British Columbia
Farm Water Dugouts

BRITISH COLUMBIA | Ministry of Agriculture

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British Columbia Farm Water Dugouts

Preface

The purpose of this manual is to guide agricultural producers in the proper construction and maintenance of a dugout. This manual does not cover dam construction. A dam is a barrier constructed across a stream, or a barrier constructed off-stream and supplied by diversion of water from a stream for the purpose of enabling the storage. Dams are generally 1 metre or more in height.

Edited by

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Acknowledgments

This publication is an adaptation of the "Quality Farm Dugouts" manual, a production of Prairie Water News, Alberta Agriculture and Rural Development. Its contents focused on Prairie type dugouts. In British Columbia there are some of the same types of dugouts and some that are different. Due to British Columbia topography and water issues the Ministry of Agriculture decided they would like to have a dugout manual that was more pertinent. A majority of the Quality Farm Dugout manual was used. The biggest change is the removal of Prairie references and the addition of B.C. content. The formatting was changed to portrait and not all the pictures were used.

The editor would like to thank the following people for contributions and proof reading:

- Nancy Portman British Columbia Ministry of Agriculture
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1 Module 1 – History

Farm water reservoirs in British Columbia have been used for many years particularly in the Peace Region and on Vancouver Island. During times when local water resources are inadequate to meet farm needs, a well-planned reservoir can mean the difference between economic success and failure. For the most part, reservoirs are intended to capture the temporary surplus of surface water that occurs during the spring. Water may also be collected as runoff from summer rains, but it is typically of very low quality. In order to guarantee reliability of supply, storage capacity must be sufficient to compensate for time periods of insufficient runoff, summer losses due to evaporation, and in some areas, winter losses due to ice formation.

During the drought of the 1930s, the Prairie Farm Rehabilitation Administration (PFRA) helped establish design standards for reservoirs in the prairies to make them a more reliable source of water. Since the 1930s, PFRA and other government agencies have continued to improve the basic design of the farm water reservoir.

Figure 1 Reservoir Construction in the 1930's

Farm water reservoirs are an important water source in some geographic areas of British Columbia wide range of uses including:

- livestock watering
- fire fighting
- irrigation and frost protection
- greenhouse production
- pesticide spray mixing
- crop harvest (cranberry bog flooding)
- environmental protection (sedimentation and retention ponds)

Different reservoir uses demand different levels of water quantity and quality, and in large part, determines the size, shape, location, and the type of management required. Over the years, the PFRA had provided information and management advice to owners of reservoirs in Canada's Prairie region. This information has been periodically updated as the result of fifty years of ongoing research. The provision of current reservoir knowledge and management practices to users helps to ensure that water is not a limiting factor in economic success or quality of rural life. "Quality Farm Dugouts", a publication produced by the Prairie Water News (revised 2007) on which this manual is based, was originally intended to aid the farming community of the prairies in the construction, operation and maintenance of on-farm water storage reservoirs. The original document can be obtained on the Alberta Agriculture and Food website.

This manual, ***British Columbia Farm Water Dugouts*** has been adapted to meet the farming needs specific to British Columbia.

Figure 2 Examples of B.C. farm dugouts

2 Module 2 – Understanding British Columbia Farm Water Dugout

It is much easier to design, operate, and maintain high quality reservoirs if the natural processes that control them are understood. This module explains some of these processes. Climate, landscape and natural hydrological features determine how much runoff will be captured by a reservoir. Once the runoff is stored, the reservoir provides an environment for a wide variety of plants, animals, and micro-organisms that can have a huge impact on water quality.

2.1 British Columbia Climate

Climate in British Columbia is influenced by latitude, mountainous topography and the Pacific Ocean. This diversity causes wide variations in average rainfall, snowfall, temperature and hours of sunshine, sometimes over very short distances. In general, however, temperatures are warmer in the south than in the north, and rainfall is heaviest along the coast and lightest in the southern interior. Figure 3 shows the mean annual precipitation by depth for British Columbia.

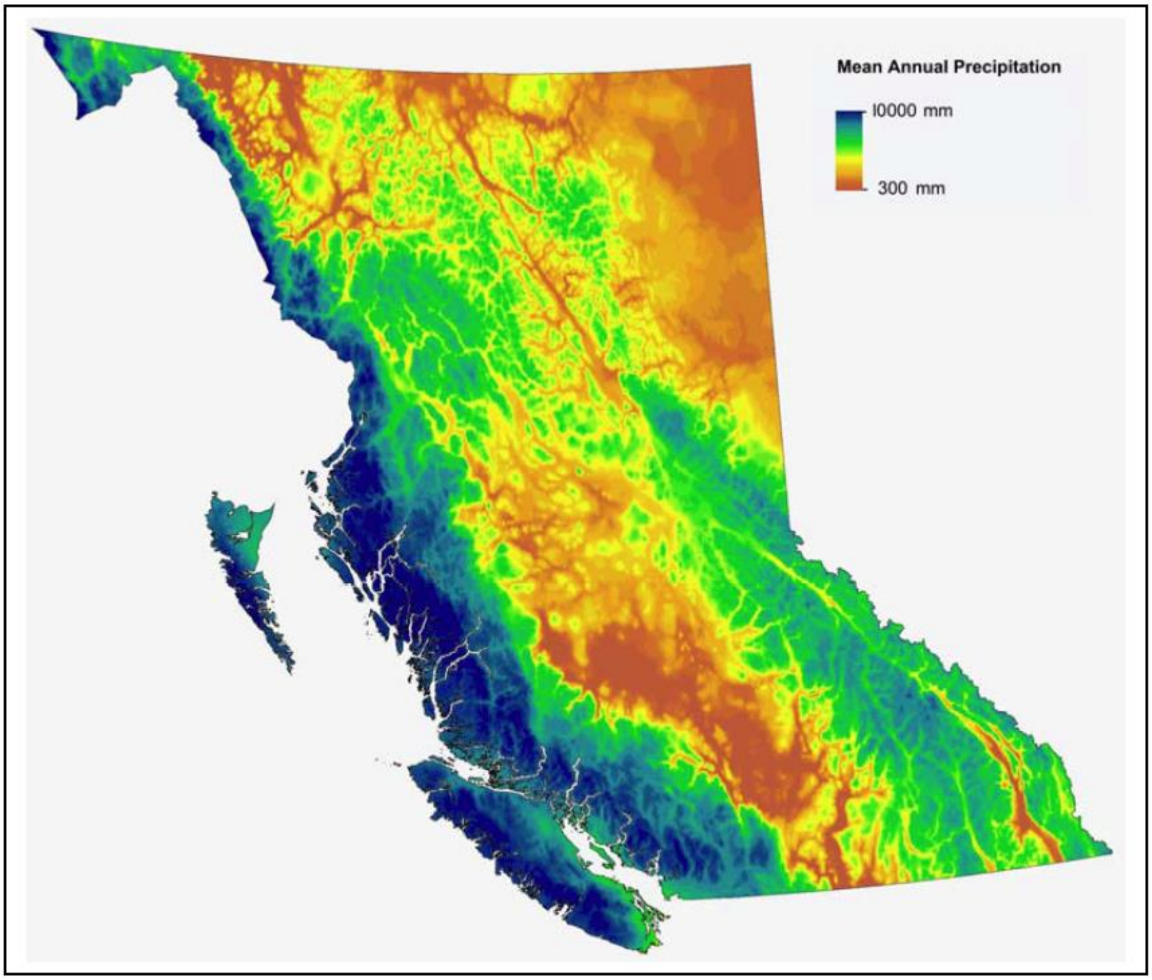

Figure 3 British Columbia Mean Annual Precipitation

(Source: B.C. ministry of Forests and Range, 2006)

2.2 Climatic Zones

Coast Mountains & the Islands: Generally an area of heavy precipitation. Apart from a wet regime, mild temperatures and long frost-free periods are the rule.

The windward outer coast of Vancouver Island – including Tofino – receives the greatest amount of annual rainfall. The Georgia Basin, which includes the east coast of Vancouver Island, the Gulf Islands, Vancouver and the Sunshine Coast, lies in the rain shadow of Vancouver Island. This more protected region has considerably less precipitation and a greater quantity of sunshine. For example, Vancouver's average maximum temperature is 6°C/43°F in January and 22°C/72°F in July, and its annual rainfall is less than half of Torino's. Autumn and winter still tend to have heavy precipitation.

The north coast – including Prince Rupert – typically receives greater annual precipitation than the Georgia Basin and cooler temperatures due to its higher latitude.

Higher elevations in the Coast Mountains get heavy snowfall in the winter.

The Interior Plateau: Because the Coast Mountains act as a barrier to the moist westerly air flow, the Interior Plateau (immediately to the east of this mountain chain) has a much drier and more continental climate. Summers tend to be warm and dry; winters cooler, but less moist. The southern interior, including the Okanagan, Similkameen, and Thompson River valleys, experiences BC's hottest summers, with temperatures often in the 30°C range/86-102°F, and occasionally rising above 40°C/104°F. Kamloops, for example, has an average maximum of -1°C/30°F in January and 28°C/82°F in July, and just 279mm/11in of annual precipitation. Areas further north on the Interior Plateau (Williams Lake and Prince George areas) tend to have a moist, cooler regime than that of the southern portions of the plateau.

Columbia Mountains & Southern Rockies: This region is in the southeast portion of the province and has marked contrasts in climate. The valley bottom localities are semi-arid with warm summers and cold winters, like those found in the Grand Forks or Cranbrook areas. Cranbrook has an average maximum of -3°C/27°F in January and 26°C/79°F in July, with 383mm/15in of annual precipitation. Upslope, and on the windward slopes of the Monashee, Selkirk, Purcell and Rocky Mountains, much higher precipitation and cooler temperatures are evident (such as in the Revelstoke area).

Northern and Central Plateaus & Mountains: This interior region in north-western BC (including Dease Lake, Smithers and Mackenzie) has much colder winters and cooler summers. The winters are generally colder and drier the further north one travels. Summers are short and fairly cool, though the long days partially compensate for these conditions. Precipitation, though quite light, is distributed evenly throughout the year. In Dease Lake, for example, the average maximum temperature in January is -13°C/9°F and in July is 19°C/66°F.

The Great Plains: To the east of the northern Rocky Mountains, in the north-eastern portion of BC (such as the Fort St. John and Dawson Creek area), lies an extension of the Great Plains so evident in the provinces of Alberta, Saskatchewan and Manitoba. This area experiences long, cold winters and short warm summers, with a relatively high number of sunshine hours, a wide range in seasonal temperatures and a precipitation maximum during the summer months. Dawson Creek, for example, has an average maximum of -9°C/16°F in January and 22°C/72°F in July.

2.3 Definition of British Columbia Farm Water Dugouts

Dugouts are earthen excavations designed to store water for use during drier times. Typically, reservoir capacity ranges from a thousand to tens of thousands of cubic metres. Reservoirs are water sources of necessity, because of the uncertainty of filling caused by annual variations in precipitation, and/or the problem of maintaining water quality.

On February 29th, 2016 the Province of British Columbia enacted the ***Water Sustainability Act.*** This new act replaces the previous ***Water Act***, bringing in a number of changes for water licencing and authorizations. The key change in the ***Water Sustainability Act*** is the introduction of groundwater licencing. Other important changes were brought into effect by regulation and include:

- New water rights and licencing requirements for non-domestic groundwater users
- Stronger protection for aquatic ecosystems
- New fees and rentals for water use
- Expanded protection for groundwater including new requirements for well construction and maintenance
- Increased dam safety and awareness, and compliance and enforcement

A majority of the previous ***Water Act*** has been brought into the new act. All existing surface water rights granted under the ***Water Act*** will continue. During times of scarcity the ***Water Sustainability Act*** has tools in it to change how water rights may be exercised.

Surface water runoff from precipitation and snow melt is not regulated by the ***Water Sustainability Act*** until it becomes part of a watercourse or percolates into the ground to become groundwater. Rain or snow melt runoff from the owner's property that is captured into a dugout does not require a water licence under this act.

If there is a berm on one end of the dugout the dam safety regulation must be followed. Contact with the appropriate government agency is required. If water is diverted from a stream or groundwater a water licence for the diversion is required.

Under the ***Water Sustainability Act*** all non-domestic groundwater use requires a licence. If a well is used to fill a dugout or the dugout is filled from groundwater seepage a licence is may be required for the water use from the dugout. Check with your local water officer to determine if a licence is required.

Dugouts vary on how they are supplied or capture water. Some of them will require a water licence from the Province to divert and store water from a stream or groundwater. The following is a reference to the British Columbia ***Water Sustainability Act*** (WSA):

From the British Columbia *Water Sustainability Act*:

1. Definitions

"stream" means

(a) a natural watercourse, including a natural glacier course, or a natural body of water, whether or not the stream channel of the stream has been modified, or

(b) a natural source of water supply,

including, without limitation, a lake, pond, river, creek, spring, ravine, gulch, wetland or glacier, whether or not usually containing water, including ice, but does not include an aquifer;

"groundwater" means water naturally occurring below the surface of the ground;

5. Vesting water in government

(1) The property in and the right to the use and flow of all the water at any time in a stream in British Columbia are for all purposes vested in the government, except insofar as private rights have been established under authorizations.

(2) The property in and the right to the use, percolation and flow of groundwater, wherever groundwater is found in British Columbia, are for all purposes vested in the government and are conclusively deemed to have always been vested in the government except insofar as private rights have been

(a) established under authorizations, or

(b) deemed under section 22 (8) [precedence of rights].

(3) No right to divert or use water may be acquired by prescription.

7. Rights acquired under authorizations

(1) A licence entitles its holder to do the following in a manner provided in the licence:

(a) divert and beneficially use the quantity of water specified in the licence;

(b) construct, maintain and operate the works authorized by the licence and related works necessarily required for the proper diversion or use of the water or the power produced from the water;

(c) make changes in and about a stream necessary for the construction, maintenance or operation of the works referred to in paragraph (b) or to otherwise facilitate the authorized diversion;

(d) construct fences, screens and fish or game guards across streams for the purpose of conserving fish or wildlife.

(2) A use approval entitles its holder to do anything described in subsection (1) for the period or at the times and in the manner specified in the use approval.

2.3.1 Types of dugouts found in British Columbia

Type 1 - It is filled completely by surface runoff and snow melt from surrounding topography. In the Province of British Columbia a water licence is not required for this type of dugout.

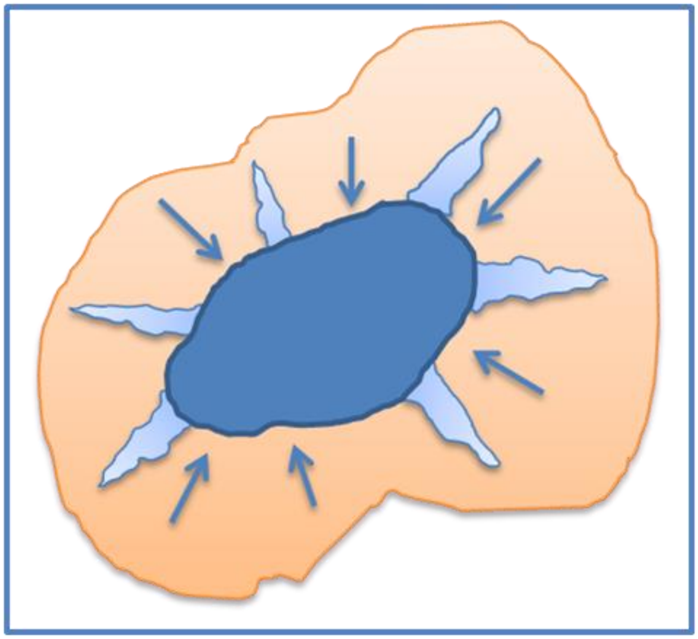

Figure 4 Type 1 Dugout

Type 2 - Is filled from a groundwater or a stream. The water source may be either pumped or diverted. To divert water from a stream or groundwater in the Province of British Columbia a water licence is required.

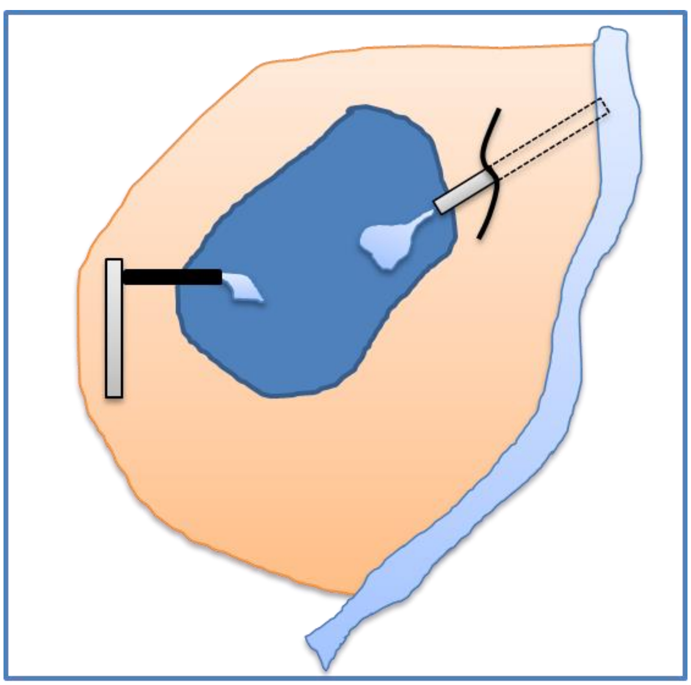

Figure 5 Type 2 Dugouts

Type 3 - Is constructed in a stream. This type is not recommended and would likely constitute a Dam which requires a storage licence and an engineered design. A water licence would also be required as well as authorization to work in and about a stream.

