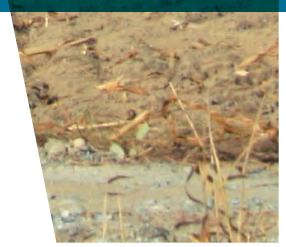
Climate Action Initiative
BC AGRICULTURE & FOOD

BC Farm Practices & Climate Change Adaptation

Drainage



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Farm Practices & Climate Change Adaptation Series

This series of six reports evaluates selected farm practices for their potential to reduce risk or increase resilience in a changing climate.

The practices selected are well known in contemporary and conservation-based agriculture. While they are not new practices, better understanding of their potential relationship to climate change may expand or alter the roles these practices play in various farming systems.

Climate change will not only shift average temperatures across the province, it will alter precipitation and hydrology patterns and increase the frequency and intensity of extreme weather events. The projected changes and anticipated impacts for agricultural systems are considered in the practice evaluations. More details regarding climate change and impacts for various production systems in five BC regions may be found in the *BC Agriculture Risk & Opportunity Assessment* at: *www.bcagclimateaction.ca/adapt/risk-opportunity*

Farming systems are dynamic, complex, and specific to the local environments in which they operate. This makes the analysis of farm practices on a provincial level particularly challenging. The approach taken for this series, is to explore the application of practices regionally and across a range of cropping systems and farm-scales. While the ratings are subjective and may not reflect suitability for a particular farm, the ratings and associated discussion help to identify both the potential, and the limitations, of selected practices on a broader scale. In some cases, the numerical ratings are expressed as a range, to reflect variation in conditions across regions and cropping systems.

The practice evaluations are informed by background research and input from agriculture producers around the province about their current use of practices. Each document includes: a practice introduction, key findings, an evaluation of suitability to help to address climate change risks, and technical practice background related to adaptation. The documents conclude with practice application examples from various regions of the province. More detailed information about the overall project may be found at: *www.bcagclimateaction.ca/adapt/farm-practices*

Like farming systems, practice applications are location specific and change over time. Continued adaptation and holistic integrated practice implementation will be required as climate conditions change. The effectiveness of most practices for mitigating climate and weather related risks will vary over a range of conditions. Ultimately, if practice adoption can reduce vulnerability and risk overall, it has some effectiveness in supporting adaptation.

This document is not intended to serve as a stand-alone technical guide. Rather, it is hoped that this evaluation supports dialogue—among producers, agricultural organizations and key government agencies—about how these and other practices may apply in a changing climate, and how to address information or resource gaps to support further adoption and adaptation.

Contents

Introduction

Draining agriculture lands to provide suitable conditions for crop production is a well established on-farm practice in BC. Most crops can withstand short periods of flooding, so the main objective of drainage is to shorten the period that fields and crops are under water or that soils are saturated. Saturated soil conditions can have devastating effects on crops, reducing crop productivity as well as delaying crop planting and harvesting, which effectively reduce the growing season. Drainage may involve directing surface runoff with land forming and constructed ditches, or the installation of subsurface drainage. Drainage is the main factor that currently limits crop production in the Fraser Valley.

Related Practices

- → Land forming, levelling
- → Irrigation
- → Field mapping and GIS
- → Riparian area management
- → Shelterbelts and buffers
- → Grassed waterways
- → Crop selection
- → Nutrient management

What Does Drainage Involve?

Drainage applications are highly site specific, and dependent on current cropping practices, soils, topography and the nature and use of surrounding lands. A farm and field assessment is required to establish physical factors affecting drainage, and whether drainage works are feasible. Agricultural drainage criteria are used to determine design specifications and whether the proposed works can be justified from an economic point of view.

There are environmental considerations as well. On-farm drainage systems involving constructed ditches are often connected to natural streams or water-ways to provide an outlet for water collected from fields. Drainage works and ditches—that have intermittent flow and are dry part of the year—are streams or watercourses under provincial and federal legislation and may provide fish habitat. Government approvals are necessary for all maintenance activities in natural and channelized streams, and care must be taken in constructed channels before works are undertaken. Nutrient management can also be negatively affected on submerged fields, as nitrous oxide production is higher on waterlogged soils.

In some regions, minor water control structures can provide a substantial benefit for agriculture. In flood prone areas like the Fraser Valley and Lower Mainland, management of surrounding lands and regional drainage works are a factor in the effectiveness of on-farm drainage.

FIGURE 1 Surface drainage ditch in the Cowichan Valley

Current Adoption in BC

The nature and location of BC's agricultural land has, to a great extent, determined the level of adoption of on-farm drainage works. In the Fraser Valley and Lower Mainland, areas of eastern Vancouver Island, and parts of the BC Interior, drainage is critical for most agriculture operations and in some cases integrated into regional dike and flood control infrastructure. Pumping may be necessary to allow drainage in diked systems. Drainage has been promoted under the *BC Environmental Farm Plan Program Plan Program*, with financial support for the preparation of Water Management Plans to deal with excess water and drainage on land producing corn and grass forage.[1]

In ranching areas of the BC Interior, natural wetlands with mostly organic soils have historically been used to produce winter forage for livestock. Many of these native hay meadows have been improved with the installation of drainage and water control works, hastening drainage in wet years and providing sub-irrigation in dry years. These native wet meadows generally occur on mid-elevation plateaus above major river valleys, where slopes are gentle.[2]

Creating surface drainage with small constructed ditches to help runoff reach natural watercourses is a practice that is used throughout the province. Land levelling is a common and related practice used in conjunction with both surface and in-field subsurface drainage applications to prevent ponding. With current GPS levelling technology this is easily accomplished on relatively flat lands. However, on gently rolling landscapes, field levelling is not practical or desirable because it destroys the integrity of soils and soil profiles. Specialized GPS technology may provide opportunities to address ponding in some rolling landscapes (see Drainage Examples page 17).

