Development and Design of Cost-Effective, Real-Time Implementable Sediment and Contaminant Release Controls

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Background

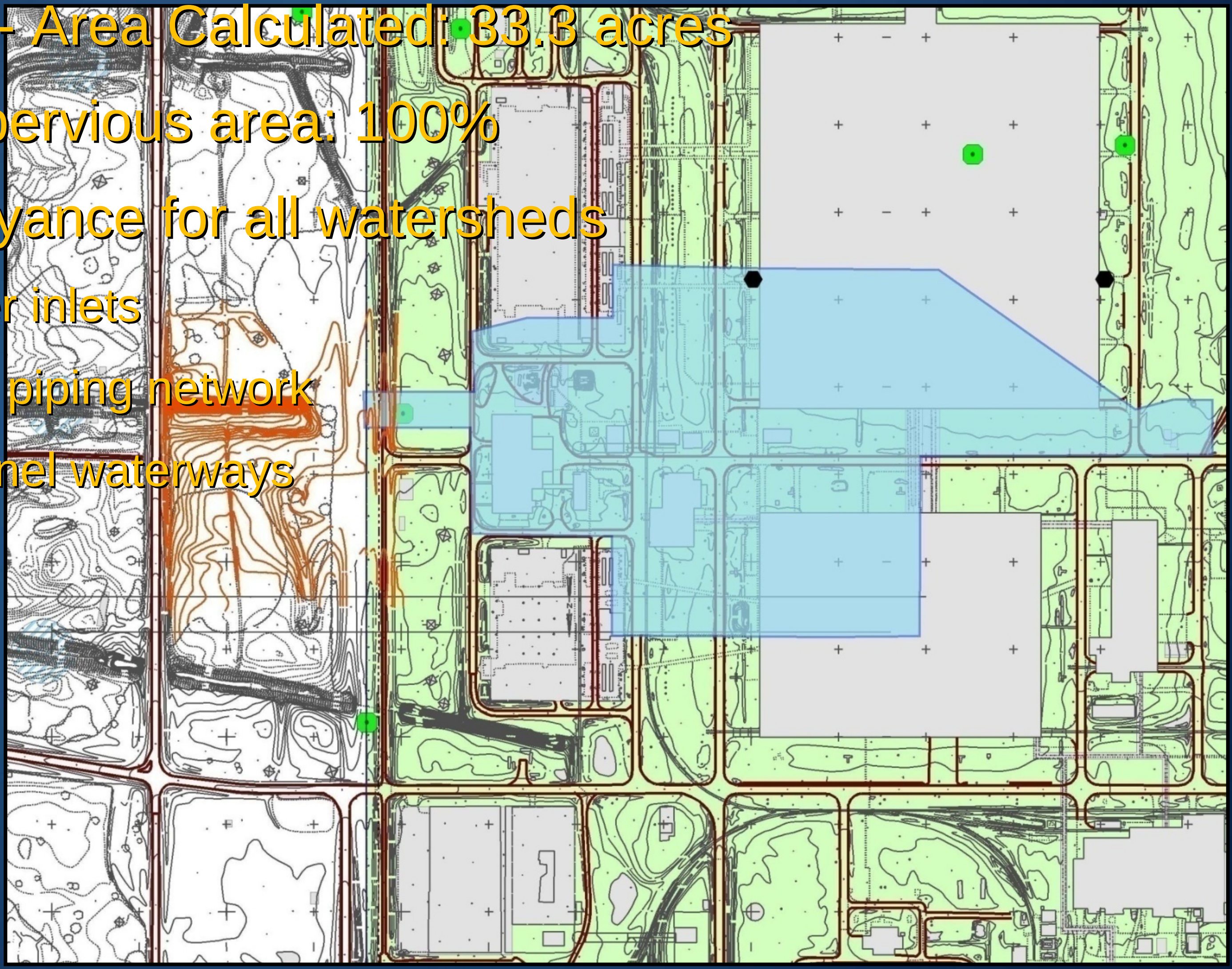
- High priority on treatment of contaminated storm water and sediment from PGDP
- Industry-standard engineering approaches have been considered
- Involve
  - **Large expenditures of capital**
  - **Long implementation timeframe**

Objectives

- Evaluate the adequacy and expected performance of existing storm water controls
- Develop alternative storm water and sediment treatment systems
- Assess and provide recommendations for identified storm water and sediment remedial options
  - cost effective
  - able to be implemented in a short timeframe

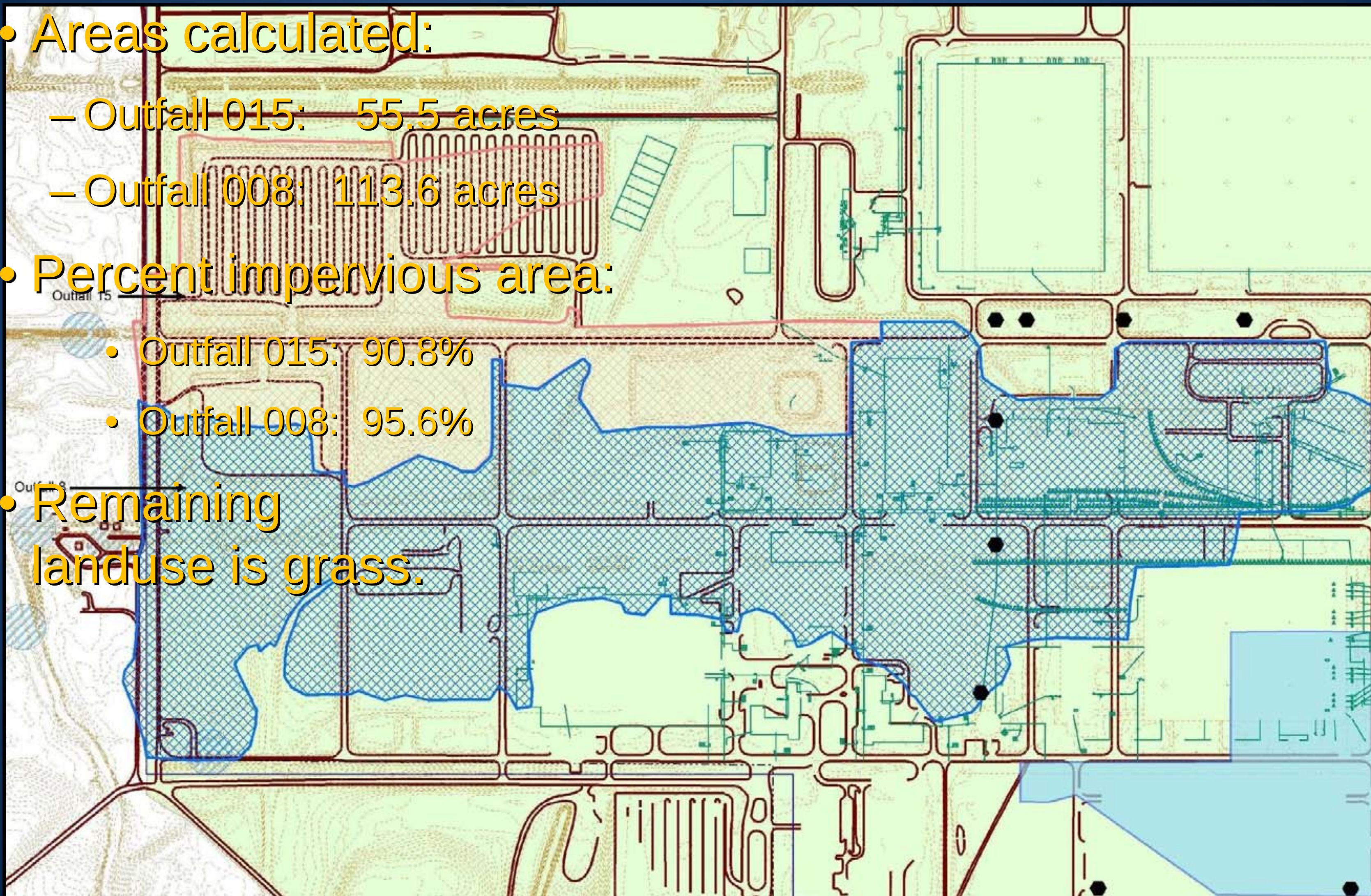
Assessment of Current Conditions - Watershed Characteristics

- Outfall 011 - Area Calculated: 33.3 acres
- Percent impervious area: 100%
- Flow conveyance for all watersheds
  - Storm water inlets
  - Associated piping network
  - Open channel waterways



Assessment of Current Conditions - Watershed Characteristics

- Areas calculated:
  - Outfall 015:   55.5 acres
  - Outfall 008: 113.6 acres
- Percent impervious area:
  - Outfall 015: 90.8%
  - Outfall 008: 95.6%
- Remaining landuse is grass.

