Preliminary Design of Alternative Treatment Systems for Outfalls 011, 015 and 008

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Design/Management Goals

- Water Quality Protection Design Storm
- Systems approach
- Positive control

Positive Control

- Enable implementation of alternative management decisions
- Availability of alternative management schemes
- Real-time decision making
- Flexibility in operation

Systems Approach

- Completely integrated components
- Integrate with natural system
  - passive/active
- During planning and design incorporate management options

Effectiveness of Water Quality Treatment for NPS

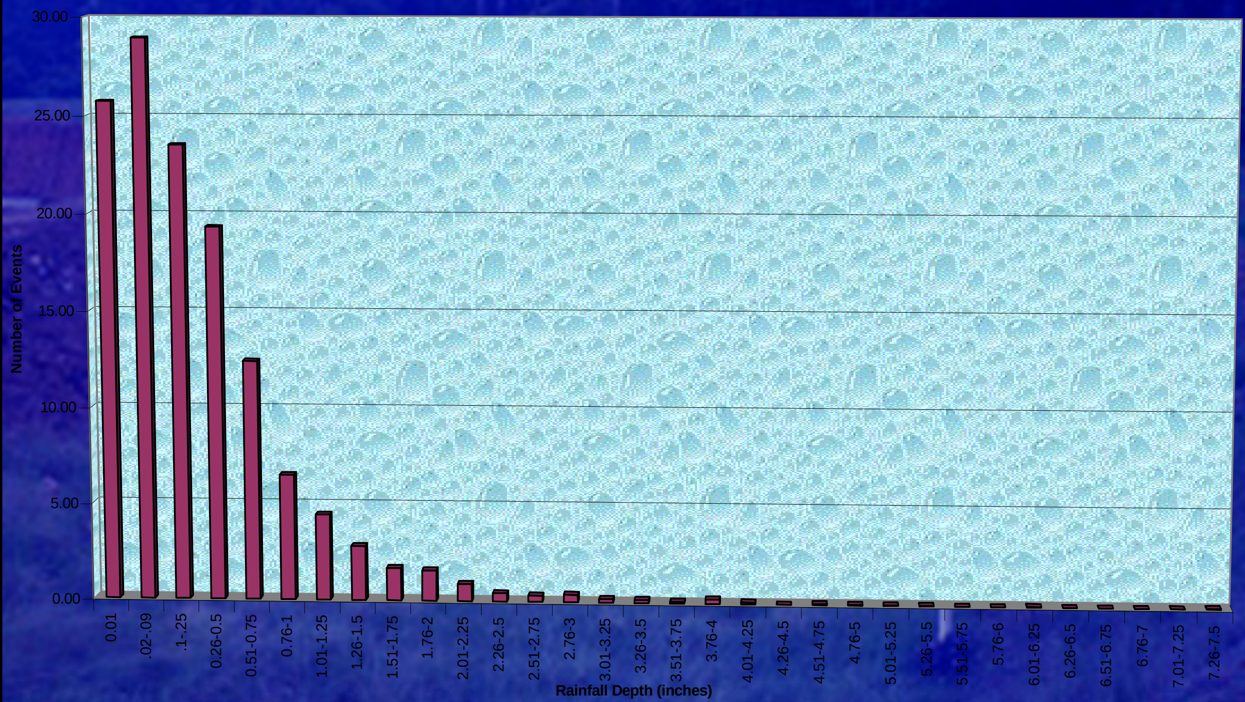
"The effectiveness of any stormwater water quality treatment practice is a function of how much stormwater is treated by the system and how much by-passes the practice".

Storm Size

- Excellent results for most storms
  - 1-inch design storm (52%)
- Very good results for large storms
  - 1.5 -inch design storm (75%)
- Structural stability for largest storms

Incremental Storm Events

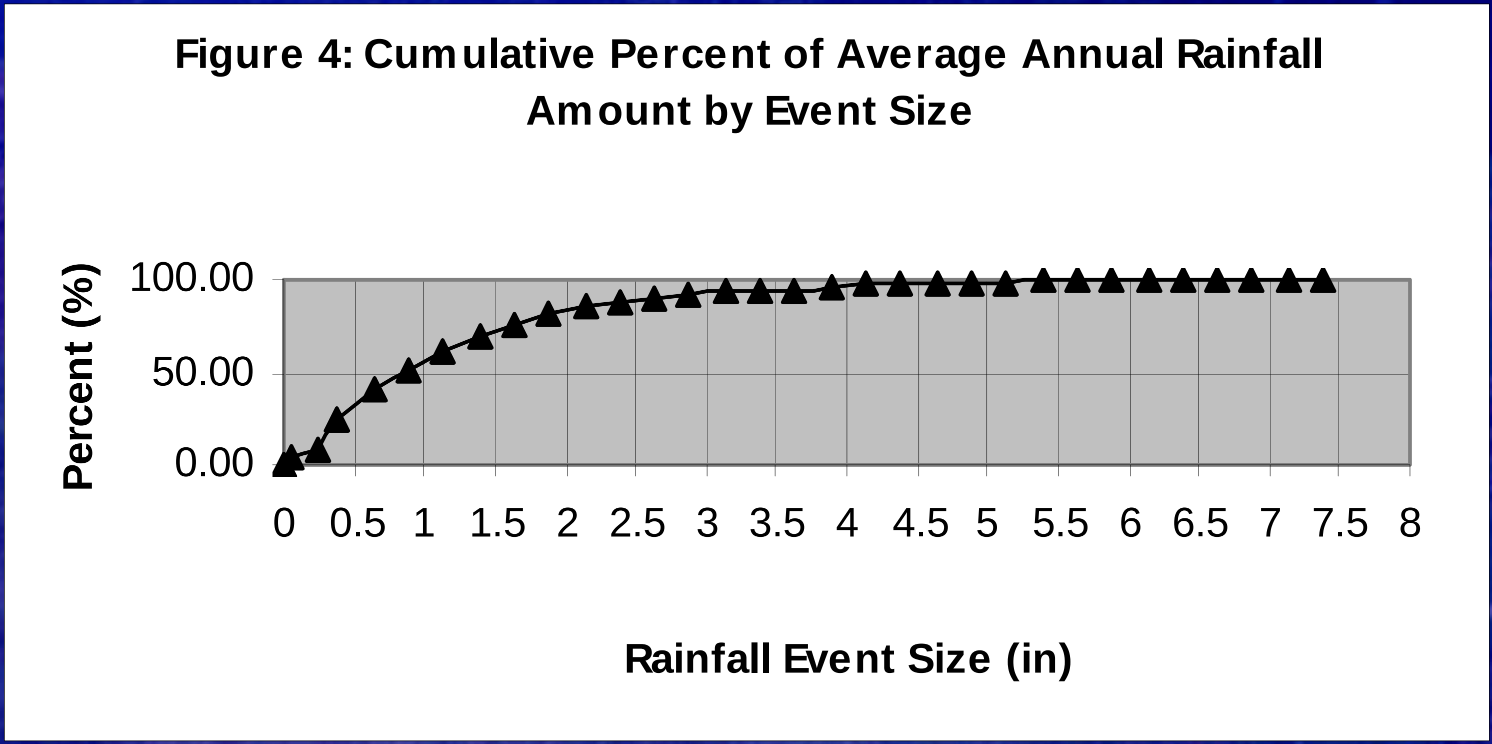
Figure 3: Average Annual Rainfall Frequency for Paducah:
30-year Historic Data



	0.01	.02-.09	.1-.25	0.26-0.5	0.51-0.75	0.76-1	1.01-1.25	1.26-1.5	1.51-1.75	1.76-2	2.01-2.25	2.26-2.5	2.51-2.75	2.76-3	3.01-3.25
Ave Annual	25.73	28.97	23.53	19.33	12.43	6.53	4.47	2.83	1.70	1.60	0.90	0.43	0.33	0.40	0.20

	3.26-3.5	3.51-3.75	3.76-4	4.01-4.25	4.26-4.5	4.51-4.75	4.76-5	5.01-5.25	5.26-5.5	5.51-5.75	5.76-6	6.01-6.25	6.26-6.5	6.51-6.75	6.76-7	7.01-7.25	7.26-7.5
Ave Annual	0.17	0.10	0.23	0.10	0.00	0.07	0.03	0.03	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.03

Paducah Rainfall Frequency



Rainfall Cumulative Frequency

Rainfall Depth (in.)	Ave # of Events (num)	Annual Amount (ave in./yr)	% of Annual Rainfall Ave (%)	Cumulative % of Ave Rainfall (%)
0.01**	25.73	0.26	0.52	0.52
.02-.09**	28.97	1.59	3.22	3.74
.1-.25	23.53	2.64	5.32	9.06
0.26-0.5	19.33	7.44	15.03	24.08
0.51-0.75	12.43	7.90	15.94	40.02
0.76-1	6.53	5.78	11.67	51.70
1.01-1.25	4.47	5.07	10.23	61.93
1.26-1.5	2.83	3.93	7.93	69.86
1.51-1.75	1.70	2.78	5.61	75.47
1.76-2	1.60	3.02	6.09	81.56
2.01-2.25	0.90	1.92	3.88	85.44
2.26-2.5	0.43	1.03	2.09	87.52
2.51-2.75	0.33	0.88	1.77	89.30
2.76-3	0.40	1.15	2.33	91.63
3.01-3.25	0.20	0.63	1.27	92.89
3.26-3.5	0.17	0.56	1.14	94.03
3.51-3.75	0.10	0.36	0.73	94.76
3.76-4	0.23	0.91	1.83	96.59
4.01-4.25	0.10	0.41	0.83	97.43
4.26-4.5	0.00	0.00	0.00	97.43
4.51-4.75	0.07	0.31	0.62	98.05
4.76-5	0.03	0.16	0.33	98.38
5.01-5.25	0.03	0.17	0.35	98.73
5.26-5.5	0.03	0.18	0.36	99.09
5.51-5.75	0.00	0.00	0.00	99.09
5.76-6	0.00	0.00	0.00	99.09
6.01-6.25	0.03	0.20	0.41	99.50
6.26-6.5	0.00	0.00	0.00	99.50
6.51-6.75	0.00	0.00	0.00	99.50
6.76-7	0.00	0.00	0.00	99.50
7.01-7.25	0.00	0.00	0.00	99.50
7.26-7.5	0.03	0.25	0.50	100.00
Sum	75.53	49.53	100	

**These events are not included in the summation in column two

Cumulative Rainfall

- **Percent Annual**
  - 81.5
  - 85.5
  - 87.5
  - 91.5
- **Storm Size (in)**
  - 2
  - 2.25
  - 2.5
  - 3

