



# SINGLE-STAGE WATER FILTER WITH DUAL SAND MEDIA SIZES

Team Hydration Station

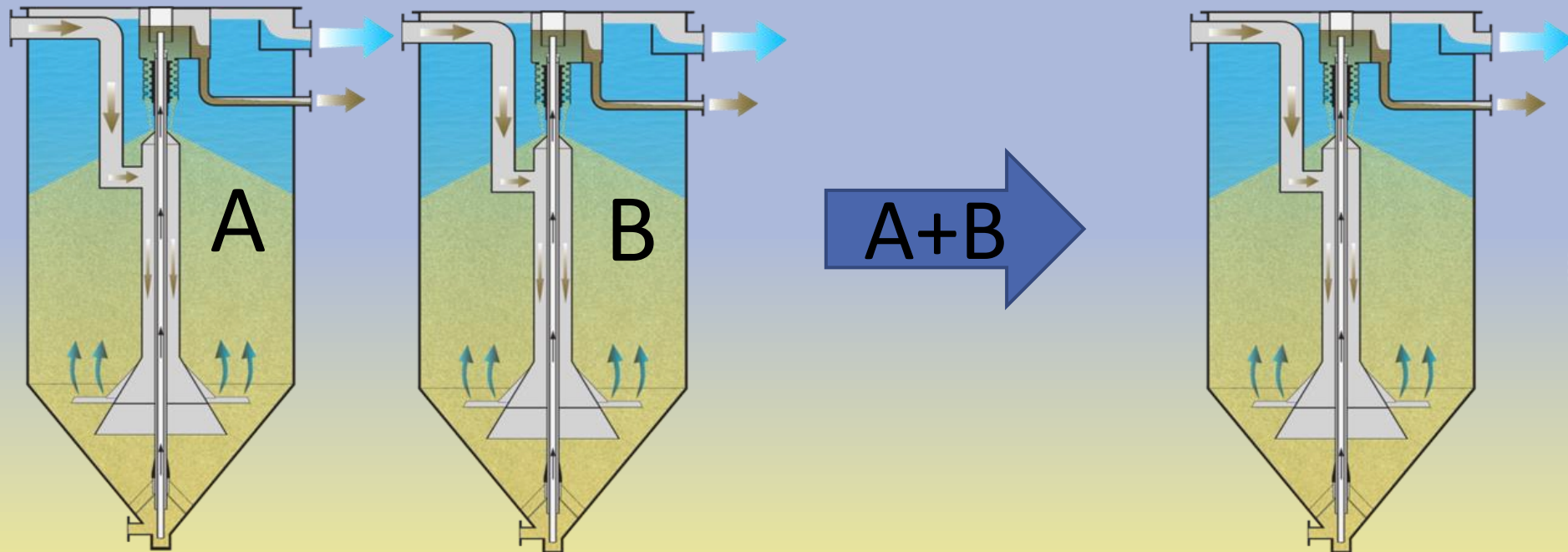
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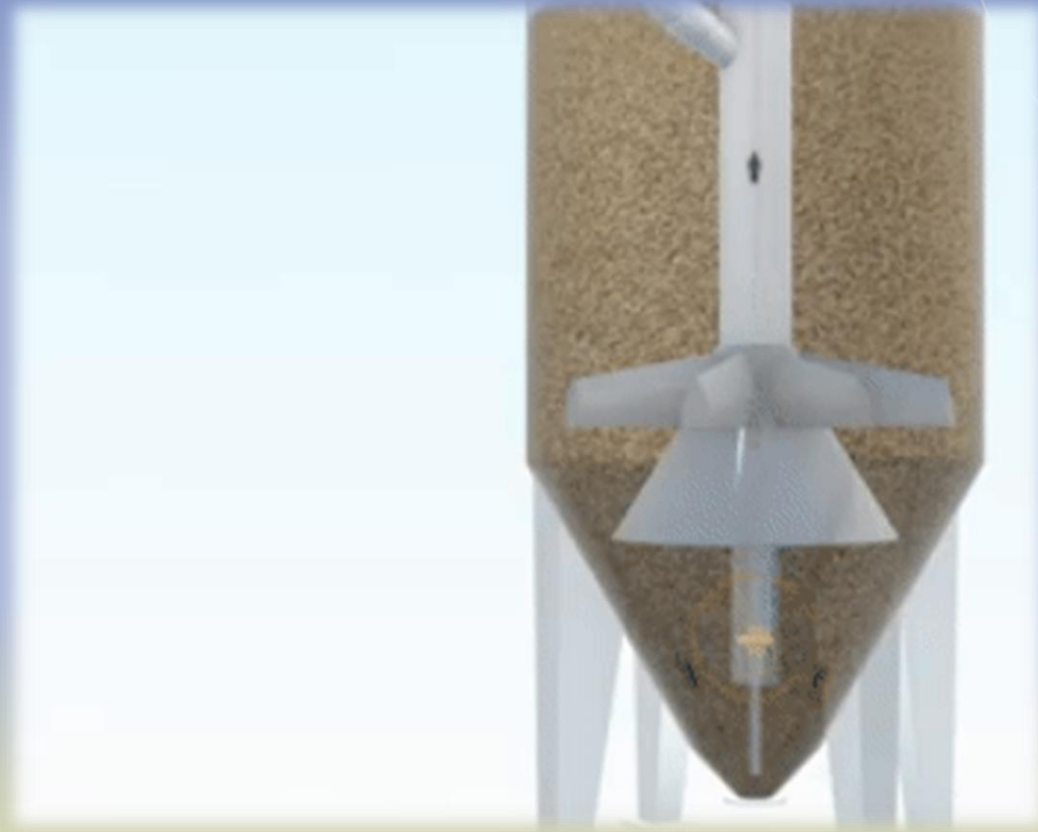
Blake Urie (BE)





# OVERVIEW

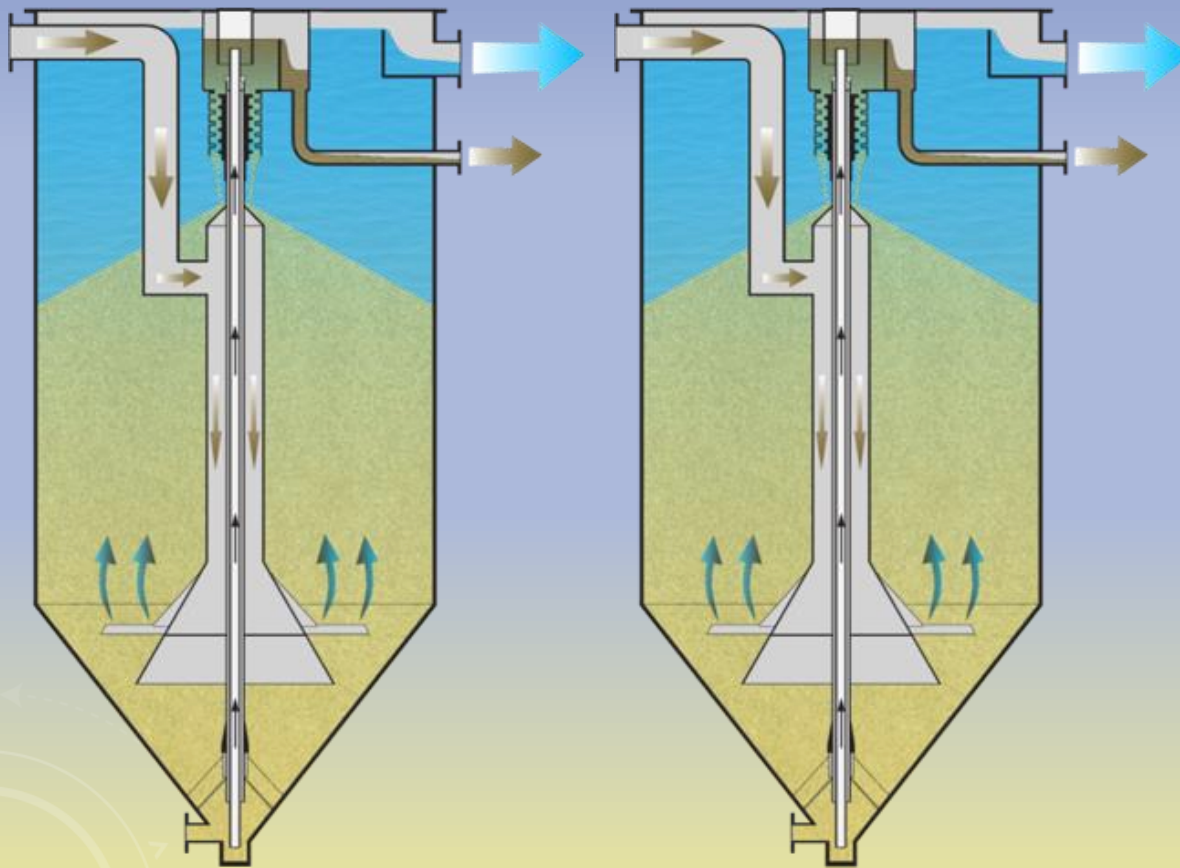
- Background
- Value Proposition
- Requirements
- System Cycle
- Concept Development
- Concept Iterations
- Recommendations
- Risks
- Validation
- Schedule
- Budget
- Recap





