Presenter: Todd S. Webster, Ph.D., P.E.

Biographical Background:

Dr. Todd Webster is a Vice President of Envirogen Technologies, Inc. He has over 20 years of experience in all aspects of biological and physico-chemical treatment system design, installation and operation in the potable water sector, with an emphasis on clean-up activities for contaminated groundwater laden with emerging contaminants of concern. He has a Ph.D. and Masters in Civil/Environmental Engineering and is a Professional Civil Engineer in the State of California.

ENVIROGEN TECHNOLOGIES

A Lifecycle Performance Company

Design, Commissioning and Operation of a Regenerable Ion Exchange System in Hawai´i for the Treatment of Groundwater Contaminated with Nitrate- Case Studies

Presented at the Hawai'i Rural Water Association Technical Conference
May 24, 2023

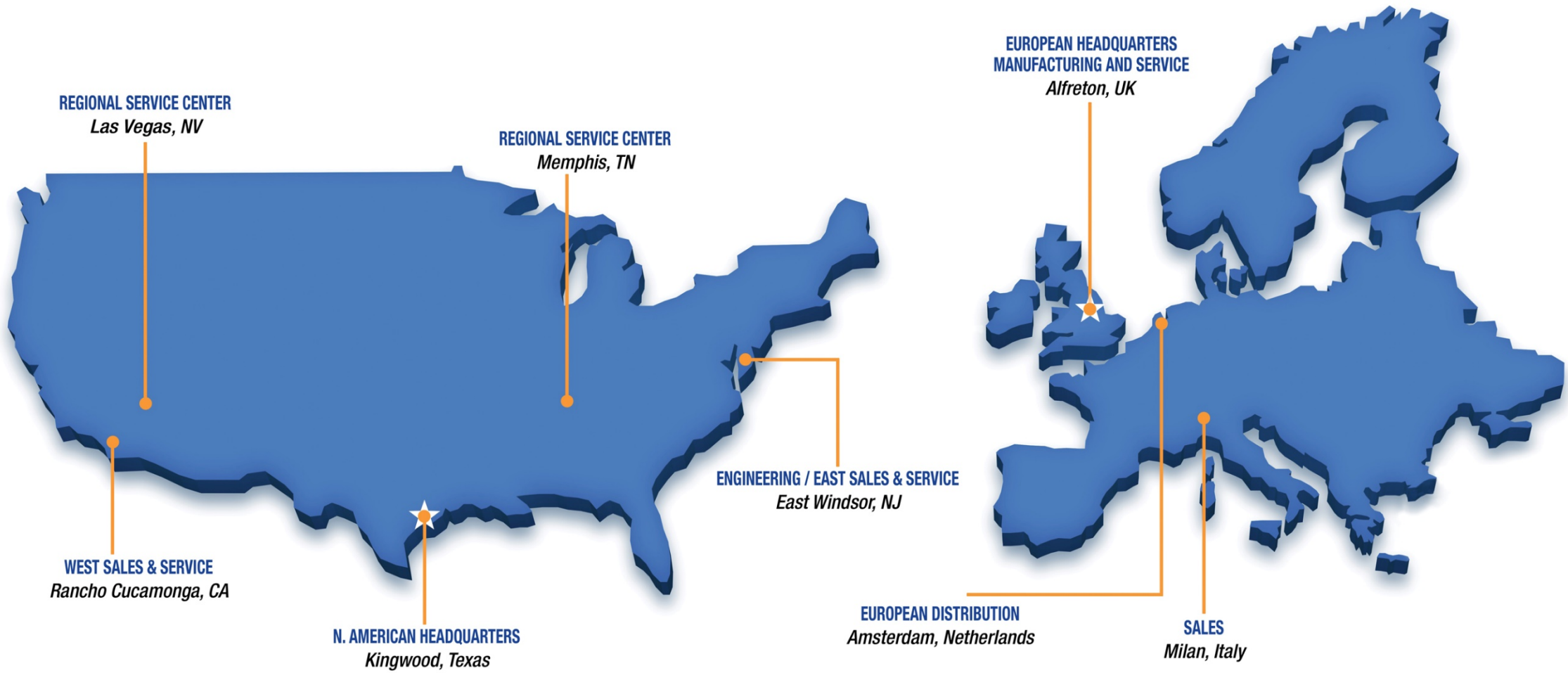
Todd S. Webster, Ph.D., P.E., Vice President, Envirogen Technologies, Inc.

Outline of Presentation

- *Envirogen Introduction*
- *Environmental Issue in Hawai'i*
- *Regenerable Ion Exchange Summary*
- *Legacy IX Design vs. New IX Design*
- *Smaller IX Systems Applied in Hawai'I*
- *Other Contaminant Treatment-Metals*
- *Life-Cycle Cost information*
- *Continued Innovation with Regenerable IX*
- *Conclusions*

What We Do and Where We Are Located

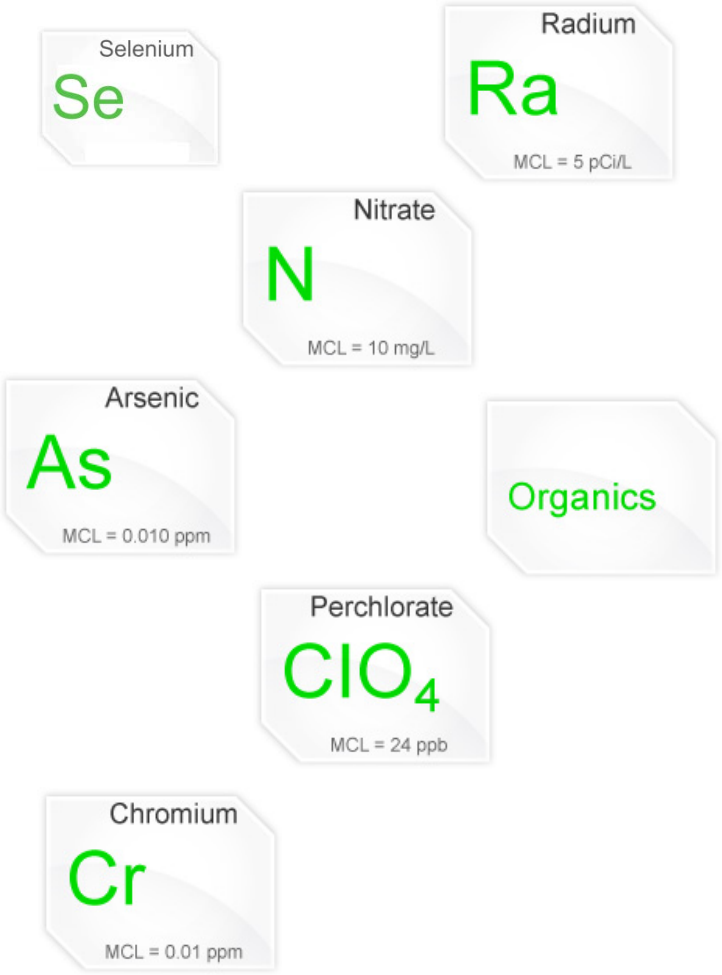
- We solve complex challenges relating to water availability and quality by providing technical solutions on a guaranteed basis
- Our goal is establishment of long term relations with our client base



What we treat…

- Arsenic
- Nitrate, Ammonia
- Perchlorate
- Chromium/Metals
- Selenium
- Radium
- Uranium
- Iron/Manganese
- Barium
- And more…

- Organics
  - VOCs
  - PCE
  - BTEX
  - MTBE
  - DCA
  - 1,4-Dioxane
  - NDMA
  - PCPPs
  - EDCs



ENVIROGEN TECHNOLOGIES

Envirogen's Proprietary Treatment Offerings

- Envirogen Technologies' Proprietary Systems for Potable and Industrial Water Treatment
  - Regenerable Ion Exchange
  - Fluidized Bed Bioreactors
  - Advanced Metals Removal Systems (AMRS)
  - Nanofiltration Membrane Systems

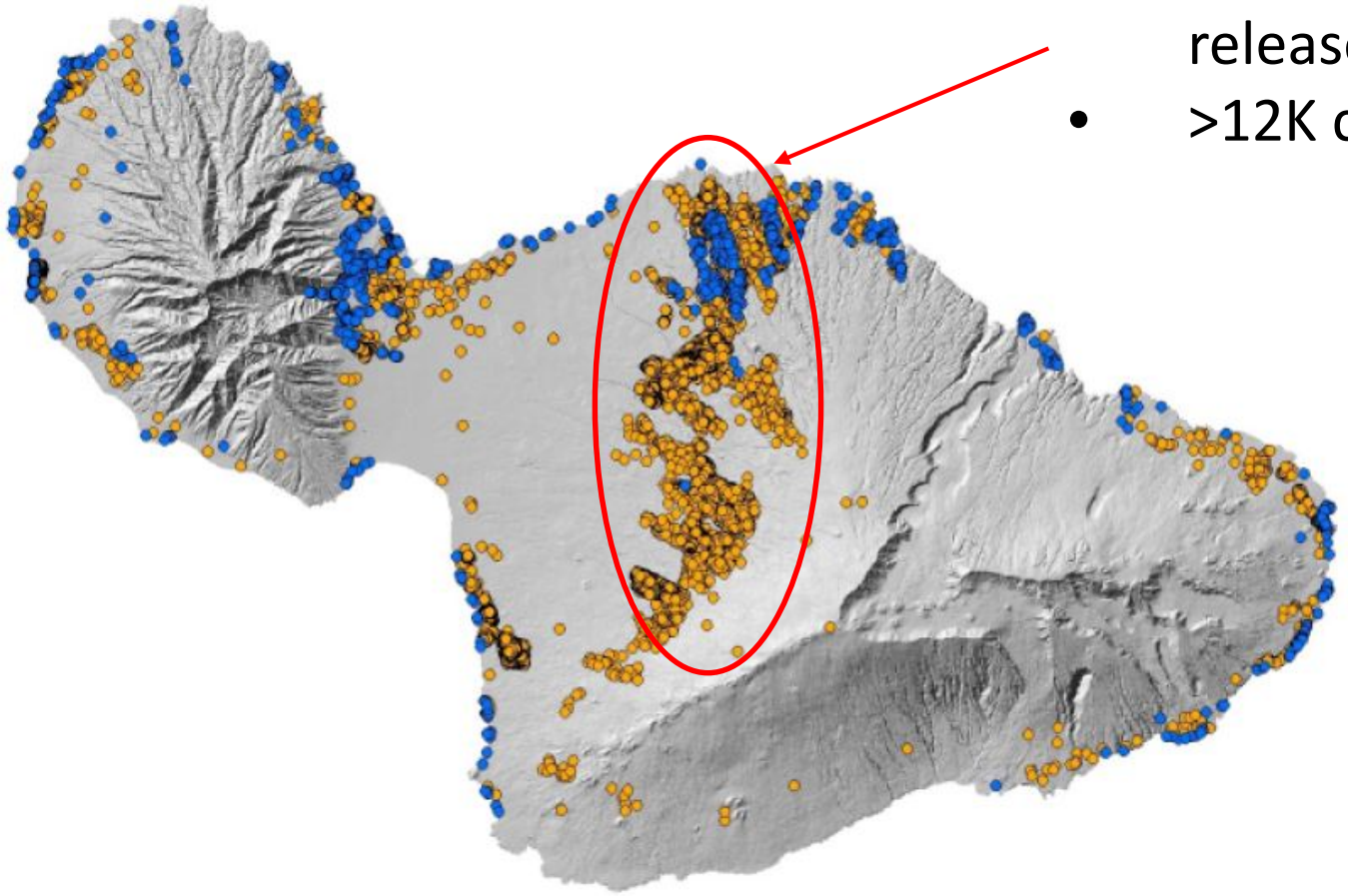
ENVIROGEN TECHNOLOGIES

Environmental Issue in Hawai’i

Cesspool Issue Across Hawai'i

- In 2016, the State of Hawaii banned the construction of new cesspools and in 2017 passed a law requiring all cesspools be converted by the year 2050 (Act 125).
- As of 2018, Hawaii had 88,000 cesspools across all islands, depositing up to 53 million gallons of raw sewage into the ground every day.
- In Keaau on the Big Island, there are over 9,400 cesspools, with 25% of drinking water wells in the area testing positive for fecal indicator bacteria.
- More than 90% of the state's drinking water comes from groundwater wells.
- These cesspools also contribute to nitrate contamination of these groundwater wells.
  - ***Source: Hawaii Department of Health, Safe Drinking Water Branch, 2018.***

