Ventilation and Safety Challenges During Clean-Out of a Colorado River Water Diversion Tunnel

A Case Study

Presentation Agenda

- Speakers Background
- Overview of Project Scope
- Safety Challenges
- Phases of Work
- Ventilation Plan
- Confined Space Entry Plan
- Lessons Learned
- Q & A

Speakers

- Tim Fabrey, QCM - FedVet Construction Corporate Safety Officer
  - Originally from PA
  - Construction oriented since the age of 15
  - 27-year Navy Seabee Combat Veteran
  - 6 years under the Naval Safety Center
  - 2 years “retired” and with FedVet

- Enrique Medina, MS, CIH, CSP - Alliance Consulting International
  - 34-year experience as EHS professional
  - Industrial ventilation system testing and design for multiple applications
  - OSHA HAZWOPER and 30-hour Construction Safety Trainer

Project Scope

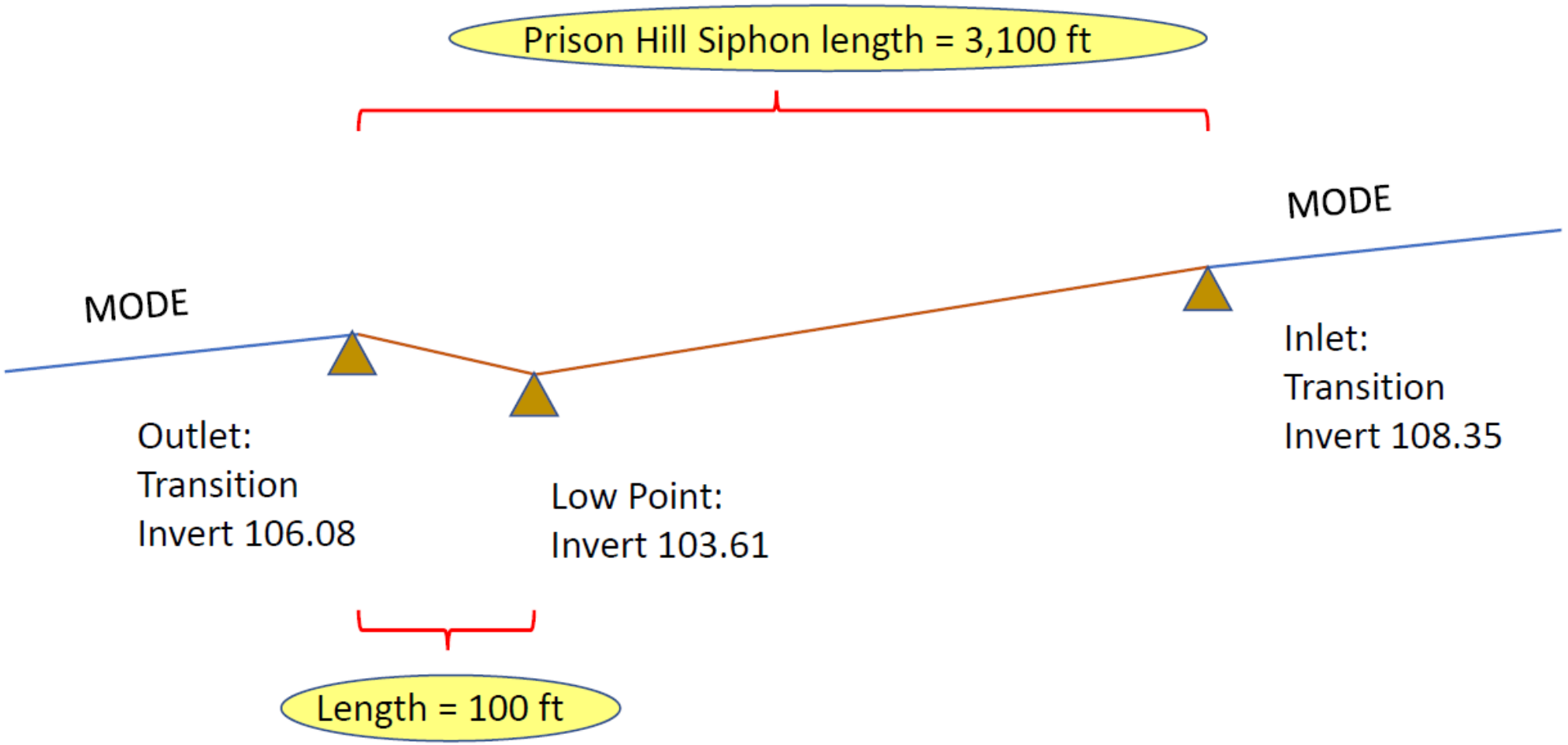
Bureau of Reclamation Project. The Prison Hill Siphon is a 3,100-foot long, 10-foot diameter siphon located in Yuma, Arizona.