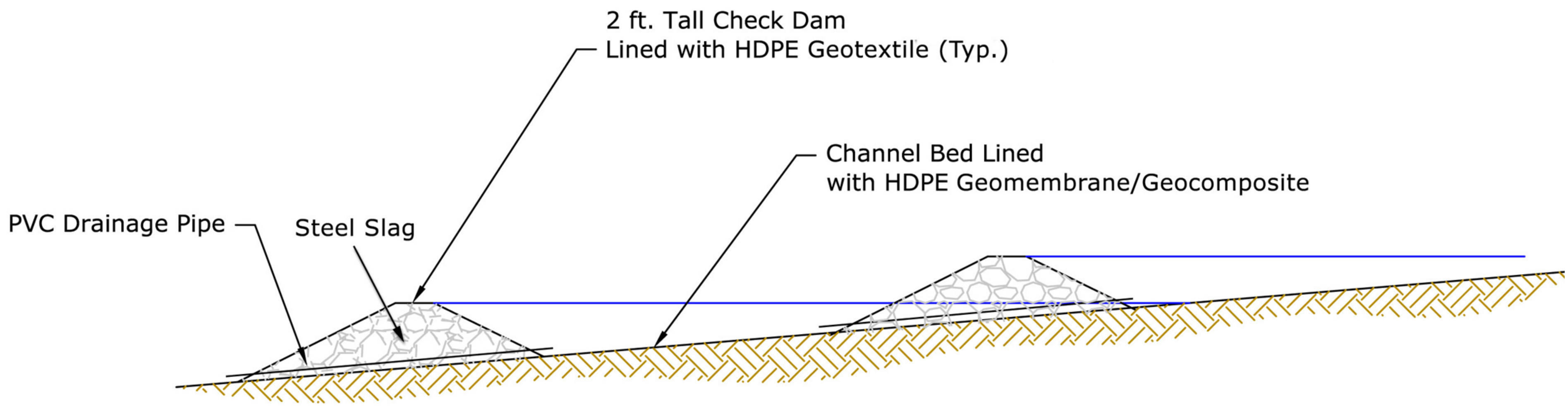
Design Methodology

- Utilize Channels and Topography to Reduce Peak Flow and Store Runoff
- Do not Excavate Soils
- Minimize Use of Equipment

Design Methodology Channels

- Geocomposte Liners
- Porous Check Dams
  - Steel Slag
  - Geotextile Facing
- Flocculation

Porous Check Dams

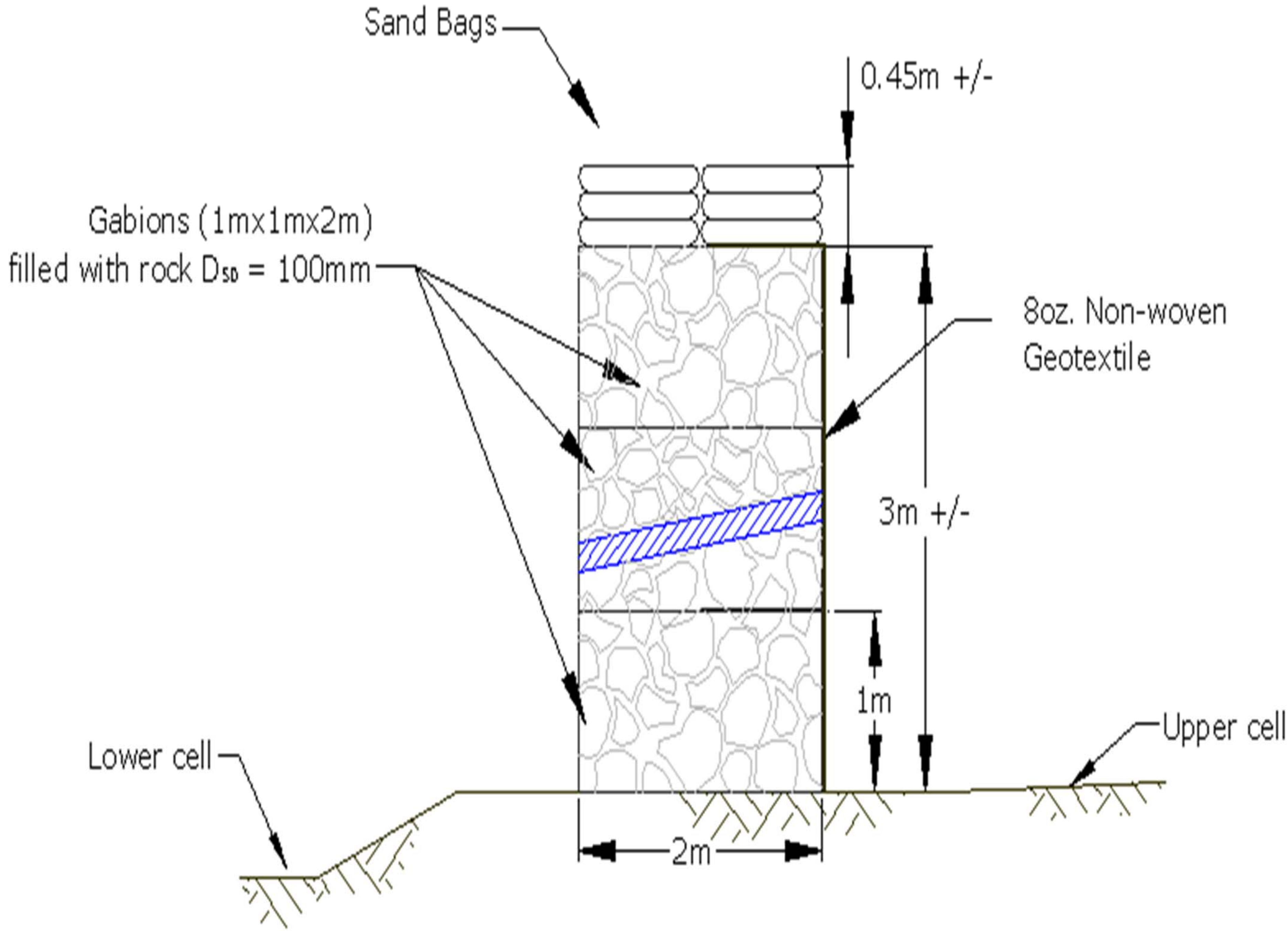


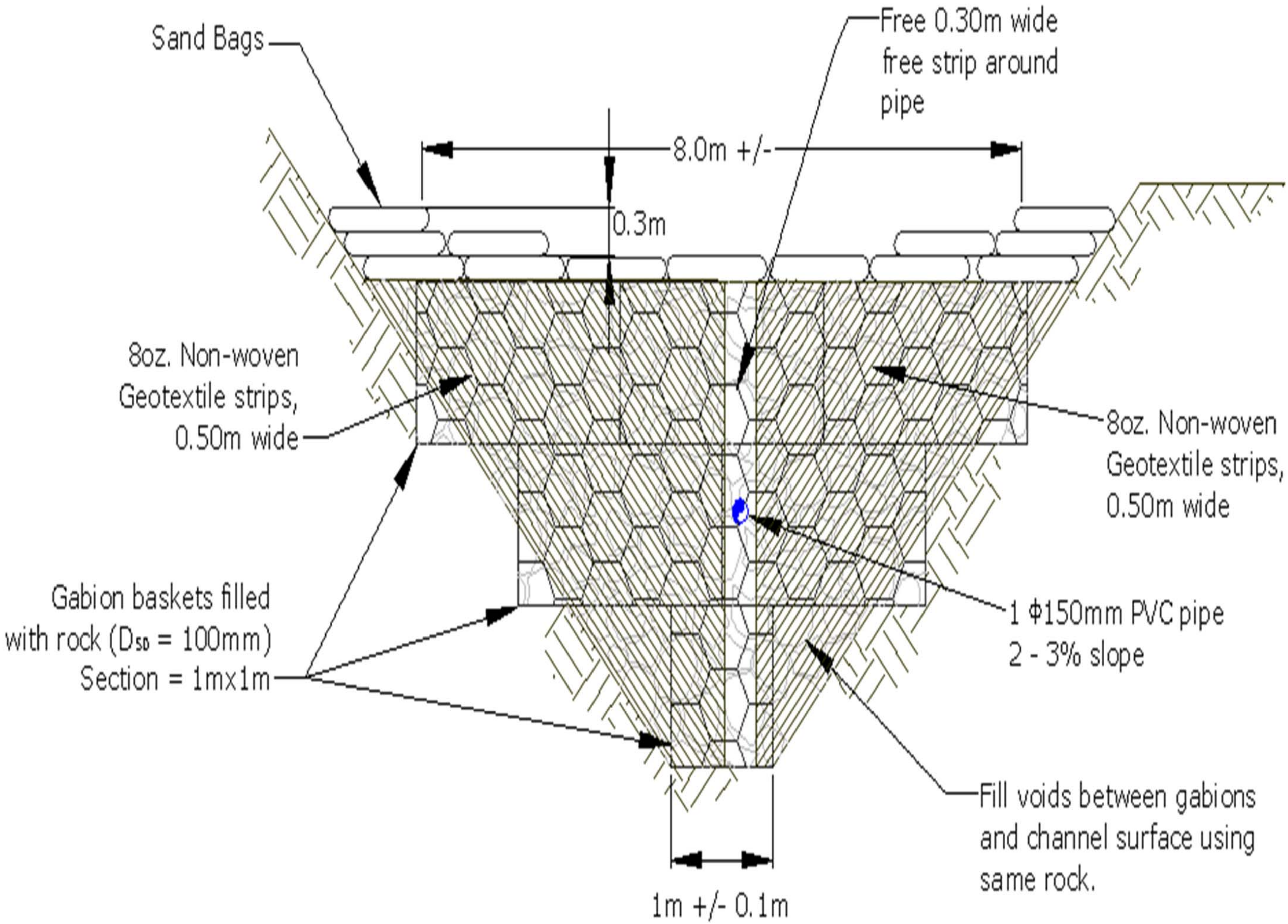
Detail 2: Check Dams Cross Section

Porous Check Dams
Stage -Discharge

termine Stage-scharge Curve	Average Depth h_{ave}(ft)	Downstream Depth h_e (ft)	Average Diameter d (ft)	Standrad Deviation S (ft)	Porosity n	Length (ft)	Viscosity (ft^2/s)	Width W(ft)
	3.50	0	1	0.001	0.4	1.25	0.000001	2
ravity g (m^2/s)	9.8							

ge H (ft)	Macro Velocity (m/s)	Reynold Number R_e	Head Loss h_l (ft)	Friction Factor f_k	Factor f_k	Change Friction Factor	Average Depth h_{ave}(ft)	q (ft^2/s)	Q (f
0.35	0.38	945179	0.35	3.83	3.831693	0.00	0.175	0.066	0.13
0.70	0.54	1336771	0.70	3.83	3.831197	0.00	0.350	0.187	0.37
1.05	0.66	1637251	1.05	3.83	3.830977	0.00	0.525	0.344	0.68
1.40	0.76	1890567	1.40	3.83	3.830846	0.00	0.700	0.530	1.06
1.75	0.85	2113743	1.75	3.83	3.830757	0.00	0.875	0.741	1.48
2.10	0.93	2315509	2.10	3.83	3.830691	0.00	1.050	0.973	1.94
2.45	1.00	2501052	2.45	3.83	3.83064	0.00	1.225	1.227	2.45
2.80	1.07	2673752	2.80	3.83	3.830598	0.00	1.400	1.499	2.99
3.15	1.14	2835955	3.15	3.83	3.830564	0.00	1.575	1.788	3.57
3.50	1.20	2989370	3.50	3.83	3.830535	0.00	1.750	2.095	4.18