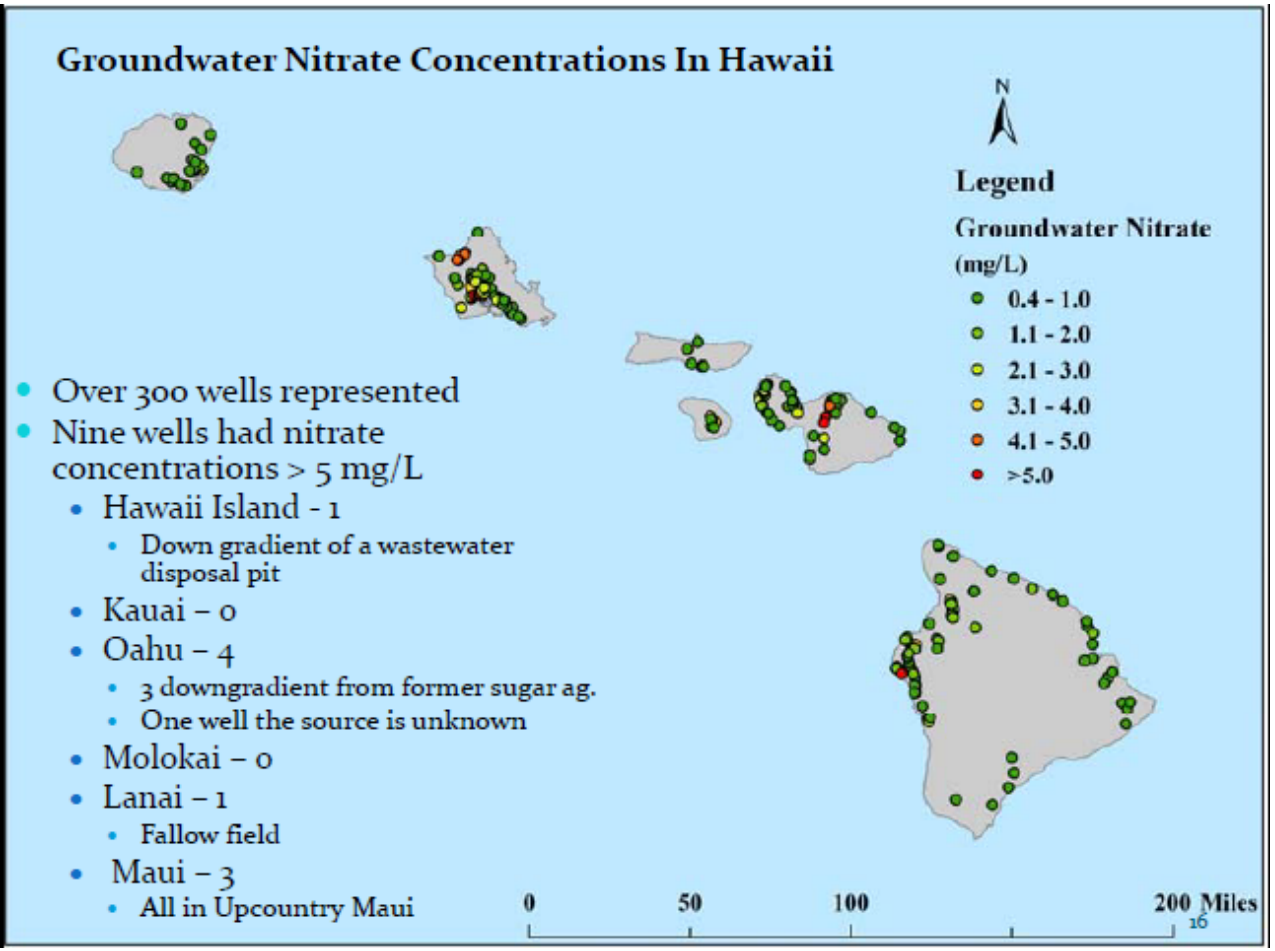
Cesspools in Maui



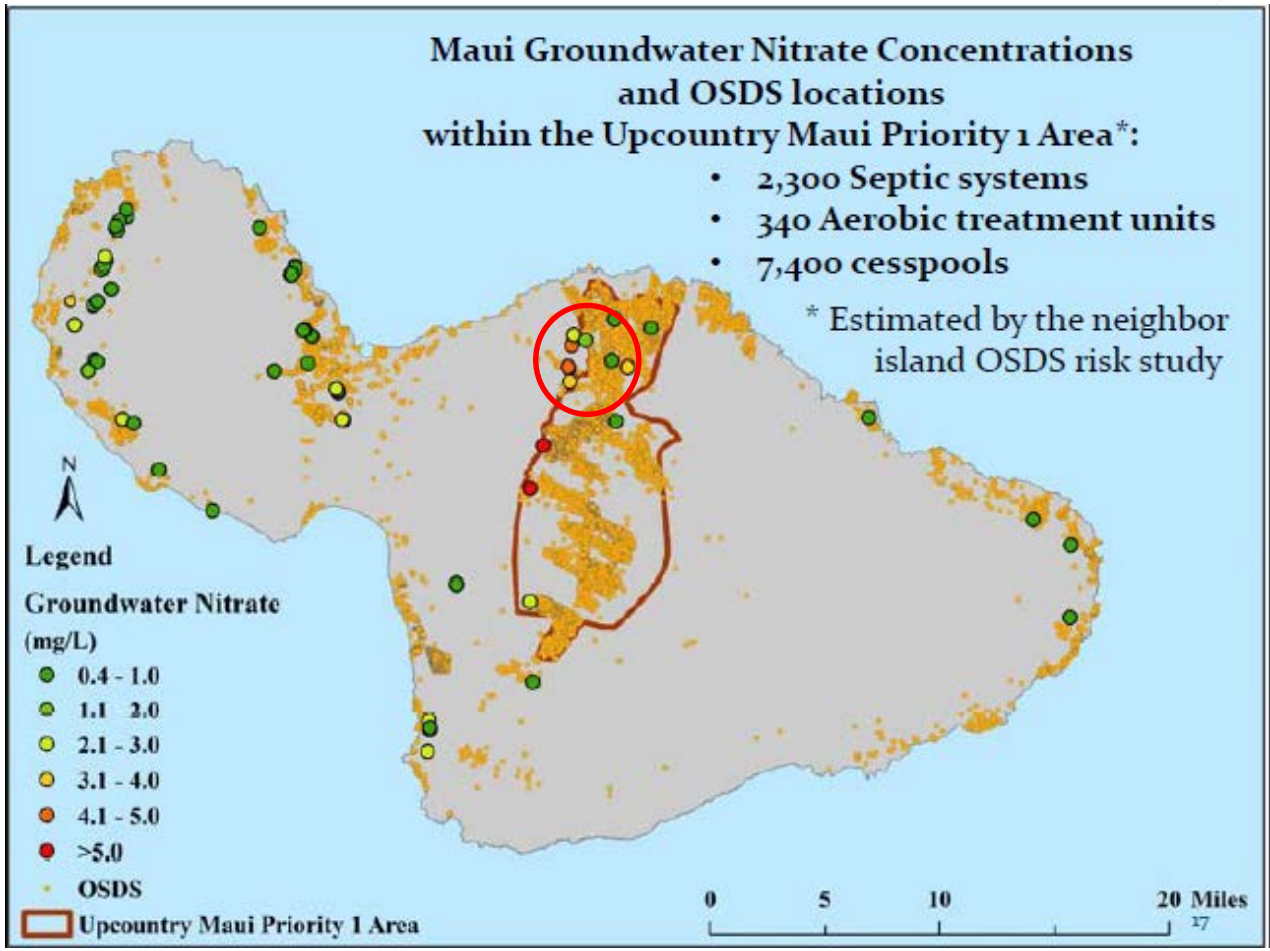
- 7.9 M gallons of effluent released/day
- >12K cesspools in the area

- ***Source: Maui County- http://www.mauicounty.us/cesspools/***

Groundwater Nitrate in Hawai'i



- Over 300 wells represented
- Nine wells had nitrate concentrations > 5 mg/L
  - Hawaii Island - 1
    - Down gradient of a wastewater disposal pit
  - Kauai – 0
  - Oahu – 4
    - 3 downgradient from former sugar ag.
    - One well the source is unknown
  - Molokai – 0
  - Lanai – 1
    - Fallow field
  - Maui – 3
    - All in Upcountry Maui

