

SURGE AND AIR POCKETS RELEASE ANALYSIS OF LOT AND OARS TUNNELS IN COLUMBUS, OHIO

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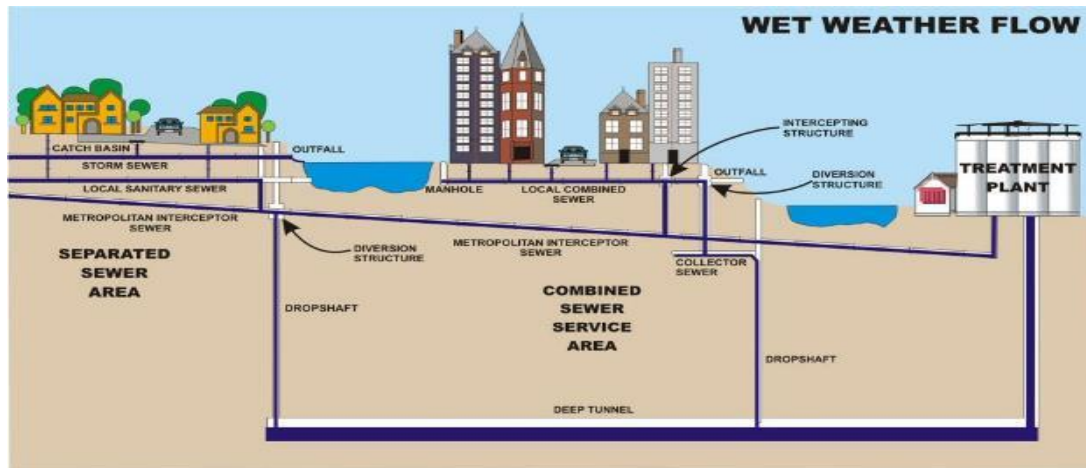
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Agenda

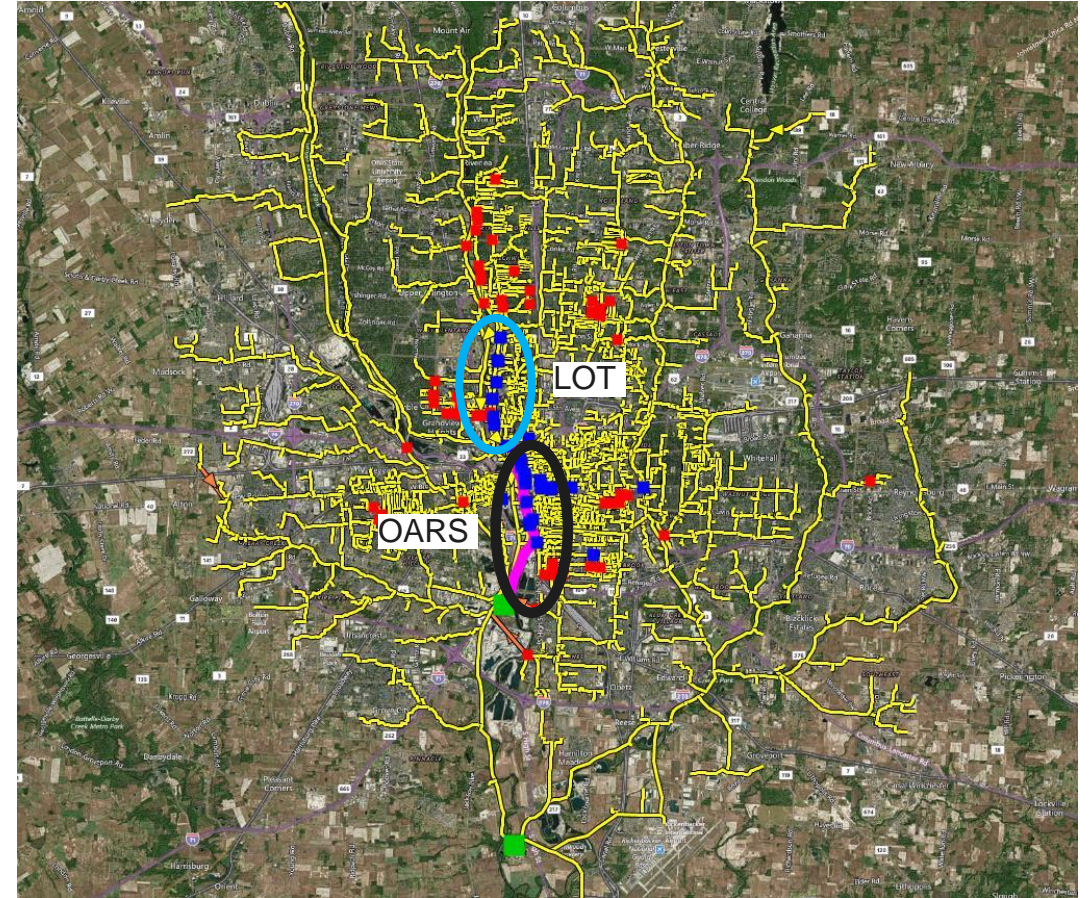
- ❑ OARS and LOT Tunnels
- ❑ Surge Modeling using HAST
- ❑ Air Pockets Modeling using CFD

OARS and LOT Tunnels in Columbus

- Mitigate active CSOs
- OARS is existing - 4.4 miles of 20' tunnel
- LOT is an extension and it is under design - 3 miles of 12' tunnel

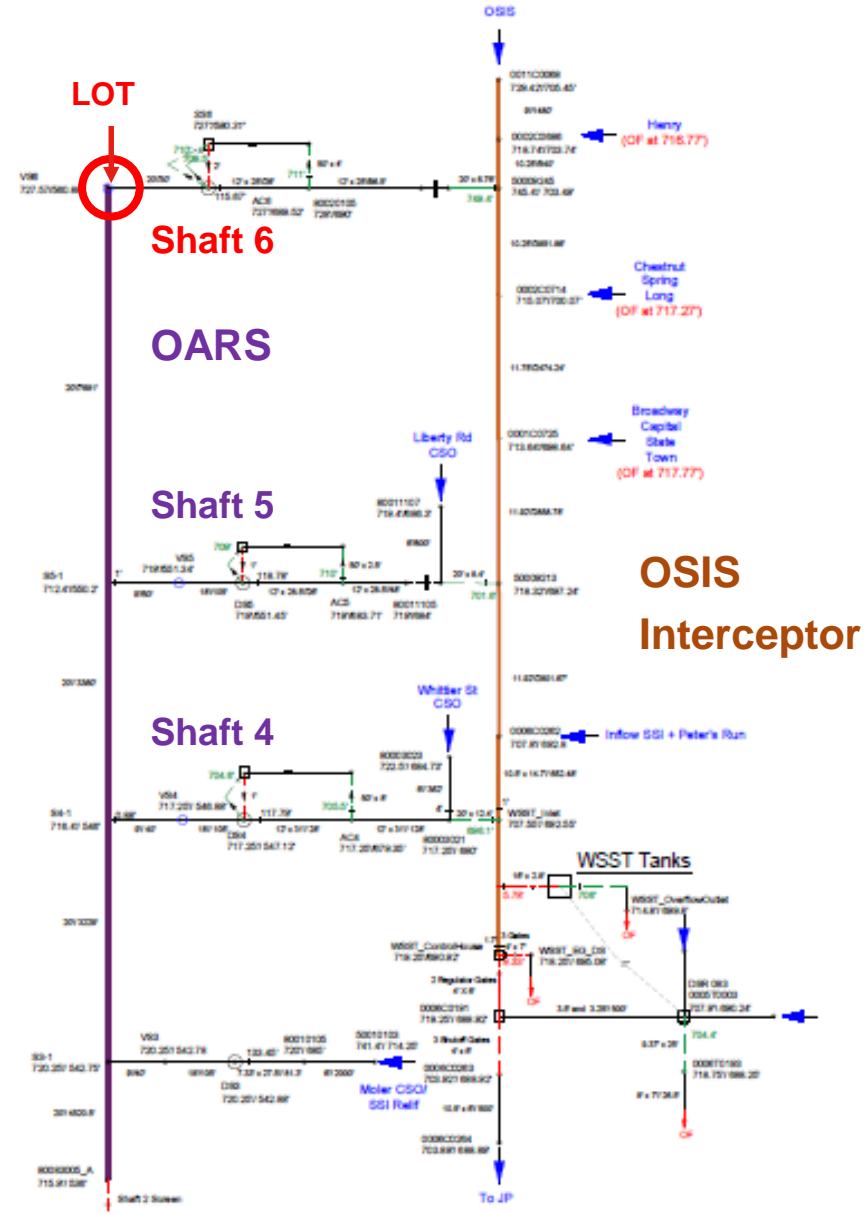


Source: <https://www.columbus.gov/utilities/projects/OARS-Deep-Sewer-Tunnel/>



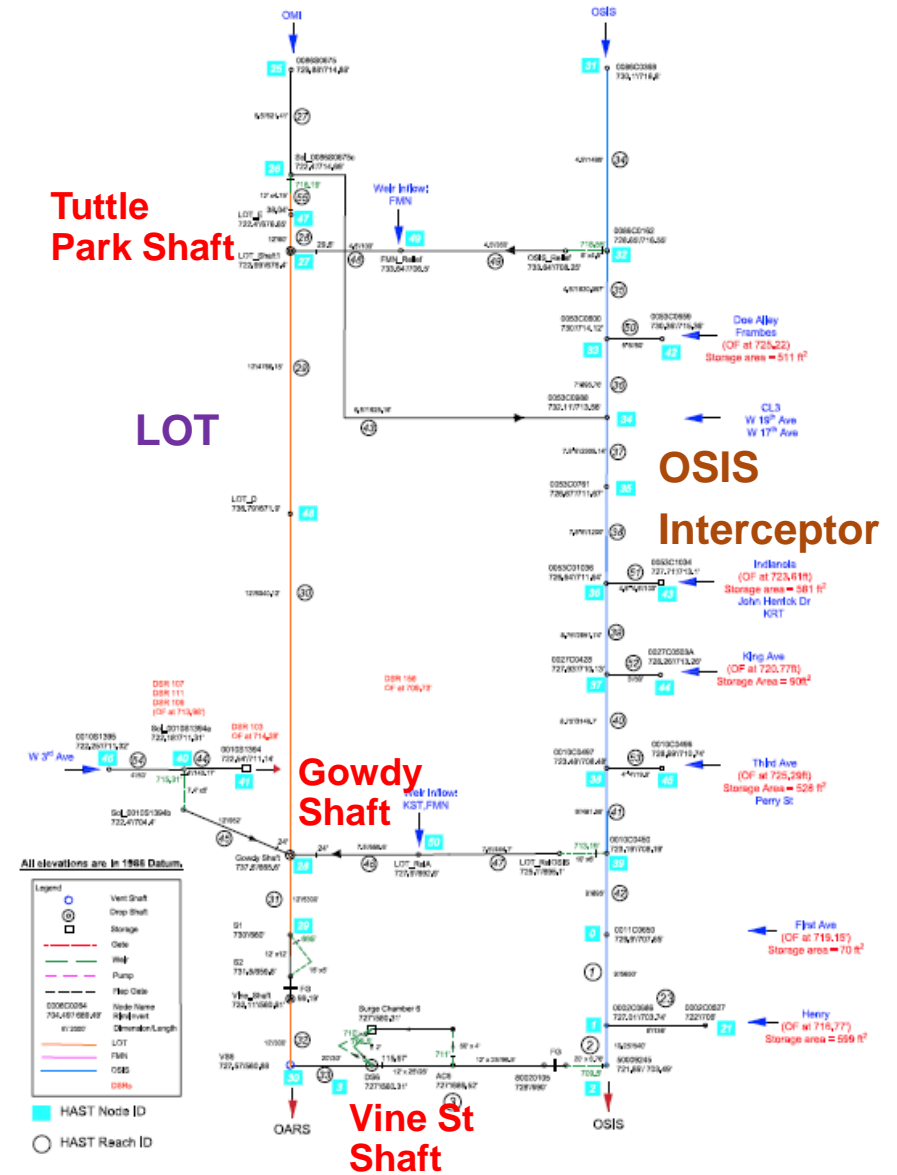
OARS Configuration

- Relieves OSIS interceptor using three weir gates and approaching channels
- Three drop shafts
 - Shafts 4 and 5 has 9 ft adit to OARS at invert
 - Flow drops directly into OARS at Shaft 6



