Pen and Runoff Management

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Take Home Message

✓ Clean pens and clean cattle are important because:
  • Muddy pens increase feeding costs,
  • Animals at the plant are docked for ‘tag’,
  • Ground and surface water quality can be affected by high organic matter runoff.

✓ Water and waste movement in feeding pens is controlled by the water holding ability of the manure pack, the impermeable soil/manure layer sealing the feeding pen, and the slope and drainage patterns of the pen, drains, and catch basins.

Nutrient Balance - N, P, K, S, Na

Materials coming into a feedlot, are balanced by the materials leaving the feedlot (Figure 1). Cattle, feed, water and energy come into the feedlot. The products are cattle and manure. The concept of environmental sustainability requires that manure and pen runoff is utilized by crop land and does not compromise surface and ground water quality.

Inputs

The nutrients brought into a feedlot as part of the feed include:
• N, nitrogen;
• P, phosphorus;
• K, potassium;
• S, sulphur;
• Na, salt or sodium;

as well as other elements or micro nutrients.

Water enters the feedlot as part of the water supply system and as snow and rainfall. Included in this fact sheet are maps of Alberta showing the annual precipitation, the accumulated winter snowfall, and the volume expected from summer storms.

Cattle and energy, electricity and natural gas, are the other inputs.
Accumulated nutrients
If some nutrients such as salt, phosphorus, or potassium are applied at a greater rate than can be removed by plants in the crop land used to manage the runoff, then they will accumulate in the soil. The accumulation rate may be balanced against the planned life of the feedlot. Management of abandoned or shut down feedlots is another consideration.

Outputs
Finished cattle, the purpose of the feedlot, is the first output. Losses are handled in an acceptable manner and picked up by an animal processing company.

Manure is the second major output containing nutrients that entered the feedlot as animal feed, and water that entered as precipitation and supplied water.

Potential losses from manure are seepage into the ground from pen surfaces, under manure stock piles, and from runoff catch basins. As well, there is potential for surface runoff from manure stockpiles and crop land used for runoff utilization. Finally there is evaporation or volatilization of nutrients from pen surfaces, manure stock piles, and runoff catch basins.

Nutrient balance - feedlot to crop land
Nutrients are gathered from a large land base in the form of barley and silage, then fed to the cattle. The waste is often spread over a relatively small area, concentrating the nutrients.

Example: A feedlot finishes 20,000 head per year using 25% silage, 75% barley ration by weight (Figure 2). Purchased barley is grown on about 50,000 acres of crop land. The feedlot may own 4,500 acres of silage land. Manure produced by the feedlot is spread on the silage land or crop land close to the feedlot. The ratio of manure spreading area to total crop area is 4,500/54,500 = 8%.

Plant nutrients
Manure contains nitrogen, (N), phosphorus (P), potassium (K), sulphur (S) and several trace elements that are useful nutrients in crop production. Beef manure is not necessarily a balanced fertilizer, therefore manure applied at a rate to satisfy one crop nutrient need, may result in over application of other nutrients. A major portion of these nutrients are in an organic form which are mineralized in subsequent years. The contribution of this
residual release must be accounted for in determining application rates, particularly on land receiving yearly application of manure. It is therefore very important to monitor both manure and soil nutrient status on a regular basis to detect buildup of nutrients in the soil. More detailed information is found in article 3J1 ‘Utilization of Feedlot Manure’.

Salts buildup (salinity)
Many Alberta water supplies are high in salts. Excess sodium, in relation to calcium and magnesium in a soil can result in physical degradation of the soil structure. Care should be taken in determining application rates where the source water and/or the soil is known to be high in salts.

Organic matter
Continued applications of manure will increase the organic matter content of the soil. Decomposition of manure in the soil has a long term effect of improving its structure, and its water holding capacity. Optimal management of feedlot manure is a link between livestock production and sustaining a fertile soil resource.

Field compaction
Trucks used to haul and spread manure in the fields typically haul over 15 tonnes. This produces very high wheel loads and axle weights. On wet soils this can lead to long lasting soil compaction. In a feedlot operation, harvesting silage and spreading manure present higher risks of soil compaction as compared to grain production.

Microbiology
Microbiological factors such as levels of fecal coliforms, fecal streptococci, and heterotrophic plate count show extreme variation through the year. Movement is dependent on the intensity and duration of rain.

