Highway Hydraulics:
Water Shuttle Operations Overview

Ohio Fire Chiefs' Association

Water Supply Technical Advisory Committee

Learning Objectives:

- Describe conditions requiring a water shuttle operation
- Identify basic components of a water shuttle operation
- Describe establishment and operation of:
  - Fill site
  - Dump site
  - Water delivery route
- Identify water tender designs and their features
- Discuss techniques for improving flow rate, efficiency and safety

Water Shuttles: *When to Establish?*

- Needed fire flow (GPM) cannot be met by water carried on first-due apparatus (engines and water tenders)
- Incident is outside hydranted area (or to supplement a weak hydrant system)
- Relay operation would not be feasible (distance or resource limits; technical capability)

Water Shuttle Advantages

- Water delivery rates in excess of 1000 GPM can be achieved
- Flexible and robust way to achieve water supply
- Cost-effective water supply system for rural areas (vs. municipal water system)

Water Shuttle Challenges

- Requires specialized equipment, training and procedures (SOPs/SOGs)
- Significant pre-incident planning required to be effective
- Risk exposure for firefighters: Tanker rollovers, dump site backing

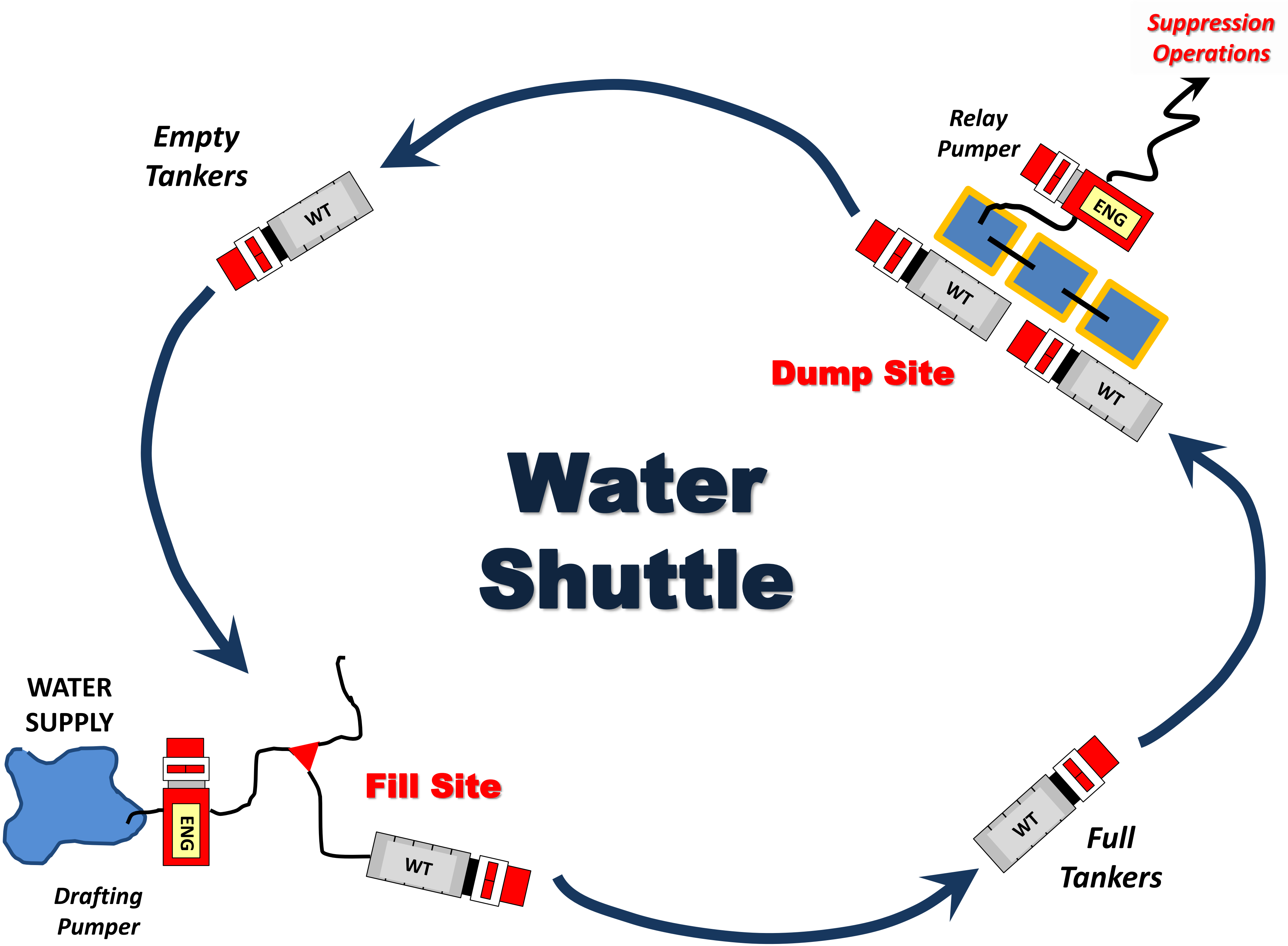
In a water shuttle: **Time is Water**

Time must be reduced whenever possible, but never at the expense of safety

Implementing an Alternative Water Supply

(Video by National Fire Academy)

