Sustainability Living Lab

Design of a Dairy Manure Effluent Utilization System for the Rayner Dairy Research and Teaching Facility

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University of Saskatchewan

Overview

- Rayner Dairy Facility Manure Handling
  - Need
  - Problem Statement
  - Project Scope
  - Client Requirements

Image Source:
http://agbio.usask.ca/news/2013/dairy-research-teaching-facility.php

- General Process Flow
- Chosen System Components
- Integration with Facility
- Economics Analysis
- Recommendations

Photo Credit: Alanna Howell

Rayner Dairy Facility

Photo Credit: Alanna Howell

Photo Credit: Alanna Howell

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Photo Credit: Alanna Howell

The Problem

The University of Saskatchewan Rayner Dairy Research and Teaching Facility currently has no way to reclaim valuable components from the manure produced by the facility

Photo Credit: Alanna Howell

The Problem

Currently, the facility is required to store manure effluent in a tank before it is hauled away for application on agricultural land

Photo Credit: Alanna Howell

Image Source: www.cedar--rapids.com

The Problem

This current process is:

- Costly
- Time-Consuming
- Odour-Producing
- Requires winter application of manure

Photo Credit: Alanna Howell

The Problem

Manure separation equipment is widely available, but there is little knowledge of how to manage the liquid component of manure following separation

Photo Credit: Alanna Howell

Project Scope

- Identify most suitable manure management technology
- Design how this technology may be incorporated into the current manure management system

Photo Credit: Alanna Howell

Primary Objective

- Reduce to zero the hauling of liquid dairy manure effluent from campus

Image Source: www.cedar--rapids.com

Secondary Objectives

Design a system that will:

- Extract a nutrient fertilizer
- Reduce greenhouse gas emissions
- Eliminate odours
- Advance environmental sustainability goals of the U of S
- Provide teaching and learning opportunities
- Demonstrate conservation practices

Constraints

- Annual operation costs must not exceed $65,000
- System must withstand Saskatchewan winters (-50° C)
- Discharges to sewer must comply with Saskatoon City Bylaw 5115
- System must fit on the dairy barn site
- Must not require any additional staff

Photo Credit: Alanna Howell

Current State of Manure Handling at the U of S

- **6 Million Litres** of dilute manure effluent produced per year
- **104 employee hours** required per year for weekly operation and maintenance of the current system
- **85 employee hours** required per year for supervision of manure effluent hauling
- **PLUS $66,500** paid annually for manure hauling

Saskatoon Wastewater Discharge Bylaw 5115

$$R = 7.2 * \frac{(X-300)}{300} + 118.1 * \frac{(Y-300)}{300} + 23.8 * \frac{(Z-100)}{100} + 28.0 * \frac{(P-10)}{10}$$

R = monthly surcharge for sewer service in cents/100 cu. ft

X = BOD concentration (ppm)

Y = Suspended Solids concentration (ppm)

Z = Grease concentration (ppm)

P = Phosphorus concentration (ppm)

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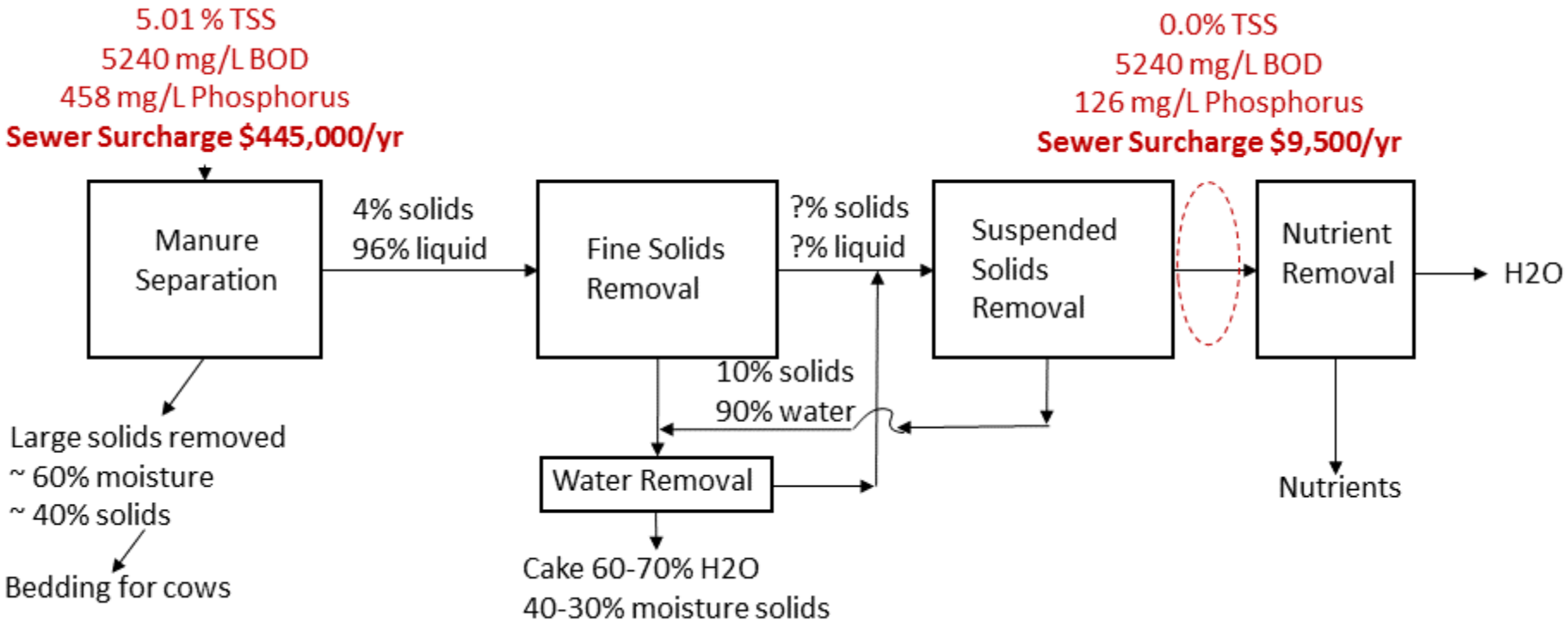
General Required Process Flow