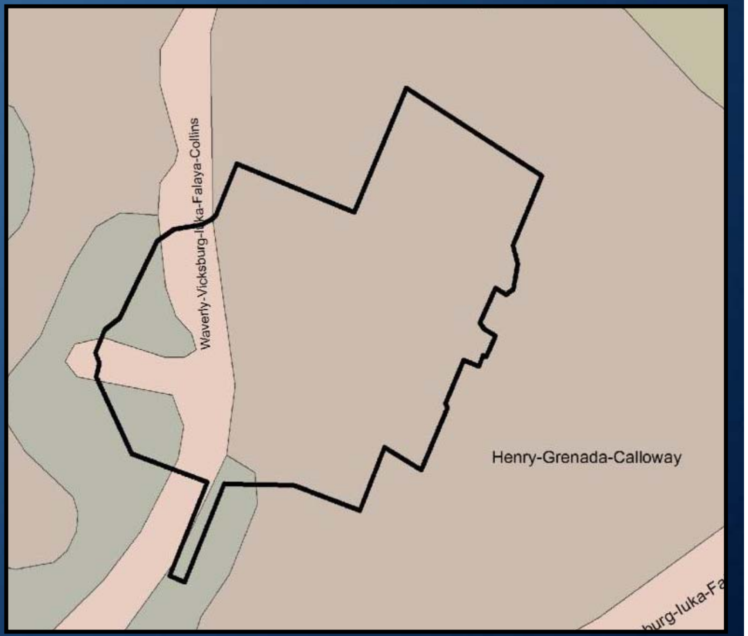


Assessment of Current Conditions – Modeling Current Conditions

- SEDCAD version 4.0 (Warner et al. 1998)
- Curve Numbers
  - 92 for impervious areas, buildings, paved and gravel areas
  - 79 for grassed areas (hydrologic soil group C)
- Time of concentration – 0.126
- Unit hydrograph response functions assigned
  - Fast for impervious areas
  - Medium for grassed areas

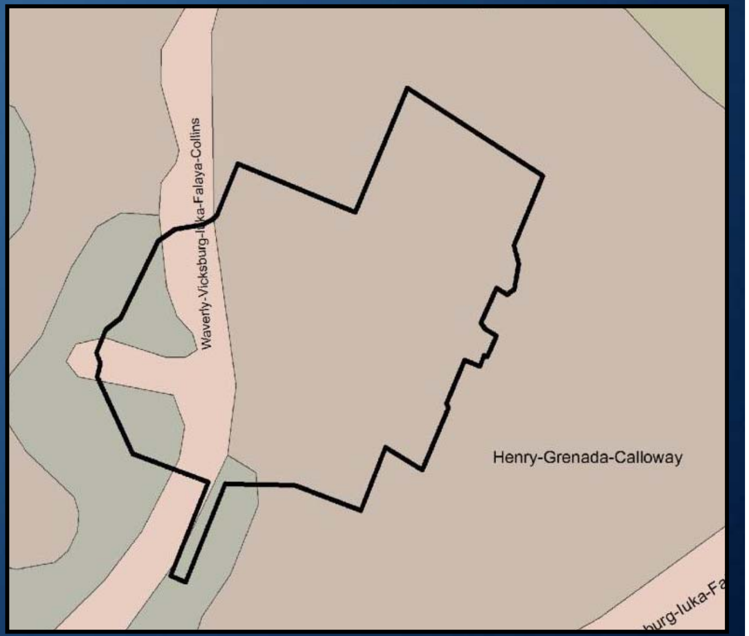
Modeling Current Conditions

- Erosion parameters similarly assigned
- Predominant soil series are:
  - Henry-Grenada-Calloway
- K-factor (erodibility) – 0.28



Modeling Current Conditions

- Representative slope lengths and gradients
  - Impervious areas
    - Slope length – 150 ft.
    - Slope gradient – 1%
  - Grassed areas
    - Slope length – 100 ft.
    - Slope gradient – 4%
- C-factor (cover factor)
  - Impervious areas – 0.02
  - Grassed areas – 0.013

