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Economics of Water Systems

Direct surface water access can result in fecal contamination that adds nutrients to the water and reduces palatability and consumption by livestock (William et al. 2002). Surface water contamination causes both environmental problems and herd health problems. Herd health problems include: increased exposure to water-transmitted diseases, bacteria, viruses and cyst infections, blue-green algae toxins, foot rot and reduced weight gain (Alberta Agriculture and Forestry 2007).

Access to clean water can improve cattle herd health, increase weight gain and backfat. Lardner et al. (2005) reported that suckling calves whose dams drank from water troughs gained on average 0.09 lbs per day more than calves whose dams had direct access to the dugout. Because water and forage intake are closely related, as cows drink more water they also spend more time eating and therefore produce more milk for their calves. Calves with access to clean pumped water were on average 18 lbs heavier at weaning time.

William et al. (2002) evaluated the effect of water selection on cattle weight gains, cow backfat thickness and activity levels under regimes of drinking **clean water** (water delivered to trough from a well, pond, or dugout), **pond water** pumped to a trough and **direct access** to the pond. They found that calves, with dams drinking clean water, gained 9% more weight than calves with dams that had direct access to the drinking pond; but cow weight and backfat thickness were not affected.

Holechek (1980) reported both a decrease in water consumption and weight gain of cattle drinking water from contaminated water sources. Lardner et al. (2005) found that calves provided water **aerated and pumped** to a trough in early summer tended to have greater (0.18 and 0.19 lb/day respectively) weight gains than calves drinking directly from a dugout. The effectiveness of any water treatment in improving cattle weight gains appeared to be related to improved water palatability. Improved water palatability increased both water and feed consumption. This suggested that improving water quality with aeration and pumping to a trough will improve weight gain 9-10% over a 90-day grazing period in most years.

Lardner et al. (2005) also found that yearling steers had 8-9% higher weight gain when they had access to water that had been coagulated or **aerated** before it was pumped compared to steers that only had direct access to dugout water. Steers gained 3% more weight with access to untreated pumped dugout water versus direct dugout access.

Overall, the potential benefits of implementing a water system include:

- Increased weight gain
- Improved herd health & decreased disease problems
- Environmental benefits through water source protection & longer water source life with decreased localized soil erosion
- Safer watering sites for livestock
- Improved pasture usage
- Enhanced wildlife habitat

Based on results of Lardner et al. (2005), a water system calculator has been developed to estimate the potential economic benefits and costs of alternative watering systems compared to direct access to dugout water.

TYPES OF SYSTEMS

There are a number of different options for watering systems such as wind-powered pumping system, solar-powered pumping system, underground pipe, and aeration treatments on dugout water.[2]

Wind-powered pumping system[3]

Windmills use a propeller to convert energy in the wind to power a pump. Windmills have been used to pump water

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[2] See the Stockman's Guide to Range Livestock Watering (1995) and Wilson and Clark (2003) for more information.

[3] Battery is required for wind-powered pumping system, solar-powered pumping system and solar-powered aeration system. Assume each battery (12V 150Ah) can support 2,500 Imp. gals water supply.

from wells for centuries. They can also be used to aerate dugouts and ponds. Windmills are simple and generally require little maintenance. They work well in remote locations. But the site must be free of windbreaks. High variability in wind speeds across the prairies increases the need for storage capacity, more storage capacity is generally required than with solar systems. The number of windmills needed is calculated based on each windmill's pumping capacity and the herd size[4].

Solar-powered pumping system

Solar panels containing photovoltaic cells convert sunshine into electrical energy to power water pumps. Solar pumps can be operated in remote locations. This kind of watering system is reliable and can provide large volumes of water. This is suitable for the cows because they travel more as a herd and tend to come all at once to a water source. Small watering troughs equipped with a less efficient waterer tend to be insufficient (Stockford, 2017).

