Application of Electrokinetic Remediation (Lasagna) Under an Active Industrial Facility

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Site Conditions

- Low permeable soils consisting of lacustrine clay deposits to a depth of 70-90 feet bgs.
- Water table 2-7 feet bgs.
- Soil and groundwater contaminated with TCE (several DNAPL zones) and other solvents from previous industrial activity.
- Plumes located around and under active industrial buildings resulting in VI pathway
- 3rd Party now owns the site – negotiations between client, site owner and state regulators

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RCRA Program

- RCRA Facility Investigation – 2003-2005
  - Soil and groundwater testing indicated 3 contaminated areas, 2 required corrective action

- Corrective Measures Study – 2006
  - Recommended Lasagna systems for source treatments in Area-1 and Area-2
  - MNA for plumes

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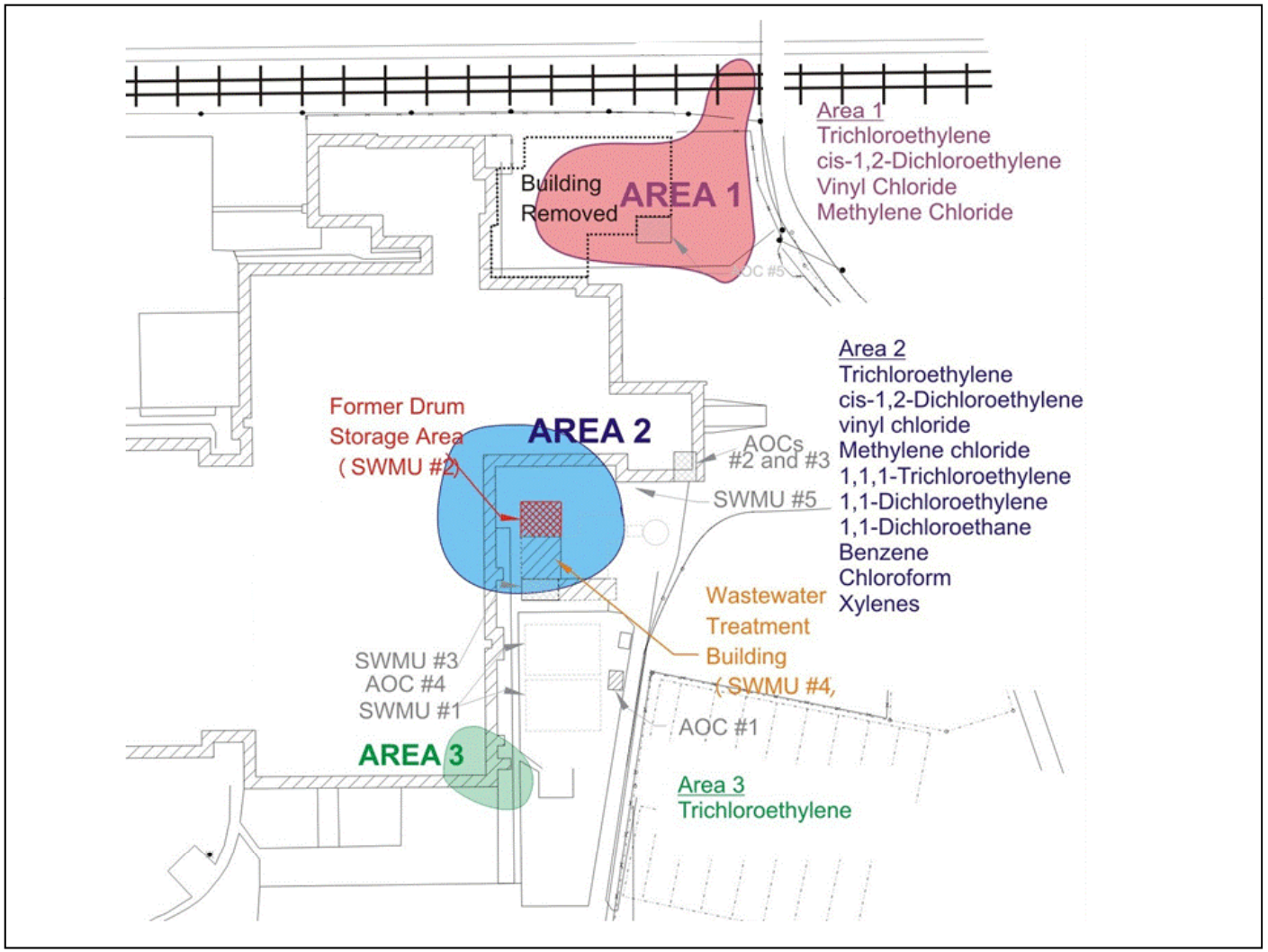
3- Areas of Contamination



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RCRA Program (cont)

- Corrective Measures Implementation
  - Active remediation (Lasagna) operations October 2008 – December 2011
  - Groundwater use restrictions
  - Site use restrictions

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Remediation Goals

- Protect human health and safety
- Reduce direct contact risks in sources areas and inhalation risks in source areas and indoor air
- Mass removal in source areas, followed by MNA
- Minimize impacts to facility and production during installation and operation of Lasagna

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What is Lasagna?

- Electrokinetic remediation: applying a DC electric field through planar electrodes
- Invokes electroosmosis and electromigration to mobilize contamination
- Soil warming through resistive heating (up to 100 C) which helps mobilize pure phase TCE

