Sustainable Constructed Wetland for Pharmaceutical Waste Leachate and Groundwater Management and Treatment

Presented to: Battelle Presentation

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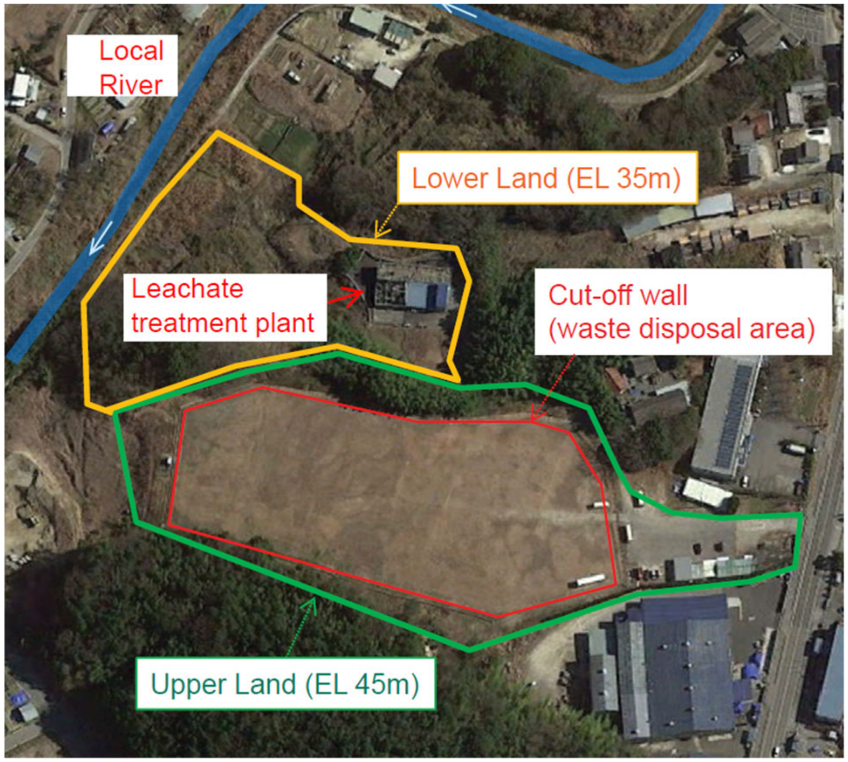
Site Condition

- Pharmaceutical waste was disposed, capped and contained on third-party leased land (“Upper Land”) with lease expiration in 2020
- Target chemicals of concern: BOD and COD
- Ongoing leachate collection and treatment is unsustainable long term
- Potential for some leachate under-flowing perimeter sheet-pile containment/cut-off wall, creating leachate seeps along the steep embankment.
- Desire to develop a remedial solution which:
  - reduces long-term operation and maintenance associated with the collection and treatment of impacted groundwater from the landfill area.
  - will be acceptable to all stakeholders.



Remedial Concept Development Activities

- Site Characterization
  - Soil borings and additional monitoring wells – existing sheet-pile not keyed into bedrock
  - Underlying geology consists of fractured and weathered granite
  - Continuous groundwater observations for period of 4 months (mid-July to mid-November 2018) with no extraction of groundwater from the Upper Land to assess hydrostatic conditions
- Topographical Survey
- Flora Survey
- Groundwater Fate and Transport Modeling and Surface-Water Runoff Modeling
- Site specific remedial concept – constructed wetland
  - Treatability Studies
  - Constructed Wetland Design

