RABAC—Rotating Activated Bacillus Contactor

Bay Area Clean Water Agency

Oct 18, 2019

Our Understanding

- Nutrients in the SF Bay are a growing concern for the Bay Area water quality
- BACWA and its 37 members have been working collectively to tackle the Bay Area nutrient removal issue
- BACWA has recently established new 3-level nutrient removal standards

BACWA Nutrient Removal Standards

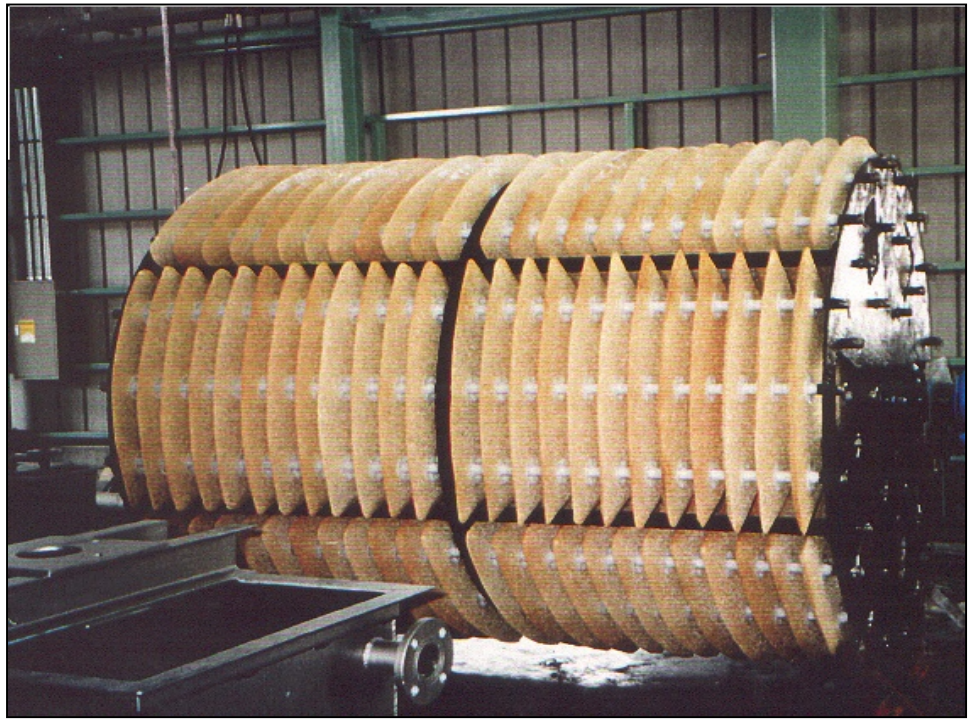
New Standards	Ammonia	Total Nitrogen	Total Phosphorus
Level 1	Varies by Facility	Varies by Facility	Varies by Facility
Level 2	2mg N/L	15mg N/L	1.0 mg P/L
Level 3	2mg N/L	6mg N/L	0.3 mg P/L

BACWA's Recommended Upgrade Strategy

- Phased, cost-effective transition from the optimization stage (Level 1) to Level 3 upgrade
- Achieve Level 2 and 3 nutrient removal standards with minimal capital investment to improve existing facilities
- Technologies with minimal additional footprints preferred due to limited space
- Minimize GHG emission impacts
- Consider both new emerging and conventional nutrient removal technologies that can significantly reduce both capital and operating costs

