The Practical Side of the Water-Energy Nexus: Water Reuse in Power Plants

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Overview of Presentation

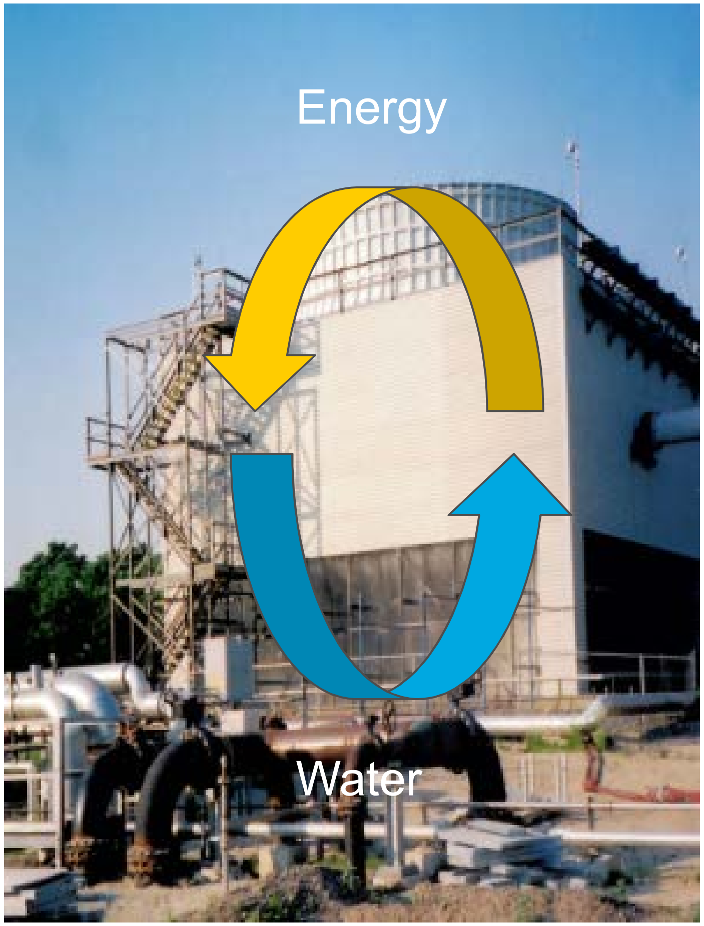
- Why Reuse for Power Plants?
- New Jersey Reuse Guidance
- Reuse for Power in New Jersey
- Case Study

Why Reuse for Power Plants?

