CLIMATE CHANGE ADAPTATION PROGRAM

Water Storage

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BC AGRICULTURE & FOOD

BC Farm Practices
& Climate Change Adaptation

Water Storage

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other project partners
BCAC/ARDCorp

project manager
Emily MacNair

author & photographer
Allen Dobb

graphic design
Rocketday Arts

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Climate Action Initiative
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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

Water is critical for all farm operations. The development and management of on-farm storage for water could potentially help to mitigate water shortages associated with climate change. On some farms in BC, water storage is already developed and is used to supplement other sources. In some areas of the province, such as the Peace River region, dugouts are sometimes the only water source available for both domestic and livestock use on some farms. The suitability and potential for future water storage development is highly dependent on location, planned use and farm scale.

Uses of On-farm Water Storage

- → Supplemental irrigation source
- → Primary irrigation source
- → Livestock water
- → Domestic water
- → Wildlife water, habitat
- → Fire suppression
- → Pesticide spray mixing

What does Water Storage Involve?

Water storage involves capturing and holding water on the farm that might ordinarily be lost as runoff, or in-stream flow, and making it available for later use in agricultural production. Conventional approaches to water storage focus primarily on water storage structures such as dams, dugouts and reservoirs. As the demand for water for all uses increases, integrated approaches that also include soil and water conservation measures (mulching and crop residue management, watershed planning and management, and irrigation efficiency improvements) will be needed to ensure there is a sufficient water supply for agriculture. Changes in water hydrology that are expected under future climate scenarios need to be incorporated into these approaches.

The amount of water storage required depends on the water demand for both crops and livestock. Crop irrigation has a relatively high water demand that varies with location, crop type, soils, irrigation efficiency and management. The large volume of water required for irrigation is often a factor in determining the feasibility of on-farm storage. Micro-storage (cisterns, tanks or other types of containment) may have some application for very small scale vegetable production using drip irrigation (plots of 200 square metres or less); however, these applications are not discussed in this summary. Storage structures of all types can be used to moderate groundwater withdrawal during periods of peak demand, and in some situations can contribute to ground water recharge. Storage structures can also play a role in capturing water from in-field drainage (see Water Storage Examples, p. 17).

In BC, a licence is required for a water storage structure whether it is a dam or a dugout.[1] However, under current legislation, dugouts that are filled only by surface water runoff from rain or spring freshette (water that cannot be defined as a stream under the *Water Act*) do not require a licence from the Water Comptroller of the Ministry of Environment. Dugouts that are in-stream, or are filled from the diversion of a watercourse do require a water licence. A process is currently underway in the province to modernize the *Water Act* to help meet future water use and management challenges.

Current Level of Adoption in BC

For many conservation based practices it is appropriate to consider current levels of adoption of the practice to evaluate potential for future adoption. However, a reasonable assessment of on-farm water storage potential must take into account local conditions, the nature of the proposed storage, and current water allocations. There are thousands of active water licences in the province registered for livestock water or irrigation purposes, and an undetermined number will have associated storage structures. There are over 2,000 dams licenced for agriculture, and most are located on Crown land; approximately 617 active dams are within the ALR, and a substantial percentage of these appear to be associated with agricultural uses.[2]

Key Findings

- Substantial land area is required for on-farm water storage where the annual irrigation requirement is high, reducing feasibility and effectiveness in parts of the province where the agricultural land base is also limited. Dugouts and pond storage may be effective for small acreages but are not practical where large acreages are irrigated.
- Feasibility and effectiveness of on-farm water storage is very sensitive to location, land availability, scale of production and intended water use.
  - → Water storage is likely to be an effective adaptation option for livestock water in most regions of the province.
  - → Water storage for irrigation may be effective in regions (such as Vancouver Island) where production scales are small.
- In some situations, on-farm storage may help to moderate withdrawals from groundwater during periods of peak irrigation demand, and control to surface water flows and negative downstream effects during extreme precipitation events.
- On-farm storage may be practical if there is a continuous flow into the storage from a well or spring.
- The economic efficiency of water storage as an on-farm adaptation will be highly variable, and dependent on farm location, scale and intended use.
- Cooperation and joint use agreements for small-scale water storage structures may facilitate joint investment in developments.
- Proper planning and design of on-farm water storage is critical to ensure effectiveness and longer-term benefits:
  - → To allow for increased future demand (with higher temperatures and potential increases in evapotranspiration); and
  - → To resist washout or failure in extreme events, and at the same time allow storage to capture sufficient runoff from increased rain precipitation, and reduced snowmelt.
- There are regulatory obligations and risks associated with the ownership of large-scale reservoir storage (dams). When the berm surrounding a dugout is higher than 6 feet there can be risks associated with the structure, similar to a dam.
- Existing institutional and legal structures allow development of on-farm water storage facilities but the regulatory system—in place to balance water demand among many uses—must be navigated before construction; existing water allocations may limit the success of some applications.
- Changes to the *Water Act*, currently under consideration, may affect future storage developments.