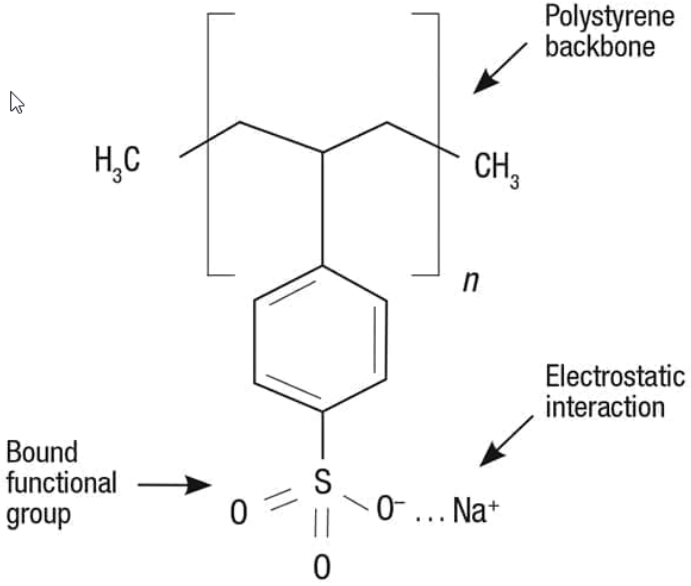


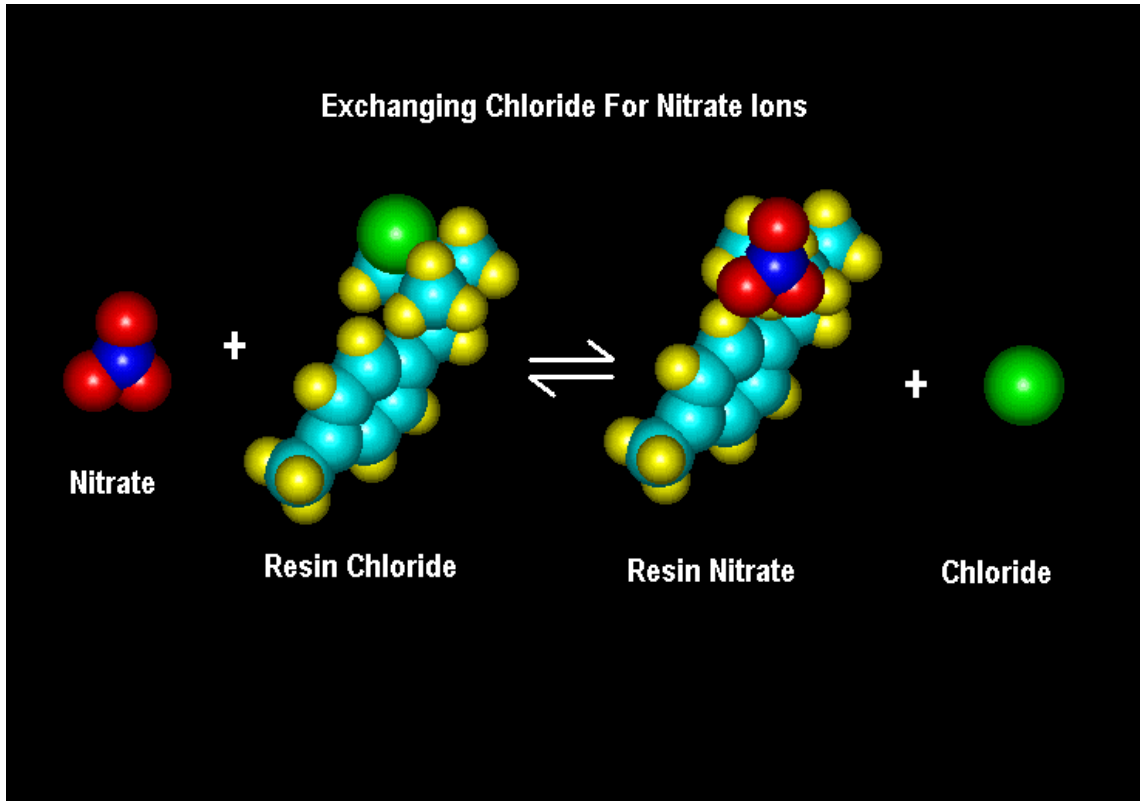
- *Source: Upcountry Maui Groundwater Nitrate Investigation, Hawaii Department of Health, Safe Drinking Water Branch, 2018.*

Regenerable Ion Exchange Summary

Ion Exchange

- Process where ions are transferred from a solid to a liquid phase (or vice versa). The driving force for the exchange is an electrical/chemical potential , i.e., a positively charged surface "attracts" a negatively charged ion.
- Ion exchange systems involve reversible chemical reactions
- Targeted ions are captured electrostatically and replaced by other ions of similar charge
- The key component of the IX system is the ion exchange resin
  - Crosslinked organic polymers shaped into small beads
  - Polystyrene with divinylbenzene crosslinks.

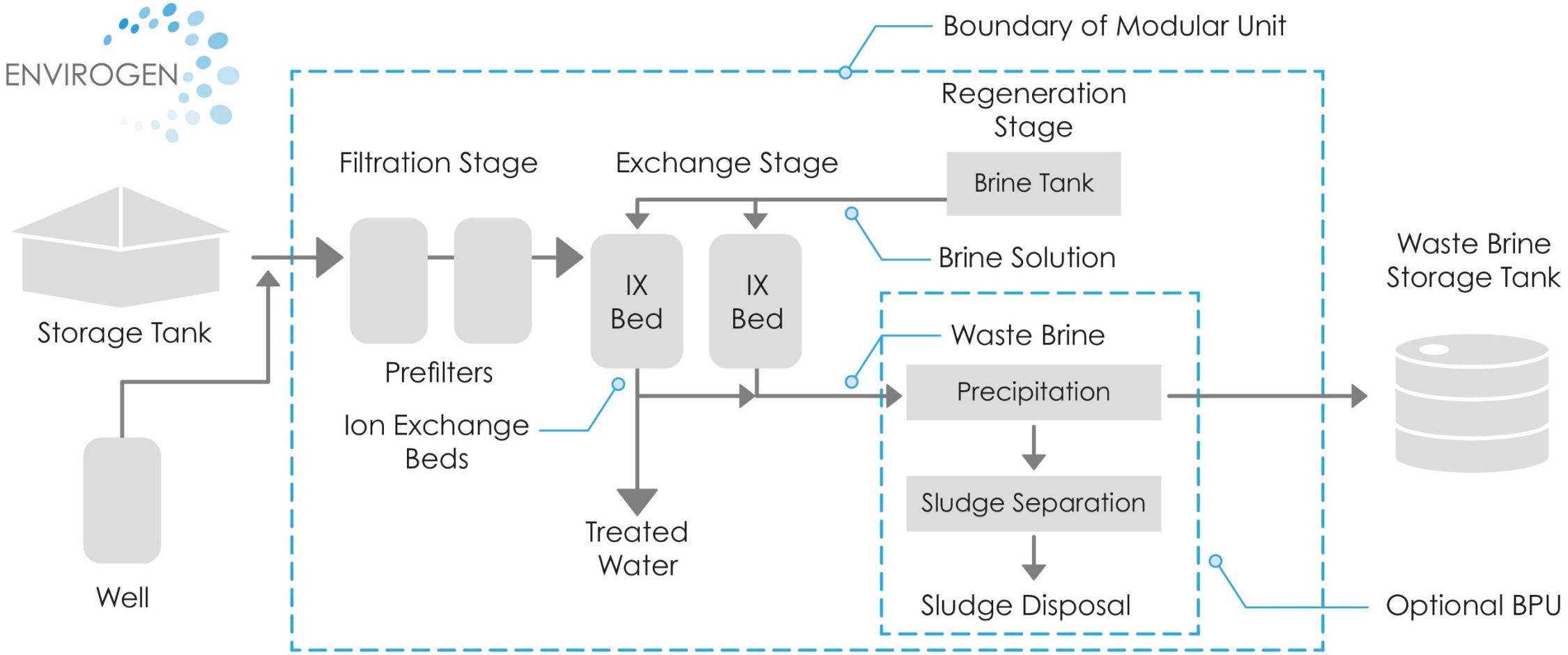




Selectivity of Strong Base Anionic Resin

CrO_4^{2-} --> SO_4^{2-} --> NO_3^- --> Cl^- --> HCO_3^-

How it is accomplished...

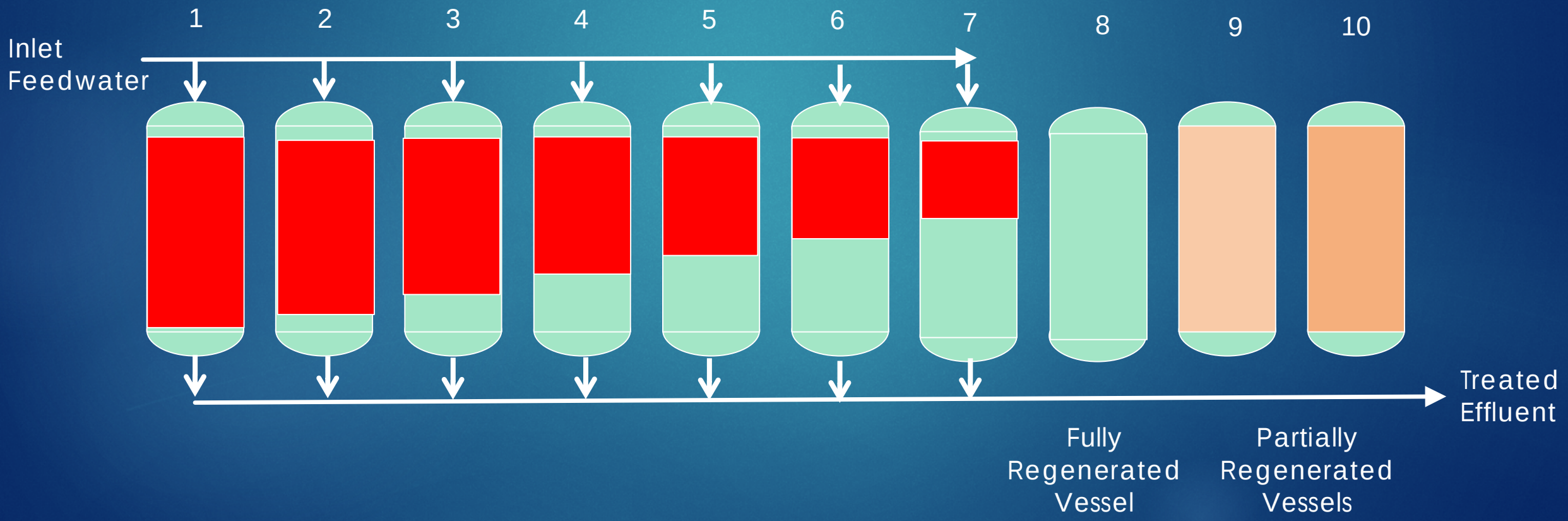


SimPACK Ion Exchange

- Simulated Staggered Packed Bed design
- N+3 design with staggered beds allows for (N = number of beds to meet pump flow):
  - Full utilization of each vessel maximizing throughput
  - Consistent blending of effluent
  - Minimization of brine waste
  - Cascading regeneration
    - Reuse of rinse water
    - Reuse of Brine
    - Reduced lbs of salt used
- Containerized or in a building
- PLC fully process controlled