Power Plants are the largest water resource users

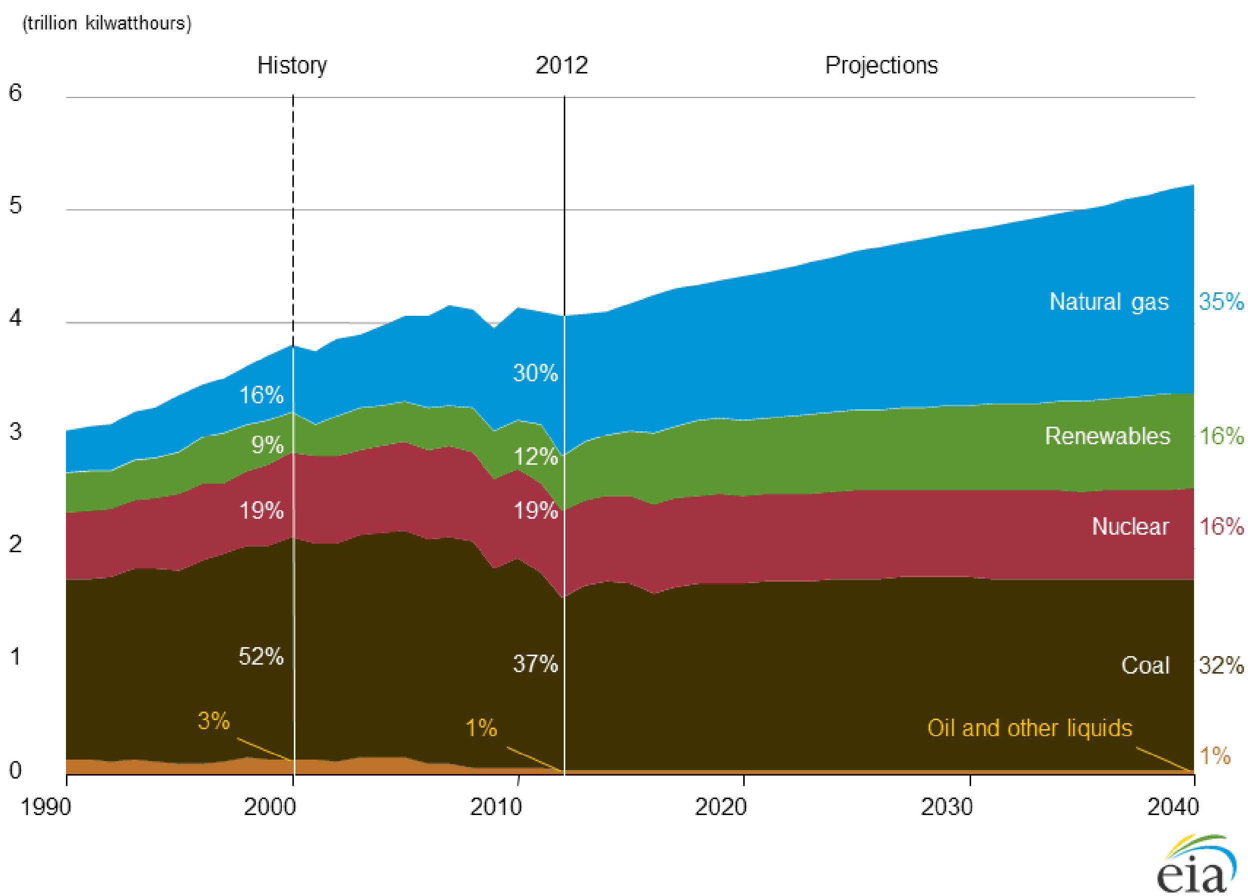
Power plants are large water users

- 60-200 Billion Gallons per Day Withdrawal (USGS, 2005)
- Up to 80% of Water Withdrawals in the US Used for Power
- 2.8 to 5.9 Billion Gallons per Day consumed
- Increase of 50% by 2030 USDOE Estimate
- Natural gas power generation consumes least amount of water
  - 0.1-0.2 gal/kWhr
- Climate change is impacting water and power
  - 2011 Texas drought- threatened reduction of several thousand megawatts (UCS, 2011)



Energy Production Will Continue to Grow and Require Water Resources

Figure 13. Electricity generation by fuel, 1990-2040



- Ref: US Energy Information Administration; [Report Number: DOE/EIA-0383ER(2014)]

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Water Uses in Power Plants

- Cooling water supply
  - Volume needed depends on cycles of concentration and plant size
- Process Water
  - Boiler makeup
  - Evaporative cooler makeup
- Fire Water
- Domestic Uses
  - Bathrooms, locker rooms, etc

Water Supply Options at Power Plants

- **Use secondary or tertiary wastewater effluent**
  - Requires proximity to municipal waste water treatment plant
  - Pretreatment required
- **Recycle cooling water**
  - Higher cycles of concentration, OR
  - Treatment of spent cooling water
  - Issues of TDS removal, metals accumulation, corrosion control
- **Potable water supply**
  - May be cost prohibitive for large quantities- both capital and O&M
  - Minimal pretreatment required
- **Surface Water**
  - Pretreatment required
  - Intake and withdrawal permitting process can be lengthy