The Western Canadian Cow-Calf Survey (2014) reports that just over 40% of respondents limit their cattle from having direct access to the water source through the provision of water pumps, troughs or gravity-fed systems. According to Census of Agricultural (2016), the adoption of renewable energy management practice is much lower than other practices on Canadian beef cattle farms. The most common are solar panels with 5.9% of farms and wind turbines on 0.8% of farms. In general, Alberta and Saskatchewan have the highest rates of technology adoption. In contrast, British Columbia, Quebec, and the Atlantic provinces have the lower rates of adoption. Wind-powered and solar-powered pumping systems must suit the environment and management conditions of the operation. This explains some of the regional differences in adoption.

Underground pipeline

The pipelines are buried to a shallow depth to supply water to the livestock away from the surface source. The water supply can come from either a pump or a gravity flow reservoir placed at an appropriated level to get decent flow. A pipeline system is particularly advantageous for producers who split their herds into multiple paddocks, but is less desirable for remote locations, and pipes must be drained in the autumn to avoid freezing (Stockman's Guide, 1995). Ray Bittner (2017) suggests that it is better off to use underground pipeline close to a yard site, versus a solar-powered pump, since it requires less maintenance and lower upkeep costs (Stockford, 2017).

Designing an effective water pipeline system could be complex. Producers will need to consider pipeline length, water requirement, as well as the elevation difference between the water source to the storage tank and the variation in elevation along the pipeline route (Stockman's Guide, 1995). The length of underground pipe is assumed at 5,000 feet (1,524 meters) in the decision-making tool.

Solar-powered Aeration System

The system uses a solar-powered compressor and diffusion system; cattle can continue to have direct access or the water can be pumped into a trough. Dugout aeration maintains dissolved oxygen levels, allowing plants and algae to decay under aerobic conditions. As such, aeration prevents the black, smelly water that develops when there is no dissolved oxygen in the dugout water (Lardner et al. 2005).

Storage

A water storage tank is normally an essential element in an economically viable water pump system. A tank can be used to store enough water during peak energy production to meet water needs in the event of cloudy weather or maintenance issues with the power system. It also provides the necessary water to livestock between pumping cycles (Alberta Agriculture and Forestry 2007). For sizing the water storage, cattle water requirements vary by age group, climate, air temperature, and the moisture content of the feed. Producers can refer to livestock watering handbooks[5] or guideline[6] for the average daily water requirements, but it should be noted that water requirement will fluctuate depending on outside temperatures. Water requirements used in the decision-making tool are:

Number of battery needed = water requirement per day/2,500 Imp. gals, the number is rounded up.

[4] Assume each windmill can pump 550 Imp. gals water per hour, 10% of herd drink at once, beef cow drinks up to 1.665 Imp. gals per minute. Water requirement per hour = 10% * number of cattle * 1.665 Imp. gals * 60 min. Number of windmills needed = water required per hour/ 550 Imp. gals, rounded up to the next whole number.

[5] B.C. Livestock Watering Handbook https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/water/water-supply-conservation/livestock-watering-handbook, accessed on January 18, 2018

[6] Alberta Agriculture, Remote Pasture Water Systems for Livestock, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex11857, accessed on January 18, 2018

- Yearling steers/heifers – 12 imperial gallons per day
- Cow-calf pairs – 15 imperial gallons per day

Dugout

The aeration treatment is conducted on dugout water and then the aerated water is pumped into storage tank, finally the gravity-fed equipment supplies water to the water trough (Alberta Agriculture and Forestry 2007). Total cost is determined by number of dugouts a producer needs at a single time. This report assumes that one dugout needs only one set of watering system (pump or aeration). Each dugout is large enough to provide water to the entire herd. For each watering system, number of equipment is determined by the amount of water required per day. For example, the number of troughs needed is determined by capacity of each trough and water requirement per minute[7]. The scenarios in this report were evaluated assuming one dugout.