Water Shuttle Components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Pumper
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Drafting
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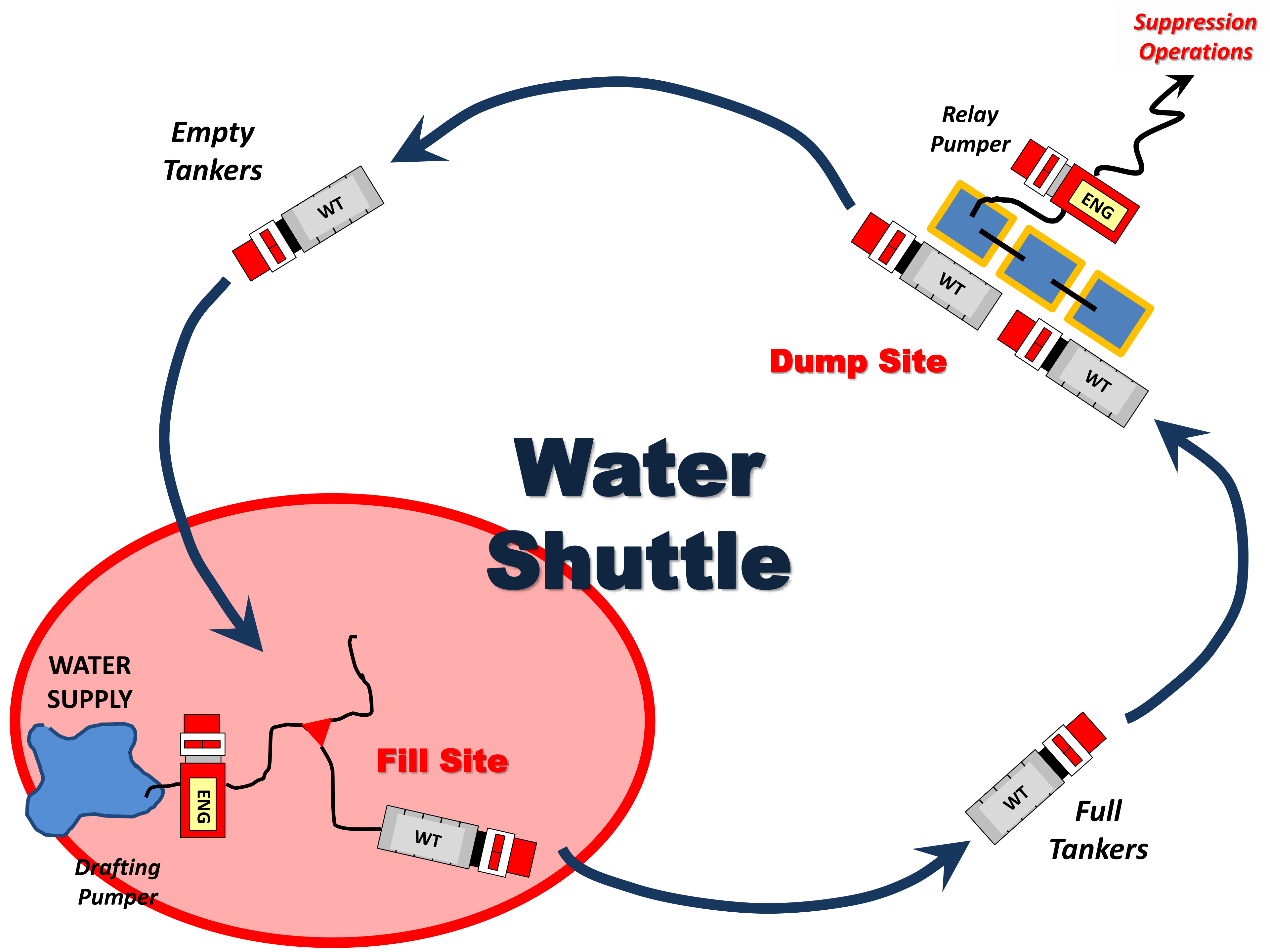
Full
