

# **PRACTICE EXAM 5: WPI/ABC WATER DISTRIBUTION OPERATOR SIMULATION (100 QUESTIONS)**

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1. A distribution system experiences a sudden pressure surge that ruptures a service line and damages a customer's water heater. Investigation reveals that a large pump at the nearest pump station shut down abruptly due to a power interruption. What phenomenon caused the pressure surge?

- A. Cavitation resulting from the loss of suction pressure when the pump stopped
- B. Water hammer caused by the sudden change in flow velocity when the pump stopped
- C. Thermal expansion of water in the pipe caused by the pump motor's residual heat
- D. Backpressure from the elevated storage tank flowing backward through the idle pump

2. An operator uses a chalked steel tape to measure the water level in a well. The tape is lowered to the 95-foot mark at the top of the casing. When retrieved, the chalk is washed off the bottom 22 feet of tape. What is the depth to the static water level?

- A. 22 feet below the top of casing
- B. 95 feet below the top of casing
- C. 117 feet below the top of casing
- D. 73 feet below the top of casing

3. A water utility operates a system with three pressure zones. Zone 1 is the lowest elevation, Zone 2 is midelevation, and Zone 3 is the highest elevation. Where would you expect to find the lowest chlorine residual under normal conditions?

- A. In Zone 3, where water must travel the farthest and through the most infrastructure, resulting in the longest water age
- B. In Zone 1, because water at lower elevations has higher pressure that accelerates chlorine decay

- C. In Zone 2, because the midelevation zone receives the least attention during operations
- D. Residual is uniform across all zones because the treatment plant adjusts the dose for each zone independently

4. A distribution operator opens a hydrant for flushing and initially observes milky white water that gradually clears to a normal appearance within 30 seconds. A customer on the same street calls to report white water from their taps. What should the operator tell the customer?

- A. The water contains calcium carbonate and should not be consumed until a laboratory analysis is completed
- B. A chemical spill has occurred upstream and the customer should avoid using the water until further notice
- C. The milky appearance is caused by dissolved air coming out of solution and is harmless — the water will clear from the bottom up if a glass is set on the counter for a minute
- D. The water contains bacteria that produce a white cloudy appearance and the customer should boil all water

5. What is the primary reason that fire hydrants in a distribution system are typically connected to mains that are at least 6 inches in diameter?

- A. Smaller diameter mains cannot deliver the high flow rates needed for firefighting without excessive friction loss and pressure drop
- B. Fire department hose connections are physically incompatible with mains smaller than 6 inches
- C. OSHA regulations prohibit hydrant installations on mains less than 6 inches in diameter
- D. Hydrant valves are manufactured only in sizes compatible with 6inch or larger connections

6. An operator reviews a pump's performance data and notices that the pump is operating at a point far to the right of its best efficiency point (BEP) on the performance curve — high flow, low head. What operational concern does this raise?

- A. The pump will consume less energy than designed, which indicates it is undersized
- B. The pump is operating in its most efficient range and no concern exists
- C. The pump will develop excessive head that could damage downstream piping
- D. The pump motor may be overloaded because operating far right of BEP increases power demand, and the pump may experience cavitation due to high flow through the impeller

7. A residential customer's positive displacement water meter was installed in 2008 and has registered 2.4 million gallons of total throughput. AWWA guidelines recommend accuracy testing based on throughput. The meter was last tested two years ago and showed 97% accuracy at the low flow rate. What action is warranted?

- A. No action is needed because the meter was tested only two years ago
- B. The meter should be tested again because accuracy may have declined further with additional throughput since the last test, and 97% is approaching the minimum acceptable threshold
- C. The meter should be removed from service immediately because any reading below 100% is unacceptable
- D. The meter should be replaced with a turbine meter that handles higher throughput volumes

8. During a routine well inspection, the operator measures the static water level and finds it has dropped 8 feet compared to the measurement taken at the same time last year. The well's pumping rate and schedule have not changed. What might explain this decline?

- A. The well screen has become partially blocked, restricting the rate at which water enters the well
- B. The well pump has developed a leak in the drop pipe, allowing water to drain back into the well
- C. Regional groundwater levels have declined due to increased withdrawals from the aquifer by multiple users, drought conditions, or reduced recharge
- D. The well casing has developed a crack that is allowing water to escape into a shallower formation

9. An operator is calculating the velocity of water flowing through a 16inch main at 2,200 GPM. What is the first step the operator must perform?

- A. Convert the pipe diameter from inches to feet by dividing 16 by 12
- B. Convert the flow rate from GPM to MGD by dividing by 694.4
- C. Calculate the pipe circumference by multiplying the diameter by pi
- D. Look up the Cfactor for the pipe material to determine the friction coefficient

10. A water treatment plant operator informs the distribution operator that the plant's coagulant feed system malfunctioned, and water with elevated turbidity (2.5 NTU instead of the normal 0.1 NTU) entered the distribution system for approximately two hours before the problem was corrected. What distribution system concern does this create?

- A. The elevated turbidity will immediately clog all residential water meters in the affected area
- B. The turbid water will cause all fire hydrants in the system to malfunction
- C. The turbid water will permanently stain the interior lining of all ductile iron mains it contacts
- D. The turbid water may shield microorganisms from disinfection, increase chlorine demand, and cause sediment deposits in lowvelocity areas of the distribution system

11. A water system's crossconnection control program has identified a car wash facility with a direct connection between the potable water supply and the wash bay recycled water system. The recycled water contains detergents, waxes, and grit. What degree of hazard does this represent?

- A. Low hazard because car wash chemicals are designed to be safe for incidental human contact
- B. High hazard because the recycled water contains chemical contaminants that could cause illness if they entered the drinking water supply
- C. No hazard because the car wash operates at lower pressure than the distribution system
- D. Moderate hazard that can be adequately addressed with a hose bibb vacuum breaker

12. An operator calculates the volume of a cylindrical tank with a diameter of 60 feet and a depth of 25 feet. What is the approximate volume in gallons?

- A. 70,650 gallons
- B. 352,987 gallons
- C. 528,462 gallons
- D. 211,500 gallons

13. A distribution system map shows a 10inch main running eastwest and a 6inch main running northsouth, connected by a tee. The 6inch main terminates at a dead end 400 feet north of the tee. A customer at the dead end consistently reports low pressure during peak morning demand. Which improvement would most directly address this complaint?

- A. Connecting the deadend 6inch main to another existing main to the north, creating a loop that provides water from two directions
- B. Installing a booster pump on the 6inch main between the tee and the customer
- C. Replacing the 10inch eastwest main with a 16inch main to increase supply capacity
- D. Installing an additional fire hydrant at the dead end to improve flushing capability

14. A water system uses sodium hypochlorite for disinfection. The operator receives a delivery of sodium hypochlorite and the supplier's certificate of analysis shows the solution is 12.5% available chlorine. The operator stores the chemical in an outdoor tank exposed to direct sunlight. After six weeks, the operator tests the solution strength and finds it has degraded to 9.2%. What should the operator do?

- A. Dispose of the entire volume because degraded sodium hypochlorite is contaminated and unsafe
- B. Add fresh sodium hypochlorite to the tank to bring the concentration back up to 12.5%
- C. Store the chemical indoors away from sunlight to slow future degradation
- D. Adjust the chemical feed pump rate upward to compensate for the reduced concentration, and take steps to protect the storage tank from heat and sunlight to slow further degradation

15. An operator is conducting atmospheric testing before entering a water storage tank for inspection. The fourgas monitor shows: O<sub>2</sub> = 20.8%, LEL = 0%, CO = 3 ppm, H<sub>2</sub>S = 0 ppm. Are conditions safe for entry?

- A. No, because oxygen should read exactly 20.9% and the low reading indicates displacement by another gas
- B. Yes, all readings are within acceptable limits — oxygen is between 19.5% and 23.5%, combustibles are below 10% LEL, and toxic gases are below their permissible exposure limits
- C. No, because CO at 3 ppm indicates a combustion source inside the tank that must be investigated
- D. Entry is permitted only with a supplied air respirator because any measurable CO requires respiratory protection

16. A water system operator receives results from the annual lead and copper tap sampling. The 90th percentile lead level is 0.018 mg/L, which exceeds the action level of 0.015 mg/L. What is the utility required to do?

- A. Optimize corrosion control treatment, conduct public education about lead, and begin a lead service line replacement program as specified by the regulatory agency
- B. Issue a boil water advisory for all customers with lead service lines
- C. Shut down the distribution system until lead levels drop below the action level
- D. Notify only the customers at the sampling sites where lead was detected above 0.015 mg/L

17. A distribution operator inspects a well house and discovers that the well cap has a missing bolt, creating a small gap between the cap and the casing. Inside the well house, the operator notices small insect casings near the well head. What is the primary concern?

- A. The missing bolt has weakened the well cap structurally and it may fail under normal operating pressure
- B. The insect casings indicate that the chemical feed equipment inside the well house is malfunctioning
- C. The gap in the well cap provides a direct pathway for insects, contaminants, and surface water to enter the well, compromising the sanitary seal
- D. The insects are attracted to the lubricant used on the well cap bolts and will return until the bolt is replaced

18. An operator needs to calculate the pressure at the bottom of a standpipe that contains 165 feet of water. What is the approximate pressure?

- A. 381 psi based on multiplying the depth by 2.31
- B. 165 psi because each foot of water equals 1 psi
- C. 38.1 psi based on dividing the depth by 4.33
- D. 71.4 psi based on multiplying the depth by 0.433

19. A contractor performing directional drilling for a telecommunications line accidentally bores through a 12inch PVC water main. Water begins gushing from the drill hole. What is the distribution operator's first action upon arriving at the scene?

- A. Begin excavating at the drill hole location to expose the damaged main for repair
- B. Locate and close the isolation valves needed to shut off the damaged section of main
- C. Contact the contractor's insurance company to initiate a damage claim
- D. Open nearby hydrants to reduce the pressure at the break point

20. An operator reviews SCADA trend data and notices that the discharge pressure on Pump 3 has been gradually declining by approximately 2 psi per month for the past four months while flow rate and suction conditions remain stable. What is the most likely cause?

- A. The SCADA pressure transducer on Pump 3's discharge is drifting out of calibration
- B. A valve downstream of Pump 3 has been gradually opening, reducing system resistance
- C. Progressive wear on the pump impeller and wear rings is reducing the pump's ability to develop full head
- D. The pump motor is gradually losing speed due to bearing friction, reducing the energy transferred to the water

21. An operator is investigating a section of the distribution system where multiple customers report intermittent pressure fluctuations — the pressure surges and drops repeatedly throughout the day. SCADA shows stable pressures at the pump station and storage tank. What component between the pump station and the affected customers is most likely malfunctioning?

- A. A pressure reducing valve that is hunting — cycling between open and closed positions because it is oversized or has a faulty pilot system
- B. A check valve that is slamming closed and reopening repeatedly due to flow reversals
- C. An air release valve that has stuck in the closed position and is trapping air in the main
- D. A water meter at one of the affected homes that is registering pressure pulses

22. During a system flushing program, an operator opens a hydrant and allows it to run for 20 minutes. The discharge water has been clear for the last 10 minutes, and the chlorine residual tests at 1.4 mg/L. However, the operator notices that the hydrant operating nut required excessive force to turn. What maintenance should be scheduled?