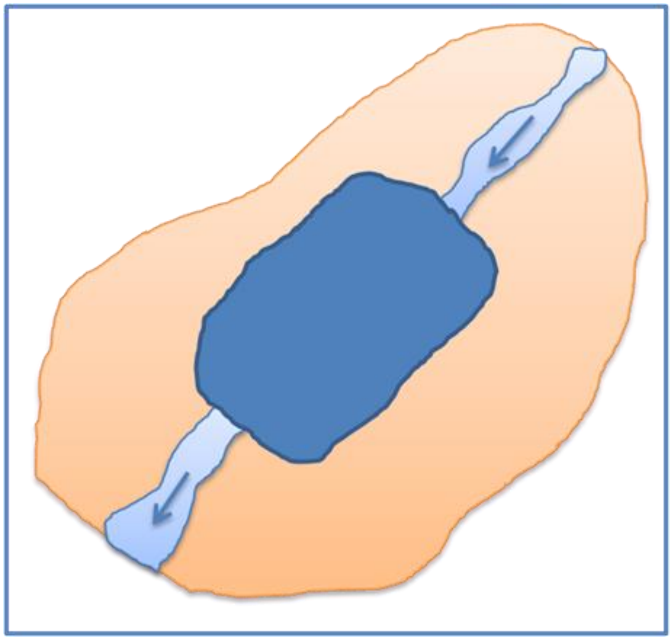

Figure 6 Type 3 Dugouts

Type 4 - Are usually installed in wet locations where ground water surfaces. This type of dugout may require a water licence. Check with your local Water Management Office if an authorization is required. Since this type is directly feed from groundwater there may be a potential for ground water contamination *so* precautions should considered if the water is used directly by livestock.

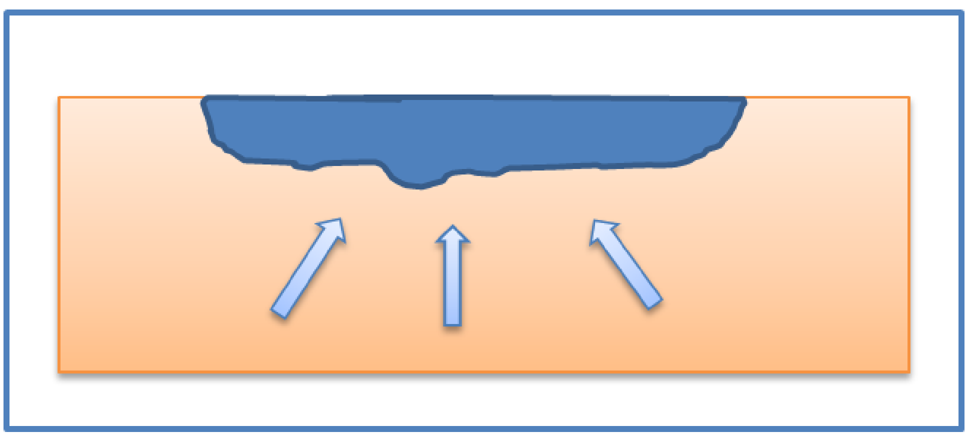

Figure 7 Type 4 Dugouts

2.4 Reservoir Water Quality

When reservoirs are used for livestock watering and irrigation, special consideration must be paid to water quality. Runoff water often brings dissolved and suspended materials that are detrimental to water quality, including:

- disease-causing organisms
- plant nutrients/dissolved fertilizers
- pesticides
- decomposed plant and algae material
- suspended sediment
- fuels, solvents, and paints
- soil minerals

The net result of contaminant-loaded runoff is poor quality reservoir water. However, reservoir water quality can be managed, improved, and treated to meet most farm needs. Attempts to manage or enhance reservoir water quality must recognize and work with the natural biological and chemical processes occurring in the reservoir. Good reservoir management starts with the reservoir watershed and extends right through to the final use.

2.5 Biology of a Reservoir

Many people see a reservoir as a stagnant, lifeless body of water. Nothing could be further from the truth. As a newly constructed reservoir fills for the first time, it is quickly occupied by a variety of organisms, including plants, microbes, insects, and animals, and develops its own unique ecosystem. The fertile soils in which most reservoirs are located contribute nutrients for plant growth. The rooted plants and algae represent an important food source for tiny animals called zooplankton. Through the food chain, the zooplankton becomes a source of food for insects that ultimately become a source of food for amphibians and fish. In fact, a reservoir is a living ecosystem driven by natural cycles and processes.

The biology of a reservoir is similar to the cycle within any other small body of water. Each summer, warm temperatures and long sunny days produce an explosion of plant and animal growth. In daylight, plants consume nutrients and pump oxygen into the water; at night time oxygen production stops and respiration consumes dissolved oxygen which can result in low dissolved oxygen levels. When the plants and animals die, micro-organisms decompose their tissues. This decomposition process consumes oxygen. On hot, still day's biological activity is high and there is little oxygen added by wind-driven mixing of the water. In winter when the surface is sealed by ice, oxygen levels can also become very low. When this occurs, anaerobic organisms that do not use oxygen take over the decomposition process. Anaerobic activity releases many unwanted compounds into water. These include forms of iron and manganese that produce coloured water and unpleasant smelling swamp gases such as methane and hydrogen sulphide. As these micro-organisms die, their decomposition also adds nutrients to the water body that become available to plants to begin the cycle again.

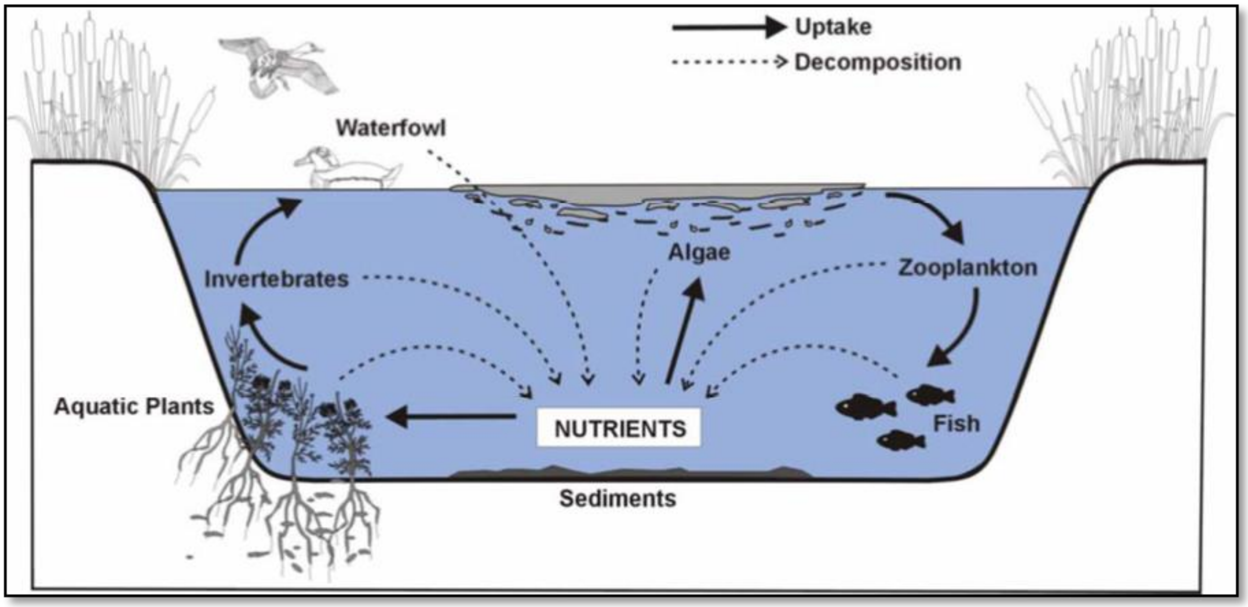

Figure 8 Simplified Nutrient Cycle

Many forms of plant life thrive in reservoirs as shown in **Figure 8: Simplified Nutrient Cycle**. Some species are rooted in the reservoir but are totally submerged. Others inhabit the margins where they are rooted in the sediments but hold their vegetation above the water. Cattails and reeds are examples of this type of plant. Although only one of the many forms of plant life in a reservoir, algae get a lot of attention. This is primarily due to the problems they cause in a water supply. Algae can be present in reservoirs but go unnoticed most of the time. When conditions are favourable however, they can reproduce very rapidly and cause a "bloom". Algae blooms cause a variety of problems:

- toxins in the water
- water turbidity tastes and odours
- clogging of filters
- ineffective disinfection treatment
- formation of toxic chlorination by-products
- fluctuating oxygen levels between day and night resulting in fish kills

There are many types of green algae. Shown in **Figure 9** is a filamentous type which is characterized by long threads attached together and found floating as a mat on the surface, often referred to as "pond scum". When an algae bloom occurs in water used for livestock, it is best to exercise extreme caution. The most effective strategy for reducing the risk is to manage a reservoir so the conditions that induce large algal populations do not develop. Much of this manual is devoted to this topic.

Figure 9 Green (Filamentous) Algae

The formation of blooms of **cyanobacteria** is of the greatest concern. There are many types of cyanobacteria; they are microscopic in size but become visible when large populations develop (**Figure 10**). Some types are capable of producing toxins that can damage the liver, nerves, lungs, and hearts of livestock. Little corrective action is possible once a cyanobacteria bloom has occurred. Cyanobacteria float near the water surface and wind action blows them to the side of the reservoir. When livestock water directly at the edge of a reservoir, they may be exposed to high concentrations of cyanobacteria in the water. Growth of cyanobacteria is greatest when the water is warm and concentrations of nutrients, especially phosphorus, are high. Phosphorus concentrations greater than 0.05 mg/L can cause unwanted plant and algal growth. It is not easy to distinguish between cyanobacteria and green algae. Positive identification requires training and use of a microscope.

Figure 10 Cyanobacteria

A much-maligned, but harmless plant called duckweed is sometimes confused with algae. It can be readily identified upon close inspection. Duckweed is an oval shaped plant that floats on the water surface and forms a mat, as shown in **Figure 11**. It can cover an entire water body with a green mat composed of millions of small plants. Duckweed can be beneficial in a reservoir by preventing light penetration of the water and thereby shading out algae. It also takes up nitrogen and phosphorus from the water. Long-lasting benefit from duckweed is only realized, however, if plants are removed before they die and the nutrients are released back into the water. To be successful, the duckweed must be removed as often as once a month.

Figure 11 Duckweed

2.6 The Life Span of a Reservoir

Like all man-made things, a farm reservoir does not last forever as shown in **Figure 12**. All bodies of water, including farm reservoirs, undergo a natural aging process. As the years go by, the reservoir accumulates sediment from wind and water erosion. In some circumstances, an average sized reservoir can collect more than 15 inches of sediment each year. This can total 50 tons or more. As the excavation fills with sediment, the holding capacity becomes greatly reduced. Some of the rehabilitation work on reservoirs has shown that from 1 to 10% of water volume can be lost in a single year. Sediment also contributes nutrients that rapidly accelerate the natural aging process by increasing plant growth and lowering water quality.

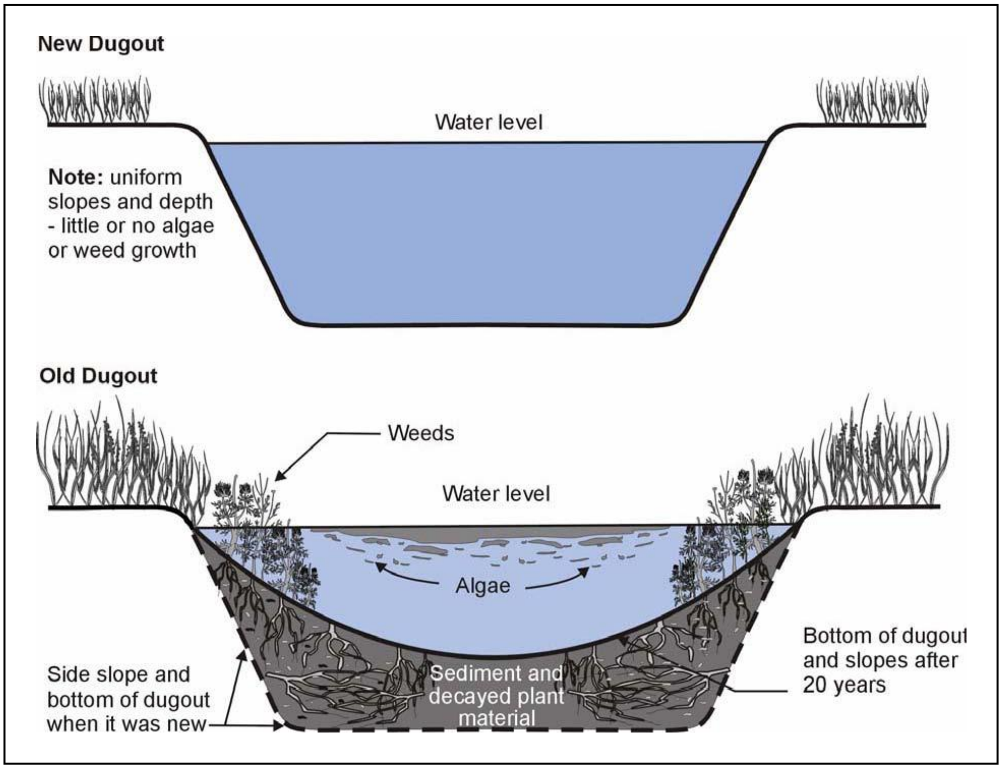

Figure 12 New vs. Old Reservoir Cross Sections

As a reservoir fills with sediment, water quality deteriorates. In addition to collecting water and sediment, reservoirs are very efficient at trapping the nutrients deposited from runoff to the reservoir. As time progresses, the accumulation of these nutrients from runoff events, plus their continual re-cycling within a reservoir cause a steady increase in plant and algae growth. This leads to an ongoing deterioration in reservoir water quality. A shallow reservoir also warms more quickly in the summer and cools more rapidly in the winter. Warm water encourages algae growth in summer. In areas of below freezing temperatures, the winter ice layer leaves even less water available and concentrates salts and nutrients in a smaller volume of water. The length of time that a reservoir can sustain the required quality for use is dependent on land-use practices in the watershed and the actual management of the reservoir. As reservoirs age, a reduction in water quality can be expected.

In general, a rule of thumb is that a reservoir will provide good water quality for about the first five years. Over the next ten years, storage capacity and water quality deteriorate. After 20 years, storage capacity and water quality have usually been reduced to the point where the reservoir no longer meets the needs of the landowner. Regardless of its uses, the life span of a reservoir can be extended significantly through effective management practices.

3 Module 3 – Planning Farm Water Supplies

Although a well-planned and designed water system may cost more initially, it will ultimately save money in the long term, as costly changes to correct future problems will be avoided. The initial planning steps include:

3.1 Determination of Water Requirements

The first step in planning is to determine the amount of water required. Estimating future needs should take into account any anticipated changes such as an expansion or diversification of farm activities. The following water quantities are daily estimations for livestock – **Table 1**.

Table 1 Estimated Average Daily Consumption for Livestock

Type of Animal	Description	US GPD	Type of Animal	Description	US GPD
Beef			Swine (with wash water)		
cow with calf*	1,300 lb	12	farrow - finish	---	24 / sow
dry cow/mature cow*	1,300 lb	10	farrow - late wean	50 lb	8 / sow
calf*	250 lb	3	farrow - early wean	15 lb	6.5 / sow
feeder - growing**	400-800 lb	6 - 9	feeder	50 - 250 lb	2 / pig
feeder - finishing**	600-1200 lb	9 - 12	weaner	15 - 50 lb	0.6 / pig
bull	---	12			
Dairy			Poultry		
milking* (with wash water)	holstien	36	broiler	per 100	4.2
dry cow/replacement	holstien	12	roaster/pullet	per 100	4.8
calf	to 550 lb	3.5	layer	per 100	6.5
Sheep and Goats			breeder	per 100	8.5
ewe/doe	---	2.5	turkey - grower	per 100	15.5
milking ewe/doe	---	3.5	turkey - heavy	per 100	19
feeder lamb/kid	---	2	Ostrich	---	1.2
			Deer, Llama, Alpaca	---	2.5
Bison, Horse, Mule	---	12	Elk, Donkey	---	6

* for peak water use on days above 25^0 C multiply gpd by 1.5

** for peak water use on days above 25^0 C multiply gpd by 2

If the dugout is being constructed for irrigation storage, then knowledge of the irrigation requirement is needed. Depending on the location in British Columbia the crop water required may differ greatly.