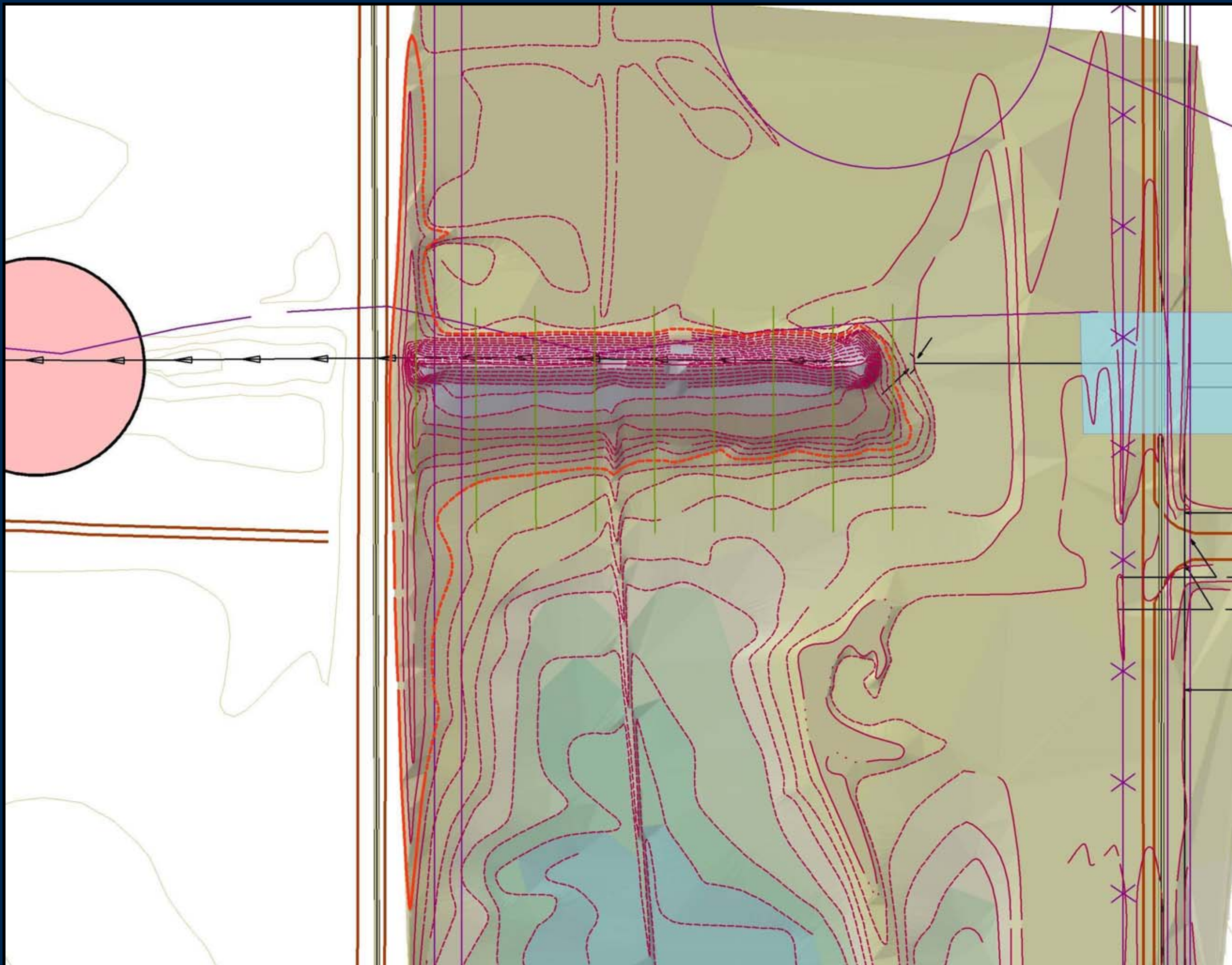


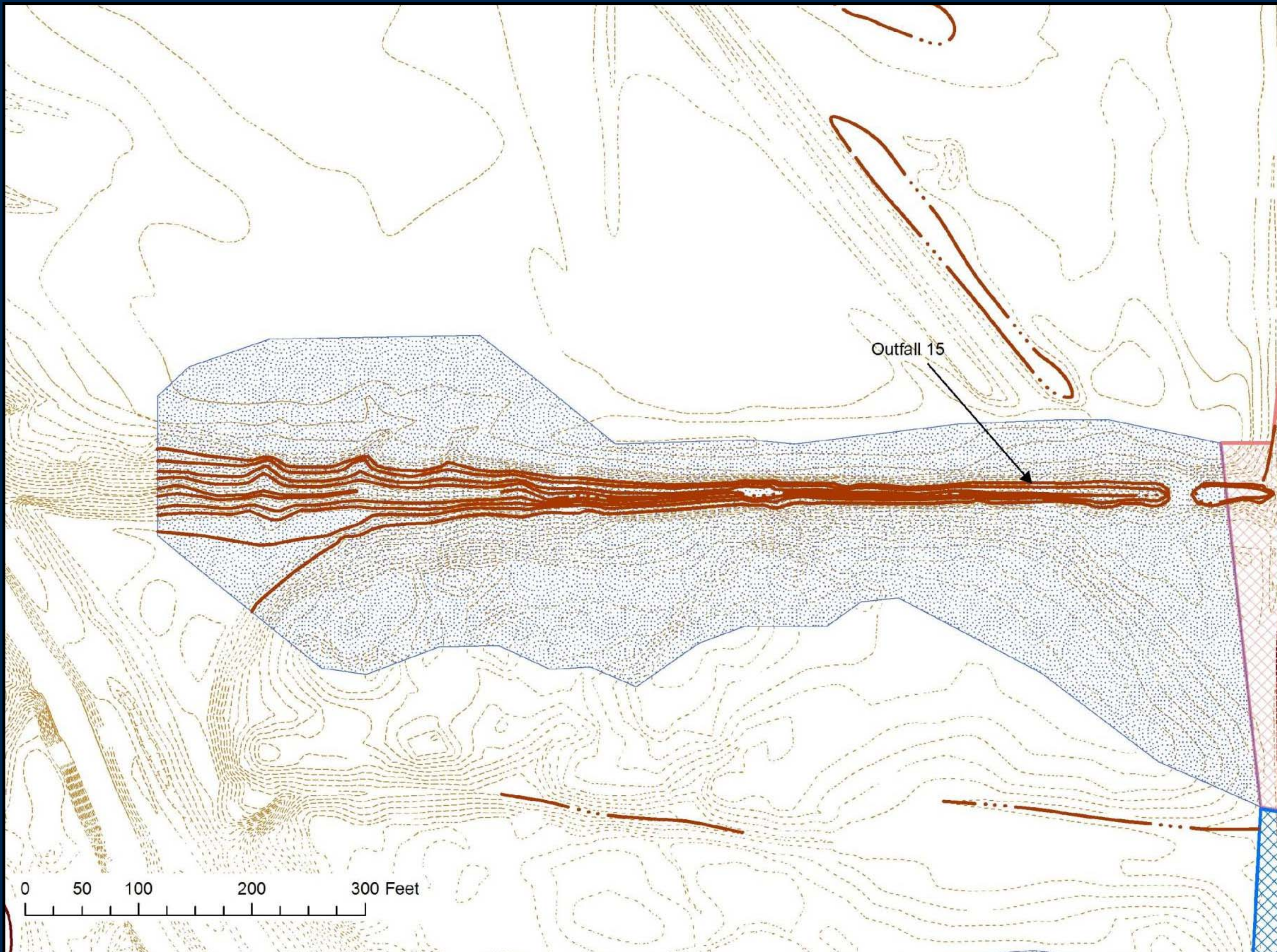
Assessment of Current Conditions - Modeling Results

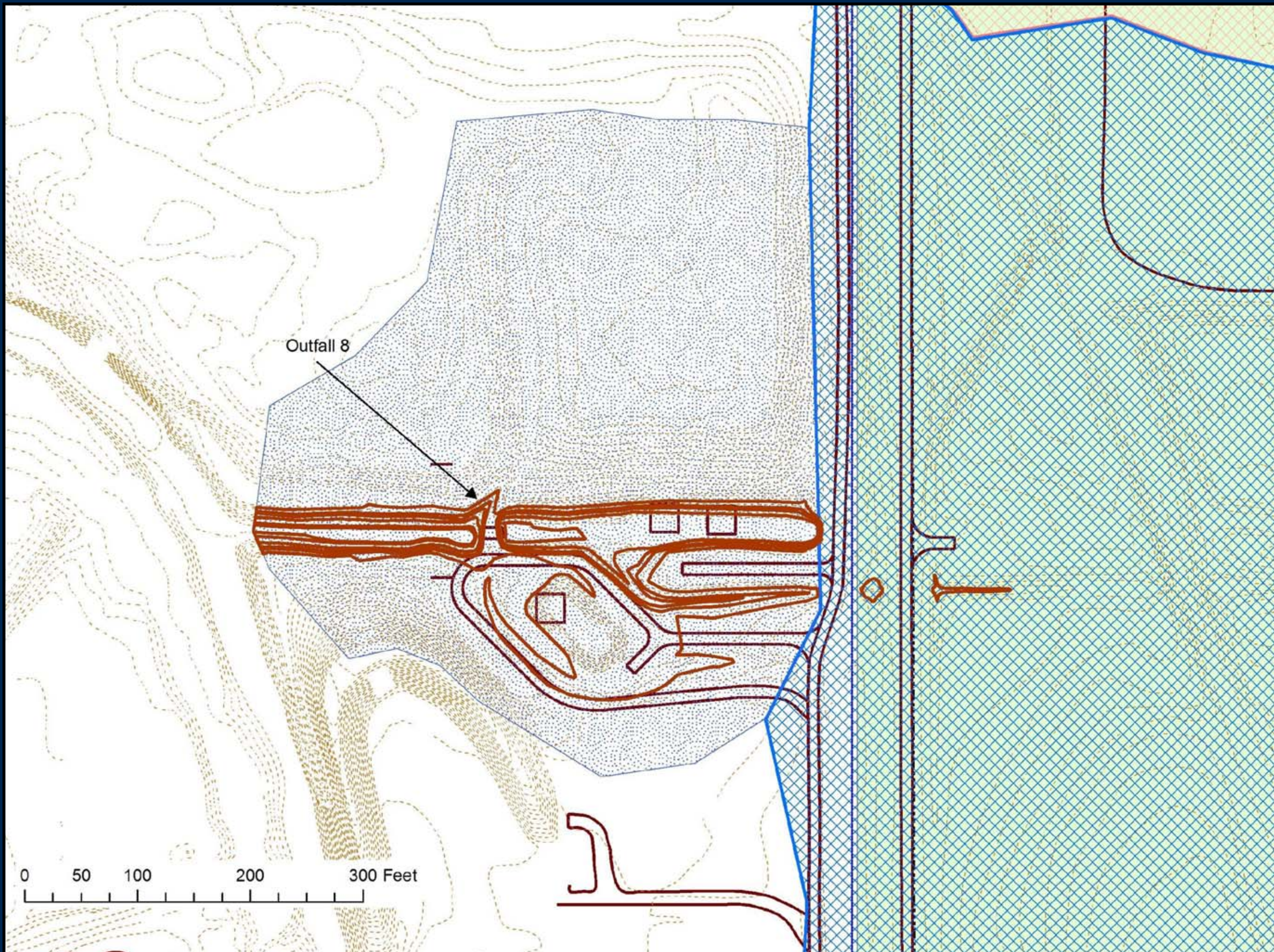
- Predicted sediment load and concentrations are low for all three outfalls
  - high density of impervious areas
  - well established grass cover
- Storms (0.5 to 3in) Outfall 015
  - peak sediment concentrations ranged from 450 – 600 mg/L
  - peak runoff – 3.8 – 99.8 cfs
  - runoff volume - 0.37 ac-ft. to 9.58 ac-ft.