Crucial water management facility in U.S.-Mexico Treaty for Colorado River water deliveries.

Cleanout and siphon inspection activities involved removing a thick layer of mineral deposits lining the pipe walls, multiple piles of mineralized debris, and sediment up to 3 feet deep.

The debris piles consisted of shopping carts, tires, rocks, and other large objects.

Prison Hill Siphon Shape and Slope

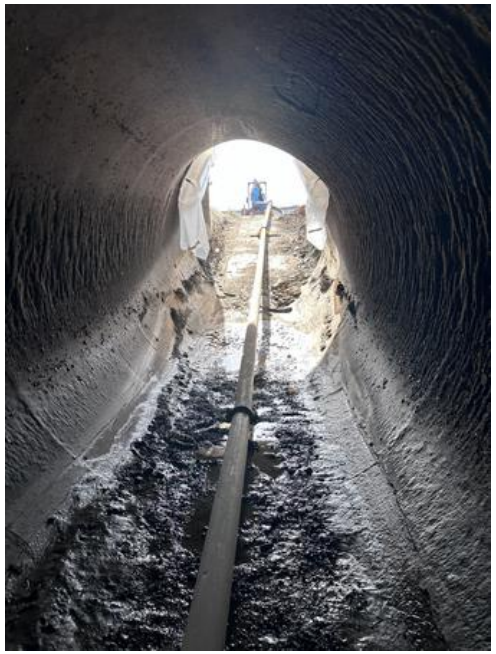


CUSTOM MADE BUCKETS

Customer Preparation

Safety Challenges

Tight Schedule with 20-hour workdays for 12 days

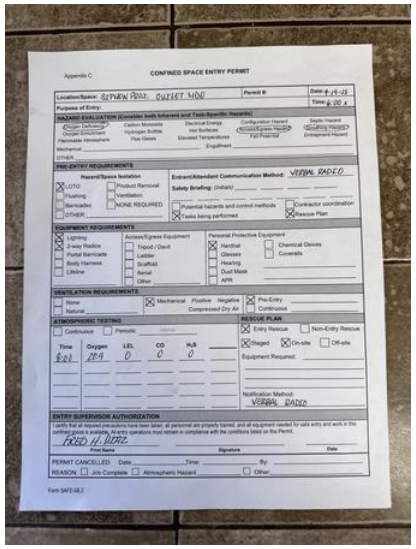


Narrow Passage

Biggest unknown:

- Air Quality
- Hazardous atmospheres
- No vent stacks

2nd biggest unknown: Communication



CONFINED SPACE ENTRY PERMIT

Confined Space Entry and Rescue

Heat exhaustion

Unsafe debris:

- Sharps
- Wildlife (lots of fish)

Phases of Work: Safety Training and Planning

- Confined space entry and rescue Team
- Rescue team practice (mock drill)
- OSHA 30-hour Construction Safety Training
- CSP & CIH requirement