RABAC Technology Key Features

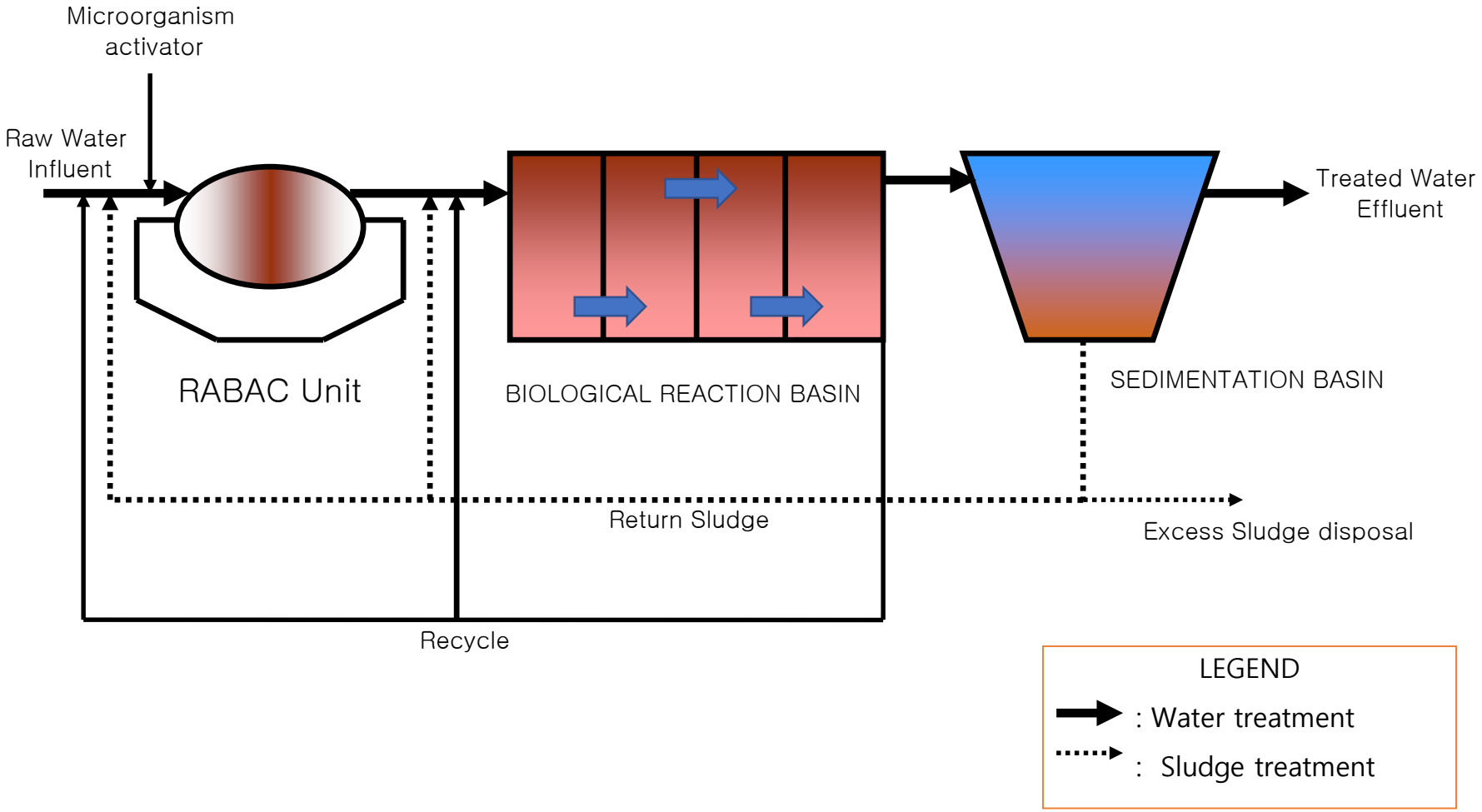
RABAC Technology Is Combined Attached Growth and Suspended Growth Process



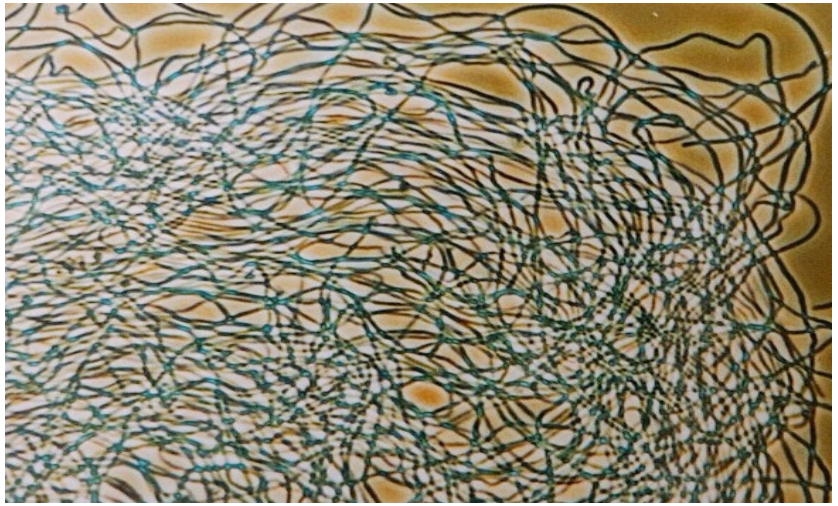
Rotating Bio Contactor (RABAC Unit)

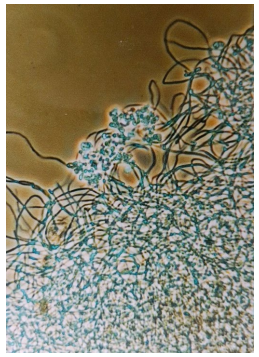
Biological Reaction Basin (BRB)

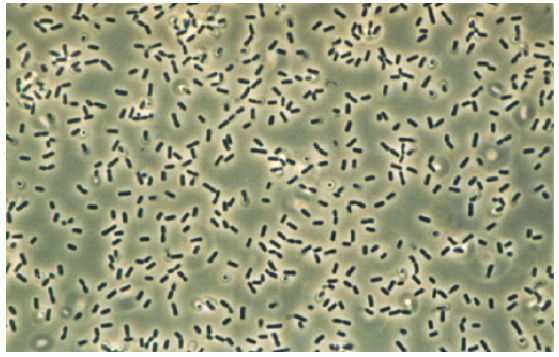
RABAC Technology Is Aerobic Treatment Process



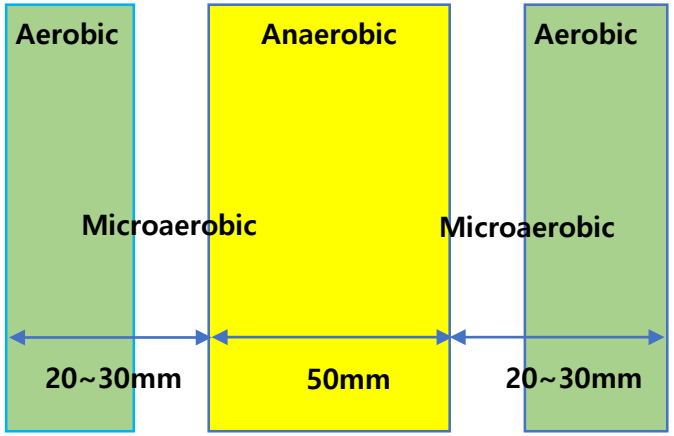
Bacillus spp. Is Predominant Microorganism