Alternative Storm Water and Sediment Control Systems

- Retention Pond Performance – Design Storm Basis
  - Outfall 011
  - Outfall 015
  - Outfall 008
- Retention Pond Performance – Annual Basis
- Alternative Secondary Treatment Systems




Outfall 15
0 50 100 200 300 Feet


Outfall 8
0 50 100 200 300 Feet

Retention Pond & Embankment Design

Attribute	Outfall 011	Outfall 015	Outfall 008
Embankment Crest Elevation (ft)	377.5	365	363
Emergency Spillway			
Invert (ft)	377	363	361
Width (ft)	60	25	25
Drop Inlet			
Invert (ft)	375	361	359
Diameter (in)	36	36	36
Pond Capacity (ac-ft)			
@ Top of Dam	6.67	3.51	3.03
@ Emergency Spillway	5.92	2.03	1.70
@ Principle Spillway	3.66	0.97	0.92
100yr 24hr Freeboard (ft)	0.0	0.17	Overflows

Retention Pond Performance – Design Storm Basis: Outfall 011

- Initial condition – empty at beginning of storm event
- Runoff contained in the pond - pumped to the treatment system located near Outfall 010
- Completely contain a 2-in rainfall event (3.43 ac-ft)
- 3-in storm –
  - reduce the peak flow from 63 to 5 cfs
  - ~100 % sediment trapping
- **Performance of Outfall's 011 pond is predicted to be excellent; essentially trapping all entering sediment for storm events less than 4 inches**

Retention Pond Performance – Design Storm Basis: Outfall 015

- Storage volume for Pond 015 much smaller than Pond 011
- Watershed area is greater: 55.5 vs. 33.3 acres
- Without excavation and starting empty, Pond 015 completely contain ¾-in storm
- **Predicted sediment trap efficiency**
  - **1.5-in storm - 98.2 %**
  - **2.0-in storm - 85.5 %**
  - **3.0-in storm- 72.3 %**

Retention Pond Performance – Design Storm Basis: Outfall 008

- Watershed area of 113.6 acres - exceeds Outfall 015 by more than a factor of two
- The pond capacity, below the principle spillway, is 0.92 ac-ft, ~ the same as Outfall 015
- Contain a ½-in storm without discharging
- **Predicted sediment trapping efficiencies**
  - **1.0-in, 96.7%**
  - **1.5-in, 77.2%**
  - **2.0-in, 67.6%**

Retention Pond Performance – Annual Basis

- Analyzed Paducah airport daily precipitation data 1971 to 2000
- Cumulative rainfall curve

Rainfall (in)	%
0.5	24
0.75	40
1.0	52
1.25	62
1.5	70
2.0	82
3.0	92

Rainfall (in)	Rainfall midpoint	Probability	Outfall 011 Runoff * (%)	Outfall 015 Runoff * (%)	Outfall 008 Runoff * (%)
0.10-0.25	0.175	5.32	100	100	100
0.25-0.50	0.375	15.02	100	100	100
0.50-0.75	0.625	15.94	100	100	66
0.75-1.00	0.875	11.67	100	73	32
1.00-1.25	1.125	10.23	100	46	20
1.25-1.50	1.375	7.93	100	32	14
1.50-1.75	1.625	5.61	100	25	11
1.75-2.00	1.875	6.09	100	20	9
2.00-2.25	2.125	3.88	100	16	7
2.25-2.50	2.375	2.09	84	14	6
2.50-2.75	2.625	1.77	73	12	6
2.75-3.00	2.875	2.33	64	11	5
3.00-3.25	3.125	1.00	58	10	4
3.25-3.50	3.375	1.14	52	9	4
3.50-3.75	3.625	0.73	48	8	4
3.75-4.00	3.875	1.83	44	7	3
4.00-4.50	4.25	0.84	39	6	3
4.50-5.00	4.75	0.95	34	5	3
5.00-5.50	5.25	0.71	30	5	2
Annual containment in ponds			**83.1%**	**34.7%**	**20.2%**

* Runoff volume contained in ponds

Retention Pond Performance – Annual Runoff Volume Treated by Secondary System

Outfall	Largest Storm
011	2
015	3/4
008	1/2

Outfall	Annual Runoff Volume (%)
011	83.1
015	34.7
008	20.2

Alternative Secondary Treatment Systems

- Designs :
  - irrigation (outfall 015)
    - evapotranspiration (ET)
      - drip
      - micro-sprayers
    - evapotranspiration-infiltration (ET-I)
      - drip
      - micro-sprayers
  - weep berm (outfall 008)

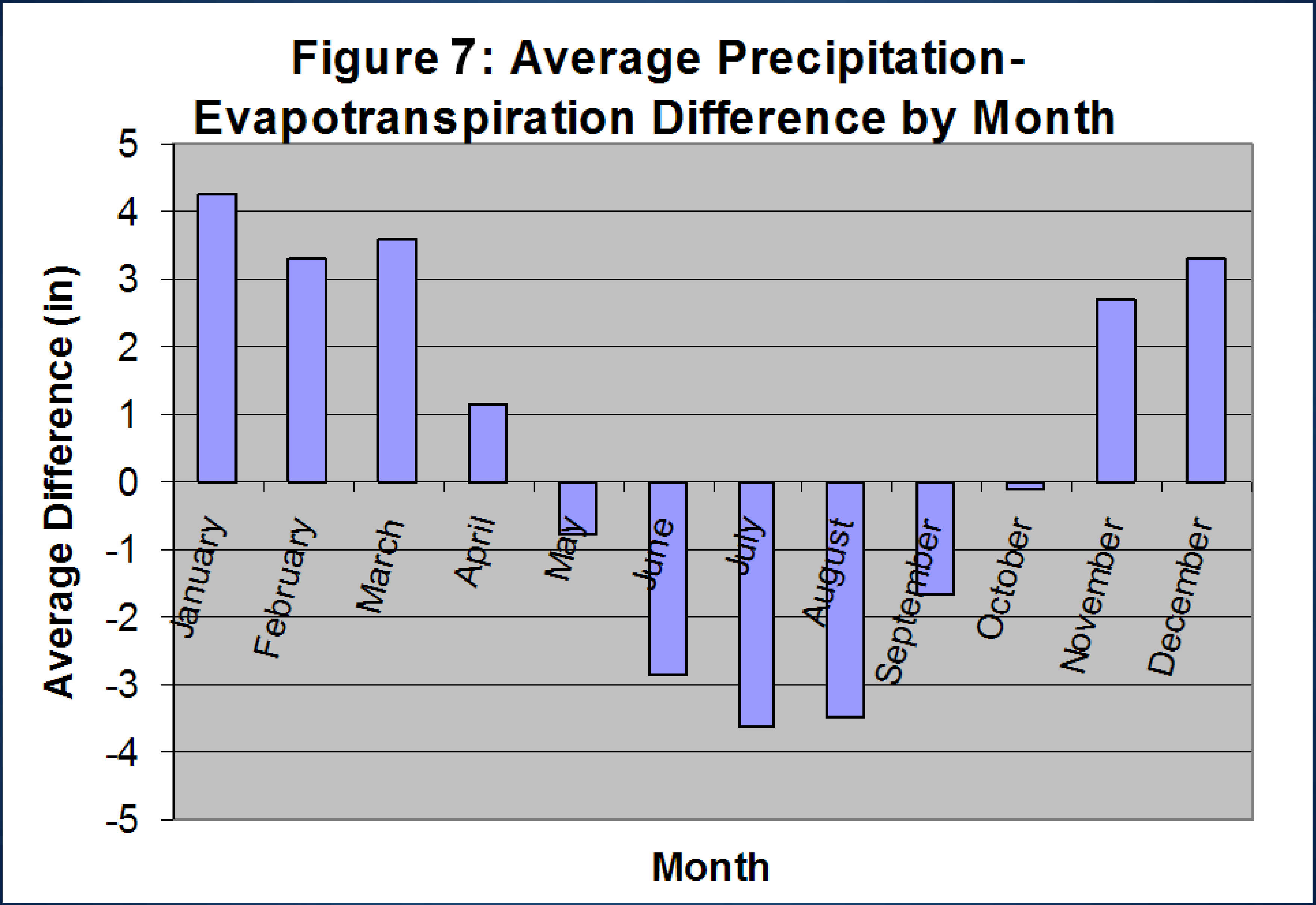
Design Alternative: ET

- Advantage of restricting application rate to match ET rate:
  - vast majority of water applied will be treated without the potential for groundwater contamination
- Disadvantage
  - slower dewatering rate of pond
  - primarily applicable April - October

