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Enabling Delta Life

TU Delft

Air pocket removal from downward sloping pipes

9th Int. IWA/IAHR Conference Urban Drainage Modelling, Belgrade

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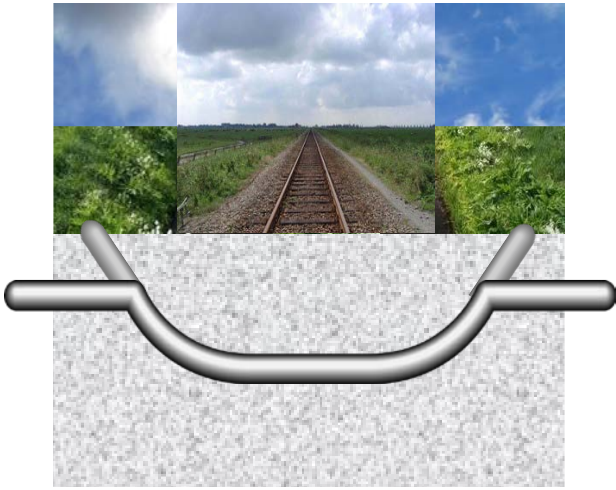
Background of Joint Industry Project CAPWAT

- CAPacity loss
- waste WATer mains
- Air accumulation in downward sloping sections
- Consequences
  - Energy losses
  - More maintenance
  - More investments
  - Unreliable transport capacity



- CAPWAT project 2003 – 2010
  - Water boards, pump manufacturer, consultants, Stowa, RIONED
  - Deltares, DUT

Facility in Hoek van Holland (video)