- Rod shaped bacteria found in natural air, water and soil
- S. Korea and Japan used them for over 100 years for Kimchi and Miso
- Most widely used bacteria for producing antibiotics, probiotics and biopesticides
- We control the bacteria's lifecycle of germination-growth-endorsporulation for efficient wastewater treatment



Nitrogen Removal

- Nitrogen removal rate exceeds 90%
- High removal rate is combination of:
  1) Aerobic autotrophic nitrification to anaerobic heterotrophic denitrification (conventional)
  2) Aerobic autotrophic nitrification to anaerobic autotrophic denitrification
  3) Aerobic heterotrophic nitrification to anaerobic heterotrophic denitrification (when BOD/N > 5)
  4) Anammox (when BOD/N is comparatively low)
- *B. Licheniformis, B. Fastidiosus, B. Pasteruii, B. Sphericuss* are main Bacillus spp. for nitrogen removal

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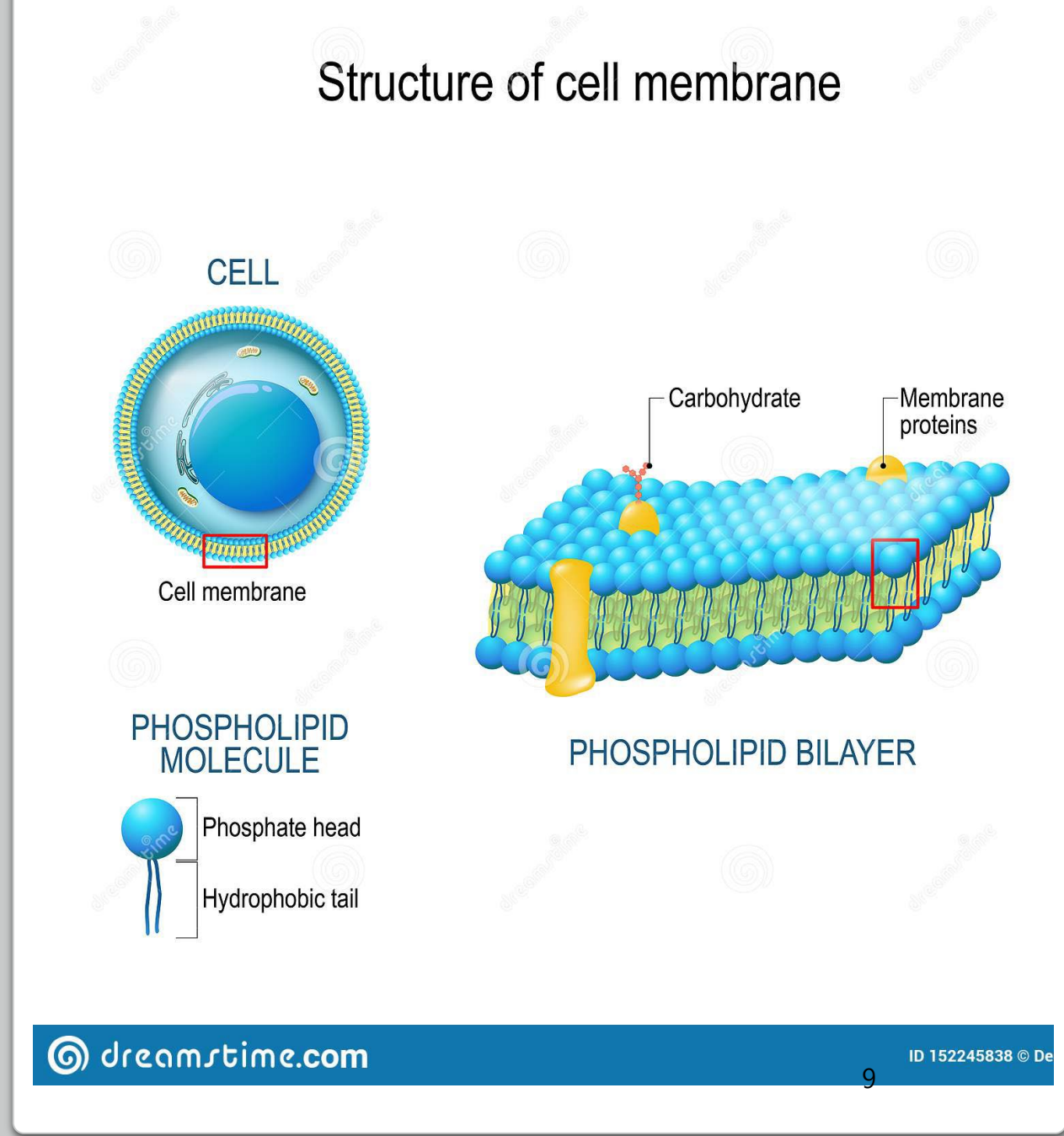
Phosphorus Removal

- T-P removal rate exceeds 85%
- In general, when DO=0.1mg/L, microbes start ingesting P to maintain their cells and metabolism; their activity reaches maximum level (luxury uptake) when DO=0.5 mg/L.
- RABAC process maintains DO level at 0.5 mg/L on average, so the process always reveals luxury uptake of phosphorus by Bacillus spp.
- Bacillus spp. consume more phosphorus than activated sludge microbes do due to thick cell structure



RABAC Technology Performance Results

Item	Sewage		Dairy Manure		Food Processing Wastewater		Lechate	
	In	Out	In	Out	In	Out	In	Out
BOD	128.6	5.2	26,022	12	2,901	4.4	2,707	32
COD	89.1	7.4	7,496	169	9,287	44.5	6,126	202
SS	142.9	3.7	24,370	16	3,801	5.1	790	6
T-N	32.4	7.4	4,281	39	324	6.3	1,560	17
T-P	2.9	0.5	724	1.3	46	0.7	26	0.8

Note: Neither chemicals nor filtration were used.