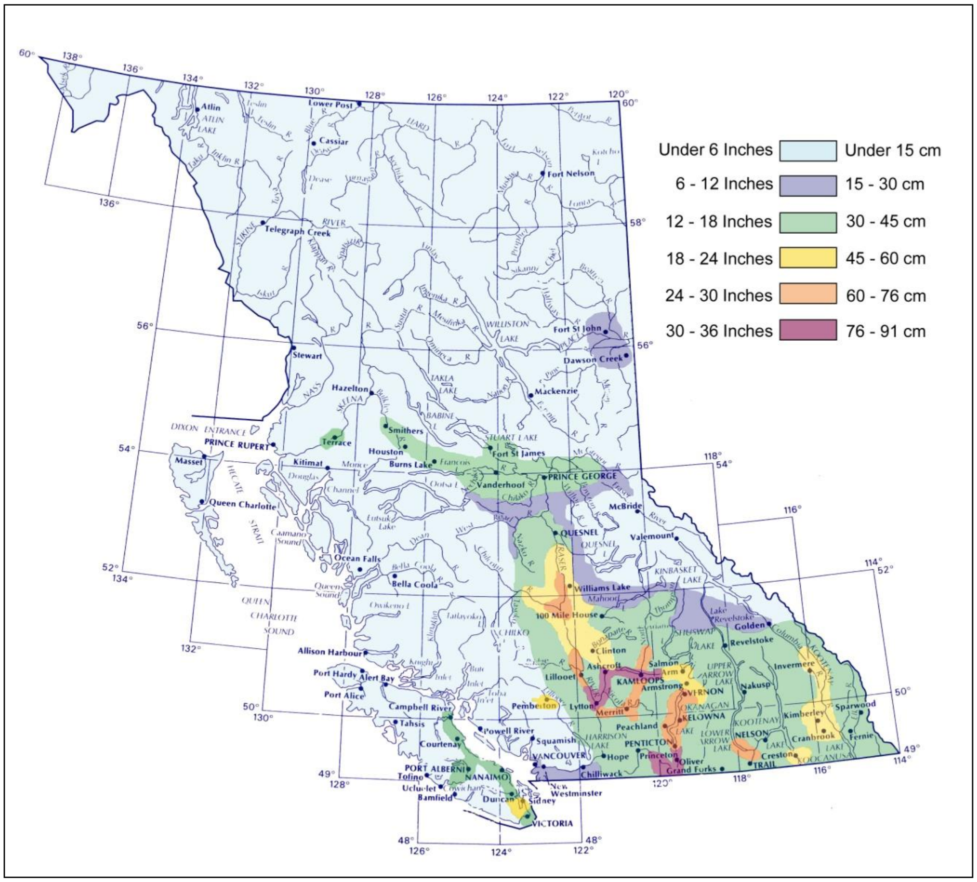

Figure 13 Estimated Annual Crop Water Requirements in B.C. [inches or cm]

The estimated annual crop water requirement shown in **Figure 13** is the amount required for a forage crop. To use these numbers the application efficiency of the irrigation system needs to be applied. **Table 2** shows the typical application efficiency of irrigation system types.

Table 2 Irrigation System Application Efficiency

Application Efficiencies of Irrigation Systems			
Irrigation System Type		Application Efficiency [%]	
		Range	Typical
Trickle	Trickle	85 – 95	92
	Microjet	80 – 90	85
Sprinklers	Hand/Wheel move	60 – 75	72
	Undertree Solid Set	65 – 75	75
	Overhead Solid Set	60 – 75	72
	Micro-sprinklers	70 – 85	80
Guns	Travelling	55 – 70	65
	Stationary	50 – 65	58
Centre Pivot	Sprinklers	65 – 75	72
	Drop Tubes	75 – 85	80
Flood	–	30 – 50	50

For example if a producer from Quesnel wants to construct a dugout to irrigate a 10 acre field, how much water would have to be stored from snowmelt for the season?

- From Figure 13 the crop water required is 12 to 18 inches. For this example 18 inches or 1.5 feet will be selected.
- If the farmer chooses to use a hand line irrigation system the application efficiency from Table 2 is 72 percent.
- Total depth water required = 1.5ft / 0.72 = 2.1 feet
- Field area = 10 acres
- Total irrigation water required = 2.1 x 10 = 21 acre feet.

How large would the dugout have to be if the average depth was 8 feet?

- Dugout Area = 21 acre feet / 8 feet = 2.6 acre.

The area can be reduced if the dugout only needs to supply the irrigation requirement for part of the year. This is often the case if sufficient flows are available earlier in the year but dry up during the summer. The climate moisture deficit can also be obtained from www.farmwest.com.

Quite often dugouts are used in conjunction with a well that is too small to supply the irrigation demand. The well will pump into the dugout 24 hours per day at a lower flow rate. The irrigation pump can then supply the irrigation system. The operating time will depend on the dugout storage size.

The above example shows that a very large dugout is required for irrigation purposes. Even if the dugout could be constructed it may not fill with the snowmelt and spring runoff. A more likely scenario is a dugout to store water for small field for a pasture or vegetables. **Table 3** shows how large the surface area of a dugout needs to be in order to store a specific acre foot volume.

Table 3 Dugout Size and Depth Required to Store Water

Dugout Size (acre) and Depth Required (ft)						
Storage (acft)	Surface Area of Dugout (acre)					
	0.25	0.5	0.75	1	1.5	2
1	4.0	2.0	1.3	1.0	0.7	0.5
2	8.0	4.0	2.7	2.0	1.3	1.0
3	12.0	6.0	4.0	3.0	2.0	1.5
4	16.0	8.0	5.3	4.0	2.7	2.0
5	20.0	10.0	6.7	5.0	3.3	2.5
6	24.0	12.0	8.0	6.0	4.0	3.0
8	32.0	16.0	10.7	8.0	5.3	4.0
9	36.0	18.0	12.0	9.0	6.0	4.5
10	40.0	20.0	13.3	10.0	6.7	5.0

For more information on irrigation refer to the BC Ministry of Agriculture fact sheets website.

- Ministry of Agriculture Water Page

3.2 Inventory of Water Sources

The next step is to take an inventory of all water sources. Many farms use more than one water supply. Account for production rates, storage volumes, and any previous problems with water quantity or quality for each source. If the reservoir is to be the only source of water for a particular use, uncertainty of runoff volume should be factored into the sizing calculation. Depending on water use and location in the province, reservoirs will generally be constructed to hold anywhere from six months to two years supply. In situations where the reservoir is not critical to operations or alternate supplies are readily available, a smaller reservoir may be chosen.

3.3 Land Use Planning to Protect Water Supply

Activities within a watershed have a large impact on water quality and quantity. Evaluating and adapting farm practice where it affects runoff can do much to increase reservoir utility.

3.4 Regulatory Issues

Before constructing a new reservoir, it is important to be aware of legal restrictions that may apply. In British Columbia, ownership of surface water is vested in the province. In most jurisdictions, municipal and provincial, there may be requirements for minimum setback distances from public roadways, as well as permit or license requirements for the drawing or storage of water. Stocking of reservoirs with fish is also controlled to minimize the risks of discharges that could introduce disease and non-native species of fish into natural waterways. Before constructing a reservoir, consult appropriate authorities to ensure compliance with existing regulations. It is also prudent to obtain approvals well in advance to avoid delays in construction. Technical assistance through federal and provincial government departments may be available for the construction or improvement of reservoir water supplies.

3.5 Water Sources for Farm Water Reservoirs

It is essential that a reservoir be located to capture the quantity of water required. There are many considerations when choosing a site. Inevitably, some trade-off between conflicting factors will be required. However, it is worth the time and effort to find the best location for a reservoir that will be in use for many years.

Permanent streams can provide a reliable water source for reservoirs. Water collected in times of surplus stream flow can be stored for use during periods of low rainfall or high demand. The majority of surface runoff occurs in late winter and early spring. Large quantities of water could be harvested from a nearby stream during these high flow periods and stored in reservoirs for use during the growing season. As noted previously a water licence is required to divert water from a stream.

3.6 Watershed Runoff

Both the quantity and quality of water are affected by the characteristics of the drainage area and the activities that take place within it. The most important characteristic in determining potential runoff into a reservoir is the size of the drainage area or watershed. In addition, soil type, land use, topography, and vegetative cover all influence the total quantity of water that will flow into a reservoir.

As a guide to estimating how much runoff a particular watershed will provide, general runoff producing characteristics are presented in **Table 4**. Associated peak flow estimates for each watershed runoff category (extreme, high, normal, and low) are shown in **Table 5**.

Table 4 Runoff Producing Characteristics of Watersheds*

Watershed Runoff Category	Runoff Producing Characteristics			
	Topography	Soil Type	Vegetation Cover	Surface Storage
Extreme	Steep, rugged terrain, with average slopes generally >30%	No effective soil cover; either rock or thin soil mantle of negligible infiltration capacity	No effective plant cover; bare or very sparse cover	Negligible; surface depressions few and shallow; drainways steep and small; no ponds or marshes
High	Hilly, with average slopes of 10-30%	Slow to take up water; clay or other soil of low infiltration capacity	Poor to fair; clean cultivated crops of poor natural cover; <10% of drainage area under good cover	Low; well-defined system of small drainways; no ponds or marshes
Normal	Rolling, with average slopes of 5-10%	Normal, deep loam soils	Fair to good, about 50% of drainage area in good grassland, woodland or equivalent cover; <50% of area in clean, cultivated crops	Normal; considerable surface depression storage; lakes, ponds, and marshes <2% of drainage area
Low	Relatively flat land, with average slopes of 0-5%	Deep sands or other soils that take up water readily and rapidly	Good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover	High; considerable surface-depression; drainage system not sharply defined; large floodplain storage or large number of lakes, ponds, or marshes

3.7 Reservoir Sizing

Factors to consider in reservoir sizing are the potential amount of water that will be captured, storage requirements based on need, evaporation loss, and the shape and dimensions of the reservoir.

Table 5 Approximate Peak Flow (per second) from Watersheds of Various Sizes and Characteristics *

Drainage Area	Watershed Runoff Category							
	Extreme		High		Normal		Low	
Ha - Ac	L	Gal	L	Gal	L	Gal	L	Gal
2 - 5	218	48	182	40	82	18	23	5
4 - 10	381	84	304	67	132	29	36	8
6 - 15	545	120	431	95	186	41	50	11
8 - 20	704	155	545	120	236	52	59	13
10 - 25	863	190	658	145	291	64	68	15
12 - 30	1022	225	772	170	341	75	82	18

(*From: Farm Ponds, ACAE Pub. No. 6 Agdex – 754)

Figure 14: Reservoir Size vs Available Water illustrates the necessity of sizing reservoirs properly so they provide a dependable source of water. In this example, the reservoir has received no runoff water in two years. The cross-sectional view shows how the supply of available water is reduced by farm use, lack of runoff, evaporation, and ice formation in winter. In addition to uses and losses, the water at the bottom of the reservoir will be of such poor quality that it is rated as dead storage and unavailable for use.

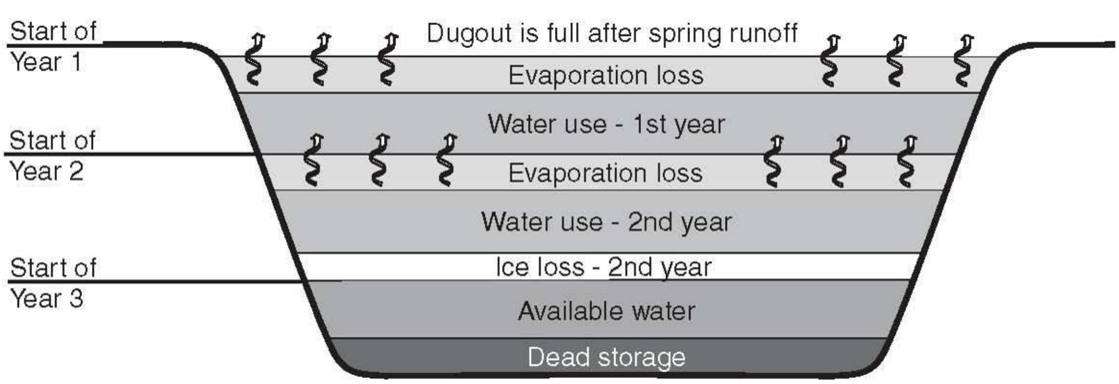

Figure 14 Reservoir Size vs. Available Water

As indicated above, runoff volume is determined by the amount and timing of snowmelt or precipitation, plus vegetation, soil type, soil moisture, and topography. Runoff varies a great deal from year to year. The uncertainty of runoff should be kept in mind when planning reservoir size. If a particular watershed is too small to provide enough runoff, you have two choices: 1) Find a larger watershed, or 2) Find an additional watershed and build a second reservoir. When faced with these choices it is a good idea to consult a water specialist.

Evaporation rate is an important factor in reservoir sizing. The shape of a reservoir can also affect the quantity of stored water. A deeper reservoir is more efficient because it has less surface area for the same capacity, and thus loses less water to evaporation. During winter, reservoirs freeze and some of the stored water becomes unavailable for use. Ice can reach up to 2 to 3 feet in thickness, which may represent up to

20-40% of total volume. Generally speaking, colder climates lead to thicker ice, and therefore a greater loss of available water. However, this can be offset by differences in snowfall, as snow cover on the ice insulates the water from further freezing.

3.8 Water Quality and Watershed Management

Good watershed management is the first line of defence for ensuring good quality, reservoir water. Using what are termed Beneficial Management Practices or **BMP's** within the catchment, or runoff area, can minimize the possibility of reservoir water contamination. Contamination occurs through a number of processes.

- Plant nutrients from natural sources, fertilizers, and manure entering a reservoir stimulate the growth of plants and algae.

- Pesticides can contaminate water when stored improperly, mixed carelessly, or spilled. They can also be present in runoff water from recently sprayed fields. Airborne drift clouds are able to travel long distances and may be deposited in streams, lakes, and reservoirs.

- Runoff from livestock confinement areas is typically rich in nutrients and likely contaminated with bacteria, viruses, and parasites.

- Poorly sited waste disposal sites or inadequate storage facilities can contribute fuels, paints, solvents, and other hazardous chemicals to reservoir in-flow water.

- Water erosion loads runoff water with soil, nutrients, and pesticides that may end up in reservoirs. Long, steep slopes in the landscape, which are not under perennial cover, are very susceptible to water erosion events. Even relatively level fields can be subject to severe water erosion during spring runoff and heavy rainfall events. Silty soils are particularly susceptible to water erosion. Suspended solids in runoff water cause turbidity in reservoirs, causing problems in water distribution systems and increasing the difficulty and cost of treatment.

- Wind erosion may lead to contamination of reservoirs when soil is blown into the water from adjacent fields or livestock areas. Sandy soils and heavy clay soils are most susceptible to wind erosion.

3.9 Beneficial Management Practices in a Watershed

The following BMPs can reduce soil erosion and contamination of inflow water as illustrated in **Figure 15**: Watershed with Best Management Practices:

Agricultural fields in annual cultivation are prone to wind and water erosion, particularly when residue cover is poor in winter and early spring. Soil surface protection practices are highly effective ways of preventing erosion:

- Seeding erosion prone land to perennial forages
- Using conservation tillage
- Maintaining crop residues in the fall
- Using winter cover crops
- Using crop rotations that follow low-residue crops with those with higher straw-yield

Practices that slow water runoff velocity and reduce water erosion:

- Grassing waterways
- Contour planting placing rows perpendicular to the slope of a field

Practices that slow wind velocity and reduce wind erosion:

- Strip farming consisting of alternating bands of annual and perennial crops
- Planting and maintaining shelterbelts

The amount of fertilizers applied in a watershed can be minimized by proper nutrient management planning. Nutrient management is based on application of only enough fertilizer to make up the difference between the amount available in the soil and the crop requirement.

Total amounts of pesticides applied to a watershed can be minimized through the principles of integrated pest management or “IPM”. IPM is a pest management system using the application of a variety of management practices and control measures.

Remote watering systems prevent livestock from having direct access to a reservoir, or to other areas in the watershed that directly contribute runoff to a reservoir.

Good manure management protects water from contamination. As with chemical fertilizers, manure should not be applied in quantities that provide plant nutrients in amounts that exceed crop requirements.

Good livestock management prevents over-grazing, which can leave soils susceptible to erosion. This can be prevented by using a rotational grazing system.