Key Findings

- The suitability of drainage for managing climate change risks will vary with location, largely depending on existing conditions, practices, terrain and soils.
- Climate factors are integral to existing provincial drainage criteria; future climate scenarios should be considered both in the design, and the economic analysis of design layouts of sub-surface drainage systems.
- Provincial drainage criteria may need adjustment to ensure new drainage installations remain effective, given the projected increase in extreme precipitation events.
- Effectiveness of farm subsurface drainage in the Lower Mainland and on Vancouver Island, may depend on effective regional drainage and flood control works.
- Comprehensive or integrated watershed management strategies are likely to be important for moderating future climate related impacts on agricultural production.
- Watershed management and maintenance of natural water flow regulation (wetlands) will need full consideration in future planning at both the on-farm and regional levels.
- The area of land that benefits from drainage could increase in future climate conditions.
- Economic considerations are likely to play a more prominent role in decision making about regional water control for agriculture, where infrastructure investments are required to create more drainage capacity.
- Drainage technologies currently in use appear to be fairly adoptable by farmers; some newer GIS applications may be limited to specific cropping systems, and production scales.
- Low impact surface drainage techniques (i.e. gentle contour furrowing) may have application on some rolling terrain; there is limited awareness of this technique in BC.

Areas for Further Adaptation Research & Support

- Research and analysis on watershed hydrology and the implications of predicted climate change scenarios on drainage engineering standards.
- Education, demonstration and research related to surface and subsurface drainage techniques in all farming systems, and in areas where well designed drainage could provide benefits.
- Economic analyses of both private and public benefits associated with drainage in regionally managed flood control areas.
- Demonstration and cost-benefit analyses of low impact surface drainage techniques in appropriate locations and with various cropping systems.
- Comprehensive or integrated watershed and regional drainage management strategies to mitigate future climate related impacts on agricultural production.
- Planning to integrate subsurface drainage and subsurface irrigation in appropriate locations.

Evaluation: Adaptation & Drainage

Multi-Criteria Evaluation

Agricultural research is typically undertaken to establish the efficacy of a product or practice under specific conditions. Similarly, cost-benefit analysis is valuable for assessing whether an investment is economically efficient (whether it pays to invest in a particular practice or asset). An evaluation of adaptation options for climate change needs to consider more than just effectiveness and economic efficiency to be useful for both farmers and those interested in supporting climate change adaptation. Multi-criteria evaluation provides a framework for this evaluation—enabling a set of decision-making criteria to be examined simultaneously.

Multi-criteria evaluation (MCE) can be highly structured, or, as it is applied here, more subjective and exploratory. To have value, the evaluation has to have the decision makers it aims to serve in mind. Often when MCE is employed, considerable time is spent gathering input on decision-making criteria and the needs of users. Given the limited scope of this project, it was not possible to gather user-specific input, and instead the criteria were developed by looking at other studies in the field of adaptation to climate change.[3] However, producers did provide input on the relative importance of the selected decision making criteria in a ranking exercise (27 of 29 participants). Perhaps not surprisingly, economic efficiency and effectiveness were the top ranked criteria followed by adoptability, adaptability, flexibility and independent benefits. Institutional compatibility was ranked last by the majority of farmers.

Often MCE is used to select the most desirable option from various alternatives. Ratings for each criterion are determined, and then added together to provide a total score for each alternative. The relative importance, or weight, given to a single criterion can affect the overall suitability rating for a practice. However, for this evaluation, it is the scores for individual criteria that provide insight into how a practice might be suitable for adapting to climate change, and what might need to change to make it even more suitable. The purpose of the evaluation is not to aggregate ratings and compare practices, but rather to improve understanding of how the individual practices relate to adaptation to climate change.

The evaluation takes a broad view (coarse-scale) across areas and farming systems in the regions (and production systems) where the practice might be applied or considered. The ratings were determined under the assumption that there is some basis for the application of a practice within certain farm types. For example, management-intensive grazing does not have application on a farm without livestock, and therefore it would be ineffective as an adaptive practice for that farm when compared to other alternatives.[4] If carried out at a fine-scale (individual farm level), the suitability rating of any practice could be quite different because the specific circumstances

of the farm would be considered for each criterion. Likewise, ratings could vary depending on the purpose (e.g., policy formulation vs. farmer adoption), and the perspective of the individual(s) carrying out the evaluation. Even though, a broad view is taken in the evaluation, the criteria in this series are considered from an on-farm perspective.

The evaluation below assesses a farm practice through the following set of decision-making criteria: *Effectiveness*, *Economic Efficiency*, *Flexibility*, *Adaptability*, *Institutional Compatibility*, *Adoptability* and *Independent Benefits*. Each of the criteria are defined and a numerical rating (in some cases a range) has been assigned across a scale from 1–5 to reflect its potential value in adapting to climate change. The discussion that accompanies the rating captures some of the issues contemplated in determining the rating, as well as some of the variation and complexity of practice application across the province and farm systems.

Effectiveness

Whether the adaptation option reduces the risk or vulnerability, and/or enhances opportunity to respond to the effects of climate change.

RATING: 1–5
very ineffective to very effective

The effectiveness of on-farm drainage could be highly variable depending on the circumstances surrounding its application. Well-designed subsurface drainage systems should be moderately effective to very effective in reducing risk (and enhancing the opportunity to respond, to) the effects of climate change on lands where drainage is needed, but not yet adopted. Best practice applications will also be effective on lands where systems are in place, but where drainage infrastructure needs improvement or replacement. Effectiveness as an on-farm practice could be substantially limited (very ineffective) on lands that depend on regional flood control or dike works to operate successfully, without concurrent upgrades to those systems. Along with predicted increases in total annual precipitation and more extreme events, these areas may also be affected by sea-level rise. Successful mitigation for agricultural drainage function will require regional consultation, co-operation, and a high level of technical input and analysis.

Likewise the adoption of surface drainage practices could be very effective in areas that may be affected by increased winter and spring precipitation (see pages 19–20). Low disturbance land-forming techniques (like low-slope grading and contour furrowing), and greater use of grassed waterways could be effective on rolling hilly landscapes. Low-slope grading and contour furrowing could also be beneficial for water conservation and water efficiency under irrigation. While on balance these on-farm drainage measures are expected to be quite effective in reducing climate change impacts, flooding associated with extreme events is unlikely to be mitigated without consideration of other measures.