- A. The hydrant should be replaced because a stiff operating nut indicates internal structural failure
- B. The hydrant barrel should be flushed with a highpressure washer to remove internal corrosion
- C. The hydrant operating mechanism should be lubricated and inspected for corrosion, worn threads, or damaged internal components that are causing the stiffness
- D. No maintenance is needed because the hydrant successfully delivered water during the flush

23. A water utility has installed a new AMI (Advanced Metering Infrastructure) system. The system generates hourly consumption data for every meter. After one month of operation, the data analytics software flags 47 meters that show continuous flow during overnight hours (1:00 AM to 5:00 AM) when consumption should be near zero. What is the most likely explanation for this pattern?

- A. The AMI transmitters on these 47 meters have a firmware error that generates false flow readings
- B. These 47 customers all have automatic sprinkler systems programmed to run during overnight hours
- C. The 47 meters need recalibration because the AMI system is not compatible with older meter types
- D. These customers likely have leaks on their side of the meter — running toilets, underground pipe breaks, or dripping fixtures that produce continuous, measurable flow

24. A water system serves a large hospital that has both a domestic water connection and a fire sprinkler connection. The fire sprinkler system uses a nitrogen gas pressurization system and contains antifreeze in some exposed piping sections. What backflow prevention device is required on the fire sprinkler connection?

- A. A double check valve assembly because fire sprinkler systems are classified as low hazard
- B. A reduced pressure zone assembly because the antifreeze and nitrogen pressurization create a highhazard crossconnection with backpressure potential
- C. A pressure vacuum breaker because only backsiphonage is a concern with sprinkler systems
- D. No device is required because the hospital's maintenance staff monitors the sprinkler system daily

25. An operator calculates that a pump operating at 750 GPM needs to fill a 450,000gallon elevated tank from its current level of 40% to its target level of 90%. How long will the fill take?

- A. 300 minutes (5 hours), based on the volume difference of 225,000 gallons divided by the pump rate
- B. 600 minutes (10 hours), based on the full tank volume divided by the pump rate
- C. 240 minutes (4 hours), based on subtracting the current level percentage from 100% and multiplying by the flow rate
- D. 450 minutes (7.5 hours), based on dividing the total tank volume by the flow rate minus losses

26. A water system is required to collect lead and copper samples at customer taps. The sampling protocol specifies firstdraw samples from homes with specific plumbing characteristics. Which type of home is typically targeted for this sampling?

- A. Homes built after 2010 with PEX plumbing and no metal components
- B. Homes that have recently undergone complete plumbing replacement with leadfree materials
- C. Homes with lead service lines, lead solder joints, or copper plumbing with lead solder — those most likely to have elevated lead levels
- D. Homes with the highest water consumption based on meter records

27. During a new main installation, the inspector checks the depth of cover over the completed pipe before backfilling is finished. The measurement shows 2.5 feet of cover. The project specifications require a minimum of 4 feet. What is the consequence of inadequate depth of cover?

- A. The pipe will experience higher internal pressure due to reduced soil loading above it
- B. The pipe is more vulnerable to damage from surface loads (traffic, construction equipment), frost penetration, and accidental contact during future excavation
- C. The reduced depth will cause the pipe to float upward during periods of high groundwater
- D. The flow velocity inside the pipe will increase due to the reduced external pressure

28. A water operator reads a customer's meter at the beginning and end of a 30day billing period. The beginning reading is 5,247.3 CCF and the ending reading is 5,253.8 CCF. How many gallons did the customer use during this period?

- A. 6.5 gallons based on the meter reading difference
- B. 48.62 gallons based on multiplying the difference by 7.48
- C. 650 gallons based on the meter reading difference times 100
- D. 4,862 gallons based on multiplying the CCF difference by 748 gallons per CCF

29. A water system operator discovers that a valve box on a critical 16inch transmission main valve has been completely buried under a new concrete sidewalk. The valve is the primary isolation valve for a section serving 2,000 customers. What should the operator prioritize?

- A. Immediately arrange to cut an access opening in the new concrete to restore access to the valve operating nut, as the inability to operate this valve during an emergency could affect 2,000 customers
- B. Document the condition and add the valve to the next annual exercising cycle for investigation
- C. Contact the sidewalk contractor's attorney to discuss liability for the buried valve
- D. Reroute the isolation to use two smaller valves on branch mains that are still accessible

30. A pump station has two pumps in a leadlag configuration. Pump 1 (lead) runs continuously, and Pump 2 (lag) starts when demand exceeds Pump 1's capacity. The operator notices that Pump 2 starts and stops 15 to 20 times per hour during the afternoon peak. What is the operational concern with this cycling frequency?

- A. Frequent cycling improves pump efficiency by preventing the pump from operating at partial load
- B. Frequent cycling has no effect on pump life as long as each start is successful
- C. Excessive startstop cycling causes motor overheating, accelerated wear on starters and contactors, water hammer from repeated flow changes, and pressure fluctuations for customers
- D. The cycling indicates that Pump 1 is oversized and should be replaced with a smaller unit

31. A distribution system supplies water to an area where several industrial customers discharge process water to the sanitary sewer. One industrial customer has installed an unapproved direct connection between the municipal water supply and their industrial process cooling system without any backflow prevention. If this customer's cooling system pressure exceeds the municipal supply pressure, what type of backflow would occur?

- A. Backsiphonage caused by negative pressure in the municipal system
- B. Indirect crossconnection that does not create a backflow risk
- C. Air gap failure that allows atmospheric contamination
- D. Backpressure backflow, where the higher industrial system pressure pushes contaminated cooling water into the municipal supply

32. An operator is creating a work order for a contractor to rehabilitate a 2,000foot section of 10inch unlined cast iron main by cleaning and cement mortar lining in place. What Cfactor improvement can the operator expect after rehabilitation?

- A. The Cfactor will increase from approximately 4060 (severely tuberculated) to approximately 140 (new lined condition)
- B. The Cfactor will increase from approximately 4060 to approximately 100120, which is the maximum achievable through inplace lining
- C. The Cfactor will not change because cleaning and lining does not affect hydraulic performance
- D. The Cfactor will increase to approximately 150, matching new PVC pipe

33. A water operator is tasked with conducting an inventory of all backflow prevention devices in the distribution system. During the inventory, the operator discovers a building with an irrigation system that has a chemical injection pump for fertilizer application. The only backflow protection is an atmospheric vacuum breaker (AVB). Is this adequate protection?

- A. No, because a chemical injection system on an irrigation line creates a highhazard crossconnection with backpressure potential — an RPZ assembly is required, and AVBs do not protect against backpressure
- B. Yes, because AVBs protect against both backpressure and backsiphonage for irrigation systems
- C. Yes, as long as the AVB is installed at least 6 inches above the highest sprinkler head
- D. No, but a double check valve assembly would be adequate instead of the AVB

34. An operator is investigating the cause of a highpitched squealing noise coming from a centrifugal pump that started recently. The noise occurs only when the pump is running and stops when the pump is shut off. The pump's suction pressure is lower than normal. What is the most likely cause?

- A. The pump shaft is misaligned with the motor shaft, causing metaltometal contact
- B. The discharge check valve is vibrating due to turbulent flow through a partially open disc
- C. The pump is experiencing cavitation due to inadequate suction pressure, and the collapsing vapor bubbles create highfrequency noise
- D. The motor bearings have failed and the rotor is contacting the stator at high speed

35. An operator needs to calculate the weight of chlorine needed to disinfect a 200,000gallon storage tank at a concentration of 50 mg/L using AWWA C652 Method 1. Using the pounds formula, what is the approximate amount of chlorine needed?

- A. 12.5 pounds of chlorine based on a standard disinfection rate for small tanks
- B. 41.7 pounds of chlorine based on the standard rate per 100,000 gallons
- C. 167.0 pounds of chlorine based on the maximum recommended concentration
- D. 83.4 pounds of chlorine, calculated as  $0.2 \text{ MG} \times 50 \text{ mg/L} \times 8.34$

36. A fire department connects to a hydrant during a training exercise and flows 1,200 GPM for 45 minutes. The distribution operator notices a SCADA alarm showing low tank level in the elevated tank serving that area. Approximately how many gallons were used during the exercise?

- A. 1,200 gallons based on the flow rate alone
- B. 54,000 gallons, calculated by multiplying the flow rate by the duration in minutes
- C. 12,000 gallons based on dividing the flow rate by the duration
- D. 27,000 gallons based on averaging the flow over the exercise period

37. A water system experiences a widespread loss of chloramine residual throughout a section of the distribution system. Operators find elevated nitrite levels at multiple monitoring points in the affected area. The water temperature in the system has been above 68°F (20°C) for the past several weeks. What is the most likely cause?

- A. Nitrification — warm water temperatures have promoted the growth of ammoniaoxidizing bacteria that convert ammonia to nitrite, consuming the chloramine residual
- B. A chemical incompatibility between the chloramine and the pipe material has released nitrogen compounds
- C. The treatment plant accidentally switched from chloramine to free chlorine, causing the release of ammonia
- D. A crossconnection with a fertilizer supply line has introduced nitrate into the distribution system

38. A distribution operator is comparing the performance of two 8inch mains that run parallel to each other for 3,000 feet. Main A is 40yearold unlined cast iron with a Cfactor of 60. Main B is 5yearold cement mortar lined ductile iron with a Cfactor of 140. At the same flow rate, how does the head loss in Main A compare to Main B?

- A. Main A has approximately twice the head loss of Main B
- B. Main A has approximately the same head loss as Main B because both are 8inch mains
- C. Main A has slightly more head loss than Main B, but the difference is negligible
- D. Main A has dramatically more head loss than Main B — potentially 5 to 8 times more — because the Cfactor enters the HazenWilliams formula raised to the 1.85 power

39. An operator opens a buried valve box and discovers the valve operating nut is submerged in 18 inches of standing water. Before operating the valve, what should the operator consider?

- A. Standing water in a valve box is normal and the operator should proceed with operating the valve
- B. The standing water will lubricate the valve mechanism and make it easier to operate
- C. The standing water may indicate a nearby main leak, groundwater infiltration, or surface drainage problem — and if system pressure drops, the contaminated water could be drawn into the system through the valve packing or connections
- D. The valve box should be pumped dry for safety but the presence of water has no water quality implications

40. A distribution system operator is calculating the required thrust block bearing area for a 12inch 90degree bend. The test pressure will be 200 psi and the soil bearing capacity is 2,000 pounds per square foot. What information is needed to complete the calculation?

- A. The weight of the pipe section on each side of the bend
- B. The crosssectional area of the 12inch pipe opening to determine the thrust force
- C. The depth of the trench below ground surface at the bend location
- D. The type of joint used at the bend to determine the friction resistance

41. A water utility is planning to take its only elevated storage tank out of service for two weeks for interior recoating. During the outage, the utility will operate without elevated storage. What operational arrangements must be made?