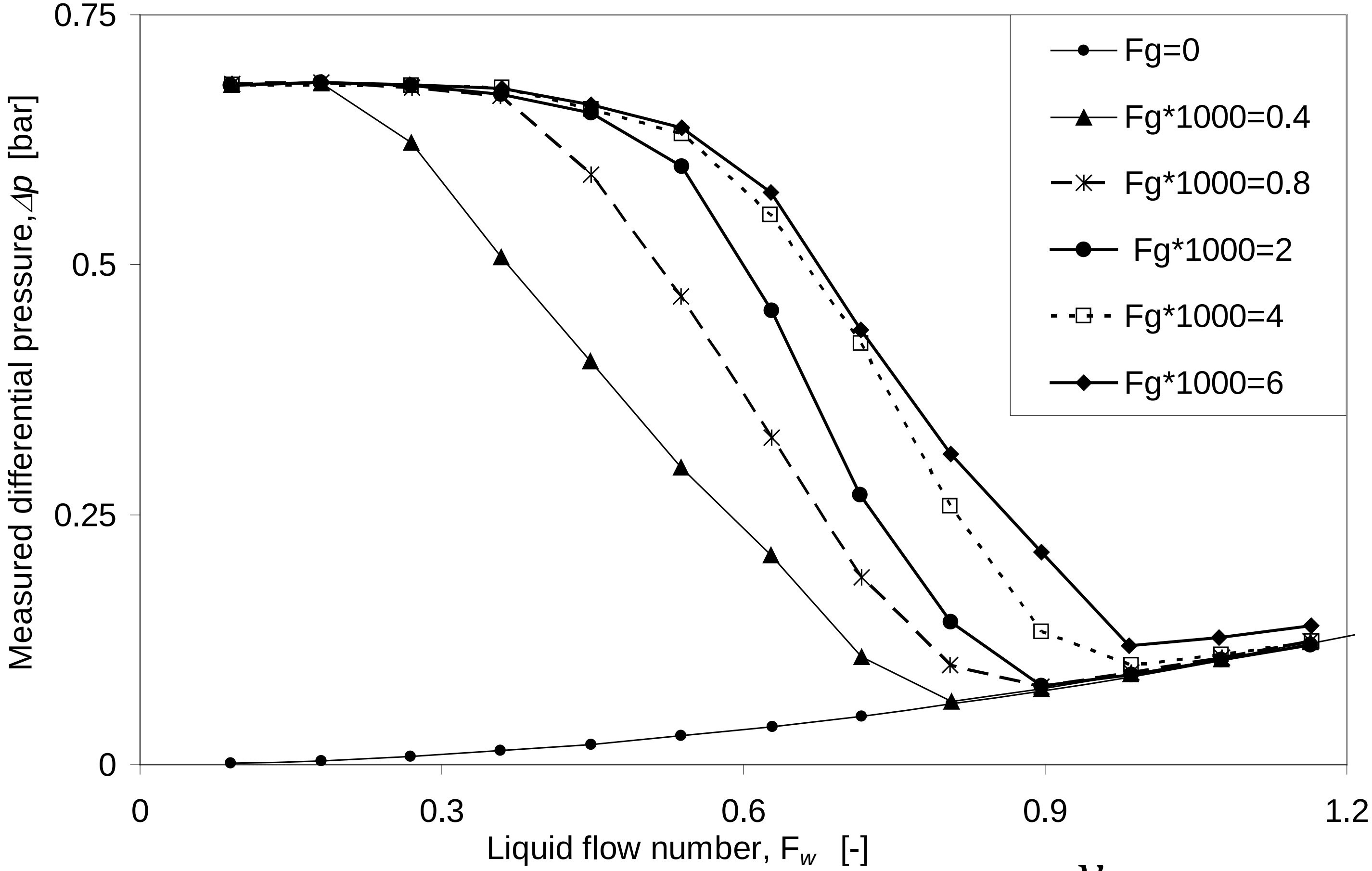

Key questions of CAPWAT

- What is required water velocity to move an elongated air pocket?
- How long should a certain water velocity be maintained to break down an air pocket?
- What are feasible mitigating measures?
- Need for practical guidelines

Approach for air pocket removal model

- Validated numerical model for steady air discharge
  - Geometry: Pipe diameter, pipe angle, length of slope
  - Operation: water discharge, gas pocket length, absolute pressure
- Assume no air inflow, then air outflow …....
  - reduces gas pocket length/head loss
  - reduces absolute pressure
  - may increase water discharge or reduce pump speed
- Integration in time yields
  - Evolution of gas pocket length and head loss,
  - Required water volume for head loss reduction

Air discharge highly varies due to gas pocket length



$$F_w = \frac{v_{sw}}{\sqrt{gD}}$$

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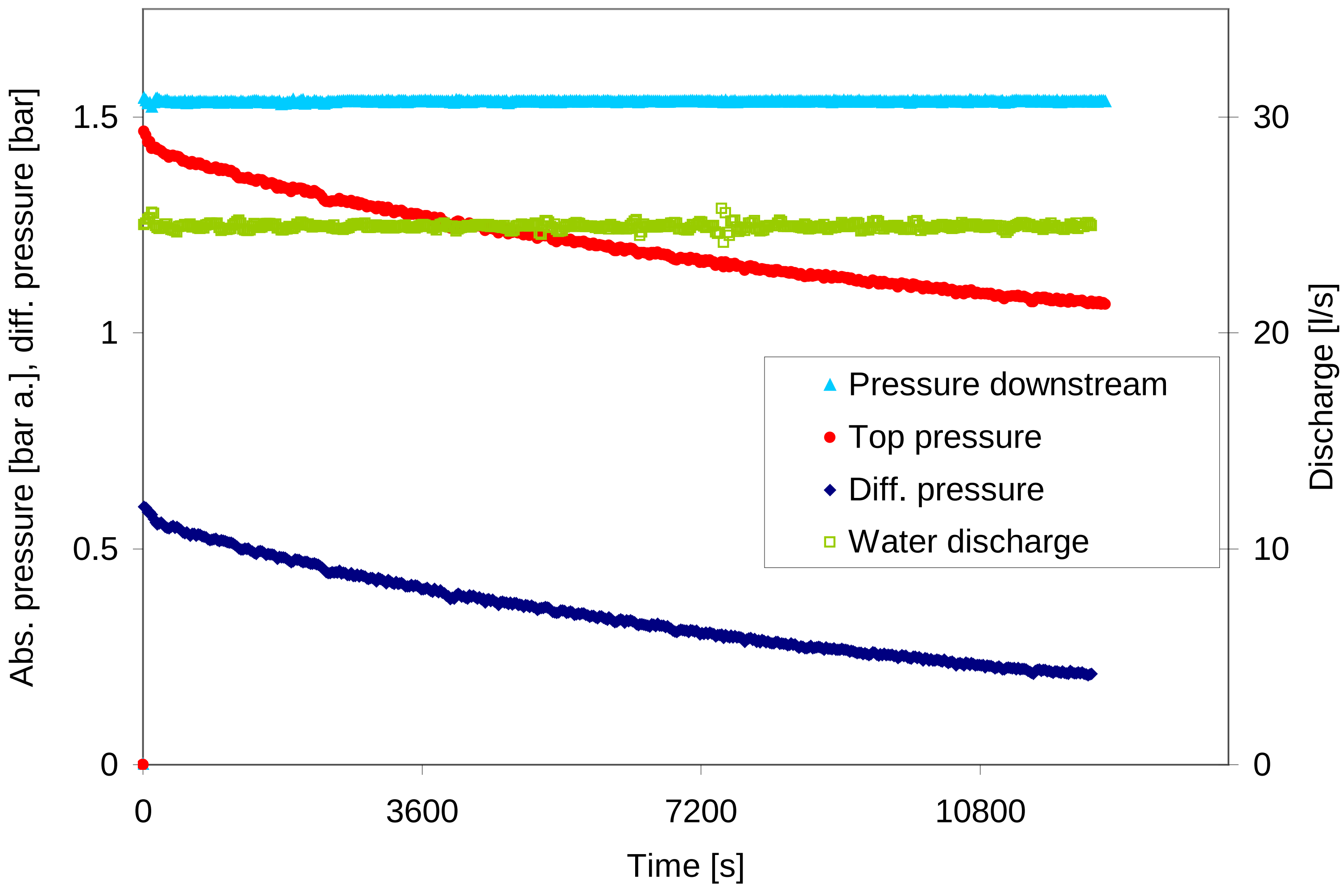
Assumptions for air pocket removal model