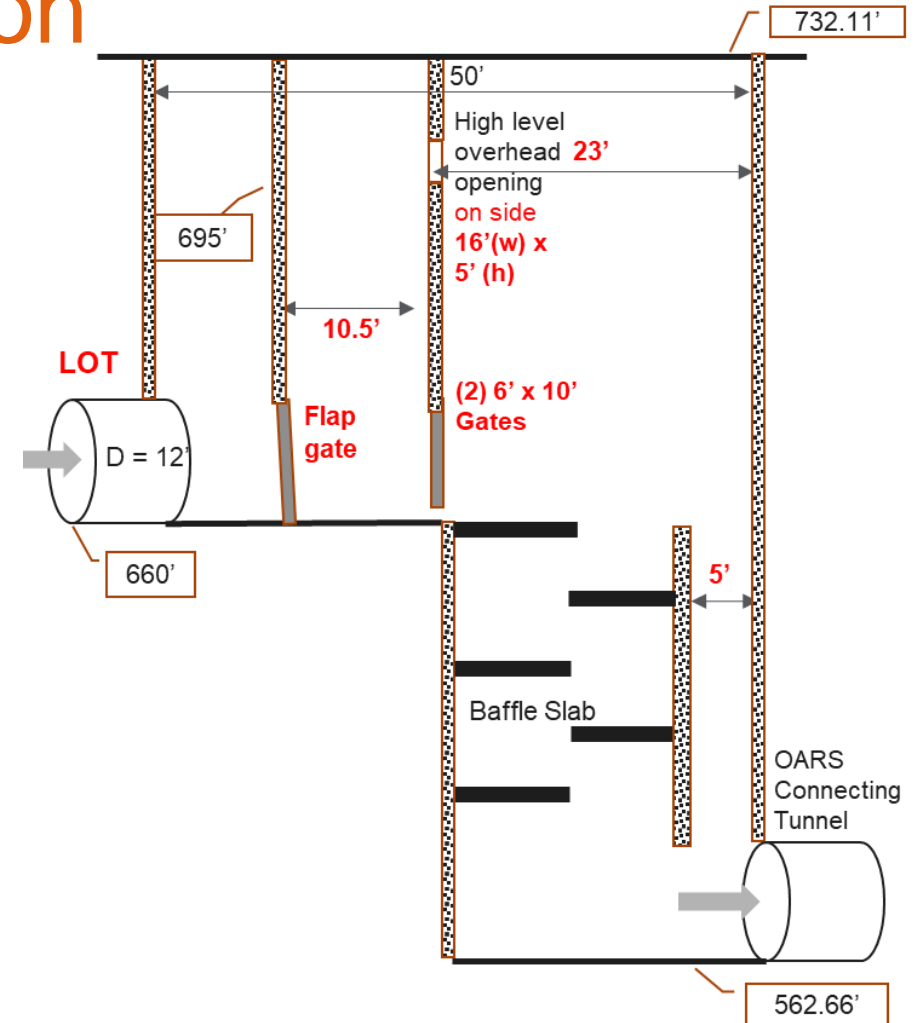
LOT Configuration

- Relieves OSIS interceptor using three six weirs and relief pipes
- Three drop shafts
 - Tuttle Park
 - Gowdy St
 - Vine St (Baffles)



LOT Vine St. Shaft Configuration

- Flap gate
- Sluice gate to be used to store flow in LOT and flush the tunnel after storms
- Baffles are to dissipate the energy associated with the large drop



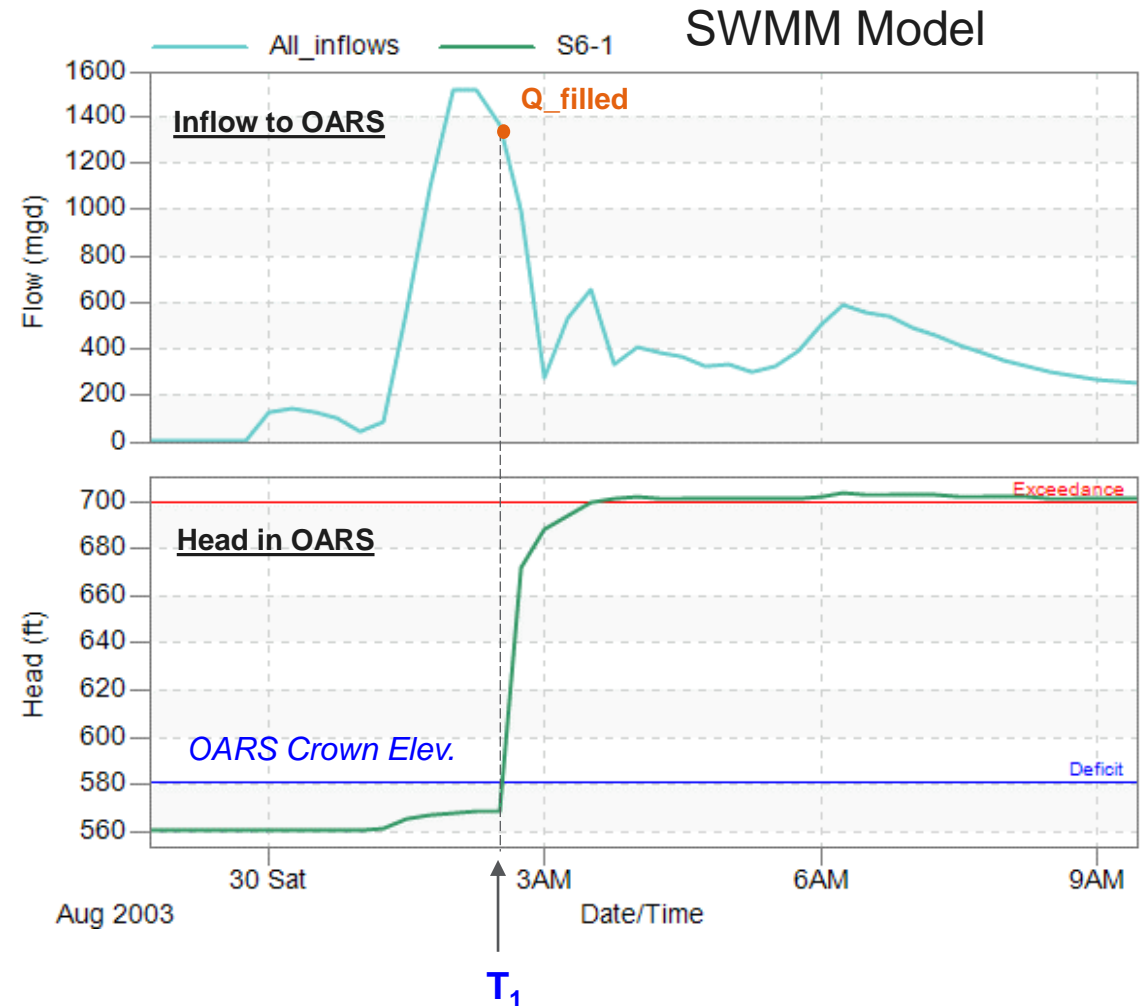
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- ❑ Surge Modeling using HAST
- ❑ Air Pockets Modeling using CFD

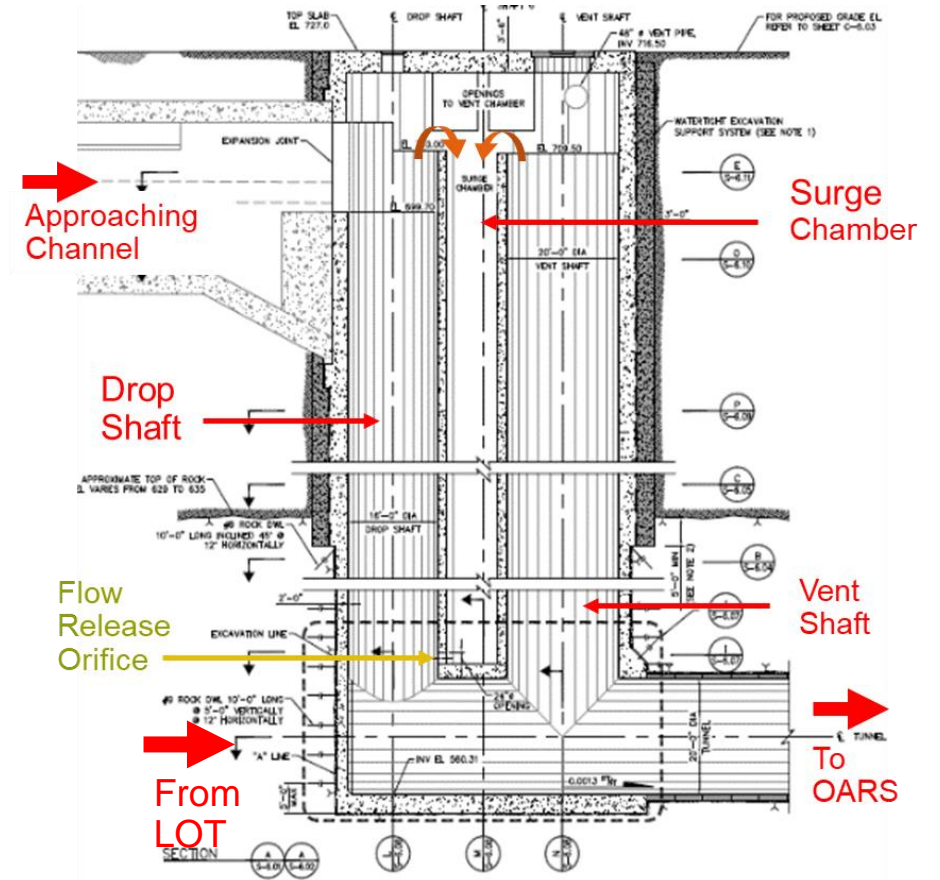
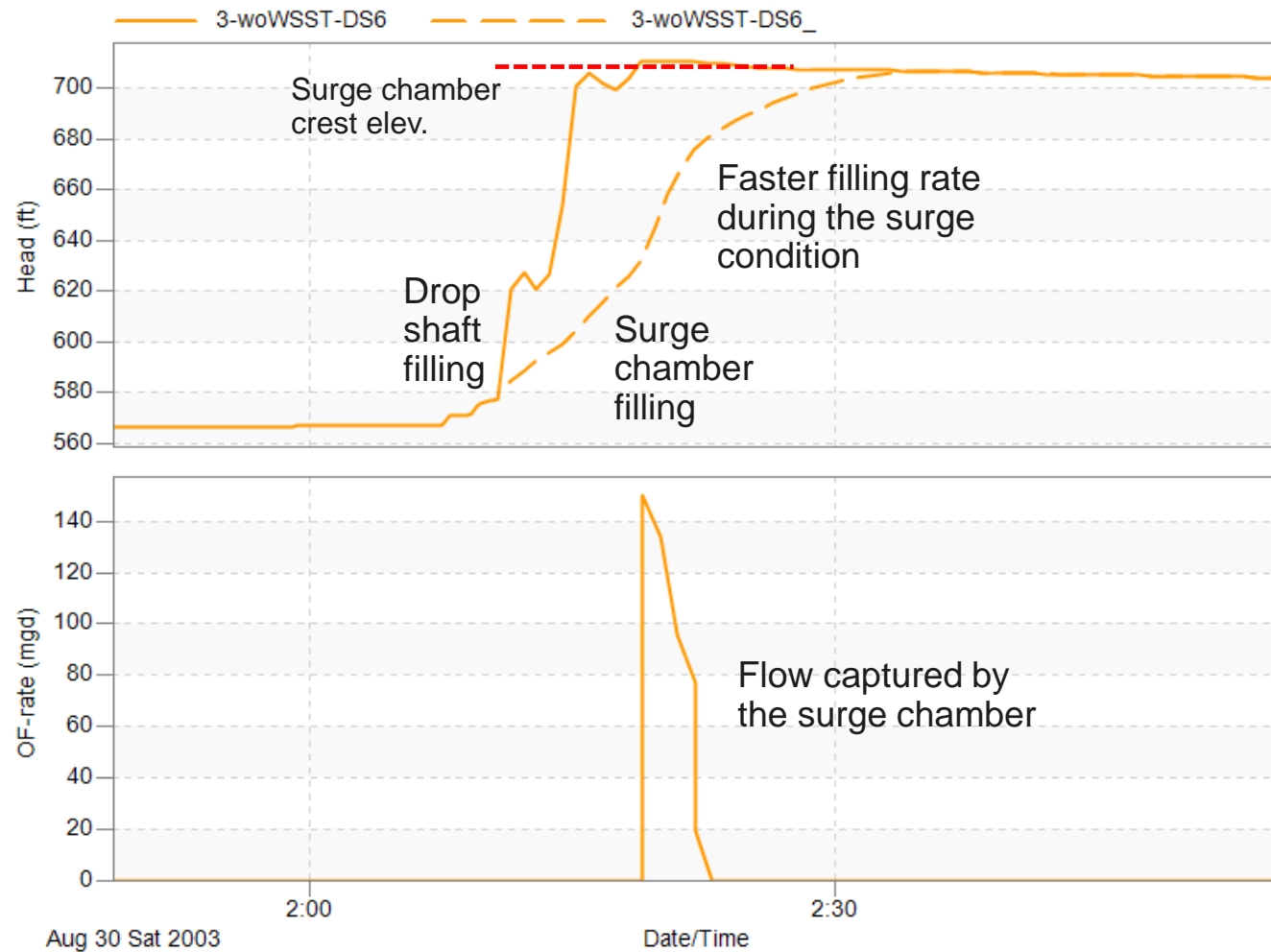
Critical Events

- Used SWMM to simulate 20 years of historical storms
- Identified storms with high risk surge condition - tunnel is full and high inflow continues

