



**CSME / CFD-SC 2023**

*International Congress*

Université de Sherbrooke | Sherbrooke, Canada | 28 – 31 May 2023



**ENGINEERING**

# An experimental study of Archimedes screw pump efficiency

**UNIVERSITY  
of GUELPH**

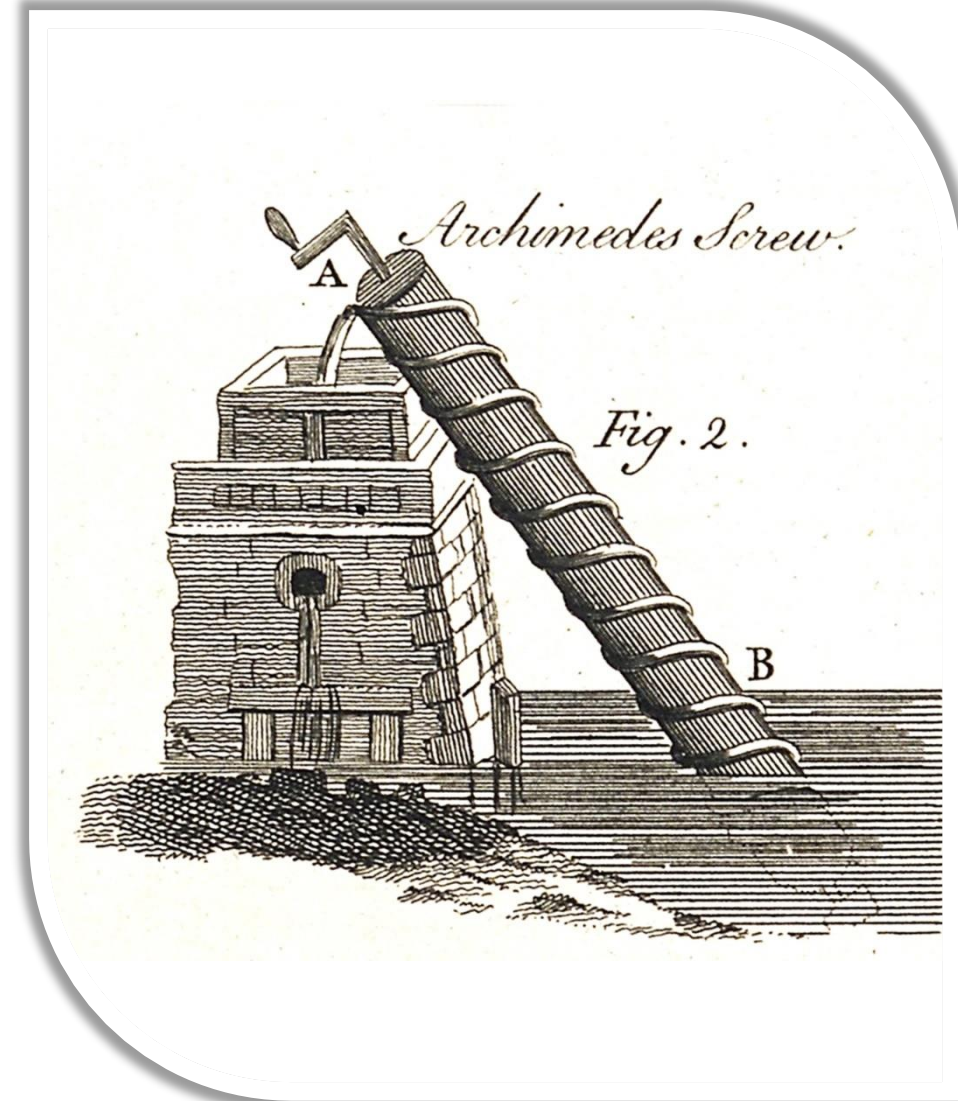
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<b>Presentation Date:</b> 29 May 2023	<b>Session:</b> Fluid Mechanics 1
<b>Paper Authors:</b> S. Simmons, L. Miller, M. Saudagar, C. Mendes, A. Yoosefdoost, W. Lubitz	