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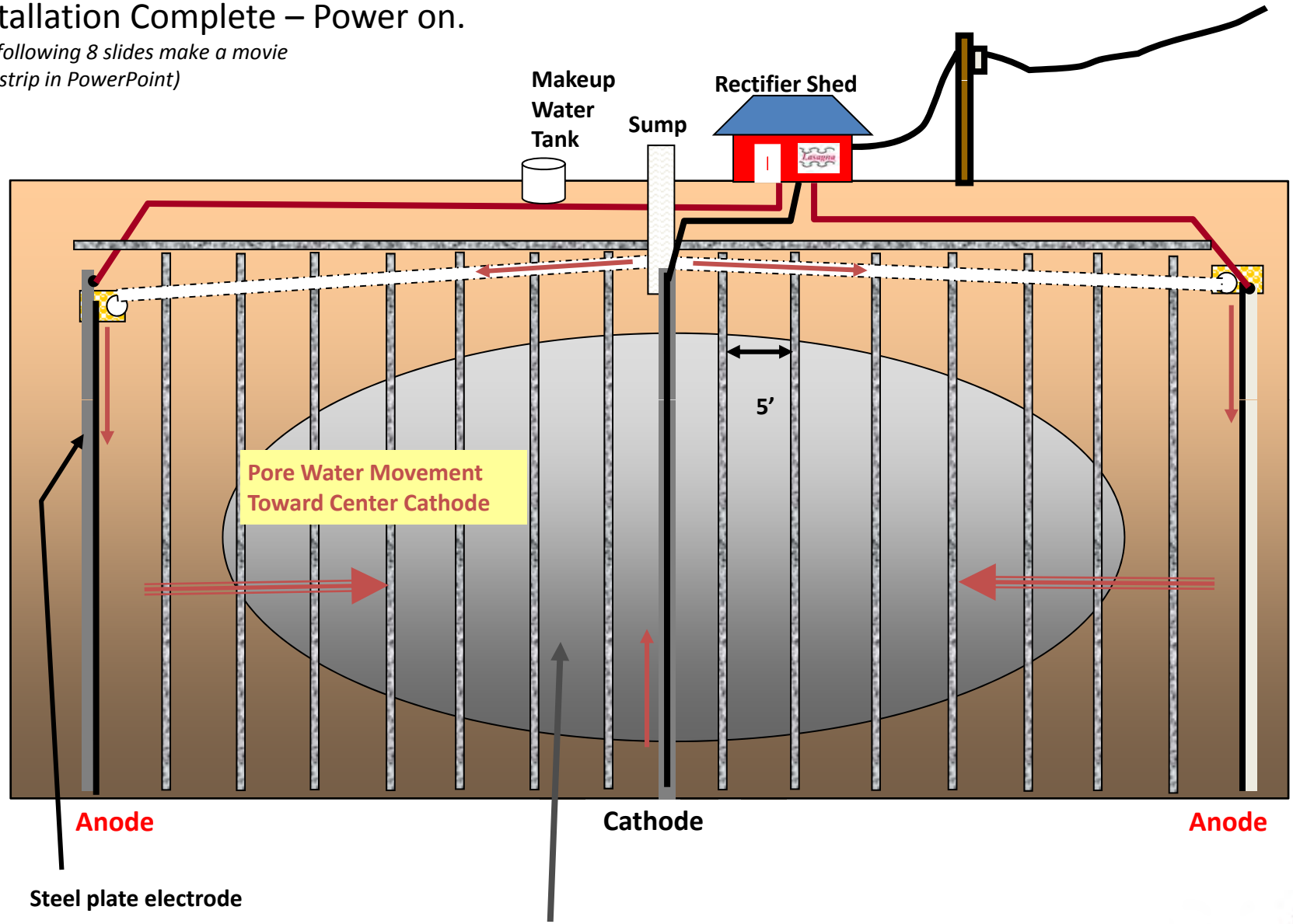
Installation Complete – Power on.

(the following 8 slides make a movie type strip in PowerPoint)



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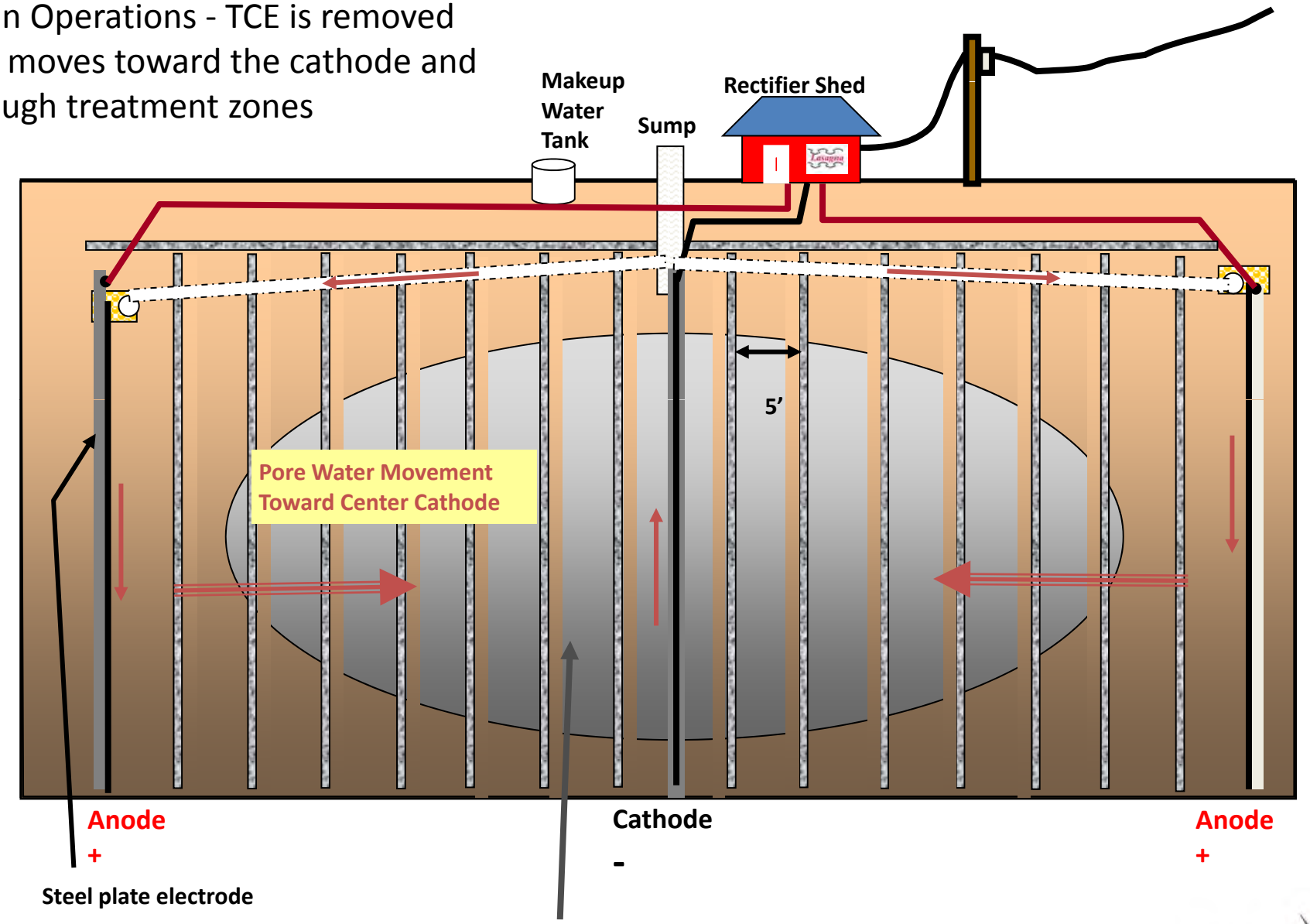
Begin Operations - TCE is removed as it moves toward the cathode and through treatment zones