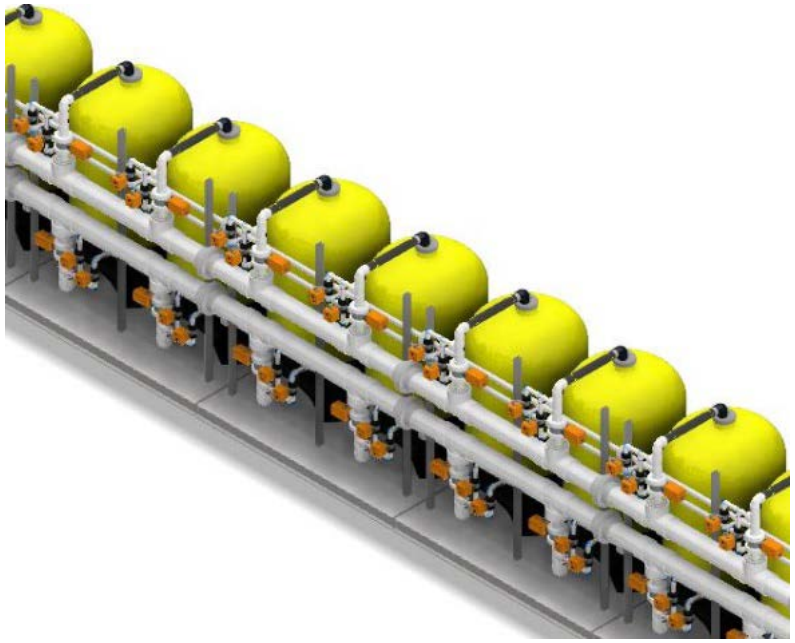
Staggered Bed Design

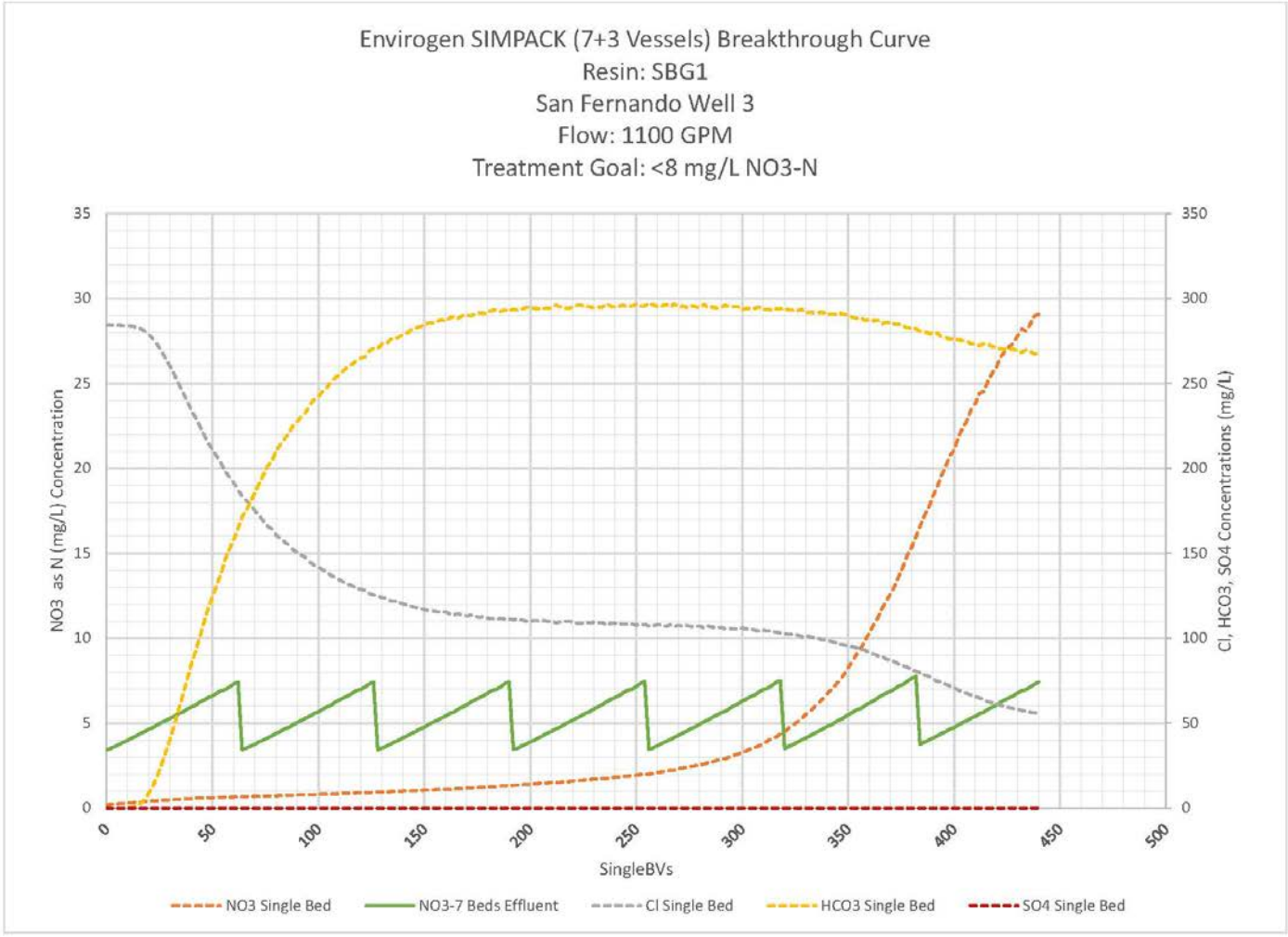
- N+3 Design- Seven vessels in operation with one in stand-by and two being regenerated.
- Influent to beds 1-7, with all beds at different levels of breakthrough (some overloaded).
- Combined effluent ensures that effluent of the overloaded beds is diluted by the effluent of the other beds.
- Cascade regeneration- Reuse of water, reuse of brine



How do we size?

- Model
  - Flowrate
  - Water chemistry
  - Treatment objectives
  - Run-time
  - Salt usage, waste rates





Legacy Design

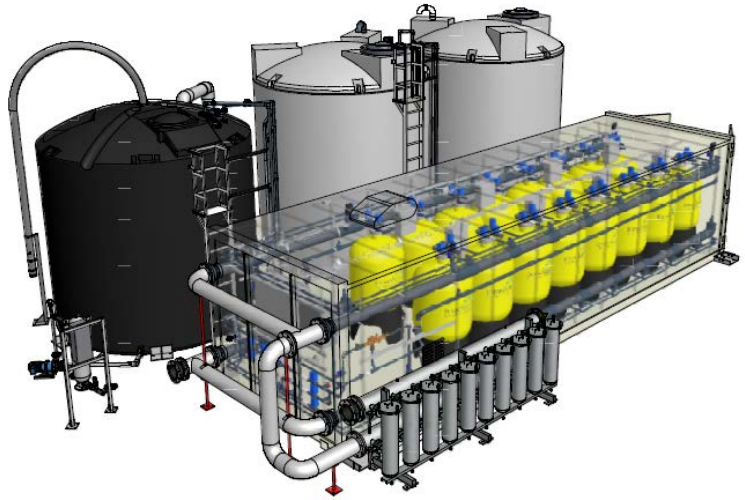
System Components

Pre-filters

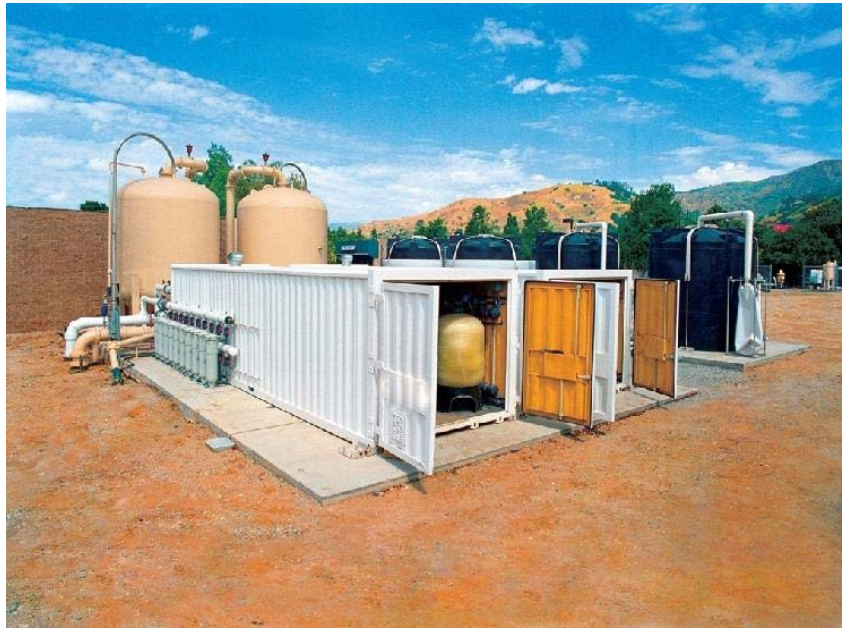
Brine Wastewater

Salt Tank

Treatment Module



Nitrate, Perchlorate, Uranium Removal Systems



2,000-GPM Perchlorate Removal System - California

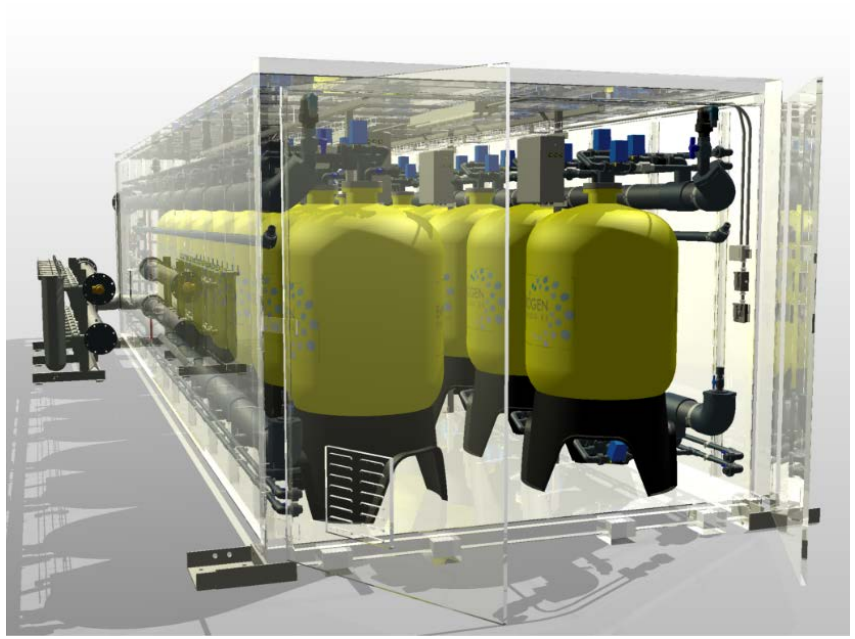
1,000-GPM Uranium Removal System - California

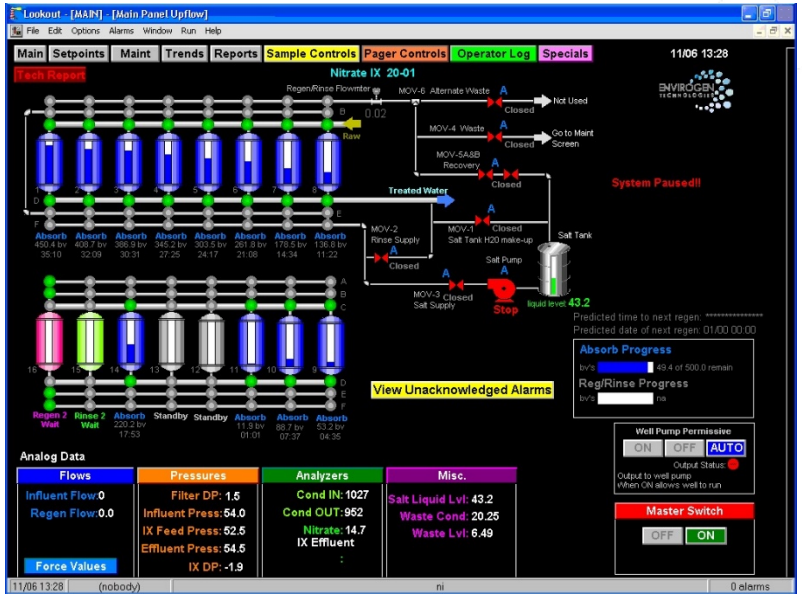
300-GPM Uranium Removal System - California