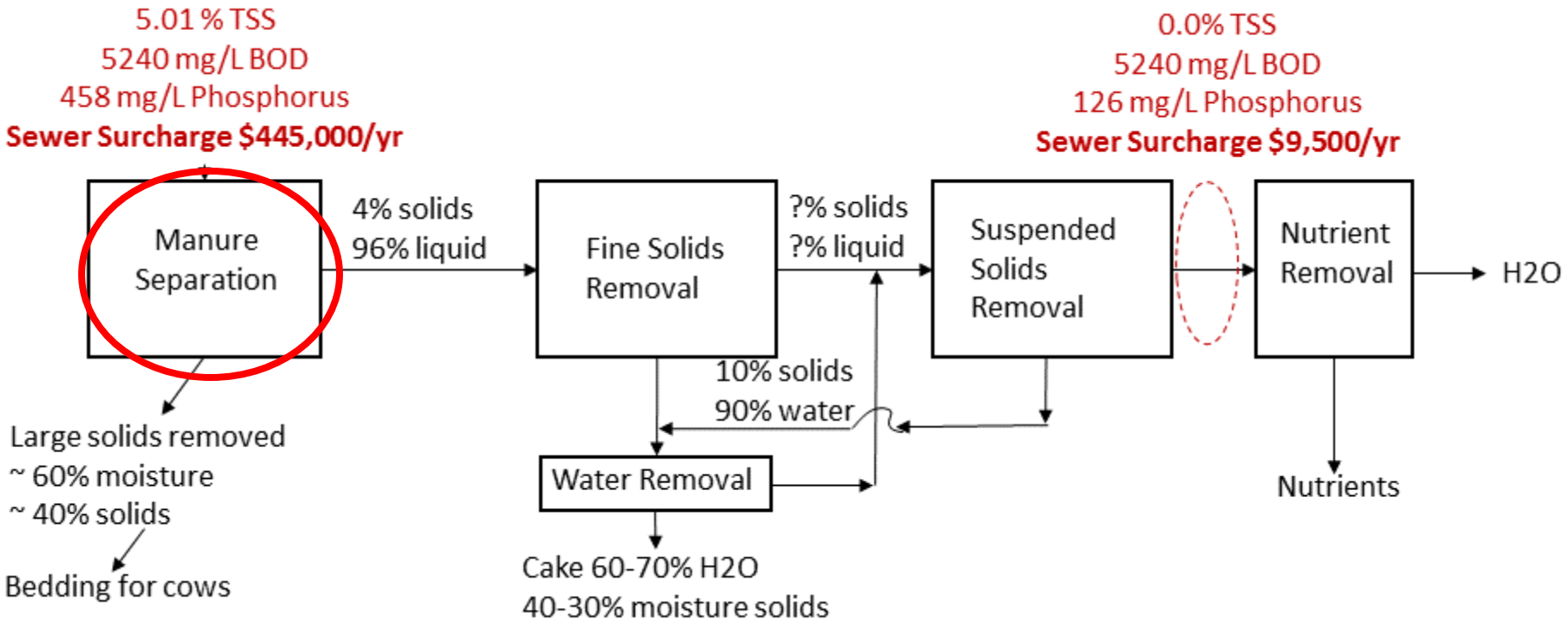
General Process Flow



Step 1 -Separation

Problem: Remove large solids from the manure

General Process Flow



Manure Separation Alternatives

Image Source: www.sikkemaequipment.com

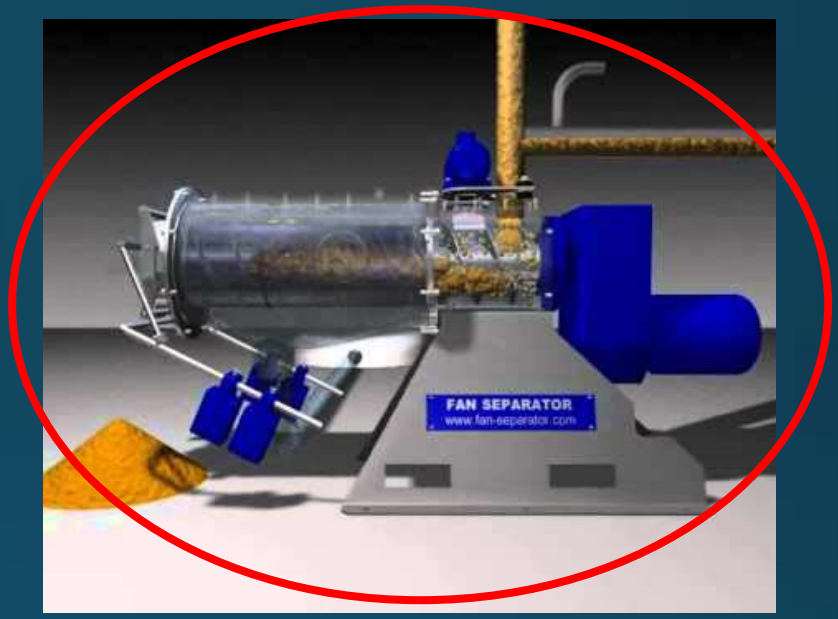


Image Source: www.youtube.com

Image Source: www.terborgagro.com

Manure Separation

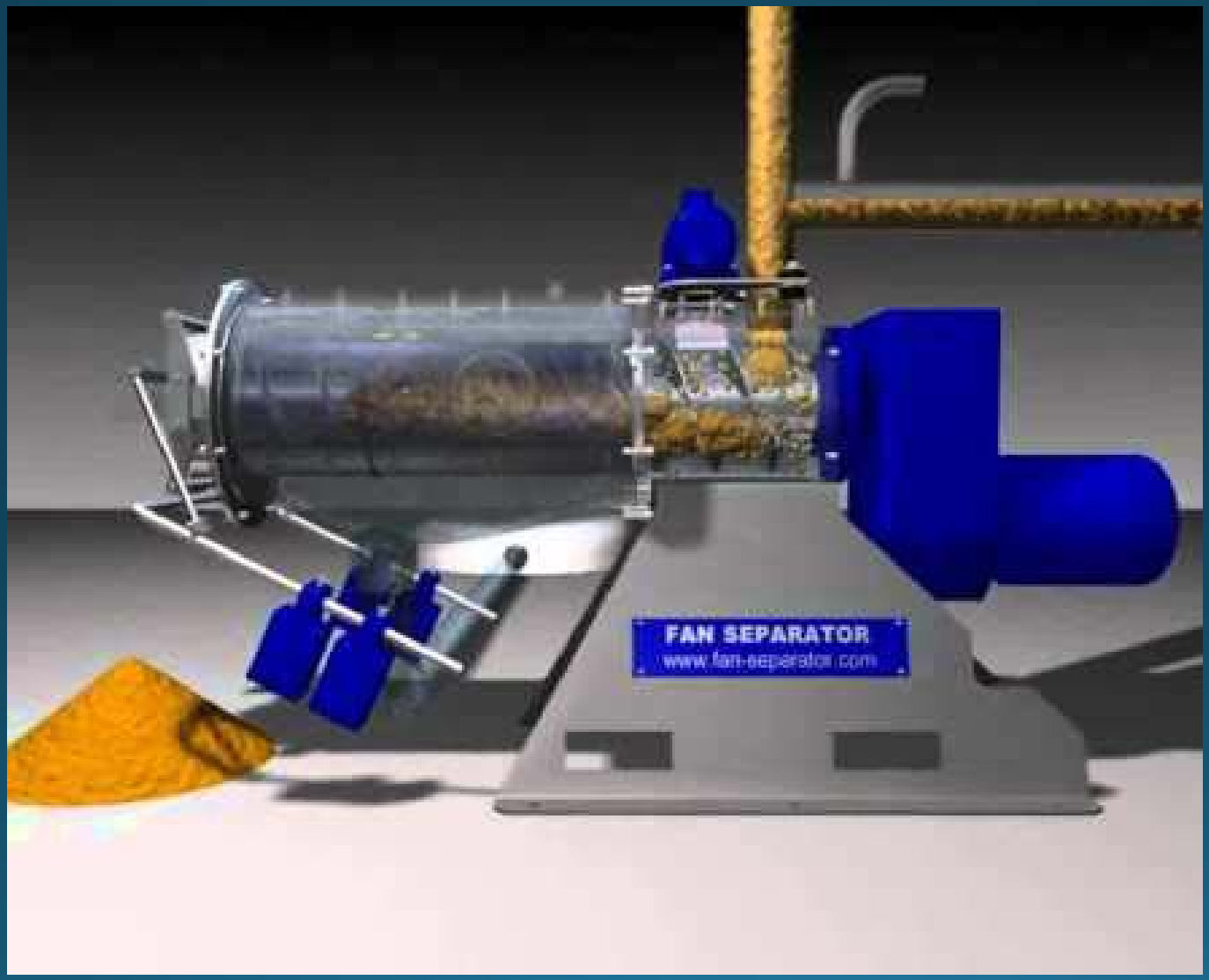
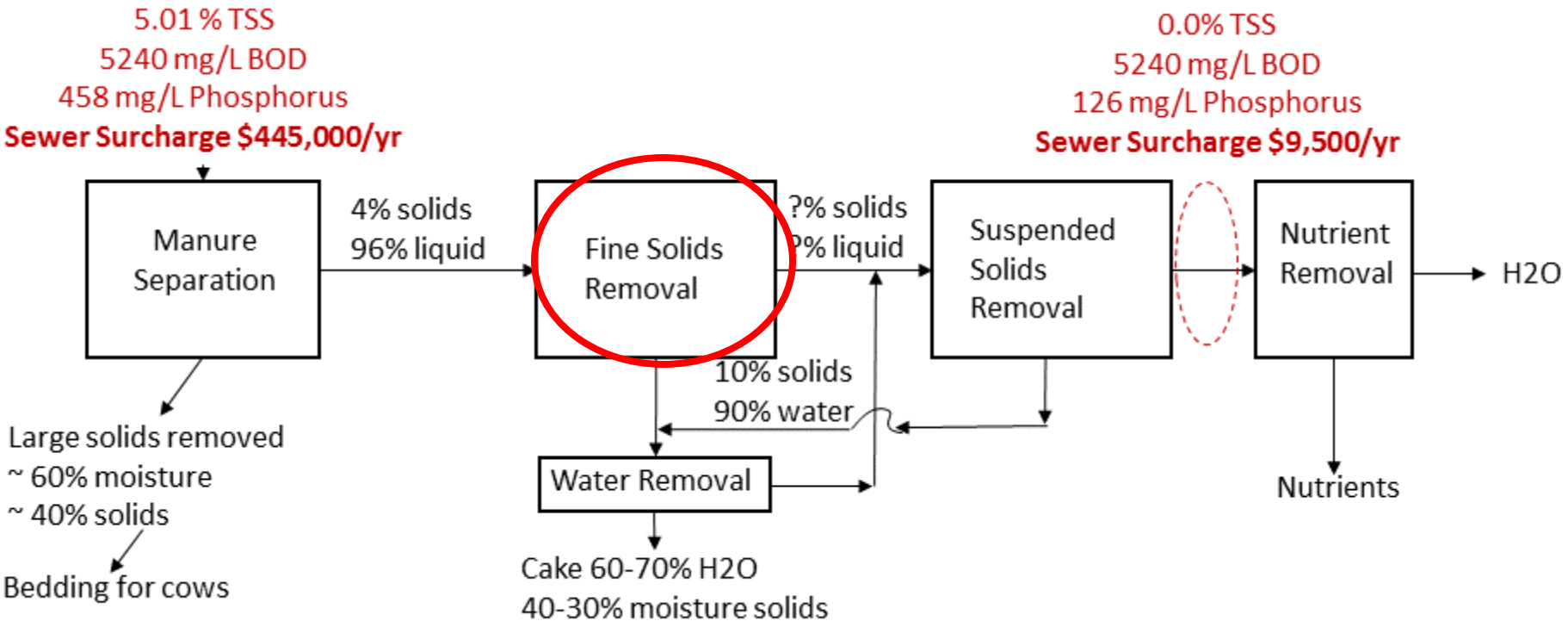