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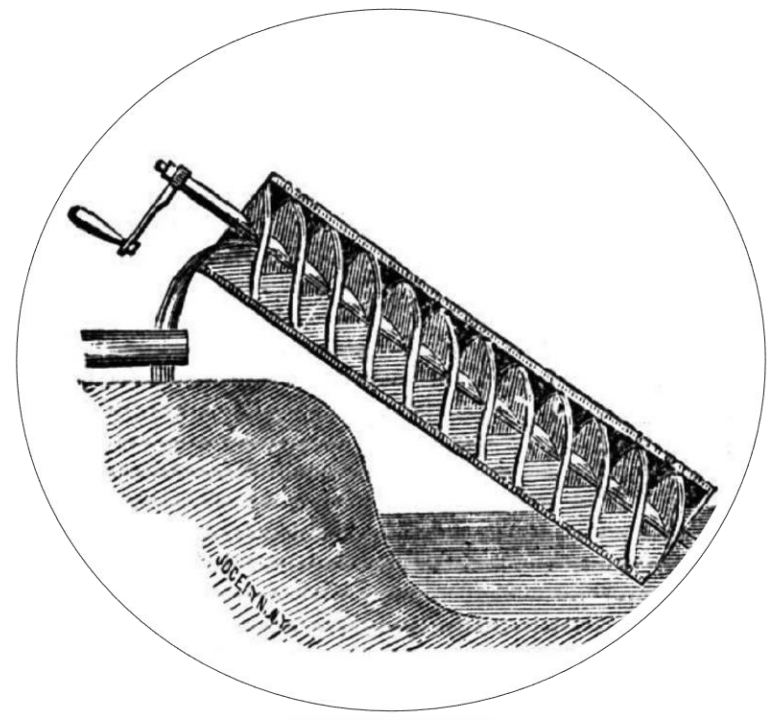




1. Introduction
2. Historical Context
3. Methods
4. Results
5. Conclusions



# 1. Introduction

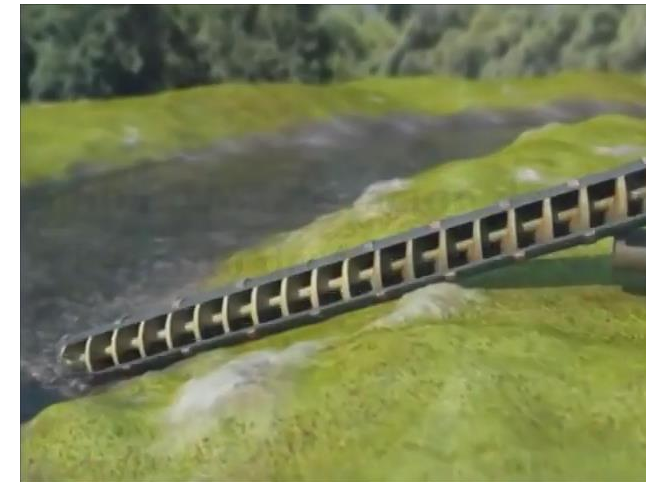


# 1. Introduction

- Archimedes screws are an ancient pumping technology
- Named after Archimedes of Syracuse (~287-212 BCE)
- Evidence suggests it was used during reign of King Sennacherib (704-681 BCE) of the Neo-Assyrian Empire
- Trap water between blades as screw rotates due to an applied torque
- Water translates along axis of rotation



PBS (2014). Secrets of the dead: Archimedes' screw and the Hanging Gardens of Babylon [https://www.youtube.com/watch?v=NhNEB\_mWwBw&ab\_channel=PBS].