Source: Eco-Star Award Test Results, S. Korea Ministry of Environment (2003~2007)

Low CAPEX and OPEX, Less Footprint

- Proven Technology
  - 30 successful commercial applications in S. Korea, Japan and China
- Low CAPEX and Less Footprint
  - No nitrification-denitrification zones needed
  - Less air blowers, no chemical dosing equipment
  - No deodorization, disinfection facility needed
  - Less civil work due to RABAC replacing 50% of BRB
- Low OPEX
  - Semi-permanent durability of RABAC biocontactors
  - Low energy consumption due to low DO level
  - No chemical costs for phosphorus removal and denitrification
  - Less biosolid production and revenue from composting
  - Less manpower from simple operational requirements

Representative Municipal Wastewater Projects

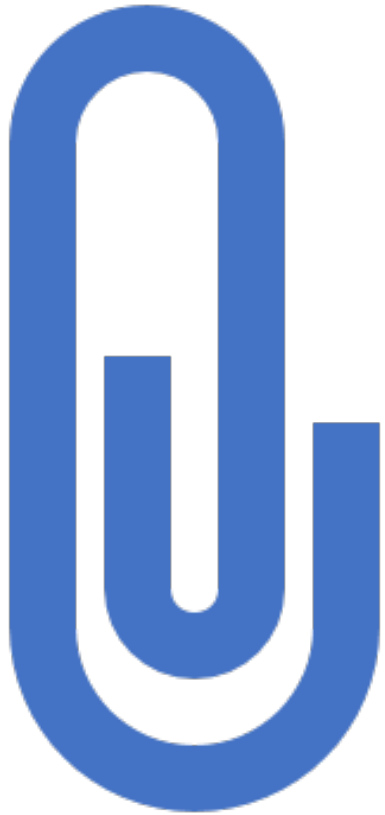
Project Name	Capacity	Location	Remark
Pyongtaek City Tongbok Sewage Treatment Plant	12.0 mgd	S. Korea	Operation
Pyongtaek City Jangdang Advanced Sewage Treatment Plant	6.6 mgd	S. Korea	Operation
Pyongtaek City Anjung Advanced Sewage Treatment Plant	5.3 mgd	S. Korea	Operation
Kunmming City Sewage Treatment Plant	1.3 mgd	China	Design
Korea Maritime University Sewage Treatment Plant	237,000 gd	S. Korea	Operation
Busan Sansung Sewage Treatment Plant	127,000 gd	S. Korea	Operation
Busan Haguen Sewage Treatment Plant	40,000 gd	S. Korea	Operation
Busan House of Children Sewage Treatment Plant	31,700 gd	S. Korea	Operation

Potential RABAC Pilot Facility

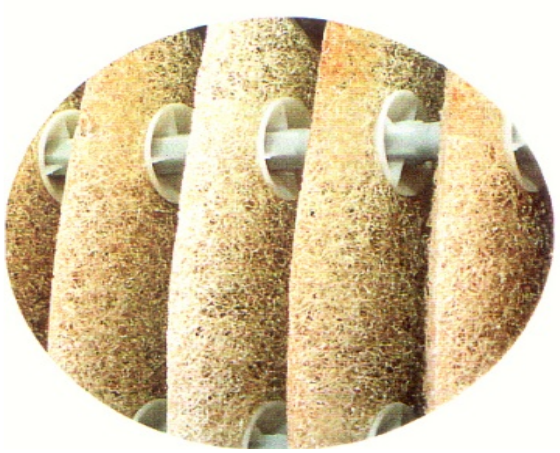
DISCUSSION TOPICS

1. Joint RABAC Pilot with Stanford Codiga Center
2. Potential RABAC Pilot on BACWA Member Site
3. Primary Funding Source: RABAC Technology Inc.
4. Potential Supplemental Funding

Additional Slides



RABAC Unit Enhances Treatment Efficiency



- High density retiform disc of Polyvinylidene Chloride with 50 mm thickness
- Light weight, low energy consumption
- Semi-permanent
- Very high treatment capacity per unit disc area due to very thick biomass (20~30mm)
- Highly concentrated biofilm (10,000~30,000mg/L) allows handling of inflow fluctuations and variant BOD loadings even under cold temperature
- Highly contaminated pollutant BOD>20,000 mg/L can be treated in aerobic conditions without dilution

Biological Reaction Basin

- Decremental aeration from chamber 1 (DO=1.0) to chamber 4 (DO=0.1)
- Bacillus concentration control

BOD (mg/L)	Bacillcus concentratin (/ml)
100~2,000	10^6~10^8
2,000~5,000	10^7~10^9
Over 5,000	10^9~10^{12}

Organic Compound Biodegradation

Bacillus spp. produce various enzymes to remove BOD:

- Starch: Amylase, Isoamylase, Glucosidase
- Pectin: Polygalacturaonate Lyase
- Protein: Metallo Carboxypetidase, Serine Protease, Metalloprotease, Rennet
- Cellulose: Cellulase
- Fat: Lipase

Most Bacillus spp. produce catalase and superoxide dismutase to help hydrolysis of organic compounds that are difficult to biodegrade.