COST BENEFIT ANALYSIS

The benefits a producer gains from utilizing a watering system will vary with location, how the operation is setup, herd size, animal type, and cattle prices.

The main benefit is the potential increase in weight gain. Lardner et al. (2005) measured the effects of improvements in water quality on cattle performance on 44 Hereford yearling steers over 5 years and 40 Angus cow-calf pairs over 3 years. Average daily gain (ADG: lb/day) of yearling steers, cows and calves were reported on four treatments including: (1) pumped water, (2) aerated water, (3) coagulated water[8], and (4) direct access to dugout water.

Table 1. Effect of Pumped Water on Cow/Calf ADG Compared to Direct Access

	Period 1 (May 23-Jul 31)	Period 2 (Aug 1-Sept 30)	Total
Additional ADG on **cows**	0.33 lb	0.44 lb	
Total Additional Weight Gain per **cow**	**22.82 lb**	**26.90 lb**	**49.71 lb**
Additional ADG on **calves**	0.15 lb	0.09 lb	
Total Additional Weight Gain per **calf**	**10.65 lb**	**5.38 lb**	**16.03 lb**

Source: Lardner et al. (2005)

Pumping without treatment appears to be the most effective option for cows and calves (Table 1). The additional weight maintained on the cow over the summer means she does not need additional feed in the winter to regain body condition. Cows with better body condition tend to have higher reproductive efficiency and produce heavier calves. The economic benefit of the additional weight gain on cows is only reflected on the revenue from the calves.

Aerated water increased ADGs from direct dugout access by 0.09-0.18 lb in the first period but were 0.18-0.20 lb lower in the second period during late summer. These differences were not statistically significant, and the effect on total weight gain over the entire experience period (130 days) is relatively minor (-5 to +0.07 lb). Therefore, aerated water is not included for the cow/calf model.

Both aerated and untreated pumped water affect yearling steer performance compared to direct access to dugout. The effects on steer ADG is presented in Table 2. Total additional weight gain in the aerated and pumped water group at 22 lbs is larger than the effect of pumped water without treatment (10 lbs).

Table 2. Effect of Water Treatments on Steer ADG Compared to Direct Access

		Period 1	Period 2	Total
Untreated Pumped	Additional ADG	0.07 lb	0.09 lb	
	Total Additional Weight Gain	**4.83 lb**	**5.49 lb**	**10.32 lb**
Pumped and Aerated	Additional ADG	0.26 lb*	0.07 lb	
	Total Additional Weight Gain	**17.9 lb**	**4.27 lb**	**22.21 lb**

* Statistically Significant
Source: Lardner et al. (2005)

It should be noted that the additional ADG on yearling steers in the aerated water treatment was the only statistically significant result in the additional ADG presented in Table 1 and 2. The inability to detect significant differences could be a result of multiple factors such as sample size and experiment methods.

The cost of each watering system for initial installation and annual general maintenance (Table 3) were sourced from the "Stockman's Guide to Range Livestock Watering from Surface Water Sources" (Prairie Agricultural Machinery Institute), Wilson and Clark (2003) and current online pricing from various water system suppliers.

The initial cost of an *aeration and pumping system is estimated to be 11% higher than the pumping system only.* Annual maintenance costs were estimated as 0.5% of initial investment and ranged between $50-100 per year. It is recognized that in some environments and conditions

[7] Assume each trough can provide water to up to 500 cow/calf pairs.

[8] Coagulation is not included in the decision-making tool.

annual maintenance costs maybe higher than what is provided here. The number of years taken to pay off initial cost of installation of watering system is calculated by diving initial cost by annual benefit per animal.

Table 3. Estimated cost of alternative watering systems*

	Windmill	Solar-powered	Underground Pipe	Aerated Windmill pumped	Aerated Solar-powered
Initial Cost	$13,274	$9,565	$15,745	$14,779	$10,070

* Not including the cost on a well

SCENARIO ANALYSIS

Scenarios were evaluated to determine the cost-benefit for different herd sizes and cattle prices to determine the time taken to pay off the initial investment and net benefit in the first 5 and 7 years.