Flora Survey

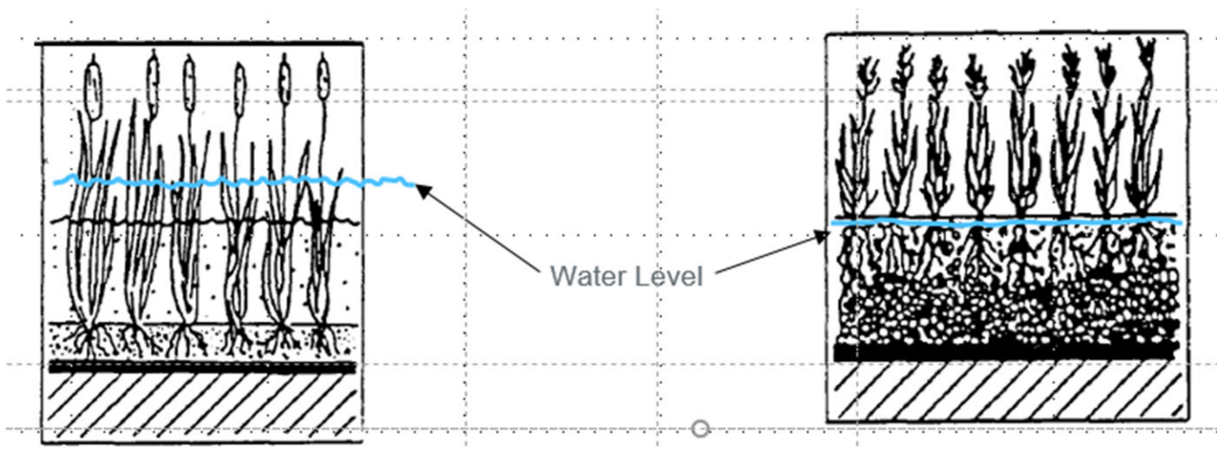
- Common reed (*Phragmites australis*) was a dominant in wetland in the site

- Common cattail (*Typha latifolia*) was a dominant in the vegetation type in open-water transitions around ponds

Wetland Treatment Concept

Two general types of treatment wetland considered:

- Free Water Surface (FWS): Wetlands with a water level that is above the ground level and water flow is primarily above ground
- Subsurface Flow (SSF): Wetlands with a water level maintained within the ground level and flow through a porous gravel bed



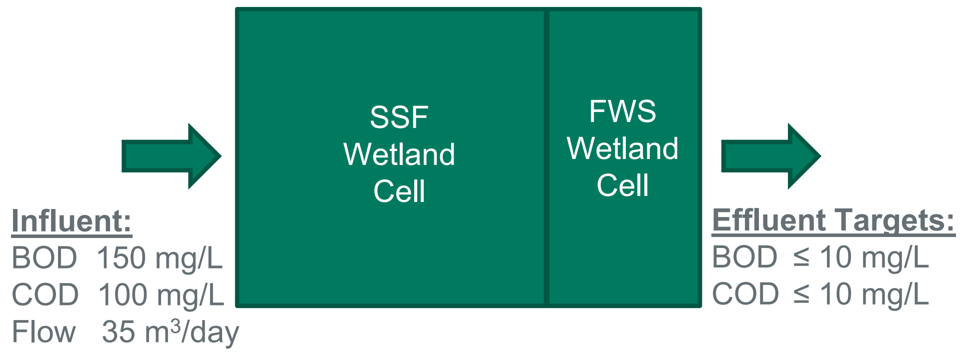
Typical Free Water Surface (FWS) Wetland

Typical Subsurface Flow (SSF) Wetland

Wetland Treatment Concept *(continued)*

Design Components:

- Leachate Flow – Groundwater modeling (consistent flow)
- Influent concentration – fate and transport modeling
- Effluent concentration – 10 mg/L (BOD and COD)
- Degradation Rate
  - Microbial degradation will be the primary treatment mechanism
  - First Order Plug Flow Model assumed for BOD/COD removal [Ce/Co = e (-KT*t)]
  - Value estimated based on literatures and treatability study results
- Hydraulic retention time (HRT) – calculated
- Wetland Type - SWS and FWS in series
- Wetland Media , Configuration and Layout – designed



Treatability/Pilot Study

Test Configurations:

- Static test (no flow) and dynamic test (flow through) setup
- In each run of dynamic test, water was run through the reactor for various HRTs (2, 5, 7, 10 days)
- Influent leachate for tests collected directly from the seepage pond (where leachate daylights at Lower Land)

FWS Dynamic Reactor

SSF Dynamic Reactor

Treatability/Pilot Study *(continued)*

Test Results:

- The site groundwater/leachate was most efficiently treated by the SSF wetland
- Free water surface (FWS) reactors did not achieve desired results due to algae growth. Likely reasons are:
  - Slow (or no) movement of water
  - Vegetation cover did not prevent sunlight from reaching the water surface.