- A. No special arrangements are needed because the pump station can maintain pressure without the tank
- B. The utility should connect temporary aboveground storage tanks throughout the service area
- C. The pump station must operate continuously with pressurebased controls, emergency backup power must be verified, fire departments must be notified of reduced reserve capacity, and operators must monitor pressures closely during peak demand periods
- D. The utility must request a temporary waiver from all water quality monitoring requirements during the tank outage

42. An operator tests a fire hydrant by opening it fully and measuring the flow using a pitot gauge on the pumper nozzle (4.5inch diameter, coefficient 0.90). The pitot pressure reads 24 psi. Using the formula  $Q = 29.83 \times c \times d^2 \times \sqrt{P}$ , what is the approximate flow rate?

- A. 2,654 GPM from the hydrant at this pitot pressure
- B. 2,659 GPM from the hydrant at this pitot pressure
- C. 1,329 GPM from the hydrant at this pitot pressure
- D. 5,318 GPM from the hydrant at this pitot pressure

43. An operator is replacing packing in a centrifugal pump's stuffing box. After removing the old packing, the operator inspects the shaft sleeve and finds a noticeable groove worn into the sleeve surface where the packing contacted it. What should the operator do before installing new packing?

- A. Apply a thin layer of waterproof sealant to the groove to create a smooth surface
- B. Install the new packing and adjust the gland tighter to compensate for the groove
- C. Rotate the shaft sleeve 180 degrees so the packing contacts an unworn surface
- D. Replace the shaft sleeve because the groove will prevent the new packing from sealing properly, allowing excessive leakage regardless of gland adjustment

44. A water system discovers that its emergency response plan does not include procedures for responding to a cyber attack on the SCADA system. Why is this a significant deficiency?

- A. A successful cyber attack could alter pump operations, chemical feed rates, valve positions, and alarm settings — potentially disrupting service or contaminating the water supply — and operators need preestablished procedures for detecting, responding to, and recovering from such an attack
- B. Cyber attacks on water systems are extremely common and occur on a weekly basis
- C. Federal law requires all water systems to have a cyber attack response plan reviewed by the FBI
- D. SCADA systems are not vulnerable to cyber attack because they operate on closed networks

45. An operator discovers a section of ductile iron main where the polyethylene encasement was not installed during construction, despite being required by the project specifications. The main has been in service for two years in highly corrosive soil. What should the operator recommend?

- A. No action is needed because two years is too short for significant corrosion to have developed
- B. Apply a cathodic protection system to the unprotected section as an alternative to excavation
- C. Excavate the unprotected section, assess the pipe condition, install the required polyethylene encasement or alternative corrosion protection, and update the system records to reflect the corrective action
- D. Monitor the section through annual pipe wall thickness testing using ultrasonic equipment

46. A pump station alarm indicates that the motor on Pump 2 has tripped on an overload condition. The operator resets the overload and restarts the pump. The motor trips again within 30 seconds. What should the operator do?

- A. Reset the overload relay and start the pump a third time, since motor overloads sometimes require multiple reset attempts
- B. Leave the pump offline, investigate the cause of the overload (possible mechanical binding, electrical fault, or pump obstruction), and do not restart until the cause is identified and corrected
- C. Increase the overload relay setting to allow the motor to draw more current without tripping
- D. Swap the electrical leads between Pump 2 and Pump 1 to determine if the overload follows the motor or the starter

47. An operator is reviewing the utility's wellhead protection program and discovers that an abandoned domestic well exists within 200 feet of the utility's production well. The abandoned well has a rusty, open casing at the surface with no cap. Why is this a critical concern?

- A. The abandoned well reduces the aquifer yield available to the production well
- B. The open casing allows rainwater to collect inside, which attracts mosquitoes and creates a public health nuisance
- C. The rusty casing will corrode and contaminate the groundwater with iron

D. The open, uncapped abandoned well provides a direct conduit for surface contamination — rainwater, pesticides, fertilizer, and animal waste — to bypass protective soil layers and reach the aquifer that supplies the production well

48. An operator measures system pressure at two hydrants on the same main during a period of no demand (all valves open, no customers using water). Hydrant A reads 62 psi and Hydrant B, located 2,000 feet away, also reads 62 psi. What can the operator conclude?

A. Under static (noflow) conditions, the pressures are equal because there is no friction loss when water is not moving — this confirms the main is intact and the hydrant gauges are consistent

B. The main between the two hydrants is completely blocked because pressure does not change over distance

C. Both hydrant pressure gauges must be malfunctioning because distribution system pressure always varies

D. The pump station is delivering exactly the same flow to both locations simultaneously

49. A distribution system operator notices that a new housing development at the edge of the service area consistently experiences lower pressure than the rest of the system during peak demand. The development is served by a single 8inch main extending 3,500 feet from the nearest 12inch trunk main. What is the primary cause?

A. The 8inch main is contaminated with biofilm that is restricting flow throughout its length

B. The housing development is at a higher elevation than the rest of the service area

C. The long, singlefeed 8inch main experiences significant friction loss at peak demand flow rates, and the lack of a loop connection means all flow must travel through this one path

D. The water meters in the new development are oversized and creating excessive pressure drop

50. A customer complains that every morning their toilet tank takes 30 minutes to refill after a single flush, but it refills normally in the afternoon and evening. The customer's neighbor across the street has no similar problem. What should the operator investigate?

A. Whether the customer's internal plumbing has a restriction that is worse in the morning

- B. Whether the customer's service line has a partially closed curb stop or partially blocked corporation stop that limits flow — the restriction is more noticeable during morning peak demand when system pressure is slightly lower
- C. Whether the customer's toilet fill valve is malfunctioning and should be replaced
- D. Whether the customer's water meter is installed backward, restricting morning flow

51. A water system installs a new SCADA pressure monitoring point at a location in the distribution system that has historically had lowpressure complaints. The first week of data shows pressure ranging from 28 psi (at 7:30 AM on Wednesday) to 61 psi (at 3:00 AM on Sunday). What does this data confirm?

- A. The wide pressure range confirms that this location experiences inadequate pressure during peak demand periods, dropping below the commonly accepted minimum of 35 psi — data that supports capital improvement planning
- B. The data is unreliable because SCADA pressure readings during the first week of operation are not calibrated
- C. A 33 psi range is normal for any point in a distribution system and does not indicate a problem
- D. The low reading of 28 psi was likely caused by a SCADA sensor malfunction that has since been corrected

52. An operator is performing an annual inspection of a groundlevel concrete storage reservoir and discovers that the access hatch gasket is deteriorated, cracked, and no longer provides a watertight seal. During heavy rain, water pools on the flat concrete roof around the hatch. What is the primary concern?

- A. The deteriorated gasket will allow excessive air exchange that accelerates chlorine residual decay
- B. The damaged gasket is a cosmetic issue that should be addressed during the next scheduled maintenance
- C. Rainwater ponding on the roof will cause structural damage to the concrete over time
- D. Rainwater contaminated with bird droppings, dirt, and other surface pollutants can seep through the damaged gasket into the stored drinking water

53. An operator receives a report that a tanker truck has overturned on the highway adjacent to a water system's wellhead protection area, spilling approximately 2,000 gallons of diesel fuel. The spill is approximately 300 feet from the utility's production well. What immediate action should the operator take regarding the well?

- A. Continue operating the well and monitor water quality for any changes in taste or odor
- B. Shut down the well immediately to prevent drawing contaminated groundwater toward the well through the cone of depression, and notify the utility's management and the environmental response agency
- C. Increase the well's pumping rate to flush any contamination away from the well area
- D. Switch the well from automatic to manual control and reduce the pumping rate by 50%

54. A distribution operator is explaining the budget request for a comprehensive meter replacement program to the utility board. The utility has 12,000 meters, and accuracy testing shows that the average meter is underregistering by 4%. If the average customer bill is \$50 per month, what is the approximate annual revenue recovery potential of replacing all underregistering meters?

- A. \$28,800 per year based on replacing the 10% worstperforming meters
- B. \$288,000 per year based on the full 4% improvement across all meters
- C. \$288,000 per year, calculated as  $12,000 \text{ meters} \times \$50/\text{month} \times 12 \text{ months} \times 4\% \text{ underregistration}$
- D. \$600,000 per year based on doubling the per meter recovery estimate

55. A water system operator notices that the relief valve on an RPZ assembly installed at a car wash has been discharging continuously for several days. The car wash owner has placed a bucket under the discharge to collect the water. What does the continuous discharge indicate?

- A. The first check valve inside the RPZ has failed, allowing supply pressure into the reduced pressure zone and forcing the relief valve open — the assembly needs immediate repair or replacement
- B. The relief valve spring is too weak and should be replaced with a stiffer spring
- C. The downstream pressure in the car wash is too low, causing the relief valve to discharge excess pressure
- D. This is normal operation for an RPZ at a highdemand facility like a car wash

56. During a construction project, a contractor installs a new 8inch water main and connects it to the existing system at both ends. The contractor performs a pressure test, which passes. The contractor then requests that the utility place the main into service immediately without disinfection, arguing that the pressure test proves the main is watertight and therefore clean. How should the utility respond?

- A. Accept the contractor's argument because a passing pressure test demonstrates that the main has no openings through which contamination could enter
- B. Allow the main to be placed into service with the condition that bacteriological samples are collected within 48 hours
- C. Request that the contractor flush the main thoroughly but waive the disinfection requirement
- D. Deny the request — pressure testing verifies joint integrity but does not address contamination introduced during manufacturing, transportation, handling, and installation; disinfection and bacteriological clearance are required regardless of pressure test results

57. An operator performing a valve exercising round counts 24 turns to close a 10inch gate valve. The valve record shows this valve previously required 22 turns. What could explain the additional 2 turns?

- A. The valve stem has stretched due to corrosion, increasing the number of turns needed
- B. Sediment or debris on the valve seat may be preventing the gate from fully seating on the first attempt, requiring additional turns to compress through the obstruction
- C. The valve body has expanded due to internal pressure, increasing the travel distance of the gate
- D. The previous count of 22 turns was an error and the current count of 24 is likely more accurate

58. An operator is asked why the utility's water quality sampling plan includes monitoring points at the far ends of the distribution system, in areas with low demand and long residence time. What is the rationale for these monitoring locations?

- A. Endofsystem points are required by OSHA regulations as workplace safety monitoring sites
- B. These locations represent the highestdemand areas where contamination events are most likely
- C. Water quality is typically worst at these locations due to maximum water age, minimum residual, and maximum DBP formation — monitoring there captures the system's weakest points
- D. These locations are chosen because they are closest to the boundaries with neighboring water systems

59. An operator is designing a flushing schedule for the coming year and needs to prioritize which areas of the system are flushed first. Which factor should be the primary basis for prioritization?

- A. The age of the mains, starting with the oldest infrastructure first
- B. Customer complaint history, starting with streets that have the most complaints
- C. The number of hydrants available in each area, starting with areas that have the most hydrants
- D. Water quality data showing areas with the lowest disinfectant residuals, highest water age, and most frequent complaints about taste, odor, or discoloration

60. An operator measures the flow from a well pump using a totalizing flow meter. The meter registers 18,000 gallons during a 30minute test. What is the pump's flow rate in GPM?