Microbial factors persist differently depending on the season and possibly other unknown factors. In general, when effluent is applied in late fall when temperatures are low, the microbial parameters persist longer than for applications made in late summer. Apply manure earlier in the season during warmer weather.
Proper construction and maintenance of the feeding pen surface is important for animal health, welfare, and productivity. A smooth, firm surface with a 2 to 4 percent slope will drain well. In densely populated pens (less than 250 to 300 square feet per head) the trampling action of cattle and the accumulation of manure and urine will cause four distinct layers to develop in a pen. From the bottom, these four layers are: the initial pen surface, a compacted soil/manure layer, a gleyed hard pan layer, and the manure pack on the surface. Proper management of these layers will control runoff, prevent seepage of nutrients down into the ground and provide a clean comfortable surface for cattle.

The action of the cattle hooves mixes manure and urine into the soil. Chemicals in the manure and urine change the soil’s physical and chemical properties. High sodium levels cause soil particles to disperse and reduce water infiltration. Organic gels, or slimes, form under low oxygen (anaerobic) conditions, further reducing infiltration or seepage.

### Initial pen surface

Remove all topsoil and landscape and compact the subsoil to provide a smooth uniform sloped surface which will drain well. A silty or clayey soil, at least 1m thick will compact and seal well. Sand or gravelly soils do not seal well enough for development of a gleyed layer. Slopes of 2 to 4 per cent are recommended. With higher slopes, up to 6%, the pen must be shorter to minimize erosion. Depth of pen depends on slope:

<table>
<thead>
<tr>
<th>Pen Slope %</th>
<th>Maximum Pen Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>230 ft</td>
</tr>
<tr>
<td>3</td>
<td>215 ft</td>
</tr>
<tr>
<td>4</td>
<td>200 ft</td>
</tr>
<tr>
<td>5</td>
<td>180 ft</td>
</tr>
<tr>
<td>6</td>
<td>160 ft</td>
</tr>
</tbody>
</table>

4% is 4 ft per 100 ft slope

### Compacted soil/manure layer

Cattle compact a layer of soil and manure to hock depth, 5 - 15 cm (2" to 6"). This layer of soil mixed with organic matter develops quickly in a new pen. At the first wet spell, the soil softens and manure is worked deeper into the soil. The characteristics of this layer are somewhat independent of the pen surface soil.

### Gleyed layer

In active feedlots, a gleyed layer develops between the soil/manure layer and the manure pack (Figure 3a). The gleyed layer is 5 - 10 cm thick, has a high resistance to penetration and when dry, resembles charcoal in texture, strength and the ability to stain. When wet, as in an active feedlot, the gleyed layer has a felt-like texture.
By limiting downward movement of moisture and air, the gleyed layer maintains constant soil moisture and anaerobic conditions in the layers below. Under these conditions nitrate turns into nitrogen gas, which is released into the atmosphere, thus limiting the leaching of nitrogen compounds deeper into the ground water.

Be careful not to damage the gleyed layer with equipment or aggressive pen cleaning. Don’t scrape a pen until the gleyed layer develops. Exposing the layer during scraping results in offensive odours.

When the pen is not in use the gleyed layer starts to break down. After a few months nutrients from a manure pack could seep into the soil and groundwater unless the soil is high in clay content. If cattle density is low, such as a dairy cow exercise area, the sealing may also not develop.

**Manure pack**

The manure pack is the accumulation of manure and bedding in the pen. It acts like a giant sponge, absorbing rain and snowmelt. It can hold up to 30mm of rainfall (**Figure 3b**).

When rain falls on a feedlot pen with a built up manure pack, the pack absorbs the water until it is saturated. The hardpan layer prevents percolation of water downwards. When the manure pack is saturated, runoff begins and the excess water runs off from the pen. Typically there is anywhere from immediate runoff to a 24 hour delay after a storm before pen runoff begins. Additional storage is created in the pens by the depressions created by the cattle’s hooves. The variables are pen slope and manure pack depth.

The infiltration and hydrology of feedlot pen soils is similar to the behaviour of Alberta’s Luvisolic and Solonetzic soils. These soils have the highest runoff and erosion potential of Alberta soils. Feedlot soils should be similar. However, the manure layer and the micro depressions created by the cattle’s hooves provide much more moisture storage than a conventional solonetzic soil’s ‘A’ horizon. The conceptual model for a feedlot pen soil is a solonetzic soil covered with 4" of peat. In Alberta’s semiarid climate, the manure layer provides a large storage reservoir for most storms. Once the manure layer is saturated after a sequence of storms or a long duration storm, the hardpan directs all the rain to runoff. With runoff there is a need to consider heavy loads of manure in the catch basins or provide sedimentation areas upstream of catch basins in your design.
Pen and feedlot drainage (Figure 3b)

There are economic and production benefits from producing cattle on clean, well drained pens.