# BACKGROUND

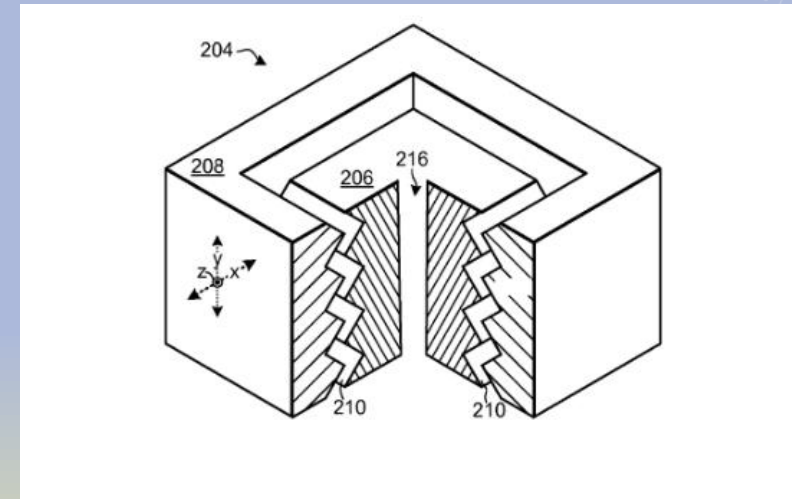
Current Design : Dual Stage Filtration



Coarse Sand Bed

Fine Sand Bed

Current Design: Adjustable Washbox

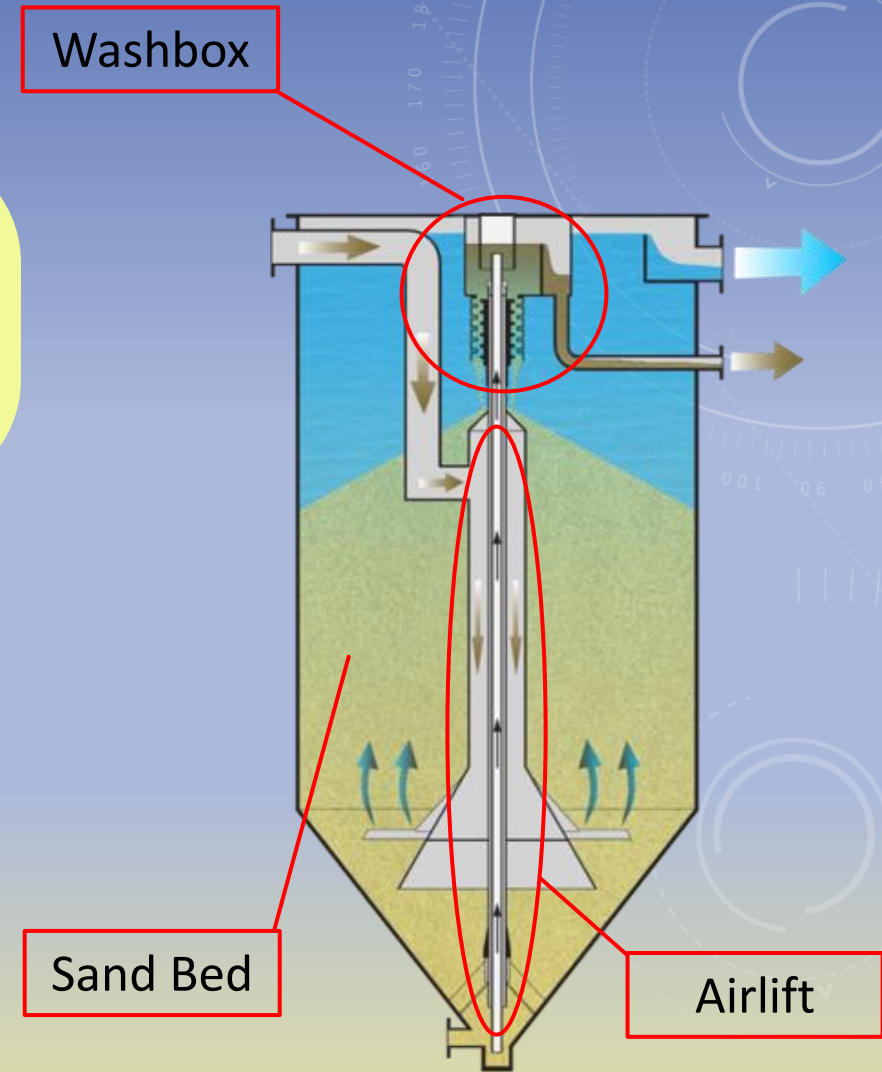
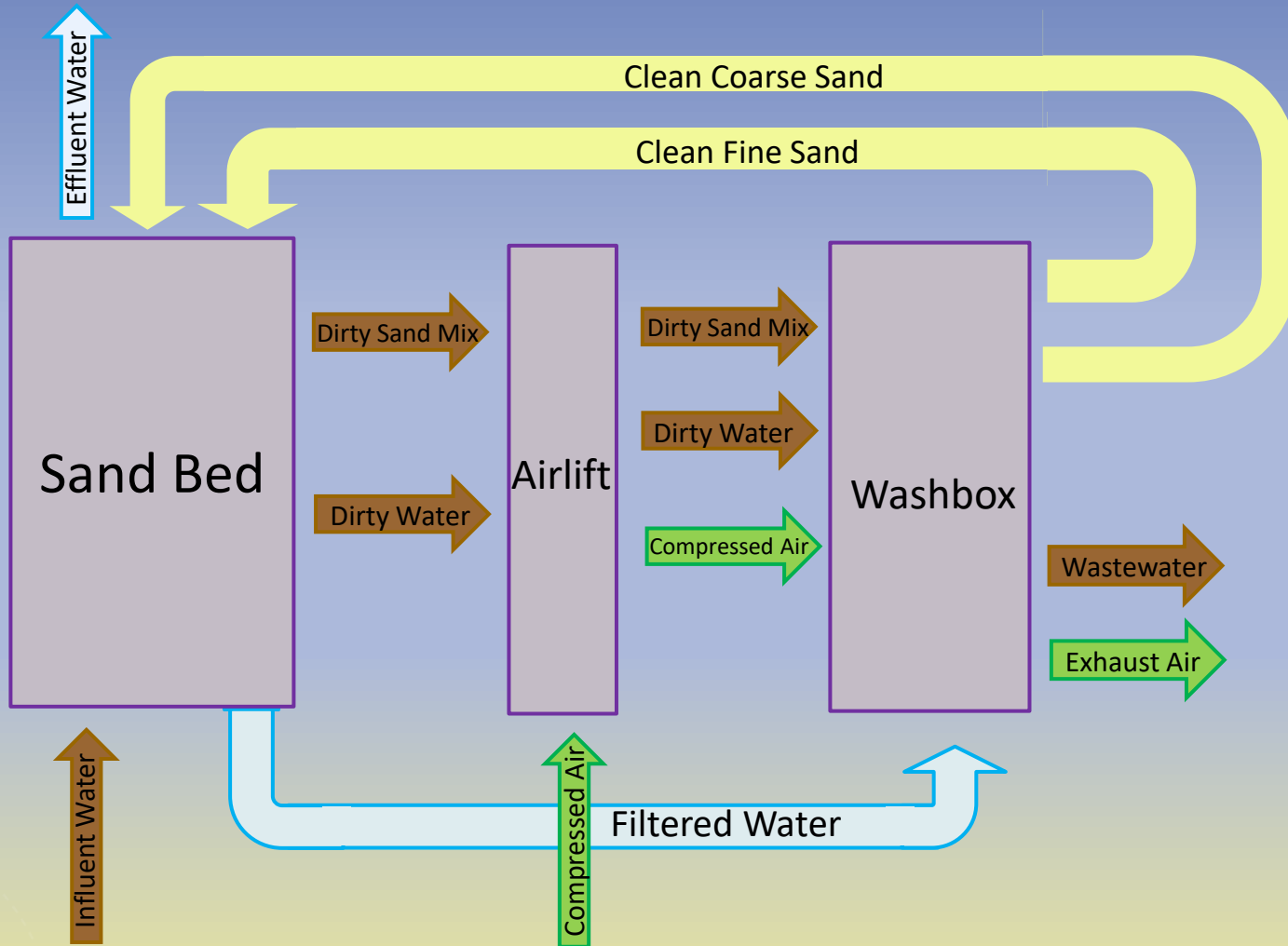