Since the solar-powered aeration system results are only available for yearling steers and do not show for cow/calf operations, the scenario analysis includes two parts. Part 1 examines three watering systems for cow/calf producers. Part 2 examines five watering systems for yearling grassers.

Part 1: Scenarios for cow/calf

Table 4 summarizes the years that cow/calf producers need to pay off the total cost for three watering systems under different **herd sizes**. As the estimated benefits are the same for these three systems, the results are driven by the costs of the watering systems, herd size and pumping capacity of each system.

Table 4. Number of Years Taken to Pay Off Initial Cost*

Herd size (calves sold)	Windmill	Solar-powered	Underground pipe
50	8.69	6.56	10.10
100	4.34	3.68	5.05
200	2.48	2.40	2.80
300	**1.65**	**1.74**	1.86
400	**1.73**	1.58	1.53
500	1.39	1.35	1.23

*Assume one dugout, one well, and calf price at $2.18/lb

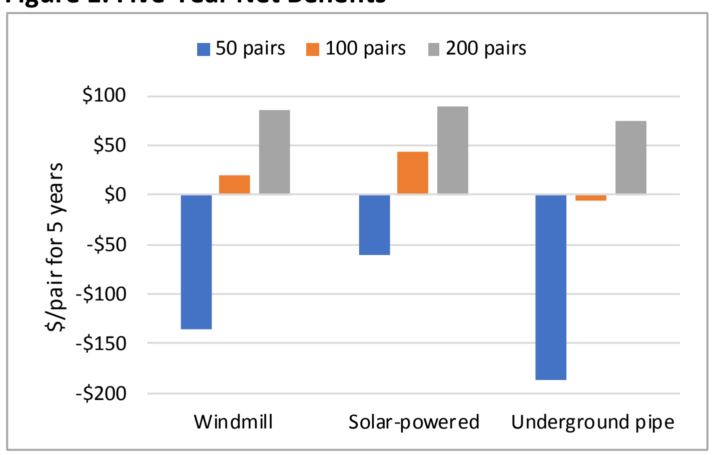
With the lowest unit cost, the solar-powered pumps take the shortest time to pay off the initial cost in most cases, followed by the windmill pumped system and the underground pipe system. Herds of 100 head or less have a substantially longer time to pay off the initial investment.

Once herd size is over 200 head all water systems are paid off in less than three years. According to the 2016 Census of Agriculture, the average Canadian beef cow herd size was 69 cows. The demographics of the cow/calf sector with a large number of small herds explains lower adoption rates of watering systems.

In general, as herd size increases, the pay-off period declines. However, due to the difference in pumping capacity of each systems (Windmill 550 gal/hour[9], Solar panel 1,424 gal/day[10]) the number of pumps required for each system varies as herd size increases, so as unit cost on a per head basis. For example, one windmill system with 550 gal/hour pumping capacity can supply sufficient water for a 366-pair cow-calf herd, while one solar-powered pump can supply water for less than 100 cow/calf pairs. Consequently, the number of year to pay off initial cost for a 300-head herd is lower for the windmill system than the solar-penal system in the model (Table 4). This indicates that *matching water requirement with water system capacity to reach the optimum utility rate is a factor to consider when choosing a watering system.*

Figure 1 presents the net benefit per head for three watering systems under different herd sizes in the first five years. This is calculated as the value of additional weight gain of entire herd less the initial costs of the watering system and maintenance costs for the five years.