Design Alternative: ET-I

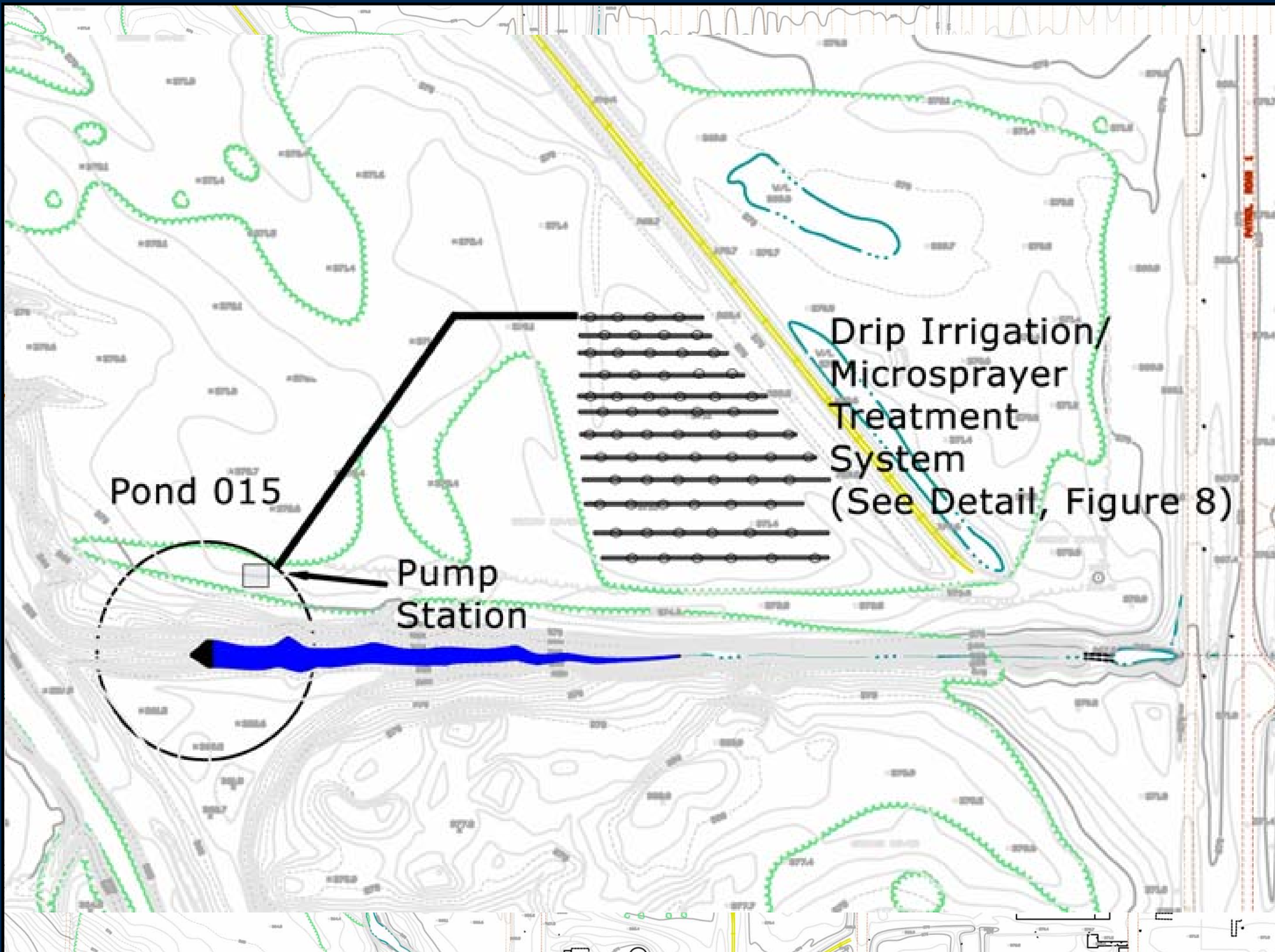
- Advantages: evapotranspiration-infiltration system:
  - ability to have a higher applications rate
  - longer duration of application -> treatment of a greater volume of water compared to the evapotranspiration method
- Disadvantage: portion of the applied water may migrate to groundwater

Evapotranspiration Method



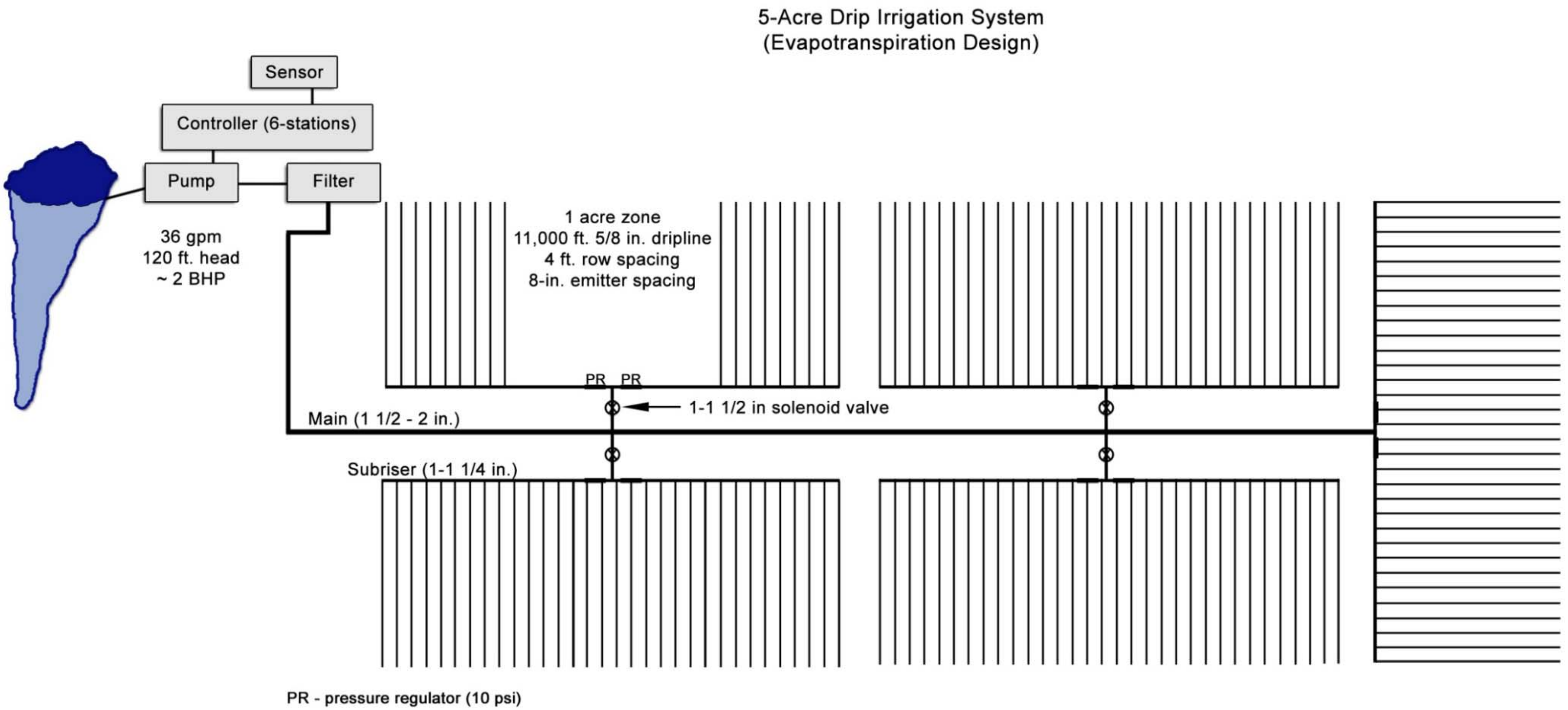
Evapotranspiration Considerations

- Daily ET
  - > 0.10 in (April - Oct)
  - > 0.16 in (May – Sept)
  - > 0.23 in (June – Aug)
- ET applicable ~ 7 months/yr