Economic Efficiency

The economic benefits relative to the economic costs that are assumed in implementing the adaptation option.

RATING: 2–4
moderately inefficient to moderately efficient

The economic efficiency of drainage will be highly variable, depending on the type of drainage, its effectiveness, and the types of crops grown. It is assumed that the wide adoption of subsurface drainage in the highly productive areas of the Lower Mainland and Vancouver Island has been moderately economically efficient, and that if new on-farm designs can remain effective they will also be efficient. However, there appears to be little formal study to fully support this assumption. In low-lying, high winter-rainfall areas, system improvements and infrastructure may at some point become inefficient if they are justified only by benefits received on the lands owned by a single farmer (see Table 2, which shows a sub-regional application of the Agricultural Drainage Criteria). At the same time, investments in on-farm drainage could also become ineffective, and therefore inefficient, if regional drainage infrastructure has not also been upgraded to remain effective under future climate scenarios.

Well-planned surface drainage is likely to be moderately efficient in areas where it remains effective. Advances in GPS technology have made

surface drainage more practical and effective in rolling landscapes (see pages 19–20). Relatively low cost contour furrowing is also likely to be moderately economically efficient.

Flexibility

The ability of an option to function under a wide range of climate change conditions. An option that reduces income loss under specific conditions, and has no effect under other conditions, would be considered inflexible.

RATING: 4
moderately flexible

Surface drainage in rolling landscapes that allows low-lying areas to be farmed in wetter years means that these areas will also be in production in drier years. They may potentially produce higher yields than the surrounding uplands, adding to the total average yield. Water distribution techniques may have moisture conserving benefits on gently undulating topography under irrigation. Subsurface drainage that incorporates water control structures and sub-irrigation, should be functional over a fairly wide range of conditions. Simple subsurface drainage on the other hand, may address only wet conditions, although these conditions could occur during spring seeding or fall harvest.

Adaptability

Whether a practice can be built upon to fit future conditions and allows further adaptation.

RATING: 4
moderately adaptable

If well-designed and planned, drainage infrastructure should be somewhat adaptable, however there may be physical thresholds that prevent further adaptation if wet conditions become more extreme. Surface drainage techniques maybe more adaptable because they can be more easily adjusted as conditions change.

Institutional compatibility

Compatibility of the adaptation option with existing institutional and legal structures.

RATING: 3
neutral

Current institutional structures are generally supportive of drainage practices, which are protected by right-to-farm legislation. Different aspects of drainage have been supported under the *Canada-BC Environmental Farm Plan Program*. Public concerns apply mainly to drainage practices that affect fisheries or fish habitat, and wetlands and the services they provide, including water flow regulation. Diversion of water from a stream—defined by the *Water Act*—to accomplish drainage requires a licence, and notification must be given for other works.[5] There may be institutional barriers that limit planning, cooperation and funding arrangements for improvements in regional drainage infrastructure. Regional watershed level planning that involves community watersheds, forestry, oil and gas, and urban development is necessary to improve watershed management practices, but will remain challenging.

Adoptability

The ease with which farms can implement the practice under existing management practices, values and resource conditions.

RATING: 2–4
moderately low adoptability to moderately adoptable

Drainage has a long history in agriculture, and is fairly readily adopted by farmers. On highly productive lands, farmers have adopted subsurface drainage and have developed considerable knowledge about its application and use. In some areas, clay drainage tiles have been in place for over 50 years. Some technical support is available through government supported programs, like the *Canada-BC Environmental Farm Plan Program* and from private industry. Surface drainage techniques and best management practices like contour furrowing, may be less adoptable because they have not been as widely demonstrated in existing cropping systems. The application of GPS supported surface drainage techniques may be

limited by farm-scale, the knowledge needed to use the technology, and equipment availability.

Independent Benefits

The potential for a practice to produce benefits independent of climate change. For example, a practice that reduces income loss regardless of climate change effects, would be rated high.

RATING: 3–4
neutral to moderate independent benefits.

The potential for drainage to produce benefits independent of climate change is moderate, if applied to lands that currently require some level of drainage. The implementation of drainage as a planned adaptation in response to anticipated climate change impacts would carry some risk, as benefits may not be realized under some conditions. Holistic approaches to drainage that incorporate watershed management and planning are likely to produce both public and private benefits regardless of climate change effects.

TABLE 1 Drainage evaluation summary

Evaluation Criteria	Rating	Meaning
Effectiveness	1–5	Very ineffective to very effective
Economic Efficiency	2–4	Moderately inefficient to moderately efficient
Flexibility	4	Moderately flexible
Adaptability	4	Moderately adaptable
Institutional Compatibility	3	Neutral
Adoptability	2–4	Moderately low adoptability to moderately adoptable
Independent Benefits	3–4	Neutral to moderate independent benefits

Drainage Background Information

Drainage for Agricultural Land

Excess water in fields and in pastures can be detrimental to plants of all kinds. Flooded fields can also delay spring tillage or seeding, harvest of crops, and the timely application of soil nutrients. Saturated soils lack oxygen and prevent desirable nutrient cycling, the breakdown of organic matter, and can contribute to NO_2 emissions. Sometimes the need for drainage is created by the physical characteristic of soils and the location or depth of natural water tables. In other instances, agricultural lands are developed in naturally occurring depressions, in or near wetlands, and require some form of improved drainage to be useable. Drainage can help in the management of saline soils by reducing evaporation at the surface, and allowing salts to be transported away with excess water. Over the years, the BC Ministry of Agriculture has produced a series of Drainage Factsheets and the *BC Agricultural Drainage Manual* that provide information on various aspects of drainage design, installation and management.[6]

Natural drainage occurs when water flows from upland areas and fields to wetlands, to streams and then to larger rivers. Typically, improved drainage is integrated with natural drainage systems (Figure 2).

Environmental Concerns

Best management practices should be followed to minimize environmental risks related to:

- Drainage water quality
- Maintenance or work in or around watercourses (fish bearing habitat)
- Changes to wetland water flow regulation and capacity *(see Drainage Management Guide: Companion Document to the Canada-BC Environmental Farm Plan Program Plan)*

There are three types of watercourses used in drainage systems:[7]

Natural streams have not been significantly altered from their historical floodplain in any manner and have headwaters (usually from wetlands or springs).