# VALUE PROPOSITION



Clean water is arguably the world's most valuable resource; therefore it is important to invest in water filtration technology. Currently the U of I's Clean Water Machine design is a two-stage dual media sand filter, but by refining the design to require a single filtration stage, a significant reduction in maintenance and increased efficiency can hopefully be achieved.





# REQUIREMENTS

- Separation of the two sand sizes
- Chemical and corrosion resistance.
- Minimum upflow rate of 1.8 gallons per minute (gpm)
- Maintain a bed turnover rate of 0.7 to 1.4 inches per minute.
- Continuous operation with a maximum of 30 minutes of routine weekly maintenance

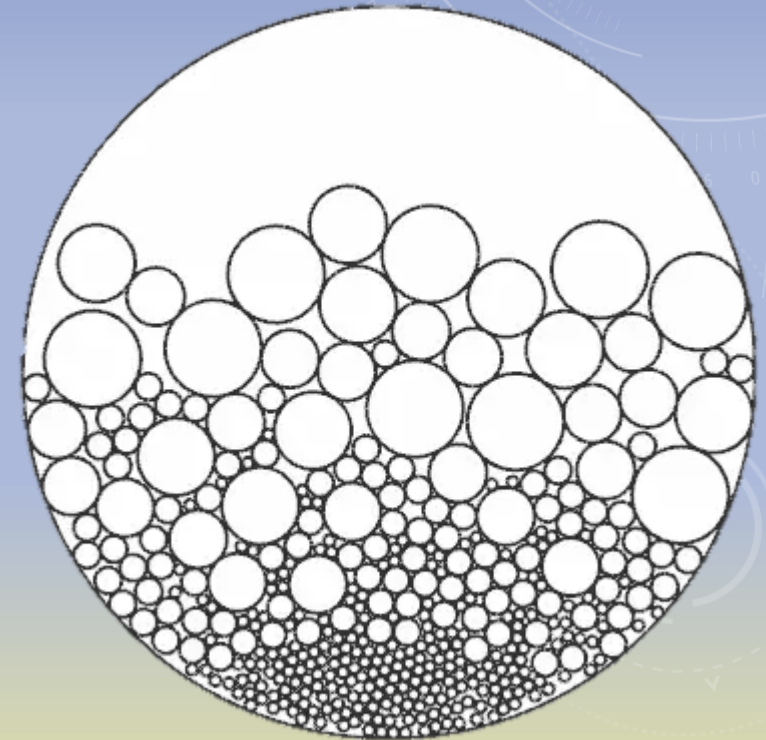
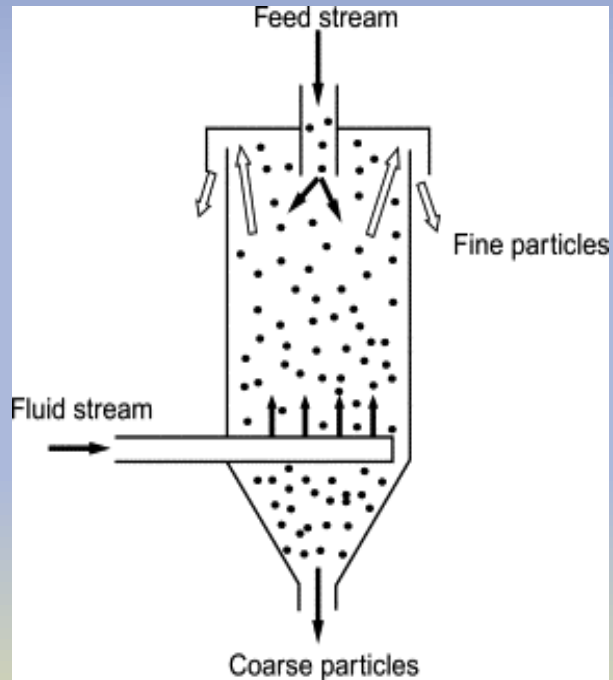


Martin Baker and Greg Möller with the Clean Water Machine



# RECOMMENDATIONS

- Granular Convection
- Screen Slope Incline and Avalanche Frequency
- Elutriation

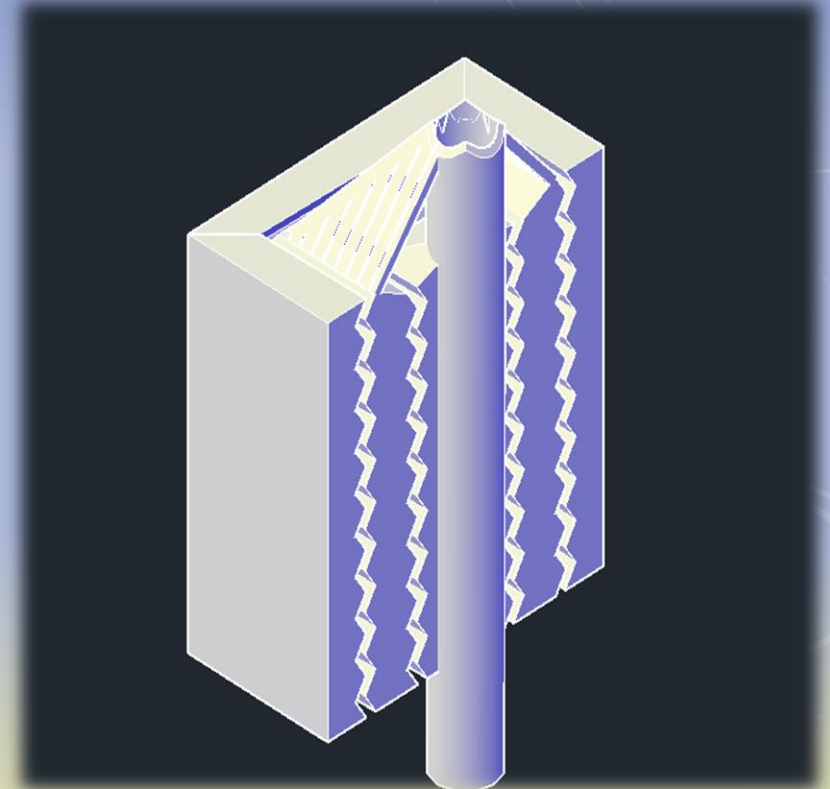
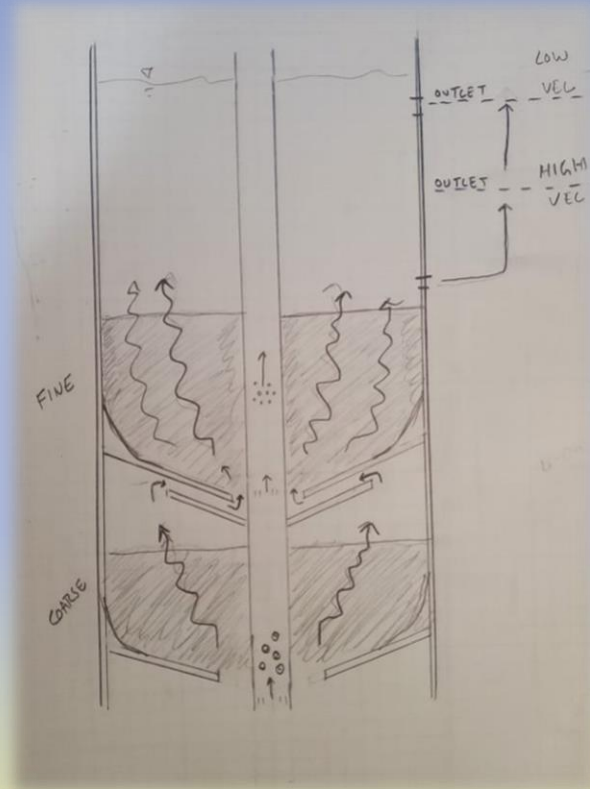
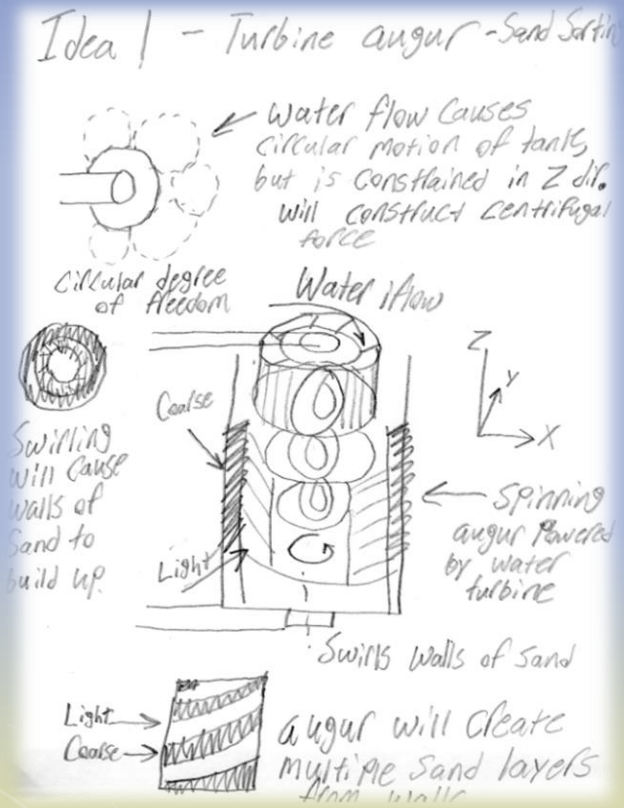


