Spring 2002

IPRO 304-b

Design of Pollution Control Devices for removal of VOC's from Ground Water

Professor Noll and Professor Abbasian
Chemical Engineering

Design of Pollution Control Devices for removal of VOCs from Ground-Water

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Outline

- **Problem Statement – Justin Van Gundy**
- **Specifications and Objectives – Adekunmi Keleko**
- **Methodology – Susan Ogunribido**
- **Decision Process – Susan Ogunribido**
- **Design and Results (Air Stripper) – Brian Kustwin**
- **Cost (Air Stripper) – Benjamin Cacace**
- **Design and Results (Carbon Sorption) – Nathaniel Brown**
- **Cost (Carbon Sorption) – Benjamin Cacace**
- **Cost Comparison – Ben Cacace**
- **Conclusions – Melissa Sarmiento**

The Problem

- Water in Wausau, Wisconsin is contaminated with VOC's
- Pose hazardous health risks
- Need to determine a unit operation that can remove VOC's effectively and cost efficiently
- TCE and PCE primary contaminants

Possible Unit Operations

- Air Stripping
- Carbon Adsorption
- Carbon Absorption
- Chemical or Biological Oxidation
- Reverse Osmosis

Background

- Examined Wausau Groundwater site
- Affects 6 of the City Well Field's production wells
- 35,000 residents depend on the well water
- 1982, half the wells were contaminated with high levels of VOC's
- Temporary carbon filter installed on one of the wells until two air strippers could be built
- Air strippers provided long-term solution to the contamination

Background

- Two sources of contamination:
  - Old municipal landfill on west bank of Wisconsin River (soils mainly contaminated with TCE)
  - Wausau Chemical facility property on east bank of Wisconsin River (soils contaminated with PCE, TCE, and other VOC's)

Methodology

- Absorption
- Adsorption
- Air stripping
- Reverse Osmosis
- Oxidation
  - Chemical
  - Biological

Decision Process

- **Reverse osmosis**
  - Infeasible because the membranes are not effective at removing lighter-weight VOCs such as TCE and PCE
- **Absorption**
  - Little information due to the poor prospects.
- **Chemical Oxidation**
  - High cost due to energy requirements, cost of hydrogen peroxide, and high capital cost of UV reactor systems.
- **Biological Oxidation**
  - High cost

Decision Process

Acceptable Processes

- **Adsorption**
  - Low cost
  - Efficiency
- **Air Stripping**
  - Low cost
  - Efficiency

Carbon Adsorption Design

Assumptions

- Transport Assumptions
  - Plug flow exists in the bed.
  - Loading rate and influent concentration are constant.
  - The Granular Activated Carbon is fixed inside the column.
  - Adsorption equilibrium can be described by the Freundlich Isotherm.

Assumptions Cont.

- Calculation Assumptions
  - Empty Bed Contact Time is ten minutes.
  - Bulk density of the carbon is 500 g/L
  - The Mass Transfer Zone is one meter in length.

Column Design Equations

- Column Area $$Total.Adsorber.Area(m^2) = n\frac{\pi D(m)^2}{4}$$
- Loading Rate $$Loading.Rate(m/h) = \frac{Flow.Rate(m^3/h)}{Total.Adsorber.Area(m^2)}$$
- Carbon Volume $$V_{Carbon}(m^3) = Flow.Rate(m^3/h) \times EBCT(h)$$
- Bed Depth $$Bed.Depth(m) = \frac{V_{Carbon}(m^3)}{s \times AdsorberArea(m^2)}$$
- Sidewall Depth $$Sidewall.Depth(m) = Bed.Depth(m) \times 1.5$$