Areas for Further Adaptation Research & Support

- Planning and technical support to identify water storage potential, and to ensure that storage designs match demand, location constraints and future conditions.

- Local demonstration to support development of suitable water storage and integrated management strategies (including the collection of in-field drainage in various regions).

- Exploration of potential for partnerships (funding and development) in agricultural water storage.

- Consideration of increased water storage for agriculture in local watershed and water demand planning.

- Continued research on water hydrology under future climate scenarios.

- Integrated watershed planning that considers future demand, conservation, water storage, wetland water retention and groundwater recharge, to improve water use efficiency.

- Consideration of future on-farm water storage development in the *Water Act* modernization process.

Evaluation: Adaptation & Water Storage

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: 1–4
very ineffective to moderately effective

Developing on-farm water storage can be an effective means of reducing risk or vulnerability to climate change in some situations. However, effectiveness is very sensitive to site location, scale of production and intended water use. Where climate related water shortages are expected to be most severe, like the southern interior and Okanagan regions, the demand for irrigation is already high, and very large capacity on-farm storage would be required to serve increasing needs in the future. This is an impractical intervention when agricultural land is already in very short supply in these regions. In this part of the province, many sites suitable for reservoirs have already been developed.[5] There may be some effective application in areas of Vancouver Island and other regions, where annual irrigation requirements are low to moderate, production scales are small, and existing ground water supplies are under stress. On-farm storage in these situations may help moderate groundwater withdrawals during periods of peak irrigation demand.

In areas of the Peace River region, management of stored water in dugouts is critical for livestock and domestic use. Here proper design, location, and management of stored water is likely to be moderately to very effective. Potential for on-farm storage for livestock water exists throughout the province. Water storage developments can allow improved grazing management and increased productivity, but should be designed to minimize evaporation. Off-site watering methods should be used to extend dugout life and maintain storage capacities.

Ground and surface water hydrology under future climate change scenarios is uncertain. Growing seasons may be longer in some areas, increasing the water demand for cropping. Though total precipitation is predicted to increase across BC, summer precipitation and precipitation falling as snow are expected to decrease. With corresponding increases in temperature, growing season moisture deficits and evapotranspiration are expected to increase. Anticipated increases in surface evaporation will need to be managed with design and storage maintenance practices. To remain effective, storage volume requirements may need to be increased. Dugouts, dams and spillways will need to be designed to resist washout or failure in extreme events, and at the same time capture sufficient runoff from increased rain precipitation, and reduced snowmelt. Adjustments in land use and improved watershed management practices will also need to be integrated into water storage plans.

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 water storage as an on-farm adaptation option will be highly variable, and dependent on farm location, scale and intended use. Large volume reservoir storage has proportionately higher costs related to planning and design requirements, regulation, and future downstream risk management related to extreme events. Economic Efficiency for this type of storage will depend on the availability of lower capability land for construction, and high value production. However, where water demands are lower and production scales are smaller, water storage development may be easily justified. Storage development, and related management practices (i.e., to reduce evaporation and to extend storage life) will likely be economically efficient in areas where risks related to future water storage are high, and in areas where on-farm storage of surface water is the only water available. Cooperation and use agreements for small storage facilities may facilitate joint investment in developments.

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

If properly planned and designed, on-farm storage of surface water should help to reduce income loss in places where increased water demand, due to higher temperatures and drier growing season conditions, is expected. Some structures may help to control surface water flows and negative downstream effects during extreme precipitation events.