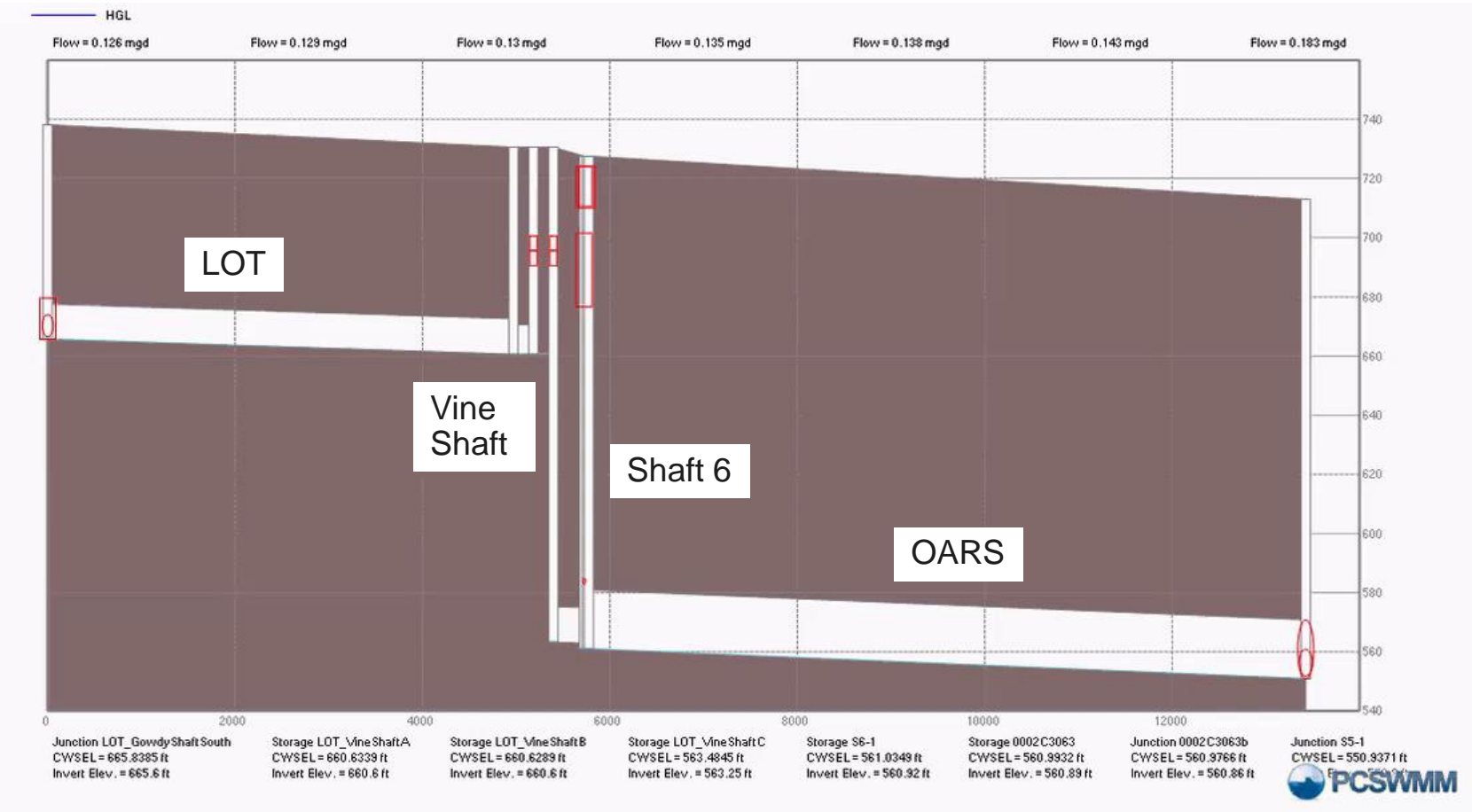
Rank	Event	Q filled (mgd)
1	8/30/2003	1365.382
2	8/28/2009	1281.328
3	6/11/2004	851.522
4	1/11/2005	686.591
5	5/31/1997	585.656
6	1/3/2000	559.088
7	12/21/1998	515.211
8	1/3/2004	422.629
9	12/5/2011	333.683
10	1/15/1995	310.615



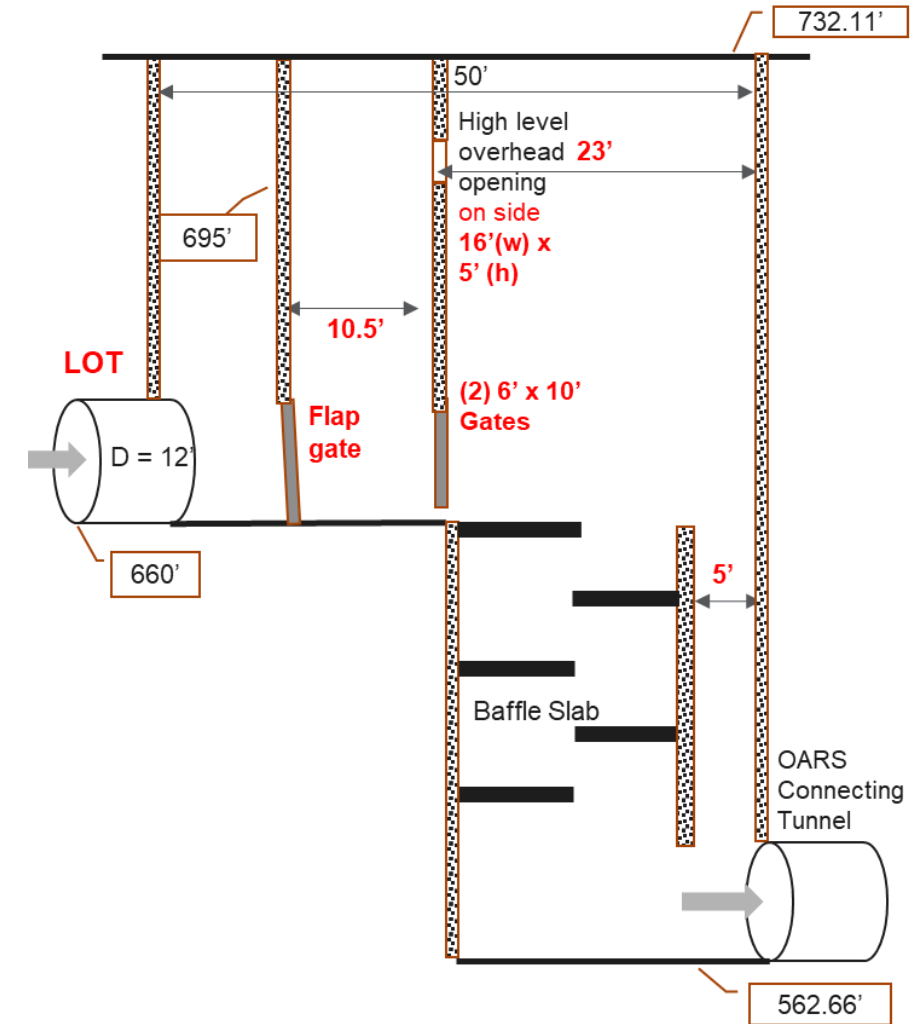
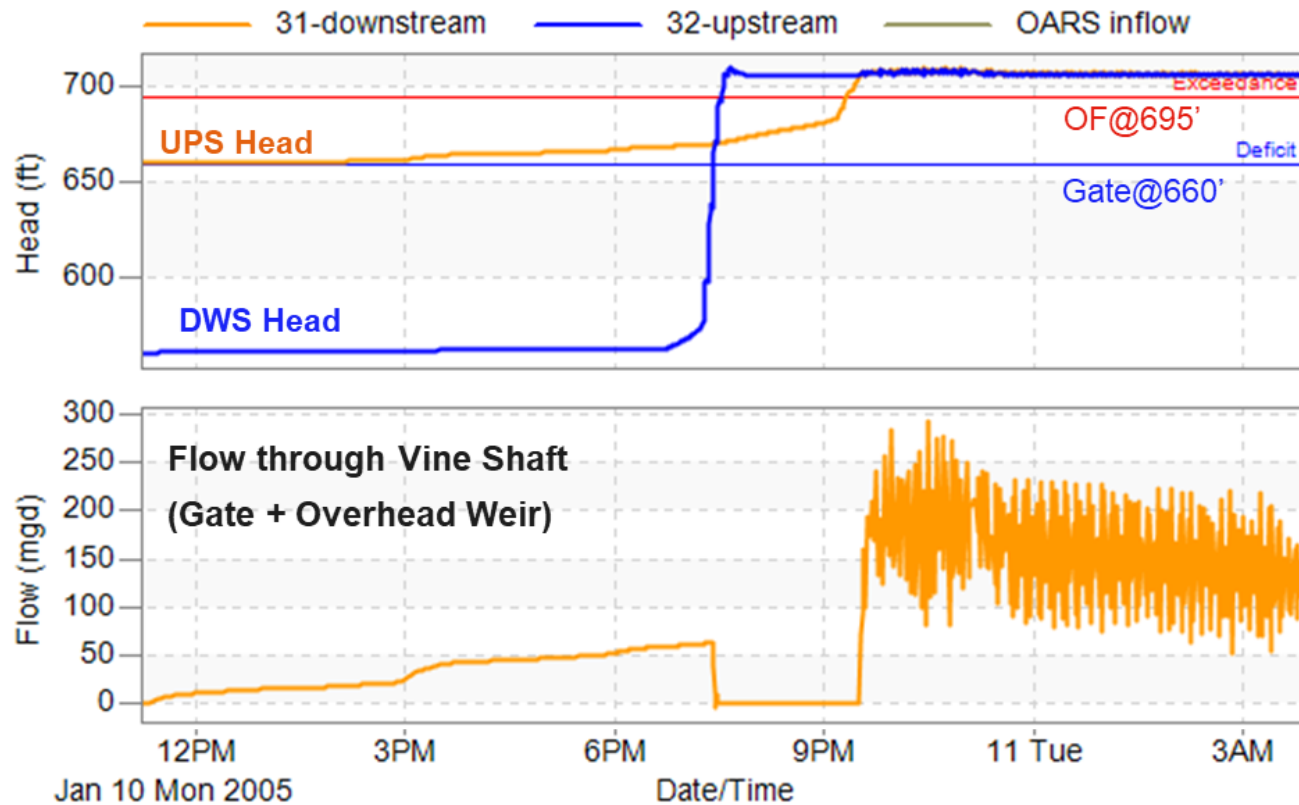
OARS Surge Chamber at Shaft 6



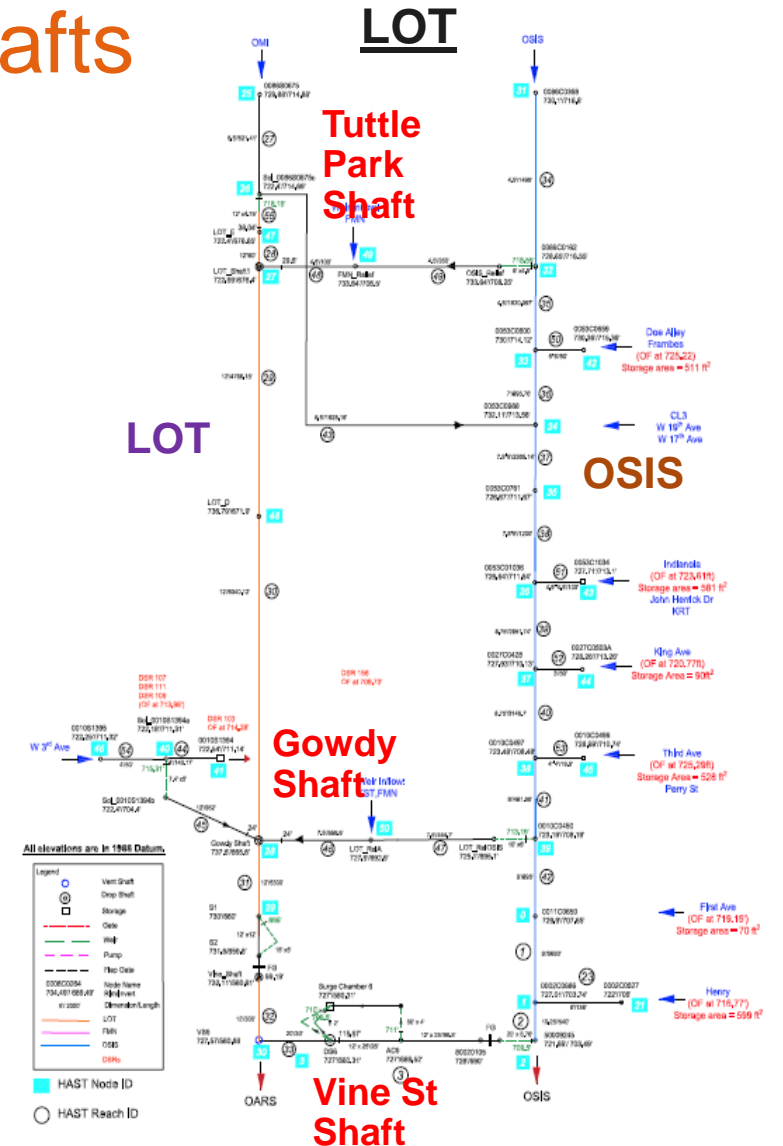
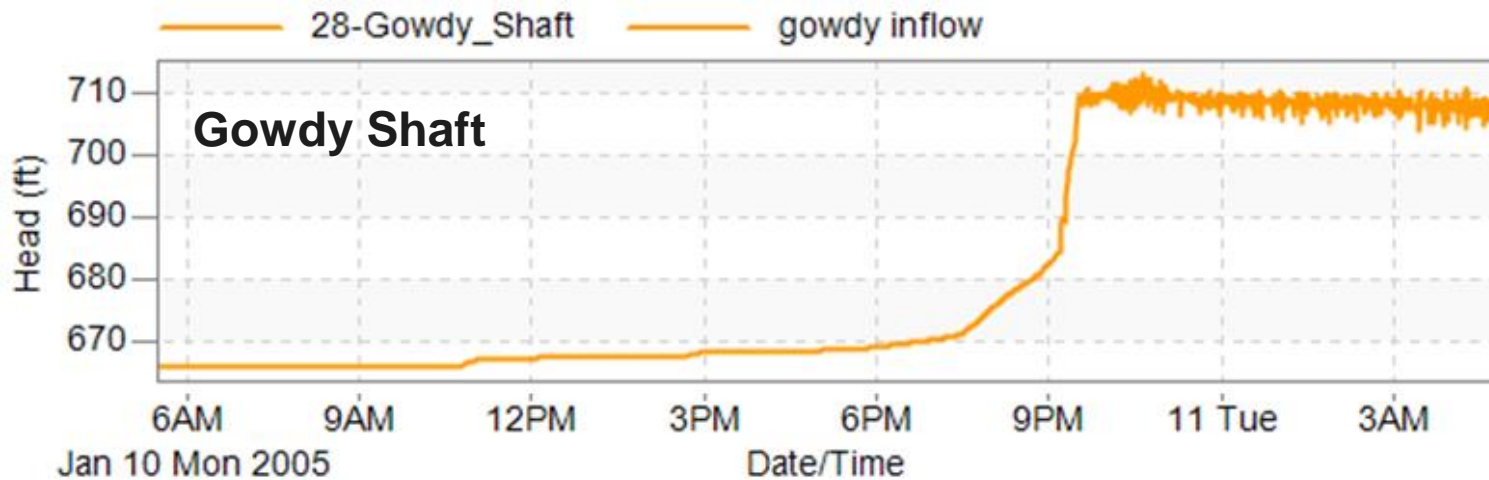
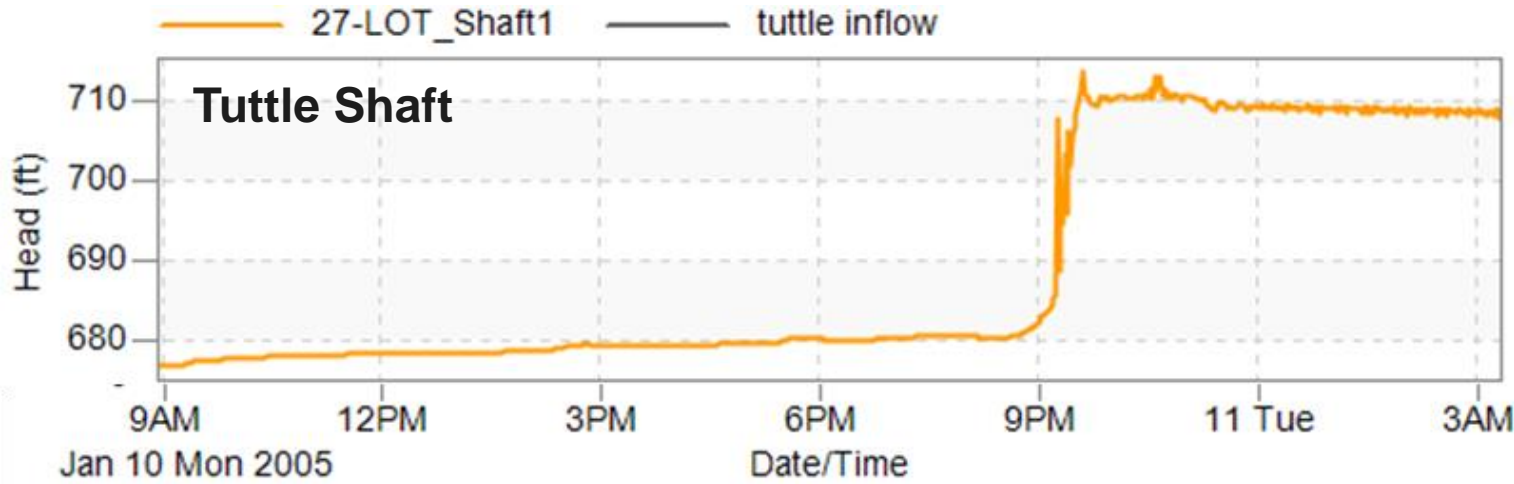
Backup Condition from OARS into LOT