<https://www.sciencedirect.com/topics/engineering/elutriation>

<https://coffeedastra.com/2020/02/01/the-physics-of-fines-migration/>



# CONCEPTUAL DEVELOPMENT





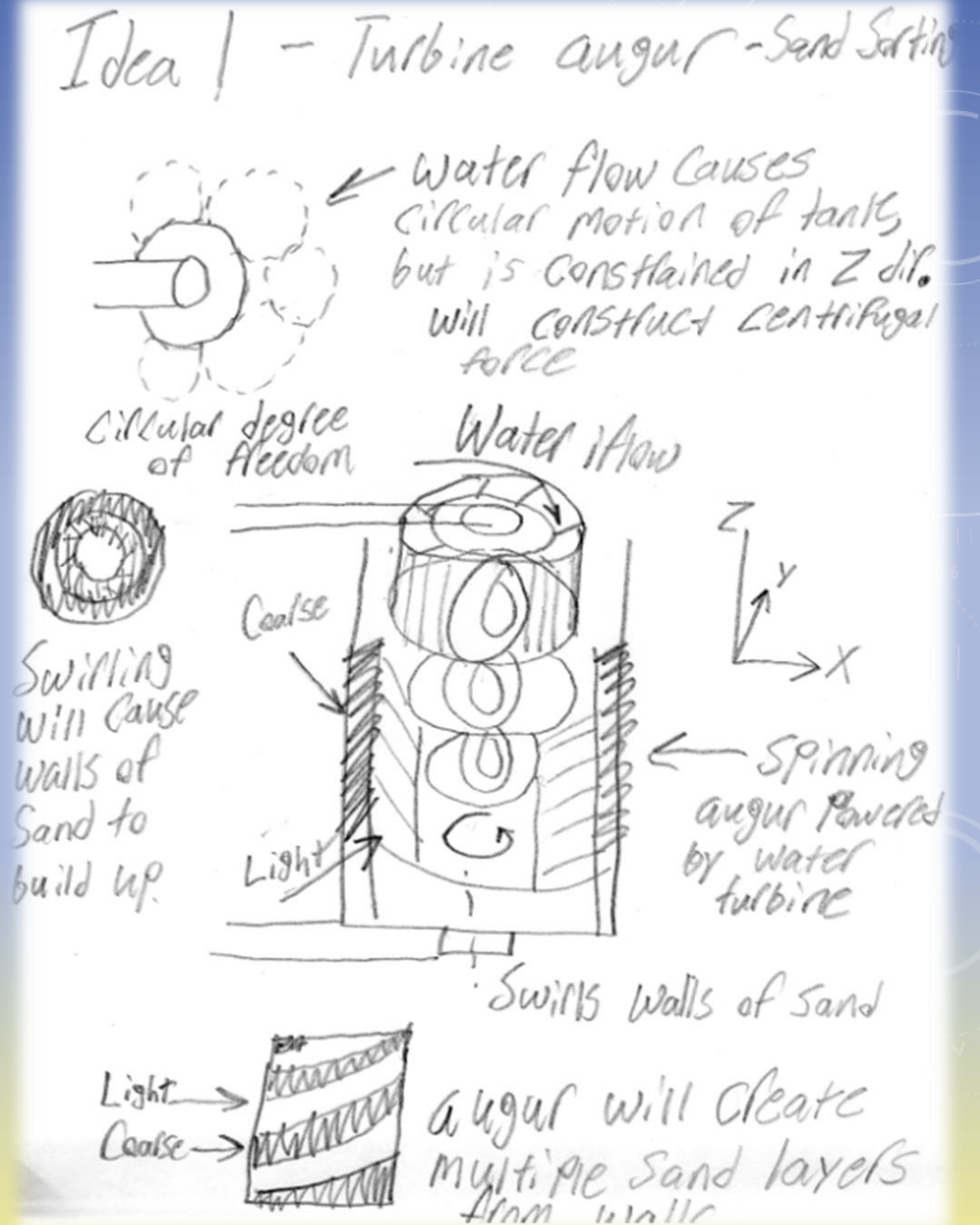


# DESIGN ONE

- Water turbine forces sand to the sides of the box
- The two sands move to have the fine sand against the walls while the coarse sand is closer to the augur
- A swirled layering of fine and coarse sand occurs, like soft serve ice cream