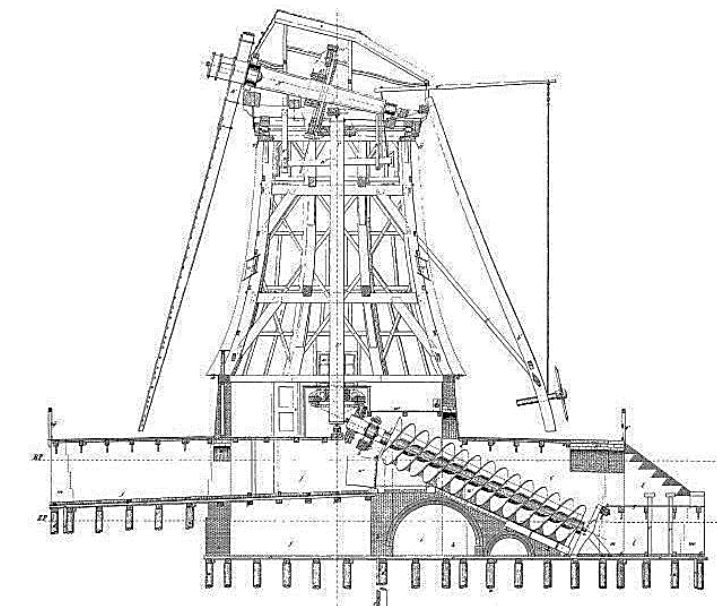


Adriana Tub (2016). Tornillo de arquimedes [https://www.youtube.com/watch?v=A\_m2Gekbtw&ab\_channel=AdrianaTub].

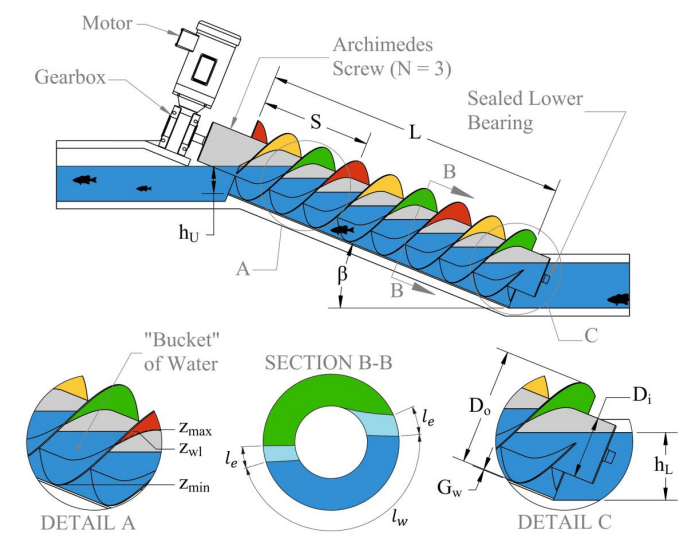


# 1. Introduction

- Archimedes screws have been designed as pumps for millennia
- Design is largely empirical or heuristic
- No extensive studies of the effects of scaling design parameters in published literature
- We have performed a comprehensive review of the literature



<https://www.notechmagazine.com/2012/10/building-plans-of-dutch-industrial-windmills-1850.html>



## 2. Historical Context



# 2. Historical Context

- Used for irrigation in:
  - Neo-Assyrian Empire of Sennacherib (c. 704-681 BCE) for irrigation
  - The Nile Delta by Archimedes of Syracuse (c. 287 BCE)
- Used for ship drainage in:
  - Hiero II's Kingdom of Syracuse by Archimedes (c. 280s BCE)
- Used for draining mines in:
  - The Roman Empire (c. 27 BCE to 400s CE)
  - Visigothic Iberia (c. 400s to 711 CE)
  - Al-Andalus Caliphates (711 – 1212 CE)



