NC STATE UNIVERSITY

Stowe Regional Water Resource Recovery Facility

Abigail Brinkman, Will Brower, Abbygail Kinlaw

CHARLOTTE WATER

WEFTEC 2021 Student Design Competition

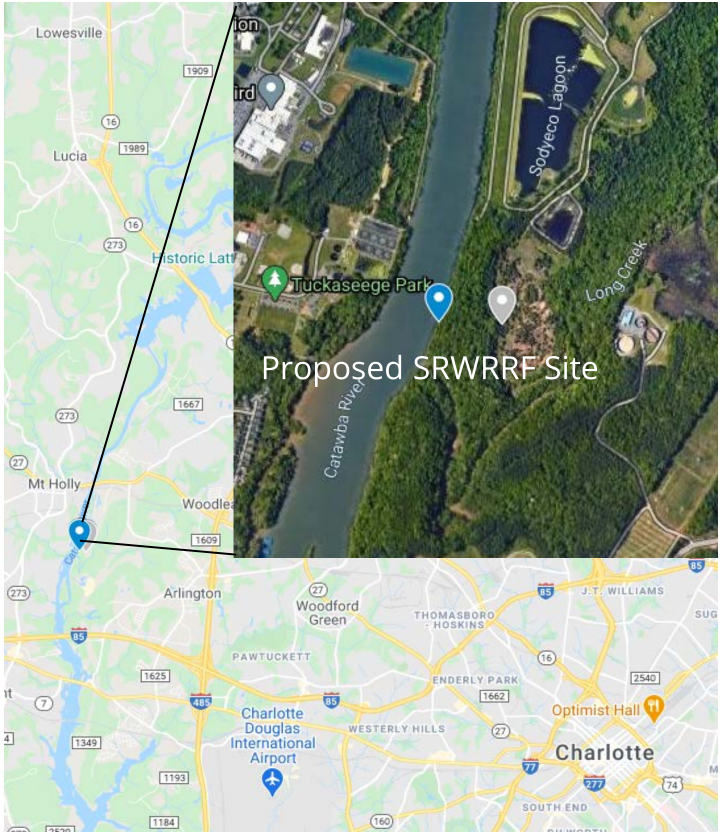
Project Scope

Mecklenburg County is one of the fastest growing areas in the state of North Carolina. Greater population and land development needs require a larger wastewater treatment plant.

For this reason, Charlotte Water requests a Professional Engineering Report by professional consultant engineering services for the Stowe Regional Water Resource Recovery Facility (SRWRRF) Project.

Project Background

- Stowe Regional WRRF will increase the wastewater treatment capacity for the growing Mecklenburg and Gaston County region
- Treatment capacity will initially be 15 MGD (2024) with a future upgrade to 25 MGD
- Intended to be a state-of-the art plant that adds value to the community and places Charlotte Water at the forefront of water resource recovery



Design Objectives

Permits and Policy

Ensure compliance with current and future regulations

Treatment Process

Research secondary/tertiary processes and provide alternatives

Plant Layout

Model the process flow and map out site

Resource Recovery

Evaluate ways to recover energy and resources

Construction

Estimate construction costs and scheduling

Future

Advise on staffing needs and future improvements

Regulations Must be Met

Riparian Buffer Protection Program:

- ➢ Must allow 50 ft. riparian buffer within the Catawba River basin for protection of nutrient-removing natural vegetation

Charlotte Public Art Ordinance:

- ➢ Inclusion of Public Art of value equal to 1% of projected construction costs. Eligible sites include any “public building, facility, or open space that is accessible and available to citizens”

	15 MGD (Initial)	
Parameters	**Monthly Average**	**Weekly Average**
$CBOD_5$ (Summer) (mg/L)	4.2	6.3
$CBOD_5$ (Winter) (mg/L)	8.3	12.5
TSS (mg/L)	30	45
NH_3-N (mg/L)	1.0	3.0
Fecal Coliform (Geometric Mean) (mL)	200/100	400/100
TN equivalent concentration (Summer) (mg/L)	6.0	
TN eq. conc. (Winter) (mg/L)	12.0	
TP eq. conc. (mg/L)	1.0	
pH	≥6.0 and ≤9.0	

Needed to Consider the Client’s Goals

- Conversations with facility operators and client yielded the following list of priorities:
  - Balance of reliability and ingenuity
  - City of Charlotte’s sustainability goals
  - Community involvement

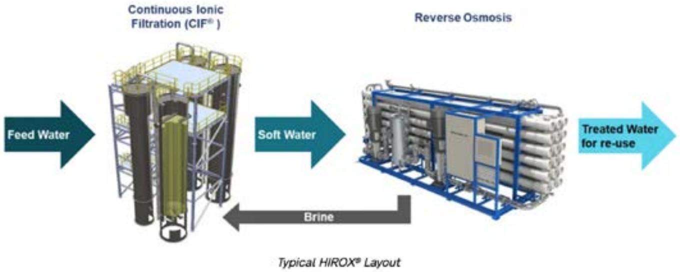
Action Area 5: Strive Toward 100% Zero Carbon Municipal Buildings by 2030