- Polyphenol, Tannin, Lignin in winery wastewater
- Fat, Oil, Grease along with lipolytic enzymes
- Hydrocarbon compounds: methane and other petroleum compound

Fundamentally Different from Conventional BNR Processess

- Simple aerobic process: no complicated process for nitrification, denitrification and phosphorus removal
- Simultaneous removal of nitrogen and phosphorus
- No carbon sources needed for denitrification
- No chemicals needed for phosphrous removal
- No coagulants needed for filamentous bulking removal
- Less biosolids (80%)
- Easy to meet BACWA Level 2 and Level 3 effluent standards
  - No SRT control required
  - MLSS: 2,500~3,000mg/L
  - DO level between 1mg/L and 0.1 mg/L maintaining 0.5 ppm on average

No Deodorization Facility Needed

Odor material	Chemical Formula	Industrial Discharging Standard	Other Discharging Standard	Remarks
Ammonia	NH_3	Under 2	Under 1	RABAC Tech meets S. Korean standards without extra deodorization facilities
Methyl Mercaptan	CH_3SH	Under 0.004	Under 0.002	
Hydrogen Sulfide	H_2S	Under 0.06	Under 0.02	
Dimethyl Sulfide	$(CH_3)_2S$	Under 0.05	Under 0.01	
Dimethyl Disulfide	$(CH_3)_2S_2$	Under 0.03	Under 0.009	
Trimethylamine	$(CH_3)_3N$	Under 0.02	Under 0.005	
Acetaldehyde	CH_3CHO	Under 0.1	Under 005	

Industrial Wastewater Projects

Project Name	Capacity	Location	Remark
Lotte Confectionery Waste Water Treatment Plant	160,000g/d	Korea	Operation
Lotte Ham & Milk Waste Water Treatment Plant	340,000g/d	Korea	Operation
Lotte Freshdelica Waste Water Treatment Plant	53,000g/d	Korea	Operation
Lotte Chilsung Waste Water Treatment Plant	400,000g/d	Korea	Operation
Lotte Samkang Waste Water Treatment Plant	480,000g/d	Korea	Operation
Lotte Freshdelica Waste Water Treatment Plant	40,000g/d	Korea	Operation
Lotte Freshdelica Waste Water Treatment Plant	53,000g/d	Korea	Operation

Septic/Leachate Wastewater Projects

Project Name	Capacity	Location	Remark
Yongin Night Soil & Livestock Sewage Treatment Plant	24,000gd	Korea	Operation
Busan Umgung Night Soil & Septic Treatment Plant	2,600gd	Korea	Pilot
Sanggok Leachate Treatment Plant	1320gd	Korea	Pilot
Sanggok Leachate Treatment Plant	530,000gd	Korea	Operation
Japan Night Soil & Septic Treatment Plant	340,000gd	Japan	Operation
Busan Umgung Night Soil & Septic Treatment Plant	925,000gd	Korea	Operation

Preliminary RABAC Retrofit Proposal to Central San

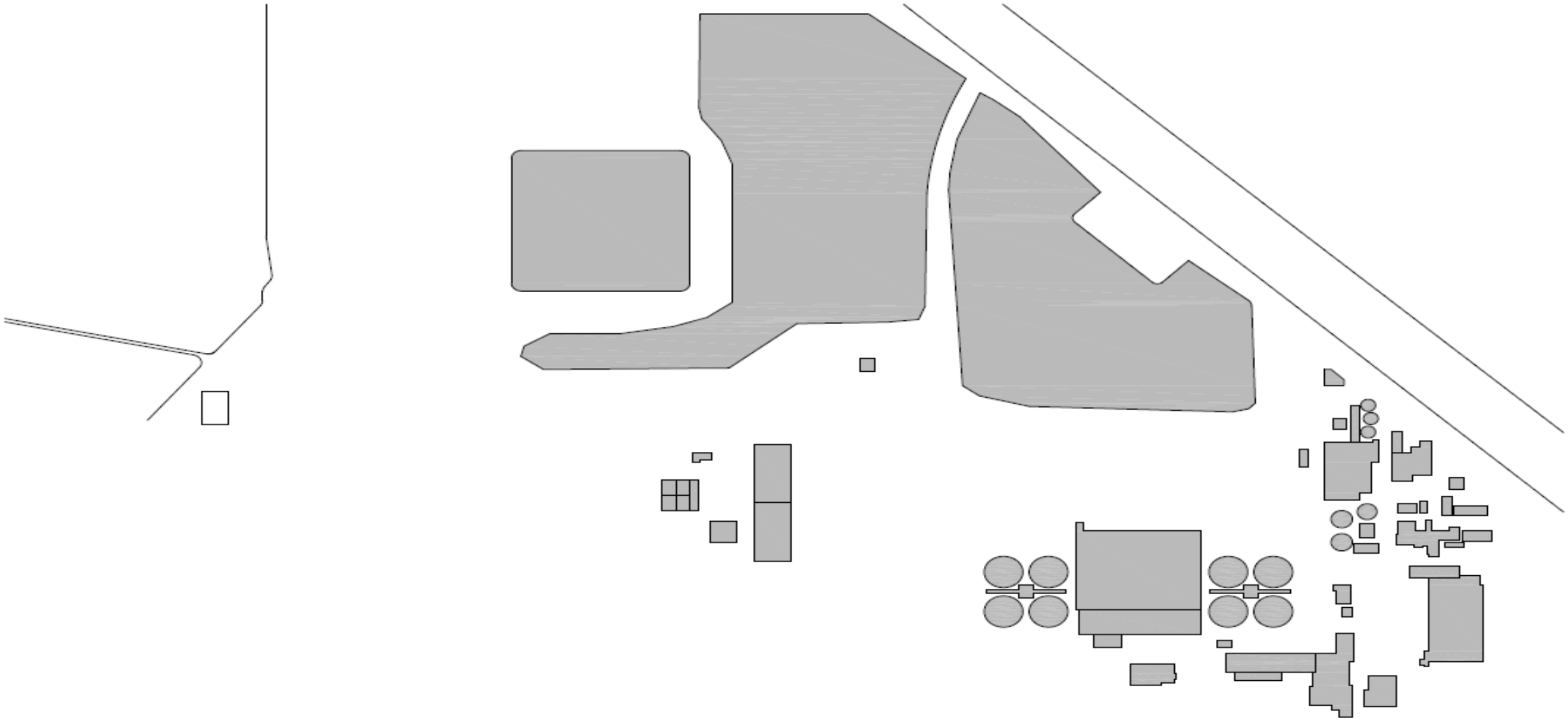
Preliminary Retrofitting Study for Central San