Regulatory Requirements in New Jersey for Reuse

Governing Rules and Regulations on Reuse in New Jersey

- January 2005 - NJDEP Technical Manual for Reclaimed Water for Beneficial Reuse
  - Not regulation, guidance document
- Regulated by the NJDEP Division of Water Quality
  - As part of a facility NJDPES permitting process
- In 2013 Over 6 Billion Gallons of reuse water utilized in New Jersey by 40 permitees
  - 2.8 Billion Gallons used for Non-Contact Cooling Water (NCCW)
- Other states have more stringent programs/requirements
  - California- Title 22
  - Arizona
  - Florida

NJDEP Effluent Reuse Treatment Guidelines

Type of Reuse	Class	Disinfection Requirements	Other Water Quality Requirements
Public Access (i.e. Golf courses, commercial car washes, other irrigation)	I	▪ 1.0 mg/L CL2 residual after 15 minutes, or ▪ UV dose of 100 mJ/cm2 ▪ Fecals < 2.2/100 ml	▪ <5 mg/L TSS ▪ < 10 mg/L total N ▪ < 2 NTU turbidity ▪ Secondary treatment
Agricultural Edible Crops	II	Same as Type I	Same as Type I
Restricted Access and Non-Edible Crops	III	▪ 1.0 mg/L CL2 residual after 15 minutes, or ▪ UV dose of 75 mJ/cm2 ▪ Fecals < 200/100 ml	▪ TSS reduction ▪ < 10 mg/L total N ▪ Secondary treatment
Industrial Systems (i.e. non-contact cooling)	IV	None Prescribed	None Prescribed
Construction, Maintenance, and Operations Systems (i.e. dust control)	IV	▪ Fecals < 200/100 ml	▪ TSS reduction ▪ Secondary treatment

Water Reuse for Power in New Jersey

Several Power Plants in NJ Practicing Reuse

- Three currently in operation, two in commissioning
- All natural gas fired power plants
- All using secondary wastewater effluent for majority of water supply needs
- Different treatment methods used to meet water quality requirements
  - Ammonia reduction
  - TSS removal
  - Biocides/Disinfection

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Capacity and Treatment of Water at NJ Power Plants

	Plant A	Plant B	Plant C	Plant D	Plant E
Size (MW)	1219	1200	720	720	700
Date in Operation	1995	2006	2014	In commissioning	In construction
Avg Cooling Tower MU (gpm)	5000	4200	4000	4000	3500
Avg POTW Effluent NH3	15	10	30	28	13
Contaminants Removed	TSS	TSS	Ammonia/TSS	TSS	TSS
Treatment	Lagoons	Sand Filtration	BAF/Disk Filters	Multimedia filter with coagulant	Self-cleaning strainer
Disinfection	Hypochlorite	Hypochlorite	Hypochlorite	Hypochlorite	Hypochlorite
Cooling Tower Biocide	Chlorine Dioxide	Chlorine Dioxide	Hypochlorite	Chlorine Dioxide	Hypochlorite

Other Water Use/Disposal for NJ Power Plants

	Plant A	Plant B	Plant C	Plant D	Plant E
Size (MW)	1219	1200	720	720	700
Service/Fire Water Source	Potable	Potable	Recycle	Recycle	Potable
Boiler Makeup Source	Potable	Potable	Recycle	Potable	Potable
Plant Discharge of Waste Streams	POTW	POTW	River/POTW	POTW	POTW

Case Study

Power Plant Description

- 750 Megawatts (MW)
  - Roughly enough power to support a city with a population of 450,000
    - Bigger than Atlanta but smaller than Kansas City
- Combined Cycle
  - Natural gas is burned in Combustion Turbine Generators (CTG)
  - Hot exhaust gas is used to heat water and create steam
  - Steam then creates additional power through a Steam Turbine Generator (STG)
- 2+1 Configuration
  - 2 CTGs and 1 STG
- 7.3 mgd service/cooling water demand at peak production
- Using secondary treated wastewater effluent as water supply

