

# ***HQ Air Force Center for Environmental Excellence (AFCEE)***

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## **Groundwater Circulation Well Technology Review**



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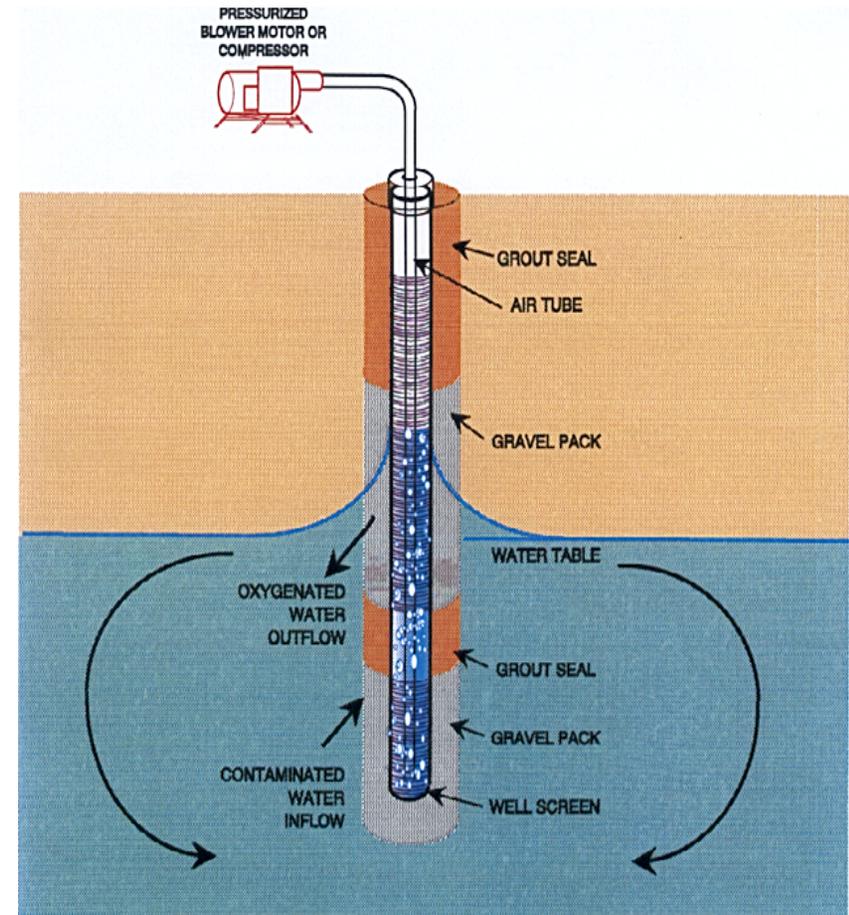
**Jim Gonzales  
AFCEE  
Technology Transfer Division  
31 Jan 01**



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# GCW BASICS

- Also Called Recirculation Wells, UVB, NoVOCs, Density Driven Convection, etc.
- Groundwater is Extracted From One Depth, Treated in Well, Usually Aerated, and Discharged to a Different Depth