- Significant retrofitting cost savings:
  - RABAC can meet BACWA Level 2 using existing facilities and BACWA Level 3 with minor expansion of the secondary treatment process.
- Not much additional land required for RABAC retrofitting
- Simple operation
  - No complicated nitrogen and phosphorus removal processes needed
- Stable and consistent treatment efficiency despite fluctuations in flow rates
- Significant operational cost savings
  - Less aeration time, no chemical and carbon sources dosing
  - No UV treatment needed for Suisan Bay discharge (number of e-coli <30/ml)
- No foul odors
- Low GHG emission effect (less energy consumption, no chemicals, less incineration)

Influent Characteristics[1] and RABAC Upgrade Guaranteed Effluent Quality

Items	Influent at Primary MMDW~ MMWW	Influent at Secondary MMDW~ MMWW	(Alt1) Upgrade without Expansion Design Capaicty Avg: 40 mgd Max: 100 mgd	(Alt2)Upgrade with Expansion Design Capacity Avg: 70 mgd Max: 127 mgd
cBOD[2]	255~172	158~119[3]	8[5]	8
TSS	280~189	76~66[4]	5	5
Ammonia	31~21	31~21	1 (2)[7]	1 (2)[8]
TKN[6]	55	55	10 (15)[7]	6[8]
Total Phosphorus	8.8~5.9	8.8~5.9	0.5 (1)[7]	0.3[8]

1) Data: CWMP TP-6
2) BOD=1.32*CBOD
3) % cBOD removal at primary 38% and 31% in Summer and Winter, respectively
4) % TSS removal at primary 73% and 65% in Summer and Winter, respectively
5) BOD
6) BACWA Nutrient Reduction Study, CCCSD, Table 2-2
7) BACWA Level 2
8) BACWA Level 3