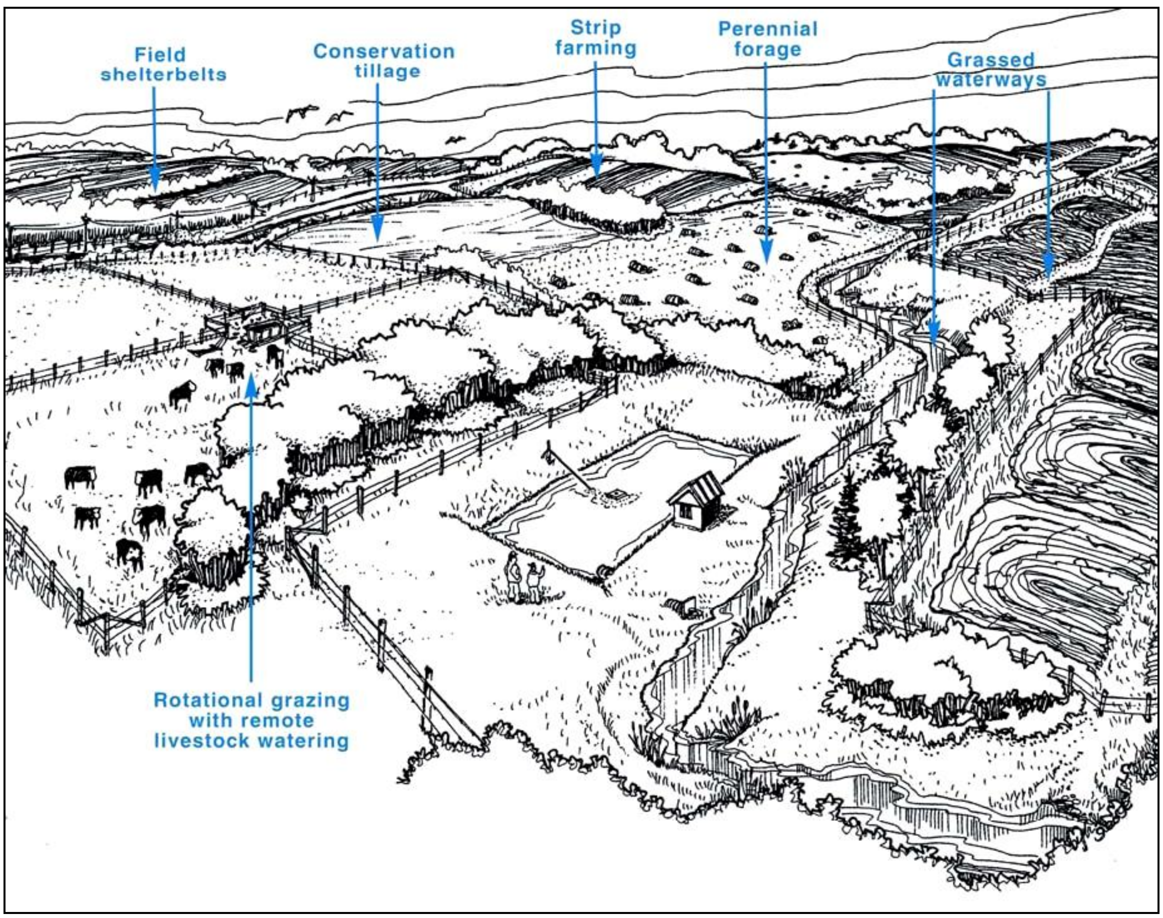

Figure 15 Watershed with Beneficial Management Practices

3.10 Reservoir Location

Locating a reservoir to collect enough water is of primary importance, but there are other factors to consider when planning the location.

3.10.1 Proximity to Water Use

By locating a reservoir close to places where the water will be used, construction and maintenance costs of water lines and power pumping costs can be minimized.

3.10.2 Proximity to Electrical Power

Most water delivery systems have the pump near the reservoir. Nearby electrical power reduces costs for extending power lines. Ready access to power also allows for easy installation of an electric aeration system.

3.10.3 Trees

Properly placed trees can act as snow traps and increase the amount of runoff collected each spring. However, trees close to the reservoir tend to block the wind and reduce the positive effects of wind on the mixing of reservoir water. Trees also reduce the effectiveness of any windmill-driven mixing devices. Leaves and twigs that are dropped by trees and deposited into reservoir water add organic matter and plant nutrients that encourage weed and algae growth and reduce water quality. Large trees planted close to a reservoir can use much of the stored water if their roots can reach the reservoir. It is recommended that deciduous trees be planted no closer than 160 feet (50 meters) and coniferous trees and shrubs no closer than 65 feet (20 meters).

3.10.4 Proximity to Other Water Sources

If possible, locating a reservoir near another water source is advisable. Reservoir water quality can sometimes be improved by dilution, such as pumping water into a reservoir from another source such as a creek.

3.10.5 Potential for Contamination

Avoid sites that could be affected by contaminated runoff or leaching:

- manure storage areas
- animal confinement areas
- waste disposal sites
- pesticide and fertilizer storage areas
- septic fields or lagoons
- commercial and industrial sites

4 Module 4 – Design and Construction

4.1 Reservoir Design

The construction and management of a reservoir can have a large impact on water quality. Design options can allow reservoir owners to control inflow and permit only the highest quality water to be stored. Once runoff has been collected, good management can prevent water quality from deteriorating, as illustrated in Figure 16.

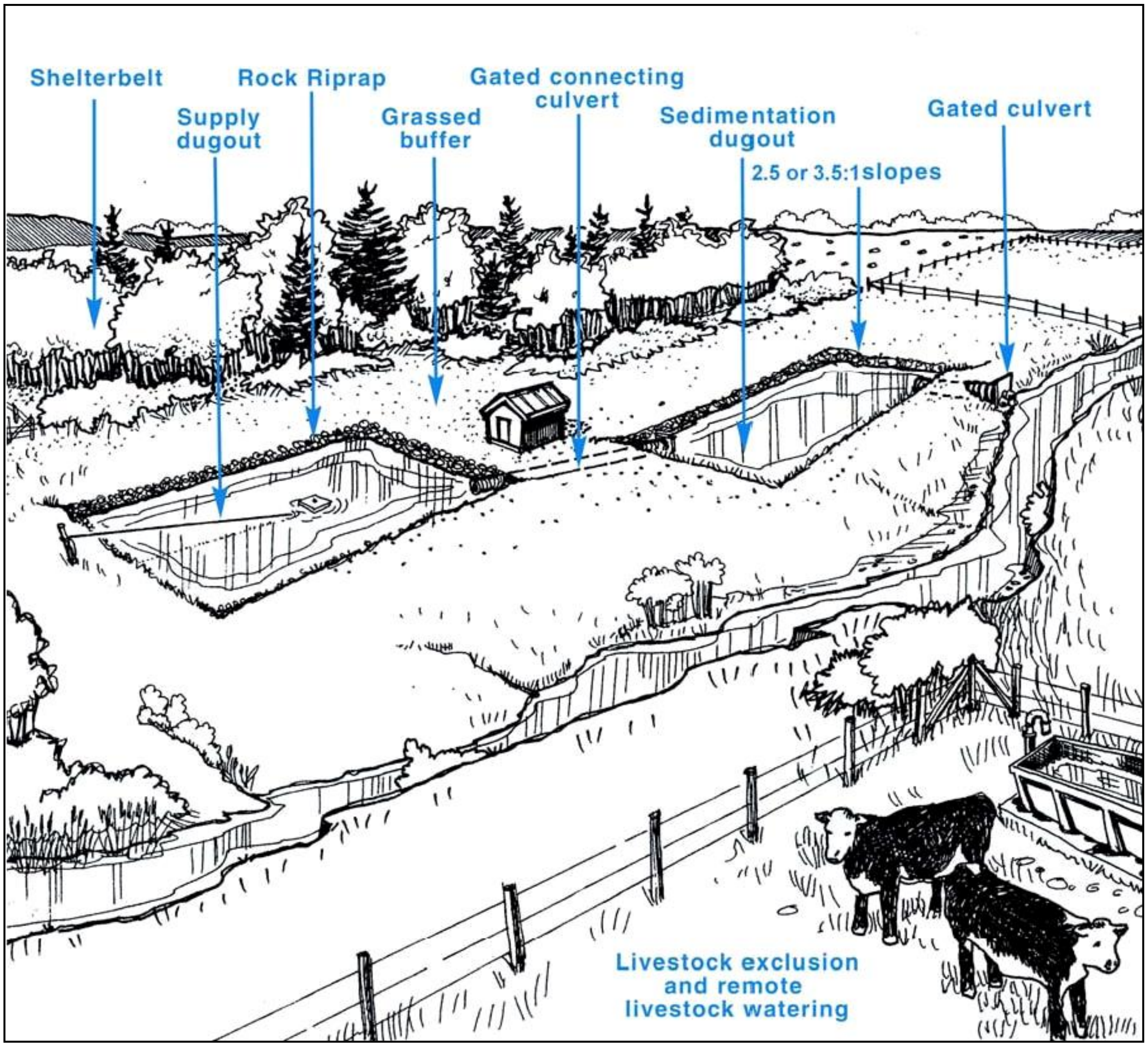

Figure 16 Reservoir with Design Beneficial Management Practices

4.1.1 Slopes

Ideally, water storage reservoirs should be constructed with 1.5 to 3.5:1 interior side-slopes and 4:1 end-slopes. The soil conditions and the construction equipment available largely dictate these specifications. Equipment capable of digging deeper excavations with steep end-slopes is now readily available. Steeper slopes reduce the growth of cattails and other aquatic plants that contribute organic matter and plant nutrients to the water. However, a reservoir with four steep sides can be a safety hazard. It is recommended that reservoirs be fenced to exclude livestock, and a floatation device should be available and used to protect children and adults from drowning.

4.1.2 Erosion Control

Spoil piles are created during the construction of a reservoir. If spoil piles are located at the edge of a reservoir, they may erode or slump into the water. Spoil piles may also act as a windbreak and reduce wind mixing, which incorporates oxygen into the water. It is recommended that the spoil piles around a reservoir be levelled to maintain bank stability, and grassed to provide a filter that reduces the entry of soil and nutrients. Although the ideal width of a grassed buffer varies between sites, the recommended **minimum** is 10 meters. Reservoir life is increased when the reservoir sides and end slopes are protected to prevent soil erosion by wave action. This can be done with a combination of grass, rocks - often termed **riprap**, heavy plastic, or **geo-textile** materials. Riprap can also be effective at discouraging muskrats from moving in.

4.1.3 Inlet Structures

A dike and gated culvert inlet can be built to give the owner control over the inflow water. Poor quality water can be prevented from entering a reservoir. The first flow of water from cultivated fields during snowmelt is typically high in sediment and dissolved nitrogen and phosphorus. Excluding this initial volume of water can improve water quality. After the reservoir has filled, the inlet should be blocked. This prevents sediment and nutrients carried by runoff from spring and summer rains from entering the reservoir. Use of this type of control structure is only practical where it is certain that there is more than enough runoff to fill the reservoir. If it is not practical to construct an inlet structure as above, the dugout should be designed such that after the dugout has filled, the remaining runoff should not flow through the dugout, but rather be redirected around and away from the dugout at the point of inlet. If water is pumped into a dugout, prevent bank erosion from occurring at the discharge point.

4.1.4 Livestock Exclusion

Allowing animals to water directly from a reservoir degrades water quality and drastically shortens the life of a reservoir. Nutrients from manure stimulate plant growth and hoof action destroys reservoir banks. It is recommended that all reservoirs be fenced off and water supplied to livestock through remote watering systems. This protects the reservoir, its water quality, and the livestock themselves. Many options are now available for supplying water to livestock on remote sites. Where a reservoir is far from electricity, alternative power sources including windmills, solar panels, gravity systems, and animal powered devices, such as “nose pumps” are reliable and affordable options.

4.1.5 Sedimentation Reservoirs

Much of the unwanted material that enters a reservoir in runoff is suspended. If water is allowed to stand, much of the suspended soil and organic matter will sink to the bottom. In locations where the soil is highly susceptible to erosion and the landscape and costs permit, two reservoirs can be constructed adjacent to one another. The first will act as a settling pond. High quality, surface water can then be either pumped into the supply reservoir or allowed to flow in by gravity. In a situation where an existing reservoir is being replaced with a new one, it may be useful to retain the original as a sedimentation structure. The new reservoir can often be positioned to fill with water that has been allowed to settle in the old reservoir. This can be more beneficial and economical than cleaning out the original reservoir.

4.2 Reservoir Construction

4.2.1 Pre-Construction Testing

In many areas of British Columbia sand, silt, and gravel layers occur close to the soil surface. Many of these layers can contain small amounts of groundwater that has seeped down from the surface. While many people installing new reservoirs believe it is good to have water seeping into the reservoir, these lenses of sand and silt can create many problems. They may provide a path for water to seep out of the reservoir leading to depleted water supplies during periods of drought. In addition, highly mineralized ground water seeping into the reservoir can adversely affect the quality of trapped runoff water. To ensure that sand lenses are avoided, at least five or six test holes or pits should be dug prior to excavating the reservoir. These holes should be dug around the outside and within the proposed reservoir area to a depth of 4 to 5 feet (1.2 - 1.5 m) deeper than the proposed reservoir bottom. They should not be located more than 30 m (100 feet) apart to minimize the possibility of missing intermittent sand layers that may occur. This testing will also identify other problems including shallow water tables, bedrock, as well as the most suitable construction equipment.

4.2.2 Reservoirs Located on Uneven Ground

For reservoirs located on uneven ground, berms can be constructed on the lower sides of the reservoir using the excavated earth to enable more water to be stored. To do this, strip the topsoil down to the subsoil where the berm is to be located, and then build up the bermed area with compacted subsoil to a level two feet higher than water level. This will prevent seepage loss under the berm and overtopping of the berm from wave action. In order to provide reservoir sealing, and prevent seepage, a soil clay content of greater than 15% is needed. Otherwise, alternatives such as geotextile liners may have to be used. Keep in mind that if the berm structure is too high then it may be classed as a dam and have regulatory over site. It is recommended that regulatory authorities should be contacted when constructing large water reservoirs.

4.2.3 Large Scale Sealing Methods and Materials

If sand layers are general in the area and no suitable site can be found, several additional test holes or pits may be required to determine the extent of the sand layers and help determine how to seal these areas. In some cases, it may be best to abandon the site and try to locate a reservoir in more favourable soil conditions. In other cases, it may be simply a matter of over-excavating the areas of concern and backfilling with expanding clay to provide the proper seal. For larger areas, the potential for seepage must be addressed at the time of construction. If it appears that seepage will be a problem, then most sealing methods will require flatter slopes of approximately 3:1 for the sealing treatment to be applied. Consult a professional soil or water specialist if large-scale sealing is required.

4.2.4 Clay Lining

If a source of good heavy clay is available, it may be feasible to haul and spread the clay over the problem areas and use packing equipment to pack the material into place to form an impermeable layer. The packing of the clay is normally carried out with specialized equipment known as “sheepsfoot” or “footed drum” packers which are capable of exerting extreme pressures to compress the material into impervious layers. Care must be taken to compact the material in thin layers of not more than six inches (15 cm) thickness each time to ensure proper compaction is achieved. In dry soil conditions, water must be added to achieve proper compaction. Generally, six passes with a packer will achieve the proper mixing and compaction for a good seal. The thickness of the clay liner that will be required depends on the clay, but should be at least one and one half to three feet thick (45 – 90 cm).

4.2.5 Bentonite

Bentonite is highly expandable clay that is mixed with the soil and packed into place to seal the excavation. Once the reservoir fills and the bentonite becomes wet, it expands and provides an impervious seal.

4.2.6 Sodium Chloride Additive

If the clay content of the soil is in excess of 20%, a sodium-bearing compound such as sodium chloride can be incorporated into the soil to produce a seal. If this practice is to be followed, soil tests are required to determine the clay content and the amount of sodium compound required.

4.2.7 Plastic Liners

While plastic liners are available to prevent seepage, they are expensive and must be installed according to manufacturer's instructions. Some plastic liners are ultraviolet light protected and have a 10-year guarantee. For plastic liners to last longer, they must be either thicker or covered with a sand layer. To place a sand-layer on a plastic liner requires a low slope. Any tears in the liner can cause it to fail. In certain cases, air trapped under the liner can float it to the water surface. For high water table conditions, drains must be installed to lower the water table. This will prevent ground water pressure from below, lifting and floating the liner.

4.2.8 Gleization

This involves covering the reservoir bottom with 6 inches of chopped straw. The straw layer is then covered with 6 inches of clay and compacted into place. As the straw decomposes under low oxygen or anaerobic conditions, a rubbery blue-grey substance is produced that seals the pores between the soil particles. Since bacteria are breaking down the organic matter, the seal takes time to develop. Water will seep out while the seal is forming.