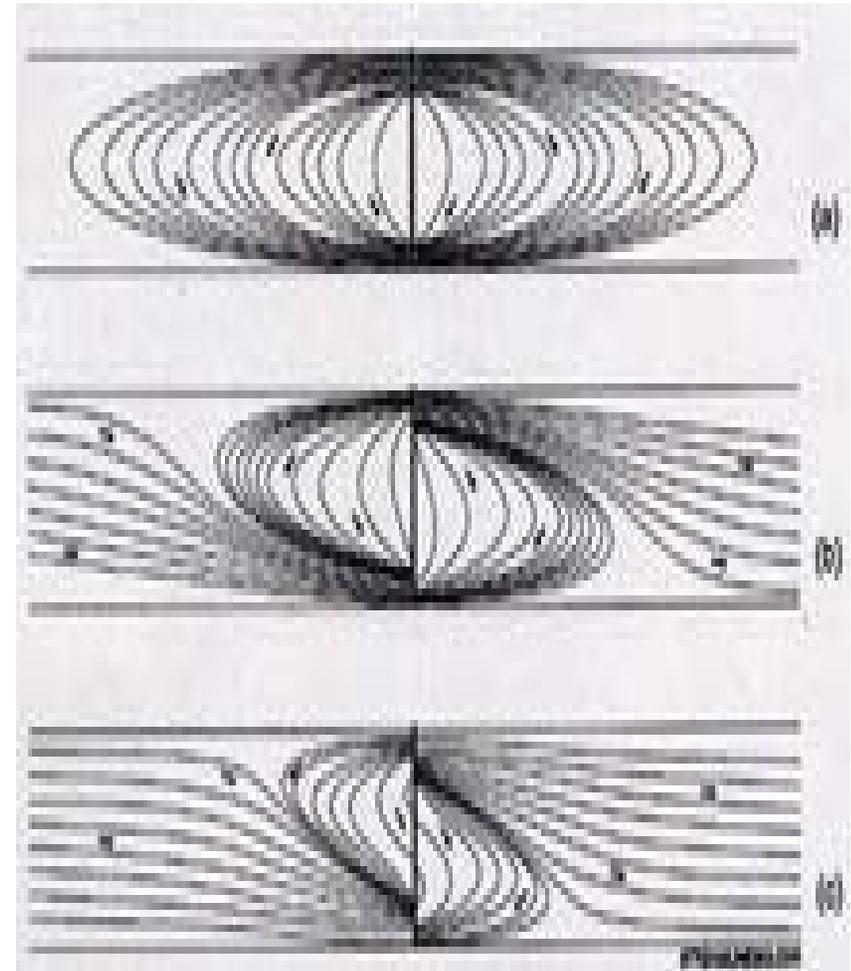
UNITED STATES PATENT NUMBER: 5,425,598



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# GCW - BASICS

- Objective is to develop “Recirculation Cell” in the aquifer
- Generally, relies on multiple passes through GCW in order to achieve “significant” reductions in concentrations

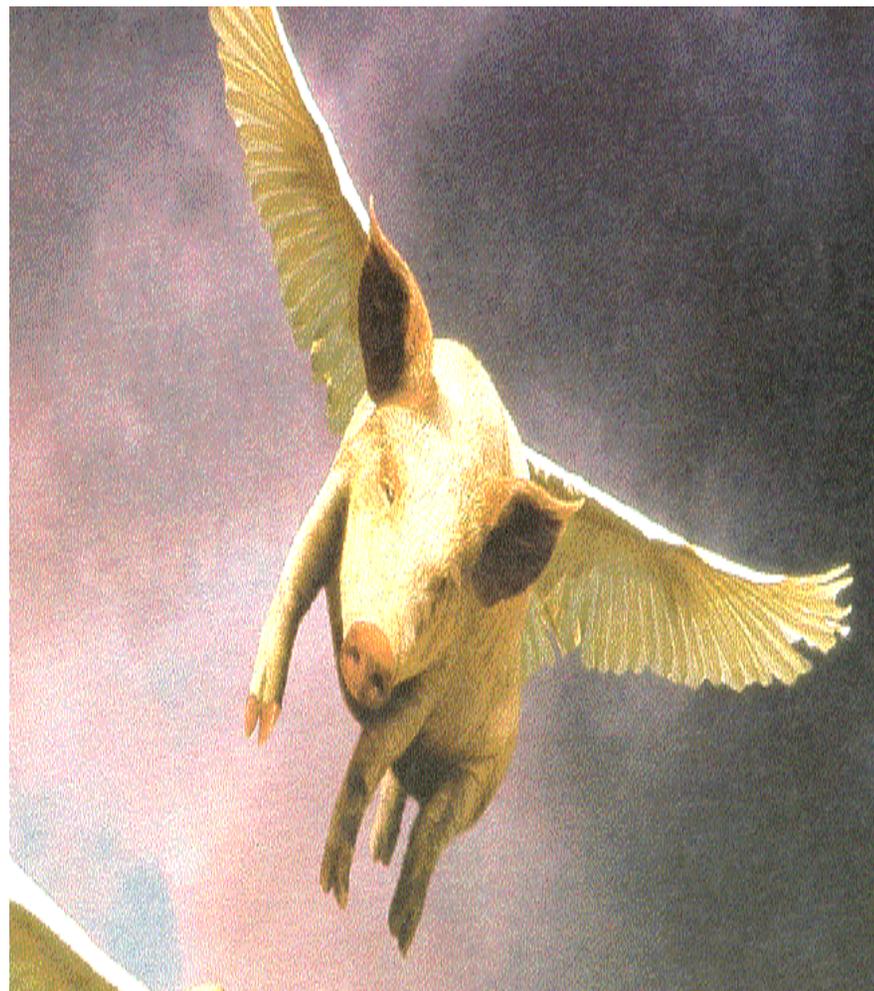




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# ***GCW - Demonstration Sites***

- **Cape Canaveral AFS**
- **Edwards AFB**
- **Hill AFB**
- **Keesler AFB**
- **March AFB**
- **Massachusetts Military  
Reservation (MMR)**
- **North Island NAS**
- **Oceana NAS**
- **Port Hueneme**
- **Tyndall AFB**
- **Yuma MCAS**
- **Others**





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# ***AFCEE Position on GCW Technology***