Address Algae Issue:

- Reduce HRT in FWS
- Field observations indicate that mature plants will provide shade and significantly reduce/control algae in the full-scale wetland design.

FWS Dynamic Reactor

Treatability/Pilot Study *(continued)*

SSF Dynamic Reactor Treatment Study -Effluent Analysis Result

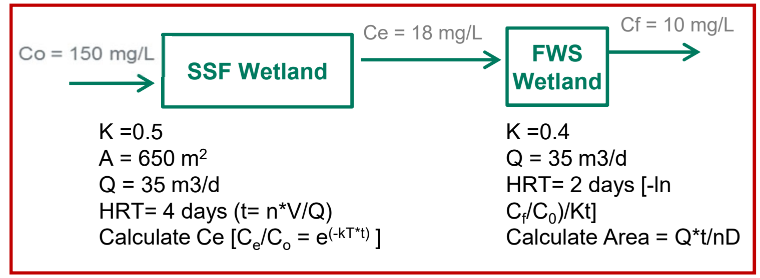
HRT (started June 1st)	Date Sampled	Analytes									
		BOD (mg/L)	COD (mg/L)	Arsenic and Its Compounds (mg/L)	Dissolved Iron (mg/L)	Total Iron (mg/L)	TSS (mg/L)	TDS (mg/L)	DO (mg/L)	pH (-)	
0	June 1, 2018	76	59	0.009	0.5	4.2	4	1000	5.2	7.8	(24.1°C)
2	June 10, 2018	47	53	0.006	0.6	0.86	15	840	< 0.5	7.4	(23.8°C)
5	June 20, 2018	28	42	0.006	0.9	1.3	3	910	< 0.5	7.7	(23.9°C)
7	June 29, 2018	5.1	23	0.004	0.2	0.3	1	800	0.6	7.3	(23.3°C)
10	July 11, 2018	4.8	23	0.001	ND	0.1	2	670	2.2	8	(24°C)

Average influent:
BOD 81 mg/L
COD 71 mg/L

Estimate from Treatability Study:
K=1.385 (BOD) @ T = 23 ^{0} C
K = 0.60 (COD) @ T= 23 ^{0} C

Full-Scale Design

- Two cells Wetland – SSF followed by FWS
- SSF will provide the majority of the treatment and the FWS wetland will provide polishing
- First order kinetic to estimate removal $C_e/C_o = e^{(-kT*t)}$
- K for SSF Cell from Treatability Study:
  - As degradation rates are dependent upon temperature, the first order rate constant observed during the treatment studies in July were adjusted for each month based on the average monthly ambient air temperature
  - The average rate constant was used to determine the HRT for SSF (0.5/day)
  - This method is considered conservative as the rate constant was adjusted based on air temperature, while groundwater temperatures were observed to vary by less than 1 C from June to November
- K for FWS- Published Data



Month	Average Temperature in °C (T)	Degradation Rate: Design (K_T)	Degradation Rate: Observed
January	3.7	0.232	--
February	4.3	0.240	--
March	7.6	0.291	--
April	13.8	0.418	--
May	18.4	0.547	--
June	22	0.674	--
July	25.8	0.841	0.6 (COD at 23^{0}C)
August	27.1	0.907	--
September	23.1	0.719	--
October	17	0.504	--
November	11.5	0.366	--
December	6.2	0.268	--
Average		0.501	

