A Presentation of the
2011 IA-MN-SD Drainage Research Forum

November 22, 2011
Okoboji, Iowa
Subsurface Drainage Pumped Outlets

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Todd Stanley
Farmer
Grygla, MN
Glacial Lake Agassiz and the Red River Valley
Typical Lift Station
Need For Lift Pump

- No Gravity Outlet
  - Shallow ditch, No permission to make ditch deeper
  - Culvert through road is at a higher elevation than the tile main
Need For Lift Pump

- Outlet (ditch) fills up after a large rain and takes several days to subside
- You want to have control of water leaving the field
- You want to gain more grade on laterals
Drainage Pump Stations

Where to Locate?
Pump Selection
Power Requirements
Pump Controls
  - Float (on/off)
    - Sump Storage Volume
  - Variable Frequency Drives
Pump Station Location

- Ideal: Near Drain Outlet and Electric Service
  - Limits pumping distance and pump size
  - No surface drainage (except tile surface inlet)

- In Some Cases: Near electric service is more desirable than near outlet
  - Trade-off: cost of extending electric lines versus cost of piping

- Other Considerations:
  - Potential for vandalism
  - Accessibility after a large rainfall event
  - Soil stability – will it wash away?
  - Impact on neighbors
Pump Selection

Need to determine:

- Flow Rate
- Total Head
  - Maximum lift + friction losses

Common pump types

- Submersible
- Motor Above Ground

Pumping Costs
Pump Capacity (Flow Rate)

\[ Q \text{ (gpm)} = 18.9 \times Dc \times \text{Area} \]

<table>
<thead>
<tr>
<th>Drainage Coefficient (acre-inches/day)</th>
<th>GPM per acre</th>
<th>Cubic feet per second per acre (ft$^3$/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>¼</td>
<td>4.7</td>
<td>0.01</td>
</tr>
<tr>
<td>3/8</td>
<td>7.1</td>
<td>0.016</td>
</tr>
<tr>
<td>½</td>
<td>9.5</td>
<td>0.021</td>
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</table>
Submersible Pump Station

- **Inflow**
- **Storage Volume**
- **Motor**
- **Pump On**
- **Pump Off**
- **Maximum Lift (feet)**
- **Minimum Submergence Depth – 30 inches**
Sump at Fairmount Demo Site
Motor Above Grade Pump Station

- **Maximum Lift (feet)**
- **Inflow**
- **Pump On**
- **Pump off**
- **Storage Volume**
- **Minimum Submergence Depth - 3 feet**
Lift Pumps

Capital investment

- Pump - $3,000 to $7,000 plus sump construction and installation costs.
- Total cost may add $15,000 to $20,000 to overall tile project with electric connection charges and if dewatering is needed
Example of Pumping Energy Costs

- Grygla, MN Area in 2010 (Todd Stanley)
  - 1 rain gage: 34.7 inches
  - 25 electric meters
  - 5020 acres (small amount of surface drainage)
  - Electric Bill – about $30,000
    - Just under $6/acre with a range of $3 to $10.50
    - Smaller fields (55 and 70 acres) were $12.50 and $15.
Pump Control Using Floats

- Drain Tile Inlet
- Float Control
- Pump
Pump Horsepower
Pump Efficiency = 30%

<table>
<thead>
<tr>
<th>Total Head (ft)</th>
<th>Flow Rate (gpm)</th>
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<tbody>
<tr>
<td></td>
<td>500</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>14</td>
<td>7.5</td>
</tr>
<tr>
<td>16</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Shaded Area – Single Phase Pumps
Pumps that Use Float Control: Sump Storage Volume

Depends on:
- Maximum Inflow Rate
- Desired Pump Cycle Time
  - 1 Cycle = Time Pump on + Time Pump off (minutes)
  - 10 cycles per hour (every 6 minutes)
  - Maximum pump cycles occur when tile inflow rate equals half the pump flow rate
  - Some pumps can handle 30 cycles per hour but check with manufacturer
How Much Storage is Needed?

Storage Volume per Acre ($\text{ft}^3/\text{acre}$) = $2\times \frac{Q}{N}$ where $Q$ is the gpm per acre and $N$ is the cycles per hour.