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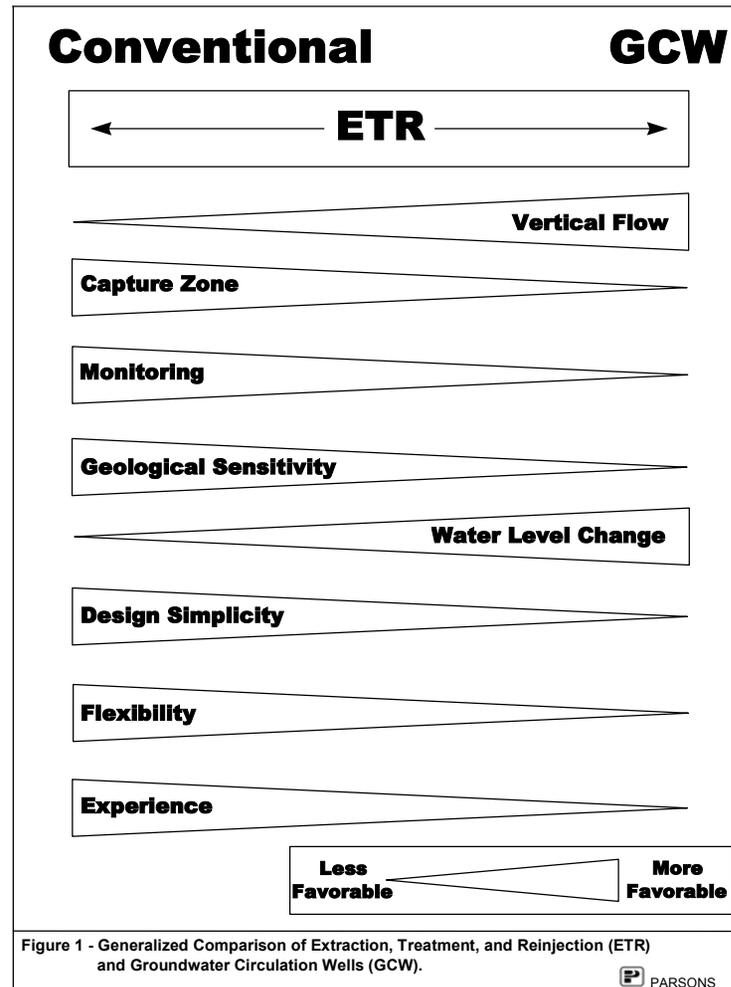
- **Special case of Extraction, Treatment and Re-injection (ETR):**
  - single well used for extraction and re-injection
  - treatment occurs down hole versus aboveground
- **GCW is not a wholly different process**
  - simply depends on chosen point of re-injection
  - ETR systems can be designed in *close-coupled configuration* with traits similar to GCW





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# Extraction-Treatment-Reinjection Continuum





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# GCW - Vendor Claims

## ■ CLAIMS:

- More Effective Than Pump and Treat (PnT)
- Lower Cost Than PnT
- Fewer Wells Than PnT
- Lower Energy Requirements Than PnT
- All Components Below Ground
- Permitting Advantages Over PnT

## ■ AFCEE EXPERIENCE:

- Not substantiated
- Not substantiated
- Not substantiated
- NO!
- Yes, but ...
- Yes, but ...



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# ***GCW - More Effective Than Pump and Treat?***