LOT Surge Condition – Vine Shaft

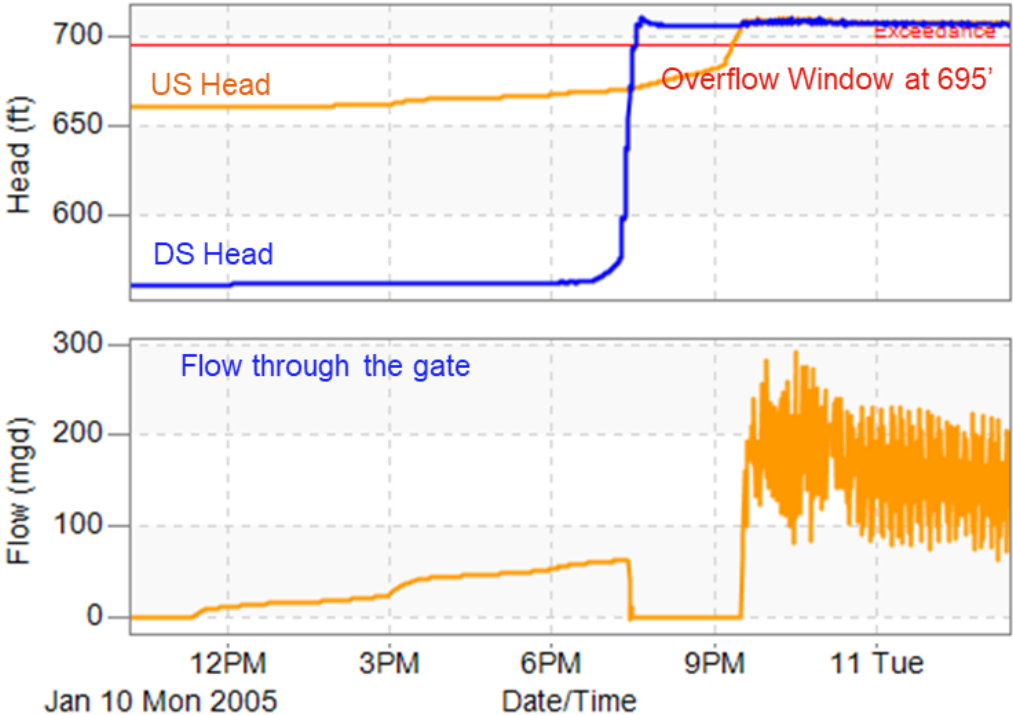


Surge Condition at Tuttle and Gowdy Shafts

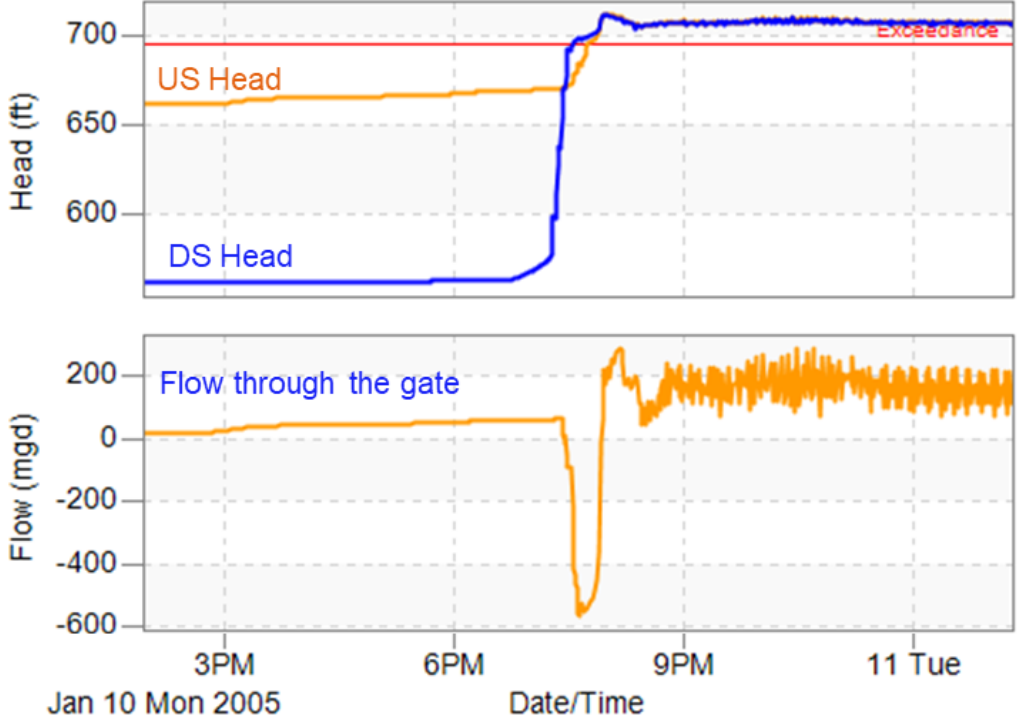


Impact of Flap Gate on Vine Shaft Surge

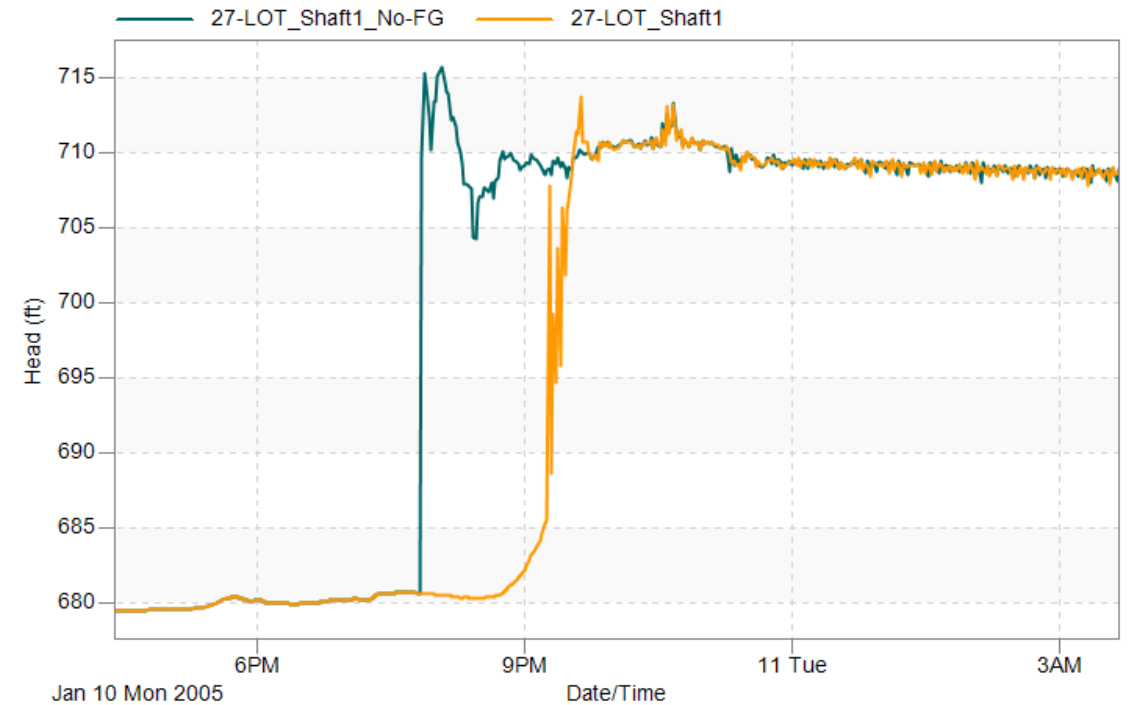
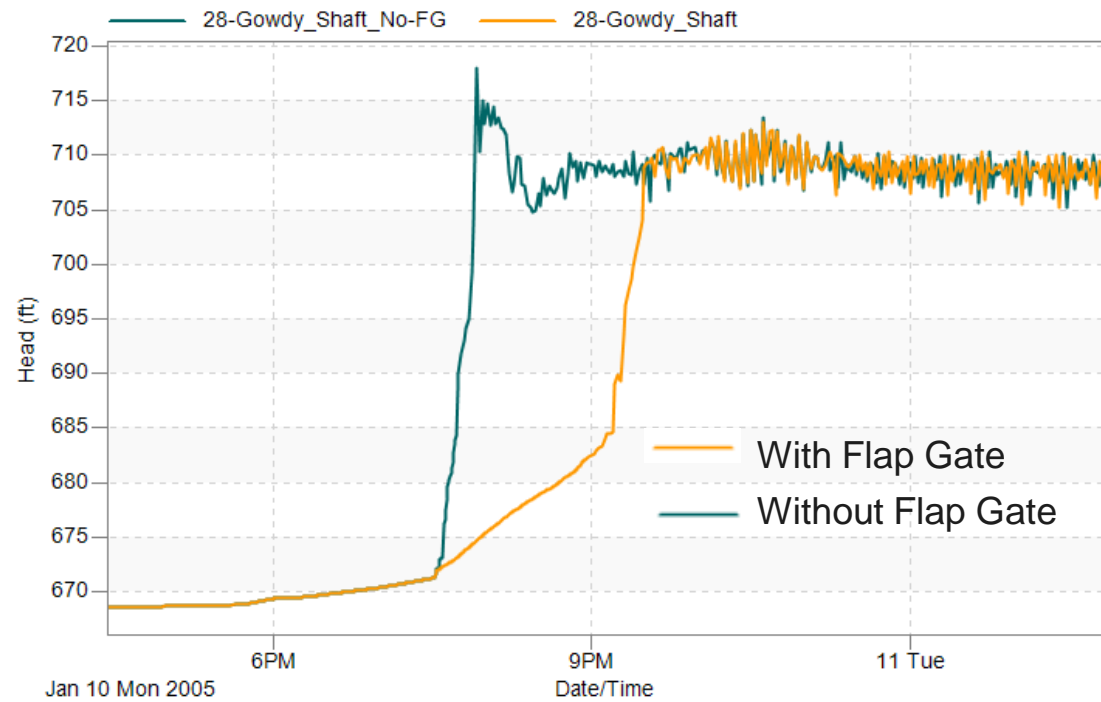
With Flap Gate