1,000-GPM Nitrate Removal System - California

1,000-GPM Perchlorate Removal System - California

Containerized System

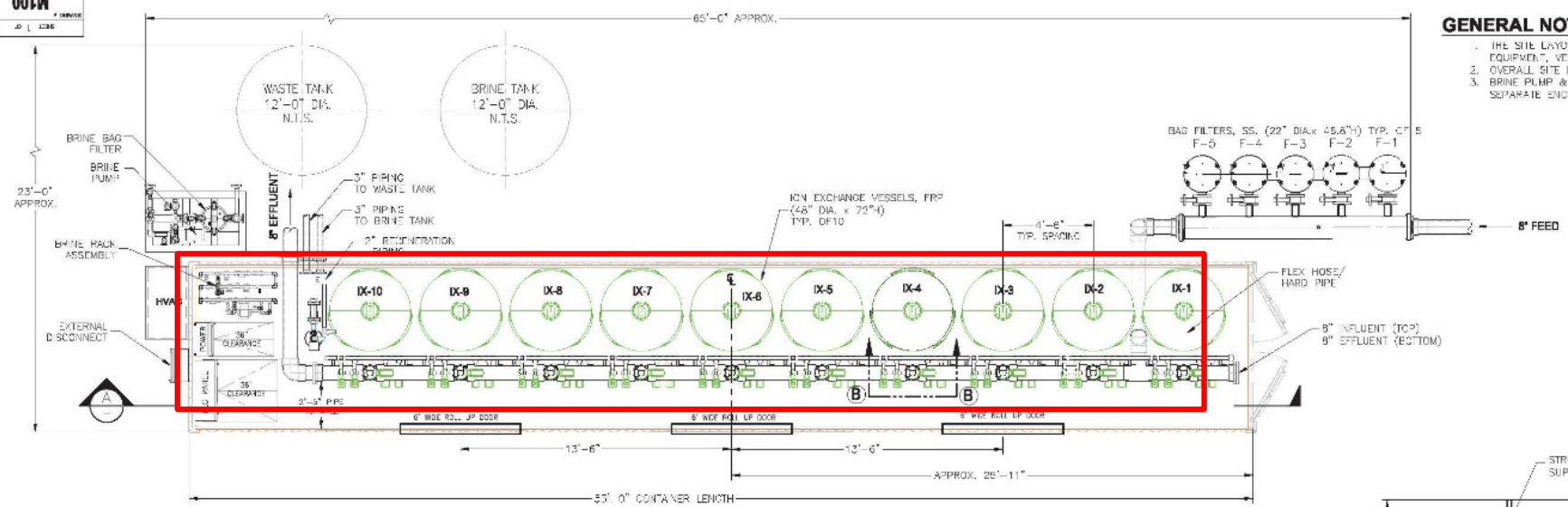




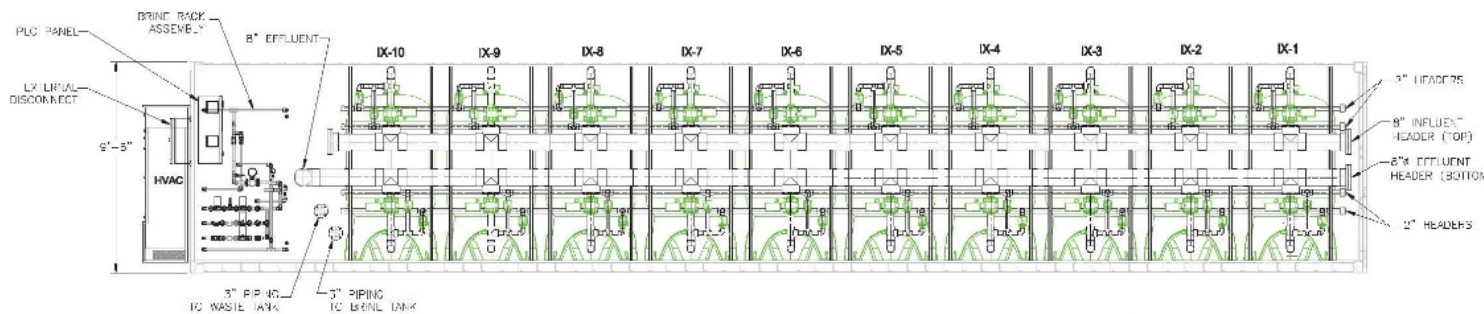
- Concerns
  - Containerization
  - Accessibility inside
  - Operational maintenance
  - Reduce salt use/waste rates

New Design

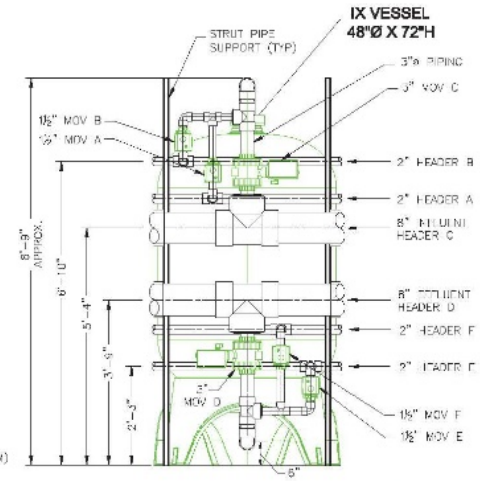
M100



PLAN VIEW
SimPACK CONTAINER SYSTEM LAYOUT
SCALE: 3/8" = 1'-0"



ELEVATION (CONTAINER) - SECTION (A)
SCALE: 3/8" = 1'-0"



IX VESSEL CONNECTIONS
SECTION (B)
SCALE: 3/4" = 1'-0"

SCALE: 3/8" = 1'-0"
0 1 3 6 FEET

REV	DATE	DESCRIPTION OF REVISION	BY	CHECKED
A	12-5-20	ISSUED FOR REVIEW (1 LEFT 12/15 DESIGN)	MAP	JLD/MDV
B	12-28-20	ISSUED FOR CONCEPT REVIEW (12/28 MDV COMMENTS)	MAP	JLD/MDV
C	11-19-20	ISSUED FOR CONCEPT REVIEW	MAP	JLD/MDV

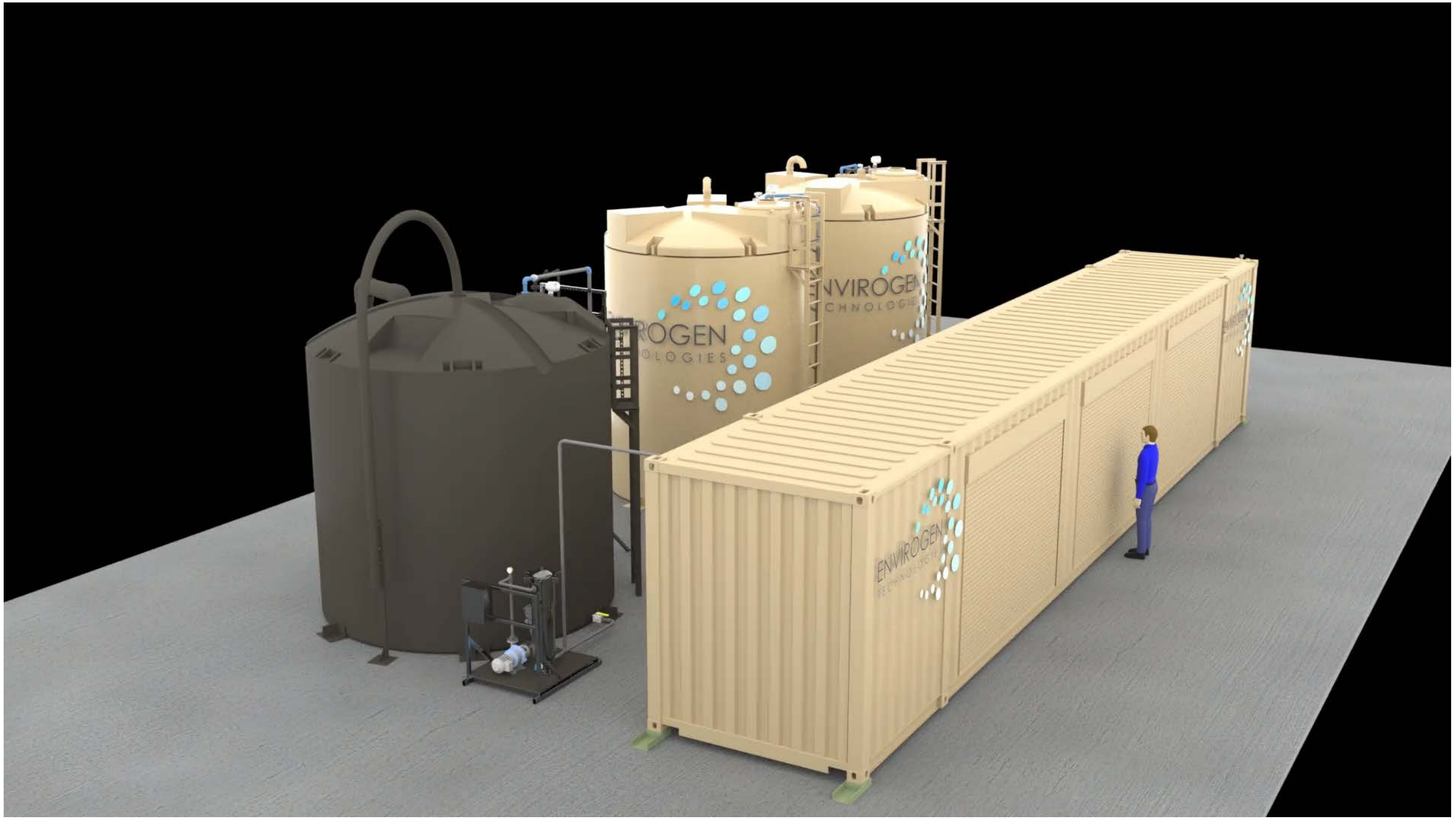
DRAWING SCALE: AS NOTED
DESIGN ENGINEER: RL 08-03-20
DRAWN BY/DATE: MAP 11-19-20
CHECKED BY/DATE: MDV/CW 11-19-20
SHEET SIZE: D
REVISION: C
SHEET 1 OF 1
DRAWING #: SimPACK
REF #: SIMPACK M100-C

COVERED BY ONE OR MORE OF THE FOLLOWING U.S. PATENTS:

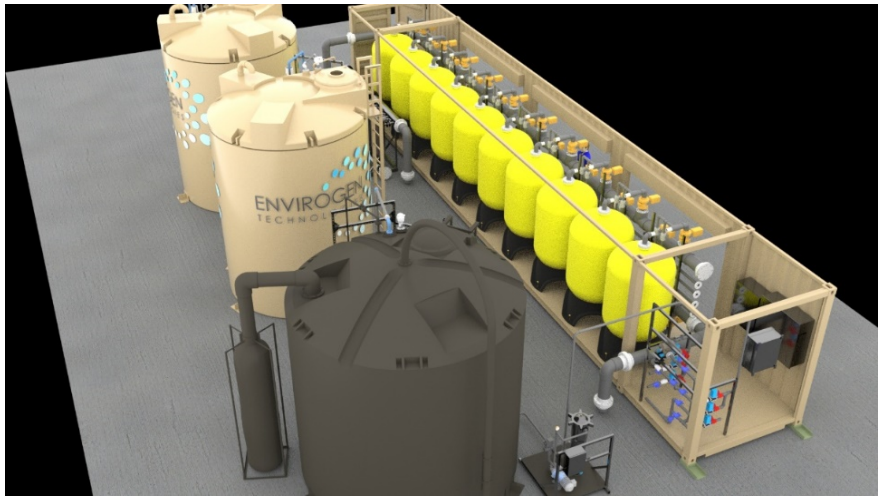
ENVIROGEN TECHNOLOGIES
A Lifecycle Performance Company
84A TWIN RIVERS DRIVE
EAST WINDSOR, NJ 08520

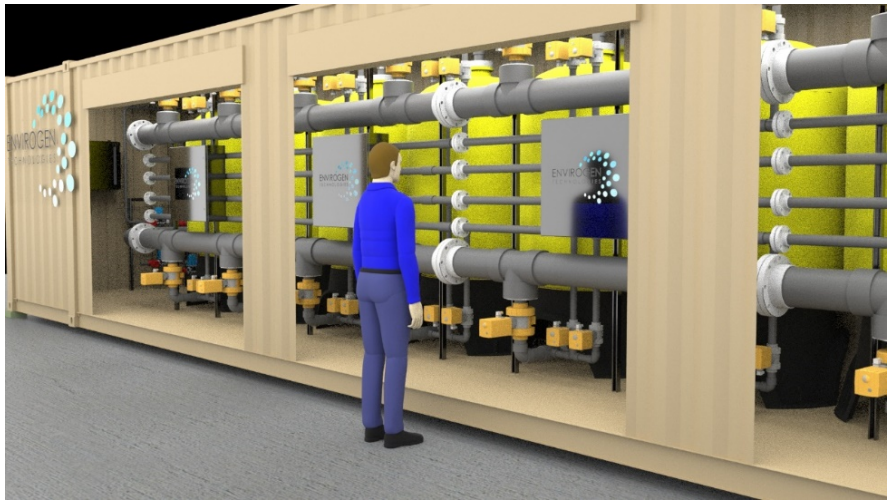
ENVIROGEN TECHNOLOGIES, INC.