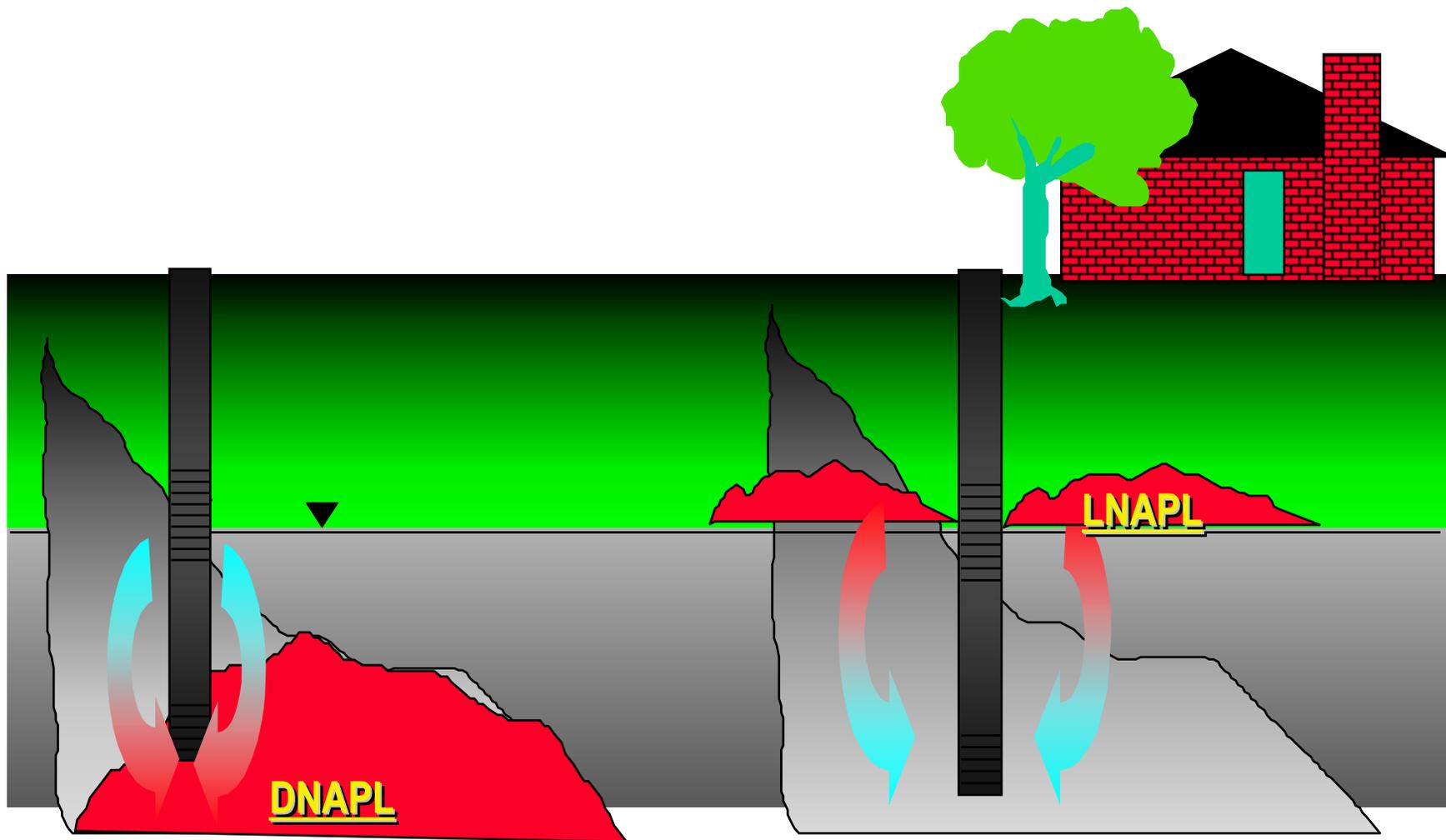
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- **Vertical flow has potential to increase removal of NAPL**
  - **However, if no highly contaminated source zone exists, then no value in inducing vertical flow**
- **Radius of Influence is generally less (at given flow rate)**
  - **Portion of effluent is recirculated**
    - **Represents previously treated Groundwater**
  - **Volume Limited with respect to first pass fraction**
- **Recirculation promotes dilution (less efficient)**
  - **Mass Flux (mg/min) = Flow rate (L/min) X Conc. (mg/L)**
  - **Mass Loading Limited due to recirculation**
- **Difficult to Assess Advantages Accurately**
  - **Usually Based on Modeling or Indirect Evidence**



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# GCW - Vertical Flow Advantage with NAPLS



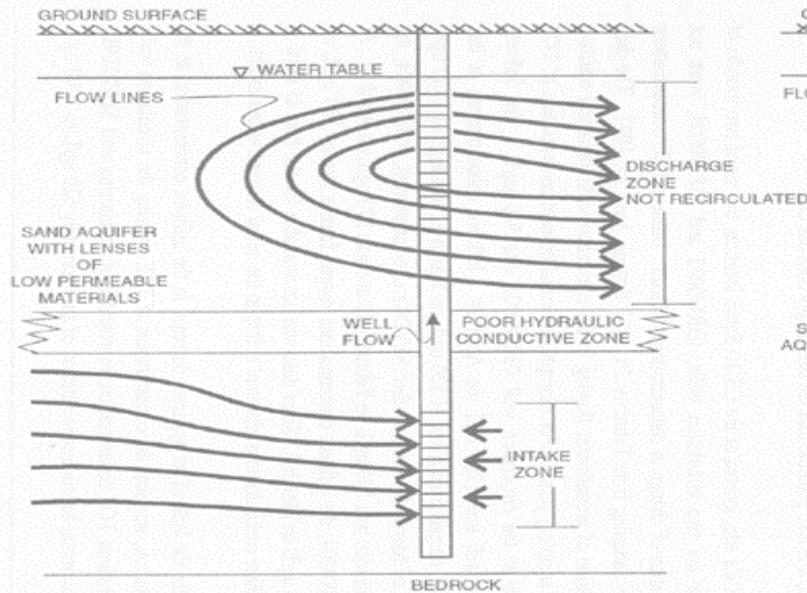
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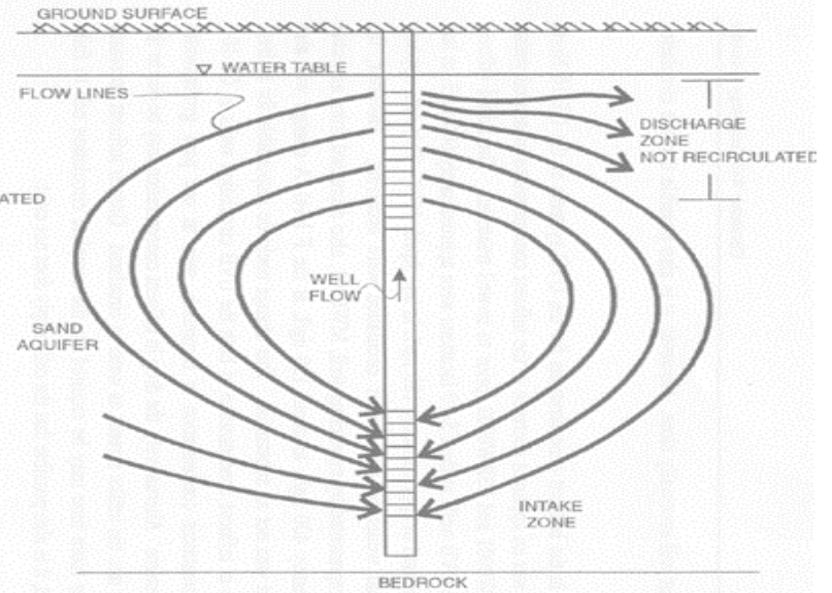
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# GCW - NAPL Dissolution

