed to provide an estimate of the desirable drain spacing based on the generalized soil profile descriptions given in the previous section. Using the soil category number from the generalized soil description in Table 5.3, a corresponding drain spacing and depth can be determined. The table also provides some indication of special requirements such as filters and subirrigation suitability.

Although some adjustments can be made to the drain spacing given in this table, see Section 5.4.3, it is strongly recommended that no adjustments be made to the drain depth or filter requirements. Maximum effective drain depth is 1.2 meters. Where soil and site conditions create significant hydrologic impediments, such as if the depth to an impervious layer is less than 0.6 meters, then a reduced spacing is recommended.

5.4.3 Adjusting the Estimated Drain Spacing Guide

The estimated drain spacings given in Table 5.4 are based on an average cropping management system. In this system it is assumed that there is an average level of drainage protection or water table control required. Also an average drainage coefficient based on water flow through the soil system and watershed of the field. Slight adjustments to the drain spacing can be made based on the adjustment factors given in Table 5.5. These factors are based on specific cropping practices or land use demand. Each decrease in spacing will increase the cost of the system, so some additional cost-benefit analysis is recommended. In addition to a drainage spacing adjustment, a subirrigation adjustment factor is given.

This subirrigation adjustment factor is based on the need for slightly greater water table control when this irrigation practice is used. Subirrigation systems also provide drainage, however, the design parameters for a subirrigation system are different. The design of subirrigation systems is covered in Chapter 11. In general, in a subirrigation system, water is added to the system with the goal of rewetting the soil profile. In drainage systems the flow of water is gravitational. In subirrigation systems, the desire is to move a saturated front of water through dry soil. This requires a hydraulic head which is greater than the force of gravity. In order to facilitate this movement of water through the soil more rapidly a tighter drain spacing is desirable. An adjustment factor of 0.65 is recommended.

For a controlled drainage system, the normal practice would not require any adjustment of the drain spacing. Controlled drainage, which is also discussed in Chapter 11, is basically the insertion of a controlled outlet on the drainage system. This controlled outlet regulates the discharge flow rate and level of the water table level within a field. Normally no water is added to the system, but rather, water is held in the soil profile within the field.

Table 5.4 Approximate Drain Spacing Recommendations Based on Generalized Soil Profiles						
Soil Category	**Depth (cm)**	**Texture**	**Drain Spacing (m)**	**Drain Depth (m)**	**Special Requirements**	**Subirrigation Suitability**
1	0-150	Medim-Coarse	20	1.2	Filter	H
2	0-150	Medium	16	1.2	-	M
3	0-150	Fine	14	1.2	-	L
4	0-100 100-150	Coarse Fine-Dense	18	1.2	Filter	H
5	0-100 100-150	Medium Fine-Dense	14	1.2	-	M
6	0-100 100-150	Fine Fine-Dense	12	1.0	Subsoiling	L
7	0-50 50-150	Coarse Fine-Dense	16	0.8	Subsoiling	H
8	0-50 50-150	Medium Fine-Dense	12	0.8	Subsoiling	M
9	0-50 50-150	Fine Fine-Dense	10	0.8	Subsoiling	L
10	0-50 50-150	Medium Coarse	18	1.2	Filter	H
11	0-100 100-150	Medium-Fine Coarse	16	1.2	Filter & Subsoiling	M
12	0-40 40-150	Organic Fine-Dense	12	1.0	Subsoiling	L
13	0-40 40-150	Organic Medium-Coarse	16	1.2	Filter	H
14	0-150	Organic	14	1.3	-	M
15	0-100 100-150	Organic Medium	14	1.2	-	L
16	0-50 50-100 100-150	Organic Coarse Fine-Dense	18	1.0	Filter	H
17	0-50 50-100 100-150	Medium-Coarse Fine-Dense Medium-Coarse	12	0.8	Filter & Subsoiling	L

If the drainage requirement is relatively low, such as for an annual crop on an imperfectly to moderately well drained site, and the system is being used more for controlled drainage during the growing season, then the adjustment factor may be about 1.1. This would effectively increase the spacing, but is not recommended without a detailed soil investigation and full understanding of the management of a controlled drainage system. Under some situations where the soil is poorly to imperfectly drained and field access is desired during the entire growing season, an adjustment factor of 0.9 may be used to obtain slightly greater control of the water table. Normally, design of a controlled drainage system, entails the use of a different drainage coefficient than that used for conventional drainage design.

CAUTION - It is essential to review all pertinent facts and make further adjustments if necessary. Corroboration of simplified drain recommendations with on-site surveys and measurements for final design purposes is recommended.

