WASTEWATER TREATMENT IN PARKER, CO

SENIOR DESIGN IN ENVIRONMENTAL ENGINEERING

April 30, 2016

INTRODUCTION

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Sustainability Engineer		Shelby Kindsvater

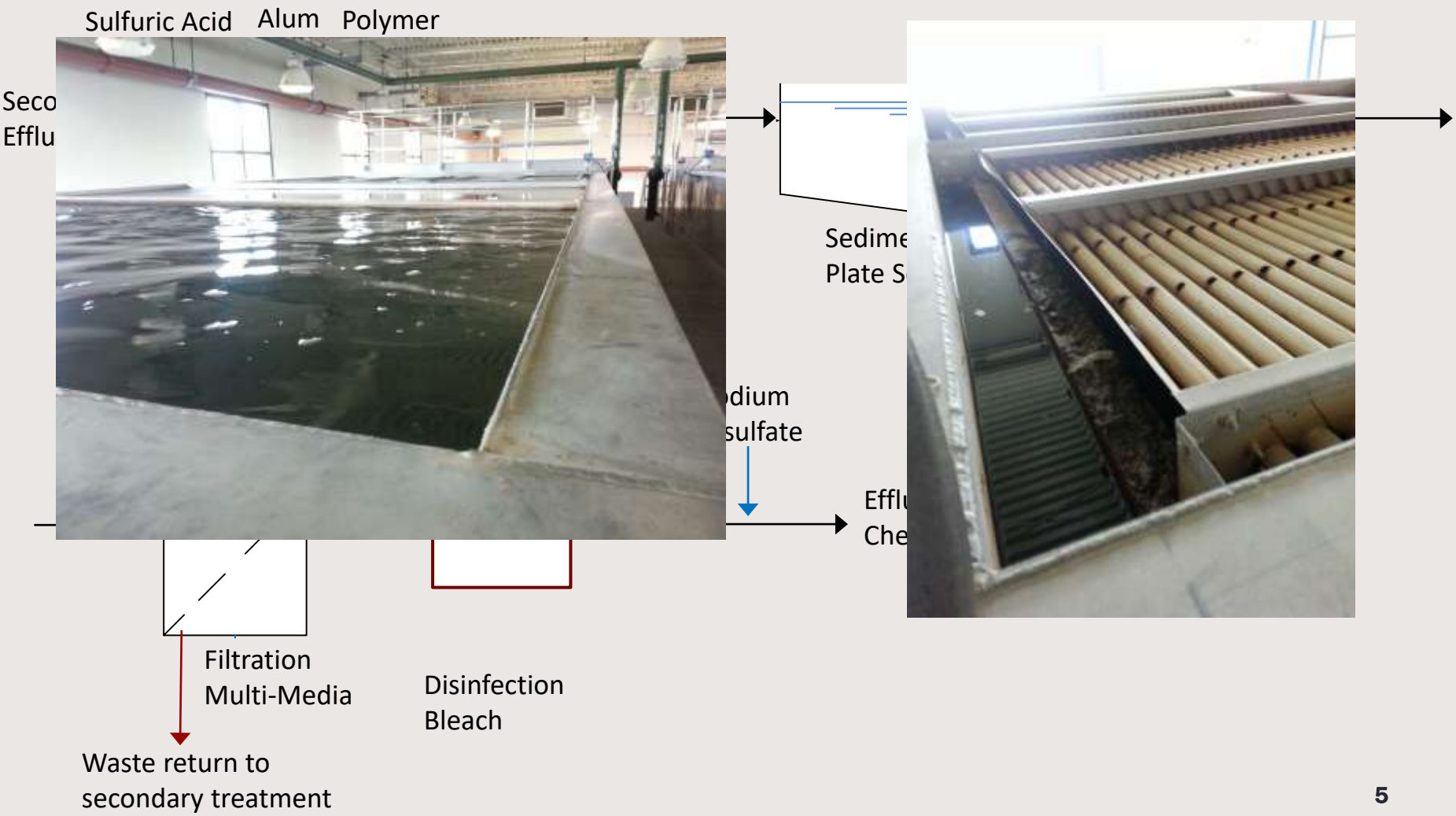
PROJECT OVERVIEW

- Goal - Select best approach to:
  - Expand tertiary treatment to meet future increase in flows due to population increase
  - Meet effluent phosphorus standards
  - Evaluate reduced chemical usage (especially for disinfection)
- Define “best” as an appropriate balance of sustainability measures of economic, environmental, and societal criteria (i.e., triple bottom line sustainability accounting)
- Develop a conceptual design for the selected “best” alternative

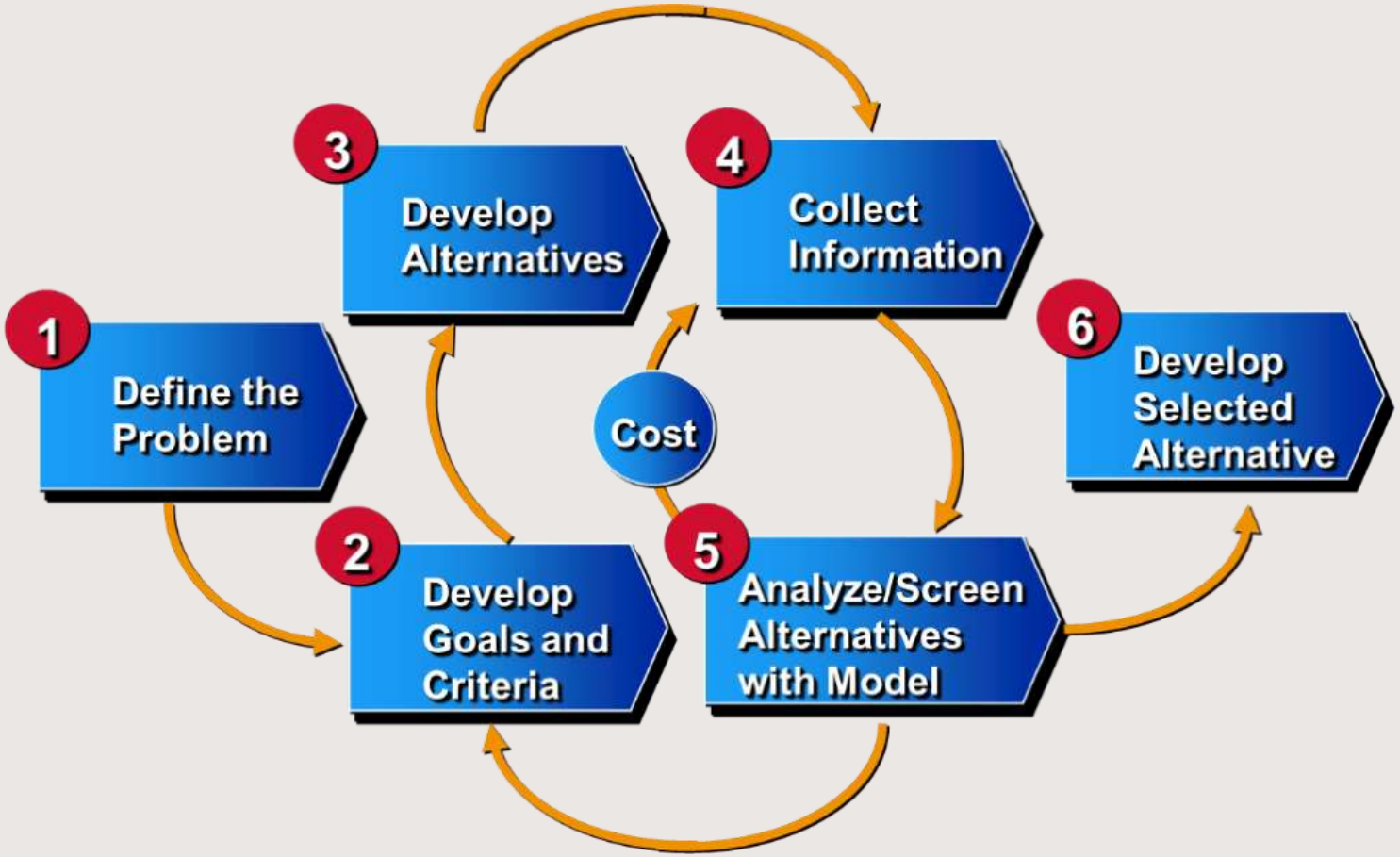
BACKGROUND

- Serves 50,000 people in and nearby Parker, CO
- 2.6 million gallons per day (mgd) currently treated in two facilities
- Capacity exceeded by 2021
- Expansion to 6.0 mgd
- Only AWT/disinfection considered
- Relevant Processes:
  - Biological Nutrient Removal
  - Tertiary treatment by MRI plate settlers and Tonka filters
  - Disinfection by chlorination