## Without Capture = Mobilization



CASE 1  
RECIRCULATION IN  
ANISOTROPIC AQUIFER



CASE 2  
RECIRCULATION IN  
ISOTROPIC AQUIFER

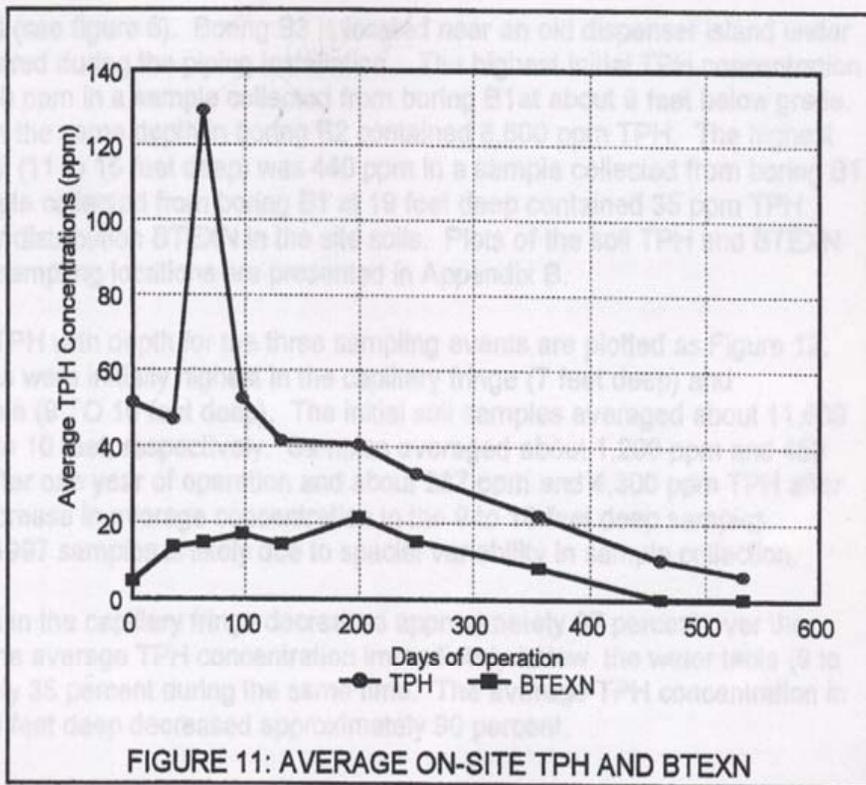
PARSONS PARSONS ENGINEERING SCIENCE, INC.	
PROJECT TITLE MASSACHUSETTS MILITARY RESERVATION RECIRCULATION WELL TECHNOLOGY EVALUATION	
DEPT ENVIRONMENTAL ENGINEERING	DWG NO 731475-01000
CONDITIONS INFLUENCING ESTABLISHING RECIRCULATION	
SCALE 1/4"	DATE FEB 1997