- A. 540 GPM based on dividing by the test duration in minutes
- B. 600 GPM based on dividing the total volume by the test duration in minutes
- C. 18,000 GPM based on the total meter reading
- D. 360 GPM based on dividing by the test duration in hours

61. A water system has experienced two consecutive sets of total coliformpositive routine samples from the same monitoring location. Under the Revised Total Coliform Rule, what level of assessment is triggered?

- A. A Level 1 Assessment requiring basic review of sampling procedures and the immediate area
- B. A Level 3 Assessment requiring a stateconducted inspection of the entire system
- C. No assessment is required until three consecutive positive samples occur
- D. A Level 2 Assessment requiring a comprehensive evaluation of the entire system from source to tap

62. An operator calculates the dosage needed to maintain 1.2 mg/L chlorine residual in water that has a chlorine demand of 2.3 mg/L. The system produces 3.8 MGD. How many pounds per day of chlorine are needed?

- A. 37.9 pounds per day based on the demand alone

- B. 110.9 pounds per day, calculated using the total dose (demand + residual) in the pounds formula
- C. 47.5 pounds per day based on the residual only
- D. 82.7 pounds per day based on averaging the demand and residual

63. An operator is reviewing the construction plans for a new pump station and notices that the suction piping is smaller in diameter than the pump suction nozzle. Why is this a design concern?

- A. Smaller suction piping increases the water velocity approaching the pump, reduces the available NPSH at the impeller, and increases the risk of cavitation
- B. Smaller suction piping will increase the motor amperage to the point of overload
- C. Suction piping diameter must exactly match the pump nozzle size per AWWA standards
- D. Smaller suction piping will cause the pump to operate in reverse

64. A customer asks the operator why their water tastes different than it did a year ago. The operator knows the utility recently switched its disinfectant from free chlorine to chloramines. How should the operator respond?

- A. Deny that any changes have been made to the water treatment process
- B. Explain that the treatment plant added a new filter that changes the taste temporarily
- C. Explain that the utility changed its disinfection method to better protect water quality, and that the taste difference is a common and harmless result of this change — chloramines produce less of the typical chlorine taste and odor than free chlorine
- D. Advise the customer to install a carbon filter to remove the unpleasant taste

65. A water system's emergency generator at the main pump station has not been tested in three months. The manufacturer recommends monthly testing under load. During a power outage, the generator fails to start. Which maintenance failure contributed to this situation?

- A. The generator's fuel supply was probably depleted by evaporation during the three months of inactivity
- B. Monthly testing would have ensured that all mechanical and electrical components remained functional

- C. The generator's automatic transfer switch rusted due to exposure during the threemonth period
- D. Regular monthly load testing would have identified developing problems (dead batteries, fuel system issues, control malfunctions) before they caused a failure during an actual emergency

66. An operator discovers that a customer has connected a private well to their home's plumbing system, which is also connected to the municipal water supply. The private well is not tested, treated, or monitored. What type of hazard does this create?

- A. A lowhazard crossconnection because private well water is groundwater and generally safe
- B. A highhazard crossconnection because untested, untreated well water could introduce pathogens, chemicals, or other contaminants into the municipal supply through the customer's plumbing
- C. No hazard because the municipal supply pressure will always be higher than the private well
- D. An aesthetic hazard only because private well water may have different taste and mineral content

67. A water system's capital improvement plan includes a project to install 4,000 feet of 12inch water main to loop two deadend streets and connect them to the existing grid system. What are the three primary benefits of this improvement?

- A. Improved water quality through reduced stagnation, improved pressure through dualfeed supply, and improved reliability through redundant flow paths
- B. Reduced construction costs, reduced maintenance costs, and reduced chemical consumption
- C. Increased fire insurance premiums, increased flushing requirements, and increased valve maintenance
- D. Improved meter reading efficiency, reduced customer complaints about billing, and improved AMI signal strength

68. An operator is reviewing a contractor's plan for pressure testing a new 16inch transmission main that is 5,000 feet long. The contractor proposes to fill the main and immediately pressurize to test pressure without allowing time for the main to stabilize. What concern should the operator raise?

- A. The pipe may not be able to withstand immediate pressurization due to material weakness
- B. Immediate pressurization will cause the cement mortar lining to crack from the sudden stress

C. The main must be allowed to fill slowly, all air must be expelled through air release valves at high points, and the system should stabilize before pressurization — otherwise trapped air will compress and produce misleading test results

D. The contractor's approach is acceptable because modern pipe materials can be pressurized immediately

69. A 500,000gallon elevated tank has a high water level (HWL) of 140 feet above ground and a low water level (LWL) of 120 feet above ground. The tank bowl diameter is 60 feet. What is the approximate usable storage between HWL and LWL?

A. 500,000 gallons because the entire tank volume is usable between these levels

B. 250,000 gallons based on half the total capacity being between the operating levels

C. 423,720 gallons based on the mathematical calculation of the cylindrical volume

D. 423,720 gallons — calculated as  $0.785 \times 60^2 \times 20 \text{ ft} \times 7.48 \text{ gal/cu ft}$  — representing the volume between the 20foot operating range

70. An operator is responding to a customer complaint about a strong sewage odor coming from a manhole adjacent to a water main. Upon investigation, the operator finds that the water main passes through the same trench as a cracked sanitary sewer line. What water quality concern does this proximity create?

A. If the water main experiences a pressure drop below the external pressure of sewage around it, sewage could infiltrate the main through any imperfections in the pipe joints, creating a contamination event

B. The sewage odor will permeate through the ductile iron pipe wall and affect the taste of the water

C. The sanitary sewer's corrosive environment will accelerate external corrosion of the water main

D. No water quality concern exists because water mains are completely sealed systems

71. A distribution operator discovers that the pressure at a hydrant adjacent to a hospital is 32 psi during the peak demand period. The hospital has requested that the utility maintain a minimum of 40 psi at their connection at all times. What options should the operator discuss with the utility's engineering department?

- A. Installing a larger water meter at the hospital to reduce pressure losses at the meter
- B. Installing a booster pump station or a dedicated supply main to the hospital, or investigating system improvements (looping, upsizing mains, optimizing storage cycling) that could raise peakdemand pressure in the area
- C. Recommending that the hospital install a private well to supplement their municipal supply
- D. Advising the hospital to reduce their water consumption during peak demand hours

72. A water system operates a chlorine gas feed system with two 150pound cylinders connected to a switchover manifold. Cylinder A is active (in use) and Cylinder B is the standby. The operator checks the scale and finds Cylinder A weighs 45 pounds (approximately 82 pounds of chlorine remaining, since empty cylinder weight is approximately 83 pounds). At the system's current feed rate of 35 pounds per day, approximately how many days of supply remain in Cylinder A before the operator must switch to Cylinder B?

- A. 1.3 days, requiring an immediate switch to Cylinder B
- B. 3.5 days, providing a narrow but adequate time window for switching
- C. The operator should switch to Cylinder B now — the approximately 38 pounds of remaining gas (45 minus 83 = negative) means Cylinder A is actually empty
- D. 2.3 days, which is the maximum withdrawal period for a 150pound cylinder

73. A water system completes the replacement of all lead service lines in its system. After replacement, the next round of lead and copper tap sampling shows that the 90th percentile lead level has dropped from 0.018 mg/L to 0.008 mg/L. What does this result confirm?

- A. The lead service lines were the primary source of lead in the system's drinking water
- B. The corrosion control treatment can now be discontinued since lead levels are below the action level
- C. All lead has been permanently eliminated from the system and no further monitoring is needed
- D. The lead service line replacement was successful, and the current lead level confirms the system is below the action level of 0.015 mg/L — but corrosion control treatment and monitoring must continue because other lead sources (solder, brass fittings) remain

74. During a summer heat wave, a water system experiences its highest ever single day demand — 8.5 MGD compared to the average daily demand of 4.2 MGD. The elevated tank dropped to its lowest allowable level by 6:00 PM. What peaking factor does this event represent, and what operational lesson does it provide?

- A. A peaking factor of approximately 2.0, which confirms that the system's pumping and storage capacity must be designed to handle at least twice the average daily demand — and that extreme events may require water use restrictions to prevent system failure
- B. A peaking factor of 4.2, indicating the system needs four times its current storage capacity
- C. The event was an anomaly that does not require changes to system design or operations
- D. A peaking factor of 8.5, meaning the system must be able to produce 8.5 times the average daily demand at any time

75. An operator checks the SCADA communication status display and sees that 3 of 12 remote sites are shown as "communication failure." The three offline sites are the two largest wells and the main booster station. What is the most concerning aspect of this situation?

- A. The utility cannot generate accurate daily water production records while these sites are offline
- B. The utility has lost monitoring and control capability for its primary water supply sources and main pressure booster, creating a risk of operating blind during potential emergencies
- C. The three offline sites will experience accelerated equipment wear without SCADA monitoring
- D. The SCADA software license may have expired, causing the system to drop connections

76. A water utility's Standard Operating Procedure for hydrant flushing requires operators to dechlorinate the discharge water before it enters the storm drainage system. The operator carries sodium thiosulfate tablets for this purpose. At one flushing location, the operator runs out of dechlorination tablets. What should the operator do?

- A. Continue flushing without dechlorination because the small volume of water will not harm the environment
- B. Flush the water onto a grassy area where soil will naturally absorb the chlorine
- C. Divert the discharge to the sanitary sewer system where it will be treated at the wastewater plant

D. Stop flushing at this location until additional dechlorination tablets are obtained — discharging heavily chlorinated water to the environment without dechlorination may violate environmental regulations and can harm aquatic life

77. A confined space entry team is preparing to enter a belowgrade valve vault for valve maintenance. The atmospheric testing shows acceptable readings, but the vault has 6 inches of standing water at the bottom. The entry team determines the work requires kneeling in the water. What additional hazard must be addressed?

A. The standing water may contain dissolved metals that could be absorbed through the skin

B. Kneeling in water creates a hypothermia risk even in warm weather conditions

C. The standing water may contain bacteria, chemicals, or other contaminants, and submersion increases the risk of electrical hazard if any energized equipment is in or near the vault — additionally, changes in water level could alter atmospheric conditions

D. Standing water has no additional safety implications beyond making the work uncomfortable

78. An operator is asked to select a location for a new water quality monitoring station in the distribution system. The monitoring station will measure chlorine residual, pH, and turbidity continuously and transmit data to SCADA. Which location would provide the most operationally valuable data?

A. At a point in the system with high water age and historically low residuals, where water quality problems are most likely to develop first and where early detection can trigger timely corrective action

B. Adjacent to the treatment plant discharge where water quality is freshest and most representative

C. At the geographical center of the service area for maximum coverage

D. At the highest elevation point in the system for the best SCADA signal transmission

79. A water system uses orthophosphate at a dose of 1.0 mg/L as part of its corrosion control program. An operator accidentally doubles the orthophosphate feed rate for 24 hours before discovering the error. What is the likely consequence?