Sand Bags
0.45m +/-
Gabions (1mx1mx2m)
filled with rock D50 = 100mm
8oz. Non-woven
Geotextile
3m +/-
1m
Upper cell
Lower cell
2m

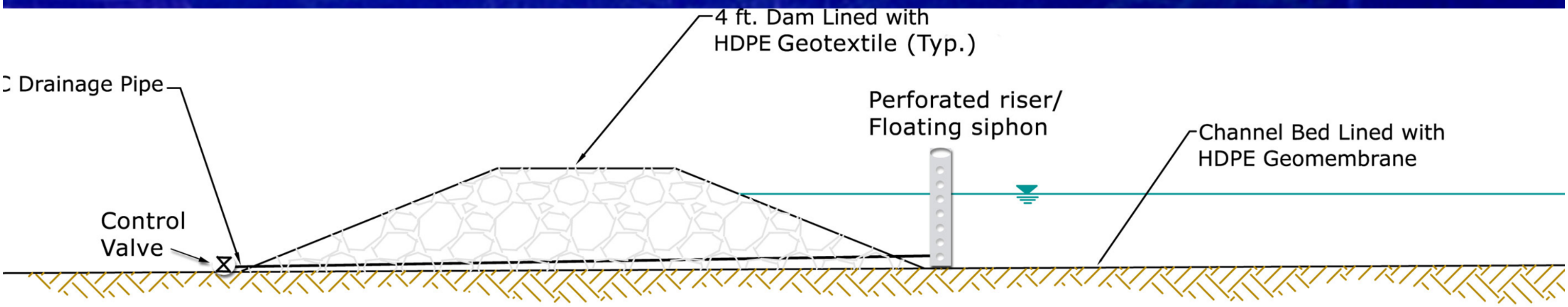


Sand Bags
Free 0.30m wide free strip around pipe
8.0m +/-
0.3m
8oz. Non-woven Geotextile strips, 0.50m wide
8oz. Non-woven Geotextile strips, 0.50m wide
Gabion baskets filled with rock (D50 = 100mm) Section = 1mx1m
1 Φ150mm PVC pipe 2 - 3% slope
Fill voids between gabions and channel surface using same rock.
1m +/- 0.1m

Design Methodology - Ponds

- Geocomposite Liner
- Attenuate Peak Flow
- Enable Treatment through Settling
- Retention on High CEC liner
- Flocculation to Increase Efficiency

Pond Details



Detail 1: Sediment Basin Cross Section

Design Methodology

- Integrate Alternative Treatment Systems
- Trade-Offs among Pond Storage, Pumping Rate and Treatment Efficiency

Outfall 011

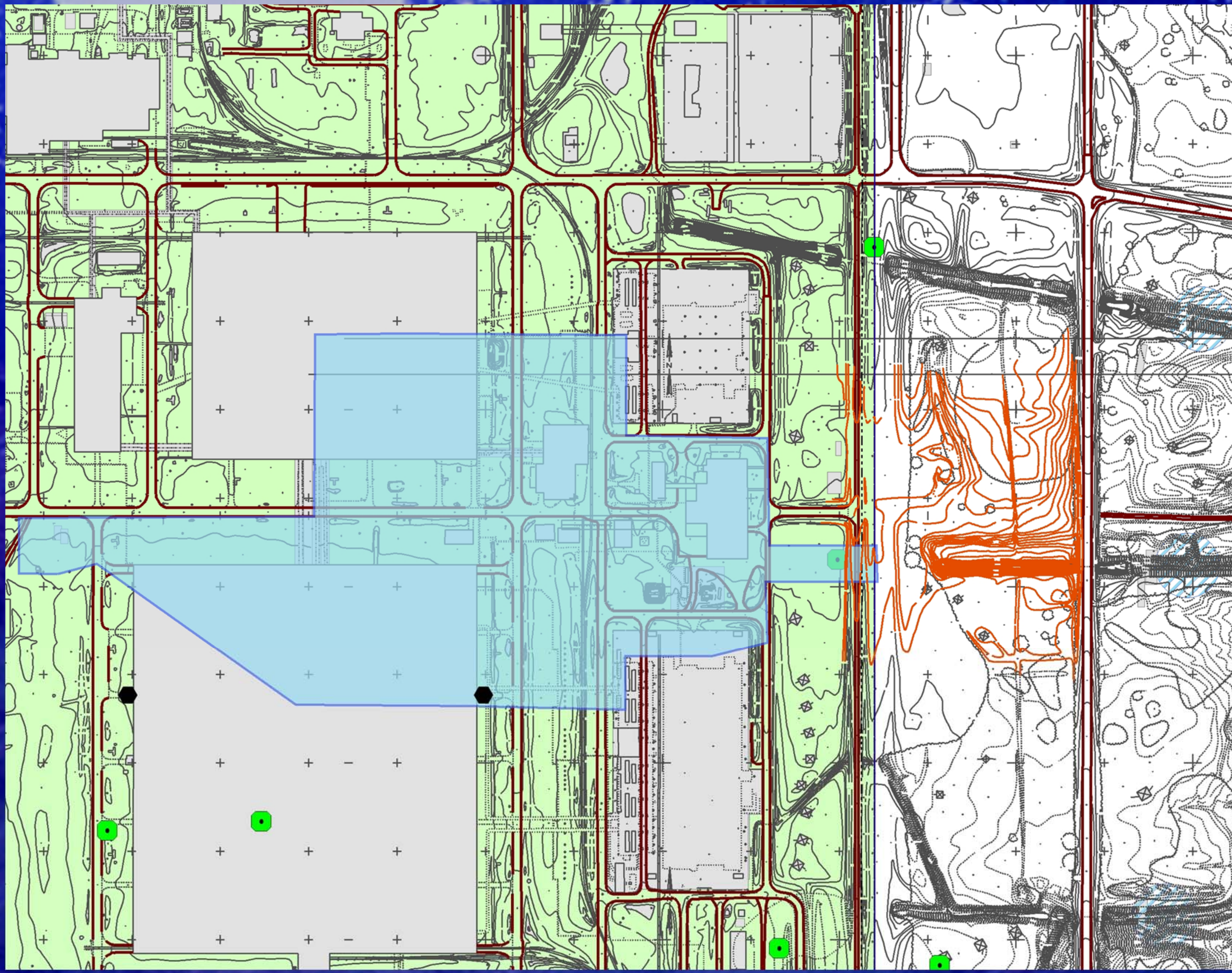
- **Pond Designed to Contain 2.0 to 2.5-inch Rainfall Event**
- **Treatment Options**
  - **Flocculation**
  - **Pump to Treatment Plant**

Outfall 011

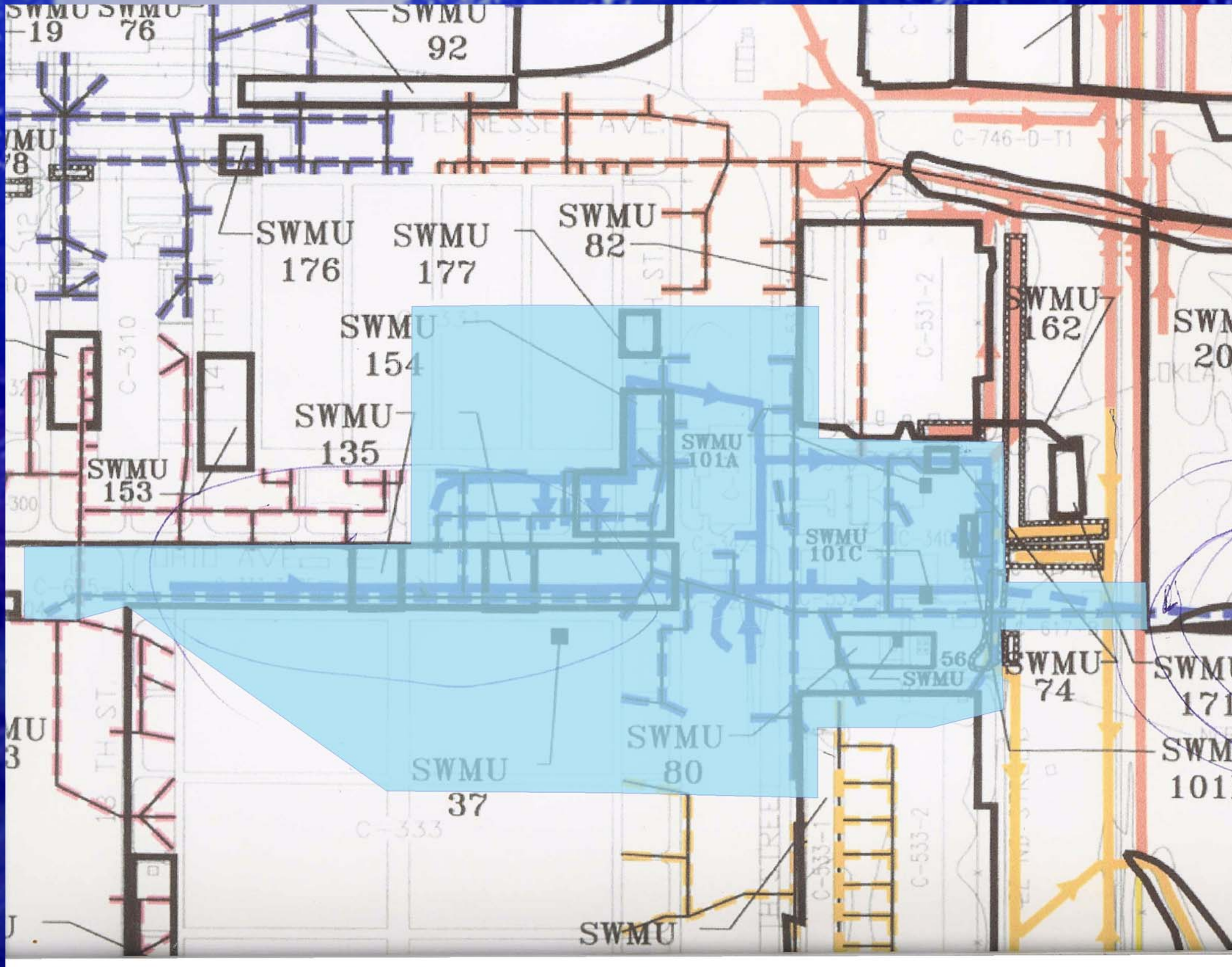
- **Watershed Area - 33.34 ac**
- **Pond Capacity – 5.97 ac-ft**
- **Sensitivity Analysis**
  - **CN 98 UHS – F and M**
  - **Rainfall 2.4 to 2.85 inches**
  - **CN 95 UHS – F and M**
  - **Rainfall 2.75 to 3.15 inches**

Design Methodology

- Utilize Channels and Topography to Reduce Peak Flow and Store Runoff
- Do not Excavate Soils
- Minimize Use of Equipment