## CONS

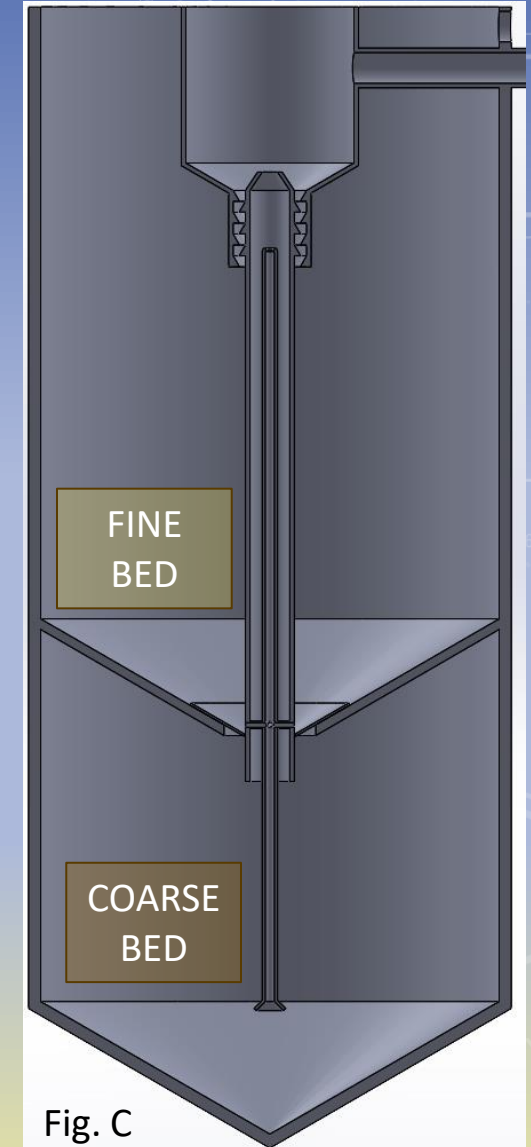
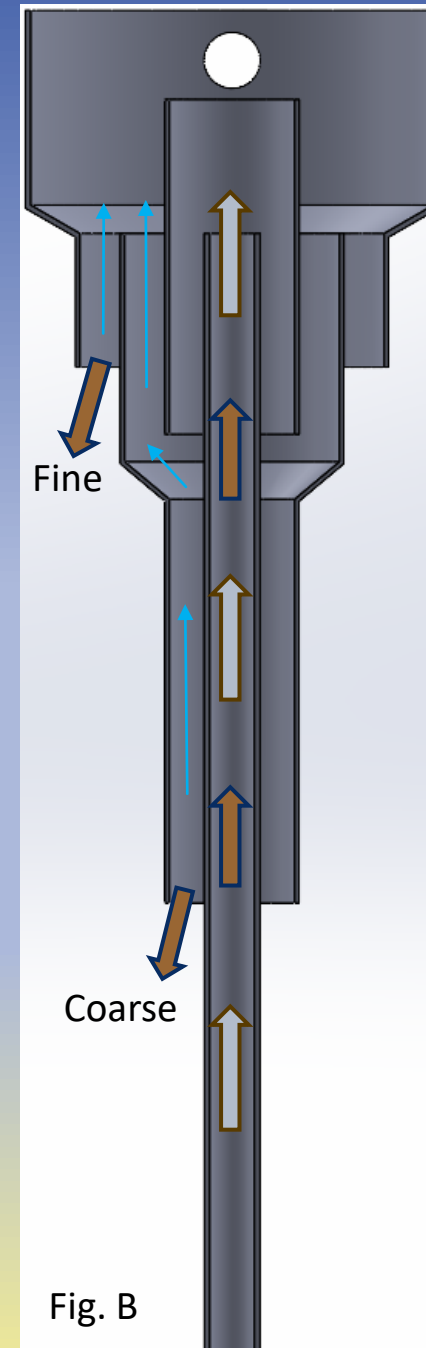
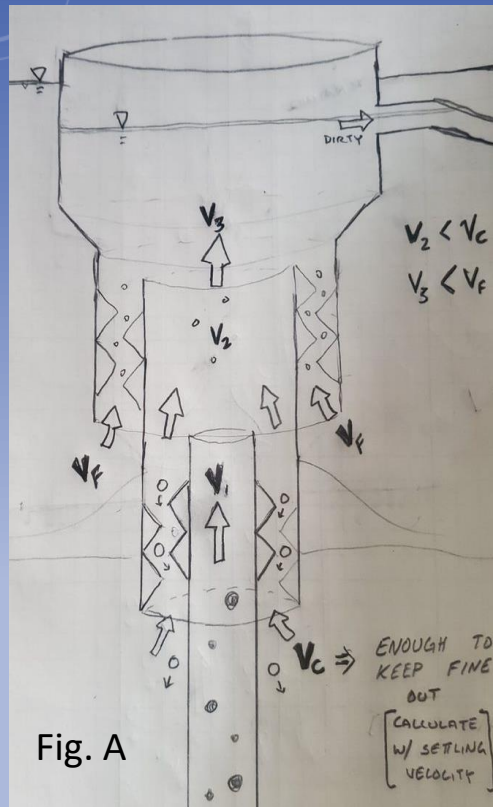
- Exacerbates erosion on surfaces with sand
- Maintaining pressure head can be difficult without the use of a pump
- Turbine and augur system add substantial complexity and cost to the system





# DESIGN TWO

- Sand Separation using Elutriation.
- Separated beds to ensure particle segregation.
- Water up flow through channels separates particles based on unique settling Velocities



## CONSI

- Changes in head pressure affect velocities
- Concentric Tubes do not allow multiple airlift inputs
- Separated beds may results in emptying/filling bed areas
- Difficult to test and adjust up flow velocities.



## DESIGN THREE

- Segregation using Wedge wire screen
- Bed segregation created by different outlet locations.
- Airlift with two inlets.

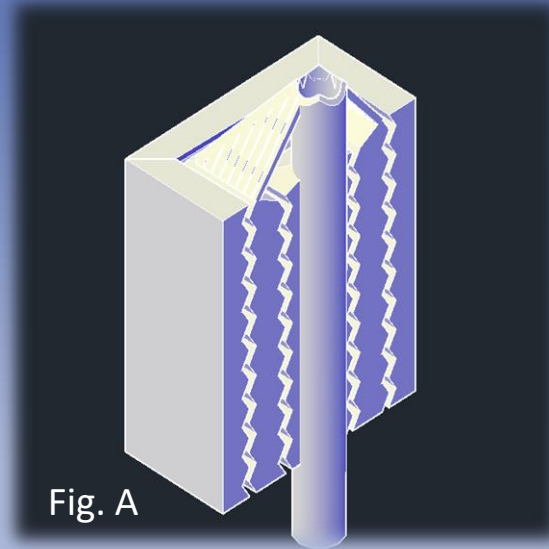


Fig. A

### CONSIDERATIONS

- Airlift inlet may result in contaminated sand getting deposited into fine bed.
- Bed turnover / airlift inlet rate must ensure no clogging from Course outlet.
- Brazilian Nut affect (Coarse sand migrating upward)
- Ensure 75% segregation.