The cost of mud - poor drainage

Muddy pens are costly - feed intake goes down, daily gains decrease, and the total feed required to finish increases. 100 steers in a muddy pen can cost $1000 extra per month. Every 4 muddy days, adds 1 day to the total time spent in the feedlot (Tables 2 and 3).

<table>
<thead>
<tr>
<th>Table 2. Effects of Mud on Feed Intake and Gain.</th>
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</thead>
<tbody>
<tr>
<td>Feed</td>
</tr>
<tr>
<td>Intake</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>4&quot;-8&quot; mud</td>
</tr>
<tr>
<td>12&quot; - 24&quot; mud</td>
</tr>
</tbody>
</table>

Pen Management

Scrape regularly

Gather and pile the manure pack whenever more than 1 inch (2.5 cm) of loose manure and bedding accumulates over the pen surface. Use a scraper-box scraper or elevating scraper to minimize damage to the gleyed layer. A scraper will ride on the gleyed layer without gouging it or breaking through it.

If the gleyed layer is removed or damaged by scraping or cleaning, a new layer will develop over several months, if cattle are in the pen. Whenever the gleyed layer is damaged, there is a risk of nutrients and salts from the pen leaching into the soil and ground water below.

Maintain moist conditions

As long as the layer of loose manure is at 25 to 35 per cent moisture content, dust and odour problems are minimized. Recent research has shown that 0.3 in (8 mm) of moisture, in the form of rain or irrigation, minimizes ammonia losses to the atmosphere.
Increasing or decreasing animal numbers in a pen can help to maintain this moisture level. In warm, dry periods, animal numbers per pen can be increased to increase the amount of urine, thereby helping to keep the pen surface damp. The limits to animal numbers per pen are feedbunk space, waterer space and pen area per animal. If sufficient water is available, sprinkler systems can also be used for dust control (Figure 4). However, remember that additional water on the pen surface can increase odours from the feedlot.

### Fill in low spots

As part of ongoing pen management, low spots that develop need to be filled in. The ideal fill is a clay or silty soil. Filling in these spots provides a smooth, even pen surface and prevents ponding of water.

### Seasonal pen management

**Winter:** During winter, bedding (chopped straw) that is added to the pens, increases animal comfort and assists in keeping the cattle free from ‘tag’ or manure cover. There is a 7% difference in cost of gain between clean and slightly muddy cattle (NRC). During warm periods in the winter, pen scraping keeps the surface clean. Build up manure mounds to help with pen drainage and initiate the decomposition of pen material.

**Winter/Spring Snow Management:** Design roadways wide enough for feed wagons or trucks plus a windrow of snow. Protect exposed feed bunks from wind with snow fences. Use windbreak fences between pens.

**Spring:** Before spring thaw, scrape and remove accumulated snow build up and manure from the pen. A box scraper behind a tractor works well. Material removed may be stockpiled in a designated area outside the pen or as windrows in fields. Timing is critical. Pens that have snow and manure removed from a frozen surface dry very quickly, resulting in virtually no spring runoff. As soon as possible, redistribute the windrows and work the manure into the fields. Be sure that any drainage stays in the fields. Quick incorporation aids nitrogen retention and significantly reduces odour.

### Table 4. Corral Cleaning Costs.

<table>
<thead>
<tr>
<th>Description</th>
<th>Operators</th>
<th>Hourly Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loader only</td>
<td>1 operator</td>
<td>$45 - $85/hr</td>
</tr>
<tr>
<td>Loader + 1 spreader</td>
<td>1 operator</td>
<td>$65 - $90/hr</td>
</tr>
<tr>
<td>Loader + 2 spreaders</td>
<td>3 operators</td>
<td>$160-$190/hr</td>
</tr>
<tr>
<td>Loader + 3 spreaders</td>
<td>4 operators</td>
<td>$180-$230/hr</td>
</tr>
<tr>
<td>Loader + 4 spreaders</td>
<td>5 operators</td>
<td>$260-$315/hr</td>
</tr>
</tbody>
</table>

Summer: Scrape pens during the summer and stockpile the manure in mounds. Cleaning pen surfaces by mounding decreases the surface area of the exposed material. A dry crust forms and seals the mound and reduces the level of dust, odour, and insects in the feedlot.

Feedlot drainage

Feedlot runoff has a high organic matter content, therefore a high pollution potential.