Adaptability

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

RATING: 4
moderately adaptable

If water storage structures are appropriately sited and designed there may be some potential for structural upgrades. However, individual on-farm water storage structures will likely be built to existing watershed and land constraints, leaving little flexibility for future adaptation in terms of capacity. On-farm storage may allow for flexibility in crop production choices, and some future adaptation will be possible in the area of watershed management, and the adoption of practices focused on reducing surface evaporation.

Institutional Compatibility

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

RATING: 2–3
moderately compatible to neutral

While existing institutional and legal structures allow development of on-farm water storage facilities, the regulatory system — in place to balance water demand among many uses — must be navigated before construction. Compatibility with existing institutional structures varies with the water storage location, type and use. At times, agriculture may compete directly with other water uses, for instance for fish, wildlife and urban settlement. Land availability for on-farm water storage, is likely to remain a constraint in some areas of the province, however, the potential for storage to help minimize in-stream withdrawals later in the season when flows are lower, should be explored. Changes to the *Water Act*, currently under consideration, may affect future compatibility. In the past, government has supported on-farm water storage development with programs such as the Water Supply Enhancement Project. In some areas, water storage efforts are supported through cooperation with conservation groups.

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

Water is required for all aspects of agricultural production, and there is substantial experience and history associated with on-farm water storage. In areas where water storage development is feasible, future adoption may be limited by inadequate financial and knowledge resources for feasibility studies, impact assessments and planning. The substantial capital investment required for design and construction may also limit adoption.

Independent Benefits

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

RATING: 1–5
high trade-offs to high independent benefits

The ability of on-farm water storage to produce benefits independent of climate change will be variable. If developments are feasible and properly planned, water storage would produce benefits that might include increased crop or livestock production, improved watershed management and greater fire protection. In these situations, independent benefits would be high.

TABLE 1 Water storage evaluation summary

Evaluation Criteria	Rating	Meaning
Effectiveness	1–4	Very ineffective to moderately effective
Economic Efficiency	2–4	Moderately inefficient to moderately efficient
Flexibility	4	Moderately flexible
Adaptability	4	Moderately adaptable
Institutional Compatibility	2–3	Moderately compatible to neutral
Adoptability	2–4	Moderately low adoptability to moderately adoptable
Independent Benefits	1–5	High trade-offs to high independent benefits

Water Storage Background Information

Types of On-farm Water Storage

On-farm water storage is usually created with the construction of an earthen dam to form a reservoir, or with an earthen excavation to form a dugout. The appropriateness of each type of storage will depend on the location, natural topography and watershed characteristics of the farm land base.

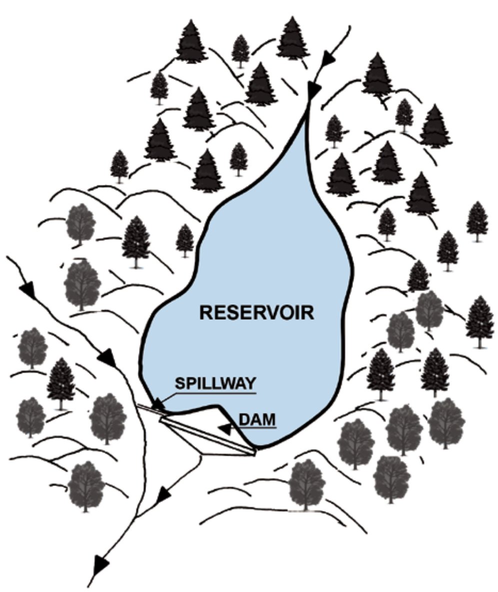


FIGURE 1 Components of an earthen dam water storage
Source: BC Ministry of Agriculture, Food & Fisheries (2003)

Dams

Dams are constructed in drainage ways that have a suitable natural reservoir area to store water. They require a spillway (overflow), and an outlet control to reduce the risk of breach or washout, and allow downstream flow (Figure 1). Dams may be constructed from earth, rock or steel, and should be designed by a professional engineer.