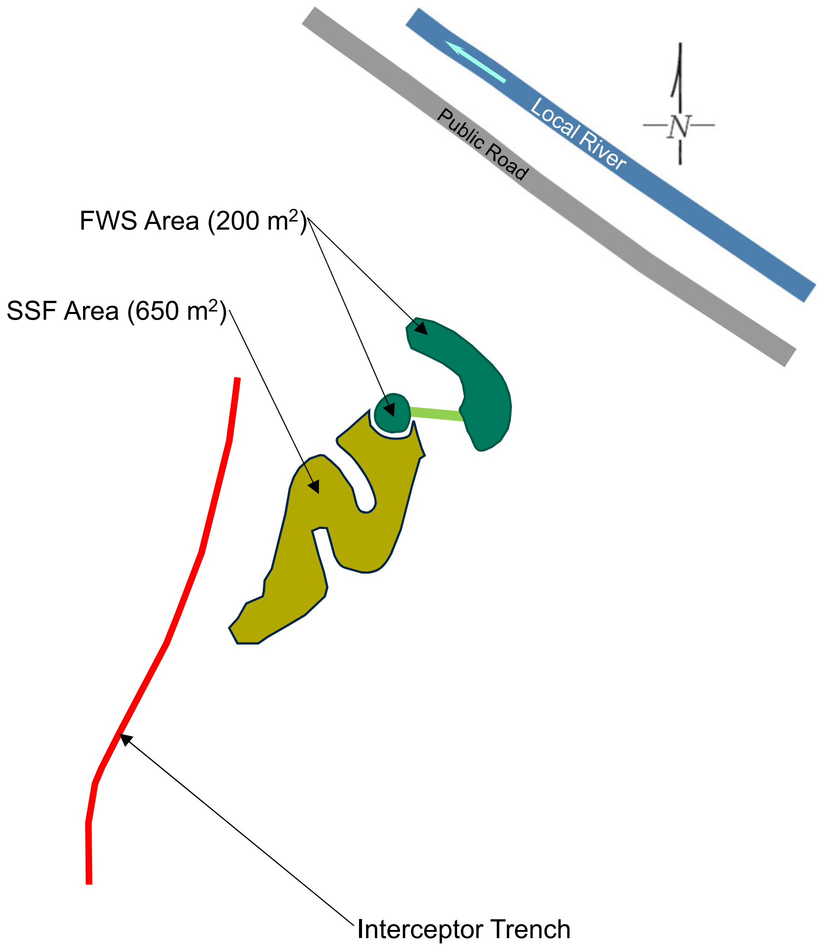
K value for SSF Design

Full-Scale Design *(continued)*

Wetland Size

Wetland Cell	HRT (days)	Area (m^2)	Depth of Wetland (m)
SSF	4	650	0.5
FWS	2	200	0.6

Due to the nature of wetlands, organic loading will be highest near the influent and will then decrease as the water progresses through the wetland