Phases of Work: Mobilization

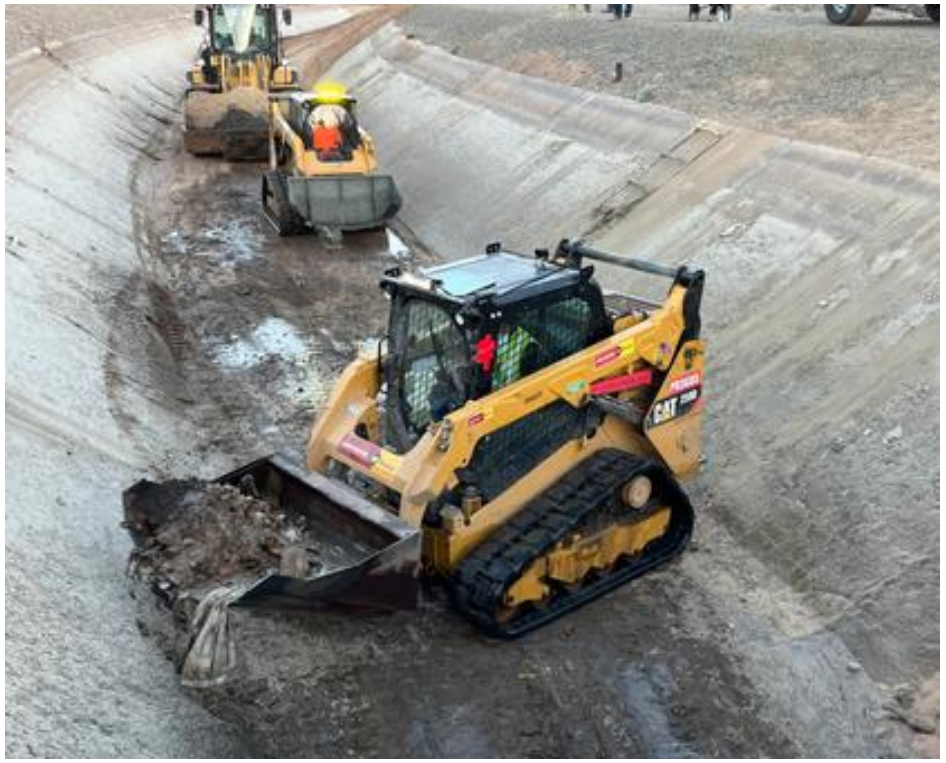
- Equipment and Debris laydown area
- Berms and ramps
- Lighting
- Ventilation system

Phases of Work: Siphon Cleaning

Siphon Cleaning -Water shut-off started the clock

- Stage 1 – Dewatering (underestimated)
- Stage 2 – Ventilation set-up/testing
- Stage 3 – Communication set-up/tests
- Stage 4 – Debris removal from outlet
- Stage 5 – Debris removal from inlet

Siphon Cleaning & Debris Removal



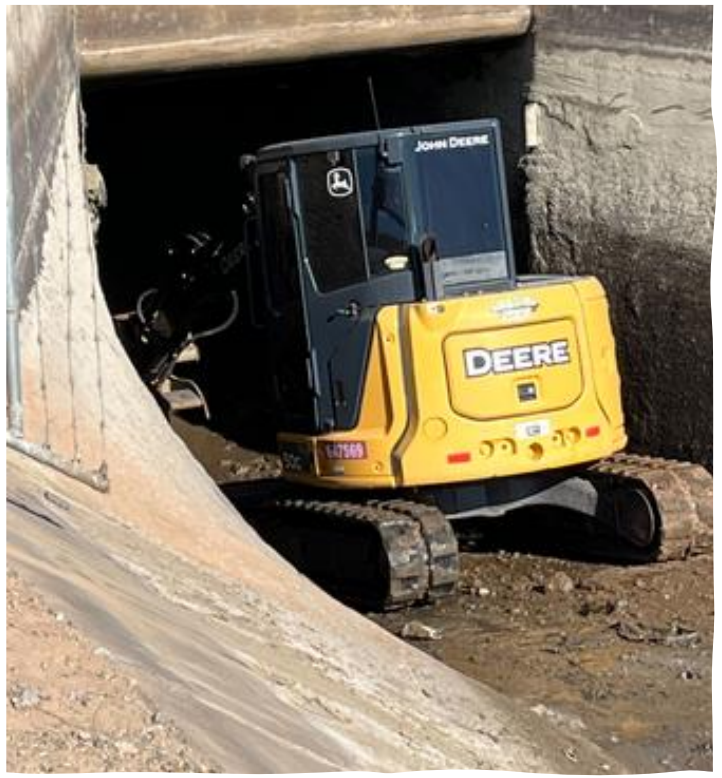
Major Equipment and Tools

- All equipment inside the siphon needed to be a Tier4F diesel engine with a built-in particulate filter (scrubber) for confined space work and safest practice for combustibility and air quality, and have a 5 min rescue air bottle
- T64 Skid Steer
- E20 Mini excavator
- Generator (x2)
- Jackhammers
- Rescue equipment
- Communication equipment
- Water pumps (x2)

Ventilation Plan Key Questions

- What are the air contaminants of concern?
- How much CO does the equipment emit?
- How much air volume is needed to dilute CO to <35 ppm?
- What minimum fan air speed and air volume do we need?
- How many fans do we need?
- Where should the fans be placed?
- What is the natural dilution ventilation inside the siphon?