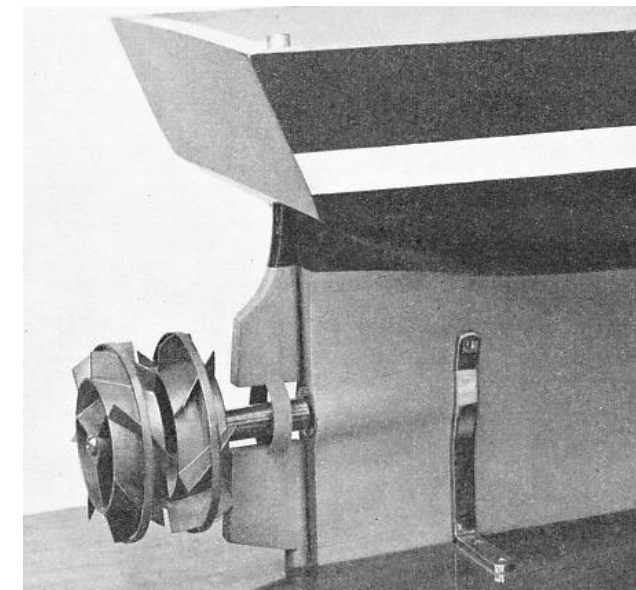
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# 2. Historical Context

- Used for land drainage/reclamation in:
  - Dutch Golden Age (c. 1500s to 1600s CE)
- Used for ship propulsion in:
  - (Possibly) Hiero II's Kingdom of Syracuse by Archimedes (c. 280s BCE)
  - Austria by Josef Ressel (1829 CE)
  - England by Francis Smith (1839 CE)



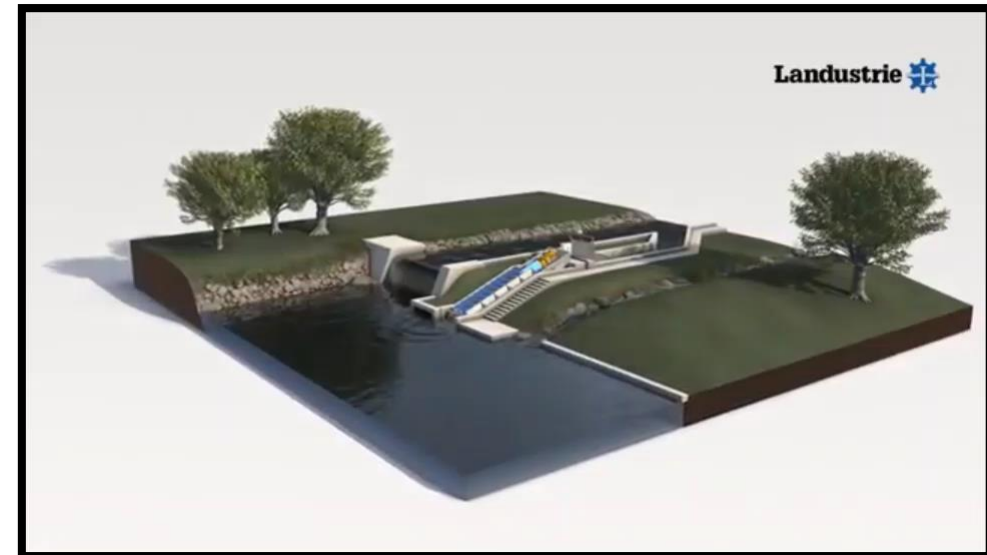
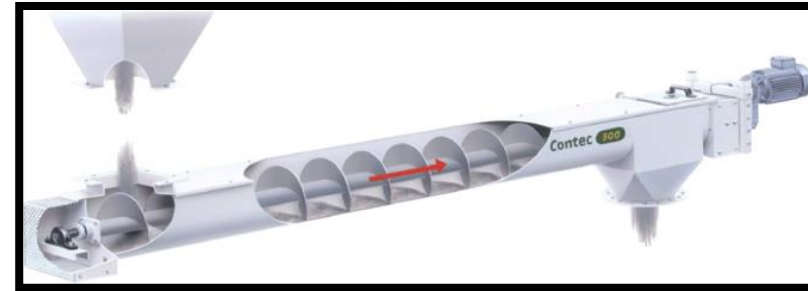
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# 2. Historical Context