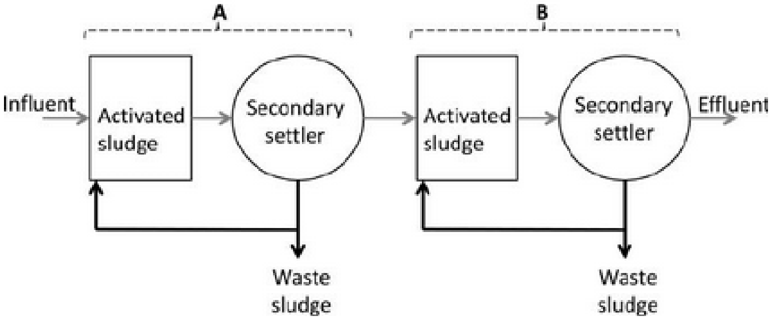
SEAP
STRATEGIC ENERGY ACTION PLAN
CITY of CHARLOTTE

Image credit: City of Charlotte, NC

Potential Technologies

- Compiled a list of technologies that would best meet the clients needs
- Considered Bardenpho, MBR, BIOCLENS & BIONEX - HIROX, Compressible Media Filtration, Adsorption/Bio-Oxidation...





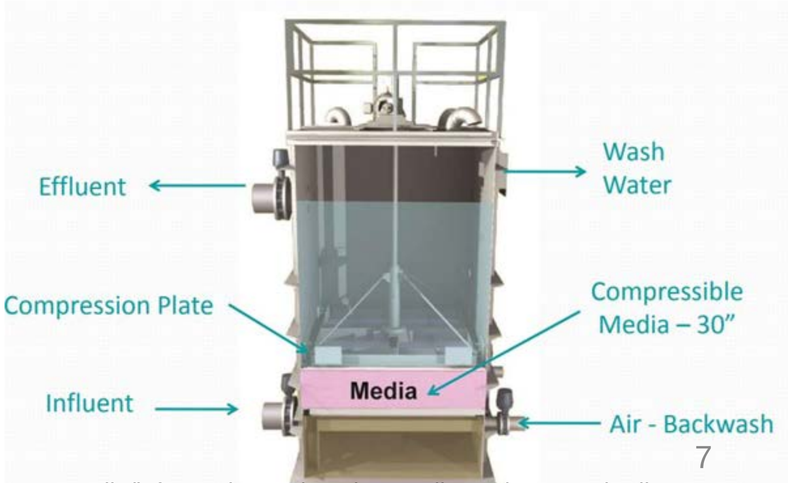


Image credit (left, top, bottom): Oskar Modin, Multotec, Schreiber water

Presented Design Alternatives

5-Stage Bardenpho	A^2O/MBR	Adsorption/Bio-Oxidation
➢ Traditional process popular for biological nutrient removal (BNR) of N+P ➢ Five individual tank zones under different aerobic conditions ➢ High head loss ➢ Reliable and efficient	➢ Anaerobic-Anoxic-Aerobic BNR scheme followed by MBR ➢ Secondary and tertiary treatment - high efficiency membrane filtration ➢ Requires fewest overall number of separate reactors	➢ 2-stage activated sludge process ➢ Innovative high-loaded A-stage removes organic matter through flocculation and sorption followed by settling ➢ B-stage biodegrades and settles remaining organic matter

Alternatives Assessment

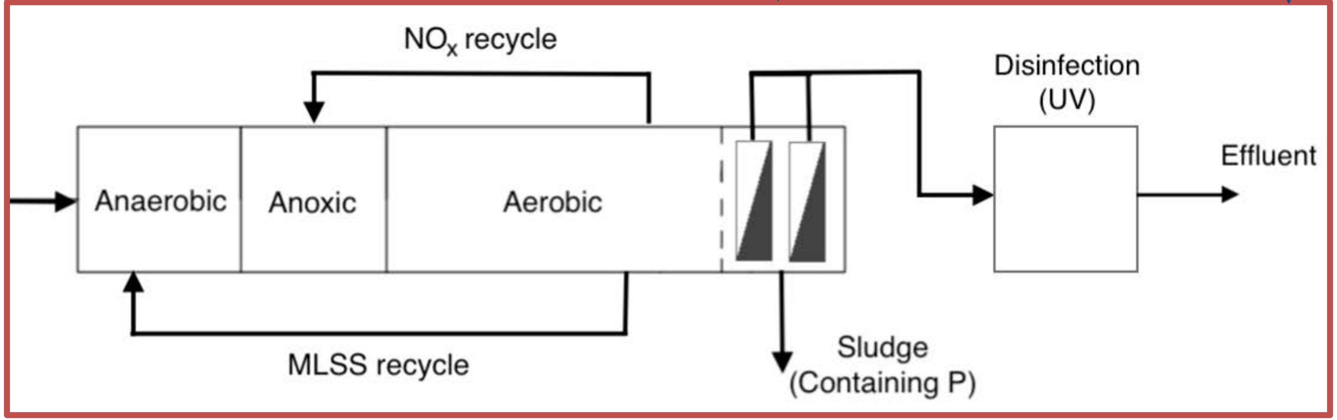
	5-Stage Bardenpho	A^2O/MBR	Adsorption/Bio-oxidation
1. Effluent Quality	Similar, high quality effluent that meets or exceeds regulatory requirements		
2. Client Goals	Reliable, but traditional	New technology with proven results	Cutting edge, requires trial and error
3. Footprint	Large	Smallest	Largest
4. Cost Estimation	Low capital cost	High capital, O&M cost	High capital, O&M cost
5. Operations and Maintenance	Least required maintenance	Prevention of MBR fouling	Low maintenance

