Quality Farm Dugouts

This publication is a product of Alberta Agriculture and Irrigation. The goal of this publication is to help rural people manage dugout water supply and water quality by providing the latest research information on improving the quality of dugout water. It identifies and explains general dugout planning, design, construction, treatment, and management practices. It also indicates practices to avoid and attempts to dispel a few myths about dugout water management.

The authors gratefully acknowledge the contribution of the current and previous editions of this publication representing Alberta Agriculture and Irrigation, Alberta Environment and Protected Areas, Government of Canada – Agriculture and Agri-Foods Prairie Farm Rehabilitation Administration, Government of Canada - Fisheries and Oceans Canada, Province of Manitoba Ministry of Agriculture, and the Saskatchewan Research Council.

This publication is available online at https://open.alberta.ca/publications/quality-farm-dugouts-fourth-edition

Quality Farm Dugouts | Fourth Edition | ISBN 978-1-4601-5712-1

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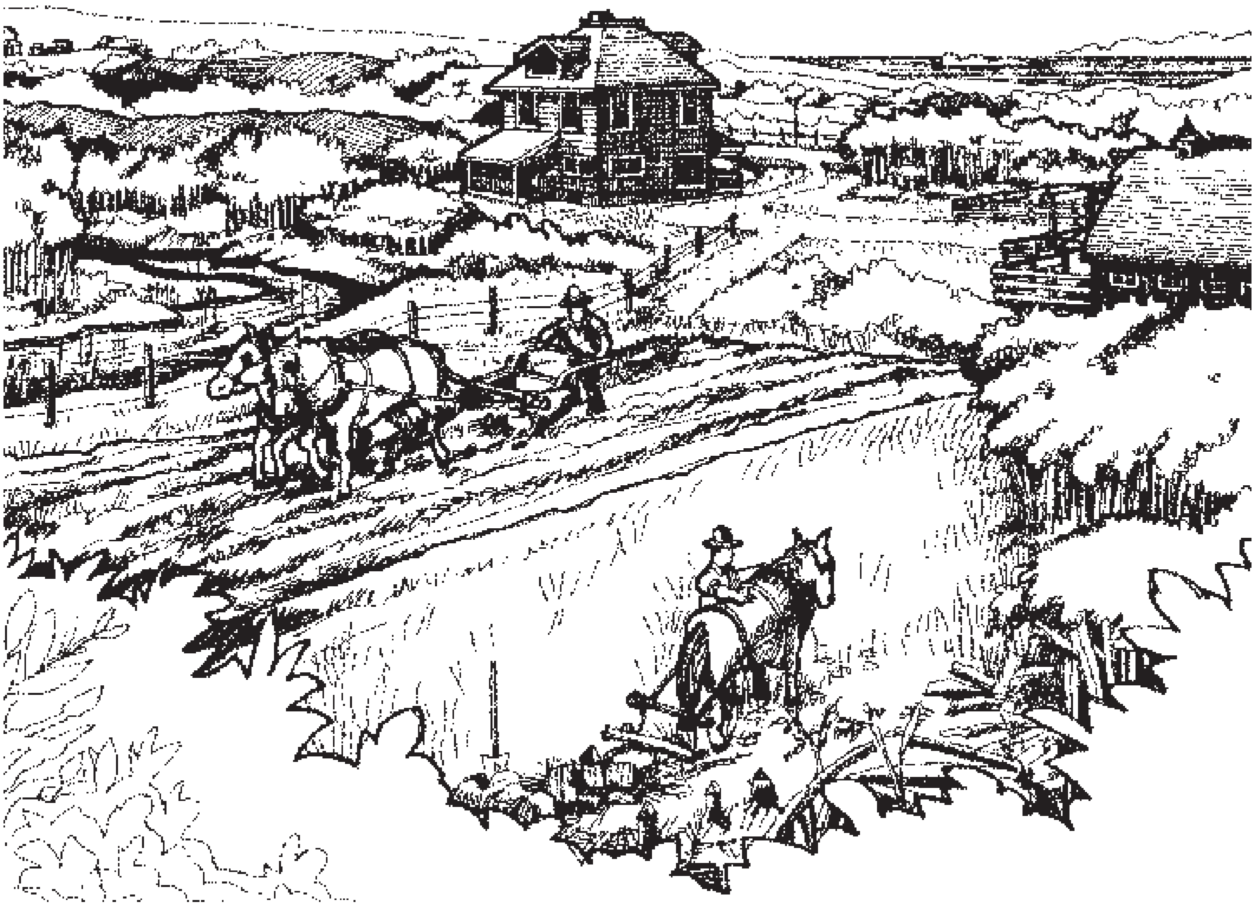


Farm dugouts on the Canadian Prairies have been used as small water storage reservoirs for many years. In areas where groundwater is either unavailable, insufficient in quantity, or of very poor quality, impounding surface runoff is often the only means of ensuring a continuous water supply. For the most part, dugouts capture the temporary surplus of surface water that occurs during snowmelt in the spring. Water may also be collected as runoff from summer rains, but it is typically of very low quality. To guarantee reliable supply, storage capacity must be sufficient to compensate for years of insufficient runoff, summer losses due to evaporation, and winter losses due to ice formation.

During the drought of the 1930s, the Prairie Farm Rehabilitation Administration (PFRA) helped establish design standards for dugouts to make them a more reliable source of water. It also began offering financial incentives to producers who constructed dugouts according to prescribed design standards.

Since the 1930s, PFRA and other government agencies have worked to improve the basic design of the farm dugout. More than 250,000 dugouts have been constructed on the Prairies over the last 100 years.

Figure 1-1 Horse-Drawn Excavation

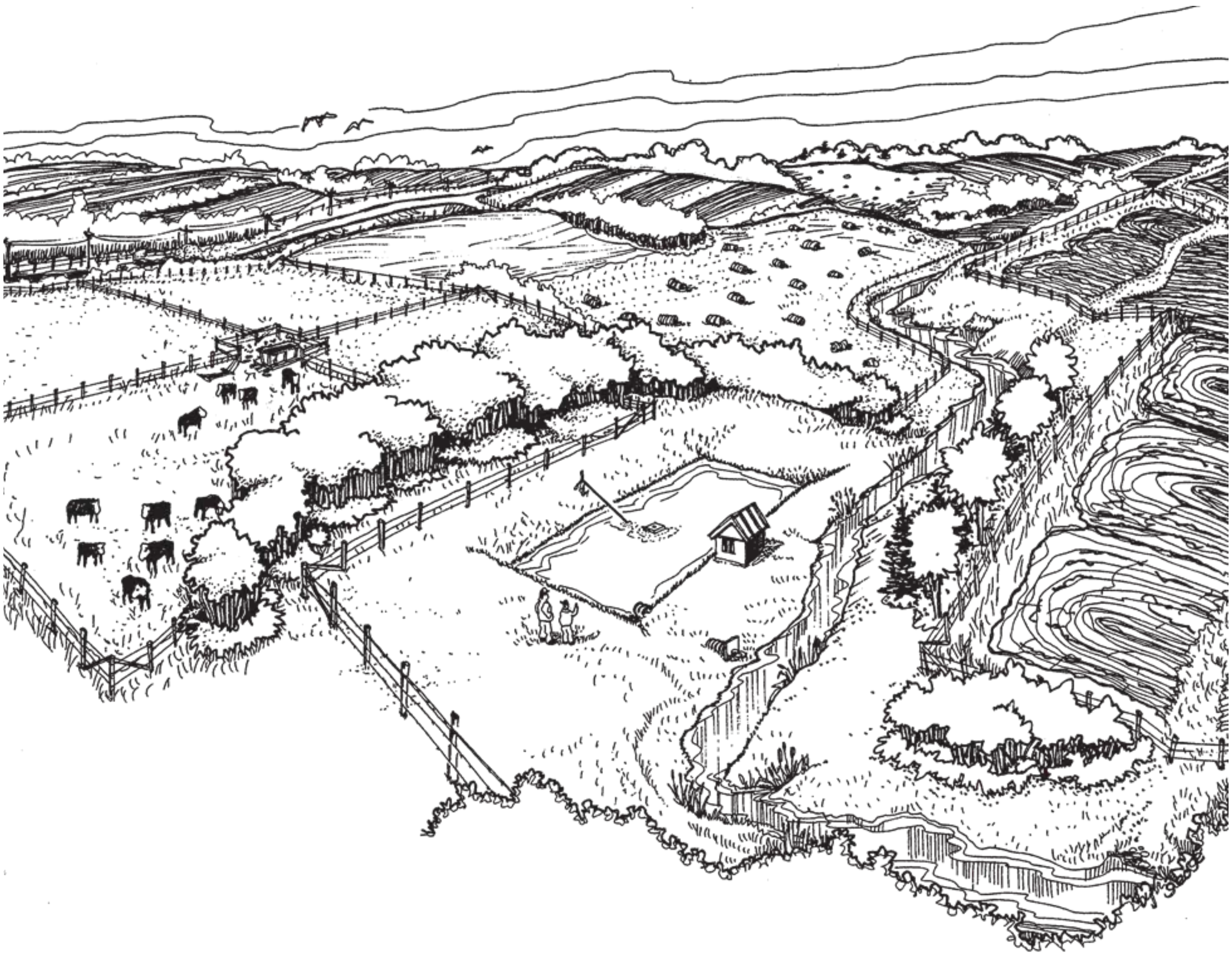
Today, many farm operations have several choices for obtaining water supplies. In addition to wells and dugouts, some have access to pressurized and treated water through rural water pipelines. Despite these advances, dugouts continue to be an important part of many farm water systems.

Dugouts are an important water source on the Canadian Prairies for a wide range of uses including:

- Irrigation
- Greenhouse production
- Pesticide spray water
- Livestock watering
- Aquaculture
- Household water supplies
- Fire fighting

Chapter 2

Understanding the Prairie Dugout



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

The Prairie Climate

The Prairie region is comprised of three broad climate zones.

Climate has an over-riding effect on water supplies. Three broad climate zones as shown in Figure 2-1 characterize the Prairie region:

- Steppe
- Continental
- Sub-artic

The steppe climate is dry year-round, with cold winters and warm summers. The continental climate is wetter, with cold winters and cool summers. The sub-arctic climate is characteristic of the boreal forest. Winters are long and cold. Summers are short and cool. Most of the Prairie grain belt is in the continental region. Southwestern Saskatchewan and southern Alberta, except for the Cypress uplands, are within the steppe region.

With the exception of the Alberta foothills, average annual precipitation across the Prairies increases from 300 mm in the southwest to 500 mm in the northeast. Most of this precipitation occurs as late spring and summer rains. Often storm events produce floods. Winter precipitation occurs as snowfall, which usually remains all winter, melts rapidly in early spring, and creates a runoff event.

Mean annual temperature generally decreases from southwest to northeast. Southern Alberta and southwestern Saskatchewan often experience warm winter winds, called Chinooks, which produce melting and evaporation of snow during winter months. The entire Prairie region experiences an annual water deficit whereby evapo-transpiration exceeds precipitation. Because of low precipitation and Chinooks, deficits are severe in the southwest. Large fluctuations in temperature and precipitation from year to year may produce periods of drought or extreme wet conditions.

Figure 2-1 Climate Zones

The Prairie Dugout

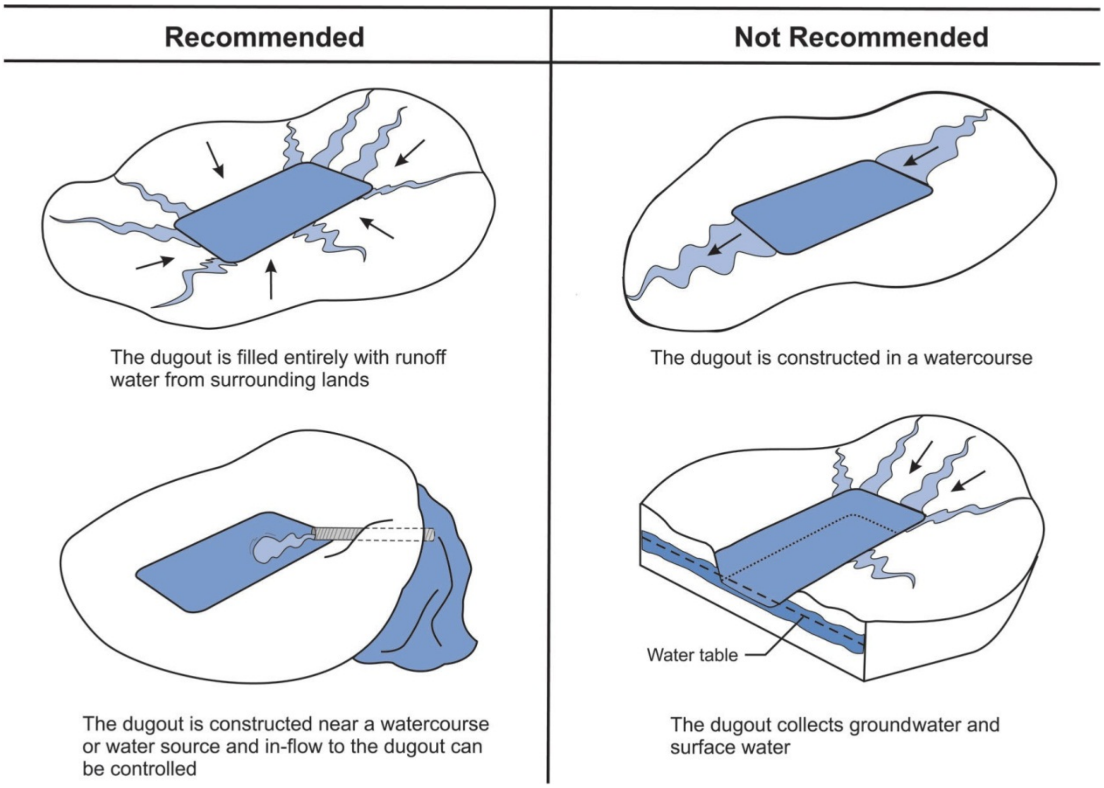
Dugouts are earthen excavations designed to collect runoff and store it for use during drier times. Typically, dugout capacity ranges from a few hundred thousand to several million imperial gallons. Dugouts are water sources of necessity, not of choice, because of the uncertainty of filling caused by annual variations in precipitation, and the problem of maintaining water quality. Generally, more reliable, superior quality water can usually be provided by groundwater formations. However, for some Prairie families and agri-food operations, dugouts are the only practical water source and are relied upon for all uses. For others, dugouts may provide water for specific purposes only, such as watering livestock. Although this publication provides information about the “typical” farm dugout, the material may also be useful to managers of very large dugouts used for irrigation or watering animals in large livestock operations.

There are four major types of dugouts as illustrated in Figure 2-2. The most common type is filled completely by runoff from surrounding fields. The second most common type is located adjacent to a flowing watercourse and is filled by either pumping or diverting water from the watercourse. For the purposes of this publication, a watercourse is defined as a creek, ditch, or other permanent or intermittent stream that has a well-defined channel with a streambed and banks.

Two other types of dugouts exist. One is an excavation made directly in a watercourse so that the stream fills the dugout and the overflow continues down the watercourse. This type of construction requires provincial approval and is not generally permitted because of downstream interests. With this type of construction, an accumulation of nutrients and organic matter can result in poor water quality as inflow cannot be controlled. The remaining type of dugout is when it is in contact with shallow groundwater. Groundwater dugouts are not recommended because it mixes surface water and groundwater. Surface water is highly susceptible to microbial contamination and groundwater is typically highly mineralized. Most often, this mixture produces water that is of lower quality and more costly to treat than either surface or groundwater alone. Dugout owners often mistakenly assume that water entering a newly excavated dugout from a shallow aquifer provides insurance against drought. Although water levels may rise in times of high groundwater recharge, in times of falling groundwater levels, valuable runoff that has collected in the dugout may actually drain into the aquifer. In addition to emptying the dugout, this may introduce surface contaminants to the aquifer.

For dugouts on uneven ground, berms can be constructed on the lower sides of the dugout 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.

Figure 2-2 Dugout Types



It is not recommended to construct a dugout in a watercourse or construct a dugout that mixes groundwater and surface water.

Dugout Water Quality

A single litre of motor oil can make two million litres of water unfit for human drinking water.

As previously noted, wells are generally preferred to dugouts because water quality in most dugouts is poor in comparison. 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
- Suspended sediments
- Petroleum products
- Soil minerals

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

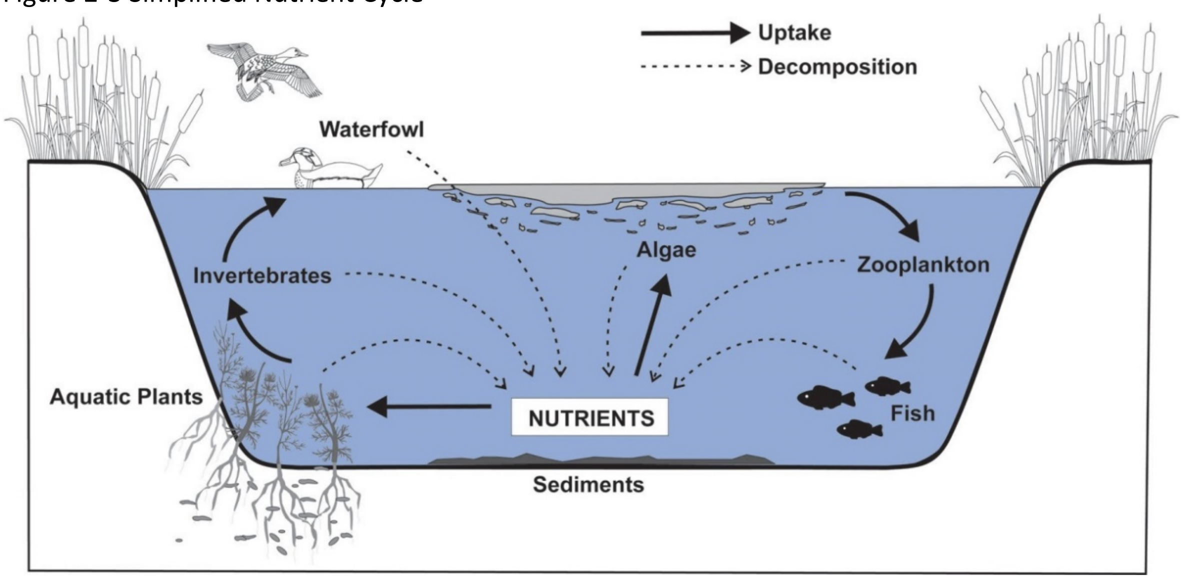
Biology of a Dugout

A dugout is a living ecosystem subject to natural cycles and processes.

As a newly constructed dugout fills for the first time, it is quickly invaded by a variety of organisms, including plants, microbes, insects, and animals, and develops its own unique ecosystem. The fertile soils in which most dugouts 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 become a source of food for insects that ultimately become a source of food for amphibians and fish. In fact, a dugout is a living ecosystem driven by natural cycles and processes.

The biology of a dugout 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, oxygen production stops and respiration consume dissolved oxygen which can result in low dissolved oxygen levels. When they die, microorganisms decompose their tissues. This decomposition process consumes oxygen. On hot, still days 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, unpleasant smelling swamp gases and substances such as methane, hydrogen sulfide, and geosmin. Odorless gases such as methane and carbon dioxide may also be release. As these microorganisms die, their decomposition also adds nutrients to the water body that become available to plants to begin the cycle again.

Figure 2-3 Simplified Nutrient Cycle



Many forms of plant life thrive in dugouts as shown in Figure 2-3 Simplified Nutrient Cycle. Some species are rooted in the dugout but are totally submerged, such as Northern Watermilfoil and White Waterbuttercup. Others inhabit the margins where they are rooted in the sediments but hold their vegetation above the water (emerged). Cattails and reeds are examples of emerged plants. Although only one of the many forms of plant life in a dugout, algae gets a lot of attention. This is primarily due to the problems they cause in a water supply. Algae can be present in dugouts but go unnoticed most of the time. When conditions are favorable, they can reproduce very rapidly and cause a bloom. Algae blooms cause a variety of problems:

- Toxins in water
- Water Turbidity
- Taste and odours
- Clogging of water filters
- Ineffective disinfected treatment
- Toxic chlorination by-products
- Fluctuating oxygen levels between day and night resulting in fish kills

Algae in dugouts are of particular concern with algae blooms causing several problems.

Cyanobacteria are often incorrectly referred to as blue-green algae. It is bacteria, not algae. The formation of toxins by cyanobacteria is of the greatest concern. Some can produce toxins that can damage the liver, nerves, lungs, and hearts of livestock. Cyanobacteria float near the water surface and wind action blows them to the side of the dugout. When livestock water directly at the edge of a dugout, they may be exposed to high concentrations of cyanobacteria in the water. Livestock deaths due to cyanobacteria have occurred in all prairie provinces.

Growth of cyanobacteria is greatest when the water is warm and concentrations of nutrients, especially phosphorus, are high. It is not easy to distinguish between cyanobacteria and harmless green algae and as shown in Figures, 2-4 and 2-5. Positive identification requires training and use of a microscope. When an algae bloom occurs in water used for livestock, it is best to exercise extreme caution. Little corrective action is possible once a cyanobacteria bloom has occurred. The most effective strategy for reducing the risk is to manage a dugout so the conditions that induce large populations do not develop. Much of this manual is devoted to this topic.

Figure 2-4 Green (Filamentous) Algae

Ron Zurawell

Ron Zurawell

There are many types of green algae. Shown here is a filamentous type which is characterized by long threads or filaments of cells attached together and found floating as a mat on the surface. It is commonly called pond scum.

Figure 2-5 Cyanobacteria

Ron Zurawell

Ron Zurawell

Ron Zurawell

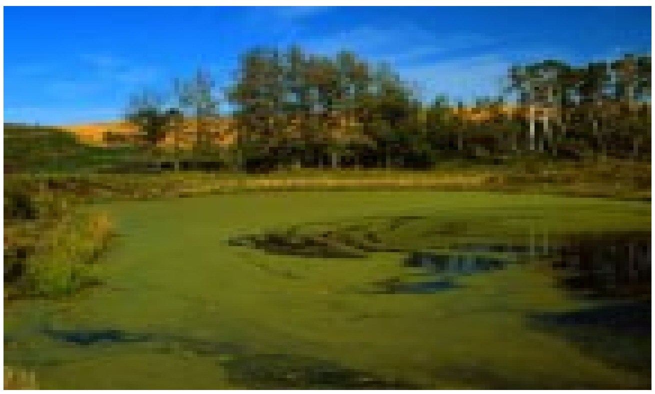
One type of cyanobacteria is highly visible due to its “grass clipping” appearance with pieces measuring from 1/2 to 3/4 inch (13-19 mm) in length.

Cyanobacteria are often incorrectly referred to as blue-green algae. It is bacteria, not algae.

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 as shown in Figure 2-6. It can cover an entire water body with a green mat composed of millions of small plants. Duckweed can be beneficial in a dugout 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 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.

Figures 2-6 Duckweed

Ron Zurawell



Ron Zurawell

Duckweed is a readily identified oval shaped plant that floats on the water surface and forms a mat that can cover the entire dugout.

The Life Span of a Dugout

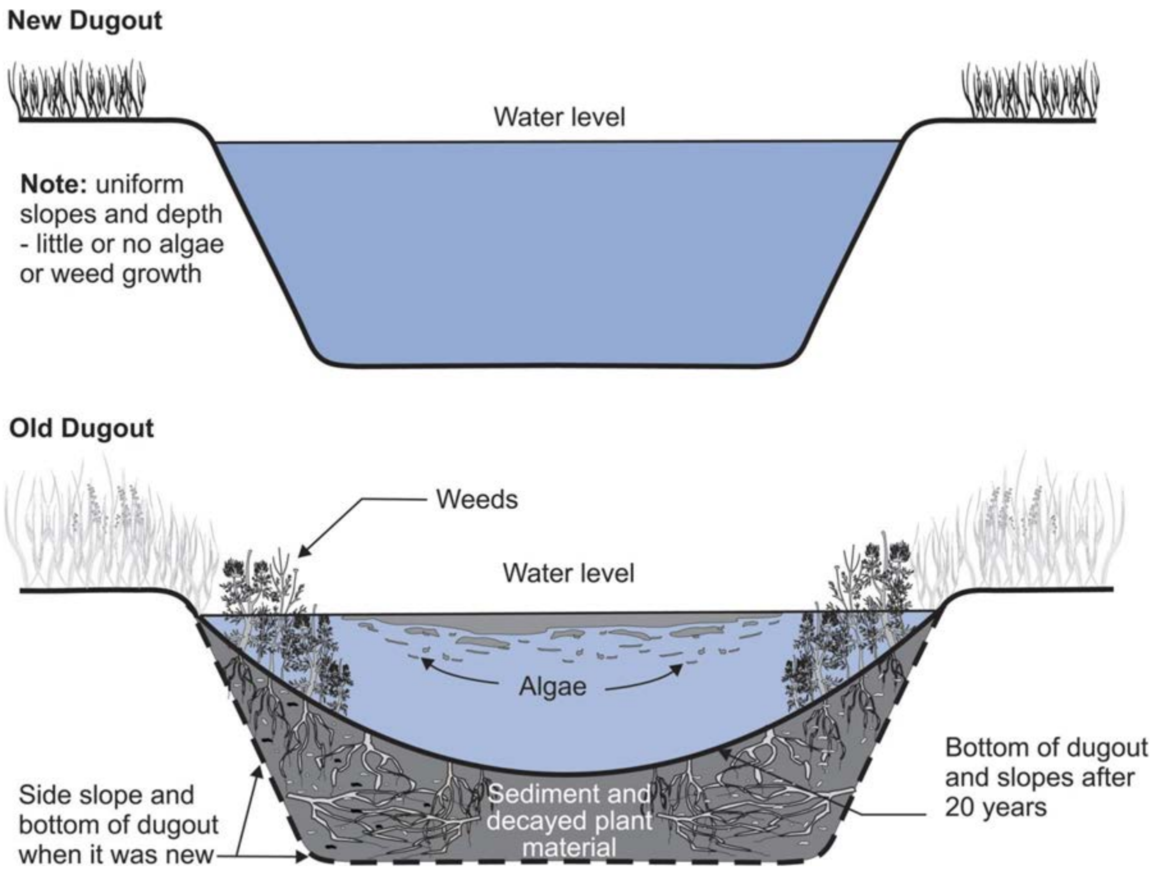
Ten per cent of dugout capacity can be lost in a single year due to sediment inflow from adjacent land.

Like many types of construction, a farm dugout does not last forever, as shown in Figure 2-7 New vs. Old Dugout Cross-sections. All bodies of water, including farm dugouts, undergo a natural aging process. As the years pass, the dugout accumulates sediment from wind and water erosion. In some circumstances, an average sized dugout can collect more than 15 inches (35 cm) of sediment each year. This can total 50 tonnes or more. As the excavation fills with sediment, the holding capacity becomes greatly reduced. Some of the rehabilitation work on dugouts has shown that from one to 10 per cent 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.

As a dugout fills with sediment, water quality deteriorates. In addition to collecting water and sediment, dugouts are very efficient at trapping the nutrients deposited from runoff to the dugout. Year after year, the accumulation of these nutrients from runoff events, plus their continual re-cycling within a dugout, resulting in a steady increase in plant and algae growth. This leads to an ongoing deterioration in dugout water quality. A shallow dugout also warms more quickly in the summer and cools more rapidly in the winter. Warm water encourages algae growth in summer. The winter ice layer leaves even less water available. The freezing of water forces out the minerals in the water which concentrates it in the reaming water. Total dissolved solids will be higher in the water below the ice than in ice free water.

The actual life span of a dugout depends on the quality of water that is required for different uses. Drinking raw water must have low biological activity to be suitable for treatment to drinking water standards. Irrigation water must have low levels of soluble salts. The length of time that a dugout can sustain the required quality is dependent on land-use practices in the watershed and the actual management of the dugout. As dugouts age, inferior water quality can be expected.

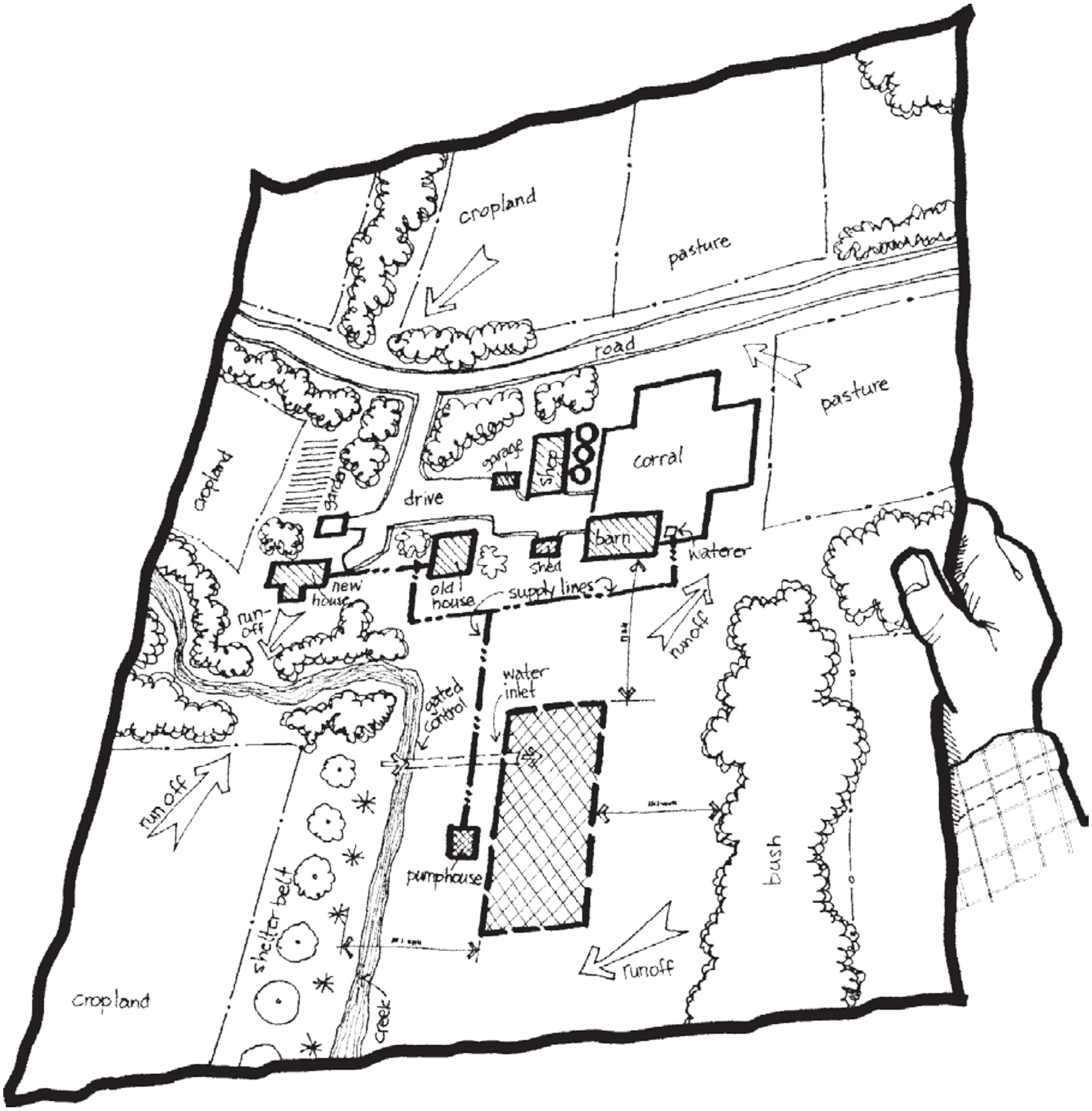
Figure 2-7 New vs. Old Dugout Cross-sections



As a dugout fills with sediment, water quality deteriorates.