EXISTING AWT AND DISINFECTION SYSTEM



DECISION METHODOLOGY

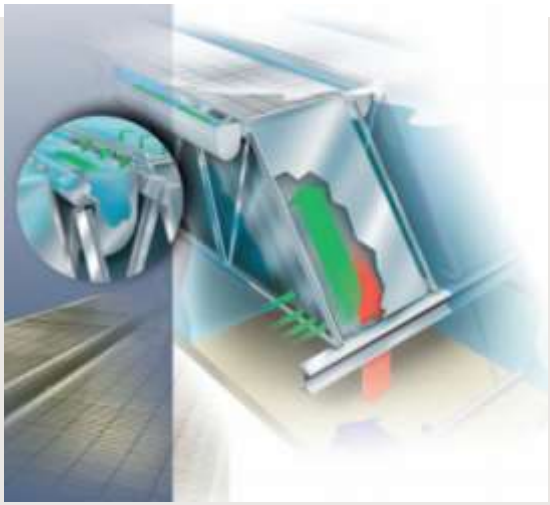


AWT ALTERNATIVES

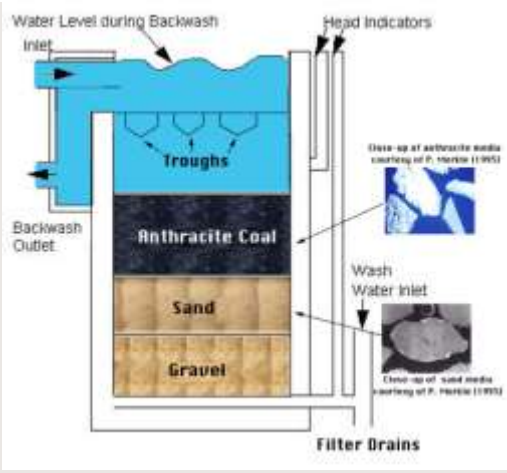
1. Coag/Floc/Plate/Media Filter
2. Coag/Floc/DAF/Media Filter
3. ACTIFLO/Media Filter
4. BluePRO
5. ACTIFLO/Membrane Filter
6. Coag/Membrane Filter
7. ~~Biological~~
8. ~~Reverse Osmosis~~
9. ~~Distillation~~
10. ~~Electrodialysis~~

PLATE SETTLER

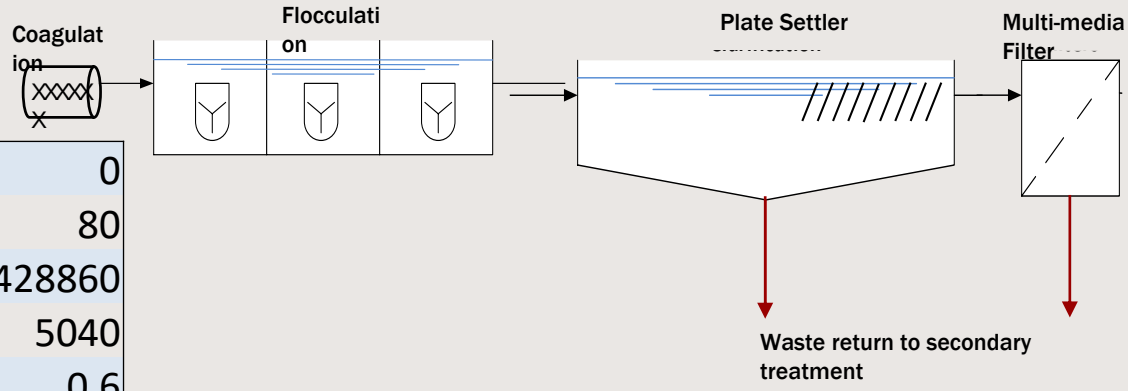
- Alum and polymer
- Flocculation through mechanical mixing
- Plate settler by Meurer Research Institute
- Filter box with anthracite, sand, gravel



http://www.meurerresearch.com/products/plate-settlers/



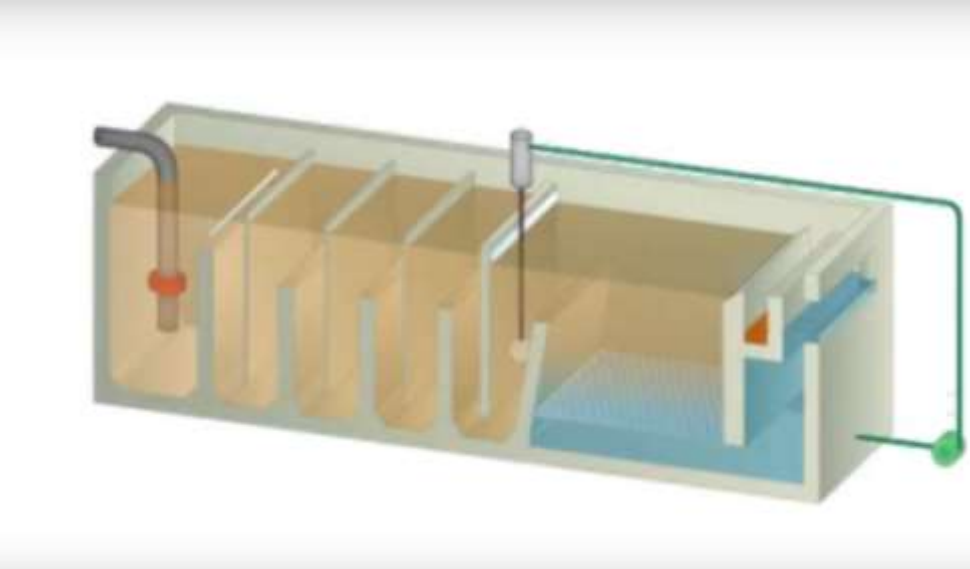
http://theglobalscientist.com/2014/07/10/780-million-people-could-gain-access-to-safe-drinking-water-by-using-manganese-oxides/



Ammonia-Nitrogen Removal (%)	0
TSS Removal (%)	80
Energy Use (kWh/yr)	1428860
Footprint (ft^2)	5040
Operational Intensity *	0.6
Number of years in use	23
Cost	$10,010,000

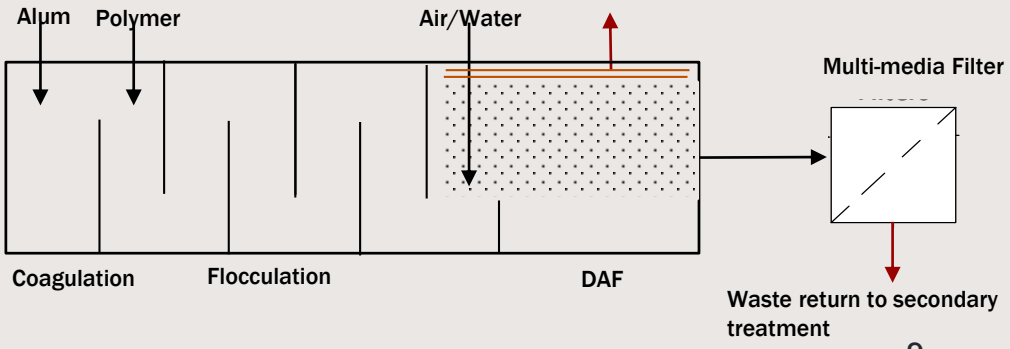
DISSOLVED AIR FLOTATION CLARIFIER

- GreenDAF by Degremont
- Flocculation through baffled chamber
- Air bubbles collect floc
- Sludge collected from surface
- Multi-media filter