Full-Scale Design *(continued)*

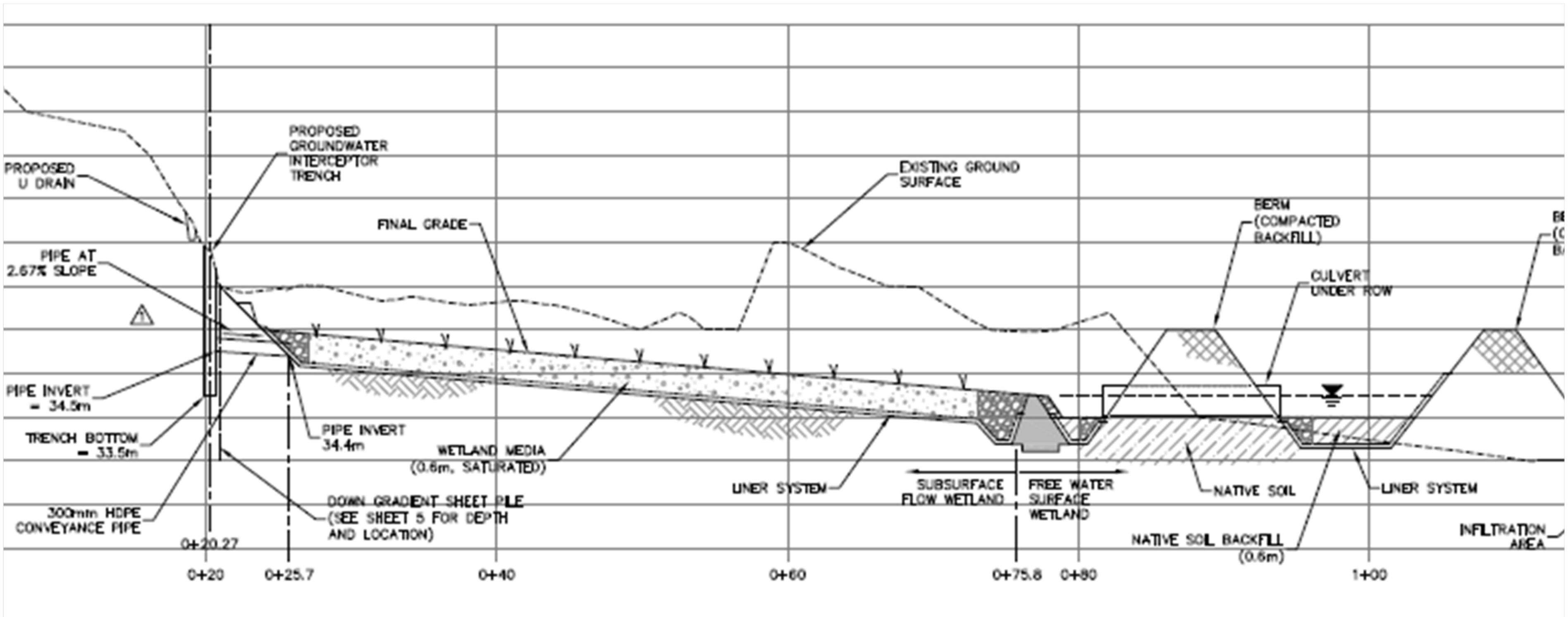
Design Consideration

- Conservatism was built in at each step of the design:
  - Influent concentration estimates
  - Groundwater flow estimates
  - First order decay constant
  - Infiltration of effluent, no discharge to river

Full-Scale Design *(continued)*

- Design considerations have been included to minimize preferential flows:
  - To minimize clogging, larger particle (16 -19 mm gravel) media that offer large voids was selected, so there will be less chance of clogging and hence less chance of flow alteration. SSF materials will be imported to match the specification.
  - Additionally, the larger media does not typically cause macropores resulting from cracks and fissures which occur mainly in fine-grained soil or sand
  - The design incorporate controls (berms) in the SSF cell to force the water through a circuitous flow path
  - The leachate has low level of suspended solids, so the system is less susceptible to solid accumulation within bed media pores
  - Inlet/Out control features are designed to provide uniform distribution and collection of flows, discouraging channeling

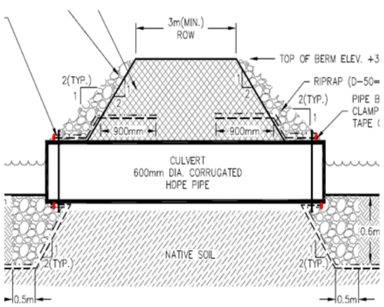
Full-Scale Design *(continued)*



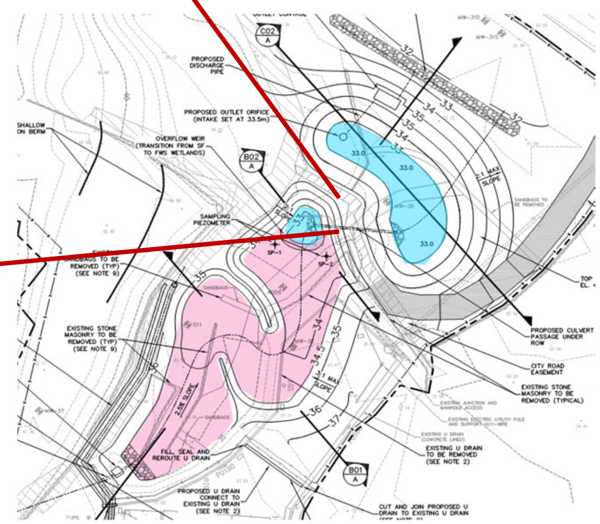
Full-Scale Design *(continued)*

Discharge
Water is allowed to infiltrate into the ground and there is no direct discharge of treated water to the local River