Without Flap Gate



Impact of Flap Gate on Gowdy and Tuttle Shafts



Flap gate reduces backups and the impact of OARS surge conditions on LOT

Agenda

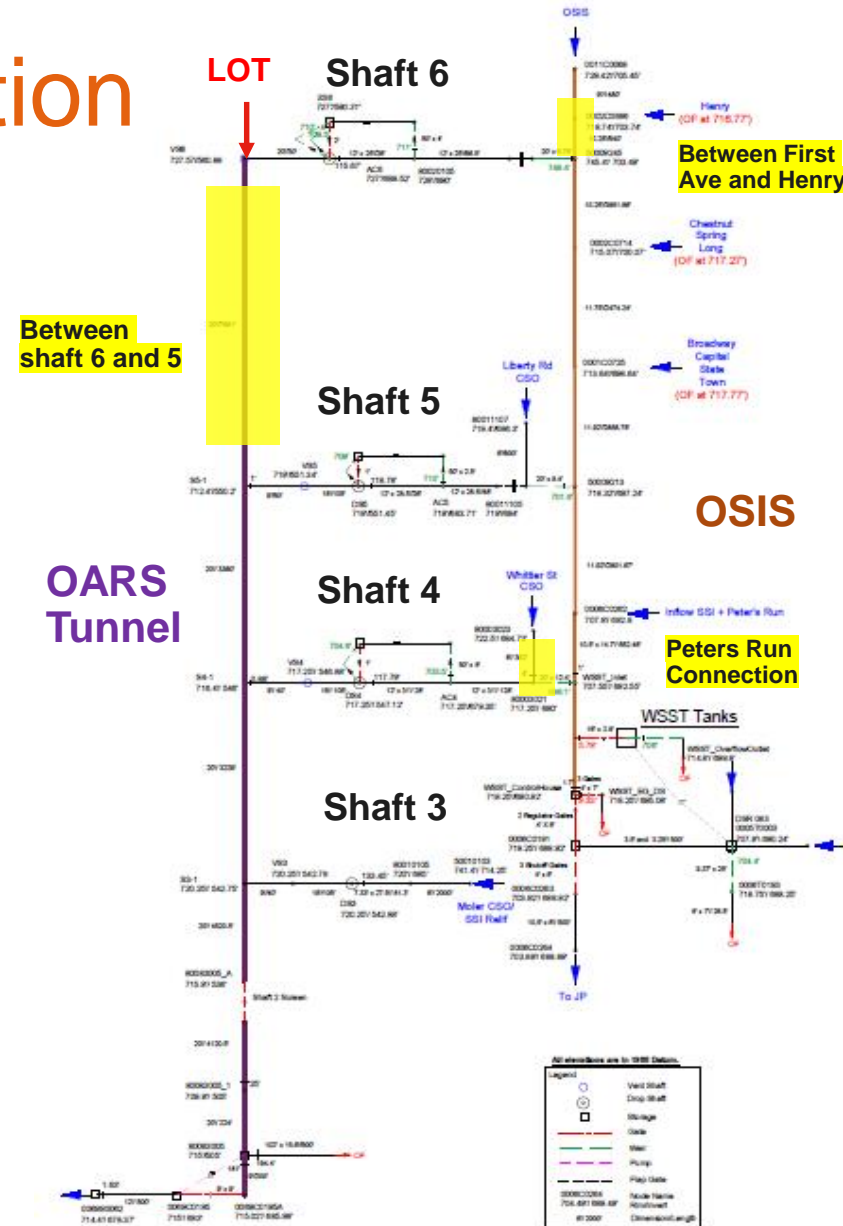
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Air Phase in Conveyance Tunnels

- Tunnel fills rapidly during intense storms
- Air can be trapped due to
 - Water waves in the tunnel
 - Back-to-back storms
- Air pockets phases
 - Compression and expansion cycles
 - Spreading and dragging with the flow
 - Potential for uncontrolled release at the vertical shafts
- Used HAST to evaluate the air pockets formation in OARS and LOT

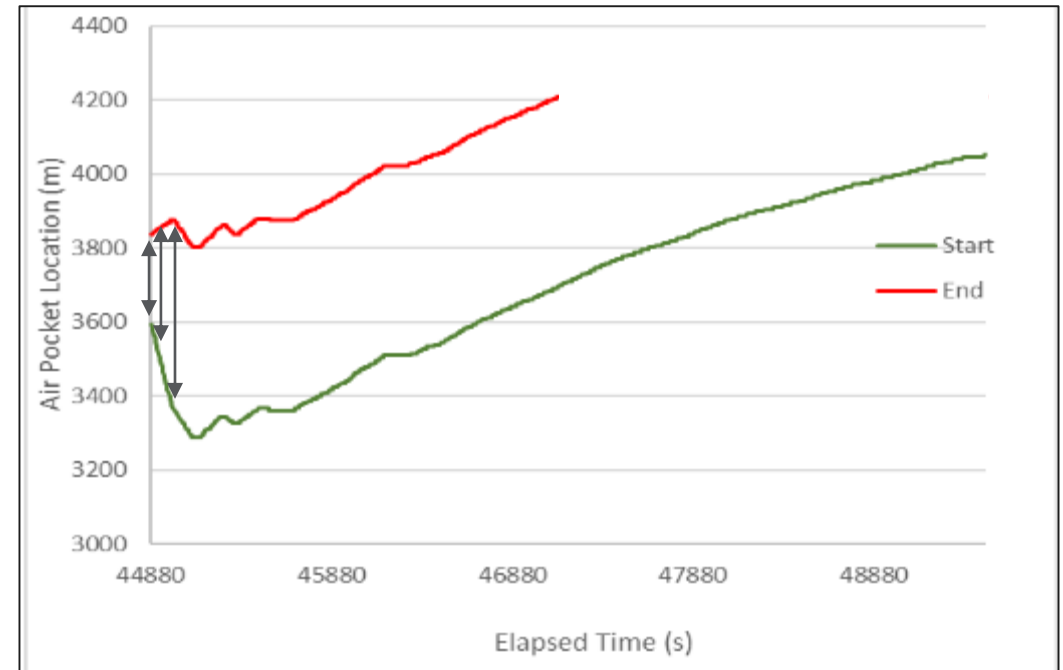
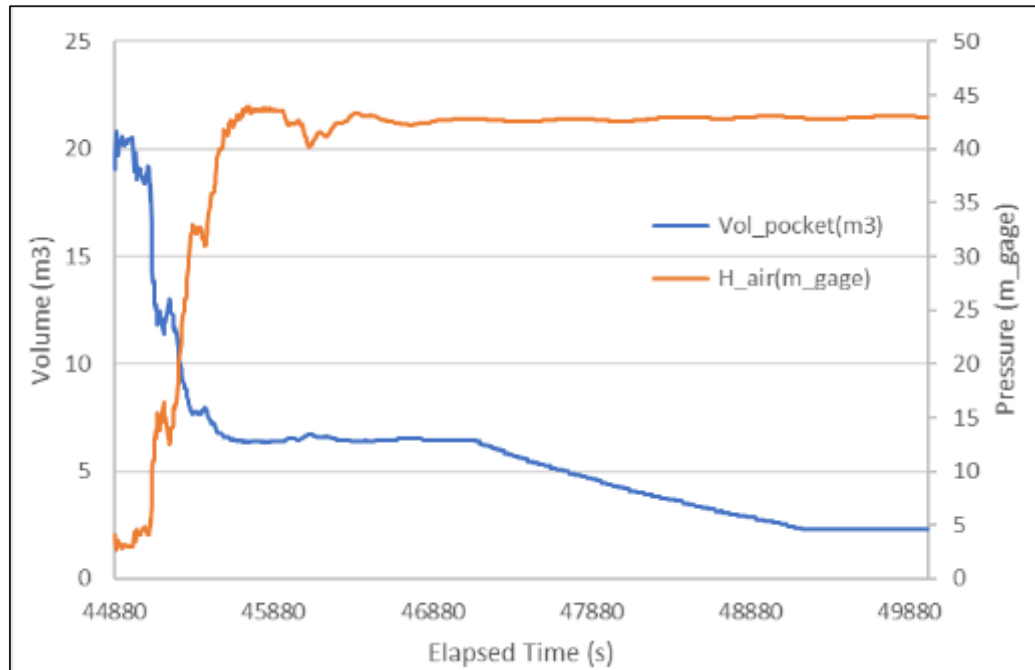
OARS Air Pockets Formation

- Based on HAST simulation, there expect to be a chronic air pocket formation at the upstream reach of OARS
- Air pockets configuration
 - First it is usually dragged downstream with the flow
 - Then moves upstream and releases through Shaft 6

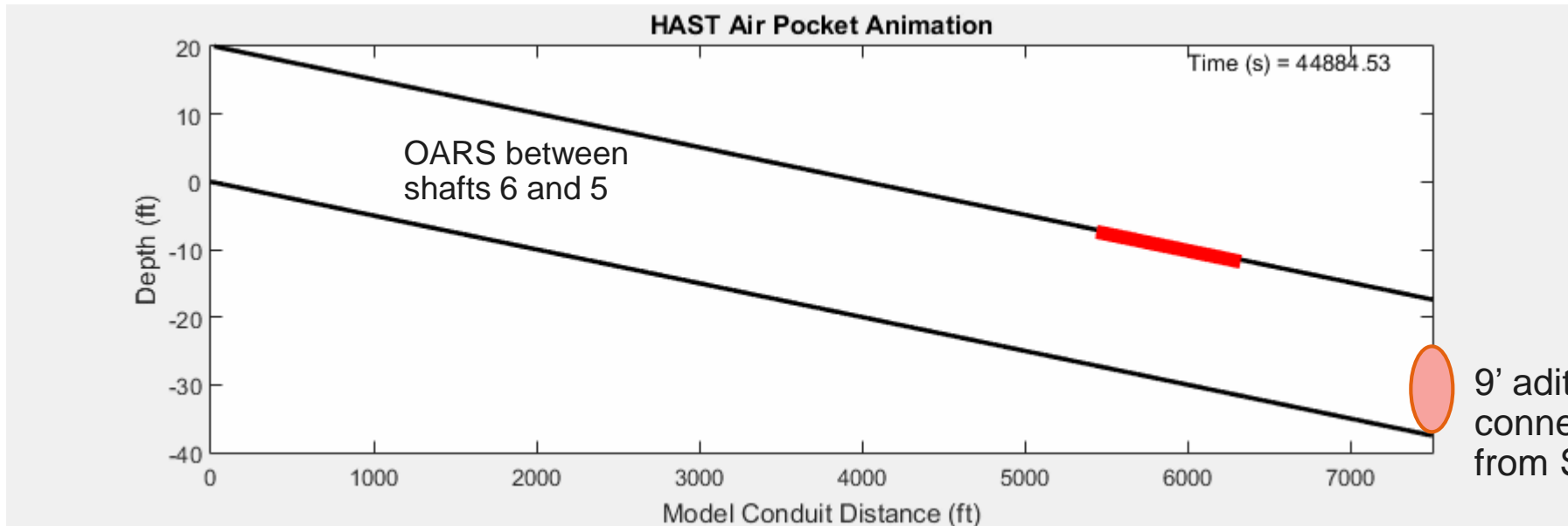
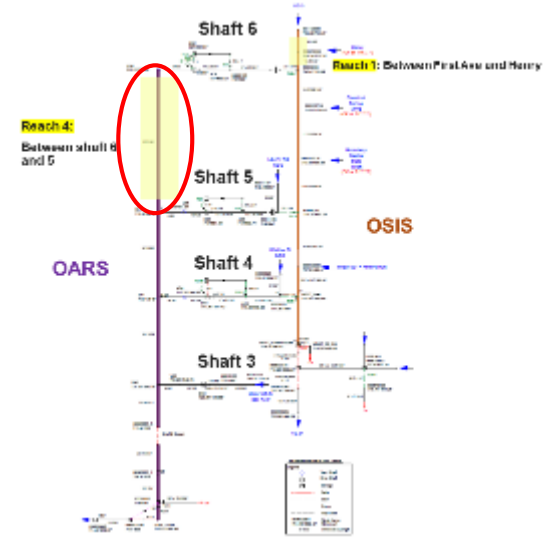


OARS Air Pockets Results

- HAST simulation indicates air pocket is pressured against pipe crown
- Volume of the air pocket decreases as its pressure increases
- Air pocket spreads while moving along the tunnel



Air Pockets Formation and Movement



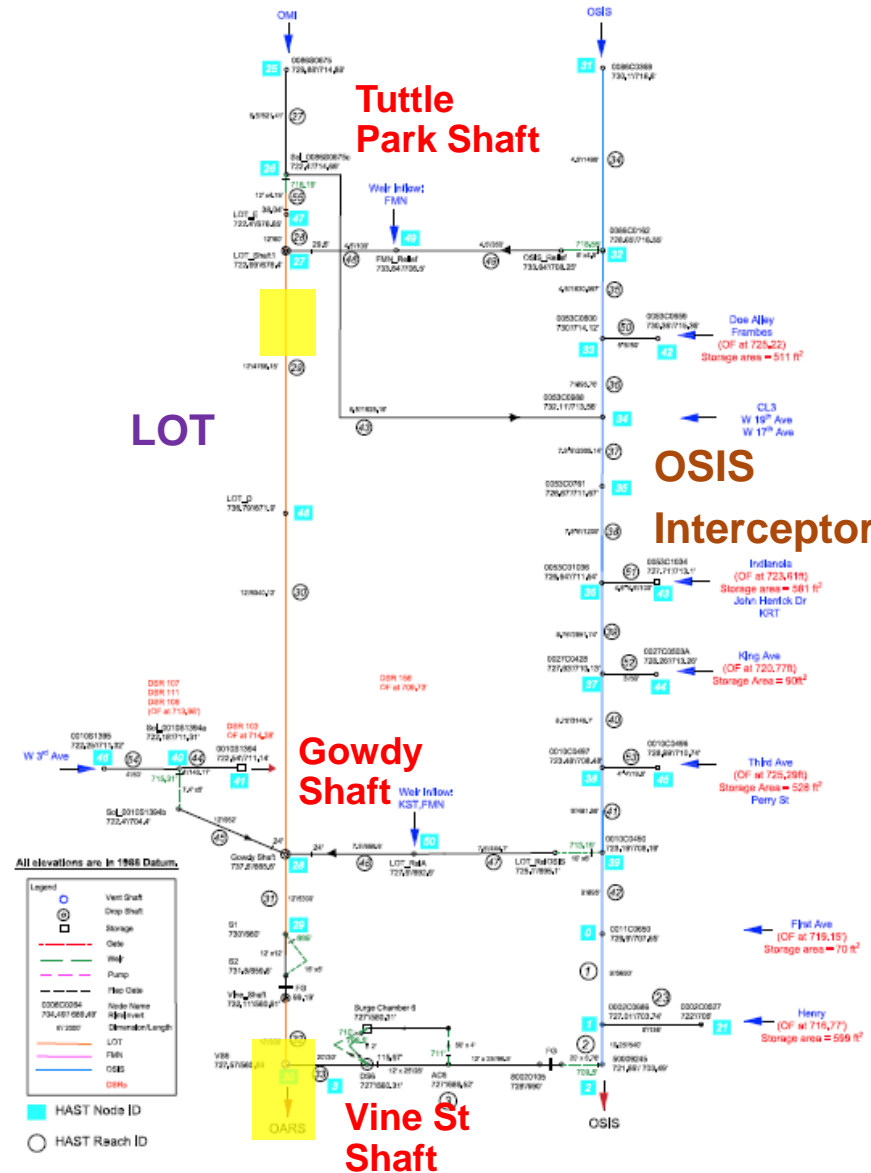
- Air pocket unlikely to escape at shaft 5 due to the small adit connection at invert
- It will then move upstream and release at shaft 6 through the vent chamber