- Water is at normal depth under air pocket(s)
- Air pocket length and head loss are linearly related
- Air expansion is isothermal
- Air expansion in upstream section is neglected

- Validation experiments
    - F_w = 0.63; 0.75 and 0.94

Experiment at 25 l/s, 0.86 m/s, F_w = 0.63



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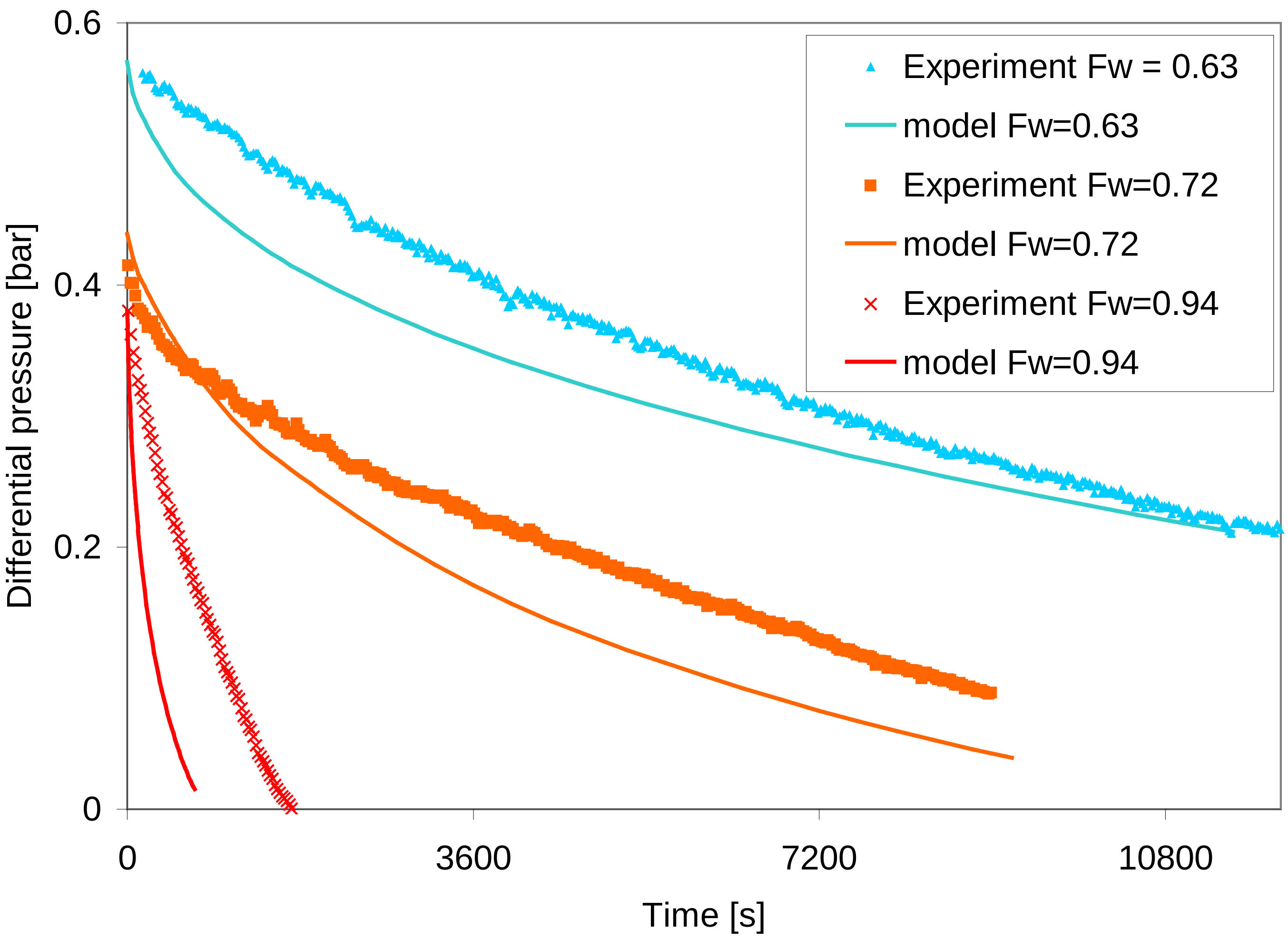
Model performance