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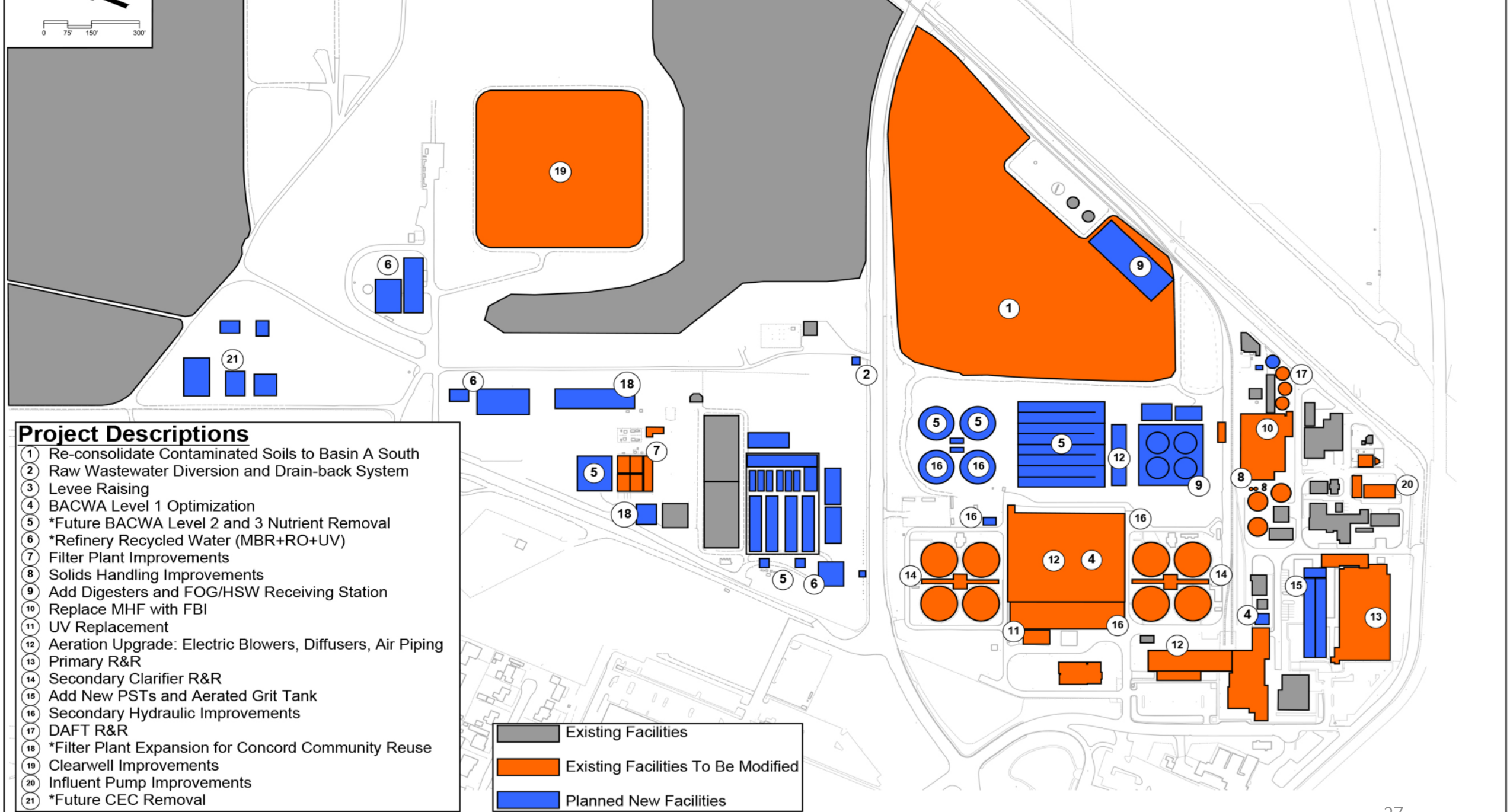
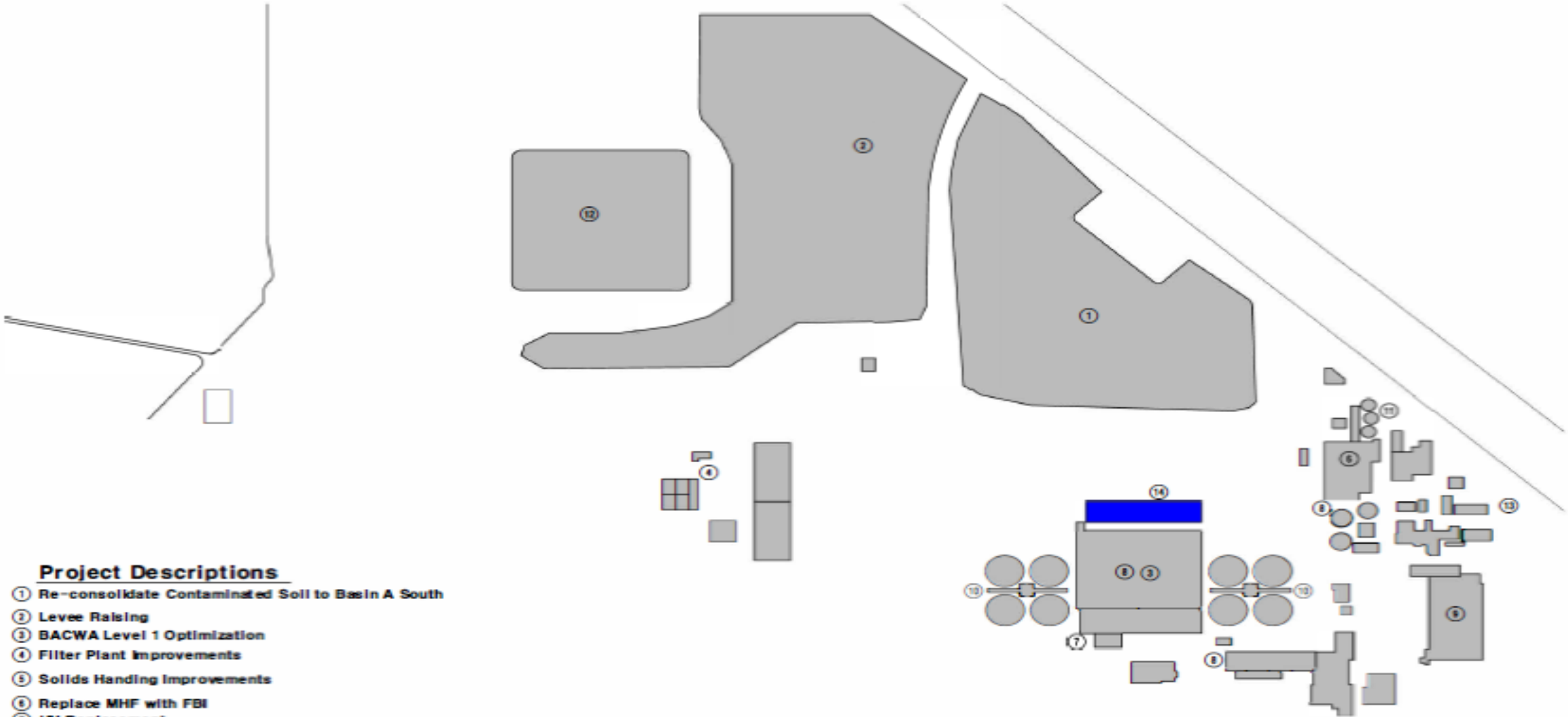
					DESIGNED BY	–	APPROVED BY	G.M. Sung	DATE	2019.09	SHEET NO	C – 02A