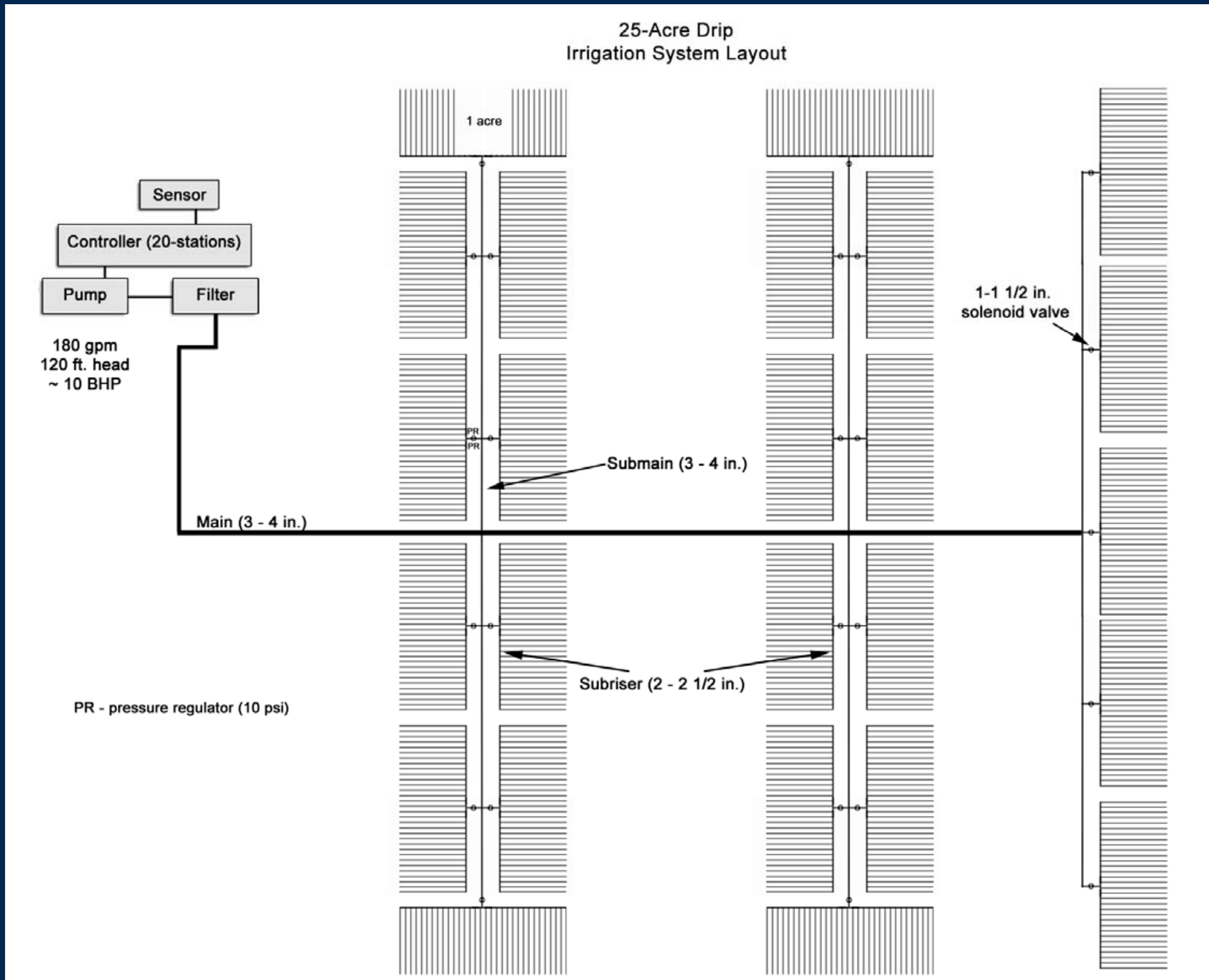
Drip Irrigation/
Microsprayer
Treatment
System
(See Detail, Figure 8)
Pond 015
Pump
Station

Drip Irrigation System



Evapotranspiration Method – Drip Irrigation System

- Dewatering Time (daily ET 0.11)
  - 21 days (5 ac)
  - 4 days (25 ac)
- Dewatering Time (daily ET 0.22) – June - August
  - 10 days (5 ac)
  - 2 days (25 ac)


25-Acre Drip
Irrigation System Layout
1 acre
Sensor
Controller (20-stations)
Pump
Filter
180 gpm
120 ft. head
~ 10 BHP
1-1 1/2 in.
solenoid valve
PR
PR
Submain (3 - 4 in.)
Main (3 - 4 in.)
Subriser (2 - 2 1/2 in.)
PR - pressure regulator (10 psi)

Infiltration Assumptions

- Soil infiltration rate based - soil texture
- Steady state infiltration rate (hydrologic soil group ‘C’) 0.05 to 0.15 in/hr
- Due to macropores, the infiltration rate may be substantially higher.
- Initial infiltration rate - 0.4 to 0.5 in/hr and short duration irrigation application rates can exceed 0.6 in/hr without runoff.

Evapotranspiration/Infiltration Method – Drip Irrigation System

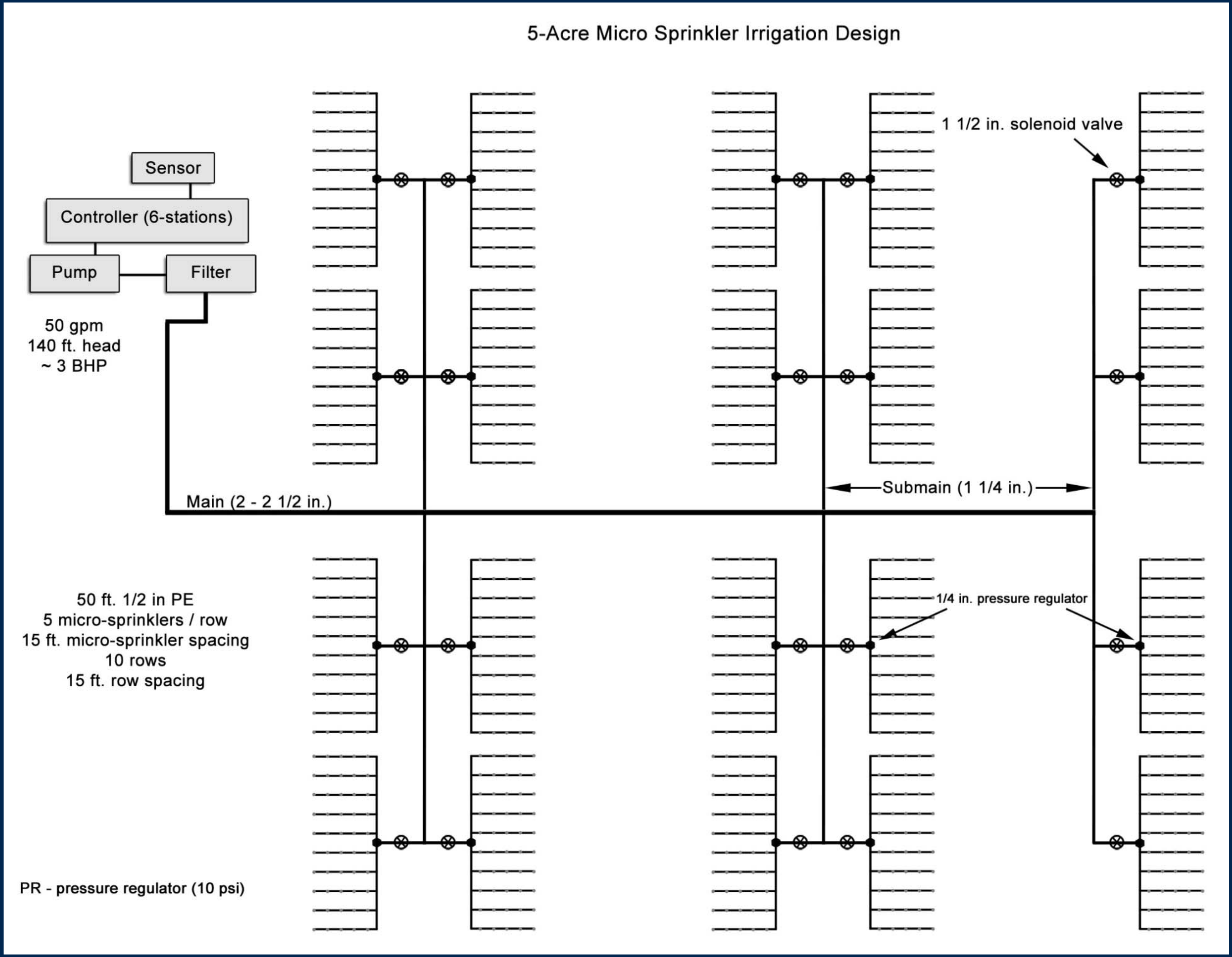
- Assumed
  - steady state infiltration rate of 0.1 in/hr
  - 10-hour irrigation duration
- Dewatering Time
  - 2 days (5 ac)

Micro-sprinkler Irrigation System

- Micro-sprinklers:
  - small rotating spray heads
  - radius ~ 15 ft
  - 1 gpm
- Close to the ground
- Limited exposure to drift
- Evaporation rate of spray ~ 20% of application rate
- Spatial coverage is better than drip - ET more uniform
- Higher irrigation application rate than drip - operating times are reduced

Evapotranspiration Method
– Micro-sprinkler Irrigation System

- Head-to-head coverage spacing: 15-ft spacing between sprayers
- ~ 200 micro-sprayers /ac
- Application rate - 0.43 in/hr
- Operation time/zone:
  - ET rate of 0.11 inch/day: 15 minutes/day
  - ET rate of 0.22 inch/day: 30 minutes/day .