A2O/MBR

Anaerobic-Anoxic-Aerobic tank scheme for improved biological nutrient removal prior to MBR

Membrane bioreactor tank performing nutrient removal and membrane filtration

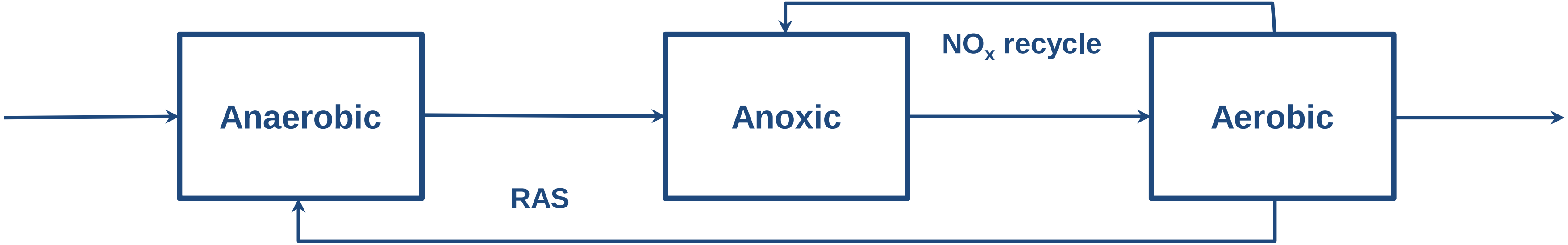
Discharge from MBR directly to disinfection



N+P Removal

In the absence of O_2, PAOs convert VFAs to PHAs using energy from the breakdown of polyphosphates - releases P

In the presence of O_2, PAOs use stored energy of PHAs to uptake P and replenish polyphosphates, autotrophic bacteria nitrify NH_3 to NO_3^- for return cycle



In the absence of O_2, heterotrophic and autotrophic bacteria consume BOD and denitrify Nitrate (NO_3^-) to Nitrogen gas (N_2) - some PAOs denitrify and uptake P

Primary Treatment

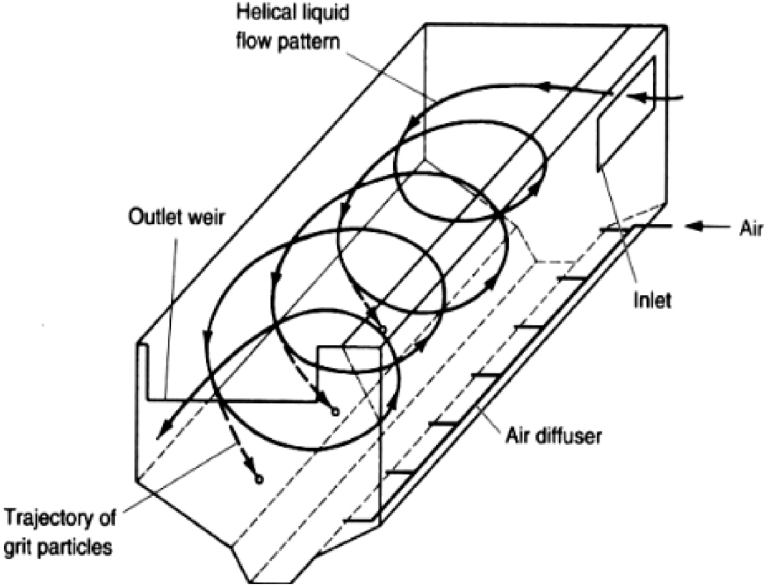


Image credit (left, right): Timex, Crites and Tchobanoglous

Tertiary Treatment: UV Disinfection

- ➢ Method by client request
- ➢ Efficient
- ➢ Avoids harmful byproducts
- ➢ Consulted a Premier Water representative to design a typical Duron UV disinfection setup with the following characteristics:
    - ○ One (1) Channel (~6 ft x 6 ft x 40 ft)
    - ○ Three (3) Banks initially
    - ○ Expand to Four (4) for 25 MGD flow
    - ○ Each bank contains 28 lamps