Direct the feedlot runoff to storage ponds or catch basins where it is stored until it can be applied to crop land. Protect ground and surface water from high organic matter content feedlot runoff with proper drainage design (Figure 5).

Diversion drains: Diversion banks prevent runoff from areas outside the feedlot from entering controlled drainage area of pens, cattle alleys, and feeding alleys. This decreases the amount of liquid to be handled. Diversions can be as simple as a plow furrow. Up slope runoff can also be excluded from the waste land spreading areas.

Pens: Allow free drainage of runoff and water spillage from waterers to exit the pen and enter the feedlot drains.

Pen requirements are:
- Feed troughs are located at the top of the pen slope and running parallel to the contour to minimize pen to pen drainage (Figure 6).
- Water trough aprons are located and shaped to shed rainfall and divert runoff around the watering area.
- Fence lines built so that manure accumulating under the fence can be easily removed.
- Construct a stable pen base with a smooth uniform surface.
- Pen slope 2% to 4%.

Feedlot mounds: Build the mound, if used, parallel to the drainage direction, avoid blocking the drainage path.

Feedlot drains: Construct drains below feeding pens to carry runoff to sediment and catch basins (Figure 7). The preferred design has the drain outside the pen. If the drain is inside the pen, increase pen areas. An option is to build a second alley for handling cattle so cattle don’t walk along the drain. Don’t build drains across roadways used for hauling feed.

Catch and sediment basins: Feedlot runoff is held until it can be utilized on crop land. Depending on the design and runoff patterns, solids may be a problem. Sedimentation basins upstream from the catch basin, will minimize solids build up in the catch basin.
Manure Stockpiles: Where short term manure stockpiling occurs outside the pen area, ensure that drainage is directed into the containment system. Also, the stock pile should be placed on a compacted clay base to protect ground water.

Drain design

Drains below the feeding pens are sized to handle storm runoff. Runoff is smaller than the storm event because of the water storage capacity of the pen. Drains must work for large flows and also small flows and velocities. As the drain picks up runoff from additional pens it can be shallower at the upstream end and large enough to handle the maximum flow at the outfall end.

The drain needs enough slope to prevent solids from settling. If the slope is too high for stable flow, erosion will occur. Design below pen drains for a 0.5 to 0.75% slope. If the slope is under 0.3%, manure will settle out and deposit. If the slope is over 1%, the flow will erode the gravel drain bed. Build the drain wide enough to be easily maintained with scrapers and mowers (Figures 7, 8 and 9).

Construct the drain with a compacted base such as pit run gravel. The drain needs to be impermeable and stable when wet to prevent bog holes. If the soil is permeable, a clay lining under the drain to prevent ground water contamination may be required.

When cattle use the drains as alleys, have them 16 ft to 24 ft wide. Grade and mow the drains on a regular basis to maintain their proper profile.

Runoff Management

The appropriate runoff management system depends on the size of the feedlot and the relative risk to ground and surface water. All the systems involve applying the runoff to crop land, where the nutrients are used by plants. When the plants are harvested as hay, cereal grains and straw, or silage the nutrients are removed, protecting surface and ground water.

Large feedlots

Large feedlots collect the runoff first in a sedimentation ditch (Figure 10). If you hold the runoff for up to 30 minutes, the large manure particles will settle out. You can land spread these nutrient rich solids on crop land. The water from the sedimentation ditch flows to a catch basin. Depending on management of the system, the catch basin can be designed to hold the annual runoff or the winter snow melt or the 24 hour
rain storm expected only once every 30 years. After the catch basin, the runoff is irrigated on to crop land where the nitrogen, phosphorus, potassium, and salt is harvested as grain and straw.

Medium feedlots

Medium feedlots may look at several options that all include a sedimentation ditch and usually some controlled storage of runoff (Figure 11). The runoff is distributed to a contained infiltration area. Backflood irrigated grasslands or control flooded meadows are one option where the runoff water is held and allowed to infiltrate the soil. High flow rate overland flow of water across vegetation is another method of irrigation. Vegetated filter strips, either grassed or treed areas are another option. Again the key is to use the nutrients before they can flow into streams or bodies of water.

Small feedlots

Small feedlots of less than 100 head or 1 acre may be able to utilize a system of direct runoff to pasture or grassland if they are well away from streams and water bodies (Figure 12).

Runoff Calculations

1. Calculate Runoff volume
   Choose:
   • Annual precipitation (Figure 13),
   • Accumulated snowfall (Figure 14),
   • Or 1 in 30 year, 24 hour storm depending on the management of your feedlot. This determines the catch basin size for larger lots (Figure 15).