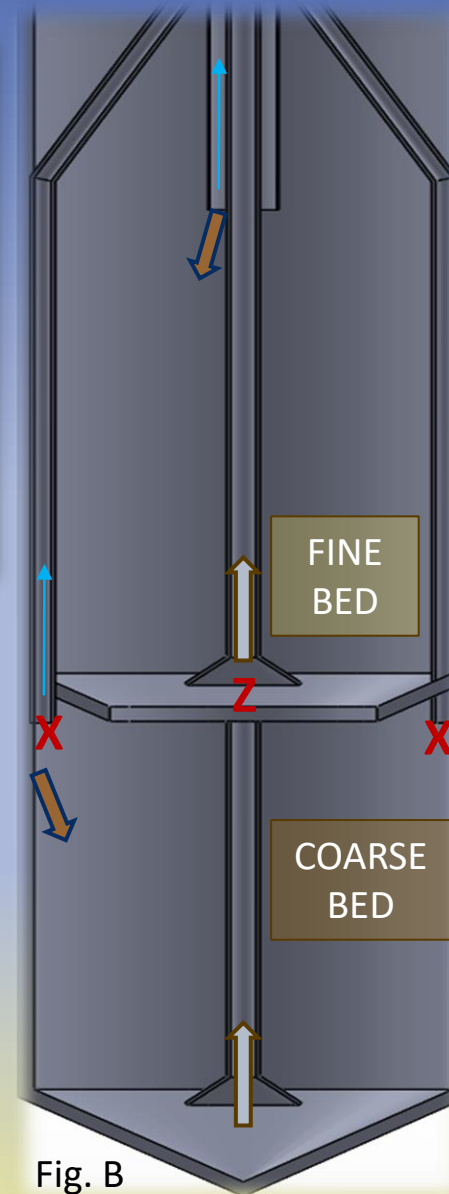


Fig. B

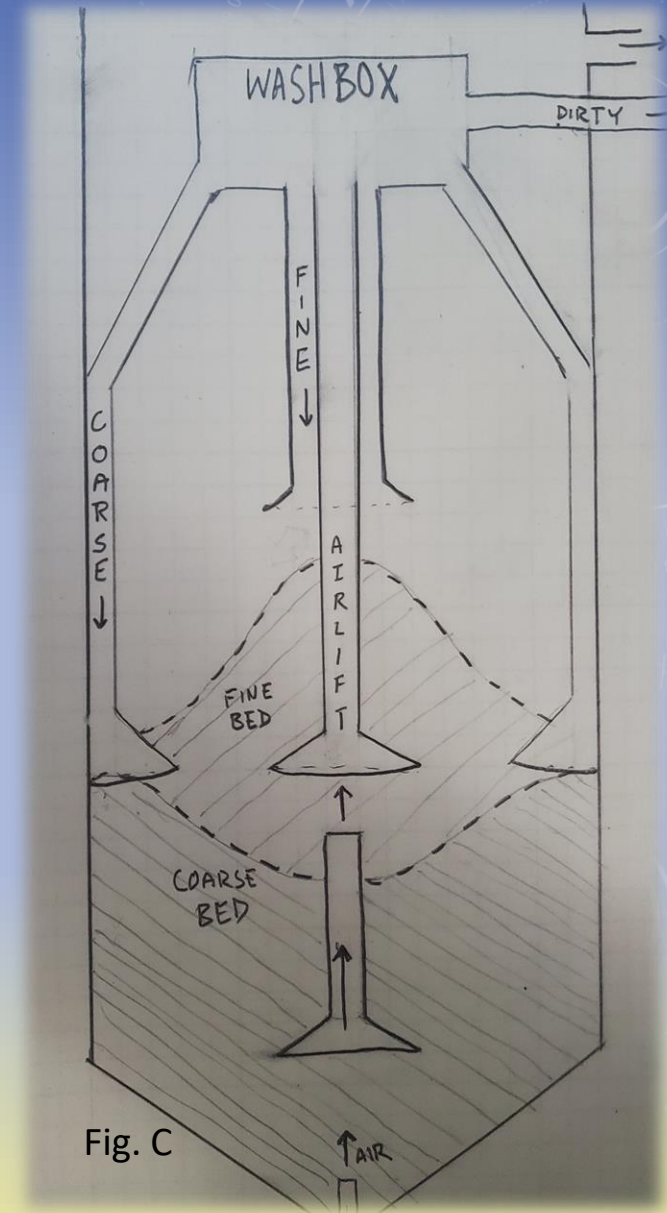


Fig. C



# DESIGN FOUR

- Separates particles by elutriation
- Lighter particles are moved upwards by the airstream and heavier particles can fall through

Pros: Gets rid of the need of screens – no blockages

Cons: Uses more air and thus more power

Fig A.

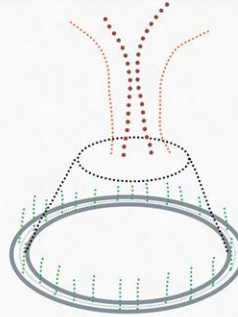


Fig B.

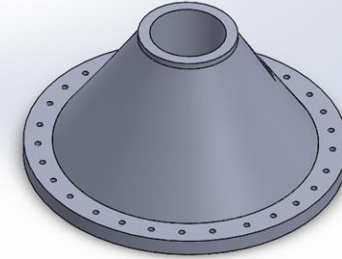


Fig C.

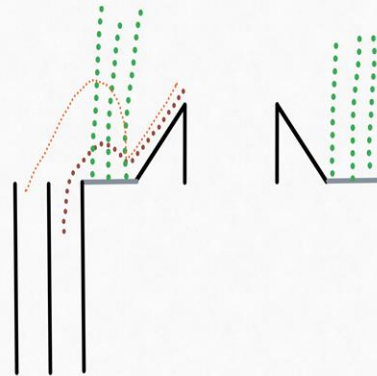
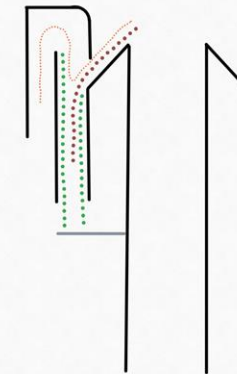
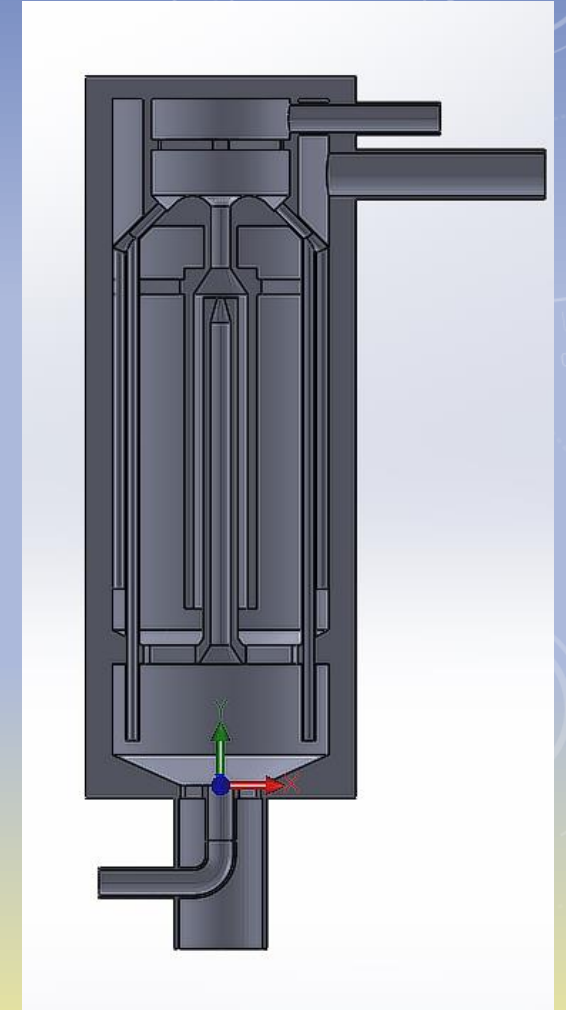
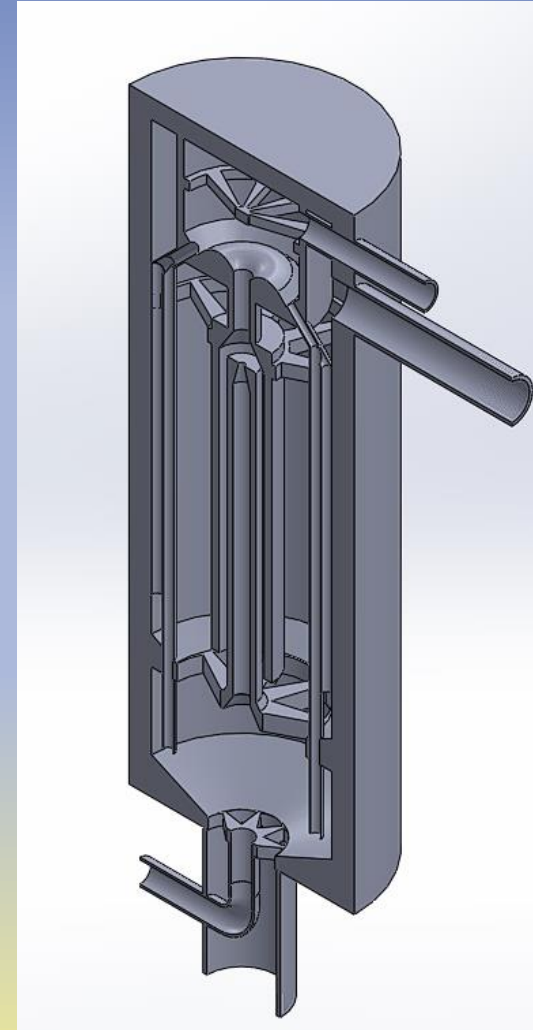


Fig D.