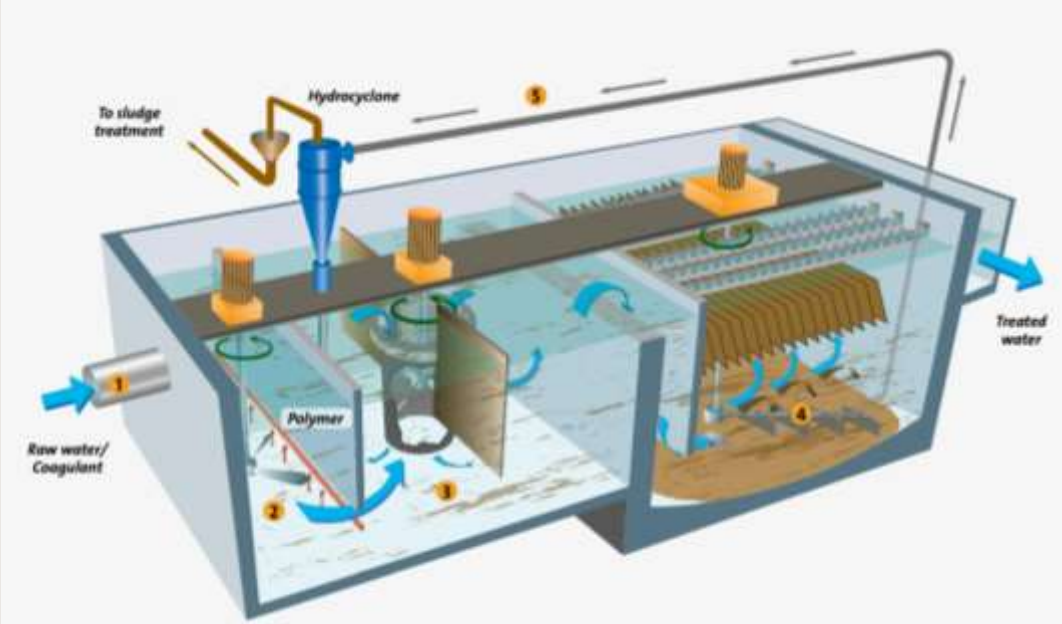
http://www.degremont.com/en/know-how/municipal-water-treatment/wastewater/phosphate-removal-greendaf/

Ammonia-Nitrogen Removal (%)	0
TSS Removal (%)	80
Energy Use (kWh/yr)	1816430
Footprint (ft^2)	2120
Operational Intensity *	0.7
Number of years in use	6
Cost	$8,940,000



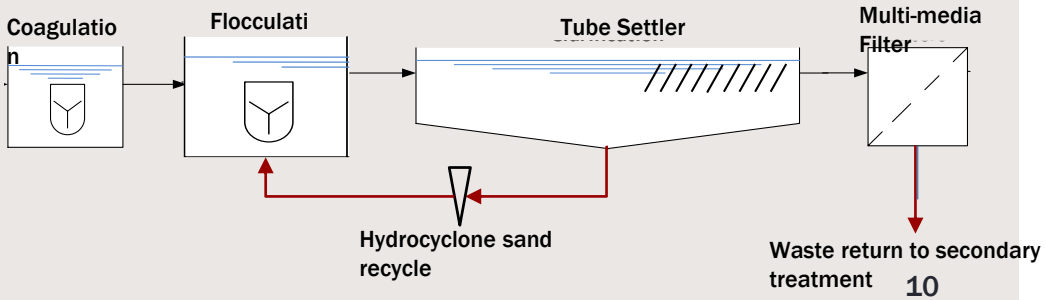
BALLASTED FLOCCULATION

- ACTIFLO by Veolia Water Technologies
- Microsand flocculation aid
- Mechanical Flocculation
- Turbomix draft tube
- Multi-media filter



http://technomaps.veoliawatertechnologies.com/processes/lib/municipal/3329,Actiflo_brochure-7_datasheets_EN_09.pdf

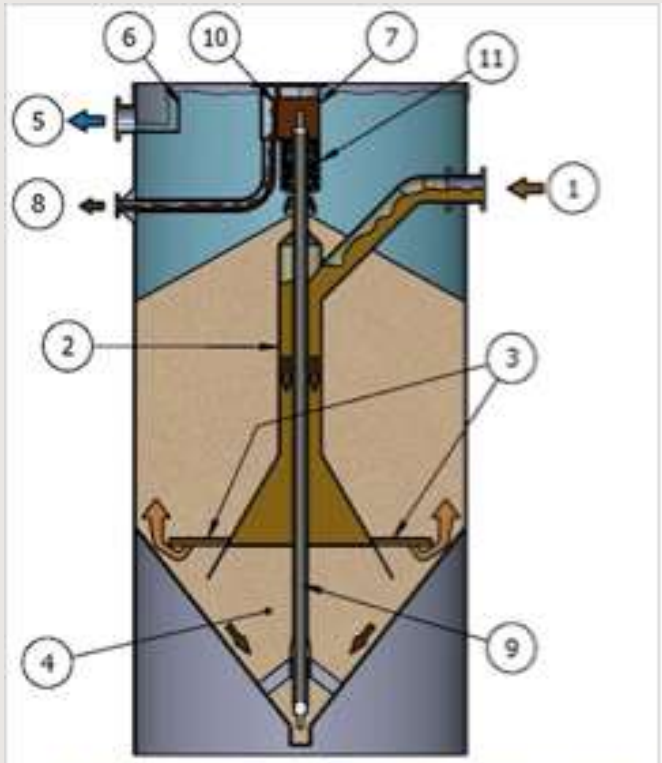
Ammonia-Nitrogen Removal (%)	0
TSS Removal (%)	80
Energy Use (kWh/yr)	1572860
Footprint (ft^2)	2100
Operational Intensity *	0.4
Number of years in use	20
Cost	$10,990,000



BLUE PRO

- Continuous backwash filter
  - 7-8% of influent rejected and recycled upstream
- Contaminant removal through adsorption
  - Media coated with hydrous ferric oxide (HFO)
- No floc or clarification basins needed

Ammonia-Nitrogen Removal (%)	85
TSS Removal (%)	80
Energy Use (kWh/yr)	125740
Footprint (ft^2)	1024
Operational Intensity *	0.8
Number of years in use	15
Cost	$3,402,047

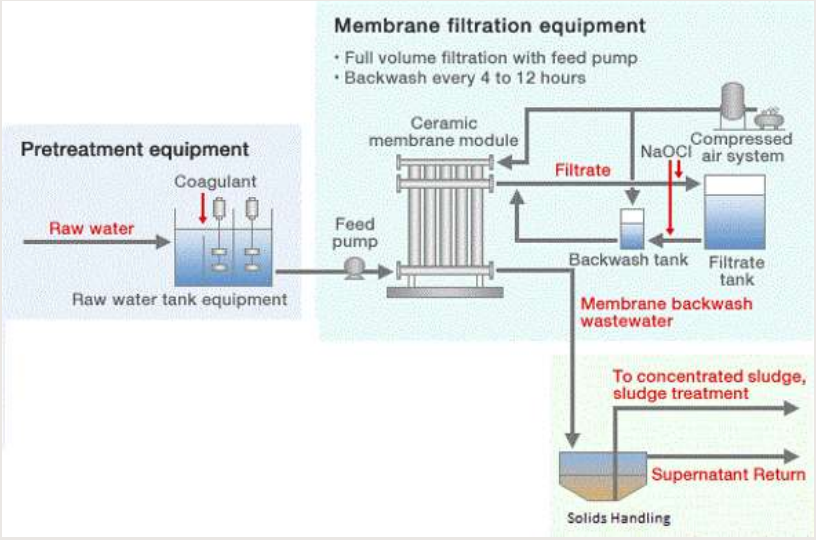


Source: bluewater-technologies.com

MEMBRANES

- Provides safer water
  - High protozoan, virus, and bacterial removal
    - Polymer-Based Nanostructure Membranes
    - Ceramic Membranes
      - Parker Water Treatment Plant has first and largest facility to employ ceramic membranes in North America
- Coagulation/Membrane Filter
- ACTIFLO/Membrane Filter