Dugouts

Dugouts collect and store run off, and are best located in a natural depression. There are two recommended arrangements for dugout storage:

- → The dugout collects water only from surrounding lands in the immediate vicinity (Figure 2); and
- → The dugout holds water diverted or pumped from a nearby watercourse.

Dugouts or ponds are also sometimes constructed:

- → in a watercourse; or
- → a spring or seepage area where ground water comes to the surface.

In-stream applications are likely to receive greater scrutiny in the authorization process. Any mixing of surface and ground water should be avoided,

FIGURE 2 Dugout water storage in the Peace River region created during oil and gas activities, and now used for livestock water

to protect ground water sources from potential contamination from surface water.

The site potential for water storage development and the expected use are the main determinants in water storage design. Both the water quality and quantity for each prospective use should be assessed. If there are groundwater sources available, these can be designated for uses where high quality water is required. Where ground water sources are limited, or cost prohibitive to develop, high quality surface water can be stored with careful planning and management.

Water Demand & Storage Capacity

Water demand varies considerably with the intended use and is a factor in determining the feasibility of on-farm storage. Weather and climate also play a significant role in determining water demand, especially for irrigated crop production, where evapotranspiration and precipitation variables are used to calculate growing season moisture deficits.

Crop Irrigation

Crop irrigation has a high water demand, and building a large capacity on-farm storage structure may be impractical in many situations. Detailed water demand models have been developed for several watersheds in southern BC, based on the crops grown, rooting depth, soils, evapotranspiration, expected irrigation period, irrigation system and management.[6] Similar detailed information should be used when designing irrigation systems. General figures for irrigation demand are useful for estimating approximate storage requirements, for undertaking a preliminary feasibility assessment. Table 2 shows irrigation demand figures for several locations across the province. These figures assume around 70% irrigation efficiency, and account for expected variation in demand over a 10 year period using historical weather data. As weather averages shift with climate change, calculated irrigation requirements will also need to be updated. Projected irrigation demand modeled under future climate scenarios should also be considered in water storage planning.

The following example uses the information provided in Table 2 for two different locations in BC, illustrating how water storage capacity might vary with an increased irrigation requirement. It also provides an estimate of the land surface taken up by the water storage structure needed to supply the necessary volume, assuming a certain set of dimensions.

TABLE 2 Estimated annual irrigation requirement

Location	mm
Abbotsford	305
Agassiz	152
Armstrong	432
Campbell River	356
Chilliwack	178
Duncan	305
Hope	330
Kamloops	813
Kelowna	660
Langley	229
Nanaimo	356
Oliver	864
Osooyos	889
Prince George	356
Sumas	229
Terrace	305
Vernon	558
Williams Lake	457

Source: BC Ministry of Agriculture and Food, 2000.[2]

Water Storage Example 1—A 4 hectare (10 acre) field with an annual irrigation requirement of 305 mm (e.g., location Duncan, BC) needs 10 acre feet of water applied.[7] This volume of water is equivalent to 12,220 cubic metres. The storage volume would need to be larger to account for evaporation loss from the surface. Without accounting for this loss, a pond 83 metres × 40 metres × 5 metres deep with 1.5 side slope, 1.5 end slope (slope = run/rise) would provide storage for just over 12,361 cubic metres.[8] The water surface area would be 3,320 square metres, or just over a third of hectare (0.82 acres). If this field were located near Kamloops, where the estimated annual irrigation requirement is 813 mm, the volume of water required would be roughly three times greater and the resulting surface area would be substantially larger (8,125 square metres, or 2 acres; see Table 3). This example also assumes that the storage facility must store the entire annual irrigation requirement. If the storage were being fed by freshet (e.g., upper watershed snowmelt) for part of the irrigation period, it could be sized to store a part of the annual requirement.

Livestock

Livestock water demand varies with the kind and class of livestock, ambient temperature, type of feed and whether female animals are lactating or dry. Pregnant dry beef cows may consume just around 23 litres/day in winter and up to 68 litres/day when lactating and temperatures are around 27° C. Table 4 provides some values for estimating average livestock water demand. For example, a small broiler operation with five production cycles of 5,000 birds each, would require around 255,000 litres (not including the barn requirement). The following example uses the information in Table 4 to estimate the annual water requirement for a livestock operation, and provides a rough estimate of the required storage dimensions.