Image Source: www.youtube.com

Step 2 – Fine Solids Removal

Problem – Remove fine solids from the separated liquid

General Process Flow



Alternatives (Fine Solids Removal)

Image Source: www.westfalia-separator.com.sg

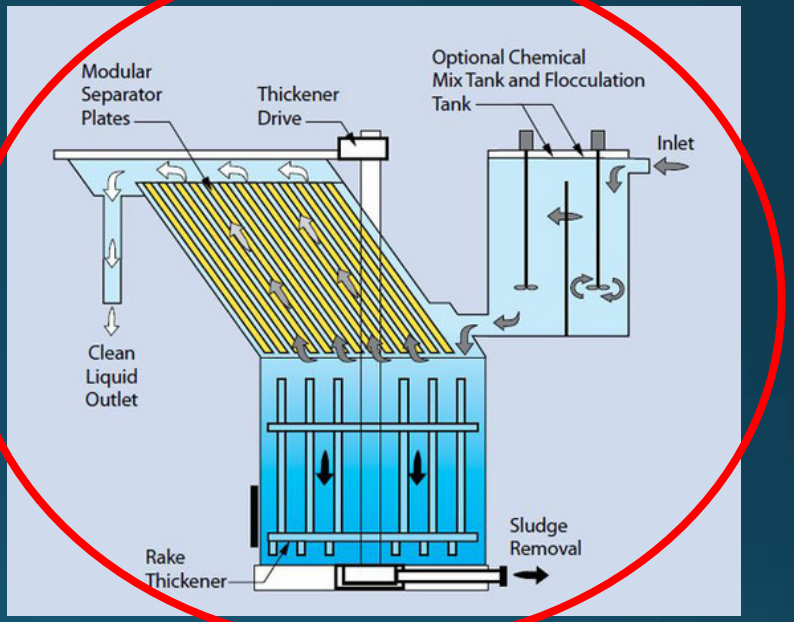


Image Source: water.me.vccs.edu

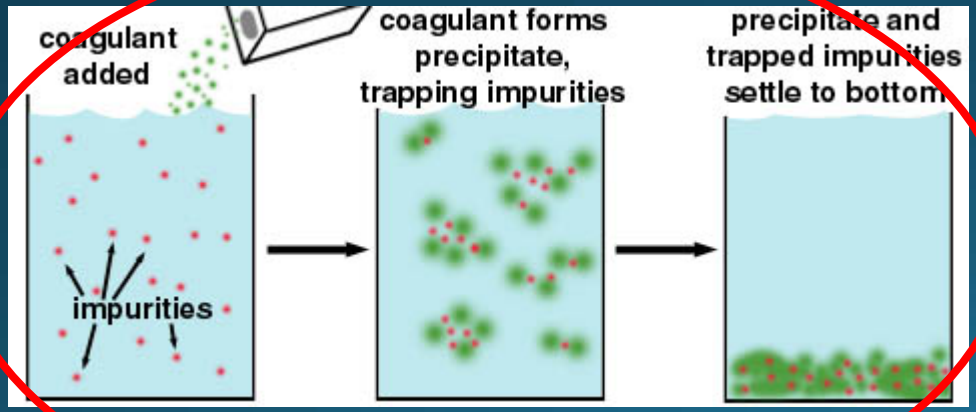


Image Source: water.me.vccs.edu

Fine Solids Removal

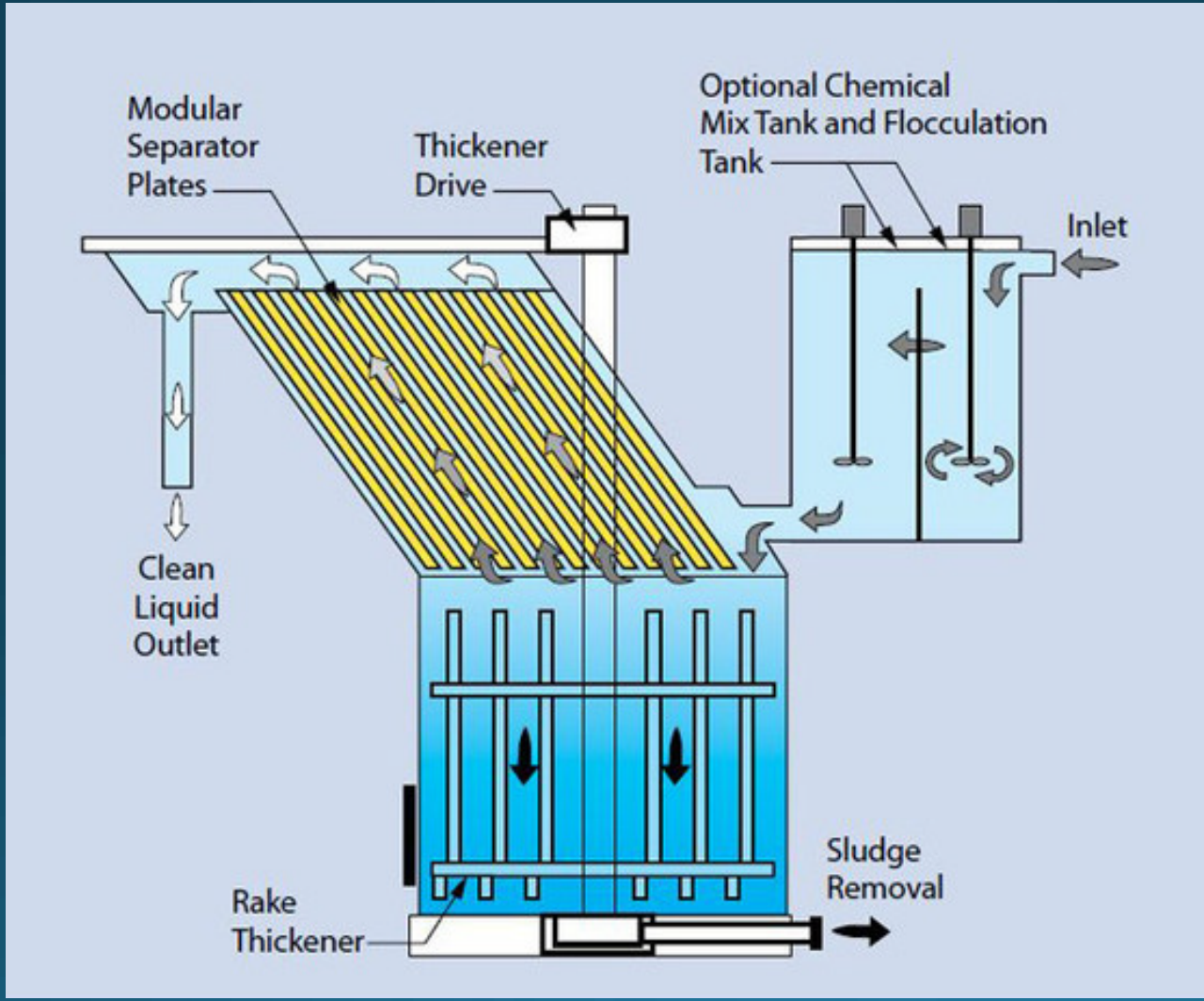
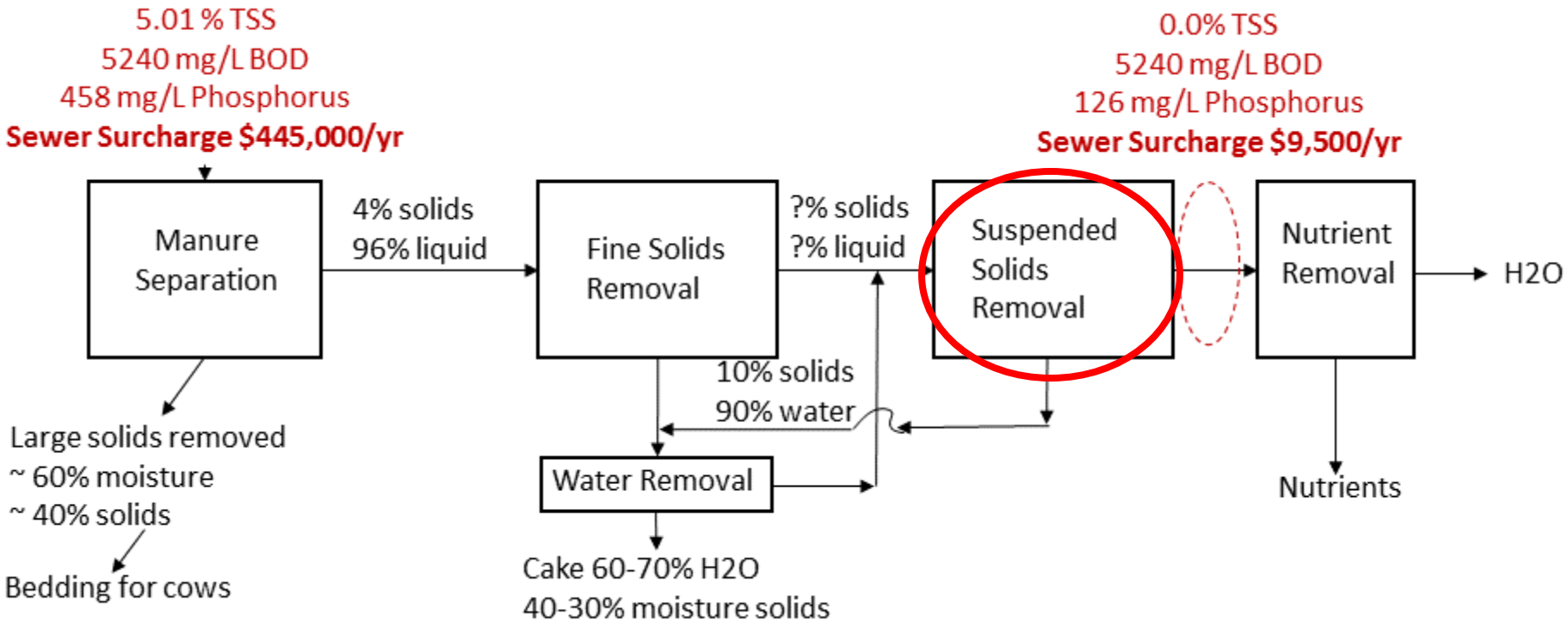