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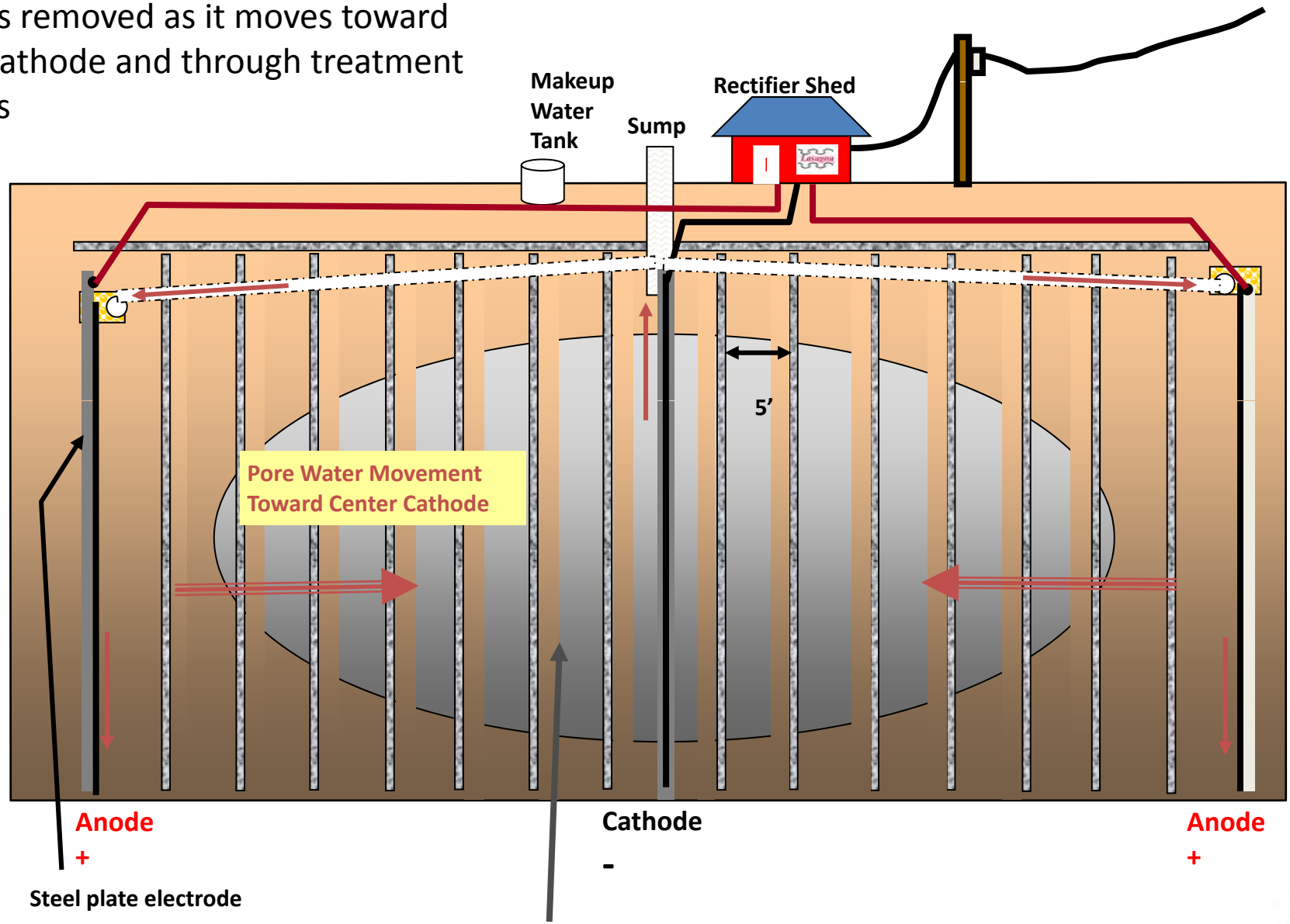

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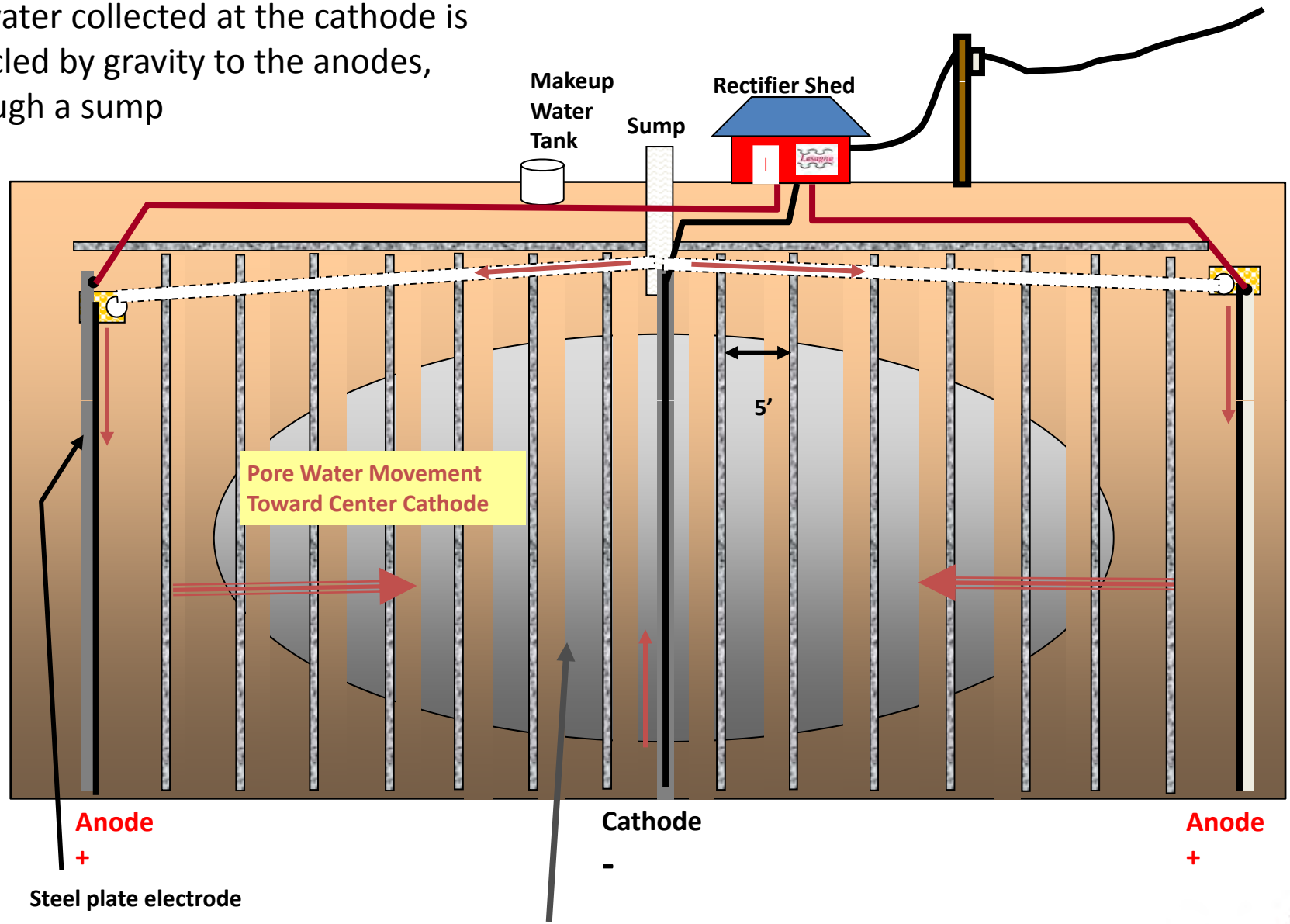
EO water collected at the cathode is recycled by gravity to the anodes, through a sump