Carbon Bed Design

- Freundlich Isotherm

$$q = KC_o^{1/n}$$

$$K = 27.4 mg/g$$

$$1/n = .61$$

- Bed Life

$$Bed.Life(BV) = \frac{q}{C_o - C_f}\rho$$

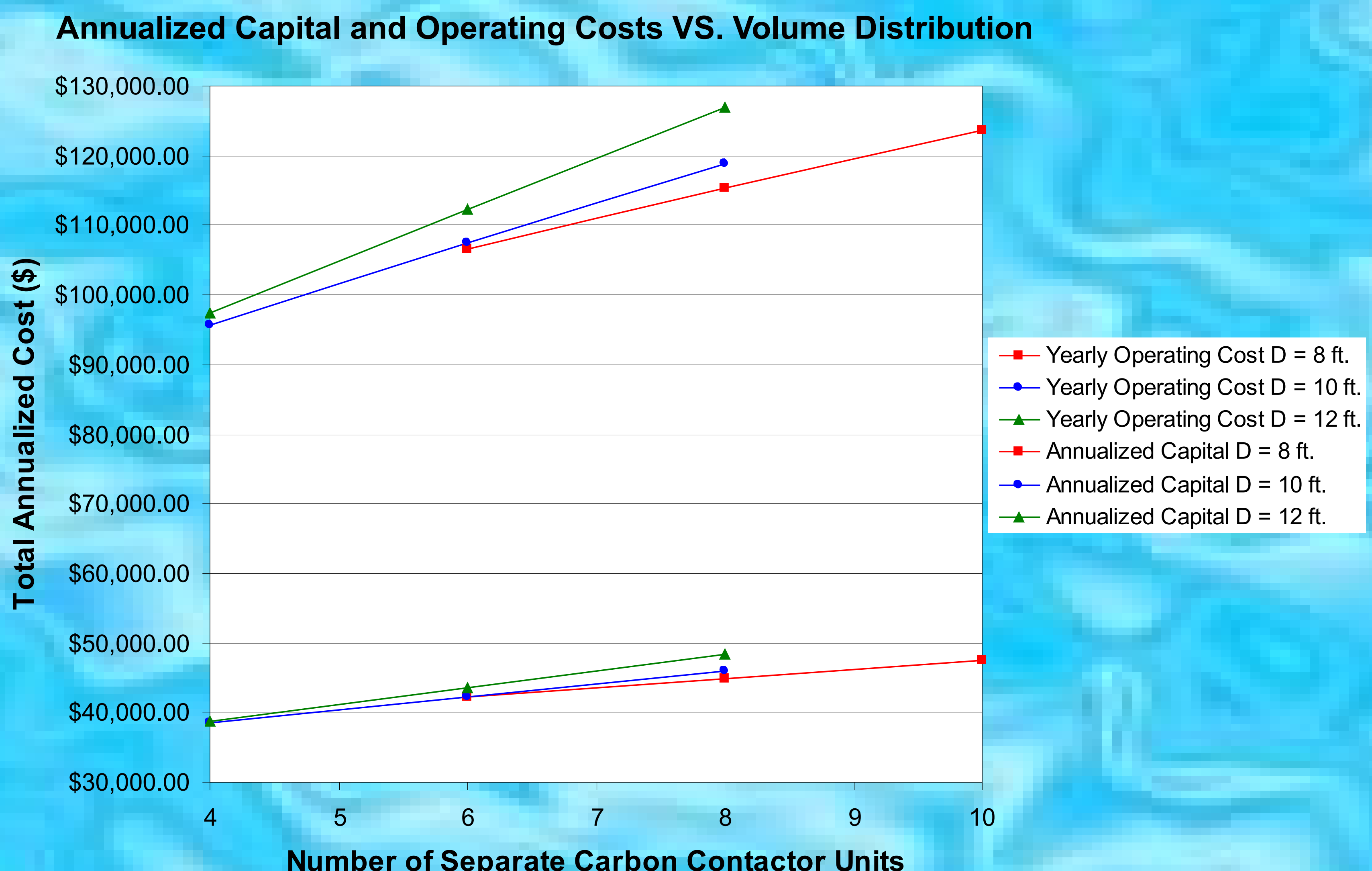
- Carbon Usage Rate

$$CUR(BV) = \frac{C_o - C_f}{q}\rho$$

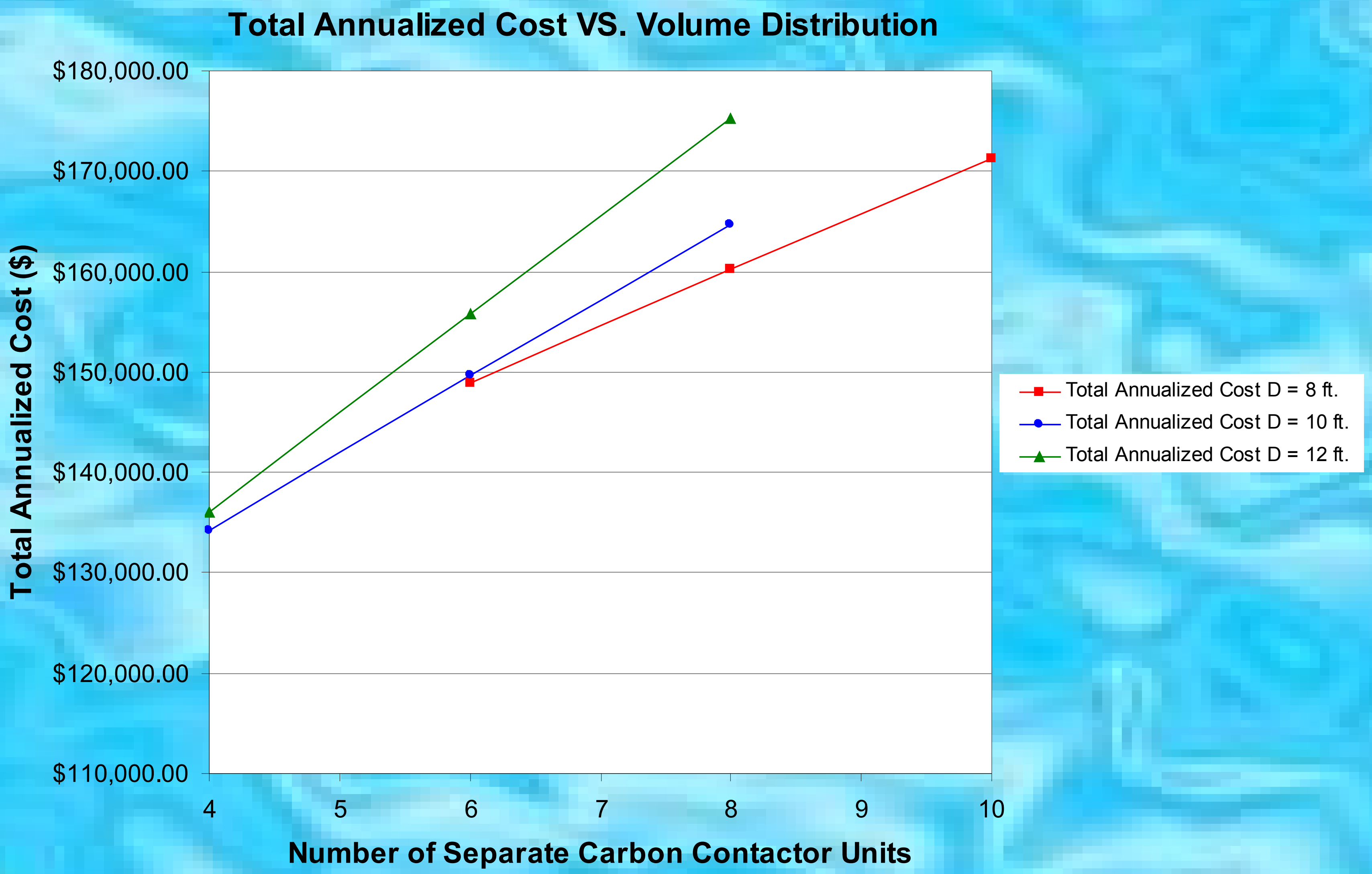
Final Design

Flow Rate (m^3/s)	340.686
Unit Diameter (m)	3.048
Unit Area (m^2)	7.296
Number of Units in Parallel	2
Total Area (m^2)	14.593
Loading Rate (m/h)	23.347
Pressure Drop (ft-H2O)	10.636
Carbon Volume (m^3)	56.781
Bed Height (m)	3.891
Numer of Units in Series	2
Bed Height Per Unit (m)	1.945
Sidewall Height Per Unit (m)	2.918
Bed Life (Bed Volumes)	39006
Bed Life (months)	9
Carbon Usage Rate (Bed Volumes)	38461
Yearly Carbon Usage (kg/year)	37980