LOT Air Pockets

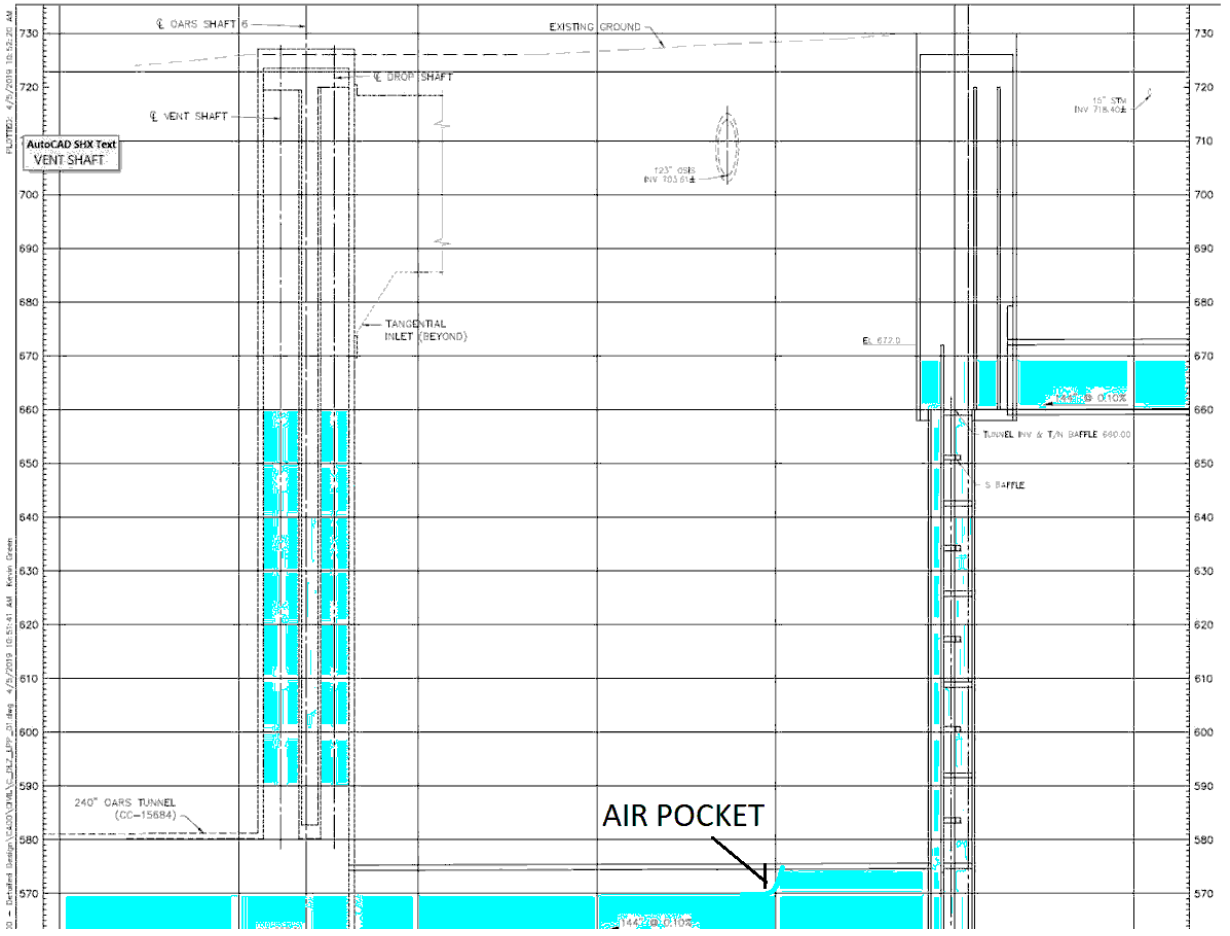
Mild air pockets formation at the upstream reach

Air pockets at Vine St shaft

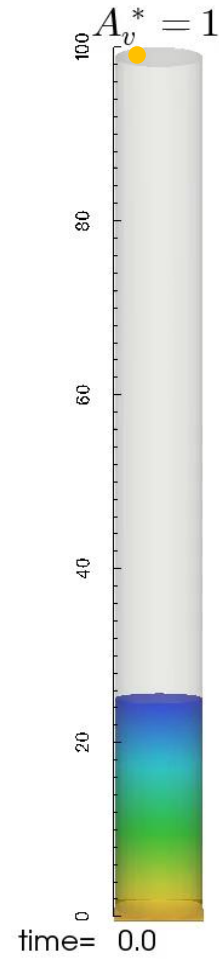
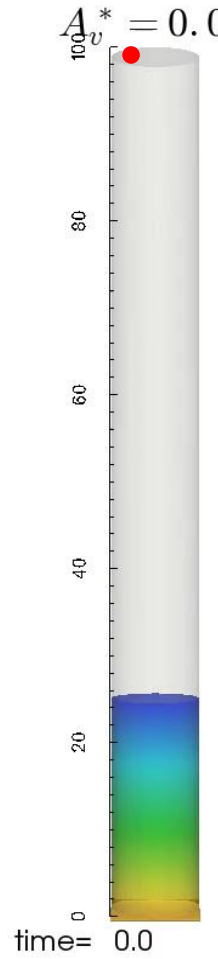
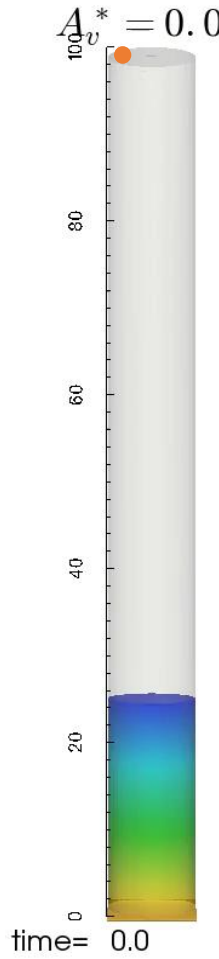
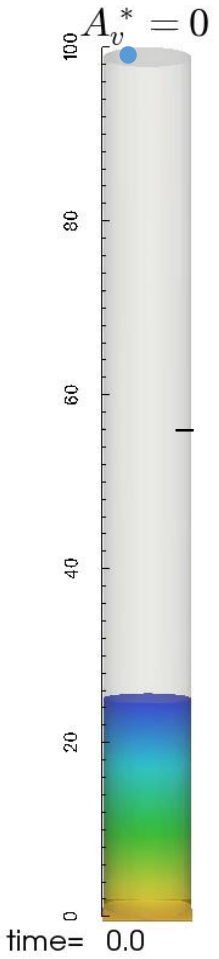
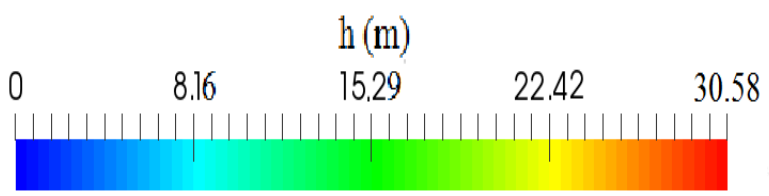
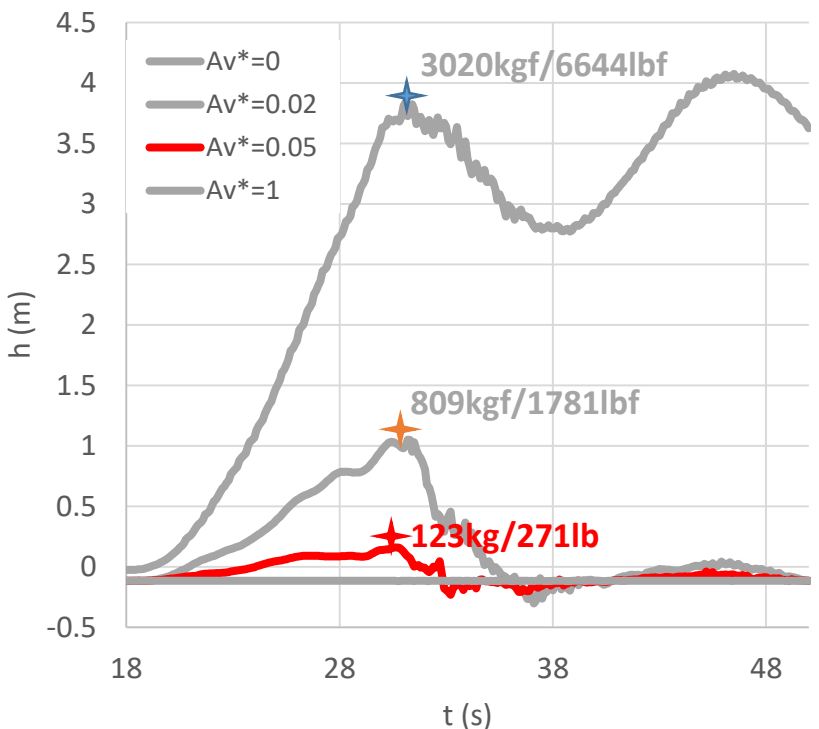
CFD Modeling



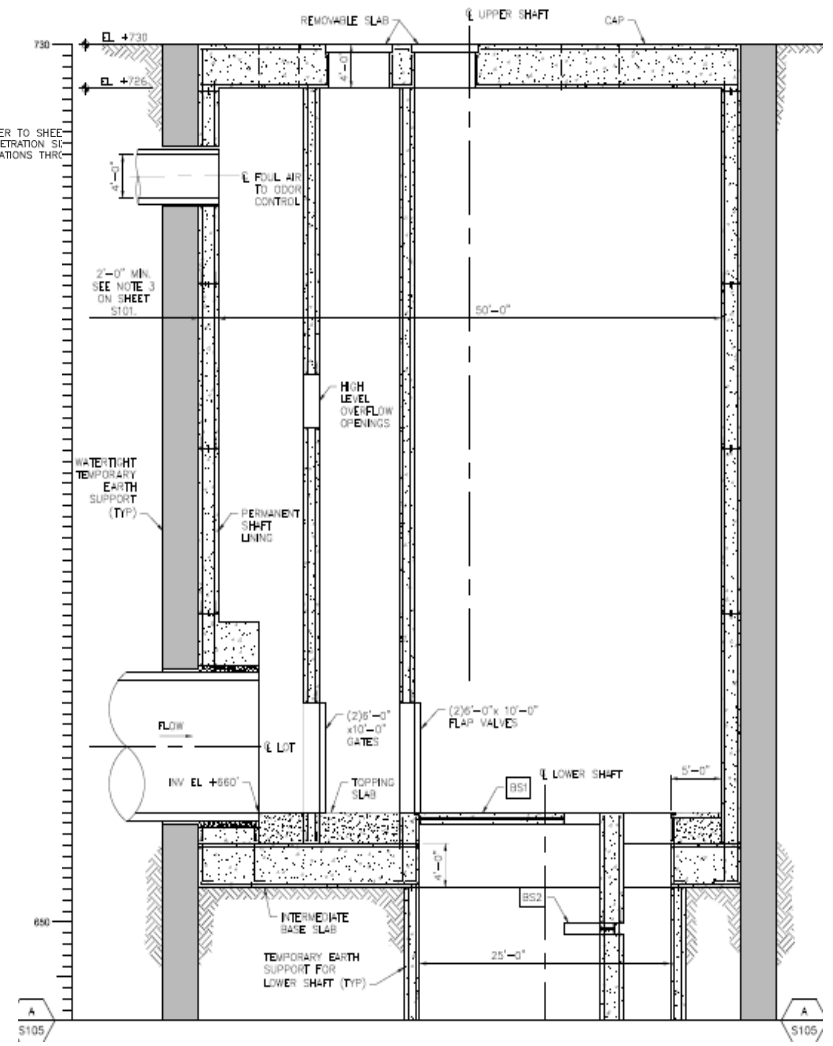
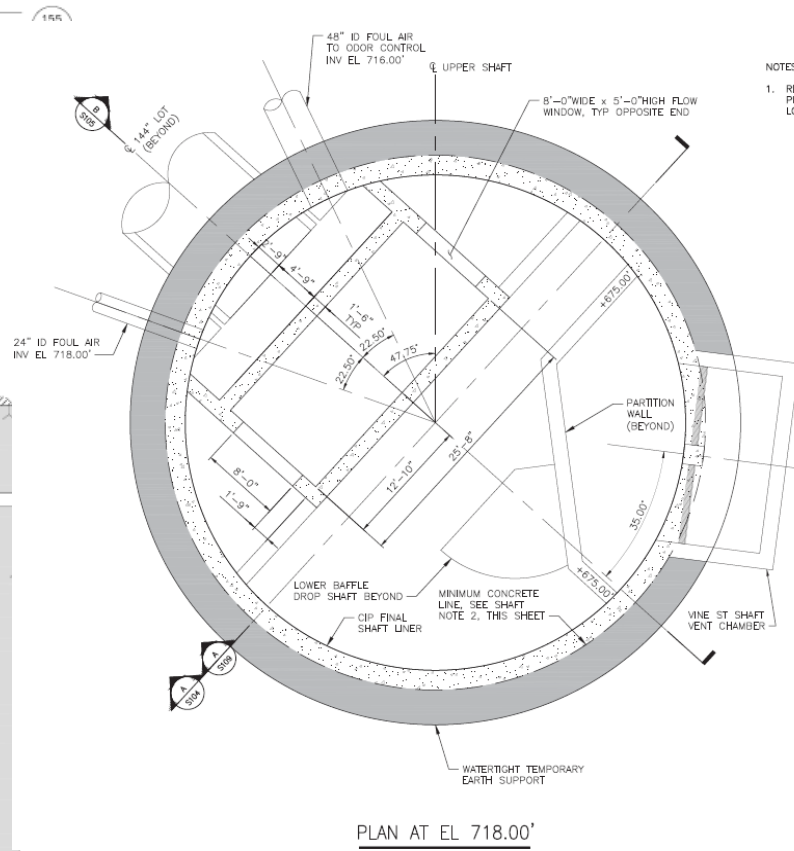
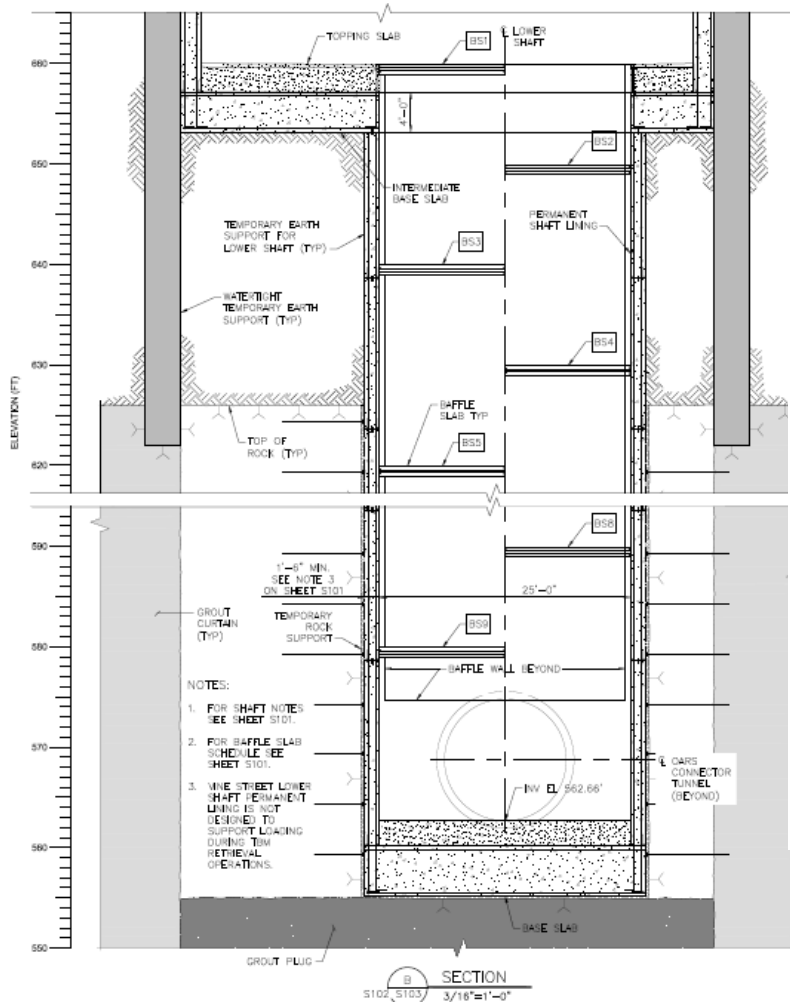
Air pockets at Vine St shaft