PREMIER WATER

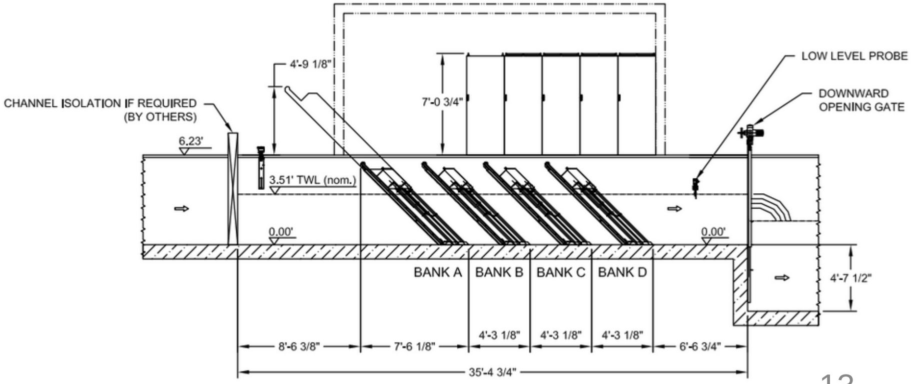
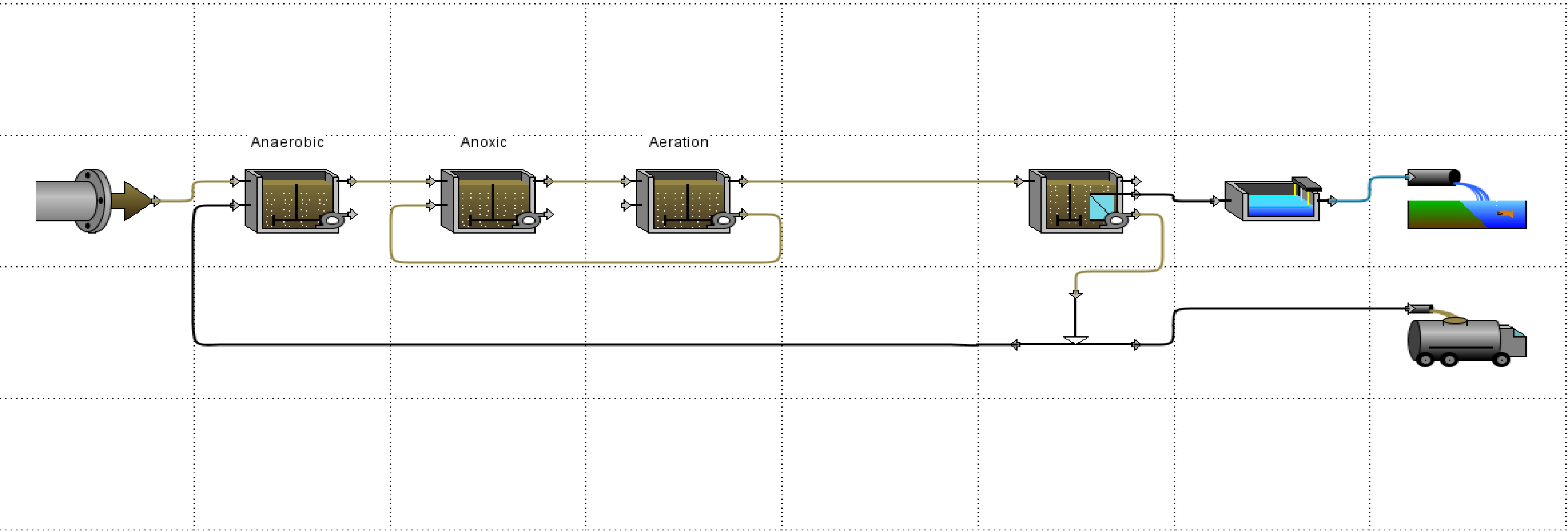