- Modern implementations include:
  - Water and wastewater pump
  - Conveyor for grains
  - Fish ladder
  - Drive mechanism for amphibious vehicles
  - Injector in plastic moulding
  - Heart valve replacements
  - Hydropower generation

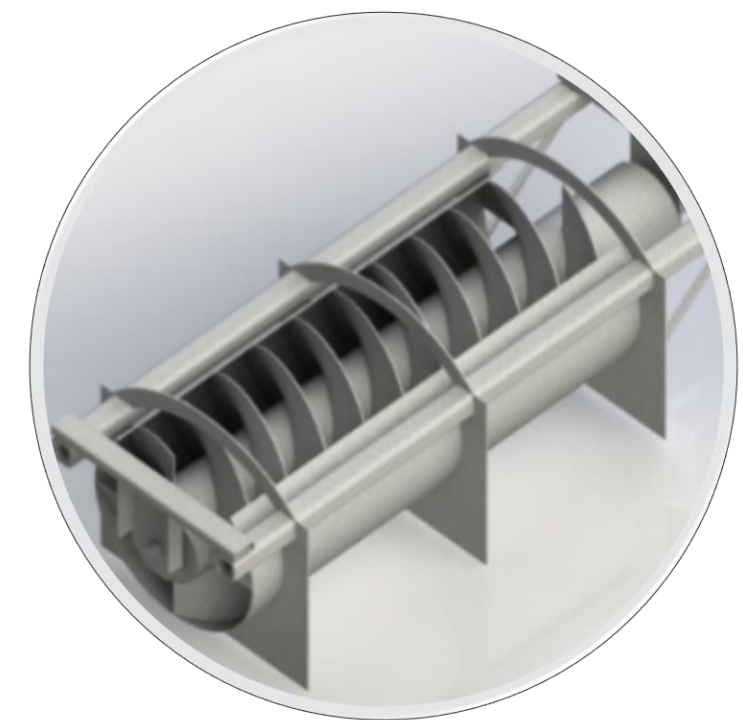


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## 3. Methods

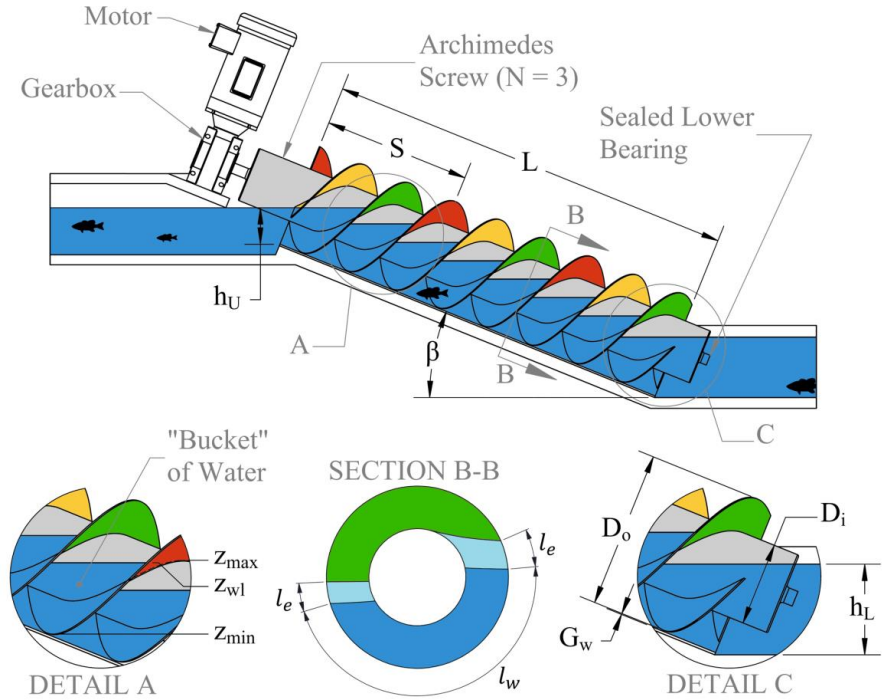


- Biological
- Biomedical
- Computer
- Systems and Computing
- Water Resources
- Mechanical
- Environmental