2. The runoff intensity (m$^3$/s) (cubic metres per second) may be used to calculate the size of a sediment settling channel which will keep 50 - 60% of the solid particles from entering the catch basin. The method may be used for 1 in 30 year, 24 hour storms.

3. The nutrient content of the runoff and the type of crop will determine the area of crop land required to harvest the nutrients.

Feedlot runoff depends on the existing moisture content of the manure pack. Sometimes feedlot runoff starts immediately, under other conditions there may be no runoff until 25 - 30 mm of rain falls. Runoff will also vary depending on the intensity of storm or on the speed of snow melt.
Total yearly runoff

The total yearly runoff may vary from 15% to 40% of the moisture that falls on a feedlot catchment area, based on a CAESA Vegreville research study. (Canada Alberta Environmental Sustainability Agreement) American studies support the 40% factor.

Total rainfall is shown on the map (Figure 13) “90th Percentile Annual Precipitation”. The precipitation is presented for each township in 25 mm classes. The 90th percentile value will be exceeded, on average, only 10 percent of the time.

A data set with 50 to 70 years of precipitation measurements was used. Most locations in southern Alberta had 70 years of data. In northern Alberta the length of data record declined. The annual total precipitation for each location was ranked from lowest to greatest.

The 90th percentile value was determined. For example, if a location had 70 years of data, the 63rd value would be the 90th percentile.

Dr. Sean McGinn, Agriculture & Agri-Food Canada provided the 90 year gridded annual precipitation data.

Yearly runoff = catchment area x annual runoff factor x annual precipitation.

Example: A 1000 head feedlot covering 1 acre per 125 head has a catchment area of 8 acres or 3.24 ha (32,400 m²). The lot is located southeast of Calgary in an area where the 90th percentile annual precipitation was 500 to 525 mm. If the runoff factor is 15% then the total runoff and required catch basin size, if it is emptied once per year is: 32,400 m² x 500 mm x 1 m/1000 mm x 15% = 2,430 m³ (85,800 ft³)

Runoff from Summer Storms

The Alberta Building Design Data map for One Day Rainfall (mm) shows the 24 hours rain fall that has a 1 in 30 chance of being exceeded. Map developed by S. Chetner, Alberta Agriculture, 1999). Figure 16, Runoff Volume from a 1 in 30 year, 24 hour storm shows how to calculate the storm runoff based on a hydrologic model calibrated to measured feedlot runoff from the Vegreville CAESA research project. The modeling was done by the Conservation and Development Branch, Alberta Agriculture. (A. Jedrych, Alberta Agriculture, SWMHYMO model, r² = 0.73, January 2000).

1. Determine the 1 in 30 year, 24 hour storm intensity for your township from the Alberta one day rainfall map.
2. Calculate the total runoff using the diagram “Runoff Volume from a 1 in 30 Year, 24-hour Storm” (Figure 16).

3. Calculate the size of catch basin using the table “Capacity of Catch Basins” (Table 5). Allow extra depth for sludge accumulation and extra freeboard. Be aware of the high potential for seepage from the catch basin.

4. Calculate the runoff intensity from each pen drain using the diagram “Runoff Intensity From a 1 in 30 Year, 24-hour Storm” (Figure 17).

5. Calculate the length of sediment settling channel at the end of each drain using the diagram “Sediment Settling Channel Design” (Figure 18).

Sediment settling channel design

Runoff from pens will carry solids in the form of soil and manure particles. It is easier to handle these solids by allowing them to separate or settle in a sediment basin (basically a long, flat ditch) where they can be removed by machinery rather than trying to agitate and pump them out of a large catch basin.

About half the suspended solids will settle in about 10 minutes, the rest settle very slowly as shown in Figure 19. Figure 18 suggests one possible design for a settling area based on a 10 minute to 30 minute retention time. Research has shown that the settling velocity of manure particles from feedlot manure is 0.003 m/s. In 10 minutes the vertical settling distance is then 0.003 m/s x 600 s = 1.8 m.

The sediment basin design is based on a given cubic metre per second (m³/s) flow of runoff. The flow intensity for a 1 in 30 year, 24 hour storm of 95 mm was used to model the runoff intensity (SWMHYMO model, Y² = .71). This will cover most storms in Alberta. The diagram may be used for catchment areas of one to 24 ha.