Image Source: water.me.vccs.edu

Step 3 – Suspended Solids Removal

Problem – Remove remaining suspended solids from the clarified liquid

General Process Flow



Alternatives (Suspended Solids Removal)

Ion Exchange Demineralization

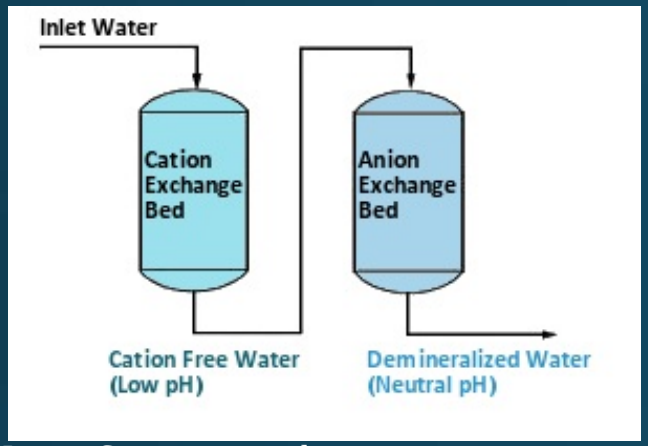


Image Source: www.dmpcorp.com

Multiple Media Filter

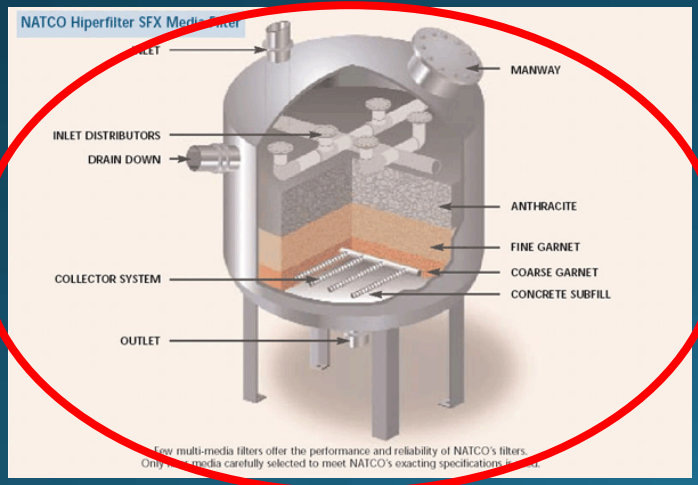


Image Source: netl.doe.gov

Bag Filters

Image Source: www.asia.ru

Alternatives (Suspended Solids Removal)