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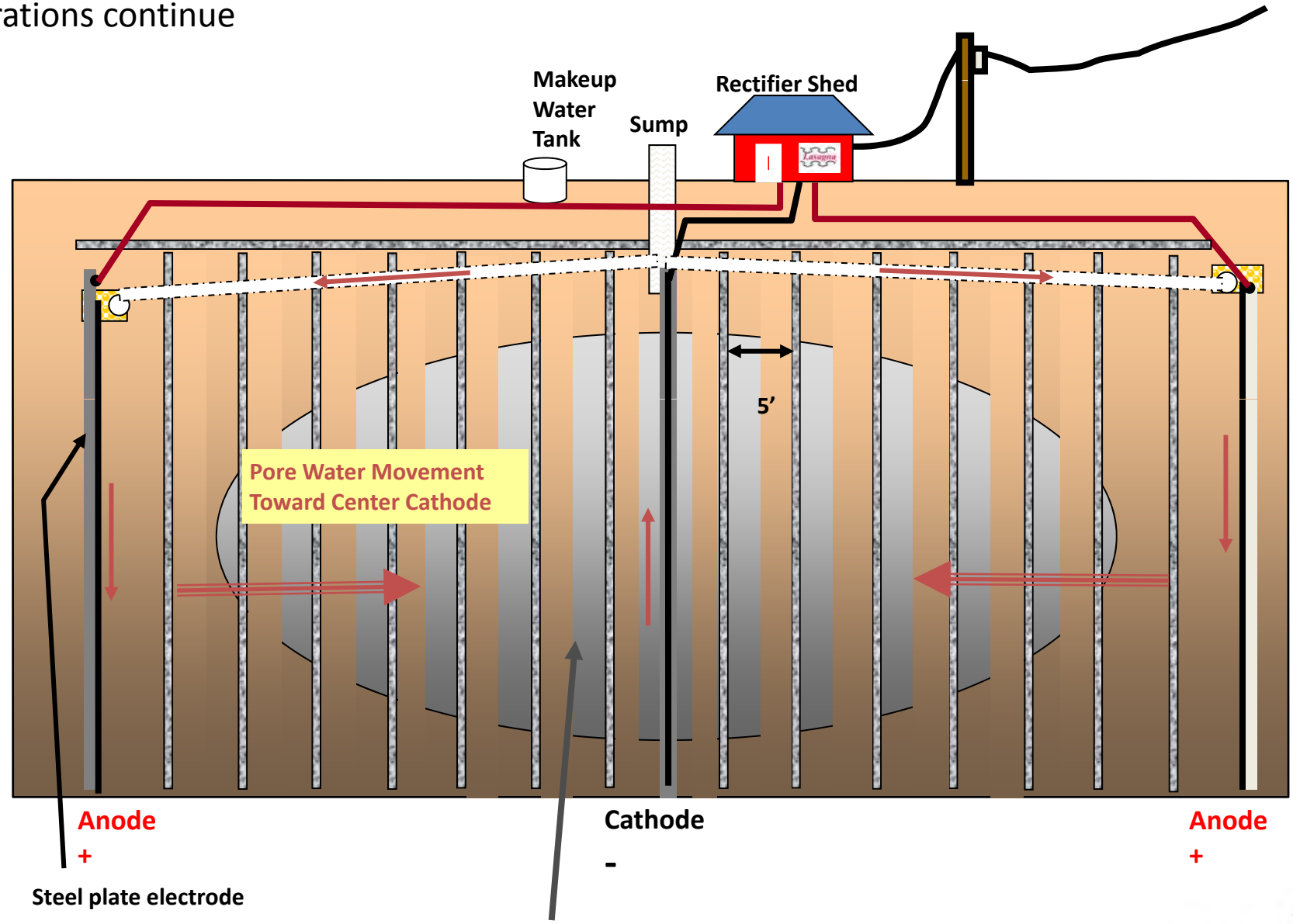
Operations continue



TCE Contamination

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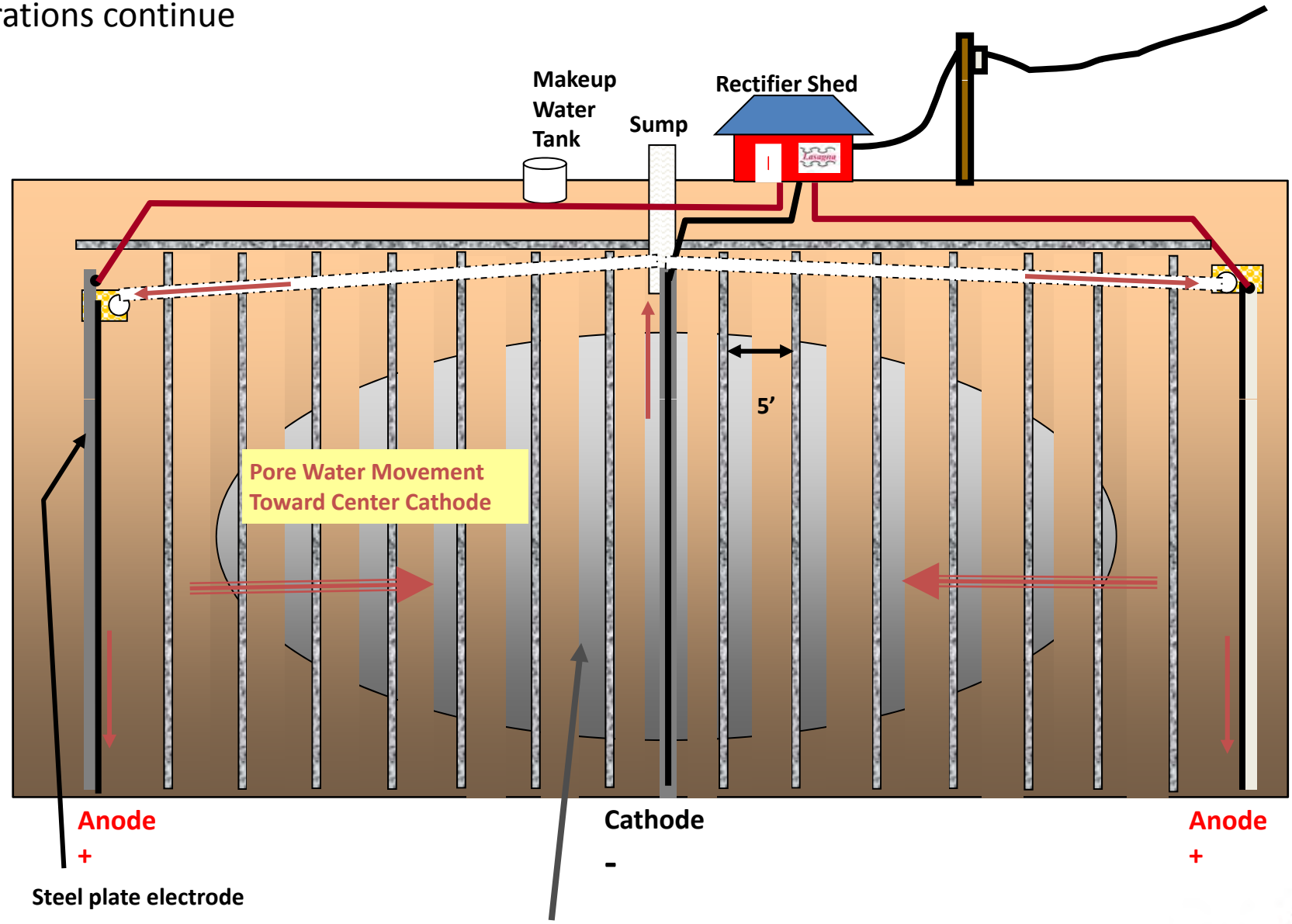
Operations continue