In general, a farm dugout provides good water quality for about the first five years. Over the next 10 years, storage capacity and water quality deteriorate. After 20 years, storage capacity and water quality have usually been reduced to the point where the dugout no longer meets the needs of the landowner. Regardless of its uses, the life span of a dugout can be extended significantly through effective management.

Chapter 3
Planning



Planning Farm Water Supplies

Make sure you carefully plan your water system. You will need to determine water requirements, take an inventory of water sources, and plan for land use practices that protect water supply.

Although a well-planned and designed water system may cost more initially, it will ultimately save money. Costly changes to correct future problems will be avoided.

The initial planning steps include:

- Determination of Water Requirements

The first step in planning is to determine the amount of water required. Estimating future needs should consider any anticipated changes such as an expansion or diversification of farm activities.

- 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 dugout is to be the only source of water, uncertainty of runoff volume should be factored into the sizing calculation. Because of frequent drought on the prairies, it is recommended that all dugouts be constructed to hold at least a two-year water supply. In situations where the dugout is not critical to operations or alternate supplies are readily available, a smaller dugout may be chosen. Calculations in this manual, however, focus on the two-year supply.

- 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 dugout utility.

Regulatory Requirements

Before constructing a new dugout, it is important to be aware of applicable legislated requirements and restrictions. Ownership of surface and groundwater is vested in the Crown as administered by the *Water Act*. The size, location, or intended use of a dugout determines if an approval or a licence is required. It is important to check with the appropriate ministry for compliance before construction commences (Appendix 1).

In most jurisdictions, municipal and provincial, there are also requirements for minimum setback distances from public roadways.

Stocking of dugouts with fish is controlled to minimize the risks of discharges that could introduce disease and non-native species of fish into natural waterways.

Before constructing a dugout, consult appropriate authorities to ensure compliance with existing regulations. Obtain approvals well in advance to avoid delays in construction.

Alberta Water Act

Dugout construction in Alberta is regulated under the *Water Act*, which is administered by the Ministry of Environment and Protected Areas. The *Water Act* is legislation that in part establishes placement, size, and method of filling of a dugout. Depending on these factors, an approval for dugout construction might be required prior to construction or there may be an applicable exemption. Review the requirements under the Water Act before construction commences (Appendix 1).

To obtain an approval to construct a dugout, the applicant will need to submit an application through the Digital Regulatory Assurance System (DRAS) which is under the Ministry of Environment and Protected Areas (Appendix 1).

To find more information on the Digital Regulatory Assurance System

Alberta Wetland Policy

Alberta also has legislation regarding wetlands that can impact the placement of dugouts. The goal of the Alberta Wetland Policy is to conserve, restore, protect and manage Alberta's wetlands to sustain the benefits they provide to the environment, society and economy.

Under the Wetland Policy, the primary goal is to avoid impacts to wetlands. Where avoidance is not possible, proponents are expected to minimize impacts on wetlands. As a last resort, and where avoidance and minimization efforts are not feasible or prove ineffective, wetland replacement is required. Replacement costs are based on the wetland classification and the geographic location.

Land owners and contractors are responsible to ensure that the proposed dugout location is in compliance with the Alberta Wetland Policy. If a dugout is planned to be constructed in or near a wetland, or it might impact a wetland, you are required to apply for a *Water Act* wetland disturbance approval prior to commencing the project (Appendix 1).

To find more information on the Alberta Wetland Policy

Watershed Runoff Potential and Water Quality

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 dugout 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 dugout.

Watershed Runoff Potential and Dugout Sizing

This section discusses factors that should be considered when selecting a site for your dugout. It is essential that a dugout 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 trouble to find the best location for a dugout that will be in use for many years.

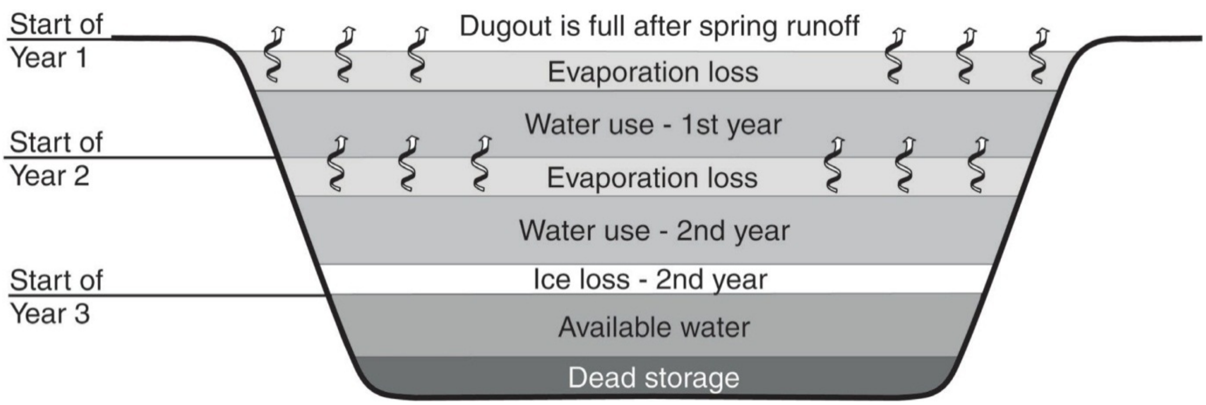
The size of the drainage area or watershed is the most important consideration when determining potential runoff into a dugout.

Dugout Sizing

Dugouts fill with runoff from the surrounding land. The most important factors to consider in sizing are the potential amount of runoff that will be captured, evaporation loss, and the shape and dimensions of the dugout.

Figure 3-1 Dugout Size vs. Available Water illustrates the necessity of sizing dugouts properly so they provide a dependable source of water. In this example, the dugout 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 dugout will be of such poor quality that it is rated as dead storage and unavailable for use.

Figure 3-1 Dugout Size vs. Available Water



Supply of available water is reduced by farm use, lack of runoff, evaporation, and ice formation.

Runoff volume is determined by the amount and timing of snowmelt or precipitation, plus vegetation, soil type, soil moisture, and topography. The smaller the quantity of runoff expected in an area, the larger the contributing area must be to fill a dugout. In some dry regions of southeastern Alberta, more than 2000 acres (800 ha) of land are required to produce enough runoff to fill a dugout with a capacity of one million Imperial gallons (4.5 million litres). In wetter areas of northern Alberta, less than 25 acres (10 ha) would be required to supply the same volume.

Figure 3-2 Runoff Map shows the approximate area of land required to provide runoff water volume equal to or greater than one million Imperial gallons (4.5 million litres). Runoff varies a great deal from year to year. The map is based on long term runoff data. In eight out of every ten years, the specified amount or more runoff occurred. In two out of ten years, there was less runoff. The uncertainty of runoff should be kept in mind when planning dugout size. If a particular watershed is too small to provide enough runoff, you have two choices:

- Find a larger watershed.

- Find an additional watershed and build a second dugout.

Consider both the area of land required to provide adequate runoff water and evaporation rate when you plan your dugout size.

When faced with these choices it is a good idea to consult a water specialist. Evaporation rate is an important factor in dugout sizing that varies widely between regions. Figure 3-3 Evaporation Zones is a map of evaporation loss zones in Alberta. The greater the evaporative losses, the greater the storage volume must be to guarantee continuous supply.

The shape of a dugout has important implications for both the quantity and quality of the stored water. Historically, most dugouts have been about 12 feet (3.7 m) deep. However, new larger structures are being excavated to depths of 15, 18, and 21 feet (4.6, 5.5, and 6.4 m) and even deeper.

A deeper dugout is more efficient because it has less surface area for the same capacity and thus loses less water to evaporation. This can have a significant effect on the required volume. Deeper dugouts tend to have better water quality, particularly in winter. Three main concerns with deeper dugouts are high water tables, seepage losses, and increased safety hazard.

During winter, dugouts freeze and some of the stored water becomes unavailable for use. Ice can reach up to 2 to 3 feet (.6 - .9 m) in thickness, which may represent up to 20 to 40 per cent of total volume. Figure 3-1 shows the amount of stored water that becomes unavailable for use during winter.

Figure 3-2 Runoff Map

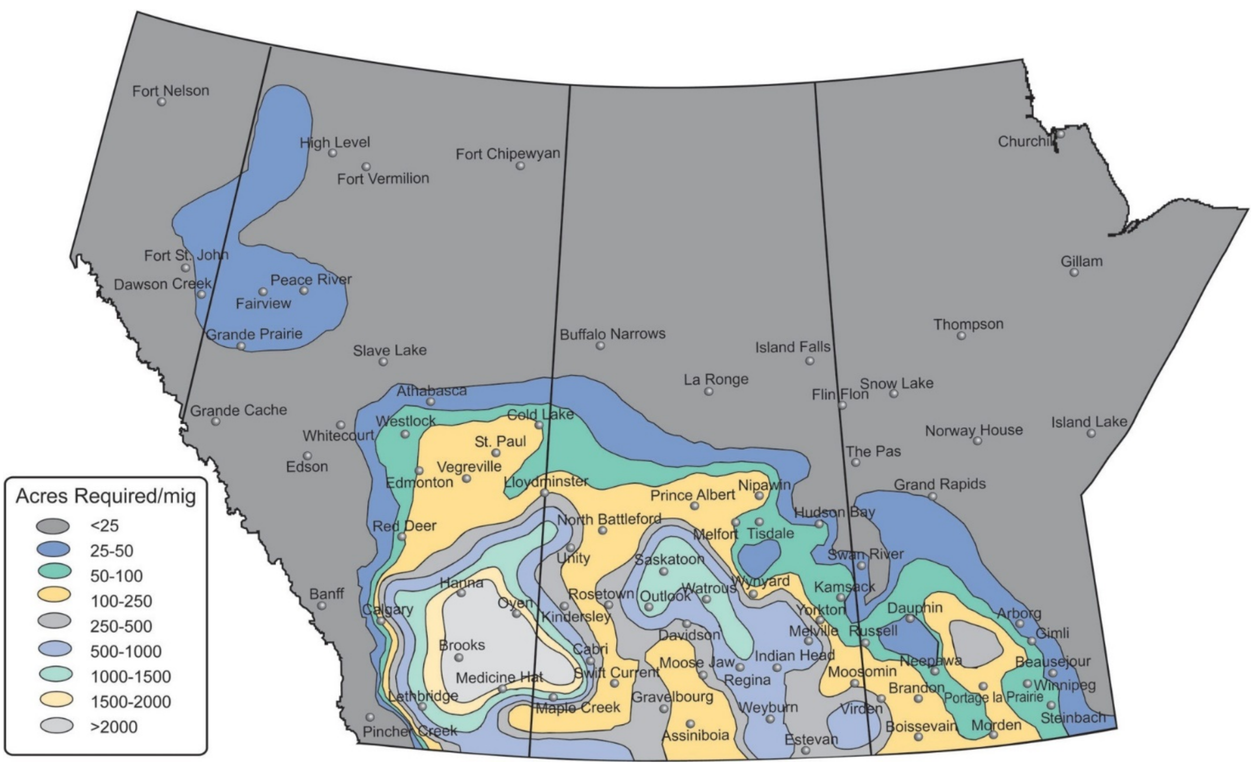
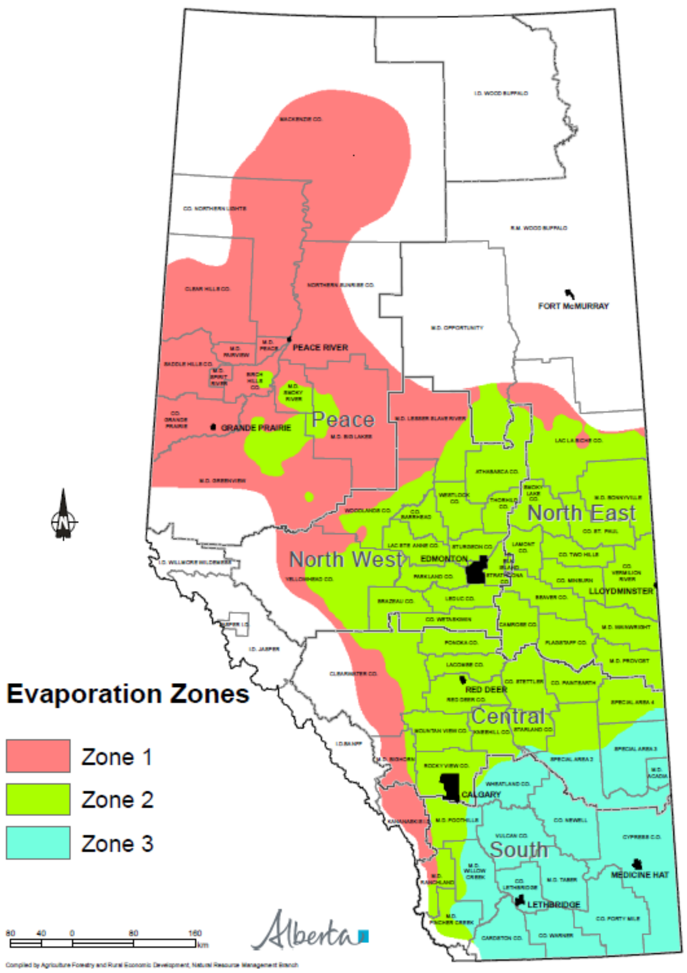
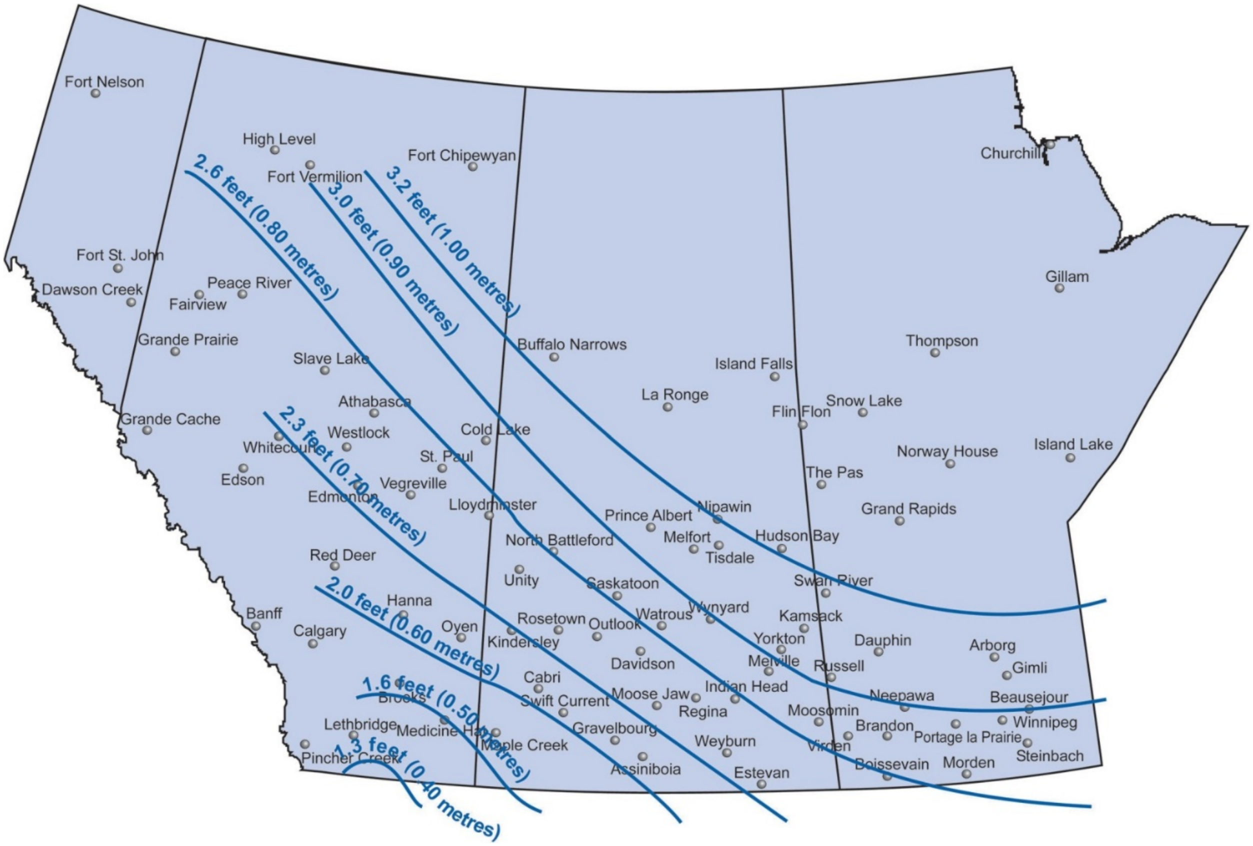


Figure 3-3 Evaporation Zones



In general, the colder the climate, the thicker the ice, and the greater the loss of available water. However, this can be offset by differences in snowfall. Snow cover on the ice insulates the water from further freezing. Figure 3-4 Ice Thickness Map shows average expected ice thickness on small water bodies in different parts of the Prairies.

Figure 3-4 Ice Thickness Map



The climate and runoff information given previously is used to plan the size of a dugout for any location on the Prairies.

Water Quality and Watershed Management

Contamination of the watershed can come from plant nutrients, pesticides, livestock confinement areas, waste disposal sites and water and wind erosion.

Good watershed management is the first line of defense for ensuring good quality dugout water. Using what are termed Best Management Practices (BMPs) within the catchment or runoff area can minimize the possibility of dugout water contamination. Contamination occurs through a number of processes.

- Plant nutrients from natural sources, fertilizers, and manure entering a dugout in field runoff 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 dugouts.

- 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 dugout in-flow water.
- Water erosion loads runoff water with soil, nutrients, and pesticides that may end up in dugouts. Long, steep slopes in the landscape that 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 dugouts, causing problems in water distribution systems and increasing the difficulty and cost of treatment.
- Wind erosion may lead to contamination of dugouts 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.

Best Management Practices in a Watershed

The following can reduce erosion and contamination of inflow water as illustrated in Figure 3-6 Watershed with Best Management Practices:

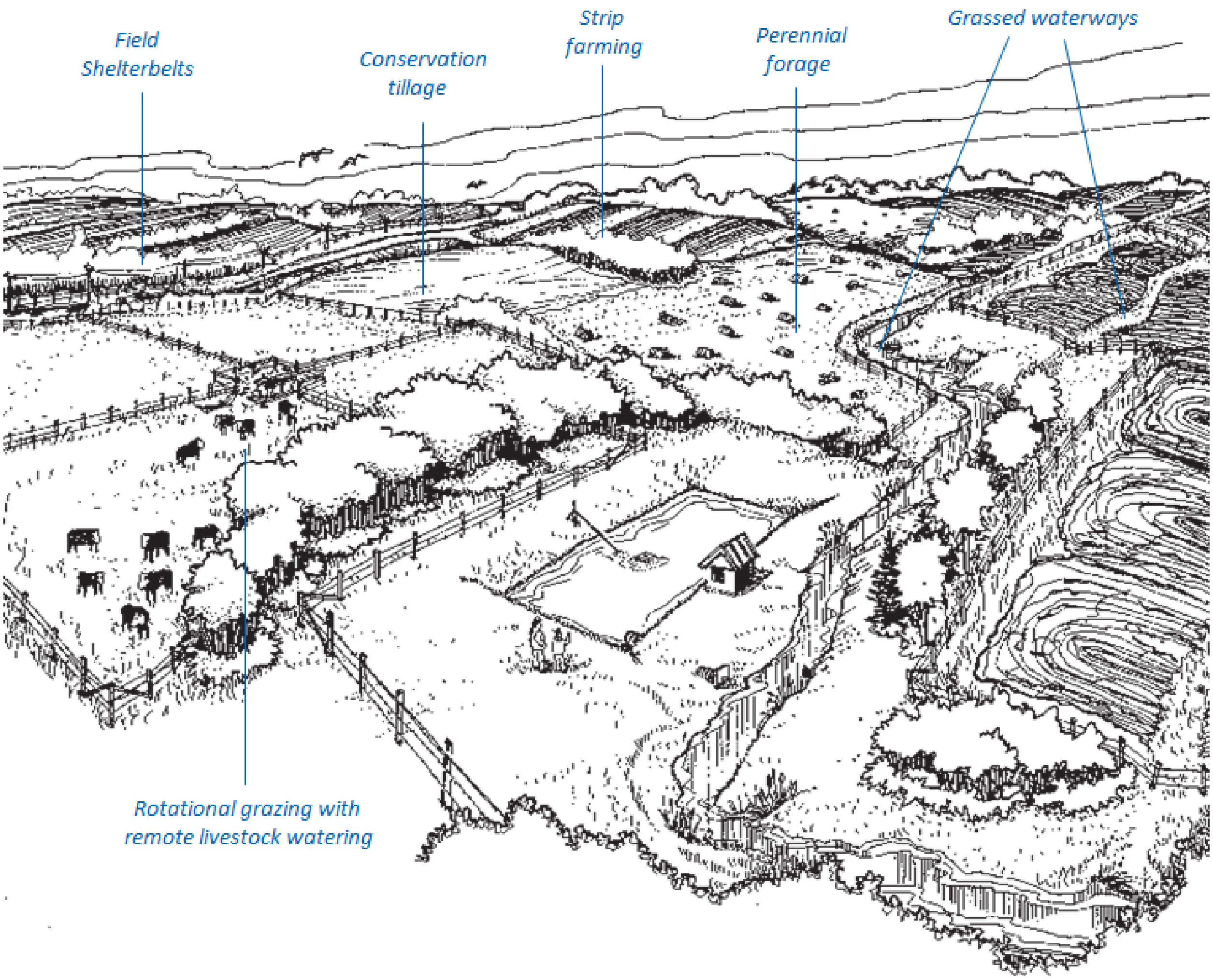
- Agricultural fields in annual cultivation are prone to wind and water erosion, particularly when residue cover is poor in winter and early spring. Soil surface protection practices are highly effective ways of preventing erosion, and include:
  - seeding erodible land to perennial forages
  - using 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, and include:
  - grassing waterways
  - contour planting that places rows perpendicular to the slope of a field

- Practices that slow wind velocity and reduce wind erosion, and include:
  - 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 (IPM). IPM is a pest management system using the application of a variety of management practices and control measures.
- Off-source watering systems prevent livestock from having direct access to a dugout or to other areas in the watershed that directly contribute runoff to a dugout.
- 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 3-6 Watershed with Best Management Practices



Dugout Siting

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

Proximity to Water Use

By locating a dugout close to places where the water will be used, construction and maintenance costs of water lines and power pumping costs can be minimized. However, these costs are insignificant relative to a location that does not reliably fill or is contaminated easily.

Proximity to Electrical Power

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

Trees

Properly placed trees can act as snow traps and increase the amount of runoff collected each spring. However, trees close to the dugout tend to block the wind and reduce the positive effects of wind on the mixing of dugout water. Trees also reduce the effectiveness of any windmill-driven mixing devices. Leaves and twigs that are dropped by trees and deposited into dugout water add organic matter and plant nutrients that encourage weed and algae growth and reduce water quality. Large trees planted close to a dugout 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 m) and coniferous trees and shrubs no closer than 65 feet (20 m). Snow fencing may be a better alternative.

Proximity to Other Water Sources

If possible, locating a dugout near another water source is advisable. Dugout water quality can sometimes be improved by pumping water into a dugout from another source such as a creek or slough.

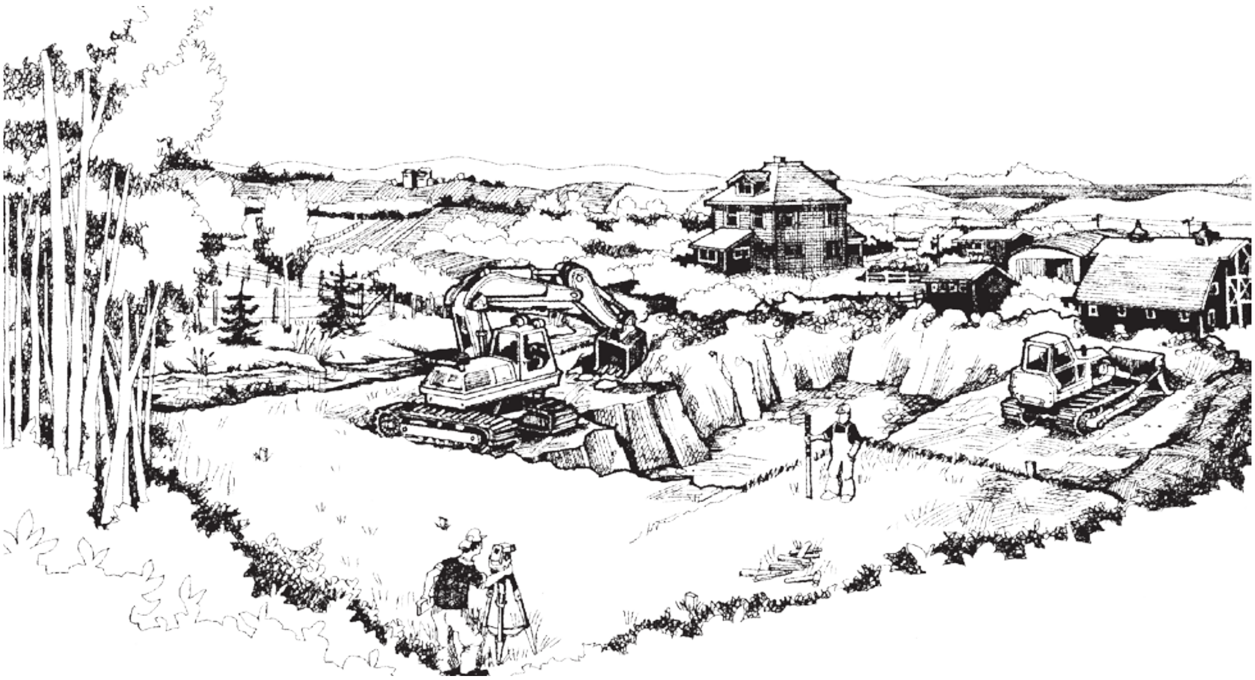
Contamination

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
- Commercial and industrial sites

Chapter 4

Design and Construction



Dugout Design

The construction and management of a dugout can have a large impact on water quality. Design options allow dugout 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 4-1 Dugout with Design Best Management Practices.

Slopes

You should be able to walk up a dugout slope of a newly constructed dugout.

Historically, dugouts on the Prairies were constructed with 1.5:1 side-slopes and 4:1 end-slopes. The soil conditions and the construction equipment available largely dictated 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 dugout with four steep sides can be a safety hazard. It is recommended that slopes be not less than 1.5:1 for safety and slope stability. It is also recommended that dugouts be fenced to exclude livestock, and a flotation device should be available and used to protect children and adults from drowning.

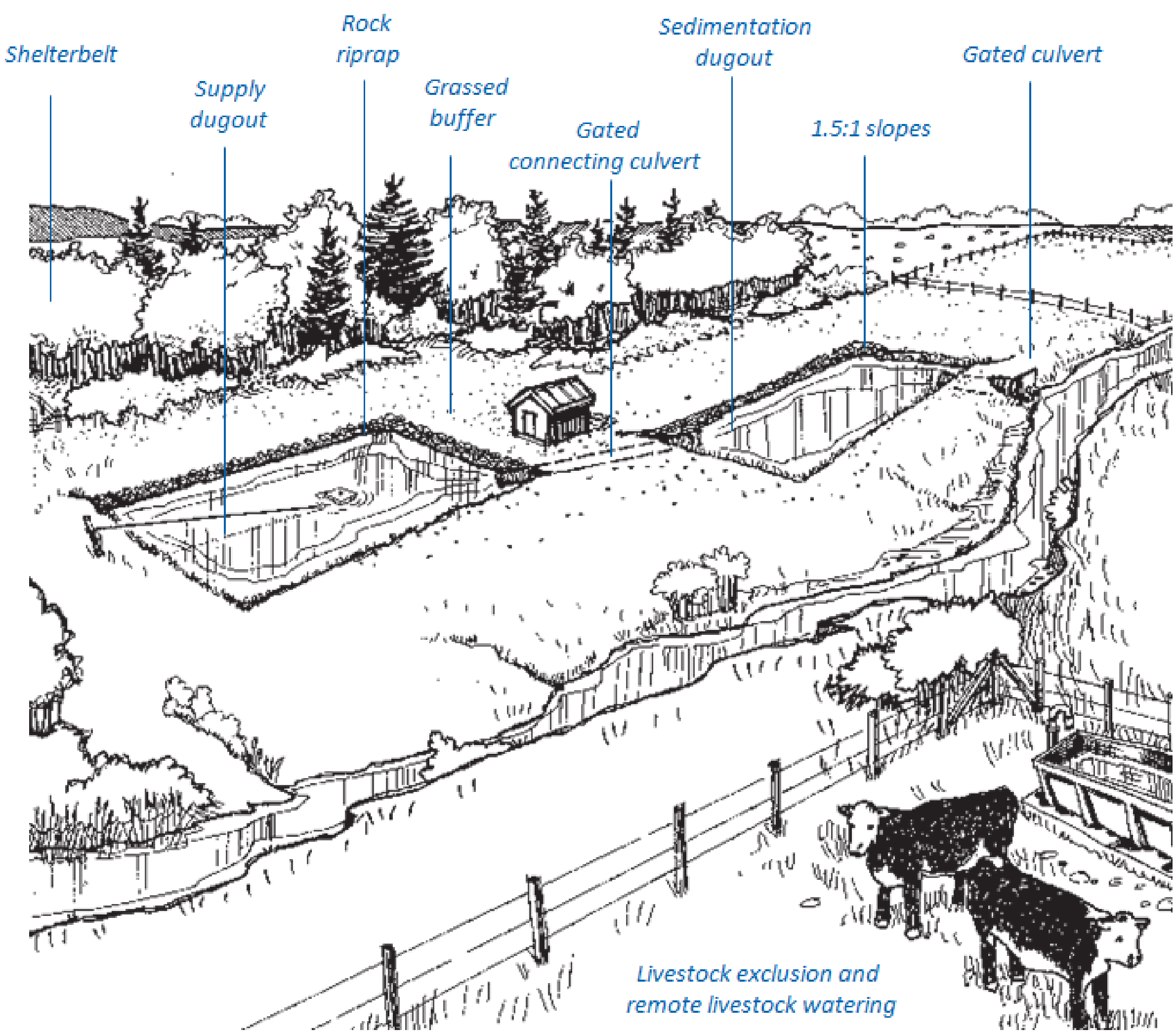
Erosion Control

Control erosion by levelling and grassing spoil piles and protecting dugout sides and end-slopes.

Spoil piles are created during the construction of a dugout. If spoil piles are located at the edge of a dugout, 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 dugout be leveled 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 33 feet (10 m).

In windy areas of the Prairies, dugout longevity is increased when the dugout 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.