BIOSYSTEMS & AGRICULTURAL ENGINEERING


SWMU 19
SWMU 76
SWMU 92
TENNESSEE AVE.
C-746-D-T1
SWMU 176
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SWMU 82
SWMU 162
SWMU 154
SWMU 135
SWMU 101A
SWMU 153
SWMU 101C
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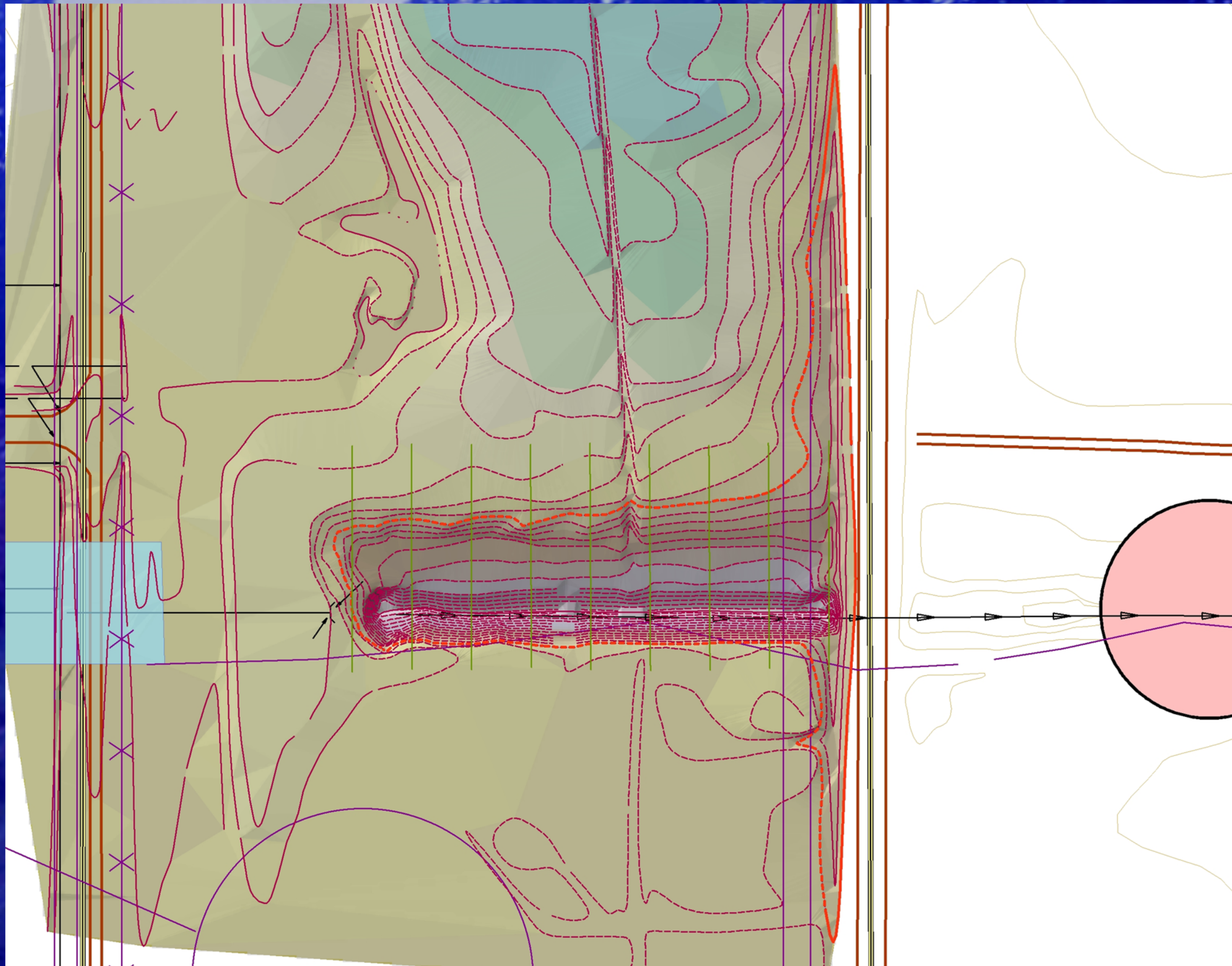
C-533-1
C-533-2
SWMU



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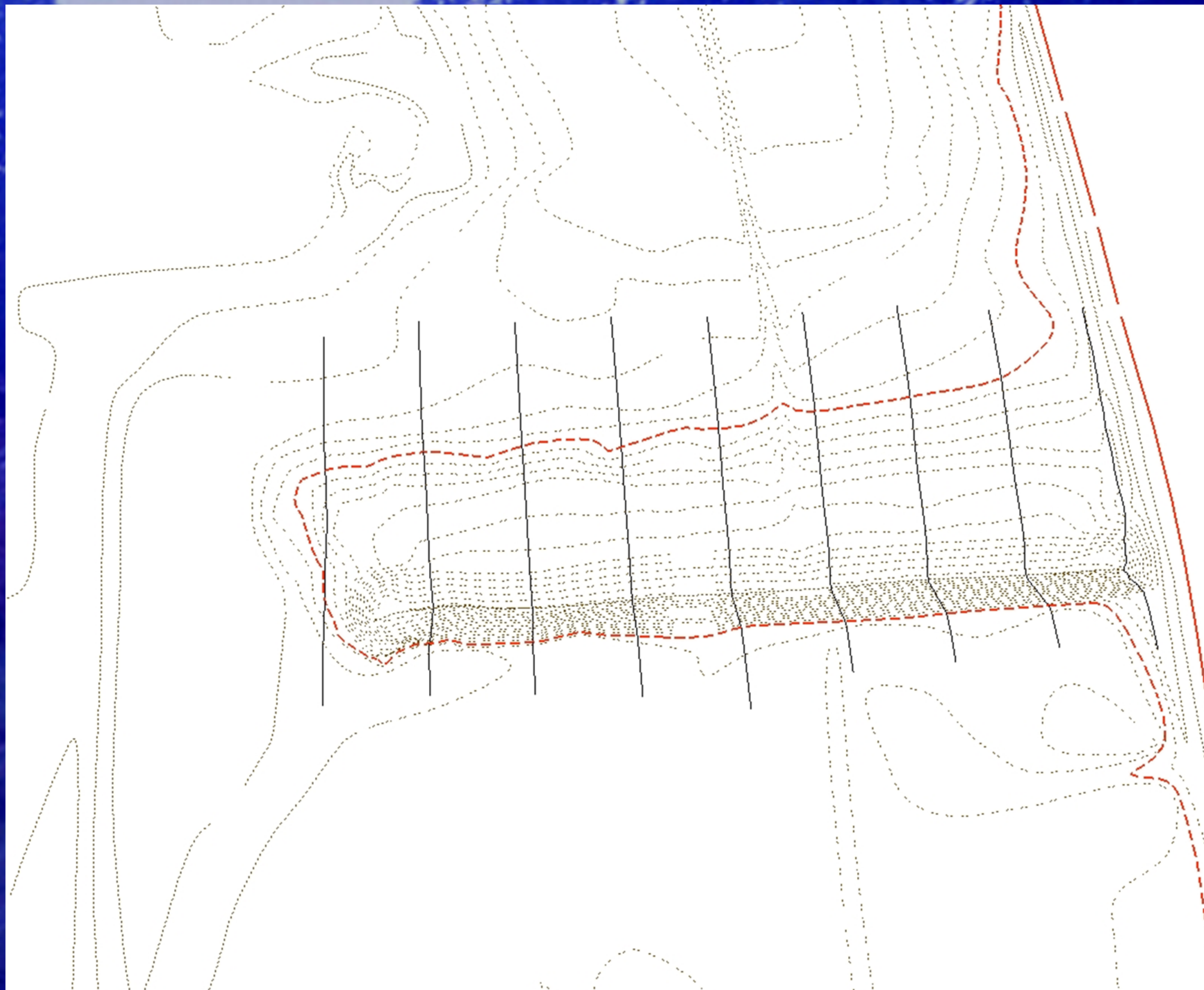
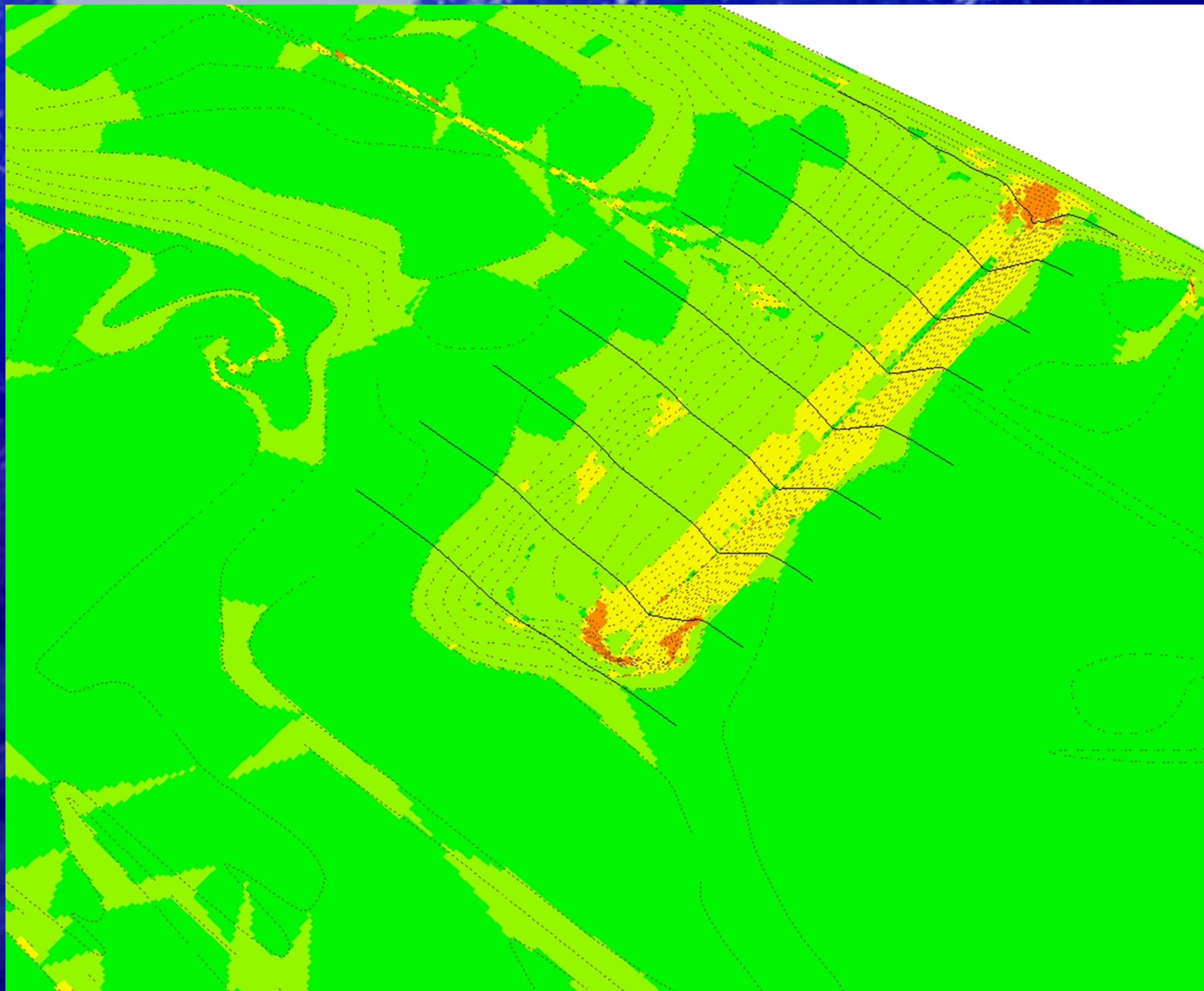
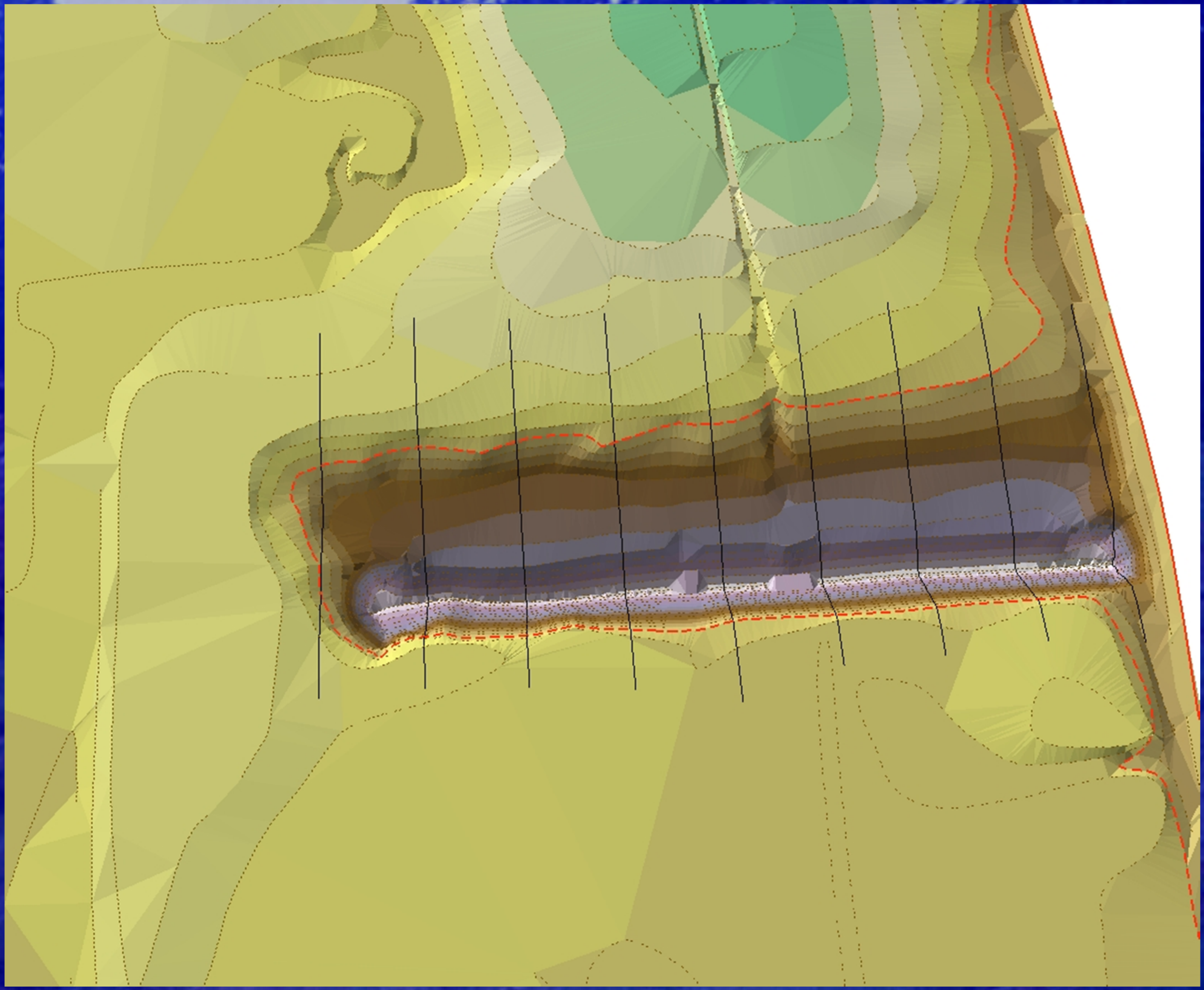