Image credit: Premier Water

GPS-X Modeling

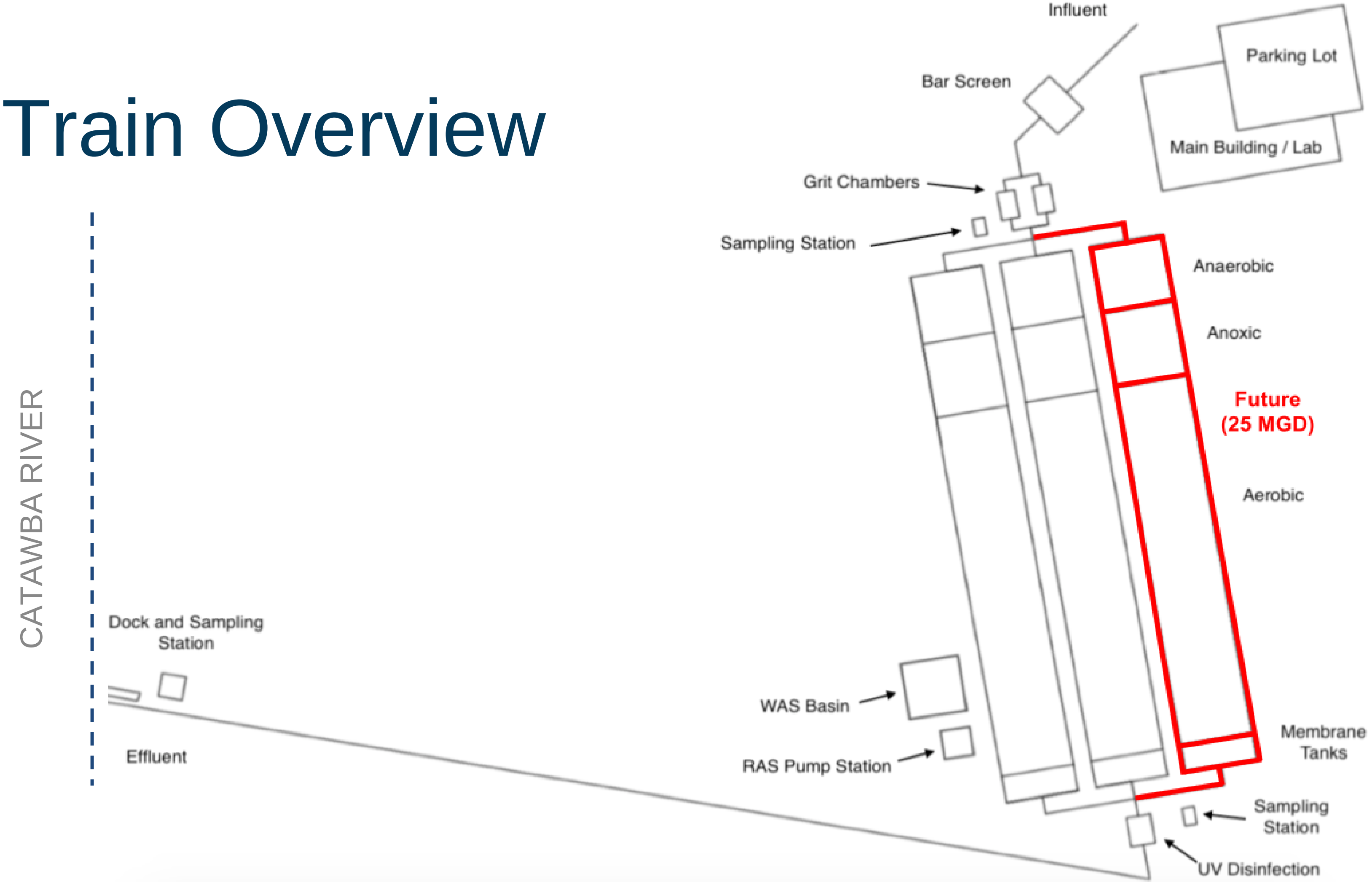


GPS-X Modeling Results

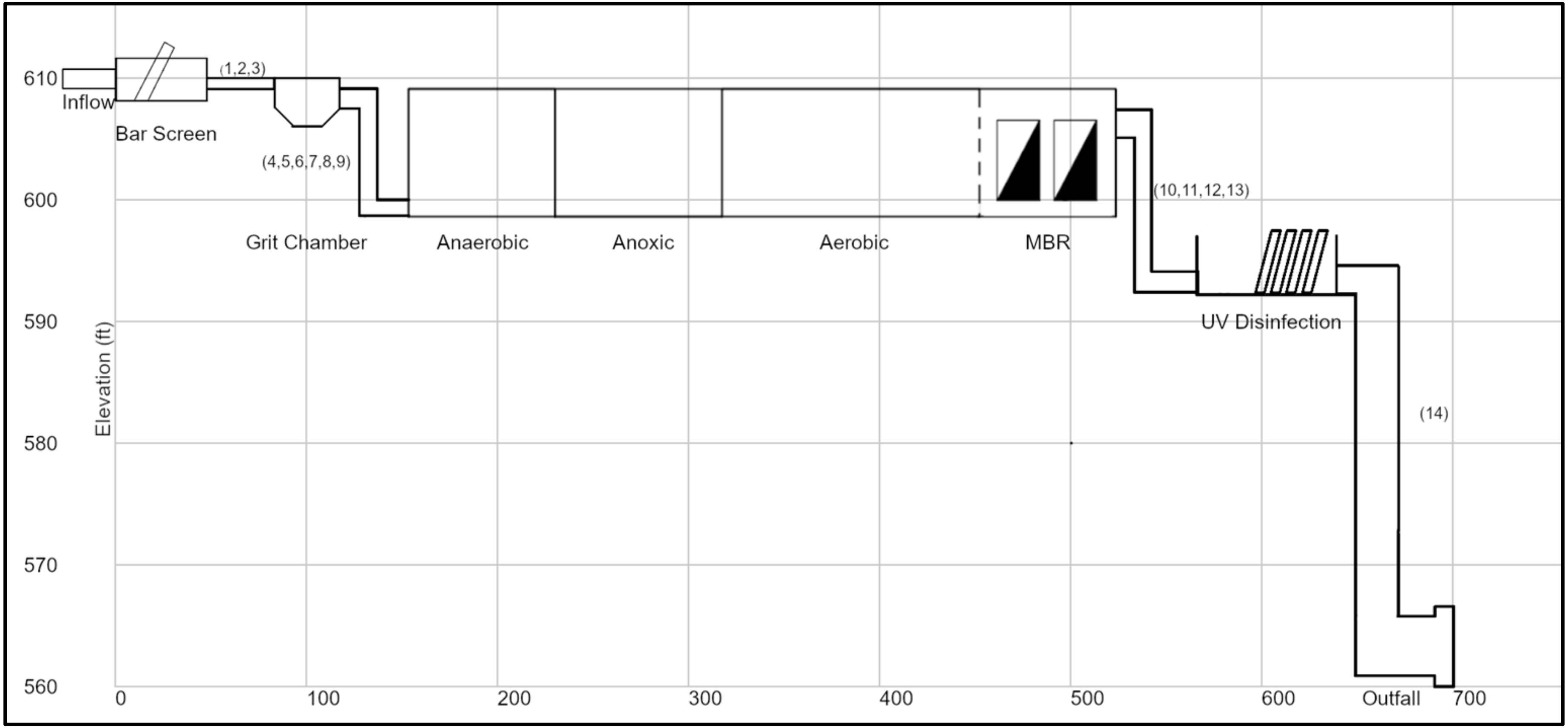
Requirement	Permit	Value
CBOD5	4.2	2.65
TSS	30	2.71
Ammonia (NH3)	1	0.36
TKN	MONITOR	2.49
TN	6	5.5
TP	1	0.3
Alkalinity	MONITOR	80
pH	6 to 9	7

- Designed at 20 degrees Celsius
- Calculate solids retention time and apply safety factor:
  SRT=1/0.137 d-1
  SRT=7.3 d(1.5)
  Design SRT=11 days
- MLSS Design Concentration = 12000 g/m3
  X=(1/2)(12000 g/m3)
  X = 6000 g/m3
- Calculate HRT of anoxic basin:
  HRT = 6509 m3(94636 m3d)(d24 h)
  HRT = 1.7 hr

Train Overview



Train Overview



610
600
590
580
570
560
Elevation (ft)
Inflow
Bar Screen
(1,2,3)
(4,5,6,7,8,9)
Grit Chamber
Anaerobic
Anoxic
Aerobic
MBR
(10,11,12,13)
UV Disinfection
(14)
Outfall
0
100
200
300
400
500
600
700

Energy and Resource Recovery Methods

Hydro Turbine

- Microhydropower cross-flow turbine
- Estimated output of 60 - 100 kW (15 - 25 MGD)
- Yearly energy savings of $50 - 90k

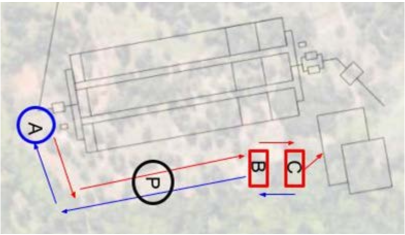
Head	**42 ft.**	
	15 MGD	**25 MGD**
Avg. Flow	**20 cfs**	**33 cfs**

Photovoltaics

- Initial allocation of 2 acres for solar energy generation
- Estimated 1.2 GWh annually
- ~$130,000 annual energy savings

Wastewater Thermal

- 60 - 80°F effluent
- System circulates effluent to North end of the plant for heat reclamation or heat rejection in office and lab buildings
- Estimated $40,000 in yearly energy savings



Resource Recovery:

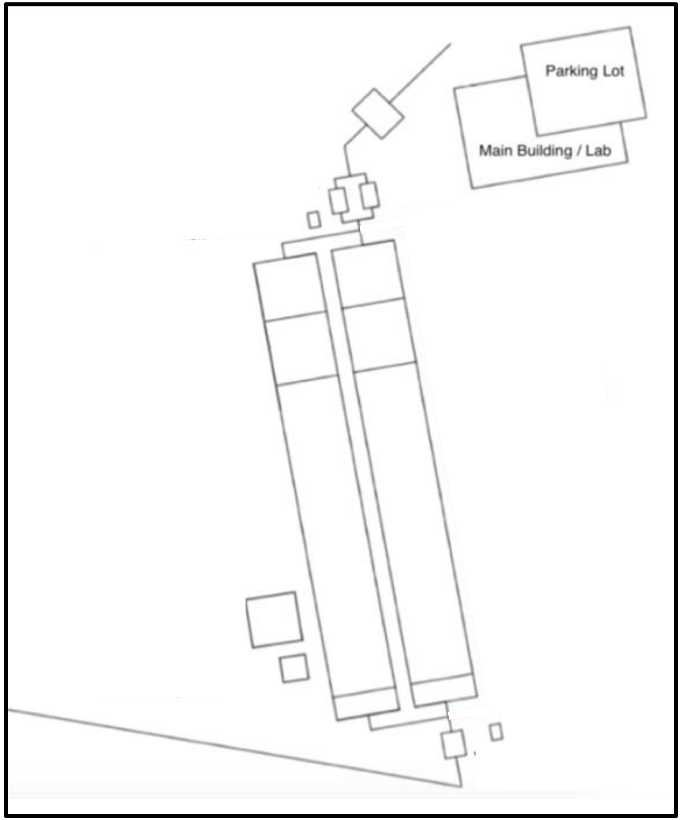
- Maximize use of on-site resources - salvage lumber, existing soil, natural vegetation for landscaping
- Large scale composting of vegetative waste

Image credit (middle): Diyana Dimitrova

Construction Phasing and Future Upgrades

15 MGD

Stage 1	Site Preparation
Stage 2	Cut, Fill, and Grading
Stage 3	Plant Construction
Stage 4	Biological Start-up and Testing
Stage 5	Site Cleanup



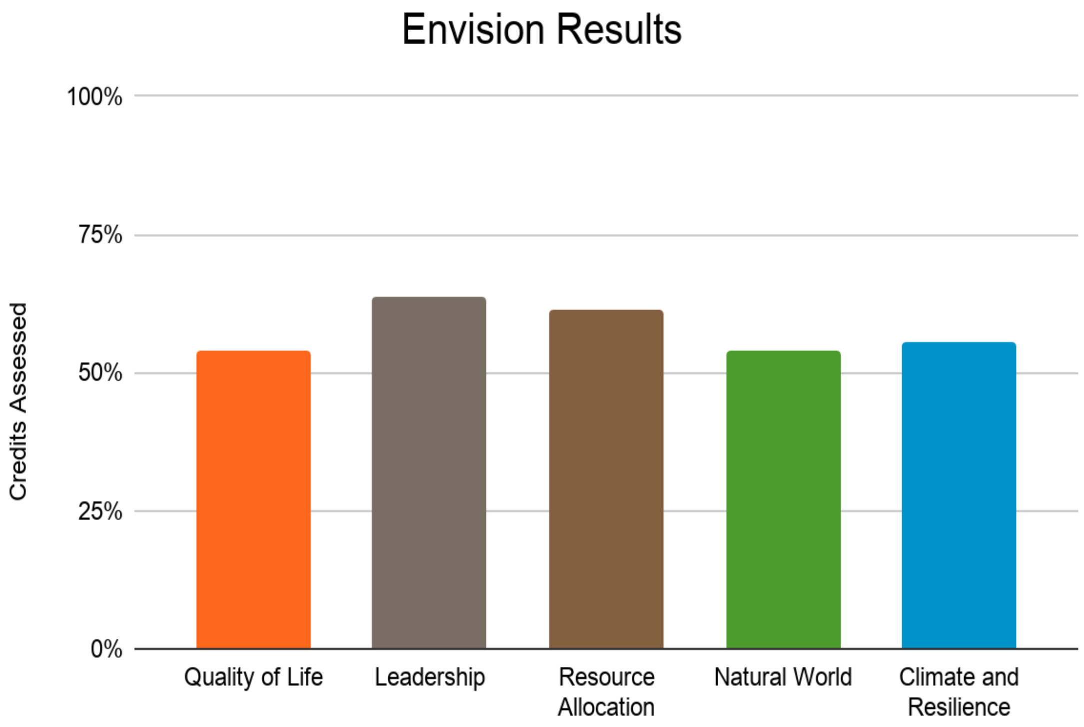
Description	15 MGD
Materials and Installation (MBR etc)	$43,010,000
Energy	$2,620,000
Turbine	$570,000
Heat Pump Station	$90,000
Solar Recovery	$660,000
Pipes, Pumps, Electrical	$10,250,000
Staff	$4,100,000
Land Prep/ Excavation	$21,500,000
Architectural/Structure	$23,520,000
Mobilization (3%)	$3,190,000
Subtotal A	**$109,510,000**