Figure 1. Five-Year Net Benefits



Assuming calf price at $2.18/lb, the five-year net benefits are negative for all three systems for a 50-pair herd, positive for windmill and solar-powered system for a 100-pair herd, and positive for all three systems for a 200-pair

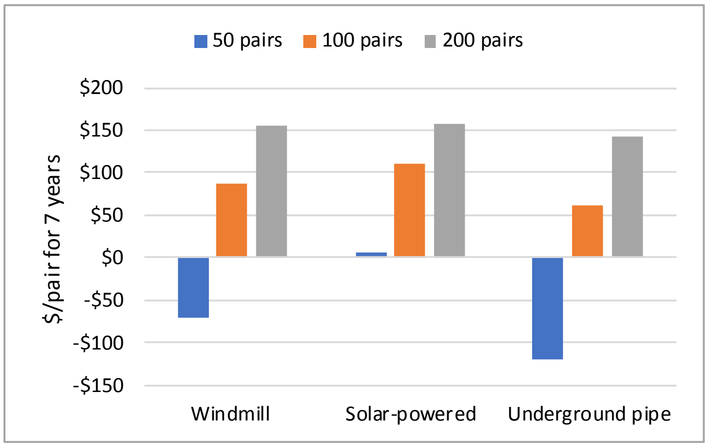
[9] Source: the Aermotor Windmill Company https://aermotorwindmill.com/pages/windmill-pumping-capacities, accessed on January 18, 2018

[10] Source: http://kellnsolar.com/, accessed on January 18, 2018

herd. This is driven by the difference in initial cost of the watering systems, lower unit cost on a per head basis, and the larger economic gain from addition weight gain in a larger herd. *A smaller herd is more likely to benefit from a watering system with lower initial costs.*

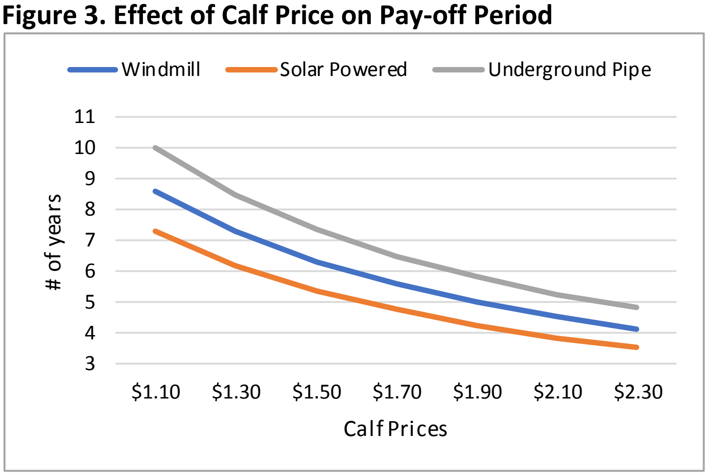
Since the breakeven is typically around the five-year mark, the model also estimates the net benefit for the first seven years to show the potential long-term benefits. Once the initial costs are paid off, the annual benefits more than the annual maintenance costs, barring any major repairs.

Figure 2. Seven-Year Net Benefits



While cows were better able to maintain body condition with pumped water the benefit comes from producing a heavier calf. Therefore calf prices affects the total benefit per year and the length of the pay-off period.

Figure 3. Effect of Calf Price on Pay-off Period



*Assume herd size at 100 pair

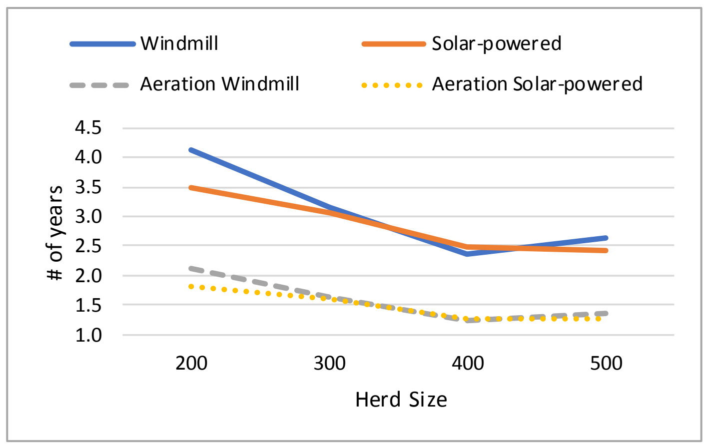
Figure 3 presents the effect of calf prices on pay-off period for a 100-pair herd, when holding other conditions constant. As calf prices have increased from the long-term average around $1.60/lb prior to 2014 to over $2/lb, the time taken to payoff the initital investment has been reduced by one-third.