BIOSYSTEMS & AGRICULTURAL ENGINEERING

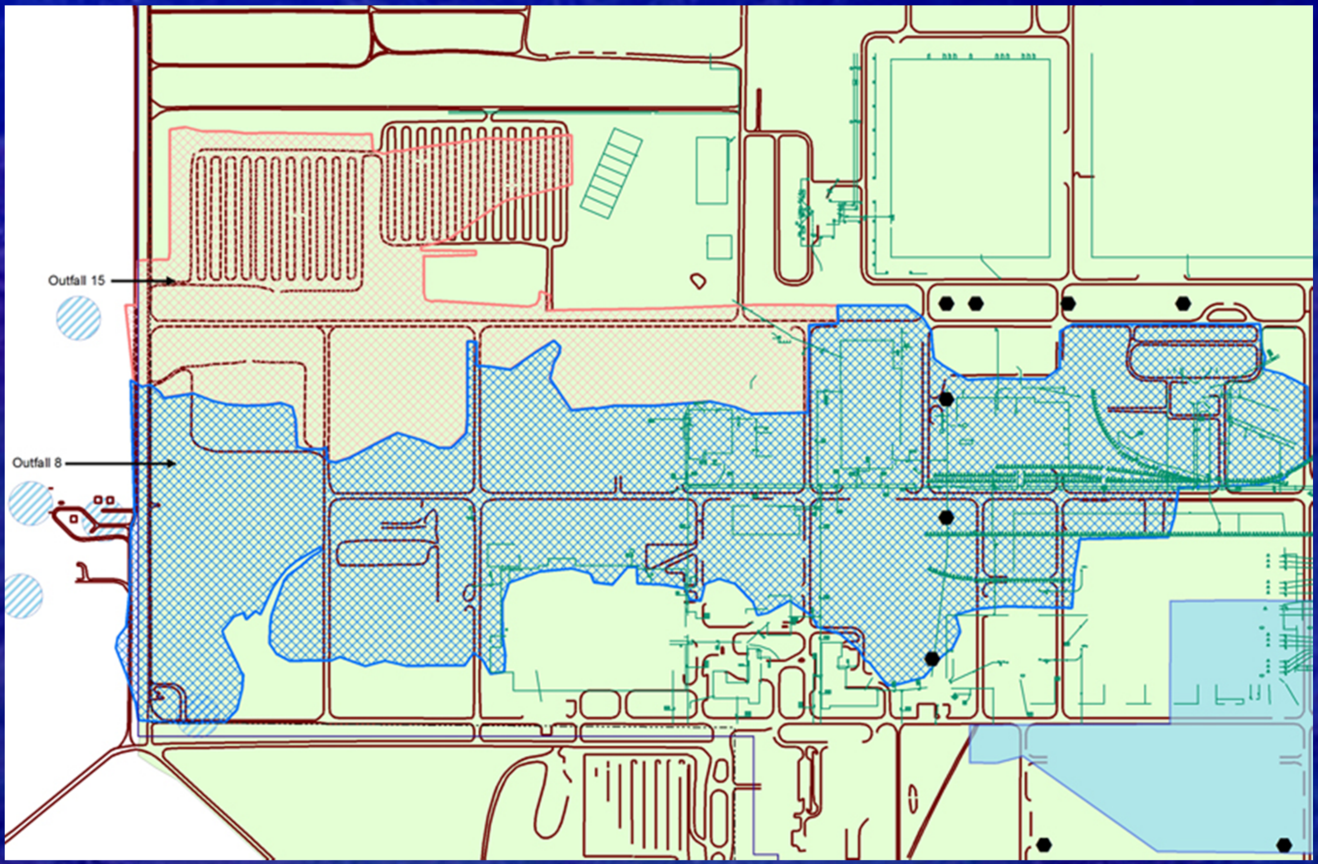
UK



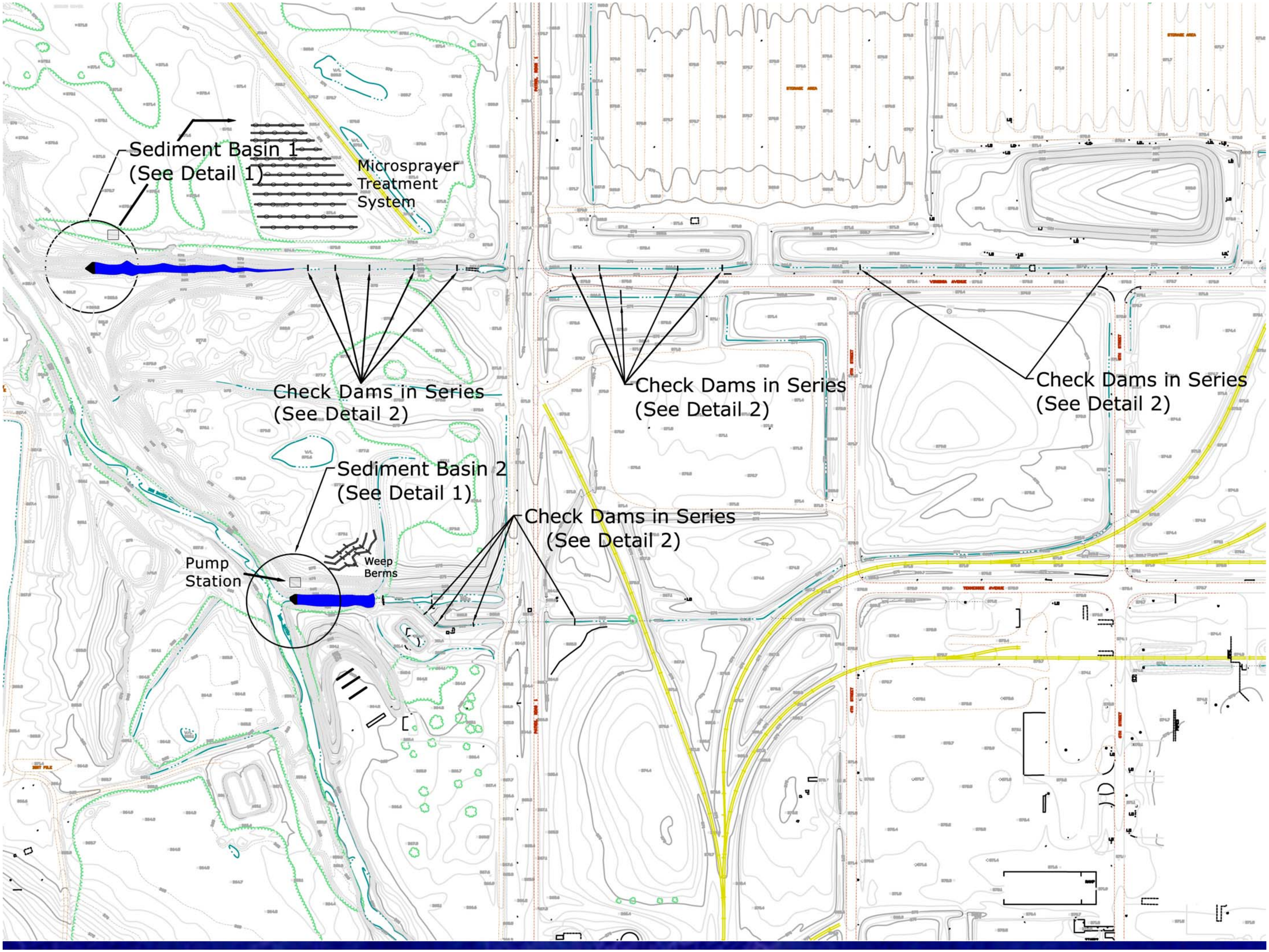


BIOSYSTEMS & AGRICULTURAL ENGINEERING

Outfall 015 Watershed



BIOSYSTEMS & AGRICULTURAL ENGINEERING


Sediment Basin 1
(See Detail 1)
Microsprayer
Treatment
System
Check Dams in Series
(See Detail 2)
Check Dams in Series
(See Detail 2)
Check Dams in Series
(See Detail 2)
Sediment Basin 2
(See Detail 1)
Check Dams in Series
(See Detail 2)
Pump
Station
Weep
Berms