Channelized streams are permanent and/or relocated streams that may have been diverted, dredged, straightened and/or diked.

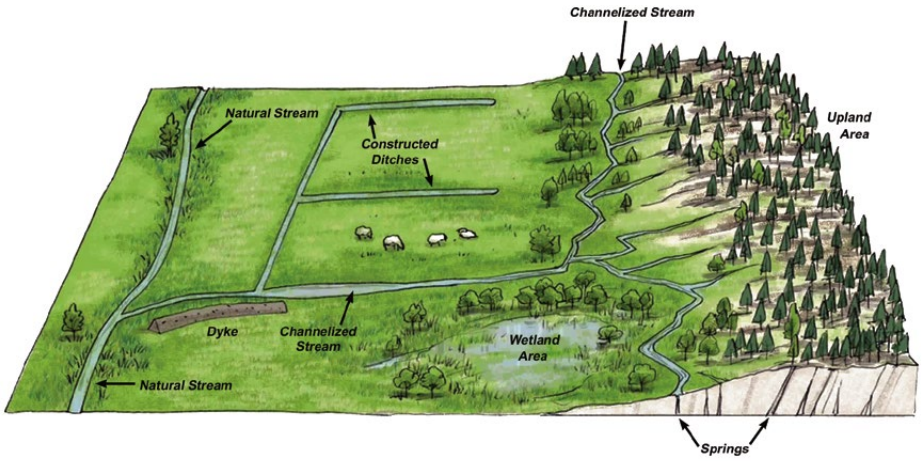


FIGURE 2 Farm sub-watershed and watercourse classification

Source: Riparian Factsheet, BC Ministry of Agriculture, 2011.

Constructed ditches convey drainage water from an individual farm or supply water to an individual farm property.

Types of Drainage

Improved drainage is needed when natural drainage is insufficient to allow efficient agricultural production on farmland. There are two main types of drainage and, in some locations, both may be required to create suitable conditions.

Surface Drainage

Agricultural lands often have depressions or low lying areas that allow runoff to pond. Surface drainage involves the construction of small open ditches or waterways that take water away from fields to larger collection ditches or natural streams. Surface drainage may involve land forming or field levelling to direct water to collection ditches or waterways (see text box, following page). Grassed waterways can be designed to carry considerable water flow, and allow easy crossing with equipment, but are not suitable for continuous flows.[8]

Subsurface Drainage

Subsurface drainage can be accomplished with a network of buried drainpipe connected to a non-perforated collector pipe at the lower edge of the field. This is a common drainage technique in the Lower Mainland and on Vancouver Island, and there is technical information available to support proper design and installation.[9] However, the number of qualified installers is limited, and some current installations may not be effective under future climate scenarios, especially where the Regional Agriculture Drainage Criteria have not been applied. There is opportunity for improvement in drainage design, as old non-functional systems are replaced. There is also potential for increased application of controlled subsurface drainage and sub-irrigation designs (see next section).

Best practices recommend carrying out both a topographic and soil survey to develop an effective drainage design and layout. A number of factors determine the size and spacing of pipes including:

- Hydraulic conductivity (soil permeability, texture);
- Kind of crop;
- Crop and soil management practices; and
- Amount of surface drainage.

Greater drainage capacity is generally achieved with closer spacing of drainpipe. However, to be economically efficient the drainage design should use the widest spacing that can effectively meet

FIGURE 3 Trucks equipped with GPS receivers

FIGURE 4 Levelling equipment

Land Forming— Field Levelling with GPS

Global positioning systems (GPS) have replaced traditional land survey techniques for aiding land forming and levelling. They have also increased precision and lowered labour inputs for surface drainage applications. Trucks equipped with GPS receivers (Figure 3) traverse fields and collect field elevation points. Elevation information is stored in a GIS (Geographical Information System) map application on a computer, and then is transmitted to the levelling equipment which automatically adjusts to cut and fill based on the elevation data it receives. Repeated leveling operations over an entire field can break down soil aggregates and increase potential for erosion. In such cases, planting winter cover crops is highly recommended.

the drainage requirements of the crops grown. Field crops have lower drainage requirements than horticulture crops. In the Lower Fraser Valley, typical widths vary from 9 to 20 metres.[9]

Controlled Subsurface Drainage & Sub-Irrigation

When there is an impervious soil layer at no more than 3 metres below the surface, subsurface drainage installations can be used for sub-irrigation.[10] In a controlled drainage sub-irrigation system, water volumes can be maintained with additional runoff for precipitation events, and where necessary water can be pumped into the top end of the system. Drainage outflow is slowed with a control device, and is used to manage the water table in the system. A relatively uniform soil profile and good hydraulic conductivity

are helpful for sub-irrigation. Fields that are hilly or have a slope of over 0.5% are generally unsuited. The spacing for drainage should be established before determining the irrigation spacing. A general rule of thumb is that suitable irrigation spacing is usually about 65% of the drainage spacing.

Regional Agriculture Drainage Criteria

On-farm surface and sub-surface drainage rely on regional drainage systems to transport water away from the farm. Regional drainage criteria were developed for the province for purposes of the Agricultural and Rural Development Subsidiary Agreement with the federal government (signed in 1977). These criteria provide broad guidance for drainage, and are particularly useful for higher level regional drainage system planning to support on-farm drainage design. The 1.2 metre freeboard in the criteria below, allows on-farm subsurface drainage systems to be designed and operated efficiently.[11]

The regional drainage criteria for agricultural areas are:[12]

- To remove the runoff from the 10 year, 5 day storm, within 5 days in the dormant period (November 1 to February 28);
- To remove the runoff from the 10 year, 2 day storm, within 2 days in the growing period (March 1 to October 31);
- Between storm events and in periods when drainage is required, the base flow in channels must be maintained at 1.2 metres below field elevation (Figure 5); and
- The conveyance system must be sized appropriately for both base flow and design storm flow.