Water Storage Example 2—A beef operation running 100 head would require approximately 1,825,000 litres (401,444 gallons) for livestock water annually. Without accounting for evaporation losses and extra capacity for drought years, this demand could be provided by a storage facility 34 metres × 22 metres x 4 metres deep with 1.5 side slope, 1.5 end slope (slope = run/rise), with a capacity for just over 1,840,000 litres (1,840 cubic metres).[8] The water surface area would be 748 square metres.

TABLE 3 Storage required for two different requirements

Location	Estimated Annual Irrigation Requirement in mm (Inches)	Volume Required for 10 Acre Field in Cubic Metres (Gallons)	Example Storage Dimensions in Metres	Storage Surface Area in Square Metres	Storage Surface Area as Percent of Area Irrigated
Duncan	305 (12)	12,335 (2,713,280)	83 x 40 x 5	3,320 (0.82 acre)	8%
Kamloops	813 (32)	32,893 (7,235,461)	125 x 65 x 5	8,125 (2.0 acre)	20%

TABLE 4 Livestock water demand estimates in litres/day[9]

Animal Type	Drinking	Milking Prep	Barn	Total
Milking Dairy Cow	65	5	15	85
Dry Cow	45		5	50
Swine	12		0.5	12.5
Poultry – Broiler	0.16		0.01	0.17
Poultry – Layer	0.08		0.01	0.09
Turkeys	0.35		0.01	0.36
Goats	8			8
Sheep	8			8
Beef – range, steer, bull, heifer	50			50
Horses	50			50

Planning Considerations & Identifying Potential Benefits

Proper planning for on-farm storage is critical. Depending on the scale and type of the storage facility, plans may require input from a professional engineer. Even small scale storage plans will need to be of a professional standard for water licence applications. Depending on the situation, input from other professionals (i.e., hydrologist, biologist) may be required. The first step is to estimate the total annual water demand for the farm, both in terms of quantity and quality. Existing water sources should be inventoried, and clear objectives for the water storage development should be identified:

- Is the storage intended to be the only or primary water source?
- Is the development intended to supplement existing water sources or to allow for increased livestock or crop production, or water use efficiency?
- Is the development intended as a backup in case of future water shortage or drought?

Once objectives are established, potential benefits can be identified. They might include:

- Reducing production risk associated with drought or longer term water shortage;
- Increasing production, or more valuable production;
- Reducing risk against future ground water shortage; and
- Hedging against increased water costs passed on from a water purveyor.

Land management practices in the watershed should also be considered in planning, as they have a direct bearing on water quantity and quality, and can determine the effectiveness of the future storage development. Planning should be guided by applicable provincial legislation and regulations, with regional guidance from the appropriate provincial ministry. A partial list of Acts and Regulations that apply include:

- *Water Act*;
- *Water Act*, Water Regulation;
- *Fish Protection Act*, Sensitive Streams and Licensing Regulation; and
- *Water Act*, Dam Safety Regulation.

Some other considerations:

- Evaporation depends on size and depth of the reservoir or dugout (the same volume storage that is deeper, will have less evaporation).
- More storage may be required if a structure does not fill on a consistent annual basis and a carryover is needed.
- Filling of storage is also dependent on the size and the run-off characteristics of the watershed supplying the storage. To have consistent supply, the watershed and capacity need to be matched.
- Can other run-off sources be diverted to the on-farm storage (e.g., in-field drainage, buildings)?
- Is the site located so the water can be used efficiently? Is the reservoir or dugout located at an elevation above the point of use to allow gravity delivery, or will pumping be required?
- For dugouts: Is there a suitable place to put excavated material? Is the area flat enough to allow complete excavation or will a large berm be required?
- For dams: Is there adequate material nearby for construction? Is there road access to facilitate construction? Are there roads, houses or transportation corridors downstream of the dam that may be at risk in case of dam failure? Are there measures that can be taken to reduce downstream risks?
- Information on future climatic and hydrologic conditions should be used in planning, to ensure both adequate capacity and adequate engineering standards for extreme events.