GRAPHICSMMRCASE.CDR

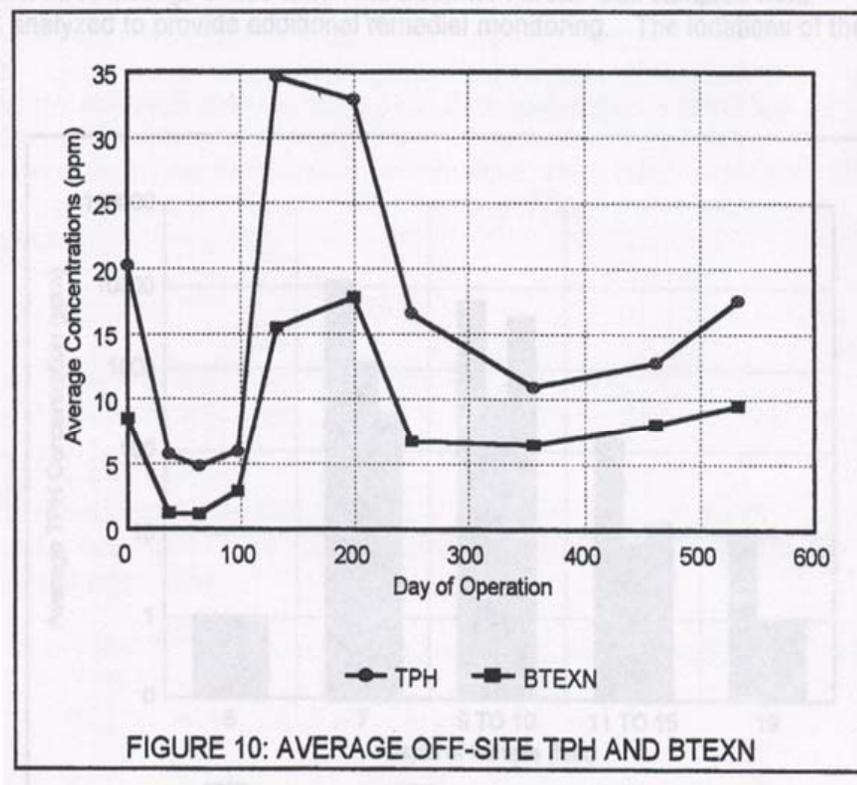


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# GCW - NAPL Mobilization at Keesler AFB MS



## Source Area Concentrations



## Down Gradient Concentrations



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# ***GCW - Lower Cost Than Pump and Treat?***

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- **Little Direct Field Evidence**
- **Cost of Monitoring GCW>PnT**
  - **Complexity**
- **Cost of Engineering GCW>PnT**
  - **Limited vendors**
- **Cost of O&M GCW>PnT**
  - **Down-hole**
- **Permitting costs GCW<<PnT**
- **Energy (Pumping Cost)?**
- **Number of Wells?**



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# ***GCW - Fewer Wells Than Pump and Treat?***

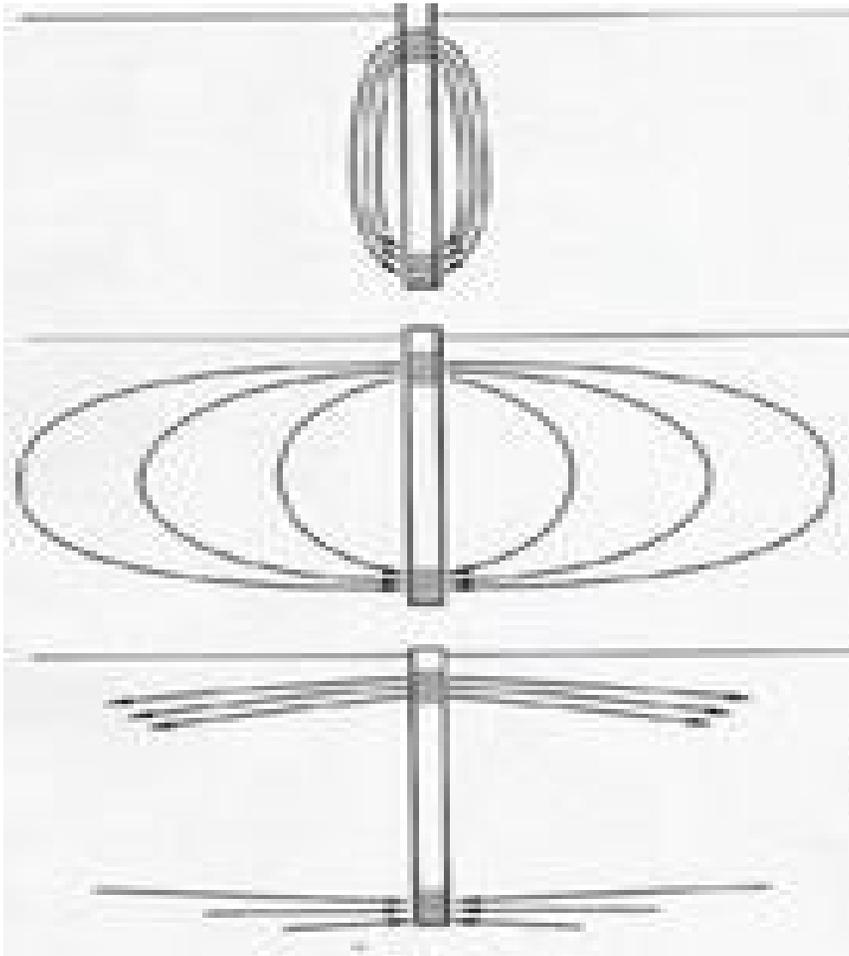
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- **GCW Single Well**
    - **Extraction & injection in same well**
    - **However, GC Well is More Expensive**
      - **More complex**
      - **Down-hole components**
      - **Larger diameter**
      - **Multiple screens**
  - **Radius of Influence of GCW < PnT (at given flow rate)**
    - **Volume limited due to Recirculation**
    - **Mass Loading limited due to Recirculation**
  - **Therefore, additional wells may be required**
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# *GCW - Radius of Influence*