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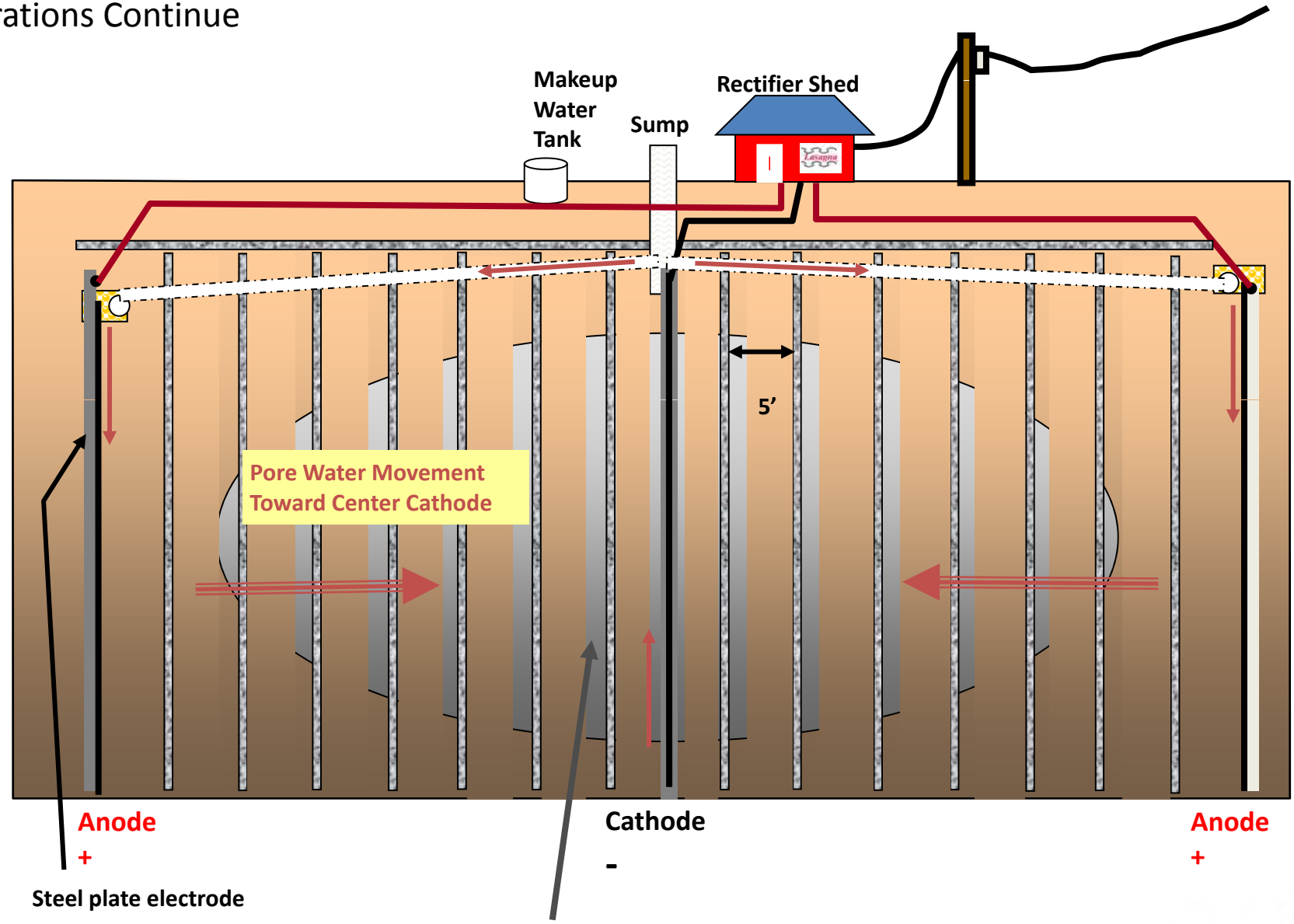
Operations Continue



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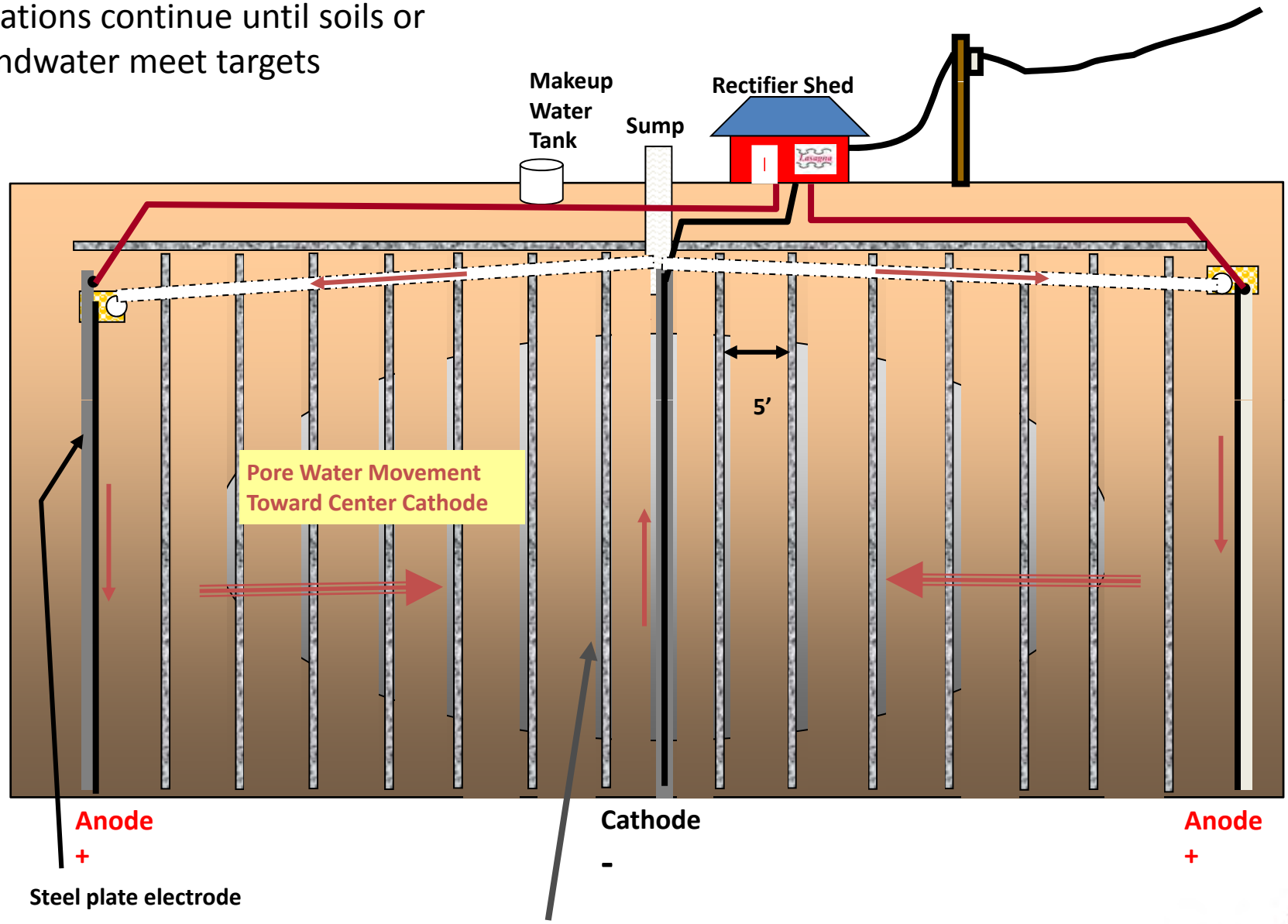
Operations continue until soils or groundwater meet targets