4.2.9 Perimeter Trench

If the sand and gravel lenses are only located in the upper portion of the excavated area, a cut-off trench can be installed. The trench should be dug as deep as the bottom of the reservoir and be extended around the total perimeter of the excavation. The trench is then filled and packed with good clay to form a perimeter seal. If the existing soil is generally high in clay content with only minor layers of sand and gravel, the material excavated from the trench can be mixed up and packed back into the trench. Since the lenses of sand and gravel are no longer continuous, the reservoir will hold water. If good clay is not readily available, a cut-off curtain made of woven polyethylene fabric can be installed.

4.3 Excavating Equipment

4.3.1 Excavator

An excavator is a large backhoe mounted on dozer-type tracks for manoeuvrability and floatation. Due to availability, ease of operation, versatility, and speed and ease of transport, the use of excavators for digging reservoirs has increased dramatically. Since these machines are very fast, they can remove large quantities of earth in a very short time. Also, they complete all the work from the top edge of the reservoir, and do not need to crawl in and out of the excavation. Excavators are able to excavate the end slopes of the reservoir to the same angle as the sides. They have a distinct advantage for excavating wet materials. The main disadvantage of this type of unit is the reach of the boom, and consequently the width of the reservoir that can be conveniently built. Some of the newer units, with extended booms, are able to dig reservoirs 60 to 70 feet in width. Due to the shorter reach, the soil removed is piled very close to the edge of the reservoir. This can lead to collapse of the banks due to the extra weight of earth. Because it is impractical to move and spread the excavated material with an excavator, the spoil pile presents a problem. For wider and deeper reservoirs, the excavator can move the excavated material a second time. A better option is to use a dozer, or a large loader to move the piles of excavated soil back away from the edge of the reservoir. The fill can be used in low areas or to establish dikes to control the flow of water.

4.3.2 Scraper or Buggy

Scrapers or buggies are large units that are used to remove, carry, and deposit the earth from the reservoir excavation. Buggies are mounted on rubber tires and have the advantage of being able to move large amounts of earth very quickly. They can easily move the material to other areas for landscaping and diking purposes. As the hole becomes deeper, and the soil more compacted, this type of unit may encounter problems with traction and in some cases may require a dozer with a ripper tooth to loosen the soil before excavation. Track-type scraper units are slow but have better traction and can work in more varied soil conditions. The main disadvantage of these units is the need for gently sloping end-slopes to allow entry and exit from the excavation. It is recommended that these flat slopes be steepened with an excavator.

4.3.3 Dozer

While a dozer can excavate a reservoir alone, it is a slow process and will result in large spoil piles at both ends of the reservoir. Wet soil conditions can cause delays and problems for a dozer. However, due to its traction, it can operate in a variety of soil types. As with other scraping equipment, dozers cannot construct steep slopes on all sides. Gently sloping end-slopes are required for entrance and exit from the excavation. The end slopes should be steepened with an excavator.

4.4 Selecting a Contractor

4.4.1 Experience

While digging a reservoir may sound easy, how it is built will determine how long it lasts and how well it performs. For example, the slope of the sides will depend largely on soil type. The more silt or sand a soil contains, the flatter the slopes must be in order to prevent collapse. Similarly, sandy pockets or veins encountered during excavation may require sealing to prevent future leakage. An experienced contractor will recognize soil problems and inform the land-owner of possible solutions. Further technical assistance can be obtained from a soil or water specialist.

4.4.2 References

A good contractor should be willing and able to provide a list of past clients. These references should be checked to see not only if the previous clients were satisfied with the work completed, but also how the reservoir is operating and if any problems have arisen due to construction techniques utilized.

4.4.3 Equipment

The availability of equipment in the area will be an important factor in choosing a Contractor. The equipment to be used should not only appear to be in good mechanical condition, but must also be appropriate for the site. The choice of the wrong equipment can lead to a very expensive reservoir and one that may not be completed to your satisfaction.

4.4.4 Reservoir Finishing

It is recommended that excavated material from the reservoir be levelled, spread, and topsoil replaced. The final steps are to install any culvert inlets and trenches for water and airlines, replace the topsoil and seed grass to a buffer area around the reservoir and the in-flowing runoff channels.

4.4.5 Costs

There is not a great deal of difference in cost between various types of excavation equipment. However, to ensure the best price available, quotations should be obtained from several contractors whenever possible. Quotations are normally given in price per cubic yard or cubic meter of material removed. If the excavated soil is to be moved and spread to fill in low areas or form dikes, the cost should be kept separate from the reservoir quote. As with any quote for work, it should always be in writing to eliminate any misunderstandings. Check to see if equipment transportation costs are included in the quoted price. Depending on the type and location of the equipment, transportation costs may be a major addition to the costs of excavation.

4.4.6 Time factor

As with any type of contracted work, acceptable times for starting and finishing the job should be spelled out before any contracts are signed or work started. In many cases, availability of equipment will be the determining factor as most contractors are extremely busy in the fall of the year. Better prices may be possible if the work can be done in early summer, during their "off season". From a reservoir construction stand point, the driest time of the year (June, July and August) is the optimum time to start and complete construction. During this dry season costs are lower, working conditions are better and the quality of the end product is usually much better.

5 Module 5 – Equipment Systems

A well-designed and efficient water system is a very important part of a farming operation. Large reservoirs of water can be pumped at a much faster rate than most wells in the Maritimes. This is only an advantage if the water intake, pump, and water distribution lines are sized to meet the peak demands of the farm. Reservoir aeration systems can make a dynamic improvement in reservoir water quality. Remote watering systems that pump out of pasture reservoirs help protect livestock from illness and injury as well as improve water quality and livestock production.

5.1 Intake Systems

Research has shown that water in the top four to five feet (1.2 to 1.5 meters) of a reservoir is of higher quality than water at the bottom and edges of the reservoir. It has also shown that many farm reservoirs become depleted of dissolved oxygen resulting in black smelly water. For these reasons, floating, water intake systems are recommended for all farm reservoirs.

5.1.1 Floating Intake Systems

In British Columbia, floating intake systems are most commonly used in farm water reservoirs. The floating intake draws the better quality water from near the reservoir water surface. These systems are sometimes installed with a wet well beside the reservoir which contains a submersible pump. However, with jet pumps, the intake assembly hooks directly to the suction line, and a check-valve is installed next to the pump. This eliminates the need for a wet well. Whatever the chosen system, it is recommended that intakes be planned and installed at the time of reservoir construction. Floating intake systems include the components shown in **Figure 17: Floating Intake**.

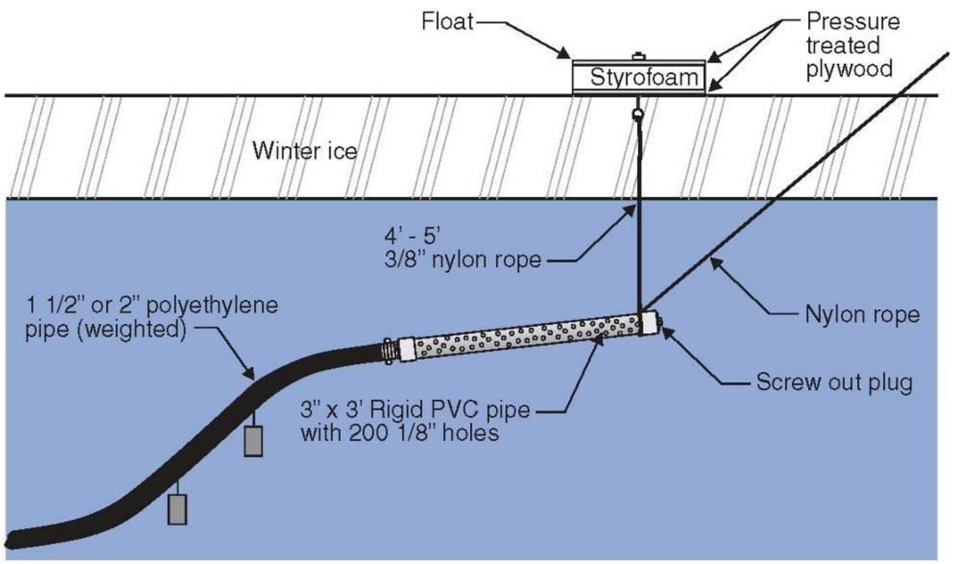

Figure 17 Floating Intake

In **Figure 18: Submersible Pump and Intake System** a submersible pump and intake system is shown. The intake pipe is installed inside another larger pipe where it enters the reservoir. This will protect the intake line from possible damage or collapse during back filling of the intake pipe trench. The perforated intake pipe supplies water to a wet well located beside the reservoir. The water flows by gravity as water is pumped from the well. Since plastic pipe is lighter than water, small concrete weights must be secured along the intake pipe. Generally, medium density 75 psi CSA rated pipe is recommended for the intake line. Install the reservoir air line in the same trench as the intake line. This installation will protect the air line from freezing.

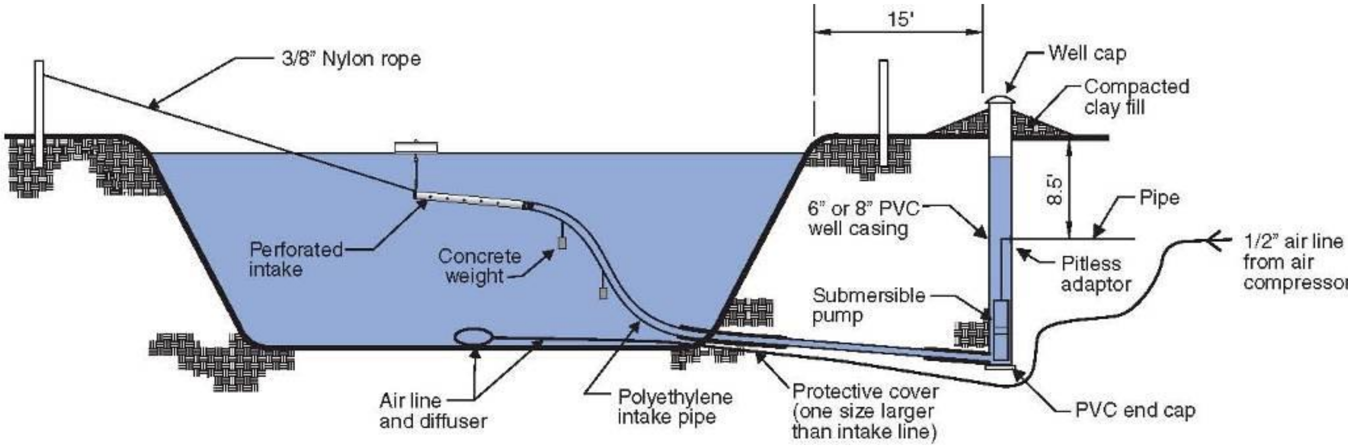

Figure 18 Submersible Pump and Intake System

In **Figure 19: Plan View of Intake System**, a plan view of a reservoir and the intake installation is shown. The intake pipe should enter the reservoir on a 45° angle to reduce the chances of kinking when the intake is pulled to shore for maintenance.

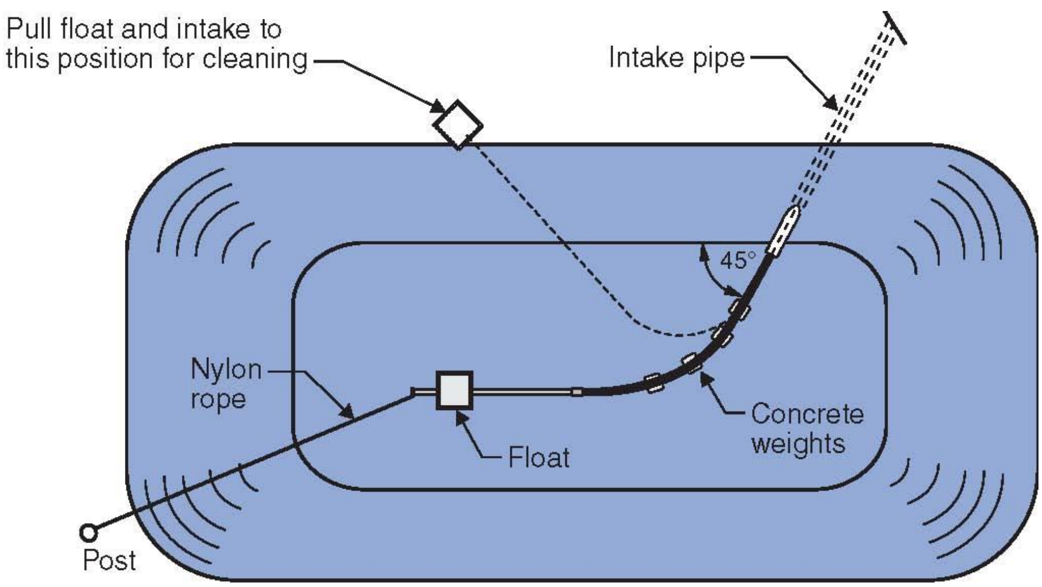

Figure 19 Plan View of Intake System

5.1.2 Other Intake Systems

Over the years, other types of water intake systems have been tried for reservoirs. They are not recommended. Two common but unsatisfactory systems are gravel infiltration trenches and reservoir bottom intakes.

Gravel-filled trenches between the reservoir and a wet well beside the reservoir have been unsuccessfully tried in the past. **They are not recommended.** The trenches can be effective filters for several years but will eventually fail due to plugging of the spaces in the gravel with soil, plant material, microorganisms, and biofilms. Flows to the wet well are inevitably reduced. Due to high levels of biological activity in the trench, oxygen levels fall which leads to the release of hydrogen sulphide gas. These conditions produce black smelly water in the wet well. It is also common to see a ten-fold increase in total dissolved solids, and greatly increased problems with iron, manganese, and hardness due to leaching of dissolved minerals from the gravel material. The only solutions are re-excavation and replacement of the gravel every few years, or replacement with an intake pipe.

For reservoir bottom intakes, large 4 to 12 inch (10 to 30 cm) horizontal piping has been used to convey water from the bottom of the reservoir to a wet well. Although these systems do not plug, poor water quality is a problem. Unless the reservoir is continuously aerated, the poorest water quality is always near the reservoir bottom. Large open-ended pipes often result in water bugs entering the wet well, pumps, and distribution system. In some cases, bugs can plug impellers on pumps and screens. Avoiding this problem requires installation of screens around the reservoir intake or the pump intake in the wet well.

5.2 Pumps

There are many types and sizes of pumps for reservoir water systems. Some are designed for drawing from the water source only. Others draw the water and force it through the rest of the distribution system. Some pumps are used for special purposes such as boosting pressure or supplying a special outlet. Therefore, it is important to select the proper type and size of pump for the application. Surface mounted fuel and/or electric powered pumps are most commonly used in British Columbia. Other pumps used for reservoir applications include shallow well jet and submersible pumps. Refer to the British Columbia Ministry of Agriculture factsheets listed in Appendix 3 for more detailed information.

5.3 Water Distribution System

The water distribution line should be sized to effectively supply the required amounts of water and pressure throughout the system. For reservoir applications in this region, high density, CSA approved, polyethylene pipe is suitable for underground burial and general use in the water distribution system. High density polyethylene is recommended because it is more resistant to damage in potential freezing locations.

For pipe connections, it is best to use fittings that will not corrode from the water or contact with corrosive soil in an underground trench. Nylon, plastic, or brass fittings are recommended. Use 100 percent stainless steel clamps for all connections and double clamp underground connections. Refer to the British Columbia Ministry of Agriculture factsheets listed in Appendix 3 for more detailed information.

5.4 Reservoir Aeration Systems

As previously outlined in the “Biology of a Reservoir” section, an important part of maintaining water quality is ensuring that the level of dissolved oxygen in the water stays high all year round. Under natural conditions in a reservoir, oxygen exchange with the environment is not sufficient. In summer, a layer of warm water forms at the surface of the reservoir, and floats on a layer of deeper, cooler water. The layer of cold water, having no contact with the atmosphere, becomes depleted of oxygen. Under low-oxygen conditions, plant nutrients, metals, and swamp gases are released from the reservoir sediments and held by the cold water layer.

In fall, air temperature and the surface waters of the reservoir cool rapidly. When the surface layer reaches the temperature of the cooler, bottom layer, the reservoir “turns over”. This means that the water in the reservoir is no longer stratified and wind mixing of all the reservoir water occurs. Nutrients and unwanted compounds become evenly distributed throughout the water.

During winter, ice cover prevents the transfer of oxygen from the atmosphere to the water. When oxygen is depleted, microbial activity in the sediments again begins to release unwanted compounds. One of these compounds, hydrogen sulphide, produces the rotten-egg smell that often develops in small water bodies in late winter.

In spring, the ice melts, the surface warms, and the water mixes completely distributing the unwanted compounds throughout the water. Dissolved nutrients become readily available to plants and algae near the surface. As the air temperature increases, the cycle begins again.

In order to prevent this cycle of low-oxygen conditions from developing, supplementary aeration is required. This adds oxygen to the water and ensures complete mixing of the water so that contact with the atmosphere is maximized. Research has shown that reservoirs should be aerated 24 hours per day, year round.