Climate Considerations in Drainage Planning

Climate considerations are a critical part of drainage design; for example, 1 in 10 year storm events are used to design drainage improvements that meet regional agriculture drainage criteria. Projected increases in

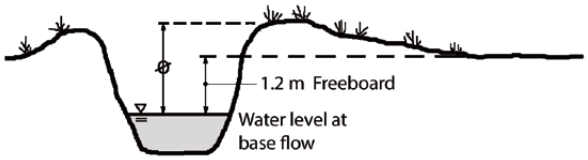


FIGURE 5 Freeboard determination

Source: Riparian Factsheet, BC Ministry of Agriculture, 2011.

FIGURE 6 Drainage ditch on the Sumas prairie near Abbotsford

Drainage Planning Definitions Under the Agricultural Drainage Criteria

- Base flow—is the amount of water flowing in the channel when there is no runoff from storm events in the system. Summer base flows are established from stream flow and precipitation data. Winter base flow is calculated for an extremely wet period defined as 20–22 days of rainfall during a wet month.
- Storm flow—is calculated using a one in 10 year storm, 2 days long (summer) and 5 days long (winter).
- Field elevation—is where 95% of the land in the flood cell lies above the determined elevation.

Source: Resource Management Branch, BCMAFF 2002.

total precipitation and the number of extreme events will need to be incorporated into new drainage designs. Existing infrastructure may need to be upgraded to maintain effectiveness. This is likely to be challenging from both an economic and a practical point of view, as both infield drainage and regional drainage systems may need to be upgraded. Some producers are finding their existing drainage to be ineffective with the longer, wetter springs that have been experienced in some areas, and are replacing, or adding to, existing infrastructure. In-field improvements may still be ineffective in some cases without regional drainage upgrades.

Sea-level rise is a major concern in the Fraser River delta, where drainage infrastructure, field elevation and diking are interdependent (see page 17). The management and use of surrounding lands can increase the amount of infrastructure required to meet drainage criteria in some areas because of reduced water infiltration. Land subdivision—which increases the area of impermeable surfaces—timber harvesting and other land activities can exacerbate drainage problems for low-lying agricultural lands. These challenges are likely to be magnified under future climate scenarios. Watershed management and maintenance of natural water flow regulation (wetlands) will need full consideration in future planning, both at the on-farm and regional levels.

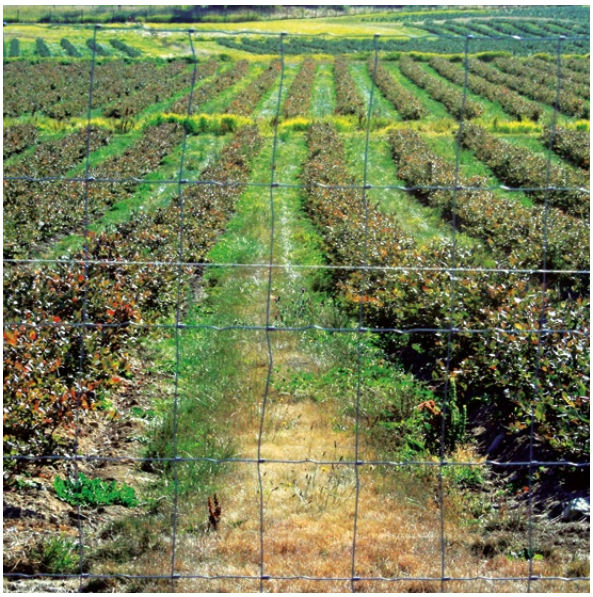


FIGURE 7 Drainage in a Vancouver Island blueberry field, with ditches running horizontally at the top of the photo

General Plant Requirements Under the Agricultural Drainage Criteria

- Perennial crops that have a well-established root system—should not have roots saturated for more than 5 days. Water levels can be higher than the root zone, but must be below the root zone after 5 days.
- Shallow rooted crops and grasses—crops may not be affected until the water is within 0.9 metres of the land surface. Drainage is inadequate when it rises above this level and adequate when it falls below this level.
- Vegetable crops—flooding during the winter may be acceptable and even desirable for some crops (e.g., as a control measure for soil-borne plant pathogens). For these types of crops, inadequate drainage would begin when water levels reach field elevation.

Source: Resource Management Branch, 2002.; additional information on the effects of surface flooding on some specific crops can be found in the BC Agricultural Drainage Manual.

FIGURE 8 Wetlands of various types are important for water flow regulation in natural drainage systems

This flooded agricultural land on Vancouver Island was likely part of a large wetland area complex before settlement.

FIGURE 9 The effects of late-spring rain that accumulated in field depressions after barley emergence

The remainder of this growing season was extremely dry.

Some Benefits & Payoffs of Drainage

- Better nutrient use efficiency
- Improved crop yield and quality
- Greater range of crops grown
- Improved trafficability and reduced risk associated with heavy precipitation near the harvest period
- Reduced soil compaction
- More efficient use of growing conditions
- Reduced environmental risks, and improved environmental quality

Some Costs & Trade-offs of Drainage

- Costs associated with capital infrastructure and pumping equipment
- On-going management and maintenance costs
- Repeated land levelling can break down soil structure, and increase potential for erosion
- Loss of water flow regulation and capacity and other potential values when wetlands are converted to agriculture
- Environmental risks associated with drainage works, including transportation of water borne contaminants nutrients

Drainage Economics

When the benefits of drainage are clear and easily predicted, assessing the economics of drainage can be fairly straightforward. For example, if drainage installations will allow crop production to take place, or allow production of higher value crops, the benefits are easily calculated. However, when the effectiveness of drainage is variable, because of changing weather or watershed conditions, determining the economic efficiency of a particular drainage system or improvements is challenging.

The substantial adoption of subsurface drainage in the high value production areas of the Lower Mainland and Vancouver Island likely indicates that benefits have outweighed costs, and that drainage is reasonably economically efficient. Current installation costs for subsurface pipe drainage on Vancouver Island are roughly $2,500–$3,750 per hectare ($1,000–$1,500 per acre). Likewise, the adoption of improved drainage for native hay meadows in the Interior has also likely been economic. In both cases, private costs may have been reduced by public or third party contributions for control structures and pumping.