Figure 4-1 Dugout with Design and Beneficial Management Practices



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 dugout. The first flow of water from cultivated fields during snowmelt is typically high in dissolved nitrogen and phosphorus. Excluding this initial volume of water can improve water quality. Diverting flow away from the dugout is only practical where it is certain that there is more than enough runoff to fill the dugout. After the dugout has filled, the inlet should be blocked. This prevents sediment and nutrients carried by runoff from spring and summer rains from entering the dugout. If water is pumped into a dugout, prevent bank erosion from occurring at the discharge point.

Livestock Exclusion

Design your dugout to exclude cattle; supply water to livestock through off-source watering systems.

Allowing animals to water directly from a dugout degrades water quality and drastically shortens the life of a dugout. Nutrients from manure stimulate plant growth and hoof action destroys dugout banks. It is recommended that all dugouts be fenced off and water supplied to livestock through off-source watering systems. This protects the dugout, its water quality, and the livestock themselves. Many options are now available for supplying water to livestock on remote sites. Where a dugout 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.

Sedimentation Dugouts

Much of the unwanted material that enters a dugout 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 erodible, and the landscape and costs permit, two dugouts 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 dugout or allowed to flow in by gravity.

In a situation where an existing dugout is being replaced with a new one, it may be useful to retain the original as a sedimentation structure. The new dugout can often be positioned to fill with water that has been allowed to settle in the old dugout. This can be more beneficial and economical than cleaning out the original dugout.

Dugout Construction

Pre-Construction Testing

In many areas of the prairies, 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 dugouts believe it is good to have water seeping into the dugout, these lenses of sand and silt can create many problems. They may provide a path for water to seep out of the dugout leading to depleted water supplies during periods of drought. In addition, highly mineralized groundwater seeping into the dugout can adversely affect the quality of trapped runoff water.

To ensure that sand lenses are avoided, dig at least five or six test holes or pits prior to excavating the dugout. Dig these holes around the outside and within the proposed dugout area to a depth of 4 to 5 feet (1.2 – 1.5 m) deeper than the proposed dugout bottom. They should not be located more than 100 feet (30 m) apart to minimize the possibility of missing intermittent sand layers that may occur. This testing will also identify other problems including shallow water tables and bedrock, as well as the most suitable construction equipment.

Large-Scale Sealing Methods and Materials

If sand layers are generally 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 dugout in more favorable 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.

Clay Lining

If a source of good heavy clay is available, it may be feasible to haul and spread the clay into 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, as shown in Figure 4-2 Footed Drum Packer, which can exert 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 1 1/2 to 3 feet (45 – 90 cm) thick.

Figure 4-2 Footed Drum Packer

Bentonite

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

Sodium Chloride

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

Plastic Liners

While plastic liners are available to prevent seepage, they are expensive and must be installed according to the 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.

Gleization

In place of the traditional methods of sealing porous soils, a dugout can be sealed using a method called gleization. This involves covering the dugout bottom with 6 inches (15 cm) of chopped straw. The straw layer is then covered with 6 inches (15 cm) 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.

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 dugout 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 dugout will hold water. If good clay is not readily available, a cutoff curtain made of woven polyethylene fabric can be installed.

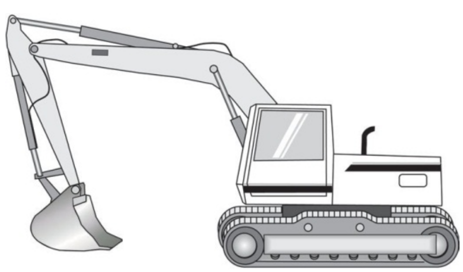
Excavating Equipment

Trackhoe

A Tracked Hydraulically operated excavator, commonly referred to as a trackhoe (as shown in Figure 4-3) is a large excavator mounted on caterpillar-type tracks for maneuverability and flotation. Due to availability, ease of operation, versatility, and speed and ease of transport, the use of trackhoes for digging dugouts are commonly used. 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 dugout, and do not need to crawl in and out of the excavation. Trackhoes are able to excavate the end slopes of the dugout 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 dugout that can be conveniently built. Some of the newer units, with extended booms, are able to dig dugouts 60 to 70 feet (18 - 21 m) in width. Due to the shorter reach, the soil removed is piled very close to the edge of the dugout. 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 a trackhoe, the spoil pile presents a problem. For wider and deeper dugouts, the trackhoe 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 dugout. The fill can be used in low areas or to establish dikes to control the flow of water.

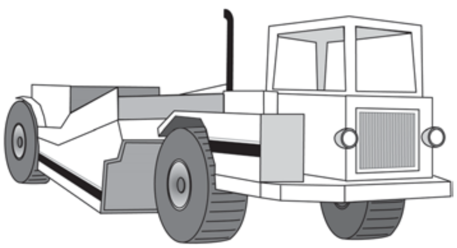
Figure 4-3 Trackhoe



Wheel Tractor - Scraper

Wheel Tractor Scrapers or “Buggies” as shown in Figure 4-4 Scraper or Buggy are large units that are used to remove, carry, and deposit the earth from the dugout 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 cat 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 a trackhoe.

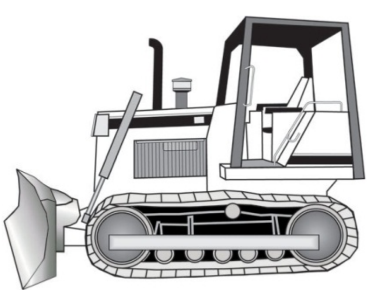
Figure 4-4 Wheel Tractor - Scraper



Dozer

While a dozer as shown in Figure 4-5 Dozer can excavate a dugout alone, it is a slow process and will result in large spoil piles at both ends of the dugout. 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 a trackhoe.

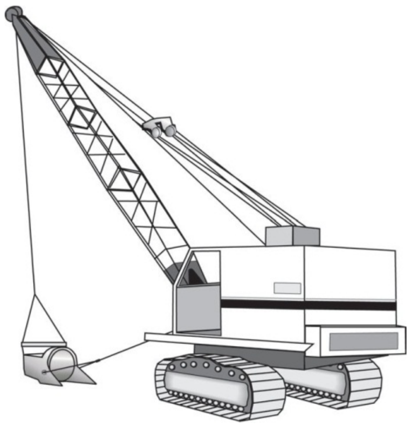
Figure 4-5 Dozer



Dragline

While the dragline shown in Figure 4-6 has been around for many years, its use in digging dugouts has declined in recent years due to the difficulty of transporting it. It is slower and less versatile than a trackhoe. Due to long reach and flotation, the dragline is ideally suited for installing dugouts in swampy or low-lying areas. Draglines can excavate dugouts up to 70 feet (21 meters) in width. In addition, because of the reach, spoil banks can be kept away from the edge of the dugout but, as with the trackhoe, it is impractical for the dragline to move and spread the excavated material to other areas.

Figure 4-6 Dragline



Selecting a Contractor

A dugout is more than just a hole in the ground.

Experience

While digging a dugout 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 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 landowner of possible solutions. Further technical assistance can be obtained from a soil or water specialist.

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 shape, but also be appropriate for the site. The choice of the wrong equipment can lead to a very expensive dugout and one that may not be completed to your satisfaction.

Dugout Finishing

It is recommended that excavated material from the dugout be leveled, 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 dugout and the in-flowing runoff channels.

When you select a contractor to construct your dugout, look at such things as experience, references, equipment availability, time, and cost.

Costs

Depending on construction conditions certain equipment may be more expensive than others. 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 dugout 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.

Time Factor

As with any type of contracted work, acceptable times for starting and finishing the job should be clarified 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 the “off season.”

Construction Estimate

The first step is to get two or three dugout construction estimates. A sample construction estimate is provided in Figure 4-7 Construction Estimate to illustrate the important information that should be obtained from a contractor. All agreements for work should be in writing and signed by both parties. Written contracts help eliminate any misunderstandings as to specifications, timing, and costs. Remember that ultimately you are responsible for any approvals needed to build the dugout and its potential effect on natural waterbodies or downstream landowners. The example is based on the Joe Agricola farm dugout that was used in the Planning chapter as an illustration of the use of the Dugout Sizing Worksheets. Carefully read through the completed example.

Figure 4-7 Construction Estimate

Dugout Construction Estimate Worksheet

This worksheet lists the items that a producer should discuss with a dugout construction contractor. A clear understanding between both parties is crucial so there are no misunderstandings or false expectations. Dugouts are far more than a deep wet hole in the ground.

Dugout Owner: *Joe Agricola* Dugout Contractor: *Dugouts R' Us*

Address: *Stettler, Alberta* Address: *Stettler, Alberta*

Dugout Location: Qtr *SW* Sec *6* Twnshp *39* Range *19* Meridian *W4*

Proposed Starting Date: *October 15, 2015* Proposed Completion Date: *October 22, 2015*

Proposed Dugout Use: Household *X* Livestock *X* Irrigation ______ Recreational (i.e., fish) ______ Other ______

Check Location of Underground Utilities: *Contact Alberta One-Call utility company to mark lines October 7, 2015*

Pre-construction testing; Test holes or test pits to identify potential problems including sand or gravel (i.e., seepage), high water tables, or shallow bedrock No. of test holes or pits *2* Depth of testing: *25 ft.*

Design Considerations for Dugout: Depth *21 ft* Width *100 ft* Length *330 ft* Volume *16,000 yd³* Side slope *1.5:1* End slope *1.5:1*

Runoff or Flood Control: *A dike will be constructed around the dugout with a gated inlet to control runoff into the dugout.*

Seepage Control or High Water Table Conditions: *None expected – testholes will confirm.*

Types of Construction Equipment: Trackhoe *$175/hr* Dozer *$140/hr* Scraper ______ Dragline ______ Buggy ______ Other ______

Equipment Transportation Costs: *0.0*

Dugout Construction Costs:

	Rate		Quantity		Cost
(a) pre-construction testing	$ *175.00* /hour	x	*2* hours	= $	*350.00*
(b) stripping top soil	$ *140.00* /hour	x	*2* hours	= $	*280.00*
(c) excavation costs	$ *2.50* /hour	x	*16,000* yd³	= $	*40,000.00*
OR	$ ____ /hour	x	____ hours	= $	
(d) seepage control	$ ____ /hour	x	____ hours	= $	
(e) spread excavated material	$ *140.00* /hour	x	*10* hours	= $	*1400.00*
(f) dike and gated culvert inlet (i.e., flood control – optional)	$ *175.00* /hour	x	*1* hours	= $	*175.00*
(g) trenching water and air lines and install wet well	$ *175.00* /hour	x	*2* hours	= $	*350.00*
(h) topsoil replacement	$ *140.00* /hour	x	*2* hours	= $	*280.00*
(i) topsoil preparation and seed to grass				= $	

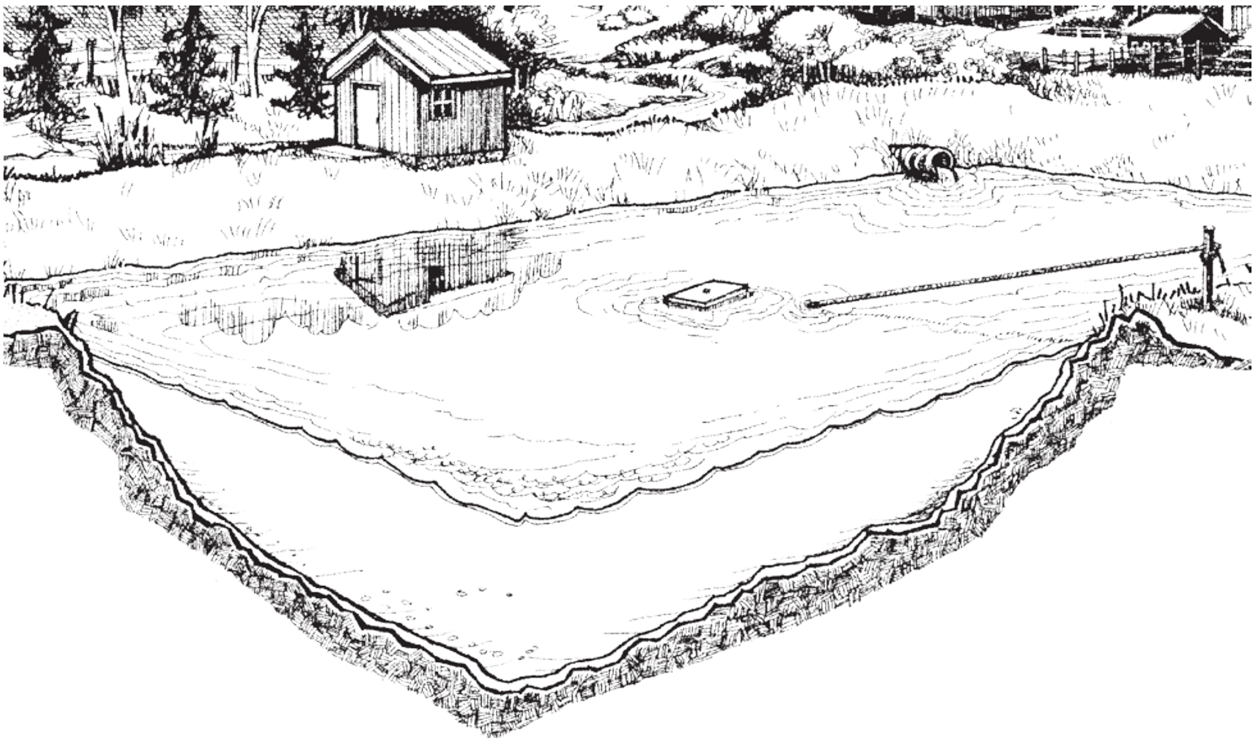
Transportation and Construction Costs $ *42,835.00*

Tax $ *2,141.75*

Payment Schedule *Within 30 days of dugout completion* Total Cost $ *44,976.75*

Chapter 5

Operating Systems



Equipment Systems

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

Intake Systems

Research has shown that water in the top 4 to 5 feet (1.2 - 1.5 m) of a dugout is of higher quality than water at the bottom and edges of the dugout. It has also shown that many farm dugouts become depleted of dissolved oxygen resulting in black smelly water. For these reasons, floating water intake systems are recommended for all farm dugouts.

Use floating intake systems to make use of the higher quality water in the top area of the dugout.

Floating Intake Systems

For the past number of years, floating water intake systems have been used in dugouts. The floating intake draws the better quality water from near the dugout water surface. These systems are usually installed with a wet well beside the dugout 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 dugout construction. Floating intake systems include the components shown in Figure 5-1 Floating Intake.

Figure 5-2 Submersible Pump and Intake System shows a submersible pump and intake system. Install the intake pipe inside another larger pipe where it enters the dugout. 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 dugout. 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 dugout airline in the same trench as the intake line. This installation will protect the air line from freezing.

Figure 5-1 Floating Intake

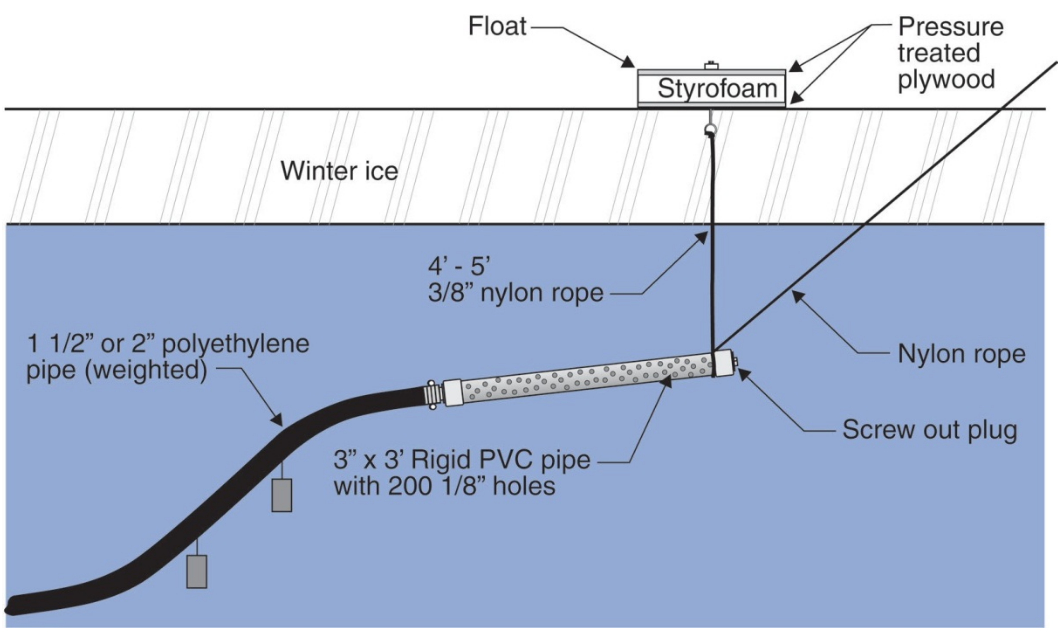


Figure 5-2 Submersible Pump and Intake System

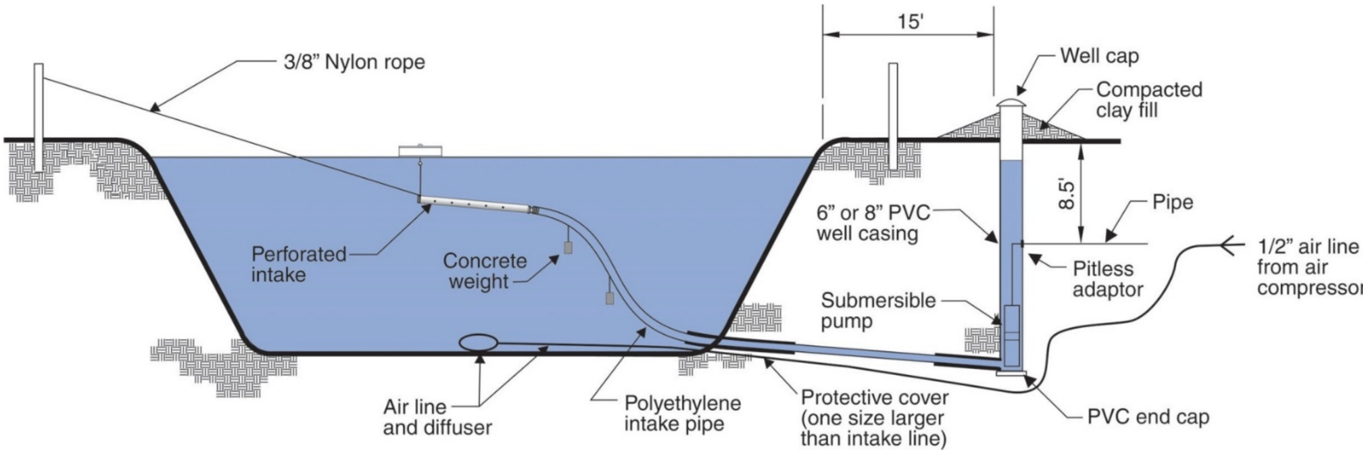


Figure 5-3 Plan View of Intake System

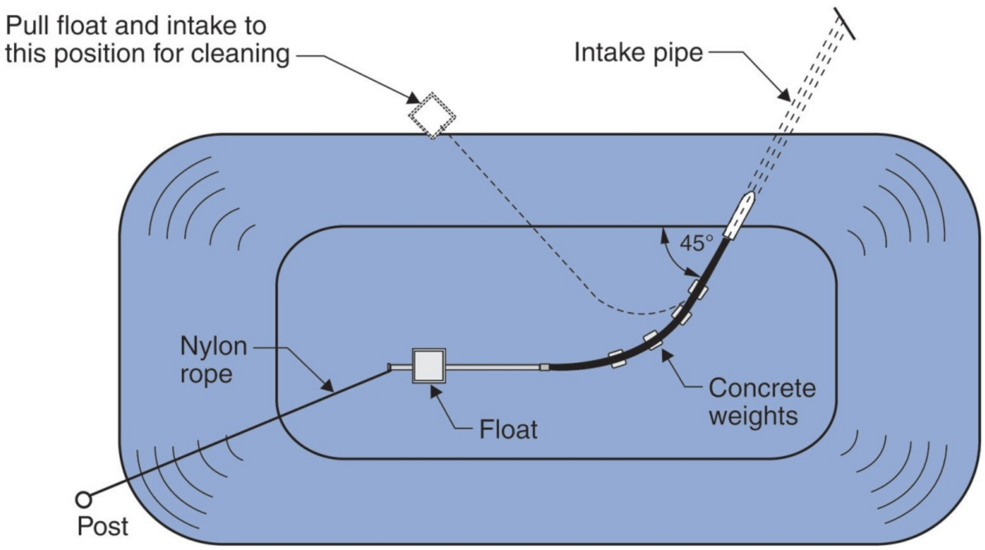


Figure 5-3 Plan View of Intake System shows a plan view of a dugout and the intake installation. The intake pipe should enter the dugout on a 45 degree angle to reduce the chances of kinking when the intake is pulled to shore for maintenance.

Other Intake Systems

Over the years, other types of water intake systems have been tried for dugouts. They are not recommended. Examples of unsatisfactory systems are:

Gravel infiltration trenches

Gravel-filled trenches between the dugout and a wet well beside the dugout 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. The ability for water to flow to the wet well is inevitably reduced. Due to high levels of biological activity in the trench, oxygen levels fall which leads to the release of hydrogen sulfide 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.

Dugout bottom intakes

Large 4 to 12 inch (10 - 30 cm) horizontal piping has been used to convey water from the bottom of the dugout to a wet well. Although these systems do not plug, poor water quality is a problem. Unless the dugout is continuously aerated, the poorest water quality is always near the 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 dugout intake or the pump intake in the wet well.

Avoid using gravel infiltration trenches and dugout bottom intakes.

Wet Wells

A wet well is usually required beside the dugout to permit easy access to the pump. The water flows by gravity into the wet well as water is pumped from the well. For many years, two to three foot diameter steel culverts were used for wet wells. Large diameter wells allow for some settling of solids to take place. However, recent monitoring of these installations has shown that dissolved oxygen levels are much lower in the wet wells than in the dugout water. The reasons for this include the large water storage capacity of wet wells and slow replenishment with fresh dugout water. Conditions in these wells can be like those that develop in gravel trenches: hydrogen sulfide gas formation, lower pH, and a high concentration of nutrients at the bottom of the wet well.

To avoid the problems associated with a large diameter wet well, there are several options:

- Hire a vacuum-truck to come in every few years and suck out the black decayed plant material and sediment at the bottom of the wet well. It is very important that vacuum equipment be clean. A dirty hose can contaminate the wet well.
- For jet pump installations, elimination of the wet well is desirable with the intake assembly installed directly below the float in the dugout.
- For new submersible pump installations, a smaller diameter, 6 to 8 inch (15 – 20 cm) PVC well casing and pitless adapter are the best option. The smaller diameter PVC casing can also be installed inside an existing larger wet well. A smaller well has a steady supply of fresh dugout water and thus eliminates the poor water quality associated with larger wet wells. The PVC casing will last much longer than steel culverts which eventually corrode.

Pumps

Select the proper type and size of pump for your application.

There are many types and sizes of pumps for dugout 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.

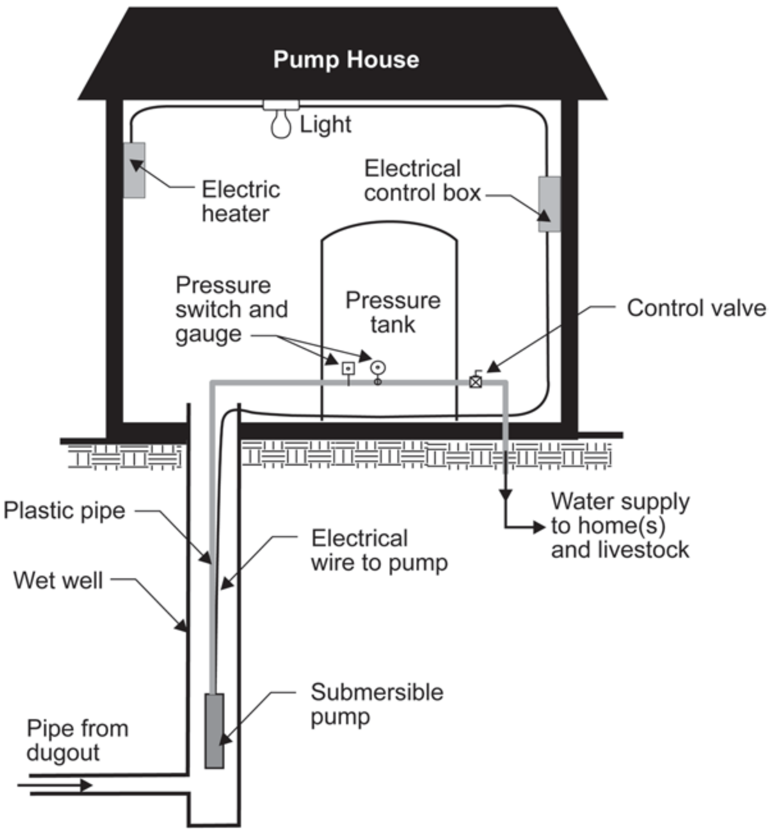
The most common pumps used for dugout supply systems are shallow well jet and submersible pumps. Shallow well jet pumps have a suction lift of approximately 20 vertical feet (7 m), including friction losses. Once water has been lifted to the pump, it can be pushed to higher elevations. Jet pumps can be installed away from the dugout in the basement of a house, heated shop, or pump house. Ensure that the suction line is adequately sized. Jet pumps require a larger intake pipe than submersible pumps but save the cost of running electrical power to the dugout. Jet pumps are not as efficient as submersible pumps and are more suited for supplying smaller volumes of water for rural residences.

A submersible pump can lift water hundreds of vertical feet. It operates like a shallow well pump but has a number of impellers or stages mounted close together on a shaft. Generally, because of the low lift required for dugout applications, a pump with six to ten stages or impellers will supply all the pressure required. The most common size of submersible pump is 4 inches (10 cm) in diameter. These pumps are available in 1/2, 3/4, and 1 horsepower motors and larger.

The pumps are placed in a wet well beside the dugout. Generally, a small heated pump house is set over or beside the wet well to house the pressure tank, pressure switch, electrical controls, and any other dugout pumping or aeration equipment. (Figure 5-4 Submersible Pump, Wet Well, and Pressure Tank).

A rural water system requires a pressure tank. Pressure tanks store water and maintain water pressure between specified limits. As the water in the tank rises, air is compressed until the upper limit or cut out point is reached and pumping stops. The compressed air in the tank acts like a spring. When the valve is opened, the compressed air in the tank forces water to flow into the system. Demands on the water supply cause the tank pressure to fall until the lower limit or cut in point is reached and the pump restarts. Without this buffer, the pump will start each time a small amount of water is drawn. Constant starting and stopping causes unnecessary wear on a pump. A larger pressure tank will save some wear on the pump from cycling. A 30 to 50 psi pressure switch is most common for farming operations. Variable rate pumps are also now commonly used to eliminate this concern.

Figure 5-4 Submersible Pump, Wet Well, and Pressure Tank



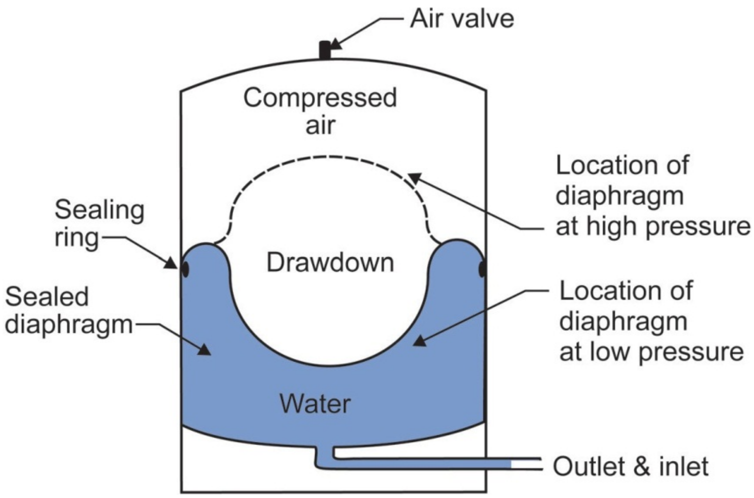
A small heated pump house can house dugout pumping and aeration equipment.

There are four types of pressure tanks:

- Bladder tank, pre-charged with air
- Diaphragm tank, pre-charged with air
- Plain galvanized steel tank with floating wafer or disk
- Plain galvanized steel tank

For dugout applications, it is best to have a sealed air diaphragm or bladder tank for submersible pumps as shown in Figure 5-5 Sealed Air Diaphragm Pressure Tank.

Figure 5-5 Sealed Air Diaphragm Pressure Tank



Dugout water has little dissolved gas and can absorb the air in a plain galvanized steel tank. When most of the air is gone from the tank, the tank is said to be waterlogged. This is like not having a pressure tank and causes premature wear of the pump motor. If a tank has no bladder or diaphragm, waterlogging can be avoided with regular addition of air to the tank. An air volume control can be added to jet pumps to add air to less expensive steel or floating wafer tanks.

The size of the pressure tank is also important. Select a pressure tank that has at least one gallon of drawdown between low and high pressure, for each gallon per minute (gpm) of pump capacity. For example, a 10 gpm pump requires a pressure tank with ten gallons of drawdown.

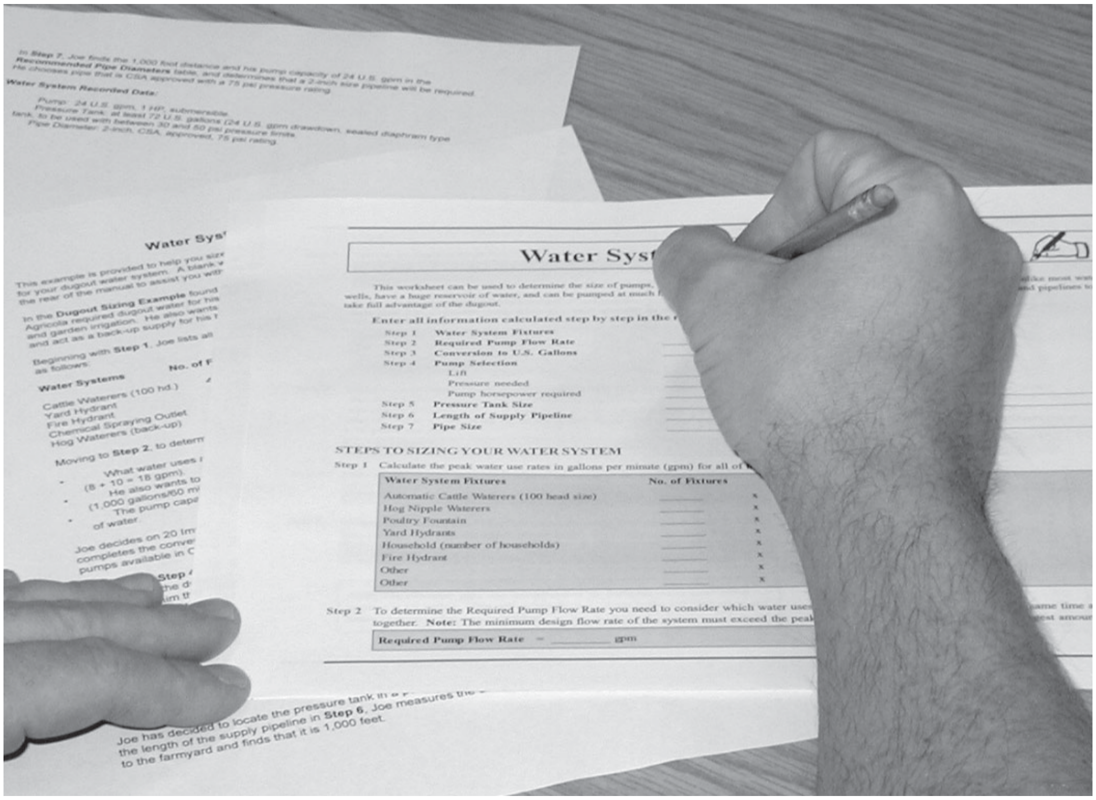
Water Distribution System

The water distribution line should be sized to effectively supply the required amounts of water and pressure throughout the system. As a rule of thumb, try to maintain no more than a five pound per square inch (psi) pressure loss due to friction, throughout the system.