Design Methodology
Outfall 015

- Treatment System
  - Channel and Pond
  - Pumping Plant
  - Micro-sprayers
    - Evapotranspiration
    - Geocomposite Adsorption

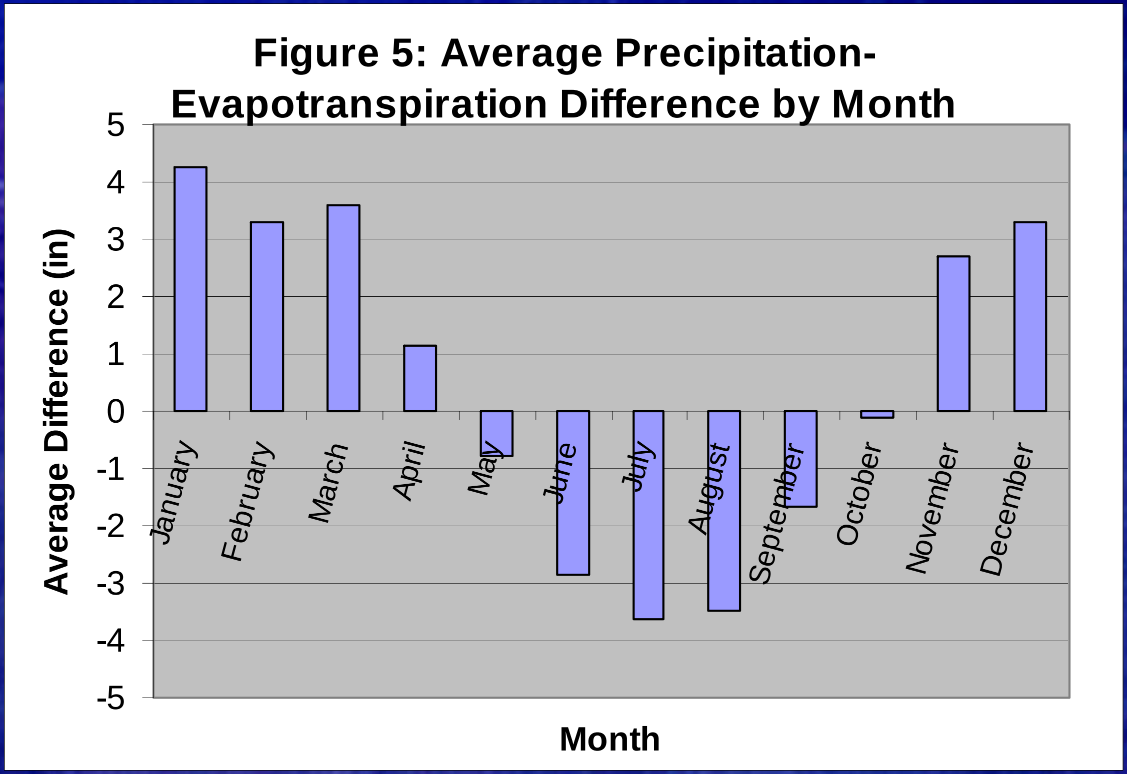
Outfall 015

- **Watershed Area – 50.4 ac**
- **Pond Capacity – 0.41 ac-ft**
- **Sensitivity Analysis**
  - **CN 98 UHS – F and M**
  - **Rainfall 2.4 to 2.85 inches**
  - **CN 95 UHS – F and M**
  - **Rainfall 2.75 to 3.15 inches**

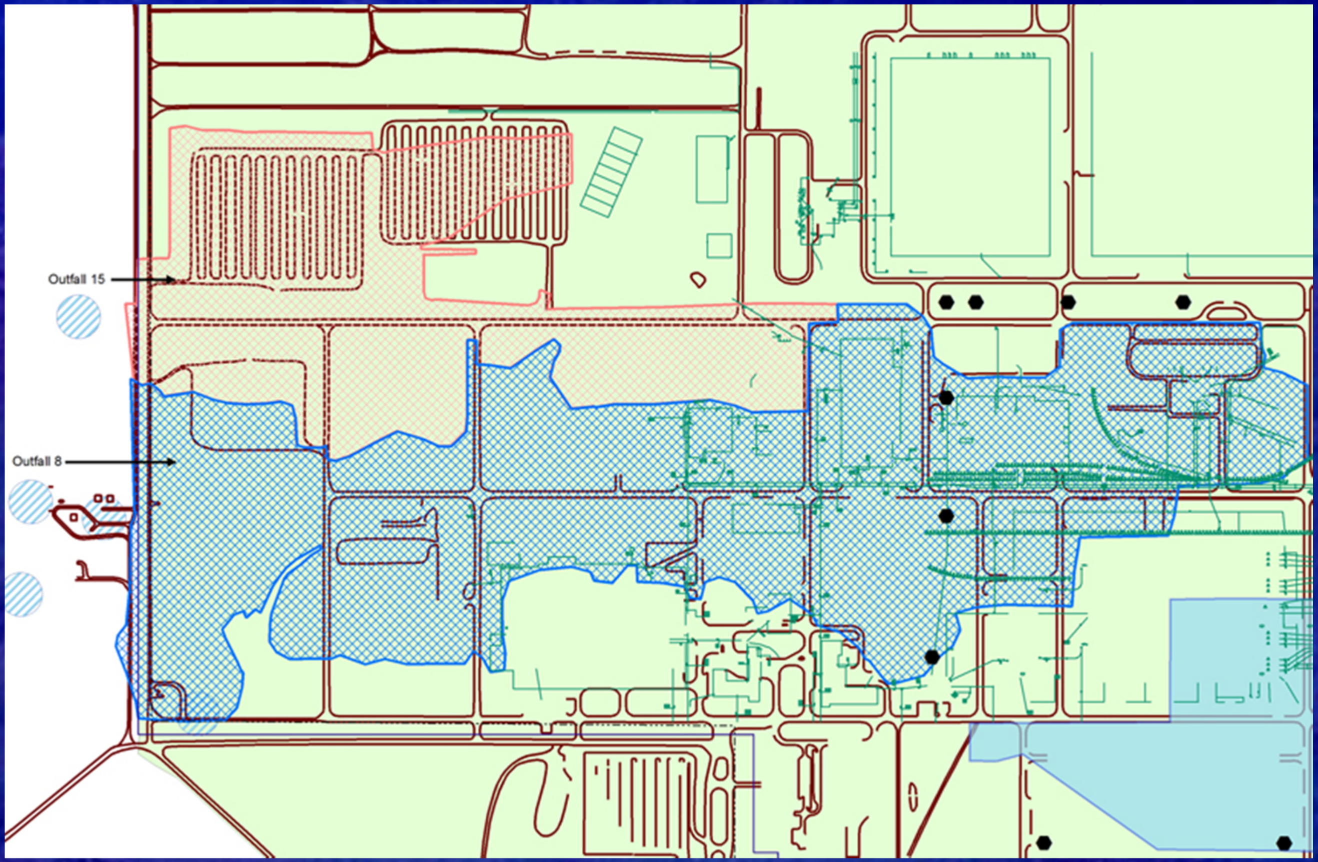
Micro-Sprayer Design

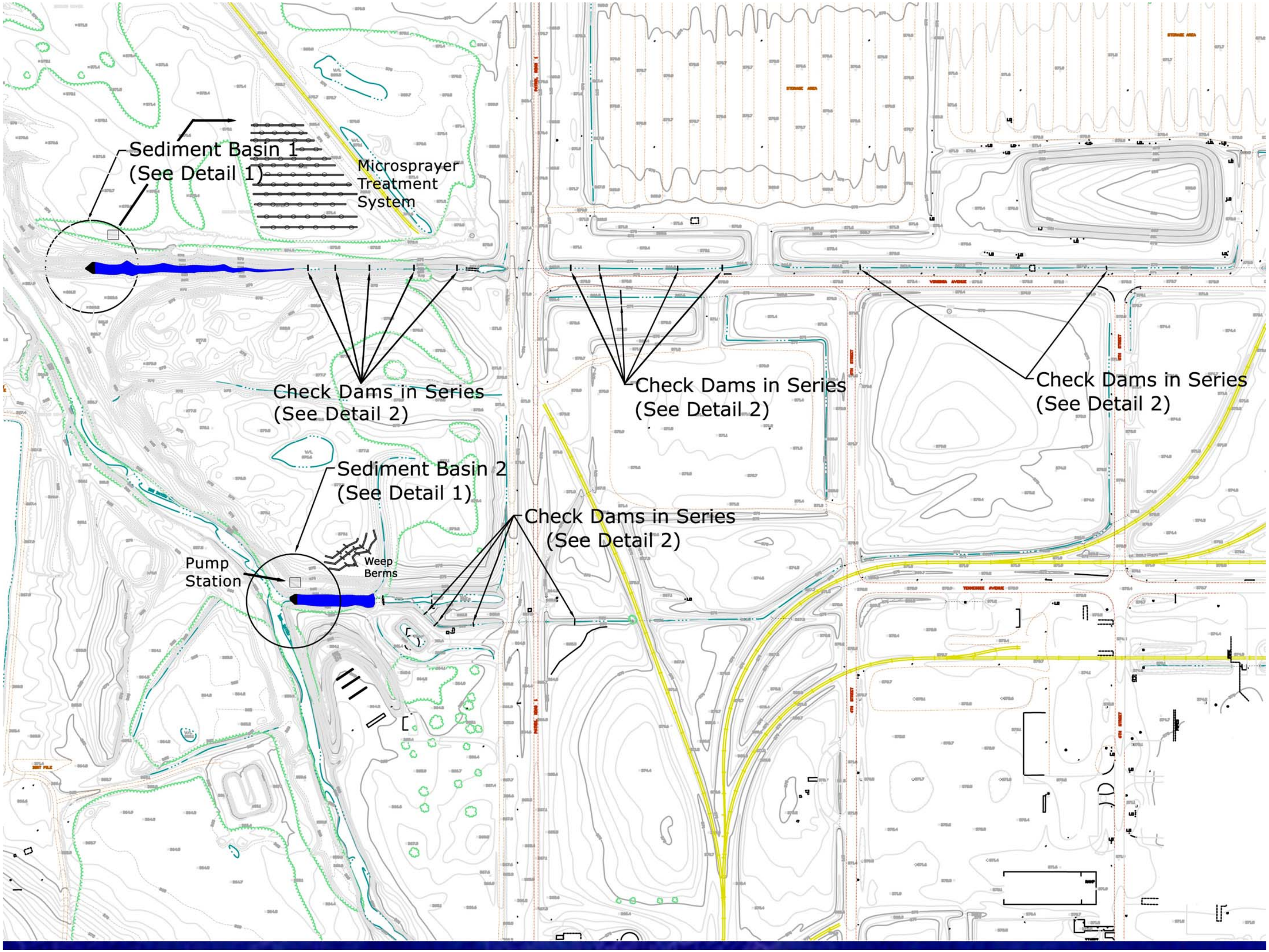
- Sprayer Diameter and GPM
- Distribution Piping
- Evapotranspiration Rate
- Distribution Area
- Grass-filter/ Geocomposite