Cost Optimization - Carbon Adsorption

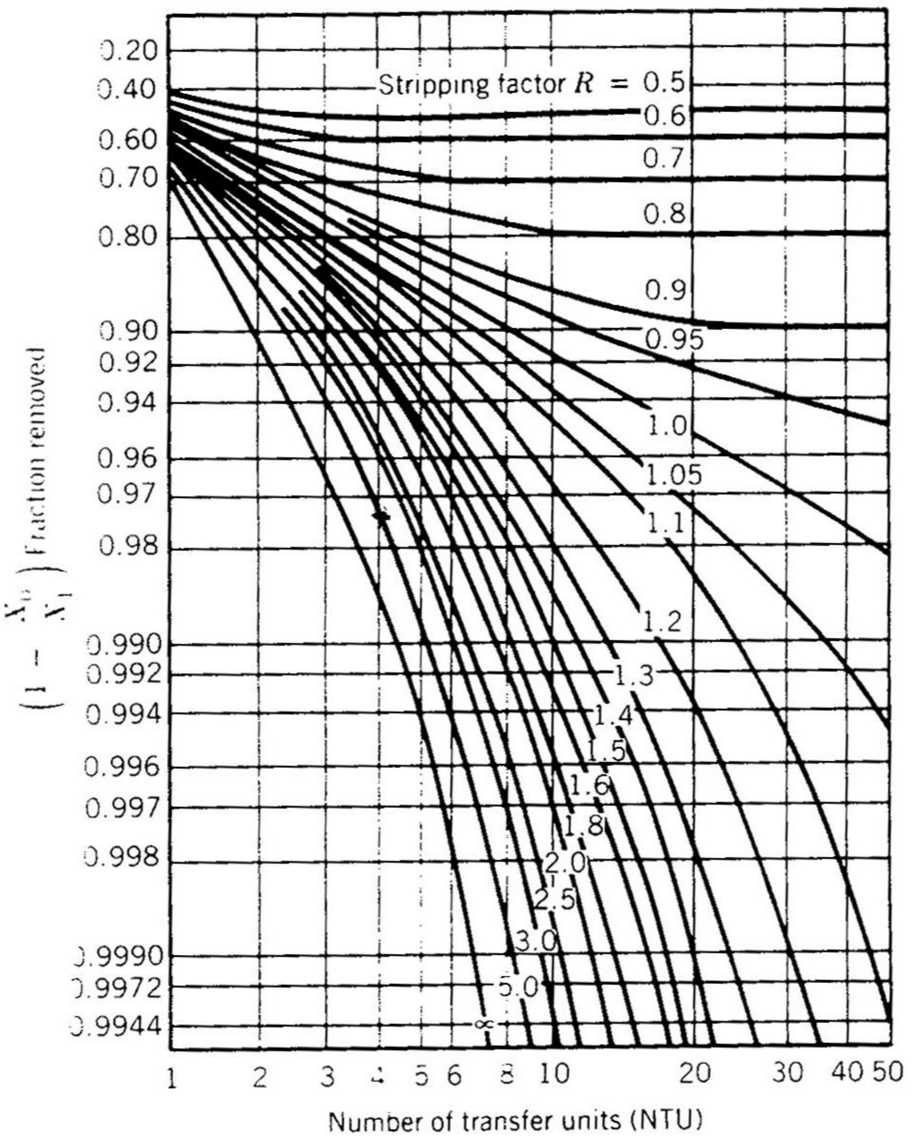


Cost Optimization - Carbon Adsorption



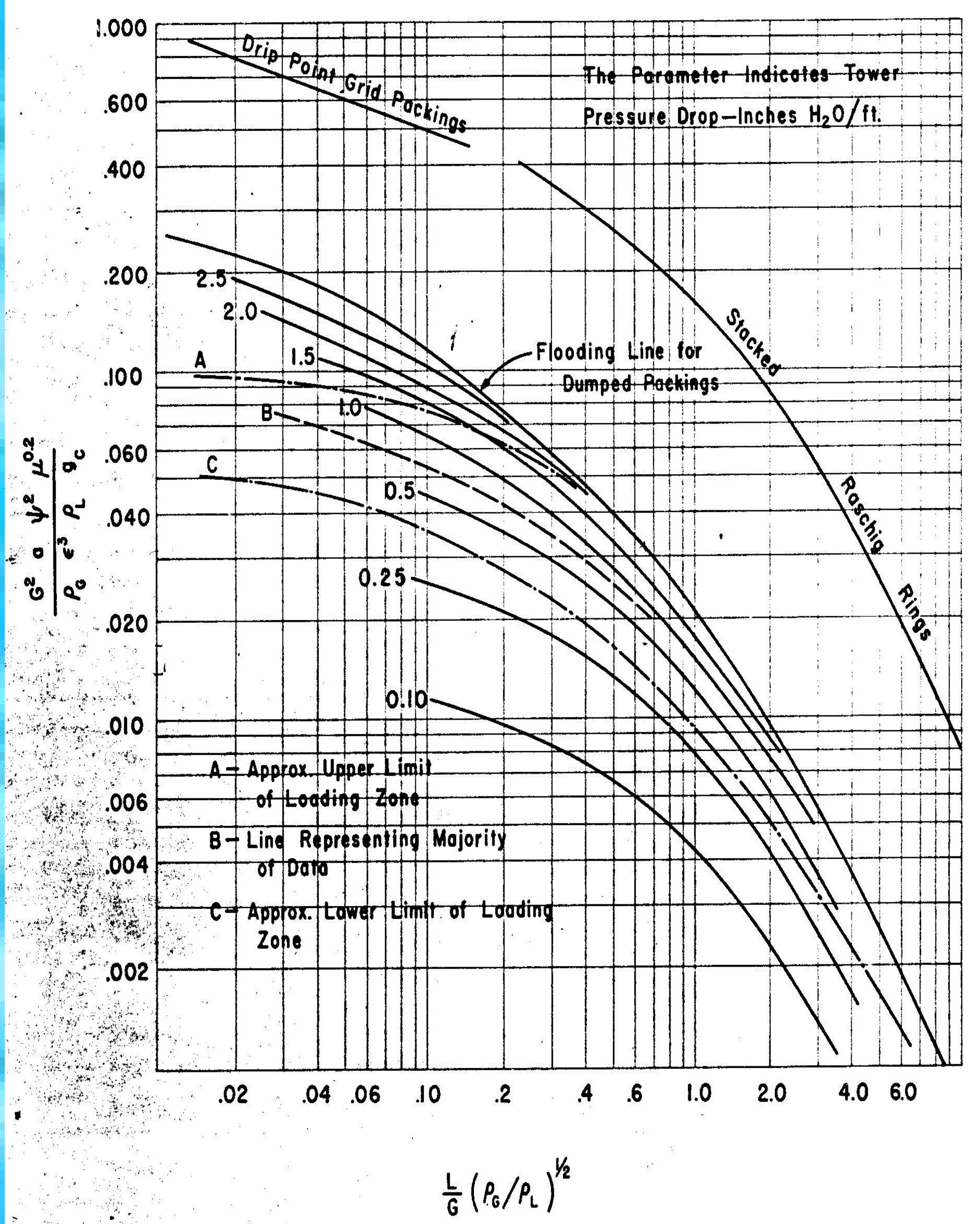
Air Stripper Design Equations

- $Q_w[C_{in}-C_{out}]=Q_A[A_{out}-A_{in}]$
- R value picked
- NTU
- $(Q_A/Q_w)=R/H'$
- K_La from Onda correlations
- D_L: D1/D2=(M2/M1)0.5
  - Benzene
  - Trichlorophenol
- D_G : Wilke-Chang method