For dugout applications generally 75 – 100 psi, CSA approved, polyethylene pipe is suitable for underground burial and general use in the water distribution system. Polyethylene pipe comes in low, medium, and high density. Low-density pipe is recommended because it is more resistant to damage, more flexible, and easier to join.

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 per cent stainless steel clamps for all connections and double clamp underground connections.

Figure 5-6 Water System Sizing Example



Work through the water system sizing example found in Appendix 5

Dugout Aeration Systems

To prevent low-oxygen conditions, aerate your dugout continuously.

As previously outlined in the Understanding Prairie Dugouts Chapter, Biology of a Dugout 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 dugout, oxygen exchange with the environment is not sufficient. In summer, a layer of warm water forms on the surface. The layer of warm water floats above 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 dugout sediments and held by the cold-water layer.

In fall, air temperature and the surface waters of the dugout cool rapidly. When the surface of the dugout reaches the same temperature as the cooler, bottom layer, the dugout "turns over." This means that the water in the dugout is no longer stratified and wind mixing of all the dugout 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 sulfide, produces the rotten-egg smell that often develops in small water bodies in late winter.

The ice melts in spring, 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.

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 dugouts should be aerated 24 hours per day all year.

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 that churn up the water on the surface and introduce air into the water are available, but research indicates that these systems are not very practical or effective for prairie dugouts.

Select an aeration system that suits your operation and geographic area.

Components of an Aeration System

There are four main components to an aeration system:

- Power supply
- Air compressor
- Aeration line
- Diffuser

Power Supply

As with pumping systems, aeration can be powered by electricity, solar power, or wind. For dugouts stocked with fish, use an electrical compressor, as it will provide a continuous supply of dissolved oxygen. This is crucial for fish survival in a dugout. Windmill type systems may not pump sufficient dissolved oxygen for fish survival during low wind conditions at night or during hot calm periods in summer.

Air Compressors

Bank-mounted windmills use a diaphragm-type pump that pushes air into an aeration hose that extends to the bottom of the dugout. 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 6 metres), 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 dugout water is adequate. For best results, locate the compressor in a heated building or enclosed box to protect the motor, diaphragm, and electrical supply.

Aeration Lines

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

Diffusers

Choose a diffuser that creates fine to medium-sized bubbles.

A diffuser releases 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, as shown in Figure 5-7 Aeration System. It is important to place the diffuser at the bottom of the deepest spot of the dugout. Recommended types of diffusers are:

- Figure 5-8 Airstone Diffuser
- Figure 5-9 Linear Diffuser
- Figure 5-10 Membrane Diffuser

Figure 5-7 Aeration System

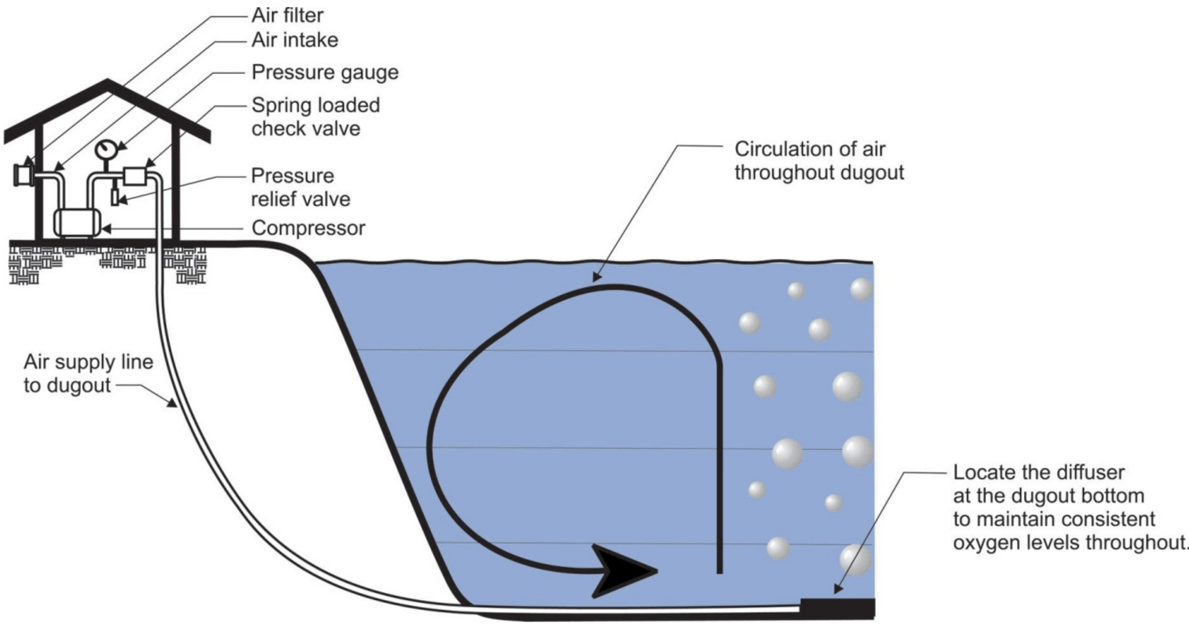


Figure 5-8 Airstone Diffuser

Figure 5-9 Linear Diffuser

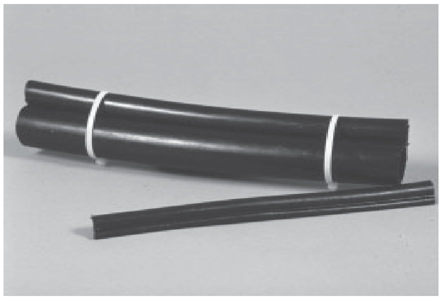
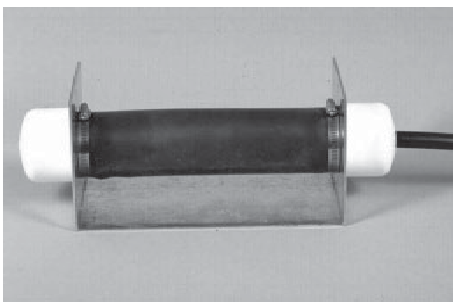


Figure 5-10 Membrane Diffuser



Safety

During winter, dugout aeration systems can result in open or weak areas in the dugout 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.

Remote Watering Systems for Livestock

In the past, livestock were turned out to summer pasture and allowed to walk through and drink from any slough, creek, river, or lake available to them. In the winter, livestock either ate snow or holes were cut in the ice of these natural sources for them to drink. When these natural water sources were not available, dugouts were constructed.

Allowing livestock direct access to surface water sources is a concern to livestock producers and to other water users. The practice is also a problem concern for livestock safety and may lead to animal health concerns from poor water quality.

Livestock producers want to provide a safe, reliable supply of quality water for their livestock and increase their management to better utilize their pastures for livestock production. Many producers are using remote water systems and applying the latest technology available for extended livestock grazing and winter feeding of livestock away from the farmyard. Livestock producers, like other water users, want to do their part to protect both natural and constructed water sources from environmental damage and address herd health problems.

Problems with Direct Watering

Allowing livestock direct access to surface water sources has led to several environmental, herd health, and pasture utilization problems.

Environmental Problems
Environmental problems with direct watering include the following:

- Damage to banks of streams and dugouts
- Siltation problems in spawning areas for fish
- Loss of riparian habitat and vegetation
- Loss of water storage in dugouts and streams
- Nutrient buildup in both the source and downstream water bodies
- Rapid growth of weeds and algae
- Deterioration in water quality

There is enough dissolved phosphorus in the manure from one cow in one day to cause an algae bloom in 250,000 gallons (over 1 million L) of water.

The amount of oxygen needed to decompose the manure from one cow for one day will deplete all dissolved oxygen in 8,000 gallons (over 30,000 L) of water.

Herd Health Problems

There are several herd health problems related to direct watering:

- Increased exposure to water-transmitted diseases, bacteria, virus, and cyst infections
- Increased exposure to blue-green algae (cyanobacteria) toxins
- Foot rot
- Leg injuries
- Stress
- Death by drowning, falling through ice or stuck in the mud
- Reduced rate of gain

Poor Pasture Utilization and Nutrient Transfer Problems
Other problems with direct watering include:

- Overgrazing near the water source
- Poor nutrient transfer caused by an accumulation of manure in the area near the water source

Pasture Water System Trials

There are many benefits to pumping water to cattle and keeping them out of water sources.

Poor access to water and poor water quality can affect livestock behavior and production on pasture. In a pasture trial, it is extremely difficult to isolate what, how, and when these factors become significant. There are so many variables in the cattle, the pasture grass, the water source, and the water quality.

Studies have generally shown an increase in cattle weight gain where water was pumped to them versus direct watering from dugouts. The studies have all shown cattle prefer that good quality water be pumped to them, versus direct watering from a dugout.

Remote Pasture Water Systems Benefits

The benefits of a well-planned and constructed pasture water system include:

- Water source protection and thus longer water source life
- Improved herd health
- Increased livestock production
- Better pasture utilization
- Riparian protection and thus a more environmentally friendly livestock industry
- An alternative winter water supply and system for livestock away from the farmyard which reduces manure hauling costs, manure buildup in the calving area, and associated animal health problems

Pasture Water Systems

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 (grid power, solar, wind, animals, etc.)
- Pumping system (amount of lift, automated versus manual)
- Flexibility and portability
- Reliability and maintenance
- Temporary or seasonal water storage
- Need for frost protection (swath grazing or winter watering)
- Cost/benefit and cost/animal
- Personal preference

Establish a list of priorities for a pasture water system and use some of the natural advantages of the site and equipment.

Livestock Watering Alternatives

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

Access Ramps

An access ramp is the minimum improvement that can be made to a water source (Figures 5-11a Cross-section View of Access Ramp and 5-11b Plan View of Access Ramp). Ramps are most appropriate for large herds of livestock in remote locations (i.e., rangeland pastures) where animals are seldom checked or moved. The reinforced ramps provide better footing for livestock drinking from dugouts, sloughs, and streams where soft soils (e.g., peat) exist.

These ramps require a relatively low slope of 5 to 6 feet (1.5 - 1.8 m) for every foot (.3 m) of drop. Lay down a strip of crushed road gravel preferably with sizes from 1-inch (2.5 cm) diameter down to 10 to 15 per cent fines. The gravel layer should be a minimum of 1 foot (.3 m) thick. Start the gravel layer 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 dugout. Use a small caterpillar or four-wheel drive tractor to spread and compact the gravel.

In soft soil conditions, place a plastic polygrid or geogrid under the gravel to provide added support. The material comes in 3 or 4 metre wide rolls and can be overlapped for wider ramps.

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.

Figure 5-11a. Cross-section View of Access Ramp

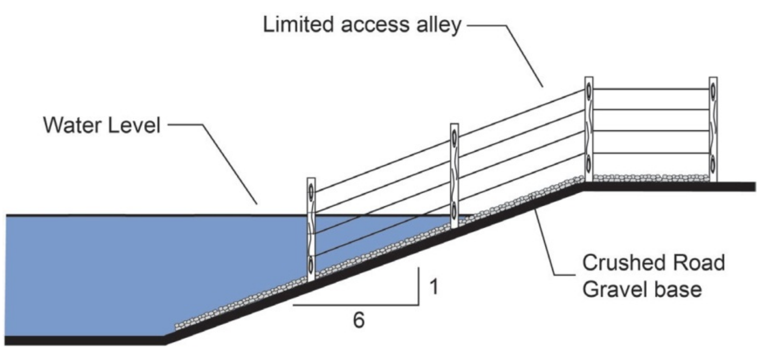
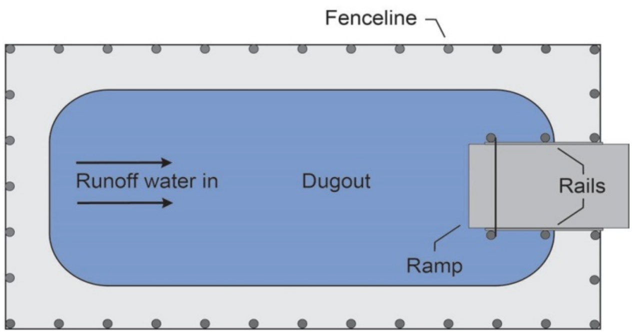


Figure 5-11b. Plan View of Access Ramp



Water Hauling

Alternative energy powered water 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 the water storage, use the following cattle water consumption rates for cattle on pasture:

- Yearling steers or heifers – 8 gallons per day (36 L)
- 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.

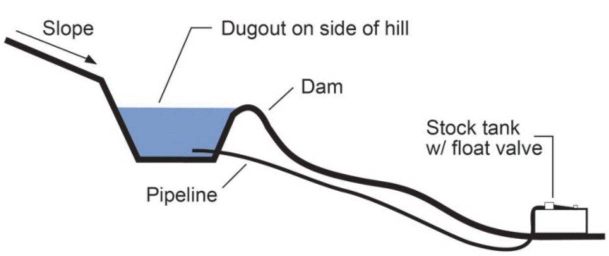
Water storages can be made from almost anything as long as they safely store water at a reasonable cost. The most common are plastic, fiberglass, concrete or metal tanks, elevated earthen reservoirs, grain bin rings, large rubber tires, or large stock watering tanks. The cost of water storages ranges from about 5 cents per gallon (1 cent per L) to well over $1 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 (Figure 5-12 Elevated Earthen Reservoir with Woven Polyethylene Liner).

Figure 5-12 Elevated Earthen Reservoir with Woven Polyethylene Liner

Gravity-fed Systems

Gravity-fed systems are ideal systems on sloping pastureland where it is possible to locate a dugout or dam upslope from a watering site. A pipeline can then be run from the dugout downslope into a stock tank. As a rule, the water level in the dugout should be at least five feet (1.5 m) higher than the stock tank plus 1 foot (.3 m) additional height for every 100 feet (30 m) of pipeline to the stock tank as shown in Figure 5-13 Gravity-fed System.

Figure 5-13 Gravity-fed System



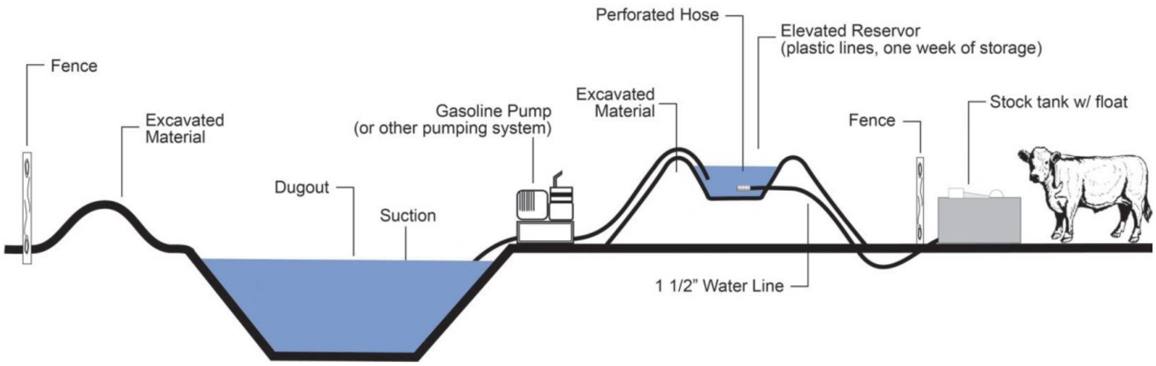
Gravity-fed systems can also be used for springs where there is sufficient elevation drop to the stock tank. On long, undulating and/or steep drops, take extra care to avoid leaks or air blockages.

Consult a knowledgeable contractor or consultant if you are constructing a gravity-fed system.

Pumped Gravity Flow Reservoirs

These reservoirs are generally constructed by digging a small reservoir on top of the excavated dirt piles from a dugout (similar to Figure 5-12). 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 reservoir through the water line and float valve assembly and into the stock tank as shown in Figure 5-14 Pumped Gravity Flow Reservoirs.

Figure 5-14 Pumped Gravity Flow Reservoirs



Selecting the proper size water line and a high capacity, low-pressure float valve are also important to ensure adequate flow rates. Table 5-1 shows the dimensions and water volumes for a typical elevated earthen reservoir.

Table 5-1 Elevated Earthen Reservoir Water Volume (5 ft deep)

Reservoir Dimensions (ft.) Top	Length x Width x Depth Bottom	Approximate Water Volume (Imperial Gallons)
25 x 15	15 x 5 x 5	6,500
35 x 15	25 x 5 x 5	9,600
40 x 20	30 x 10 x 5	16,600
45 x 20	35 x 10 x 5	19,000
45 x 25	35 x 15 x 5	25,000
45 x 45	35 x 35 x 5	50,000

Animal Operated Pasture Pumps

Nose pumps provide a very low-cost pumping system; however, cattle must be given time to learn how to operate them.

These pasture pumps are commonly called nose pumps because cattle operate them by pushing them with their noses as shown in Figure 5-15 Nose Pump. The pump provides a very low-cost pumping system (approximately $20 per cow-calf pair) and is good for about 30 to 40 20 cow-calf pairs.

There are a number of manufacturers of nose pumps currently being sold, including frost-free pumps that is suitable for winter use. Some of the pumps are slightly easier to push than others. They all supply about one litre of water for every stroke of the nose device. The conventional pumps can lift water 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 dugout 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 dugout to the pump is recommended to protect the pipeline.

Figure 5-15 Nose Pump

Although pasture pumps are very reliable and easy to move from pasture to pasture, cattle will take a few days 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. Small calves will generally not learn to operate the pumps until they are about 300 pounds (136 kg). There are several options to overcome this problem. One is to fill a 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.

Do not try to train livestock to operate the pumps during extremely hot temperatures.

Pipelines

*Caution: Contact **Alberta Click Before You Dig** to identify the location of shallow buried utility lines before you do any trenching.*

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

For shallow pipeline burial (approximately one foot or 0.3 m deep), some producers use a ripper type plough mounted on either a three-point hitch of a tractor or a pull type unit. 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.

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.

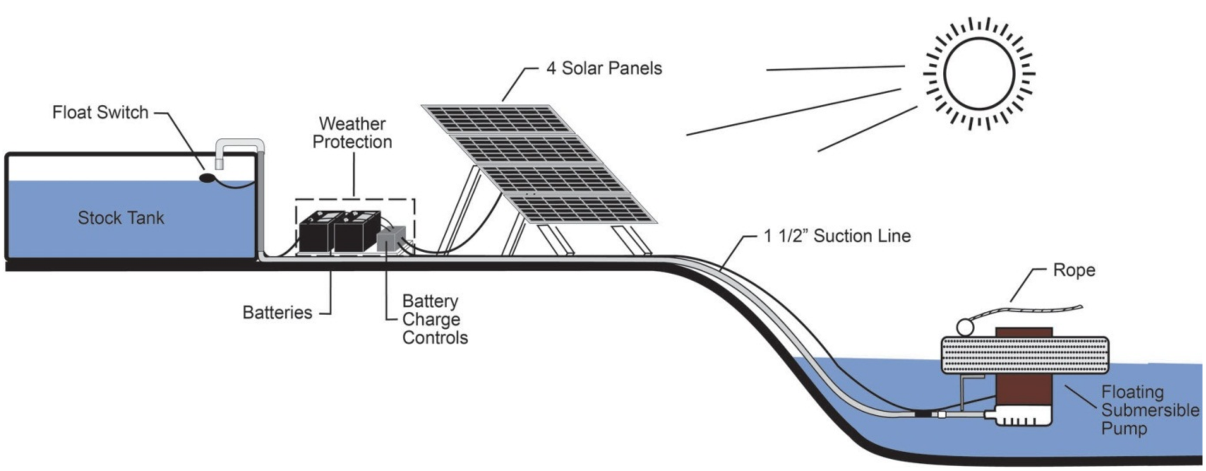
Some producers use a gas-powered generator to run a submersible dugout pump. These systems can be automated to start on a float switch device located in a stock tank or reservoir. Both pumps and generators can be used for other purposes on the farm. These systems can be sized to pump a large volume of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

Gas-powered pumping systems are a low-cost alternative for pumping water to large herds.

Solar-powered Pumping Systems

Solar systems are popular because of their reliability and low maintenance. They can be used to pump water from dugouts. An array of solar panels collect and convert sunshine into electrical energy, which can be used to pump water or be stored by rechargeable batteries as illustrated in Figure 5-16 Solar-powered Pumping System. Due to the variation in sunshine intensity, a minimum of three days or greater of water or battery storage is required.

Figure 5-16 Solar-powered Pumping System



Solar-powered systems can be portable and are durable.

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.

Solar powered systems have the added 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.

Wind-powered Pumping Systems

Windmills perform best in areas that have higher than average wind speeds, such as the southern parts of the Prairie Provinces. For central and northern areas of the prairies, where wind speeds are lower, consider adding additional water storage such as an elevated earthen reservoir.

Windmills can be used to pump from dugouts and wells. Place windmills on higher ground where they have good exposure to the wind, such as the excavated dirt pile from a dugout. Also, locate them away from trees as far as possible, at least 15 to 20 times the height of the trees as shown in Figure 5- 17 Wind-powered Pumping System.

Figure 5-17 Wind-powered Pumping System

Windmills must be located on higher ground away from trees, so they perform efficiently.

There are windmills that can be used for both dugout water pumping and dugout aeration. 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.

Options for Winter Watering Livestock at Remote Locations

Although livestock prefer water, snow can be an acceptable water source for mature cows and young cattle in good condition and veterinarian approved. 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.

Benefits of winter watering systems include:

- Extending the pasture grazing season and fall and winter swath grazing
- Lessen water demand at farmyard (i.e,. low producing well)
- Winter feeding of cattle on pasture and cropland to reduce manure hauling costs
- Preventing manure buildup in the calving areas
- Improved manure management
- Reduces livestock stress and health problem
- Prevent death from 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 use a combination of the two. 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 dugout locations on the Prairies, watering systems must be durable and able to withstand temperatures that drop to - 40°C.

Most winter watering systems available on the market today have a common setup. The main components are an intake water line from the dugout, wet well, power source, and pump (see Figure 5-18 Watering Bowl with a Drain Back System).

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-insulated1 trough system. The basic components of a solar system itself are:

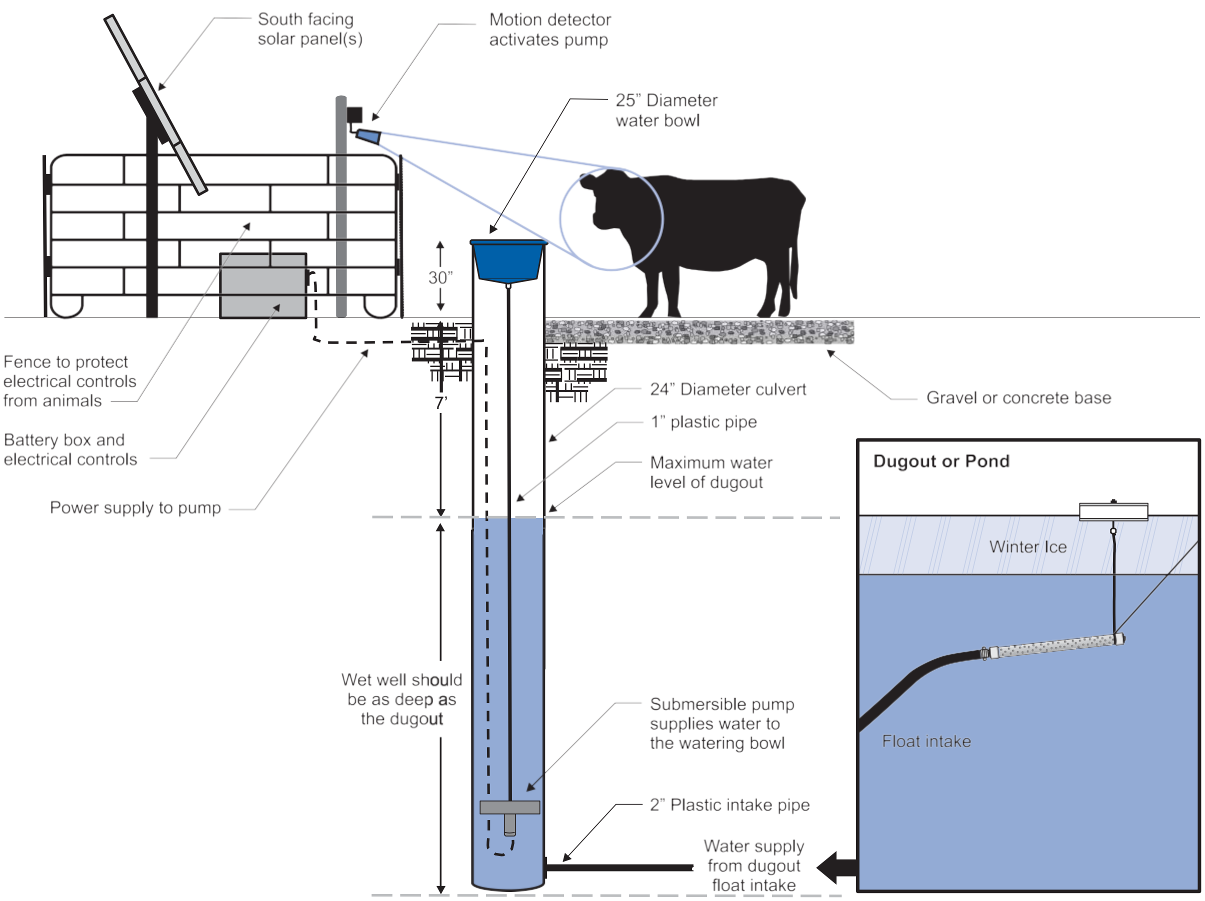
- Solar panels
- Deep cycle batteries
- Control box
- Pump
- Motion detector or float switch
- Intake line
- Water bowl or trough

Watering Bowl with a Drain Back System to Prevent Freezing

This system is set up directly over the wet well beside the dugout 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. Water remaining in the bowl after the cattle have finished drinking drains back to the wet well through the bottom of the bowl so that no water remains in the bowl to freeze. Motion detection systems are adaptable to a variety of setup configurations as shown in Figure 5-18 Water Bowl with a Drain Back System.

The ground level at the watering bowl site should be at least 7 feet (2.13 m) higher than the dugout's maximum water level. 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.

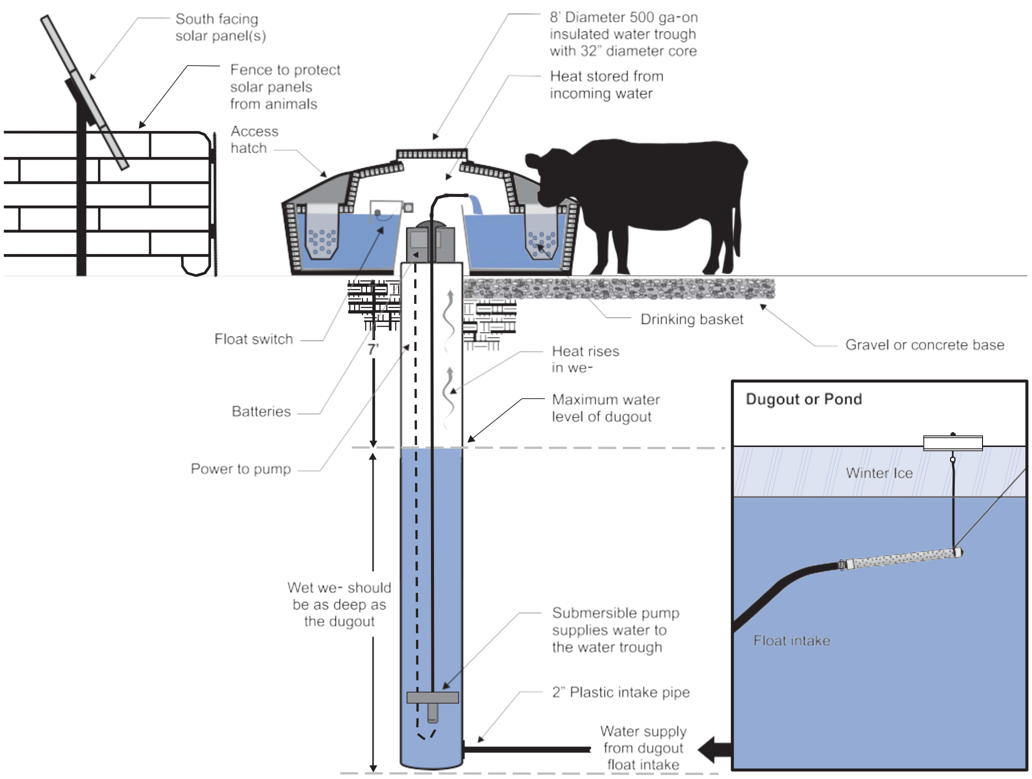
Figure 5-18 Watering Bowl with a Drain Back System



Well-Insulated Trough System to Prevent Freezing

Like the drain back system, this system is set up directly over the wet well beside the dugout. 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. This system is shown in Figure 5-19 Well Insulated Trough System.

Figure 5-19 Well-Insulated Trough System



The Frost-free Nose Pump

The frost-free nose pump is also a drain back type of winter watering system as shown in Figure 5-20 Frost-free Nose Pump. 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 inspections of the functioning and icing of pump are recommended especially during extremely cold and windy conditions to ensure adequate water availability for livestock.