CFD simulation in a simple shaft geometry, varying ventilation conditions

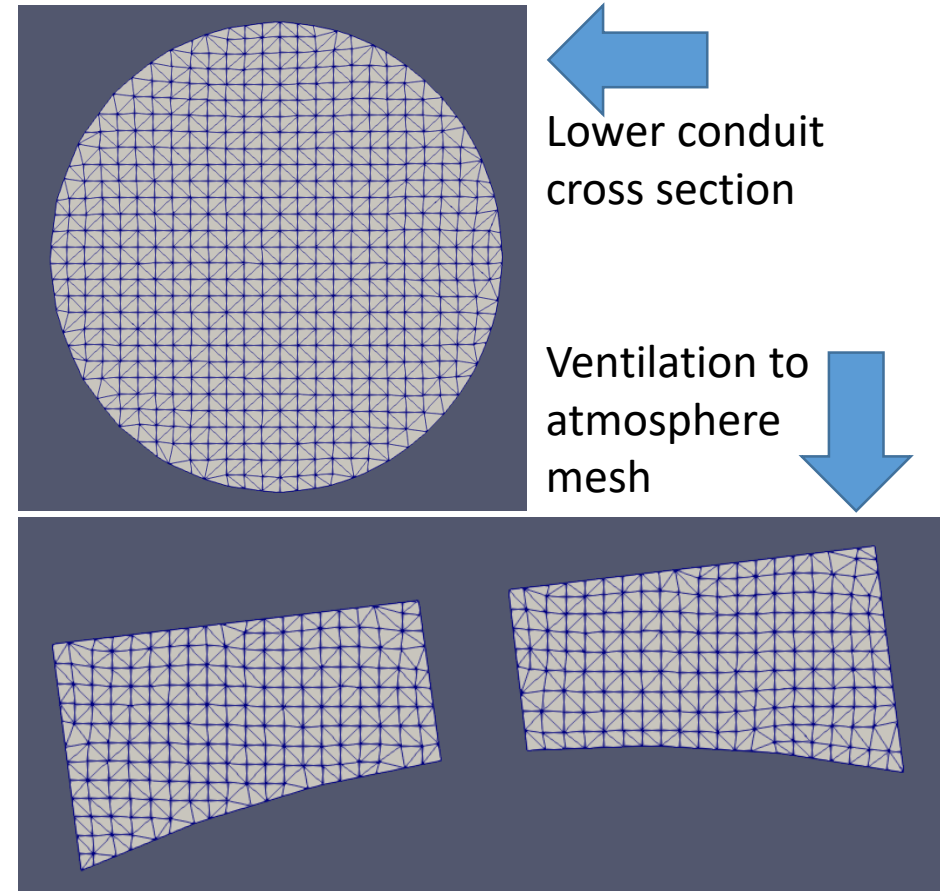


Vine Shaft geometry – baffles, ventilation shaft, and expansion of plan area near grade

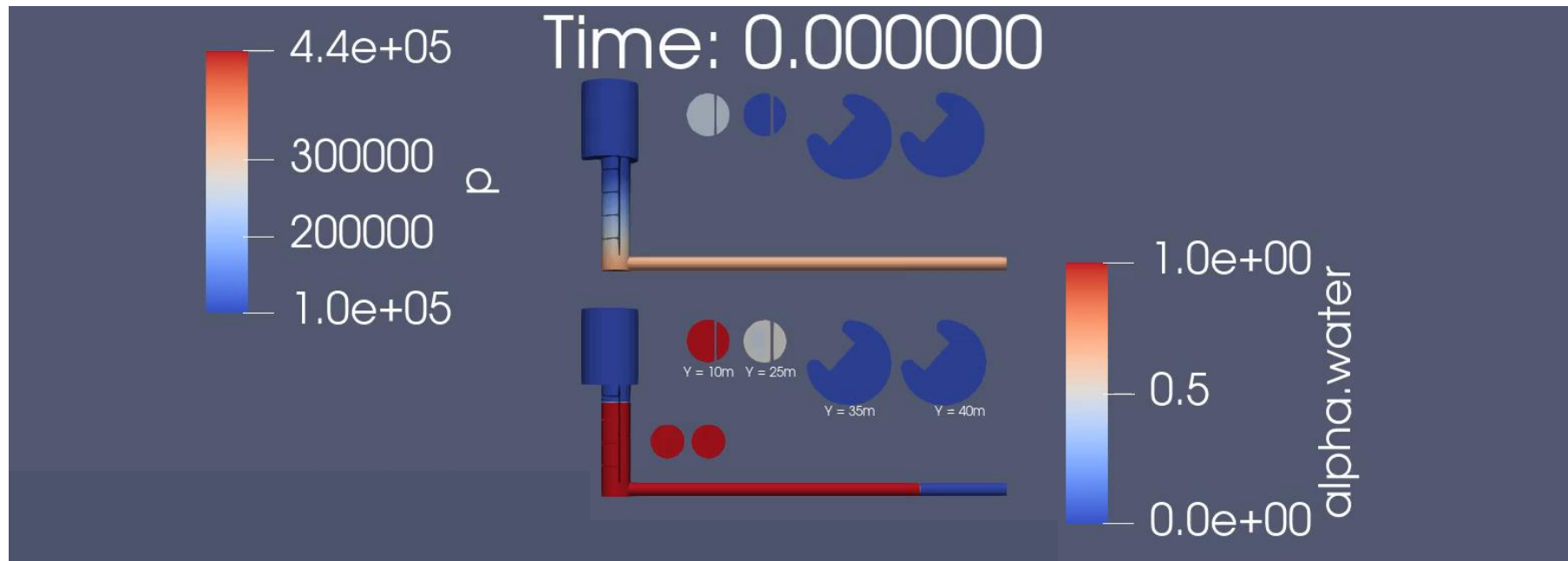


General characteristics of the CFD study

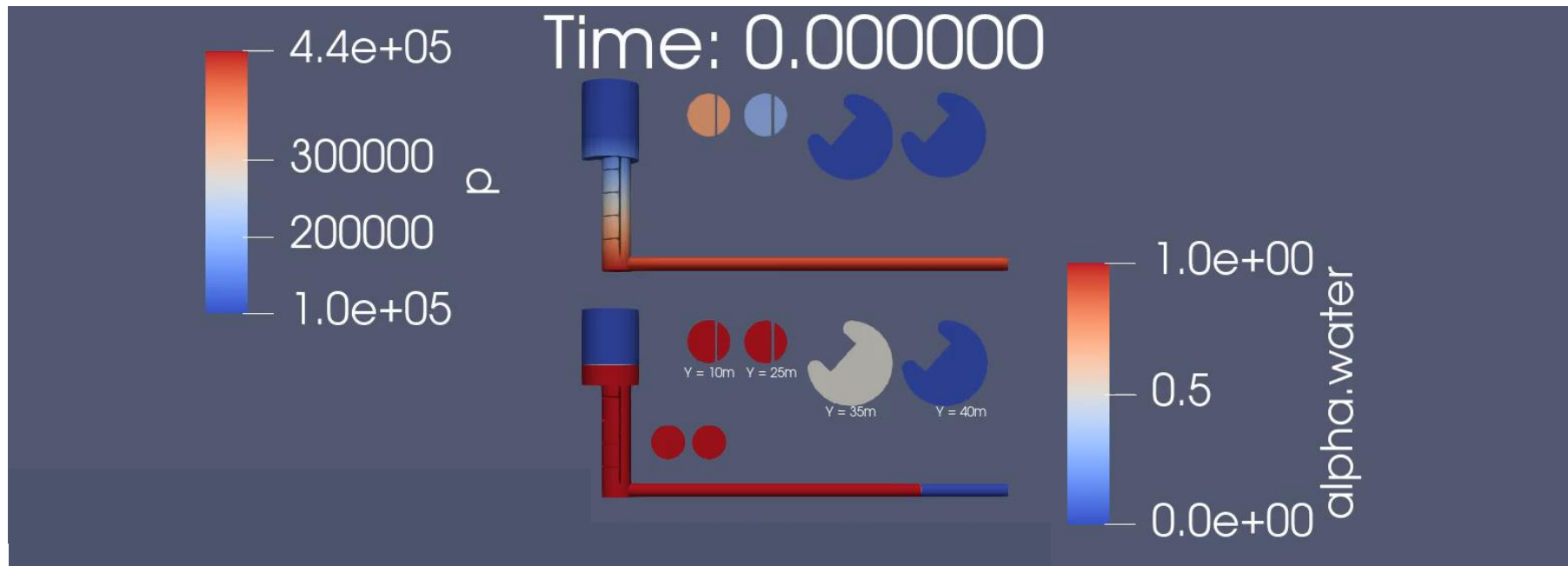
- Used OpenFOAM
- CompressibleInterFOAM solver
- Turbulence model: Realisable k- ϵ
- Number of Cells: 5.09 million
- Number of cells in transversal direction of conduit: 29