- Half flooding line
- Pressure drop
- Back out diameter
  - Mass Loading Rate

- $HTU = L / M_W K_L a$
- $Z = (NTU * HTU) * 1.2$



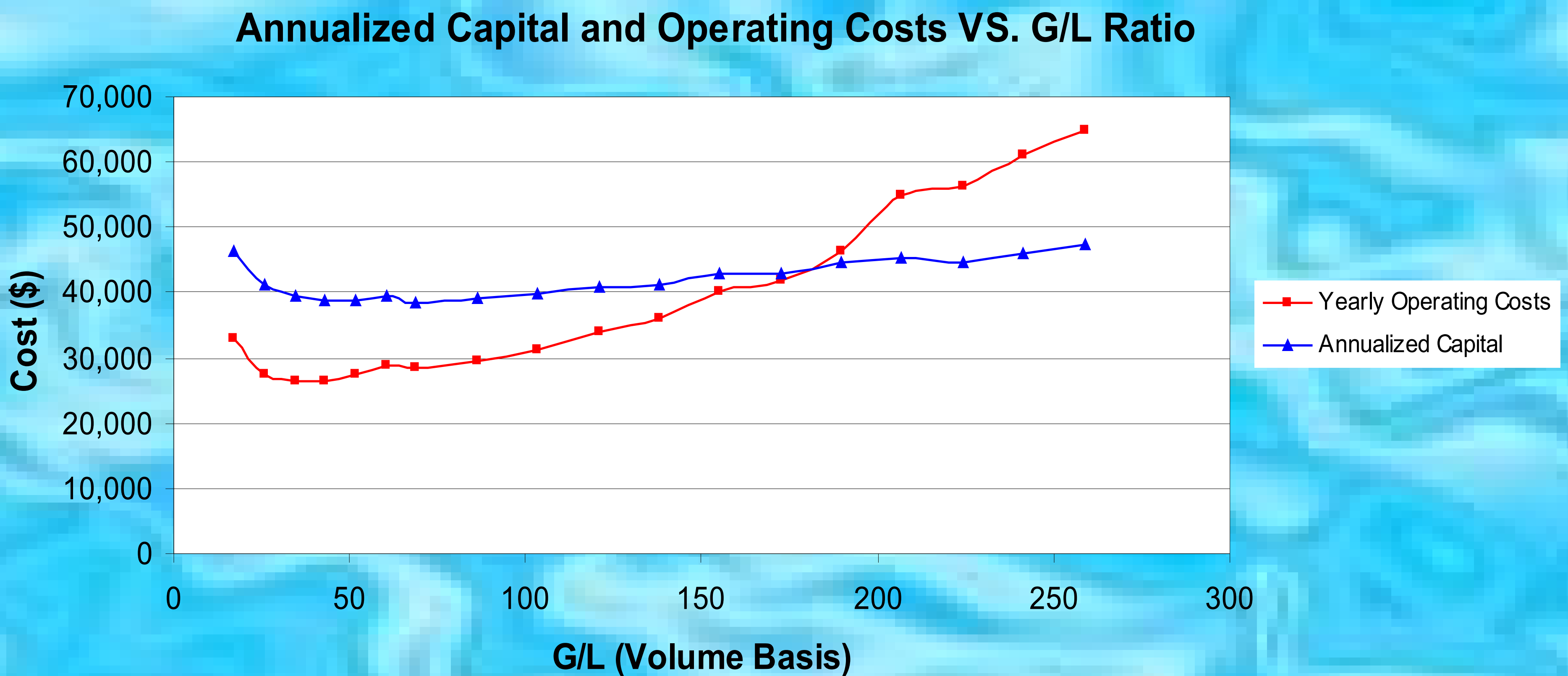
Air Stripper Specifications

- R=5
- Q_A=64,655 GPM
- NTU=4.33
- HTU=4.4 ft
- dP=0.42 in H_2O/ft
- Diam=5.55 ft
- $H_{packing}$=23 ft
- H_{tower}=36 ft