The solids will contain significant amounts of nutrients. Apply at agronomic rates. Incorporation into the soil immediately after application will reduce odor.
Catch basin design

Capacity of catch basins are shown in Table 5 for a typical 12’ deep basin:

Catch basins differ somewhat from anaerobic lagoons or earthen storages used for storing manure from other intensive livestock operations. First the loading rate is quite variable depending on weather conditions and pen management. Second, the nutrient levels are much more dilute. Third, the potential for leakage from unlined catch basins is high. Figure 20 emphasizes the importance of good liner design.

Spring snow melt

Spring snow melt may be fast or take place over a two week period. The volume of water from melting snow depends on management. For example, a feedlot manager may haul snow from the pens on to crop land during the feeding season.

The weather map from the Alberta Building Code (Figure 14) shows the accumulated ground snow load over the winter converted to mm of water equivalent. The accumulated snow values have a probability of 1 - in - 30 of being exceeded in any one year. The depth of water shown has the same weight as the snow load in the building code.

Runoff from snow melt = catchment area x snow runoff factor x accumulated ground snow load.

The Code of Practice for the Safe and Economic Handling of Animal Manures suggests a snow runoff factor of 0.22 for unpaved lots. A North Dakota study suggested that 30% of the yearly runoff came from snow, 20% from the largest summer storm and the remainder from the next 10 storms.

<table>
<thead>
<tr>
<th>Table 5. Capacity of Catch Basins.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width (feet)</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>200</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>400</td>
</tr>
</tbody>
</table>

\(^1\)Slope is horizontal: vertical distance and will depend on soil conditions.

\(^2\)To convert: cubic metres x 35.31 = cubic feet. A basin of 100' wide x 150' long would have a volume of 62,400 ft \(^3\) + 50 ft x 8,400 ft \(3/10\) ft = 104,400 ft \(^3\).
Figure 21 explains the concept of controlling soil nutrient levels in the runoff management crop land by removing them in the form of crop material, grain, straw or silage or as beef from grazing cattle.

Feedlot Abandonment - A Checklist

When a feedlot is shut down, several steps are required to protect surface and groundwater. A checklist is:

- Remove solid manure to crop land or a manure composting area. The soil surface becomes permeable after animals are removed - soil cracking from freeze/thaw and wet/dry cycles, and no maintenance of gleyed layer.
- Establish a plant cover to take up nitrogen. Salt tolerant plants are required. Removing the top 30 cm of soil is an option. Consult an agrologist before land spreading. Perennial crops are preferred.
- Clean all feeding and feed storage areas.
- Shut down all utilities.
- Decommission water wells according to Alberta Water Act standards.
- Control weeds.
- Reclaim areas of petroleum spillage.
- Remove debris, medical supplies, sharps, pesticides.

For more detailed information obtain the fact sheet 'Managing Feedlot Shutdowns'; Agdex 420/580-1 from Alberta Agriculture.
Figure 1. Feedlot Nutrient Balance.

INPUTS

- Cattle
- Feed
- Water

Feeding Pens

- Rain Snow
- Runoff storage

Cropland or Vegetation for Runoff Management

- Accumulated Nutrients
- Manure stockpile
- Cropland for Manure Utilization
- Losses

OUTPUTS

- Beef
- Harvested Plants
Figure 3b. Feeding Pen Water Movement.

1. Rain falls on the pen.
2. The manure pack absorbs the water until it becomes saturated.
3. Water cannot move down through the impermeable soil/manure interface layer.
4. Immediately or up to 24 hours delay (when the manure pack is saturated), runoff from the pens is high and mimics rainfall peaks from the storm. 
15 to 40% of the yearly rainfall runs off the pens.
Sprinklers for Dust Suppression.

Sprinkler Guidelines

If evaporation of water from the pen exceeds the rate at which cattle add water by manure, dust may become a problem.

Maintain pen surface moisture at 25 to 35% moisture. Higher moisture levels increase biological activity leading to increased odour levels.

Application rate is 1/2" to 1" of water per week (12.5mm to 25mm). Apply 2.5mm to 3.5 mm per day. Initial application rate at 5mm/day until surface is at 25% moisture.

High Capacity Systems

Large droplet sizes, low pressures. Can be operated less frequently, for shorter periods. More likely to lead to water ponding.

Low Capacity Systems

Higher pressures, smaller droplets. Less ponding but more affected by wind, more evaporation.
Figure 5. Feedlot Runoff Pattern.
Figure 6. Feeding Pen Drainage.
Figure 7. Below Pen Drains - Cross Section View.

Drain designs from: "Designing Better Feedlots", Watts and Tucker
Figure 8. Feeding Alley Drains - Cross Section.