Evaporation Potential



Outfall 008 Watershed



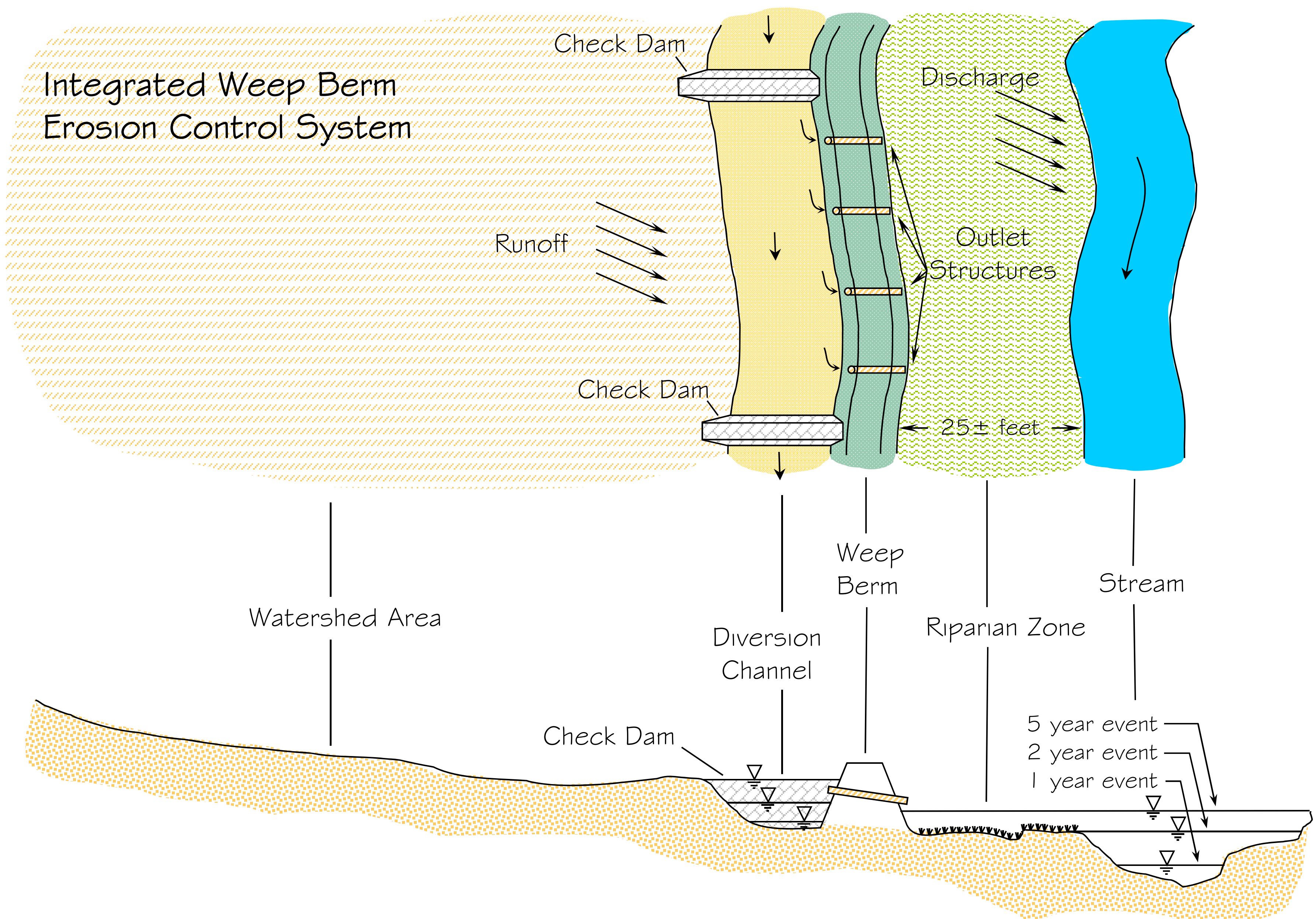

Sediment Basin 1
(See Detail 1)
Microsprayer
Treatment
System
Check Dams in Series
(See Detail 2)
Check Dams in Series
(See Detail 2)
Check Dams in Series
(See Detail 2)
Sediment Basin 2
(See Detail 1)
Check Dams in Series
(See Detail 2)
Pump
Station
Weep
Berms

Outfall 008

- Watershed Area – 108.6 ac
- Pond Capacity – 0.37 ac-ft
- Treatment System
  - Channel and Pond
  - Pumping Plant
  - Weep Berm

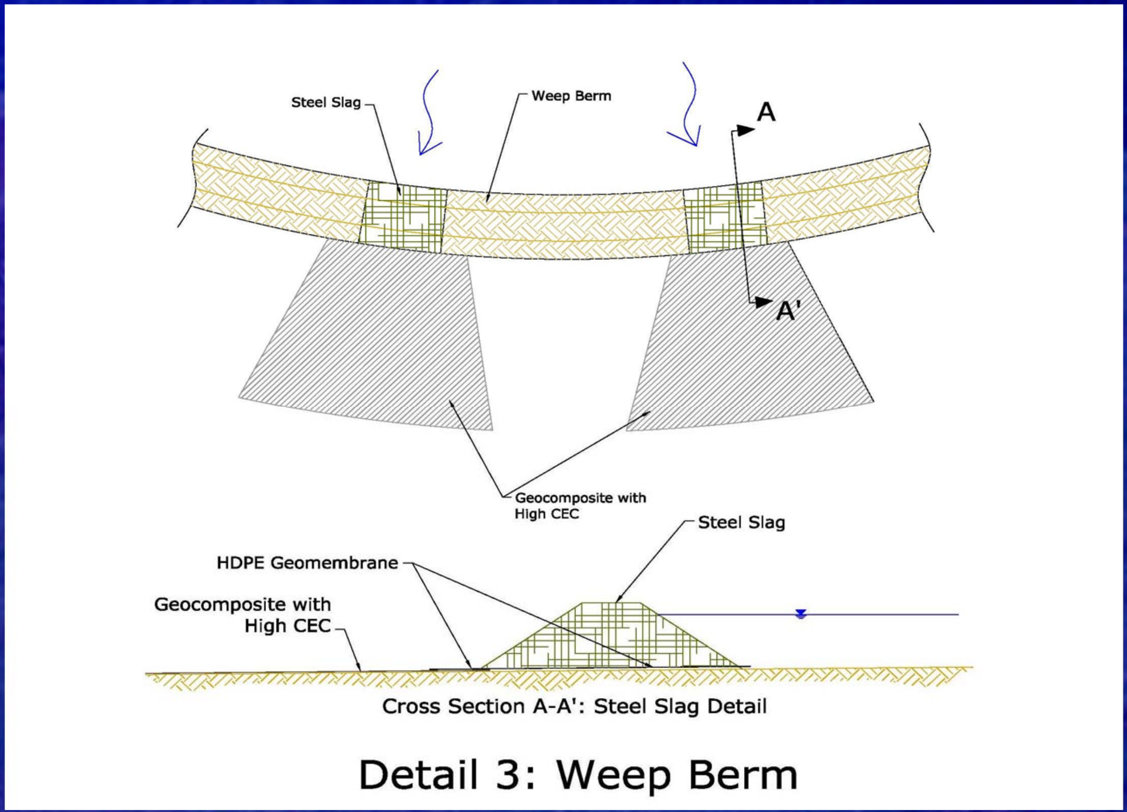
Weep Berm

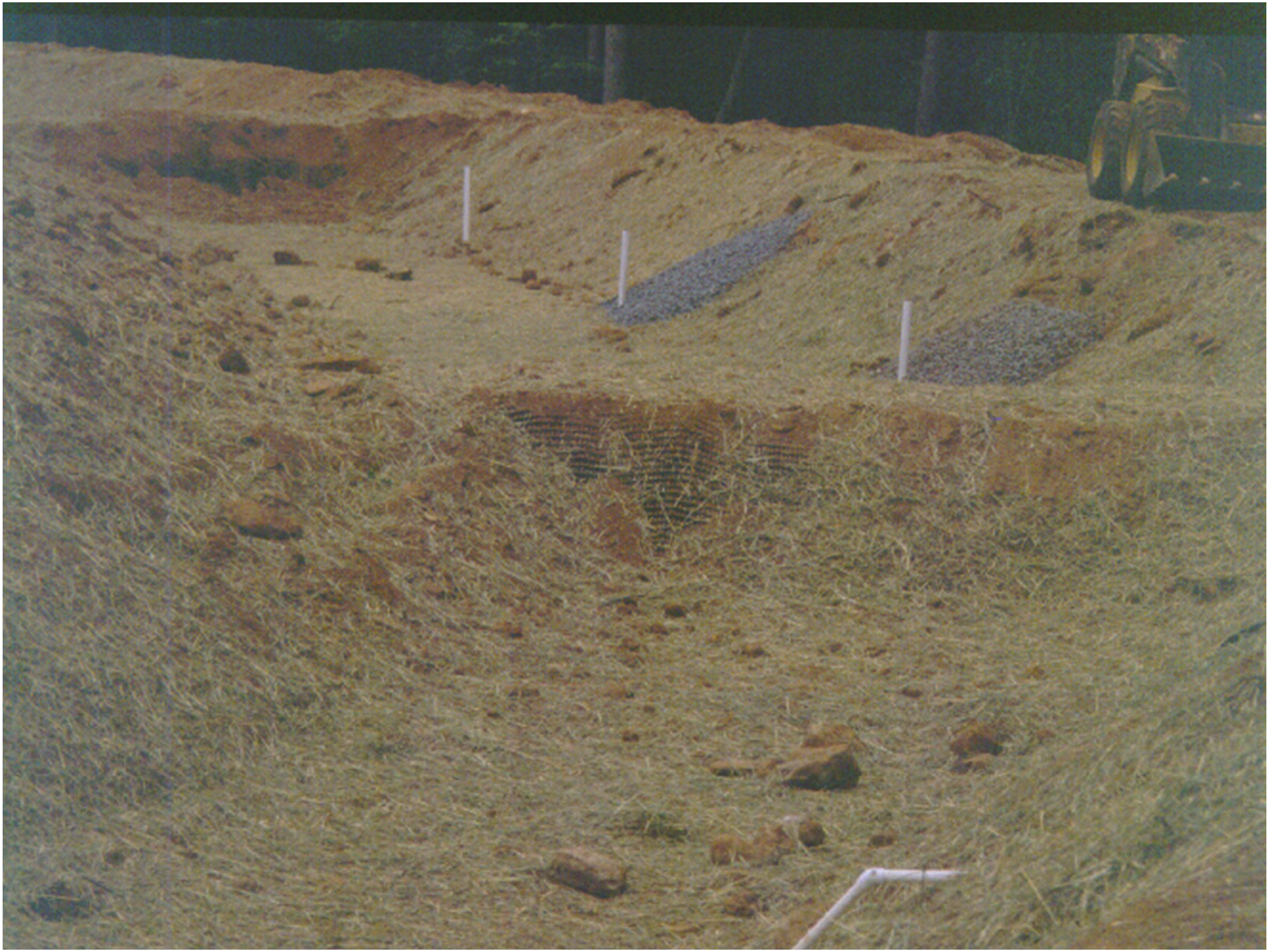
- **Incorporates check dams within the diversion**
  - **Backwater collection at specified locations**
  - **Facilitates the settling of sediment**
  - **Temporary stormwater storage**
- **Low cost passive dewatering controls are used to drain backwater through the *weep berm* into the down-gradient riparian zone**