General Conditions (3%)	$5,475,500
Subtotal B	$114,985,500
Contractor OH/P (20%)	$22,997,100
Subtotal C	$137,982,600
Mid Term Escalation	$10,624,660
Subtotal D	$148,607,260
Bonds/Insurance (3%)	$4,458,218
Subtotal E	$153,065,478
Contingency (30%)	$45,919,643
Subtotal F	$198,985,000
Engineering (15%)	$29,847,750
Probable Cost Total	**$228,833,000**

AACEi Class III 20-yr Life Cycle Cost Estimation

	With Energy Generation	Without Energy Generation
Initial Cost (15 MGD)	$113,670,000	$112,350,000
Annual Cost (15 MGD)	$11,642,000	$11,765,000
Initial Cost (25 MGD)	$43,761,000	$43,884,000
Annual Cost (25 MGD)	$17,266,000	$17,425,000
Net Present Value Over 20 Years	**$259,572,000**	$259,674,185

Evaluation of ENVISION Criteria



- Project sustainability rating system to aid in decision-making process
- Due to limited scope, based ratings on the degree to which each area had been addressed so far in the design process
- At the preliminary stage, project has adequately addressed over 50% of each category

Design Review

- Project Scope: Construction of a greenfield WRRF @ 15 MGD
  - Energy and resource recovery methods
  - Community consideration and outreach
  - Expansion to 25 MGD capacity
- Chosen Design Alternative: A^2O/MBR treatment process
- Process modeling
- Hydropower, photovoltaics, thermal energy recovery, and positive resource management
- Alignment with City of Charlotte's sustainability goals and client's goals
- Construction phasing
- Cost estimation
- ENVISION Report

Works Cited

Abbas, Ahmad & Qandil, Mohammad & Al-Haddad, Muhannad & S. Saravani, Mandana & Amano, Ryoichi. (2018). “Utilization of Hydro-Turbines in Wastewater Treatment Plants (WWTPs).” V001T01A003. 10.1115/ES2018-7349.

City of Charlotte. “About the Public Art Ordinance”. *City of Charlotte: Charlotte Future*. Web. Accessed from https://charlottenc.gov/charlottefuture/Pages/PublicArtOrdinance.aspx.

Fu, Ran, David Feldman, and Robert Margolis (2018). “U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018.” Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-72399. https://www.nrel.gov/docs/fy19osti/72399.pdf.

Luccio, Matteo. (2012). “Sewer Heat Recovery Provides Low-Cost Recycled Energy.” *Informed Infrastructure* Web. Accessed from https://informedinfrastructure.com/2237/sewer-heat-recovery-provides-low-cost-recycled-energy/.

Maier, Olaf. (2015). Operation & Maintenance Costs of Photovoltaic Power Plants: a Swiss Benchmark and Outlook.

Mays, L. W and Tung, Y (2002). Hydrosystems Engineering and Management. McGraw-Hill Water Resources and Environmental Engineering Series

Metcalf & Eddy Inc., Tchobanoglous, G., Burton, F. L., Tsuchihashi, R., & Stensel, H. D. (2013). *Wastewater engineering: Treatment and resource recovery* (5th ed.). McGraw-Hill Professional.

MWRD, City of Chicago (2012). “James C. Kirie Plant Fact Sheet”. Web. Accessed from https://legacy.mwrd.org/irj/go/km/docs/documents/MWRD/internet/protecting_the_environment/Water_Reclamation_Plants/pdfs/FactSheet_WRPs_Kirie.pdf

Works Cited

North Carolina Administrative Code. Title 15A, Chapter 2B, Section .0614. Catawba River Basin: Protection and Maintenance of Existing Riparian Buffers.

Ossberger. "Ossberger Crossflow Turbine" Web. Accessed from https://ossberger.de/en/hydropower-technology/ossbergerr-crossflow-turbine/

Schreiber. "Compressible Media Filtration" Web. Accessed from http://www.schreiberwater.com/product/fuzzy-filter/

Solar Energy Industries Association (SEIA). "Solar Market Insight Report 2020 Q2" Web. Accessed from https://www.seia.org/research-resources/solar-market-insight-report-2020-q2

The Right-to-Know Network (2018). City of Mount Holly Wastewater Treatment Plant. Web. Accessed from https://rtk.rjifuture.org/rmp/facility/100000166562

US EPA (2006) "Biosolids Technology Fact Sheet: Multi-stage Anaerobic Digestion". *US EPA Office of Water.* Web. Accessed from https://www.epa.gov/sites/production/files/2018-11/documents/multistage-anaerobic-digestion-factsheet.pdf

Westerling, Kevin (2013). "Nutrient Removal: Is Bardenpho Right For You?" *Water Online.* Web. Accessed from https://www.wateronline.com/doc/nutrient-removal-is-bardenpho-right-for-you-0001

Xylem (2018). "Duron UV Wastewater Treatment". Web. Accessed from https://www.xylem.com/en-us/products-services/treatment-products-systems/disinfection-and-oxidation/uv-disinfection-systems/duron-uv-disinfection-system/

Questions?