Maintenance & Management

The *Water Act* Dam Safety Regulations set out a series of maintenance requirements for dam owners (reservoir storage). Maintenance and inspection schedules are based on the downstream risk classification for the dam. Each classification category, from low to extreme, is based on the consequences of failure measured in potential loss of life, impacts on the environment and cultural values, and economic losses affecting infrastructure. The specified maintenance schedule is more frequent and detailed for dams with higher risk classifications. Owners of these dams must prepare an operation manual and emergency preparedness plan and submit these to a dam safety officer.

Maintenance and management of dugouts and ponds will depend, to some extent, on the water quality expected from the storage. These inputs will be greater when higher water quality is needed. Ponds and dugouts are typically small water bodies, which have limited circulation and low oxygen. They undergo a natural process called pond succession, and over a long period of time will fill with sediment, organic material and eventually become revegetated. Therefore storage capacity will decrease over the lifetime of the dugout. An illustration of this process is shown in Figure 3.

Design & Aeration

Storage capacity can be extended over a longer period with management and good design. Steeper side and end slopes will prevent the accumulation of sediment,

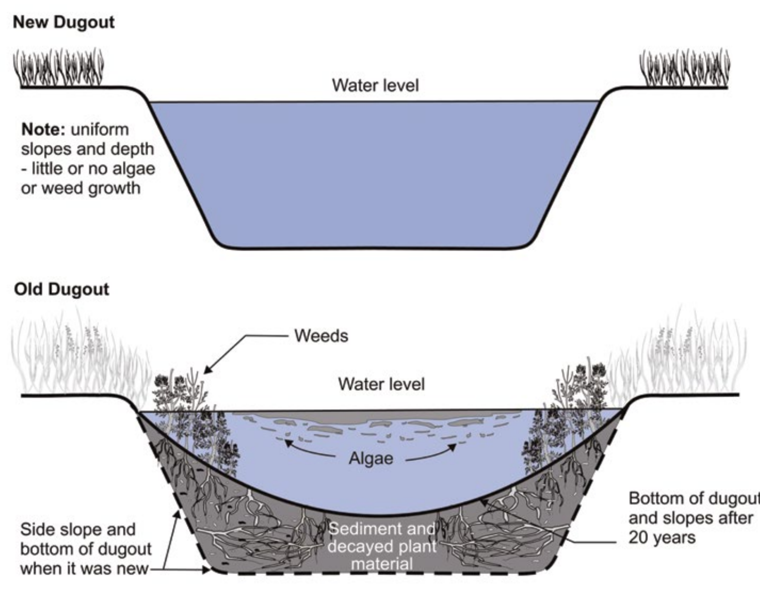


FIGURE 3 Process of dugout (pond) succession[12]

TABLE 5 Estimated annual evaporation loss for small water storage example in 2012

Location	Calculated Annual Evapo-transpiration in mm (ET) 2012	Estimated Surface Evaporation in mm	Volume of Water Loss from Storage in Cubic Metres (Surface Area 748 Square Metres)	Annual Water Loss in Litres	Annual Evaporation Loss as a Percent of Storage Volume (1,840 Cubic Metres)
North Cowichan	840	588	440	440,000	24%
Kamloops (Airport)	977	683	511	511,000	28%
Dawson Creek (Airport)	749	524	392	392,000	21%

Notes: This example is for illustration purposes, and is specific to only the locations in the table. Evaporation from a water source varies with size, depth and the energy exchange within the water body, and between the water body and the air. Here the annual water loss is an estimate for the storage structure in Example 2 above, based on calculated evapotranspiration (ET) provided by Environment Canada for the weather stations at the locations in the table. A coefficient of 0.7 was used to convert ET to an estimate of surface evaporation from a water body with a depth greater than 2 metres.[11] *The ET is calculated for a grass reference crop using a modified Penman Monteith equation, which is the standard method recommended by the UN Food and Agriculture Organization. In this example, Dawson Creek evapotranspiration was 50mm above the long-term average. North Cowichan data was incomplete, but also likely above the long-term average. Kamloops evapotranspiration for 2012 was normal.*

and slow the succession process. A deeper dugout will also have a longer life. Continuous injection of oxygen with an aeration device is the single most effective practice for maintaining water quality and extending dugout life.[10] Sediment removal may be necessary every 5–10 years in some situations, but is costly. Proper siting, design and management are better alternatives for extending dugout life.