Multiple Media Filter

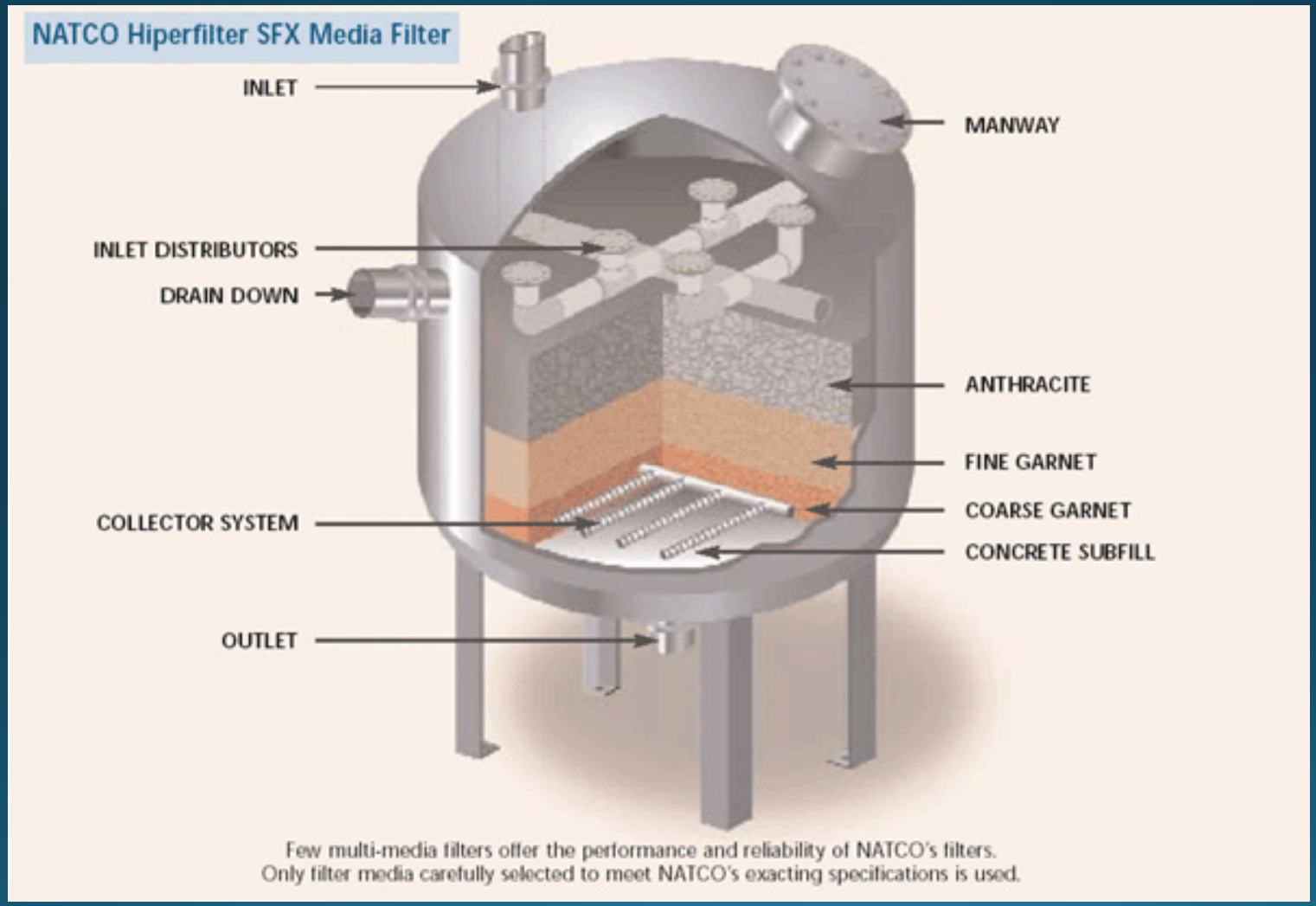
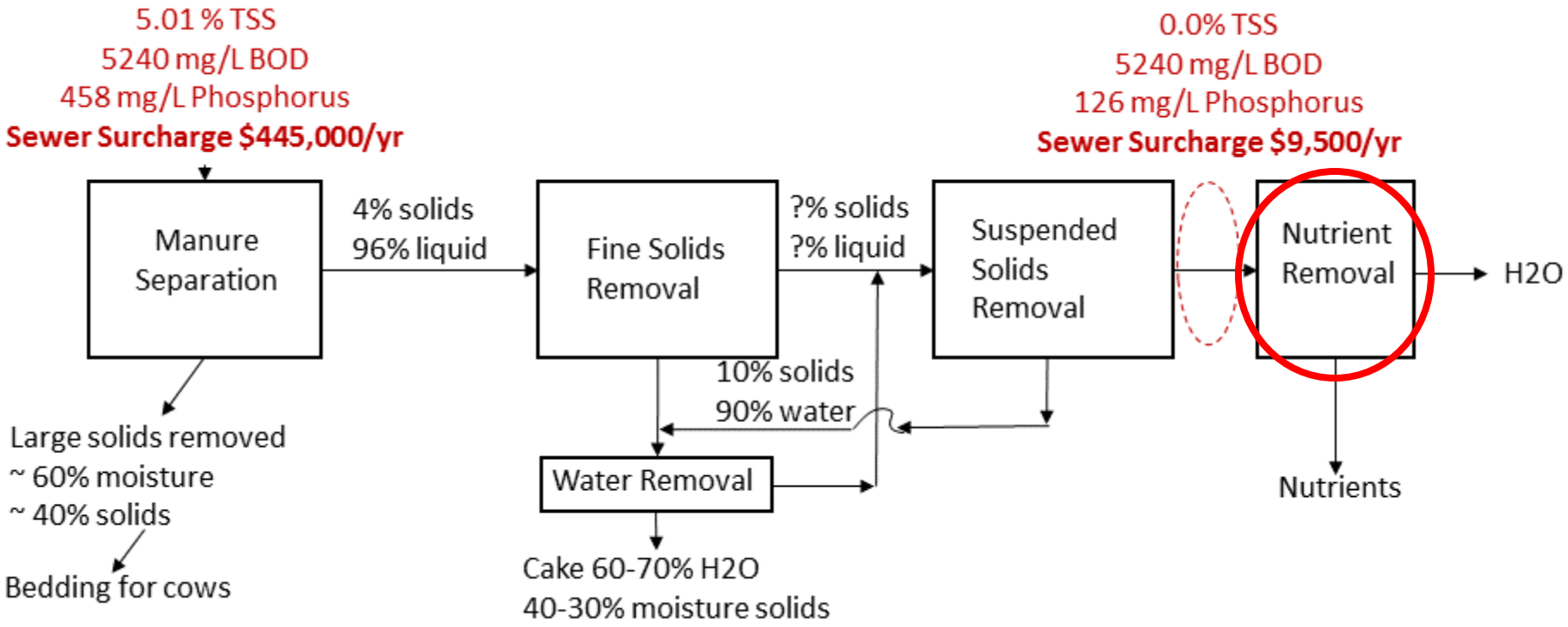


Image Source: netl.doe.gov

Step 4 – Nutrient Removal

Problem – Remove nutrients from 0% TSS water

General Process Flow



Alternatives (Nutrient Removal)