IX PACKAGE CONTAINERIZED
SimPACK SYSTEM ARRANGEMENT


ENVIROGEN

- **Improvements in Design**
  - **N+3 with ten (10) vessels**
  - **53-foot container**
  - **Compact site- 60’x40’**
  - **All valves front-facing**
  - **Roll-up access doors**



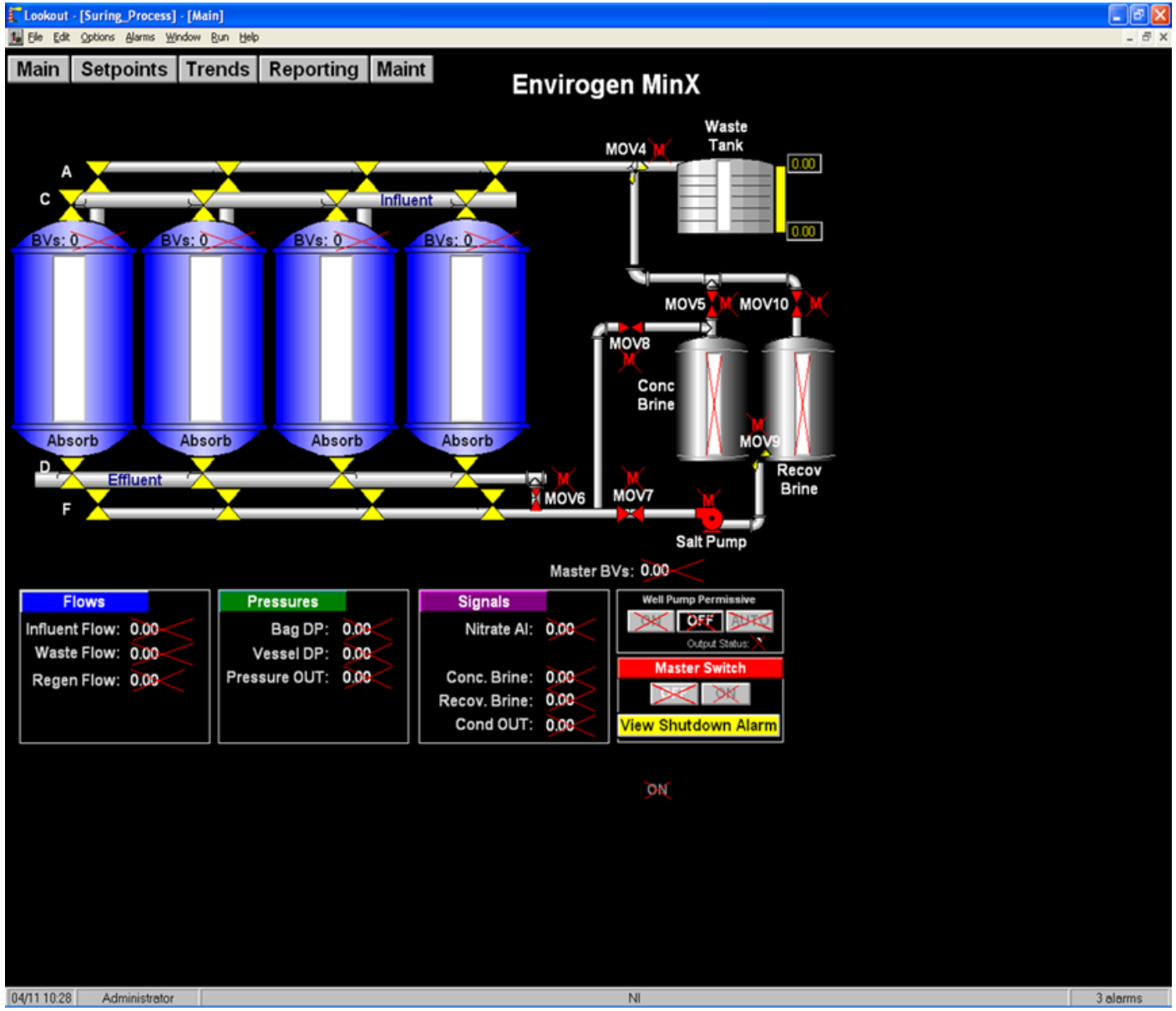


MinX for Smaller Flows

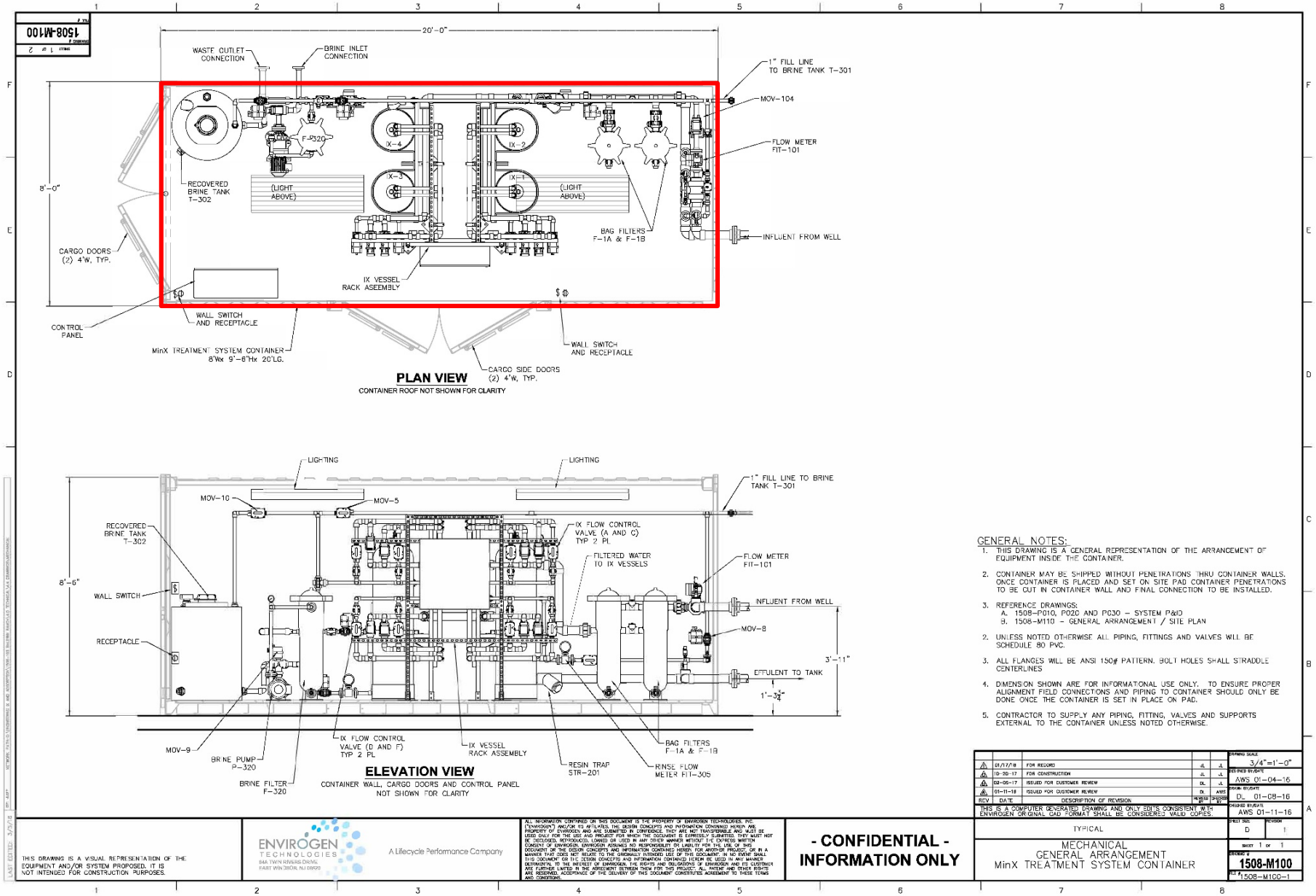
MinX Ion Exchange Treatment System

- Alternative regenerable ion exchange system
  - Applied to low flow and/ or low volume applications
  - Lower capital, but slightly higher waste rates
  - Ion exchange and regeneration process similar to SimPACK
  - Typically installed in building or container next to well pump equipment
  - Process control and monitoring similar to SimPACK
- External brine recovery/ reuse tank
- N+1 design (N = number of IX vessels required on line)
- Space requirements
  - Smaller footprint
  - Modular design

MinX Controls



MINX Design


1508-M100
20'-0"
WASTE OUTLET CONNECTION
BRINE INLET CONNECTION
1" FILL LINE TO BRINE TANK T-301
MOV-104
FLOW METER FIT-101
F-320
IX-4
IX-2
IX-3
IX-1
8'-0"
RECOVERED BRINE TANK T-302
(LIGHT ABOVE)
(LIGHT ABOVE)
BAG FILTERS F-1A & F-1B
INFLUENT FROM WELL
CARGO DOORS (2) 4'W, TYP.
IX VESSEL RACK ASEEMBLY
CONTROL PANEL
WALL SWITCH AND RECEPTACLE
MinX TREATMENT SYSTEM CONTAINER 8'Wx 9'-6"Hx 20'LG.
WALL SWITCH AND RECEPTACLE
CARGO SIDE DOORS (2) 4'W, TYP.
PLAN VIEW
CONTAINER ROOF NOT SHOWN FOR CLARITY
LIGHTING
LIGHTING
1" FILL LINE TO BRINE TANK T-301
MOV-10
MOV-5
RECOVERED BRINE TANK T-302
IX FLOW CONTROL VALVE (A AND C) TYP 2 PL
FILTERED WATER TO IX VESSELS
FLOW METER FIT-101
8'-6"
WALL SWITCH
INFLUENT FROM WELL
RECEPTACLE
MOV-8
3'-11"
EFFLUENT TO TANK
1'-3½"
MOV-9
BRINE PUMP P-320
IX FLOW CONTROL VALVE (D AND F) TYP 2 PL
IX VESSEL RACK ASSEMBLY
BAG FILTERS F-1A & F-1B
RESIN TRAP STR-201
RINSE FLOW METER FIT-305
BRINE FILTER F-320
ELEVATION VIEW
CONTAINER WALL, CARGO DOORS AND CONTROL PANEL NOT SHOWN FOR CLARITY
GENERAL NOTES:
1. THIS DRAWING IS A GENERAL REPRESENTATION OF THE ARRANGEMENT OF EQUIPMENT INSIDE THE CONTAINER.
2. CONTAINER MAY BE SHIPPED WITHOUT PENETRATIONS THRU CONTAINER WALLS. ONCE CONTAINER IS PLACED AND SET ON SITE PAD CONTAINER PENETRATIONS TO BE CUT IN CONTAINER WALL AND FINAL CONNECTION TO BE INSTALLED.
3. REFERENCE DRAWINGS:
A. 1508-P010, P020 AND P030 – SYSTEM P&ID
B. 1508-M110 – GENERAL ARRANGEMENT / SITE PLAN
2. UNLESS NOTED OTHERWISE ALL PIPING, FITTINGS AND VALVES WILL BE SCHEDULE 80 PVC.
3. ALL FLANGES WILL BE ANSI 150# PATTERN. BOLT HOLES SHALL STRADDLE CENTERLINES
4. DIMENSION SHOWN ARE FOR INFORMATIONAL USE ONLY. TO ENSURE PROPER ALIGNMENT FIELD CONNECTIONS AND PIPING TO CONTAINER SHOULD ONLY BE DONE ONCE THE CONTAINER IS SET IN PLACE ON PAD.
5. CONTRACTOR TO SUPPLY ANY PIPING, FITTING, VALVES AND SUPPORTS EXTERNAL TO THE CONTAINER UNLESS NOTED OTHERWISE.
REV DATE DESCRIPTION OF REVISION
A 01/17/18 FOR RECORD
10-20-17 FOR CONSTRUCTION
02-06-17 ISSUED FOR CUSTOMER REVIEW
01-11-16 ISSUED FOR CUSTOMER REVIEW
THIS IS A COMPUTER GENERATED DRAWING AND ONLY EDITS CONSISTENT WITH ENVIROGEN ORIGINAL CAD FORMAT SHALL BE CONSIDERED VALID COPIES.
DRAWING SCALE 3/4"=1'-0"
ISSUED BY/DATE AWS 01-04-16
DRAWN BY/DATE DL 01-08-16
DESIGNED BY/DATE AWS 01-11-16
SHEET SIZE D
REVISION 1
SHEET 1 OF 1
DRAWING # 1508-M100
FILE # 1508-M100-1
THIS DRAWING IS A VISUAL REPRESENTATION OF THE EQUIPMENT AND/OR SYSTEM PROPOSED. IT IS NOT INTENDED FOR CONSTRUCTION PURPOSES.
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A Lifecycle Performance Company
ALL INFORMATION CONTAINED ON THIS DOCUMENT IS THE PROPERTY OF ENVIROGEN TECHNOLOGIES, INC. ("ENVIROGEN") AND/OR ITS AFFILIATES. THE DESIGN CONCEPTS AND INFORMATION CONTAINED HEREIN ARE PROPRIETARY OF ENVIROGEN AND ARE SUBMITTED IN CONFIDENCE. THEY ARE NOT TRANSFERABLE AND MUST BE USED ONLY FOR THE USE AND PROJECT FOR WHICH THE DOCUMENT IS EXPRESSLY SUBMITTED. THEY MUST NOT BE DISCLOSED, REPRODUCED, LOANED OR USED IN ANY OTHER MANNER WITHOUT THE EXPRESS WRITTEN CONSENT OF ENVIROGEN. ENVIROGEN ASSUMES NO RESPONSIBILITY OR LIABILITY FOR THE USE OF THIS DOCUMENT OR THE DESIGN CONCEPTS AND INFORMATION CONTAINED HEREIN FOR ANOTHER PROJECT OR IN A MANNER THAT DOES NOT RELATE TO THE ORIGINALLY INTENDED USE OF THIS DOCUMENT. IN NO EVENT SHALL THIS DOCUMENT OR THE DESIGN CONCEPTS AND INFORMATION CONTAINED HEREIN BE USED IN ANY MANNER DETRIMENTAL TO THE INTEREST OF ENVIROGEN. THE RIGHTS AND OBLIGATIONS OF ENVIROGEN AND ITS CUSTOMER ARE THOSE STATED IN THE AGREEMENT BETWEEN THEM FOR THIS PROJECT. ALL PATENT AND TRADE RIGHTS ARE RESERVED. ACCEPTANCE OF THE DELIVERY OF THIS DOCUMENT CONSTITUTES AGREEMENT TO THESE TERMS AND CONDITIONS.
- CONFIDENTIAL - INFORMATION ONLY
TYPICAL
MECHANICAL GENERAL ARRANGEMENT MinX TREATMENT SYSTEM CONTAINER