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Conclusions and discussion

- Reasonable performance
  - required time and
  - water volume for air pocket removal
- However,
  - Air discharge is over-predicted for very large air pockets
  - If multiple air pockets are present (F_w>0.6), pressure recovery in hydraulic jumps should not be neglected.


Range of applications

- Air pocket removal in inverted siphons
- Air pockets behaviour in hydropower bottom outlets
- Air pockets behaviour in stormwater storage tunnels

- Questions?

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Approach – scientific track

- Lab measurements of co-current air-water flow in downward sloping pipes
  - Pipe diameter, pipe angle, air-water discharge ratio, equilibrium gas pocket length, absolute pressure
- Experiments at large-scale facility at WWTP
  - Length of sloping reach, water quality
  - 3 series of experiments
    - > Clean water
    - > Water with detergents
    - > Untreated wastewater

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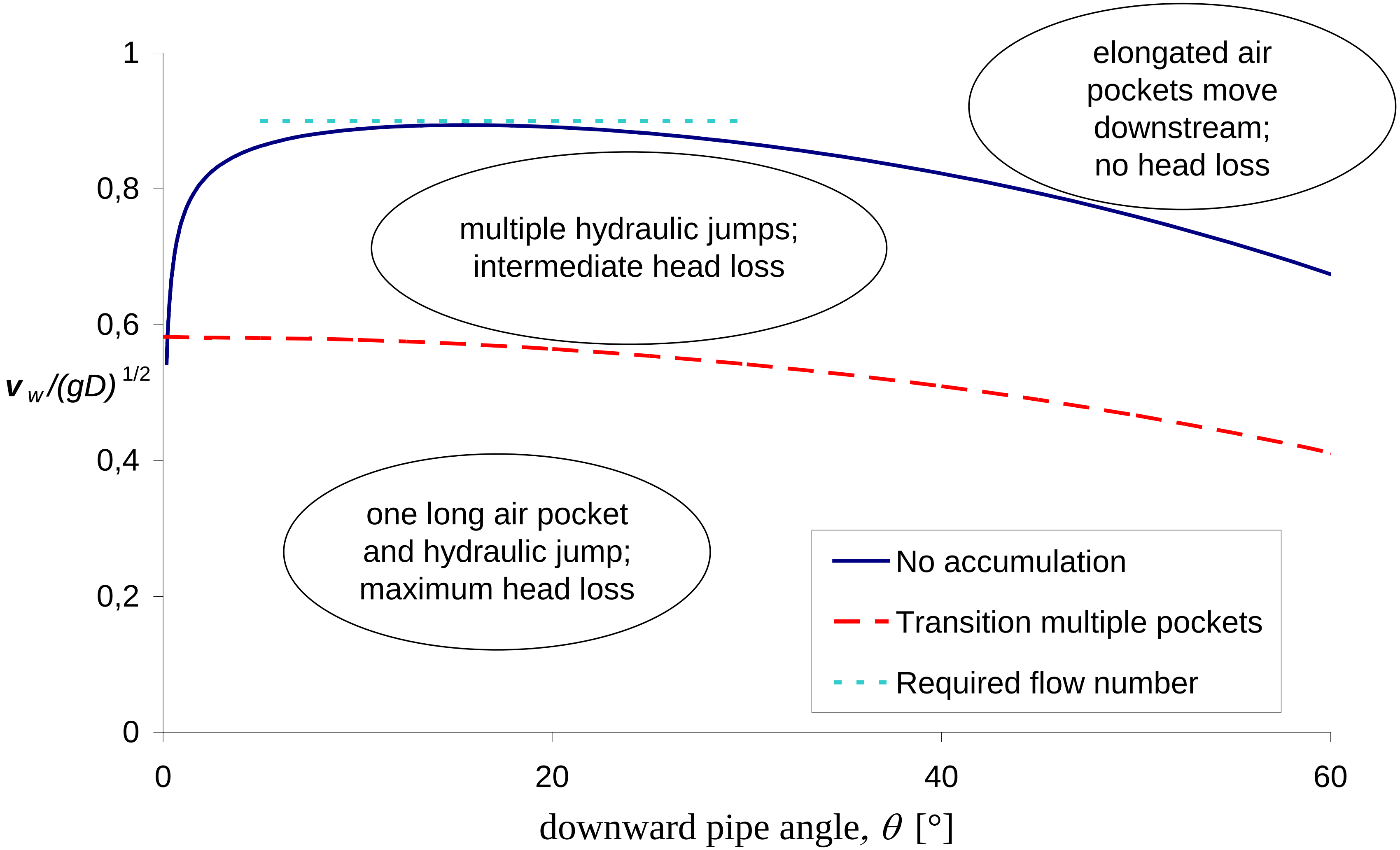
Overview of air-water flow experiments