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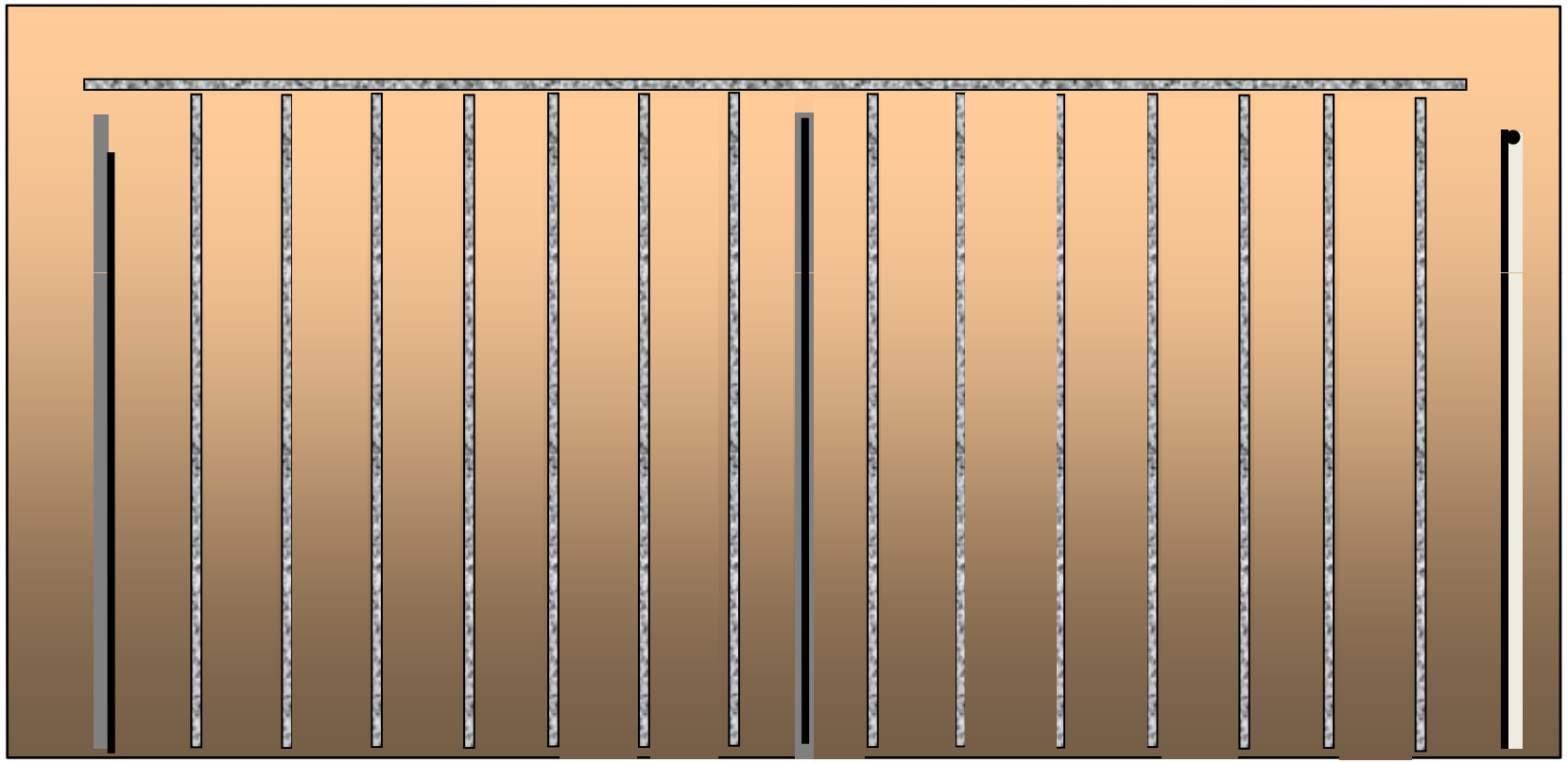
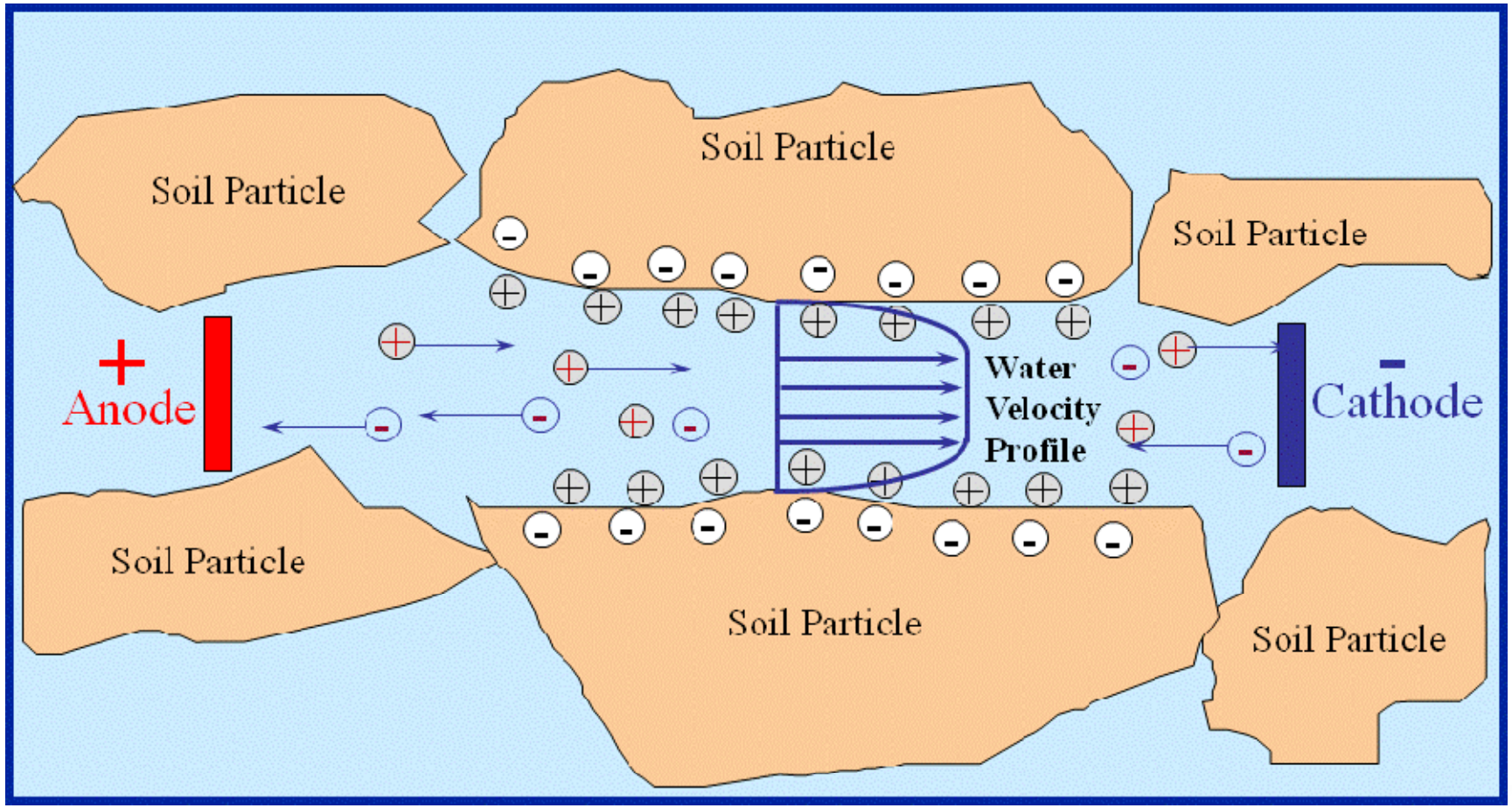
Operations Complete – Aboveground equipment is removed and treatment materials remain to treat residuals