- compacted road bed
- stabilized median
- clay lined

**flat site**

- combined cattle alley and drain
- feed alley
- clay lined

**contoured or sloped site**

- below pen drains
  - sloped 0.5 to 0.75%
  - in drainage direction

Drain designs from: "Designing Better Feedlots", Watts and Tucker
Figure 9. Processing Area Drainage.
Figure 10. Runoff - Large Lots.

- irrigation to cropland, annual or several times per year
- grass filter strips
- wetland cells
Figure 11. Runoff - Medium Lots.

- runoff to contained infiltration areas
- back flood irrigated grassland or grassed filter strips that will not flow into streams or watercourses.
- gated pipe irrigation system to hayland
Figure 12. Runoff - Small Lots.

Small lots

- direct runoff to infiltration area (pasture or grassland)
- typically under 100 head, located well away from streams, water bodies.
Figure 14. Accumulated Snowfall.

Accumulated Ground Snow Load
1 in 30 year probability of exceedance
(mm water equivalent)

100 - 115
115 - 130
130 - 145
145 - 160
160 - 175
175 - 190
190 - 205
205 - 220
220 - 235
235 - 250
above 250

Alberta Building Design Data

Source: Atmospheric Environment Service, Environment Canada.
Based on Alberta Building Code 1987
Prepared by: Conservation and Development Branch, Alberta Agriculture, December 1989
Figure 15. One in 30 Year Summer Storm.
Figure 16. Runoff Volume from a 1 in 30 Year, 24-hour Storm.

Runoff Volume = Drainage Area (sq m) x Rainfall (mm)/1000 x Runoff Coefficient

<table>
<thead>
<tr>
<th>One Day Rain (mm)</th>
<th>Runoff Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>65-85</td>
<td>0.15</td>
</tr>
<tr>
<td>85-90</td>
<td>0.20</td>
</tr>
<tr>
<td>90-95</td>
<td>0.20</td>
</tr>
<tr>
<td>95-105</td>
<td>0.25</td>
</tr>
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</table>

Based on initial pen moisture storage of 30 mm. SCS runoff curve of 0.65.

The runoff coefficients were developed using the SWM-HM0 Model (Storm Water Hydrologic Model, Babourin & Associates, Ottawa). The model was calibrated against the actual runoff from a feedlot near Vegreville (CAESA research project) and using a measured storm. The model was applied to four Alberta locations to develop the runoff coefficients. The calculations were based on the sample 1 ha area pen modules shown in the diagram.

Example Calculation: A feedlot is located in an area where the 1 in 30 year 24-hour rainfall is 90mm. The dimensions of the feedlot are shown in the drawing as A x B = 590m x 509m (1935' x 1668') = 30 ha.

In the table, the runoff coefficient is 0.20

Volume = (590m x 509m) x 90 mm x 1m/1000mm x 0.20

= 5406 cubic metres (5406 x 35.31 = 191,000 cubic feet)

When selecting the catch basin dimensions, allow for freeboard or extra safety height.

Conversion Factors - Area

<table>
<thead>
<tr>
<th>1/4 section = 800m x 800m</th>
<th>64 hectares (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ha = 100m x 100m</td>
<td>10,000 sq m</td>
</tr>
<tr>
<td>ha x 2.471 = acres</td>
<td>acre = 43,560 sq ft</td>
</tr>
<tr>
<td>acres x 0.4047 = ha</td>
<td>square feet x 0.0929 = square metres</td>
</tr>
</tbody>
</table>

Conversion Factors - Volume

| 1 cubic metre x 35.31 = cubic feet |
| 1 cubic metre x 220 = gallons (Br.) |
| 1 cubic foot x 6.229 = gallons (Br.) |
| 1 cubic foot x 0.02831 = cubic metres |
Figure 17. Runoff Intensity from a 1 in 30 Year, 24-hour Storm.

Flows calculated with SWM/HYMO and 30 year return storm of 96 mm for 24 hours. Model calibrated with Vegreville, CAESA research project feedlot measurements. Symmetrical cross-section channel 5:1 side slope, 0.8m depth.
Figure 18. Sediment Settling Channel Design.

The main flow is over the settling channel outlet dam. The dam retains the flow for 10 to 30 minutes. 50% of the solids will settle in 10 minutes. The floating pipe, slotted pipe, picket dam, and weir options allow complete drainage after the storm is over and allows access for manure handling equipment. Maximum solids collected = 65%.