Tankers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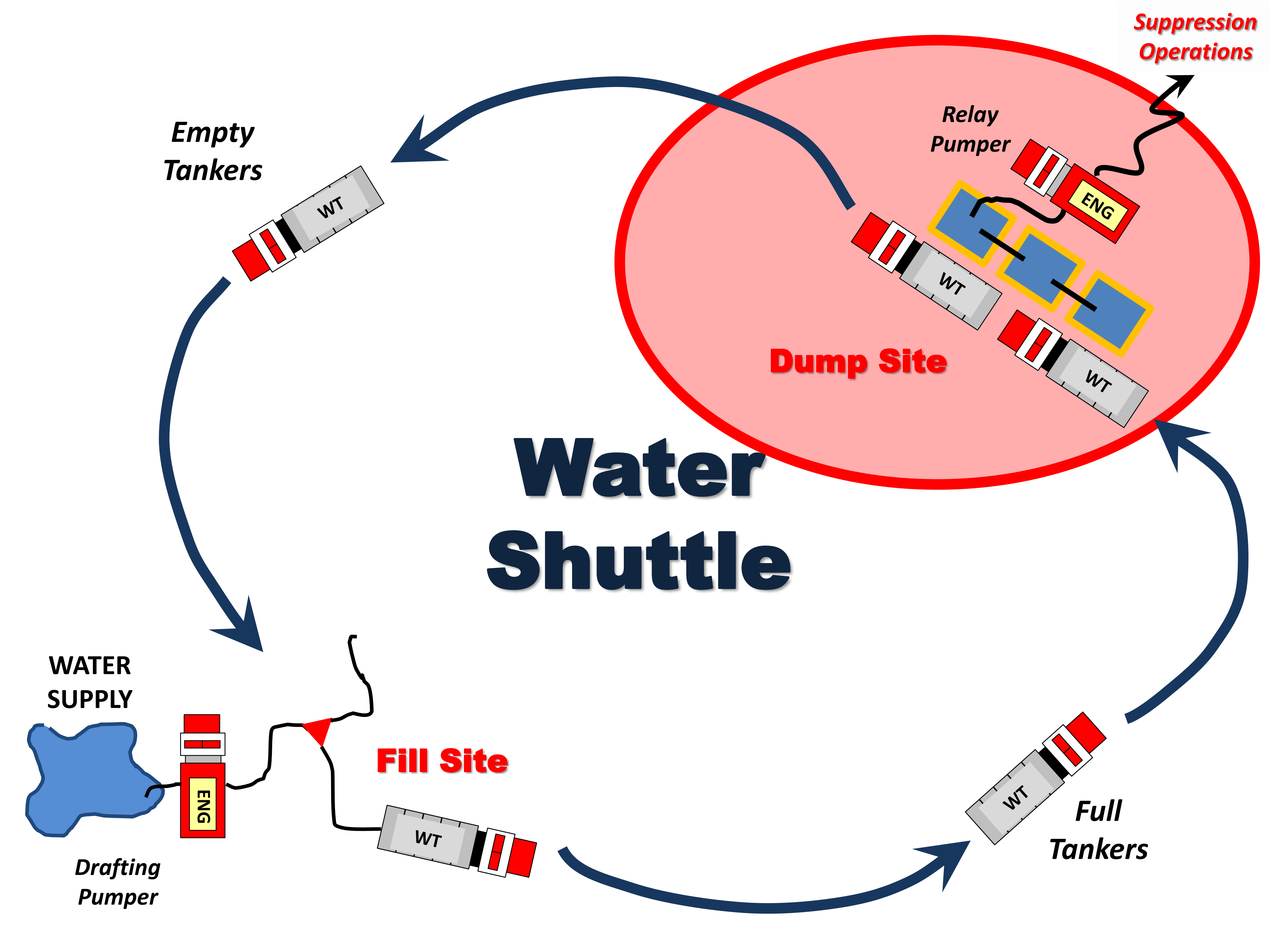
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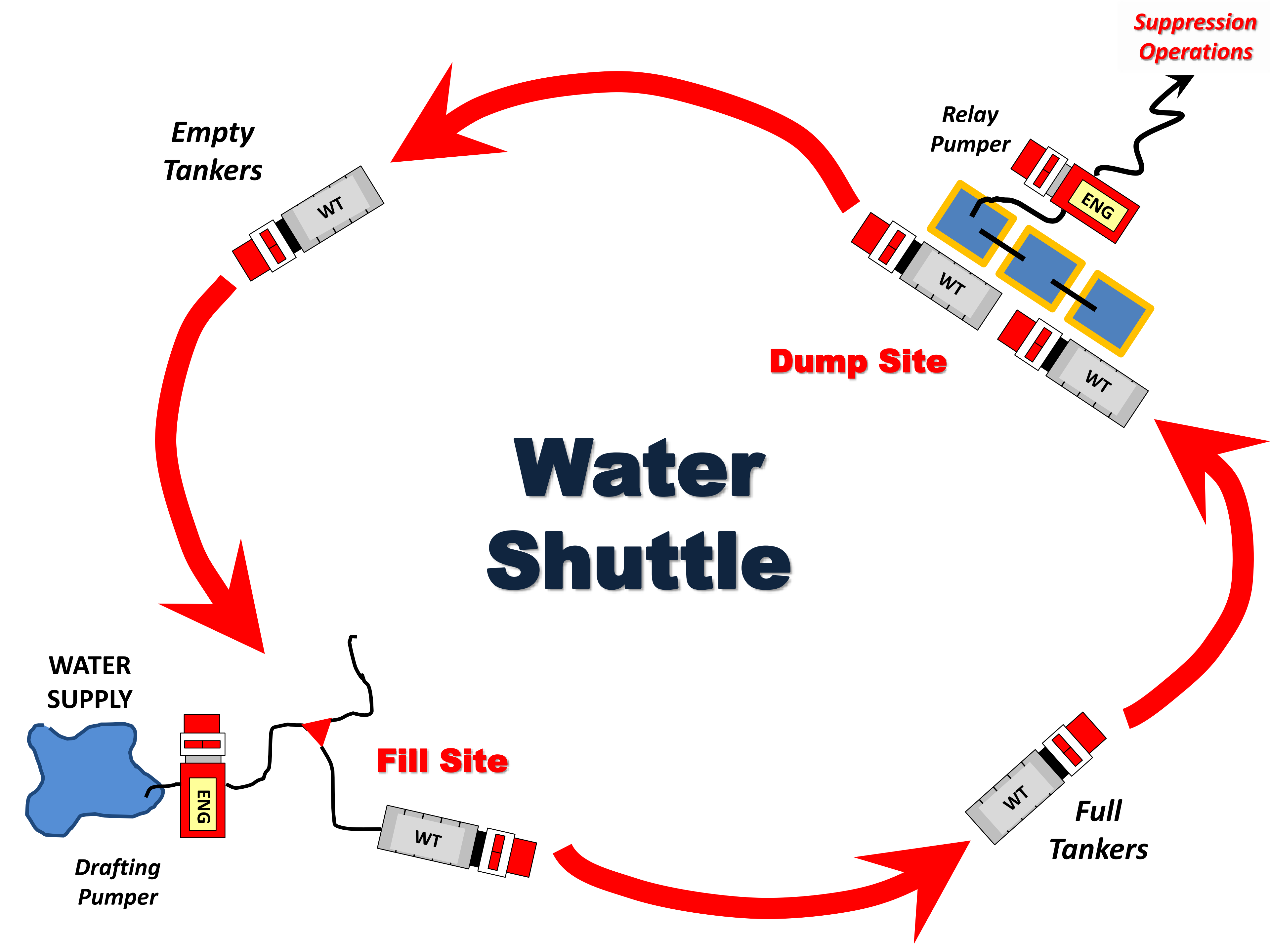
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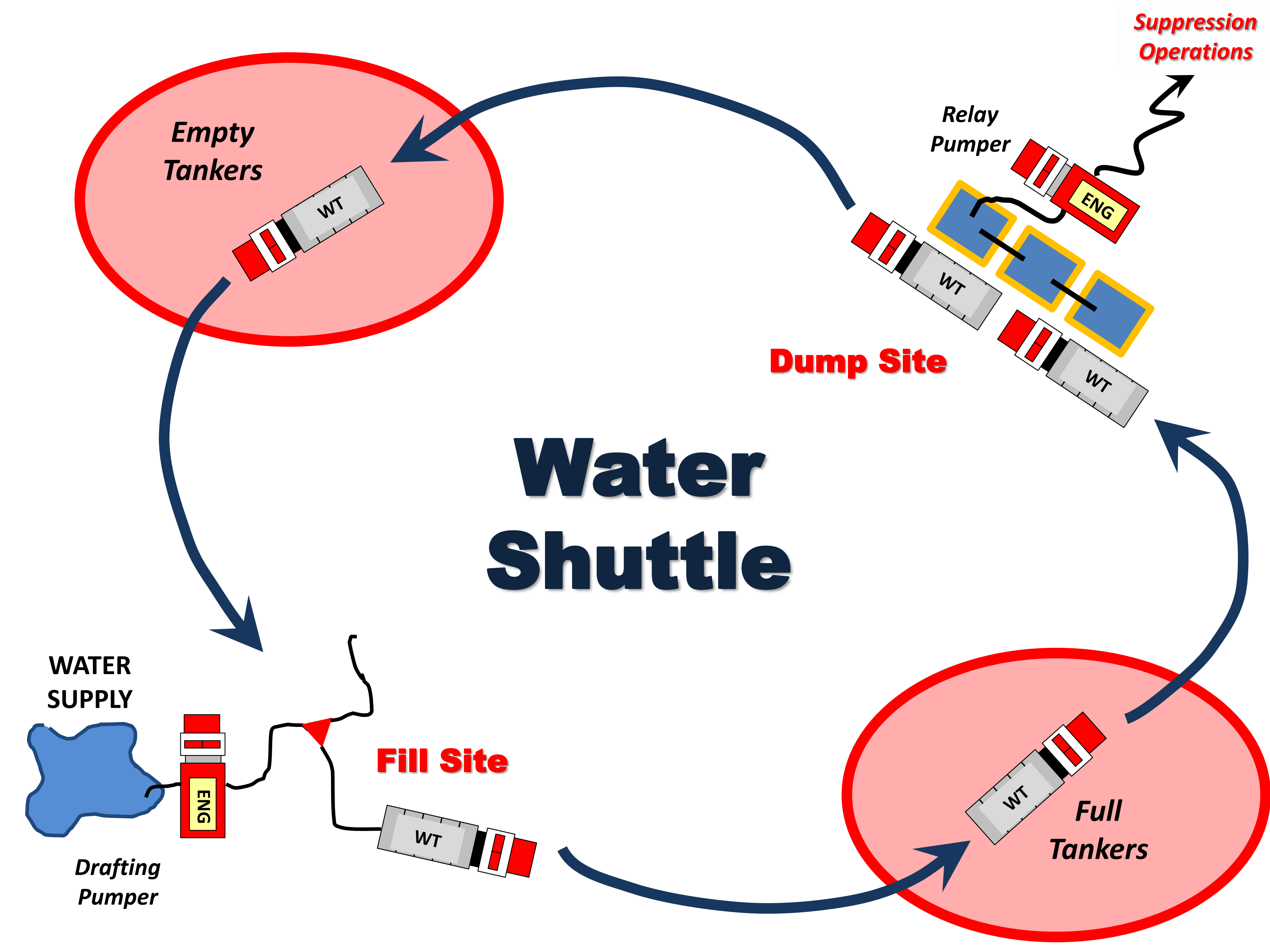