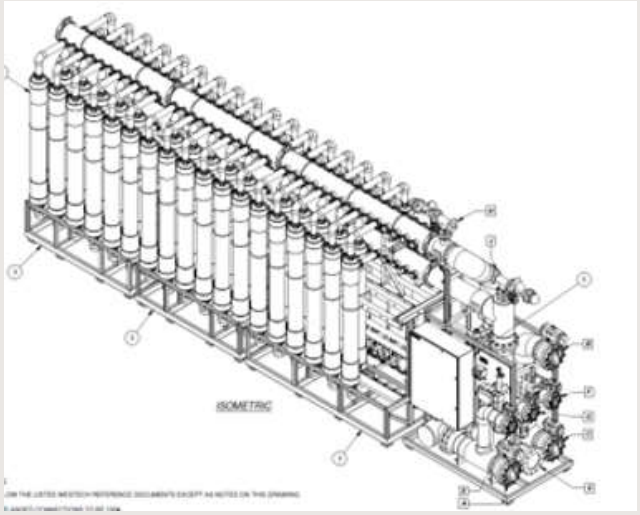
http://www.metawater.co.jp/eng/product/plant/water/membrane_clarify/



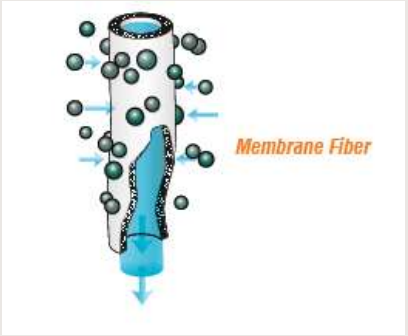
http://www.metawater.co.jp/eng/product/plant/water/membrane_clarify/

ULTRAFILTRATION HOLLOW-FIBER MEMBRANES

- Automated operation
  - Built on skids for easy installation
- Low pressure filtration
- Excellent particle barrier
  - Pore size of 0.01 micron
    - TSS < 1 mg/L
    - Virus > 1.5 log removal
    - Giardia > 5.5 log removal
    - Cryptosporidium > 5.5 log removal
    - Bacteria > 5.5 log removal
    - Turbidity < 0.1 NTU
    - 0.03 mg/L P



1001-GENERAL ARRANGEMENT, ALTAFILTER, 74 MODULE CAPACITY.pdf



http://www.westech-inc.com/en-usa/products/ultrafiltration-membrane-package-system-altapac

ULTRAFILTRATION HOLLOW-FIBER MEMBRANE CRITERIA SCORES

- Coag/Membrane Filter

Ammonia-Nitrogen Removal (%)	0
TSS Removal (%)	98
Energy Use (kWh/yr)	585000
Footprint (ft^2)	1700
Operational Intensity *	0.3
Number of years in use	10
Cost	$10,100,000

- ACTIFLO/Membrane Filter
  - 30% higher membrane loading rate
  - 30% fewer modules

Ammonia-Nitrogen Removal (%)	0
TSS Removal (%)	98
Energy Use (kWh/yr)	720000
Footprint (ft^2)	2400
Operational Intensity *	0.1
Number of years in use	10
Cost	$15,200,000

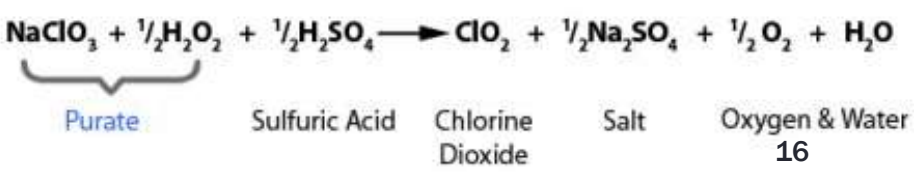
DISINFECTION ALTERNATIVES

1. Chlorine Dioxide
2. Sodium hypochlorite, delivered
3. Sodium hypochlorite Onsite Generation
4. UV
5. Ozone
6. ~~Gaseous Chlorine~~
7. ~~Solid calcium hypochlorite~~
8. ~~Chloramine~~
9. ~~Pasteurization~~
10. ~~E-beam~~

CHLORINE DIOXIDE – PURATE SYSTEM

- No chlorine gas used or produced
- Simple two-chemical feed
  - Purate and sulfuric acid
- Effectively deactivates the chlorine-resistant Giardia and Cryptosporidium
- Two new hazardous chemicals

Protozoa (Log Removal)	2
Energy Use (kWh/yr)	13140
Chemical Use (Y/N)	Yes
Footprint (ft^2)	476
Operational Intensity*	0.8
Operator Safety*	0.7
Public Safety (Yearly Truck Traffic)	12
Cost	$1,261,000



DELIVERED SODIUM HYPOCHLORITE

- Currently used at the plant
- Safer to handle than gaseous chlorine
- Corrosive
- Cannot be stored for more than a month

Protozoa (Log Removal)	0.5
Energy Use (kWh/yr)	6570.0
Chemical Use (Y/N)	Yes
Footprint (ft^2)	3390.0
Operational Intensity*	1.0
Operator Safety*	0.8
Public Safety (Yearly Truck Traffic)	17.0
Cost	$965,000

SODIUM HYPOCHLORITE GENERATION

- A salt and water solution is exposed to an anode and a cathode
- The solution separates into sodium hypochlorite and hydrogen gas
- 0.8% solution concentration

Protozoa (Log Removal)	0.5
Energy Use (kWh/yr)	109500.0
Chemical Use (Y/N)	Yes
Footprint (ft^2)	875.0
Operational Intensity*	0.8
Operator Safety*	0.9
Public Safety (Yearly Truck Traffic)	8.0
Cost	$1,754,124

http://www.severntrentdenora.com/products-and-services/seawater-electrochlorination-systems/clortec/750-0210.pdf

UV DISINFECTION

- Pathogens get exposed to UV light which penetrates cell walls and disrupts DNA chains
- Once these chains are disrupted, the pathogen cannot reproduce and become harmless

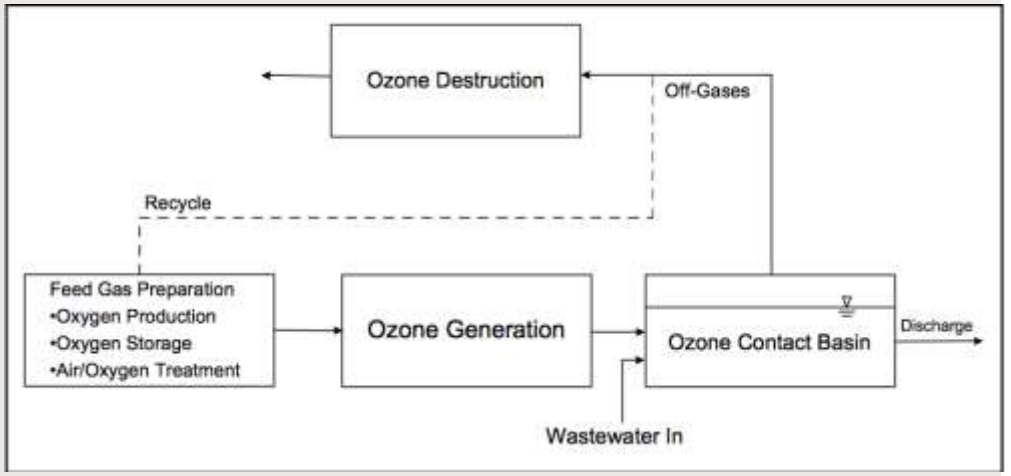
Protozoa (Log Removal)	4
Energy Use (kWh/yr)	340000
Chemical Use (Y/N)	No
Footprint (ft^2)	198
Operational Intensity*	0.7
Operator Safety*	0.9
Public Safety (Yearly Truck Traffic)	0
Cost	$1,464,899

http://upload.ecvv.com/upload/Product/20119/China_welnic_Wastewater_automatic_cleaning_UV_sterilizer20119271538024.jpg