Cross-section A-A

- depth = 0.8m
- 1:5 side slopes
- 4 m
- 5 m
- 4 m

End View

Design with a solid base to allow for machinery access for cleaning out sludge for application to cropland after storm runoff.

Top View

Flow into channel

Flow out to catch basin

Outlet dam

Side View

inlet

solids settle at 0.003 m/s

outlet

solids and manure solids

L (m) x Area of cross-section (m²) = m³ retention time (minutes) x 60 s/min

inflow rate

Picket dam outlet

Weir outlet (open for emptying)

Slotted pipe outlet
Figure 20. Seepage Potential from Unlined Catch Basins.

Options to prevent seepage:
- site selection to minimize risk
- compacted, engineered clay liner
- geosynthetic membrane

Measurements of seepage:
- seepage volume, cubic metres per year (m³/y)
- seepage rate, (cm²/cm² area of flow per day = cm/day)
- hydraulic conductivity (permeability), cm/sec
  (average annual, short term, or instantaneous)

Seepage rate = hydraulic conductivity \times \text{hydraulic gradient}
- hydraulic gradient is a measure of the mechanical driving force, weight or depth of liquid, causing water to flow.
- hydraulic conductivity is a property of the soil, the resistance to flow of water.

Applications for Feedlot Runoff
- Fertilizer for crop production
- Liquid for pen sprinkling for dust control
- Liquid available if compost is too dry

Unlined Pond Seepage Potential
Seepage rate decreases as sludge thickness increases.
In a poorly designed catch basin, seepage could account for 50 to 75% of the total liquid losses and as much as three times the evaporation loss (Nebraska data,
### Figure 21. Harvesting Runoff Nutrients with Crops.

#### Examples of Published Feedlot Runoff Analysis

<table>
<thead>
<tr>
<th>Property</th>
<th>Reported low value (mg/L = ppm)</th>
<th>Average from CAESA study</th>
<th>Reported high value</th>
<th>Feedlot</th>
<th>Your feedlot</th>
</tr>
</thead>
<tbody>
<tr>
<td>chloride</td>
<td>410</td>
<td>668</td>
<td>1729</td>
<td></td>
<td></td>
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<tr>
<td>chemical oxygen demand</td>
<td>2160</td>
<td>4636</td>
<td>17800</td>
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<tr>
<td>sodium</td>
<td>230</td>
<td>340</td>
<td>588</td>
<td></td>
<td></td>
</tr>
<tr>
<td>potassium</td>
<td>340</td>
<td>510</td>
<td>1864</td>
<td></td>
<td></td>
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<tr>
<td>total Kjeldahl Nitrogen</td>
<td>3000</td>
<td>240</td>
<td>17700</td>
<td></td>
<td></td>
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<tr>
<td>Phosphorus</td>
<td>47</td>
<td>58</td>
<td>300</td>
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<tr>
<td>Calcium</td>
<td>181</td>
<td>81</td>
<td>688</td>
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<tr>
<td>Magnesium</td>
<td>69</td>
<td></td>
<td>199</td>
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</tr>
</tbody>
</table>

To calculate nutrient levels in the irrigated catch basin liquid, use the following calculation:

\[
\text{Volume irrigated from catch basin (m}^3\text{)} \times \frac{\text{Nutrient content (mg/L)}}{1000} = \text{Weight of nutrient (kg)}
\]

#### Average Nutrient Levels of Alberta Crops (Alberta Agriculture)

Nutrients Removed in 1 Hectare of Crop

<table>
<thead>
<tr>
<th></th>
<th>Barley straw 60 bu/</th>
<th>Barley 12% mc 3.2 t/</th>
<th>Silage 65% mc 6.7 t/</th>
<th>Alfalfa 13% mc 3 T/</th>
<th>Mixed Hay 10% mc 6.7 t/</th>
<th>Beef 100 kg 3 T/</th>
<th>Brine 14% mc 6.7 t/</th>
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<tbody>
<tr>
<td>Nitrogen</td>
<td>57</td>
<td>24</td>
<td>43</td>
<td>169</td>
<td>144</td>
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<tr>
<td>Phosphorus</td>
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<td>2.6</td>
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<td>13</td>
<td>11</td>
<td>.88</td>
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<tr>
<td>Potassium</td>
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<td>43</td>
<td>41</td>
<td>105</td>
<td>82</td>
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<td>86</td>
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<tr>
<td>Sodium</td>
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<td>15</td>
<td>.15</td>
<td>9.3</td>
</tr>
</tbody>
</table>

Original data compiled by N. Miller, Alberta Agriculture.

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Alberta Feedlot Management Guide