Suppression Operations
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Water Shuttle
WATER SUPPLY
ENG
Drafting Pumper
Fill Site
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Full Tankers

Fill Site Operations

Water Supply Sources

What are some potential water sources?

Water Supply Sources

Pressurized Sources

- Municipal hydrant systems
- Irrigation pivots
- Elevated on-site tanks

Static Sources

- Ponds and lakes (natural and man-made)
- Streams (creeks, rivers, etc.)
- Ditches
- Cisterns
- Swimming pools

Fill Site Time Costs

Total Fill Site Time = Fill Time + Handling Time

Fill Time

- Water tender tank capacity
- Water tender maximum fill rate
- Water source fill rate
- Drafting engine/pump flow rate

Handling Time

- Skill of fill site crew
- Capability of water tender driver
- Fill site design

Reducing Fill Site Restrictions

Water Source Improvements

- Install dry hydrants, sumps, and other drafting facilitators
- Design dry hydrants to support high flows (1000 gpm minimum)
- Maintain and flow-test dry hydrants once installed

Reducing Fill Site Restrictions

Handling Time Improvements

- Fill Site Layout: One-way traffic flow and minimize backing
- Use manifold, but only fill one water tender at a time
- Drafting engine/pump capability does not create chokepoint
- Fill site crew is well-trained and experienced
- Automatic Air Primers

Reducing Fill Site Restrictions

Fill Time Improvements

- Fill direct to tank if possible, not through a pump
- Ensure tank is properly vented
- Fill from ground level if possible
- Driver should remain in cab, ready to leave – fill site crew does all work

Dump Site Operations

Dump Site Time Costs

Total Dump Site Time = Dump Time + Handling Time

Dump Time

- Water tender tank capacity
- Water tender maximum dump rate

Handling Time

- Skill of dump site crew
- Capability of water tender driver
- Dump site design/layout
- Water tender dump configuration (side/rear, multiple dumps)

Reducing Dump Site Restrictions

Flow Management

- Maximize use of side dumps; minimize need to back tenders
- Don’t dump down to the “last drop” – only use most efficient flow
- Favor more efficient water tenders – allow to “leap frog” those that dump slower

Reducing Dump Site Restrictions

Handling Time Improvements

- **Dump Site Layout: One-way traffic flow and minimize backing**
- **Set up adequate drop tanks to handle flow**
- **Dump site crew well-trained and experienced**

Reducing Dump Site Restrictions

Dump Time Improvements

- Ensure tank is properly vented
- Use largest possible dump outlet
- Use multiple dump outlets if possible
- Driver should remain in cab, ready to leave – dump site crew does all work

Reducing Dump Site Restrictions

Multiple Drop Tanks

- Always use at least two portable dump tanks (more is better)
- Keep largest tank full by transfer-pumping water from smaller tanks

Reducing Dump Site Restrictions

Single-Lane Tanks (SLT)

- Rectangular shape better for deployment on narrow roadways
- Flange allows low-profile 90-degree hookup to pumper

Reducing Dump Site Restrictions

Locating Dump Sites

- If possible, pre-plan dump sites for limited-access developments and long driveways
- Be prepared to relay pump water from dump site to attack engines via LDH
- Dump site operations and water tender traffic will interfere with suppression operations and EMS access

Route Operations

Shuttle Route Time Costs

Total Travel Time = Route Distance x Minutes/Mile

Route Distance

- Depends on location of water supply sources (fill sites) and incident (dump site)

Travel Speed

- Road conditions (weather)
- Road characteristics (surface, slope, curves, etc.)
- Capability of apparatus

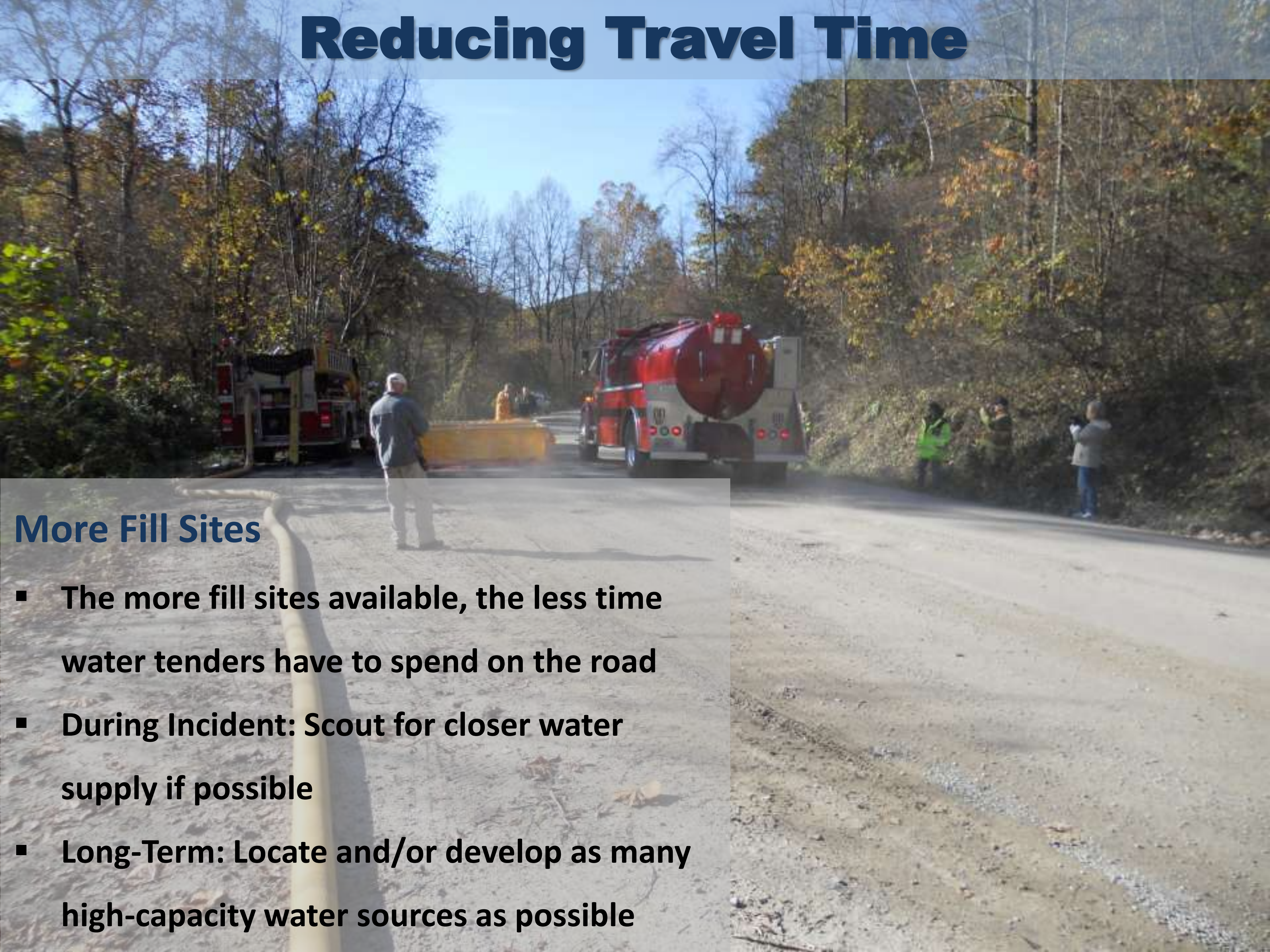
Shuttle Route Safety

Route Layout

- One-way (loop) routes
- May be longer, but safety is increased

Road Conditions

- Shortest route may not be suitable for repetitive tanker traffic
- Use best road for the job, even if longer