Sequencing Batch Reactor

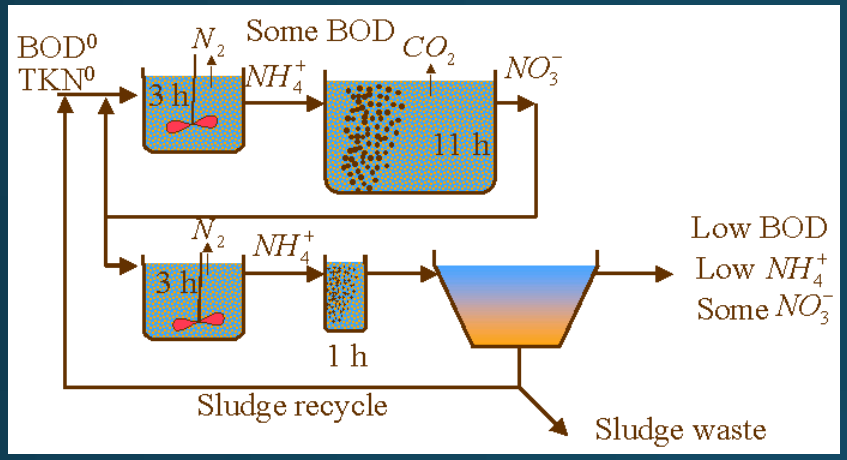


Image Source: ceeserver.cee.cornell.edu

Multiple Media Filter

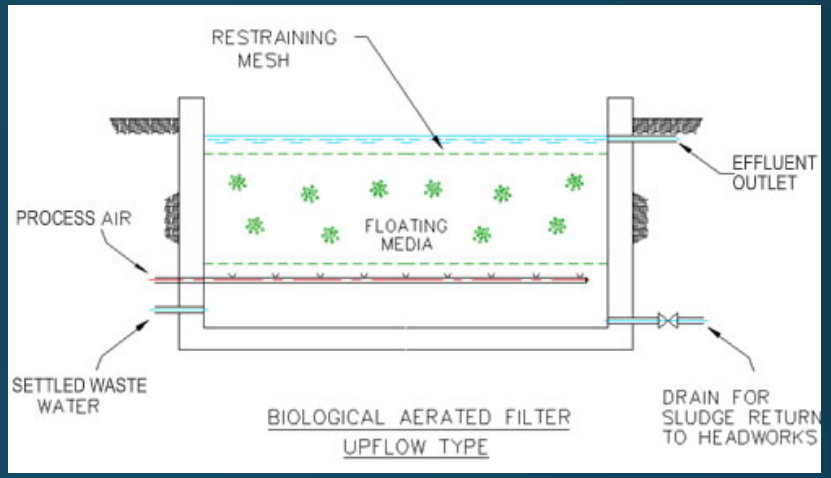


Image Source: www.watermaxim.co.uk

Membrane Filtration

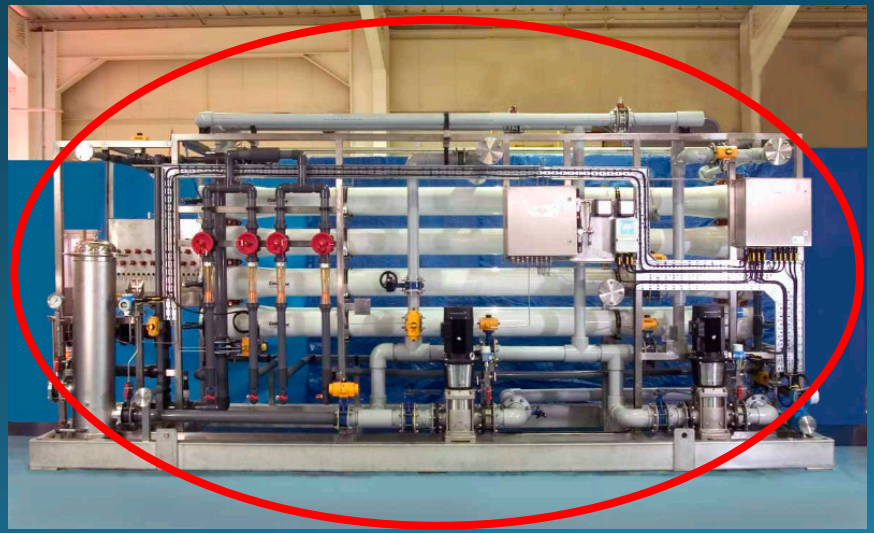


Image Source: www.axiumprocess.com

Nutrient Removal

Membrane Filtration

Image Source: www.axiumprocess.com

Is there a commercially available system rather than designing a complete one from components?

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YES

Alternative Systems

- Livestock Water Recycling (Calgary, AB)
- Clearwater Clarification (Regina, SK)
- McLanahan Nutrient Separation System (Michigan, USA)

Constraints and Criteria to pick a commercial system:

- Support
- Western Canadian Experience
- Proven Commercialization
- Appropriate for 100 Cow Dairy

Livestock Water Recycling (LWR)

- Calgary, AB
- Systems installed in Canada and the US
- Can meet all the project objectives
- Can reuse water for wash and/or discharge to the city

Is this more economical AND less risk than designing our own?

- Implementation time
- They've tested and worked out the bugs
- Experience and support

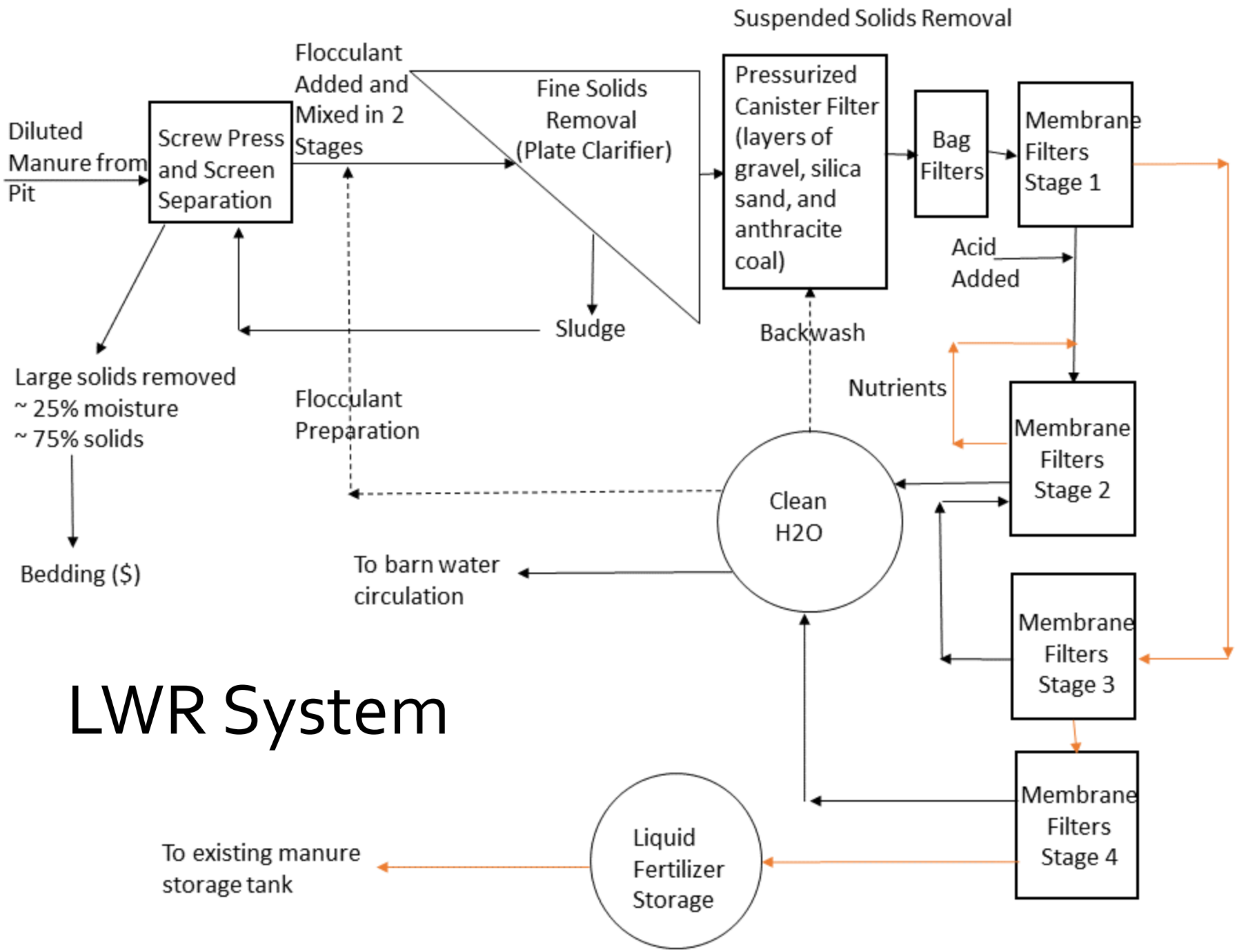
Images Source: Livestock Water Recycling

LWR
LIVESTOCKWATERRECYCLING.COM

How do we design this system into the current barn?