- GCW circulation geometry is effected by anisotropy
  - Anisotropy is basically the ratio of  $K_h:K_v$
- Short Circuiting Condition
  - $K_h:K_v = 0$  to 3
  - Ratio too low
- Ideal Conditions
  - $K_h:K_v = 3$  to 10
  - Optimum Ratio
- No Circulation Condition
  - $K_h:K_v = >10$
  - Ratio too high



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# ***GCW - Lower Energy Requirements Than Pump and Treat?***

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- **Energy costs are proportional to height to which water must be lifted for treatment**
  - **However, Hill AFB study indicated GCW at 100 ft. would require more energy than PnT**
- **More Air is Required for Co-current Stripper**
  - **Most Air Strippers use Counter-Current Flow**
    - **Air and liquid flow in opposite directions**
    - **More efficient, requiring a lower Air:Water ratio**
    - **99.9% efficiency air strippers widely available**
  - **Most GCW systems use Co-current Flow**
    - **Air and liquid flow in the same direction**
    - **Less efficient, requiring a higher Air:Water ratio**
    - **70-93% operational stripping efficiencies generally seen**



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# ***GCW - All Components Below Ground?***

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- **Not Always**
  - **Carbon Canisters for off-gas capture**
  - **Down-Hole Carbon Canisters have been discussed**
- **Also Possible with Pump and Treat**
  - **Air Stripper could be placed in vault - if you wanted**



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# ***GCW - Permitting Advantages Over Pump and Treat?***

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- **YES - No Question!**
  - **“As long as groundwater is not brought to surface ...”**
  - **No re-injection issues**
  - **But EPA is taking notice**
  - **Things may change**