<table>
<thead>
<tr>
<th>Drainage Coefficient</th>
<th>N – Cycles per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td>1/4</td>
<td>1.6</td>
</tr>
<tr>
<td>3/8</td>
<td>2.4</td>
</tr>
<tr>
<td>1/2</td>
<td>3.2</td>
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</table>
Volume Storage Options

Vertical Storage

Vertical and Horizontal Storage
Example – Vertical Storage

$Dc = \frac{3}{8}, \ N = 10, \ 3 \text{ ft on/off}$

- 40 acres – 5 foot diameter
- 80 acres – 7 foot diameter
- 120 acres – 9 foot diameter
- 160 acres – 10 foot diameter
- 240 acres – 12 foot diameter
- 320 acres – 14 foot diameter
Vertical Storage:
Sump is 6 ft in diameter
Floats are set 3 feet apart
750 gal of storage
100 acre field, 50 acres tiled
Example – Horizontal Storage

- $D_c = 3/8$, $N = 10$, 4’ dia sump, 3 ft on/off

- 2 foot diameter horizontal storage
  - 40 acres – 7 feet
  - 80 acres – 25 feet
  - 120 acres – 44 feet
  - 160 acres – 63 feet
  - 240 acres – 100 feet
  - 320 acres – 140 feet
Horizontal Storage, 70 ft of 2’ dia Dual-wall pipe, 4’ diameter vertical Concrete riser pipe
New Technology – Variable Frequency Motor Controllers
VFD’s for Pump Control

- Just coming on the market
- Eliminates the need for storage
- Sump depth can be less
- Less wear on motors
  - Soft start options
- Uses water level sensor to control speed of pump
- Reduces energy use
Water Level Control

Level Control

Power In

Drive

Pump

Courtesy of Steve Clayton
Fusion Technologies
Control of Centrifugal Pumps

Input Power is proportional to cube root of the ratio of rpm change

Example: If you reduce the rpm in half (800 to 400 rpm) the input power will be 1/8th or 12.5% of the power used at 800 rpm
VFD Pump Control

Lift Stays Constant

Inflow

Pump Cooling and Anti-Vortex Depth

Water Level Sensor
Sump Construction

- Casing Materials
  - Corrugated Metal
  - Plastic
  - Concrete
- Main Line entrance into sump – must be sealed very well on the outside to prevent “washouts”.
- Bottom Material
  - Concrete
  - Gravel or Rocks (at least 6 inches thick)
- Dewatering to install casing
Lift Pump Management

During the Season
- Check if Pump is Operating

Annual Maintenance
- Ice damage to floats, wires, vertical piping
- Silt accumulation in the sump
- Some above ground pumps require oil or grease
Lift Station Advantages

- You control water table in the field
- Allows you to pump water even when drain outlet is full
- If water not loaded with salts, could be used to fill sprayers
Lift Station Disadvantages

- Ice and Winter Conditions
- Operating Costs per year
- Wash Outs
- Maintenance
- Installation Problems
  - High water table
  - Sealing inlet pipe
  - Gravel or concrete bottom?
- Visible sign of flowing water can cause public concerns about flooding
Measuring the Flow Rate from a Float Operated Lift Station
Raw Data from Event Logger showing Pump-On Times (solid black portion shows high frequency pump operation)
Raw Data from Event Logger showing Pump-On Times (zooming in to when pump cycling begins to increase)
Raw Data from Event Logger showing Pump-On Times (zooming in to pump on/off cycles)
Rain from 7:30 am to 2 pm
Peak Flow at 5 pm
Flow Increasing at 11 am
Rain Started 4:45 am 10/1
Rain Ended 11 am, 10/2
Peak Flow at 3:10 am, 10/2
2010 Cass Co Tile Site

¼ inch DC – 510,000 gal/day
3/8 inch DC – 766,000 gal/day
$\frac{1}{4}$ inch DC 966,000 gal/day
$\frac{3}{8}$ inch DC 1.45 million gal/day
The graph represents the tile outflow volume in gallons for the year 2010 at the Walsh Co Tile Site. The diagram includes data for ¼ inch DC, 3/8 inch DC, and 1.3 million gal/day. The x-axis represents the dates from April 8 to November 18, 2010, and the y-axis represents the tile outflow volume in gallons.
Questions? Observations! Thoughts!!