Air Contaminants of Concern



Hazardous Atmospheres Assessment

- Potential hazardous atmospheres – hydrogen sulfide and methane explosive gases
- Carbon monoxide and diesel particulate matter from equipment exhaust
- Potential oxygen deficient atmosphere from fuel combustion
- Dust from chipping siphon walls
- 0.6 miles long tunnel with limited air circulation

Air Quality Occupational Exposure Targets

- OSHA PEL-TWA for Carbon Monoxide = 35 ppm for 8-hours
- ACGIH TLV-TWA for CO = 25 ppm for 8 hours
- EPA Carbon Monoxide Limits inside tunnels = 35 ppm one hour limit and,
- 6 air changes per hour (ACH) of dilution ventilation.
- OSHA Underground Construction Orders and Tunneling Guidance air velocity requirements = 30 feet per minute of air flow

Task-Specific Risk Assessment

Tasks	Hazards	Engineering Controls	Work Practices	PPE
Siphon pre-entry air monitoring	Oxygen-deficient, toxic, and flammable atmospheres	Ventilation; real-time detection instruments	Regulated Work and controlled Zones	Level B
Equipment installation (fans, communication)	Oxygen-deficient, toxic, and flammable atmospheres	Ventilation; real-time detection instruments	Regulated Work and controlled Zones	Level B
Siphon Cleanout	Oxygen-deficient, toxic, and flammable atmospheres	Ventilation; real-time detection instruments	Regulated Work and controlled Zones	Level B, Level C or Modified Level D
Surface chipping (during cleanout)	Oxygen-deficient, toxic, and flammable atmosphere, dust	Ventilation; real-time detection instruments	Regulated Work and controlled Zones	Level B, Level C or Modified Level D
Post-cleanout equipment removal	No air exposure hazards	Ventilation; real-time detection instruments	Regulated Work and controlled Zones	Modified Level D or Level D

Ventilation Calculations

- Dilution Ventilation Formula: $Q = K*G/C \times 10^6$

- T4 diesel engine CO emissions
  - 5 gm CO/KW-hr. x 50.7 KW = 254 gm CO/hr. = 4226 mg CO/minute.

- Siphon air volume:
  - $\pi r^2 * L$ = 175,900 cubic feet (at restricted 8.5 feet diameter & 3,100 feet long)

- Mechanical Dilution Ventilation:
  - 4 supply fans x 7,800 cfm = 1,872,000 cf/hr. /175,900 cf = 10.6 ACH
  - 2 exhaust fans x 5,500 cfm = 660,000 cf/hr /175,900 cf = 3.8 ACH

Push-Pull Ventilation System

Four 7,800 cfm fans pushing air into the Siphon Outlet

Two 5,500 cfm fans pulling air out of the Siphon Inlet

Real-Time Ventilation Test

Smoke Color PNG Transparent HD Photo

Color Smoke Flare Tests

- Natural Ventilation Air Velocity:
  - 22 seconds/3100 ft = 141 fpm
  - 7,995 cfm
  - 16.2 ppm CO

- Fan Ventilation Air Velocity:
  - 9 seconds = 344 fpm
  - 19,544 cfm
  - 6.6 ppm CO

Air Monitoring Action Levels

Hazard	First Action Level	2nd Action Level	Protection Action
Oxygen	Less than 22%	Less than 19.5%	First: Increase ventilation 2nd: Evacuate siphon
Carbon Monoxide	10 ppm	35 ppm (one hour TWA*)	First: Increase ventilation 2nd: stop Bobcat; upgrade to Level "B" or leave area
Hydrogen Sulfide	1.0 ppm	5.0 ppm	First: Increase ventilation 2nd: upgrade to Level "B" or leave area
Methane or flammable gases (LEL)	5% LEL	10%LEL	First: Increase ventilation 2nd: Evacuate siphon
Respirable Dust	3 mg/m^3	5 mg/m^3	First: Increase ventilation; wet dusty area 2nd: upgrade to Level "C"

Confined Space Entry Protocols

- Monitoring Equipment – BW Max III Gas Alert
- Proper logging
- PPE – Sharps (gloves & boots), Tyvek suites, hip waders etc.
- Respiratory equipment – voluntary N95 masks, everything was naturally soaking wet
- Personnel (20+ per shift) – communication was key and keeping track of everyone on site
- Rescue equipment

Surprises

- Underestimated amount of water left over after shut-off
- Simple radio communication worked
- Far less trash/sediment than anticipated

Lessons Learned

- Budget properly for the experts
- Train a back-up to the back-up
- Work with customers and encourage the creation of consistent contractor/customer teams for 24-hour operations
- Don’t trust the as-builts
- Verify Ventilation Design Calculations with Real-Time Conditions

Q & A

Thank you

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