Angle(°) Pipe D (m)	5	10	12.5	20	30	90
0.080			*30* / 77			
0.110		*27* / 78				
0.150		*30* / 105				
0.192		*209* / 130*)				
0.220	*30* / 90	*30* / 95		*30* / 51	*30* / 83	*10* / 98
0.220		*21* / 61		*57* / 55		
0.500		*25* / 23				

Key results - Flow regimes



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Approach – practical track

- 3 progress meetings / workshops per year
  - Input for Handbook
- Handbook on hydraulic design & operation of pressurised wastewater mains
  - Editorial Board from participants
  - Input from scientific track

  - First release 2010, update 2011 (Dutch)

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Handbook structure – Flow diagrams

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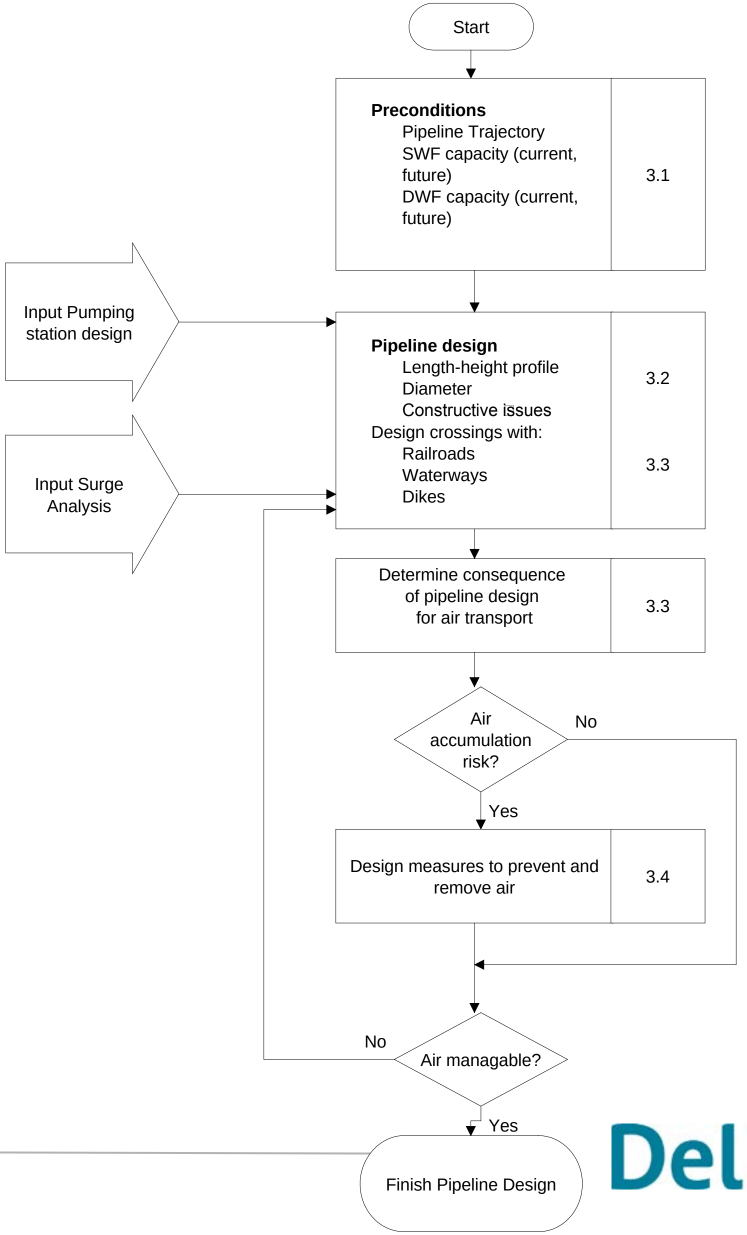