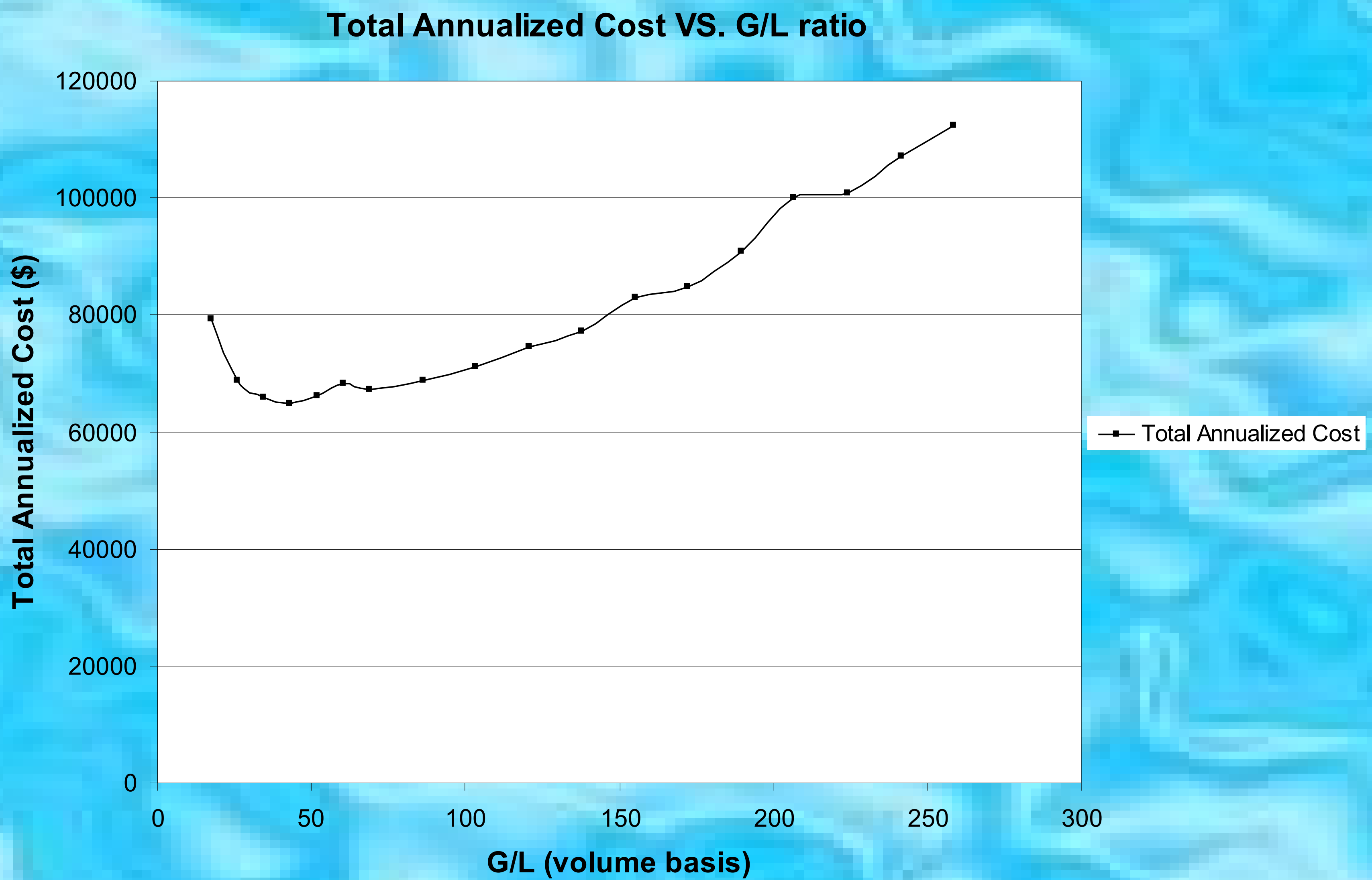
- Packing- Tellurite
  - 88mm
- Annualized Costs
  - Capital=$38,645
  - Operating=$26,266
  - Total=$64,911

- $0.08/1000 Gal

Cost Optimization - Air-Stripping



Cost Optimization - Air-Stripping



Cost Optimization - Comparison

Carbon Adsorption System			Air-Stripping System	
Capital Costs			**Capital Costs**	
Contactors Shells, SS.	$509,507.04		Packing	$5,572.00
Initial and Reserve Carbon	$66,159.02		Tower Shell, FRP	$57,294.08
Pump	$24,000.00		Pump	$24,000.00
Carbon Storage Tank	$28,228.57		Fan	$11,069.09
Auxiliary Equipment	$52,228.57		Auxiliary Equipment	$36,376.75
Equipment Cost	$245,764.35		Equipment Cost	$99,242.83
Total Depreciable Capital	$638,004.26		Total Depreciable Capital	$257,634.39
Operating Costs			**Operating Costs**	
Yearly Carbon	$6,102.00		Air Flow Rate (cfm)	$8,644.40
Electricity	$504.78		Electricity	$13,384.73
Indirect Annual Costs	$31,900.21		Indirect Annual Costs	$12,881.72
Annual Operating Costs	$38,549.70		Annual Operating Costs	$26,266.45
Total Cost			**Total Cost**	
Annualized Cost	$134,207.63		Annualized Cost	$64,911.61
Cost per 1,000 gal	$0.17		Cost per 1,000 gal treated	$0.08

Pathway to Design Success

- Narrowing the field of alternatives
- Preliminary design report and presentation
- Detailed part and process design
- Estimation of capital and operating costs
- Final report and presentation

Conclusion

- Goals that were reached:
  - Students were able to bring together the diverse elements of science and engineering introduced in earlier courses and apply basic ideas to develop designs of actual equipment and processes
  - An optimized economic evaluation of the result was performed
  - Successful teamwork and valuable interaction with group members and faculty