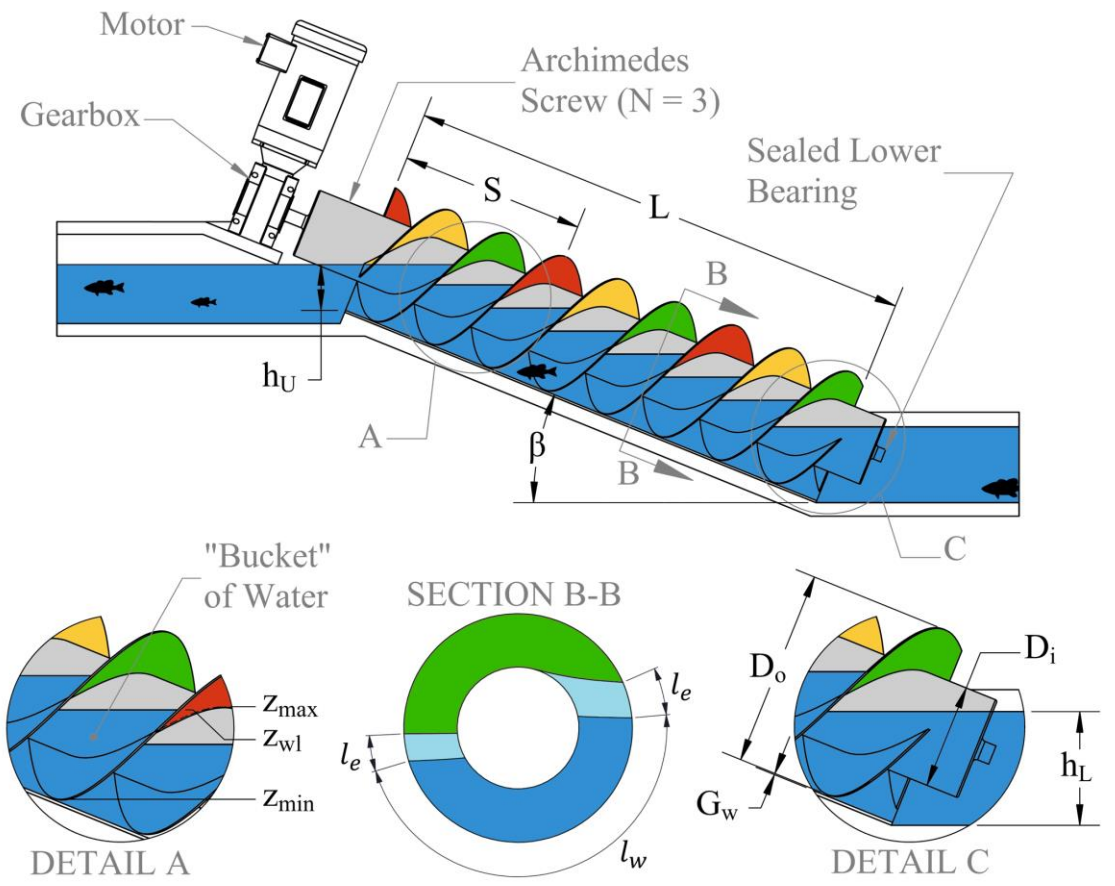


# 3. Methods

- Laboratory apparatus can vary lower water level ( $h_L$ ), upper water level ( $h_U$ ), and rotation speed ( $\omega$ )
- Want to quantify effect of above parameters on performance (flow rate, power usage) and mechanical efficiency