Principles of EK



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+/- of EK

+ Independent of pore size or hydraulic conductivity
+ Useful in low permeability or heterogeneous soils
+ Extremely thorough – works on the pore level
+ Relatively efficient in clay
+ Treatment is done *in-situ*
+ Low operation costs
+ Straight forward scale up

- Slow (cm/day rates)
- Consumes electrodes
- Influenced by large convective gradients
- High installation costs
- Need to manage stray current
- Relatively unknown

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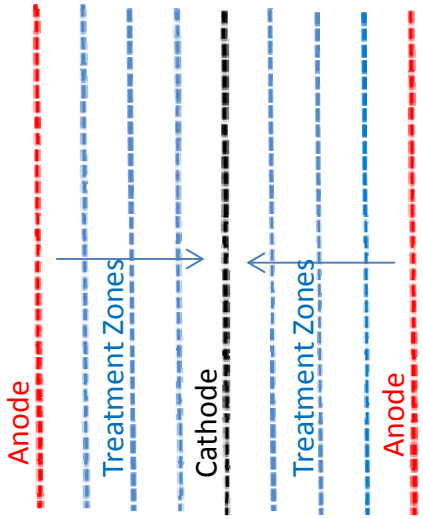
Lasagna Design

- Anode at east/west boundaries, cathode at center
- Pore water and contamination migrate toward the central cathode
- Contamination is reduced by treatment zones



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Lasagna™

Lasagna Installation

- Electrodes of steel plate and wickdrain, side by side to make effective planar electrode rows
- Treatment rows, installed parallel to electrodes and spaced 5 feet apart consisted of 50% ZVI in kaolin clay slurry
- Emplacements are direct push so no waste soil or spoils to manage and minimal exposures to contamination
- EO water is recycled by gravity
- All emplacements, wiring and plumbing installed below grade

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Lasagna Operation

- Large DC rectifier supplied up to 200 volts and 600 amp to Area-1
- Smaller DC rectifier supplied up to 200 volts and 400 amps to Area-2
- Soil temperature (resistive heating) was maintained at 80-90°F
- Periodic soil sampling monitored performance
- Average DC power delivered was 75kW for Area-1 and 15kW for Area-2