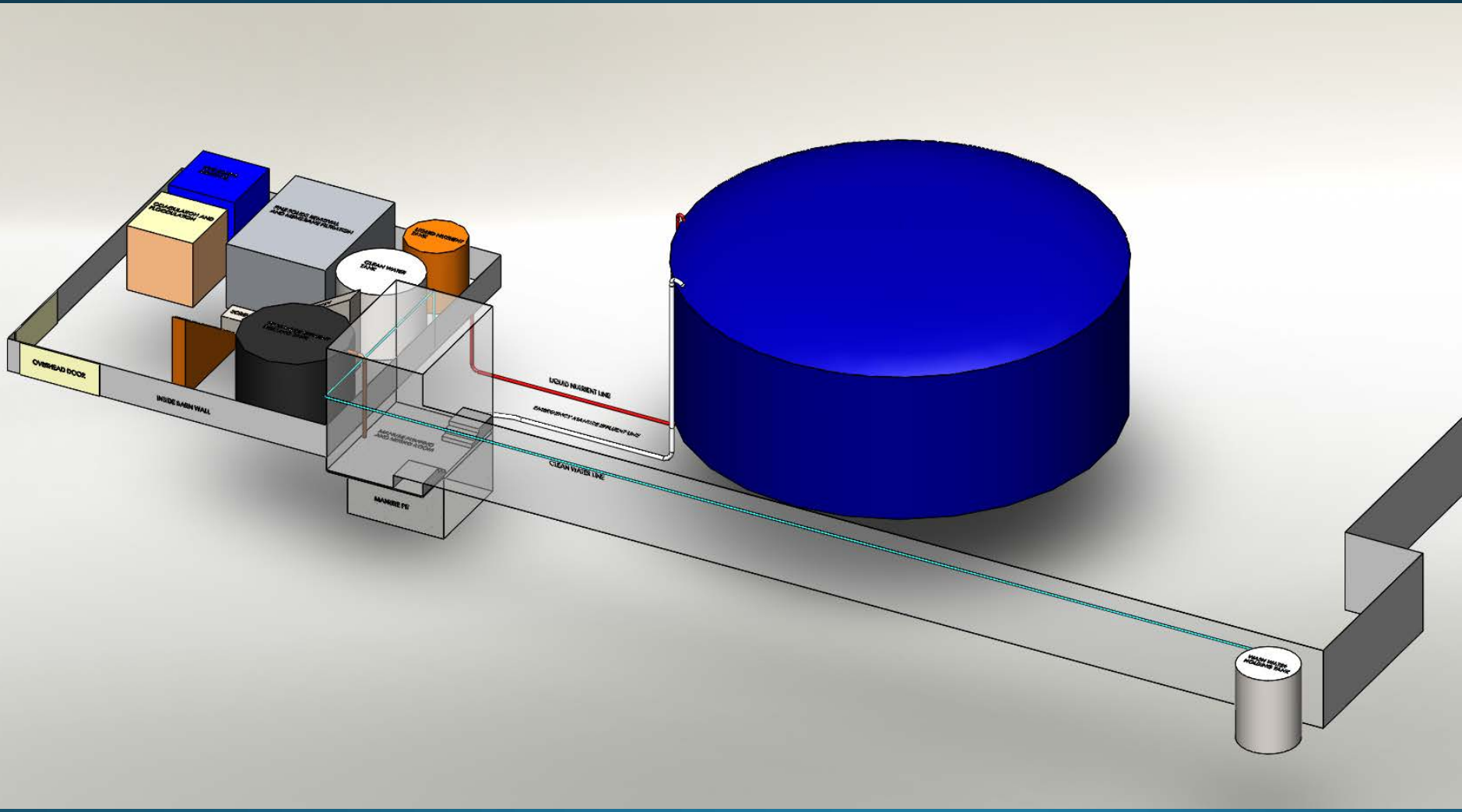
Problem: LWR does not provide details

Solution: Check the patent

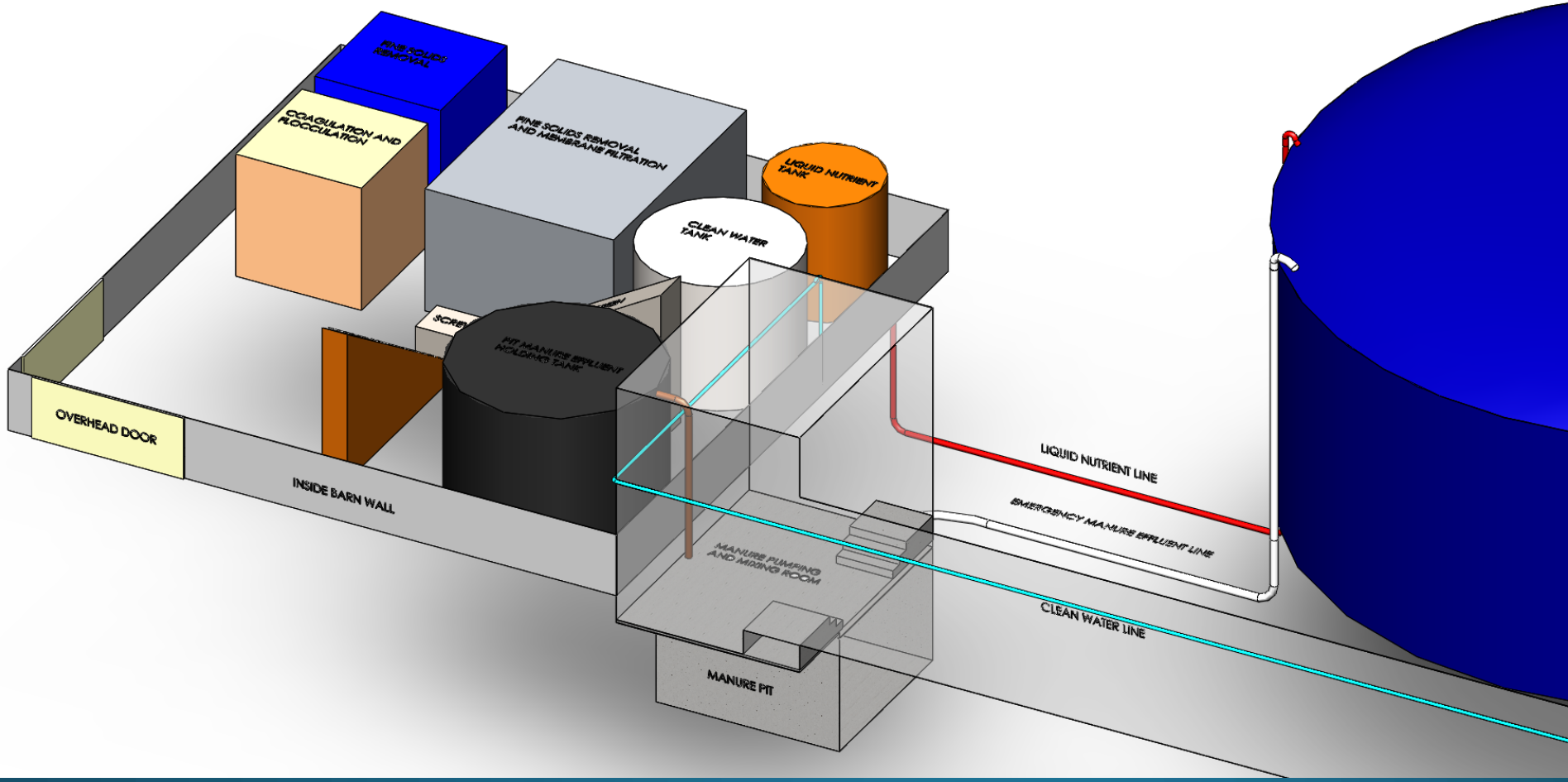

Suspended Solids Removal
Flocculant Added and Mixed in 2 Stages
Fine Solids Removal (Plate Clarifier)
Pressurized Canister Filter (layers of gravel, silica sand, and anthracite coal)
Bag Filters
Membrane Filters Stage 1
Diluted Manure from Pit
Screw Press and Screen Separation
Acid Added
Sludge
Backwash
Large solids removed
~ 25% moisture
~ 75% solids
Flocculant Preparation
Nutrients
Membrane Filters Stage 2
Clean H2O
Bedding ($)
To barn water circulation
Membrane Filters Stage 3
LWR System
Membrane Filters Stage 4
Liquid Fertilizer Storage
To existing manure storage tank

Detailed Design

Complete System Layout



Close-Up View



Manure Solids Separation

Images Source: Livestock Water Recycling

Use of Manure Solids

Photo Credit: Terry Fonstad

Dairy several km North of Saskatoon

Each cow produces 2x the bedding it needs

Photo Credit: Terry Fonstad

Liquid nutrient component

Clean Water Recycling

Photo Credit: Alanna Howell

Full Treatment System Cost Estimate

One-Time Capital Costs		**Cost**
LWR System Equipment Portion	$	640,000.00
Installation Costs	$	60,000.00
Building Costs	$	350,000.00
New Tanks and Piping	$	50,000.00
Total One-Time Capital Costs:	**$**	**1,100,000**
Yearly Operation Costs		
Electricity	$	14,500.00
Cost of Chemical Additives	$	26,600.00
Labour and Maintenance	$	30,000.00
Total Yearly Operation Costs	**$**	**71,100**