5.5 Types of Aeration Systems

Many types of aeration systems have been tried over the years including electrical, wind-powered, and solar-powered systems. Where possible, electrical systems are always preferred, but for remote locations, other power sources are required. All systems have advantages and disadvantages.

Wind-powered systems can be effective in low-sunlight winter conditions but only in areas where winds are relatively constant. Solar systems are very portable and work best in hot sunny conditions coinciding well with peak demand for water. Producers should try to find options that suit their operations and their geographic area. Some floating systems are available but research indicates that these systems are not very practical or effective for farm water reservoirs.

5.6 Components of an Aeration System

There are four components to an aeration system:

- power supply
- air compressor
- aeration line
- diffuser

5.6.1 Power Supply

As with pumping systems, aeration can be powered by electricity, solar power, or wind. An electrical type compressor can provide a continuous supply of dissolved oxygen. Windmill and solar power type systems may not pump sufficient dissolved oxygen during low wind conditions, at night or during hot calm periods in summer.

5.6.2 Air Compressors

Bank-mounted windmills use a diaphragm-type pump that pushes air into an aeration hose that extends to the bottom of the reservoir. Windmills are suitable for areas with good wind conditions and for remote sites where electrical power is too costly to install. However, they perform poorly on sites where winds are obstructed by hills or trees, water is deep (over 20 feet), or there are high concentrations of organic matter in the water.

The most common types of electrical compressors are the oil-less diaphragms or piston pumps. These compressors are quiet, relatively inexpensive to purchase and operate, and require little maintenance. When choosing a pump, make sure it is rated for continuous use. As a rule, a diaphragm-type compressor that pumps approximately one cubic foot per minute (cfm), for every million gallons of reservoir water is adequate. For best results, locate the compressor in a heated building or enclosed box to protect the motor, diaphragm, and electrical supply.

5.6.3 Aeration Lines

Aeration lines convey air from the pump to the reservoir. For new reservoirs, the aeration line should be buried with the water intake line. This will prevent damage from frost, ultraviolet light, ice, and animals.

5.6.4 Diffusers

A diffuser is a device to release air into the water. Research has shown that the type of diffuser is very important. Diffusers that create fine to medium-sized bubbles are more efficient at circulating and aerating water than open-ended hoses that produce large bubbles. An open-ended hose requires three times the volume of air to saturate water with dissolved oxygen compared to an air stone or perforated hose. Proper location of the diffuser maintains oxygen levels from top to bottom. Recommended types of diffusers include air stone diffusers, linear, fine bubble diffusers, or membrane diffusers.

5.6.5 Safety

During winter, reservoir aeration systems can result in open or weak areas in the reservoir ice. These conditions can be very dangerous for young children, pets, and people snowmobiling at night. It is essential to educate your children about these hazards and post the area with highly visible warning signs and fluorescent snow fence around open water areas.

5.7 Water Systems for Livestock

Livestock producers want to provide a safe, reliable supply of good quality water for their livestock and increase their management to better utilize their pastures for livestock production. Direct watering of livestock from reservoirs causes a number of environmental, herd health, and pasture utilization problems.

5.7.1 Problems with Direct Watering

- Direct reservoir access watering has a negative effect on water quality, herd health, and the lifespan of the farm reservoir:
- Fecal pathogens are directly added to the water allowing for rapid spread throughout the herd. Problems may also arise due to pathogens causing footrot.
- Nutrient loading from excrement will lead to proliferation of algae populations and in some cases the production of toxins from cyanobacteria.
- Oxygen depletion results from the biological breakdown of excrement.
- Destruction of side-slopes from hoof action speeds sedimentation and shortens the life of a reservoir.
- Cattle are sensitive to taste and odour in water supplies, and may limit their intake of less palatable water, possibly leading to reduced feed conversion and productivity.
- Increased risk of livestock leg injuries or death by drowning from falling through the ice or being stuck in the mud.
- Overgrazing near the water source.

5.7.2 Pasture Water Systems

There are many benefits to pumping water to livestock and keeping them out of water sources. A well planned and constructed pasture water system can provide improved herd health, increased livestock production and better pasture utilization. A remote watering system will also offer water source protection and thus longer water source life, as well as riparian protection.

A variety of livestock watering methods are available to suit any type of pasture and location. The power options to move water to livestock include solar, wind, fuel, stream flow, mainline electricity, and gravity flow. Selecting the most appropriate one can be a challenge.

Consider the following factors when you select a pasture water system:

- type and location of available water sources
- site locations and conditions (remote location, topography, riparian features)
- type of grazing system (intensive or extensive)
- number of livestock
- access to power source (mainline power, solar, wind, animals, etc.)
- pumping system (amount of lift, automated versus manual)
- flexibility and portability
- reliability and maintenance
- temporary or seasonal water shortage
- cost per benefit and cost per animal
- personal preference

5.8 Alternatives to Direct Watering of Livestock

There are many viable alternatives to direct watering. These alternatives are described below.

5.8.1 Access Ramps

An access ramp is the minimum improvement that can be made to a water source. Ramps are most appropriate for large herds of livestock in remote locations (i.e., rangeland pastures) where animals are seldom checked or moved. Reinforced ramps provide better footing for livestock drinking from reservoirs or streams where soft soils exist. These ramps require a relatively low slope of 5 to 6 feet (1.5-1.8 m) for every foot (0.3 m) of drop. A layer of road gravel approximately one foot (0.3 m) thick should be laid 10 to 15 feet (3-4.5 m) back from the water's edge and continue down to below the lowest water level of the reservoir.

The water source is usually fenced off, so livestock can only drink from the access ramp. Some producers have found that fencing is not necessary because once the cattle have convenient access to water, with good footing; they will water almost exclusively from the ramp. Refer to the British Columbia Ministry of Agriculture factsheets listed in Appendix 3 for more detailed information.

5.8.2 Water Hauling

Although it might seem like a step back in time, water hauling can be a viable alternative. In intensive livestock grazing management, cattle are sometimes moved daily from pasture to pasture. Access to water is often the limiting factor. By utilizing an old truck with a main storage tank and an easily moved stock tank, the watering source can be continuously relocated throughout the pasture along with the cattle. The nutrients from the manure are more evenly distributed and are kept on the same field.

5.8.3 Water Storage

Alternative energy powered pumping systems (including fuel, solar, and wind powered) all require water storage. The water storage tanks or reservoirs provide the necessary livestock water between pumping cycles. Most are raised above the stock tank to allow for the gravity flow of water. They are generally sized to hold a three to seven day supply of water for cattle. For sizing water storage, use the following cattle water consumption rates for cattle on pasture:

- yearling steers or heifers – 8 gallons (36 L) per day
- cow-calf pairs - 12 gallons (55 L) per day

These are average water consumption rates for cattle on pasture. On hot summer days, peak water consumption can reach 1.5 times these numbers.

Water storages can be made from about anything as long as they safely store water at a reasonable cost. The most common are plastic, fibreglass, concrete or metal tanks, elevated earthen reservoirs, grain bin rings, large rubber tires, or large stock watering tanks. The cost of water storages ranges from about 5 cents per gallon (1 cent per L) to over $1.00 per gallon (23 cents per L). The lowest cost water storage (5 to 10 cents per gallon or 1 to 2 cents per L) is the elevated earthen reservoir.

5.8.4 Gravity-fed Systems

Gravity-fed systems are ideal systems on sloping pasture land where it is possible to locate a reservoir or dam upslope from a watering site. A pipeline can then be run from the reservoir down slope into a stock tank. As a rule, the water level in the reservoir should be at least five feet (1.5 m) higher than the stock tank plus one foot (0.3 m) additional height for every 100 feet (30 m) of pipeline to the stock tank. Gravity-fed systems can also be used for springs where there is sufficient elevation drop to the stock tank. On long, undulating and/or steep drops, take extra care to avoid leaks or air blockages.

5.8.5 Pumped Gravity Flow Reservoirs

These reservoirs are generally constructed by digging a small reservoir on top of the excavated dirt piles from a reservoir. A standard backhoe can construct these in a few hours. The reservoir is then lined with a woven polyethylene liner to prevent seepage and to keep the water clear. The reservoir bottom must be higher than the top of the stock tank. This approach will provide adequate gravity flow from the elevated reservoir through the water line and float valve assembly and into the stock tank. Selecting the proper size water line and a high capacity, low-pressure float valve are also important to ensure adequate flow rates.

5.8.6 Animal Operated Pasture Pumps

These pasture pumps are commonly called **nose pumps** because cattle operate them by pushing them with their noses. The pump provides a very low cost (approximately $15 per cow-calf pair) pumping system and is good for about 30 to 40 cow-calf pairs.

There are five or six manufacturers of nose pumps currently being sold, including one frost-free pump that is suitable for winter use. Some of the pumps are slightly easier to push than others. They all supply approximately 0.2 gallons (1 L) of water for every stroke of the nose device. The conventional pumps can lift water to a maximum of 20 vertical feet (6 m) and, with the use of a shallow buried pipeline, can also be offset a quarter of a mile or more from the water source. The frost-free nose pump uses a piston pump and has been used with over 40 feet (12 m) of lift, but must be located directly above the reservoir wet well.

Minimize the amount of elevation lift from the water to make it easier for cows and calves to operate the pump. Shallow burial of the pipeline from the reservoir to the pump is recommended to protect the pipeline.

Although pasture pumps are very reliable and easy to move from pasture to pasture, cattle will take a day or so to learn how to operate the pump. This training period is done best at the farmyard after calving and before the cows go out on pasture. It is best not to train livestock to operate the pumps during extremely hot temperatures. Small calves will generally not learn to operate the pumps until they are about 300 lbs (136 kg). There are several options to overcome this problem. One is to fill the stock tank with water where only calves have access. Another option is to collect some of the water pumped by the cows into a small tub or stock tank for the calves to drink.

5.8.7 Pipelines

Shallow buried pipelines are ideal for farms with a very intensive rotational grazing system within one or two miles distance of existing water and mainline power. Pipelines allow livestock producers to better utilize their water source (i.e., usually a well or reservoir) rather than constructing many small reservoirs scattered around the pastures. They are flexible systems, and watering sites can be located at the preferred location rather than where a reservoir will fill from runoff.

For shallow burial (approximately one foot or 0.3 m deep) of the pipeline, some producers use a ripper type plough mounted on either a three-point hitch of a tractor or a pull type unit. A 1 inch (2.5 cm) diameter plastic pipe can be installed for about 50 cents per foot ($1.60 per m). It is important to design the system properly to ensure the right combination of pipe size and stock tank.

Some producers are also using deeply buried pipelines in several of their pastures close to home. They can then use these pastures year round for pasture as well as for feeding, bedding, calving, and weaning. This approach helps to reduce animal disease problems as well as manure hauling and spreading costs.

In the future, shallow buried pipeline systems will likely become more popular because of their many advantages and due to the shift to more intensive grazing systems.

5.8.8 Gas-powered Pumping Systems

These systems are a low cost alternative for pumping water to larger herds of livestock. They work well in combination with an elevated reservoir system, containing about one week's water storage. The pumps are very portable and can be moved easily from one water source to the next.

Some producers use a gas-powered generator to run a submersible reservoir pump. These systems can be automated to start on a float switch device located in a stock tank or reservoir. Both pumps and generators can be used for other purposes on the farm. These systems can be sized to pump a large volume of water from reservoirs.

5.8.9 Solar-powered Pumping Systems

Solar systems are becoming more popular because of their reliability and low maintenance. They can be used to pump water from reservoirs. An array of solar panels collects and converts sunshine into electrical energy, which can be used to pump water or be stored by rechargeable batteries as illustrated in **Figure 20: Solar Watering System**. Due to the variation in sunshine intensity, a minimum of three days water or battery storage is required.

For the solar direct systems without batteries, it is important to match the solar panel's output (in watts) to the power requirements of the pump for maximum efficiency. For solar systems with batteries, it is important to select good quality deep cycle type batteries (e.g., recreation vehicle type). It is also important to install electrical controls that have both low and high voltage disconnects. These protect the battery from under or over charging conditions, which will drastically reduce battery life. Obviously, a sunny spot is desired for these systems, but also choose a location that is not in plain view and is sheltered from high winds.

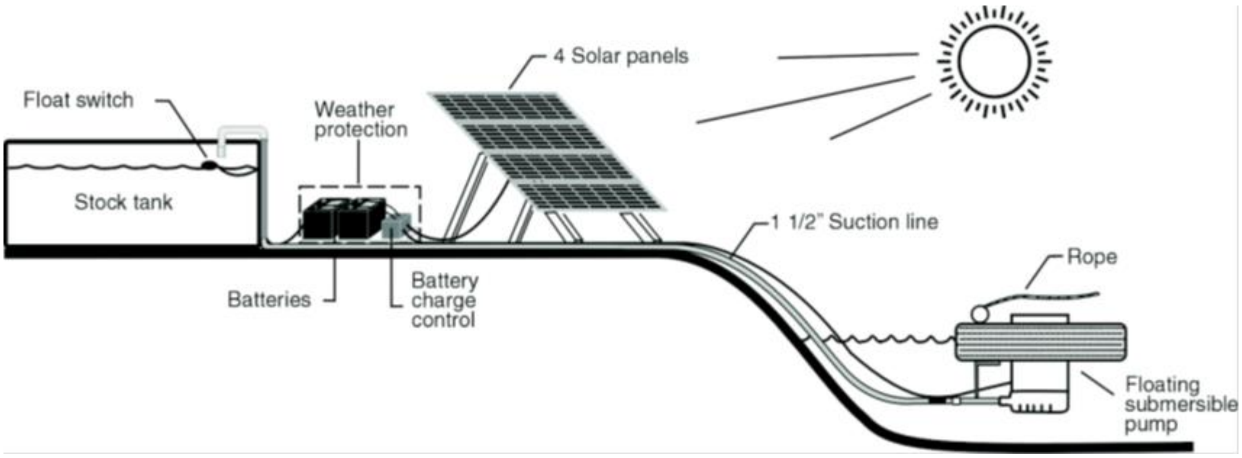

Figure 20 Solar Watering System

Solar powered systems have the advantage of pumping the most water on hot sunny days when cattle are drinking lots of water. Excess power can be used to energize an electric fence for the pasture. Although the initial costs of this system are somewhat higher than for others, they will last for many years. The portability of the solar pumping system is another advantage.

5.8.10 Wind-powered Pumping Systems

Windmills perform best in areas that have higher than average wind speeds. Windmills can be used to pump from reservoirs and wells. Place windmills on higher ground where they have good exposure to the wind, such as the excavated dirt pile from a reservoir. Also, locate them away from trees as far as possible, at least 15 to 20 times the height of the trees.

The initial costs of the system are somewhat high, but most of the windmill systems are very reliable and will last for many years. A windmill system should have at least three days of water storage. Be prepared to use an alternate pumping method or haul water during prolonged calm periods.

5.9 Options for Winter Watering Livestock at Remote Locations

Although livestock prefer water, snow is an acceptable water source for mature cows and young cattle in good condition. For snow to be used as a water source, there must be an abundant supply, and it must be clean, unpacked, and with no crust so that it's easily accessible by livestock. Provide lactating cows with calves, as well as first and second calf heifers, with water to maintain body condition during the winter months.

In the last few years, more producers are installing winterized pasture water systems from reservoirs and water wells to supply water to their livestock. The reasons for these systems include:

- extending the pasture grazing season and fall and winter swath grazing
- lack of water at the farmyard site
- winter feeding of cattle on pasture and cropland to reduce manure hauling costs
- providing increased flexibility for separating cattle at weaning and calving times

- preventing manure build-up in the calving areas
- reducing animal health problems associated with the above
- death losses due to drowning

With the proper planning and design, almost all the traditional summer pasture water systems can be modified and used throughout the winter. To prevent freezing, you need to supply heat, reduce heat loss, or a combination of these. There are many options for winter watering including commercially available "earth-heated" waterers, super insulated "energy free" waterers and water troughs that rely on the heat stored in the water itself to keep it from freezing, and propane heated waterers. There are also continuous water flow-through systems to prevent freezing, frost-free animal operated nose pumps, and solar and wind powered pumping systems for winter use.

Each system has its place, and personal preference, reliability, livestock herd size; cost, remoteness, and the site location are all factors to consider when choosing an appropriate system. For remote reservoir locations in British Columbia, watering systems must be durable and able to withstand temperatures that drop as low as -40ºC, especially in the Northern parts of the province.

Most wintering watering systems available on the market today have a common setup. The main components are an intake water line from the reservoir, wet well, power source, and pump.