Secondary Effluent from WWTP Water Quality

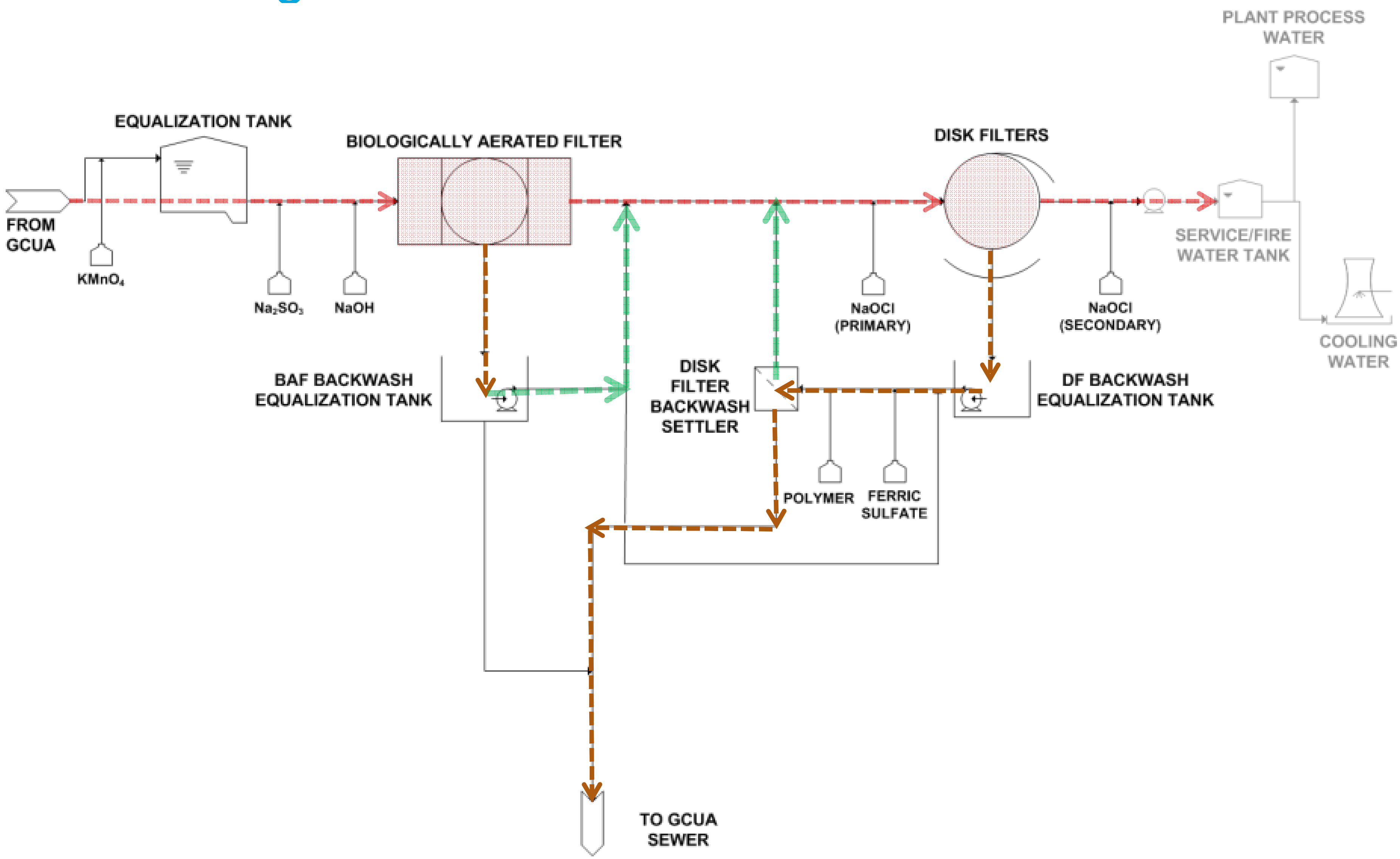
Parameter	2010-2011		
	Min	Avg	Max
pH (S.U.) [c]	7.08	7.36	7.65
Alkalinity (mg/L CaCO3)	137	190	242
Hardness (mg/L)	78	92	117
Temperature (deg F)	58.1	67.3	77
TSS (mg/L)[a]	10	12.4	20.5
Fecal Coliform (colonies/100 ml)	<1	20	27.2
Total Chlorine Residual (mg/L) [a]	0.16	0.45	1.7
CBOD (mg/L)	3.7	8.0	13.6
Total Organic Carbon (mg/L)	11.9	16	22.5
Ammonia Nitrogen (mg/L) [b]	2.03	17.17	25
Total Iron (mg/L)	0.16	0.34	0.71
Total Manganese (mg/L)	0.037	0.060	0.095