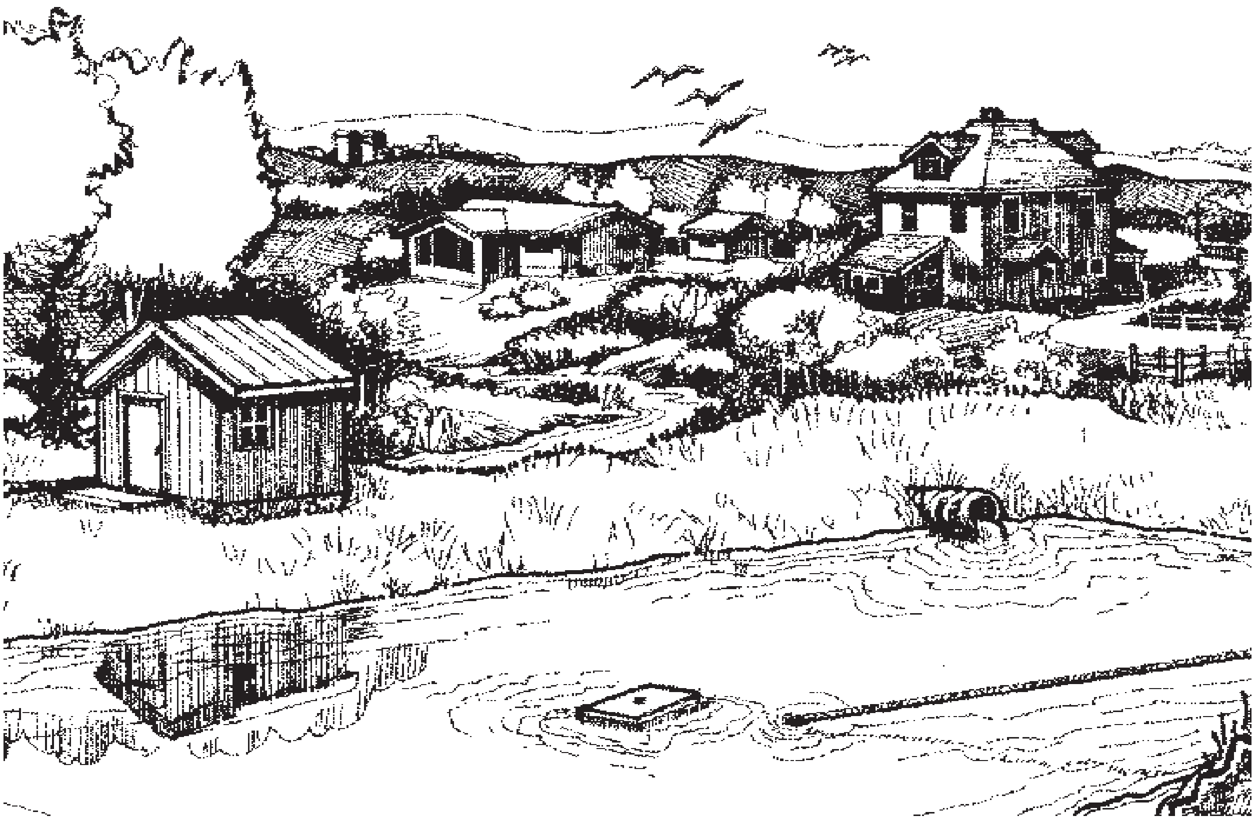
Figure 5-20 Frost-Free Nose Pump

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. Dugout and off-stream livestock watering systems are an important tool in protecting water sources, riparian areas, and livestock.

Chapter 6

Water Quality for Domestic and Human Drinking Water Supplies



Domestic and drinking water supplies have higher quality requirements than most other uses. Water that appears to be acceptable based on visual appearance, taste, odour, and colour may contain contaminants that affect human health. Risks can be chemical or microbiological. It should be remembered that water that has been successfully treated for human consumption might become re-contaminated and present real health risks. Re-contamination sometimes occurs in the distribution system.

On the other hand, water that is otherwise harmless may have such objectionable appearance, taste, and odour that it is unacceptable for household use.

Health Risks and Water Quality

Waterborne microbiological diseases are caused by bacteria, protozoa, and viruses.

On first appearance, water would appear to be a relatively simple liquid. It is, however, a powerful solvent that can contain 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 human health.

Microbiological Factors

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

- Bacteria
- Protozoa
- Viruses

Examples of each of these three groups of pathogenic organisms are given in Table 1, Appendix 2 Water Quality Guide, along with the symptoms of the resulting disease. It should be noted that all of the symptoms listed for a particular disease are not always observed. It should also be noted that this list is not exhaustive but contains examples of microscopic organisms that have been linked with waterborne diseases in the past.

In many cases, the association of a disease outbreak with exposure to contaminated water is not recognized. Many of the symptoms that are exhibited in some of these diseases are attributed to other factors such as the “flu” or food poisoning. As such, many cases related to waterborne disease are never reported to health officials and therefore available statistical data are understated.

In Canada, notifiable disease statistics are the responsibility of each province and considerable variation exists in the manner and completeness with which this information is collected. Consequently, the number of individuals affected by waterborne diseases is not known in Canada.

In many cases where disease outbreaks have been linked to drinking water, the cause is never determined. In the U.S. from 1991 to 1998, the identity of the agent causing waterborne disease outbreaks was not determined in 40 per cent of these cases.

Bacteria

Floodwater usually contains high levels of bacteria.

Most bacteria found in water do not cause diseases in humans. 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 dugouts, provide an excellent breeding ground for bacteria.

Protozoa

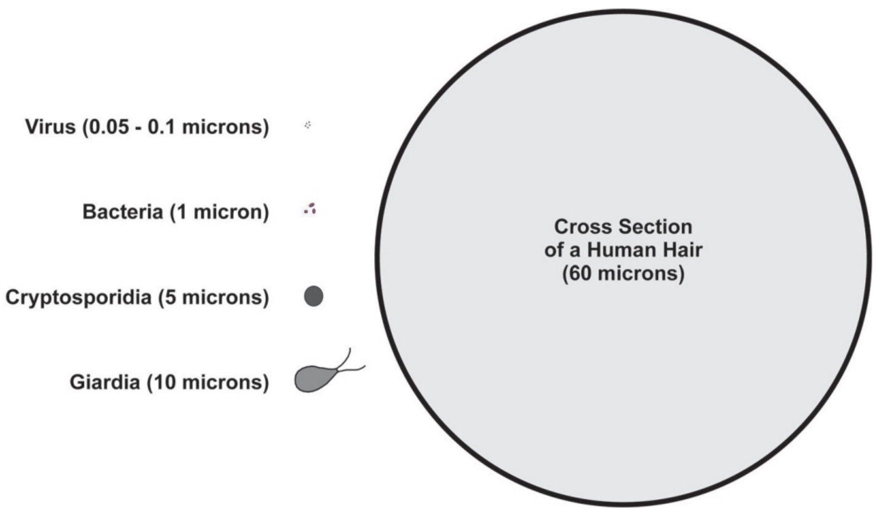
Protozoa are a group of microscopic parasites that are frequently present in surface waters. Some protozoa, notably giardia and cryptosporidia, exist in the form of cysts. The protective covering of the cyst permits the parasite to survive in harsh environmental conditions. The cyst also protects the 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 per cent of reported waterborne disease outbreaks in the U.S. between 1991 and 1998. Giardia is 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.

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. Figure 6-1 illustrates why pathogenic organisms are not visible to the human eye.

Figure 6-1 Relative Sizes of Pathogenic Organisms



Chemical Factors

There are many chemicals that can pose a human 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 human health include naturally occurring minerals, metals, and toxins as well as a variety of synthetic, organic chemicals including many different types of pesticides. A list of the various chemicals, their source, and their adverse health effects are listed in Appendix 2, Water Quality Guide, in Table 2, Chemicals and Their Associated Risk to Human Health.

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 Alberta Health Services office to obtain contact information for water-testing laboratories.

Aesthetics and Water Quality

Numerous chemical compounds and microbiological species affect the aesthetic quality of water. Certain compounds and 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 human health. The most commonly nuisance water problems are summarized in Appendix 2, Water Quality Guide, Table 3, 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 because 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.

Standard Testing of Drinking Water

"The Rural Water Quality Information Tool" provides an abundance of information on water quality, water sampling, and testing. The tool allows you to input your own water test results, and it then provides a detailed interpretation of the test results.

To find out more on the Rural Water Quality Information Tool

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.

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 may also be present and caution needs to be exercised due to the risk to human health. 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 in Canada, and for that matter many other countries, perform 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 milliliter 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. Municipal and community water supplies typically monitor turbidity on a routine or continuing basis.

In 1989, the Mistahia Health Unit, formerly South Peace Health Unit, located in Grande Prairie, Alberta conducted a survey of bacteria levels found in local farm dugouts. Health Unit staff reviewed the results of bacteriological analysis conducted on raw (untreated) dugout water samples from the 1960s to 1989.

Bacteria Found	**Samples Containing Bacteria**
Total coliform	31.5%
Fecal coliform	23.7%
Total bacteria population (>500)	1.2%
Confluent growth (unidentified bacteria)	1.7%
Meets Canadian Drinking Water Guidelines (1989)	41.9%
Total water samples tested	**578**

Note: Information provided by Elmer Spilchen, Public Health Inspector, Grande Prairie, Alberta.

Water testing is done for indicator bacteria rather than a number of individual species.

The survey results indicate that dugouts are at risk of contamination with bacteria, and confirm the need for effective treatment of dugout water to be used for household purposes.

Drawbacks of Standard Water Testing Techniques

If a treated municipal drinking water supply is found free of coliform bacteria, it is generally assumed that the water treatment process is working adequately and that the distribution system is functioning properly. 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 dugout does not indicate anything regarding the presence or absence of protozoa or viruses.

Non-routine Testing of Drinking Water

While there are many laboratories that have the capability to test for coliform bacteria, total and fecal, as well as E. coli, relatively few have the capability to test for specific pathogens such as cryptosporidia, giardia, and various viruses. Many environment and health officials do not recommend routine monitoring of drinking water supplies for cryptosporidia and giardia due to the complex and expensive testing methods and the widespread existence of these protozoans in surface water. Instead of monitoring for protozoans, many agencies have preferred to focus on ensuring that adequate treatment procedures are in place for public and private water supplies and that best management practices are observed in the watershed.

Very few laboratories have the capability to test water routinely for viruses. This is mainly due to the lack of established testing procedures for many viral organisms. A second factor is that most laboratories perform microbiological testing on a very large number of samples. Testing all samples for even a small number of viruses would be practically impossible. This type of testing is normally only performed on larger municipalities' drinking water supplies.

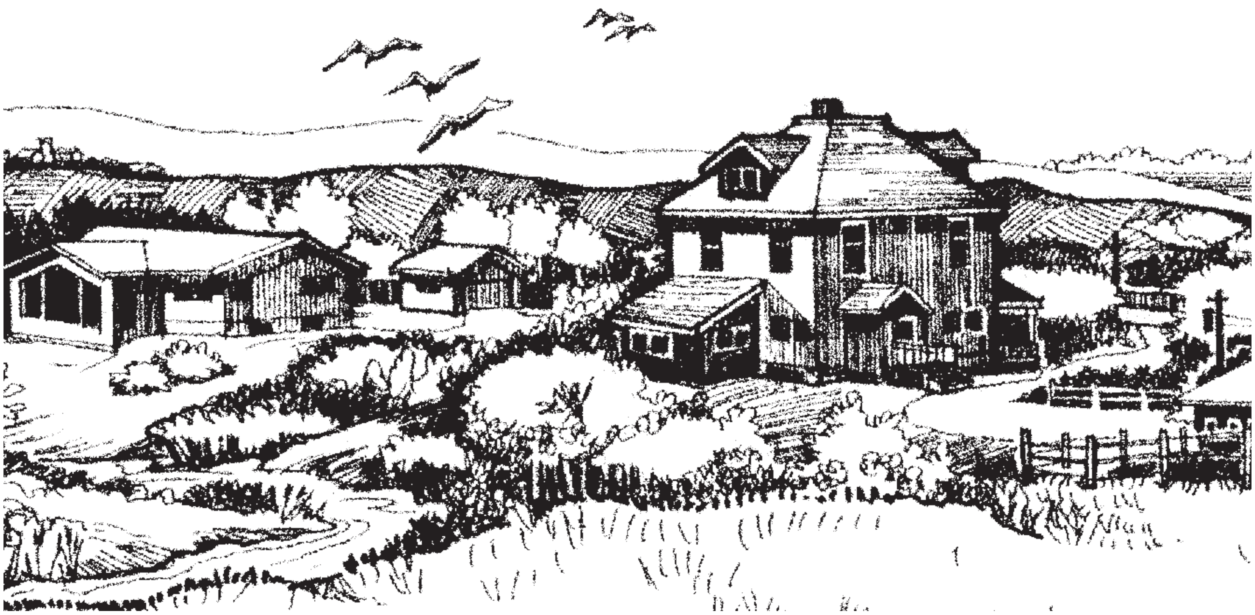
General Testing Recommendations

Test drinking water from a well or dugout at least twice a year, or more if there is a problem.

It is not feasible 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 drinking water derived from a privately operated source such as a well or dugout 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.

Chapter 7

Water Treatment for Domestic Water Supplies



Water treatment is essential for all dugout water supplies used for household/drinking purposes.

Water Treatment Systems

Water Treatment of surface water for human drinking purposes is a complex and often difficult task. In this chapter, we discuss a basic description of methods and procedures of surface water treatment, but we are not able to provide exhaustive methods and details in the space available in this publication. Technicians that work in the water treatment industry require extensive education. Hopefully this chapter will help you begin to understand some basic methods of surface water treatment principles.

Water treatment involves a series of treatment processes in a standard sequence to produce a safe and aesthetically acceptable product. This sequence of treatment processes improves the quality of the water with each step, providing a multi-barrier, water treatment system. For surface water supplies, treatment must include steps to remove particulate and organic matter, followed by disinfection. Water treatment equipment can be expensive and always requires good maintenance practices to operate effectively over the long-term.

Surface runoff is usually high in particulate matter and plant nutrients. Algae and weed growth can be significant, particularly during the summer months, and dugouts generally have high levels of organic matter. While disinfection is an essential part of the water treatment process, high organic carbon levels can react with the disinfectant, producing potentially harmful by-products. The reduction of organic matter prior to disinfection is therefore an important step in the treatment process to produce biologically and chemically safe water.

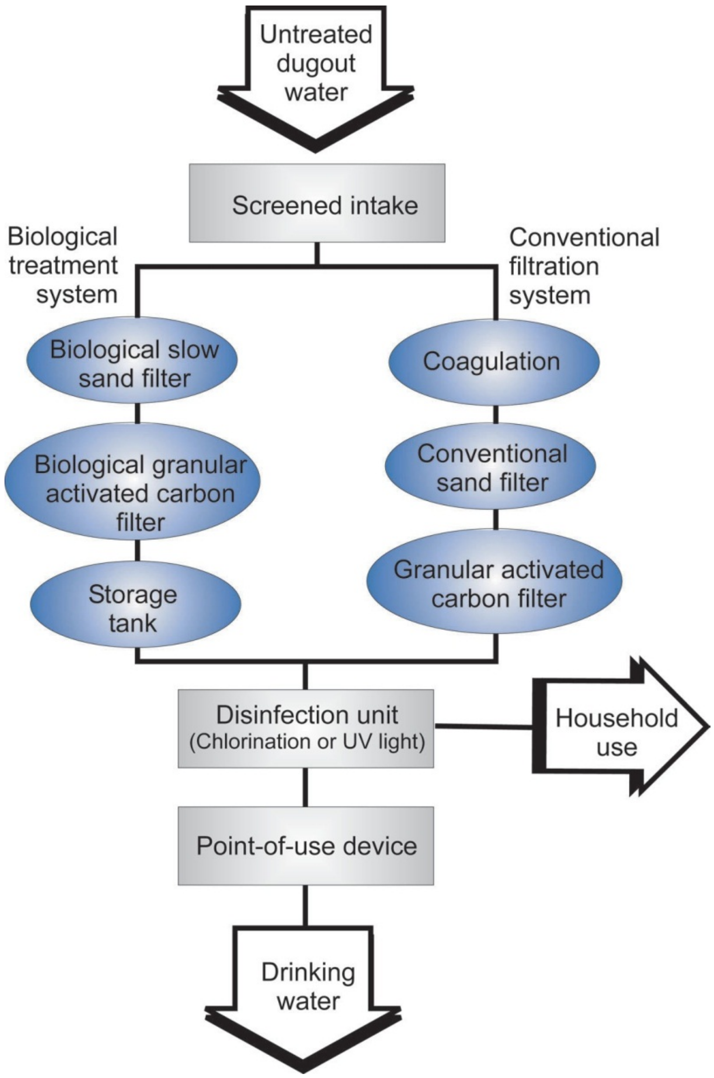
Traditionally for domestic use, dugout water treatment has consisted of either no treatment at all, or a combination of chlorination, rapid sand filtration, and/or granular activated carbon filtration. These types of treatments, by themselves, have not been successful at producing a high-quality water product over the long term. Water produced from this type of treatment system should only be considered utility water and should not be consumed. While these processes can be effective to some extent, more effective pre-treatment is essential.

Figure 7-1 Surface Water Treatment Steps shows a schematic of two effective systems for treatment of dugout water as it enters the house. These systems are called point-of-entry (POE) treatment systems. The first system includes chemical coagulation, filtration, and disinfection. The second system includes slow sand and biological activated carbon filtration followed by disinfection. In both cases, a final barrier such as a reverse osmosis (RO) membrane or distiller for drinking water, cooking water, and water for brushing teeth is added. This final barrier is called a point-of-use (POU) water treatment device. This type of treatment following point-of-entry treatment is referred to as “polishing.” Polishing devices are designed for use on high-quality treated water and are not capable of treating raw dugout water.

An effective in-house treatment system should be represented by one of the configurations in Figure 7-1. Other technologies, such as micro filtration, may be used to replace some of the processes identified in Figure 7-1 if they are properly designed and operated.

The treatment processes described can effectively treat most dugout water. Effective systems are designed to treat specific water problems. Therefore, dugout water should be tested before designing the system. Water problems that are not typical of dugouts may require system modifications.

Figure 7-1 Surface Water Treatment Steps



Steps in Water Treatment

The recommended systems in Figure 7-1 consist of several consecutive steps. As previously discussed in Chapter 3 – Planning, the first step in a multi-barrier water treatment system is protection of the source water.

Screened Intake

A screened intake in the dugout is recommended as a pre-treatment to sieve out larger particles including algae, as well as reduce high turbidity.

Coagulation

Coagulation is a chemical process that can reduce turbidity, dissolved organic compounds, and colour. The chemicals most often used for coagulation are aluminum sulphate, ferric chloride, ferric sulphate, and polyaluminum chloride.

The coagulant causes small particles to join to form larger particles. During mixing, more particles combine to form even larger particles called floc. The floc is visible to the naked eye and can be removed from the water through sedimentation or direct filtration.

Coagulation can be done in dugouts or coagulation cells, or by using in-house coagulation systems. The two most common methods of coagulation for rural use are:

- Constructing a small lined dugout or coagulation cell to treat a six to twelve month supply of household water
- Utilizing a commercial in-house coagulation system for continuous treatment of household water

Coagulant chemicals must be dosed and mixed properly to achieve maximum benefits. On-farm coagulation has been experimentally successful, using simple treatment techniques for rural water supplies. Simple predictive tests have been developed for use on-site to determine the required dose rate.

Conventional Filtration

Conventional filtration is also known as rapid filtration, to distinguish it from slow sand or biological filtration. Figure 7-2 Coagulation and Conventional Filtration System shows continuous coagulation treatment followed by conventional filtration. Filtration is an important step in the treatment sequence to remove particles from water. Types of filter media that can be used include sand, dual media, multi-media, and granular activated carbon. Pressure sand filters and granular activated carbon filters are commonly used in domestic systems. Granular activated carbon filters can be used as a final step to remove taste and odour. In all cases, filters require backwashing to maintain performance. Backwashing is accomplished by reversing the flow of the water and lifting the media bed. Solids clogging the filter are dislodged and flushed out with the backwash water, which is discarded.

Biological Filtration

As an alternative to conventional filtration, biological filtration, as shown in Figure 7-3 Biological Filtration System, can be a simple but effective treatment for small water supplies. Slow sand filtration, followed by disinfection, represents one of the earliest systems developed for the treatment of surface water supplies. While these filters are commonly employed in many European treatment systems, they are not heavily used in North America.

Biological filtration makes use of naturally occurring microorganisms to purify water. By providing the right environment, certain populations of microorganisms can be encouraged to grow in the filter. The process is simple. Water is percolated slowly through a filter bed and into a storage tank. A storage tank is required for the treated water because filtration is slow. A constant supply of air must be introduced to the filter and the flow of water must be continuous to ensure survival of the microbial colonies. As with the rapid sand filter, backwashing is required to maintain the operation of the filter. Some biological systems are ideally suited to treat surface water problems, like dissolved organic carbon, turbidity, colour, taste and odour. One system that has been successful in the treatment of surface water consists of a gravity-fed, slow sand filter, followed by a biological, granular, activated carbon filter and a storage tank.

This system offers an effective alternative to more conventional treatment systems and produces high quality, household water. With further treatment, water from these systems can be made safe for drinking. Although no chemicals or bacteria must be added to these systems, regular backwashing with a mixture of air and water in a "reverse" up-flow through each filter is a necessary maintenance procedure.

Biological filtration is an effective treatment for small water supplies.

Figure 7-2 Coagulation and Conventional Filtration System

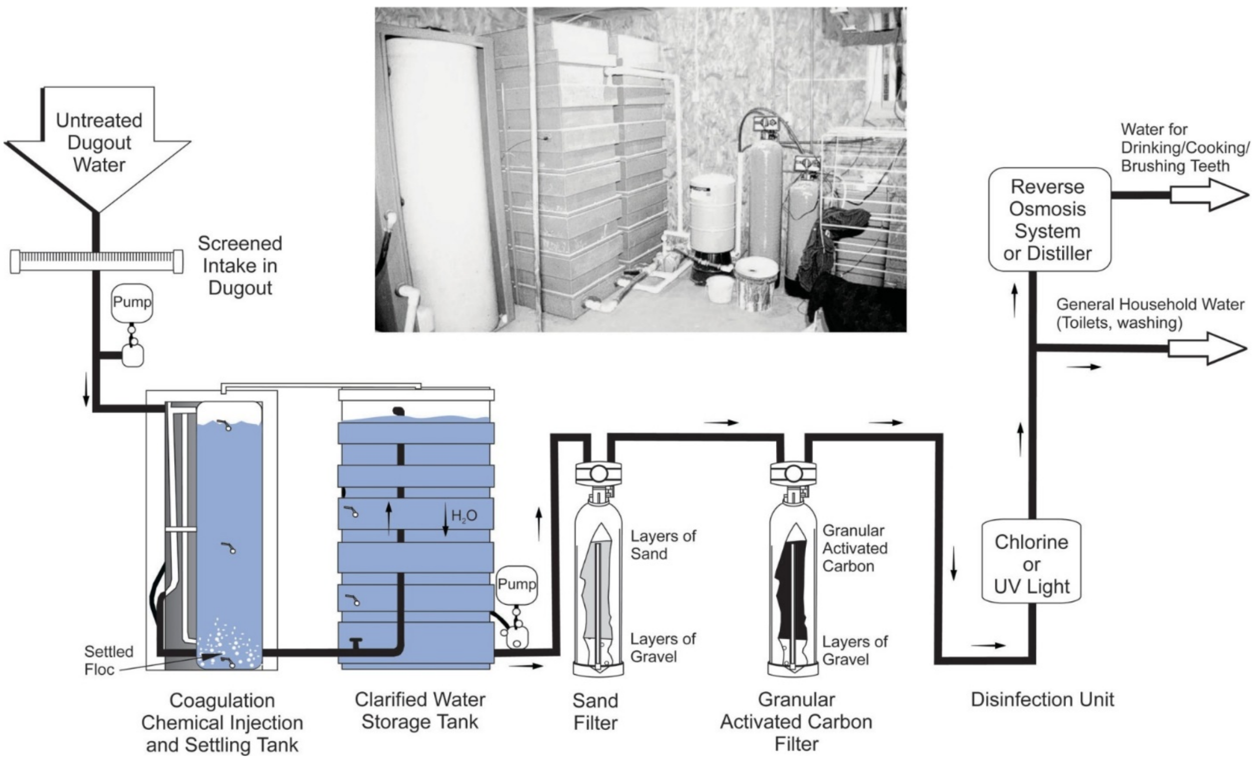
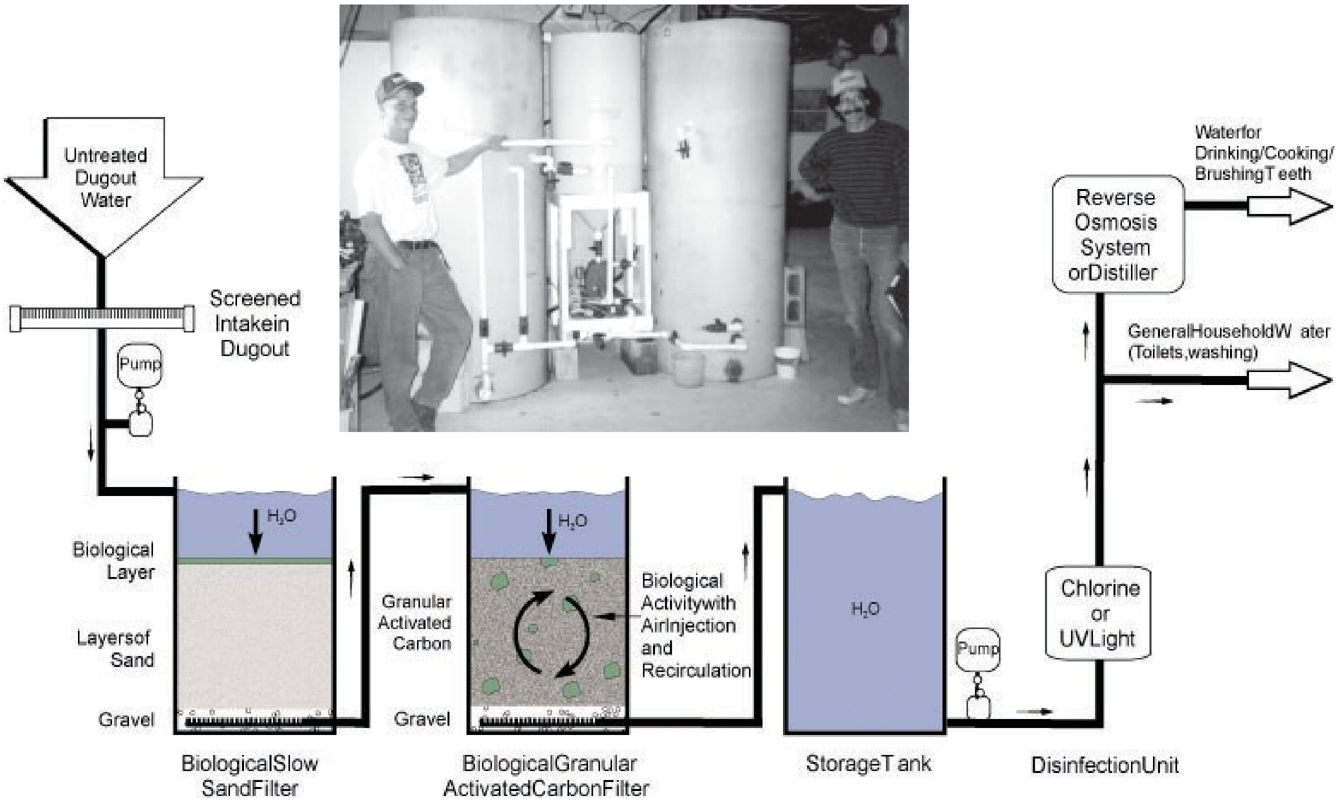


Figure 7-3 Biological Filtration System



Disinfection

You must disinfect dugout water for domestic use.

Disinfection is an essential step in the treatment of dugout water for domestic use. The purpose of disinfection is to reduce populations of pathogenic microorganisms to prevent the transmission of water borne diseases. This is different from sterilization, which destroys organisms. Common disinfectants include chlorine, chloramines, and ultraviolet (UV) light disinfection. It is important that the water has been successfully filtered prior to the disinfection step.

Organic material and mineral particles can shield microorganisms from the disinfectant, resulting in water that may be unsafe even after treatment. In addition, if chlorine is used as the disinfectant, and organic matter has not been reduced to low levels, potentially harmful chlorination by-products may form.

Contact time, pH, water temperature, organic concentration, and chlorine dose influence the effectiveness of chlorine disinfection.

Many rural residents prefer UV light disinfection, as it imparts no smell, taste, or odour to the water. UV light disinfection does not require chemical feed pumps and mixing tanks; however, it does not leave a disinfectant residual like chlorine for protection throughout the household distribution system. Wavelength, exposure time, water temperature, intensity of the light, and the presence of turbidity affect the effectiveness of UV light disinfection.

Polishing Treatment for Drinking Water

While it is recommended that the entire household water supply be disinfected to protect all water outlets in the home, a final barrier to supply safe drinking and cooking water is also recommended. This additional polishing step requires a distiller or kitchen sink reverse osmosis (RO) unit. For additional detail on distillers and RO systems found in this chapter.

Treatment System Maintenance

Operation and maintenance of in-house treatment systems is critical. Some treatment systems can be purchased with maintenance contracts to reduce the time and work associated with proper maintenance. A well-operated system will ensure the water supply is safe and aesthetically pleasing. Regular monitoring of systems will give users confidence that the water they are using is safe. Maintenance should be tracked in a record book. If changes in quality are observed, corrective measures should be taken.

Be prepared to invest time and money into maintenance of treatment systems.

Conventional Pressure Sand or Multi-Media Filters

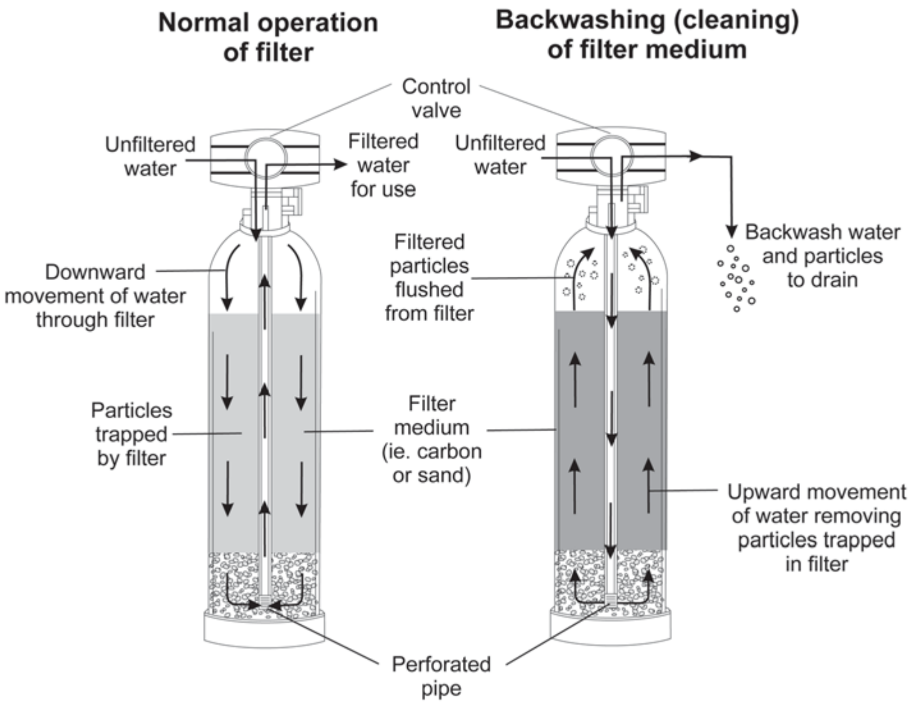
Pressure sand filters require regular backwashing as shown in Figure 7-4 Filter Backwashing. The backwash cycle can be set to start automatically. Backwashing frequency will depend on how much loading is placed on the filter by the feed water. In summer, when particulate loading is high, backwashing may be required as frequently as once a day. In winter, backwashing may only be required once every three to seven days. If water is pre-treated with continuous coagulation before the filter, the requirements for backwashing may be increased as unsettled floc from the coagulation process may clog the filter.

Organic matter will accumulate and plug pressure sand filters over time. For this reason, a manual backwash should be done at least twice annually, once in spring after snowmelt and once in fall, just before freeze-up. A manual backwash involves turning on the filter in backwash mode, unplugging the timer, and running a large quantity of water through the filter. Clean filtered water is preferred for backwashing. However, if raw water is used in this process, the wastewater should look as clear as the raw water. The backwash water should be inspected every five minutes for clarity. The manual backwash should be repeated until the backwash water is clean. If a filter is very dirty, backwashing may have to be repeated. If organic slime buildup is a problem, the filter can also be shock-chlorinated after the manual backwash. Filter media rarely require replacement unless the coarse filter gravel is displaced during overly aggressive backwashing.