Yearly Savings due to Process Products		
Savings due to using manure solids as bedding	$	8,800.00
Savings due to recycling clean water	$	6,000.00
Total Yearly Savings due to Process Products	**$**	**14,800**
Yearly Operation Costs - Yearly Savings	**$**	**56,300.00**

New Manure Handling System

- Each year, the system would produce:
  - 2 Million Litres of 0.2 – 0 -0.6 liquid nutrient
  - 4 Million Litres of clean water
  - 1 Million Litres volume of reclaimed manure solids

- **104 employee hours** required per year for weekly operation and maintenance of the current system
- **450 employee hours** required per year for operation of the system
- **~$60,000** in net annual operation and maintenance

Conclusions

Based on a complete manure treatment system:

- Capital costs ~ $1.1 M
- Yearly operating costs ~ $60,000
- Valuable by-products
- Significantly reduced odour
- Hauling once per year, in the summer
- More weekly labour input required

Recommendations

- Consider using reclaimed manure solids as bedding
- Consider eliminating the final nutrient removal step in the process
- Continue with the current system if cost and labour are the most significant criteria

Acknowledgements

- Dr. Terry Fonstad, P.Eng.
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- Dr. Bernard Laarveld
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- Margret Asmuss, U of S Office of Sustainability
- Erin Akins, U of S Office of Sustainability

Questions

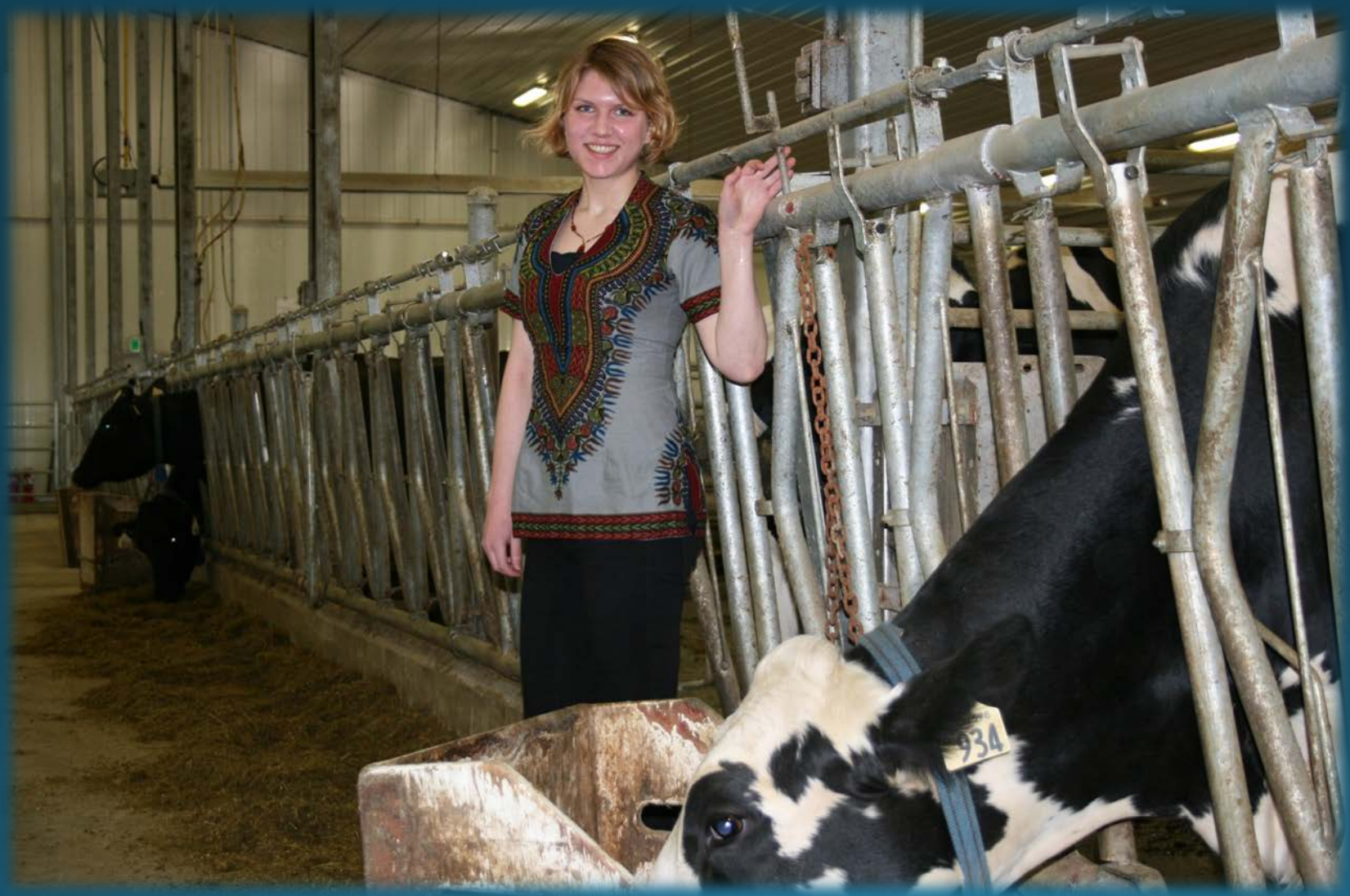

Photo Credit: Michael Robin