* Potential improvements identified but not included in the CIP



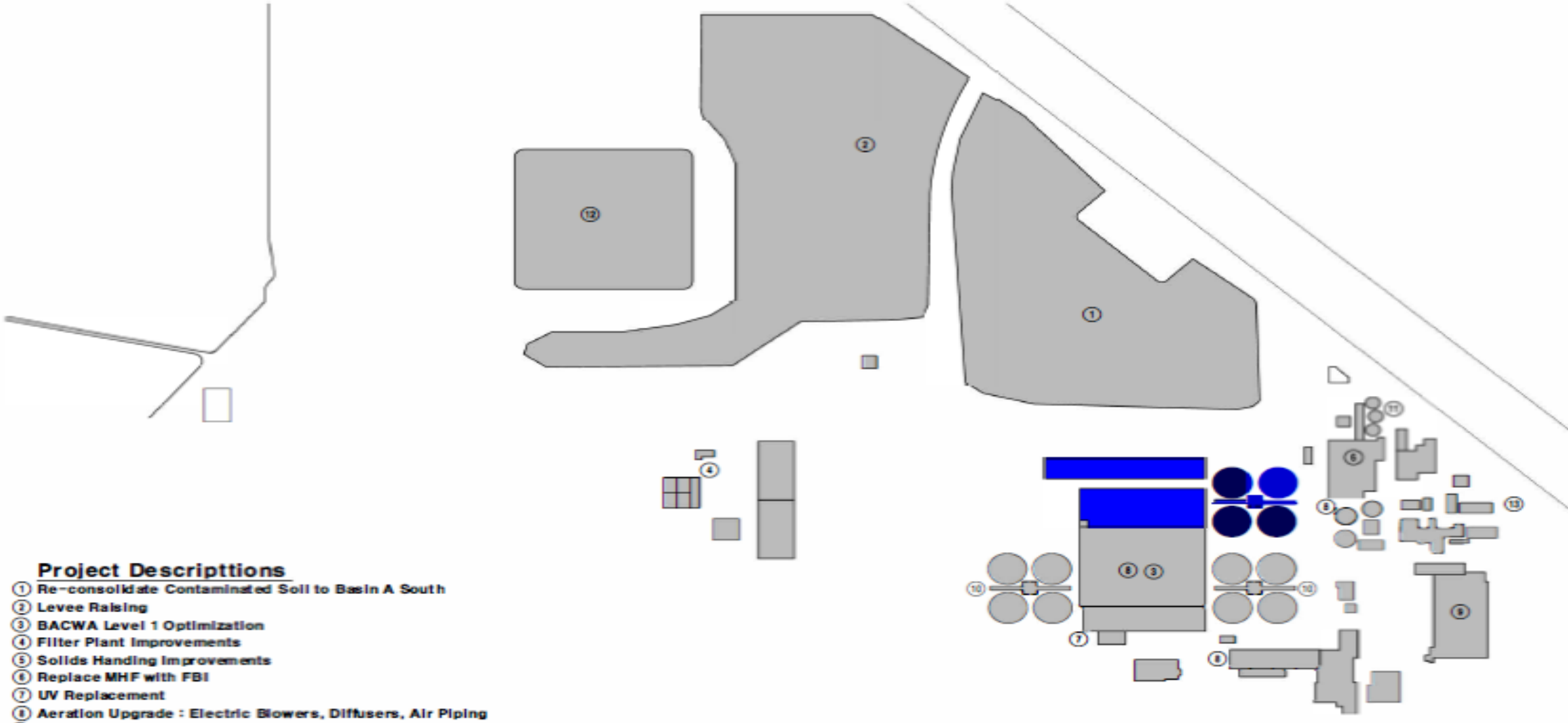
Project Descriptions

① Re-consolidate Contaminated Soil to Basin A South
② Levee Raising
③ BACWA Level 1 Optimization
④ Filter Plant Improvements
⑤ Solids Handing Improvements
⑥ Replace MHF with FBI
⑦ UV Replacement
⑧ Aeration Upgrade : Electric Blowers, Diffusers, Air Piping
⑨ Primary R&R
⑩ Secondary Clarifier R&R
⑪ DAFT R&R
⑫ Clearwell Improvements
⑬ Influent Pump Improvements
⑭ Planned New Facilities (RABAC)

Potential Improvements identified but not include in the CIP

EXISTING FACILITIES
NEW FACILITIES TO BE ADDED

RABAC	PROJECT TITLE: CCC SD RETROFIT	DRAWING TITLE: ALT 1 LAYOUT	DRAWN BY: H.S Eo / DESIGNED BY: –	CHECKED BY: K.H. Kim / APPROVED BY: G.M. Sung	SCALE: – / DATE: 2019.09	FILE NAME: – / SHEET NO: C – 02B



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RABAC

PROJECT TITLE
COC SD RETROFIT

DRAWING TITLE
ALT2 RETROFIT

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DESIGNED BY	-	APPROVED BY	O.M. Suen	DATE	2019.09	SHEET NO.	C - 02C