The most common pumping systems currently being used during the winter are solar powered. The solar panels are used to charge batteries which supply electrical power for running a pump. Two basic design concepts prevent freezing – a drain back system or a well-insulated trough system. The basic components of a solar system itself are:

- solar panels
- deep cycle batteries
- battery charge controls
- pump
- a motion detector or float switch to start and stop the pump
- water lines
- a watering bowl or water trough
- other options including a wind turbine to supply additional power for the batteries during extended cloudy periods and an aerator to improve reservoir water quality

5.9.1 Watering Bowl with a Drain Back System to Prevent Freezing

This system is set up directly over the wet well beside the reservoir and uses a motion sensor to activate the solar-powered pump. The motion sensor starts the pump when livestock approach the watering bowl to drink. Water is pumped into the bottom of a 25 inch (63.5 cm) diameter round watering bowl located on top of a 24 inch (60.96 cm) diameter culvert or wet well. The water level rises in the bowl to a set of overflow holes that return excess water back into the wet well. These holes are located near the top edge of the bowl to prevent overflow onto the ground. The pump will run as long as there is livestock motion within the range of the motion detector. To prevent the pump from starting and stopping, a delay is built in to allow the pump to continue running for a preset time. This delay allows the next animal to approach the watering bowl and get water before the pump shuts off. To prevent freezing water remaining in the bowl drains back to the wet well through the bottom of the bowl. The motion detection systems are adaptable to a variety of setup configurations.

The ground level at the watering bowl site should be at least 7 feet (2.13 m) higher than the maximum water level of the reservoir. This amount of soil cover will prevent frost penetration and freezing of the water in the wet well. Slope the site away to provide good drainage to ensure a dry, clean, safe watering site during mild thaw events.

5.9.2 Well Insulated Trough System to Prevent Freezing

Similar to the drain back system, this system is set up directly over the wet well beside the reservoir. The solar powered system pumps water from the wet well into an insulated, doughnut-shaped trough. The float switch signals the pump when the water level is low to keep the trough full. Livestock drink water through access hatches in a fitted, insulated lid that sits on top of the wet well. The trough has several access hatches that can be opened for larger herds. On extremely cold nights, all but one of the access hatches may have to be covered to prevent heat loss and freezing. This system relies on the heat stored in the incoming water to keep it from freezing and thus must have a minimum number of livestock drinking from it each day during freezing temperatures.

5.9.3 The Frost-free Nose Pump

The frost-free nose pump is also a drain back type of winter watering system. The cows push a nose pad that operates a piston in the bottom of the wet well. The piston lifts the water up into a small drinking bowl. The cow drinks the water out of the bowl, then pumps more water. When the cow is finished drinking, the water in the drop pipe that brings the water up from the well drains below frost. The pump supplier recommends a maximum of 50 cow/calf pairs per pump. For larger herds a second pump can be mounted on top of the wet well. Daily inspection of the functioning and icing of pump are recommended especially during extremely cold and windy conditions to ensure adequate water availability for livestock.

5.9.4 Summary

No matter the size of a livestock watering system, proper planning and design play an important role. Good installation cannot compensate for an inadequate water source. Good quality water and quantity are both vital to livestock. Reservoir and off-stream livestock watering systems are an important tool in protecting water sources, riparian areas, and livestock. Refer to the British Columbia Ministry of Agriculture factsheets listed in Appendix 3 for more detailed information.

6 Module 6 – Water Quality

Water that appears to be acceptable based on visual appearance, taste, odour, and colour may contain contaminants that affect livestock health. Risks can be chemical or microbiological. It should be remembered that water that has been successfully treated for consumption might become re-contaminated and present real health risks. Re-contamination sometimes occurs in the distribution system. It must be stressed that reservoirs are not an approved method for storing water for human consumption.

6.1 Health Risks and Water Quality

On first appearance, water would appear to be a relatively simple liquid. It is, however, a powerful solvent that is capable of containing a very complex mixture of chemical substances. Water also provides a suitable medium in which a diverse range of microbiological organisms can exist. The presence of various chemical constituents and microscopic organisms in water may impact upon livestock health.

6.2 Microbiological Factors

There are three major groups of microbiological organisms that cause waterborne diseases:

- bacteria
- protozoa
- viruses

6.2.1 Bacteria

Most bacteria found in water do not cause diseases. Types of bacteria that do cause disease are found in the intestinal tract of warm-blooded mammals, including humans. These bacteria are excreted in waste matter and may be carried into water supplies.

Seepage from septic tanks and sewage lagoons, plus runoff from livestock feedlots, pastures, and cropland to which manure has been applied may contain bacterial contaminants. Similarly, fecal matter may also be introduced from rodents, birds, and other wildlife. Surface water supplies are therefore highly susceptible to bacterial contamination.

Once bacteria have entered a water supply, they may continue to reproduce, thereby maintaining or even increasing the degree of contamination. Surface water supplies that are largely immobile, like reservoirs, provide an excellent breeding ground for bacteria.

6.2.2 Protozoa

Protozoa are a group of microscopic parasites that are frequently present in surface waters. Some protozoa, notably giardia and cryptosporidia, exist in the form of cysts. The protective covering of the cyst permits the parasite to survive harsh environmental conditions. The cyst also protects the parasite against disinfectants such as chlorine. Once ingested, the parasite germinates and reproduces. Encysted parasites may subsequently be evacuated from the animal or human host through the feces.

Cryptosporidia and giardia have been suggested as the causative agent in approximately 60% of reported waterborne disease outbreaks in the U.S. between 1991 to 1998. Giardia are found in feces from humans, beavers, muskrats, and dogs. Cryptosporidia have been found mainly in fecal matter from cattle, sheep, and pigs. However, they have also been detected in the feces of humans and other mammals. Contamination of water supplies occurs when fecal matter containing the parasites is deposited or washed into the water.

6.2.3 Viruses

Relatively little is known regarding the incidence of diseases resulting from waterborne viruses. However, a number of different waterborne viral agents have been found in contaminated water supplies and linked to disease including hepatitis A, rotavirus, Norwalk agent, over 30 types of adenoviruses, and over 70 types of enteroviruses.

6.3 Chemical Factors

There are a number of chemicals that can pose a livestock health risk. In some cases, these materials are naturally present in water through weathering and erosion. In other cases, human activities result in the introduction of these chemicals into water.

Chemicals that potentially have an adverse effect upon health include naturally occurring minerals, metals, and toxins as well as a variety of synthetic and organic chemicals including many different types of pesticides. If you suspect that your water contains elevated levels of naturally occurring chemicals, or if you believe that your water has become contaminated, specific tests may be performed in a laboratory. There are numerous laboratories with a diverse range of analytical testing capabilities located in each province. Contact your regional health authority to obtain contact information for water-testing laboratories.

6.4 Aesthetics and Water Quality

Numerous chemical compounds and microbiological species affect the aesthetic quality of water. Certain species impart an objectionable taste or odour to water while others may cause staining or leave behind a residue or solid precipitate. These chemical agents and microbiological species are generally regarded as nuisances that typically do not pose a risk to livestock health. The most commonly encountered nuisance water problems are summarized in Appendix 1, Table 1: Chemical Agents and Microbiological Species Affecting Aesthetic Quality of Water. The source of the nuisance impurities and organisms are listed along with the symptoms typically observed as a result of their presence in water. The presence of these impurities and organisms can be confirmed by laboratory tests. Once their presence has been determined, appropriate steps may be taken to eliminate or minimize the associated problems.

6.5 Standard Testing For Water Quality

Regular testing of water is necessary to monitor the effectiveness of a treatment system. From the point of view of health and safety, microbiological testing of water is of prime importance.

6.5.1 Testing for Coliforms

Coliform bacteria are commonly found in the environment. While most of these organisms are not harmful, their presence is an indicator that other harmful or pathogenic microorganisms may be present. An assumption is made that if coliform bacteria are absent, then pathogenic bacteria are also probably absent. Similarly, if coliform bacteria are present, it is assumed that pathogenic organisms are also present. Therefore, in public water supplies, the presence of coliform bacteria indicates a problem with the water treatment system. It could also indicate inadequate disinfection within the distribution system, or a break in the water pipes. Similarly, the presence of coliform bacteria in private water supplies may be indicative of a contaminated water source or a faulty treatment system.

Most water testing laboratories perform what is known as the analysis for total Coliforms. This test is used to indicate the presence of a diverse group of bacterial organisms. In some test procedures, an estimation of the quantity of bacteria present is determined, and listed as the number of colony forming units per millilitre of water tested. However, other tests simply indicate the presence or absence of coliform bacteria.

If a water sample is found to contain coliform bacteria, the next step is to determine whether any of these bacteria are due to fecal contamination. This is generally done by testing the water for fecal Coliforms or specifically for *E. coli*. The presence of fecal Coliforms or *E. coli* indicates that the water is contaminated by either human or animal waste. Microorganisms from these wastes can cause diseases.

It must be emphasized that if a water sample is positive for total Coliforms but does not contain fecal Coliforms or *E. coli*, the sanitary quality of this water is still considered unacceptable. If coliform bacteria can survive, there is the potential for pathogenic microorganisms to exist in the future.

Suspended particles or cloudiness in water is a potential indicator of water contamination and may indicate problems with treatment processes. Highly turbid water also reduces the efficiency of disinfection processes such as chlorination and UV treatment. The amount of suspended particles or cloudiness may be measured as a turbidity test.

6.5.2 Pitfalls of Standard Water Testing Techniques

While most pathogenic bacteria and viruses are destroyed by disinfection, some organisms such as cryptosporidia and giardia may not be inactivated. Therefore, an acceptable result for coliform bacteria does not guarantee that all pathogenic organisms have been eliminated. Furthermore, an acceptable result for coliform bacteria on an untreated water supply such as a private well or reservoir does not indicate anything regarding the presence or absence of protozoa or viruses.

6.5.3 General Testing Recommendations

It is impossible to test a water sample for all known pathogens. It is also very expensive to test for a large number of different pathogens. Many health agencies have designated total Coliforms as a standard indicator test to determine the bacteriological safety of drinking water. Test water derived from a privately operated source such as a well or reservoir at least twice a year for bacterial safety. More frequent testing may be necessary if contamination is suspected or unexplained illness occurs. If continuing illness is observed, discontinue use of the water until a sample has been tested.

7 Module 7 – Reservoir Management

The goal of reservoir management is to protect and improve water quality. Some of the strategies for doing this through reservoir location and design have been discussed in Module 3 – Planning. This module provides suggestions for preserving and enhancing water quality in existing reservoirs. The cost and effort to properly manage a reservoir is generally small and most often rapidly recovered in the form of improvements in water quality. Improving water quality reduces treatment costs, improves productivity of livestock, and generally improves the quality of rural life.

At a minimum, reservoirs need to be inspected weekly during April to September and monthly from October to March. Early detection of problems allows corrective action before water quality deteriorates significantly. When inspecting, look for:

- any peculiar signs of animal entry
- signs of failure of the aeration systems
- incorrect positioning of the water intake
- algae growth or blooms, and increased plant growth
- damage to grass buffer areas and diking
- signs of contaminated runoff
- Keep a record of your inspections. This will enable you to document and analyze both short-term and long-term occurrences.

7.1 Reservoir Management Practices

There are a great number of reservoir management practices. Many are known to be highly effective, while others are still in the experimental stages. Some techniques are common sense and do not require special or highly processed products or services. Other treatments involve chemicals and make use of commercial products. This module outlines some of these practices, including their strengths and weaknesses. The practices presented in this module are well-established methods of greatly improving reservoir water quality.

7.1.1 Continuous Aeration

Continuous injection of supplementary oxygen is the single most effective practice for maintaining and improving water quality. Aeration is discussed further in Module 5 – Operating Systems, Reservoir Aeration Systems.

7.1.2 Sediment Removal

Excavation of accumulated sediment from a reservoir, every five to ten years, is an effective technique for improving water quality and extending the life of a reservoir. Unfortunately, it is costly and excavation may exceed the cost of new reservoir construction. Make careful cost estimates prior to deciding to clean out a reservoir. Where two or more reservoirs exist, divert all runoff away from the reservoir to be excavated. Let the reservoir dry up during summer, and excavate the sediment in early fall. Where only one reservoir exists, the only way to excavate sediment under water is with a dragline or hydraulic backhoe. After excavation under water, expect the water to have high turbidity for up to several weeks or perhaps months.

7.1.3 Vegetation Control

Routine maintenance of the area around a reservoir is important for maintaining water quality. Grassed buffers and runways surrounding reservoirs should be mowed regularly. This prevents long grass from lying down and becoming ineffective as a sediment trap. Proper setback of shelterbelts ensures that the amount of fallen leaves entering the water is at a minimum. Steep end-slopes reduce the amount of emergent plants than can grow in the reservoir. If possible, aquatic plants should be removed from the reservoir before they die and decompose. Shrubs and trees will take root on the banks of the reservoir. Left alone, they can grow quite large and contribute significant amounts of vegetation to the water in fall. Annual cutting and removing of willows and volunteer saplings every fall can make a significant contribution to protecting reservoir water.

7.1.4 Removal of Animals

Animals such as salamanders, also called mud puppies, and muskrats can create problems in a reservoir by burrowing, house building, and foraging for plant roots. This disturbs the sediments and keeps the water constantly turbid. Specially designed fencing can be used to keep them from taking up residence.

7.1.5 Copper Sulphate

Copper sulphate, also known as **bluestone**, is perhaps the most common chemical used to treat reservoirs as shown in **Figure 21**. It is also the least understood. Copper is an essential element for both plants and animals, but at high concentrations, it can be toxic. Copper treatments can be very effective at controlling cyanobacteria. However, copper sulphate treatments are most effective when done in early summer before large populations develop.

Copper may also kill beneficial organisms, like zooplankton, which feed on some algae species. Overuse and repeated treatments can also cause a build-up of copper in the sediments of a reservoir. This can harm or kill beneficial organisms and disrupt the normal biology of the reservoir. In fact, a single overdose can also cause a man-made green algae bloom.

Health Canada recommends that the concentration of copper in drinking water for humans not exceed 1 mg/L copper. However, this is far below what would be a toxic level.

Copper treatments should therefore be done very selectively. It is not reasonable to expect reservoirs to be completely free of green or brown algae, nor free of aquatic plants. The primary target organism of a copper treatment is cyanobacteria. If copper is applied during an algae bloom, there may be an immediate release of large quantities of toxin. As a result of the toxins they produce, it is recommended that you wait

a minimum of 14 days before the water is used for animal consumption. This should allow toxin levels to dissipate. Continuous diffused aeration during this period may also help degrade toxins.

Figure 21 Solar Watering System

Copper is found in a variety of products. The active ingredient is always the copper element (Cu) itself. Contact the Canada Pest Management Regulatory Agency for the copper products currently registered for the control of algae in reservoirs. More information on the procedures for treating reservoirs with copper is provided in Appendix 2: Using Copper Products to Control Cyanobacteria.

7.1.6 Coagulation

For coagulation treatment, as opposed to treating the entire reservoir, it is more economical to treat the small volume of water required for high quality use in a specially constructed treatment cell, separate from the reservoir, as shown in **Figure 22**. However, coagulation chemicals have successfully treated entire reservoirs and have remediated flood affected turbid reservoirs. The addition of Powdered Activated Carbon has proven to be helpful for increased removal of dissolved organic matter, taste, and odour compounds. If a reservoir is coagulated regularly, chemical residues should be monitored.

Figure 22 Coagulation Cell

7.1.7 Herbicides

Some herbicides are registered for use by the Canada Pest Management Regulatory Agency to control aquatic weeds and algae. These compounds may only be used on privately owned reservoirs where water does not flow into other water bodies, as shown in **Figure 23: Herbicide Treatment**. Always follow label directions, and use safe handling practices to protect yourself from the product. In order to calculate the proper dosage, you must accurately estimate the existing volume of water in the reservoir to be treated.

Figure 23 Herbicide Treatment

7.2 Experimental Practices

A number of practices are being tried to manage reservoir water quality. Research into their feasibility and effectiveness is ongoing. Although this module outlines some of these practices, they cannot be recommended at this time.

7.2.1 Reservoir Covers

Floating synthetic plastic reservoir covers, as shown in **Figure 24**, have been used experimentally on reservoirs to prevent algae and plant growth by limiting light penetration into the water and to minimize evaporative losses. Plastic tarp-like covers are floated on top of the water and anchored to the banks at several points. Since the water level in the reservoir will vary during the year, the anchor straps must be left slack or adjusted on a regular basis to allow for fluctuating water levels. Individuals who have used reservoir covers have reported a significant reduction of evaporative losses in periods of drought.

Supplemental diffused aeration is essential to maintain oxygen levels in a covered reservoir. Well-designed covers are perforated with special slits to release any accumulated air from the aeration system that collects underneath the tarp. Due to the nature of these slits, they allow the release of air while preventing the passage of light through the perforations. Reservoir covers have a life expectancy of only three to five years due to degradation by ultraviolet light, but problems can arise sooner from wind and ice damage. If tarp anchors are not properly adjusted, wind can destroy a reservoir cover.