Evaporation

Evaporation losses from dugouts and reservoirs can be a concern during periods of severe drought. Normal evaporation may result in substantial losses of water from storage and should be accounted for in planning, with allowance for extremes (see Table 5 for an example of evaporation estimates). Evaporation from water surfaces can vary substantially depending on local weather conditions. Site specific information should be used when calculating reference evapotranspiration. Adjustment factors may need to be applied if distant weather station estimates are used.

Careful placement of planted or retained shelterbelts can reduce evaporation from water surfaces. Shelterbelts can also limit natural aeration, and are best combined with a mechanical aeration system.

In areas where runoff from snowmelt contributes to dugout storage, shelterbelts and snow-fences can help to accumulate snow where it can be captured by the dugout. Dugout covers and floats have been used to reduce evaporation losses from dugouts.[13] The storage capabilities of dugouts used for livestock water can be extended by using off-site water methods such as nose pumps, gravity-fed troughs or with solar powered pump troughs (Figure 4).

Costs

The cost of developing on-farm water storage can be highly variable and dependent on the site characteristics, planning requirements, and volume of the storage. Costs can generally be divided into three categories: 1) planning and site preparation; 2) construction; and 3) on-going maintenance. A primary cost consideration, if irrigation is the main intended use, is the amount of land required for the storage structure. Feasibility is sensitive to farm scale and the expected irrigation requirement. Storage development is also likely to be more beneficial if higher value crops are grown. Storage that is combined with other water sources and used as pumped storage may be a more economically efficient alternative.

FIGURE 4 Portable solar powered water trough for off-site watering

Investment in on-farm water storage can sometimes come from third parties. Ducks Unlimited have supported on-farm water storage projects to provide waterfowl habitat. In the Peace River region, dugouts are sometimes created on private lands as a result of oil and gas activities and associated road construction. If properly planned and situated, these structures can provide mutual benefits. Farm specific planning and some form of cost-benefit analysis are necessary to fully assess the suitability of on-farm water development. Some of the potential cost considerations for two water storage applications are outlined in Table 6.

TABLE 6 Potential cost considerations for two water storage applications

Costs	Earthen Dam & Reservoir	Dugout
Planning & site preparation	▪ Planning, time, specialist services, engineered design ▪ Site testing, land clearing	▪ Planning time and/or specialist services ▪ Site testing, land clearing
Construction	▪ Dam construction ▪ Outlet and spillway construction ▪ Grass seeding ▪ Opportunity costs associated with production values lost from flooded land ▪ Piping, pumping to use area	▪ Top soil stripping ▪ Excavation ▪ Sealing in coarse textured soils (not required for finer textured soils) ▪ Distribution or movement of excavated material, topsoil replacement ▪ Grass seeding ▪ Opportunity costs associated with production values lost from land ▪ Aeration equipment, shelterbelt planting ▪ Pump, offsite water installation or other access
Maintenance	▪ Weekly, monthly or quarterly inspections (depending on downstream risk classification) ▪ Monitoring/instrument costs ▪ Fence maintenance, security ▪ On-going risk associated with dam ownership (depending on classification and scale) ▪ Potential increased ownership risk with extreme weather events	▪ Monthly inspections (depending on quality requirements) ▪ Fence maintenance ▪ Vegetation maintenance