A recent study of wetland drainage in grain and oilseed cropping areas of east-central Saskatchewan, estimated a positive annual average net benefit of $28 to $41/hectare drained, depending on farm size.[13] This example may have some relevance to the Peace River region, where naturally vegetated low spots in fields are sometimes drained and then cultivated. However, benefits of drainage vary depending on the type of wetland and its permanence in the field, and so findings are unlikely to be directly transferable. The study is highlighted because it identifies what are called nuisance costs for farmers, in working around low spots and wetlands, in addition to the increased production. However, as with all drainage, careful planning and assessment is required to make sure that the benefits of water regulation and flood control that might be provided by these lands are not underestimated.

Key pieces of information required for economic analysis include an assessment of the area affected by the drainage installation, the effectiveness of the drainage—to estimate the value for crop production—and the costs associated with the installation. The following sub-regional drainage improvement example (Table 2, options A and B) adapted from the *Drainage Factsheet: Agriculture Drainage Criteria,* is useful for identifying some preliminary considerations. In this example, several landowners and individual properties would be involved. Some properties may benefit more from the project options than others, and this would need to be accounted for in a cooperative project within a specified drainage area. Pump systems like those used in this example are necessary when there is insufficient gravity for the drainage outlet. They are often a requirement when lands are behind dikes or when the drainage provided by the local authority is insufficient. In some situations, small pumps may be more economical than installing a lengthy subsurface drainage pipe, or deepening or extending an outlet ditch.[14]

Additional information (i.e., crop production, management, expected life of the improvements and appropriate discount rate) would be needed for a detailed cost-benefit analysis to fully assess the economic efficiency—or the net present value—of these two drainage improvement options. If additional regional flood control benefits can be identified in a project, this may be useful for broadening the standing of the analysis (i.e., number of beneficiaries), and increasing options for funding the improvements.

TABLE 2 Summary for sub-regional subsurface drainage improvements and costs example

	Option A	Option B
Description of work	Clean channels. Install small pump station	Clean and improve channels. Install large pump stations.
For winter storm events		
Area not meeting 1.2 metre freeboard	92 hectares (227 acres)	20 hectares (49 acres)
Area not meeting 0.9 metre freeboard	82 hectares (203 acres)	11 hectares (27 acres)
Percent of area meeting drainage criteria	74%	95%
Freeboard achieved within criteria time period (within zone not meeting 0.9 metre freeboard)	0.4 metres	0.7 metres
Time required to meet the 1.2 metre freeboard*	9 days	6 days
For summer storm events		
Area not meeting 1.2 metre freeboard	85 hectares (210 acres)	5 hectares (12 acres)
Area not meeting 0.9 metre freeboard	75 hectares (185 acres)	5 hectares (12 acres)
Percent of area meeting drainage criteria	76%	98%
Freeboard achieved within criteria time period (within zone not meeting 0.9 metre freeboard)	0.7 metres	0.75 metres
Time required to meet the 1.2 metre freeboard*	3 days	3 days
Costs		
Improvements	$250,000	$600,000

** This is assuming that the 1.2 metre freeboard criterion is met when there are no storm events.*

Drainage Examples

Drainage Control Issues *(Fraser River Delta)*

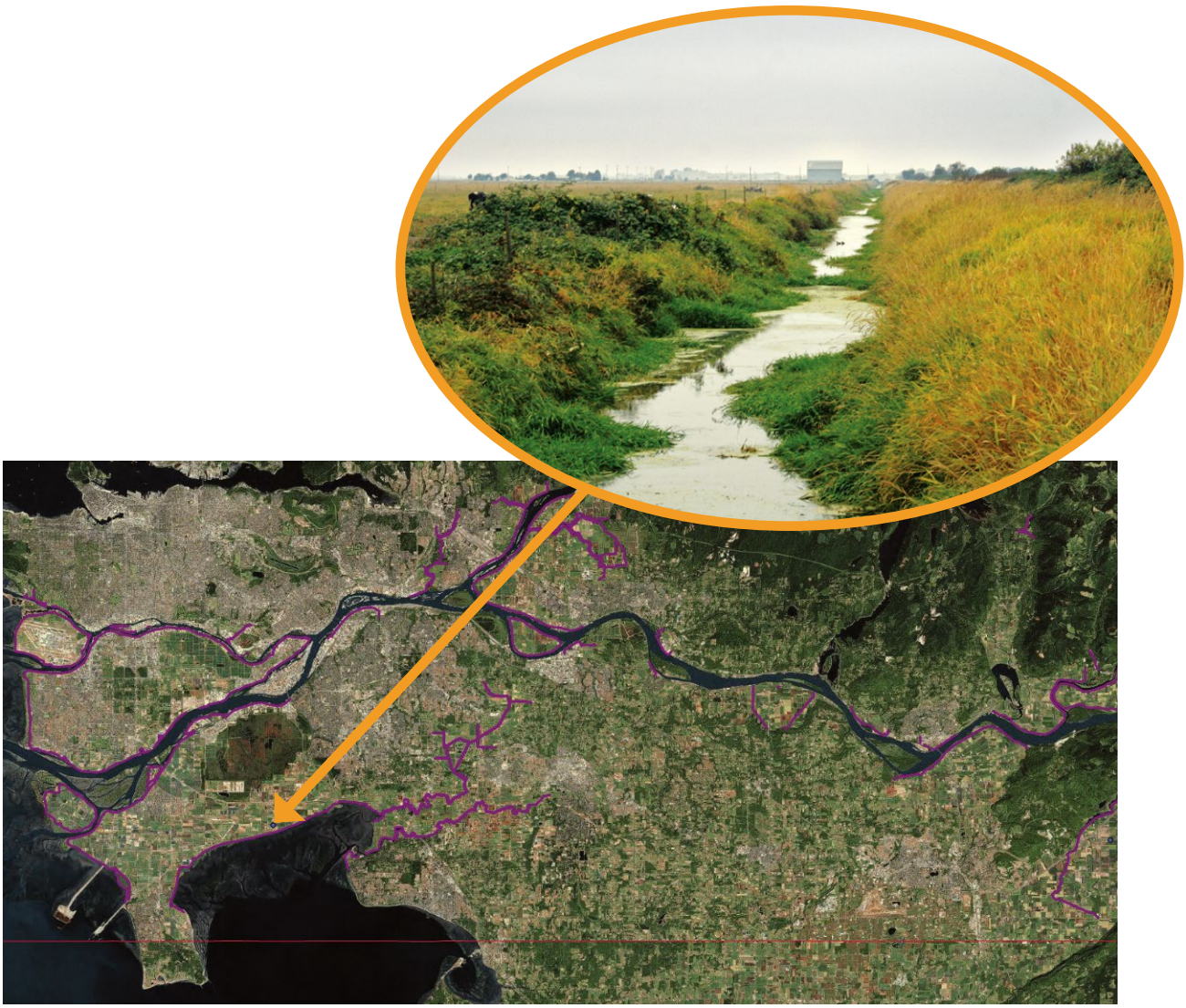
Water and weather related issues already impact farm operations in the Fraser River delta. Lower water levels in the Fraser River mean the salt wedge moves further up the river, making the water pumped at those places unsuitable for irrigation. Consequently, irrigation intakes have been moved up river. The maintenance and improvement of the regional drainage system could be critical for on-farm drainage systems to function in the future. The wet fall of 2010 was a disaster for potato growers in the delta, and this producer describes the conditions and the implications for drainage, recognizing it may have been a 1 in 90 year event:

> *"The whole soil profile was saturated, it didn't matter if was levelled or not levelled… the tile drains don't work when the ditches are full. We got 8 inches of rain in September. The ditches were full all month and it wasn't sunny enough long enough to drain, the soil was just muck and after first two weeks of September the soil was totally saturated. It never dried up, it never quit raining. The potatoes were already starting to rot.*

Since this event, new pumps have been installed to move water from drainage channels over the dike works. However, whether capacity will be sufficient to meet drainage demands during extreme events in the future is uncertain. Regional flood control works will be further stressed by sea-level rise.

Highlights

- → Importance of drainage
- → Regional integration of drainage systems
- → Limitations and thresholds for on-farm drainage function
- → Regionally planned improvements



Constructed drainage ditch in the Fraser delta, in the very dry fall of 2012.
The aerial map shows regional flood control works (linear features shown in purple).

Precision Technology for Surface Drainage *(Peace River region)*

At this grain, oilseed, pulse and forage seed operation, precision equipment technology (GPS) and field mapping are being used to accomplish surface drainage on a rolling landscape. Surface drainage has been practiced on this farm since the 1980s, but had limited effectiveness because accurate line-of-sight measurements were difficult to make in this terrain.

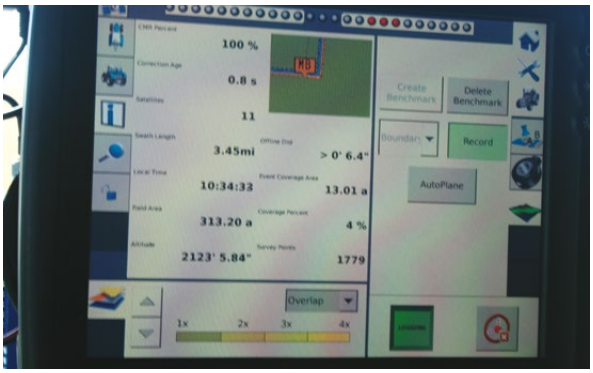
In years with wet springs, crop damage occurs in low lying areas:

> *"In a dry year it doesn't pay [referring to surface drainage improvements], but like this spring in June we had a wet spell… we got 6 inches in 1 month, and the water was laying everywhere… It takes a few years to know how much you actually gain because we take yield recording too in the combines [referring to harvest yield monitors linked to GPS, see next page].*

The amount of land improved by drainage is estimated to be as much as 10 percent in some fields.

Highlights

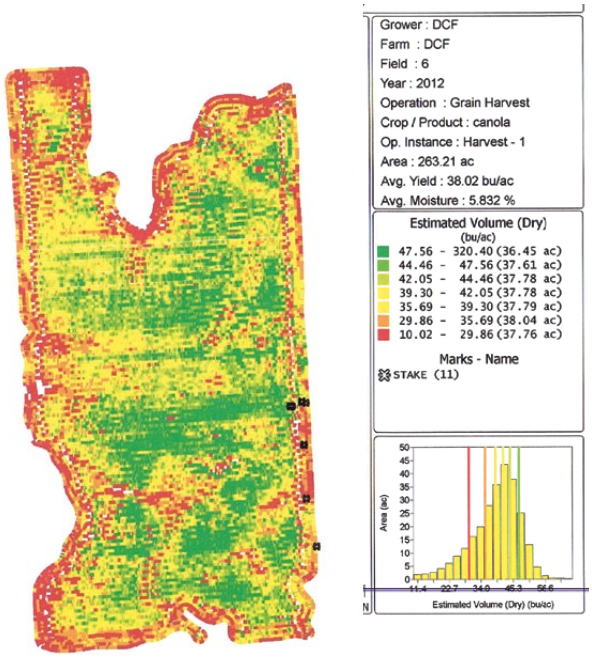
- → Precision GPS technology for surface drainage
- → Low-slope, low impact land forming
- → Results monitoring



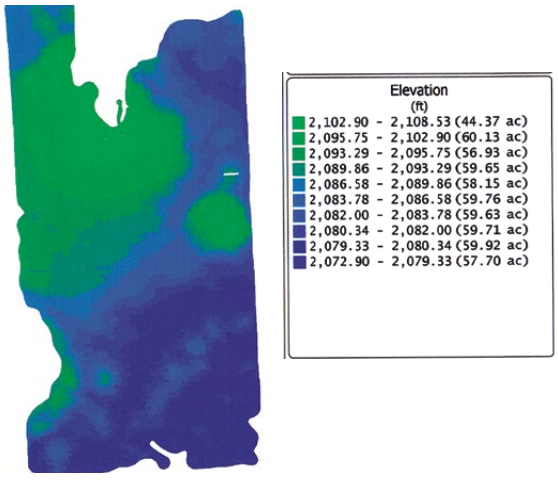
GPS auto-steer technology in a swather working in a canola field. Additional software has been added to measure field elevation every 10 feet. This data is saved and used to create a field elevation map (see next page). The elevation data is saved and then transferred from a computer unit mounted in a four wheel drive tractor to the cutting edge of a reconditioned 10 foot Steiger scraper. Computer controlled hydraulics adjust the blade height automatically to get the specified grade. Cut and fill depths are typically 25mm (1 inch) or less.