OZONE DISINFECTION

- Uses air or liquid oxygen to produce ozone (O_3)
- Strong oxidant kills pathogens
- Added to wastewater at 5-10mg/L
- Low contact time
- Thermal destruction of ozone

Protozoa (Log Removal)	1
Energy Use (kWh/yr)	1314000
Chemical Use (Y/N)	No
Footprint (ft^2)	1800
Operational Intensity*	0.4
Operator Safety*	0.5
Public Safety (Yearly Truck Traffic)	31
Cost	$5,374,952

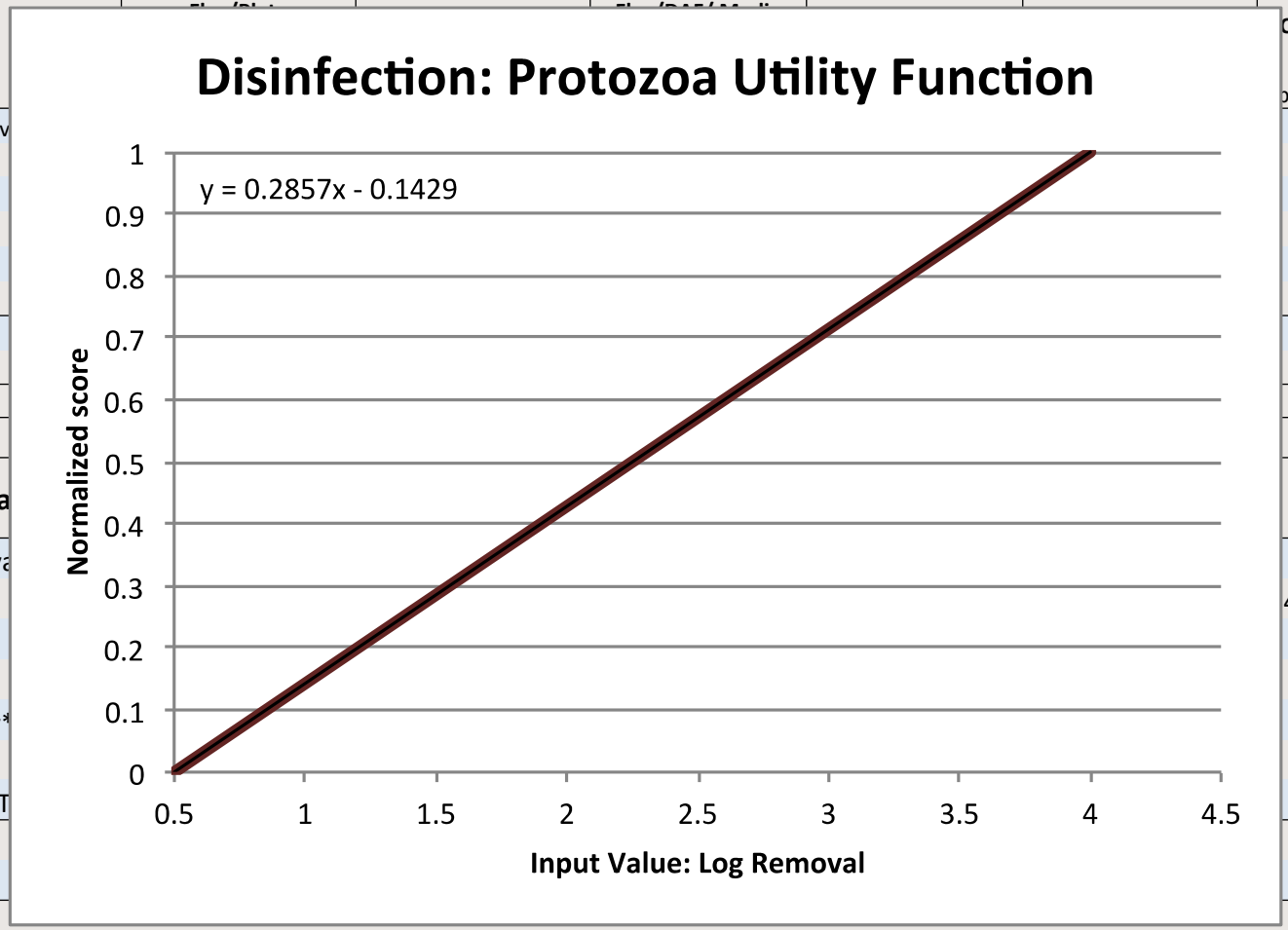


http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_ozon.pdf

DATA INPUTS

Advanced Water Treatment							
Criteria						Coag/ Membrane	
						ut	WNScore
Ammonia-Nitrogen Remov						0	0.000
TSS Removal (%)						98	0.150
Energy Use (kWh/yr)						585,000	0.114
Footprint (ft^2)						1700	0.139
Operational Intensity *						0.3	0.050
Number of years in use						10	0.039
Total							0.492
25-Year PV ($)							10,100,000

Criteria						Ozone	
							WNScore
Protozoa (Log Remova						1	0.020
Energy Use (kWh/yr)						4,000	0.000
Chemical Use (Y/N)						No	0.143
Footprint (ft^2)						1800	0.071
Operational Intensity*						0.4	0.057
Operator Safety*						0.5	0.071
Public Safety (Yearly T						31	0.000
Total							0.363
25-Year PV ($)							5,374,952