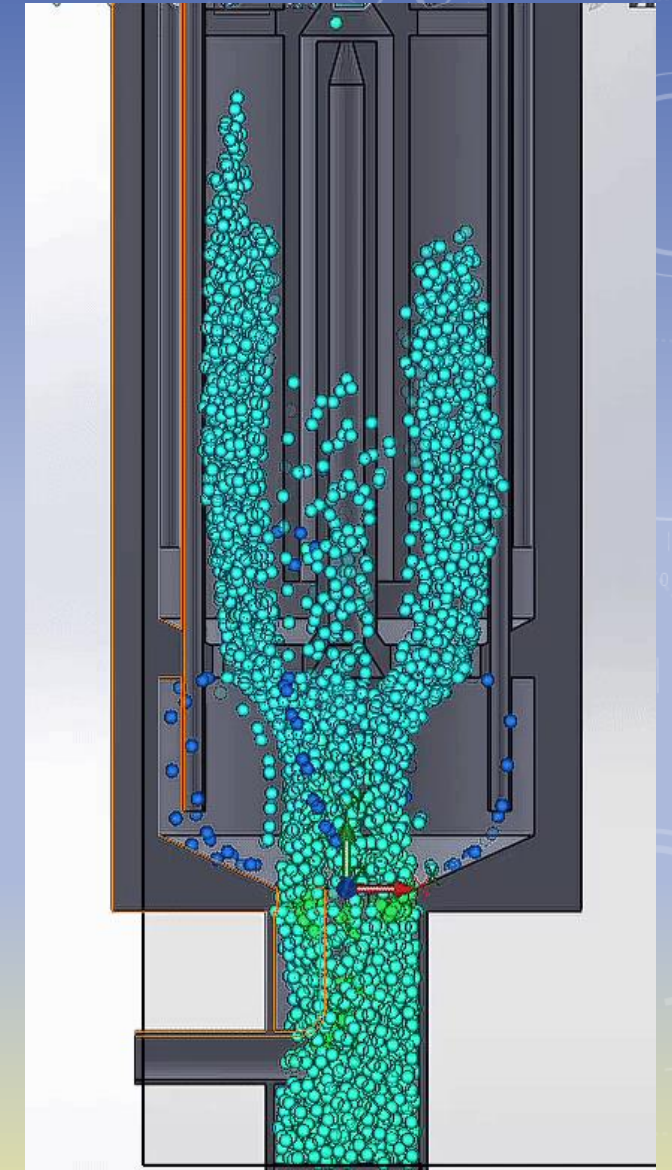
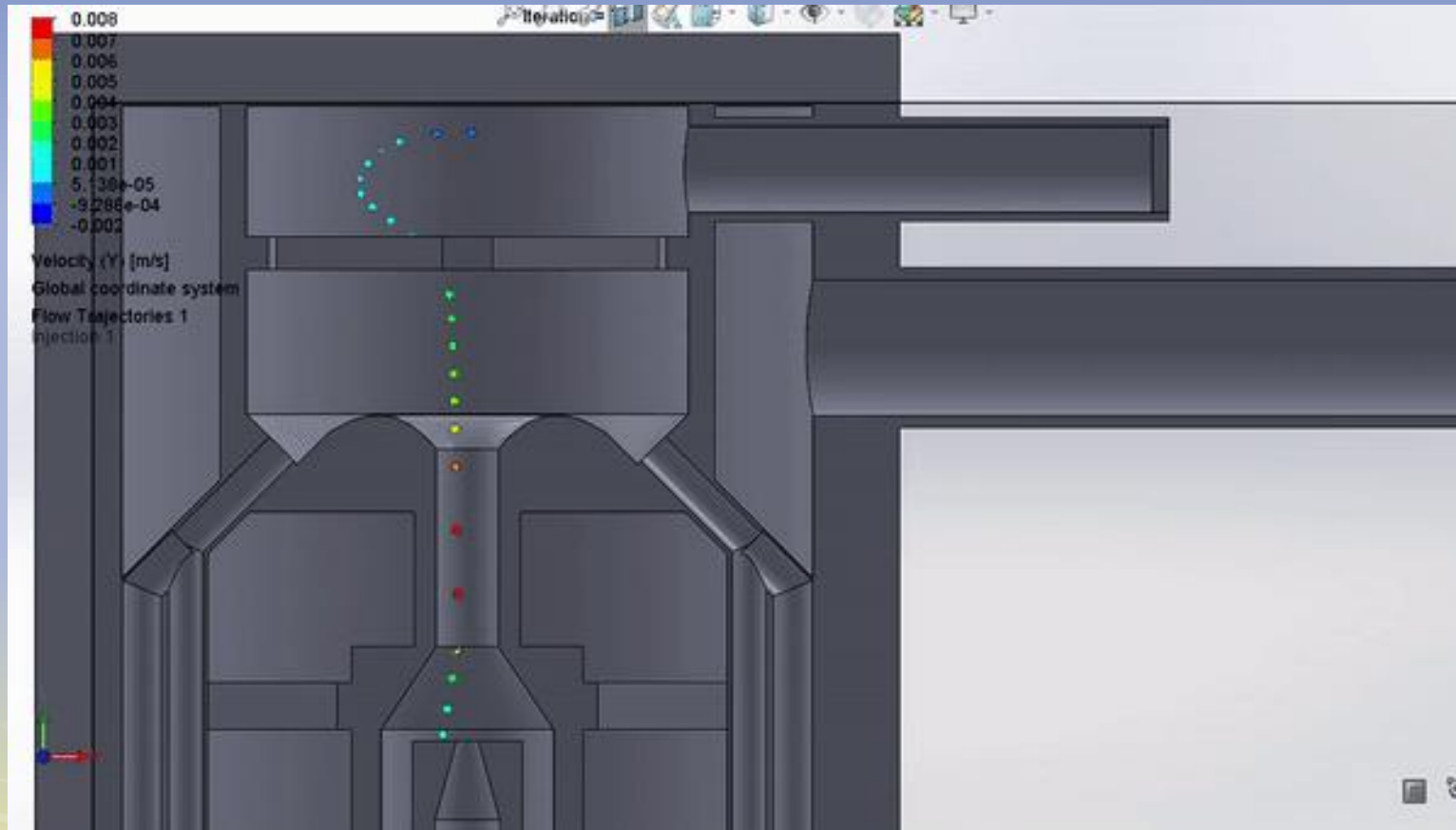


# VALIDATION VIA SIMULATION

- A mock wash box geometry was modeled, and fluid analysis was conducted on water particles.
- Inlet pressure and outlet effluent and clean water were modeled. Velocities were visualized using colored spheres.

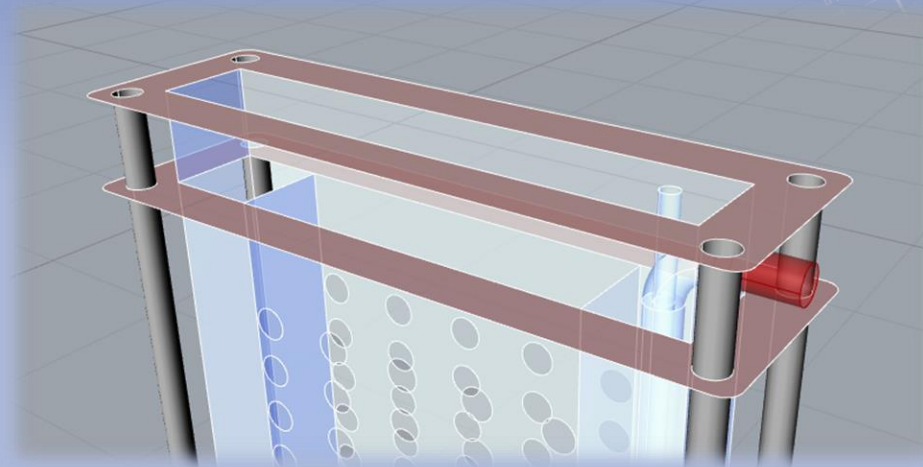
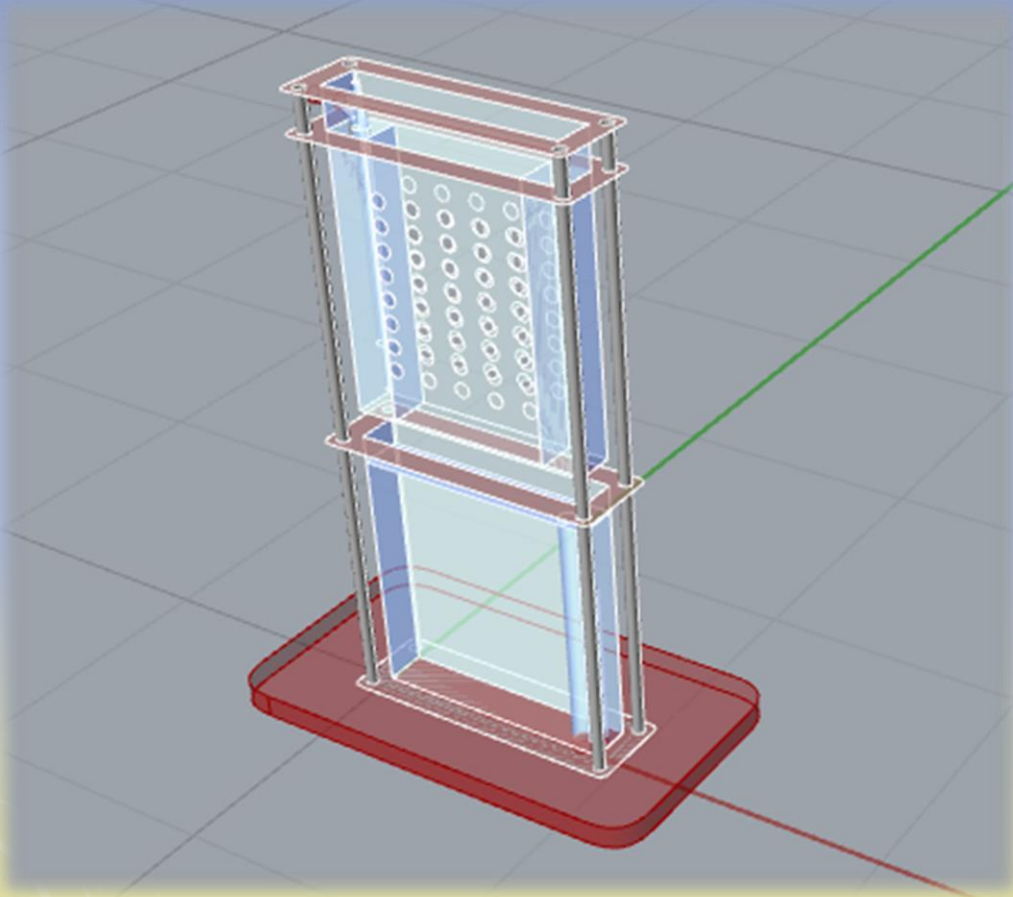