City Easement
cannot be part of wetland



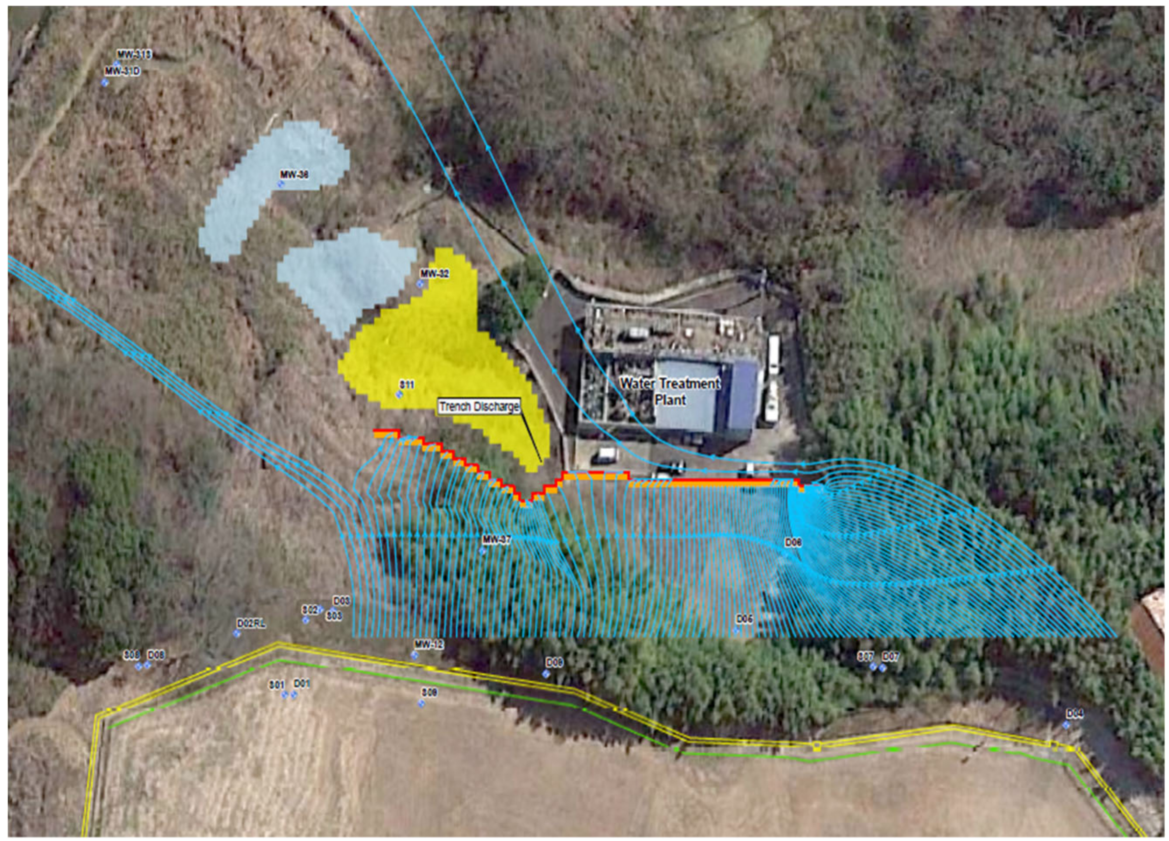
Collection Trench (with sheet pile behind)
high-permeability interceptor trench, then flows by gravity into the head of wetland



SSF FWS

Full-Scale Design *(continued)*

Groundwater Flow Pattern – With Wetland and its infrastructure (Interceptor trench with Sheet Pile in-place)