Reducing Travel Time

More Fill Sites

- **The more fill sites available, the less time water tenders have to spend on the road**
- **During Incident: Scout for closer water supply if possible**
- **Long-Term: Locate and/or develop as many high-capacity water sources as possible**

“Drive Faster” is ***NEVER*** the right answer

Dresser-Osceola-Garfield FD (WI) 3200-gal tanker following rollover accident, 23 Mar 2010; photo source URL: http://www.presspubs.com/article_4a0a61c5-bfbe-5a3b-be47-5df42063d329.html?mode=story

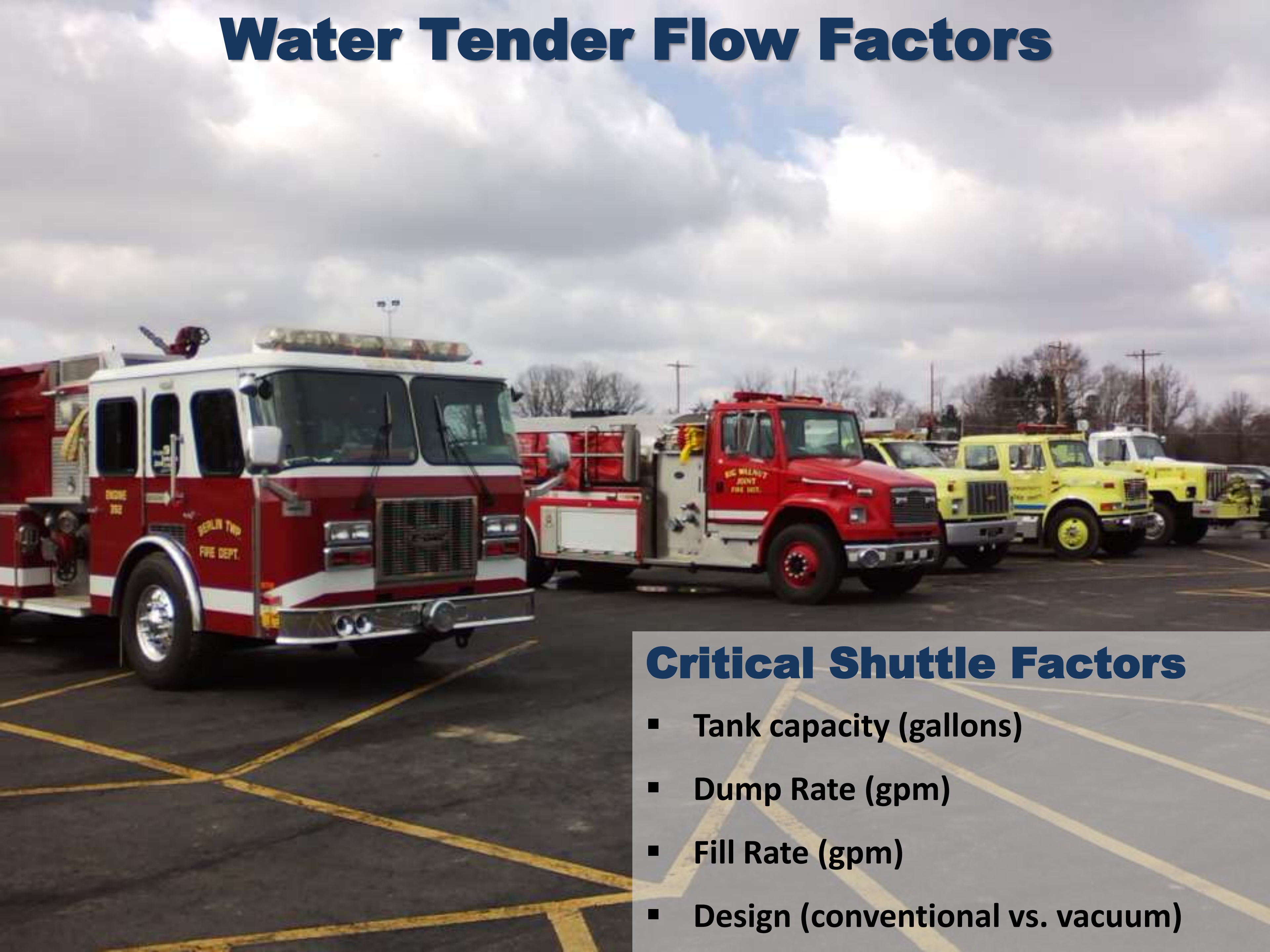
Reducing Travel Time

"Respect the Rig"

Water Tender Rollover Case Studies

Water Tenders

Water Tender Flow Factors



Critical Shuttle Factors

- Tank capacity (gallons)
- Dump Rate (gpm)
- Fill Rate (gpm)
- Design (conventional vs. vacuum)

Water Tender Flow Factors

Photo courtesy Ohio Dept. of Natural Resources

Tank Capacity

- Rated Capacity vs. <u>Effective</u> Capacity
- Large is not always the best choice – local conditions drive choice
- Larger tanks have longer dump and fill times

Ohio Fire Chiefs' Association – Emergency Response Plan

Water Tender Resource Typing Standard

Resource Typing Standard			Shuttle Route Distance (miles)			
Type	*Minimum Tank Capacity (gal)*	*Representative Sizes (rated tank capacity)*	1	3	5	10
4	1000	1000, 1200, 1500	125-175	75-125	50-100	25
3	1800	1800, 2000, 2200	200	150	100-125	75
2	2400	2400, 2500	225	175	125-150	100
1	3000	3500, 4000	250	200	150	125
			Expected Continuous Flow Contribution (CFC) (gpm)			

Model Assumptions (Standard Conditions):

- **Fill Site:** Water source flows 1000 gpm; handling time is one minute (maneuvering, hook-up, etc.); apparatus fills at 1000 gpm
- **Dump Site:** Handling time is one minute (maneuvering, hook-up, etc.); apparatus dumps at 1000 gpm
- **Travel Conditions:** Average speed is 35 mph with 0.65 minute modifier added per NFPA 1142

Water Tender Flow Factors

Dump Rate

- How quickly can the tank be emptied?
- Make sure large tanks are designed with high dump rates
- NFPA 1901 calls for a minimum of 1000 gpm
- Considerations:
  - ❖ Tank design
  - ❖ Dump chute design
  - ❖ Dump chute placement
  - ❖ Dump chute size

Water Tender Flow Factors

Fill Rate

- How quickly can the tank be filled?
- Large tanks should be designed to allow high fill rates
- NFPA 1901 calls for a minimum of 1000 gpm
- Maximum fill rate limited by manufacturer warranty on tanks in many cases