Table 5.5 Land Use and Subirrigation Adjustment Factors

Land Use Demand Level	Description	Adjustment Factor
Highest Demand	Access to land is desirable all year round. Crops to be grown are very sensitive to excess water and are of the highest value. Use only in the most stringent cases.	0.8
High Demand	Perennial ornamentals, early or year-round pasture, alfalfa, other high value or water sensitive crops and soft fruits with the exception of blueberries and cranberries.	0.9
Normal Demand	Mid-season vegetable crops, hay and pasture land, over wintering cereals used as cover crops, cole crops and blueberries.	1.0
Subirrigation	All crops.	0.65
Controlled Drainage	All crops and depending on soil conditions a range of factors.	1.0 to 1.1

5.5 Cautions About Some Improvements

5.5.1 Acid Sulfate Soils

Although, drainage improvements are desirable when wet or waterlogged conditions exist in a field, there maybe cases when improvements could be detrimental. In soils where the mineral jarosite may occur, which appears as straw to bright yellow coloured mottles, drainage may induce acid sulfate conditions. Aeration of soil containing high levels of sulfates and pyrites will promote the oxidization of these minerals which will produce sulfides and extremely acidic conditions (pH = 2 to 3) and high levels of soluble iron, aluminum and manganese. High levels of these soluble elements can be toxic to plant roots. This phenomenon is often referred to as the "cat clay phenomena" and it occurs in coastal regions where soils have developed in water-logged conditions and contain high levels of sulfates and organic matter. These conditions have been found in lowlands of the municipalities of Delta and Richmond. Ditch construction and land levelling may bring these undesirable materials to the surface. Caution should be used when constructing and maintaining ditches in these areas.

5.5.2 Peat Soils

Detrimental impacts from drainage may also occur in organic soils. Drainage and tillage activities on the newly drained soil may increase oxidation and decomposition of the peat. This process is known as subsidence. For the first few years after unripened soils are cleared for agricultural production, drainage should only be provided by surface drainage techniques. This will allow changes in topography due to subsidence to occur without harm to the system. Subsurface drainage systems should only be designed and installed after the initial subsidence has occurred.

Over drying peat or muck soils may also cause these soils to become hydrophobic, repelling water and in some extreme cases the surface layers may float when wetted. Controlled drainage during the growing season and the use of cover cropping can reduce the impact of over drying and subsidence on peat soils. During the fallow seasons, care must be taken not to damage the soil or kill the winter cover crop by allowing the soil to become water logged. Cover cropping must be used on peat soils to protect them from eroding during the winter.

Another caution with peat soils is that they are often associated with mineral soil ridges and layers. The combination of two or three distinctly different soil types in one field can make drainage system design a challenge.

5.5.3 Saline Soils

Subsurface drainage, ditching, alternate cropping practices, leaching and application of soil amendments are all necessary components in dealing with salt affected soils.

Draining and subsoiling salty soils requires special care. In saline soils excess salts greatly affect yield, soil properties and the response to soil loosening. Salinity may be the result of natural processes, such as residual salts from a marine formed soil or by salts accumulating in the soil as a result of groundwater or irrigation without proper drainage. Cultural practices, such as irrigating with saline water or applying excess fertilizer may also cause salinity problems.

Often the presence of saline soils is demonstrated by good hydraulic conductivity in the surface soil, good tilth and the soil surface may appear white from salt crystals. Electrical conductivity (EC) tests should be completed on soil samples taken from at least three soil layers, the root zone (0 to 20 cm), the middle tier (20 to 50 cm) and the subsoil (50 to 100 cm). If any soil layer is over 2 decisiemens per meter (dS/m), the soil is somewhat saline. In this case, soil loosening should be avoided. Desalinization, using leaching and subsurface drainage and altered cropping strategies, should be utilized.

Sodium adsorption ratios (SAR) should be determined as there is a potential for the soil to form a hardpan during leaching. SAR's that are greater than 15 indicate a potential for hardpan formation. Subsoiling, used by itself, may increase the salinity problem by bringing salts to the surface, lowering the infiltration rate and making the soil harder to desalinize. The normal desalinization practice on these soils is to add soluble calcium, such as gypsum, to replace the sodium on the soil exchange sites. This will improve the soil drainage. Then irrigate with low-salt water to leach salts from the root zone. After drainage has been established, subsoiling may be required to help breakup a clay or salt enriched (Bnt or Bt) horizon. During the period of desalinization, lower yields may occur on the subsoiled areas.

Sodic Soils

Sodic soils are also referred to as alkali or solonetzic soils. They are often characterized by the presence of a sodium and clay enriched layer in the lower root zone. The surface topsoil layers may yield a reasonable crop in moist years or when irrigated, however, the hardpan and EC of the subsoil restrict root development and air/water movement.

Subsoiling, to physically break this hardpan, has been very successful under dryland conditions. In some cases where the topsoil pH was low or the topsoil layer was shallow, lime or gypsum has been added to the surface prior to subsoiling. Lime alters the pH, and adds calcium to the soil to displace the sodium salts from the subsoil, but is an expensive process. pH adjustment should only be used for fine-textured lacustrine type soils. If a very shallow topsoil layer exists and there is a hardpan layer, subsoiling should be avoided. Drainage may be required if sodic salts are a result of salty subsoil or salty groundwater conditions.

5.5.4 Subsoiling on Sloping land

Although subsoiling or soil loosening will improve percolation of water through the soil, if not used properly on sloping land this practice can lead to serious soil loss. When soil loosening operations are implemented on land with slopes greater than 5%, every effort should be made to integrate the subsoiling operation with other drainage improvements such as grassed waterways, subsurface drainage and cover cropping. Subsoiling up and down slopes should be avoided as this creates channels in the soil where concentrated water flow will occur. The subsoil shank openings act as mini-pipelines that are easily eroded.

Subsoiling after the cover crop is well established or in a forage crop helps protect the soil from uncontrolled runoff. Subsoil in a manner that the shank channels start or stop on the uphill side of a grassed waterway. This will slow the water velocities and reduce sediment loss.