Biological Sand Filters

Biological gravity sand filters may be designed for two types of maintenance regimes. The first regime involves backwashing the filter once every two to four weeks. The second involves replacement of the top layer of sand with new sand. Each spring and fall, the sand filter may require several cycles of backwashing to remove any accumulated material.

Figure 7-4 Filter Backwashing



Conventional Pressure Carbon Filters

Granular Activated Carbon Filters are often referred to as GAC filters or Activated Carbon filters or even Carbon Filters. Pressure carbon (GAC) filters also require regular backwashing. If a sand filter is operating efficiently, the pressure carbon filter will require backwashing once every three to 14 days. It is always important to follow manufacturer's recommendations and adjust the frequency of backwashing to the type of water being treated. Manually backwashing for a longer time than the automated backwash may be useful if particulate matter has overloaded the filter. This should be done any time overloading is suspected.

A significant problem associated with carbon filters is carbon exhaustion. This occurs when the carbon simply cannot adsorb any more taste and odour compounds or dissolved matter. Carbon exhaustion is identifiable by treated water that is coloured or has a bad odour. The adsorption capacity of activated carbon in a pressure carbon filter will not last forever. For dugout water supplies, carbon exhaustion times can be highly variable, depending on water quality and the volume of water treated. Carbon media should be replaced at least twice a year, once in fall and once in spring. Fall replacement, when organic matter has died off, provides better carbon filtration throughout the winter months. Spring carbon replacement, after spring runoff, provides for more effective filtration of water high in organic matter.

Granular activated carbon in the filters is often only effective for two to three months. Carbon can be an excellent surface for unwanted microorganisms to grow on. Backwashing may not remove them and pre-treatment with chlorine will not prevent them from growing. Carbon must be replaced regularly to guarantee high quality water.

Biological Granular Activated Carbon Filters

Biological, granular activated carbon filters should be backwashed every 6 months. After the backwash, the filter should be drained of treated water until the water runs clear. Some fine carbon particles will wash through the system and should be discarded. Periodic shock chlorination is not required on biological carbon filters. If carbon media degrade, they require replacement. Long-term experiments on biological carbon filters have shown that the filters have performed well for seven years without any need for carbon replacement. The keys to successful biological carbon filtration are:

- Ensuring that the system is sized properly
- Providing a continuous air supply
- Backwashing frequently

Raw water should not be chlorinated before passing through the filter, nor should it contain any compounds, such as copper, that may poison the organisms.

For dugout water supplies, replace the carbon media at least twice a year, once in the fall and once in the spring.

Chlorination Disinfection

To ensure the water is safely disinfected, chlorine must be applied after filtration. The chlorine feed pump is set to feed the chlorine solution into the filtered water. Chlorine solutions must be batched to a mixing tank and enough contact time must be maintained. The chlorine feed pump is then set to feed the chlorine solution into the filtered water. To ensure the water is safely disinfected, chlorine must be applied after filtration. Contact time must be 10 to 20 minutes and the dose must be large enough to ensure that the residual at the tap is at a suitable level.

The only way to know the concentration of chlorine at the tap is to test it. Test kits are cheap and easy to use. Testing must be done at least once a week and doses adjusted if necessary. A loss of chlorine residual at the tap may be due to the loss of prime at the chemical feed pump, or the failure of the treatment system. This type of monitoring is an excellent way to track the system’s performance. Keep a logbook and record the results. Take any necessary corrective action if a problem is noticed. Properly managed and monitored, chlorination systems are the most effective way of ensuring that filtered water is safe for domestic use.

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Ultraviolet Light Disinfection

Ultraviolet disinfection lamps occasionally become impaired by poor quality water. If the lamp becomes coated with organic material or mineral scale, disinfection will be incomplete. Lamp maintenance under these conditions is not practical, and it is therefore critical that UV is not used to treat hard water or under conditions where bio-fouling occurs.

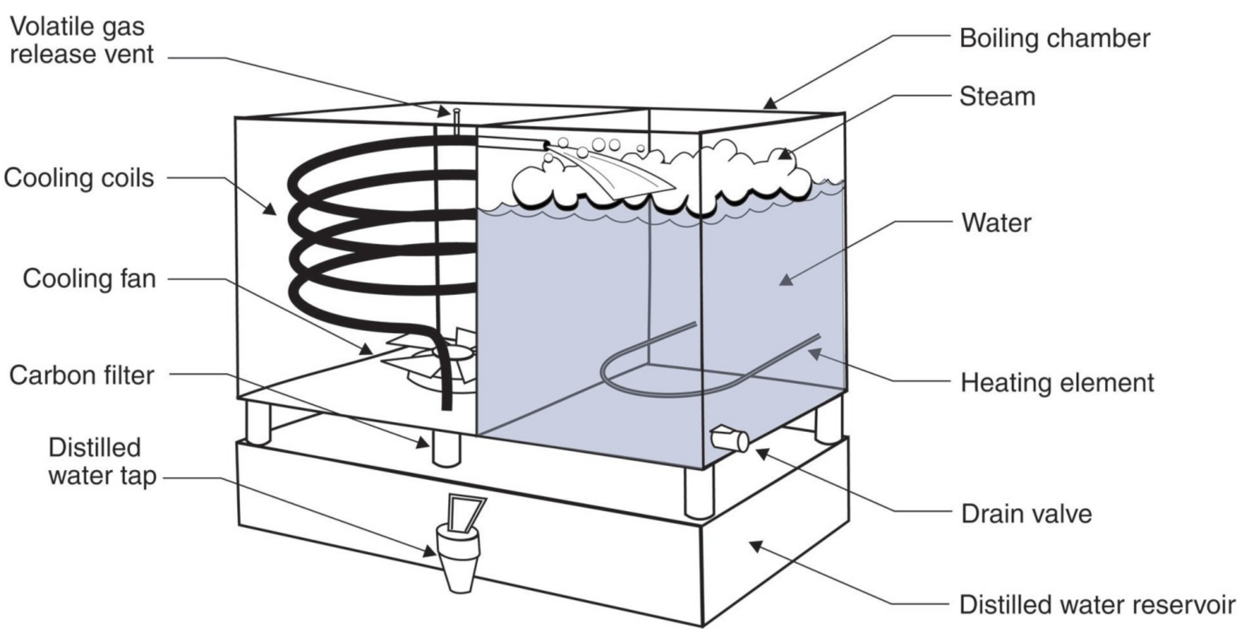
UV bulbs must be routinely replaced in accordance with manufacturer's instructions or when so indicated by warning lights. There is no way of knowing if the lamp is disinfecting properly, other than to test the water at a laboratory for microbial contamination. There are concerns that UV performance can be critically impaired by electrical supply variations. A dedicated power supply to the lamp is recommended. Do not install lamps on circuits that have other high load demands. It is extremely important that the bulb be functioning properly and that units be equipped with indicator lights to serve as a reminder for bulb replacement.

UV lamps must be routinely replaced.

Distillers

Distillers, as shown in Figure 7-5 Water Distiller, require regular cleaning using compounds recommended by the manufacturer. Cleaning frequency will depend on the type of water being treated. Distillers remove chlorine, so when testing for chlorine residual, draw the sample ahead of the distiller.

Figure 7-5 Water Distiller



Reverse Osmosis Units

There are many types of reverse osmosis (RO) membrane units available. All are designed for use on very high-quality feed water. It is common to incorporate a 5-micron filter, followed by a granular activated carbon filter, before the membrane as shown in Figure 7-6 RO Treatment Process. A compressed carbon block filter cannot be used in place of granular activated carbon filter. Both the 5-micron and the granular carbon filters require replacement at least four times per year. If the canister housings of the filters are slimy, they can be shock chlorinated and scrubbed as a part of the maintenance regime.

RO membranes as shown in Figure 7-7 RO Membrane reject most of the dissolved solids in water. If a total dissolved solids (TDS) test shows more than 50 TDS, the membrane is not working satisfactorily. Some units have indicators to warn of this condition. The RO membrane requires replacement once every one to three years. Sealing rings and end caps are critical features of the membranes. If they are damaged or incorrectly installed, water will by-pass the membrane and remain untreated. Corrective action is required immediately. If an RO unit stops producing water, the filters or the membrane are likely plugged. Replacement is required.

Figure 7-6 RO Treatment Process

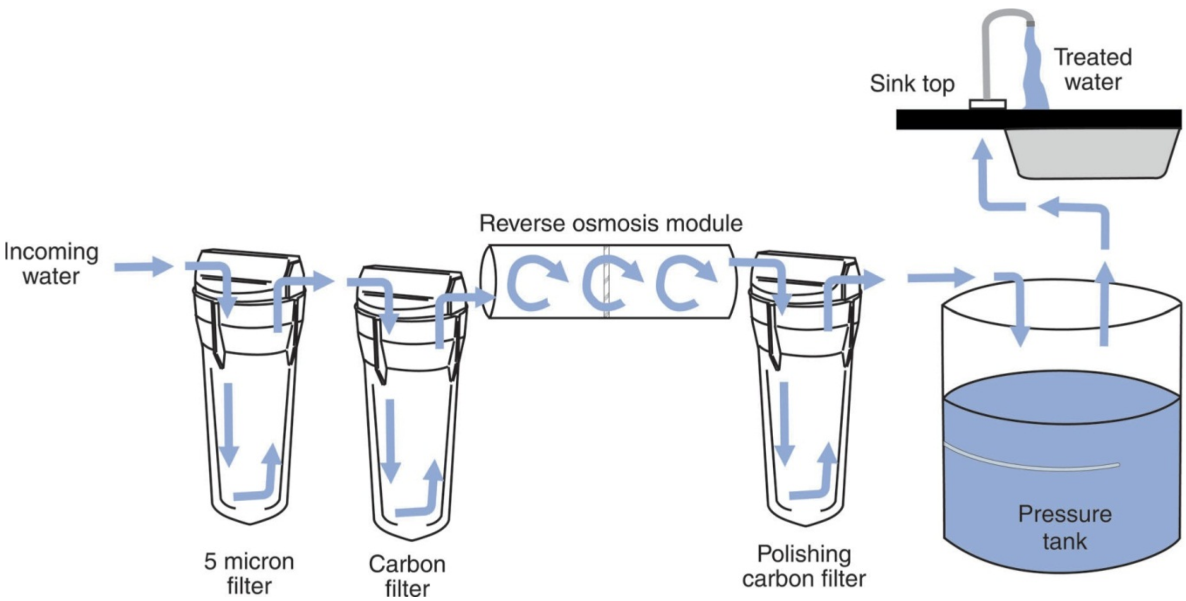
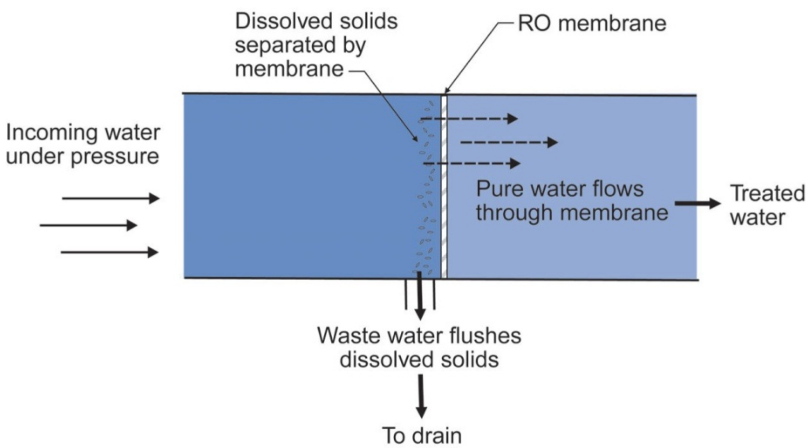


Figure 7-7 RO Membrane



Do not shock chlorinate RO membranes since they only tolerate low levels of chlorine. RO membranes remove chlorine, so when testing for chlorine residual, draw the sample ahead of the RO membrane.

A granular activated carbon, polishing filter is often incorporated after the RO unit. This filter should be replaced at least four times per year. Granular activated carbon, polishing filters do not have to be discarded when replaced. They can be re-used once as the carbon filter in front of the RO unit.

Always follow manufacturer's recommendations for correct operation and maintenance procedures. The procedures must be suited to the specific treatment device.

Monitoring

Regular monitoring is the only way to determine how well a treatment system is performing. Keep a record of chlorine residuals, backwashing frequency adjustments, source water appearance, clarity, smell, and taste. Monitoring costs very little and increases confidence that the system is working well.

To judge the performance of a treatment system, test tap water for microbial safety at least twice per year. Critical times for water testing are:

- Following spring runoff
- Following any major runoff event
- Mid-summer
- During maximum ice thickness

Collect water in sterile bottles following the instructions of the lab performing the tests. Samples must be properly labeled and packaged and delivered to the lab within the allotted time. Keep all results in a binder.

The following two Operation and Maintenance Schedule examples, Figures 7-8 Conventional Water Treatment System Schedule and 7-9 Biological Water Treatment System Schedule, show both the conventional treatment system and biological treatment system. Carefully review the examples to see the type of information recorded.

Equipment Certification

In Canada, water treatment equipment for private systems is not required to meet any standards or regulations. Furthermore, there is no Canadian certification mechanism for the effectiveness of water quality treatment.

Figure 7-8 Conventional Water Treatment System Schedule

Operation and Maintenance Schedule

Conventional Water Treatment System Operation and Maintenance Log — *N.B. Chlorine always tested at kitchen sink tap*

Date	Coagulation	Sand Filter	Carbon Filter	Chlorinator	Distiller
Feb 28	*Little floc visible*	*Backwash once/7 days*	*Backwash once/7 days*	*Tot. Cl = 0.5 mg/L*	*Cleaned Unit*
March	*Not tested; on holidays*				
April 2	*Adjusted dose for spring water*	*Manual backwash for 30 minutes and shock chlorinated filter; backwash once/4 days*	*Replace carbon media; backwash once/6 days*	*Tot. Cl = 0.0 mg/L increased to 0.5 mg/L*	*Cleaned unit; replaced elements*
April 9	*Settled floc OK*	*Backwash once/4 days*	*Backwash once/6 days*	*Tot. Cl = 0.2 mg/L; new batch and re-set to 0.5 mg/L*	*Working OK*
April 16	*Floc seems to be thickening*	*Backwash changed to once/3 days*	*Changed backwash to once/5 days*	*Tot. Cl = 0.1 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
April 23	*More floc evident*	*Backwash changed to once/2 days*	*Changed backwash to once/4 days*	*Tot. Cl = 0.3 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
April 30	*Floc is similar to last week*	*Backwash once/2 days*	*Backwash once/4 days*	*Tot. Cl = 0.6 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 7	*Floc turning brownish*	*Backwash once/2 days*	*Backwash once/4 days*	*Tot. Cl = 1.0 mg/L Re-set to 0.5 mg/L*	*Working OK*
May 14	*Floc brownish, same density*	*Backwash once/2 days*	*Backwash once/4 days*	*Tot. Cl = 0.1 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 21	*Thick floc (algae and sediment from rain)*	*Re-set backwash to once/day*	*Backwash once/4 days*	*Tot. Cl= 0.3 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 28	*Floc is still thick*	*Backwash once/day*	*Changed backwash to once/3 days*	*Tot. Cl = 0.2 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
June 7	*Floc is thinner*	*Re-set backwash to once/2 days*	*Re-set backwash to once/4 days*	*Tot. Cl = 0.7 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*

Figure 7-9 Biological Water Treatment System Schedule

Operation and Maintenance Schedule

Date	Slow Sand Filter	Biological Carbon Filter	Storage Tank	Ultraviolet Light	Reverse Osmosis
Feb. 28	*Air pump working*	*Air pump working*	*Air pump working*	*UV lamp is on*	*TDS is 350 mg/L (RO needs replacement)*
March	*On holidays; neighbours opened taps to flow 500 L of water weekly; air pump OK*			*Removed lamps; stained!*	
April 2	*Two manual backwashes with air and water and shock chlorinated filter*	*Three manual backwashes with shock chlorinated air and water, filtered water was the tank dirty, drained until clean*		*Replace UV bulb and quartz sleeve*	*Replaced membrane and all filters (5 micron, both carbon filters); TDS is 50 mg/L*
April 9	*Air stone replaced; old air stone was plugged*	*Air stone was replaced*	*Air pump and air stone is OK*	*Farm power surge. UV on/off test performed to check UV, OK*	*TDS measured 45 mg/L*
April 16	*Air pump working*	*Air pump working*	*Air pump working*	*UV lamp OK*	*TDS measured 45 mg/L*
April 23	*Air pump OK*	*Air pump OK*	*Air pump OK*	*UV quartz sleeve cleaned*	*TDS measured 53 mg/L*
April 30	*Manual air and water backwash*	*Air pump OK*	*Air pump OK*	*Replaced UV ballast (damaged by power surge)*	*TDS measured 55 mg/L*
May 7	*Air pump OK*	*Air pump OK*	*Air pump OK*	*UV lamp OK*	*TDS measured 150 mg/L ?? calibrated meter, TDS 65 mg/L*
May 14	*Dirty water but filter working OK*	*Filter OK, air supply OK*	*Water still OK and air system working*	*UV lamp OK*	*TDS measured 57 mg/L*
May 21	*Filter starting to plug, so performed mini-backwash*	*Flow rate slowing down*	*Air system OK*	*UV on/off self-test performed*	*TDS measured 70 mg/L*
May 28	*Manual air and water backwash*	*Filter flow OK after sand backwashed*	*Air system OK*	*UV lamp indicator OK*	*TDS measured 60 mg/L*
June 7	*Air pump working*	*Air pump working, stone OK, circulation seems fine*	*Air system OK*	*UV quartz sleeve dirty; cleaned sleeve*	*Replaced plugged 5 micron filter TDS measured 55 mg/L*

Although private treatment systems are not regulated in the United States and Canada, the National Sanitation Foundation International (NSF International) does certify small treatment devices if the manufacturer is willing to apply and pay for the third-party evaluation. Try to find equipment that meets certification by NSF International to ensure that equipment performance has been validated against accepted standards. Be aware, however, that the test was probably not performed using water as challenging to treat as dugout water

Devices may also be registered with the United States Environmental Protection Agency (USEPA). This registration means the equipment has been tested to ensure the device will not give off contaminants that may harm the consumer. The USEPA does not test equipment performance.

Most importantly, work with a dependable water treatment company.

Try to use water treatment equipment that has been certified by NSF International.

In 1999, Health Canada conducted the "Survey of Drinking Water Treatment Services Available on the Canadian Retail Market." The survey covered seventeen cities across Canada, including seven on the prairies. The treatment devices studied included softeners, distillers, reverse osmosis systems, filtration systems, microbial purifiers, and UV systems. About half the devices surveyed were filtration systems, and about one-quarter were reverse osmosis systems. The devices were divided into three groups:

- Treatment devices for disinfecting water contaminated by microorganisms
- Treatment devices for improving taste, odour, and appearance
- Treatment devices for removing chemical contaminants

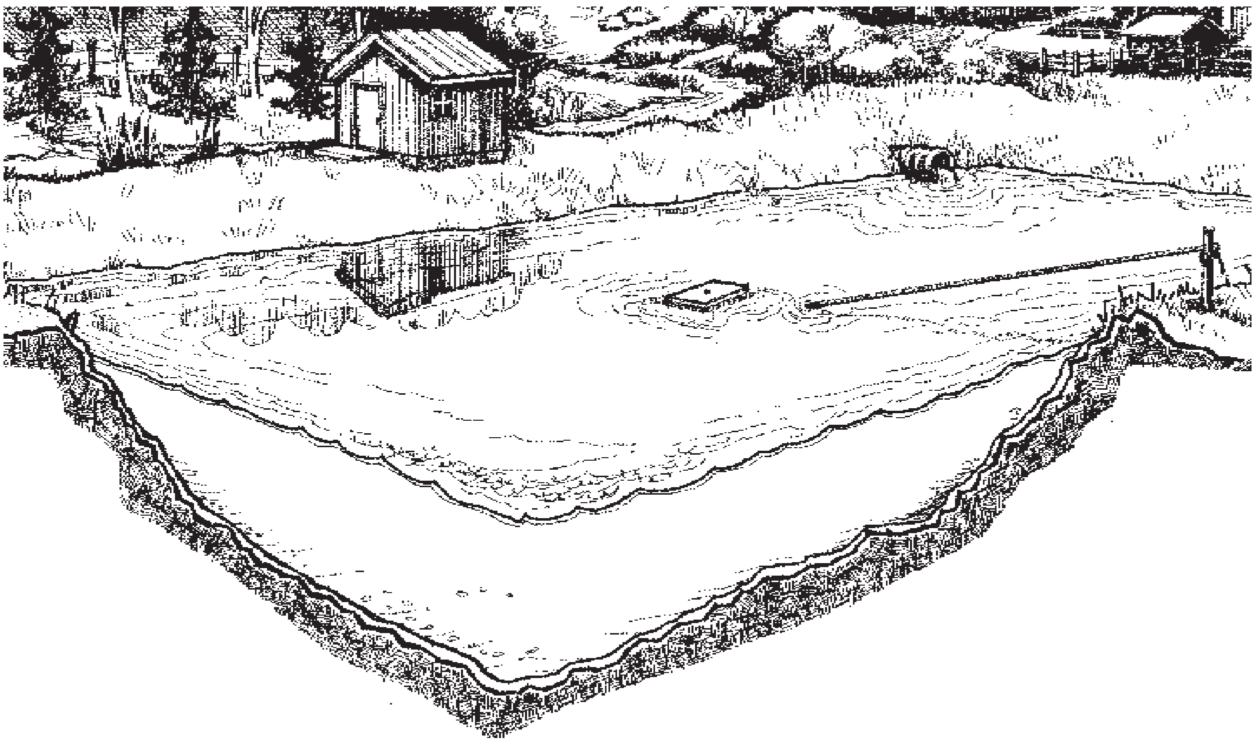
Health Canada Survey of Treatment Devices

Models Surveyed	318
Certified	34.0%
Uncertified	62.0%
Not NSF, but bearing name/logo	4.0%

The survey indicated that only one-third of the devices sold by retail were tested and certified by professional testing agencies such as NSF, Canadian Standards Association (CSA), or Underwriters Laboratories (UL). This leaves many questions unanswered as to the effectiveness and reliability of such devices in the treatment of dugout water.

Chapter 8

Dugout Management



The goal of dugout management is to protect and improve water quality. Some of the strategies for doing this through dugout location and design have been discussed in Chapter 3 – Planning. This chapter provides suggestions for preserving and enhancing water quality in existing dugouts. The cost and effort to properly manage a dugout 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.

Inspect dugouts weekly during April to September and monthly during October to March.

At a minimum, dugouts 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. The example in Figure 8-1 Dugout Maintenance Schedule shows a filled out Dugout Maintenance Schedule. Review the example to see the type of information recorded. Use the blank form located in the pocket at the rear of the manual to record dugout inspections.

Figure 8-1 Dugout Maintenance Schedule

Dugout Maintenance Schedule

Year: 2000 - 2001 Dugout No.: 1 Legal Land Description: *NW 30-50-30-W4*

Season	Date	Water Level	Comments (runoff, water quality, treatment, and maintenance)
Spring	*March 25*	*4 ft. from full*	*- very little runoff; only added 2 ft. of water* *- increase in sediment in water* *- checked aeration pump*
Summer	*June 15*	*5 ft. from full*	*- water clarity decreased because of cyanobacteria growth* *- treated dugout with 4 litres of copper algecide to control cyanobacteria*
	July 17	*6 ft. from full*	*- spot treated water weeds around dugout edge with 1/2 litre of Reward (diquat)*
	Aug 12	*7 ft. from full*	*- water clarity decreased* *- re-treated for cyanobacteria with 4 litres of copper algaecide*
Fall	*Oct 5*	*7.5 ft. from full*	*- approximately a 10 ft. depth of water left in dugout which will be adequate for winter use* *- pulled floating intake to bank and cleaned perforations* *- thoroughly checked dugout aeration pump diaphragm, and checked valves in preparation for winter* *- ensured runoff control gate opens and closes in preparation for next spring's runoff*
Winter	*Jan 15*	*10 ft. from full*	*- about a 5 ft. depth of water below ice* *- checked aeration pump*
	Mar 1	*11.5 ft. from full*	*- open runoff control gate prior to spring runoff*

Summary of comments for the year and proposed improvements/changes

- Water levels were very low because of the lack of spring runoff and high evaporation losses.
- Try to increase runoff into dugout with additional snow fencing and make plans for new shelterbelt.
- Need to clean air diffuser as it seems to be restricting air flow into the dugout.

Dugout Management Practices

There are a great number of dugout management practices. Many are known to be highly effective, while others are still in the experimental stages. Some techniques do not require special or highly processed products or services or a high level of knowledge. Other treatments involve chemicals available in commercial products. This chapter outlines some of these practices, including their strengths and weaknesses.

Established Practices

The practices presented in this chapter are well-established methods of greatly improving dugout water quality.

Continuous Aeration

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

Sediment Removal

Excavation of accumulated sediment from a dugout, every five to ten years, is an effective technique for improving water quality and extending the life of a dugout. Unfortunately, it is costly, and in some cases, excavation may exceed the cost of new dugout construction. Make careful cost estimates prior to deciding to clean out a dugout. Where two or more dugouts exist, divert all runoff away from the dugout to be excavated. Let the dugout dry up during summer and excavate the sediment in early fall. Where only one dugout 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. One option might be to pump the water to another location while the dugout is cleaned out and then pump the water back in.

Vegetation Control

Routine maintenance of the area around a dugout is important for maintaining water quality. Grassed buffers and runways surrounding dugouts 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 dugout. If possible, aquatic plants should be removed from the dugout before they die and decompose. Shrubs and trees will take root on the banks of the dugout. 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 dugout water.

Removal of Animals

Animals like salamanders, also called mud puppies, and muskrats can create problems in a dugout by burrowing, house building, and foraging for plant roots. This disturbs the sediments and keeps the water constantly turbid. The most effective way to remove muskrats is through trapping or hunting. Specially designed fencing can be used to keep them out in the first place.

Registered Copper Products

Copper based products are perhaps the most common chemical that was historically used to treat dugouts. It is also the least understood. Copper is an essential element for both plants and animals, but at high concentrations, it can be toxic. All herbicides and pesticides are regulated in Canada by the Canada Pest Management Regulatory Agency and must be licensed for use. This includes any product that are used to treat dugouts. Copper has be registered and licensed in the past to treat dugouts by various companies. Most licensed products that have copper in their ingredients come in a liquid form. It is important to read and follow the directions of a licensed product to avoid environmental contamination and maximize effectiveness. Copper treatments can be very effective at controlling cyanobacteria. However, copper 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 buildup of copper in the sediments of a dugout. This can harm or kill beneficial organisms and disrupt the normal biology of the dugout. 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 dugouts 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. Because of the toxins they produce, it is recommended that you wait a minimum of 14 days before the water is used for human or animal consumption. This should allow toxin levels to dissipate. Continuous diffused aeration during this period may also help degrade toxins.

Don't overdose! Copper is not effective on green algae!

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 dugouts.

More information on copper products and procedures for treating dugouts is provided in Appendix 3 Using Copper Products to Control Cyanobacteria.

Coagulation

As opposed to treating the entire dugout, 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 dugout as shown in Figure 8-3 Coagulation Cell. However, coagulation chemicals have successfully treated entire dugouts and have remediated flood affected turbid dugouts. The addition of powdered activated carbon has proven to be helpful for increased removal of dissolved organic matter, taste, and odour compounds. If a dugout is coagulated regularly, chemical residues should be monitored.

Figure 8-3 Coagulation Cell

The coagulation process is outlined in Chapter 7 – Water Treatment for Domestic Water Supplies.

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 8-4 Herbicide Treatment. Always follow label directions and use safe handling practices to protect yourself from the product. To calculate the proper dosage, you must accurately estimate the existing volume of water in the dugout to be treated.

Figure 8-4 Herbicide Treatment

Colourants

Colourants, known as pond dyes, were developed for golf courses to limit aquatic growth. They accomplish this by blocking ultraviolet light that aquatic plants use for photosynthesis. These products have shown been to have some beneficial effects for farm dugouts. Some dugout owners have reported some improvement of water quality due to reduced aquatic growth. It should be noted that these products will not compensate for poor dugout management and maintenance practices as previously discussed. Several companies have licensed these products through the Canada Pest Management Regulatory Agency (PMRA). Only PMRA-licensed colourant products licensed by Canada PRMA should be used.

Dugout Covers

Floating synthetic plastic dugout covers, as shown in Figure 8-5 Dugout Cover, have been used experimentally on dugouts 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 dugout 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 dugout covers have reported a significant reduction of evaporative losses in periods of drought.

Figure 8-5 Dugout Cover

Dugout covers have been used experimentally to prevent algae and plant growth.

Supplemental diffused aeration is essential to maintain oxygen levels in a covered dugout. 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. Dugout 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 dugout cover.

Disinfectants

Disinfectants are chemicals containing concentrated oxidants, such as chlorine, hydrogen peroxide, and ozone. Disinfectants are non-selective and will kill off many beneficial organisms. Disinfectants can also create byproducts that are potentially harmful to humans and should not be used in dugouts. Accordingly, they are not registered for use in dugouts.

Disinfectants are not registered for use in dugouts.

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, 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.

Because 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 can take up large amounts of phosphorus from water but must be constantly harvested and removed from the dugout. 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 dugouts to reduce algae problems. Both duckweed and water hyacinth can be harvested using a floating boom, as shown in the Figure 8-6 Harvesting Duckweed.

Figure 8-6 Harvesting Duckweed

Harvesting can be accomplished by dragging a floating timber boom across the dugout to the opposite shore, and removing the plants.

Fish

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

For the same reasons that plants should be removed from a dugout, fish should be harvested before they die and decompose. Grass carp or Tilapia are effective at removing plants in dugouts 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 dugout. Some fish, notably rainbow trout, can actually degrade water quality by eating phytoplankton and adding excrement to the water.

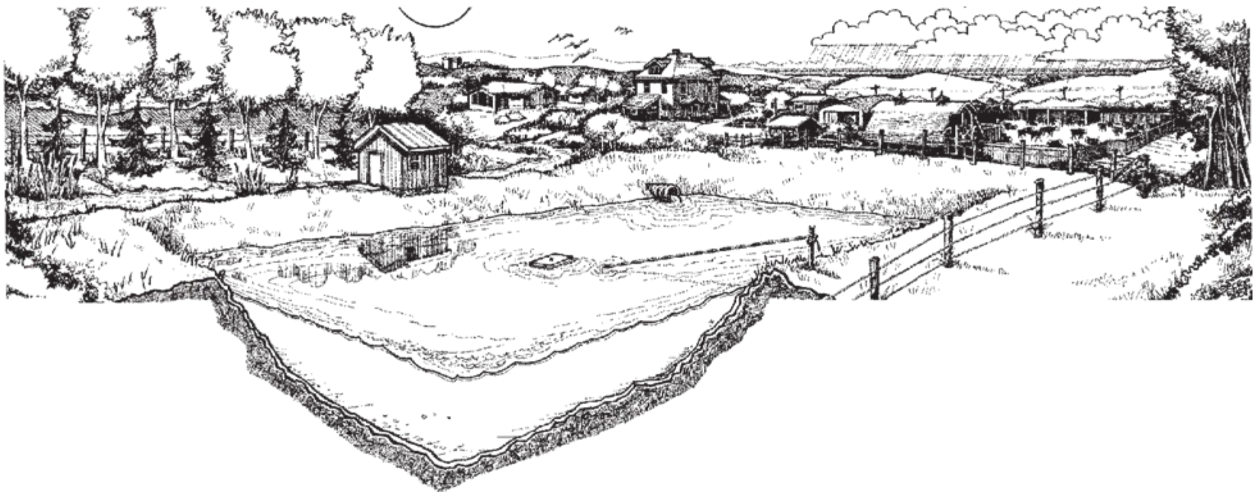
Miscellaneous Biological and Chemical Products

Many products are now available on the market that are advertised as having 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 various type of bacteria and chemical toxins. 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.