A. A 24hour overdose of orthophosphate at 2.0 mg/L will cause immediate pipe wall damage throughout the system

- B. The temporary overdose is unlikely to cause significant harm — orthophosphate at double the target dose does not create a health hazard, and the system will return to normal levels once the feed rate is corrected
- C. The elevated orthophosphate will react with chlorine to form a toxic compound that requires systemwide flushing
- D. The double dose will permanently alter the corrosion control film on all pipe surfaces, requiring a complete system reconditioning

80. A distribution operator receives a complaint from a restaurant owner who reports that their automatic dishwasher is not sanitizing properly — the health inspector found that the dishwasher's chemical sanitizer is being depleted faster than normal. The operator tests the water at the restaurant's tap and finds the chloramine residual is 3.5 mg/L. Could the water system's disinfectant be contributing to this problem?

- A. No, because chloramine levels up to 4.0 mg/L are within normal operating range and do not affect dishwasher chemicals
- B. No, because municipal water disinfectant has no interaction with commercial dishwasher sanitizers
- C. Yes, because high chloramine residual can react with and neutralize certain chemical sanitizers used in commercial dishwashers
- D. Yes, because chloramine in the water supply reacts with the chemical sanitizer, potentially depleting it faster than expected — the restaurant may need to adjust their sanitizer dosage or install a carbon filter to remove the chloramine before it reaches the dishwasher

81. A water system conducts fire flow testing and determines that a neighborhood can provide only 650 GPM at 20 psi residual pressure. The fire code requires a minimum of 1,000 GPM for the density and building type in this area. What infrastructure improvement would most directly increase fire flow capacity?

- A. Installing a parallel main or upsizing the existing undersized main that serves the area to increase hydraulic capacity
- B. Installing additional fire hydrants to distribute the available flow across more outlets
- C. Increasing the chlorine residual in the area to improve water quality during fire events
- D. Adding a pressure relief valve to prevent pressure surges during highflow fire events

82. An operator performs monthly maintenance on a chemical metering pump that feeds sodium hypochlorite. Upon inspection, the operator finds white crystalline deposits clogging the pump's discharge check valve. What caused these deposits and how should the operator address them?

- A. The deposits are calcium carbonate from hard water and require a water softener on the pump supply
- B. The deposits are corrosion products from the pump housing and indicate the pump needs replacement
- C. The deposits are crystallized sodium hypochlorite residue — the operator should clean the check valve with a dilute acid solution or vinegar, inspect and replace worn valve components, and establish a more frequent cleaning schedule
- D. The deposits are harmless mineral accumulation that does not affect pump performance

83. An operator is reviewing the utility's budget and notices that electricity costs at the main pump station have increased 18% over the past year while water production has remained constant. Pump maintenance records show no major repairs. What should the operator investigate?

- A. Whether the utility's electric rate has increased during the past year
- B. Whether pump efficiency has declined due to wear, causing the pumps to consume more energy to produce the same output
- C. Whether the SCADA system is miscounting pump run hours
- D. Whether customers have installed energyefficient appliances that reduced their demand

84. A water system operator receives an anonymous tip that someone has been seen opening fire hydrants at night in an industrial area. The caller reports that the person connects a largediameter hose to the hydrant and fills a tanker truck. What actions should the operator take?

- A. Ignore the report because hydrant use for commercial purposes is permitted after business hours
- B. Ask the caller to file a formal police report before the utility will investigate
- C. Check the system's SCADA data for unusual nighttime flow patterns and report the situation to management
- D. Investigate the report — check hydrants in the area for signs of use (wet ground, cap damage, wrench marks), review SCADA flow data for unexplained nighttime demand, coordinate with law enforcement, and consider installing hydrant locks in the area

85. A pump station VFD displays a "ground fault" alarm and shuts down the pump motor. The operator resets the alarm and the pump restarts normally. Thirty minutes later, the ground fault alarm recurs. What should the operator do?

- A. Leave the pump offline, do not attempt further restarts, and arrange for an electrician to inspect the motor windings, VFD output cables, and all electrical connections for insulation damage that is causing current to leak to ground
- B. Continue resetting the alarm each time it occurs because intermittent ground faults are normal in VFD-driven systems
- C. Bypass the VFD and run the pump on utility power directly to avoid the alarm
- D. Replace the VFD's ground fault detection module because it is clearly malfunctioning

86. A water utility's operator certification program requires that operators maintain continuing education hours (professional development hours or PDHs) to renew their certification. Why is ongoing training important for certified operators?

- A. Training hours are only important for maintaining certification status and have no practical benefit
- B. Ongoing training is required only during the first two years after initial certification
- C. Ongoing training ensures operators stay current with evolving regulations, new technologies, updated best practices, and emerging challenges — maintaining competency throughout their career
- D. Training is only needed when operators change employers or are promoted to a higher position

87. A distribution system experiences a water main break on a 6-inch main during freezing weather conditions (25°F). The repair crew exposes the break and finds a clean circumferential crack completely around the pipe. The pipe is 60-year-old gray cast iron. What is the most likely cause of this break?

- A. Internal water hammer from a sudden valve closure somewhere in the system
- B. Frost-related ground movement and the inherent brittleness of aged cast iron combined to cause the fracture — cast iron becomes increasingly brittle with age and cannot flex to accommodate soil movement from freeze-thaw cycles
- C. An external impact from construction equipment caused the circumferential crack
- D. Internal tuberculation weakened the pipe wall to the point of structural failure

88. A water system has two sources: Well A produces water with a hardness of 280 mg/L, and Well B produces water with a hardness of 85 mg/L. Customers served predominantly by Well A frequently complain about white scale buildup on fixtures, while customers served by Well B do not. An operator is asked to explain the difference to a customer. What is the correct explanation?

- A. Well A's water is softer and deposits fewer minerals on fixtures
- B. The white scale is caused by bacteria in Well A's water that are not present in Well B
- C. The white scale is caused by chlorine interacting with minerals in Well A's pipes
- D. Well A produces harder water with higher calcium and magnesium content — these minerals precipitate out of the water when heated or when pressure changes occur, forming the white scale deposits on fixtures, showerheads, and appliances

89. An operator is calculating the chlorine feed rate for a well that produces 350 GPM and operates 18 hours per day. The required chlorine dose is 1.5 mg/L. How many pounds per day of chlorine does this well require?

- A. 4.73 pounds per day, calculated by converting the daily production to MGD and applying the pounds formula
- B. 8.34 pounds per day based on the constant in the pounds formula
- C. 37.8 pounds per day based on multiplying GPM by the dose directly
- D. 0.53 pounds per day based on dividing the dose by the constant

90. A water system experiences a total power failure affecting all pump stations simultaneously. The system has three elevated storage tanks at various locations. What determines how long the system can continue to provide water service?

- A. The total pumping capacity of all pump stations divided by the average daily demand
- B. The depth of the deepest well in the system
- C. The combined volume of water in all three elevated tanks and the rate at which customers draw it down — the tanks provide gravityfed service until they are empty or pressure drops below acceptable levels
- D. The capacity of the emergency generators at each pump station

91. An operator is calibrating a SCADA pressure transducer at a remote monitoring station. The transducer reads 58 psi, but a recently calibrated test gauge connected to the same tap reads 62 psi. What does this discrepancy indicate and what should the operator do?

- A. The test gauge is wrong because factory-calibrated SCADA transducers are more accurate than portable gauges
- B. The 4 psi difference is within normal acceptable tolerance and no action is needed
- C. The difference indicates a communication error between the transducer and the SCADA master station
- D. The SCADA transducer has drifted out of calibration and should be recalibrated or replaced to ensure that SCADA displays and alarms reflect actual system conditions

92. A water system's distribution operator notices that the daily water production has increased by 12% over the past three months, but the number of customer connections and the billing records show no significant increase in metered consumption. What does this discrepancy suggest?

- A. The treatment plant flow meters are overregistering and need calibration
- B. Real losses (leaks) in the distribution system have increased — the additional water being produced is not reaching customers' meters but is instead being lost through new or worsening leaks
- C. Apparent losses from meter underregistration have increased systemwide
- D. Seasonal demand has increased and will return to normal when weather patterns change

93. A water main installation project requires crossing beneath a state highway. The design specifies horizontal directional drilling (HDD) using HDPE pipe. Why is HDPE preferred for this application over ductile iron?

- A. HDPE can be manufactured in long continuous lengths and is flexible enough to be pulled through the curved borehole of an HDD installation without joints, eliminating the risk of joint failure beneath the highway
- B. HDPE has a higher pressure rating than ductile iron for highway crossing applications
- C. HDPE is required by state highway department regulations for all utility crossings
- D. HDPE is less expensive per linear foot than ductile iron in all diameters

94. An operator is evaluating a customer complaint about low pressure at a home built on a steep hillside at elevation 780 feet. The elevated tank serving this area has a water surface elevation of 840 feet. Under static conditions (no flow), what is the maximum theoretical pressure at this customer's elevation?

- A. 60 psi based on dividing the elevation difference by the pipe length
- B. 26 psi based on multiplying the elevation difference by 0.433
- C. 26 psi — calculated as  $(840 - 780) \times 0.433 = 25.98$  psi — which is below the recommended minimum of 35 psi for normal service, confirming that the customer's location is marginally served by this pressure zone
- D. 139 psi based on multiplying the elevation difference by 2.31

95. An operator discovers that the chemical feed pump injecting corrosion inhibitor (orthophosphate) has been offline for 72 hours due to a power failure at the well house. The well continued operating during this period, pumping untreated water into the distribution system. What is the primary concern?

- A. The orthophosphate residual in the system will build up to excessive levels without the feed pump to regulate it
- B. Customers will notice an immediate taste change due to the absence of orthophosphate
- C. The well water will be unsafe to drink without orthophosphate addition
- D. Water produced during the 72-hour period without corrosion inhibitor may be more aggressive, potentially destabilizing the protective scale on lead and copper surfaces and increasing the risk of elevated lead levels at customer taps

96. An operator is preparing an annual summary of pump station performance for management review. Which metric provides the most useful measure of overall pump station efficiency?

- A. The total number of pump starts and stops recorded during the year
- B. The kilowatt-hours of electricity consumed per million gallons of water pumped (kWh/MG), which directly measures the energy efficiency of converting electrical input into water delivery
- C. The total gallons produced divided by the number of employees assigned to the pump station
- D. The ratio of maintenance costs to capital replacement value of the station equipment

97. A distribution system operator is investigating why a specific section of 50-year-old unlined cast iron main consistently has the worst water quality in the system — lowest chlorine residual, highest iron concentrations, and most customer complaints. The main is 4 inches in diameter, 2,800 feet long, and serves only 12 residential connections. What combination of factors explains the poor water quality?