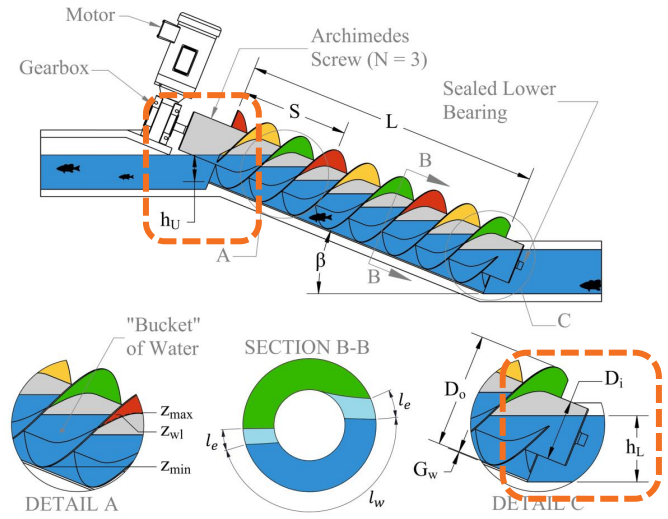


# 3. Methods



# 3. Methods

- In water and wastewater pumping systems, upper water level is often set to  $h_U = 0$  m (or  $\psi_U = 0\%$ )
- Lower water level ( $h_L$ ) is often set to an optimal height



Variable	Description
$\psi_L$	Dimensionless lower water level (-)
$\psi_U$	Dimensionless upper water level (-)
$h_L$	Lower water level (m)
$h_U$	Upper water level (m)

**About 75%  
Submerged  
[Near Optimal]**



**Over 100%  
Submerged  
[Not Optimal]**



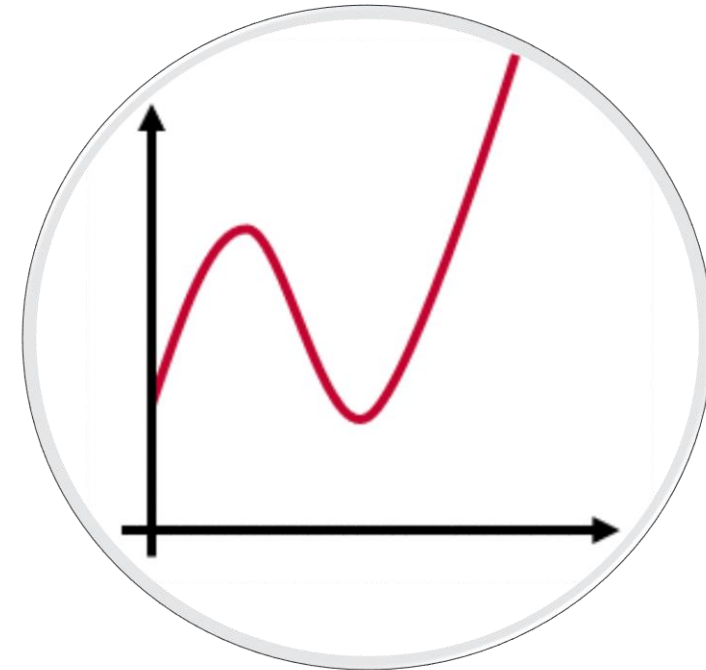
# 3. Methods

- We gathered data for every combination of the values shown in the table below ( $5^3 = 125$  data points)

Upper Water Level	Lower Water Level	Rotation Speed
$\psi_U$ (%)	$\psi_L$ (%)	$\omega$ (rev/min)
0 %	20 %	18
15 %	40 %	36.5
30 %	60 %	55
45 %	80 %	73.5
60 %	100 %	92



## 4. Results



# 4. Results



## 5. Conclusions



# 5. Conclusions

- The “state-of-the-art” is outdated
  - Lacks accuracy, lots of room for improvement
- More data is necessary for development of more accurate models
- There is a lot of room to improve models for flow and leakage rates, hydraulic losses, and geometric optimization



Thank you all very much for your time.

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