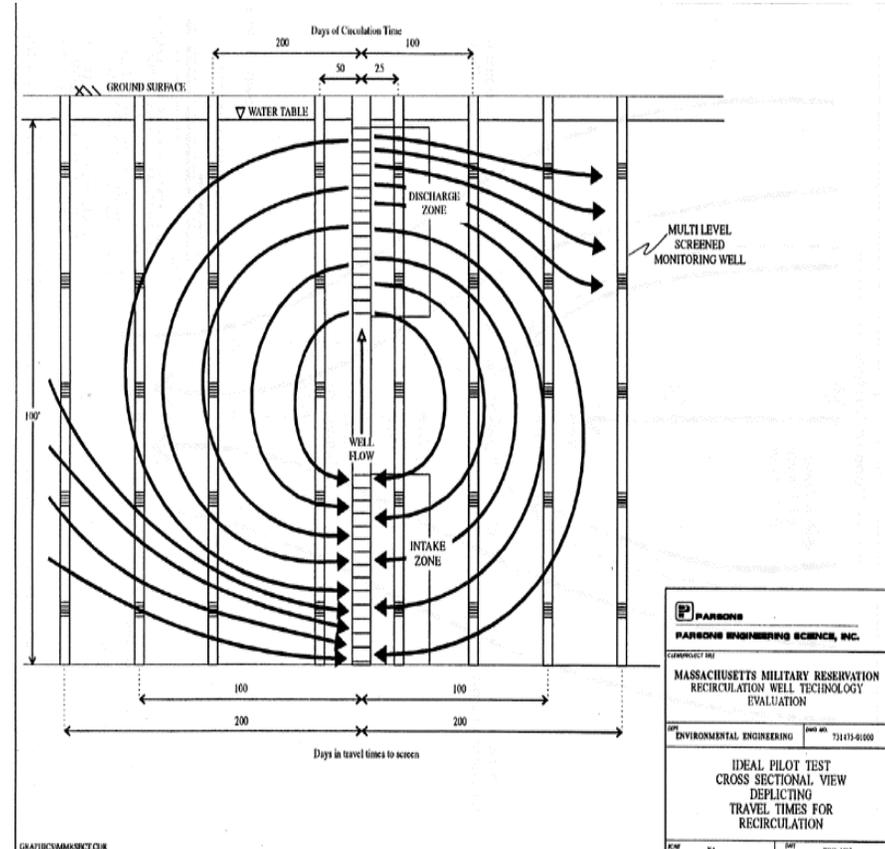
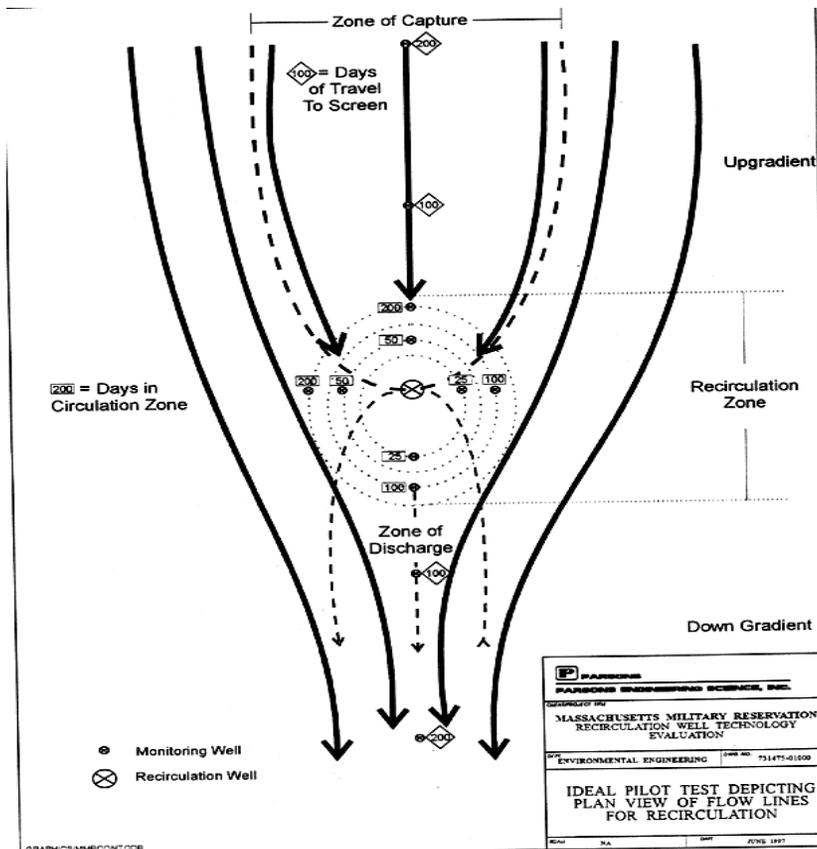


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# Other Issues: Monitoring Considerations

## PLAN VIEW

## CROSS SECTION





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# *Other Issues: Monitoring Considerations*

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- **Monitoring is more difficult than PnT**
  - **Recirculation Cell is very difficult to prove or quantify**
    - **Zone of Influence is 3-Dimensionally, Heterogeneous**
    - **Requires extensive tracer studies**
    - **Often relies on pressure transducers, changes in gradient heads, and extensive modeling**
  - **GCW process monitoring is difficult**
    - **Geochemical changes within aquifer**
    - **Mass balances difficult to calculate**
      - **Degree of Recirculation**
      - **Inaccurate flow rate measurements**
      - **Mass = Concentration X Flow rate**
  - **Therefore, monitoring optimization maybe more difficult**
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# *Other Issues: O&M Considerations*

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- O&M is more difficult - Everything is down-hole
  - Assume Reliability(i.e., Mean-Time-Between-Failure) for PnT and GCW is equal,
  - Maintainability (Mean-Time-to-Repair) has to be greater due to down-hole nature of GCW
- Injection Well Plugging is more problematic
  - Iron
  - Carbonate
  - Biofouling
- Effluent screen & well replacement: GCW vs PnT
- Process Optimization may be more difficult due to operational and design limitations of GCW system



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***“What we got here is a failure to recirculate ...”***



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# ***GCW - an Emerging Technology?***

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- **10+ year old technology**
- **Not well understood or documented**
- **No widespread commercial acceptance**
- **Potential value for NAPL treatment unproven**
  - **Keesler AFB**
  - **Cape Canaveral AFS**



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# ***GCW - Reasons to Use***

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- **Vertical Flow for Improved NAPL Treatment**
- **Severe Permitting Problems**
- **A placebo needed**



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# ***Conclusion***

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- **There are good reasons for promoting the use of emerging or innovative technologies**
  - **When potential to either be more effective, or less costly than conventional technology there is logic in taking risk**
  
- **Unfortunately, no widespread potential for GCW to be either more effective or less costly than ETR**