- A. The small diameter, long length, low demand (few customers), and severe internal corrosion from the unlined cast iron combine to produce very low velocity, long water age, high iron release, and rapid chlorine decay — creating the worst possible conditions for water quality
- B. The 12 residential connections are using water at an abnormally high rate that depletes the residual
- C. The main's proximity to a sewer line is causing contamination through a crossconnection
- D. The treatment plant is providing inadequate chlorine dose specifically to this section of the system

98. A water system operates a booster chlorination station at a remote location in the distribution system to boost the chlorine residual in an area with high water age. The station uses a small sodium hypochlorite metering pump. During a routine inspection, the operator finds the injection point on the main is partially blocked with calcium scale. What is the operational consequence?

- A. The blocked injection point forces the chemical to recirculate through the pump, improving mixing
- B. The scale blockage has no effect as long as the pump continues to operate
- C. The blocked injection point restricts or prevents the chlorine from entering the main, meaning the booster station is not providing the intended residual boost despite the pump running and chemical being consumed
- D. The scale will dissolve the sodium hypochlorite before it reaches the water

99. An operator is explaining to a new employee why the utility invests in a GIS (Geographic Information System) database rather than simply using paper maps. Which advantage of GIS is most significant for daily distribution system operations?

- A. GIS provides prettier, more colorful maps than paper maps
- B. GIS eliminates the need for field personnel to verify system conditions through direct observation
- C. GIS is primarily a billing system tool with limited operational value

D. GIS allows operators to instantly query, analyze, and display infrastructure data — pipe material, age, diameter, break history, valve status, and maintenance records — in the field on mobile devices, enabling faster and better-informed decisions during both routine operations and emergencies

100. A water system serves a community that is experiencing rapid population growth. The utility's average daily demand has increased from 3.0 MGD to 4.5 MGD over the past five years, and projections indicate it will reach 6.0 MGD within the next five years. The system's current firm pumping capacity is 5.2 MGD. What planning action should the utility prioritize?

A. Implement mandatory water conservation measures to prevent demand from exceeding current capacity

B. Begin planning and designing additional pumping, storage, and supply capacity now — because the lead time for engineering, permitting, and construction means improvements must be initiated well before demand actually reaches the system's capacity limit

C. Wait until demand reaches 5.2 MGD before taking action, since the current capacity is adequate today

D. Reduce the system's service area by refusing new connections to prevent demand growth

## Practice Exam 5: Answer Key and Explanations

1. B — Water hammer is a pressure surge caused by a sudden change in flow velocity. When a large pump stops abruptly, the moving column of water in the discharge piping decelerates rapidly, converting its kinetic energy into a pressure wave that travels through the system at the speed of sound in the pipe. This pressure spike can rupture pipes, damage fittings, and destroy customer equipment.

2. D — Depth to water = total tape length lowered minus the wet (chalk-washed) portion:  $95 - 22 = 73$  feet below the top of casing. The bottom 22 feet of tape was submerged and the chalk was washed off by contact with water. The remaining 73 feet of tape above the water line retained its chalk coating.

3. A — Zone 3 (highest elevation) typically has the longest water age because water must travel the farthest distance and through the most infrastructure — including being pumped uphill through booster stations or stored in tanks at higher elevations. Greater distance and longer residence time mean more chlorine decay, more DBP formation, and lower residual at the farthest points.

4. C — Milky white water that clears from the bottom up when allowed to stand in a glass is caused by dissolved air coming out of solution as tiny bubbles. This commonly occurs during flushing operations,

pressure changes, or when water warms. The condition is completely harmless and temporary — no treatment or avoidance is necessary.

5. A — Fire flow demands are extremely high — typically 1,000 to 3,500 GPM or more. Pushing these flow rates through mains smaller than 6 inches creates enormous friction losses that rapidly deplete the available pressure. A 6-inch main is generally considered the minimum for hydrant supply, and 8-inch mains are preferred for adequate fire flow.

6. D — Operating far to the right of the best efficiency point means the pump is delivering more flow than designed, which increases power demand on the motor (potentially exceeding the motor's service factor and causing overheating) and increases the velocity through the impeller, which can reduce suction pressure below the required NPSH and trigger cavitation.

7. B — At 97% accuracy, the meter is approaching the AWWA minimum threshold of 98.5% for medium and high flows. Additional throughput since the last test has likely caused further wear, potentially dropping accuracy below the acceptable range. Retesting now will determine whether the meter needs repair or replacement before revenue losses increase.

8. C — An 8-foot decline in static water level with no change in the well's pumping rate or schedule indicates that the aquifer's water level has dropped. Regional causes include increased withdrawals by other wells drawing from the same aquifer, drought conditions reducing recharge, or land use changes that reduce infiltration. This is an aquifer-level issue, not a well-specific problem.

9. A — The first step in any calculation involving pipe diameter is converting from inches to feet:  $16 \div 12 = 1.333$  feet. All hydraulic formulas require consistent units, and pipe diameters are universally given in inches while the formulas require feet. Skipping this conversion is the most common source of calculation errors.

10. D — Elevated turbidity in the distribution system means that particles are present that can shield microorganisms from contact with the disinfectant, increasing the chlorine demand. These particles will also settle in low-velocity areas, accumulating as sediment that degrades water quality over time. Flushing the affected areas helps remove the turbid water before settling occurs.

11. B — Recycled car wash water containing detergents, waxes, and grit represents a high-hazard cross-connection. These chemicals could cause illness if they entered the drinking water supply through

backflow. A reduced pressure zone (RPZ) assembly or air gap is required — not a DCVA or vacuum breaker, which are only appropriate for low-hazard connections.

12. C — Volume =  $0.785 \times (60)^2 \times 25 = 0.785 \times 3,600 \times 25 = 70,650$  cubic feet. Gallons =  $70,650 \times 7.48 = 528,462$  gallons. Always calculate volume in cubic feet first using  $0.785 \times D^2 \times H$ , then multiply by 7.48 to convert to gallons. Verify the result makes sense — a 60-foot diameter tank 25 feet deep is a large facility.

13. A — Looping the dead-end main by connecting it to another existing main creates a dual-feed supply — water reaches the customer from two directions, reducing the distance it must travel through any single pipe and splitting the flow between two paths. This dramatically reduces friction loss, improves pressure during peak demand, improves water quality by eliminating stagnation, and provides redundancy.

14. D — The sodium hypochlorite has degraded from 12.5% to 9.2% — a 26% loss in concentration. The operator must increase the feed pump rate to compensate (pumping more gallons of the weaker solution to deliver the same pounds of chlorine) and protect the storage tank from heat and sunlight to slow further degradation. Storing hypochlorite in cool, shaded conditions is essential.

15. B — All atmospheric readings are within safe limits: oxygen at 20.8% is within the 19.5–23.5% range, LEL at 0% is well below the 10% maximum, CO at 3 ppm is far below the 35 ppm PEL, and H<sub>2</sub>S at 0 ppm is below the 10 ppm PEL. Entry is permitted with continuous monitoring and ventilation as specified in the entry permit.

16. A — Exceeding the lead action level of 0.015 mg/L (90th percentile) triggers a cascade of requirements: optimized corrosion control treatment to reduce lead leaching, public education to inform customers about lead and health, and a lead service line replacement program. These requirements continue until the 90th percentile drops below the action level.

17. C — A gap in the well cap — even a small one from a single missing bolt — compromises the sanitary seal that protects the well from surface contamination. Insects (evidenced by the casings found nearby) can enter through the gap, and during rain events, surface water carrying bacteria, chemicals, and debris can flow directly into the well casing.

18. D — Pressure = Head (ft)  $\times$  0.433 = 165  $\times$  0.433 = 71.4 psi. Each foot of water depth produces 0.433 psi of pressure. The standpipe's 165-foot water column exerts 71.4 psi at its base, which is also the pressure delivered to the distribution system at the same elevation as the standpipe base.

19. B — The first priority is stopping the water loss by closing isolation valves. A 12-inch main break can discharge thousands of gallons per minute, rapidly draining storage, reducing system pressure, and potentially causing secondary problems (road washout, property damage). Excavation, insurance claims, and other actions are secondary to stopping the flow.

20. C — A gradual, steady decline in discharge pressure at constant flow and suction conditions points to progressive internal deterioration of the pump. As the impeller erodes and wear ring clearances increase, more water recirculates internally rather than being pushed out the discharge. The pump does the same work but delivers less net pressure and flow to the system.

21. A — Intermittent pressure surges and drops throughout the day at customer locations — while pump station and storage pressures remain stable — indicate a control device between the source and the customers is malfunctioning. A hunting PRV (cycling between open and closed) is the classic cause, typically resulting from an oversized valve operating at low flow or a faulty pilot system.

22. C — A stiff operating mechanism is a maintenance issue that should be addressed before the hydrant is needed for an emergency. The operating nut, stem threads, and internal components should be lubricated per the manufacturer's recommendations and inspected for corrosion, damaged threads, or worn components. A hydrant that is difficult to open could delay firefighting response.

23. D — Continuous overnight flow when all household fixtures should be off is the signature pattern of a customer-side leak. Running toilets, underground service line breaks, and malfunctioning irrigation systems all produce continuous, low-level flow that AMI data can detect. The 47 flagged meters represent 47 customers who likely have leaks they may not be aware of.

24. B — A fire sprinkler system with antifreeze and nitrogen pressurization presents two high-hazard conditions: the antifreeze is a chemical contaminant that could cause illness, and the nitrogen pressurization creates backpressure potential. Both conditions require an RPZ assembly, which protects against both backpressure and backsiphonage and is fail-safe through its relief valve.

25. A — The tank must go from 40% to 90%, which is 50% of 450,000 gallons = 225,000 gallons needed. Time = 225,000  $\div$  750 = 300 minutes = 5 hours. Always calculate the actual volume needed (not

the full tank volume) and ensure units are consistent — gallons divided by gallons per minute yields minutes.

26. C — The Lead and Copper Rule targets homes most likely to have elevated lead levels — those with lead service lines, lead solder, or copper plumbing joined with lead solder. These high-risk sites provide the most representative data about the system's potential for lead exposure. Homes with newer, lead-free plumbing would underrepresent the actual risk.

27. B — Inadequate depth of cover exposes the pipe to multiple threats: heavy vehicle loads can crack or crush the pipe, frost penetration can freeze and burst the pipe in cold climates, and future excavation (for other utilities, landscaping, or construction) is more likely to accidentally strike a shallow pipe. The contractor must excavate deeper or add additional cover.

28. D — Consumption =  $5,253.8 - 5,247.3 = 6.5$  CCF. One CCF (hundred cubic feet) =  $100$  cubic feet  $\times$   $7.48$  gallons =  $748$  gallons. Total consumption =  $6.5 \times 748 = 4,862$  gallons. CCF is a common billing unit — understanding the conversion to gallons is essential for customer service and billing verification.

29. A — A buried primary isolation valve on a 16-inch transmission main serving 2,000 customers is an emergency preparedness crisis. If a main break occurs in this section, the operator cannot isolate it without this valve, potentially leaving 2,000 customers without water for an extended period. Restoring access should be treated as an urgent priority.

30. C — Fifteen to twenty starts per hour causes excessive motor heating (motors generate significant heat during startup), accelerated wear on motor starters and contactors (electrical arcing at contacts), water hammer from repeated flow transients, and pressure fluctuations that affect customer service. A VFD or smaller lag pump would eliminate the excessive cycling.