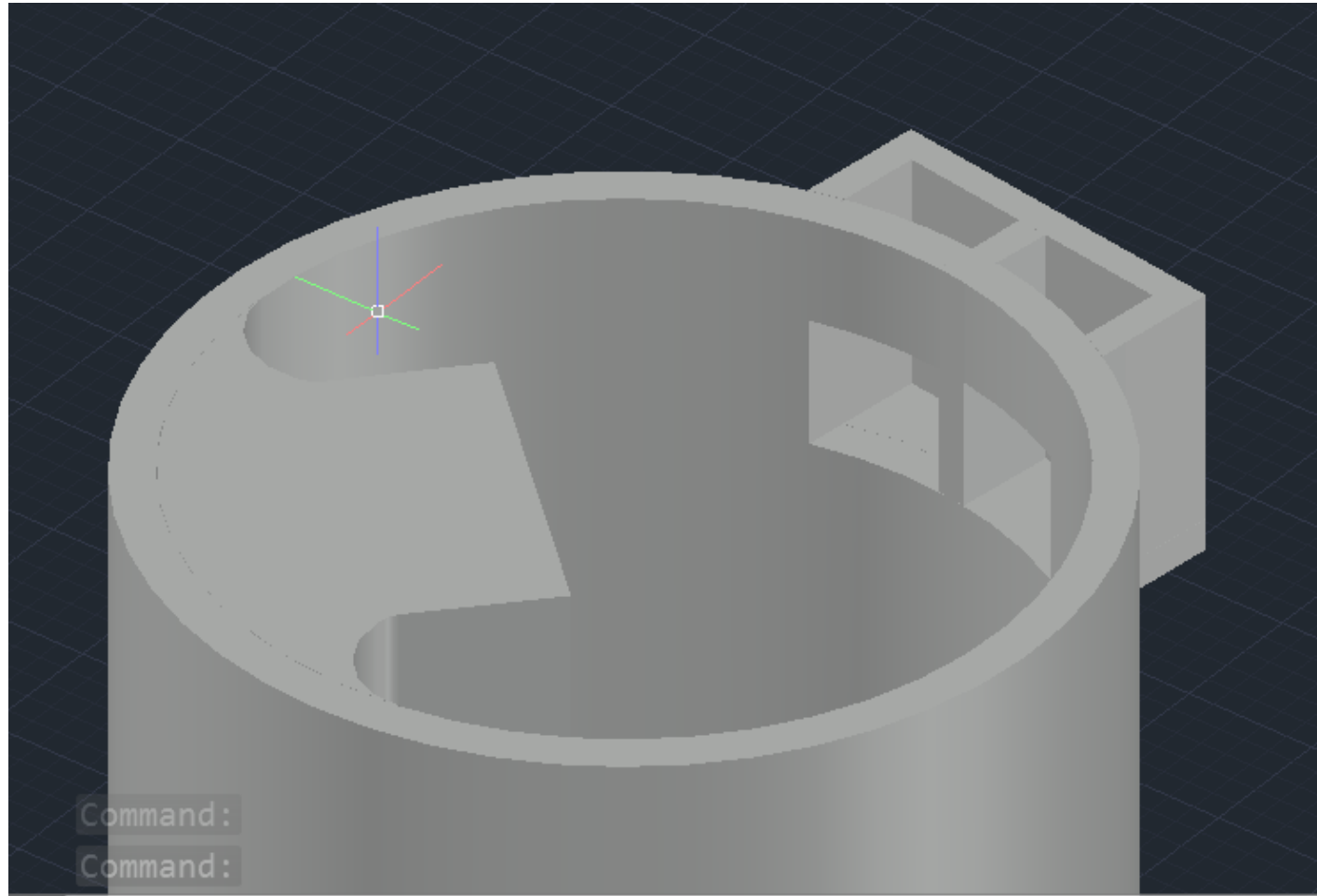
Preliminary CFD simulation: medium-sized air pocket release with no ventilation, lower WL



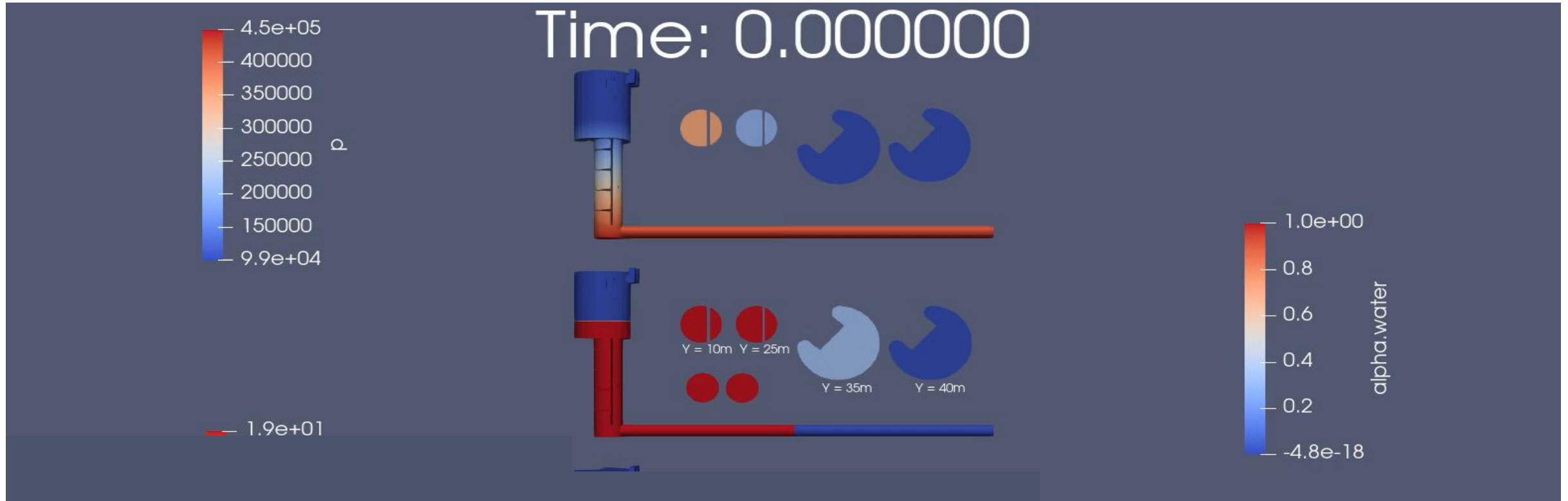
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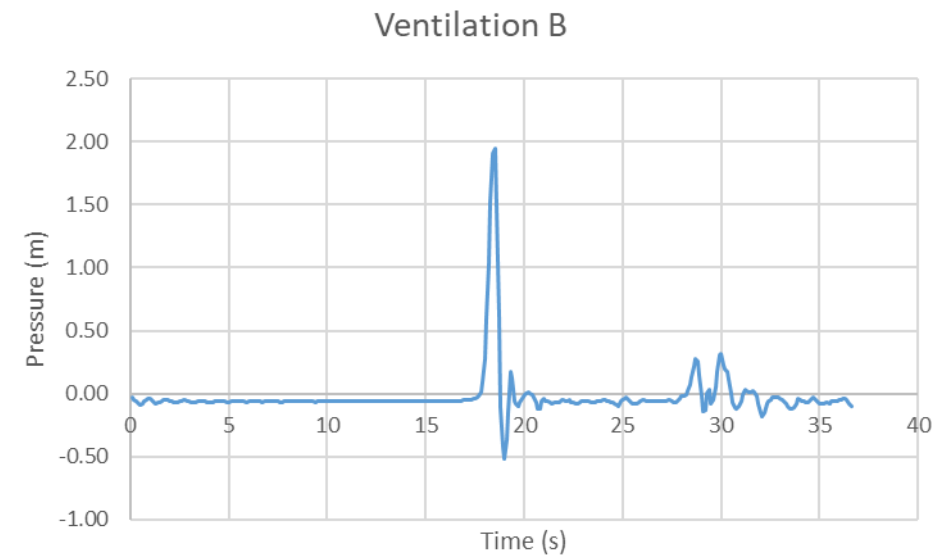
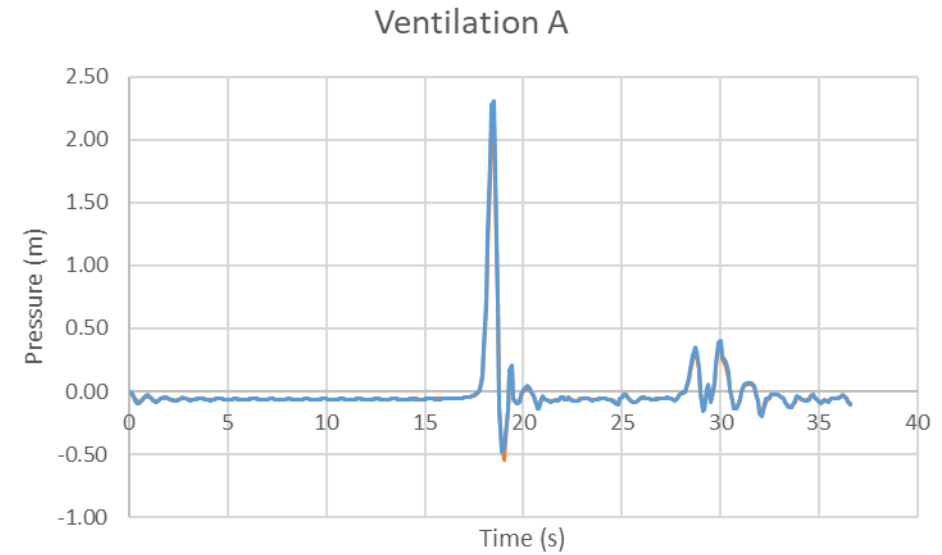
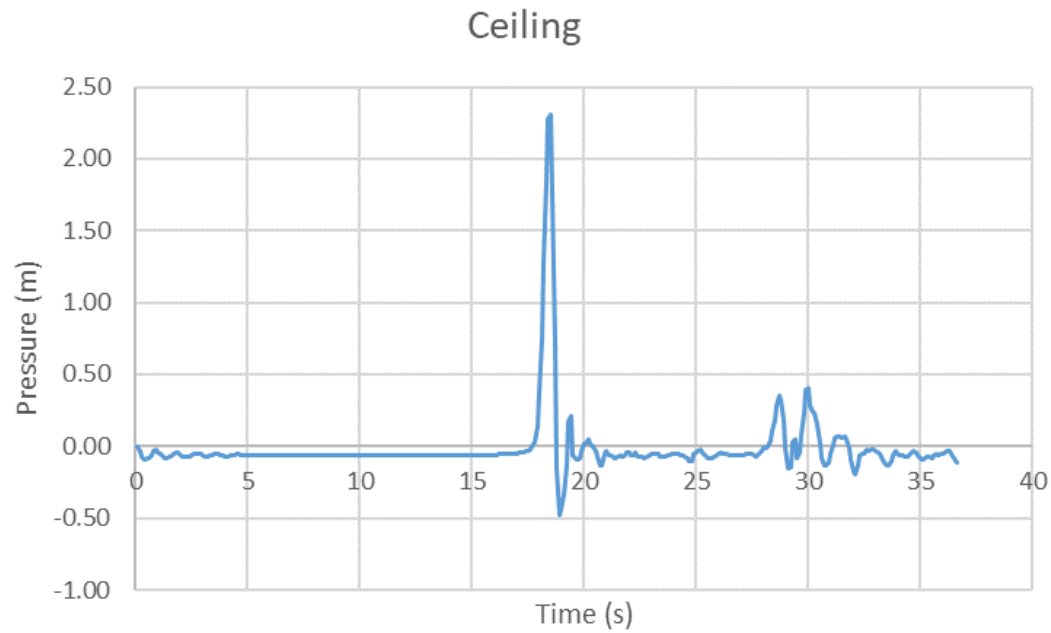
Selected ventilation geometry – two 8'x8' ventilation ports



Animation of air pocket discharge – final ventilation



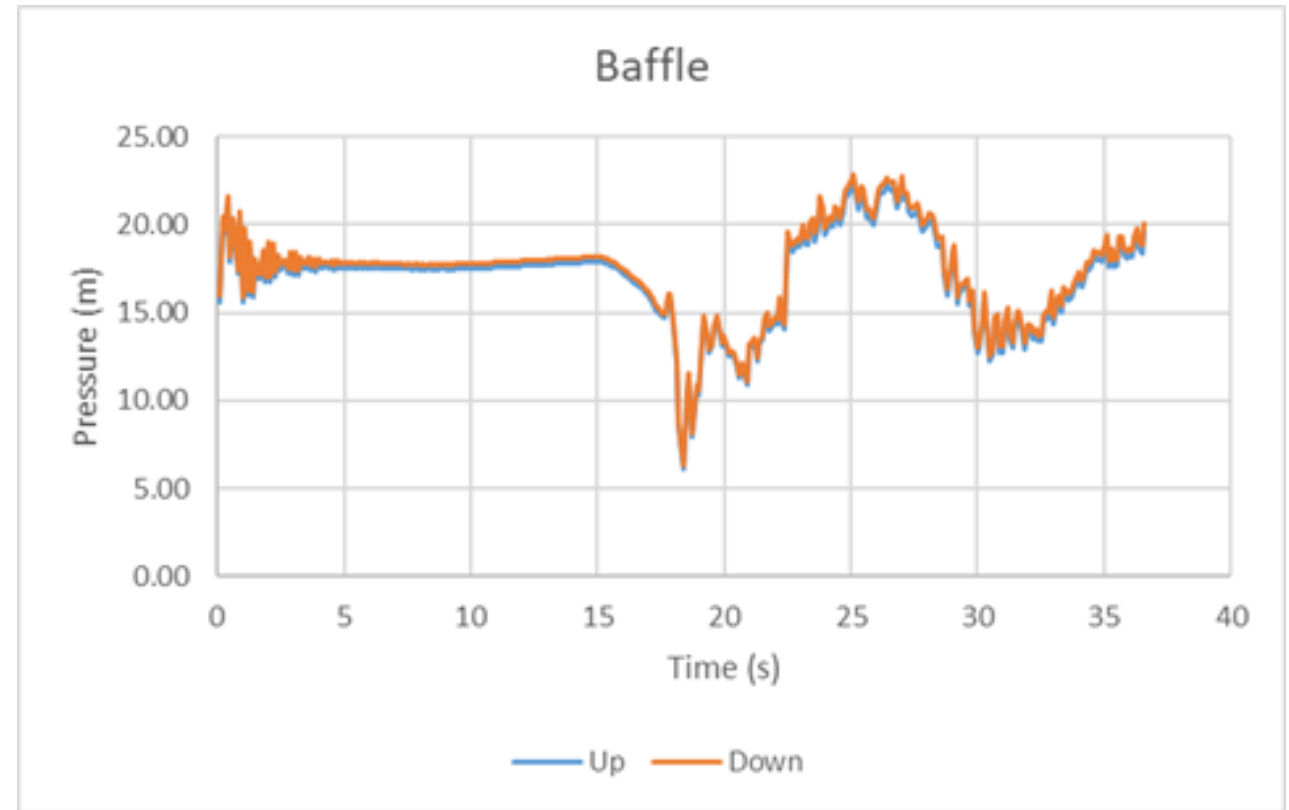
Air phase pressure underneath concrete slab and at ventilation ports



Vine Shaft Baffles Air Pressure

Pressures underneath baffles are investigated.

Example pressure underneath the slab at elevation 619'.



Conclusion

- HAST simulation proves the geometric advantages of OARS design to control surge condition
- Flap gate at Vine shaft reduces the risk of backups and propagation of OARS surge into LOT
- Entrapped air pockets appear in OARS and LOT upstream ends.
- Air release pressure at the ceiling of the Vine shaft is expected to be mild and could be controlled by the cover slap



Thank You

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Imagine the result