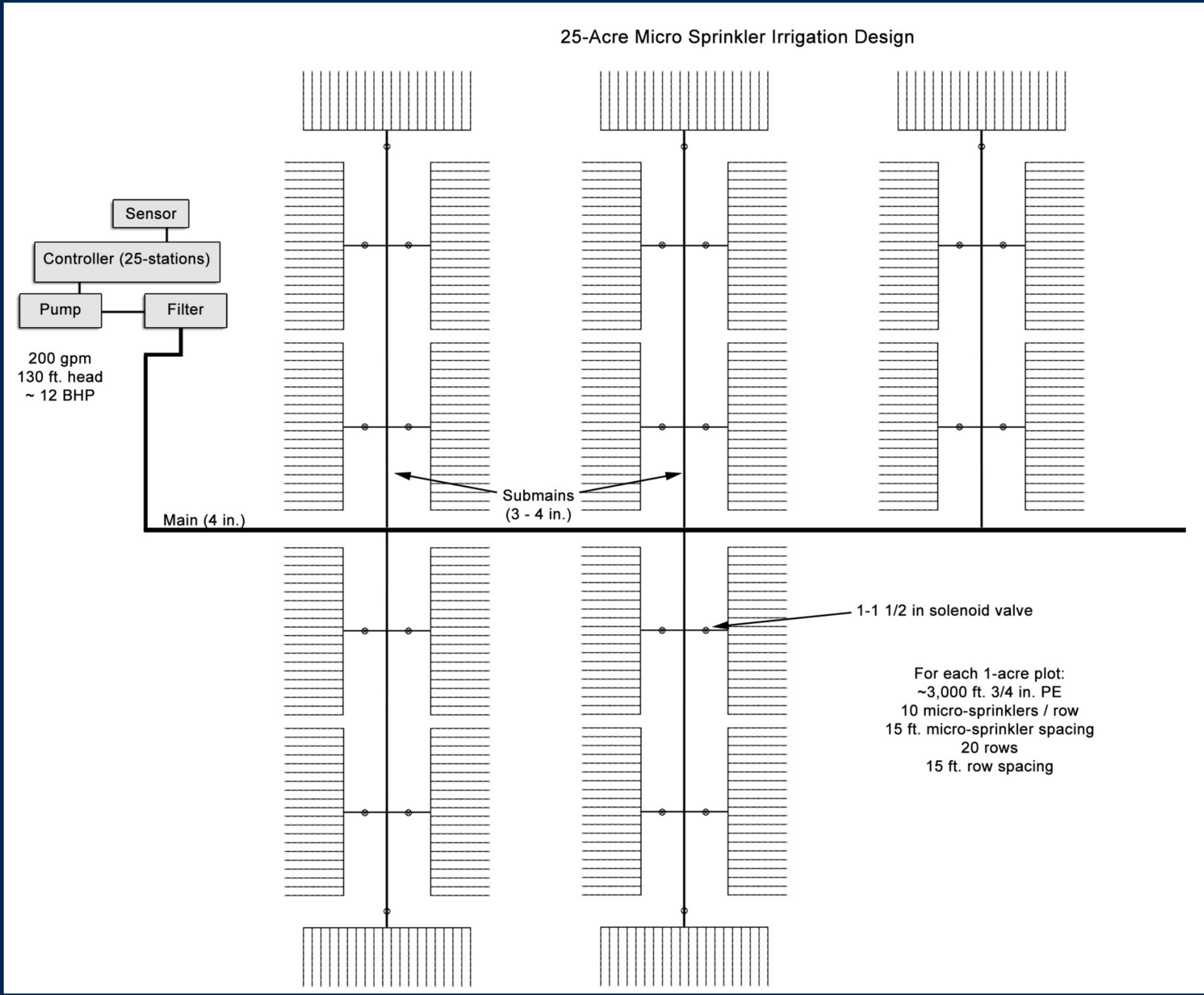


5-Acre Micro Sprinkler Irrigation Design
Sensor
Controller (6-stations)
Pump
Filter
50 gpm
140 ft. head
~ 3 BHP
1 1/2 in. solenoid valve
Submain (1 1/4 in.)
Main (2 - 2 1/2 in.)
50 ft. 1/2 in PE
5 micro-sprinklers / row
15 ft. micro-sprinkler spacing
10 rows
15 ft. row spacing
1/4 in. pressure regulator
PR - pressure regulator (10 psi)

Evapotranspiration Method
– Micro-sprayer Irrigation System

- Operate on a pulse irrigation method
- 1.0 inch daily infiltration (1.3 in/day)
- 0.54 ac-ft/day applied
- Each 1-ac zone - operate ~ 3 hrs/day
- Total operating time (5 zones): 15 hours/day

- Time to dewater Pond 015:
  - 8 days (5 ac)
  - ~1 ¾ days (25 ac)