Water Tender Design

Conventional Design

- Modern designs use gravity to rapidly dump water via large chutes
- Older designs may use jet assist or pump water off
- May have rated pump (or not)
- Should have rear and side dumps (or directional dump on rear)
- Generally: Effective tank volume is 90% as dump rate declines with decreased pressure head

Conventional Water Tenders

Best Design Practices

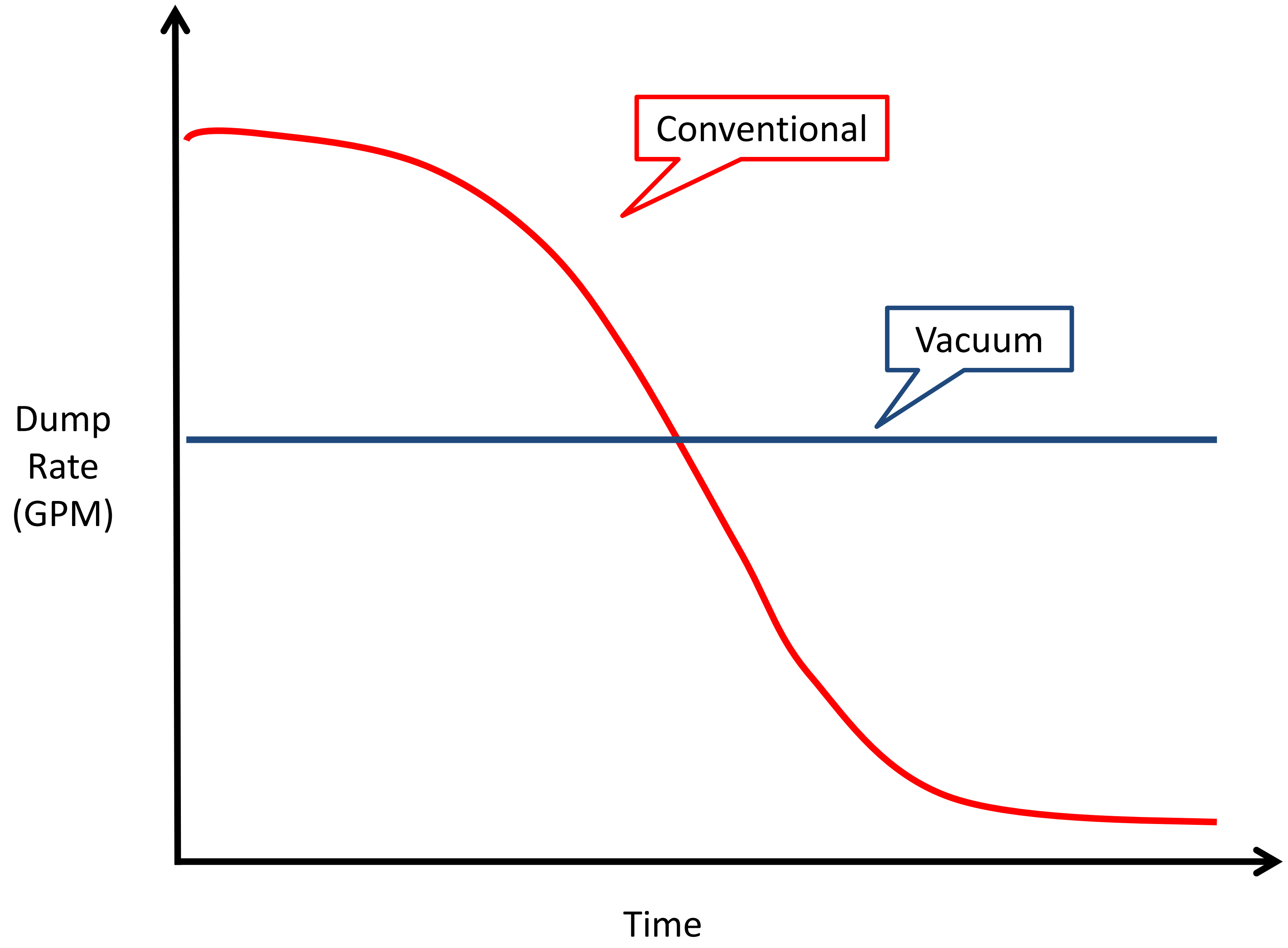
- Ability to dump side and rear (or directional dump on rear)
- Multiple side dumps
- Remote-controlled dumps (driver stays in cab)
- Automatic venting
- Large-diameter, direct-to-tank fill connection
- "Fireman's Friend" type valve on fill connection
- Fill connection accessible from ground

Water Tender Design

Vacuum Design

- Can perform all functions of conventional water tenders
- 100% of tank volume usable (effective = rated capacity)
- Consistent dump rate
- Fill site engine not required
- Functionality may offset higher up-front costs