a – 90%th percentile value is listed as maximum

Pretreatment System Design Basis

- Treatment processes to handle
  - Iron and Manganese Precipitation
  - Ammonia Removal
  - De-chlorination
  - pH adjustment
  - Chlorination (Breakpoint and Disinfect)
  - Suspended Solids (SS) Reduction
  - Residuals Collection/Concentration
- Flow- 7.31 MGD max day, 4.68 mgd average day
  - hydraulic capacity 7.7 mgd

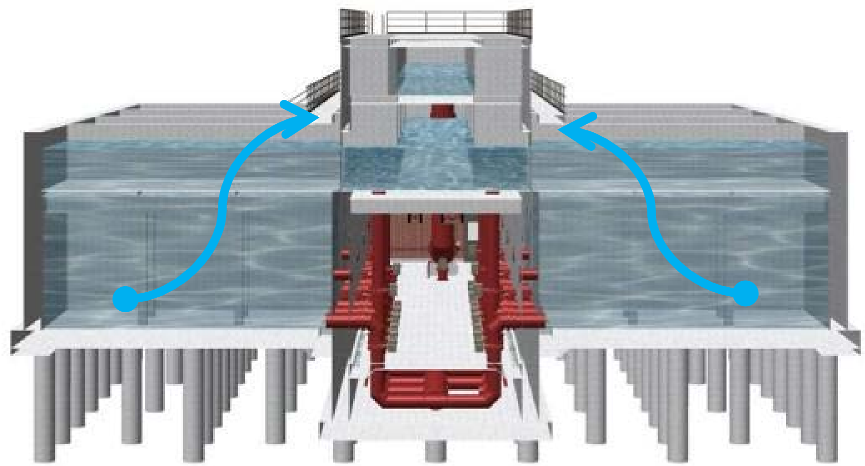
Pretreatment System Process Flow Diagram



Raw Water Pretreatment

Biological Aerated Filter (BAF) – Ammonia Removal

- •Attached Growth Nitrification
- •Up-flow Filter
- •4mm expanded polystyrene media
- •8 parallel cells, 304 sf each
- •1 MGD/filter capacity