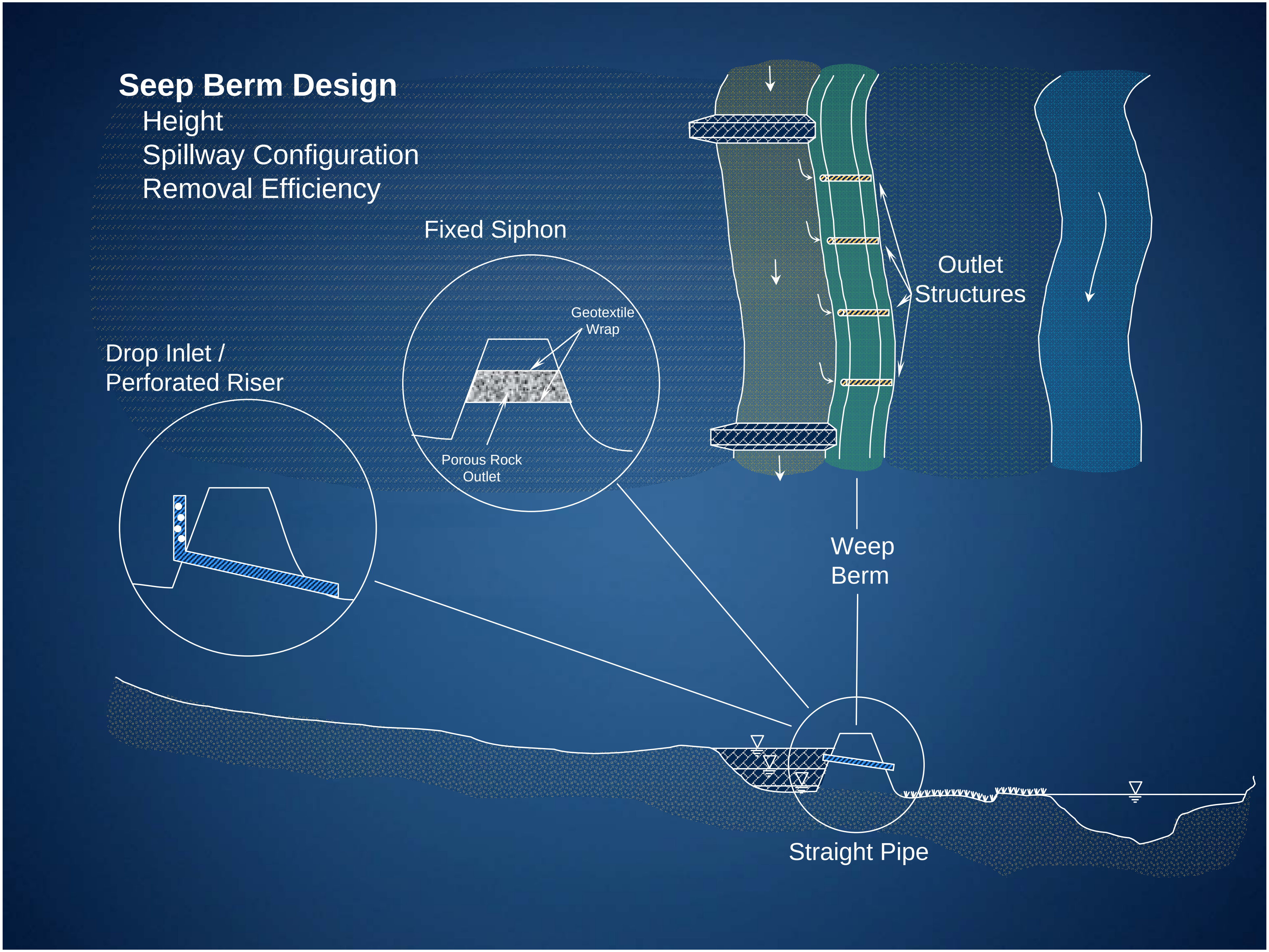

25-Acre Micro Sprinkler Irrigation Design
Sensor
Controller (25-stations)
Pump
Filter
200 gpm
130 ft. head
~ 12 BHP
Main (4 in.)
Submains
(3 - 4 in.)
1-1 1/2 in solenoid valve
For each 1-acre plot:
~3,000 ft. 3/4 in. PE
10 micro-sprinklers / row
15 ft. micro-sprinkler spacing
20 rows
15 ft. row spacing

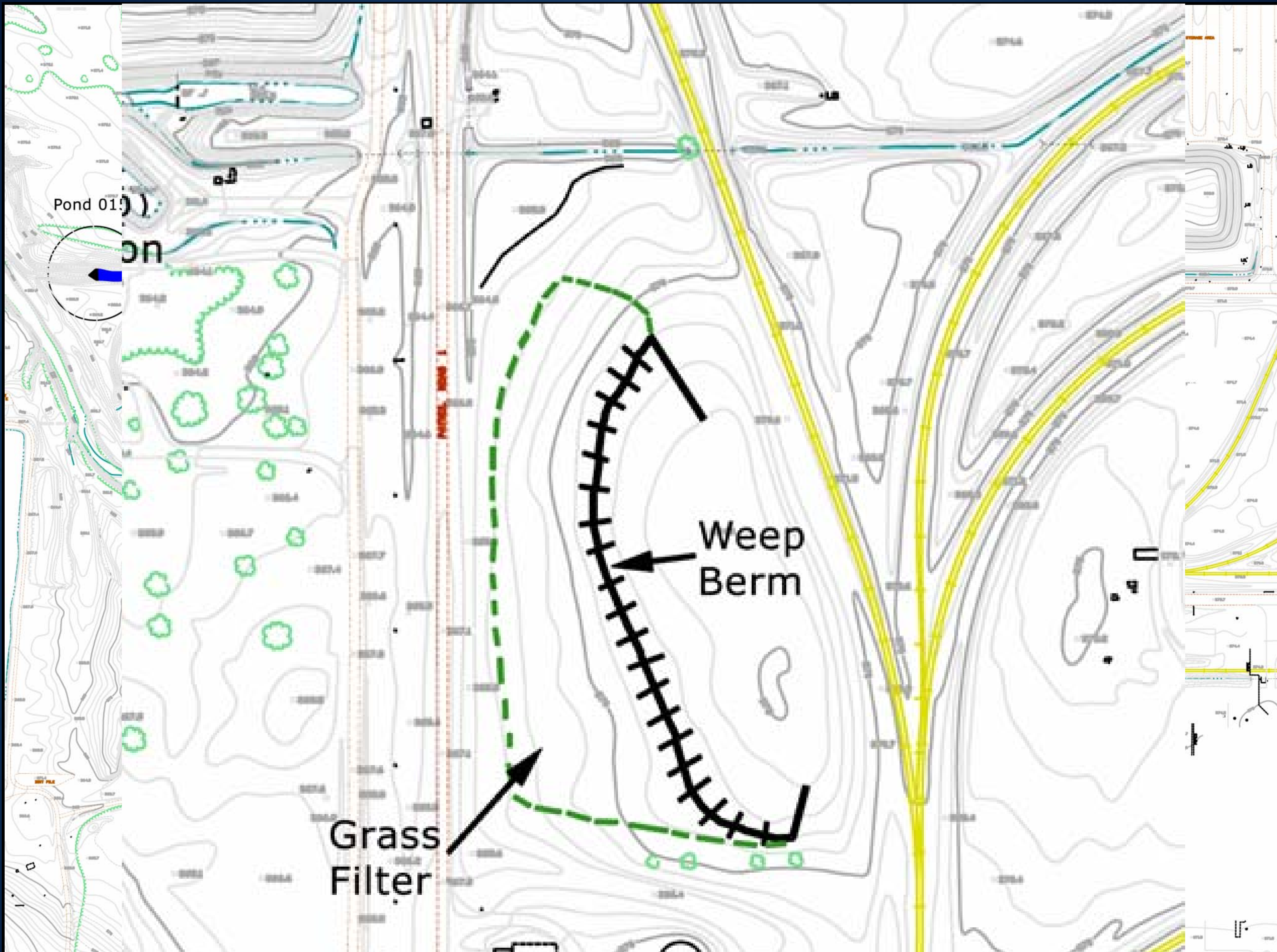
Evapotranspiration/Infiltration Method – Micro-sprayer Irrigation System

- Operate on a pulse irrigation method
- 5-ac site
  - 1.0 inch daily infiltration (1.3 in/day)
  - 0.54 ac-ft/day applied
- Each 1-ac zone - operate ~ 3 hrs/day
- Total operating time (5 zones): 15 hours/day
- Time to dewater Pond 015: ~ 1 3/4 days (5 ac)

Combined Weep Berm – Grass Filter

- A weep berm - simply an earthen berm that temporarily detains water that is slowly and passively discharged through multiple pipes, to the down-gradient grass filter.
- Low cost, easily constructed, and highly effective
- Further treatment and infiltration occurs along the grass filter prior to any residual runoff re-entering Outfall 008's retention pond.
- Works synergistically with the down-gradient riparian zone *and* blends into the natural landscape
- A combination weep berm-grass filter reduces sediment concentration


Seep Berm Design
Height
Spillway Configuration
Removal Efficiency
Fixed Siphon
Geotextile Wrap
Porous Rock Outlet
Drop Inlet / Perforated Riser
Outlet Structures
Weep Berm
Straight Pipe



Pond 015
Weep
Berm
Grass
Filter

Combined Weep Berm – Grass Filter

- Weep Berm Design Parameters
  - length – 450 ft
  - height – 2 ft
  - storage capacity – 0.275 ac-ft
  - 1-in PVC pipes at 10 ft spacing and 1 ft invert
  - pumping rate from Pond 008 – 450 gpm
  - pump operating time – 6 hr/day
- Dewatering time for Pond 008 ~ 2 days

Combined Weep Berm – Grass Filter

- Grass Filter Design Parameters
  - length – 250 ft
  - slope – 4 %
  - steady-state infiltration rate – 0.1 in/hr
  - grass – existing vegetation

Weep Berm – Grass Filter Performance

- Storm – 0.7 in
- Weep berm steady state stage – 1 ¾ ft
- Freeboard – ¼ ft
- Sediment trap efficiency of weep berm – additional 36%
- Peak effluent – 88 mg/L
- Sediment trap efficiency of grass filter - ~ 100 %
- Peak effluent - 2 mg/L

Findings - Sediment Trap Efficiency of Ponds

Outfall	Sediment Trap Efficiency (%)	Storm Size (in)
011	99.7	4
015	72.3	3
008	67.6	2

Findings - Annual Runoff Volume Treated by Secondary System

Outfall	%
011	83.1
015	34.7
008	20.2

Findings – Dewatering Time Pond 015

	Dewatering Pond 015 (days)	
Treatment System	5 ac	25 ac
ET		
Drip	21	4
Micro	8	1 3/4
ET-Infiltration		
Drip	2	n/a
Micro	1 3/4	n/a

General Findings – Weep Berm-Grass Filter

- Pond 008
- ~ 100% sediment retention