Water Storage Examples

Captured Field Drainage & Irrigation Water Storage *(Vancouver Island)*

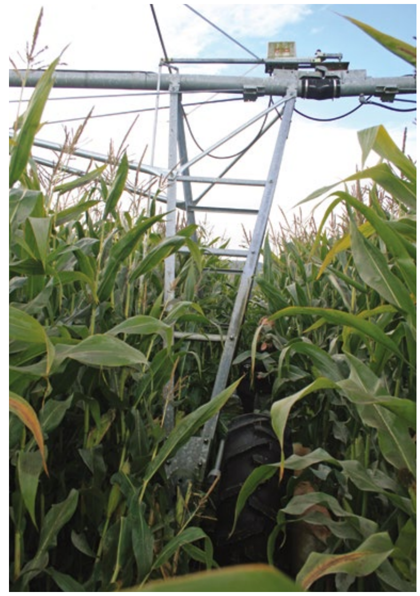
Over time, this dairy farm on Vancouver Island has developed an integrated drainage and water storage system for forage crop irrigation. Now the farm has two large pond (dugout) storage facilities that have a combined surface area of 3.5 hectares (8.6 acres) and are used to irrigate approximately 80.9 hectares (200 acres). Water is collected from subsurface drainage in the irrigated fields and from farm buildings. A small part of the crop water demand is met with liquid manure injection, with the remainder supplied with high efficiency irrigation equipment. Available resources, site characteristics and good long-term planning made this development highly effective. With this level of integration, the water supply is sufficient to maintain current production levels. However, the ability to develop more large-capacity water storage in the future will likely be limited by land availability. Adaptation for expected climate change, and any increased growing season water demand, would then need to come from additional irrigation efficiency, soil moisture conservation and the reduction of evaporative losses from storage.

Highlights

- → Large volume on-farm storage
- → Fed from in-field drainage
- → Water recovery from farm buildings
- → Liquid manure injection
- → High efficiency irrigation

One of the large storage ponds, depleted near the end of the irrigation season, October 1, 2012.

A pond which is much deeper, and still has significant usable supply on October 1, 2012 near the end of the irrigation season, and after well over 90 days without any effective precipitation..



A linear irrigation system in silage corn just before harvest.

A high efficiency emitter.

Small Scale Dugout Irrigation Water Storage *(Vancouver Island)*

On this small but highly productive mixed farm in the Cowichan Valley, a small dugout was established to provide minimal sprinkler irrigation for a pastured poultry and sheep operation. The primary production for the farm is mixed greens and vegetables, marketed directly to the restaurant trade. This high value production is drip irrigated from a well. While the poultry and livestock side of the operation makes up a smaller part of the total farm income, the product diversification complements the direct market approach. The water development is used in just one part of this integrated production unit, but it also provides insurance against future water shortage. With additional filtering this development could be used to supplement ground water use for the high value vegetable crop production.

A small dugout used for pasture irrigation in the pastured-poultry and sheep enterprise.

Highlights

→ Small dugout water storage

→ Appropriate scale

→ Enterprise diversification

→ Complementary integration of surface and groundwater use

The primary production for the farm—green and mixed vegetables drip irrigated with groundwater.

Cooperative Dugout Water Development for Livestock & Waterfowl
(Peace River region)

Dugouts are a common feature in the Peace River region, and are sometimes the only water source available for both livestock and domestic use. With cooperation and support from Ducks Unlimited and PFRA, the Double M ranch developed three different dugouts, each demonstrating a different livestock watering method. One allows fenced access on a gravel ramp over an erosion control blanket, another provides water to a gravity fed off-site trough, and a third uses a solar powered pump to supply water to an offsite trough. The dugouts are 4.3 metres (14 feet) deep, and all have wind powered aeration pumps. The dugouts have allowed for more intensive grazing management.

The Peace River region has recently experienced a series of very dry years, combined with extreme precipitation events. In the fall of 2007 a dugout used for domestic water was so low that water had to be piped over a mile from one of these Ducks Unlimited dugouts to supply the ranch.

Highlights

- Dugout development for livestock water
- Proper location and design
- Dugout management, including aeration and off-site water methods to maintain storage capacity
- Wildlife benefits
- Improved grazing management
- Used for domestic water during drought

Sign for cooperative dugout project between Ducks Unlimited and Double M Ranch.

One of three dugouts constructed by the project, and a wind-powered aeration pump in the background.

Endnotes

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11 Food and Agriculture Organization of the United Nations, *Crop evapotranspiration: guidelines for computing crop water requirements*, FAO irrigation and drainage paper 56 (Rome: Food and Agriculture Organization of the United Nations, 1998); M. E. Jensen, "Estimating evaporation from water surfaces," in *CSU/ARS Evapotranspiration Workshop*, 2010, *http://ccc.atmos.colostate.edu/ET_Workshop/ET_Jensen/ET_water_surf.pdf*

12 *Quality Farm Dugouts*

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