MinX Systems in Maui

- **2019: Baldwin Ranch Estates in Hali´imaile**
  - **50 gpm feed, 35% uptime operation (8.5 hr/day)**
  - **Effectively was treating nitrate-N levels from 9.0 to ≤2.0 mg/L of NO_3-N**
  - **Elevated nitrate level has come down over the years to same levels of neighboring subdivisions**
  - **Unique design features:**
    - **Discharge of produced brine to evaporation ponds**
    - **First nitrate treatment system permitted in the State of Hawai'i**
  - **Owner quoted "*We're really stoked with our system… the subdivision HOA water association is extremely pleased that we can basically remove any traces of nitrates thanks to our ion exchange process.*"**
- **2023: Confidential Client in Hali´imaile**
  - **110 gpm, 24/7 uptime**
  - **Designed to treat nitrate-N levels from 10.0 to ≤2.0 mg/L of NO_3-N**
  - **To be installed, Summer, 2023**

Baldwin Ranch Estates- Water Quality Model Assumption and Results

Parameter	Values
Feed Water Flow	**50 gpm**
Feed Nitrate Concentration	**≤9 mg/L (as N)**
Treated Water Nitrate Concentration	**≤ 2 mg/L (as N)**
Other Feed Anions	
Sulfate	**≤100 mg/L**
Chloride	**≤60 mg/L**
Bicarbonate (asHCO3)	**≤67 mg/L**
Chrome (as Cr VI)	**<1.0 µg/L**
Arsenic (Total)	**<1.0 µg/L**
Selenium	**<0.5 µg/L**
Other Physical Chemistry Concentrations	
Feed TDS	**≤250 mg/L**
Hardness (as CaCO3)	**≤140 mg/L**
Feed TSS	**< 1.0 mg/L**
pH	**6.0 -8.5**
Other Water Quality Parameters	
Iron	**≤50 µg/L**
Manganese	**≤5.0 µg/L**
TOC	**< 5.0 mg/L**

At 35% utilization of the well:

Brine Waste Volumes	Salt Consumption
145 gallons per day	100 pounds per day
1,866 gallons of brine produced per acre-foot water treated	1,286.9 pounds of salt used per acre foot water treated

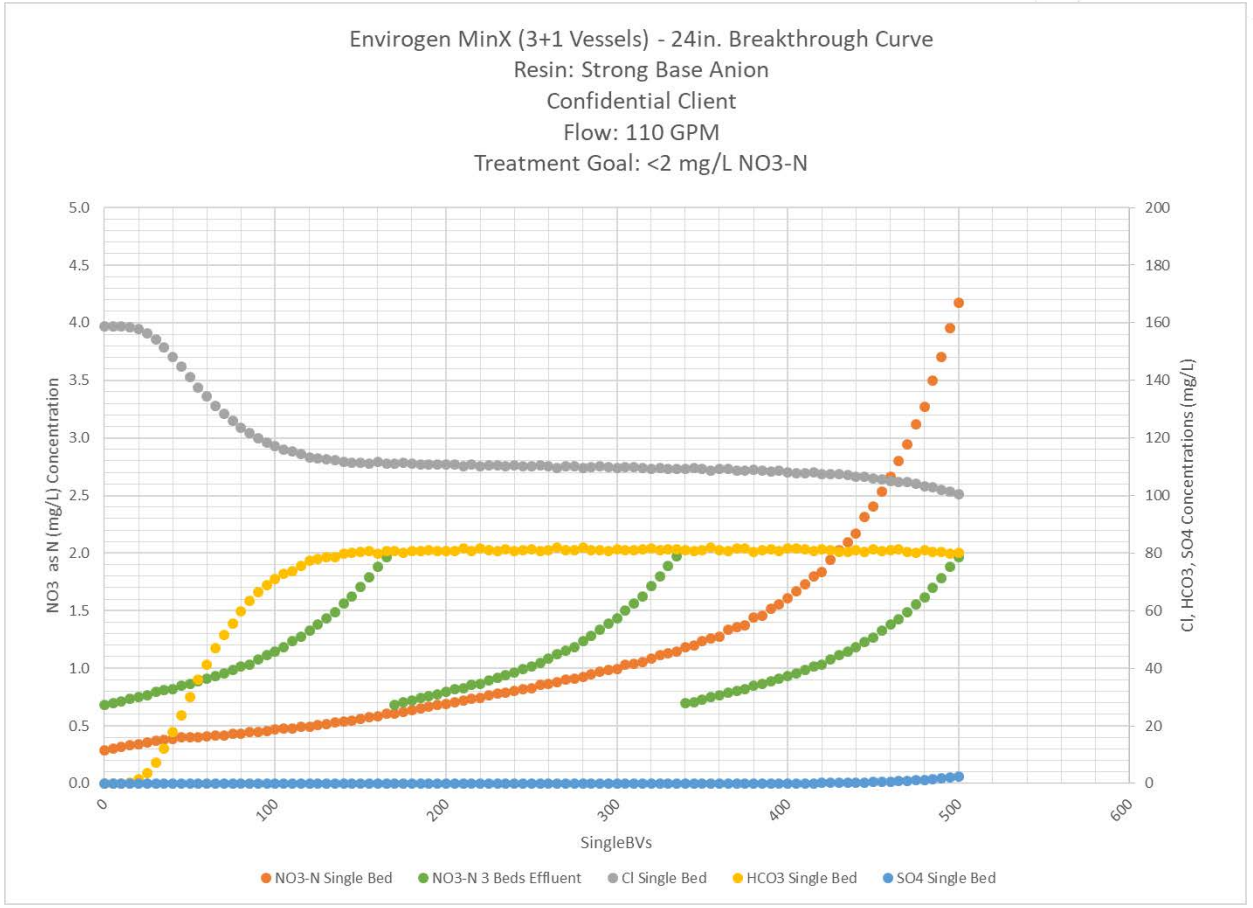
50 GPM MinX System Design (Maui, HI)

Confidential Maui Client- Water Quality Model Assumption and Results

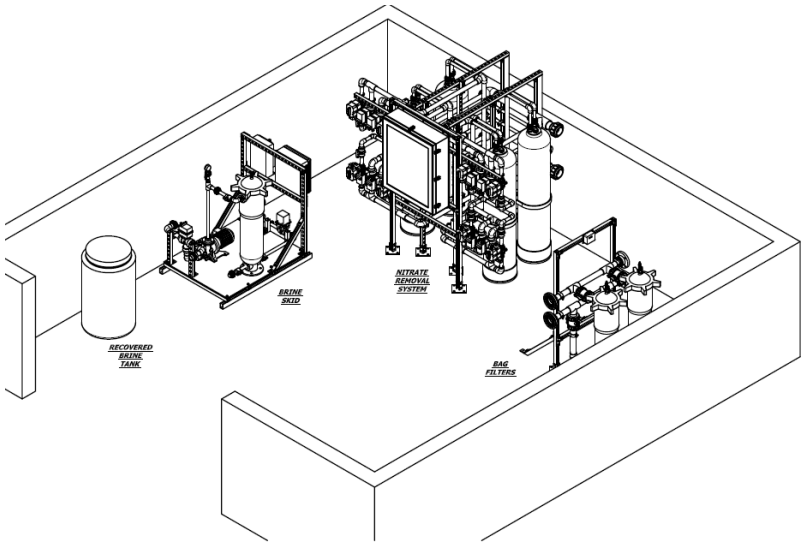
Influent and Target Effluent Flow			
Analyte	**Units**	**Influent Target**	**Effluent Target**
Flow Rate	gpm	110	110
Nitrate (as N)	mg/L	≤10	≤2

Influent Water Modeling Assumptions		
Analyte	**Units**	**Influent Range**
Sulfate	mg/L	≤37
Chloride	mg/L	≤64
Alkalinity (as $CaCO_3$)	mg/L	≤62
pH	SU	7.6-8.0

The modeling effort has predicted, in operating the MinX unit 24 hours/7 days per week at 110 gpm, the waste rate is calculated to be at 0.50% and the salt usage at 0.23 tons/day.