Many of these products are not registered by the PMRA for dugouts or farm ponds used for consumptive purposes and therefore should not be used. Until research proves the effectiveness and safety of these chemicals in dugouts, their use is not recommended.

Chapter 9

Trouble Shooting Guide for Dugout Problems



Dugout problems fall into two broad categories: water quantity and water quality. Problems can result from the watershed; the dugout location, design, and construction; the systems and equipment for pumping, aeration, and treatment; as well as management practices. This chapter 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, suggestions for corrective action, and references for further information within the manual.

Symptom 1 Low Dugout Water Levels

Possible Causes	***What to Check For***	***How to Correct (Options)***	***For More Information See Section On:***
Inadequate watershed	• observe or measure the area contributing water to the dugout during runoff events	• enhance snow trapping in the watershed with shelterbelts, snow fences or crop stubble • pump water to fill dugout • develop another water source	• Watershed Runoff Potential and Dugout Sizing, page 19. • Appendix 4 Contacts and References, page 106.
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	• Planning Farm Water Supplies, page 18. • Watershed Runoff Potential and Dugout Sizing, page 19.
Dugout too small	• compare annual water use and ice and evaporation losses with dugout size recommended • consider any future expansion, etc. • steady drop in water levels	• increase dugout size and/or add another source	• Watershed Runoff Potential and Dugout Sizing, page 19.
Possible Causes	What to Check For	How to Correct (Options)	For More Information See Section On:
Upstream blockages or drainage	• upstream beaver dams, snow damming or sediment blockages in water courses	• use a tractor to remove snow dams or drifts that re-direct water runoff	

Soil depositing in dugout	• soil erosion in watershed or watercourses draining to dugout	• use soil erosion techniques such as a grass cover and gated culvert inlets to the dugout to prevent sedimentation • sediment from dugout with a large trackhoe or dragline • use a 2 dugout system: one for a settling pond and the second for use	• Water Quality and Watershed Management, pages 22–24. • Dugout Design, page 27–39. • Sediment Removal, page 29. • Sedimentation Dugouts, page 29.
Seepage from dugout	• sand lenses or layers of silts and fractured clay	• use dugout sealing techniques • relocate dugout to suitable soil condition	• Large Scale Sealing Methods and Materials, pages 30 – 32.

Symptom 2 Human or Animal Sickness Caused by Water Contamination

Possible Causes	***What to Check For***	***How to Correct (Options)***	***For More Information See Section On:***
Water Contamination	• identify potential sources of contamination in the runoff area and seek professional advice on specific test parameters	• discontinue using the water source and consult local health unit, doctor or veterinarian for their assistance	• Health Risks and Water Quality, page 62. • Standard Testing of Drinking Water, page 65.
		• remove the source of contamination wherever possible and replace gravel trench filters with floating dugout intakes	• Health Risks and Water Quality, page 62. • Intake Systems, pages 37–40.
		• seek advice from water treatment specialists	• Steps in Water Treatment, pages 70 - 74.
		• provide another source of uncontaminated water or install appropriate water treatment equipment	• Steps in Water Treatment. pages 70 - 74.
		• install filtration and disinfection equipment	• Steps in Water Treatment, pages 70 - 74.
		• install polishing treatment equipment, such as R.O. or water distillers	• Steps in Water Treatment, pages 70 - 74.
		• install cistern to haul in water for household use and drinking	

Symptom 3 Black Smelly Water in Dugout

Possible Causes	***What to Check For***	***How to Correct (Options)***	***For More Information See Section On:***
Depletion of dissolved oxygen levels in dugout water (summer)	• abundant algae and weed growth and decay • cyanobacteria growth or • grass clipping appearance to water • dark green slime floating or deposited along dugout banks • dirty water after runoff • organic plant material deposited in dugout • recycling of nutrients from dugout sediments causing increased algal growth • water intake near dugout bottom • deterioration of water quality in wet well	• control algae and weed growth by employing control techniques • replenish oxygen with dugout aeration system • employ soil erosion techniques in watershed or watercourses, gated inlets, or two dugout system • clean dugout with excavation equipment and steepen all slopes to reduce weed and algal growth • use screened culvert inlets and locate deciduous trees away from dugout • ensure dugout aeration use a diffuser at the dugout bottom • raise floating intake near surface • clean out large-diameter wet wells or abandon in favour of small- diameter wet wells	• Dugout Management Practices, page 85. • Dugout Aeration Systems, pages 44 - 48. • Sedimentation Dugouts, pages 29, 85. • Water Quality and Watershed Management, pages 23–24. • Sediment Removal, pages 29, 85 • Vegetation Control, page 85. • Dugout Aeration Systems, pages 44 - 48. • Intake Systems, pages 37-38. • Wet Wells, pages 37- 38.
Depletion of dissolved oxygen levels in dugout water (winter)	• dugout aeration equipment not installed or working properly • snow cover on dugout reducing sunlight and oxygen produced by growing plants	• check and maintain dugout aeration equipment • where feasible carefully clean snow-cover from a portion • of dugout surface	• Dugout Aeration Systems, pages 44 - 48.
Black smelly water after Home Treatment System	• filter system fouled with organic material and organic sediments in pressure tank and/or hot water	• clean or replace filter medium • ensure adequate disinfection of water	• Steps in Water Treatment, pages 68 - 79.
Bottom dugout water entering from damaged intake pipe	• damaged intake pipe	• hire a diver to repair water intake pipe	• Steps in Water Treatment, pages 37 - 38.

Symptom 4 Dirty Dugout Water

Possible Causes	***What to Check For***	***How to Correct (Options)***	***For More Information See Section On:***
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-dugout system • use coagulants in dugout to clear water	• Dugout Design, page 28. • Water Quality and Watershed Management, page 29. • Sedimentation Dugout, page 29. • Coagulation, page 71.
Erosion in dugout	• soil erosion by wave action	• protect eroded dugout banks with erosion prevention materials like filter cloth, plastic, or riprap • install water treatment system including coagulants and sand filter	• Dugout Construction, page 27. • Steps in Water Treatment, page 74.
Muskrats, ducks, mud-puppies	• abundance of cattails and tunnels into dugout banks • floating cattails	• control cattails and remove muskrats by trapping, etc.	• Dugout Management Practices, page 85.
Contaminated runoff	• test water for bacteria, chemicals, and pesticides	• remove contaminants and/or cause from watershed • divert any contaminated runoff around dugout • install water treatment equipment	• Water Quality and Watershed Management, pages 27 – 29. • Steps in Water Treatment, pages 70 – 74.
Human activity	• swimming	• eliminate swimming	

Symptom 5 Discoloured Water and Staining

Possible Causes	***What to Check For***	***How to Correct (Options)***	***For More Information See Section On:***
Iron in Water	• brown to rusty coloured stains on clothes and plumbing fixtures	• install dugout aeration system and/or iron removal treatment equipment if required • replace gravel trench filters with floating water intakes	• Dugout Aeration Systems, pages 44 - 48. • Steps in Water Treatment, pages 70 - 74. • Intake Systems, pages 37 - 39.
Organic Matter in Water	• sloughy conditions around dugout • staining • abundance of organic material and peat soil in watershed or dugout area	• prevent flooding and slough conditions • re-locate dugout • coagulation treatment • re-locate dugout • cover organic material around the dugout with clay soil and grass cover	• Dugout Aeration, pages 44 – 48. • Dugout Design, pages 27 – 29. • Water Quality and Watershed Management, pages 23 – 24. • Dugout Management Practices, page 35.
	• decomposing plants and animals • excessive plant and algal growth in dugout	• install aeration equipment • use gated inlet to allow clear water into dugout • control nutrients coming into dugout which encourage plant and algal growth	
	• green to yellow colour (dissolved or particulate organic colour)	• control algae and plant growth with a combination of biological, physical and chemical methods • install aeration equipment	
	• shallow dugout with flat slopes	• steepen dugout slopes and deepen dugout	• Dugout Construction, page 27. • Water Quality and Watershed Management, pages 23 – 24.
	• watershed/watercourse vegetation containing clover etc.	• avoid planting vegetation that imparts colour	
	• excessive dosages of chemicals including copper sulphate for algal control resulting in man-made blooms of green algae	• reduce/eliminate chemical dosages and allow zooplankton to re-establish and control green algae	• Appendix 3 Using Copper Products…, pages 104 - 105.

Symptom 6 Mineral Scale and Grey Discolouring of Clothes

Possible Causes	***What to Check For***	***How to Correct (Options)***	***For More Information See Section On:***
groundwaum and magnesium hardness	• scale on plumbing fixtures, humidifier • grey colouring of clothes • test for hardness • gravel infiltration trench	• install ion-exchange water softener • use water additives such for hardness • install a direct intake	• Steps in Water Treatment, pages 70 – 74. • Intake Systems, pages 37 - 38.

Symptom 7 Taste and Odour in Water

Possible Causes	***What to Check For***	***How to Correct (Options)***	***For More Information See Section On:***
Iron in water	• refer to Symptom 5 for comments		
Sloughy, musty, fishy smell	• algal growth	• use algal control techniques • install activated carbon filtration	• Dugout Management Practices, page 85. • Steps in Water Treatment , pages 70 - 74.
Rotten egg smell	• refer to Symptom 3 for comments		
Salty, bitter taste	• high total dissolved solids caused by groundwater seepage or increased mineralization in gravel trench	• prevent poor quality water from seeping into dugout or relocate dugout • replace gravel filter trench with floating water intake	• Planning, pages 8 - 9. • Intake Systems, page 39.

Appendix 1

Alberta Provincial Regulations

Approvals and Water Licencing

The Water Act establishes that the Crown, the Province of Alberta, has ownership of all water. In Alberta, no licence is required for household purposes up to 275,000 imperial gallons (1250 cubic metres of water) per year. Under the *Water Act*, household purposes are defined as water used for human consumption, sanitation, fire prevention, and watering animals, gardens, lawns, and trees.

Approvals

A Water Act approval for dugout construction from Environment and Protected Areas is required if a dugout:

- is located in a watercourse frequented by fish or in lake or wetland
- is located in a watercourse, lake or wetland in an area that is subject to a reservation by order of the Minister under section 35 of the *Water Act* or to a Director's decision under section 53 of the *Water Act*,
- would change the flow of water on an adjacent parcel of land
- has a capacity greater than 2,500 cubic metres (550,000 Imperial gallons)
- is located in the same water course and parcel of land as an existing dugout
- is restricted by an approved water management plan

Licences

Licences are required to divert water from a dugout where:

- water is pumped into the dugout
- the dugout has a capacity greater than 12,500 cubic meters (2,750,000 imperial gallons)
- the total diversion of water from the dugout is greater than 6250 cubic meters (1,375,000 imperial gallons) per year
- the diversion of water is restricted by an approved water management plan
- the dugout is located in a watercourse, lake or wetland in an area that is subject to a reservation by order of the Minister under section 35 of the *Water Act* or that is subject to a Director's decision under section 53 of the Water Act.

To find out more about the Water Act and Dugouts

If an Approval or Licence is required, the applicant will need to make an application by accessing the Digital Regulatory Assurance System.

Digital Regulatory Assurance System (DRAS)

Online system designed to clarify regulatory requirements and manage a project's life cycle from application to closure. Water Act *Approval and licence* applications are submitted in the Digital Regulatory Assurance System (DRAS).

To find out more about the Digital Regulatory Assurance System (DRAS)

Alberta Wetland Policy

The Alberta Wetland Policy provides strategic direction and tools to make informed management decisions in the long-term interest of Albertans. The policy minimizes loss and degradation of wetlands, while allowing for continued growth and economic development in the province.

The goal of the Alberta Wetland Policy is to conserve, restore, protect and manage Alberta's wetlands to sustain the benefits they provide to the environment, society and economy.

Alberta Wetland Policy Implementation

Anyone planning an activity within a wetland must submit a Water Act approval application and adhere to the regulations.

- The application must include a wetland assessment by an authenticating professional as outlined in the Professional Responsibilities in Completion and Assurance of Wetland Science, Design, and Engineering Work in Alberta

To find out more about the Alberta Wetland Policy Implementation

Recreational Fish Culture Licence

This licence allows the holder to keep cultured fish, as specified, in the water body named on the licence. The licence is intended for the recreational, non-commercial use of the applicant or community. Fish cannot be commercially sold under the authority of this licence.

To find out more about Recreational Fish Culture Licence

Appendix 2

Water Quality Guide

Table 1 Causes and Symptoms of Some Waterborne Diseases

Disease	*Microbiological Agent*	*Symptoms*
Bacterial gastroenteritis	Bacteria –various organisms including E. coli,	Diarrhea or bloody diarrhea, abdominal cramps, fever, nausea, vomiting
Campylobacteriosis	Bacteria – campylobacter jejuni	Fever, abdominal pain, diarrhea or bloody diarrhea, nausea, vomiting
Cryptosporidiosis	Protozoa – cryptosporidia	Diarrhea, abdominal discomfort, slight fever, nausea, vomiting, headaches
Cyclospora infection	Protozoa – cyclospora	Diarrhea, bloating, abdominal cramps, nausea, vomiting, fever
Giardiasis	Protozoa – giardia	Diarrhea, abdominal cramps, nausea, vomiting, chills, headache, fever
Hepatitis	Virus – hepatitis A	Fever, chills, abdominal pains, jaundice, dark urine
Shigellosis	Bacteria – shigella	Diarrhea, or bloody diarrhea, fever, abdominal cramps
Typhoid fever	Bacteria – Salmonella typhi	High fever, headache, constipation, loss of appetite, diarrhea, vomiting, abdominal rash
Viral gastroenteritis	Viruses – Norwalk type, rotaviruses, adenoviruses, enteroviruses	Diarrhea, vomiting, fever, headache, abdominal cramps

Table 2 Human Health Chemicals and Their Associated Risk to Human Health

Chemical	***Source***	***Potential Health Effect***	***Canadian Drinking Water Quality Guideline (mg/L)***
Aluminum	Natural deposits in earth and alumi- num-based	Unknown; unproven links to Alzheimer's and Parkinson's	2.9
Barium	Natural deposits in earth	Circulatory system effects	2
Boron	Natural deposits in earth	Damage to reproductive system	5
Copper	Natural deposits; corrosion products from piping	Gastrointestinal irritation at levels much higher than guideline	1*
Lead	Natural deposit and corrosion prod- ucts from piping, solder, and some	Damage to kidneys, reproductive and nervous systems; development damage in young children	0.005 ALARA******
Nitrate	Fertilizers; human or animal wastes	Methemoglobinemia in infants under six months; unproven link to some cancers	45 as nitrate; 10as nitrate-nitrogen
Pesticides (including various fungicides, herbicides, rodenti- cides and insecticides)	Agricultural activities (spraying and water runoff)	Various effects depending upon type of pesticide; suggested links to cancers, damage to liver, kidneys, nervous and reproductive systems	Varies depending upon pesticide (see Health Canada website or contact local health authority for specific details)
Petroleum hydrocarbons	Leak in fuel oil or gasoline tanks allowing seepage into water	Some hydrocarbons have been linked to various cancers, damage to liver, kidneys, nervous system	Under review
Phytoplankton toxins	Natural toxins produced and released by microscopic	Liver and nervous system damage	Under review
Sodium*	Natural deposits in earth	Health risk only for individuals on salt-	200**
Sulphate	Natural deposits in earth; some flocculants	At elevated levels causes laxative effect leading to	500***
Trihalomethanes	By-products of disinfection of	Cancer	0.1****
Turbidity	Suspended mineral or organic material	Shelters pathogens from disinfection. In- creases requirement for disinfectant	1 NTU*****

* Guideline established based on aesthetic quality. Adverse health effects are possible at levels much higher than guideline.

** Guideline established based on aesthetic quality. Adverse health effects possible only for those on salt-restricted diets.

*** Guideline established based on aesthetic quality. Consumption of water with elevated levels of sulphates may result in gastrointestinal irritation including diarrhea.

**** Average of four quarterly samples.

***** Nethelometric Turbidity Units

****** ALARA reasonably achievable – As low as

Table 3 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 Sulfide	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

Appendix 3

Using Copper Products to Control Cyanobacteria

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.

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 liters. 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. It is best to follow the manufacturer's instructions/guidelines. In general, the recommended copper dosage is 0.25 mg/L for all dugouts. The following formulas can be used to calculate the amount of granular or liquid copper based products to treat the top 1 metre depth for cyanobacteria control.

- Formula for Granular Copper-Based Products

$$\frac{1}{\text{Percent (\%) Copper (Cu) in registered product}} \ X \ \begin{matrix}\text{Dugout Volume}\\ \text{to be Treated}\\ \text{(in top 1 metre)}\end{matrix} \ X \ \begin{matrix}\text{Treatment Dosage}\\ \text{(milligrams per litre)}\end{matrix} \ X \ \frac{\text{1 gram}}{\text{1000 milligrams}} \ X \ \frac{\text{1 kilogram}}{\text{1000 grams}} = \_\_\_\_\_ \text{ kilograms}$$

- Formula for Liquid Copper-Based Products

$$\frac{1}{\text{Percent (\%) Copper (Cu) in registered product}} \ X \ \begin{matrix}\text{Dugout Volume}\\ \text{to be Treated}\\ \text{(in top 1 metre)}\end{matrix} \ X \ \begin{matrix}\text{Treatment Dosage}\\ \text{(milligrams per litre)}\end{matrix} \ X \ \frac{\text{1 gram}}{\text{1000 milligrams}} \ X \ \frac{\text{1 kilogram}}{\text{1000 grams}} = \_\_\_\_\_ \text{ Litres (* specific gravity)}$$

* Specific gravity of liquid product being used.

Note: Contact the Canada Pest Management Regulatory Agency for a list of registered copper based products for the control of algae in dugouts.

For further information regarding the use and application of copper-based products for algae control, contact an Agriculture Water Specialist with Alberta Agriculture and Irrigation at 310-FARM (3276).

How to Apply Copper Treatments

Although cyanobacteria may be controlled, over-dosing a dugout with copper may cause a subsequent increase in the growth of green and brown algae.

Read the label and product literature for any restrictions on product use. Use a safe target dose as recommended on the label, being careful not to exceed the label rate.

Dilute the required amount of copper product into a volume of water so that it can be sprayed over the surface of the dugout. Spray the entire surface, with particular focus to areas where cyanobacteria populations are greatest. Spraying can be done from shore or from a boat. Alternatively, dry copper chemical can be put into a nylon sock, with ropes tied to both ends of the sock. Drag the chemical sock back and forth along the top of the water, covering the entire surface area. The dry compound will dissolve in the water. Spot treatment is also possible using one teaspoon (5 ml) of PMRA licensed dry copper sulphate product added to 1 gallon (5 liters) of water. Spot treat by spraying areas where cyanobacteria are starting to grow. Spot treatment may be useful when wind blows the bacteria against one shoreline.

Inspect the dugout once per week after treatment. Blooms can grow and die off within a one-to-two-week period. A dugout should not be treated with copper more than four times during one open-water season.

Appendix 4

Contacts and References

Contacts

Alberta Agriculture and Irrigation

J. G. O'Donoghue Building 7000 - 113 Street NW

Edmonton, Alberta T6H 5T6

Phone: 310-FARM (3276)

https://www.alberta.ca/agriculture-and-irrigation.aspx

Alberta Environment and Protected Areas

Phone : 310-000

https://www.alberta.ca/environment-and-protected-areas.aspx

Health Canada

Pesticide Product Information Database

https://pr-rp.hc-sc.gc.ca/pi-ip/index-eng.php

Appendix 5

Dugout Sizing Worksheet

Dugout Sizing Worksheets

Enter all information calculated step by step in the recording section below as follows:

Step 1	**Annual Water Supply Inventory**	____________	million Imperial gallons (mIg)
Step 2	**Annual Water Requirement**	____________	million Imperial gallons (mIg)
Step 3	**Sustainability of Water Sources**	______ Yes, or	______ No
Step 4	**Water Required From New Source**	____________	million Imperial gallons (mIg)
Step 5	**Evaporation Zone Number**	____________	
Step 6	**Required Dugout**	____________	ratio
Step 7	**Volume of Excavation**	____________	cubic yards
Step 8	**Dugout Depth**	____________	feet
Step 9	**Dugout Width**	____________	feet
Step 10	**No Data Recorded**		
Step 11	**Dugout Length**	____________	feet
Step 12	**Runoff Area Required**	____________	acres/mIg
Step 13	**Total Runoff Area Required**	____________	acres

STEPS TO SIZE YOUR DUGOUT

Step 1 Complete the **Annual Water Supply Inventory Worksheet**, and calculate the total volume of water available from all existing farm and non-farm sources for the purpose intended – wells, other dugouts, pipelines, canals, springs, rivers, and hauling, etc. To calculate the Expected Annual Volume Supplied by each well, multiply its well production in gpm x 8 hours per day x 60 minutes per hour x 365 days per year. For existing dugouts and other sources determine the expected annual volume supplied, based on past use and experience with these sources. The table provided in **Step 2** can be used to calculate the water requirements for various farm uses. Convert gallons to million Imperial gallons and round to the nearest 0.1 mIg.

Step 2 Estimate the volume of water required from the dugout by using the **Annual Water Requirement Worksheet**, and fill in accurate data for your existing operation or planned expansion. Convert gallons to million Imperial gallons and round to the nearest 0.1 mIg.

Step 3 Complete the **Sustainability of Water Sources Worksheet** provided to determine if the supply, construction materials, and water quality will last. Start by subtracting the Annual Water Supply Inventory in **Step 1**, from the Annual Water Requirement in **Step 2,** to determine either a water surplus or deficit. Based on all your responses in the worksheet, are your sources sustainable?

Step 4 Complete the **Water Required From New Source Worksheet** by totaling only the water uses you plan to supply from this new water source. Use the totals or subtotals you calculated for the various farm water uses in **Step 1**. Convert gallons to million Imperial gallons and round up to the nearest 0.1 mlg.

Step 5 Determine your Evaporation Zone number by locating your farm on the **Evaporation Zones Map**.

Step 6 Use the **Required Dugout** tables for this step. Use the table that matches the slope of your proposed construction. Locate the **Water Required From New Source** as determined in **Step 4**, in the first column of the **Required Dugout** table. Then read across to your Evaporation Zone number as determined in **Step 5**. The figure in the chosen column represents a ratio. It is important to understand that this number designates the recommended **two-year supply of water, accounting for the water use over a two years and water at the bottom of the dugout that is of poorer quality.**

Step 7 Multiply the Additional Demand as determined in **Step 4** and the Required Dugout Ratio determined in **Step 6** by **1,000,000** to convert it to gallons and then divide by **169**, which is the number of Imperial gallons in a cubic yard. The resulting number is the Volume of Earth to be excavated in cubic yards.

Step 8 From the **Dimensions and Capacity** tables, select the Dugout Depth chart appropriate to your planned construction dugout slope design. Charts are based on **15 foot depth.**

Note: For difference size options you can use the **Dugout/Lagoon Calculator** to size a dugout.

Step 9 Using the chosen **Dugout Slope** chart from **Step 8**, select the desired Dugout Width from the top row of the table. As a rule of thumb for dugouts with a side slope ratio of **1.5:1**, **the width should be at least four times the depth.** This is a good starting point, although further adjustment may be required to include factors created by topography, road setbacks, water courses, and construction equipment. **Steps 9** and **10** may have to be repeated to finalize your dimensions.

Step 10 From your selected Dugout Width in **Step 9**, read down to find the required volume in cubic yards as determined in **Step 7**.

Step 11 From the volume number selected in **Step 10**, read back across to the far, left-hand column to obtain the required length of the dugout.

Step 12 Locate your farm on the **Runoff Map**. This map allows you to determine the number of acres of land area required to collect each million Imperial gallons of dugout capacity. Acres required is given as a range of values as indicated in the legend to the left of the map. Use an average value of the range in your calculation or use the higher value for increased confidence.

Step 13 Multiply the Number of Acres Required determined in **Step 12**, by the Dugout Capacity Required in millions of Imperial gallons as determined in **Step 6**. The resulting number is the total Runoff Area for the dugout.

Note: The calculated runoff acreage or watershed obtained in Step 13 represents the land area needed to supply sufficient water to this dugout. A field trip will be needed to confirm that the dugout site or sites you have chosen actually receive the expected runoff. If a particular watershed is too small to provide enough water, you have three choices:

- find another watershed
- find an additional watershed and build a second dugout
- find another water source.

For further assistance on dugout and watershed sizing, contact a local water specialist.

Step 1 Annual Water Supply Inventory Worksheet

Existing Wells

Purpose	Land Location	Date Constructed	Depth (feet)	Casing Diameter (inches)	Well Production (gal/min)	Expected Annual Volume Supplied (gal)
1.						
2.						
3.						
					Well Subtotal A	

Existing Dugouts

Purpose	Land Location	Date Constructed	Length (feet)	Width (feet)	Depth (feet)	Capacity (million Imperial gallons)	Expected Annual Volume Supplied (gal)
1.							
2.							
3.							
						Dugout Subtotal B	

Other Existing Water Sources

1.	
2.	
3.	
Other Subtotal C	

Annual Water Supply Inventory Total (A+B+C)	= ____________ gallons	**Annual Water Supply Inventory**	= ____________ gallons / 1,000,000 = ____________ (nearest 0.1) million Imperial gallons

Step 2 Annual Water Requirement Worksheet

This worksheet can be used to estimate the total annual farm water requirement, and assist producers in sizing farm dugouts. The water requirements are based on typical average outside or in-barn temperatures experienced throughout the year. Livestock water consumption is much higher on hot summer days and pumping capacity requirements must be considered when designing farm water systems.

Household Use	No. of People		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Totals
People	________	x	60.0 gpd	x ________	= ________	= ________

Livestock Use	Animal Size	No. of Animals		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Totals
Beef							
Feeder (on silage)	550 lb.	________	x	4.0 gpd	x ________	= ________	
	900 lb.	________	x	7.0 gpd	x ________	= ________	
	1250 lb.	________	x	10.0 gpd	x ________	= ________	
Cows with Calves	1300 lb.	________	x	12.0 gpd	x ________	= ________	
Dry Cow (on pasture or hay)	1300 lb.	________	x	10.0 gpd	x ________	= ________	
Calves	250 lb.	________	x	2.0 gpd	x ________	= ________	
					Sub Total A gallons per year	________	
Swine							
Farrow to Finish		________	x	18.0 gpd	x ________	= ________	
Farrow to Late Wean	50 lb.	________	x	6.5 gpd	x ________	= ________	
Farrow to Early Wean	15 lb.	________	x	5.5 gpd	x ________	= ________	
Feeder	50-250 lb.	________	x	1.5 gpd	x ________	= ________	
Weaner	15-50 lb.	________	x	0.5 gpd	x ________	= ________	
					Sub Total B gallons per year	________	

Livestock Use	Animal Size	No. of Animals		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Total
Dairy							
Milking Cow **	Holstein	________	x	30.0 gpd	x __________	= __________	
Dry Cows/Replacemen Heifer	Holstein	________	x	10.0 gpd	x __________	= __________	
Calves	600 lb.	________	x	5.0 gpd	x __________	= __________	
** includes 3 gpd/cow for wash water					**Sub Total C** gallons per year	__________	
Poultry							
Broilers		________	x	0.035 gpd	x __________	= __________	
Roasters/Pullets		________	x	0.040 gpd	x __________	= __________	
Layers		________	x	0.055 gpd	x __________	= __________	
Breeders		________	x	0.070 gpd	x __________	= __________	
Turkey Growers		________	x	0.130 gpd	x __________	= __________	
Turkey Heavies		________	x	0.160 gpd	x __________	= __________	
					Sub Total D gallons per year	__________	
Sheep/Goats/Horses							
Ewes/Does		________	x	2.0 gpd	x __________	= __________	
Milking Ewes/Does		________	x	3.0 gpd	x __________	= __________	
Horses		________	x	11.0 gpd	x __________	= __________	
					Sub Total E gallons per year	__________	
					Livestock Total (A+B+C+D+E) gallons per year	= __________	= __________

Other Water Uses					Total
Irrigation of garden and yard use in the summer (assume 6 in. application)					
Irrigated area (sq ft)	0.5 ft x ________ sq ft	x	6.25 gal/ft^3	= ____________ gal	
Chemical spraying (acres)	10 gal/acre	x	_________ acres	= ____________ gal	
Greenhouse				= ____________ gal	
Fire (1200 gal/2 hour period)				= ____________ gal	
			Other Water Use Total gallons per year	= ____________	= __________

Annual Water Requirement Total	= ____________ gallons	**Annual Water Requirement**	= ____________ gallons / 1,000,000	= __________ (nearest 0.1)	million Imperial gallons

Step 3 Sustainability of Water Sources Worksheet

(a) To determine if the supply is sustainable:

________________ gallons	-	________________ gallons	=	________________ gallons
Annual Water Supply Inventory (Step 1)		Annual Water Requirement (Step 2)		Water Surplus or deficit

For wells:
Is your groundwater supply depleting, as indicated by a steady drop in non-pumping water levels over a period of months or years? _____ Yes, or _____ No

For dugouts:
Is the water level in your dugout(s) continuing to drop over a period of years? _____ Yes, or _____ No

Has your dugout(s) lost considerable volume and depth due to sediment deposition? _____ Yes, or _____ No

For other sources:
Are these sources sustainable? _____ Yes, or _____ No

(b) To determine if the construction materials will last:

For wells:
Does your well(s) have metal casing and/or liner? The life expectancy of this is about 20 years. _____ Yes, or _____ No

Do you notice more sediment being pumped from your well(s)? This can result from rusted well casing or liner. _____ Yes, or _____ No

(c) To determine if the water quality is sustainable:
Is it becoming increasingly difficult to maintain the water quality in your well or dugout by regular maintenance treatments such as shock chlorination for well(s) and algae and weed control in your dugout(s)? _____ Yes, or _____ No

Based on your previous experience with your water sources and your responses to (a), (b), and (c), in your opinion are your existing water sources sustainable for the next 5 year period?
_____ Yes (No new water source is required - stop here!)
_____ No (A new water source is required, go to Step 4)

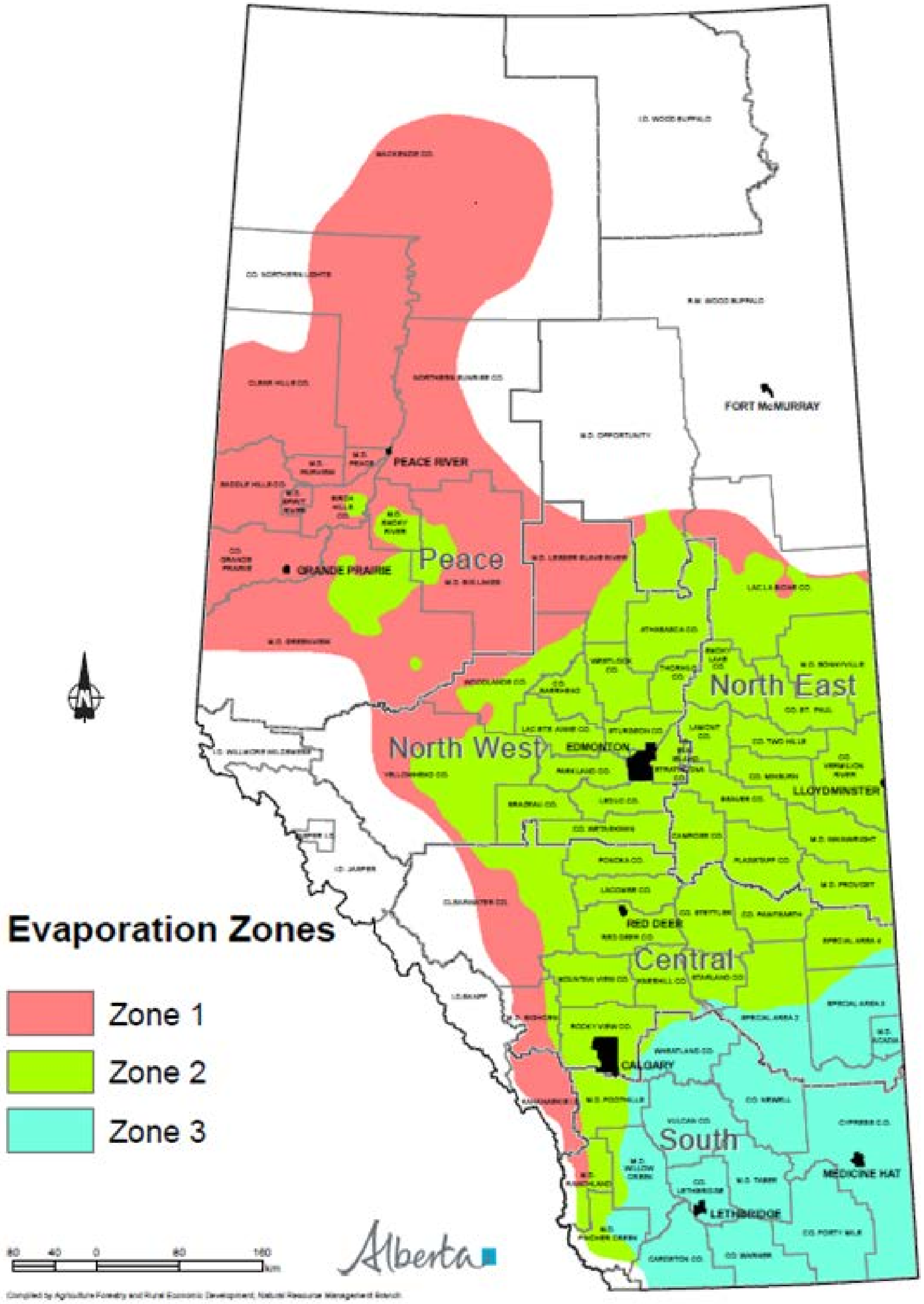
Step 4 Water Required From New Source Worksheet

Add together only the water uses to be supplied from this new water source.