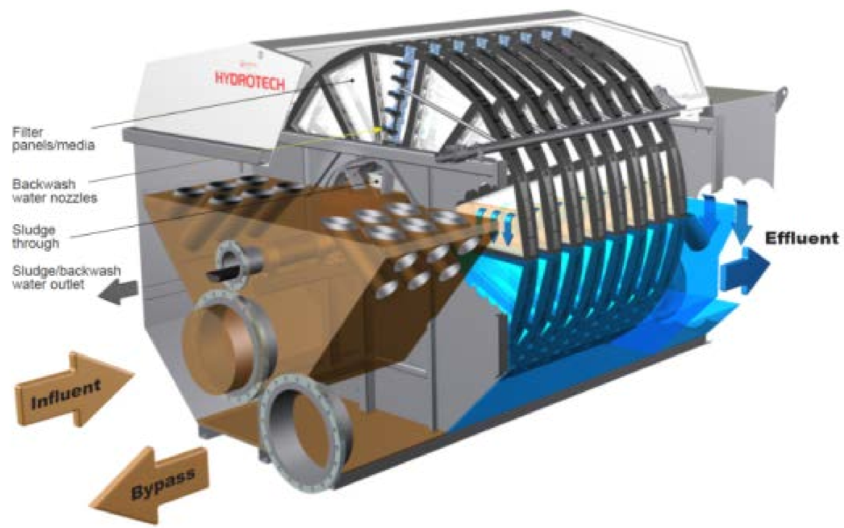
Kruger Biostyr

BAF Design Basis

Parameter	Units	Value	Notes
Peak Flow (Daily average), mgd	mgd	7.35	
Daily Average Effluent NH4, mg/L	mg/L	<2.5	
Monthly Average Effluent NH4, mg/L	mg/L	< 1.0	
NH4 Mass Loading Rate @ peak,	lbs/kcf/day	55.6	
NH4 loading- max day	lbs/day	1530	
NH4 loading- average day	lbs/day	730	

Disk Filters for TSS Reduction

- Inside-Out Filtration
- Polyester Fabric Media Panels with 10 um nominal pore size
- When panels clog, unit goes into backwash mode.
  - Drum rotates placing clean panels in the flow path
  - Pressurized water used to spray filter panels clean during backwash