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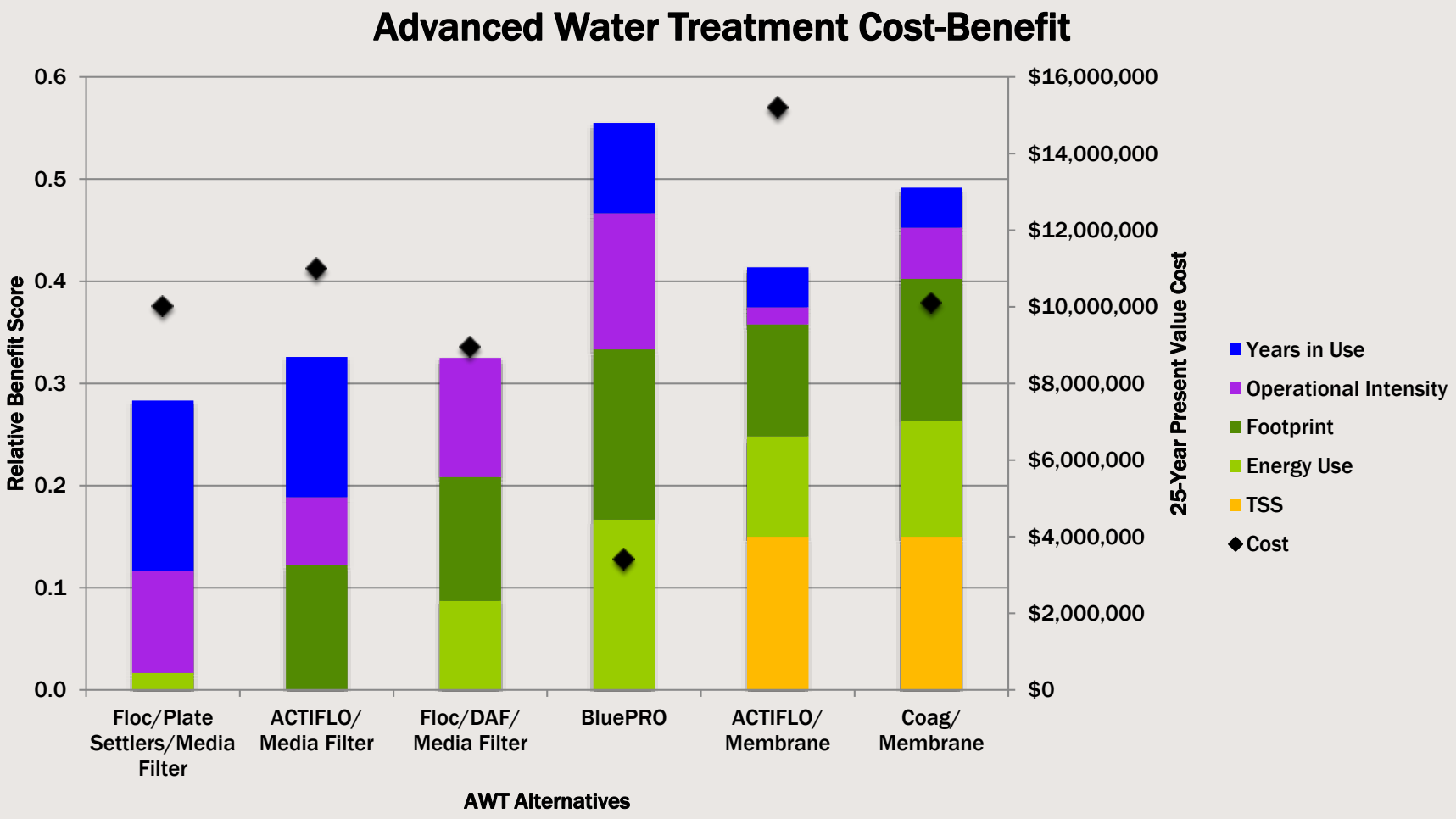
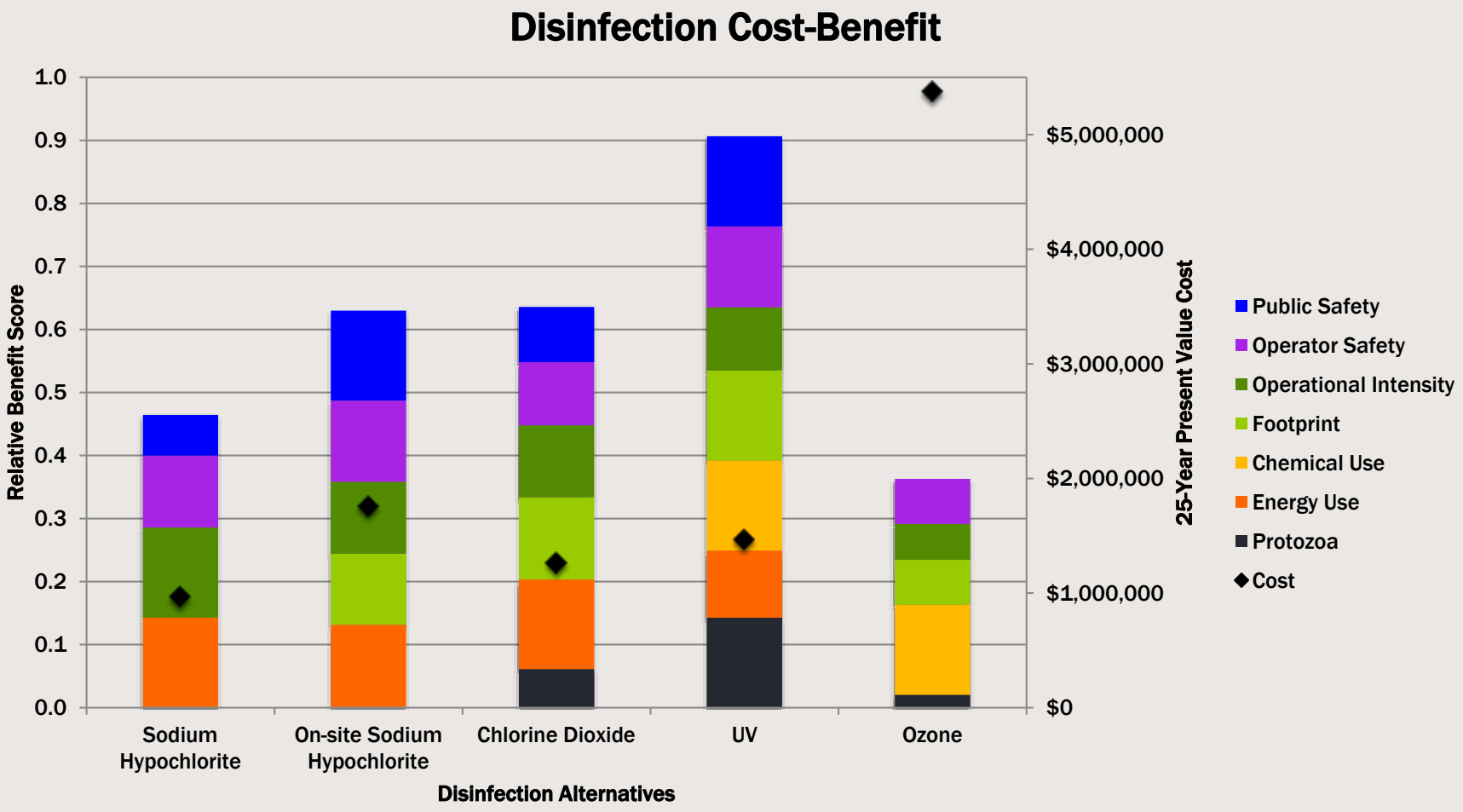
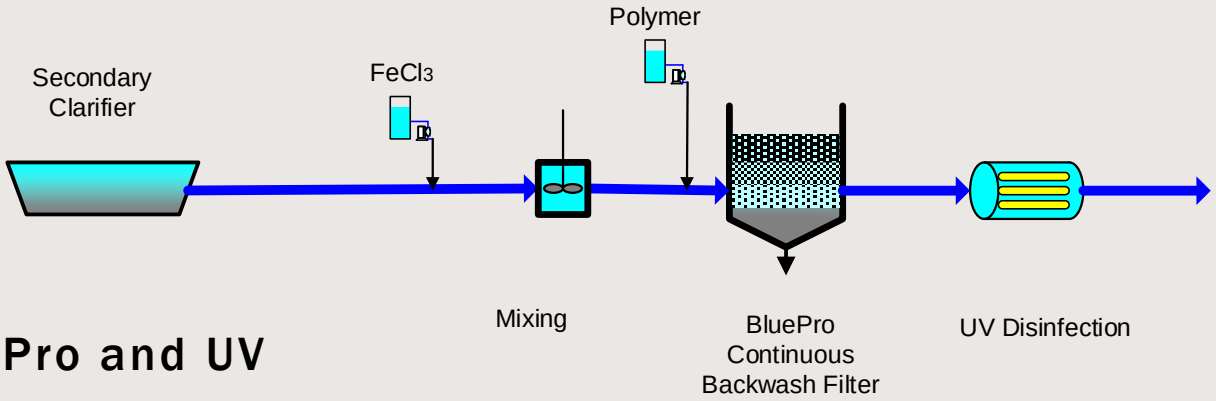

Advanced Water Treatment Cost-Benefit
Relative Benefit Score
0.6
0.5
0.4
0.3
0.2
0.1
0.0
$16,000,000
$14,000,000
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$0
25-Year Present Value Cost
Floc/Plate Settlers/Media Filter
ACTIFLO/ Media Filter
Floc/DAF/ Media Filter
BluePRO
ACTIFLO/ Membrane
Coag/ Membrane
AWT Alternatives
Years in Use
Operational Intensity
Footprint
Energy Use
TSS
Cost