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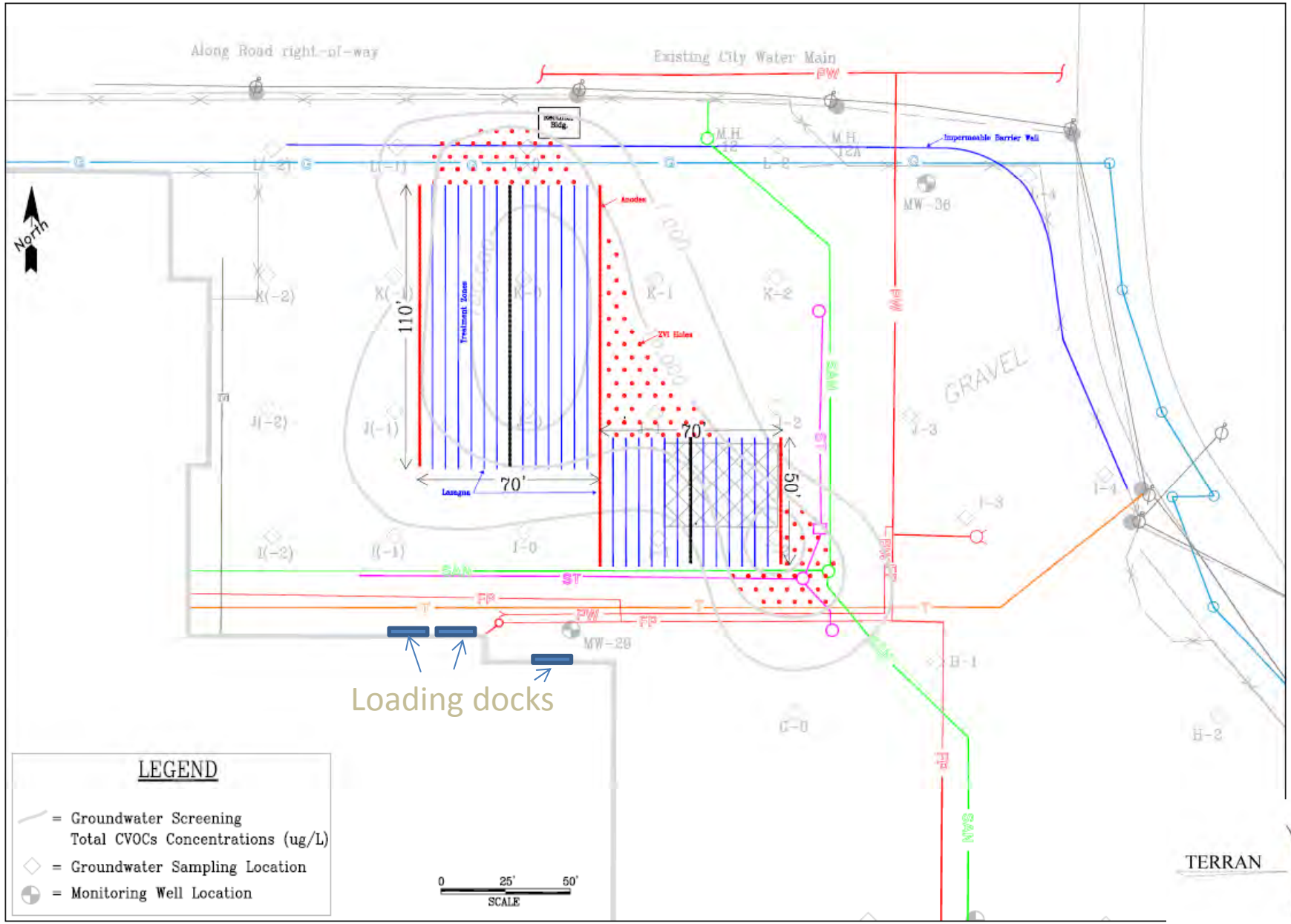
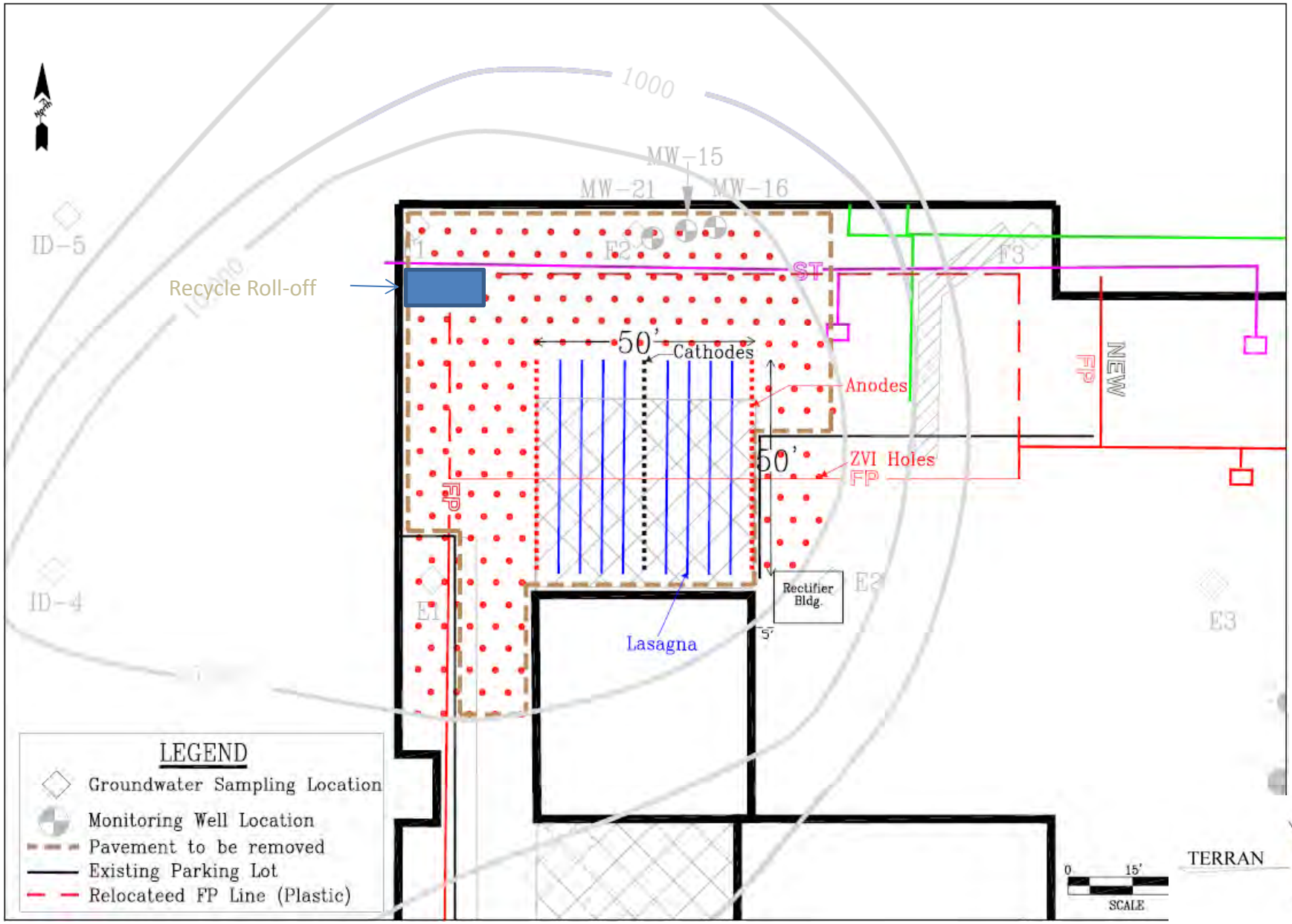
Area-1 Remediation Plan



Area-2 Remediation Plan



Site Prep

- Existing pavement/blacktop was removed, crushed and placed back as working surface
- 480V 3-phase power was brought in for rectifier feed
- Utility barn in each area served as rectifier shed with DAQ systems and cable modems

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Equipment used to install Lasagna Electrodes

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Equipment used to install Lasagna Treatment Zones

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Picture showing tops of steel plate electrodes and wickdrains. Steel plates are welded to buss bars and wicks are in connection with drains for EO water recirculation

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Covering up electrode trench

Completed Area-1

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Completed Area-2

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Area-1 Lasagna Performance

Average Concentration (ug/kg) at Soil Sampling Events					
	Performance	Performance	Verification		
Area-1	**Sep-09**	**Jul-10**	**May-11**		**Reductions**
Number of samples	16	16	44		
TCE Avg	11,929	6,501	2,887		76%
cis-DCE Avg	2,796	810	1,398		50%
VC Avg	116	41	33		72%

Statistical results from within Lasagna areas only

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Area-2 Lasagna Performance

Average Concentration (ug/kg) at Soil Sampling Events					
	Performance	Performance	Verification		
Area-2	**Sep-09**	**Jul-10**	**Jul-12**		Reductions
Number of samples	8	8	24		
TCE Avg	93,249	83,860	15,908		83%
cis-DCE Avg	28,093	5,750	10,566		62%
VC Avg	699	396	627		10%

Statistical results from within Lasagna areas only

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Conclusions

- Mass removal targets met
  - >76% removal in Area-1 Lasagna footprint
  - >83% removal in Area-2 Lasagna footprint
- Direct contact risk-based targets were met in all treated areas

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Conclusions (cont)

- Indoor air sampling results remain stable well below risk thresholds
- Groundwater trends are steady or decreasing across the site
- Facility was able to maintain full production during installation and operation of Lasagna systems
- 5-year review lead to continued GW and IA monitoring with reduced sampling plans

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