Part 2: Scenarios for yearlings

Figure 4 shows the number of years needed to pay off the total cost of four kinds of treatments for a yearling grasser operation: 1) solar-powered aeration treatment on windmill pumped water; 2) solar-powered aeration treatment on solar-powered pumped water; 3) untreated windmill pumped water and; 4) untreated solar-powered pumped water. The comparison was done under different herd sizes.

As adding aeration treament results in only an 11% increase in the initial costs of the pumping sytems with a more than double increase in ADG, the results show that *it will take a yearling grasser operation less time to pay off a water system that includes an aeration treatment based on the improved gains* (22 lb/year vs 10 lb/year) observed by Lardner (2005). The time taken to pay off the initial costs flattens between 400 and 500 head as additional infrasturcture is needed, offseting the benefits from economies of scale.

Figure 4. Number of Years Taken to Pay Off Total Cost Under Different Steer Herd Sizes*

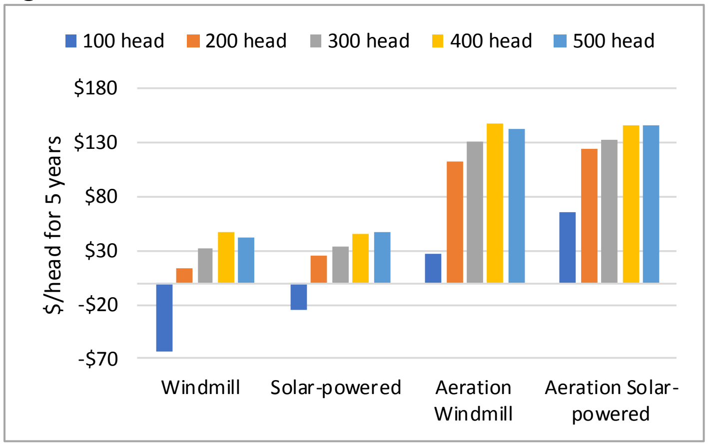


*Assume one dugout, one well, and Yearling Steer Price at $1.78/lb

Figure 5 shows five-year net benefit per head for four water treatments under different herd sizes when the yearling steer price is $1.78/lb. Despite the additional initial investment for the aeration treatment, the larger additional gain over simply pumped water results in a shorter time to pay-off the initial investment and higher net benefits in the first five years.

In general, the potential net benefits generally increase as herd size increases. Similar to the cow/calf scenario, the *economies of scale are constrained by the pumping* *capacity* of a watering system. For example, assuming the pumping capacity of a windmill system can supply water for up to 458 head of steers, when herd size exceeds the maximum capacity, an extra windmill will be needed, and costs will increase. This is shown in Figure 5 where net benefits decline as herd size increase from 400 head to 500 head.

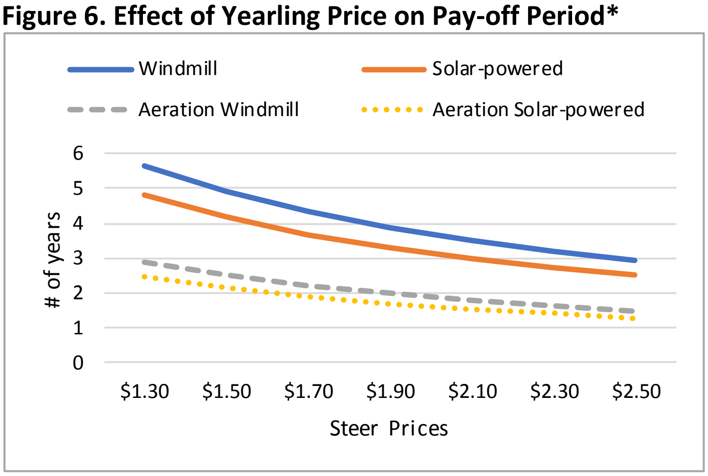
Figure 5. Five-Year Net Benefit Under Different Herd Sizes