# CFD RESULTS





# TEST STAND



Model designed by Martin Baker

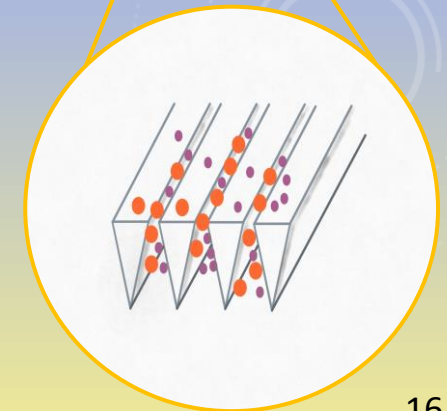
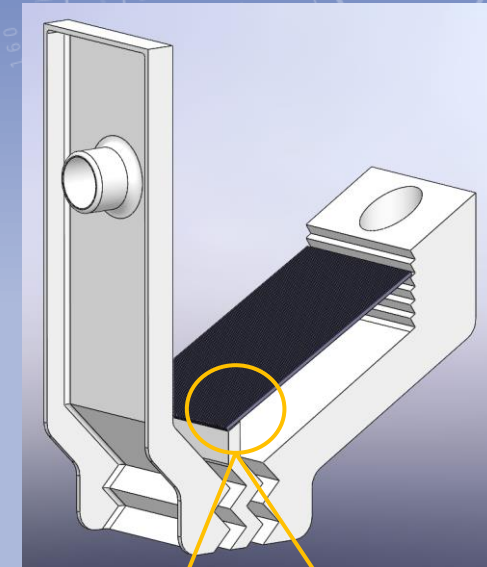
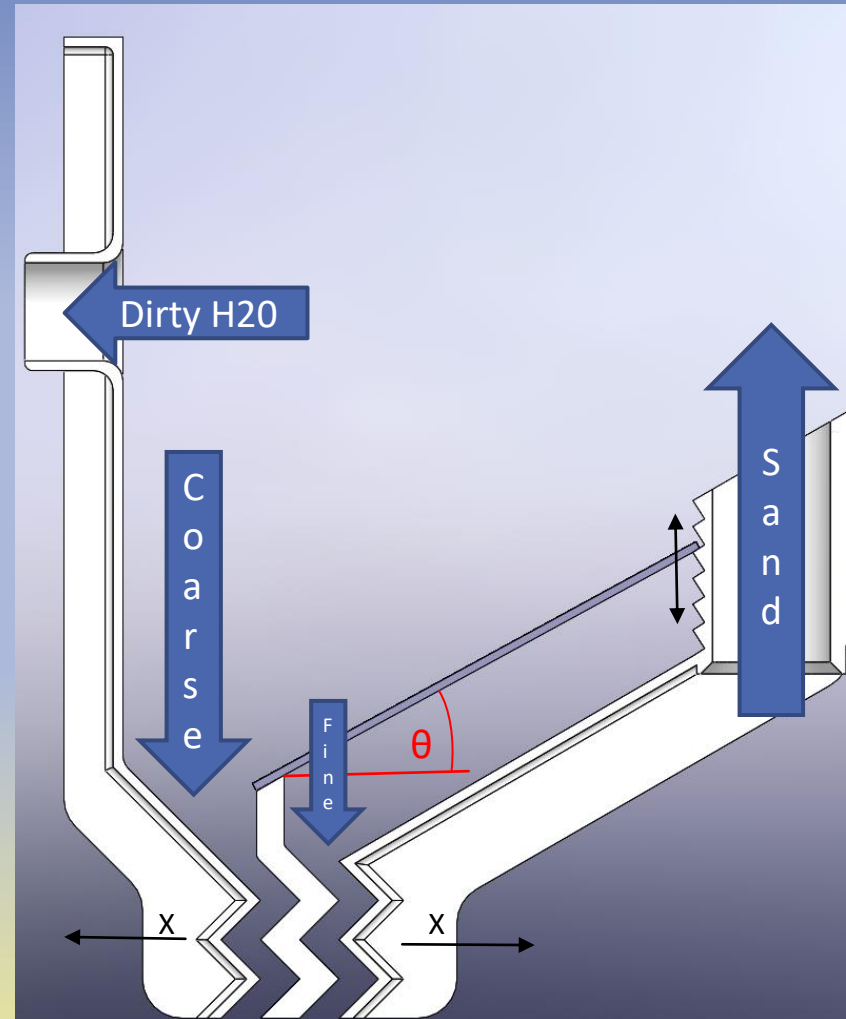


# WASHBOX VALIDATION

- Design Validation is being conducted on an experimental model.
- The part will model sand separation and screen resistance.

## Adjustability

- Channel Velocity
  - .43 -.87 in/s
- Screen Angle:  $\theta$ 
  - 16 -42 degrees



Above: Screen separated wash box assembly.





## POTENTIAL RISKS

- Clogging of the wedge wire screen.
- Upflow water working against wedge wire screen particle separation.
- Abrasion due to sand movement at high velocity.
- Granular convection at sand bed interfaces and insufficient sand segregation.
- Incompatibility with current filtration system.





# DESIGN VALIDATION PLAN

Requirement	Test	Test Subject	Target Date	Result	Recommendation
Submit design considerations for scale model testing stage filter design.	Determine if the scale model will be customizable and accurate enough to be useful during testing.	Testing stage apparatus.	11/06/2020		
Achieve 75% sand separation in a continuously run dual media water filtration unit.	CFD analysis in SolidWorks and with the help of undergraduate specialists and possible wear analysis/consideration.	Fully functional model #1	11/20/2020	CFD Results were unable to model multiphase flow. Upwards water flow was analyzed	Sand interactions and settling velocities will need to be modeled via experiments.
Achieve 75% sand separation in a continuously run dual media water filtration unit.	Live test of fabricated prototype in small scale testing stage filter.	Fully functional model #1	12/04/20		
Maintain banding of separated sand in filter bed.	Live test of fabricated prototype in small scale testing stage filter.	Fully functional model #1			
1.8 to 3.6 gallons per minute upflow rate maintained.	Live test of fabricated prototype in small scale testing stage filter.	Fully functional model #1			
Percent removal of total suspended solids (TSS)	Before and after mass analysis of known volume of sample.	Fully functional model #1	12/11/20		

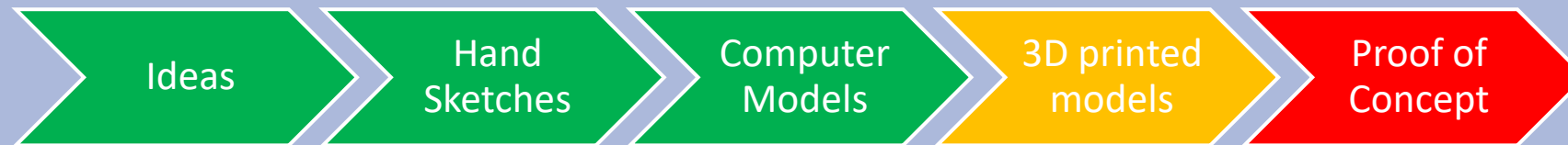






# RECAP

Our objective is to combine a two-stage filtration system into a single-stage dual media filter.



# ACKNOWLEDGEMENTS

- Dr. Sarah Wu our advisor
- Mr. Martin Baker and Dr. Greg Möller our sponsors