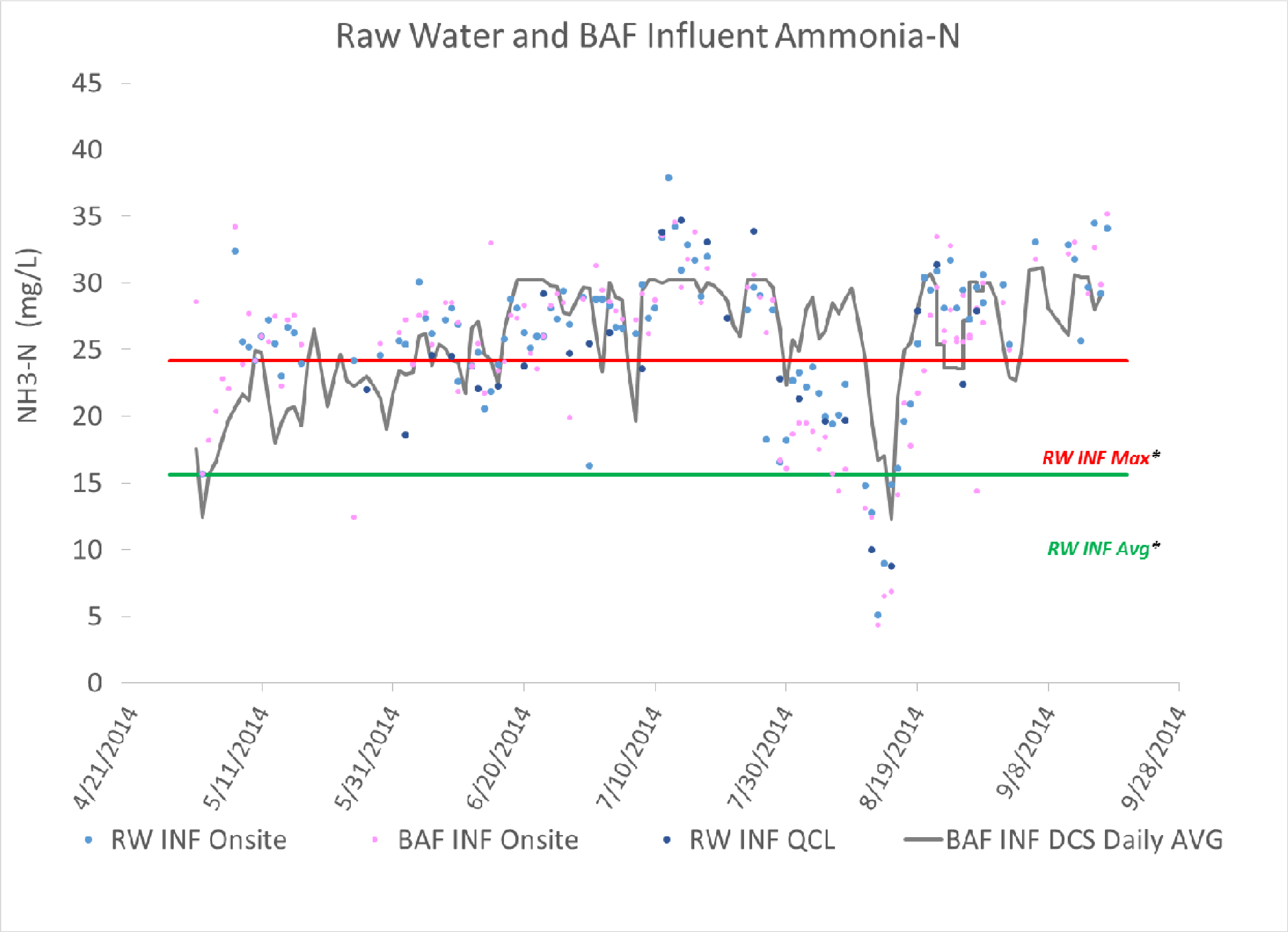
Disk Filter Design Basis

Parameter	Value	Notes
Peak Flow (Instantaneous), mgd	8.04	
Peak Influent TSS, mg/L	24	Expected Loading Rate from BAF process
Average Influent TSS, mg/L	16	Expected Loading Rate from BAF process
Average Effluent TSS, mg/L	5	
Peak Hydraulic Loading Rate, , gpm/ft^2	4.65	With two units in service (one in standby)
Number of Units	2 + 1	