Note: Assumes Yearling Steer Price is $1.78/lb.

Figure 6 presents the effect of steer prices on pay-off period for a 200-head herd, showing producers can pay off the initial cost of watering system faster when steer prices are higher. As yearling prices have increased from the historic average around $1.30/lb prior to 2014 to around $2.00/lb the time taken to pay off the initial investment has been reduced by 1 to 2 years. This indicates that *it may be a better time to invest in watering system when cattle market is strong.*

Figure 6. Effect of Yearling Price on Pay-off Period*



* Assume herd size at 200 head

CONCLUSIONS

Watering systems which provide cattle access to pumped water with better palatability can improve ADG of calves and yearlings on grass. The initial cost of a watering system, herd size, the system's capacity, cattle prices and the type of water treatment are factors that affecting the economics of a cattle watering system.

The Solar-powered pumping system has the lowest initial costs compared to Wind-mill and Underground-pipe system and has the shortest pay-off period in most of the scenarios.

Herds of 100 head or less have a substantially longer time to pay off the initial investment. Once herd size is over 200 head all water systems are paid off in less than three years. According to the 2016 Census of Agriculture, the average Canadian beef cow herd size was 69 cows. The demographics of the cow/calf sector with a large number of small herds explains lower adoption rates of watering systems.

When herd size increases, the unit cost of a watering system on a per head basis generally declines, and results in a shorter pay-off period and higher net benefits. However, the economies of scale are constrained by the capacity of a watering system. If the herd size exceeds the system's maximum capacity and new infrastructures or equipment are needed, the unit cost may increase, and net benefits decline.

When cattle prices increase, and the cost of a watering system stays steady, and the pay-off period shortens as the net benefits increase. This indicates that it may be a better time to invest in watering system when the cattle market is strong.

For a yearling grasser operation, adding aeration treament is estimated to result in 11% increase in the initial costs of a pumping sytem, but have an 120% increase in additional weight gains. Hence it will take less time to pay off a water system that includes an aeration treatment.

It is worthwhile to notice that there is potential for more effective and efficient products that are being used internationally. For example, the equipment that combines the function of storage tank and trough produced in Australia is cheaper and more user-friendly than separately produced equipment in Canada, which would make the adoption more feasible with proper importing approval. Given the large variety in cost of different types of equipment available to producers, the assumptions are outlined in the decision-making calculator that producers are always encouraged to price out equipment on their own.

Water System Calculator

There are two variations of the model:

1. Cow/calf Model – Evaluates a windmill pump, solar-powered pump, or underground pipe supplied from a well or dugout.
2. Yearling Grassers Model - Evaluates a windmill pump, solar-powered pump or underground pipe supplied from a well or dugout with or without aeration treatment.

Each model allows producers to enter (1) **herd size** for yearlings or cow-calf pairs, which will determine the total water volume needed and appropriate storage; (2) **infrastructure,** producers can choose whether they need a well, storage tanks, and number of dugouts they need at a single time; (3) producers need to enter the current/projected **market price** ($/lb) for the animal types being watered at the time of sale.

The models estimate total costs (installation and annual maintenance) and benefits from different types of water systems, years needed to pay off the initial cost and net benefits after 5 and 7 years. The tool is available at:

http://www.beefresearch.ca/research/water-systems-calculator.cfm

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