40 GPM MinX System Design (Lake Morena, CA)

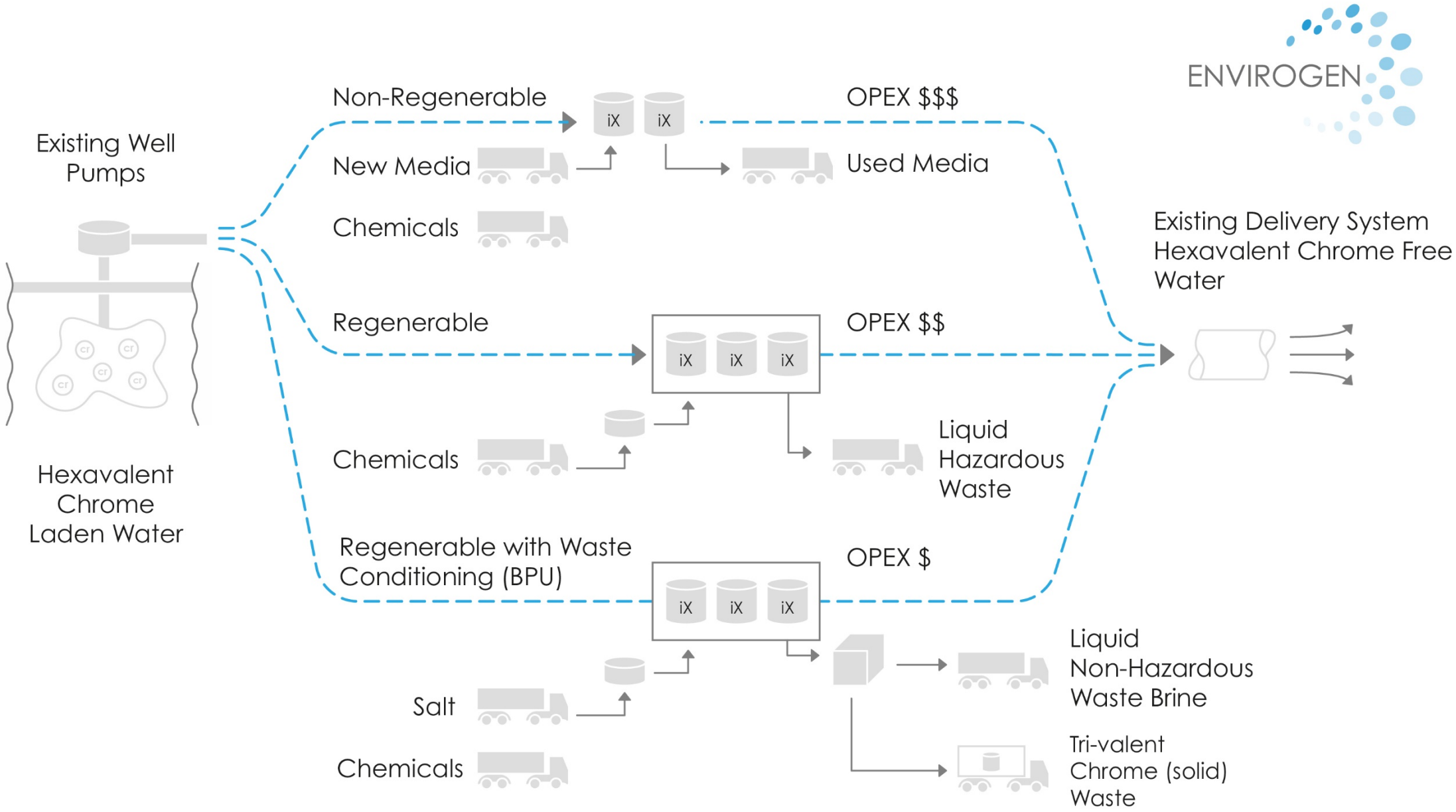


CleanPoint ion exchange treatment system

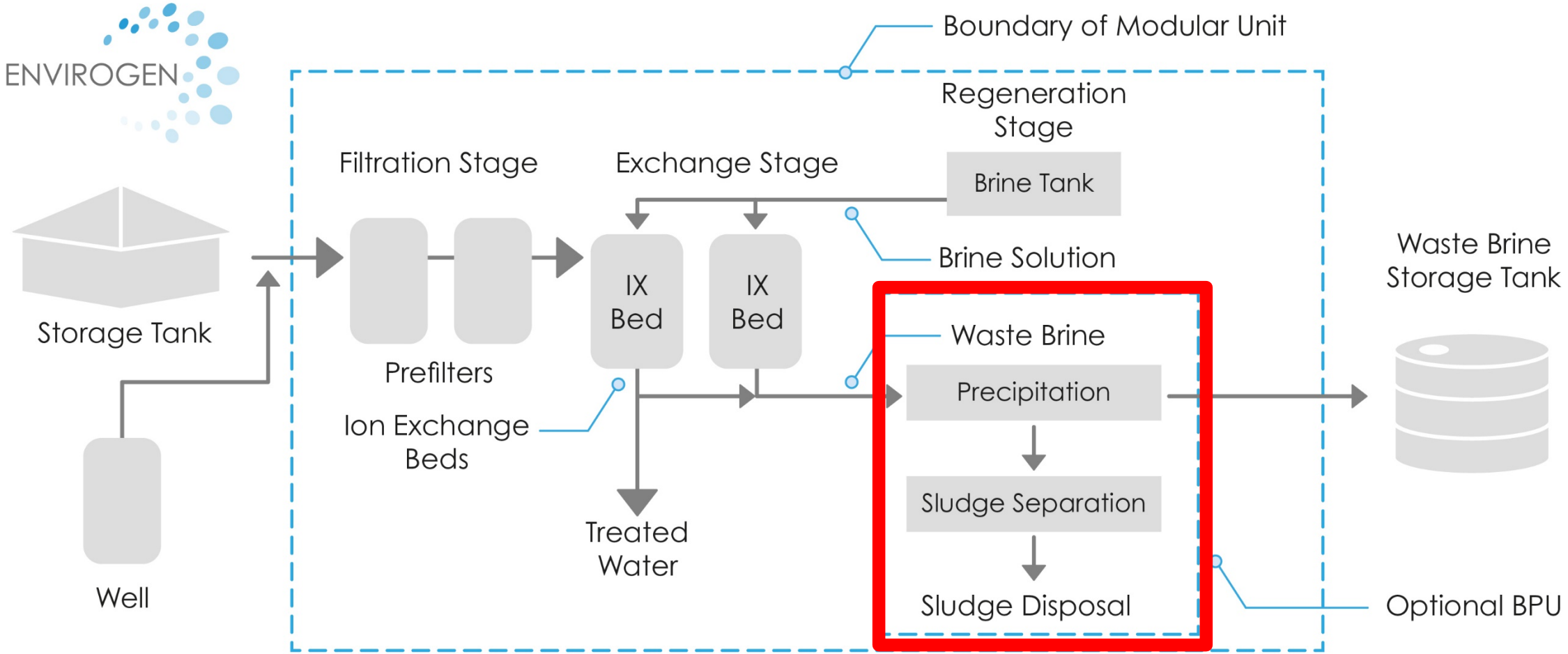
- Replaceable resin ion exchange system
  - Applied to low flow applications
  - Low capital cost
  - Point of Entry (POE) applications
  - Process monitoring with local alarms
- Unit major components
  - Pre-filtration
  - Lead-lag vessel
  - Post- Chlorinator
  - 500 gallon internal storage tank, delivery pump with pressure accumulator
- Options- Environmental control, telemetry, external feed tank, 3rd iX vessel polisher
- Space requirements
  - 10’ x 10’
  - Modular design

Contaminant Treatment

Metals


ENVIROGEN
Existing Well Pumps
Hexavalent Chrome Laden Water
Non-Regenerable
iX
iX
OPEX $$$
New Media
Used Media
Chemicals
Regenerable
iX
iX
iX
OPEX $$
Chemicals
Liquid Hazardous Waste
Regenerable with Waste Conditioning (BPU)
iX
iX
iX
OPEX $
Salt
Chemicals
Liquid Non-Hazardous Waste Brine
Tri-valent Chrome (solid) Waste
Existing Delivery System Hexavalent Chrome Free Water

Key Requirement



California Permitted Hexavalent Chrome Treatment Plants

Wells 203/303, Salinas, CA

Life-Cycle Cost Information

Life-Cycle Cost Considerations

- Capital Costs
  - Flow dependent
  - Containerized or in a building
  - Base cost for core infrastructure (i.e., engineering, controls, PLC, fabrication, etc.)
  - Resin type-Water chemistry dependent
- Operational Costs
  - Water chemistry dependent
  - Site specifics
    - Haul off waste
    - Direct pumping to a POTW
    - Direct pumping to a brine line (to ocean)
    - Deep well injection, drying/evaporation ponds, others
  - Operated continuously or via an on-needed basis
  - Level of monitoring required
  - On-site personnel requirements

Life-Cycle Cost Considerations

- Capital Costs
  - SimPACK: Equipment is $1.5K/gpm of treatment capacity (economy-of-scale above 1000 gpm)
  - MinX: Equipment is ~$0.5M (25-150 gpm)
  - Volatile cost
    - Resin-$250+/$ft^3$ depending on resin type, manufacturers, availability, etc.
- Operational Costs
  - Salt costs: $150/ton including freight
  - Disposal of non-hazardous brine
    - Haul off waste of non-hazardous brine-$0.35/gallon
    - Direct pumping to a POTW- Variable and site specific
    - Direct pumping to a brine line-Variable and site specific
    - Evaporation ponds-Variable and site specific
  - On-site personnel-3x per week
    - Dependent on the operational usage and the regulator requirements

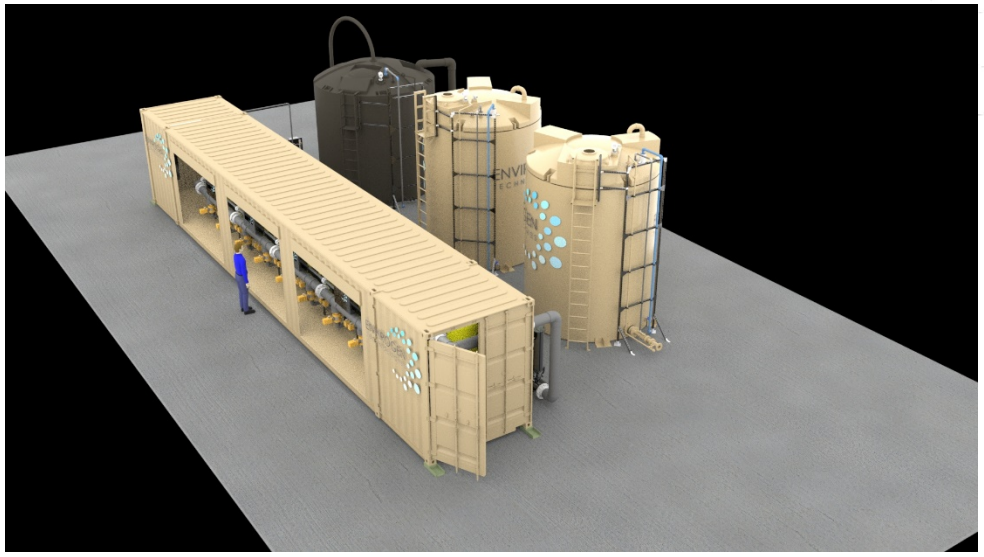
IX Innovation

Regenerable IX Process Improvements

- Goals
  - Waste reduction 35%
  - Salt usage reduction 25%
  - Mass balances and process simulations indicate goals achievable
- Evaluation areas
  - BPU integration work critical
    - Secondary technologies at lower flowrates to reduce waste volume further
      - Nanofiltration/Reverse Osmosis
      - Low Temperature Distillation
      - Electrodialysis
      - Chemical Treatment
  - Waste stream segregation using existing advanced regeneration controls
  - Conductivity measurement used for rinse control
- Demonstration Tests: Pilot- and Full-Scale Systems
  - City of San Fernando
  - Quiet Oaks Mobile Home Park

Conclusions

- The SimPACK and MinX regenerable IX designs have proven cost-effective for nitrate and metals water treatment for two decades.
- Several improvements in the past five years have resulted in even more efficient and simpler to operate systems.
- The life-cycle costs are site specific, highly dependent on flowrate, type of operation, and water chemistry.
- One nitrate treatment plant in Maui has been successfully operating continuously since 2019, and another is coming on line in the Summer, 2023.
- Innovations are continually being developed to reduce salt usage and waste brine production.



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QUESTIONS?/MAHALO