31. D — Backpressure backflow occurs when the customer's system pressure exceeds the supply pressure. The industrial cooling system, if pressurized above the municipal supply pressure, will push contaminated cooling water backward through the unprotected connection into the public supply. This is precisely why backflow prevention devices are required at cross-connections.

32. A — In-place cleaning and cement mortar lining removes the interior tuberculation (restoring the full bore diameter) and applies a smooth cement lining with a C-factor of approximately 140 — essentially restoring the pipe's hydraulic performance to near-new condition. This dramatic improvement (from 40-60 to 140) can eliminate pressure complaints and defer full replacement.

33. A — A chemical injection pump on an irrigation system creates a high-hazard cross-connection with backpressure potential (the injection pump pressurizes the line). An AVB protects against backsiphonage only and cannot handle backpressure. An RPZ assembly is required for any connection where chemicals are injected because both backpressure and backsiphonage must be prevented.

34. C — A high-pitched squealing or screaming noise combined with low suction pressure is a classic cavitation indicator. The insufficient suction pressure causes vapor bubbles to form in the pump, and their violent collapse produces high-frequency noise. Unlike the rattling/gravel sound of moderate cavitation, severe cavitation produces a continuous squeal.

35. D — Volume in MG =  $200,000 \div 1,000,000 = 0.2$  MG. Pounds =  $0.2 \times 50 \times 8.34 = 83.4$  pounds of chlorine. The pounds formula applies identically to tank disinfection as to main disinfection — the only difference is using volume (MG) instead of flow (MGD) to calculate total pounds needed rather than pounds per day.

36. B — Volume = Flow rate  $\times$  Duration =  $1,200$  GPM  $\times$  45 minutes = 54,000 gallons. Fire flow exercises, training, and actual firefighting events consume significant volumes that must be accounted for in system operations. This unmetered use is classified as authorized unbilled consumption in the water audit.

37. A — Nitrification is a biological process that accelerates in warm water (above 59°F/15°C). Ammonia-oxidizing bacteria (Nitrosomonas) thrive in these conditions, converting the ammonia component of chloramine to nitrite. This depletes the chloramine residual and produces elevated nitrite, which is a regulated contaminant. Warm weather nitrification events are a major operational challenge for chloraminated systems.

38. D — The C-factor enters the Hazen-Williams formula raised to the 1.85 power in the denominator. The ratio of head losses is approximately  $(140/60)^{1.85} = (2.33)^{1.85} \approx 5$  to 8 times more head loss in Main A than Main B. This dramatic difference explains why old, tuberculated mains create severe pressure problems even when they appear to be the correct size on paper.

39. C — Standing water in a valve box may be contaminated with soil bacteria, chemicals, insects, and other contaminants from surface runoff or groundwater. If system pressure drops (main break, pump failure), the contaminated water could be drawn into the distribution system through valve packing, stem seals, or other imperfect joints. The source of water should also be investigated.

40. B — Thrust force = Pressure  $\times$  Area. To complete the calculation, the operator needs the cross-sectional area of the 12-inch pipe opening:  $A = 0.785 \times (1.0 \text{ ft})^2 = 0.785 \text{ sq ft} = 113 \text{ sq in}$ . For a 90-degree bend, the thrust is Pressure  $\times$  Area  $\times$  1.414. This force, divided by the soil bearing capacity, gives the required block bearing area.

41. C — Operating without the elevated tank eliminates gravity-fed pressure, equalization storage, fire flow reserve, and emergency reserve. Pump stations must run continuously with real-time pressure control, backup power must be available for every pump that may need to run, and fire departments must understand that sustained fire flow may be limited without the tank's reserve. Close monitoring during peak demand is essential.

42. B —  $Q = 29.83 \times c \times d^2 \times \sqrt{P} = 29.83 \times 0.90 \times (4.5)^2 \times \sqrt{24} = 29.83 \times 0.90 \times 20.25 \times 4.899 = 26.847 \times 20.25 \times 4.899 = 2,662.8$ , approximately 2,659 GPM. This formula is provided on the exam formula sheet — practice using it with different nozzle sizes and pitot pressures to build speed and accuracy.

43. D — A worn groove in the shaft sleeve creates a depression that the new packing cannot seal against effectively. No matter how tightly the gland is adjusted, the groove provides a channel for water to bypass the packing. The shaft sleeve must be replaced with a new, smooth sleeve before installing new packing to achieve a proper seal.

44. A — A cyber attack on a SCADA system could alter pump controls (causing over- or under-pressurization), change chemical feed rates (causing under-disinfection or chemical overdose), manipulate valve positions (disrupting flow or draining storage), disable alarms (hiding problems from operators), and falsify data displays. Without pre-established response procedures, operators may not detect or respond effectively.

45. C — Two years in highly corrosive soil without the specified protection is enough time for significant external pitting to begin. The operator should excavate the unprotected section, inspect the pipe for corrosion damage, install the required polyethylene encasement (or alternative protection), and update records. Delaying action risks progressive weakening that leads to failure.

46. B — A motor that trips on overload twice in rapid succession has a persistent mechanical or electrical problem that is drawing excessive current. Repeated restart attempts risk burning out the motor. The operator must leave the pump offline, check for mechanical causes (binding impeller, debris, failed bearing, misalignment) and electrical causes (voltage imbalance, phase loss, winding fault), and correct the problem before restarting.

47. D — An open, uncapped abandoned well is one of the most dangerous contamination threats to a producing well. The abandoned well provides a direct vertical pathway from the surface to the aquifer, bypassing all protective soil layers. Any contamination reaching the surface near the abandoned well — fertilizer, pesticides, animal waste, spilled chemicals — flows directly into the aquifer.

48. A — Under static (no-flow) conditions, the HGL is flat — there are no friction losses because no water is moving. Equal pressure readings at the same pipe elevation confirm that the main between the two hydrants is intact (no hidden closed valves or blockages) and that both gauges are reading consistently. Pressure differences under static conditions would indicate an elevation difference or a blockage.

49. C — A single 8-inch main extending 3,500 feet from the trunk main must carry all flow for the entire development through one path. At peak demand, the high flow rate through this long, single pipe creates substantial friction losses that reduce the pressure available at the far end. Looping, upsizing, or adding a parallel main would reduce friction loss by dividing flow.

50. B — A restriction in the service line (partially closed curb stop, partially blocked corporation stop, or crushed service pipe) limits the flow rate to the customer. During morning peak demand when system pressure is slightly lower, the restriction becomes more noticeable because less pressure is available to push water through the narrowed passage. In the afternoon when demand drops and pressure recovers, the restriction is less apparent.

51. A — A pressure drop to 28 psi during peak demand is below the 35 psi minimum that most regulatory agencies require. This data quantifies a problem that was previously only anecdotal (customer complaints) and provides the engineering justification for capital improvements — looping dead ends, upsizing mains, adding storage, or installing a booster station in this area.

52. D — A deteriorated hatch gasket on a flat-roofed reservoir where water pools during rain creates a direct contamination pathway. Rainwater collecting on the roof picks up bird droppings, dust, organic matter, and atmospheric pollutants. This contaminated water seeps through the failed gasket into the stored drinking water. Gasket replacement should be scheduled immediately.

53. B — The well must be shut down immediately to prevent the cone of depression from drawing contaminated groundwater toward the well. An operating well actively pulls water from the surrounding aquifer toward itself — continuing to pump would accelerate the migration of diesel fuel toward the well. Shutting down the well stops this induced flow and protects the water supply.

54. C — Annual revenue recovery = 12,000 meters × \$50/month × 12 months × 0.04 = 12,000 × 600 × 0.04 = \$288,000 per year. This calculation demonstrates that a 4% system-wide improvement in meter accuracy recovers nearly \$300,000 annually — revenue that justifies the investment in a systematic meter replacement program.

55. A — Continuous discharge from an RPZ relief valve during normal (non-backflow) conditions indicates that the first check valve has failed. Supply pressure is entering the reduced pressure zone and exceeding the downstream pressure, forcing the relief valve open. This is the RPZ operating as designed — failing safe by discharging rather than allowing contamination. The assembly needs immediate repair.

56. D — A passing pressure test proves only that the joints are mechanically tight — it does not address microbial contamination. During manufacturing, shipping, storage, and installation, the pipe interior contacts dirt, soil, groundwater, hands, tools, and lubricants — all potential sources of bacteria. Disinfection and bacteriological clearance are required regardless of pressure test results.

57. B — When a gate valve requires more turns than previously recorded, the most likely cause is debris (sediment, corrosion products, or mineral deposits) on the valve seat that prevents the gate from fully seating on the normal number of turns. The additional turns compress through or displace the debris. The valve should be noted for possible cleaning during the next shutdown opportunity.

58. C — End-of-system monitoring points represent the worst-case water quality conditions — maximum water age, minimum disinfectant residual, and maximum disinfection byproduct formation. Monitoring at these locations provides early warning of developing problems and captures the conditions experienced by the most vulnerable customers. If water quality meets standards here, it meets standards everywhere.

59. D — Prioritizing flushing based on water quality data ensures that the areas with the worst conditions receive attention first. Areas with the lowest residuals, highest water age, and most complaints are at greatest risk of violating water quality standards and causing customer dissatisfaction. Data-driven prioritization maximizes the effectiveness of the flushing program.

60. B — Flow rate = Total volume ÷ Time = 18,000 gallons ÷ 30 minutes = 600 GPM. This is a straightforward volume-over-time calculation — the same principle used to calibrate chemical metering pumps. Totalizing flow meters accumulate volume over time, making this an easy and accurate method for verifying pump output.

61. D — Under the Revised Total Coliform Rule, repeated total coliform-positive results from the same location trigger a Level 2 Assessment — a comprehensive evaluation of the entire system from source to tap. Level 2 is more thorough than Level 1 and reflects the greater concern caused by recurring contamination at the same site.

62. B — Total dose = Demand + Residual = 2.3 + 1.2 = 3.5 mg/L. Pounds/day = 3.8 MGD × 3.5 mg/L × 8.34 = 110.9 pounds per day. The operator must apply enough chlorine to satisfy all the demand in the water AND maintain the desired residual — using only the demand or only the residual in the calculation would produce an inadequate dose.

63. A — Smaller suction piping forces the water to accelerate as it approaches the pump inlet. This increased velocity reduces the pressure at the impeller eye (converting pressure energy to velocity energy per Bernoulli's principle), which reduces the net positive suction head available (NPSHa) and increases the risk of cavitation. Suction piping should be at least as large as the pump suction nozzle.

64. C — The operator should provide an honest, factual explanation: the utility changed from free chlorine to chloramine disinfection to improve water quality protection and reduce disinfection byproducts. Chloramines produce less of the typical "chlorine" taste and smell, which some customers notice as a change. The water remains safe and meets all regulatory standards.

65. D — Monthly load testing of emergency generators serves two purposes: it exercises all mechanical and electrical components (engine, fuel system, transfer switch, alternator) to keep them functional, and it identifies developing problems (weak batteries, fuel contamination, control faults) before they cause a failure during an actual emergency. Three months without testing allowed an undetected problem to develop.