____________ gallons	+	____________ gallons	+	____________ gallons	=	________________ gallons
Household Use		Livestock Use Subtotal or Total		Other Water Uses		Water Required From New Source

Convert gallons to million Imperial gallons:	____________ gallons	÷	1,000,000	=	______________	mlg
	Water Required From New Source				(nearest 0.1)	

Step 5 Evaporation Zones Map



Step 6 Required Dugout (Ratio)

Note: Use Table that is associated with planned construction slopes

All Slopes 1.5:1

Additional Annual Water Required (million Imperial Gallons)	Zone 1	Zone 2	Zone 3
0.05	4.91	5.35	5.81
0.1	3.81	4.08	4.35
0.2	3.21	3.33	3.55
0.3	2.98	3.11	3.25
0.4	2.85	2.96	3.08
0.5	2.77	2.87	2.97
1.0	2.57	2.64	2.71

All Slopes 2:1

Additional Annual Water Required (million Imperial Gallons)	Zone 1	Zone 2	Zone 3
0.05	4.76	5.26	5.74
0.1	3.90	4.16	4.49
0.2	3.36	3.53	3.71
0.3	3.10	3.27	3.42
0.4	2.97	3.09	3.25
0.5	2.88	3.01	3.13
1.0	2.67	2.75	2.84

End Slopes 4:1 - Side Slopes 1.5:1

Additional Annual Water Required (million Imperial Gallons)	Zone 1	Zone 2	Zone 3
0.05	4.63	5.06	5.51
0.1	3.82	4.10	4.40
0.2	3.32	3.52	3.72
0.3	3.11	3.28	3.44
0.4	2.99	3.13	3.28
0.5	2.91	3.04	3.17
1.0	2.70	2.80	2.89

1 End Slope 4:1 - 3 Slopes 1.5:1

Additional Annual Water Required (million Imperial Gallons)	Zone 1	Zone 2	Zone 3
0.05	4.73	5.16	5.61
0.1	3.79	4.06	4.34
0.2	3.25	3.43	3.62
0.3	3.04	3.18	3.33
0.4	2.91	3.04	3.17
0.5	2.83	2.95	3.06
1.0	2.63	2.72	2.80

All Slopes 3:1

Additional Annual Water Required (million Imperial Gallons)	Zone 1	Zone 2	Zone 3
0.05	5.99	6.66	7.39
0.1	4.62	5.04	5.48
0.2	3.81	4.08	4.38
0.3	3.48	3.70	3.93
0.4	3.30	3.48	3.68
0.5	3.17	3.34	3.51
1.0	2.87	2.99	3.12

End Slopes 4:1 - Side Slopes 2:1

Additional Annual Water Required (million Imperial Gallons)	Zone 1	Zone 2	Zone 3
0.05	4.75	5.22	5.71
0.1	3.98	4.29	4.62
0.2	3.46	3.68	3.91
0.3	3.24	3.42	3.60
0.4	3.10	3.26	3.42
0.5	3.01	3.15	3.30
1.0	2.78	2.89	2.99

Step 7 Volume of Excavation (cubic yards)

Additional Demand (Step 4)	______ mlg	**X**	**1,000,000**	**X**	**Ratio (Step 6)**	______ ratio	**=**	______ Imperial gallon	**÷**	**169**	**=**	**Volume of Earth** ______ cubic yard

Step 8-11 Dimensions and Capacity (cubic yards)

Chart for 15 Foot Depth -All Slopes 1.5:1 (volume in cubic yards)

Width (feet)	60	70	80	90	100	110	120
Length (feet)							
60	875						
80	1,292	1,611	1,931				
100	1,708	2,139	2,569	3,000	3,431		
120	2,125	2,667	3,208	3,750	4,292	4,833	5,375
140	2,542	3,194	3,847	4,500	5,153	5,806	6,458
160	2,958	3,722	4,486	5,250	6,014	6,778	7,542
180	3,375	4,250	5,125	6,000	6,875	7,750	8,625
200	3,791	4,777	5,764	6,750	7,736	8,722	9,708
220	4,208	5,305	6,403	7,500	8,597	9,694	10,792
240	4,625	5,833	7,042	8,250	9,458	10,667	11,875
260	5,041	6,361	7,681	9,000	10,319	11,639	12,958
280	5,458	6,888	8,319	9,750	11,181	12,611	14,042
300	5,874	7,416	8,958	10,500	12,042	13,583	15,125
320	6,291	7,944	9,597	11,250	12,903	14,556	16,208
340	6,708	8,471	10,236	12,000	13,764	15,528	17,292
360	7,124	8,999	10,875	12,750	14,625	16,500	18,375
380	7,541	9,527	11,514	13,500	15,486	17,472	19,458
400	7,957	10,054	12,153	14,250	16,347	18,444	20,542

Note: For difference size options you can use the **Dugout/Lagoon Calculator** to size a dugout

Chart for 15 Foot Depth -All Slopes 2:1 (volume in cubic yards)

Width (feet)	60	70	80	90	100	110	120
Length (feet)							
60	667						
80	1,000	1,278	1,556				
100	1,333	1,722	2,111	2,500	2,889		
120	1,667	2,167	2,667	3,167	3,667	4,167	4,667
140	2,000	2,611	3,222	3,833	4,444	5,056	5,667
160	2,333	3,056	3,778	4,500	5,222	5,944	6,667
180	2,667	3,500	4,333	5,167	6,000	6,833	7,667
200	3,000	3,945	4,889	5,833	6,777	7,722	8,667
220	3,333	4,389	5,444	6,500	7,555	8,610	9,667
240	3,667	4,834	6,000	7,166	8,332	9,499	10,667
260	4,000	5,278	6,555	7,833	9,110	10,387	11,667
280	4,333	5,723	7,111	8,500	9,888	11,276	12,667
300	4,667	6,167	7,666	9,166	10,665	12,165	13,667
320	5,000	6,612	8,222	9,833	11,443	13,053	14,667
340	5,333	7,056	8,777	10,499	12,220	13,942	15,667
360	5,666	7,501	9,333	11,166	12,998	14,830	16,667
380	6,000	7,945	9,888	11,833	13,776	15,719	17,667
400	6,333	8,390	10,444	12,499	14,553	16,608	18,667

Note: For difference size options you can use the **Dugout/Lagoon Calculator** to size a dugout

Chart for 15 Foot Depth - End Slopes 4:1- Side Slopes 1.5:1 (volume in cubic yards)

Width (feet)	60	70	80	90	100	110	120
Length (feet)							
60							
80							
100							
120	1,500	1,833	2,167	2,500	2,833	3,167	3,500
140	1,917	2,361	2,806	3,250	3,694	4,139	4,583
160	2,333	2,889	3,444	4,000	4,556	5,111	5,667
180	2,750	3,417	4,083	4,750	5,417	6,083	6,750
200	3,167	3,944	4,722	5,500	6,278	7,056	7,833
220	3,583	4,472	5,361	6,250	7,139	8,028	8,917
240	4,000	5,000	6,000	7,000	8,000	9,000	10,000
260	4,417	5,528	6,639	7,750	8,861	9,972	11,083
280	4,833	6,056	7,278	8,500	9,722	10,944	12,167
300	5,250	6,583	7,917	9,250	10,583	11,917	13,250
320	5,667	7,111	8,556	10,000	11,444	12,889	14,333
340	6,083	7,639	9,194	10,750	12,306	13,861	15,417
360	6,500	8,167	9,833	11,500	13,167	14,833	16,500
380	6,917	8,694	10,472	12,250	14,028	15,806	17,583
400	7,333	9,222	11,111	13,000	14,889	16,778	18,667

Note: For difference size options you can use the **Dugout/Lagoon Calculator** to size a dugout

Chart for 15 Foot Depth -1 End Slope 4:1 - 3 Slopes 1.5:1 (volume in cubic yards)

Width (feet)	60	70	80	90	100	110	120
Length (feet)							
60							
80							
100	1,396	1,722	2,049	2,375	2,701		
120	1,813	2,250	2,688	3,125	3,562	4,000	4,438
140	2,229	2,778	3,326	3,875	4,424	4,972	5,521
160	2,646	3,306	3,965	4,625	5,285	5,944	6,604
180	3,062	3,833	4,604	5,375	6,146	6,917	7,687
200	3,479	4,361	5,243	6,125	7,007	7,889	8,771
220	3,896	4,889	5,882	6,875	7,868	8,861	9,854
240	4,312	5,417	6,521	7,625	8,729	9,833	10,937
260	4,729	5,944	7,160	8,375	9,590	10,806	12,021
280	5,146	6,472	7,799	9,125	10,451	11,778	13,104
300	5,562	7,000	8,438	9,875	11,312	12,750	14,187
320	5,979	7,528	9,076	10,625	12,173	13,722	15,271
340	6,396	8,056	9,715	11,375	13,035	14,694	16,354
360	6,812	8,583	10,354	12,125	13,896	15,667	17,437
380	7,229	9,111	10,993	12,875	14,757	16,639	18,521
400	7,646	9,639	11,632	13,625	15,618	17,611	19,604

Note: For difference size options you can use the **Dugout/Lagoon Calculator** to size a dugout

Chart for 15 Foot Depth –All Slopes 3:1 (volume in cubic yards)

Width (feet)	60	70	80	90	100	110	120
Length (feet)							
60							
80							
100				1,750	2,056		
120				2,250	2,667	3,083	3,500
140				2,750	3,278	3,806	4,333
160				3,250	3,889	4,528	5,167
180				3,750	4,500	5,251	6,000
200				4,250	5,111	5,973	6,834
220				4,750	5,722	6,696	7,667
240				5,250	6,333	7,418	8,501
260				5,750	6,944	8,141	9,334
280				6,250	7,555	8,863	10,168
300				6,750	8,166	9,586	11,001
320				7,250	8,777	10,308	11,835
340				7,750	9,388	11,031	12,668
360				8,250	9,999	11,753	13,502
380				8,750	10,610	12,476	14,335
400				9,250	11,221	13,198	15,169

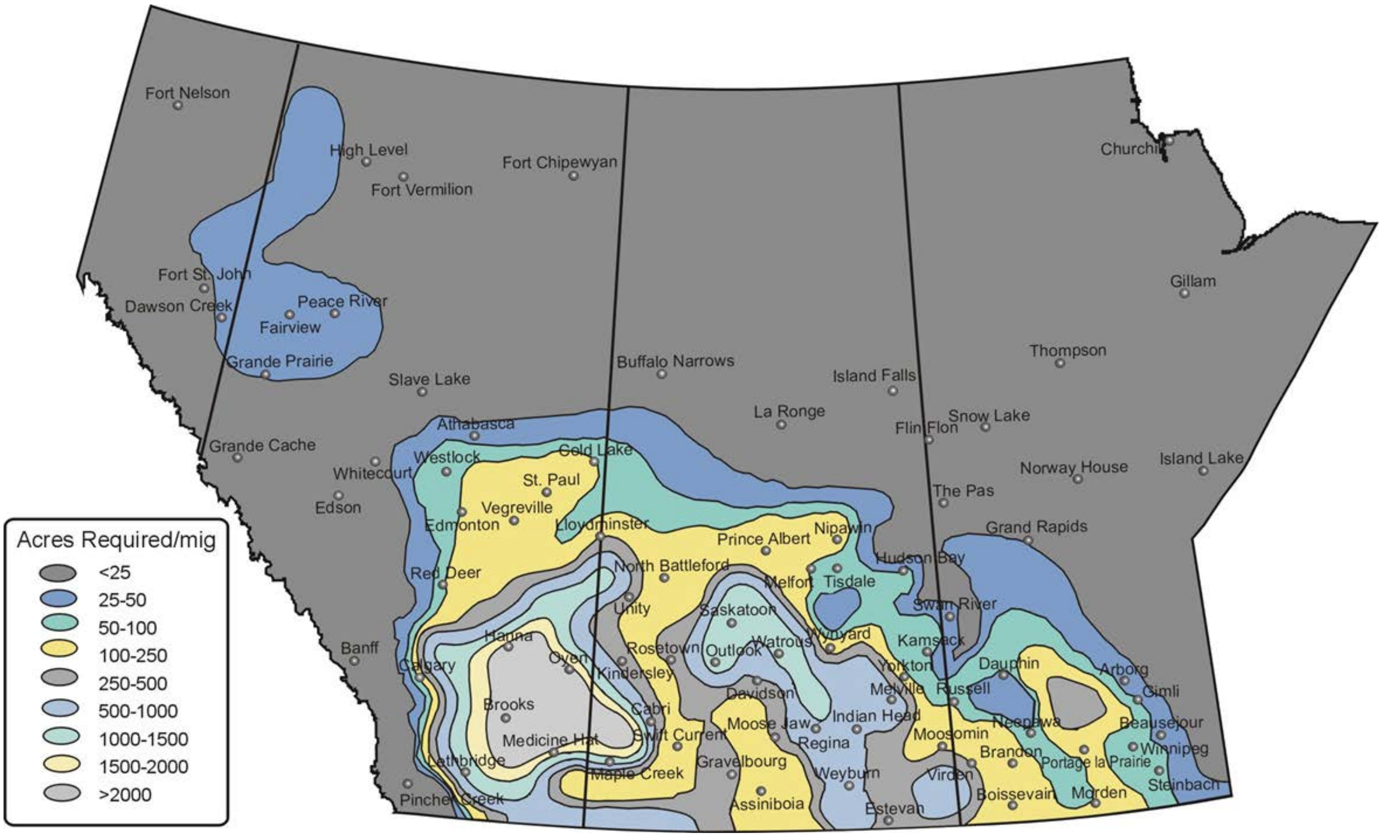
Note: For difference size options you can use the **Dugout/Lagoon Calculator** to size a dugout

Chart for 15 Foot Depth - End Slopes 4:1 - Side Slopes 2:1 (volume in cubic yards)

Width (feet)	60	70	80	90	100	110	120
Length (feet)							
60							
80							
100							
120	1,333	1,667	2,000	2,333	2,667	3,000	3,333
140	1,667	2,111	2,556	3,000	3,444	3,889	4,333
160	2,000	2,556	3,111	3,667	4,221	4,778	5,333
180	2,334	3,000	3,667	4,334	4,998	5,667	6,333
200	2,667	3,445	4,222	5,001	5,775	6,556	7,333
220	3,001	3,889	4,778	5,668	6,552	7,445	8,333
240	3,334	4,334	5,333	6,335	7,329	8,334	9,333
260	3,668	4,778	5,889	7,002	8,106	9,223	10,333
280	4,001	5,223	6,444	7,669	8,883	10,112	11,333
300	4,335	5,667	7,000	8,336	9,660	11,001	12,333
320	4,668	6,112	7,555	9,003	10,437	11,890	13,333
340	5,002	6,556	8,111	9,670	11,214	12,779	14,333
360	5,335	7,001	8,666	10,337	11,991	13,668	15,333
380	5,669	7,445	9,222	11,004	12,768	14,557	16,333
400	6,002	7,890	9,777	11,671	13,545	15,446	17,333

Note: For difference size options you can use the **Dugout/Lagoon Calculator** to size a dugout

Step 12 Runoff Map



Step 13 Runoff Area

Number of Acres Required (Step 12)		x	Dugout Capacity Required		=	Runoff Area	
	acres required/mlg			mlg			acres

Appendix 6

Dugout Sizing Worksheet Example

Joe Agricola Example

This example is provided to help you size your farm dugout and determine if the runoff area selected will supply sufficient water.

Mr. Joe Agricola lives near Stettler Alberta. He farms with his wife, son, daughter-in-law, and two grandchildren (six people in total). They currently have a 150 sow, farrow to finish hog operation and use two wells to supply water for the hogs and their two households. They also require water for their farmyard, gardens, and crop spraying. They plan to expand their farming operation to include 200 cow-calf pairs. The cattle will be at home for 7 months of the year and then moved away to summer pasture.

Step 1 - Joe is concerned that his existing farmyard wells may not supply sufficient water for the planned expansion. To determine this, he completed the Annual Water Supply Inventory Worksheet. Joe calculated the total, annual water volume that could be expected from the two existing wells to be 1,226,400 gallons or 1.2 million Imperial gallons (mIg).

Step 2 - Joe then completed the Annual Water Requirement Worksheet and calculated this to be 1,773,025 gallons or 1.8 mIg. The two wells are connected into the same water system, and are currently supplying approximately 1,116,900 gallons or 1.1 mIg of this total. The household uses 131,400 gallons, and the hog operation uses 985,500 gallons annually.

Step 3 - Joe completed the Sustainability of Water Sources Worksheet and decided that his two wells are only sustainable to supply the existing water requirements for the two households and the hog operation resulting in a deficit of 546,625 gallons. From experience Joe knew it was extremely difficult to find a good producing well on his farm and therefore decided on a dugout to meet the remaining farm water requirements.

Step 4 - Joe used the Water Required From New Source Worksheet to calculate the amount of water he will require from the new dugout. For the cattle he needed 504,000 gallons, plus 152,125 gallons for yard watering and crop spraying, for a total of 656,125 gallons or 0.7 mIg (rounded to the nearest 0.1).

Step 5 - From the Evaporation Zones Map he determined that his farm was located in Zone 2.

Step 6 - Joe uses 0.7 million Imperial gallons from Step 4, for the Required Dugout Capacity table. He plans on construction a dugout with a track-hoe with 1.5:1 slopes on all sides and 15 feet in depth. He uses the table with All Slopes 1.5:1. Reading down the left column he notices that there is not a figure for 0.7. He chooses the closest number that is smaller 0.5. Then reading to the right for Zone 2 he obtains a factor of 2.87. He will confirm with his dugout construction contractor that this depth was possible at the proposed site.

Step 7- Joe calculated the volume of earth to be excavated by multiply the Additional Demand, as determined in Step 4**, 0.7** and the Dugout Capacity Ratio, as determined in Step 6**, 2.87** by **1,000,000** to convert it to imperial gallons The resulting number is the Volume of Earth to be excavated in imperial gallons. 0.7 mIg X 1,000,000 X 2.87 = 2,009,000.

Step 8 - Joe finds the volume in cubic yards to be excavated by dividing 2,009,000 by 169 = 11,888 cubic yards.

Step 9 - In his initial conversation with the dugout contractor Joe has decided to use 1.5:1 slopes for the construction. Joe chooses the chart that matches his proposed slope design for the dugout. All Slopes 1.5:1 Dimensions and Capacity table.   The charts are based are for 15 foot depth.

Step 10 -Joe chooses a 120 foot width.

Step 11 - Moving down the table to find the closest capacity to 11,900 cubic yards as shown. He reads to the far left column to obtain the required length of dugout to meet the required capacity. Joe decides on the 240 length since it will provide him with a capacity of 11,875 cubic yards.

Step 12 - Joe located his farm on the Runoff Map to find that it required between 250 and 500 acres to fill a one million Imperial gallon dugout. To be safe he selected the higher end of the range at 500 acres.

Step 13 - He multiplied 500 acres by 2.0 (Step 7: 2,009,000/1,000,000 = 2.0) to determine the size of the runoff area required for his dugout (500 acres x 2.0 = 1000 acres).

There appeared to be a good dugout location within 500 feet of the farmyard. With his calculated information in hand, and a local topography map, Joe set off on a field trip to determine local runoff patterns and confirm the location for the proposed dugout. At the site, 500 feet from his buildings, there was approximately 750 acres of runoff area, which was less than the 1000 acres his dugout required. For this reason, he selected another site 500 feet further downstream where a second waterway contributes another 350 acres of runoff area. Joe considered the additional runoff water was well worth the costs for 500 feet of additional trenching and piping.

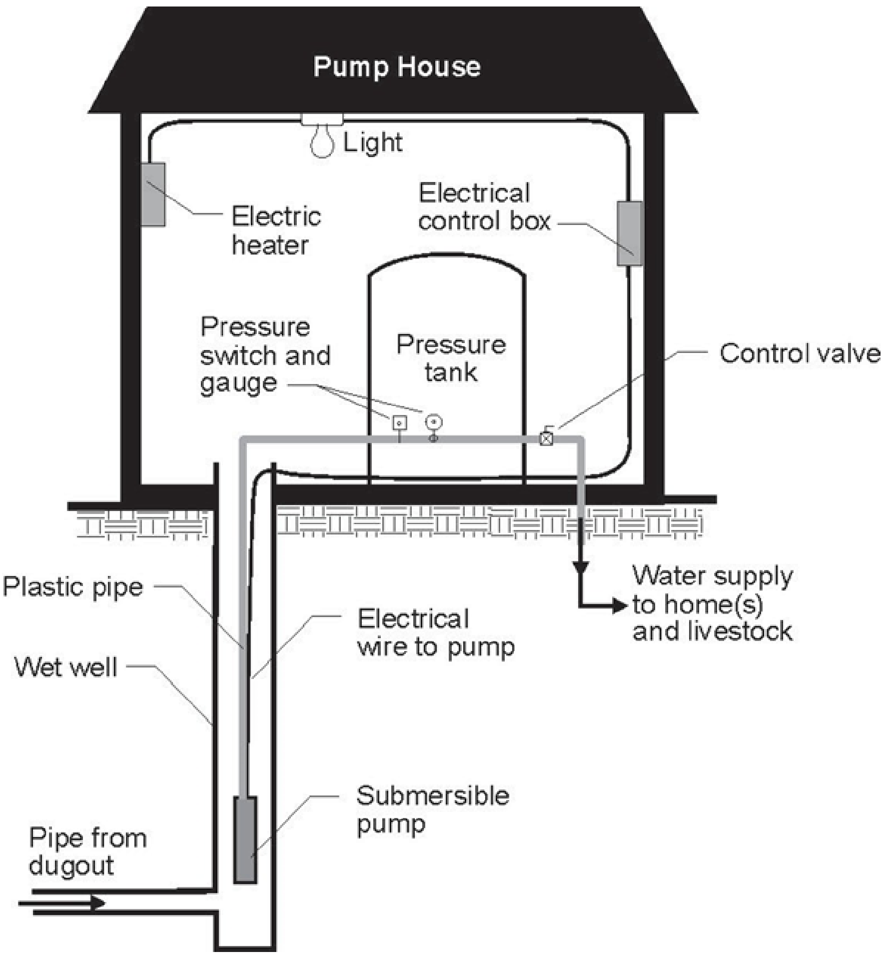
Since the proposed size is larger than 550,000 Igal (2,500 cubic metres), Joe accesses the Digital Regulatory Assurance System to obtain an approval from Alberta Environment and Protected Areas (EPA) prior to proceeding with the construction.

Note: For additional information on dugout and runoff area sizing contact a water specialist in your area.

Appendix 7

Water System Sizing Worksheet

Water System Sizing Worksheet



Water System Sizing Worksheet

This worksheet can be used to determine the size of pump, pressure tank, and water pipe required for a farm water system. Dugouts, unlike most water wells, have a huge reservoir of water, and can be pumped at much higher flow rates. Therefore, it is important to properly size dugout pumps and pipelines to take full advantage of the dugout.

Enter all information calculated step by step in the recording section below as follows:

Step 1	**Water System Fixtures**			
Step 2	**Required Pump Flow Rate**	________	gallons per minute	
Step 3	**Conversion to U.S. Gallons**	________	U.S. gallons per minute	
Step 4	**Pump Selection**			
	Lift	________	feet	
	Pressure needed	________	psi	
	Pump horsepower required	________	hp	other specifications ____________________
Step 5	**Pressure Tank Size**	________	U.S. gallons	other specifications____________________
Step 6	**Length of Supply Pipeline**	________	feet	
Step 7	**Pipe Size**	________	inches	other specifications ____________________

STEPS TO SIZING YOUR WATER SYSTEM

Step 1 Calculate the peak water use rates in gallons per minute (gpm) for all of the existing and proposed water system fixtures.

Water System Fixtures	No. of Fixtures		Peak Use Rate		Totals
Automatic Cattle Waterers (100 head size)	_____	x	5 gpm	=	________ gpm
Hog Nipple Waterers	_____	x	1 gpm	=	________ gpm
Poultry Fountain	_____	x	1 gpm	=	________ gpm
Yard Hydrants	_____	x	5 gpm	=	________ gpm
Household (number of households)	_____	x	5-10 gpm	=	________ gpm
Fire Hydrant	_____	x	10 gpm	=	________ gpm
Other ______________________	_____	x	____ gpm	=	________ gpm
Other ______________________	_____	x	____ gpm	=	________ gpm

Step 2 To determine the Required Pump Flow Rate you need to consider which water uses, listed in **Step 1,** will likely occur at the same time and total those together. **Note:** The minimum design flow rate of the system must exceed the peak use rate of the fixture(s) that use the largest amount of water.

Required Pump Flow Rate = ________ gpm

Step 3 Convert the Required Pump Flow Rate from **Step 2** into U.S. gallons because practically all pumps available in Canada are rated in U.S. gpm.

Conversion to U.S. Gallons
Required Pump Flow rate ________ gpm x 1.2 = ________ U.S. gpm

Step 4 To select a pump you need to determine the lift and pressure. It is recommended that you take this information plus the Converted Pump Flow Rate from **Step 3**, to a reputable pump dealer or a water specialist for correct pump selection. They will recommend the required pump horsepower and other specifications.

Pump Selection		
Lift	Depth of dugout ______ feet + Farmyard elevation above dugout ______ feet =	_______ lift in feet
Pressure needed		_______ psi
Pump horsepower required		_______ HP

Step 5 Sizing a pressure tank is based on the Converted Pump Flow Rate and the amount of useable water volume or drawdown. The drawdown is the amount of water that can be withdrawn from the pressure tank between high and low pressure settings. For dugouts, the sealed diaphragm or bladder type tanks are the best choice. In these types of tanks only 1/3 of the volume of the tank is available as drawdown. Therefore, the Pressure Tank Size must be 3 times the drawdown and match the gpm rating (flow rate) of the pump. For example, a 10 gpm pump requires 10 gallons of drawdown or a 30 gallon tank size.

Pressure Tank Size = 3 x Pressure tank drawdown _________ U.S. gallons = _________ U.S. gallon capacity or larger

Step 6 Measure the distance from the dugout to the center of the distributing system.

Length of Supply Pipeline = _________ feet

Step 7 To determine the Required Pipe Size match the pump flow rate from **Step 3**, in the left column of the adjacent table with the length of the supply line from **Step 6.**

Required Pipe Size = _________ inches

Flow Rate (U.S. gpm)	Length of Pipe 200 ft	400 ft	600 ft	800 ft	1000 ft
2	1	1	1	1	1
4	1	1	1	1	1
6	1	1	1¼	1¼	1¼
8	1	1¼	1¼	1¼	1¼
10	1¼	1¼	1¼	1½	1½
12	1¼	1¼	1½	1½	1½
14	1¼	1½	1½	1½	2
16	1½	1½	1½	2	2
18	1½	1½	2	2	2
20	1½	1½	2	2	2
25	1½	2	2	2	2
30	2	2	2	2	2½
35	2	2	2½	2½	2½
40	2	2½	2½	2½	2½

Note: In sizing the above lines, no allowance has been made for elevation differences. For more specific information contact a water specialist in your area.

Note: The minimum pipe size recommended for farmyard water distribution systems is 1¼ inches. This will reduce friction losses in the pipe and allow for future expansion that was unforeseen.

Appendix 8

Dugout Maintenance Schedule

Dugout Maintenance Schedule

Date:______________ Dugout Number:__________ Legal Land Location_______________________________

Season	Date	Water Level	Comments (runoff, water quality, treatment, and maintenance)
Spring			
Summer			
Fall			
Winter			

Summary of comments for the year and proposed improvements/changes:

____

____

____

____

Appendix 9

Operation and Maintenance Schedule

Operation and Maintenance Schedule

Conventional Water Treatment System

Conventional Water Treatment System Operation & Maintenance Log				*N.B. Chlorine always tested at kitchen sink tap*	
Date	**Coagulation**	**Sand Filter**	**Carbon Filter**	**Chlorinator**	**Distiller**

Operation and Maintenance Schedule

Biological Water Treatment System

Biological Water Treatment System Operation & Maintenance Log					
Date	Slow Sand Filter	Biological Carbon Filter	Storage Tank	Ultraviolet Light	Reverse Osmosis