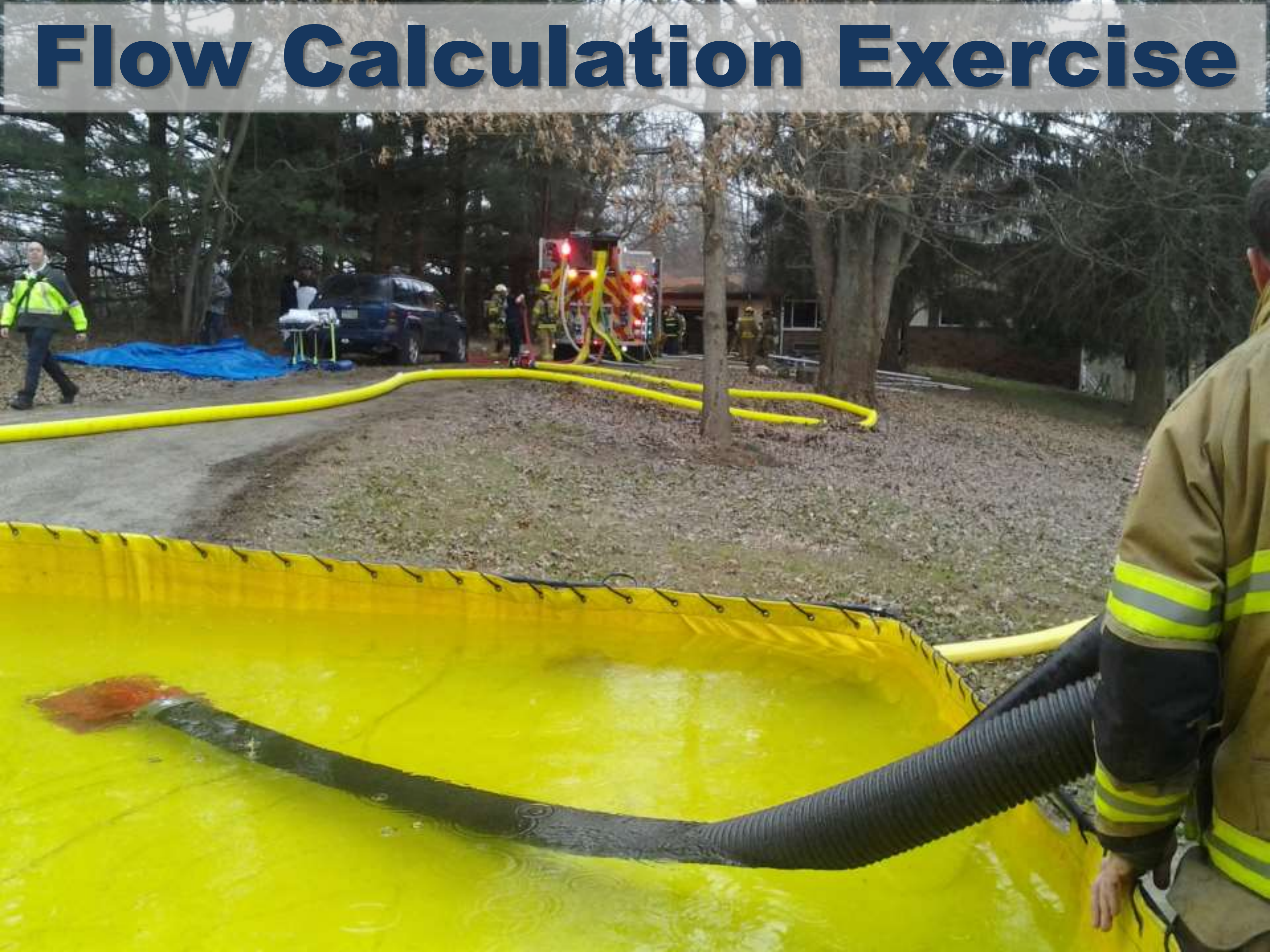
Effective Tank Capacity



Keep Water Tenders Moving

$175,000 is a lot to pay for a portable tank

Flow Calculation Exercise



Water Shuttle Tactical Resources Worksheet

Ohio Fire Chiefs' Association
Water Supply Technical Advisory Committee

1. Required Water Supply	**2. Fill Site**		**3. Dump Site**	**4. Shuttle Route**	
Water Supply Zone / Incident	Fill Site	Drafting Engine	Dump Site	Route	Travel Time (TR) __________ X __________ Distance x (60 / mph)
Minimum Water Supply	Exploitable Volume (VEx)	Engine Flow Rate (EQ)		Total Distance (miles)	
Water Delivery Rate	Maximum Flow Rate (FSQ)	Fill Site Crew Handling Time (HTF)	Dump Site Crew Handling Time (HTD)	Travel Speed (mph)	= __________ **minutes**

5. Water Tenders							**6. Fill Site Time**				**7. Dump Site Time**			**8. Travel Time**	**9. Flow Calculations**	
No.	Unit Designator	Nominal Tank Capacity (RV) gallons	Residual Water Factor (k) Conv = 0.9 Vac = 1.0	**Adjusted Tank Capacity (V)** **RV x k**	Fill Rate (RF) gpm	Dump Rate (RD) gpm	Restricted Fill Rate (FSR) lesser of FSQ, EQ & RF	Fill Time (V/FSR)	Handling Time HTF	**Total Fill Time (TF)** **(V/FSR)+HTF**	Dump Time (V/RD)	Handling Time HTD	**Total Dump Time** **(V/RD)+HTD**	**Total Travel Time** **TR**	Total Time (T) TF+TD+TR	Continuous Flow (V/T)
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																

TOTAL SHUTTLE FLOW (GPM) __________

Cannot exceed Fill Site Flow Rate (FSQ)

Section 1. Required Water Supply
What Do We Need?

Water Supply Zone:
Maple Ridge Estates subdivision (MRE)

Min. Water Supply: 11,700 gallons
Water Delivery Rate: 750 gpm

1. Required Water Supply

Water Supply Zone / Incident

Maple Ridge Estates

Minimum Water Supply

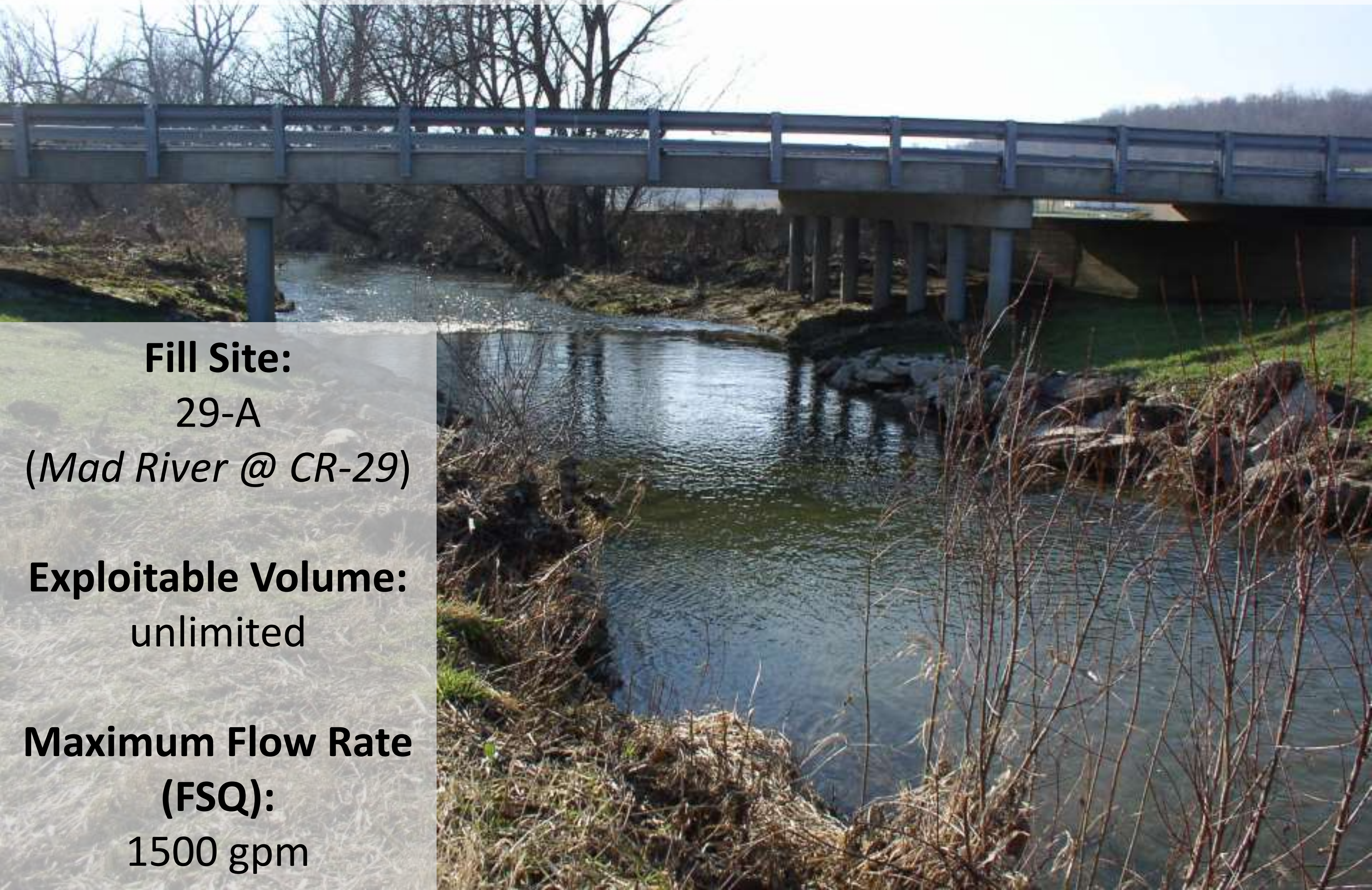
11,700

Water Delivery Rate

750

Section 2. Fill Site

Available Water



Fill Site:

29-A

(*Mad River @ CR-29*)

Exploitable Volume:

unlimited

Maximum Flow Rate (FSQ):

1500 gpm

Section 2. Fill Site (continued)

Drafting Engine

Drafting Engine:
E-382
(mutual aid pumper)

Engine Flow Rate (EQ):
1,250 gpm

Fill Site Crew Handling Time:
1.5 minutes

2. Fill Site

Fill Site 29-A	Drafting Engine E-382
Exploitable Volume (VEx) unlimited	Engine Flow Rate (EQ) 1,250
Maximum Flow Rate (FSQ) 1500	Fill Site Crew Handling Time (HTF) 1.5

Section 3. Dump Site

Dump Site:
MRE-1
(pre-planned site)

Dump Site Crew Handling Time:
1.0 minute

3. Dump Site

Dump Site MRE-1
Dump Site Crew Handling Time (HTD) 1.0

Section 4. Shuttle Route

Route Name:
HT-8
(pre-planned one-way loop)

Total Distance:
4.9 miles

Travel Speed:
35 mph

4. Shuttle Route

Route	Travel Time (TR)
HT-8	4.9 x 1.7
Total Distance (miles)	Distance x (60 / mph)
4.9	
Travel Speed (mph)	**8.4** **minutes**
35	

Section 5. Water Tenders

First Alarm Assignment

Unit	Nominal Tank Capacity (gal)	Design	Fill Rate (gpm)	Dump Rate (gpm)
Tanker 111	1,814	Vacuum	844	1,400
Tanker 21	1,994	Conventional	814	3,365
Tanker 81	2,306	Conventional	860	1,186

5. Water Tenders

No.	Unit Designator	Nominal Tank Capacity (RV) gallons	Residual Water Factor (k) Conv = 0.9 Vac = 1.0	**Adjusted Tank Capacity (V)** **RV x k**	Fill Rate (RF) gpm	Dump Rate (RD) gpm
1	Tanker 111	1,814	1.0	**1,814**	844	1,400
2	Tanker 21	1,994	0.9	**1,795**	814	3,365
3	Tanker 81	2,306	0.9	**2,075**	860	1,186

Section 6. Fill Site Time
Handling Time + Fill Time

Restricted Fill Rate:
What is the chokepoint?
- Fill Site Maximum Flow Rate (1500 gpm)
- Engine Flow Rate (1250 gpm)
- Tanker Rate of Fill (depends on unit)

Fill Time (minutes):
Adjusted Tank Capacity ÷ Restricted Fill Rate

Fill Site Handling Time (minutes):
- Time to maneuver, hook up, etc.
- Same for all water tenders

6. Fill Site Time			
Restricted Fill Rate (FSR) lesser of FSQ, EQ & RF	Fill Time (V/FSR)	Handling Time HTF	**Total Fill Time (TF)** **(V/FSR)+HTF**
844	2.1	1.5	**3.6**
814	2.2	1.5	**3.7**
860	2.4	1.5	**3.9**

Section 7. Dump Site Time

Handling Time + Dump Time

Dump Time (minutes):
Adjusted Tank Capacity ÷ Dump Rate

Dump Site Handling Time (minutes):

- Time to maneuver, open dumps, etc.
- Same for all water tenders

7. Dump Site Time		
Dump Time (V/RD)	Handling Time HTD	**Total Dump Time** **(V/RD)+HTD**
1.3	1.0	**2.3**
0.5	1.0	**1.5**
1.7	1.0	**2.7**

Section 8. Travel Time

Travel Time (minutes):

- Route Distance x (60 ÷ Travel Speed)
- Time required to travel entire route
- Same for all units

8. Travel Time
Total Travel Time TR
8.4
8.4
8.4

Section 9. Flow Calculations

What is the total flow?

Total Time:

- Fill Time + Dump Time + Travel Time

Continuous Flow Rate (by Water Tender):

- Adjusted Tank Capacity ÷ Total Time
- Sum all for total shuttle flow (gpm)

9. Flow Calculations

Total Time (T) TF+TD+TR	Continuous Flow (V/T)
14.3	126
13.6	132
15.1	138

TOTAL SHUTTLE FLOW (GPM) | **396**

Cannot exceed Fill Site Flow Rate (FSQ)

Will This Shuttle Work?

Requirement	Needed	Delivered
Total Water Supply (gallons)	11,700	**Unlimited** ✓
Water Delivery Rate (gpm)	750	**396** ✗

What can we change?

More Water Tenders?

Needed	Delivery Rate
Current	396 gpm
Add Two x 2,000 gallon	644 gpm (+248 gpm / +63%) *Each adds 124 gpm*
Add Two x 3,500 gallon	762 gpm (+366 gpm / +92%) *Each adds 183 gpm*

Work Harder?

Needed	Delivery Rate
Current Fill Site Handling Time: 1.5 minutes	396 gpm
Decrease to 0.5 minutes	426 gpm (+30 gpm / +8%)

Drive Faster?

Needed	Delivery Rate
Current: 35 mph	396 gpm
Increase to 45 mph	455 gpm (+59 gpm / +15%)
Increase to 55 mph	503 gpm (+107 gpm / +27%)

Closer Fill Site?

Needed	Delivery Rate
Current: 4.9 miles	396 gpm
Decrease to 2.5 miles	555 gpm (+159 gpm / +40%)
Decrease to 1.0 mile	743 gpm (+347 gpm / +88%)

What's the Right Answer?

Need 354 gpm more

Change	Result	Risk	Difficulty
Current	396 gpm		
Add Two x 2,000 gallon	+248 gpm	*Low*	*Moderate*
Add Two x 3,500 gallon	+366 gpm	*Low*	*Moderate*
Fill Site Handling	+30 gpm	*Moderate*	*Moderate*
Drive Faster (45 mph)	+59 gpm	*High*	*Low*
Drive a lot Faster (55 mph)	+107 gpm	*Very High*	*Low*
Closer Fill Site	+159 gpm	*Low*	*High*
A Lot Closer Fill Site	+347 gpm	*Low*	*High*

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http://www.ohiofirechiefs.org/aws/OFCA/pt/sp/water_TAC

Presentation Developed By: Jeremy Keller, Bellefontaine Fire Department (March 15, 2015)