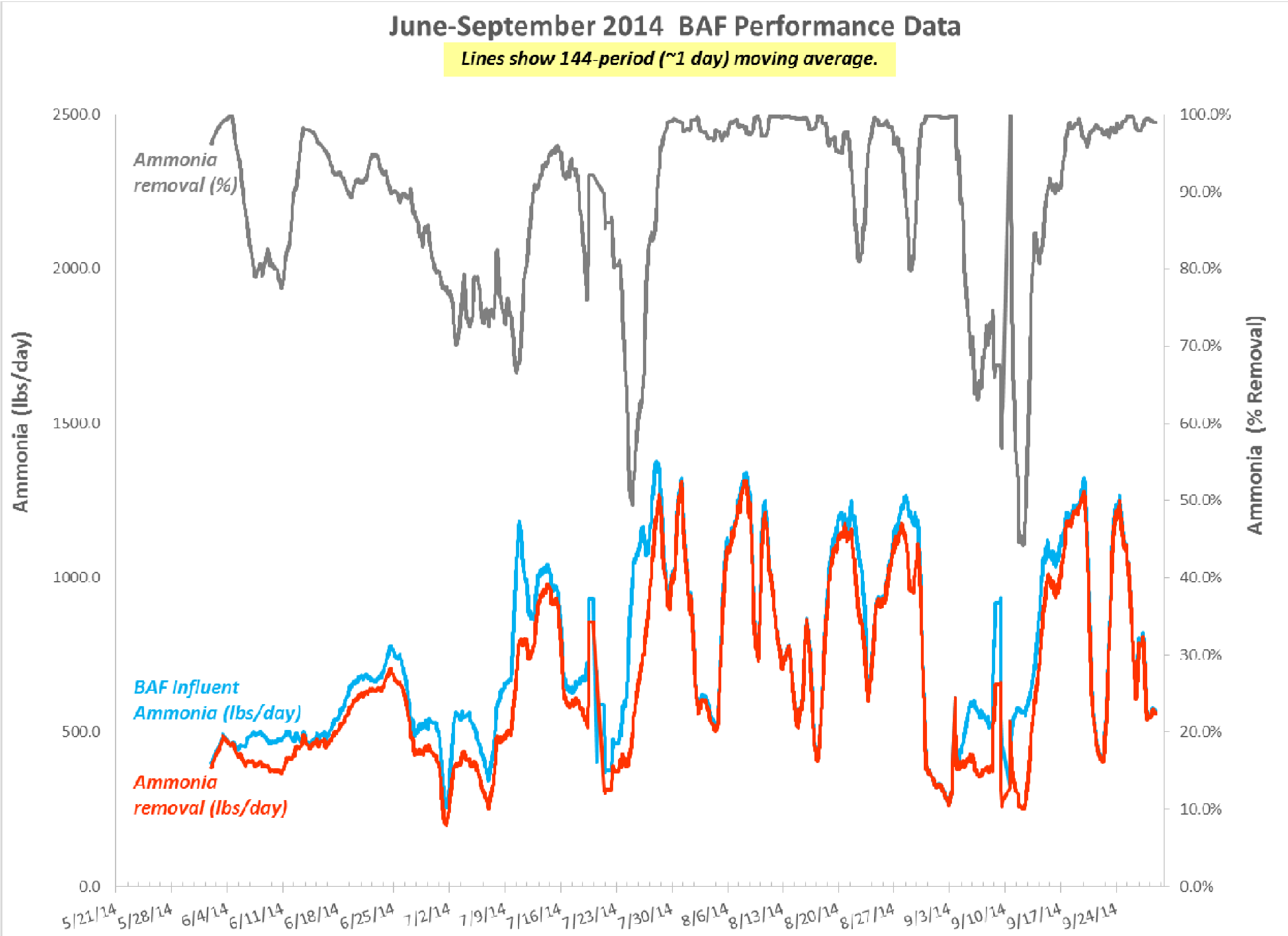
Disk Filter Backwash Waste and Treatment

- Treat to reduce TSS in backwash waste using plate settler
  - Continuous feed to plate settler
  - Add ferric chloride and/or polymer to assist in settling
- Plate settler sized for 150 gpm (0.30 gpm/sf loading)
- Includes rapid mix and two stage flocculation
  - 10 minutes floc time
- Treated water recycled to influent of disk filters
- Settled solids returned to WWTP
  - 2,000-3,000 gallons/day at 0.3% solids

Daily Raw Water Ammonia was Higher than Design Basis



BAF Has Performed Well



Lessons Learned

- Understand water quality variability
  - Daily/weekly changes in alkalinity and ammonia can affect efficiency of nitrification process
  - May need to do additional sampling for selected parameters – many not monitored daily at WWTP effluent
- Biological System stability during startup can be a challenge
  - Water system was first to start up; no heat load=minimal water demand
  - Need base load of ammonia to provide food for nitrifiers
- Understand your recycle streams
  - Slug loads at start of recycle of backwash water to disc filters caused blinding
- Careful using reuse water for process water needs- i.e. feed to RO/EDI for boilers
  - Careful characterization needed and may require additional pretreatment

Summary

- Beneficial Reuse in New Jersey is a viable option for power plants and other large water quantity users
  - 5 power plants in state currently practicing or planning for reuse
- NJDEP guidance allows flexibility for end users to tailor reuse treatment needs to process needs
  - In case study, needed ammonia removal for water quality considerations for equipment
- Case Study
  - Biological process for ammonia removal was the least expensive option and most sustainable
  - Disc filters for TSS reduction offered greatest treatment reliability at smallest footprint
  - Recycling/treatment of backwash waste to minimize off-site waste streams and maximize reuse

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Questions?

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