STACK GRAPH

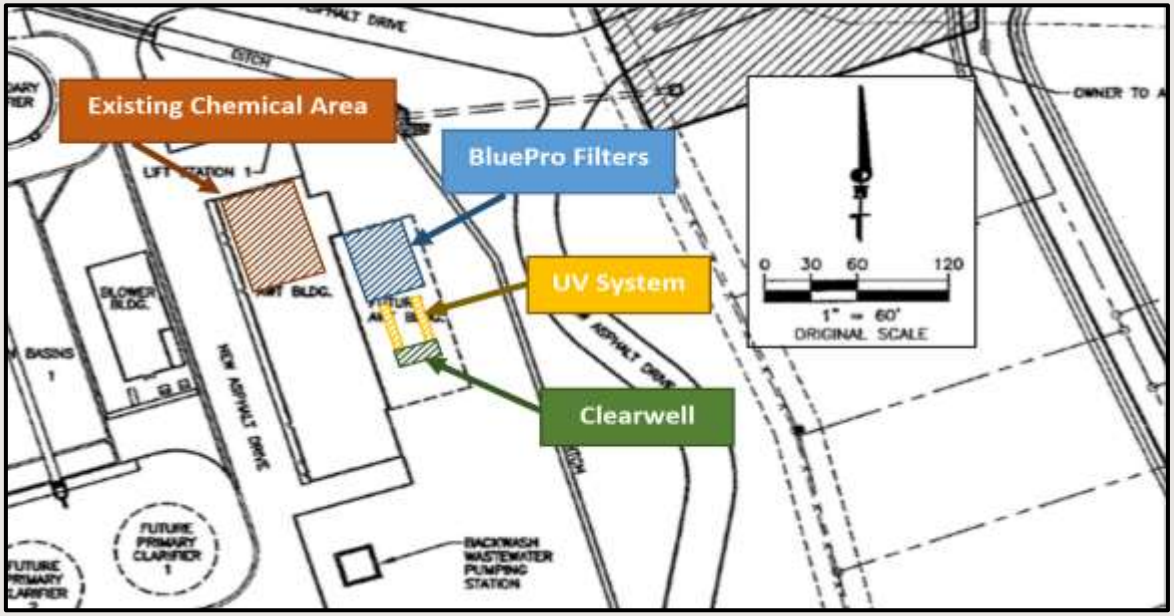

Disinfection Cost-Benefit
Relative Benefit Score
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
$5,000,000
$4,000,000
$3,000,000
$2,000,000
$1,000,000
$0
25-Year Present Value Cost
Sodium Hypochlorite
On-site Sodium Hypochlorite
Chlorine Dioxide
UV
Ozone
Disinfection Alternatives
Public Safety
Operator Safety
Operational Intensity
Footprint
Chemical Use
Energy Use
Protozoa
Cost

CONCEPTUAL DESIGN

Process Flow Diagram



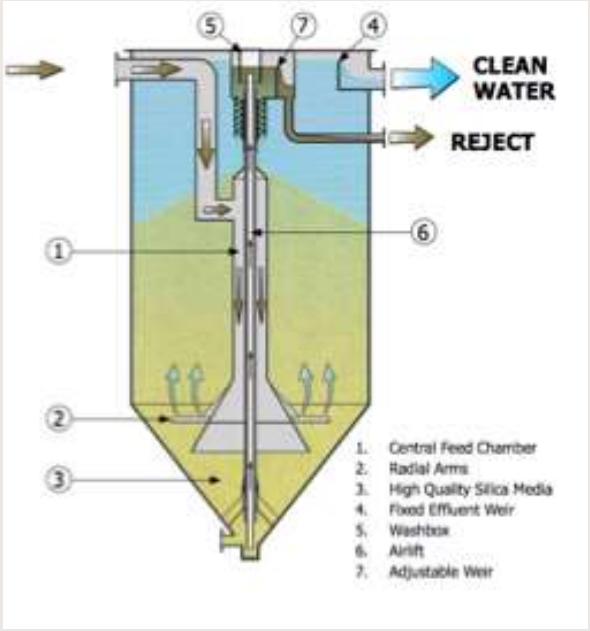
Site Plan for Blue Pro and UV



CONCEPTUAL DESIGN-BLUE PRO

Design Criteria

- 18 filters at 7.5X7.5X7 feet each (Model CF64-80AG)
  - 14 and 16 filters online during ADF and PHF, respectively
- 2000 sq ft of expansion required
  - 1024 sq ft of filter area
- 90-95% contaminant removal in single stage of treatment
  - FeCl dose of approximately 5-10 ppm



Pictures retrieved from email from manufacturer

Total Capital Cost: **$1,247,340**

Annual O&M Costs: **$137,927**

Total Present Value: **$3,402,047**

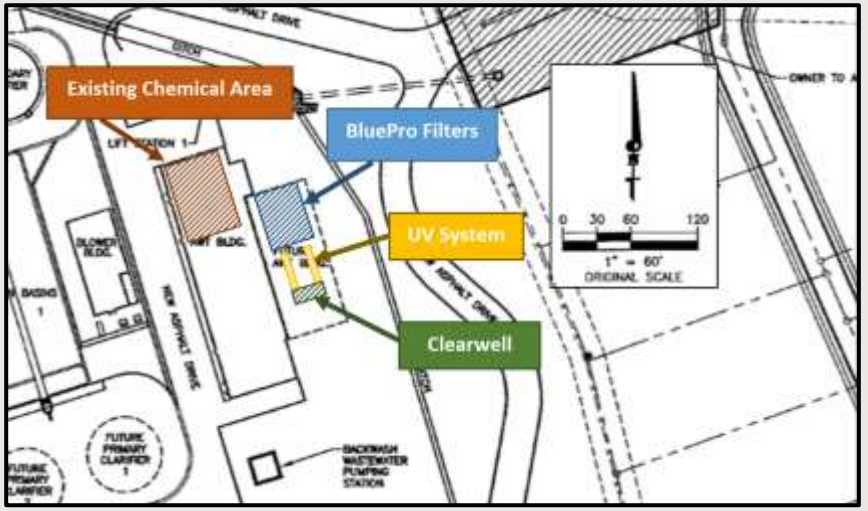
CONCEPTUAL DESIGN-UV

Design Criteria

- TrojanUV3000Plus Lamps
- 2 - 3MGD Channels with total area of 198ft^2 and depth of 6ft
- Energy use: 340,000 kWh/yr
- >2-log *E.coli* >4-log *Giardia* & *Crypto* inactivation

http://www.trojanuv.com/products/wastewater/trojanuv3000plus

Site Plan



Total Capital Cost: **$758,656**

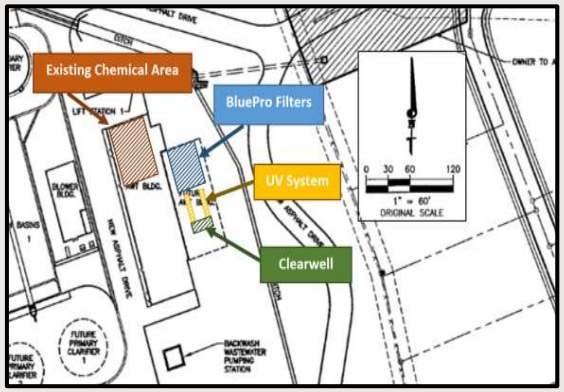
Annual O&M Costs: **$45,208**

Total Present Value: **$1,464,899**

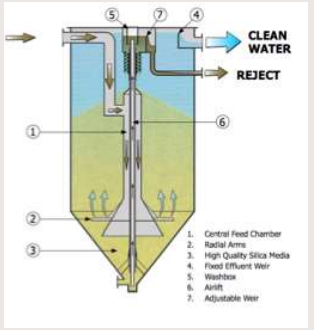
CONCLUSION

After studying six final advanced water treatment alternatives, we chose a Blue PRO system based on its highest benefit score and lowest cost.

After studying five final disinfection alternatives, we chose UV disinfection based on its highest benefit score and reasonable cost.



Questions?