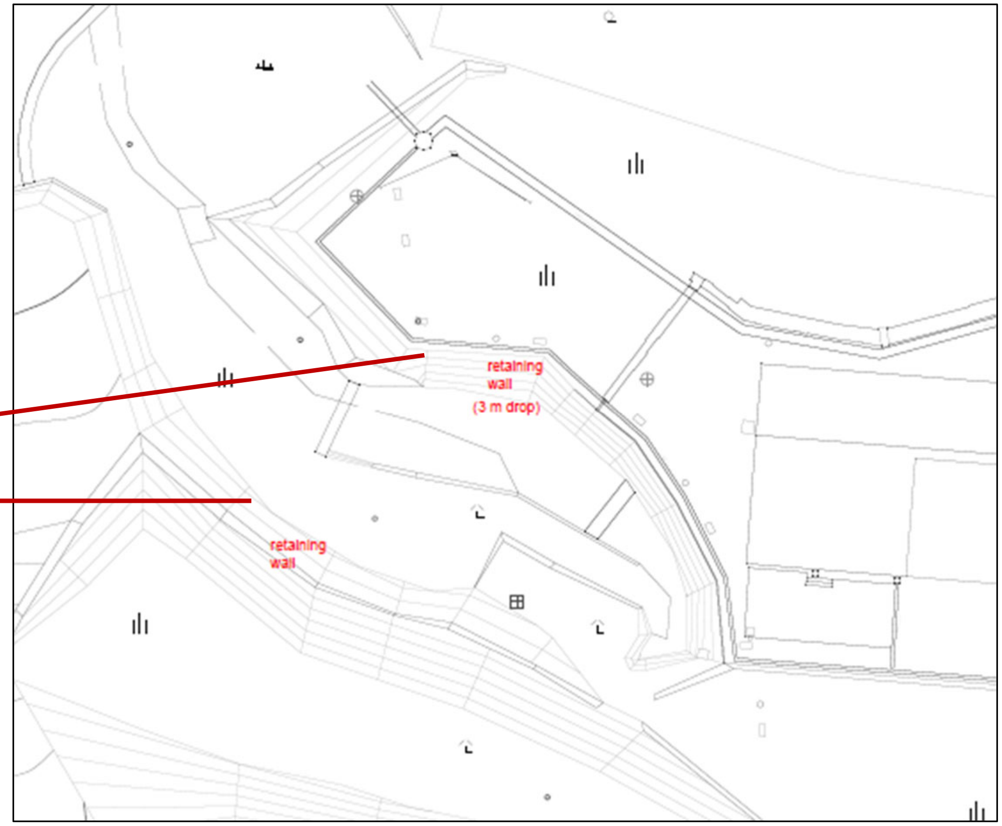
Legend

- Groundwater Flow Path Solution
- Groundwater Interceptor Trench (Drain Boundary)
- Surface Water Wetlands (River Boundary)
- Subsurface Wetlands (Hydraulic Conductivity Zone)
- Groundwater Interceptor Trench Sheet Pile
- Monitoring Well
- Cut-Off Wall
- Gravel Trench

Design Challenges

Limited Space

Steep Slope/Vertical Cliff



Operations and Maintenance

O&M program:

- Some clogging of the system is possible and may result in micro preferential flow paths due to biofilm growth, vegetation debris, etc. These are not a big concern as long the effluent targets are met. If an extreme condition occurs, such as surficial runoff in the SSF wetland, maintenance will be required.
- Maintenance would include periodic inspecting and cleaning distribution pipes and removal of accumulated organic matter.
- In an extreme condition we can clean and rework (agitate) the specific areas of the SSF media that are causing a problem to break up the clogs. This is easy to accomplish because the SSF media particle size is large and not cohesive.
- Removal of dead organic matter to prevent it from contributing to effluent BOD

Operations and Maintenance

Performance Monitoring:

- Collection and analysis of effluent samples to confirm achievement of treatment goals
- Collection and analysis of groundwater samples to confirm water quality at the dike
- Visual inspection of the system to identify malfunctions, such as clogging of the SSF media or failed plantings
- Removal of dead organic matter to prevent it from contributing to effluent BOD

Thank you

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