Integrated Weep Berm
Erosion Control System
Check Dam
Runoff
Check Dam
Discharge
Outlet
Structures
25± feet
Watershed Area
Diversion
Channel
Weep
Berm
Riparian Zone
Stream
Check Dam
5 year event
2 year event
1 year event

Weep Berm Outlet





Additional Benefits

- *Weep berm* operates like many small sediment ponds in series
  - Based on design components and geometry
- Efficiently reduces effluent sediment concentration

Cu Removal

- Dewatering Sediment Ponds
  - 26% all storms, 11% large storms
- Compost Filters
  - 67%
- Grass Channels
  - 46%

Cu and TSS Removal

- Quality swales (high infiltration)
  - Cu 46-89%
  - TSS 80-98%
- Grass filter strip (TSS)
  - 54% for 75 ft
  - 84 % for 150 ft

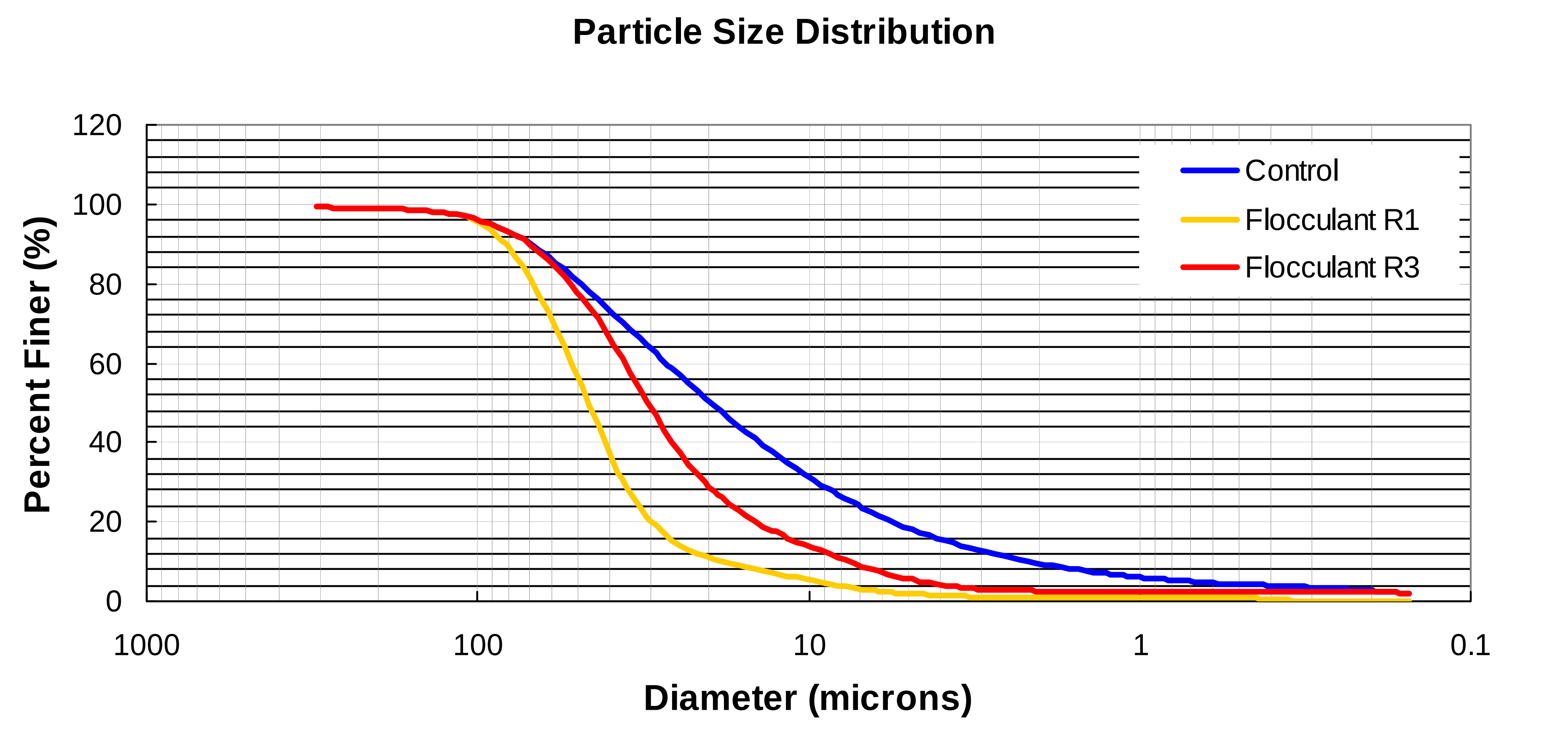
Polymeric Flocculation Design Experience

- Yanacocha (Newmont)
- Conducted flocculation analysis
  - Jar test for screening/selecting flocculent
  - 2m column testing
  - Preparation for site application/modifications

Results
Inflow 1,500 mg/L, Si and Cl

Flocculant Concentration (mg/L)	Effluent TSS (mg/L)
1	<15
2	<15
3	<15
4	20

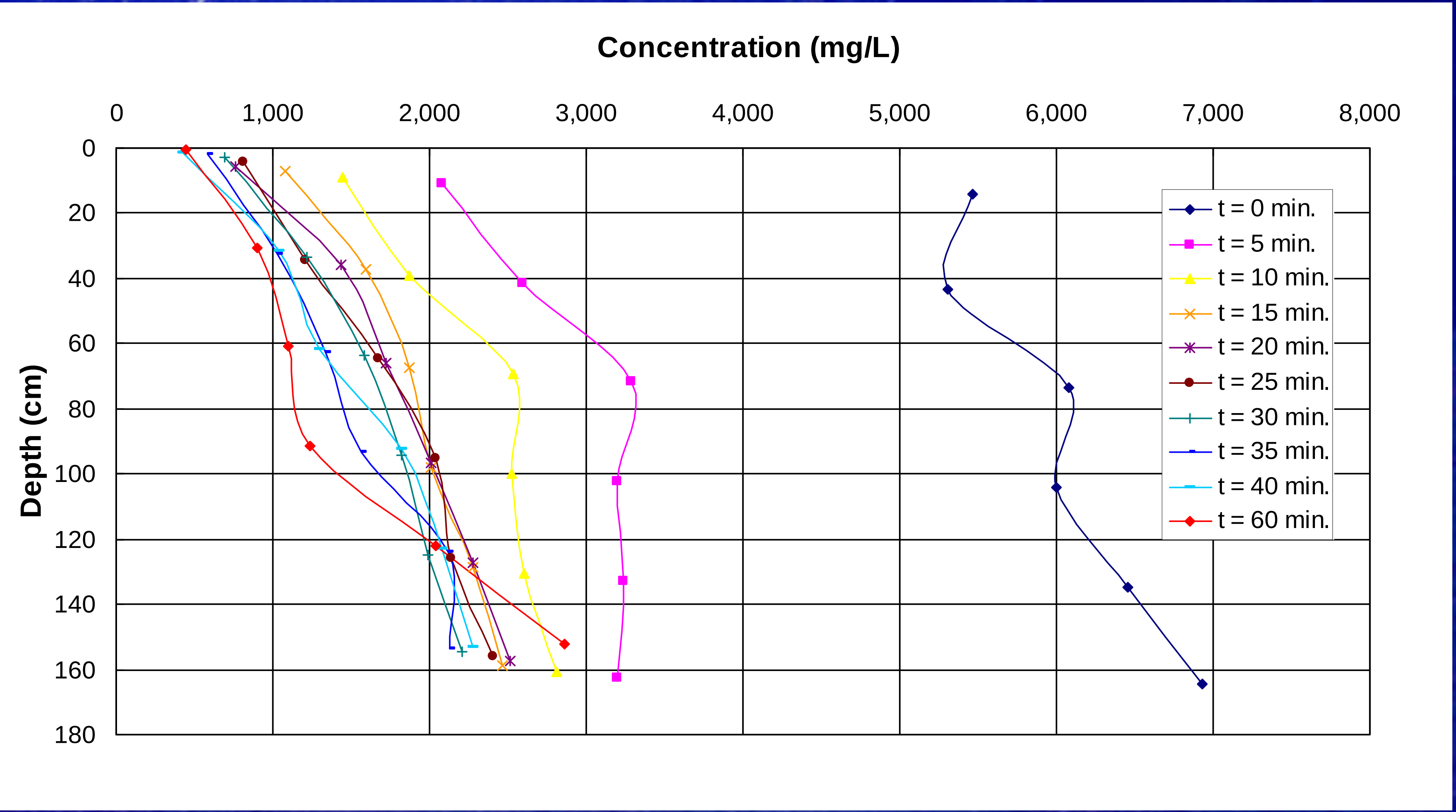
Screening Test



Column Tests

- **9, 12 in. PVC columns**
- **6 ports located at 1 ft intervals**
- **TSS**
- **Sediments characterization**
  - **Specific gravity**
  - **Particle size distribution**

Column Tests



BIOSYSTEMS & AGRICULTURAL ENGINEERING

Control case (Sediment Type R – Low Conc.)