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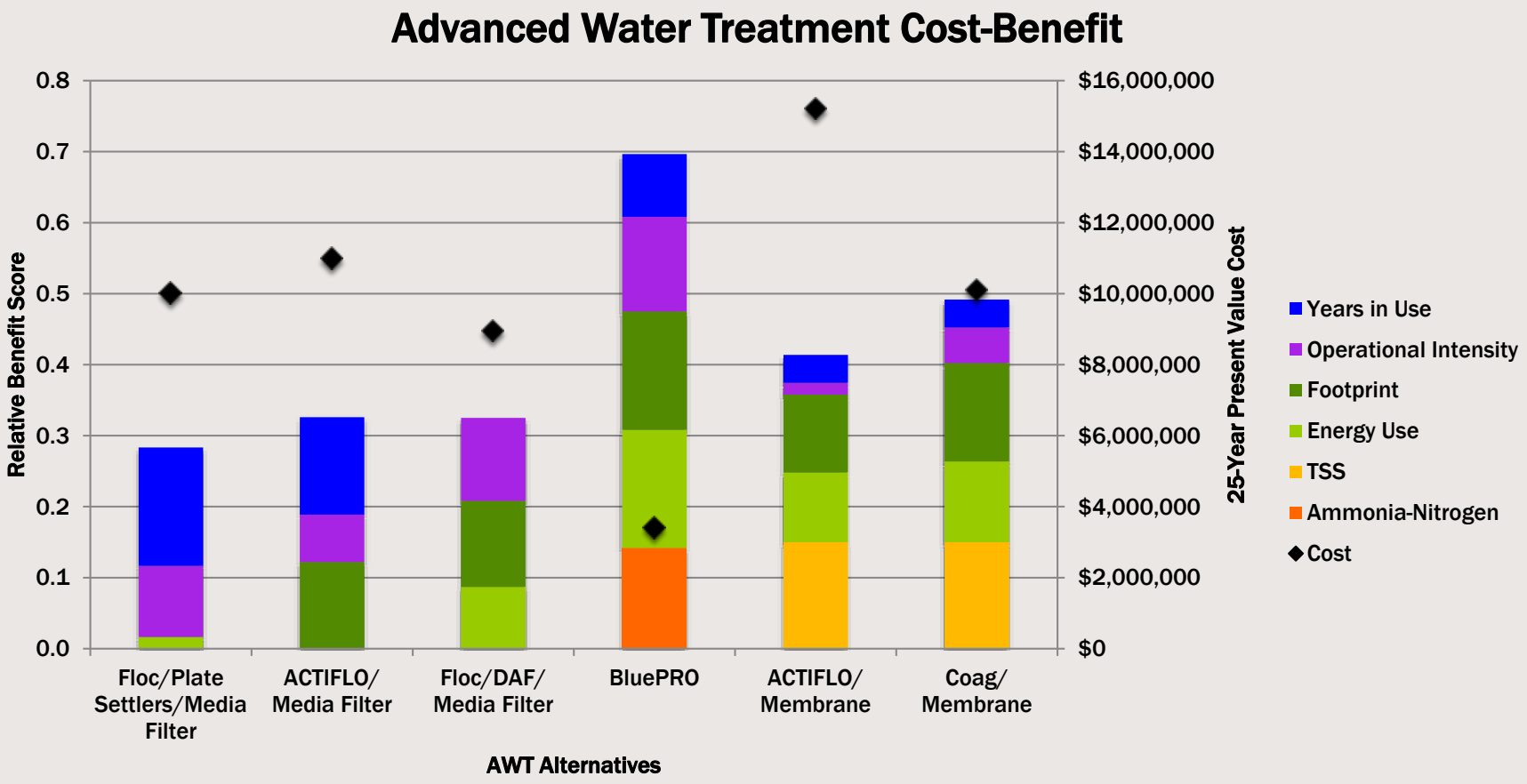
REFERENCE SLIDES

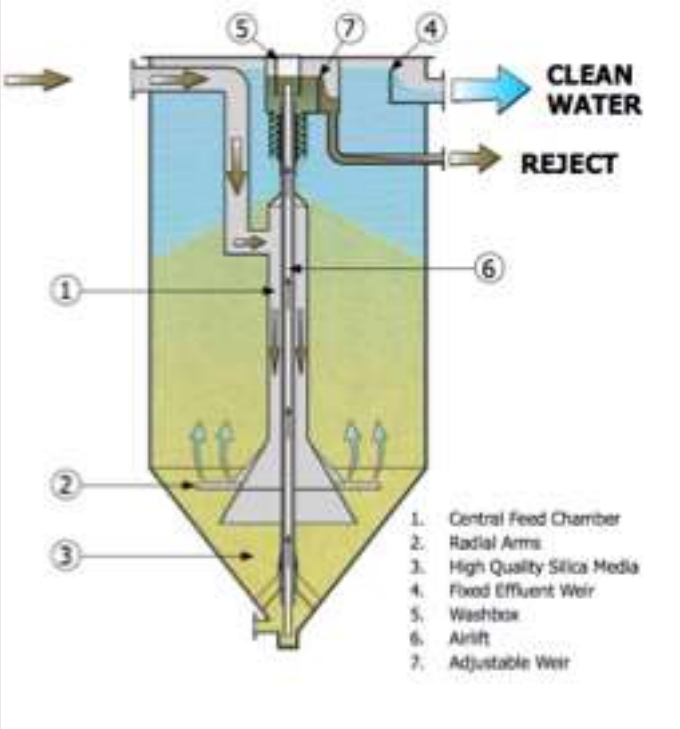
	Worst						Best			
Criteria	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
Safety	Certain death caused by implementation			Accidents can be avoided with knowledge of alternative				Zero chance of an accident, harmless when operated incorrectly			
Operational Intensity	Several points of failure, little to no points of redundancy			Average points of failure, average points of redundancy				Little to no failure points, several points of redundancy			

REFERENCE SLIDES

AWT	Criteria	Sub-Criteria	Units	Min Limit	Max Limit	High or Low?	Scale	Weight (%)
Environmental	Water Quality Obtained	Ammonia-Nitrogen Removal	%	0	100	High	0.010000	0.1667
		TSS Removal	%	80	100	High	0.050000	0.1667
	Energy Use	.....	kWh/yr	125740	1572860	Low	0.000001	0.1667
	Footprint	.....	square feet	1024	5040	Low	0.000249	0.1667
Societal	Operational Intensity *	.....	Number	0	1	High	1.000000	0.1667
	Number of years in use	.....	Number	6	23	High	0.058824	0.1667
	* Qualitative criteria (See "Qualitative Scales" page)						Total-->	1

Disinfection	Criteria	Sub-criteria	Units	Min Limit	Max Limit	High or Low?	Scale	Weight (%)
Environmental	Water Quality Obtained	Protozoa	Log removal	0.5	4	High	0.2857143	0.1429
	Energy Use	.....	kWh/yr	6,570	1,314,000	Low	0.0000008	0.1429
	Chemical Use	.....	Yes/No	0	1	Low	1.0000000	0.1429
	Footprint	.....	square feet	198	3,390	Low	0.0003133	0.1429
Societal	Operational Intensity*	.....	Number	0	1	High	1.0000000	0.1429
	Safety	Operator*	Number	0	1	High	1.0000000	0.1429
		Public	Trucks/yr	0	31	Low	0.0322581	0.1429
	* Qualitative criteria (See "Qualitative Scales" page)						Total-->	1


Advanced Water Treatment Cost-Benefit
Relative Benefit Score
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
$16,000,000
$14,000,000
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$0
25-Year Present Value Cost
Floc/Plate Settlers/Media Filter
ACTIFLO/ Media Filter
Floc/DAF/ Media Filter
BluePRO
ACTIFLO/ Membrane
Coag/ Membrane
AWT Alternatives
Years in Use
Operational Intensity
Footprint
Energy Use
TSS
Ammonia-Nitrogen
Cost


5
7
4
CLEAN WATER
REJECT
6
1
2
3
1. Central Feed Chamber
2. Radial Arms
3. High Quality Silica Media
4. Fixed Effluent Weir
5. Washbox
6. Airlift
7. Adjustable Weir