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Possible air management measures

- Pump stop procedure (soft-stop)
- Raise switch-off level
- Vertical deflection plate in pump pit
- Include pigging facility (Y-piece)
- Reduce diameter of inverted siphon

- See paper for more

CAPWAT applications

- Wastewater engineering
  - Design – minimise air-entrainment into pipeline
  - Operation – prevent capacity issues and excessive energy consumption
  - Operation – compute water volume to breakdown air accumulation
- Stormwater storage tunnels and hydropower stations
  - Better understanding of air pocket motion
  - Prevent blow-back events
  - Proper venting
- Two-phase flow applications
  - Donwardly inclined pipe as efficient separator
  - Possibly improve slug prediction models


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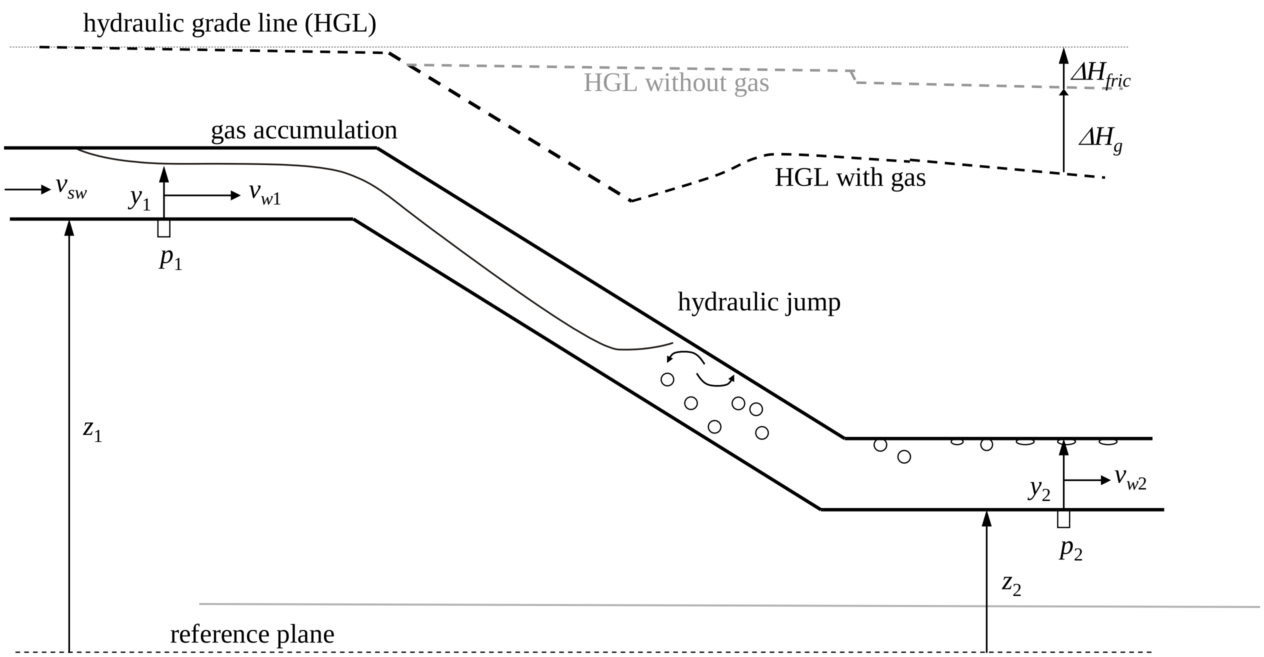
Approach – co-current air-water experiments

- Measured variables
  - Air discharge (controlled)
  - Water discharge (controlled)
  - Differential pressure
  - Absolute upstream pressure
  - Water temperature
  - Air pocket characteristics (length, max. height)



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