Soil Map Unit for this Example

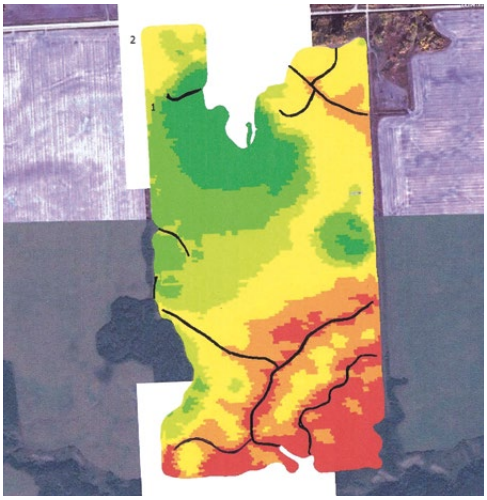
(FA-JU) Falher-Judah, 13,528 hectares (33,428 acres): This map unit occupies large complex soil landscapes near Shearerdale, Clayhurst, and Fort St. John. Typically, the topography is moderately and strongly rolling, ridged and hummocky, with 30–50%, Judah soils on better drained sites. Lesser amounts of the more poorly drained Nampa soils occupy level and depressional sites.[15]



Yield map for the 2012 canola crop before drainage—red low yield areas mid-field correspond to low elevation draws.



Field map showing elevations collected in the swathing operation (gradient is shown at coarse scale for illustration purposes).



Gradient map showing where surface drainage was implemented. Each line represents a cut-fill width of about 20 feet, or 2 scraper passes, carried out in fall 2012 after harvest. The low impact land forming (25 mm or less) operation took about 2 days.

Endnotes

1 "Growing Forward Beneficial Management Practices 2012/2013 – The Canada-BC Environmental Farm Plan Program Plan Program" (BC Agricultural Research & Development Corporation, 2011), *http://www.bcefp.ca/userfiles/file/efp/2012-13%20Growing%20Forward%20BMP%20List%206Dec11.pdf*

2 BC Ministry of Agriculture, Fisheries and Food and Cariboo Poorly Drained Soils Development Extension Committee, *Forage Production on Poorly Drained Soils in the Southern Interior of British Columbia* ([Victoria]: Province of British Columbia, Ministry of Agriculture, Fisheries & Food, 1992).

3 A.H. Dolan et al., *Adaptation to Climate Change in Agriculture: Evaluation of Options* (University of Guelph, Department of Geography, 2001), *http://www.uoguelph.ca/gecg/images/userimages/Dolan%20et%20al.%20(2001).pdf*

4 Enterprise diversification may be a suitable adaptive strategy to minimize the impacts associated with climate change; however, it is not among the practices evaluated in this series.

5 BC Ministry of Agriculture, Sustainable Agriculture Management Branch, Department of Fisheries & Oceans, and BC Ministry of Water, Land & Air Protection. *Drainage Management Guide:Companion Document to the Canada-BC Environmental Farm Plan Program Plan*, ed. by Ted Van der Gulik, First Edition (BC Agriculture Council, 2005), *http://www.al.gov.bc.ca/resmgmt/EnviroFarmPlanning/EFP_Drainage_Mgmt_Guide/Drainage_Management_Guide.pdf*

6 BC Ministry of Agriculture Drainage Factsheets can be found at: *http://www.agf.gov.bc.ca/resmgmt/publist/Water.htm#drainage*; Vincent Lalonde et al., *BC Agricultural Drainage Manual* ([Abbotsford, B.C.]: BC Ministry of Agriculture & Food Ministry, 1997), *http://www.agf.gov.bc.ca/resmgmt/publist/500Series/525500-1.pdf*

7 BC Ministry of Agriculture, Sustainable Agriculture Management Branch, Department of Fisheries & Oceans, and BC Ministry of Water, Land & Air Protection, *Drainage Management Guide: Companion Document to the Canada-BC Environmental Farm Plan Program Plan.*

8 Lalonde et al., *BC Agricultural Drainage Manual.*

9 BC Ministry of Agriculture & Food, Resource Management Branch, *Drainage Fact Sheet: Subsurface drainage plan.* (BC Ministry of Agriculture, Food & Fisheries, 1999), *http://www.agf.gov.bc.ca/resmgmt/publist/500Series/532000-1.pdf*

10 BC Ministry of Agriculture & Food, Resource Management Branch, *Drainage Fact Sheet: Controlled Drainage / Subirrigation* (BC Ministry of Agriculture, Food & Fisheries, 1998), *http://www.agf.gov.bc.ca/resmgmt/publist/500Series/564000-1.pdf*

11 Freeboard refers to the difference between the elevation of the water level in the drainage way at base flow and the field elevation (Figure 5). The field elevation is often set where 95% of the land in the flood cell lies above the determined elevation.

12 Resource Management Branch, *Drainage Fact Sheet: Agricultural Drainage Criteria* (BC Ministry of Agriculture, Food & Fisheries, 2002), *http://www.agf.gov.bc.ca/resmgmt/publist/500Series/535100-2.pdf*

13 Brett G. Cortus et al., "The Economics of Wetland Drainage and Retention in Saskatchewan," *Canadian Journal of Agricultural Economics* 59, no. 1 (March 1, 2011): 109.

14 Lalonde et al., *BC Agricultural Drainage Manual.*

15 T. M. Lord, *Soils of the Fort St. John-Dawson Creek area, British Columbia*, British Columbia soil survey report no. 42 ([Ottawa] : Victoria, B.C: Research Branch, Agriculture Canada ; Available from Maps B.C., Ministry of Environment, 1986).