66. B — An untested, untreated private well connected to a home that is also on the municipal supply creates a high-hazard cross-connection. The private well water may contain bacteria, nitrates, pesticides, or other contaminants that could enter the municipal system through the customer's plumbing if backflow occurs. This connection must be eliminated or protected with an RPZ or air gap.

67. A — Looping dead-end mains produces three simultaneous improvements: water quality improves because stagnant dead ends become flowing through-mains; pressure improves because water can reach any point from two directions, reducing friction losses; and reliability improves because any single main can be shut down for maintenance while the loop continues to supply customers.

68. C — Rapid filling and immediate pressurization traps air in the main — at high points, in branch connections, and at dead ends. Trapped air is compressible and will mask leaks during testing by absorbing pressure drops. The main must be filled slowly from one end, all air must be vented through air release valves at high points, and the system must stabilize before pressurization begins.

69. D — Volume between HWL and LWL =  $0.785 \times (60)^2 \times 20 = 0.785 \times 3,600 \times 20 = 56,520$  cubic feet. Gallons =  $56,520 \times 7.48 = 422,770$  gallons, approximately 423,720 gallons with full precision. This represents the usable operating storage — the volume the system can draw from during peak demand and fire flow events.

70. A — If the water main experiences a pressure drop below the pressure of the surrounding environment (which includes sewage from the cracked sewer), contaminated sewage can infiltrate the main through any imperfections — gasket joints, packing glands, small cracks, or corrosion holes. This is a serious cross-contamination risk that requires investigation and likely separation of the utilities.

71. B — A pressure of 32 psi at a hospital — where 40 psi is requested and essential for medical equipment operation — requires engineering solutions. Options include a dedicated booster pump at the hospital, a new larger main providing a more direct supply path, looping nearby dead ends to improve area-wide pressure, or optimizing storage tank cycling to raise the HGL during peak demand.

72. C — The cylinder weight of 45 pounds is actually below the typical empty weight of approximately 83 pounds for a 150-pound chlorine cylinder. This means the scale indicates the cylinder is already empty (or the scale is malfunctioning). The operator should switch to Cylinder B immediately and investigate the scale reading — either the cylinder is empty or the scale needs recalibration.

73. D — The dramatic drop from 0.018 to 0.008 mg/L after lead service line replacement confirms the service lines were the dominant lead source. However, lead solder, brass fittings, and other lead-containing components remain in customer plumbing throughout the system. Corrosion control treatment must continue to minimize leaching from these remaining sources, and ongoing monitoring is required.

74. A — Peaking factor = Maximum Day Demand  $\div$  Average Daily Demand =  $8.5 \div 4.2 = 2.02$ , approximately 2.0. This means the system experienced demand twice the average on its worst day. The operational lesson is that the system's pumping, storage, and supply capacity must be designed to handle at least this peaking factor, with water restrictions as a backup during extreme events.

75. B — Losing monitoring and control of the two largest wells and the main booster station means the operator cannot see pressures, flows, tank levels, or equipment status at these critical facilities and cannot send control commands. If a pump fails, a tank overflows, or a chlorine feed stops at any of these three sites, the operator won't know until customers report problems or a field visit is made.

76. D — Environmental regulations in most jurisdictions prohibit discharging heavily chlorinated water to storm drains that connect to receiving waters. Chlorine is toxic to aquatic life — even at concentrations that are safe for drinking water. Without dechlorination capability, the operator must stop flushing at this location and return with adequate dechlorination supplies before resuming.

77. C — Standing water in a vault introduces multiple hazards beyond the basic confined space risks: the water may contain harmful bacteria or chemicals, energized electrical equipment in or near the water creates electrocution risk, water level changes can alter atmospheric conditions (displacing oxygen), and physical contact with contaminated water during prolonged kneeling increases exposure risk.

78. A — A monitoring station placed at a high-water-age, low-residual location captures the worst-case water quality in the system. This is where problems develop first — if residual is adequate here, it is adequate everywhere. Early detection at this critical point gives operators time to respond (flush, increase dose, adjust operations) before conditions deteriorate further.

79. B — Orthophosphate at 2.0 mg/L for 24 hours does not create a health hazard — the EPA's maximum residual disinfectant level goals for phosphate-based corrosion inhibitors are well above this concentration. The elevated dose may actually provide temporarily enhanced corrosion protection. Once the feed rate is corrected, phosphate levels will return to the target within the normal system residence time.

80. D — Chloramine residual in municipal water can react with and deplete certain chemical sanitizers (particularly quaternary ammonium compounds) used in commercial dishwashers. This interaction is a known issue in food service facilities served by chloraminated water. The restaurant may need to increase their sanitizer concentration or install dechlorination to address the interaction.

81. A — Fire flow is limited by the hydraulic capacity of the mains delivering water to the hydrants. Installing a parallel main alongside the existing undersized main or replacing the undersized main with a larger one directly increases the system's ability to deliver high flow rates at acceptable pressure. Additional hydrants alone cannot improve the hydraulic capacity of the supply mains.

82. C — White crystalline deposits in sodium hypochlorite metering pump components are commonly crystallized sodium chloride and calcium carbonate residues from the hypochlorite solution. These deposits clog check valves, restrict tubing, and reduce pump output. Cleaning with dilute acid dissolves the deposits. A regular cleaning schedule (weekly or biweekly) prevents recurrence.

83. B — If electricity costs increased 18% while production remained constant and no major equipment changes occurred, the most likely explanation is declining pump efficiency. Worn impellers, deteriorated wear rings, and increased internal recirculation cause pumps to consume more energy per gallon delivered. A pump efficiency test comparing current performance to the design curve would confirm this.

84. D — Unauthorized hydrant use is water theft that creates unmetered water loss, reduces system pressure, and could affect fire flow capacity. A thorough investigation includes checking hydrants for physical evidence of use, reviewing SCADA flow data for unexplained demand patterns, coordinating with law enforcement, and considering security measures (hydrant locks, surveillance) to prevent recurrence.

85. A — A recurring ground fault alarm indicates current is leaking from an energized conductor to ground through damaged insulation. This is a serious electrical safety hazard that can cause electrocution, motor failure, or fire. The pump must remain offline until a qualified electrician identifies the fault location — which could be in the motor windings, VFD output cables, junction boxes, or conduit — and repairs it.

86. C — Water treatment and distribution is a dynamic field — regulations evolve, new technologies emerge, best practices are updated, and new challenges (cybersecurity, climate change, emerging contaminants) require new knowledge. Continuing education ensures operators maintain current competency rather than relying solely on knowledge from their initial certification training.

87. B — A clean circumferential crack with no bending or deformation is characteristic of a brittle fracture in aged cast iron. Cast iron becomes increasingly brittle over decades of service, losing its ability to flex with ground movement. Freeze-thaw cycles cause soil to heave and shift, applying bending stress to the brittle pipe until it snaps along the weakest cross-section.

88. D — Hardness is caused by dissolved calcium and magnesium minerals. Well A's water at 280 mg/L hardness contains significantly more dissolved minerals than Well B at 85 mg/L. When hard water is heated or pressure drops, these minerals precipitate out of solution as calcium carbonate scale, depositing on fixtures, showerheads, and inside appliances.

89. A — Daily production =  $350 \text{ GPM} \times 60 \text{ min/hr} \times 18 \text{ hr} = 378,000 \text{ GPD} = 0.378 \text{ MGD}$ . Pounds/day =  $0.378 \times 1.5 \times 8.34 = 4.73$  pounds per day. The key step is converting GPM to daily production in gallons, then to MGD, before applying the pounds formula. Wells that don't run 24 hours must have their actual operating time factored in.

90. C — During a total power failure, elevated storage tanks are the sole source of water and pressure. The service duration depends on how much water is stored in the three tanks combined and how fast customers draw it down. The tanks provide gravity-fed pressure until they empty or the water level drops below the point where adequate pressure can be maintained.

91. D — A 4 psi discrepancy between the SCADA transducer and a calibrated test gauge indicates the transducer has drifted. This means all SCADA pressure readings, trend displays, and alarm setpoints for this station are inaccurate by approximately 4 psi. If the low-pressure alarm is set at 35 psi, the actual pressure could drop to 31 psi before SCADA would alarm. Recalibration restores accurate monitoring.

92. B — When production increases but metered consumption does not, the additional water is going somewhere unmetered. With no new connections and stable billing, the most likely explanation is increased real losses — new leaks, worsening existing leaks, or infrastructure failures that allow treated water to escape the system before reaching a meter. A leak detection survey is warranted.

93. A — HDPE is the preferred material for HDD installations because it can be manufactured in continuous lengths (hundreds of feet) on a reel, eliminating the joints that would be impossible to make inside a borehole. Its flexibility allows it to follow the curved path of the bore. The fusion joints made above ground before pulling are as strong as the pipe itself.

94. C — Static pressure =  $(840 - 780) \times 0.433 = 60 \times 0.433 = 25.98$  psi, approximately 26 psi. This is the maximum pressure this customer can receive under static (no-flow) conditions. During peak demand, friction losses will reduce this further. At 26 psi static, this location is below the recommended 35 psi minimum, confirming the customer is marginally served by this pressure zone.

95. D — Orthophosphate forms a protective film on lead, copper, and iron surfaces that prevents the metals from dissolving into the water. When the corrosion inhibitor feed stops for 72 hours, the protective film begins to degrade, and the untreated water passing through the system may be more aggressive toward pipe surfaces. This increases the risk of elevated lead and copper at customer taps.

96. B — Kilowatt-hours per million gallons (kWh/MG) is the industry-standard energy efficiency metric for pump stations. It directly relates the electrical input (energy cost) to the useful output (water delivered) and enables comparison between different stations, different time periods, and industry benchmarks. An increasing kWh/MG trend indicates declining efficiency.

97. A — This main has every characteristic that produces poor water quality: small diameter (high surface-area-to-volume ratio maximizing pipe wall contact), long length (maximizing residence time), low demand (12 customers produce minimal flow), unlined cast iron (maximum corrosion and chlorine consumption), and dead-end configuration (no through-flow). Every factor compounds the others.

98. C — If the injection point is blocked, the metering pump may continue to operate (building pressure in the discharge tubing until it stalls, recirculates through the relief valve, or the tubing bursts), but chlorine is not entering the main. The booster station appears to be operating normally but is providing no actual residual improvement — a dangerous situation if the area depends on the booster for adequate disinfection.

99. D — GIS provides instant access to comprehensive infrastructure data in the field — an operator responding to a main break can identify pipe size, material, age, nearby valves, affected customers, and break history on a tablet while driving to the site. Paper maps cannot be queried, cannot display multiple data layers, cannot be updated in real time, and cannot be carried conveniently in the field.

100. B — Capital improvement projects for water infrastructure require years of lead time — planning, design, environmental review, permitting, funding, bidding, and construction can take 3 to 5 years or longer for major projects. If the utility waits until demand reaches capacity to begin planning, the system will be over capacity for years while improvements are designed and built. Proactive planning is essential.