Figure 24 Reservoir Cover

7.2.2 Disinfectants

Disinfectants are chemicals containing concentrated oxidants, such as chlorine, hydrogen peroxide, and ozone. They are effective at killing microorganisms when the:

- water is clean enough
- dosage is strong enough
- contact time is long enough

However, disinfectants are non-selective and will kill many beneficial organisms. Accordingly, they are not registered for use in reservoirs, although they are widely used in water treatment plants.

7.2.3 Plants

Plants have been used experimentally to improve water quality. Some species of aquatic plants may improve summer water quality by taking up nitrogen and phosphorus. With the fertility of the water reduced, the growth of unwanted algae species may be suppressed. Rooted plants such as cattails can serve this purpose. However, in order to maintain the water quality, the plants must be removed in the fall. If not removed, the plants will eventually die off, and plant nutrients will be returned to the water. Since bottom-rooted plants can be difficult to harvest, there is interest in using floating plants to improve water quality. Duckweed is a floating, native plant that is able to take up large amounts of phosphorus from water but must be constantly harvested and removed from the reservoir. It only survives in relatively sheltered locations and often blows to the downwind side of a water body. Water hyacinth is a floating, tropical plant that has only been used experimentally on Canadian reservoirs to reduce algae problems. Both duckweed and water hyacinth can be harvested using a floating boom, as shown in the **Figure 25**.

Figure 25 Harvesting Duckweed

7.2.4 Fish

Fish are sometimes added to reservoirs to improve water quality by eating aquatic plants. However, they may often compound reservoir water quality problems by making it difficult to use other chemical methods of algae and plant control.

For the same reasons that plants should be removed from a reservoir, fish should be harvested before they die and decompose. Grass carp or *Tilapia* are effective at removing plants in reservoirs but because of concern about the possibility of escape into the wild, their use is not permitted in some provinces. Check with provincial authorities before considering the addition of fish to a reservoir. Some fish, notably rainbow trout, can actually degrade water quality by eating phytoplankton and adding excrement to the water.

7.2.5 Miscellaneous Biological and Chemical Products

There are a number of products now available on the market that advertises the ability to improve water quality. Many of these products have been developed for non-consumptive ponds such as golf courses, ornamental ponds, and zoo ponds. The range of products includes bacteria, chemical toxins, and light inhibiting dyes. Check for registration with the Canada Pest Management Regulatory Agency of Health Canada, and if registered, check the registration/certification information for any specified water use limitations.

The vast majority of these products are **not** registered by the Canada Pest Management Regulatory Agency for application to reservoirs or farm ponds used for consumptive purposes. Until research proves the effectiveness and safety of these chemicals in reservoirs, their use is not recommended.

8 Module 8 – Troubleshooting Guide for Reservoir Problems

Reservoir problems fall into two broad categories – water quantity and water quality. Problems can result from the:

- watershed
- reservoir location, design and construction
- systems and equipment for pumping, aeration and treatment
- management practices

This module is designed to identify the source of a problem and provide suggestions for correction. The troubleshooting guide starts by identifying typical symptoms of water quantity or quality problems. It systematically lists possible causes, identification features, and suggestions for corrective action.

8.1 Symptom 1: Low Reservoir Levels

Possible Causes	What to Check For	How to Correct (Options)
Inadequate Watershed	Observe or measure the area contributing water to the reservoir during runoff events	• Enhance snow trapping in the watershed with shelterbelts; snow fences, or crop stubble • Pump water to fill reservoir • Develop another water source
Drought	What are normal snow and rainfall amounts for your area? Information available from Environment Canada	• Snow trapping • Pump water from another source • Increase water storage • Develop another water source (back up) for drought proofing purposes
Reservoir Too Small	• Compare annual water use and ice and evaporation losses with reservoir size recommended. • Consider future expansion, etc. • Steady drop in water levels.	Increase reservoir source and add another water source
Seepage From Reservoir	Sand lenses or layers of silts and fractured clays	• Use reservoir sealing techniques • Relocate reservoir to suitable soil condition

Soil Depositing in Reservoir	Soil erosion in watershed or watercourses draining to the reservoir	• Use soil erosion techniques such as a grass cover and gated culvert inlets to the reservoir to prevent sedimentation • Remove sediment from reservoir • Use a 2 reservoir system: one for a settling pond, and the second for use
Upstream Blockages or Drainage	• Upstream beaver dams, snow damming, or sediment blockages in watercourses • Upstream drainage or diversion reducing runoff to reservoir	• Use a tractor to remove snow dams or drifts that re-direct water runoff • Contact appropriate agencies responsible for beaver control and/or watercourse changes • Contact provincial government agencies responsible for drainage approvals

8.2 Symptom 2: Animal Sickness Caused by Water Contamination

Possible Causes	What to Check for	How to Correct (Options)
Water Contamination	Identify potential sources of contamination in the runoff area and seek professional advice on specific test parameters	• Discontinue using the water source for livestock watering and consult local veterinarian for their assistance • Remove the source of contamination wherever possible and replace gravel trench filters with floating intakes • Seek advice from water treatment specialists • Provide another source of uncontaminated water or install appropriate water treatment equipment (e.g., filtration/disinfection)

8.3 Symptom 3: Black Smelly Water in Reservoir

Possible Causes	What to Check For	How to Correct (Options)
Depletion of Dissolved Oxygen Levels in Reservoir Water (Summer)	• Abundant algae and weed growth and decay • Cyanobacteria growth • Grass clipping appearance to water • Dark green slime floating or deposited along reservoir banks • Dirty water after runoff and reduced water depths in reservoirs • Organic plant material deposited in reservoir • Recycling of nutrients from reservoir sediments causing increased algal growth • Water intake near reservoir bottom	• Control algae and weed growth by employing control techniques • Replenish oxygen with reservoir aeration system • Employ soil erosion techniques in watershed or watercourses, gated inlets, or two dugout system • Clean reservoir with excavation equipment and steepen all slopes to reduced weed and algal growth • Use screened culvert inlets and locate deciduous trees away from dugout • Ensure reservoir aeration is diffused at the dugout bottom • Use a perforated pipe or device to diffuse oxygen instead of open ended hose • Raise floating intake near surface
Depletion of Dissolved Oxygen Levels in Reservoir Water (Winter)	• Reservoir aeration equipment not installed or working properly • Snow cover on dugout reducing sunlight and oxygen produced by growing plants	• Check and maintain aeration equipment • Where feasible, carefully clean snow-cover from a portion of dugout surface
Bottom Reservoir Water Entering from Damaged Intake Pipe	• Damaged intake pipe	• Hire a diver, if necessary, to repair intake pipe

8.4 Symptom 4: Dirty Reservoir Water

Possible Causes	What to Check For	How to Correct (Options)
Soil Erosion of Watershed and Watercourses	• Soil erosion • Recent runoff event • Suspended clay particles that will not settle	• Employ soil erosion techniques and gated inlet • Use a two reservoir system • Use coagulants in reservoir to clear water
Erosion in Reservoir	• Soil erosion by wave action	• Protect eroded reservoir banks with erosion prevention materials such as filter cloth, plastic or riprap • Install water treatment measures such as coagulants and filtration

Muskrats, ducks and mud-puppies	• Abundance of cattails and tunnels in reservoir banks • Floating cattails that have been dug up	• Control cattails and remove muskrats by trapping, etc.
Contaminated Runoff	• Test water for bacteria, chemicals and pesticides	• Remove contaminants and/or cause from watershed • Divert any contaminated runoff around reservoir • Install water treatment measures

8.5 Symptom 5: Mineral Scale

Possible Causes	What to Check For	How to Correct (Options)
Calcium and Magnesium Hardness	• Scale on plumbing fixtures • Test for hardness • Gravel infiltration trench	• Install water softener • Install a direct intake

8.6 Symptom 6: Taste and Odour in Water

Possible Causes	What to Check For	How to Correct (Options)
Iron	See symptom 5 for comments	
Musty, Fishy Smell	Algal growth	• Use algal control techniques • Install activated carbon filter
Rotten Egg Smell	See symptom 3 for comments	
Salty, Bitter Taste	High dissolved solids caused by groundwater seepage or increased mineralization in gravel trench	• Prevent poor quality water from seeping into reservoir or relocate reservoir • Replace gravel trench with floating water intake

8.7 Symptom 7: Discoloured Water and Staining

Possible Causes	What to Check For	How to Correct (Options)
Iron in Water	Brown to rusty coloured stains on plumbing fixtures	• Install reservoir aeration system and/or iron removal treatment measures if required • Replace gravel trench filters with floating water intakes
Organic Matter in Water	• Muddy conditions around reservoir • Staining • Abundance of organic material and peat soil in watershed or reservoir area • Decomposing plants and animals • Excessive plant and algal growth in reservoir • Green to yellow colour (dissolved or particulate organic matter) • Shallow reservoir with flat slopes • Watershed/watercourse vegetation containing clover, etc. • Excessive dosages of chemicals including copper sulphate for algal control resulting in man-made blooms of green algae • Test for dissolved organic carbon	• Prevent flooding and muddy conditions • Relocate reservoir • Coagulation treatment • Cover organic matter around the reservoir with clay soil and grass cover • Install aeration equipment • Use gated inlet to allow clear water into reservoir • Control nutrients coming into reservoir which encourage plant and algal growth • Control algae and plant growth with combination of biological, physical, and chemical methods • Install aeration equipment • Steepen reservoir slopes and deepen reservoir • Avoid planting vegetation that imparts colour • Reduce/eliminate chemical dosages and allow zooplankton to re-establish and control algae • Use coagulants in the reservoir to remove

9 Glossary

A

absorption	a process by which one substance is trapped throughout the volume of another, usually a liquid by a solution
adsorption	a process by which a substance is trapped on the surface of a solid substance
algae	single-celled plants, capable of photosynthesis
alkalinity	the ability of a solution to neutralize acids
aquaculture	production of aquatic plants or animals, particularly fish, for commercial purposes
aquifer	an underground layer of relatively porous, saturated soil or rock that is capable of yielding a useful supply of water

B

backwashing	the cleaning cycle of a water treatment system where clean water is forced back through the filter media.
bacteria	single-celled organisms that do not contain chlorophyll and are not capable of photosynthesis.
bentonite	a swelling clay used to construct liners for lagoons and reservoirs.
blue-green algae	common expression used to refer to cyanobacteria, an aquatic microorganism which can produce powerful toxins.
bluestone	copper sulphate.
BMPs	beneficial management practices.

C

coagulation	the addition of certain chemicals to water that allow very small particles to collide, stick together, and form flocs.
cfm	cubic foot per minute.
coliform	a common group of bacteria used as a biological indicator of water pollution.
contour planting	planting crops in rows that are at right angles to the direction of the slope.
cryptosporidia	a single-celled, disease-causing, parasite whose life-cycle includes a cyst-forming phase which allows the organism to survive in harsh environments.
cyanobacteria	single-celled organisms that are capable of photosynthesis but are more closely related to bacteria than plants. They are often referred to as 'blue-green algae'.

D

diffuser	a device for introducing small air bubbles into water.

disinfection — the process of eliminating nearly all disease-causing organisms from water.

duckweed — a floating green plant that obtains nutrients from the water using dangling roots. It often forms large floating mats.

E

E. coli — a species of fecal coliform bacteria, some strains of which cause disease in humans. The strain, *E. coli 0157:H7*, has been identified as the pathogen in the Walkerton water supply contamination event of 2000.

F

fecal coliform — coliform bacteria that live in the intestines of warm-blooded animals.

floc — a particle formed in coagulation-flocculation process which is large enough to settle out of water.

G

geo-textile — a manufactured material used to protect soil surfaces from erosion.

gpm — gallons per minute.

giardia — a single-celled, disease-causing parasite whose life-cycle includes a cyst-forming phase which allows it to survive in harsh environments. The disease is commonly referred to as 'beaver fever'.

gleization — a dugout sealing technique which involves packing a layer of clay over a layer of organic matter. The term is derived from a natural soil-forming process.

I

integrated pest management — a system of agricultural pest management based on a wide variety of practices and control measures that are economically feasible and environmentally sound.

L

lift — when applied to water pumping, lift indicates the distance or elevation water is to be moved vertically.

M

mg/L — milligrams per litre.

mIg — million Imperial gallons.

N

Nutrient management	a system of fertilizer management that minimizes the amount of fertilizer applied on a farm.

O

ozonation	a process of water disinfection that uses ozone. Ozone is the next most powerful oxidant after fluorine.

P

pathogen	a microorganism that can cause disease.
pH	pH is a measure of the acidity of a solution. It is measured on a logarithmic scale from 1 to 14. Solutions of pH 7 are neutral, solutions below 7 are acidic and solutions above 7 are basic.
phosphorus	an essential plant nutrient but one that often causes algae blooms when an excess is present in a water-body.
pitless adapter	a mechanical device designed to provide frost-free, sanitary well conditions.
psi	pounds per square inch.
plant nutrients	mineral elements required by plants.
Point of entry	a system used to treat all or part of the water at the inlet to a facility.
Point of use	a plumbed-in or faucet-mounted system used to treat water at a single tap or multiple taps but not used to treat all the water for a facility.
pressure tank	a component of a water distribution system which holds water at higher than atmospheric pressure.
protozoa	single-celled microorganisms that consume bacteria and algae.

R

Reverse Osmosis	a system used to remove dissolved solids from water.
riprap	a wall or bank of stones used to provide strength and prevent erosion.

S

submersible pump	a centrifugal pump which is run by an electric motor and operates while submerged under water.

T

total dissolved solids (TDS)	the sum of the weights of all mineral compounds dissolved in a specific volume of water.

turbidity a measure of the light-scattering effect of small particles suspended in water.

U

ultra violet a water purification process using ultraviolet (UV) light to kill microorganisms by disrupting their DNA and preventing reproduction. In order to be effective, UV must actually strike the cell.

VWZ

virus a large group of sub microscopic organisms consisting of an RNA or DNA core, which is surrounded by a protein coat. Many viruses cause disease in humans.

watershed the area of land that drains runoff to a point on a stream or other water body. Also called a drainage basin.

wet well a structure installed next to a surface water supply, rather than directly in it, to provide a safe and convenient location for a distribution pump.

zooplankton a diverse group of tiny aquatic animals that feed on algae and bacteria.

10 Appendix

10.1 Appendix 1 Water Quality Guide

Table 6 Chemical Agents and Microbiological Species Affecting Aesthetic Quality of Water

Chemical/Species	Source	Symptom
Calcium	Natural deposits (limestone)	Hard water; scales and deposits in kettles and water heaters
Copper	Natural deposits; corrosion products from piping	Green staining of fixtures; metallic taste
Hydrogen Sulphide	Present in water with high iron content and low pH	Rotten egg odour
Iron	Natural deposits and iron-based coagulants	Rusty reddish-brown staining of fixtures and laundry; metallic taste
Iron bacteria	Bacteria feeding on iron in water	Reddish-brown slime on fixtures
Magnesium	Natural deposits	Hard water; scales and deposits in kettles and water heaters
Manganese	Natural deposits	Black staining of fixtures and laundry; metallic taste
Sodium	Natural deposits	Salty taste
Sulphate	Natural deposits; some flocculants	Objectionable taste
Sulphate	Bacteria feeding on sulphates in water	Rotten egg odour; blackish slime on fixtures
Tannins and Humic Acids	Natural organic matter (decaying plants and animals)	Various odours (aromatic, fishy, musty, earthy, woody) and tastes
Turbidity	Excessively fine sand or silt; runoff from soil	Abrasive texture to water; residue left in sink and tub
Zinc	Natural deposits; corrosion products from plumbing	Objectionable metallic taste

10.2 Appendix 2 Using Copper Products to Control Cyanobacteria

10.2.1 The Timing of Copper Treatment

Copper can be used to control cyanobacteria, often referred to as blue-green algae. If a treatment seems ineffective, do not repeat or increase the dose. Copper will not control green or brown algae.

Cyanobacteria grow fast when water temperature starts to rise, usually after a period of warm sunny weather. Always treat at the beginning of the bloom. This will provide much better control. If you treat with copper, always wait a minimum of two weeks before using the water. A waiting period is critical to allow any toxins from cyanobacteria to dissipate. Copper treatments are most successful when pH is between 7 and 8, alkalinity is between 50 to 150 mg/L, water temperature is above 15 degrees C, and the weather is sunny and calm. Never compensate for poor conditions by increasing the chemical dose - this can create serious water quality problems, and make the water unsafe or even dangerous for use.

10.2.2 Calculating a Copper Dose

Cyanobacteria use sunlight and live near the water surface. Therefore, it is only necessary to treat the top meter of water. A simple calculation can be used to approximate treatment volumes. Measure the surface length and width in meters, and multiply to get the volume of the top meter of water. Multiply by 1,000 to convert the volume from cubic meters into litres. The chemical that causes toxicity is called the active ingredient. Copper is the active ingredient in most products for controlling cyanobacteria. Different products have different amounts of actual copper in the formulation.

10.3 Appendix 3 British Columbia Livestock Watering Factsheets

To access the livestock watering factsheets click the following link.

[British Columbia - Livestock Watering]